OR

5. (a) With help of neat sketch, describe the main parts and working of a slotter. (Unit-II / Q66)

   (b) Find the machining time required for machining the surface 600 × 800 mm, on a shaping machine. Assume, cutting speed as 8 m/min. The return to cutting time ratio is 1:4 and the feed is 2 mm/stroke. The approach and over run at each end is 70 mm. (Unit-II / Q64)

6. (a) With the help of neat sketch, explain the geometry of milling cutter. (Unit-III / Q46)

   (b) Sketch and explain three methods of cylindrical grinding. (Unit-III / Q58)

OR

7. (a) Write about cutting action of a grinding wheel and state the factors effecting wheel selection. (Unit-III / Q72)

   (b) Give a comparison of grinding machine with lapping, honing and broaching machines. (Unit-III / Q98)

8. (a) Explain Hole basis system and shaft basis system. (Unit-IV / Q51)

   (b) Design the general type of GO and NO-GO gauge for components having 20H7/f8 fit. i (microns) = 0.45 (D 1/3)+0.001 D, upper deviation of "f" shaft = –5.5 $D^{0.41}$, 20 mm falls from the diameter step of 18-30, IT7 = 16i, IT8 = 25i, wear allowance = 10% of gauge tolerance. (Unit-IV / Q69)

OR

9. (a) What is optical flat? What are their types? State the limitations of optical flat. (Unit-IV / Q82)

   (b) Bring out the importance and utility of straight edge and surface plate in laboratories. (Unit-IV / Q87)

10. (a) Explain various alignment tests to be conducted on milling machine. (Unit-V / Q103)

    (b) The heights of peak and valleys of 22 Successive points on a surface are 32, 28, 41, 24, 35, 19, 31, 21, 40, 18, 44, 24, 41, 25, 40, 26, 35, 18, 40, 18, 39, 21 microns respectively, measured over a length of 20 mm. Determine CLA and RMS values of roughness surface. (Unit-V / Q56)

OR

11. (a) Describe with a neat sketch the construction, principle and operation of talysurf surface meter. (Unit-V / Q58)

    (b) Describe the screw thread measurement with sketch. (Unit-V / Q77)

UNIT 1

METAL CUTTING AND LATHE MACHINES

Syllabus

Metal Cutting : Introduction, Elements of cutting process – Geometry of single point tools. Chip formation and types of chips. Engine lathe – Principle of working, Types of lathe, Specifications. Taper turning – Lathe attachments, Capstan and Turret Lathe – Single spindle and Multi-spindle automatic lathes – Tool layouts.

Learning Objectives

On the completion of this unit, the student shall be able to understand the following concepts,

- Methods of metal cutting
- Nomenclature of single point cutting tool
- Concept of chip formation
- Conditions required for the formation of various chips
- Constructional features of lathe
- Various operations performed on lathe
- Methods of taper turning
- Differences between capstan and turret lathes
- Single spindle and Multi spindle automatic lathes
- Tool Layouts

Introduction

In the present world of engineering, there are thousands of machines in the shop which cut, turn, face, drill, bend, grind and much more. The underlying concept of all the processes is the material removal from the workpiece which refers to metal cutting or machining. It is the term which includes large collection of manufacturing processes to remove unwanted material in the form of chips which results in the final desired shape. The predominant cutting action in machining involves shear, deformation of the work material to form a chip. As the chip is removed, a new surface is exposed. Even though, theoretical analysis of the cutting process is complex, the application of these processes in the industrial world is widespread. Generally, machining is performed after the bulk deformation process to obtain the accurate final shape of the work part. And the process is performed using a single point or multi point cutting tool.

The very ancient tool, also known as Mother of Machine tools and the one which played crucial role in industrial revolution is Lathe. The origin of lathe dates to 1300 BC in Egypt. Evolution of lathe started from two-person lathe. Then, spring pole lathe came into existence before 20th century, where a pedal is used for rotating the workpiece. Almost in every industry, lathe has its unique application and importance. Lathe machine works on the principle of producing product of desired shape by removing material from the rotating workpiece in the form of chips. And a wide range of operations can be performed on lathe using different tools and attachments.

PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. Define metal cutting, machine tool and machinability.

Answer :

Metal Cutting

It is defined as a process of removing the excess material from the workpiece, in the form of chips with the help of a wedge-shaped device called cutting tool. Metal removal takes place, due to the relative motion between the workpiece and sharp edge of the cutting tool.

Machine Tool

A machine tool is a power driven machine used for removing the excess material from the workpiece to obtain required shape or form or finish with the help of cutting tool.

Machinability

Machinability is the characteristic of the workpiece material, which describes the ease with which it can be machined. A material having high machinability, can be machined at a faster rate with good surface finish and at low cost. The machinability of tool materials, process parameters, etc., are influenced by material properties such as hardness, strength, composition, etc.

Q2. List the physical functions of a machine tool in machining.

Answer :

Functions of Machine Tool

1. It holds and guides the workpiece.
2. It transmits required motions (feed, depth of cut) to facilitate cutting action.
3. It drives and directs the cutting tool.
4. It transmits the required power from prime mover to cutting plane.
5. It provides passage for cutting fluids.
6. It transmits vibrations and forces to ground.

Q3. What is the essential criteria for a cutting tool to give maximum production with minimum maintenance and trouble?

Answer :

The following are the pre-requisites or essential criterion of a good cutting tool to give maximum production with minimum maintenance and trouble.

1. The cutting tool should have sufficient strength to maintain sharp edge during machining operation.
2. The cutting tool should have sufficient resistance to resist the wear of cutting edge.
3. The tool should possess sufficient hardness so that the chips will not damage the surface of the tool.
4. The tool material should be selected correctly, based on the workpiece material, i.e., it should not react with the workpiece material.
5. The tool should be heat treated properly, so that it will have good mechanical and technological properties.
6. The tool should be designed accurately to meet the basic requirements.

Q4. Describe the basic elements of machining.

Answer : [Nov./Dec.-17, (R15), Q1(a) | Model Paper-I, Q1(a)]

The basic elements of machining are as follows,

(i) Workpiece

(ii) Tool

(iii) Chips.

Q5. What are the methods of metal cutting.

Answer :

There are two basic methods of metal cutting using a single point cutting tool. They are,

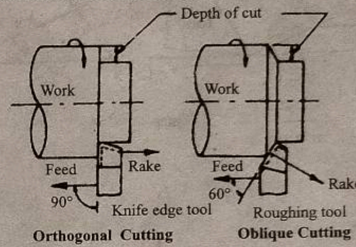
1. Orthogonal cutting
2. Oblique cutting.

1. Orthogonal Cutting

If the cutting face or edge of the tool is perpendicular (90°) to the direction of tool travel, (i.e., direction of velocity), that cutting operation is called orthogonal cutting.

2. Oblique Cutting

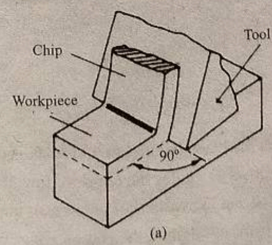
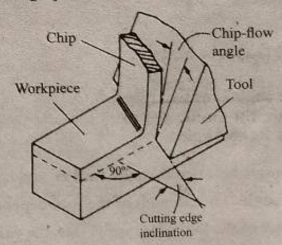
Oblique cutting takes place, when the cutting edge of the tool is inclined at an angle less than 90° to the cutting direction. It is also called as three dimensional cutting. The width of the tool may or may not be more than that of the workpiece. The cutting forces acts on a larger area. Hence, the tool life is more.



Figure

Q6. Distinguish between orthogonal cutting and oblique cutting?

Answer : [May/June-19, (R16), Q1(b) | Model Paper-II, Q1(a)]

	Orthogonal Cutting		Oblique Cutting
1.	The cutting edge of the tool is perpendicular to the cutting direction.	1.	The cutting edge of the tool is inclined at an angle less than 90° to the cutting direction.
2.	It is also called as two-dimensional cutting.	2.	It is also called as three-dimensional cutting.
3.	The cutting edge of the tool is wider than that of the workpiece.	3.	The cutting edge of the tool may or may not be wider than that of the workpiece.
4.	The cutting force acts on smaller area. Hence, the heat developed per unit area due to friction along the tool work interface is more and the tool life is less.	4.	For same feed and depth of cut, cutting force acts on larger area. Hence, the heat developed per unit area due to friction along the tool-work interface is less and the tool life is more.
5.	The chip flow is perpendicular to the cutting edge.	5.	The chip flows on to the tool face making an angle.
6.	This method of cutting is used in parting off in lathe, broaching and slotting operations.	6.	This method of cutting is used in almost all machining operations.
	 (a) Figure (1): Orthogonal Cutting		 (b) Figure (2): Oblique Cutting

Q7. What is the relation between velocities of orthogonal cutting?

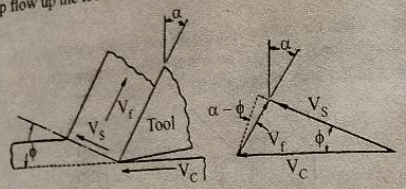
Answer :

The velocities in orthogonal cutting are,

V_S – Shear velocity

V_C – Cutting velocity

V_f – Velocity of chip flow up the tool face.



Figure

From the above figure,

$$V_S = V_C \frac{\cos\alpha}{\cos(\phi-\alpha)}$$

$$V_f = V_C \frac{\sin\phi}{\cos(\phi-\alpha)}$$

Where,

α – Rake angle

φ – Shear angle

Since, chip thickness ratio, $r = \frac{\cos(\phi-\alpha)}{\sin\phi}$

$$\therefore V_f = \frac{V_C}{r}$$

From principle of kinematics, the vector difference between the velocities with reference to the workpiece (reference body) is equal to the relative velocity of two bodies.

$$V_C = V_S + V_f$$

Q8. How can tool rake angle and clearance angle defined?

Nov./Dec.-18, (R16), Q1(b)

Answer:

Tool Rake Angle

Rake angle is of two types.

1. **Back Rake Angle**

The angle between the rake surface and base of the tool and measured on the plane parallel to the shank is called as back rake angle. The strength of the tool depends on rake angle. This angle allows or guides the chips to flow plastically over the face of the tool. Because of this, the chip pressure on the face is reduced and increases the keenness of the tool, thereby decreasing the power required for cutting. Greater the rake angle, lower is the strength of the cutting edge. Thus, tools for cutting soft metals has larger rake angle and that for cutting hard metals have a smaller rake angle.

2. **Side Rake Angle**

The angle between the rake surface and base of the tool and measured on the plane perpendicular to the shank is known as side rake angle.

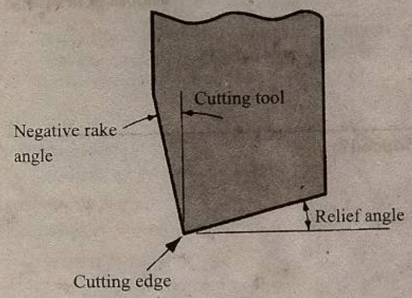
Clearance or End Relief Angle

It is the angle between the plane perpendicular to the base of the tool and the front portion of the tool. It allows the tool to cut freely, without any frictional drag of the tool on the workpiece and avoid the tool from rubbing on the surface of the workpiece which is already cut.

Q9. What is negative rake angle?

Answer :

A tool is said to have negative rake angle, when the tool face slopes away from the cutting edge and slants upwards towards the side or back of the tool as shown in below figure.



Figure

Negative rake angles are mostly used for carbide tipped tools. Negative rake angles are best suited for rough machining and intermittent cuts. It is also advantageous for machining hard and brittle materials such as titanium or stainless steel. In tougher metals, high amount of heat is absorbed by the carbide tipped tools.

Q10. Write the advantages of negative rake angle.

Answer :

Advantages of Negative Rake Angle

1. High cutting speeds can be obtained.
2. It enhances the life of cutting tool by the reduction in tool wear.
3. It offers more economical machining processes.
4. A larger tip angle is provided by the negative rake, which strengthens the cutting tool.
5. Rough, scaly and interrupted surfaces can be easily machined.
6. It minimizes the temperature at the tip of the tool, by transferring the heat to the chips.
7. The cutting tool absorbs the shock from the work piece through tool face rather than its tip or edges, which increases the life of the tool.

Q11. Explain the conditions favoring the use of negative back rake angle on a single point cutting tool.

Answer : [Dec.-19, (R16), Q1(a) | Model Paper-III, Q1(a)]

Conditions favouring the use of negative rake angle are as follows,

1. When more strength of the tool is required.
2. When the machining is done through intermittent cuts.
3. When the tool is subjected to impact loadings.
4. When machining involves in high cutting temperature.

Q12. Briefly discuss about tool signature with an example.

Answer : Nov.-10, Set-3, Q1(a)

Tool signature is a designation or a numerical method used to denote the principle tool angles of a signal point cutting tool.

The following are some of the standard systems used for tool designation,

1. American Standard Association (ASA) system
2. British system
3. Continental system
4. International system.

Example

A tool shape specified as per ASA system is given as,

8-14-6-6-20-15-4

The tool signature of above specified tool shape under ASA system is given as shown below,

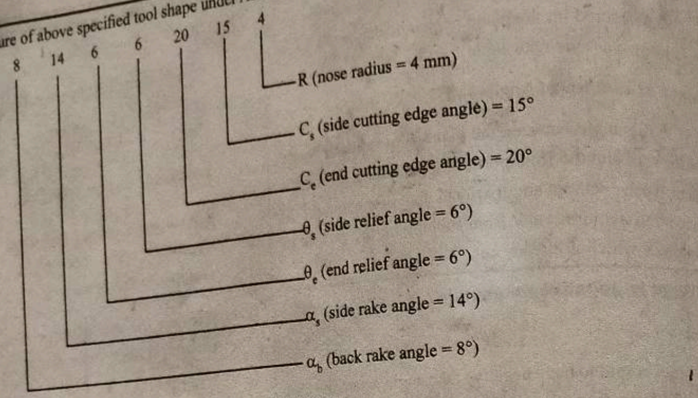


Figure: Tool Signature

Q13. What are the different types of Chips. Nov./Dec-18, (R16), Q1(a)

Answer:

Chips are broadly classified into three types. They are,

1. Discontinuous or segmental type
2. Continuous or ribbon type
3. Continuous with build-up edge.

Q14. What are the variables that influence the type of chip produced?

Answer :

The variables that influence the type of chip produced are,

1. Workpiece material
2. Material and geometry of cutting tool
3. Cutting speed, feed and depth
4. Machining environment or the type of cutting fluid which affects the temperature and friction generated at the chip-tool and work-tool interface.

Q15. What are the conditions that would allow a continuous chip to be formed in metal cutting?

Answer:

Conditions For Formation of Continuous Chips

1. High ductility of the material
2. High cutting speeds
3. Sharp cutting edge and large rake angle
4. Good lubricating system
5. Low feed and depth of cut.

Q16. Name the factors that contribute to the formation of segmental chips.

Answer:

Factors that Contribute to Segmental or Discontinuous Chip Formation

1. High brittle nature of the work material
2. Small rake angle
3. Lower cutting speed
4. Large feed and greater depth of cut.

Q17. How does a build up edge is formed? Explain its effects.

Answer : Nov./Dec.-17, (R15), Q1(b)

Formation of Build-up Edge

While machining ductile materials at low cutting speeds, the friction at chip-tool interface increases and results in localised welding, i.e., chip adheres to the rake surface.

This extra metal welded to the tip of the tool is called built-up edge, which acts as a cutting edge in place of actual cutting tip.

Effects

(i) It changes the rake angle and increases the cutting force and power consumption for producing same work without BUE.

(ii) It also reduces the finishing of the surface of metal and forms rough surface.

(iii) Tool life gets reduced.

Repeated formation and dislodgement of BUE leads to fluctuation in cutting forces and induce vibrations which are harmful for the tool, workpiece and machine tool.

Q18. Draw the schematic diagram illustrating the characteristics of Built-up Edge (BUE) formation in the machining process.

OR

Mention the conditions that induces the formation of Built up edge.

Answer:

Conditions For Formation of Built up Edge

1. Small rake angle
2. Less supply of cutting fluid
3. High feed to the work material
4. Low cutting speed
5. Large depth of cut.

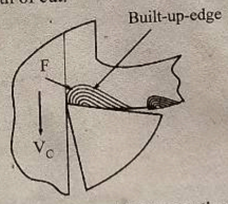


Figure: Scheme of BUE Formation

Q19. How the formation of built-up edge is avoided?

Answer :

The formation of build-up edge is avoided by,

(i) Increasing the cutting speed.
(ii) Decreasing the feed rates.
(iii) Increasing the tool rake angle.
(iv) Reducing the friction by applying coolant.
(v) Increasing the surrounding temperature of workpiece.

Q20. What is a lathe, what are the types of lathe.

Answer : [Nov./Dec-17, (R15), Q1(c) | Model Paper-I, Q1(b)]

Lathe was introduced by a British inventor, Henry Mauldsay in the year 1800. It is considered as the father of machine tools. The main function of the lathe is to remove the metal from the workpiece to give it the required shape and size. The principle of the lathe is to produce cylindrical surfaces by removing the unwanted material from a rotating workpiece in the form of chips. This can be achieved by moving the tool against the rotating work (depth of cut) and then moving the tool across the work (feed).

The different types of lathes are,

1. Bench lathe
2. Speed lathe
3. Engine lathe
4. Tool room lathe
5. Capstan and turret lathes
6. Automatic lathes
7. Special purpose lathes.

Q21. What are the basic parts of an engine lathe? Why are engine lathes called by that name?

Answer :

The basic parts of an engine lathe are,

1. Bed
2. Headstock
3. Tailstock
4. Feed shaft and lead screw mechanism.

This lathe is called as Engine Lathe, since it was driven by steam engine during early days of its development.

Q22. Why two sets of guideways are required in lathe machine.

Answer :

Guideways are machined on top surface of lathe bed, which supports all the other parts of the machine. Two sets of guideways namely inner ways and outer ways are provided. Inner ways acts as rails and support for tailstock and outer ways for the carriage. Thus, two sets of guideways and required in lathe machine.

Q23. Mention the uses of tailstock.

Answer :

Tailstock is one of the important part of lathe machine. It is also known as loose headstock. It is usually located at the right end of the machine bed. It is mainly used for,

1. Holding one end of the workpiece, while its other end is being machined.
2. For holding different tools such as drill tool, knurl tool, tap tool etc.
3. For performing various operations such as drilling, threading, centering, reaming and tapping.

Q24. What are chucks? Differentiate between independent and universal holding chuck.

Answer :

Chuck is a device used for holding the work effectively on the lathe during operation.

	Independent Chuck		Universal Chuck
1.	It consists of four jaws.	1.	It consists of three jaws.
2.	All the jaws of an independent chuck should be adjusted individually.	2.	By adjusting a single jaw, all the jaws moves simultaneously.
3.	Irregular jobs can be held effectively in this chuck.	3.	It is difficult to hold irregular jobs in this chuck.
4.	Setting time required is more.	4.	Setting time required is less.
5.	It is more reliable.	5.	It is less reliable.

Q25. What is face plate? Where will you prefer its use and why? Nov./Dec.-16, (R13), Q5(a)

Answer :

Face plate is a circular cast iron disc, which has a threaded hole at its centre so that it can be screwed to the threaded nose of the spindle. It consists of a number of holes and slots, which are useful for securing the workpiece firmly. It also requires bolts, nuts, washers, clamping plates and metallic pieces, etc., to hold the workpiece properly on the face plate. The below figure represents the structure of faceplate.

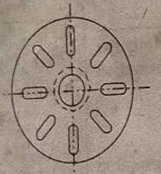


Figure: Face Plate

Uses of Face Plate

1. Face plate is preferred when the component is of irregular shape, large and difficult to be held by the work holding devices such as three jaw and four jaw checks.
2. It is also used to machine a hole in the square block.

Q26. What are the different types of operations done on a lathe?

Answer :

The different types of operations performed on a lathe machine are as follows,

1. Facing
2. Plain turning
3. Step turning
4. Taper turning
5. Drilling
6. Boring
7. Reaming
8. Threading
9. Undercutting or grooving
10. Knurling
11. Forming
12. Chamfering
13. Parting-off.

Q27. How do you specify a Engine Lathe?

Answer : May/June-19, (R16), Q1(a)

1. The height of the centres
2. Maximum swing over the bed
3. Maximum swing over the carriage
4. Maximum swing over the gap
5. Distance between the centres
6. Length of the bed
7. Maximum diameter

Q28. What is taper.

Answer :

It is defined as the uniform change (increase or decrease) in diameter of workpiece, measured along its length.

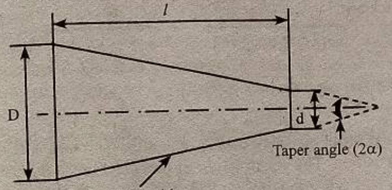


Figure: Taper

Taper angle is given as,

$$\tan \alpha = \frac{D-d}{2l}$$

$$\alpha = \tan^{-1}\left(\frac{D-d}{2l}\right)$$

Where,

D – Larger diameter

d – Smaller diameter

l – Length of the taper

α – Half taper angle.

Q29. Name the methods of taper turning on lathe.

Answer :

The various methods of taper turning are listed as follows,

1. Taper turning by compound rest method
2. Taper turning by tailstock set over method
3. Taper turning by form tool method
4. Taper turning by taper attachment method
5. Taper turning by combination of longitudinal and cross feeds.

Q30. With the help of suitable sketches describe the taper turning by combining longitudinal feed and cross fed.

Answer :

Taper Turning by Combining Longitudinal and Cross Feed

In this method of taper turning, both longitudinal and cross feeds are provided simultaneously. This results in the diagonal motion of the tool. The angle of the diagonal motion can be controlled by the varying rate of either crossfeed or longitudinal feed or both. This can be achieved by altering the gear ratios inside the apron.

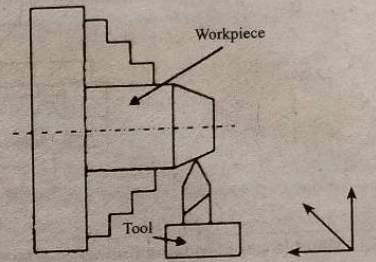


Figure: Taper Turning by Combining Feeds

Q31. List out various types of Lathe attachment explain any one.

[Nov./Dec-17, (R15), Q1(d) | Model Paper-II, Q1(b)]

OR

Discuss about attachment of lathe.

Answer : Nov.-15, (R13), Q1(c)

The attachment is an auxiliary system employed on the lathe, to increase the efficiency and rate of production of the lathe machine, and is also used to perform special operations like milling, taper turning, etc., that are not performed by the conventional lathe machine. The commonly used lathe attachments are,

1. Stops
2. Milling attachment
3. Grinding attachment
4. Taper-turning attachment
5. Copying attachment
6. Relieving attachment

Milling Attachment

The tool holder of the lathe machine is replaced by a milling attachment to perform various milling operations. It consists of a spindle and base. The base is fastened to saddle and milling cutters are mounted in spindle. Milling attachment can also be mounted on the lower side of compound rest. The workpiece is held between two centres of lathe. The cutter, in rotating motion is fed into stationary work piece. The movement of cutter is obtained by raddle movement. The various milling operations that can be performed are face milling, slot cutting, dovetail milling etc. Indexing of job can be obtained by dividing head.

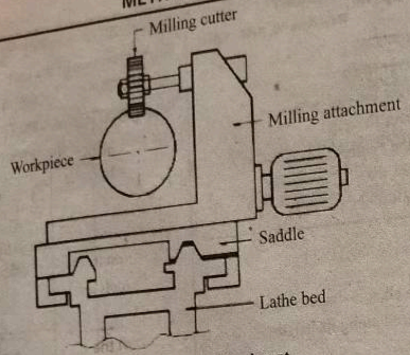


Figure: Milling Attachment

Q32. What is capstan lathe and write about turret saddle?

Answer :

Capstan Lathe

Capstan Lathe is a ram type turret lathe which has an hexagonal turret mounted on the ram slide. The ram is supported by the turret saddle which can be clamped on the bed at any desired position. The construction of this machine is lighter and is suitable for machining of small diameter bars. Stroke of turret usually depends upon the length of the ram. In this machine, four tools can be mounted on square tool post, along with six tools on the hexagonal turret. The main parts of the capstan lathe are bed, head stock, turret saddle, cross slide and carriage.

Turret Saddle

Turret saddle replaces the tail stock in centre lathe, and is mounted on the same side on the lathe bed similar to tail stock in centre lathe. The turret saddle supports the ram on which hexagonal turret is mounted. It can be moved over the bed and clamped at any desired position.

Q33. What are the main parts Capstan and Turret lathes? Nov.-15, (R13), Q1(d)

Answer :

Main parts of capstan and turret lathe are as follows,

1. Bed
2. Head stock
3. Turret saddle
4. Turret
5. Carriage
6. Legs.

Q34. What are the attachments used commonly on capstan and turret lathes? Nov./Dec.-16, (R13), Q1(d)

Answer :

The various attachments that are used on turret and capstan lathe are as follows,

1. Pilot bar
2. Multiple turning head
3. Cutter holders
4. Taper attachment
5. Adjustable slide tool
6. Screw cutting self opening die head.

Q35. Differentiate between capstan and turret lathe. Dec.-19, (R16), Q1(b)

Answer :

	Turret Lathe		Capstan Lathe
1.	The turret is mounted on a saddle which slides directly on the bed.	1.	The turret is mounted on a short slide or ram which slides on the saddle.
2.	The turret can be moved over the entire length of the bed and can machine longer workpieces.	2.	It is difficult to move turret over entire length of bed.
3.	As the saddle is directly mounted on to the lathe bed, it provides high rigidity to the tool support.	3.	As the ram feeds into the work, the over hanging of ram results in a less rigid construction.
4.	The entire saddle is to be moved for feeding the tools.	4.	The tools are fed by moving slide on the saddle.

Q36. What is an automatic machine? State the factors which effect the classification of automatic machines. [Dec.-19, (R16), Q2(b) | Nov.-10, Set-1, Q4(a) | Model Paper-III, Q1(b)]

Answer :

A machine, in which the handling of workpiece and the metal cutting operations are automatically performed without much attention of operator is known as automatic machine.

In these machines, all operations starting from feeding of stock/material to clamping, machining and the inspection of the workpiece are carried out automatically without the intervention of human activity.

The factors that effect the classification of automatic machines are as follows,

1. Size of the machine
2. Processing capacity (different operations performed)
3. Accuracy of machining
4. Design characteristics
5. Principle of operation
6. Type of operation performed
7. Type of feed control
8. Type of blank to be machined
9. Number of spindles
10. Position of work and spindles, etc.

Q37. What are the different types of automatic machines? Explain. Nov.-10, Set-1, Q4(b)

Answer :

The automatic machines are mainly classified into three categories. They are,

1. Magazine loaded automatic machines
2. Automatic bar machines.
3. Automatic transfer machines.

1. **Magazine Loaded Automatic Machines**

   These machines are used for producing required parts from the work pieces which are in the form of blanks. These blanks are pre-machined to appropriate dimensions before feeding to these machines. These machines are also called as automatic checking machines.

2. **Automatic Bar Machines**

   These machines are used for machining workpieces from bar or pipe stock. These are used for manufacturing high quality fasteners such as screws and nuts, bushings, shafts, rings, rollers, handles which are generally made of bar or pipe stock. These machines are further classified as follows,

   (i) Single spindle automatic machines
   - (a) Automatic cutting off machines
   - (b) Automatic screw machines.

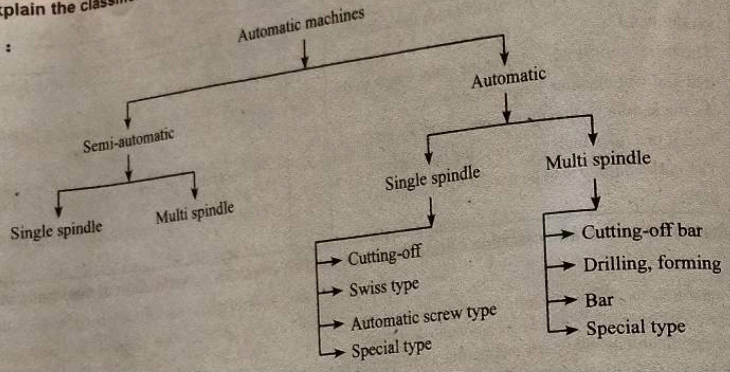
   (ii) Multiple spindle machines

3. **Automatic Transfer Machines**

   These machines are used for carrying out a number of operations on semi-finished components. These machines consist of a number of tool stations or tool positions, which are arranged in a straight line. The sequence of tool stations can be adjusted according to the requirements of part produced.

Q38. Explain the classification of automatic lathes.

Answer :



Figure

Q39. Give a sketch illustrating the principle of operation of Swiss type automatic lathe.

Answer :

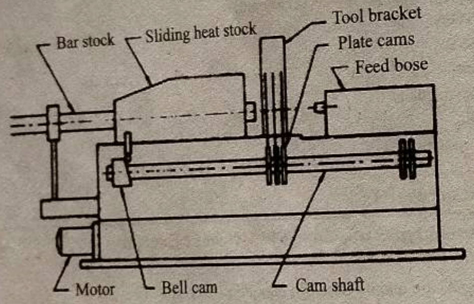


Figure: Swiss Type Automatic Lathe

Q40. Write the advantages of automats over convectional lathes.

Answer :

The advantages of automats over conventional lathes are as follows,

1. The cost of maintenance and production is low.
2. Skilled operator is not required, since the entire operation is automatic.
3. It is provided with upto five radial tool slides, which are moved by cams.
4. It is used for small identical jobs and for mass production.
5. It occupies less space.

PART-B ESSAY QUESTIONS WITH SOLUTIONS

1.1 METAL CUTTING

1.1.1 Introduction – Elements of Cutting Process

Q41. Explain different processes available for shaping the metal into required form.

Answer :

In engineering industry, different components are manufactured with different metals of various shapes, sizes and dimensions. The methods available for shaping the metal into required form are categorised into two types,

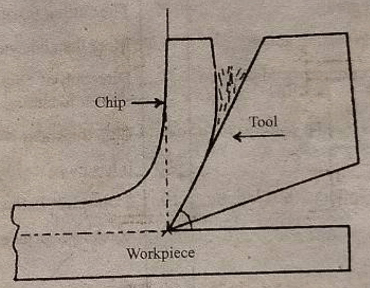
1. **Cutting Shaping Method**
   In this method, the required shape of components is obtained by removing undesired material from the workpiece. This method includes operations such as turning, boring, milling, drilling, shaping, broaching, etc. These operations are known as machining or metal cutting operations.
2. **Non-cutting Shaping Method**
   In this method, the required shape of metal is obtained by the action of heat, pressure or the combination of two. Operations such as forging, drawing, spinning, rolling, extruding, etc., comes under this category.

Q42. With a neat sketch, explain the basic elements of any machining operation.

OR

Describe basic requirements of machining.

Answer : [Nov.-15, (R13), Q2(a) | Model Paper-I, Q2(a)]



Figure

The basic elements of machining operation are as follows,

1. Workpiece
2. Tool
3. Chips

1. **Workpiece**
   Workpiece is a parent metal, from which the unwanted or excess metal is removed by different machining operations to obtain the required shape and size of the component.
   The chemical composition and the physical properties of the metal workpiece has the significant effect on the machining operation.
2. **Tool (Including Holding Devices)**
   Cutting tool is an important element of metal cutting which removes the unwanted metal from the workpiece. A relative motion between tool and workpiece is provided for cutting action, which may be either
   (a) By keeping the workpiece stationary and moving the tool or
   (b) By keeping the tool stationary and moving the workpiece or
   (c) By the relative motion of both workpiece and tool.
   The tool material and geometry of tool effects the performance of machining operation.

3. **Chips**

Chips are the removed unwanted material from the workpiece or parent metal. Based on the type of material of workpiece, geometry of cutting tool, method of cutting, etc., the different types of chips are produced, such as continuous chips and discontinuous chips.

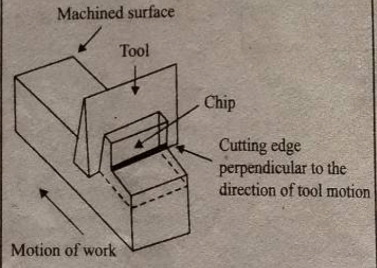
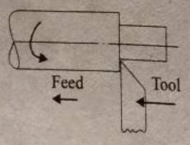
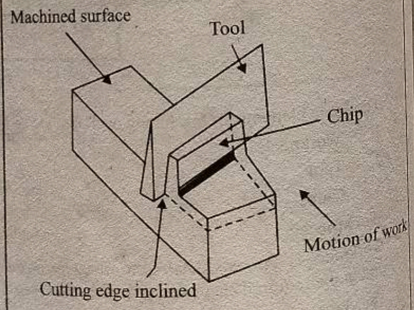
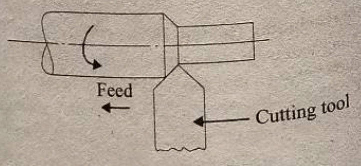
Q43. List the various methods of metal cutting using single point cutting tool. And state the differences between them.

Answer :

The various methods of metal cutting using a single point cutting tool are,

1. Orthogonal cutting
2. Oblique cutting.

Differences Between Orthogonal Cutting and Oblique Cutting

	Orthogonal Cutting		Oblique Cutting
1.	It takes place, when the cutting edge of the tool is perpendicular to the cutting direction.	1.	It takes place, when the tool cutting edge is inclined at an angle less then 90° to the cutting direction.
2.	Two mutually perpendicular forces act on the tool.	2.	Three mutually perpendicular forces act on the tool.
3.	It is also called as two-dimensional cutting process.	3.	It is also known as three dimensional cutting process.
4.	The width of the tool is more than the workpiece width.	4.	The width of the tool may or may not be more than that of workpiece.
5.	The cutting forces act on a small area.	5.	The cutting forces act on large area.
6.	Only one cutting edge involves in cutting action.	6.	More than one cutting edges performs the action.
7.	Chip flow velocity is in the direction perpendicular to cutting edge.	7.	Direction of chip flow velocity makes an angle with normal to cutting edge.
8.	Chip thickness is maximum at its middle portion.	8.	Chip thickness is not maximum at its middle portion.
9.	It has less tool life.	9.	It has more tool life.
10.	**Examples:** Sawing, Broaching, Slotting, Knife turning.	10.	**Examples:** Lathe tools, milling cutting, drills.
	 Figure (1): 3D View  Figure (2): 2D View		 Figure (1): 3D View  Figure (2): 2D View

Q44. Classify the cutting tools with brief description.

May/June-12, Set-4, Q6(b)

Answer :

Classifications of Cutting Tools

1. **According to the Number of Cutting Edges**
   (a) Single point cutting tool
      (i) Ground type
      (ii) Tipped type
      (iii) Forged type
      (iv) Bit type
   (b) Multi point cutting tool
      (i) Solid tool
      (ii) Inserted bit tool
      (iii) Brazed tool
2. **According to the Tool Motion**
   (a) Linear tools
   Example: Shaping tool, broaching tools, lathe tools, etc.
   (b) Rotary tools
   Example: End mill cutter and grinding wheel
   (c) Combined linear and rotary motion tools
   Example: Honing tools, drill bits, etc.

1.1.2 Geometry of Single Point Cutting Tools – Chip Formation and Types of Chips

Q45. Briefly discuss about Geometry of single point cutting tool? Also, explain the following; (i) Rake angle (ii) Clearance angle (iii) Cutting angle (iv) Lip angle, with neat sketch.

Dec.-19, (R16), Q3(a)

OR

Explain importance and functions of different tool angles and other parameters associated with a single-point cutting tool.

Nov./Dec.-12, (R09), Q1(b)

OR

Explain with the help of neat sketch the complete geometry of a single point cutting tool.

[May/June-12, Set-3, Q5(b) | Model Paper-II, Q2(a)]

Answer :

Cutting tool is used to remove the material on the workpiece to obtain the required shape. It consists of sharp cutting edges to accomplish the cutting action. It is placed rigidly on the machine and does not provide any motion for cutting.

Various elements of a single point cutting tool are,

1. Back rake angle
2. Side rake angle
3. Clearance or End Relief angle
4. Side Relief angle
5. End cutting edge angle
6. Side cutting edge angle
7. Lip angle
8. Nose radius.

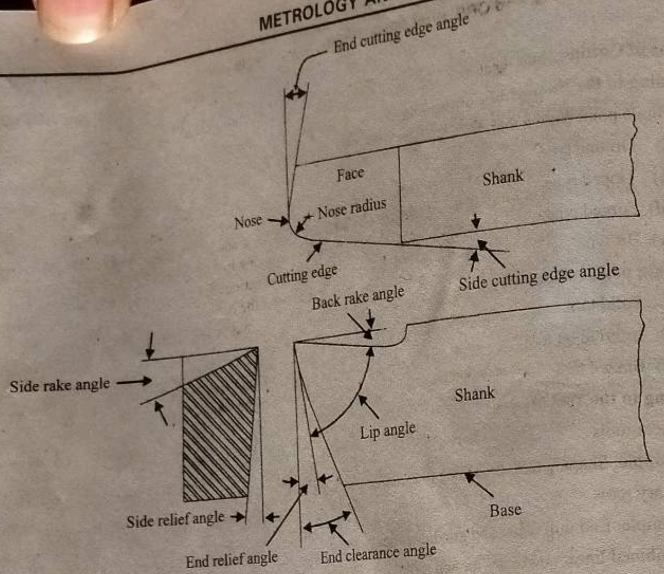


Figure: Nomenclature of Single Point Cutting Tool

1. **Back Rake Angle:** The angle between the rake surface and base of the tool and measured on the plane parallel to the shank is called as back rake angle. The strength of the tool depends on rake angle. This angle allows or guides the chips to flow plastically over the face of the tool. Because of this, the chip pressure on the face is reduced and increases the keenness of the tool, thereby decreasing the power required for cutting. Greater the rake angle, lower is the strength of the cutting edge. Thus, tools for cutting soft metals has larger rake angle and that for cutting hard metals have a smaller rake angle.

2. **Side Rake Angle:** The angle between the rake surface and base of the tool and measured on the plane perpendicular to the shank is known as side rake angle.

3. **Clearance or End Relief Angle:** It is the angle between the plane perpendicular to the base of the tool and the front portion of the tool. It allows the tool to cut freely, without any frictional drag of the tool on the workpiece and avoid the tool from rubbing on the surface of the workpiece which is already cut.

4. **Side Clearance or Relief Angle:** It is the angle between the plane perpendicular to the base and side flank. It directs the cutting force to the metal area, which is adjacent to the cutting edge.

5. **End Cutting Edge Angle:** It is the angle between the end cutting edge and a line perpendicular to the shank of the tool. The function of this angle is to prevent the front edge of the tool from rubbing against the workpiece. A larger value of this angle weakens the tool. This angle ranges from 8° to 15°.

6. **Side Cutting Edge Angle:** It is the angle between straight cutting edge on the side of the tool and the side of the shank of the tool. This angle varies from 0° to 90°. Generally, the value its about 15°. Increasing this angle leads to the following
   - (i) Increases the tool life, as for the same depth of cut the cutting thrust is distributed over the greater surface
   - (ii) Improves surface finish.
   - (iii) Dissipates heat quickly.
   - (iv) Reduces the chip thickness.

7. **Lip Angle:** It is the angle between the face of the tool and the ground end surface of the flank. It is also called as metal cutting angle or angle of keenness. The strength of cutting point of the tool is directly affected by this angle, i.e., higher the lip angle stronger the cutting edge or point and vice versa. This angle varies inversely with rake angle. The tools used for machining hard metals are provided with large lip angle and for machining soft metals small lip angle is provided.

8. **Nose Radius:** it is the radius of rounding provided at the tip of the cutting tool.

Q46. Compare ASA system and ORS system in designating a single point cutting tool?

Answer : May/June-19, (R16), Q2(b)

Tool nomenclature is the designation of the cutting tool angles with respect to set to planes and axes and it is designated by following two systems,

1. American Standards Association System (ASA)
2. Orthogonal Rake System (ORS).

1. **American Standards Association System (ASA):** This system is also known as coordinate system of tool nomenclature, as the reference planes used for designating the tool angles are X-X, Y-Y and Z-Z. In this system, the tool face angles are defined in two orthogonal planes, one parallel to the axis of cutting tool and the other being perpendicular. The plane Z-Z contains the base of the cutting tool. This system defines various angles such as side rake, back rake, side cutting edge, end cutting edge, etc. But, gives no information about the cutting tool behaviour and the flow of chip, during cutting operation. The various angles designated by this system is shown in figure (1).

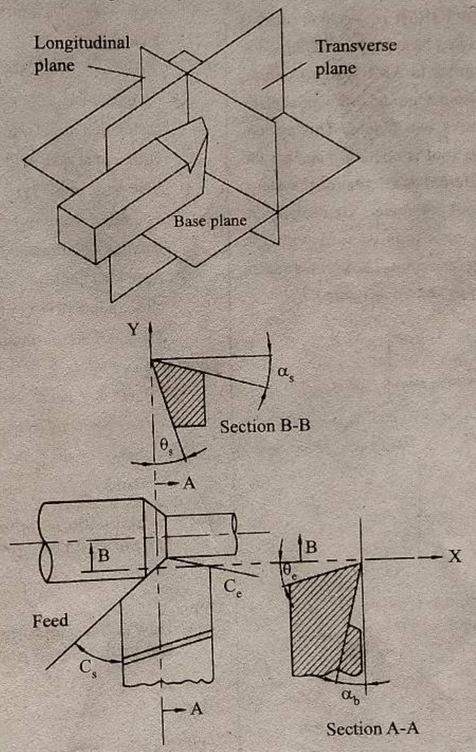


Figure (1)

Where,

- α_s – Side rake angle
- α_b – Back rake angle
- θ_e – End relief angle
- θ_s – Side relief angle
- C_e – End cutting edge angle
- C_s – Side cutting edge angle.

Example

A tool with 8, 10, 5, 6, 5, 9, 2 signature in ASA system is designated as,

Back rake $(\alpha_b) = 8°$

Side rake $(\alpha_s) = 10°$

End relief angle $(\theta_e) = 5°$

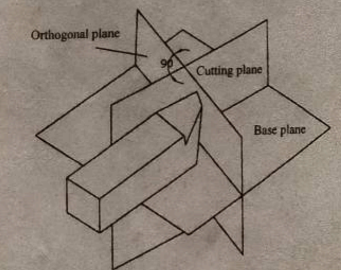
Side relief angle $(\theta_s) = 6°$

End cutting edge angle $(C_e) = 5°$

Side cutting edge angle $(C_s) = 9°$

Nose radius $(R) = 2$ mm.

2. **Orthogonal Rake System (ORS):** This system consists of three reference planes i.e., base plane containing the base of cutting tool (similar to ASA system) cutting plane is parallel to the cutting edge and orthogonal plane perpendicular to the above two planes. This system considers that the cutting tool is operating against the work piece and is also referred as international system. In this system, various tool parameters are designated, which are effected by positions of tool with the workpiece, during cutting operation. The various angles designated by this system is shown in figure (2).



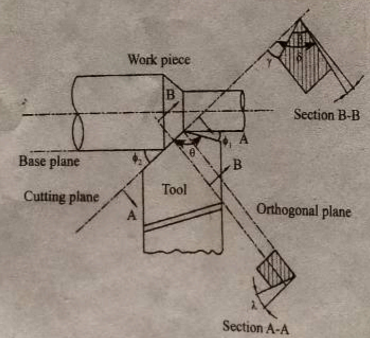


Figure (2): Designation of various angles by ORS system

Where,

α – Orthogonal rake angle

β – Wedge angle

γ – Side relief angle

δ – Cutting angle $(\alpha + \beta)$

α_1 – Side rake angle

β_1 – Side wedge angle

γ_1 – End relief angle

λ – Angle of inclination

ϕ_0 – Approach angle

ϕ_1 – Auxiliary cutting edge angle.

Example

A tool with 0-9-5-5-8-90°-2 signature in ORS system is designated as,

Inclination angle $(\lambda) = 0°$

Orthogonal rake angle $(\alpha) = 9°$

Side relief angle $(\gamma) = 5°$

End relief angle $(\gamma_1) = 5°$

Auxiliary cutting angle $(\phi_1) = 8°$

Approach angle $(\phi_0) = 90°$

Nose radius $(R) = 2$ m.

The interrelationship between ASA and ORS systems is given as,

$$\tan \alpha = \tan \alpha_s \sin \phi_0 + \tan \alpha_b \cos \phi_0$$

$$\tan \alpha_b = \cos \phi_0 \tan \alpha + \sin \phi_0 \tan \lambda$$

$$\tan \alpha_s = \sin \phi_0 \tan \alpha - \cos \phi_0 \tan \lambda$$

$$\tan \lambda = \tan \alpha_b \sin \phi_0 - \sin \alpha_s \cos \phi_0$$

Q47. Explain the geometry of chip formation with proper sketches and equations.

Dec.-19, (R16), Q2(a)

OR

How is the chip formed in metal cutting? Explain the terms Shear plane and Shear Zone.

Nov./Dec.-16, (R13), Q3(b)

OR

Explain the mechanism of chip formation in metal cutting with a neat sketch.

Answer : Nov./Dec.-13, (R09), Q1(a)

Machining is a finishing or semi-finishing process and is defined as the process of removing the excess material from the workpiece in the form of chips to provide proper shape, dimensional accuracy and surface finish. The knowledge regarding how a chip is formed will help in determining the characteristics and form (shape) of chips.

Mechanism of Chip Formation

Consider a workpiece moving towards the stationary cutting tool as shown in the figure. When the work is forced into the tool, the region immediate to the tool will be compressed as a result, shear stresses are developed in various directions in that region (primary shear zone). On further forcing the work into the tool, the magnitude of shear stress increases and when it exceeds the ultimate shear strength of the work material, it gets yielded and deforms. Thus, results in the formation of the chip. The plane, where shear deformation takes place is termed as shear plane and the angle at which it is inclined to the work surface or work direction is called as the shear angle (ϕ). If it is small, thick chips are formed and vice – versa. And when the forcing of work into the tool is continued, the length of the chip goes on increasing and moves along the rake surface of the tool. The lower surface of the chip is burnished and compressed, and the top surface is serrated due to shearing action. Apart from the primary shear zone, there is another shear zone at chip and tool surface interface. This region is formed due to friction generated due to movement of the chip over tool surface.

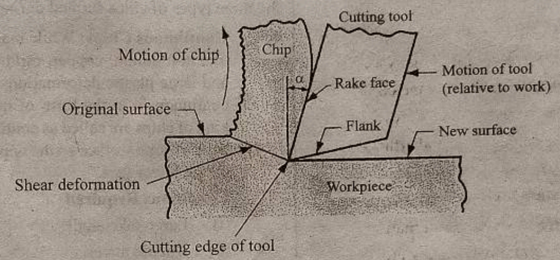


Figure: Mechanism of Chip Formation

Q48. Derive an expression to determine chip thickness ratio and shear angle?

May/June-19, (R16), Q2(a)

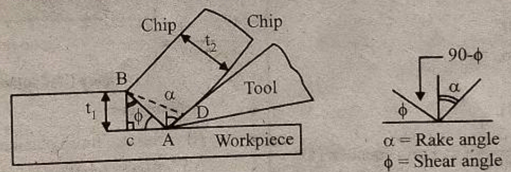
OR

Derive the expression for chip thickness ratio.

[Nov./Dec.-17, (R15), Q2(a) | Nov.-10, Set-1, Q3(a) | Model Paper-III, Q2(a)]

Answer :

During machining, certain depth of unit is given to the tool initially, this represents the thickness of chip before cut. The chip thickness after cutting is always greater than the chip thickness before cutting.



Figure

Let,

t_1 – Thickness of chip before cut

b_1 – Width of chip before cut

l_1 – Length of chip before cut

t_2 – Thickness of chip after cut

b_2 – Width of chip after cut

l_2 – Length of chip after cut

ϕ – Shear angle

α – Rake angle

Chip thickness ratio is given as, $r = \dfrac{t_1}{t_2}$ ... (1)

Where, $t_2 > t_1$.

Therefore, r is always less than one.

According to the equation of continuity, there is no change in volume of the metal, when it is cut.

i.e., Volume of metal before cut = Volume of metal after cut

$$t_1 b_1 l_1 = t_2 b_2 l_2$$

Assume that, there is no side flow of metal. Then,

$$b_1 = b_2$$

$$\therefore \quad t_1 l_1 = t_2 l_2$$

From figure,

Consider triangle ΔABC,

$$\sin\phi = \frac{BC}{AB}$$

$$AB = \frac{BC}{\sin\phi} = \frac{t_1}{\sin\phi} \quad \ldots (2)$$

Consider triangle ΔABD,

$$\sin(90 - \phi + \alpha) = \frac{BD}{AB}$$

$$AB = \frac{BD}{\sin(90 - \phi + \alpha)}$$

$$= \frac{t_2}{\sin(90 - (\phi - \alpha))}$$

$$= \frac{t_2}{\cos(\phi - \alpha)} \quad \ldots (3)$$

From equations (2) and (3),

$$\frac{t_1}{\sin\phi} = \frac{t_2}{\cos(\phi - \alpha)}$$

$\therefore$ Chip thickness ratio,

$$r = \frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi - \alpha)}$$

$$r = \frac{\sin\phi}{\cos\phi\cos\alpha + \sin\phi\sin\alpha} \quad (\because \text{From equation (1)})$$

$$r(\cos\phi\cos\alpha + \sin\phi\sin\alpha) = \sin\phi$$

$$\frac{r\cos\phi\cos\alpha}{\sin\phi} + \frac{r\sin\phi\sin\alpha}{\sin\phi} = 1$$

$$\frac{r\cos\alpha}{\tan\phi} + r\sin\alpha = 1$$

$$\frac{r\cos\alpha}{\tan\phi} = 1 - r\sin\alpha$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$$

$\therefore$ Shear angle,

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

Q49. How are the chips classified? Specify the condition under which they are formed.

OR

Explain different types of chips produced in cutting with neat sketches.

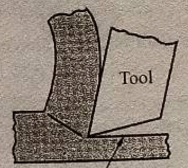
Answer :

In machining, the excess material is removed from the work in the form of chips. For a machinist, it is important to have an idea regarding various kinds of chips as they aid in predicting the conditions prevailing during machining. The following are the three types of chips formed during metal machining.

1. **Continuous Chips:** While machining ductile materials like aluminium, copper, mild steel, due to continuous and large plastic deformation, longer chips are formed continuously in the form of helical coils. Hence, this kind of chips are called as continuous chips. These chips have a rough surface on the upper face and shiny surface on the lower face.

Conditions Required

(i) Large rake angle
(ii) Ductile materials
(iii) High cutting speeds
(iv) Sharp cutting edge
(v) Proper application of lubricants
(vi) Low feed and depth of cut.



Good finish

Figure (1): Continuous Chips

Advantages

(i) Surface finish obtained is good.
(ii) Forces involved are stable. Therefore, vibrations are less.
(iii) High cutting speeds can be used.

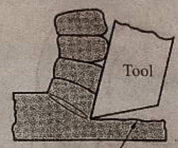
Disadvantages

(i) Difficult to collect, handle and disposal. Therefore, chip breakers are used.
(ii) These chips may entangle around the work or tool and sometimes may cause an accident to machinist due to its sudden fracture.

2. **Discontinuous or Segmental Chips:** While machining hard and brittle materials like bronze, brass, cast irons, etc., at low speeds, due to brittle nature of the work material, the chip gets fractured easily and results in the formation of small segments of chips. This kind of chips are termed as discontinuous or segmental chips.

Conditions Required

(i) Brittle materials
(ii) Small rake angle
(iii) Lower cutting speeds
(iv) Greater feed and depth of cut
(v) Inadequate usage of cutting fluids.



Irregular finish

Figure (2): Discontinuous Chips

Advantages

(i) Chips are in the form of small segments. Hence, friction at the chip-tool interface is low and good surface finish is obtained.
(ii) Easy to collect, handle, and dispose.

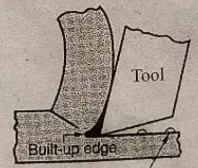
Disadvantages

(i) Forces are varied continuously while machining. This may result in vibration and chatter and to avoid this most rigid and stiff tool and work holders, clamps are required.

3. **Continuous Chips with Built-up Edge (BUE):** While machining ductile materials at low cutting speeds, the friction at chip-tool interface increases and result in localized welding i.e., chip adheres to the rake surface. This weldment on the tooltip is called as a built-up edge (BUE) and it starts growing in size. When the wedging force F increases, it breaks the BUE and is carried away with flowing chip. The formation and breaking of built-up edge is repeated.

Conditions Required

(i) Small rake angle
(ii) Improper application of cutting fluid
(iii) High feed
(iv) Large depth of cut.



Particle with BUE

Figure (3): Continuous Chips with BUE

Advantages

(i) In fewer cases, BUE may reduce the tool wear on the rake surface and increase the tool life. But, it is generally undesirable.

Disadvantages

(i) As some portion of BUE gets stuck on tool's rake surface, its geometry gets affected and results in the increased requirement of cutting forces and increased power consumption.
(ii) The repeated formation and separation of BUE leads to fluctuation in cutting forces and this further imparts vibration which is hazardous to the work, tool and the machine tool.
(iii) Poor surface finish is obtained on work.
(iv) Tool life gets reduced.

Q50. What factors are responsible for formation of these different types of chips?

Answer :

Following three types of chips are formed in metal cutting.

1. Continuous chips without Built-up edge.
2. Discontinuous or segmental chips.
3. Continuous with Built-up edge.

Factors Responsible for Formation of Different Types of Chips

The factors affecting chip formation are as follows,

1. **Velocity:** Velocity does not have any effect on the direction of flow of chip. When the velocity is low, discontinuous chips and the chips with built-up edge are formed. But, when the velocity is high, continuous chips are formed. However, the temperature at cutting point, varies directly in relation with the velocity.
2. **Material of Workpiece:** If the workpiece is made of ductile material, then continuous chips are produced and if it is made of brittle material, discontinuous chips are produced.
3. **Depth of Cut:** When the depth of cut is increased, there will be an increase in chip distortion. Also, there is a change in the direction of chip flow. This results in the development of built-up edge and reduction in surface finish.
4. **Tool Geometry:** When the positive rake angles are provided, the direction of chip flow will be away from the component, which prevents scratching of the machined surface. And, when the negative side rake angles are provided, the chips produced are of small size, which are easier to handle.

Q51. What are the problems due to continuous chip? Explain how these can be avoided.

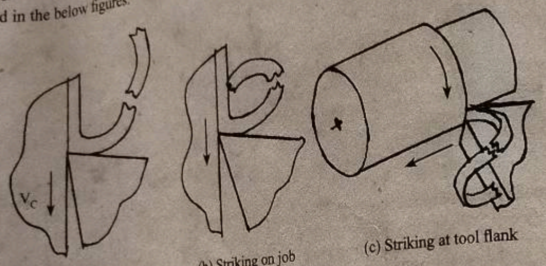
Answer :

In case of machining ductile materials, continuous chips are produced. These sharp-edged long chips may cause following problems,

1. Hazardous to the operator.
2. Disposal of long chips is difficult.
3. Long chips may entangle with the job or the tool and create rough surface and cutting resistance.

Hence in order to avoid these problems, chips are needed to be broken into small pieces. This is obtained by two methods.

1. **Self-breaking:** In oblique cutting, the chips get deviated and result in helical coiling of chips. These chips may break due to strain hardening followed by spring back effect. This effect is caused due to cooling after a certain time or due to the hitting of chips on the job's cutting surface or due to the hitting of chips on the flank of the cutting tool. These three cases are illustrated in the below figures.



(a) Natural (b) Striking on job (c) Striking at tool flank

Figure (1)

2. **Forced Chip Breaking:** In this kind, the tool is provided with special geometrical features or additional devices called chip breakers. There are three types of chip breakers based on the geometry or device added to the tool.

 (i) **Stepped Type:** In this kind, the tool is provided with a step on its rake surface as shown in the figure. When the chip hits the heel, it gets bent and results in breaking.

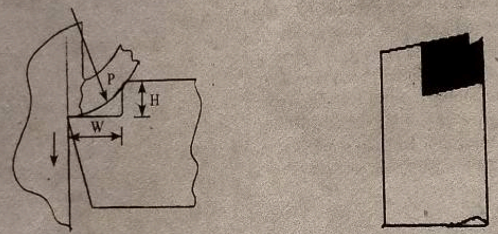


Figure (2)

 (ii) **Grooved Type:** This is similar to the stepped type but, instead of step a small groove is provided behind the cutting edge as shown in the figure.

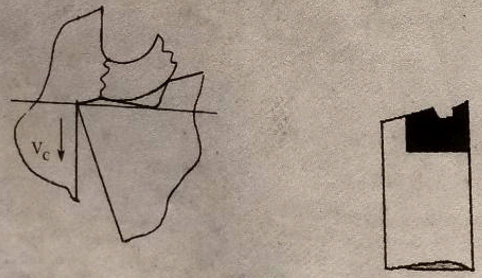


Figure (3)

 (iii) **Clamped Type:** In this kind, a thin carbide clamp or plate is fastened on the tool's face as shown in the figure.

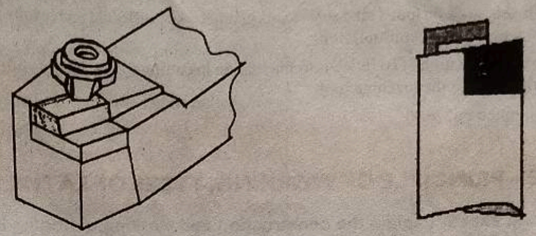


Figure (4)

Q52. What is meant by built-up edge? State the causes of it.

Nov./Dec.-13, (R09), Q1(b)

Answer :

While machining ductile materials such as steel, the chip flow over the rake surface increases i.e., the length for which the tool's surface and the chip are in contact increases. This leads to an increase in the magnitudes of stress and temperatures in secondary deformation zone. This results in local welding of the chip over the tool surface and this weldment on the tool tip is called as a built-up edge (BUE) and it starts growing in size. When the wedging force (F) increases, it breaks the BUE and is carried away with flowing chip. The major portion of the separated BUE is carried away by the flowing chip, while sometimes a small portion of the BUE may remain attached on the machined surface or tool tip and produce a poor surface finish. Then a new BUE is formed and eventually broken. This process of forming BUE is shown in figure (1). Usually, this BUE is observed in continuous machining of ductile materials with higher speeds and feeds.

Note:

In fewer cases, BUE may reduce the tool wear on the rake surface and increase the tool life.

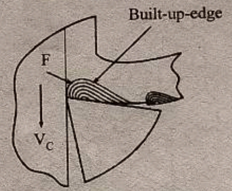
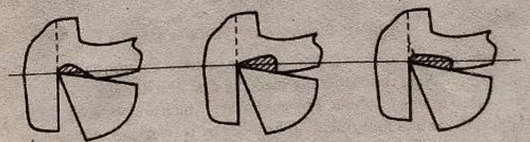


Figure (1): BUE Formation

There are three different shapes of BUE are formed based on the material of tool and work, feed, cutting velocities, application of cutting fluid. They are illustrated in the following figure.



(a) Positive wedge (b) Negative wedge (c) Flat type

Figure (2): Shapes of BUE

The major factors that are responsible for the formation of BUE are as follows,

1. Rake angle of the tool
2. Cutting speed and feed
3. Improper application of cutting fluid
4. Condition of the cutting tool.

Effects Caused by the Formation of BUE

1. As some portion of BUE gets stuck on tool's rake surface, its geometry gets affected and results in the increased requirement of cutting forces and increased power consumption.
2. The repeated formation and separation of BUE leads to fluctuation in cutting forces and this further imparts vibration which is hazardous to the work, tool and the machine tool.
3. Poor surface finish is obtained on work.
4. Tool life gets reduced.

1.2 ENGINE LATHE – PRINCIPLE OF WORKING, TYPES OF LATHE, SPECIFICATIONS

Q53. With the help of a neat sketch explain the construction and working of Engine lathe? May/June-19, (R16), Q3(b)

OR

Explain the construction and working principle of a lathe with neat sketch. Nov./Dec.-16, (R13), Q5(b)

OR

Explain with a neat sketch the working of an engine lathe. Nov./Dec.-12, (R09), Q2(b)

OR

Explain the various parts of lathe machine in detail, with neat sketches. [Dec.-11, Set-3, Q3 | Model Paper-I, Q2(b)]

Answer :

A schematic diagram of a lathe machine with various parts labelled is shown in figure(1). The basic parts of the lathe machine are as follows.

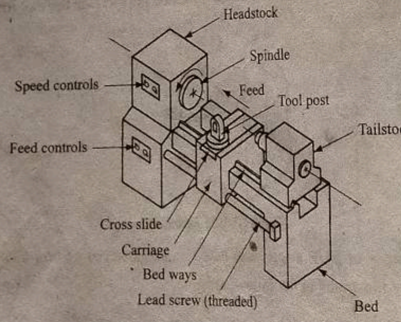


Figure (1): Constructional Features of Lathe

1. **Bed:** It is the base of the lathe located on the vertical columns (cabinet column and end column), upon which, all the other parts are mounted. It is a heavy single rigid structure made by cast iron through casting, having high damping capacity to absorb the vibrations generated by the machine. The guideways which are present on the top of the bed made of grey cast iron, act as rails and support the lateral movement of the other parts (carriage and tailstock). The accuracy of the machine depends upon the rigidity, alignment and accuracy of the lathe bed.

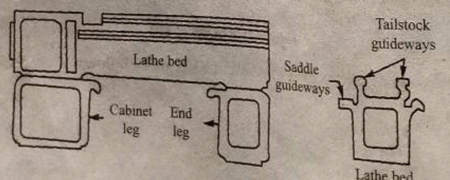


Figure (2)

2. **Headstock:** It is located on the left side of the lathe bed which is permanently mounted on inner guideways of the bed. It acts as a housing for hollow spindle and transmission mechanism consisting of the main spindle, feed reverse lever, live centre, cone pulley, etc. The tapered bar with a pointed end is used to grip the workpiece between the two centres of the lathe bed. The hollow spindle is made of nickel or carbon chrome steel. Holding centres and standard accessories with morse taper shank can be mounted on front end of the spindle. The accessories that can be mounted on the spindle are three jaw chuck, four jaw chuck, faceplate, lathe dog, etc.

3. **Tailstock:** It is located at the right side of the lathe bed and is a movable member that can slide on the guideways. It is mainly used for aligning and supporting the work with the headstock. The tailstock can be moved by either hand or wheel, depending upon the design parameters and requirements. The tailstock can also be used for performing some operations like drilling, tapping, etc.

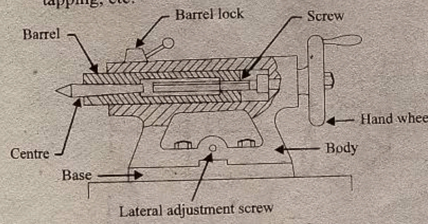


Figure (3)

4. **Carriage:** It controls the movement of cutting tools either parallel (or) perpendicular to the lathe axis. The carriage is located between headstock and tailstock, which slides along the bed ways of the lathe. Schematic diagram of the carriage is shown in figure (4). It holds the tool and provides feed for cutting operation. For turning the workpiece longitudinally, the normal feed is given whereas, for taper turning, cross feed is required. It consists of the following parts,

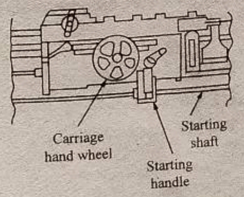


Figure (4)

(i) **Saddle:** It is an H shaped cas... k spindle ... fferent flat guideways on one side ... the lathe bed and another si... to support the remaining part... compound rest and tool post. T... saddle is to move along with the guide... lathe bed.

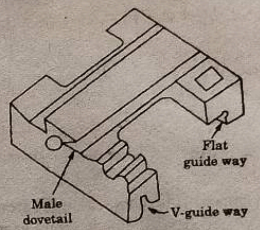


Figure (5)

(ii) **Cross Slide:** It is a casting provided with the female dovetail on one side such that it can be mounted on the saddle and another side with T slots in order to mount the tool post or coolant nozzle. The function of the cross slide is to provide cutting action to the tool in the direction perpendicular to the centre line of the lathe.

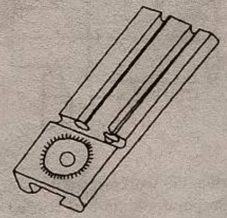


Figure (6)

(iii) **Compound Rest:** It is located over the cross slide and is hand operated. It consists of a graduated circular base that can be swivelled. It is used for machining short tapers, angular cuts and proper positioning of the tool.

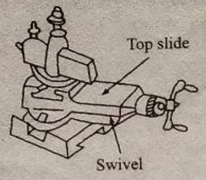


Figure (7)

Effects Of

1.

Tool Post: It is mounted on the top of the compound rest, used for holding the tool in a specific position. There are various types of tool posts based on the type of work need to be performed. The types of tool posts are single screw tool post, open side tool post, four bolt tool post and four-way tool post.

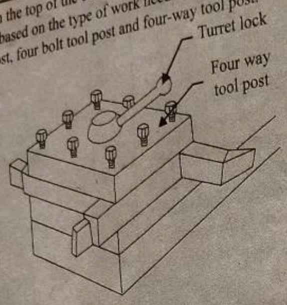


Figure (8)

(v) **Apron:** It is mounted on the front end of the saddle. It consists of the transmission mechanism that contains hand wheels, levers, clutches, and gears to operate the carriage either by hand or power feed. It also contains a split nut to engage the lead screw to provide automatic feed to the carriage for thread cutting.

5. **Legs (Vertical Columns):** These are the main support for the lathe to withstand the loads and are generally made by casting methods. The left side leg acts as a housing for the electric motor, shafts, etc. They are properly fixed on the machine shop floor to avoid vibrations caused by forces developed during machining.

Working Principle of Engine Lathe

The working principle of lathe is shown in below figure,

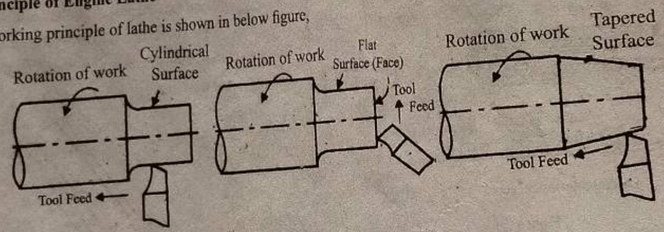


Figure: Working Principle of Lathe

In the lathe, the workpiece is held in a check or between the centres, and is rotated against the stationary cutting tool. Generally, single point cutting tool is used for machining operations on lathe machine. The cutting tool removes the excess material from the surface of the rotating cylindrical workpiece. The cutting tool is fed linearly in a direction parallel to the axis of rotation, i.e., along the axis if workpiece, so that the cylindrical surface of workpiece is obtained. A flat surface is produced, of the tool is fed normal to the axis of workpiece. When the tool is fed at an angle against the rotating workpiece axis, a tapered surface is produced.

Q54. What are the various work holding devices of lathe?

Answer :

The work holding devices are utilized to grip and turn the workpieces along with the spindle. Various work holding devices are employed based on the shape, diameter, length, and weight of the workpiece and also, the position on the work, where operations are performed. The following are the various work holding devices of lethe.

1. Chucks
2. Centres
3. Face plate
4. Catch plate
5. Mandrels
6. Carriers.

1. **Chucks:** It is a device used for holding the workpiece by means of adjustable jaws. It is attached to the headstock spindle of the lathe. The external threads of the spindle engage with internal threads of the chuck. The following are the different types of chucks.

 (i) Universal or three-jaw chuck or self-centering chuck
 (ii) Independent or four jaw chuck
 (iii) Collet chuck
 (iv) Magnetic Chuck
 (v) Air or hydraulic operated chuck
 (vi) Combination chuck
 (vii) Drill Chuck.

2. **Centres:** These are required, work is to be held between headstock and tailstock. Centres are used to support long workpieces during operations. The centre which is fitted in headstock spindle is called ''Live revolving centre'' and it rotates with the work. The other end is called as ''dead centre'', which is kept stationary at the tailstock. These are made hardened and tempered, to withstand the operational loads. Some of the types of centres are standard centre, half centre, etc.

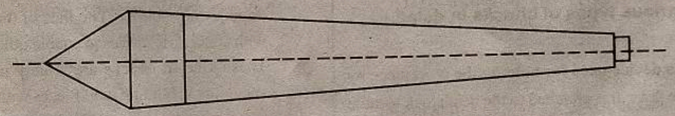
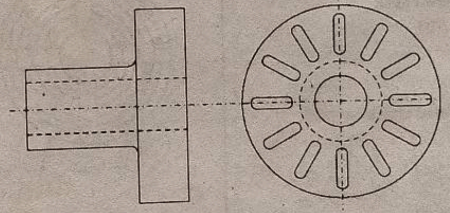


Figure (1): Centres

3. **Faceplate:** These are used to hold the workpieces which are complicated in shape and difficult to hold in chucks. It is usually a circular cast iron disc provided with radial plain and T slots as shown in the figure to hold the work with the aid of clamps and bolts.

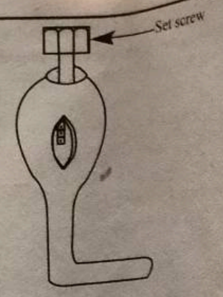


Figure

4. **Catch Plate:** These plates are provided with aU shaped or elliptical slot on their periphery and are mounted on the nose of the headstock spindle, with the help of screw or bolts. It is used for driving the workpiece held between two centres. A slot is provided such that projecting pin from the dog fits into the slot, to enable a positive drive between the spindle and workpiece.

5. **Mandrel:** It is a device used to hold the hollow workpiece and is held in between centres. It is driven by a catch or a drive plates. Hence, work rotates along with the spindle. There are various kinds of mandrels plain mandrel, stepped mandrel, collared mandrel, screwed mandrel, cone mandrel, gang mandrel.

6. **Carriers:** These are the devices used to hold the work between centres, one end of carries is provided with an eye in which work piece is held and the other end fits into drive plate or catch plate. These are two types of carriers i.e., straight tail carries and bent tail carries.



Figure(5) : Lathe Carrier

Q55. Briefly explain with a neat sketch, the types of work holding devices that are commonly employed in automatic lathe. Also specify its limitations.

OR

Explain various types of chucks in detail.

Ans:

A chuck is a device used for holding the workpiece by means of adjustable jaws. It is attached to the headstock spindle of the lathe. The external threads of the spindle engage with internal threads of the chuck. The following are the different types of chucks.

1. Universal or three-jaw chuck or self-centring chuck
2. Independent or four jaw chuck
3. Collet chuck
4. Magnetic Chuck
5. Air or hydraulic operated chuck
6. Combination chuck
7. Drill Chuck.

1. **Universal or Self-Centring Chuck:** In this chuck, the motion of the three jaws is achieved by rotating any one of the pinions. The scroll disc which teeth are cut exactly meshes with the pinion further, these teeth also mesh with the teeth provided on the underside of the jaws. Hence, if any one of the pinions is rotated, all the three jaws move forward or backwards by the same length. These type of chucks are mainly used for holding hexagonal, round and other similar shaped workpieces. As the three jaws move simultaneously, the work is centred automatically. But the accuracy in this kind of chucks does not remain for longer times due to wear of jaws.

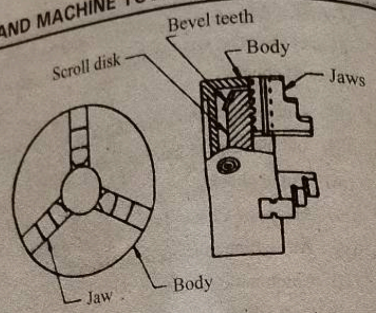


Figure (1): Three-jaw chuck

2. **Four Jaw Chuck or Independent Chuck:** The body of the chuck contains four jaws which can be moved independently in the slots. Each slot contains a scroll which meshes with the jaw such that the jaw can be slid by rotating the pinion. And the working of the other three jaws is similar. The face of the chuck is provided with concentric circles to enable quick centring of work. These kind of chucks are widely used because of the versatility in holding workpieces with various shapes and sizes (irregular shapes). The jaws are made of tough steel and the accuracy of centering is greater when compared to three jaw chuck.

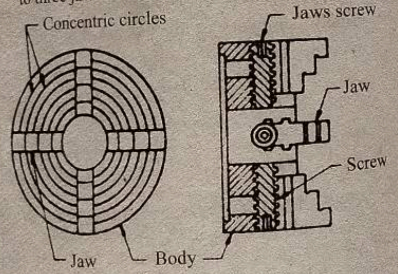


Figure (2): Four Jaw chuck

3. **Collet Chuck:** It is a work holding device used to hold finished or semi-finished components to carry out additional operations. By using collets, symmetrical parts can be held firmly and accurately. It is designed for different shapes like round, square and hexagonal holes. The maximum diameter of the collet ranges from 0.05 to 0.08 mm and the elastic deformation of the collet gives total travel of the jaws. The collet principle can be applied to internal as well as external clamping. When pressure is applied and distributed uniformly along the circumference of the sleeve, the segment inside the component will elastically deflect and gets clamped. This method of clamping is fast in operation and is accurate.

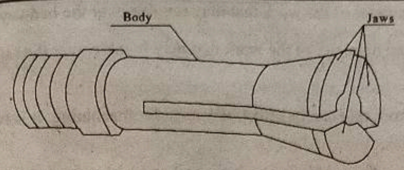


Figure (3): Sessional view of collet

4. **Magnetic Chuck:** These are used to hold thin workpieces which are difficult to hold by conventional chucks. These are also used where deformation of the workpiece is to be avoided. Generally, the deformation occurs due to the pressure of jaws. The body of these chucks is provided with permanent magnets or electromagnets. In the case of permanent magnets, keepers used to short-circuit the magnetic flux. In on position, the keeper allows magnetic flux to pass through the workpiece thereby it sticks to the chuck whereas in off position keeper does not allow to pan the flux. Hence, workpiece is released. In the case of electromagnets, the current supply is used to hold and release the workpieces.

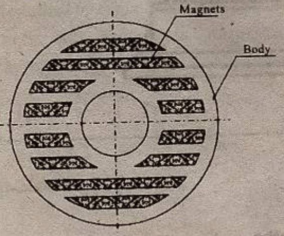


Figure: Magnetic chuck

Q56. Classify the lathe machines and explain their uses.

Answer :

Various types of lathes are as follows,

1. **Bench Lathe:** It is a small lathe generally fitted on a bench or a cabinet. It contains all the parts similar to the engine lathe only the difference is the size and is used for accurate and precision machining of smaller size jobs.
2. **Speed Lathe:** It is the simplest lathes among all types of lathe machines and its size of this larger than bench lathe. It has a headstock, tailstock, bed, sliding tool post and supporting legs fitted to the bed. But, they do not have provision for power feed, carriage, gearbox and lead screw. The tool is mounted on the sliding tool post and fed manually. These lathes are employed for wood turning, metal spinning, centring and polishing operations.
3. **Engine Lathe:** It is most widely used and robust lathe than other types of lathe. It has a headstock of large size, incorporated with suitable transmission mechanisms (pulley or geared) to obtain multiple speeds of the spindle, a tailstock to support the work between centres and to hold various other tools like drills, reamers, etc. This lathe is equipped with carriage, lead screw, feed rod such that the tool can be fed in longitudinal and cross directions. These features made engine lathe as the most versatile and widely used machine.
4. **Tool Room Lathe:** It is similar to engine lathe but provided with some extra mountings for obtaining a wide range of spindle speeds ranging from 0-2500 RPM. It is used to perform various operations like taper turning, thread cutting etc. This kind of lathe is mostly employed for more accurate and precision type of works.
5. **Capstan and Turret Lathes:** These are advanced versions of engine lathes specially designed for mass-production. In these lathes, tailstock is replaced with hexagonal turret upon which multiple tools can be mounted to perform various operations simultaneously. These lathes are considered as semi-automatic lathes as they provide a wide range of operations and facilities in mass production of identical parts with minimum time.
6. **Automatic Lathes:** This kind of lathes are employed only in case of mass production. As these lathes are provided with automatic speed, feed, and tool changing mechanisms, they perform all the operations automatically without the surveillance of the operator.
7. **Special Purpose Lathes:** These lathes are designed to perform certain specified operations that cannot be performed on conventional lathe machines. The most common special purpose lathes are,
   (i) **Wheel Lathe:** It is provided with two tool posts and a headstock and used for threading on locomotive wheels and railroad cars.
   (ii) **Duplicating Lathe:** This kind of lathe machines are provided with hydraulic and electric mechanisms to manage the motion of the tool. These are mainly used for reproduction of shapes and contours.

Q57. How do you specify the lathe machine?

Answer : [May/June-12, Set-4, Q3(a) | Model Paper-I, Q3(a)]

A lathe is generally specified by the following terms.

1. **The Height of the Centres:** It is the height of the axis of lathe measured from the lathe bed.

- **Maximum Swing Over the Bed:** It indicates the maximum diameter of the work that may revolve over the bedways.
- **Maximum Swing Over the Carriage:** It indicates the maximum diameter of the work that may revolve over the saddle. Generally, it is less than swing over the bed.
- **Maximum Swing Over the Gap:** It is the largest diameter of work that can be effectively used for machining. It is twice the height of the centre measured from the lathe bed.
- **Distance between the Centres:** It is the maximum length of the work that can be accommodated for machining, between the lathe centres.
- **Length of the Bed:** It is the length of the floor space occupied (floor area) by the lathe.
- **Maximum Diameter:** It is the maximum diameter of the work or bar that can pass through the hole of the head stock spindle.

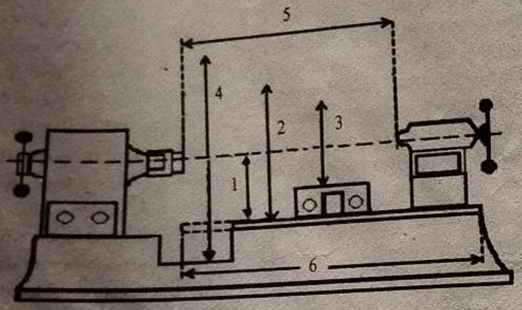


Figure: Specification of Lathe

Describe the turning process in lathes.

Nov./Dec.-18, (R16), Q2(a)

OR

What machining operations can be performed on a center lathe.

[Nov./Dec.-16, (R13), Q4(a) | Model Paper-II, Q2(b)]

er :

Operations: The operations performed on the centre lathe are,

Turning: In this operation, the tool is fed against the rotating workpiece. Based on the movement of the tool there are three types of turning operations,

(i) **Straight Turning:** In this operation, the cutting tool is fed parallel to the axis of the lathe. The main purpose of this operation is to produce cylindrical surfaces with a uniform diameter.

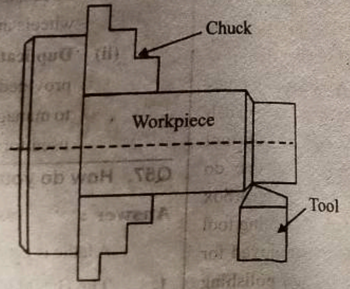


Figure (1)

(ii) **Step Turning or Shoulder Turning:** This kind of operation is performed in order to produce steps of different diameters on the workpiece. Based on the shape of shoulder produced there are four types of shoulder turning namely, square shoulder, bevelled shoulder, radius or form shoulder, undercut shoulder.

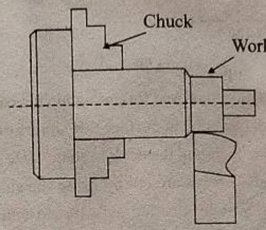


Figure: (2)

(iii) **Taper Turning:** In this operation, the surface with a gradual increase or decrease in diameter is produced by feeding the tool at an angle to the axis of the lathe. Short tapers are produced by using a form tool or by swivelling the compound rest.

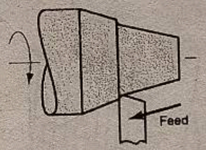


Figure (3)

Turning finally reduces the diameter of the workpieces and the above operations can be performed both internally and externally.

2. **Facing:** This operation is used to reduce the length of the workpiece performed by feeding the tool perpendicular to the lathe axis which is achieved by the movement of cross slide or compound rest. This operation is performed mainly for producing flat and smooth ends or for finishing the ends.

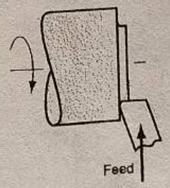


Figure (4)

3. **Knurling:** It is defined as the operation in which a pattern on the tool is reproduced on the work surface. This operation requires a special knurl tool made of hardened steel rollers whose surface consists of certain pattern. The diamond pattern is the commonly used pattern. The purpose of knurling is to build the grip on the workpiece, so as to avoid the slipping.

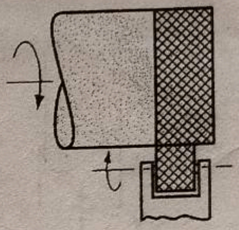


Figure (5)

4. **Grooving:** The process of decreasing the diameter of the workpiece over a narrow region is called grooving. It is usually done at the end of the threaded portion on the workpiece. Different types of grooves such as an angular groove, round and square grooves can be machined as per the requirement. Generally, a round groove is more preferred as it does not induce stresses. The tool is fed perpendicularly to the axis of rotation of the workpiece.

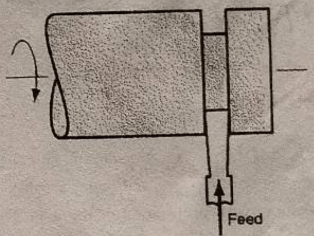


Figure (6)

5. **Parting Off:** This process is mainly used for cutting the workpiece into two parts. In this process, the parting tool is feed in the direction perpendicular to the axis of the lathe up to the centre of the work. This operation is similar to grooving because the same tool is used for the machining of square grooves. If the cutter does not reach beyond the centre of workpiece then a rectangular or square groove is obtained on the workpiece.

6. **Forming:** In this operation, concave, convex or any irregular shape of surfaces are generated on the workpiece, as shown in the figure. This can be obtained in three ways i.e., feeding the tool with the combination of cross and longitudinal feed, form tool or tracing a template. In case of form tool, the shape of the forming tool is selected, based on the shape required on the workpiece.

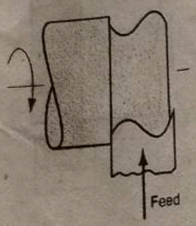


Figure (7)

7. **Drilling:** It is the operation of producing a cylindrical hole in a workpiece, by means of a multipoint cutting tool called drill. In centre lathe, the drill is held and fed by the tailstock. In this process, feed is given in the direction parallel to the axis of rotation of the workpiece.

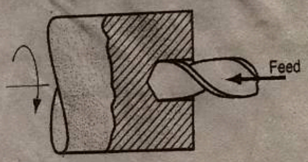


Figure (8)

8. **Boring:** It is the process of enlarging an existing hole. It gives the required size and better finish to the hole and also corrects the location of the hole. During the process, work is held in a chuck and rotated with gear mechanism. The tool is fitted to the tailstock and is fed into the work. The operation is performed by using a single point cutting tool.

9. **Reaming:** It is the process of finishing and resizing an existing drilled or bored hole. The tool used for this process is a multipoint cutting tool called reamer. During the process, the reamer is held in a tailstock or hexagonal turret and the work is rotated. In this process, feed varies from 0.5 mm to 2 mm per revolution.

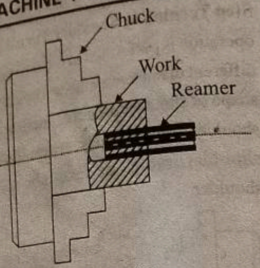


Figure (9)

10. **Thread Cutting:** It is used for producing helical grooves on cylindrical or conical surfaces. It is performed on a lathe machine to obtain the desired shape, size and pitch of the thread. Threads are cut by using the single point cutting tool, which is called as a thread cutting tool. The workpiece on which threads are to be cut is placed between the centres and the cutting tool is held on the tool post. In order to complete one rotation, the tool must travel at a distance equal to pitch 'p'. Initially, a small depth of cut is given to the tool, with the help of cross-slide the tool engages with the workpiece. The rotary and linear motion of the tool is controlled by locking and unlocking the carriage with a lead screw.

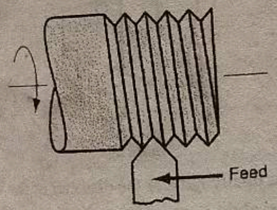


Figure (10)

11. **Chamfering:** It is the operation of bevelling the end of a workpiece, in order to protect the end of the workpiece from damage and to remove burrs, etc. This operation is performed either by using a form tool or by setting the compound slide at required angle.

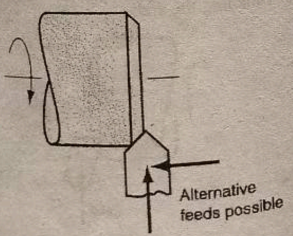


Figure: (11)

Q59. Explain about parting operation, finish turning, grooving, undercutting and shoulder turning in lathe machines with proper sketches.

Answer : [Dec.-11, Set-2, Q3 | Model Paper-III, Q2(b)]

Operations on Lathe Machines

(i) Parting operation
(ii) Finish turning
(iii) Grooving
(iv) Undercutting
(v) Shoulder turning.

(i) **Parting Operation**

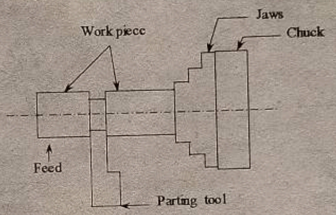


Figure (1): Parting Operation

For answer refer Unit-1, Q58, Topic: Parting Off.

(ii) **Finish Turning**

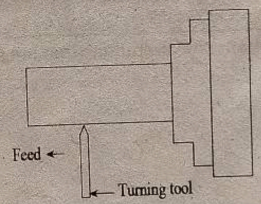


Figure (2): Finish Turning Operation

The main purpose of finish turning operation is to machine the workpiece to the desired size and to obtain good surface finish. In this operation, the workpiece is held between the jaws of chuck and the tool is feed parallel to the axis of rotation of workpiece at a relatively high speed, as shown in figure (2).

(iii) **Grooving**

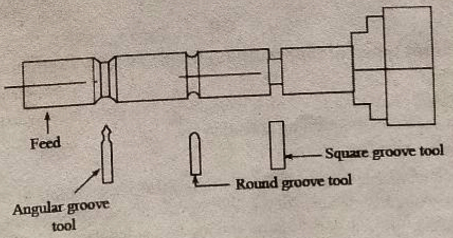


Figure (3): Grooving Operation

For answer refer Unit-1, Q58, Topic: Grooving.

(iv) **Undercutting**

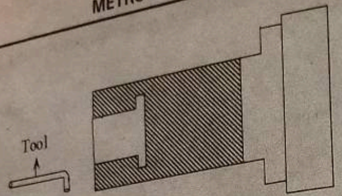


Figure (4): Undercutting Operation

This operation is similar to that of grooving operation, but it is performed inside a hole. Parting tool can be used for this type of operation. This is usually performed at the end of internal threaded region for the provision of clearance between the tool or any mating part during cutting process.

(v) **Shoulder Turning**

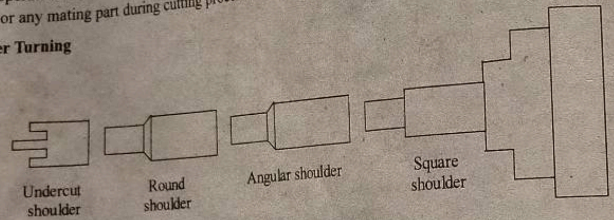


Figure (5): Shoulder Turning Operation

Formation of steps on the surface of workpiece due to change in diameter is termed as shoulder. Machining of shoulder is known as shoulder turning. Different types of shoulder turning can be obtained as required, as shown in figure (5). Different cutting tools are required for different types of shoulders.

Q60. How lathe is specified? Explain briefly the operations that are performed on a lathe.

Nov./Dec.-17, (R15), Q5(a)

Answer :

Specifications of Lathe Machine

For answer refer Unit-I, Q57.

Operations Performed on Lathe Machine

For answer refer Unit-I, Q58.

1.3 TAPER TURNING, LATHE ATTACHMENTS

Q61. Briefly discuss about the different type of taper turning methods with sketches.

Dec.-19, (R16), Q3(b)

OR

Explain in detail the different methods of Taper Turning?

May/June-19, (R16), Q3(a)

OR

Discuss about the different types of taper turning methods with sketches.

[May/June-12, Set-2, Q8 | Model Paper-II, Q3(a)]

Answer :

Taper turning is the process of producing taper on a workpiece. The taper may be external or internal according to the requirement. The various methods used for taper turning operation are,

1. **Tail-stock Set Over Method**

This method is used for producing small tapers on long workpieces. The principle of this method is "shifting the axis of rotation of the workpiece at an angle to the axis of the lathe and feeding the tool parallel to the lathe axis. In this method, the tail stock is displaced away from the axis of lathe and the tool is fed parallel to the axis of lathe against the rotating workpiece to produce the tapered surface. The angle by which the axis of workpiece is shifted is equal to half the angle of taper. If the larger diameter is required at the head stock side, the tail stock is shifted towards the operator and if the larger diameter is required at the tail stock side, the tail stock is shifted away from the operator.

The tail-stock offset or set over is obtained from the following relation,

$$h = \frac{L(D-d)}{2l} \text{ mm}$$

Where,

L – Length of the workpiece

l – Length of the taper.

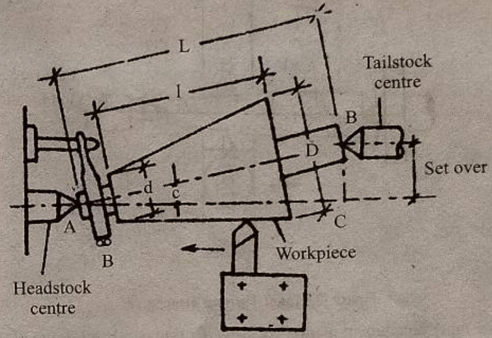


Figure (1): Tail-stock Set Over Method

2. **Compound Rest Method**

In this method, the workpiece is rotated on the lathe axis and the tool is fed at angle to the axis of rotation of the workpiece. The compound rest is swivelled or rotated by an angle equal to half the angle of taper. The compound rest on which tool is mounted is attached to the circular base graduated in degrees, and can be swivelled and clamped at any desired angle. After swivelling the compound rest to half the taper angle, the compound slide screw is rotated so that the tool is fed at that angle to generate required taper. It is generally used for high angle of tapers and short lengths.

The angle of swivelling is given by,

$$\tan\alpha = \frac{D-d}{2l}$$

Where,

l – Length of the taper

α – Half taper angle

d – Smaller diameter

D – Larger diameter.

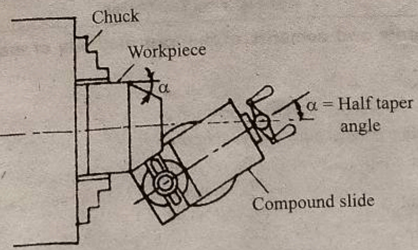


Figure (2): Compound Rest Method

3. Taper Turning Attachment

The principle of this method of taper turning involves guiding the tool in a straight path, inclined to the axis of rotation of the workpiece.

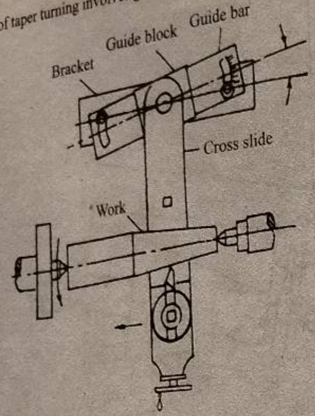


Figure (3): Taper Turning Attachment

As shown in the figure, the taper attachment mainly consists of a frame or bracket attached to the rear end of the bed and supports a guide bar which is pivoted at the centre. The guide bar is provided with graduations, and it can be swivelled or rotated on either side of the zero graduation.

During turning operation, first the cross slide is disengaged from the lathe feed and is fastened or tightened to the guide block by means of a bolt. When the longitudinal feed is engaged, the tool mounted on the cross slide will move in the angular path, as the guide block slides over the guide bar which is set at the required angle and generates taper on the workpiece. With the help of compound slide, the required depth of cut is provided.

4. Taper Turning with a Form Tool

This method is used for producing tapers on small length jobs. This method employs a form tool, which is already ground with the required taper angle (equal to half the taper angle). The tool is fed perpendicular to the lathe axis.

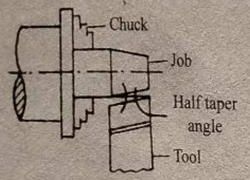


Figure (4): Form Tool Method

Q62. Discuss the relative merits and demerits of the four methods of machining external taper on the lathe.

Answer :

The four methods of machining external taper on the lathe are,

(i) Form tool turning

(ii) Taper turning attachment

(iii) Offsetting the tail stock

(iv) Compound rest method.

	Methods	Merits	Demerits
1.	Form tool turning	(i) This method can be used for mass production of small tapers.	(i) It is suitable only for short external tapers. (ii) The tool is subjected to excessive cutting pressure, which may damage the workpiece and results in poor surface finish.
2.	Taper turning attachment	(i) It can produce lengthy tapers within the limits. (ii) The dead and live centre's alignment is not disturbed, and both straight and taper turning operations are possible with same setting. (iii) Tapers can be produced with good surface finish. (iv) It is easy to produce internal tapers.	(i) The angle of taper is limited to 10° to 12°.
3.	Off-setting the tail stock	(i) The tapers produced with this method have good surface finish. (ii) This method allows the use of power feed.	(i) It is suitable to produce only external tapers. (ii) It is very difficult for setting the offset.
4.	Compound rest method	(i) Both internal and external tapers can be produced. (ii) It is possible to produce steep tapers by this method. (iii) Easy setting of the machine as per the requirement.	(i) It allows only hand feeds, thus the production capacity is less and poor surface finish. (ii) The length of the taper produced is limited to the movement of the top slide. Thus, only short tapers are produced.

Q63. What are the different attachments used in lathe machine? Explain any two attachments?

Nov./Dec.-18, (R16), Q3(b)

OR

What are the different types of lathe attachments? Discuss them briefly.

Model Paper-III, Q3(a)

Answer :

Different types of lathe attachments that are commonly used are,

1. Milling attachment
2. Taper attachment
3. Grinding attachment
4. Carriage stops
5. Relieving attachment
6. Miscellaneous attachment.

1. **Milling Attachment**: The tool holder of the lathe machine is replaced by a milling attachment to perform various milling operations. It consists of a spindle and base. The base is fastened to saddle and milling cutters are mounted in spindle. Milling attachment can also be mounted on the lower side of compound rest. The workpiece is held between two centres of lathe. The cutter, in rotating motion is fed into stationary work piece. The movement of cutter is obtained by raddle movement. The various milling operations that can be performed are face milling, slot cutting, dovetail milling etc. Indexing of job can be obtained by dividing head.

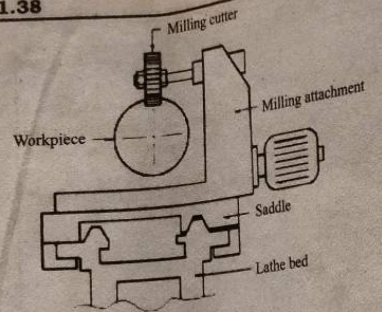


Figure (1): Milling Attachment

2. **Taper Attachment:** It consists of guide bar, which has a graduated scale on one side and the other end is tapered. It is attached at the back of carriage. The main purpose of taper attachment is to turn and bore tapers on the workpieces. Effective working of attachment is obtained only when the slide and compound rest moves easily, but there should not be any looseness or play.

3. **Grinding Attachment:** Grinding attachment is a combined device, which is connected to compound rest. It is generally used for internal grinding purpose.

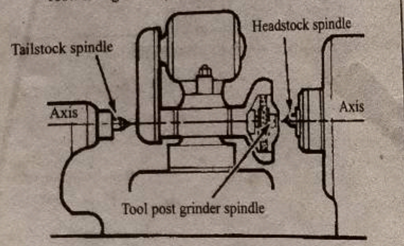


Figure (2): Grinding Attachment

4. **Carriage Stops:** These are one of the attachments of lathe, through which high accuracy can be obtained. It is placed on the outer side of the lathe. It provides accurate grooves, square shoulders, etc., by stopping the carriage as required.

5. **Relieving Attachment:** It is a device attached to headstock of lathe by a universal joint. It oscillates the tool slide with cam and a driving shaft. It is usually used for internal, external and end relieving of cutting tools, taps, etc., to accomplish easy and faster cutting of material.

6. **Miscellaneous Attachments:** Some of the other attachments that can be used on lathe are,
   (i) Ball turning rest
   (ii) Turret attachment
   (iii) Gear cutting attachment
   (iv) Rapid traverse attachment.

Q64. Explain what is meant by a Taper. Discuss in detail the taper turning by compound rest swivelling method?

Nov./Dec.-17, (R15), Q5(b)

Answer :

For answer refer Unit-I, Q28.

Taper Turning by Compound Rest Swivelling Method

For answer refer Unit-I, Q61, Topic: Compound Rest Method.

1.4 CAPSTAN AND TURRET LATHE

Q65. How do you classify turret lathes? Give a brief description of different types you know.

Nov./Dec.-16, (R13), Q4(b)

Answer :

Turret lathes are classified as,

1. Horizontal turret lathes
   (i) RAM type turret lathe
   (ii) Saddle type turret lathe
2. Vertical turret lathes
3. Numerical controlled (NC) turret lathes.

1. **Horizontal Turret Lathes**

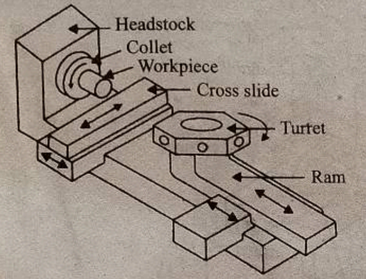
There are two types of horizontal turret lathes based on their design.

(i) **RAM Type Turret Lathe**

It consists of a RAM or slide which moves freely back and forth on the saddle. The saddle is clamped to the lathe bed. The slide is mounted with hexagonal turret carrying various tools. The saddle can be moved and clamped at the required position and the feed is given to the tool by moving the slide on the saddle. The speed range varies from 50 to 400 r.p.m depending on the size of lathe. The larger lathes have lower speeds.

To stop the feeding motion of the turret at predetermined position, trip stops are provided.

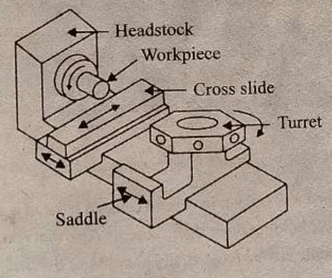
These lathes are recommended for bar and light duty chucking work.



Figure

(ii) **Saddle Type Turret Lathe**

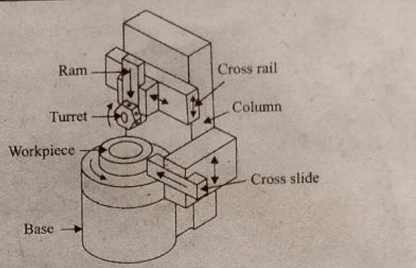
In this type of lathe, the turret head is mounted directly on the saddle. For feeding the tool, the saddle is moved forward and the turret head is automatically indexed during the backward stroke to set the required tool for the next operation. Since chucking tools overhang and are unconnected with the work through some type of support, high strain develops on both work and tool. Thus, chucking tools must have rigidity. The speed varies from 20 to 1500 r.p.m depending upon the size of the machine.



Figure

2. **Vertical Turret Lathes**

It consists of a rotating chuck or a circular table mounted on heavy base, vertical column carrying a cross-rail. The turret head is mounted on the ram which slides above the cross rail. The table rotates about its vertical axis and carries slots for clamping the work piece. In addition to turret head, a side head is provided with a square turret for machining the work from sides. During operation, the cross-rail is moved up and down and adjusted at the required position. The feed to the tool is provided by moving the turret slide or ram up and down vertically and to and fro along the cross-rail. The side head performs the operations simultaneously or separately depending upon the requirement without interference of operations carried out by main turret head. It is generally used for larger or heavier work, as it provides very robust support to the work.



Figure

3. **Numerical Controlled (N/C) Turret Lathes**

These machines works on the pre-programmed numerical data and very economical for heavy duty production of parts. They are highly productive machines compared to manually operated machines. The machining accuracy and surface finish obtained from these machines are more superior compared to the other types of lathe machines. This machine can be setup quickly for small lot jobs, generally changing only jaw chucks, control tape and one or two cutters.

Q66. Enumerate with neat diagram the principle parts and working of capstan and turret lathe.

Answer :

Working of Turret Lathe

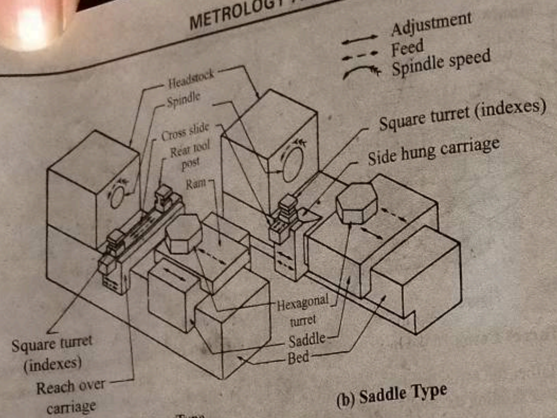
In this type of lathe, the workpiece is held by collets but for larger workpieces, jaw chucks are required. These chucks are operated by hydraulic and pneumatic means. It consists of bar feeding and indexing mechanisms, which are operated automatically. On this machine, 11 tools can be mounted at a time.

Among all the tools, six tools are mounted on turret faces that are used for performing different operations such as drilling, boring, reaming, counter boring, turning and threading. Other four tools are provided on front tool post, used for operations such as necking, chamfering, form turning and knurling. And, one parting off tool is provided on rear tool post, used for cutting off the workpieces.

In order to control the movement of the front and rear tool post, pre-stops are provided in turret lathes. During machining, the turret head moves forward and performs a particular operation and returns back to its original position upon completion of the task. By indexing, the next tool takes the respective position and the process is continued. The motion of turret with respect to each position is controlled independently. The carriage of turret lathe does not travel over the entire bed and thus no rear tool post is provided on cross-slide. This allows accommodating larger workpieces.

Working of Capstan Lathe

Working principle of both capstan and turret lathes is similar and used for mass production but in various constructional aspects. The common principal parts of both capstan and turret lathes are explained as follows. The figure 1 and figure 2 illustrates the constructional features of capstan and turret lathes respectively.



(a) Ram Type (b) Saddle Type

Figure

1. **Bed:** The bed of the capstan and turret lathes is a large casting acts as the base of the machine. It is made up of cast iron and supports headstock on one side and cross slide saddle, which travels over the bed and on the other side and turret saddle. It has the ability to absorb all the vibrations occurring in the machine. It also withstands all the cutting forces acting on the machine.

2. **Headstock:** It is similar to that of a centre lathe but is heavier and larger in construction. It is housed with a motor to run the machine and for regulating the spindle speed, which ranges from 30 to 2000 r.p.m. In capstan or turret lathes, following types of headstocks are used.

   (i) Step-cone pulley headstock

   (ii) Pre-optive or pre-selective headstock

   (iii) Electric motor driven headstock

   (iv) All-geared headstock

3. **Turret Head and Saddle:** Turret head is usually an hexagonally shaped tool holder. In case of capstan lathe, it is mounted on a ram (auxiliary slide) which is mounted on guideways. It is used for holding more than six tools. The ram reciprocates on a saddle, which in turn slides over the bed of the machine. The saddle can be fixed at any position of the bed.

   In case of turret lathes, the hexagonal turret head is directly mounted on the turret saddle. Hence, turret head can be moved by moving the saddle.

4. **Cross Slide:** It is mounted on the bed of the machine. It is located between headstock and turret saddle. It consists of two posts, one is mounted at front of the machine and the other at the rear of the cross slide. The rear tool post carries a parting tool, that is fixed. The front tool post can carry four tools and moves in both perpendicular and parallel directions with respect to the spindle axis. The carriage can be operated manually by hand in small size lathes and motor driven in large size lathes. It is designed in such a way that works with large diameter can be machined conveniently without being interrupted by cross-slide. The longitudinal feed of the tool is controlled by stop bars or shafts.

Q67. Enumerate the constructional details and working principle of turret indexing mechanism in Capstan and turret lathes.

Answer :

Turret indexing mechanism: In turret lathe, the tailstock is replaced by a hexagonal turret. On the faces of the hexagonal turret, different tools can be mounted. Thereby a turret can hold six different kinds of tools which can be brought into the axis of lathe by indexing mechanism.

In order to index the turret, it has to be rotated by 60 degrees or multiples of 60 degrees.

A typical line diagram of the turret indexing mechanism from the top view is illustrated in figure (1).

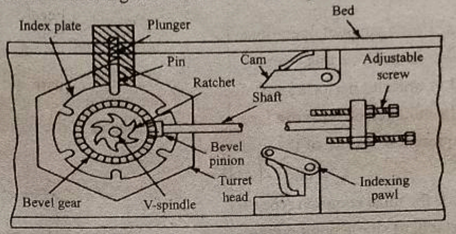


Figure: Turret Indexing Mechanism

A vertical spindle is mounted on the turret saddle. This vertical spindle is mounted with indexing ratchet, bevel gear, indexing or geneva plate and turret head. On one side of the saddle, a plunger pin is provided to lock the rotation of turret while feeding axially.

On lathe bed, spring-loaded indexing pawl and actuating cam are attached. As the turret moves backwards, the plunger pin is moved out of the groove on indexing plate by the cam thereby unlocks the indexing plate. Simultaneously, the spring-loaded pawl engages the ratchet plate which rotates the turret head. As the turret head rotates through 60 degrees the plunger pin is automatically dropped. This locks the indexing plate at next groove thereby the turret is locked in a new position. The tool held by this face of the turret is fed. This releases the pawl from ratchet due to spring pressure.

The turret of the capstan lathe is lighter, therefore, it can be indexed automatically and manually, whereas the turrets of turret lathes cannot be indexed automatically, as the saddles upon which they are mounted are heavy. The automatic indexing mechanism may differ from manufacturer to manufacturer.

The forward movement of the turret head is stopped when the set-screw corresponding to the working tool (turret face) is restricted by the mechanical stop (screw stop rods).

The forward distance to be travelled by the tool or turret head is controlled by presetting the screw. There are six such kinds of screws, each one for each face of the turret. The drum supporting the screws with various distances is rotated along with the rotation of the turret head through a pair of bevel gears.

Q68. List various tools and attachments used on turret and capstan lathe.

Answer :

Following tools are common to both capstan and turret lathes,

1. Work stops or bar stops
2. Centering and chamfering tools
3. Turning tools
4. Tap and die holders
5. Box tools
6. Boring tools
7. Reaming tools
8. Knurling tools
9. Drill and reamer holders
10. Centres and supports
11. Attachments used on cross slide

Following are some of the special attachments used on turret lathes.

1. Pilot bar
2. Cutter holders
3. Multiple turning head
4. Adjustable slide tool
5. Taper attachment
6. Screw cutting self opening die head.

Q69. Explain various types of tool holders.

Answer :

On capstan and turret lathes, a wide range of operations are performed for mass production. To achieve this, various kinds of tool holders are designed in order to perform typical operations. These tool holders can be mounted on the turret face or cross slide according to the requirement. Some of the tool holders are explained as follows.

1. **Straight Tool Holder:** This is the most common type of tool holder used to mount standard single point cutting tool. This holder can be fixed either in the hole of the turret or in the multiple turning head. In this case, the orientation of the tool is perpendicular to the axis of work. It is mainly used for performing facing, turning, boring etc.

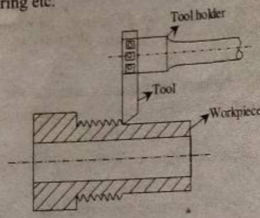


Figure (1)

2. **Plain or Adjustable Angle Cutter Holder:** In this type of tool holder, an angular slot is provided in which tool is fastened with the aid of set screws and the tool is oriented at an angle to the axis of work and the angle can be adjusted by adjusting set screws. This kind of tool holder is preferred to perform machining operation near to the chuck.

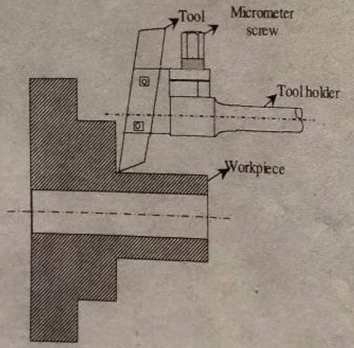


Figure (2)

3. **Multiple Cutting Holder:** This kind of tool holders are used to hold multiple types of tools like straight, angular, offset etc. ,in order to perform multiple operations like turning and facing simultaneously. The tool holder is provided with multiple slots in which shanks of the tools are inserted and tightened with the aid of set screws and the shank of the tool holder is fixed into the face of the turret.

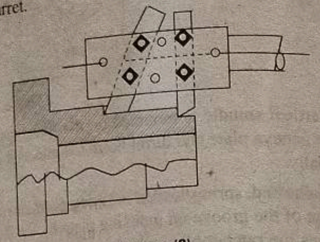


Figure (3)

4. **Knee Tool Holder:** Figure(4) illustrates a knee tool holder which contains a lower hole and an adjustable block with the hole and this block can slide on the holder body. The lower hole's axis coincides with the axis of lathe and is used to hold tools like drills, reamers, boring tools etc., to perform respective operations. And the turning tools are held in hole present on the adjustable block. Therefore, operations like turning and boring or turning and drilling are performed simultaneously.

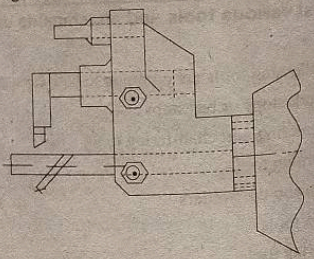


Figure (4)

5. **Slide Tool Holder:** This is an important kind of tool holder used for the mass production of small and medium-sized parts. The figure (5) shows a typical slide tool holder. And is mainly employed for performing rough and finishing operations of facing, grooving, boring etc, the tool holder contains a vertical base on which a slide is mounted, which can be adjusted in the vertical plane. And is provided with two holes lower and upper. The lower hole is used to hold tools like drills, reamers etc, and upper hole is used to hold turning tools. The holder is directly mounted on turret face with the aid of studs.

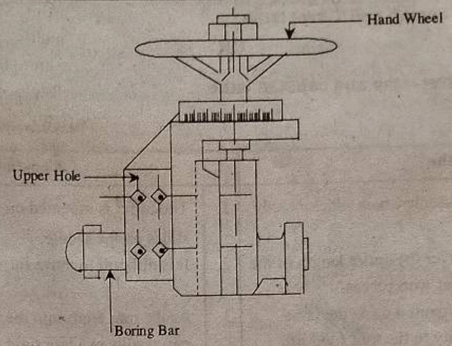


Figure (5)

6. **Knurling Tool Holder:** This can be fixed to either turret face or to tool post on the cross slide. The operation is similar to that of knurling operation performed on the engine lathe. The tool consists of a set of rollers and teeth cut on their surface with a specific pattern. The distance between rollers can be adjusted so as to machine the works with different diameters.

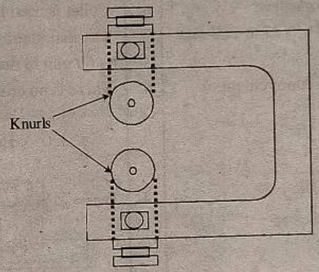


Figure (6)

Q70. How are the sizes of turret and capstan lathes specified?

Answer :

The sizes of turret and capstan lathes are specified as follows,

Turret Lathes

(i) Maximum size or diameter of work or bar that can be passed through the spindle.

(ii) Swing diameter of the workpiece.

(iii) Speeds of spindle

(iv) Range of feeds

(v) Size of chuck

(vi) Capacity of the drive motor

(vii) Cost of machine.

Capstan Lathe

(i) Overall bed length

(ii) Vertical distance (height) of the spindle centre above the bed.

(or)

(i) Working length of the bed

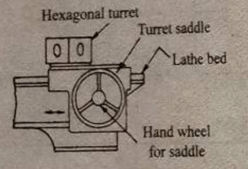
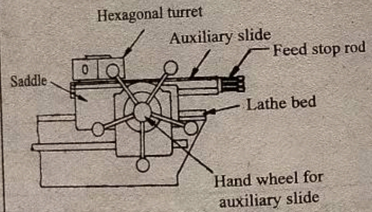
(ii) Swing diameter.

Q71. Differentiate between Capstan and Turret lathe. Nov./Dec.-18, (R16), Q3(a)

OR

Distinguish between turret lathe and capstan lathe. [May/June-13, (R09), Q2(b) | Model Paper-I, Q3(b)]

Answer :

	Turret Lathe		Capstan Lathe
1.	The turret is mounted on a saddle which slides directly on the bed.	1.	The turret is mounted on a short slide or ram which slides on the saddle.
2.	The turret can be moved over the entire length of the bed and can machine longer workpieces.	2.	It is difficult to move turret over entire length of bed.
3.	As the saddle is directly mounted on to the lathe bed, it provides high rigidity to the tool support.	3.	As the ram feeds into the work, the over hanging of ram results in a less rigid construction.
4.	The entire saddle is to be moved for feeding the tools.	4.	The tools are fed by moving slide on the saddle.
5.	Due to its rigid construction, heavier jobs involving heavy cutting forces can be handled.	5.	It cannot be used for heavy cutting loads and speeds and is used for relatively lighter and small jobs.
6.	The chuck is used to holed the workpiece	6.	Collet is used ti hold the workpiece.
7.	These are capable of turning bars of 125 to 200 mm in diameter.	7.	The maximum size of the bar that can be accommodated is 60 mm in diameter.
8.	These are equipped with crosswise movement of the hexagonal turret.	8.	There is no crosswise movement of turret.
	 Figure		 Figure

1.5 SINGLE SPINDLE AND MULTI-SPINDLE AUTOMATIC LATHES – TOOL LAYOUTS

Q72. Explain principal features of automatic lathes. Nov.-15, (R13), Q4(a)

OR

What is automatic and semi-automatic lathe? Write their principal features.

Answer :

In automatic lathes, the operations including changing of speeds and feeds, tool movements, etc., are carried out automatically. The important features of automatic lathe are as follows,

1. The cost of maintenance and production is low.
2. Skilled operator is not required, since the entire operation is automatic.
3. It is provided with upto five radial tool slides, which are moved by cams.
4. It is used for small identical jobs and for mass production.
5. It occupies less space.
6. It has minimum flexibility and utilizes special attachments in some operations.
7. Production time is less.
8. High accuracy and smooth finish on the workpiece can be obtained.

Semi-automatic Lathe

In semi-automatic lathes, all the machining operations are performed automatically, but the loading and unloading of workpiece is to be done manually. It is generally used for manufacturing identical components, in batch or mass production. The important features of semi-automatic lathe are as follows:

1. The cost of production is low.
2. It possesses two tool posts (i.e. Front and rear tool post)
3. Hexagonal turret is equipped, instead of tailstock.
4. A semi-skilled operator can also perform the operations.
5. It requires less inspection.
6. The time required for machining is less compared to conventional engine lathe.
7. It is suitable for small scale production.
8. The cost of equipment is comparatively high.

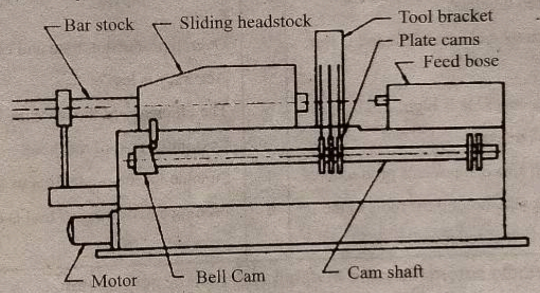
The turret and capstan lathes are the examples of semi-automatic lathe and are explained in detail in the previous topic i.e., turret lathe and capstan lathe.

Q73. Explain about swiss automatic screw machine.

Answer :

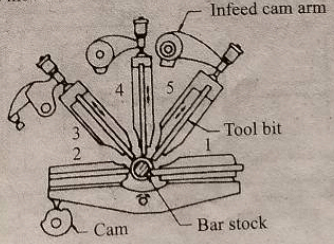
Swiss-type automatic lathe is a single spindle automatic lathe, developed for the precision turning of small jobs up to a tolerance ranging from 0.005 mm to 0.0125 mm. As this machine was designed in Switzerland, this machine is termed as the Swiss-type automatic screw machine and also called as sliding head screw machine.

In this machine, the cutting tool is held in a radial slide, due to which the tool can move only in a radial direction. The longitudinal feed of the stock is provided by moving the headstock. The radial movement of the slides is obtained by actuating the rocker arms and disc arms, which provides the radial feed of the tool.



Figure

During machining, the stock is held firmly and securely in a collet and the machining is carried out with single point cutting tools. As the tools are close to the headstock while working, the deflection of the workpiece is minimized. Due to this, it is commonly used for the machining of very small components from thin bar stocks. The cam moves the tool and provides the radial feed into the work and the longitudinal feed is obtained by moving the headstock forward or backwards on the guideways, provided at the top of the bed. The control in the diameter is obtained by four cams, which feeds the tool into the work in the radial direction only. A fifth cam is used to move the work along the ends under the cutting tools.



Figure

Applications

1. Swiss-type screw machines are mostly used in the automotive, IT, and consumer electronics industries.
2. Products can be produced with high accuracy and surface finish.
3. Due to fewer production times and low variable costs, these machines can manufacture a large number of small parts with great precision and quickly at low cost.
4. As these machines can handle all most all types of standard metals of varying strengths and composition, they are widely adopted and made it as an integral process in various different industries.

Tools: The following type of tools are used to improve the versatility of the machine.

1. **External Turning Tools:** Tools like hollow mills, swing tools, balance turning tools, box tools and knee tools are used in single spindle automatic lathes.
2. **Internal Tools:** Drills, reamers, boring tools, dies and taps are some of the internal cutting tools used in automatics.
3. **Form Tools:** These tools are used to produce various contours on the work.

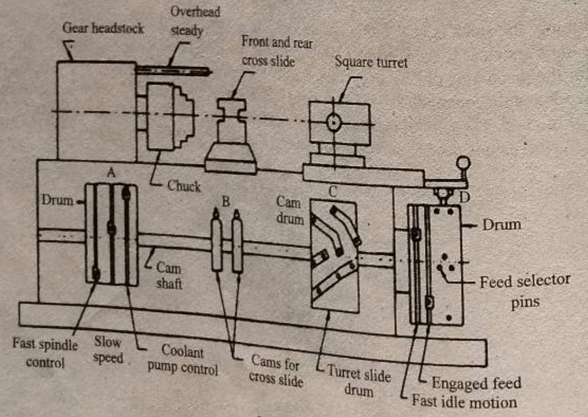
Q74. Write the differences between Semi-automatic and Automatic Lathes.

Answer :

	Automatic Lathe		Semi-automatic Lathe
1.	All the operations related to the manufacturing cycle and also the loading of blanks and unloading of machined parts are performed by machine itself.	1.	The actual machining operations are performed by machine, but loading and unloading operations are performed by the operator.
2.	A single operator is required when a number of machines are grouped together.	2.	An operator can attend to only one or two machines at a time.
3.	Overall production time and cost of the job is less.	3.	Overall production time and cost of the job is more.
4.	Accuracy is high.	4.	Accuracy is less.
5.	The efficiency of the machine is high.	5.	The efficiency of the machine is less.
6.	High initial cost of machine.	6.	Less initial cost of machine.
7.	Best suited for small size components production.	7.	Suitable for the production of large size components.
8.	Feeding of bar stock and moving the tools to the machining point is done automatically.	8.	Feeding and moving of tool is done manually.

Q75. Describe single spindle automatic lathe in detail with help of neat sketch.

Answer :



Figure

Single Spindle Automatic Lathe Machine: A typical single spindle automatic lathe is shown in the figure. It consists of all geared headstock, individual cross slides for rear and front tool posts, square or hexagonal turret and a camshaft at the front end of lathe mounted with multiple mechanisms to operate headstock, cross slides and turret. Trip dogs present on the drum A, alters the spindle speeds, an adjustable cam drum C manipulates the movement and indexing of turret, and drum B controls the individual movements of the front and rear tool posts. The feed selector pins on the drum D provide the exact amount of feed to perform machining operations. The following are the three different types of single spindle automatic lathe machines.

1. Automatic cutting off machines
2. Automatic screw cutting machine
3. Swiss-type automatic screw machine.

Q76. Explain the working of a multi spindle lathes and its applications.

Nov./Dec.-18, (R16), Q2(b)

OR

Explain about multi-spindle automatic lathe machines.

Answer :

Multiple Spindle Automats: These machines consist of 2 to 8 spindles to machine multiple workpieces at a time. Based on the design, these machines are classified as parallel action machines and progressive action machines.

1. **Parallel Action Machines:** These machines are suitable for producing components of small size and simple shapes. During operation, similar operations are performed at all the spindles simultaneously. And, machining of a component is completed in a single cycle of operation. Therefore, the number of finished components produced is equal to the number of spindles. Thus, the rate of production is high compared to progressive action machines. A parallel action multi-spindle machine is shown in figure.

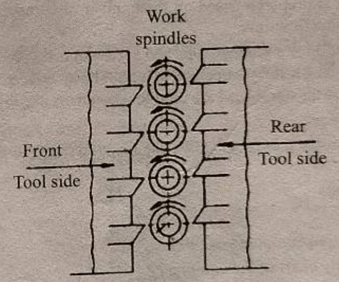


Figure (1)

2. **Progressive Action Machines:** In this machine, machining is performed in stages. The machine is provided with multiple spindles, and at each spindle, a set of operations are performed. Once the operations at a spindle are completed, the work is transferred to another spindle where further operations are performed. A finished product is obtained once the work is travelled through all the spindles. These type of machines are suitable for producing parts, which require a large number of operations. As the spindle transfers work to another spindle, a new workpiece is loaded in the previous spindle as a result, production is continuous. As the work is progressed from one spindle to another spindle, this kind of machines are termed as progressive type automatics. A six spindle progressive type automatic is illustrated in the figure (2).

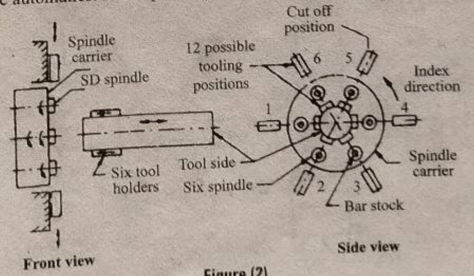


Figure (2)

Q77. Differentiate between single spindle and multi-spindle automatic lathes.

[Nov.-15, (R13), Q5(a) | Model Paper-II, Q3(b)]

Answer :

Differences between Single Spindle and Multi-spindle Automatic Lathes

	Single Spindle Automatic Lathe		Multiple Spindle Automatic Lathe
1.	It consists of a single spindle.	1.	It consists of 2 to 8 spindles.
2.	Machine only one workpiece at a time.	2.	Machine number of workpieces at a time.
3.	The example of these lathes are swiss type automatic screw machine and automatic cutting off machines.	3.	The example of this lathe is automatic bar machine.
4.	The rate of production is low.	4.	The rate of production is high.
5.	The machining accuracy is high.	5.	The machining accuracy is low.
6.	There is no indexing of the spindle.	6.	The indexing of spindles takes place through 90° to 60°.
7.	Tool setting time is less.	7.	Tool setting time is more.
8.	Economical for shorter and longer runs.	8.	Economical for longer runs only.
9.	Tools in turret are indexed.	9.	Workpiece held in spindles are indexed.
10.	Time required to produce one component is the sum of all the turret operations time.	10.	Time required to produce one component is the time of the longest cut in any one spindle.

Q78. Write briefly about tooling layout of automatic lathes.

Answer :

Tool Layout

It is a predetermined plan that gives the information regarding the types of tools and their sequence of usage in the machining process. An effective tool layout is prepared based on the number of components being machined and it gives greater accuracy in machining and minimum production time.

The tools used in the operation must be of a standard type and in case of mass production, cutting tools with large tool life are used in order to minimize the loading, unloading and re-sharpening of tools. The tools on cross-slide are used for operations like turning, facing, necking, parting etc., and the tools on the turret head are used for operations like drilling, boring reaming, etc.

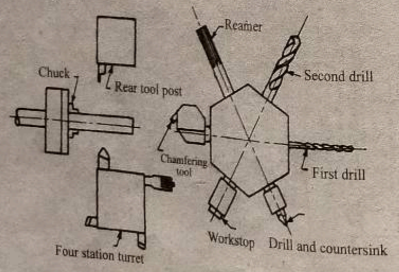
Requirements for Preparing a Tool Layout

1. **Capacity Chart of the Lathe:** Mostly it is provided by the manufacturers of the machine and it contains all the details regarding the machine.
2. Drawing of the part to be machined.
3. List of tools and tool holders.

The steps involved in designing a tool layout are as follows,

1. Firstly, consider the current capacity chart of the equipment.
2. Prepare the drawing of the final part to be machined.
3. From the final drawing, List out the operations to be performed and respective tools.
4. Superimpose the final drawing on the capacity chart and then draw the tools on the turret head and tool post at their respective positions.
5. Determine the length travelled by the tool for each face of the turret head and decide the positions of stops accordingly.
6. Determine the cutting parameters, i.e., speed, feed, depth of cut for every operation.
7. Then the tools and the work are mounted on the machine according to the layout.

A typical tool layout is shown in figure.



Figure

Q79. Draw the tool layout of Hexagonal head bolt.

Answer :

[Nov./Dec.-17 , (R15), Q4(a) | Model Paper-III, Q3(b)]

Tool Layout of Hexagonal Bolt

The tool layout for producing hexagonal bolt is shown in the following figure.

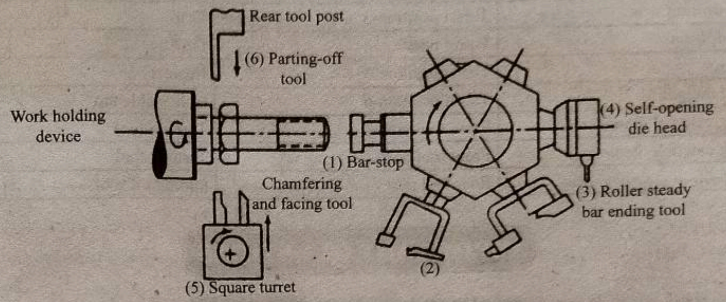
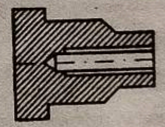


Figure: Tool Layout of Hexagonal Headed Bolt

The sequence of operation and tooling arrangement to obtain the required hexagonal head are as follows,

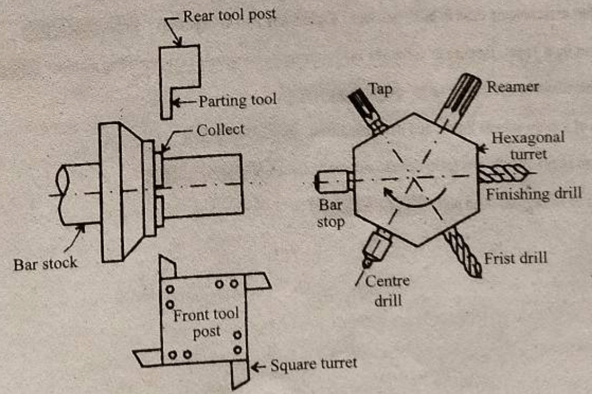
1. Feed the hexagonal bar stock to bar stop, i.e., turret (1) or tool (1). Perform parting off operation and provide clearance from collet face for the extra distance.
2. Using roller steady box turning or turret (2), turn the bar to obtain required diameter and length.
3. Using roller steady ending tool, round the bar end, i.e., chamfering operation.
4. Threads are cut on the bar upto required length using chasers fitted in the self-opening die head, i.e., turret (4).
5. Facing and chamfering of the head of the bolt are done by the tool (5) fitted in the square turret on the front side.
6. The required hexagonal bolt is obtained and it is separated by the parting off (tool (6)) fitted on the rear tool post.

Q80. Draw the tool layout for the component shown in the figure.



Figure

Answer :



Figure

The description about the sequence of operations and tool layout is explained in below table.

Operation	Tool Position	Tool Used
Feed the bar to the required length	Turret position-1	Bar stop
Centre drilling	Turret position-2	Centre drill
Rough drilling	Turret position-3	Drill
Finish drilling	Turret position-4	Drill
Reaming	Turret position-5	Reamer
Internal threading	Turret position-6	Collapsible tap
Turning external diameter-1	Front tool post-1	Turning tool
Turning external diameter-2	Front tool post-2	Turning tool
Parting off	Rear tool post	Parting off tool

IMPORTANT QUESTIONS

Q1. With a neat sketch, explain the basic elements of any machining operation. Refer Unit-I, Q42

Q2. Classify the cutting tools with brief description. Refer Unit-I, Q44

Q3. Briefly discuss about Geometry of single point cutting tool? Also, explain the following, (i) Rake angle (ii) Clearancele (iii) Cutting angle (iv) Lip angle, with neat sketch. Refer Unit-I, Q45

Q4. Compare ASA system and ORS system in designating a single point cutting tool? Refer Unit-I, Q46

Q5. Explain the geometry of chip formation with proper sketches and equations. Refer Unit-I, Q47

Q6. Derive an expression to determine chip thickness ratio and shear angle? Refer Unit-I, Q48

Q7. What is meant by built-up edge? State the causes of it. Refer Unit-I, Q52

Q8. With the help of a neat sketch explain the construction and working of Engine lathe? Refer Unit-I, Q53

Q9. How do you specify the lathe machine? Refer Unit-I, Q57

Q10. Describe the turning process in lathes. Refer Unit-I, Q58

Q11. How lathe is specified? Explain briefly the operations that are performed on a lathe. Refer Unit-I, Q60

Q12. Briefly discuss about the different type of taper turning methods with sketches. Refer Unit-I, Q61

Q13. What are the different attachments used in lathe machine? Explain any two attachments? Refer Unit-I, Q63

Q14. Explain what is meant by a Taper. Discuss in detail the taper turning by compound rest swivelling method? Refer Unit-I, Q64

Q15. Differentiate between Capstan and Turret lathe. Refer Unit-I, Q71

Q16. Explain the working of a multi spindle lathes and its applications. Refer Unit-I, Q76

Q17. Differentiate between single spindle and multi-spindle automatic lathes. Refer Unit-I, Q77

Q18. Draw the tool layout of Hexagonal head bolt. Refer Unit-I, Q79

UNIT 2

DRILLING, BORING, SHAPING, SLOTTING AND PLANING MACHINES

Syllabus

Drilling and Boring Machines – Principles of working, Specifications, Types, Operations performed, Twist drill. Types of Boring machines and applications. Shaping, Slotting and planning machines – Principles of working – Machining time calculations.

LEARNING OBJECTIVES

On the completion of this unit, the student shall be able to understand the following concepts,

- Terminology and various operations of drilling machine
- Geometry of twist drill
- Various types of boring machines and applications
- Construction and working of shaper and planar machine
- Construction and working of slotting machine
- Quick Return Mechanism for shaper
- Machining time calculations

INTRODUCTION

Drilling is a cutting operation performed by a special tool called drill, where a cylindrical hole is produced by forcing the rotating drill at the specified location.

Boring is the process of enlarging the existing hole with the aid of a single point cutting tool. This operation makes the hole to proper dimensions and also roundness is imparted.

Shaping machine was introduced by an English man James Nasmyth in the year, 1836. It is a reciprocating type of machine tool used for producing flat surfaces, which can be horizontal, vertical or inclined. In this machine, cutting tool reciprocates against the stationary workpiece and the metal is removed in the form of chips. Shaper is generally used for producing small size products. The planar is used for machining larger workpieces, in which the tool is stationary and workpiece reciprocates.

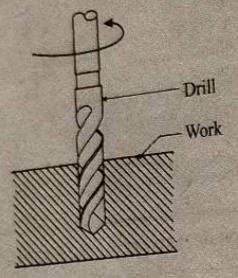
PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. What is drilling?

Model Paper-I, Q1(c)

Answer :

Drilling is a cutting operation performed by a special tool called drill, where a cylindrical hole is produced by forcing the rotating drill at the specified location. In order to perform drilling, the centre of the hole to be drilled is marked on the work by making an indentation with a centre punch. Then the chisel edge of the drill is forced into the indentation while it is rotating. As a result, a hole is produced. But the dimensions of the hole formed are slightly greater than the dimensions of drill due to the vibrations.

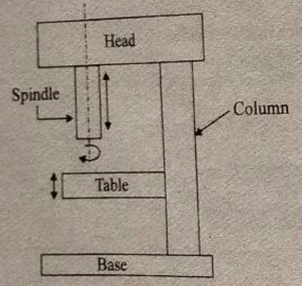


Figure

Q2. Write short notes on drilling machine.

Answer :

Drilling machine is a power operated machined tool which holds the drill (cutting tool) in its spindle rotating at high speed when it is manually actuated to move linearly against the workpiece produces a hole.



Figure

Q3. Classify different types of drilling machines.

Nov./Dec.-17, (R15), Q1(c)

Answer :

Various types of drilling machines are as follows,

1. Portable drilling machine
2. Upright drilling machine
   (i) Round column
   (ii) Box column.
3. Radial drilling machines
   (i) Plain
   (ii) Semi-universal
   (iii) Universal.
4. Sensitive drilling machine

5. Gang drilling machine
6. Deep hole drilling machine
   (i) Vertical
   (ii) Horizontal.
7. Multiple spindle drilling machine
8. Automatic drilling machine.

Q4. Describe the Portable drilling machine and its applications.

[Nov./Dec.-18, (R16), Q1(c) | Model Paper-II, Q1(c)]

Answer:

A portable drilling machine is a small, compact and self-contained drilling machine, provided with an electric motor. The components that cannot be transported to the shop floor due to their size or weight are drilled using this machine. These drills are light in weight and hence can be handled easily. They vary in terms of their sizes and capacities and hence can be used for producing a wide range of holes. Also, another advantage of the portable drilling machine is that the drilling of holes is possible at any desired inclination. These machines are used for drilling holes up to 18 mm diameter.

Applications

This machine can be used for drilling holes in large workpieces which cannot be easily held in other drilling machines.

Q5. List the operations performed on a drilling machine.

OR

Distinguish between drilling and tapping.

Nov./Dec.-16, (R13), Q1(f)

Answer :

The different operations that can be performed on drilling machines are,

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Spot facing
6. Lapping
7. Tapping
8. Counter sinking
9. Trepanning.

Difference Between Drilling and Tapping

For answer refer Unit-II, Q42, Topic: Drilling and Tapping.

Q6. What is a twist drill? What are the advantages of using it?

Answer :

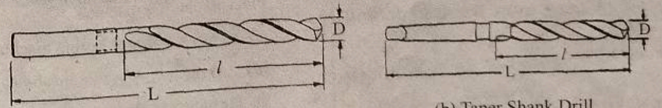
Twist drills are the most commonly used drills where the flutes are oriented at an angle to the axis of drill and permit the easy removal of chips formed while drilling and also, allow coolant or cutting fluid to flow up to the cutting zone. There are two types of twist drills based on shank style i.e., parallel shank twist drill and taper shank twist drill.

(i) **Parallel Shank Twist Drill**

The diameter of the shank is same as that of cutting end.

(ii) **Taper Shank Twist Drill**

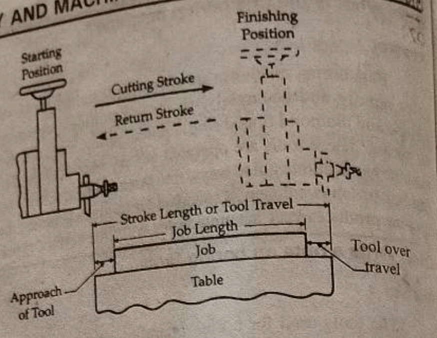
The shank of the drill conforms to the Morse taper.



Figure

Twist drills are made from high speed steel or carbon steel. These are available in various sizes.

2. **Position and Travel of Ram**
   (i) Horizontal type
   (ii) Vertical type
   (iii) Travelling head type.
3. **Type of Table Design**
   (i) Standard shaper
   (ii) Universal shaper.
4. **Type of Cutting Stroke**
   (i) Push type
   (ii) Draw type.



Figure

Q18. Name any four work holding devices in shaper.

Answer :

The following are the work holding devices used in shaper.

1. Vices
2. Parallel strips
3. Angle plate
4. Vee block
5. Stop pins toe dogs
6. Centres
7. Jack
8. Clamps.

Q19. Explain how to and fro motion is imparted to the ram in shaper.

Answer : [Dec.-19, (R16), Q1(d) | Model Paper-I, Q1(d)]

In a shaping machine, the metal is removed during the forward stroke of the ram and during return stroke, no metal is removed. The return stroke is known as idle stroke. In order to reduce the total machining time, the return stroke is made faster than cutting stroke. The motion during forward and return strokes is known as to and fro motion. This motion is achieved by using any one of the following quick return mechanisms.

1. Crank and slotted link mechanism.
2. Whitworth quick return mechanism
3. Hydraulic shaper mechanisms.

Q20. How the length of stroke and ram position in shaper can be adjusted?

Answer :

The length of stroke can be varied by adjusting the distance between the bull gear centre and the centre of the crankpin. As the bull gear centre is fixed, the variation can be provided by adjusting the slide block, such that the crankpin towards or away from the bull gear centre.

The position of the ram i.e., the tool travel can be adjusted by tightening the handle and moving the ram to the extreme rear position, which is the starting position of tool travel. Then, the handle is released and the ram is moved to desired position, which indicates the ram finishing position and the handle is tightened again. The position of ram should be adjusted such that some clearance should be provided on both the sides of the job length.

Q21. How is shaper machine specified?

Answer :

Shaper machine is specified by the following parameters,

1. Length of stroke.
2. Type of quick return mechanism.
3. Power of the drive motor.
4. Required floor space.
5. Weight of the machine.
6. Ratio of cutting stroke to return stroke.
7. Size (length, width and depth) of the table.

Q22. What are the various operations performed on shaper?

Answer :

The various operations performed on shaper are as follows,

1. Machining vertical surface
2. Machining horizontal surface
3. Machining angular surface
4. Machining irregular surface.
5. Cutting grooves, slots and keyways
6. Machining splines or cutting gears.

Q23. List the advantages of shapers.

Answer : Nov.-15, (R13), Q1(f)

The various advantages of shapers are as follows,

1. The arrangement, loading and unloading of workpieces is very easy and quick in shaper.
2. The work is held firmly with ease.
4. Flat and contour shapes can be machined on small sized workpieces.
5. The single point tools used are of low cost and can be formed to any desired shape.
6. The cutting stroke has a particular stopping point.
7. Thin and brittle workpieces can easily machined since the cutting force in shaper is low.
8. The cost of equipment is low.

Q24. Define the following terms used in shaper:
(a) Speed
(b) Feed
(c) Depth of cut.

Answer :

(a) Speed

The average linear speed of the cutting tool during the cutting stroke in m/min. It depends on the number of ram strokes per minute and the length of the stroke. Cutting speed of shaper is expressed as,

$$\text{Cutting speed} = \frac{\text{Length of cutting stroke}}{\text{Time required by the cutting stroke}}$$

(b) Feed

It is defined as the relative motion of the workpiece in a direction perpendicular to the axis of reciprocation of ram.

(c) Depth of Cut

The thickness of the material removed in one cut, in 'mm' is known as depth of cut. It is the perpendicular distance between the machined and non-machined surface of the workpiece.

Q25. Explain the working principle of slotter.

Answer : [Nov./Dec.-17, (R13), Q1(f) | Model Paper-II, Q1(d)]

In slotter, single point cutting tool reciprocates against the stationary workpiece which is held in a vice or clamped directly on the table. Generally, the slotting machine is a vertical axis shaper in vertical direction. Where as, in shaper it is in horizontal direction. The cutting action takes place in downward stroke of the tool and the upward stroke remains idle. The feed is given by the cross movement or rotary movement of the table. The depth of cut is given by the longitudinal movement of the table.

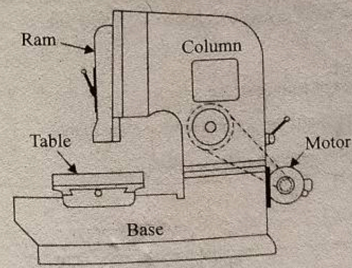


Figure: Working Principle of Slotter

Q26. Classify the slotting machines.

Answer :

Slotting machines are classified into following types.

1. Puncher slotter
2. General production slotters
3. Precision tool room slotter.
4. Key seater.

1. **Puncher Slotter**

   It is used for machining large amount of metal from the heavy workpiece that has been forged, stamped or sawn roughly to shape.

2. **General Production Slotters**

   These are mainly used for general production work.

3. **Precision Tool Room Slotter**

   It is mainly used for tool room work, where accuracy is most important.

4. **Key Seater**

   This type of slotter is specially used for machining keyways on the inside of wheel and gear hubs.

Q27. What are the operations performed on a slotter.

Answer :

The following operations can be performed on slotter.

1. Machining flat surfaces
2. Machining cylindrical surfaces
3. Machining keyways or grooves
4. Machining irregular surfaces

Q28. What is a planer? List out the operations performed on planer.

Answer :

Planer is a machine tool, used to produce flat surfaces on workpieces too large or too heavy which cannot be machined on shaper. The work is securely fixed on the table called 'platen'. Unlike the shaper, in planar the table reciprocates against the stationary cutting tool during operation.

The various operations performed on a planer are,

1. Planing horizontal surfaces
2. Planing vertical surfaces
3. Planing at an angle and machining dovetails
4. Planing curved surfaces
5. Planing slots and grooves.
6. Planning of helix.
7. Gang or multiple planning.

Q29. Give the classification/types of planers.

Answer :

The common types of planers used in machining are as follows,

1. Standard or Double housing planer.
2. Open side planer.
3. Pit planer.
4. Edge or Plate planer.
5. Divided table or Tandem planer.
6. Planer type milling machine.

Advantages of Twist Drill

(i) It requires less power for same size and depth of hole compared to other type of drills.

(ii) Flute provides easy passage for the chips to escape automatically from the hole.

(iii) Cutting edges remain in good condition for longer period. Thus, the frequent regrinding is avoided.

(iv) High speeds and feeds can be employed safely, which reduces the operating time significantly.

Q7. Why a flat drill is considered obsolete in modern drilling practice while it is the cheapest of all the drills?

May/June-12, Set-3, Q7(a)

Answer :

Though flat drill is the simplest and cheapest of all forms of drills, it became obsolete in modern drilling practice due to its following disadvantages.

1. It is not suitable for producing deep holes.
2. The cutting edge becomes dull very frequently due to the presence of metal chips inside the drilled holes, i.e., tool life is less.
3. High speeds and feeds are not employed with this drill.
4. The holes drive with this drill are not accurate.

Q8. What is the function of flutes on a twist drill?

May/June-19, (R16) Q1(d)

Answer :

The flutes on twist drill are oriented at an angle to the axis of the drill and permit the easy removal of chips formed while drilling, and also allow the coalant or cutting fluid to flow up to the cutting zone.

Q9. Why are straight flute drills used for non-ferrous material and sheet metal?

Answer :

Straight flute drills consists of grooves or flutes parallel to the axis of the drill. These are generally used to drill non-ferrous materials and sheet metals as it prevents the digging action and also eliminates the contact of chips with rake face which is caused due to the ductility and softness of the material. Use of straight flute drills for machining non-ferrous materials and sheet metals results in accurate hole diameter with good surface finish.

Q10. Specify the precautions to be taken in drilling operation.

Dec.-11, Set-4, Q8(a)

Answer :

The following are the safety precautions to be considered in drilling operation.

1. Exact size of drill bit should be used.
2. Cutting speed must be always within the allowable limit.
3. Appropriate, feed force and sufficient coolant should be used, to avoid excessive heating.
4. Ensure continuous chip flow from the drilled hole to prevent drill clogging, excessive heating and drill breakage.
5. Protective eye shielding should be used during operation.
6. Loose clothing should be avoided.
7. Any adjustments should not be made while machine is operating.
8. Never clean away the chips with hand, always use a brush.

Q11. What is boring? Sketch a boring tool?

May/June-19, (R16), Q1(e)

OR

Explain clearly what is meant by boring.

Answer : [Nov./Dec.-12, (R09), Q4(a) | Model Paper-III, Q1(e)]

Boring is the process of enlarging an existing hole which are either drilled or punched or produced in casting or forging. It gives required size and better finish to the hole and also corrects the hole location. This process is carried out with a single point cutting tool. As compared to reaming, boring gives high accuracy of about ± 0.0125 mm. Boring of small holes on small work pieces can be effectively done on a centre lathe. Whereas, boring a large hole on a large workpiece requires special boring machines. The machining accuracy and surface finish obtained depends on the type of tool used like rough boring tools or finish boring tools.

Q12. List out the types of boring machine.

Nov.-15, (R13), Q1(f)

Answer :

1. Horizontal boring machine
   (i) Table type boring machine
   (ii) Floor type boring machine
   (iii) Planer type boring machine
   (iv) Multiple head type boring machine.
2. Vertical boring machine
   (i) Vertical Turret machine
   (ii) Standard Vertical Boring machine.
3. Precision boring machine
   (i) Horizontal type boring machine
   (ii) Vertical type boring machines
4. Jig boring machine
   (i) Vertical type jig boring machine
   (ii) Planer type jig boring machine.

Q13. What is the fine boring machine?

Answer :

Fine boring machines are specially designed for boring holes rapidly and accurately. In these machines, cemented carbide and diamond tipped single point cutting tools are used for boring. These tools are operated at very high speeds. This machine has accurate guide ways, fine threaded feed screws and gear box to achieve different speeds. Due to these features, this machine produces very accurate holes with fine surface finish.

Q14. Write a note on boring tools.

Answer :

The tools used for boring operation are mostly single point cutting tools. They are broadly divided into two types they are,

1. Rotating type tools
2. Non-rotating type tools

1. **Rotating Type Tools**

These are either single cutting edge tools or multi cutting edge tools. In these tools, the tool bits are directly inserted in the slot of boring bars which have taper shanks so that is can fit in the spindle easily. If the bar is long, bearings are used for support. Sometimes, boring head also used for holding the tools.

2. **Non-rotating Type Tools**

These are two types,

(i) Forged type boring tool
(ii) Inserted type boring tool

(i) **Forged Type Boring Tool**

In these type of tools, the end is forged and ground to the required shape as shown in below figure. These tools are used for boring small holes.

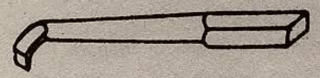


Figure: Forged Type Boring Tool

(ii) **Inserted Type Boring Tool**

In this type, HSS tool bits are ground to required shape and inserted in the slot of the bar. The tool bit is secured firmly with the help of screws. The recommended rake angles and cutting edge angles similar to the tools used for lathe work.

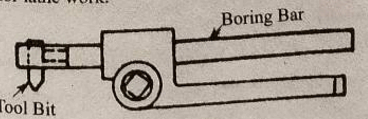


Figure: Inserted Type Boring Tool

Q15. Give the specification of boring machine.

Dec.-19, (R16), Q1(c)

OR

What factors are considered to specify a boring machine?

Answer :

The following factors are considered for the specification of a boring machine.

1. Horse power of the spindle motor
2. Speed of the spindle
3. Required floor space
4. Machine weight
5. Length of feeds.

Generally, to specify a horizontal boring machine, spindle diameter is considered which ranges from 75 mm to 355 mm.

Q16. State the working principle of shaper.

Answer :

In a shaper machine, a single point cutting tool reciprocates over a stationary workpiece. The workpiece is held in a vice and the cutting tool is held in the tool head, mounted on the ram. When the movement of ram is in the forward direction (cutting stroke) then the tool cuts the material from the workpiece. During the backward stroke, the tool does not remove the material and it is an idle stroke. Thus, the duration of return (backward) stroke is less than the forward stroke. The depth of cut can be obtained by lowering the tool towards the workpiece.

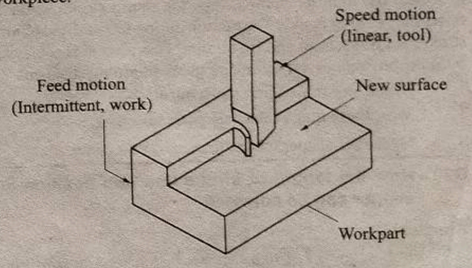


Figure: Working Principle of Shaping Machine

Q17. How are shapers classified?

Answer :

Shapers are classified based on the following parameters.

1. **Type of Mechanism**
   (i) Crank type
   (ii) Geared type
   (iii) Hydraulic type.

Q30. Discuss the characteristics of planer machined parts. Nov./Dec.-18, (R16), Q1(...)

Answer:

Characteristics of Planar Machine Parts

1. Flat and large sized work parts like machine tool beds and slides, etc., are machined by planing operation. Planer can also generate contours and different irregular configurations like deep slots on large rotors, helical grooves on large rolls, etc.
2. The dimensions of the workpiece preferred to undergo planing process are 4m × 1m × 1m.
3. The large parts obtained after casting and welding are mainly preferred.
4. Thickness of surface of workpart to be machined should be greater than 0.3 m.

Q31. Can we use shapers and planers for mass production? Justify your answer. [Dec.-11, Set-1, Q5(a) | Model Paper-III, Q1(...)]

Answer :

Shaping is a metal removing process, which is used for machining flat surfaces by using a tool called shaper tool. It can also machine components of irregular and curved surfaces. But, the ram which reciprocates to cut the material has limited length due to which it is used for machining small sized components. It is a slower metal removing process, as it cuts the material only in forward motion. Thus, shaping is suitable for batch production rather than mass production. Planing is a process of machining large sized flat components. It uses multiple cutting tools at a time and can be able to hold large and heavy jobs. Simultaneously, planer can also machine the small sized components, that are arranged on the table. Planers are mostly suitable for machining large sized components. Hence, it can be used for mass production. Therefore, it can be justified that shaper cannot be used for mass production, but planer can be used.

Q32. Discuss the advantages of planer over shaper and slotter.

Answer :

Advantages of planer over other machining processes are as follows,

(a) Possibility of taking much heavier cuts.

(b) It can handle large sized workpieces easily.

(c) In planer, the work is mounted on a table which supports the workpiece through its entire movement, hence maximum support is obtained.

(d) There is no work or tool deflection or distortion.

(e) It can be possible to take multicuts at various places in a single pass of cutting stroke.

(f) Planer can machine a number of small parts simultaneously, as these parts are set in-line on a planer table.

(g) Planers can produce heavy work at lowest cost in comparison to other machining processes.

Q33. State the main differences between shaper and planer.

Answer :

	Shaper		Planer
1.	The workpiece is held stationary and the tool reciprocates.	1.	The workpiece reciprocates and the tool is held stationary.
2.	It is suitable only for machining small sized workpieces.	2.	It is suitable for machining large sized workpieces.
3.	Only one cutting tool is used at a time. Hence, machining time is longer.	3.	More than one tool can be used at a time. Hence, machining time is less.
4.	These machines are lighter and smaller.	4.	These machines are heavier and larger.

Q34. A 10 mm drilled hole in a casting of 10 mm thickness is to be brought in alignment by boring. Calculate the time taken in boring operation, assuming cutting speed 30 m/min and feed 0.13 mm/rev.

Answer :

Given that,

Drilled hole diameter, $D = 10$ mm

Thickness, $t = 10$ mm

Cutting speed, $S = 30$ m/min,

Feed, $f = 0.13$ mm/rev.

Spindle speed,

$$N = \frac{S \times 1000}{\pi D}$$

$$= \frac{30 \times 1000}{\pi \times 10}$$

$$= 954.929 \text{ rpm}$$

∴ Machining time,

$$T = \frac{t}{N \times f}$$

$$= \frac{10}{954.929 \times 0.13} \text{ min}$$

$$= \frac{10 \times 60}{954.929 \times 0.13} \text{ sec}$$

$$= 4.83 \text{ sec}$$

Q35. In a shaper work the length of stroke is 300 mm. Number of cutting strokes per minute is 40 and the ratio of return time to cutting time is 1:2. Find the cutting speed.

Answer :

Given that,

Number of cutting strokes per minute, $n = 40$

Length of cutting stroke, $L = 300$ mm

Ratio of return time and cutting time, $m = \frac{1}{2}$

Cutting speed is given by,

$$= \frac{nL(1+m)}{1000}$$

$$= \frac{40 \times 300\,(1 + (1/2))}{1000}$$

$$= \frac{12000\,(1 + 0.5)}{1000}$$

∴ Cutting speed = 18 m/min

PART-B ESSAY QUESTIONS WITH SOLUTIONS

2.1 DRILLING MACHINES: PRINCIPLES OF WORKING - SPECIFICATIONS - TYPES - OPERATIONS PERFORMED - TWIST DRILL

Q36. Write short notes on the elements of drilling machine. Also specify the precautions to be taken in drilling operation.

[Nov.-10, Set-3, Q4(a) | Model Paper-I, Q4(a)]

Answer :

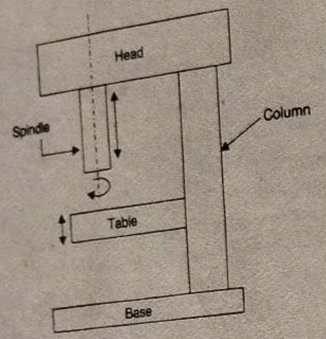


Figure: Drilling Machine

1. **Base**

   It is the bottom most part of the machine, which acts as foundation to machine, on which all other components are mounted.

2. **Column**

   It acts as a pillar, supporting drill head and work table and it is attached to base perpendicularly.

3. **Work Table**

   It is a flat surface provided with *T*-slots, for clamping the workpiece. It can move up or down and swing, with respect to column to perform operations accordingly.

4. **Motor**

   Motor transmits power to the spindle, by means of pulleys and gear box, to give different range of spindle speeds.

5. **Spindle Head**

   It is mounted at the top of the column. It has drive motor on one side and spindle assembly on the other side.

6. **Drive Mechanism**

   The motor dirves the spindle through V-belt and stepped cone pulley. By shifting the belt from one pully to the other, the spindle speeds can be changed.

Precautions to be taken in Drilling Operation

The following are the safety precautions to be considered in drilling operation,

1. Exact size of drill bit should be used.
2. Cutting speed must be always within the allowable limits.
3. Appropriate, feed force and sufficient coolant should be used, to avoid excessive heating.
4. Ensure continuous chip flow from the drilled hole, to prevent drill clogging, excessive heating and drill breakage.
5. Protective eye shielding should be used during operation.
6. Loose clothing should be avoided.
7. Any adjustments should not be made while machine is operating.
8. Never clean away the chips with hand, always use a brush.

Q37. Give a brief description of portable drilling machine and their uses and compare with pedestal drilling machine.

Answer :

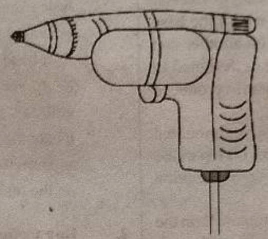


Figure: Portable Drilling Machine

A portable drilling machine is a small, compact and self-contained drilling machine, provided with an electric motor. The components that cannot be transported to the shop floor, due to their size or weight, are drilled using this machine. These drills are light in weight and hence can be handled easily. They vary in terms of their sizes and capacities and hence can be used for producing a wide range of holes. Also, another advantage of the portable drilling machine is that the drilling of holes is possible at any desired inclination. These machines are used for drilling holes upto 18 mm diameter.

A pedestal drilling machine or bench drilling machine is used for light duty works. In this machine, the drill is fed into the work by hand only. The operator has to sense or feel the travel of the drill into the work, and handle the machine, hence it is called sensitive drilling machine. The pressure on the drill may be released immediately to prevent it from breaking, if the drill is worn out. It is also called as pedestal drilling machine, as the pressure has to be applied by hand, to push the drill into the work. These machines are used for drilling holes of 1.5 mm to 15 mm in diameter. These drills are rotated at higher speeds than the portable drilling machines.

Q38. Explain the working of radial drilling machine with a sketch. Nov./Dec.-18, (R16), Q4(a)

OR

With the help of neat sketch explain the radial drilling machine.

[Nov./Dec.-17, (R15), Q7(a) | Model Paper-II, Q4(a)]

Answer :

Radial drilling machines are most suitable for drilling on large and heavy workpieces and can drill holes up to 50 mm in diameter. The radial and vertical motion of the arm, horizontal motion of drill head over radial arm makes the machine more versatile.

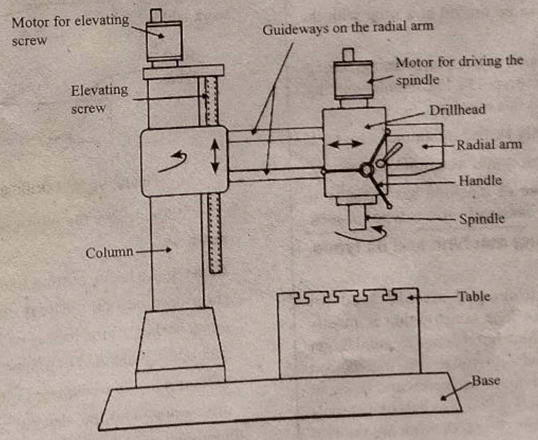


Figure: Radial Drilling Machine

The main parts of a radial drilling machine are as follows,

1. **Base:** It is a heavy rectangular structure made of graded steel whose upper surface is accurately finished and provided with T slots to clamp work holding devices or to mount heavy works directly. On one end of the base has a vertical column is supported and on another end is mounted with a work table. The base is designed in such a way that it can tolerate heavy vibrations produced while drilling.
2. **Column:** It is a vertical cylindrical structure mounted on the base and is equipped with the motor on top of the column and an elevating screw to provide vertical motion to radial arm in either direction.
3. **Radial Arm:** It is a horizontal extension mounted on the vertical column and can slide vertically on the guideways provided on the column and also can swing around the column up to 180° or more. Guideways are provided on front vertical face upon which drill head is slid.
4. **Drill Head:** It is a heavy rigid casting mounted on the guideways of the radial arm and can slide along the guideways to alter the position of the spindle according to the workpiece. It acts as a housing for all the mechanisms of speed and feed.
5. **Spindle Speed and Drive Mechanism:** In most of the cases, a constant speed motor is directly mounted on top of the drill head and spindle obtains multiple speeds and feeds through motor via gear trains. In some cases, the motor is mounted on another side of the radial arm to partially balance the weight of the drill head. And is connected to spindle through bevel gears.

Q39. Write the advantages of Radial drilling machine.

Answer :

Advantages of Radial Drilling Machine

1. The arrangement is simple and any improvements or modifications can be done easily.
2. More than two holes can be drilled at a time with the help of proper jigs.
3. The various operations such as tapping, reaming, boring, counter-boring, trepanning, spot facing, counter-sinking, etc., can also be done on this machine.
4. It does not requires highly skilled operator.
5. The cost of operation is less and is a quick process.
6. The work table and base of machine has capacity to accommodate different sizes and various types of jobs.

Q40. Explain upright drilling machine and its types.

Answer :

Upright drilling machines are mainly used for machining medium sized works. The construction is mostly similar to sensitive drilling machine but it is heavier and larger comparatively. It is also equipped with power feed mechanism and another mechanism to obtain multiple speeds and feeds, in order to make it suitable for machining various kinds of materials and performing various operations. The following are the two types of the upright drilling machine.

1. **Pillar or Round Column Section Drilling Machine:** The construction of this kind of machines is mainly intended for machining lighter works and can produce holes up to 50 mm in diameter. These machines are provided with a round column mounted on the base, a drill head and a round table. The arm and the table can be moved in up and down i.e., in the vertical direction and can also be swivelled upto 180° to mount and locate the works of different sizes. In case of heavy and asymmetrical workpieces, they can be directly placed on the machine base.
2. **Box Column Section:** This is mostly similar to pillar drilling machine but the only difference is the table is of square shape and column is designed in a box shape which is very heavy to ensure the strength and rigidity of machine. The table is mounted on the slides provided on the front face of the column and can be moved up and down. These features allow the machine to drill the holes of diameter more than 50 mm and deal with heavier works.

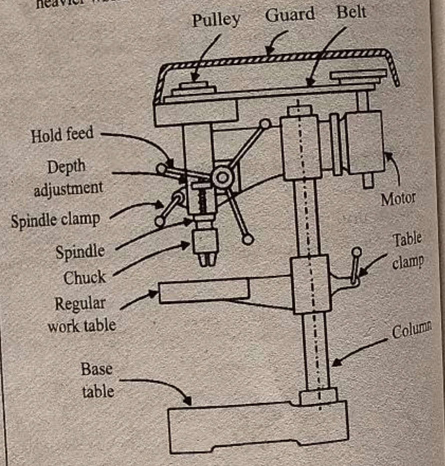


Figure: Upright Drilling Machine

The following are the main parts of an upright drilling machine,

1. **Base:** It is a heavy casting fixed to the floor of machine shop upon which vertical column is mounted. The upper surface of the base is provided with T slots and is accurately machined to mount work holding devices or to mount heavy workpieces directly. In the case of belt driven machines, the driving mechanism consisting of cone pulley and fast and loose pulleys are fixed to the base.

2. **Column:** It is a heavy and rigid vertical member which can be either box section or round section. The front surface of the column is provided with guideways upon which the table and head are mounted along with their driving mechanism and can be slid in the vertical direction with the aid of lever provided.
3. **Table:** The table can be either rectangular or circular in shape. It is mounted on the slides provided on the front face of the column and can be moved up and down. The upper surface of the table is accurately finished and provided with T-slots for clamping work holding devices or work directly.
4. **Head:** It acts as housing for driving and feed mechanisms and is mounted on the guide provided in the column. An electric motor is mounted on the head and is connected to spindle through a gear train to obtain multiple spindle speeds and feeds. In the case of small machines, the electric motor is mounted on another side of the head to balance the weight of the head.
5. **Spindle Speed and Drive Mechanism:** There are multiple mechanisms involved in proper and accurate working of the drilling machine. The mechanisms are to obtain multiple speeds with multiple feeds, to machine wide range of materials.
   (i) Mechanisms for driving spindle
      (a) Step cone pulley drive
      (b) Step cone pulley drive with back gear
      (c) Gear trains.
   (ii) Mechanisms for feed
      (a) Quick traverse hand feed
      (b) Sensitive hand feed.

Q41. How is the size of drilling machine specified? Discuss.

Answer :

A drilling machine is specified as follows,

1. Maximum diameter of the drill bit that can be held in the spindle.
2. Maximum size of workpiece that can be centered under the spindle.
3. Size of the drilling machine table.
4. Length of arm and column diameter for radial drilling machine.
5. The distance through which spindle can traverse.
6. The number of spindle speeds and feed.
7. Power of the motor.

Q42. Explain various operations performed on drilling machine.

[Nov./Dec.-16, (R13), Q6(b) | Nov.-15, (R13), Q6(a) | Model Paper-III, Q4(a)]

OR

Explain the operations done on a drilling machine in detail with neat sketches.

[Dec.-11, Set-3, Q2 | Nov.-10, Set-1, Q2]

Answer :

The various operations performed on drilling machine are,

1. Drilling
2. Boring
3. Reaming
4. Counter boring
5. Counter sinking
6. Spot facing
7. Tapping
8. Trepanning.

1. **Drilling:** It is a cutting operation performed by a special tool called drill, where a cylindrical hole is produced by forcing the rotating drill at the specified location. In order to perform drilling, the centre of the hole to be drilled is marked on the work by making an indentation with a centre punch. Then the chisel edge of the drill is forced into the indentation while it is rotating. As a result, a hole is produced. But the dimensions of the hole formed are slightly greater than the dimensions of drill due to the vibrations.

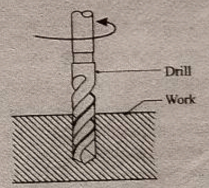


Figure (1)

2. **Boring:** It is the process of enlarging the existing hole with the aid of a single point cutting tool. This operation makes the hole to proper dimensions and also roundness is imparted.

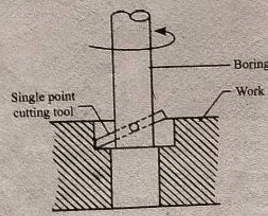


Figure (2)

3. **Reaming:** It is the process of finishing a drilled or enlarged hole to a greater extent of accuracy. This operation is either performed manually or by a machine. The allowance for machine reaming ranges from 0.13 to 0.1 mm.

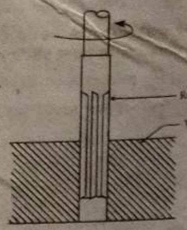


Figure (3)

4. **Counter Boring:** It is similar to the process of boring but, the hole is enlarged only upto certain depth thereby it forms a square shoulder to accommodate the heads of screws, studs, bolts, and pins such that they can lay flush with the work surface.

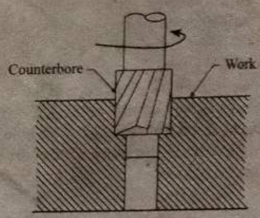


Figure (4)

5. **Counter Sinking:** It is also similar to boring but the only difference is the hole is enlarged in the form of a cone shape upto certain depth. The standard included angles of cone shapes produced are 60, 82, and 90 degrees. This operation is mainly performed to provide a recess for countersink rivet or a flat head screw.

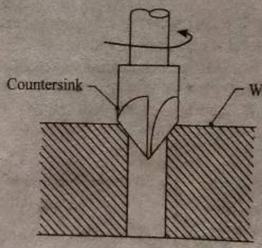


Figure (5)

6. **Spot Facing:** It is the process of removing the material on the surface of the work around hole to obtain a flat surface. This forms a proper seat for head or nut.

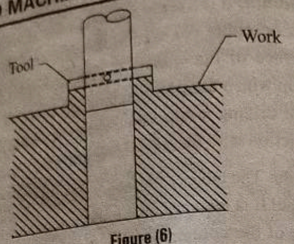


Figure (6)

7. **Tapping:** The process of producing internal threads in a hole by using screw like cutting tool (called tap) is known as tapping. The threads on the cutting tool (tap) are hardened and grounded. These act as cutting edges and perform the cutting action. When the tap is turned into the hole, it cuts the internal threads by removing the metal from the surface of the hole. The process of tapping can be explained by the following figure.

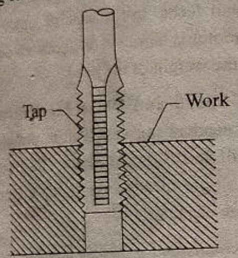


Figure (7)

8. **Trepanning:** It is the process of producing holes of large diameters by a specially designed tool which looks visually similar to a hollow tube. One end of the tube has cutting edges while the other end has a shank to fit into the spindle. The material is removed by cutting a narrow groove along the circumference.

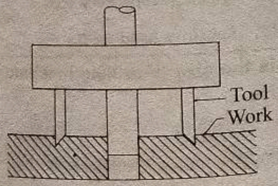


Figure (8)

Q43. What is deep hole drilling? List the measures to be taken to avoid drill run off and to drill straight holes.

Answer :

Deep hole drilling is a drilling process of producing holes of depth, larger than the standard length of drill. It is performed on deep hole drilling machine and is performed at low feed, in order to prevent deflection of drill.

Twist drills cannot be used for drilling deep holes because of certain problems like carrying the coolant to the hole and flushing out the chips from the hole. Gun drilling using high-pressure coolant is best suited method for deep holes. Gun drills produce very straight holes of good surface finish and close tolerance. In gun drill, a portion of the hole machined by the tool acts as a continuation of the guide bushing, hence the tool continues to cut a straight hole in the direction it was started. It represents a single point end cutting tool. The depth of hole is limited by the shank torsional rigidity.

Gun drills may be either,

1. External chip removal type or
2. Internal chip removal type.

Either, the drill may be stationary and work rotates or the drill may rotate and work is stationary. Both the drill and the workpiece are rotated for high accuracy and minimum drift of the drill.

The following measures are taken to avoid drill run off and to drill straight holes,

1. Initially, the hole should be spotted by a twist drill of 90° point angle.
2. Required amount of cutting fluid should be provided.
3. Adhesion between chips and drill is avoided.
4. Drilling is performed at low feed rate.
5. For drilling deep holes, work piece is rotated to reduce run-off.
6. Sharpening of drills is done carefully to maintain same inclination angle of both lips.
7. For low length to diameter ratio drilling holes, twist drills are guided by jig bushes.

Q44. With the help of a neat sketch show the different angles of a drill and explain their influence on drilling performance.

May/June-12, Set-3, Q7(b)

Answer :

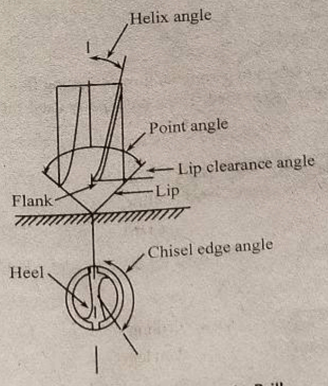


Figure: Different Angles of a Drill

Different Angles of a Drill

Some of the major angles which has greater influence on drilling are,

1. Chisel edge angle
2. Helix angle
3. Lip clearance angle
4. Point angle.

1. **Chisel Edge Angle**

The obtuse angle formed between the cutting lip and chisel edge is known as chisel edge angle. It indicates the clearance on the cutting lip near the chisel edge. As the value of this angle increase, the clearance on the cutting lip also increases. The value of this angle ranges form 130° to 145°. For smaller drills, bigger chisel edge angles are preferred.

2. **Helix or Rake Angle**

The included angle between the drill axis and the leading edge of the land is referred as Helix angle. This angle has greater influence on the power or torque required to rotate the drill, thus, higher the value lesser the torque and vice-versa. It can be either positive or negative, depending upon the flute direction. However, it ranges between 0° to 48°. Generally, for harder metals, the angle is smaller, whereas for softer materials, its value is higher. For common materials it ranges from 16° to 32°.

3. **Lip or Chip Clearance Angle**

The angle subtended between the plane normal to the drill axis and the flank measured at the circumference of drill is termed as lip clearance angle. This angle is formed by grinding the relief adjacent to the cutting edges. This angle facilitates easy insertion of drill into the material. It is also called as lip relief angle and ranges form 8° to 15°, but most commonly used is 12°.

4. **Point or Cutting Angle**

The angle formed by two cutting edges (or lips) of a drill at a point, which includes the drill axis is known as point angle. It is generally taken as 118° for most of the metals. However, its value ranges between 80° to 140°. For harder materials, the point angle is larger whereas, for brittle materials it is smaller.

Q45. What are the different types of drill are used? Describe any one of the drill bits.

Nov./Dec.-18, (R16), Q4(b)

OR

State the different types of drills used. Explain their functions.

Answer : [May/June-13, (R09), Q4(a) | Model Paper-I, Q4(b)]

A drill is a kind of cutting tool, whose surface is made of flutes and is used to generate holes in a solid material. Based on the geometry of flutes there are various types of drills as follows,

1. **Flat Drill:** The cutting edges of this tool are flat with two cutting lips, as shown in the figure. These drills are usually used when twist drill of the same size is unavailable. These drills are visually similar to gun drills and are also called as a spade drills. The angle between the two cutting lips varies from 90 to 120 degrees. This type of drills are mainly used for drilling holes in walls and wood. The major problem with these drills are, they will not push out the chips formed which result in clogging of the hole.

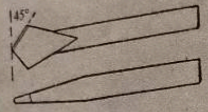


Figure (1)

2. **Straight Fluted Drill:** The flutes or grooves are oriented in parallel to the axis of drill and are considered as tools with zero rake angle. Mostly, these drills are not preferred as the chips formed while drilling does not come out and also these tools cannot be fed as fast as twist drills. Hence, their use is limited to drill holes in softer materials like brass copper etc.

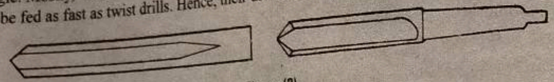
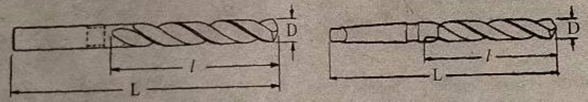


Figure (2)

3. **Twist Drills:** These are the most commonly used drills where the flutes are oriented at an angle to the axis of drill and permit the easy removal of chips formed while drilling and also, allow coolant or cutting fluid to flow up to the cutting zone. There are two types of twist drills based on shank style i.e., parallel shank twist drill and taper shank twist drill.
   (i) **Parallel Shank Twist Drill:** The diameter of the shank is same as that of cutting end.
   (ii) **Taper Shank Twist Drill:** The shank of the drill conforms to the Morse taper.



(a) Parallel Shank Drill (b) Taper Shank Drill

Figure (3)

4. **Taper Shank Core Drill:** the main purpose of this drill is to enlarge the holes generated. This type of drill is provided with three or four flutes and is mainly used for enlarging the holes produced earlier. These are designed in such a way that, these are only intended for enlarging, sizing and finishing holes rather than producing them.

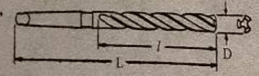


Figure (4)

5. **Oil tube Drill:** The flutes of these drills consist of tiny holes along their length to permit the flow of cutting fluid through them to the cutting zone for lubricating, cooling and carrying away the chips formed. These are mainly used for drilling deep holes.

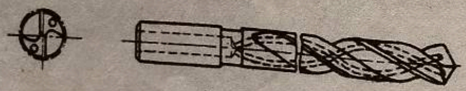


Figure (5)

6. **Centre Drill:** These drills consist of two flutes and straight shank. These are mainly used for drilling centre holes at the ends of the shaft.

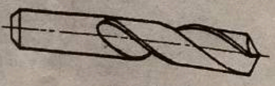


Figure (6)

Q46. Explain the twist drill geometry with neat sketch.

Answer : Dec.-11, Set-14, Q7(a)

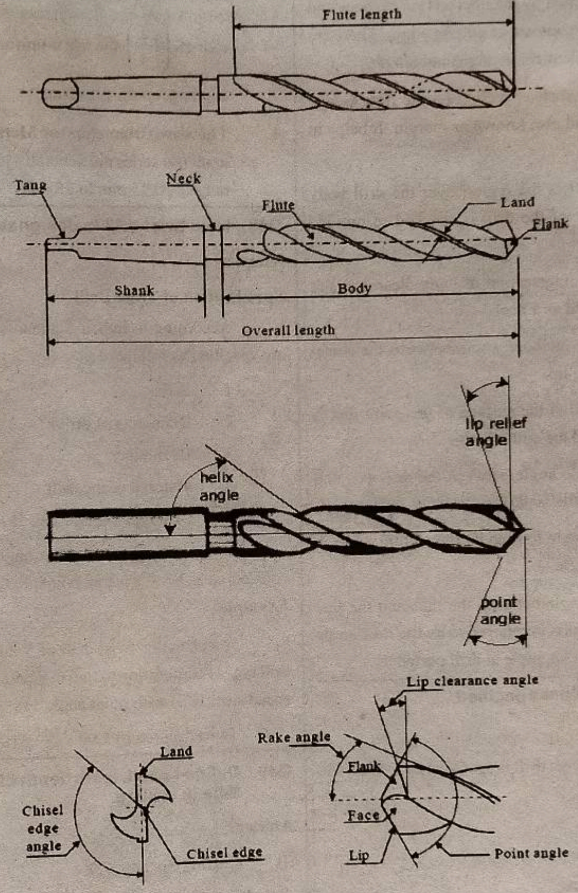


Figure: Twist Drill Nomenclature

The nomenclature of the twist drill include the following.

1. **Body:** The region on the drill from the extreme point to the shank or neck is called body.
2. **Shank:** The cylindrical region on the drill which is extending from the neck is called a shank and is used to mount the drill on drilling machine spindle. The shape of the shank may be tapered or straight.
3. **Tang:** This can be observed only in case of taper shank drills as it is the flattened end of the tapered shank that gets into drill holder or socket. It assures positive drive of the drill.
4. **Neck:** The portion of drill that connects shank and the body is called as neck.
5. **Flutes:** The long helical grooves which are diametrically opposite and run throughout the length of the drill are called as flutes. These allow cutting fluids to flow to the region of cutting and also permit chips to flow out.

6. **Web:** The central region of the body that separates the flutes and run throughout the length of the drill.

7. **Lips:** These are formed by the intersection of faces and flanks. These are also known as cutting edges. There are two cutting edges identical in angle and length.

8. **Land:** The narrow surface ground on the flute's edge is called as land, and also known as margin. It helps in aligning the drill.

9. **Body Clearance:** It is the region over the drill body where the diameter of the drill is reduced to provide clearance.

10. **Heel:** The point of intersection of body clearance and flute surface is called as a heel.

11. **Chisel Angle:** The included angle between the chisel edge and the cutting lip.

12. **Lip Relief Angle:** It is the surface of the point that is relieved, just behind the cutting edge.

13. **Helix Angle:** It is the angle between the drill axis and the leading edge of the land.

14. **Point Angle:** The angle formed by the cutting edges at the point is point angle.

15. **Rake Angle:** The angle between the face and the line parallel to the drill axis is referred to as the rake angle and is equal to the helix angle at drill periphery.

Q47. How are drill size are specified.

Answer:

The size of stanard twist drill is specified by four series. They are,

1. Number series
2. The letter series
3. Fractional series
4. The metric series

1. **Number (Wire Gauge) Series:** The standard set of number sized drill consists of 80 drills, numbering 1 to 80. In this drill series, higher the number, smaller is the drill size i.e., diameter of No.1 drill measures 0.228 inches and of No. 80 measures 0.0135 inches.

2. **The Size of Letter Series:** The standard set of this series of drills are designated by letters from A to Z, in which Z represents the largest drill size and A represents the smallest drill size.

3. **The Fractional Series:** In this series, the size of drill starts from $\left(\frac{1}{64}\right)''$ upto 5" in diameter and till the drill size of $\left(1\frac{3}{4}\right)''$ the rise is uniform i.e., in steps of $\left(\frac{1}{64}\right)''$ and beyond this, it varies.

4. **The Sizes (Diameters) or Metric Series:** The drills used in metric series are generally given in millimeter, in the range of 0.35 mm to 25 mm.

Q48. How twist drill is designated.

Answer :

Specification of Twist Drill

According to Indian Standards system, the twist drills are specified as follows,

1. Series
2. Diameters of drill
3. I.S number
4. Material of the drill
5. Drill type (N-Normal, H – Hard and S – Soft)

If the drill type and point angle is not specified, it is considered as N – Type and point angle as 118°.

Example

A stub series twist drill of 5 mm nominal diameter of drill type N conforming to Indian Standard and made up of high speed steel (HS) with point angle 118° is designated as,

Twist drill (stub) 5.00 – IS : 5100 HS

Q49. Define speed, feed, depth of cut and machining time in drilling.

Answer :

(i) **Cutting Speed**

Cutting speed is defined as the peripheral speed of a point on the surface of the drill in contact with the workpiece. It is expressed in meters per minute.

i.e,, Cutting speed,

$$V_c = \frac{\pi \times \text{Diameter of the drill in mm} \times \text{Speed in r.p.m}}{1000}$$

$$= \frac{\pi DN}{1000} \text{ m/min}$$

Where,

D – Diameter of the drill (mm)

N – Rotation speed of the drill (r.p.m)

(ii) **Feed**

It is defined as the distance, the drill advances into the workpiece, for each revolution of the spindle. It is expressed in millimeter per minute or millimeter per revolution.

Feed per min is given by,

$$\text{Feed/min}, f_m = f \times N$$

Where,

f – feed/rev

N – Revolutions of drill (r.p.m)

(iii) **Machining Time in Drilling**

It is defined as the time taken for the drill to produce a hole in the workpiece.

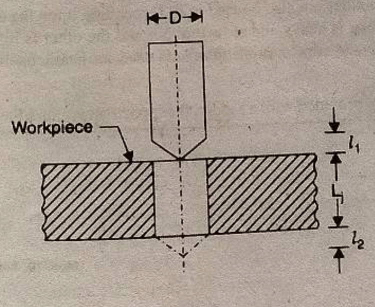
$$\text{Machining time}, T = \frac{L_1 + L_2 + L_3}{f_m} = \frac{L}{f \times N}$$

Where,

L_1 – Tool approach (= 0.29D)

L_2 – Hole length or depth in mm

L_3 – Tool over travel (1 to 2 mm)



Figure

(iv) **Depth of Cut in Drilling**

The depth of cut in drilling is given by,

$$t = \frac{D}{2} \text{ mm}$$

Where,

t – Depth of the cut in mm

D – Diameter of the drill in mm

Q50. Estimate the time required to drill a hole on a wider face of a give workpiece of size 2m × 1m × 50 mm. Assuming the cutting angle as 230 degrees, approach and overrun be 30 mm each, cutting velocity 52 m/min, feed be 2 mm/ stroke and clearance on both side be 20 mm.

Answer : [Nov./Dec.-17, (R15), Q7(b) | Model Paper-III, Q4(b)]

Given that,

Length, $l = 2$ m

Width, $w = 1$ m

Thickness of workpiece = Hole depth, $L_2 = 50$ mm

Cutting angle = 230°

Approach, $L_1 = 30$ mm

Over run, $L_3 = 30$ mm

Cutting velocity, $V_C = 52$ m/min

Feed, $f = 2$ m/stroke

Clearance on both sides, $c = 20$ mm

But, approach = 0.3D

$$30 = 0.3D$$

$$D = \frac{30}{0.3} = 100 \text{ mm}$$

∴ Diameter of the drill is 100 mm.

Cutting speed of drilling operation is given by,

$$V_C = \frac{\pi DN}{1000}$$

$$N = \frac{V_C \times 1000}{\pi D}$$

$$N = \frac{52 \times 1000}{3.14 \times 100}$$

∴ Revolution of drill, $N = 165.605$ rpm.

Drilling time is given by, $T = \frac{L}{f \times N}$

Where,

$$L = L_1 + L_2 + L_2$$

$$= 30 + 50 + 30 + (2 \times 20)$$

$$\therefore L = 150 \text{ mm}$$

$$\therefore \text{Drilling time} = \frac{150}{165.605 \times 2}$$

$$= 0.453 \text{ min}$$

∴ Time required to drill a hole on the given workpiece is 0.453 min

2.2 BORING MACHINES: TYPES OF BORING MACHINES AND APPLICATIONS

Q51. Explain in detail with neat sketches horizontal type of boring machines. Dec.-19, (R16), Q5(b)

OR

Explain clearly with a neat sketch the construction of a horizontal boring machine.

Answer :

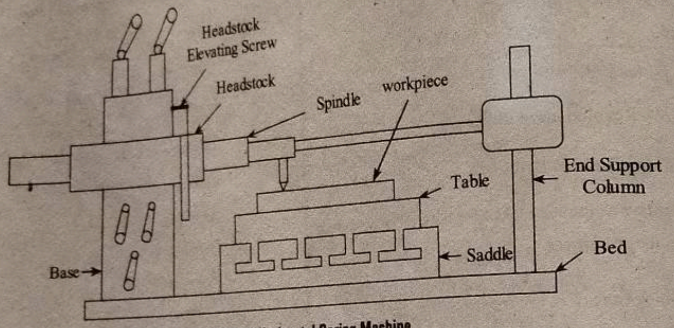


Figure: Horizontal Boring Machine

The main parts of the horizontal boring machine are,

1. **Bed:** It is made of cast iron. It houses the guideways and supports the column, head stock, end supports, table, saddle and other parts. It resists vibrations and damping and also supports the feed mechanism.
2. **Main Column:** It consists of a heavy body, which provides support for the tailstock. Accurate movement of the tailstock is provided by means of guideways. In most of the horizontal boring machines, column is directly mounted on bed, for permanent horizontal and vertical alignment with the bed ways.
3. **Column Base:** It supports the column and houses the various gear and drive mechanisms.
4. **Headstock:** It guides and feeds the cutting tool. The machine spindles are also housed in it. Depending upon the design, the headstock consists of one or two spindles. In two spindles, one is heavy and slow moving and the other is light and fast moving. The fast moving spindle is used for light operations and slow moving spindle is used for heavy operations. The spindle is used for supporting and driving the cutting tools.
5. **Saddle:** The movement of the table at right angles to the spindle is provided with a saddle. It supports and guides the table.

Q52. Write a short note on the following,

(a) Floor type boring machine

(b) Planer type boring machine

(c) Multiple head type boring machine.

Answer : Nov.-10, Set-2, Q

(a) Floor Type Boring Machine

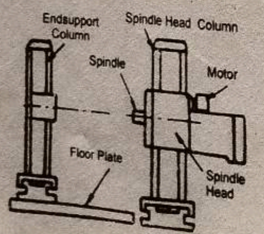


Figure (1): Floor Type Boring Machine

It is a heavy horizontal boring machine as shown in figure (1). This machine is not provided with the table, as it is designed to work heavy jobs which are difficult to mount on table. The work is directly mounted on the floor. There are two supporting columns, i.e., headstock supporting column and end supporting column, which are mounted on runways. These runways are perpendicular to the axis of spindle to give cross-feed movement.

(b) Planer Type Boring Machine

It is also a type of horizontal boring machine as shown in figure (2). It has all major parts similar to the table type. In this, the table slides directly on the bed and reciprocates perpendicular to spindle similar to planar. The head stock supporting column is rigidly fixed. For accommodating different width of jobs, the end supporting column can be moved towards or away from the bed.

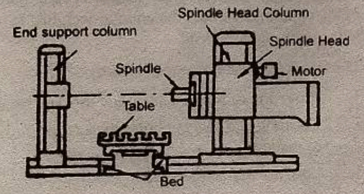


Figure (2): Planer Type Boring Machine

(c) Multiple Head Type Boring Machine

The block diagram of this machine is shown in below figure. It consists of two vertical columns mounted on base, and are bridged by a cross rail. The table is supported by a long bed, and it reciprocates on it. The cross slide carries one or two vertical head stocks, and each vertical column carries one horizontal head stock. These four tools can be mounted simultaneously on this machine. This machine is similar to planar type milling machine. All spindles in this machine have vertical, horizontal and angular movements.

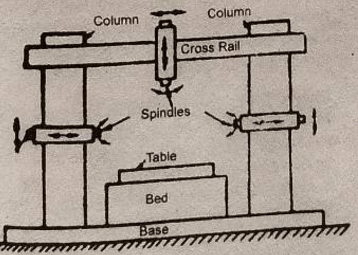


Figure (3): Multiple Head Type Boring Machine

Q53. Explain in detail the construction and working of Boring machine? May/June-19, (R16), Q4(a)

OR

Explain operation of vertical boring machine. [Nov.-15, (R13), Q7(b) | Model Paper-II, Q4(b)]

OR

Write short notes on elements of vertical boring machine.

Answer : [Nov./Dec.-12, (R09), Q4(b) | Nov.-10, Set-3, Q4(b)]

A vertical boring machine consists of the following elements,

1. Bed
2. Table
3. Housing
4. Cross-rail
5. Tool-head assembly.

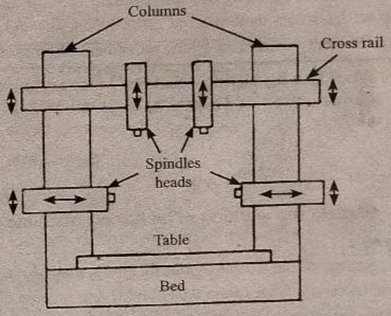


Figure: Schematic Diagram of Vertical Boring Machine

1. **Bed:** It is the bottom most part of the machine, which is a hollow circular casting attached to the floor. The table is attached to the top of the bed. Spindle and pinion are housed in the bed for rotating the table.
2. **Table:** The workpiece is clamped on the horizontal surface of the table, by means of T-slots or chuck jaws. In small machines, bevel gear is provided underside of table, which meshes with driving pinon. Helical pinion is provided underside of table, which meshes with gear, in case of large machines.
3. **Housing:** Two vertical members known as housings are mounted along the two sides of the bed, to ensure the rigidity of the machine. The front of housing is provided with guideways, on which cross-rail slides.

4. **Crossrail:** It is the horizontal element mounted on the two front faces of the housing. Rotation of screws makes the crossrail to move up and down for work of various heights. Cross-rail front face is finished precisely, to hold and slide the saddle.
5. **Tool-head Assembly:** It consists of saddle, ram and tool post. The saddle slides on the cross-rail, to produce flat horizontal surface by the tool. The movement of ram takes place in the saddle at any angle or perpendicular to table, to produce taper and cylindrical surfaces.

Working: Vertical boring machine consists of either single column or double column. The figure shown is a double column vertical boring machine. The cross rail mounted on the vertical slide ways can be moved up and down for the tool advancement into the material. Cross rail consists of two tool heads. The tools mounted in tool heads have vertical and horizontal motions. For angular cuts, the tool head is swivelled to required angle. The workpiece is placed on a horizontal table of rotation motion. For setting job on the table jaw chucks are used for circular workpieces and T-slots are used for irregular shapes. In vertical boring machine, the tool has longitudinal motion and the workpiece has rotary motion about vertical axis. The tool is fed against the rotary workpiece by the movement of cross slide.

Q54. What is a jig-boring machine? Describe its construction and working in detail with a neat sketch.

Dec.-19, (R16), Q4(b)

OR

Explain the working of jig boring machine?

Answer :

Among all the machine tools, jig boring machine is most accurate (accuracy ranges from 0.0025 mm) and precise. These machines are mainly used to manufacture components which need a greater degree of accuracy like jigs, fixtures, tools, etc. A typical diagram of jig boring machine is shown in the figure.

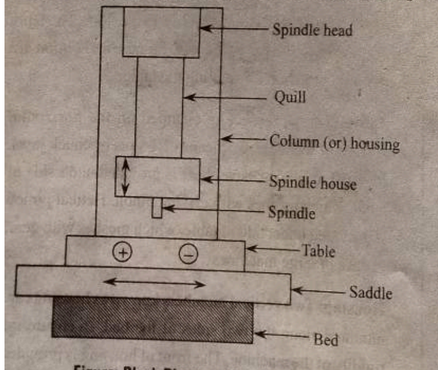


Figure: Block Diagram of Jig Boring Machine

Functions of Various Elements of Jig Boring Machine

1. **Bed:** It is a box type and rigid construction. It acts as main supporting member. It supports a vertical column at the back and saddle at the front.
2. **Table and Saddle:** The saddle is mounted on the base. It gives cross feed to the work. The table is mounted over the saddle and it can be adjusted cross-wise. The table and saddle is provided with measurement reading and clamping mechanisms. A separate motor supplies power for the movement of table and saddle.
3. **Spindle Head:** It slides in front of the column. It houses drive gear box, quill and feed gear box for the spindle. An indicator device is provided on spindle head, in order to measure the boring depth accurately. The driving mechanism provided to it is capable of giving speeds ranging from 300-1500 revolutions per minute. The quill is attached to it, which slides in the housing.
4. **Column:** It is a hollow vertical structure. The column is provided with vertical guideways and it supports spindle head. The spindle head slides on the vertical guideways of the column. It houses the counter weights, in order to balance the spindle head.

These machines are charactérized by,

1. Provision of highest accuracy through rigidity.
2. Locating and spacing holes by accurate measuring of distance.
3. Low thermal expansion.

A jig boring machine is visually similar to the vertical milling machine but not in case of operation and accuracy. In order to avoid deflections and vibrations, the spindle and other components of the machine are made extremely rigid. Antifriction bearings are used to run the spindle and housings of the spindle are made of invar to avoid its expansion during working at various temperatures. These machines are operated at temperature controlled rooms to avoid inaccuracy in the machine and work.

The jig boring machines are classified into two types. They are,

1. **Vertical Milling Machine Type:** This machine is visually similar to vertical milling machine it consists of a spindle, column, bed, work table. The spindle is arranged in the vertical axis and the work table is mounted on the bed in front of the column. The table can be moved in parallel, perpendicular and combined directions with respect to column face.
2. **Planer Type:** This machine is designed in such a way that it consists of vertical columns on both sides of the work table which is mounted on the base. The table can be moved to and fro for adjusting the work. A cross rail is arranged on two vertical columns in the form of a bridge and the spindle is mounted on it. In this machine, the movements of the table (longitudinal) and spindle along with cross rail (cross) are used to locate the hole

Q55. Write the specifications of boring machine.

Answer :

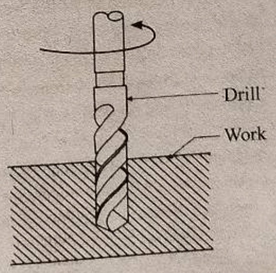
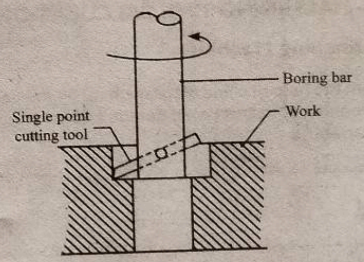
Specifications of Boring Machine

1. The size of horizontal is boring machines specified by the diameter of spindle which ranges from 75 mm to 350 mm. The other major specifications of horizontal boring machine includes the following,
   (i) Power of drive motor.
   (ii) Range of spindle speeds and feeds
   (iii) Overall weight of the machine
   (iv) Floor space required.
2. The size of vertical boring machine is specified,
   (i) The diameter of its table or check.
   (ii) Swing diameter of the largest work that can be accommodated in the machine.

Q56. How do Drilling and Boring differ from each other?

Answer :

Differences Between Drilling and Boring

	Drilling		Boring
1.	It is the process of producing cylindrical holes on a metal by using multipoint cutting tool called drill.	1.	It is the process of enlarging a existing hole by using single point cutting tool.
2.	It is a roughing operation.	2.	It is a finishing operation.
3.	The holes are not accurate	3.	Corrects the hole alignment and brings the hole to accurate size.
4.	The operations that can be performed on drilling machine are drilling, reaming, boring, counter-boring, counter-sinking spot facing and tapping, etc.	4.	The operations performed on boring machine are boring, drilling, milling, facing, counter boring, counter sinking, trepanning, etc.
	 Figure		 Figure

Q57. Explain machining parameters in boring.

Answer :

The basic machining parameters involved in boring operation are, depth of cut, feed, cutting speed.

Depth of cut

It is defined as the thickness of layer of metal removed in a single pass of the tool. It is measured perpendicular to the axis of the work. It is given by,

i.e., $t = \frac{D-d}{2n}$ mm

Where,

D – Diameter of the bored hole

d – Initial diameter of the hole

n – Number of passes of the tool

Feed

It is defined as the distance moved by the cutting tool parallel to the axis of the work/job per revolution or per minute. It is expressed in mm/rev or mm/min.

Cutting speed

It is defined as the number of revolutions made by the boring tool per minute to generate certain diameter of hole. It is expressed in m/min.

i.e., $V_c = \frac{\pi DN}{1000}$ m/min

Where,

D – Diameter of the bored hole in mm

N – Number of spindle or face plate revolutions.

2.3 SHAPING, SLOTTING AND PLANING MACHINES: PRINCIPLES OF WORKING - MACHINING TIME CALCULATIONS

2.3.1 Shaping Machine

Q58. With the help of a line diagram, explain the basic principle, constructional details and working of shapers.

[Nov./Dec.-12, (R09), Q3 | Nov.-10, Set-1, Q5 | Model Paper-I, Q5(a)]

Answer :

Shaper is a machine tool, used to produce flat surfaces, which can be horizontal, vertical or inclined. The advantage of this machine tool is flexibility in quick and easy adjustment of work holding devices. It uses a single point cutting tool.

Working Principle of Shaper

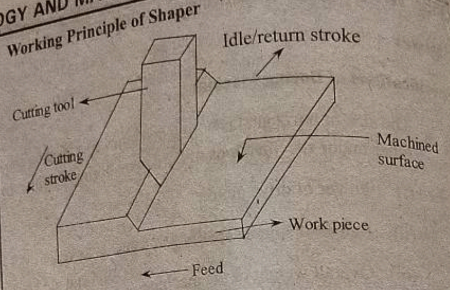
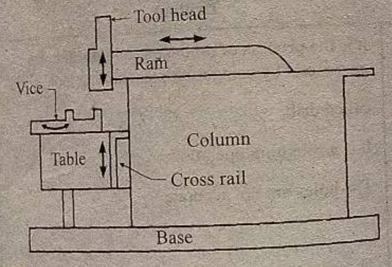


Figure: Working Principle of Shaping Machine

In shaper, a single point cutting tool is used, which reciprocates over the workpiece that is held stationary in a vice, clamped on the machine table. The cutting tool is held, in the tool head mounted on the ram. The reciprocating action of the ram in the forward stroke (cutting stroke) cuts the material from the workpiece and there is no cutting of material in the backward stroke (idle stroke). Thus, duration of the return stroke is less than the forward stroke.

Construction of Shaper



Figure

The important constructional parts of shaper are,

1. **Base:** It acts as a support for whole machine and all the other parts are mounted on it. It is made of cast iron and is designed in such a way that it withstands all the cutting forces and vibrations. The size of the bed depends on size of the machine. It is either bolted to the floor or mounted on bench according to its size.
2. **Column:** It is a vertical casting mounted on the base of the machine. It is box like structure enclosing mechanisms of the machine. Guideways are provided on the top and front of the column on which ram and cross rail reciprocates respectively. One side of the column contains handles, levers etc., for operating the machine and the other side is provided with a lid, which can be opened for oiling and inspection of internal mechanism.

3. **Cross Rail:** It is a heavy cast iron construction mounted on the vertical guideways of the column. It has guideways on it to mount the saddle. Crossrail consists of two mechanisms, one for elevating (i.e., sliding the table up and down) and the other for moving the table in longitudinal direction. These mechanisms are performed by screws enclosed in cross rail.
4. **Saddle:** It is mounted on the crossrail and holds the table firmly. A cross feed screw is provided to give longitudinal movement to the saddle. This feed screw can be operated manually or by external power. Motion of saddle causes the table to move sideways.
5. **Table:** It is bolted to the saddle and can be moved in horizontal and vertical directions from saddle and crossrail respectively. The table has T-slots both on top and sideways for holding the workpiece or work holding devices. The table is made of cast iron and it may be either plain type with vertical and cross feed motions or universal type where, table can be swivelled on horizontal axis.
6. **Ram:** It is a reciprocating part of a shaper, which holds the tool head. It slides on the guideways to provide reciprocating line motion to the tool. The ram receives motion from a reciprocating mechanism enclosed in the column. Ram consists of a screwed shaft for changing the motion with respect to the work.
7. **Tool Head:** It is mounted on front end of the ram and consists of tool slide, tool post and clapper box. The tool head holds the cutting tool firmly. It can slide up or down or can be rotated at any angle for making angular cuts.

Q59. Describe the operation of quick return motion in mechanical shaper. Nov./Dec.-17, (R15), Q6(a)

OR

Explain the working of a slotted disc mechanism for driving the ram of slotter. Nov./Dec.-16, (R13), Q7(a)

Answer :

A crank and slotted lever mechanism is one of the quick return mechanisms used in reciprocating machine tools like shaper machine. In this mechanism, the driving pinion is in mesh with the bull gear. The power from the motor is transmitted to the bull gear through a driving pinion. A bull gear slide is mounted at the centre of the bull gear which consists of a sliding block of the slotted link (rocker arm) and a crank pin. The slotted link (rocker arm) and the crank pin passes through the sliding block and is fixed on the bull gear sliding block.

The bottom end of the slotted link is fixed to the frame whereas the upper end of the slotted link is fastened to the ram. As the bull gear rotates it causes the crankpin to rotate at a uniform speed. This rotation of crankpin causes the sliding block (rocker arm) to move up and down in the slotted link, which produces a rocking movement in the ram. Thus, the rotary motion of the bull gear is converted to reciprocating motion of the ram.

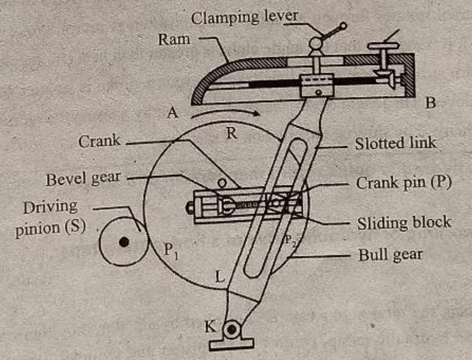


Figure (1): Crank and Slotted Link Mechanism

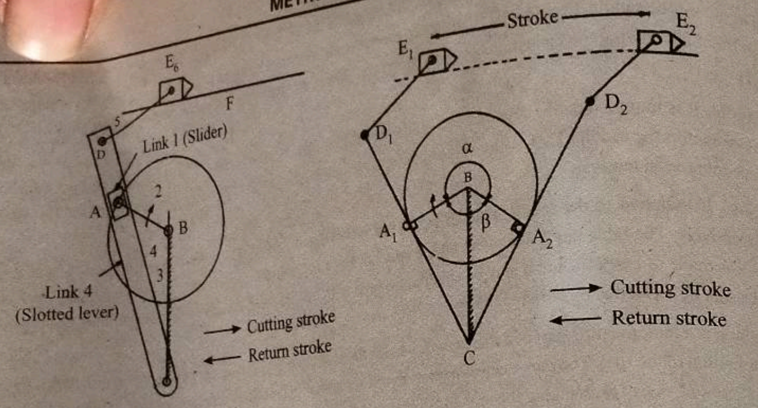


Figure (2)

The quick return mechanism involved in crank and slotter mechanism is explained below.

This mechanism consists of four links as shown in figure.

Link–4 is the slotted link which oscillates at pivot C.

Link–3 forms a fixed link and corresponds to crank.

Link–2 is the driving crank which rotates at a constant angular speed in the clockwise direction.

Link–1 is a slider fixed to the crank pin at B and slides along link–4.

In this mechanism, the link–1 slides in link 4. As the link–3 is fixed and due to the rotation of the crank, i.e, link–2, the link-4 oscillates at pivot

The connecting rod (link-5) DE moves the ram from position $D_1 E_1$ to $D_2 E_2$. The movement of the cutting tool which is connected at the end of link 5 is forced along the dotted line.

When the link 4 is in the position CD1, the position of ram is at E1 i.e., extreme left end, and when the position of link 4 is at CD2, the position of ram is at the extreme right end. The line CD1 and CD2 act as tangents to the crank pin circle. Therefore, cutting stroke is performed when crank rotates through an angle of alpha whereas return stroke is performed when it rotates through an angle beta. From figure 3, it is evident that the angle alpha is greater than beta i.e., the distance travelled by the crank in cutting stroke is greater than return stroke. Thereby the time taken by return stroke is smaller compared to cutting stroke. In this way, quick return motion is achieved. The length of stroke can be adjusted by altering the radius of rotation of the crank pin. The position of the stroke may be changed by shifting the position of ram pin.

Q60. Explain the working of a hydraulic quick return mechanism of a shaper. Nov./Dec.-16, (R13), Q6(a)

OR

Sketch and explain the working of hydraulic drive of a horizontal shaper. Nov.-15, (R13), Q6(b)

Answer :

In hydraulic shaper mechanism, the motion to a ram is controlled by a piston moving in a cylinder. This mechanism consists of oil reservoir, double gear hydraulic pump, control valve, piston and cylinder, throttle valve and relief valve as shown in the figure.

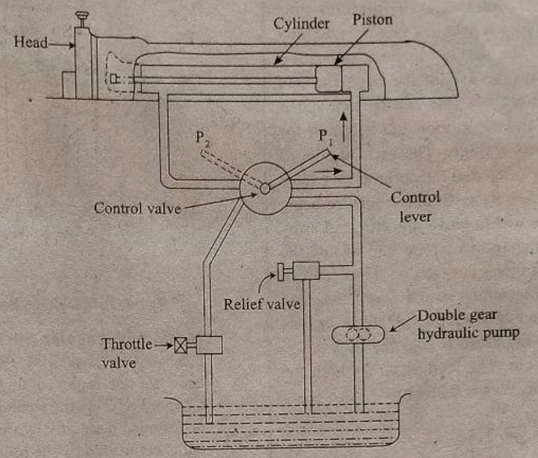


Figure: Hydraulic Quick Return Mechanism of a Shaper

The oil from the reservoir is pumped to a control valve at medium pressure by a hydraulic pump, which is powered by an electric motor. This valve allows the oil to enter on either side of the piston in cylinder. Consider that, oil enters from the right end of the cylinder and exerts pressure on the piston. This direction of the oil is shown by a control lever at position P_1.

When the piston moves from right to left, the ram and cutting tool also moves along it as they are connected to piston. The oil present at the left hand side of the piston is discharged to the reservoir through control valve. This movement of the ram is called forward stroke. At the end of forward stroke, the control lever of the valve moves from position P_1 to P_2 and reverses control valve connections. Then, the oil is pumped from control valve to the left side of the piston. As a result, it moves from left to right and ram performs return stroke. Oil on right side of the piston is discharged to the reservoir. At the end of this stroke, the lever is moved from position P_2 to P_1 and cycle is repeated. In this mechanism, volume of oil delivered to both sides of the piston is same. Hence, called as constant volume hydraulic mechanism.

The ram travels at a faster rate in a return stroke than in the forward stroke because of the difference in effective area of the piston on either sides of piston. The length and position of stroke is adjusted by shifting the trip dogs and the cutting speed may be changed by regulating the flow of oil by means of a throttle valve.

Advantages

1. Hydraulic shaper has constant cutting speed throughout the operation.
2. It has very large range of cutting speeds.
3. Control of cutting speeds is easy.
4. It has the ability to slip in case of overload.
5. Hydraulic shaper consumes less power.
6. More cutting strokes are obtained as the return speed is very high.
7. The safety of the tool is controlled by a relief valve.
8. The operation is smoother and noiseless.

Q61. Explain the operations performed on shaper with suitable sketches. [May/June-12, Set-4, Q4(b) | Model Paper-II, Q5(a)]

Answer :

The various operations performed on shaper are,

1. Machining vertical surface
2. Machining horizontal surface
3. Machining angular surface
4. Machining irregular surface (concave surface)
5. Cutting grooves, slots and keyways
6. Machining splines or cutting gears.

1. **Machining Vertical Surface:** To perform this operation, the workpiece is held in a vice or is directly fitted on the table. The surface to be machined is carefully aligned with the axis of the ram. The tool used for this machining is a side cutting tool and is set on the tool post and its position and length of the stroke are adjusted accordingly. The vertical slide is set exactly at zero position and the apron is swivelled (revolved) in a direction away from the surface being cut. This enables the tool to move upwards and away from the work during return stroke and avoids the side of the tool from being dragged on the machined vertical surface during return stroke. The down feed screw is rotated manually to provide feed for the workpiece and the work table is adjusted by hand to control the depth of cut. The feed given for both the roughing and finishing cuts is 0.25 mm.

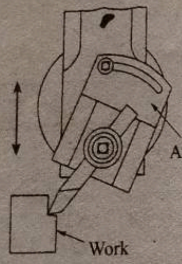


Figure (1): Machining Vertical Surfaces

2. **Machining Horizontal Surface:** These type of surfaces are machined by moving the work at a cross direction with respect to the movement of the ram. The clapper box can be positioned either vertical or slightly inclined towards the uncut surface. This arrangement allows the tool to raise automatically while the return stroke, such that the tool will not be dragged on the machined surface. The figure illustrates the machining of horizontal surfaces. In order to machine, firstly work is mounted either directly on the table or on the vice. Then the tool is mounted on the tool post. Then a distance of 25 to 30 mm is maintained between work and tool to provide clearance. Then the parameters like length and position of stroke, speed, feed and depth of cut are adjusted. Initially work is machined roughly with the depth of cut ranging from 1.5 to 3 mm then, finishing cuts are made by providing depth of cuts ranging from 0.075 to 0.2mm and the feed is adjusted accordingly. Long strokes are performed at minimum speed whereas short stokes are carried out at high speeds.

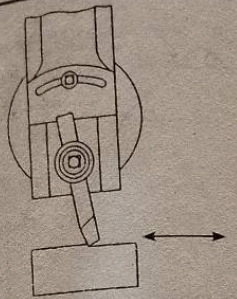


Figure (2): Machining Horizontal Surfaces

3. **Machining Angular Surface:** Angular surfaces are produced by swivelling the vertical slide of the tool head to the required angle and turning away the clapper box from the surface to be machined. The feed is provided manually by downfeed screw the depth of cut is controlled by the movement of worktable.

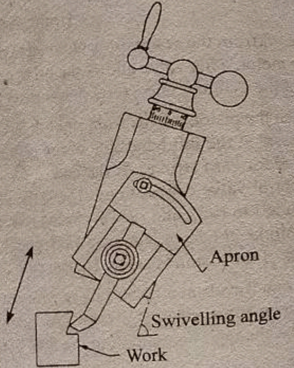


Figure (3): Machining Angular Surfaces

4. **Machining Irregular Surface:** In this kind of operation, special surfaces like concave, convex or both are produced. In case of producing small contours, form tools are used and for large contours, round nose tool is used. The feed is provided by both work table (cross feed) and down feed screw according to the contour to be produced. For producing normal deep cuts, the apron is set vertical. In case of sharp curves, the apron is swivelled right or left away from the surface to be machined.

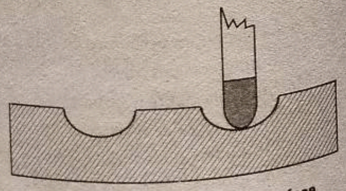


Figure (4): Machining Irregular Surface

5. **Cutting Grooves, Slots and Keyways:** This operation is performed on shaper with the help of a square nose tool for cutting slots, grooves or external keyways on shafts and internal keyways on pulleys or gears.

For cutting external keyways, a hole is drilled at the place where the keyway ends, to provide clearance on the tool at the end of the stroke. The size of hole diameter and the depth of hole should be larger and deeper than the width and depth of the keyway. In order to end the stroke at clearance hole, the stroke length and position of ram are adjusted carefully. The process of cutting an external keyway is performed at minimum speed.

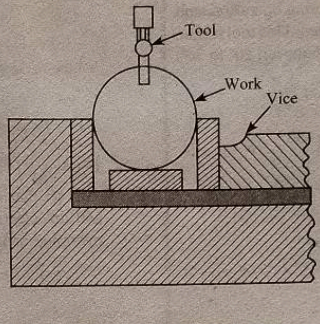


Figure (5): External Keyway Cutting

The tool in internal keyway cutting is clamped on a special tool holder. This is done to avoid the hitting of tool post against the work at the end of the stroke. The lifting of tool is restricted by locking clapper box and due to that the workpiece is lubricated in order to avoid wear of the cutting edge caused by dragging.

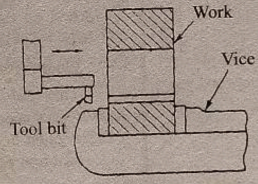


Figure (6)

6. **Machining Splines or Cutting Gears:** The splines and gears are produced with the help of an indexing mechanism. In machining a spline, the work is placed between the two centres. The index plate and index pin are used to rotate the workpiece by a specific angle after cutting each spline. To machine a gear, the circumference of the gear blank is divided and the grooves are cut at equal distances with the help of an index plate consisting of proper hole circles. A form tool is used for gear cutting and a square nose tool is used to cut splines.

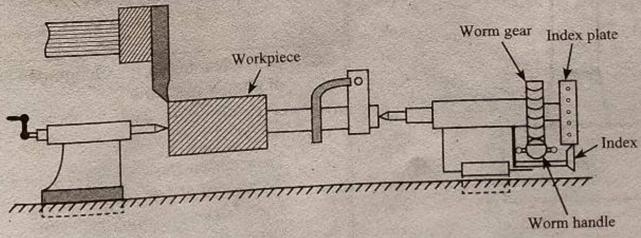


Figure (7): Cutting of Spline or Gear by Index Centre on Shaper

Q62. Briefly describe about shaper tools.

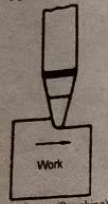
Answer :

In shaper, only single point cutting tools are used. The angles like rake angle, clearance angle, etc., are similar to the tools used on a lathe machine. The common shaper tools sued for machining operation are as follows.

1. Round Nose Tool

These tools is used for rough machining operation, and it can be of right handed or left handed. This tool has no top rake, and it has side rake angle between 10° to 20°. These tools are of two types.

(i) Plain/Straight type



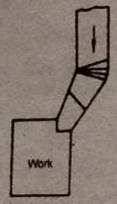
Round nose (Roughing)

Figure

It is used for rough machining of horizontal surfaces.

(ii) Bent Type

It is used for machining vertical surfaces. It is also called as 'cutting down tool'.

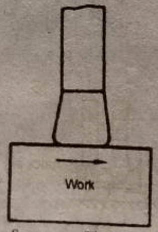


Down Cutting

Figure

2. Square Nose Tool

This tool is used for finishing operations. It is also used for machining the bottom surfaces of the keyways and grooves. The width of cutting edge is not uniform.

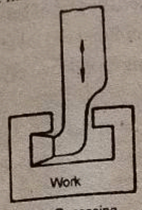


Square nose (Finishing)

Figure

3. Side Recessing Tool

This tool is especially used for machining T-slots and narrow vertical surfaces. This tool can be of both right handed and left handed.

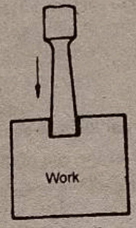


Side Recessing

Figure

4. Parting off Tool

This too has no side rake angle, and it has both front and side clearance angles of 3°. It is used for parting off operation and for cutting narrow slots.

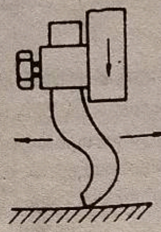


Parting off

Figure

5. Goose Neck Tool

This tool is also called as spring tool. It is designed with a special shape to reduce chapter and prevent the digging of tool into workpiece. It is used for finishing cast iron parts.


Goose neck

Figure

Q63. Give advantages, disadvantages and applications of shaper machine.

Answer :

Advantages

1. The arrangement, loading and unloading of workpieces is very easy and quick in shaper.
2. The work is held firmly with ease.
4. Flat and contour shapes can be machined on small sized workpieces.

5. The single point tools used are of low cost and can be formed to any desired shape.
6. The cutting stroke has a particular stopping point.
7. Thin and brittle workpieces can easily machined since the cutting force in shaper is low.
8. The cost of equipment is low.

Disadvantages

1. It is a slow machining process.
2. Large size workpieces cannot be machined.
3. It is used for producing only simple profiles.
4. It is suitable for low production rates.
5. Close tolerances and fine finish cannot be achieved.
6. The single point cutting tool requires number of strokes to complete a work.
7. It is not suitable for assembly and production line since, the cutting speed is usually low.
8. It requires skilled labour.

Applications

It is suitable for small and medium size works such as in tool room, dove-tail bearing workshops, die or jig workshops, etc.

Q64. Find the machining time required for machining the surface 600 × 800 mm, on a shaping machine. Assume, cutting speed as 8 m/min. The return to cutting time ratio is 1:4 and the feed is 2 mm/stroke. The approach and over run at each end is 70 mm.

Answer : [Nov./Dec.-17, (R15), Q6(b) | Model Paper-III, Q5(b)]

Given that,

Length of the job $L = 600$ mm

Width of plate, $W = 800$ mm

Approach and over run, $c = 70$ mm

Cutting speed, $V_c = 8$ m/min

Return to cutting time ratio, $k = 1:4 = \frac{1}{4} = 0.25$

Feed, $f = 2$ mm/stroke

Length of stroke = Length of job + Approach + Over run

i.e., $L = l + 2c$

$= 600 + 2 \times 70$

$= 740$ mm

$\therefore \; L = 0.74$ mm

Machining time required is given by,

$$T = \frac{WL(1+k)}{1000 V_c f}$$

$$= \frac{800 \times 740\,(1+0.25)}{1000 \times 8 \times 2}$$

$\therefore \; T = 46.25$ ms

Q65. A C.I plate measuring 300 mm × 100 mm × 40 mm is to be rough shaped along its wider face. Calculate the machining time taking approach = 25 mm, over travel = 25 mm, cutting speed = 12 m/min, return speed = 20 m/min, allowance on either side of the plate width = 5 mm and feed per cycle = 1 mm.

Answer : [Dec.-19, (R16), Q5(a) | May/June-13, (R09), Q3(b) | Dec.-11, Set-2, Q5(a)]

Given that,

Length of plate, $L_l = 300$ mm

Width of plate, $W = 100$ mm

Approch and over travel, $c = 25$ mm

Cutting speed, $V_C = 12$ m/min

Return speed, $V_r = 20$ m/min

Allowance on width of plate = 5 mm

Feed per cycle, $f = 1$ mm

Length of stroke = Length of plate + 2c

$= 300 + 2 \times 25 = 350$ mm

$\therefore \; L = 0.35$ m

Machining time is given by,

$$T = \frac{W}{f}\left(\frac{L}{V_C \times 1000} + \frac{L}{V_r \times 1000}\right)$$

$$= \frac{100}{1}\left(\frac{350}{12 \times 1000} + \frac{350}{20 \times 1000}\right)$$

$\therefore \; T = 4.667$ min

2.3.2 Slotting Machine

Q66. With the help of a neat sketch explain the construction of vertical shaping machine?

May/June-19, (R16), Q5(a)

OR

With help of neat sketch, describe the main parts and working of a slotter.

Answer : Model Paper-III, Q5(a)

Slotter or slotting machine is a vertical axis shaper used for making slots, keyways, grooves, etc.

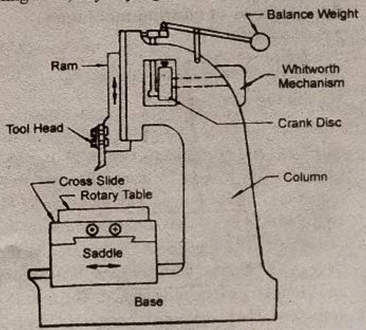


Figure: Slotting Machine

The main parts of slotting machine are,

1. Base
2. Column
3. Table
4. Ram.

1. **Base**

It is a rigid and heavy cast iron structure the column the driving mechanism, ram, table and other fittings. It carries horizontal guideway on its top, along which the told can be traversed.

2. **Table**

It is mounted on the top of the cross-slide. It is usually circular in shape, which can be rotated by hand or power. On top of it, T-slots are proveded, to clamp the workpiece or to allow the use of different clamping devices.

3. **Column**

It is a rigid massive structure made of cast iron. It houses the complete driving mechanism. On front face of the column, guideways are provided to slide the ram upwards and downwards during the slotting operation.

4. **Ram**

It moves up and down in vertical direction between the vertical guide ways provided in front of the column. The ram supports the tool head which carries the a cutting tool. The cutting action occurs during the downward motion of the ram.

Q67. Give the specifications of slotter machine tool.

Answer : Dec.-11, Set-3, Q4(a)

Slotting machines (slotters) are specified as follows,

1. Maximum length of the stroke.
2. Diameter of rotary table.
3. Maximum movement of the saddle and cross slide.
4. Type of drive used.
5. Motor power rating.
6. Total weight of the machine
7. Number and amount of feeds available.
8. Floor area required.

Q68. Show and describe the various machining applications of slotting machines.

Answer: Nov./Dec.-18, (R16), Q5(a)

The various slotter operations are,

1. **Machining Flat Surfaces**

A slotter machine can easily machine external flat surfaces on a workpiece. The work is supported on parallel strips to give clearance for over travel of the tool. The work is clamped with the help of T– Bolts and lamps. Stroke length and stroke position can be adjusted as required. The depth of cut is provided by moving the table in longitudinal direction, and then the longitudinal and circular movement is locked. The feed is given by cross feed. The machining is completed by giving rough and finish cut.

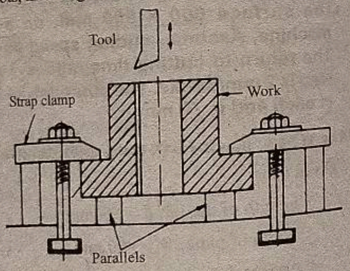
To machine internal surfaces, the work should have large hole. The setting of work and machining process similar to that of external machining. In order to machine the opposite surface of work, the table is rotated through 180°. To machine the other surface perpendicular to the first surface, the table is rotated by 90°.

2. **Machining Cylindrical Surfaces**

During the machining of cylindrical surfaces the work is clamped centrally on the table by means of clamps and packing pieces. The tool is set radially and the longitudinal and cross movement is locked. During machining, the feed is given by rotating the table. The machining of work is completed with rough and finish cuts. Both internal and external surfaces can be machined.

3. **Machining Keyways or Grooves**

By means of slotting machine, keyways and grooves can be cut easily, as compared to other machine tools. These machines are specially designed for cutting internal grooves. The axis of hole is aligned with the axis of rotary table. The keyway tool of required width is selected and held in the tool post. The stroke length and stroke position can be adjusted, and the feed is given by the hand. The feed given by the hand. The keyway is cut following the layout on the work. Both internal and external keyways can be cut. For cutting equally spaced slots, indexing is done using graduations on rotary table.



Figure

4. **Machining Irregular Surfaces**

Any irregular surfaces can be machined by properly setting the work and adjusting the tool. Required contours can be produced by combining the cross, longitudinal and rotary feed movement of the table.

Q69. Describe various slotting tools.

Answer :

In slotter, the tool removes the metal during its vertical downward stroke. Thus, the cutting pressure acts along the length of the tool. Hence, the slotter tools are very thick in cross-section. The tool angles are specified with respect to vertical plane. The tools are forged from solid bars of tool steel. The bit tools, heavy tool holders are also used in slotting machines. These are provided with top rake, front clearance and side clearance and side rake is provided. The nose of the tool projects slightly beyond the shank, to provide clearance for cutting.

A typical slotter tool is shown in below figure.

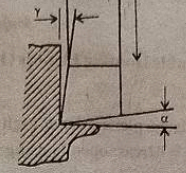


Figure: Slotter Tool

The below figure, shows the different slotter tools.

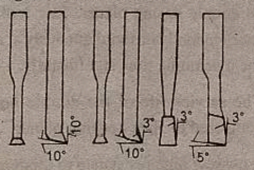


Figure: Various Slotter Tools

Keyway Cutting Tools

Thinner at the cutting edge.

Round Nose Tools

These are used for machining contoured surfaces.

Square Nose Tools

These are used or machining flat surfaces.

2.3.3 Planing Machine

Q70. Explain the mechanism of material removal in planning machine?

May/June-19, (R16), Q4(b)

OR

Explain the working of planing machine with a sketch.

[Nov./Dec.-18, (R16), Q5(b) | Model Paper-I, Q5(b)]

OR

With a neat sketch, explain construction and working of a planer.

Nov./Dec.-17, (R13), Q3(b)

OR

What is the planer? Illustrate and describe its working principle.

Answer : Nov.-15, (R13), Q7(a)

Planer is a machine tool, used to produce flat surfaces on workpieces too large or too heavy which cannot be machined on shaper. The work is securely fixed on the table called 'platen'. Unlike the shaper, in planar the table reciprocates against the stationary cutting tool during operation.

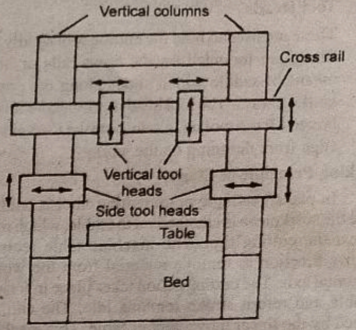


Figure: Planer

The most commonly used planer is stand and planer, which is also called double housing plamar. The various parts of the planer are,

1. Bed
2. Table
3. Column or Housing
4. Cross-rail
5. Tool head

1. **Bed**

It is a very large and heavy cast iron structure, acts as the foundation for the machine. The bed supports are other parts like table, columns, etc. The length of bed is usually twice the length of the table. On top of the bed, guideways are provided, for reciprocation of the table. The table driving mechanism is housed inside the bed.

2. **Table**

It is a large and heavy casting of cast iron, and its top surface is machined accurately. And it also provided with T-slots to clamp the workpieces with the help of T-bolts. It is provided with hollow space at each end, which acts as trough for collecting chips. The table is driven by quick return mechanism.

3. **Column or Housing**

Housings are vertical rigid column like castings placed on each side of the bed. The front face of the columns provided with guideways which enables the movement of the cross rails up and down.

4. **Cross-rail**

It is mounted on the precision machined guide ways on two housings or columns. It supports tool heads and can be moved up and down on the guide ways to accommodate different heights of the work on the table and to allow for the adjustment of jobs.

5. **Tool Heads**

These are used to hold the cutting tool rigidly and firmly. These are mounted on the cross rails or housings by means of saddle which slides along the cross rail and housing ways. The tool head is provided with the clapper box to lift the tool up in return stroke to avoid the cutting edge from dragging on the work.

Working Principle of Planer

In planer, a single point cutting tool is held stationary while the workpiece is clamped on the table, which reciprocates against the cutting tool. The machine table reciprocates to and fro direction to remove material from the workpiece, in horizontal axis. The cutting action takes place in forward stroke of table and return stroke remains idle. The cutting feed is applied by the linear movement of table. This machine is used for machining large flat surfaces.

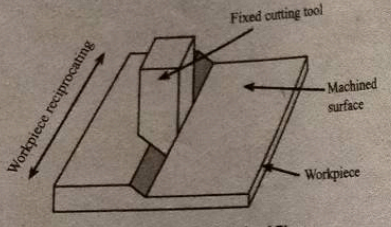
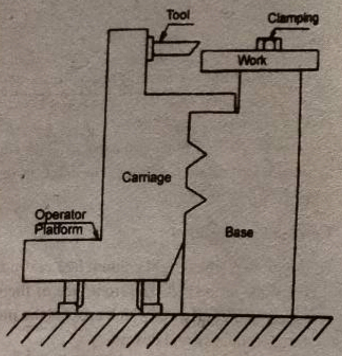


Figure: Working Principle of Planer

Q71. Explain the working of Edge planer with neat sketch.

Answer :

The edge planer is used for machining the edges of plates. Hence, this machine is also called as plate planer. The schematic diagram of this planer is shown in below figure.



Figure

During the machining process the bed and table remain stationary. The tool head is mounted on the carriage, which travels on guideways longitudinally. A platform is provided in the carriage, on which the operator can stand and travel along with it during operation. Squaring or beveling the edges of plate can also be done with this machine.

Q72. What advantages double housing planers have when compared to open housing planners?

May/June-12, Set-2, Q6(b)

Answer :

Advantages of Double Housing Planers Over Open Housing Planers

1. Double housing planers have high resistance against deflections. Whereas, open housing planer is subjected to more deflections due to its cantilever type of column.
2. Since the construction is rigid the double hosing planers have no vibrations during the operation.
3. In double hosing planer, four tool heads are operated independently or simultaneously at a time which reduces the machining time significantly.
4. The service life of the double house planer is more compared to open housing planer.
5. It possess high resistance to torsion.
6. This type of machine can be used for machining of heavy duty components such as machine beds, plates, tables, columns, etc.
7. In double housing planers, heavy cross-slide enables heavy cuts of material.

Q73. How is planer specified.

Answer :

The planar can be specified as follows.

1. The horizontal distance between the two vertical housings.
2. Distance between the table and the cross-rail.
3. Maximum stroke length of the table.
4. Number and amount of speeds and feeds available
5. Size of the bed and table.
6. Power rating of motor.
7. Type of drive.
8. Floor space required.
9. Weight of the machine.

Q74. Describe planer tools.

Answer :

In planars, single point cutting tools are used for machining operation. The angles and shape of these tools are similar to that of the tools used in lathe and shaper machines. These tools are heavier and larger in size, since these tools

involve in cutting the material with large depth of cut with fast feed rates. The below figure illustrate the different types of tools used in planar machine.

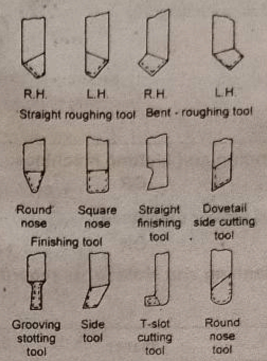


Figure: Planar Tools

Rough Tools

These are used for taking the roughing cuts.

Straight Tools

These are used for machining the horizontal surfaces.

Bent Rough Tools

hese are used for machining vertical surfaces.

Round Nose Tool, Square Nose Tool and Straight Finishing Tool

These tools are used for finishing cuts.

Dovetail Cutting Tools

These tools are used for cutting dovetails.

Grooving Tools

These tools are used for cutting slots and grooves.

Side Tools

These are used for finishing operation on vertical surfaces.

T-Slot Cutting Tools

These tools are used for cutting T-slots

Q75. Give advantages, disadvantages, applications of planer machine.

Answer :

Advantages

1. It is capable of producing deep cuts and coarse feeds.
2. It can be mounted with several tools and machine the workpieces simultaneously.
3. Rate of production is high.
4. Flat and contour shapes can be machined easily on large workpieces.
5. As machine does not consist of any overhanging parts, there is no tool or work deflections.
6. It requires low tooling cost.

Disadvantages

1. Close tolerances and fine finish cannot be achieved.
2. It is time consuming process.
3. It requires skilled labour.
4. It requires large floor area.

Applications

Planer is used for machining flat or angular surfaces along with cutting grooves and slots in medium and large sized workpieces. The application of planar is found in machining of.,

1. Beds
2. Columns
3. Marine diesel engine blocks
4. Bending plates for sheet metal works, etc.

Q76. Differentiate among shaping, planning and slotting machines. Dec.-19, (R16), Q4(a)

OR

Compare and contrast shaper and slotter machines? [May/June-19, (R16), Q5(b) | Model Paper-II, Q5(b)]

OR

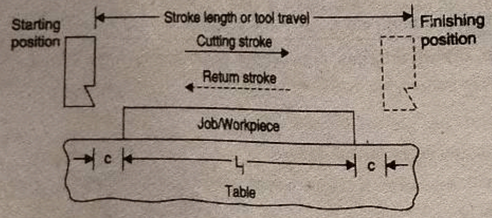
Differentiate between shaping, planning and slotting, as regards relative tool and work motions. Nov./Dec.-16, (R13), Q7(b)

Answer :

Shaper	Planer	Slotter
1. The work is held stationary and the tool reciprocates across the work	1. The tool is held stationary and the workpiece reciprocates back and forth under the tool	1. The work is held stationary and the tool reciprocates back and forth across the work
2. It is used for shaping smaller work pieces.	2. It is used for machining much larger jobs.	2. It is used for making slots on small workpieces.
3. It is a light duty machine	3. It is a heavy duty machine	3. It is a light duty machine
4. Used for light cuts with finer feeds	4. Used for heavier cuts with coarse feed	4. Used for light cuts with finer feeds
5. Only one cutting tool can be used at a time	5. Multiple cutting tools can be used at a time	5. Only one cutting tool can be used at a time
6. The table is driven by quick return mechanism	6. It uses either gears or hydraulic mechanism for driving table	6. It uses either cank driven mechanism or hydraulically driven mechanism
7. It is less rigid and less robust	7. It is highly rigid and robust	7. It is less rigid and less robust.

Q77. Derive an expression for estimating machining time of shaper, planer and slotter.

Answer :



Figure

Let,

L – Length of the cutting stroke

L_j – Length of the job workpiece

W – Shaping width

V_C – Cutting speed (mm/min)

V_r – Return stroke speed (mm/mim)

f – Feed (mm/stroke)

Length of cutting stroke,

$$L = \text{Length of the job/work} + 2 \times \text{Clearance}$$

$$L = L_j + 2c$$

Where, clearance is the distance travelled by ram to attain desired cutting speed and come to rest at the end of each stroke. It is similar to approach and over travel in metal cutting processes.

The cutting speed is given by,

$$V_C = \frac{\text{Length of cutting stroke } (L)}{\text{Cuttig time or time for cutting stroke}}$$

Then, cutting time or time of cutting stroke is given as,

$$\text{Cutting time} = \frac{L}{V_C}$$

Similarly, the non-cutting or idle time is given as,

$$\text{Idle time} = \frac{\text{Length of stroke}}{\text{Return stroke speed}}$$

$$= \frac{L}{V_r} = k \times \frac{L}{V_C}$$

Where,

$$k = \frac{\text{Return stroke time}}{\text{Cutting stroke time}}$$

Total machining time for complete cycle is given as,

Machining time/Cycle, t = Cutting time + Idle time

$$= \frac{L}{V_C} + \frac{L}{V_r}$$

$$= \frac{L}{V_C} + k \times \frac{L}{V_C}$$

$$\therefore \quad \text{Machining time per cycle} = \frac{L(1+k)}{V_C}$$

Number of cycle required to machine complete width of the workpiece is given by,

$$n = \frac{\text{Shaping width}}{\text{Feed per cycle}} = \frac{W}{f}$$

Where,

Shaping width, W = Width of the work + 2 × Allowance

$\therefore$ Total machining time,

T = Number of cycles × Machining time per each cycle

$$= n \times t$$

$$= \frac{W}{f} \times \frac{L(1+k)}{V_C}$$

$$\therefore \quad T = \frac{WL(1+k)}{1000 V_C f} \quad \text{(Where, } V_C \text{ and } V_r \text{ in m/min)}$$

In terms of ram strokes N,

$$T = \frac{W}{fN} \qquad \left(\because N = \frac{1000 V_C}{L(1+k)}\right)$$

Machining time can also be calculated as,

$$T = \frac{W}{f}\left(\frac{L}{V_C \times 1000} + \frac{L}{V_r \times 1000}\right) \text{min}$$

The above equation is used for calculating machining time for shpaer, planer and slotter.

IMPORTANT QUESTIONS

Q1. Write short notes on the elements of drilling machine. Also specify the precautions to be taken in drilling operation. **Refer Unit-II, Q36**

Q2. Explain the working of radial drilling machine with a sketch. **Refer Unit-II, Q38**

Q3. Explain upright drilling machine and its types. **Refer Unit-II, Q40**

Q4. Explain various operations performed on drilling machine. **Refer Unit-II, Q42**

Q5. With the help of a neat sketch show the different angles of a drill and explain their influence on drilling performance. **Refer Unit-II, Q44**

Q6. What are the different types of drill are used? Describe any one of the drive bits. **Refer Unit-II, Q45**

Q7. Explain the twist drill geometry with neat sketch. **Refer Unit-II, Q46**

Q8. How are drill size are specified. **Refer Unit-II, Q47**

Q9. Write a short note on the following.

(a) Floor type boring machine

(b) Planer type boring machine

(c) Multiple head type boring machine. **Refer Unit-II, Q52**

Q10. Explain in detail the construction and working of Boring machine? **Refer Unit-II, Q53**

Q11. How do Drilling and Boring differ from each other? **Refer Unit-II, Q56**

Q12. With the help of a line diagram, explain the basic principle, constructional details and working of shapers. **Refer Unit-II, Q58**

Q13. With a help of a diagram explain crank and slotted link mechanism. **Refer Unit-II, Q59**

Q14. Explain the operations performed on shaper with suitable sketches. **Refer Unit-II, Q61**

Q15. A C.I plate measuring 300 mm × 100 mm × 40 mm is to be rough shaped along its wider face. Calculate the machining time taking approach + over travel = 25 mm, cutting speed = 12 m/min, return speed = 20 m/min, allowance on either side of the plate width = 5 mm and feed per cycle = 1 mm. **Refer Unit-II, Q65**

Q16. Give the specifications of slotter machine tool. **Refer Unit-II, Q67**

Q17. Explain the mechanism of material removal in planning machine? **Refer Unit-II, Q70**

Q18. Explain the working of Edge planer with near sketch. **Refer Unit-II, Q71**

Q19. Give advantages, disadvantages, applications of planer machine. **Refer Unit-II, Q75**

Q20. Differentiate among shaping, planning and slotting machines. **Refer Unit-II, Q76**

UNIT 3

MILLING, GRINDING, LAPPING, HONING AND BROACHING MACHINES

Syllabus

Milling machines – Principles of working – Types of milling machines – Geometry of milling cutters – Methods of indexing. Grinding – Theory of grinding – Classification of grinding machines. Types of abrasives, bonds – Selection of a grinding wheel. Lapping, Honing and Broaching machines – Comparison and Constructional features, Machining time calculations.

Learning Objectives

On the completion of this unit, the student shall be able to understand the following concepts,

- Principle of working of various milling machines
- Geometry of milling cutter
- Various Milling operations
- Types and working of grinding machines
- Types of abrasives and bonding materials
- Selection of grinding wheel
- Lapping and Honing machines
- Various broaching elements
- Types of broaching machines

Introduction

Milling is an important process of machining, which employs a multi-point cutter known as milling cutter. When the workpiece is fed against the rotating cutter, the cutting edges removes the material, in the form of chips. Thus, due to this multi-point cutter, metal removal rate is high. Different types of milling machines are available for accomplishing this process, such as plain milling machine, universal milling machine, drum type milling machine, etc.

The process of sizing or shaping a workpiece, by removing small amount of material, using an abrasive wheel is called as grinding. Different types of grinding machines are available, such as cylindrical grinder, surface grinder, tool and cutter grinder, etc. Applications of grinding are tool sharpening, thread grinding, machining bearing surface, etc.

Finishing process is also an abrasive process, which is employed, to increase accuracy, surface finish to eliminate geometrical errors, etc. Some of the finishing processes are lapping, honing and superfinishing.

Broaching is a machining process, in which a toothed tool called 'broach', is used to remove the material from the workpiece. A broach is a multi-point cutting tool. The broaching tool moves in "to and fro" motion, but the cutting action takes place in any one stroke (i.e, either forward or backward).

PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. Explain the principle of milling machaine. [Nov./Dec.-17, (R15), Q1(g) | Model Paper-I, Q1(a)]

Answer :

Milling is a metal cutting operation, in which metal is removed by feeding the workpiece against a rotating multi-point cutting tool. The multi-point cutter is provided with many cutting edges, that remove the metal at a faster rate.

During operation, workpiece is fixed on a table and cutter is mounted on an arbor. When, the feed is given to the table, the workpiece contacts the rotating cutter, whose multiple cutting teeth removes the material in the form of chips.

Q2. What are the basic functions of milling? Nov./Dec.-18, (R16), Q1(a)

Answer:

Milling is a versatile machining process because it is used to machine flat surfaces as well as contour shapes. The cutting tool is milling cutter and the workpiece is placed on a work table. Milling machine is also used for various other operations like drilling, boring, gear cutting and to produce slots. The work table in milling process has reciprocatory motion and can be swivelled to desired angle.

Q3. How is milling machine specified?

Answer :

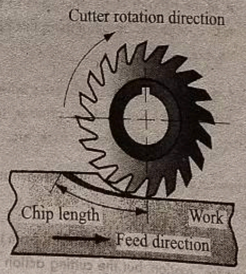
A milling machine is generally specified by the following.

1. Dimensions of the table.
2. Number of spindle speeds and feeds.
3. Horse power of the driving motor.
4. Maximum length of longitudinal, cross and vertical travel of the table.
5. Spindle nose taper.
6. Net weight and the floor space required, etc.

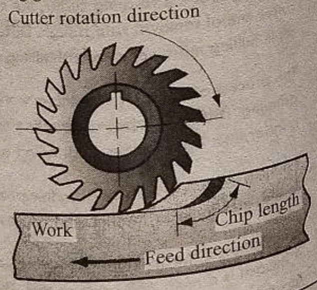
Q4. Compare up milling and down milling? May/June-19, (R16), Q1(e)

Answer :

Up Milling	Down Milling
1. It is also called as conventional milling process.	1. It is also called as climb milling process.
2. The force is induced upwards.	2. The force is induced downwards.
3. The chip thickness increases gradually.	3. The chip thickness decreases gradually.
4. Its surface finish is lower.	4. Its surface finish is higher.
5. It is commonly used for machining, castings and forgings.	5. It is useful for finishing operations such as slot cutting, milling grooves, slitting, etc.



Figure



Figure

Q5. Distinguish between peripheral milling and face milling.

Answer :

Peripheral Milling	Face Milling
1. The teeth are located on the periphery of the cutter body.	1. The teeth are located on both the periphery and face of the cutter.
2. The axis of the cutter is parallel to the surface of the workpiece.	2. The axis of the cutter is perpendicular to the surface of the workpiece.
3. It can be applied for cutting both flat and formed surface.	3. It is mostly used for finishing operations.
4. It is usually done on horizontal spindle machine.	4. It can be done on both horizontal and vertical spindle machines.
5. Low surface finish is obtained.	5. High surface finish is obtained.

Q6. Describe a 'milling cutter'.

Answer : [Model Paper-II, Q1(e) | Nov.-15, (R13), Q1(g)]

The multipoint cutting tool used in milling machines for metal removal is known as milling cutter.

The geometry of milling cutters include four angles such as radial rake angle, axial rake angle, radial relief angle and axial relief angle. Milling cutters are generally are of five types. They are,

1. Plain milling cutters
2. Side milling cutters
3. Metal slitting saw
4. Angle milling cutter
5. T-slot cutter.

Q7. List out the merits of indexing method on milling machine.

Answer :

Advantages of Indexing on Milling Machine

1. Indexing method divides the periphery of the work piece into equal divisions, which cannot be possible by simple milling method.
2. Rotation of the workpiece must be correct to fractions of minutes to cut each slot and is possible with indexing.
3. Through indexing, the workpiece can be rotated to the desired angle.

Q8. What is direct indexing?

Answer :

It is rapid indexing method. It is used for small number of divisions on work piece the index plate has 24 equal spaced holes.

The number of turns of index crank = $\frac{24}{N}$.

Where, N = number of divisions on the workpiece.

Q9. Write the principle of difference indexing? May/June-19, (R16), Q1(f)

OR

What do you mean by differential indexing?

Answer :

The differential indexing method overcomes the drawbacks of simple indexing, by providing simultaneous movement of the index plate, even when the crank is rotated. In this type of indexing, additional gears are incorporated, between the indexing plate and spindle of dividing head. During indexing, the motion of index plate takes place by a set of gears, which obtain their motion from the worm wheel. At every indexing position, the actual movement of the crank can be increased or decreased, according to the desired index movement of the spindle. Hence, this type of indexing is considered to be an automatic method of performing compound indexing.

Let 'N' be the number of divisions to be indexed and 'n' be the number greater or lesser than N. Then, the relation to determine the change of gears, when placed between the spindle and the worm shaft is given by,

$$\frac{\text{Driver}}{\text{Driven}} = \frac{40}{\pi} \times (n - N) \text{ and crank movement, } T = \frac{40}{n}$$

The difference between 'n' and 'N' causes the index plate to rotate in a particular direction. If $n > N$, the index plate will rotate in the direction of the crank and if $n < N$, the plate will rotate in opposite direction to crank.

Q10. Define grinding operation. [Model Paper-III, Q1(e) | Nov.-15, (R13), Q1(i)]

Answer :

Grinding is defined as the process of removing metal in small quantities, by using an abrasive wheel called grinding wheel. This process is used in order to bring the workpiece to required size and shape, to obtain better quality of work surface and dimensional accuracy. The metal removal is in small quantities, which bring the machining process to desired accuracy. The microscopic examination of removed chips are similar to that of machined metal chips. This process, also removes material in a small area where machining is impossible. It is an efficient method of removing material from the machine parts, which are hardened. Due to high hardness of abrasives, complex profiles can be produced with extremely low pressure. Extremely smooth finish at bearing surface can be produced only by this process.

Q11. Define the following from the point of grinding process,

(i) Grindability

(ii) Sensitivity

(iii) Finishability

(iv) Grinding ratio.

Answer :

(i) Grindability

The ability of grinding wheel to remove metal easily is called grindability. To obtain good surface finish, wheel wear should be less and process should be rapid.

(ii) Sensitivity

It is defined as the property of grinding, which indicates the degree of response to surface cracking.

(iii) Finishability

It is the grinding property, by which a good surface finish can be easily obtained.

(iv) Grinding Ratio

It is defined as the ratio between the volume of metal removed from workpiece and the volume of wear of grinding wheel.

$$\text{Grinding ratio} = \frac{\text{Volume of metal removed}}{\text{Volume of wear of griding wheel}}$$

Generally, grinding ratio ranges from 75–130 and is used to determine grindability of material and grinding wheel performance.

Q12. Why a coolant is used in grinding work? Nov./Dec.-16, (R13), Q1(f)

Answer :

The use of coolant in grinding work serves the same function as that of cutting fluids or coolants used in other metal cutting operations. These coolants include water solutions, emulsions and oils. The use of coolant provides following benefits during grinding operation.

1. It reduces the excessive heat produced during the operation. Coolant distributes this heat to avoid extreme localisation.
2. It helps in maintaining uniform temperature to prevent the distortion of jobs as well as breakage of the grinding wheel.
3. To prevent the clogging of metal chips into the grain spaces, thus, the loading of wheel face is avoided.
4. It also helps to drive away the chips and abrasive grains. Thus, there wont be any scratching on the finished surface.

Q13. What is the difference between 'rough' grinding and 'precision' grinding?

Answer : [Dec.-11, Set-4, Q1(a) | Nov.-15, (R13), Q1(i)]

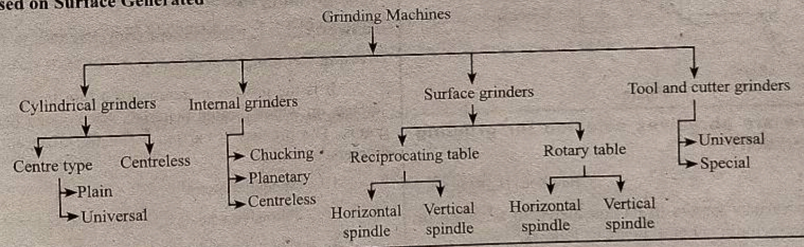
	Rough Grinding		Precision Grinding
1.	Large amount of metal is removed.	1.	Small amount of metal is removed.
2.	The quality of surface finish obtained is low.	2.	The quality of surface finish obtained is high.
3.	It is employed on the following machines, (i) Bench or pedestal grinders (ii) Belt grinders (iii) Portable grinders (iv) Swing frame grinders, etc.	3.	It is employed on the following machines, (i) Cylindrical grinders (ii) Centreless grinders (iii) Surface grinders, etc.
4.	These machines are usually portable.	4.	These machines are fixed to their respective installations.

Q14. Give the classification of grinding machines.

Answer :

Classification of Grinding Machines

1. **Based on the Surface Finish Quality**
   - (i) **Rough/Non-Precision Grinders:** These are used for high material removal. The surface finish quality is low. Though grinders are classified as follows.
     - (a) Bench and floor grinders
     - (b) Portable and flexible shaft grinders
     - (c) Swing frame grinders
     - (d) Abrasive belt grinders.
   - (ii) **Precision Grinders:** These are used for finishing operation. Accurate dimensions are obtained.
2. **Based on Surface Generated**



Q15. Write about abrasive belt grinder.

Answer :

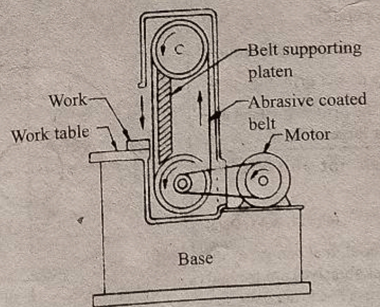


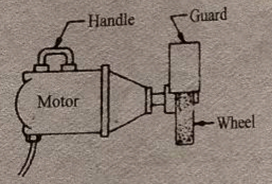
Figure: Abrasive Belt Grinder

In abrasive belt grinder, an endless abrasive belt is used instead of a grinding wheel. The belt is pasted with small abrasive grains on one of its sides. The work is fed against the abrasive coated belt, which revolves around the pulleys or rollers. A metal plate called platen is provided under the belt for support, as shown in the figure. The workpiece to be ground is manually fed against the moving abrasive belt for grinding. This grinder is used for rough grinding. The dimensional accuracy is not very important in this operation. This grinder is best suited for grinding small and irregular shaped workpieces.

Q16. Write short notes on portable grinder.

Answer :

A portable grinder is a manually operated small size grinding machine. It can be carried from one place to the other place. It consists of a small electric motor and a grinding wheel is attached to the end of the motor. The maximum diameter of grinding wheel is limited to 15 cm. The electric supply is given through the long wire which is connected to the power source. This grinder is used for rough grinding of large forgings and welded joints. The typical portable grinder and its components is shown in below figure.



Figure

Q17. How are abrasives selected for grinding operation?

Answer : Nov./Dec.-17, (R15), Q1(l)

The various factors to be considered in selection of abrasives for grinding operation are as follows,

1. Type and condition of material of work.
2. Type of grinding operation used.
3. Complexity of grinding operation.
4. The speed of the grinding wheel during operation.
5. Usage of coolant, i.e., dry or wet grinding.
6. Area of contact between the grinding wheel and workpiece (i.e., narrow or large area).

Q18. Why are natural abrasives not suitable for making grinding wheels?

Answer : Dec.-11, Set-1, Q8(a)

An abrasive is defined as a material, that can wear-out the other material softer than it. Natural abrasives are formed naturally as a mineral deposit in earth's crust, due to uncontrolled forces of nature.

These abrasives can be formed into fine or coarse grade and removes the material at faster rate, but cannot meet the demand of modern manufacturing processes. They are not suitable for grinding wheels, due to the presence of impurities and varying (non-uniform) percentage of important cutting element i.e., aluminium oxide (harder element in composition). Emery and Corundum are commonly used abrasives in industries. The other natural abrasive used in grinding wheel is diamond, which is economically not suitable for industries. Therefore, the natural abrasives are not suitable for grinding wheels.

Q19. What is wheel glazing and loading of the grinding wheel?

Answer : Nov.-10, Set-4, Q4(b)

Due to continuous use of the grinding wheel, the sharp points of the abrasive grains become dull, which leads to loss of cutting ability and sharpness. As the wheel face becomes smooth, it provides rubbing action only. This phenomenon is called 'glazing' of grinding wheel. This occurs mostly in hard wheels and at higher speeds.

During the grinding process, the particles which are cut from the work material adhere to the face of the grinding wheel and occupy the open space between the cutting points. Due to this, the sharpness of the cutting points is reduced and the face becomes smooth, depriving the wheel of its cutting ability. This phenomenon is called 'loading' of wheel.

Q20. What do you mean by dressing and truing in grinding wheel?

Answer : [Model Paper-I, Q1(f) | Nov./Dec.-16, (R13), Q1(i)]

Dressing Grinding Wheels

It is the process of removing a thin layer of grinding surface, on which foreign materials are clogged between the grains. The process is carried out using different types of dressers, as follows.

1. Wheel dressers
2. Abrasive wheels dressers
3. Abrasive sticks
4. Diamond
5. Crush dressing fixtures.

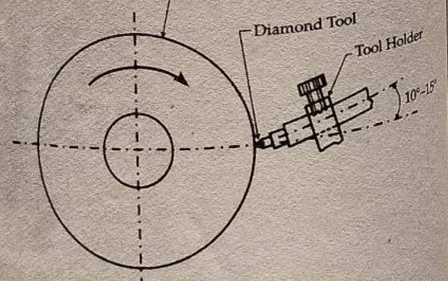


Figure: Dressing Grinding Wheels

Wheel Truing

In this process, the cutting face of the grinding wheel is restored by the removal of the abrasive material from the cutting face and sides of the wheel. This operation is performed to make the periphery of the wheel concentric with its axis. The sides of wheel are made true and for recovering the lost shape of its sides.

Truing and dressing operations are performed with the same tools, but for different purposes. The method of truing a grinding wheel uses diamond tool and produces many grains with flat surfaces.

Q21. What do you mean by lapping?

Answer :

It is a finishing process used to improve the surface finish and dimensional accuracy or to obtain a perfect contact between two mating surfaces. It is a process of removing surface roughness tool marks, surface cracks from grinding, slight distortions and other minor defects from previous operations. This process is extensively used for the finishing of gauge blocks and flats. In this process, a layer of fine abrasive particles suspended in liquid is held between the work and lap. Mostly used abrasives are iron oxide, corundum, emery, chromium oxide, etc.

Q22. Is honing a material removing process? What inaccuracies does the honing process eliminate?

Nov.-10, Set-2, Q1(a)

OR

What is honing? Nov./Dec.-16, (R13), Q1(g)

OR

Define honing process.

Answer : [Model Paper-II, Q1(f) | Nov.-15, (R13), Q1(h)]

Honing is a finishing process, in which the material is removed from a stationary hole by means of a rotating and reciprocating honing tool, It removes very small amount of material, usually contained to amount less than 0.25 mm and maximum of 3 mm in diameter. This process in mainly used for,

1. Holes and bores, which require a fine surface finish and high degree of accuracy.
2. Correcting the out of roundness, taper marks and axial distortions of a bore.

Q23. Which machines are used for performing honing sketch any one of them.

Nov.-11, Set-1, Q7(a)

Answer :

Following are the most commonly used honing machines.

1. Vertical honing machine
2. Horizontal honing machine

Vertical Honing Machine

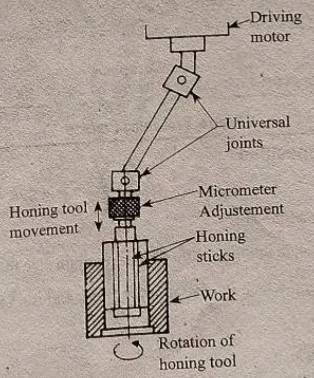


Figure: Vertical Honing Machine

Q24. Write about various advantages and limitations of honing and lapping. Nov./Dec.-17, (R15), Q1(h)

Answer :

Process	Advantages	Limitations
Lapping	1. Good surface finish. 2. High production rate. 3. Used for any kind of material.	1. Flatness and surface finish is not uniform. 2. Limited amount of material is removed. 3. Cost is high.
Honing	1. High dimensional accuracy. 2. High production rate. 3. Multiple holes on be honed at the same time.	1. Tool wear is high. 2. Initial cost is high. 3. Difficult to perform on non-ferrous metals with high toughness.

Q25. Compare and contrast grinding, lapping and honing. Nov./Dec.-17, (R15), Q1(i)

Answer :

Grinding	Lapping	Honing
1. It is a process of removing metal from a work-piece, which is in contact with a grinding wheel.	1. It is an abrasive process, used to improve the surface finish.	1. It is a process of removing metal from a workpiece in small amounts by means of a rotating tool called hone.
2. It employs, abrasives in bonded form.	2. The abrasives used are in loose form.	2. It uses bonded abrasive stones.
3. It can be used on hard surfaces for cutting metal.	3. It removes only thin layers of metal, i.e., about 0.005 to 0.01 mm.	3. It can be used for hard surface and it remove material upto a thickness of 0.0025 mm.

Q26. Define Broaching? Nov./Dec.-16, (R13), Q1(h)

Answer :

Broaching is a machining process which is used to remove material from workpiece. It is performed by broach (tool) which is a multi point cutting tool. In broaching, work is held stationary in a fixture and tool is mounted on a spindle (horizontal or vertical). The reciprocating tool is fed against a stationary work and the cutting action takes place either in forward or backward stroke.

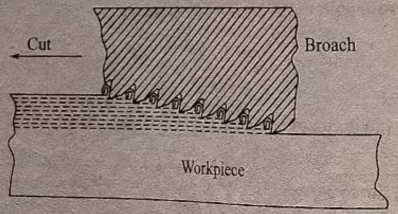


Figure: Broaching Process

Q27. How a broaching machine is specified?

Answer :

The specifications of a broaching machine are,

1. The pressure applied on broach which is 290 kN – 390 kN for medium size machines and 1170 kN for heavy machines.
2. The maximum length of stroke of ram, which is 1350 mm for 1 ton, and for 5 ton, it is 1800 mm.
3. Range of speeds and feeds.
4. Type of drive, i.e., hydraulic or electric.
5. Power rating of electrical motor.

Q28. What are the applications of broaching machines? Nov./Dec.-18, (R16), Q1(f)

OR

List the applications of broaching. [Model Paper-III, Q1(f) | Nov.-10, Set-2, Q1(c)]

Answer :

Applications of Broaching

1. Large variety of shapes along with complex contours can be manufactured effectively.
2. By the process of external broaching, flat surfaces and marked contours can be easily manufactured.
3. By internal broaching, regular geometrical shapes and irregular shapes can be produced.
4. Machining of bearing caps, bearing bodies, cylindrical blocks, connecting rods, cylindrical heads. Machining of crank cases, rotors, toothed sprockets for chain drives, gears, turbine blades, sleeves, bushings, aircraft engine parts can be done effectively through broaching.

Q29. Write about the material used for broaching tools. Dec.-19, (R16), Q1(e)

Answer :

The various materials of broaching tools are,

1. High speed steel
2. Carbide insert broaches are used for machining cast iron.
3. Brazed carbides are used for cutting edges for close tolerances.
4. High carbon steel.

Q30. What are the differences between grinding and broaching.

Answer :

Grinding	Broaching
1. It is a process of removing metal from a workpiece, which is in contact with a revolving grinding wheel.	1. It is the metal removing process, in which metal is removed by the push or pull of the cutting tool called broach.
2. It consists of abrasives in bonded form for cutting action.	2. Broaching tool is used for cutting the metal.
3. It can be used on hard surface for cutting metal.	3. It is applied on surfaces which do not have any obstruction.
4. It is generally used where a high degree of accuracy is required, i.e., of the order of 0.3 to 0.5 µm.	4. It is used on straight or irregular surfaces either externally or internally.
5. This process requires highly skilled operator.	5. This process requires moderate skilled operator.

Q31. Define lapping? Compare lapping with honing and grinding. Dec.-19, (R16), Q1(f)

Answer :

Lapping

For answer refer Unit-IV, Q21.

Comparison of Lapping, Honing and Grinding

For answer refer Unit-IV, Q25.

Q32. Calculate the machining time required for broaching a square hole in a hub. The effective length of the broach is 400 mm and the cutting speed is 2.5 m/min. May/June-12, Set-3, Q8(b)

Answer :

Given that,

Effective length of broach, $L_E = 400 \text{ mm} = 0.4 \text{ m}$

Cutting speed, $V = 2.5$ m/min

Machining time for a broaching operation is given by,

$$T_m = \frac{\text{Effective length of broach}}{\text{Cutting speed}}$$

$$= \frac{L_E}{V} = \frac{0.4}{2.5}$$

$$= 0.16 \text{ minutes} = 0.16 \times 60$$

$$\therefore \quad T_m = 9.6 \text{ seconds}$$

PART-B ESSAY QUESTIONS WITH SOLUTIONS

3.1 MILLING MACHINES

3.1.1 Principles of Working, Types of Milling Machines

Q33. How are milling machines classified?

Answer :

Milling machines are categorized into 6 types, which are again sub divided into different types as listed below.

1. **Column and Knee Type Milling Machines**
   (i) Hand milling machine
   (ii) Plain or horizontal milling machine
   (iii) Vertical milling machine
   (iv) Universal milling machine (Horizontal spindle, swivel table)
   (v) Omniversal milling machine (Horizontal spindle, swivel table, swivel knee).
2. **Manufacturing Type (or) Fixed Bed Type Milling Machine**
   (i) Profile milling machine (Rise and fall type)
   (ii) Simplex milling machine (Single horizontal spindle)
   (iii) Duplex head milling machine (2 horizontal spindles)
   (iv) Triplex head milling machine (2 Horizontal spindles, one vertical spindle).
3. **Planer Type Milling Machine**
   (i) Single column milling machine
   (ii) Double housing plane milling machine.
4. **Production Milling Machine**
   (i) Continuous milling machine
   (ii) Drum milling machine
   (iii) Bed type milling machine.
5. **Machine Centres**
   (i) Numerical control milling machine
   (ii) Computer numerical control milling machine.
6. **Special Purpose Milling Machines**
   (i) Rotary table milling machine
   (ii) Planetary milling machine
   (iii) Pantograph, profile milling, tracer controlled milling machines.
   (iv) Cam milling machine
   (v) Gear cutting, gear hobbing milling machine
   (vi) Spar milling machine
   (vii) Thread milling machine
   (viii) Double end milling machine.

Q34. With a neat sketch, describe the rotary table milling machine and drum-type milling machine.

Answer :

It is the modified form of the vertical milling machine. It consists of a heavy and robust structure. It is mostly used for large scale production. Since there is no idle time is involved in locating the component on its bed, it is called as continuous milling machine. It consists of a heavy base, column and a spindle carrier as shown in below figure.

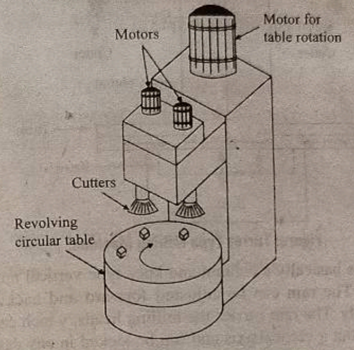


Figure: Rotary Table Milling Machine

The column carries two vertical spindles. One face milling cutter is used for rough machining, the other cutter is used for finishing operation. The machine has a heavy circular table mounted on the base. It rotates about the vertical axis and holds the work/job. Variety of fixtures are used for holding different shapes of workpieces. The production rate of these machines is thrice that of planer-type milling machines, Hence, these machines are best suited for mass production. The main drawback of this type of milling machine is that, it can machine only flat surfaces.

Drum-type Milling Machine

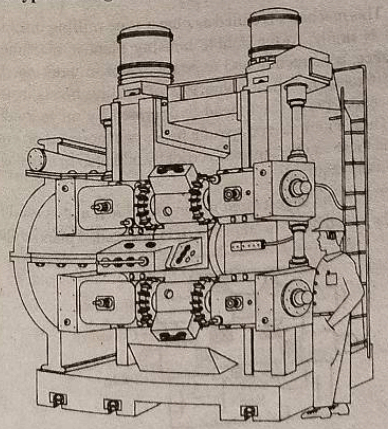


Figure: Drum Type Milling Machine

This machine consists of two vertical columns, mounted on a base. A heavy drum is mounted centrally between the columns which rotates about a horizontal axis. The spindle heads for milling are mounted on the two columns and can be adjusted in vertical direction. The cutters mounted on these spindles are face mills. The roughing cutters are mounted on the upper spindles and finishing cutters on the lower spindles. The jobs to be worked are held in the fixtures attached to the periphery of the drum. The operation is continuous, since machined parts are replaced by new parts after each cycle of work.

These machines are mostly used in large-lot and mass production shops for production of large parts like motor blocks, gear cases, clutch housings, etc. The production rate depends upon the number of parts simultaneously machined and speed of rotation of drum.

Q35. Write a short notes on the following,
(a) Omniversal milling machine
(b) Rise and fall type milling machine
(c) Tracer controlled milling machine.

Answer : [Model Paper-I, Q6(a) | May/June-12, Set-3, Q4]

(a) Omniversal Milling Machine

In this type of milling machine, the knee is attached to a circular base, to have a rotational movement about horizontal axis parallel to the spindle. This machine has five movements, i.e., longitudinal movement, cross movement, vertical movement, rotation about vertical axis similar to universal milling machine and the fifth movement is rotation about horizontal axis. The rotation about horizontal axis is its special feature, through which the table can be tilted and moved horizontally. Thus, it enables various machining operations to be carried at different angles and in different planes, with the same setting of the work. In tool rooms, this machine is usually used for machining tapered spiral grooves in reamers, teeth on bevel gears and angular holes, etc.

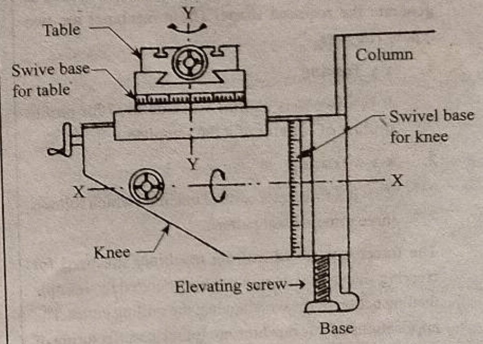
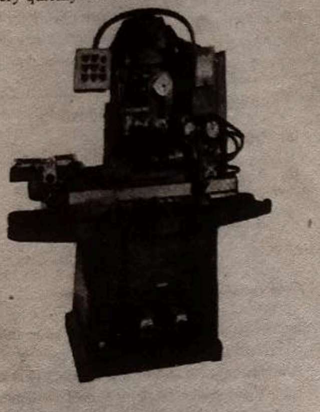


Figure: Omniversal Milling Machine

(b) Rise and Fall Type Milling Machine

Rise and fall type milling machine is an hydraulically operated machine. The rise and fall feature of this machine allows the raise or lower of the cutter spindle to perform the required work. The complete operation is automatic and is synchronised with the automatic transeverse movement of table. Due to this feature, this machine is used for machining of surfaces located in different planes, curried profiles, blind portions, etc., very quickly and economically.



Figure

(c) Tracer Controlled Milling Machine

A tracer mill or tracer controlled milling machine is used for reproducing an irregular part geometry which has been created on a template. The tracing probe is controlled to follow the template by providing either manual feed or automatic feed by machine tool, and the milling head follows the path taken by the probe to generate the required shape. These machines are two types. They are,

1. **x-y Tracing**

   It is a two axis control machine used for profile milling of contour of a flat template.

2. **x-y-z Tracing**

   This is a three axis control machine which follows three dimensional pattern.

The tracer controlled milling machines are used for creating shapes that cannot easily generated by a simple feeding action of the work against the milling cutter. The applications of this machine are found manufacturing of molds and dies.

Q36. Sketch and describe the working of a 'Turret type milling machine'.

Answer :

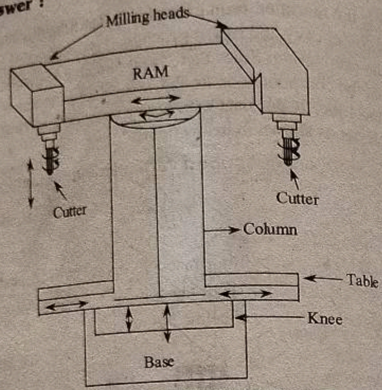


Figure: Turret Type Milling Machine

It is basically a column and knee type vertical milling machine. The ram can be adjusted forward and backward horizontally. The ram carries the milling heads, which can be rotated about a vertical axis and can be locked in any desired position. The directions of movements of the table and the knee are, as shown in figure. The spindles, which are mounted with cutters can be tilted to left or right and sometimes forwards and backwards. The work is held firmly on the table and the rotating cutter is fed against the work surface. The movement of all the components, together facilitate milling in horizontal or vertical or angular directions. In this machine, two different cutters can also be used simultaneously.

Q37. What are the planer type milling machines? Explain their features.

Answer :

This machines is called as planer type milling machine, since it is similar to the double housing planner machine in appearance, construction and to some extent in working. The main difference is that, it comprises of milling heads instead of planer tool posts. Each head is operated by an individual motor. These motor driven spindle heads are mounted on cross rails, and these can be adjusted vertically and also in transverse directions as required.

This is the largest sized milling machine, and is used for milling large and heavy workpieces. It is also called plano-miller.

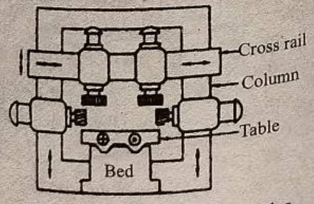


Figure: Planer Type Milling Machine

The milling operation is carried out by,

(i) The table is kept stationary and the cutters are fed by moving the milling heads.

(ii) Moving or feeding the table against rotating cutters.

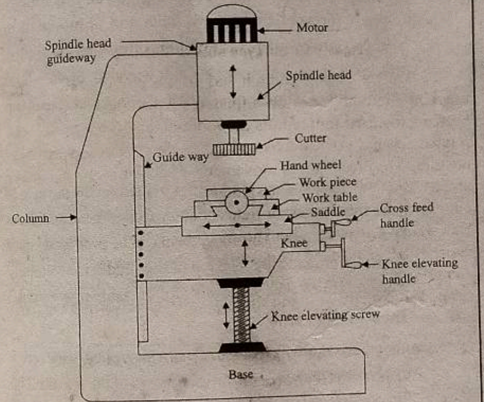
(iii) Moving the table and the milling heads simultaneously.

Generally, these machines are constructed for heavy-duty work with flat surfaces.

Q38. Sketch and describe a vertical milling machine.

Answer : Nov.-15, (R13), Q8(a)

In vertical milling machine, all the principal parts work similar to the horizontal milling machine, except that the spindle head is vertical and the axis of the spindle is perpendicular to the work table as shown in below figure.



Figure

In this machine, both the base and column are casted integrally as a single rigid component. The spindle head can be moved up and down over the guide ways, and the head may be of fixed type or swivelling type or slidable swivelling type. The knee can be moved up and down over the guideways provided on the column face, similar to horizontal type drilling machine. On top of the knee, the saddle is mounted on the knee guideways, over which it can be moved horizontally by hand or power feeding. The work table is mounted on the guideways provided on top of the saddle, over which it can be moved longitudinally. The table can be moved in vertical direction with the help of knee elevating screw.

When the work is moved past the rotating milling cutter, metal is removed form the work surface.

This machine is used for machining grooves, slots and flat surfaces using end mill and face mill cutters.

Q39. Sketch and explain the working of plain column and knee type milling machine.

Dec.-19, (R16), Q7(a)

OR

With a neat block diagram, explain the features and working of a horizontal milling machine.

OR

What is a plain milling machine? Describe its main features with help of block diagram.

Answer : Model Paper-II, Q6(a)

Following are the main parts of a milling machine.

1. **Base**

   It is a heavy and rigid casting made of grey cast iron and supports all the other parts of the machine tool. A vertical column is fixed upon the base. In some machines, the base acts as a reservoir for coolant. It is fixed to the shop's floor to withstand the vibrations produced while machining.

2. **Column**

   It is a box like structure mounted on the base. It accommodates the mechanism to drive the spindle. Dovetail guideways are accurately machined on the front vertical face to allow the knee to slide on them. An overhanging arm is mounted on top of the column.

3. **Knee**

   It is also a casting made of grey cast iron but forms a support for saddle and work table and is mounted on vertical guideways of the column. the top surface of the knee is provided with guideways to upon which saddle slides. it houses the feed and control mechanisms required for feed.

4. **Saddle**

   It is mounted on the guideways provided on the surface of knee and traverses towards or away from the vertical front face of the column. This movement can be provided either by power or manually. The top of the saddle is accurately machined to provide guideways for the table movement.

5. **Table**

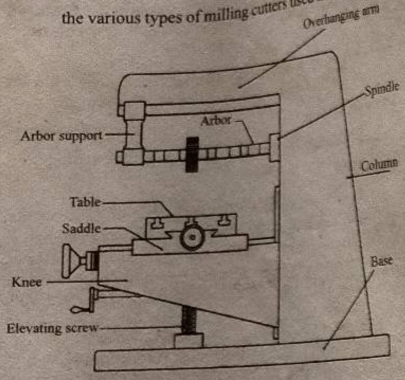
   The table is moved longitudinally in a horizontal plane either by power or manually on the guideways of the saddle. The trip dogs placed on the table to control the displacement of the table. In case of a universal milling machine, the table can be swivelled horizontally to machine helical works. The upper surface of the table is provided with 'T' – slots to mount the workpieces or work holding devices.

6. **Spindle**

   It is found in the upper region of the column. It is driven by the motor via belt, gears and clutches. The front end of the spindle has a tapered hole into which the arbor or different cutters are mounted into it.

7. **Arbor**

It is a shaft, which acts as an extension to the spindle, one end of the arbor has taper shank to fit into the spindle while the other end is fixed in arbor support. It supports the various types of milling cutters used in the machine.



Figure

Working

In horizontal milling machines, the workpiece is clamped on the table with help of any work holding devices. The table is mounted on the guide ways of saddle, and it can be moved longitudinally by providing hand feed or power feed. The elevating screw is used to move the table in vertical direction, i.e., either upward or downward.

The multipoint milling cutter is mounted on the rotating arbor. The cutter rotates with a specified speed selected by the operator, and feed is given to the workpiece which moves slowly past the cutter. Then, the cutting edges of the milling cutter removes the metal from the work surface. The feed can be given in longitudinal, cross wise and in vertical direction as per the requirement.

Q40. With the help of a line diagram, explain the constructional features of a universal milling machine. Nov./Dec.-16, (R13), Q9(b)

OR

Make a neat sketch of universal milling machine indicating the various controls and constructional features. Give brief description.

Answer : Nov.-10, Set-1, Q7

Universal milling machine is exactly similar to the plain column and knee milling machine but only differ in the aspect of table movements. As this machine is employed for a wide range of operations it is called as a universal milling machine and is most suitable for cutting helical grooves. A typical illustration of the universal milling machine is shown in the figure.

Following are the main parts of a milling machine.

1. **Base**

It is a heavy and rigid casting made of grey cast iron and supports all the other parts of the machine tool. A vertical column is fixed upon the base. In some machines, the base acts as a reservoir for coolant. It is fixed to the shop's floor to withstand the vibrations produced while machining.

2. **Column**

It is a box-like structure mounted on the base. It accommodates the mechanism to drive the spindle. Dovetail guideways are accurately machined on the front vertical face to allow the knee to slide on them. An overhanging arm is mounted on top of the column.

3. **Knee**

It is also a casting made of grey cast iron but forms a support for saddle and work table and is mounted on vertical guideways of the column. the top surface of the knee is provided with guideways to upon which saddle slides. it houses the feed and control mechanisms required for feed.

4. **Saddle**

It is mounted on the guideways provided on the surface of knee and traverses towards or away from the vertical front face of the column. This movement can be provided either by power or manually. The top of the saddle is accurately machined to provide guideways for the table movement.

5. **Table**

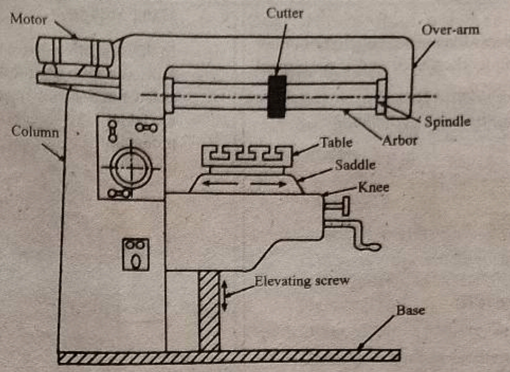
The table is moved longitudinally in a horizontal plane either by power or manually on the guideways of the saddle. The trip dogs placed on the table to control the displacement of the table. In case of a universal milling machine, the table can be swivelled horizontally to machine helical works. The upper surface of the table is provided with 'T'–slots to mount the workpieces or work holding devices. Apart from these movements, the table of universal milling machine can be swivelled in a horizontal plane. This motion makes the machine more versatile.

6. **Spindle**

It is found in the upper region of the column. It is driven by the motor via belt, gears and clutches. The front end of the spindle has a tapered hole into which the arbor or different cutters are mounted.

7. **Arbor**

It is a shaft, which acts as an extension to the spindle, one end of the arbor has taper shank to fit into the spindle while the other end is fixed in arbor support. It supports the various types of milling cutters used in the machine.



Figure

Q41. Distinguish between horizontal, vertical and universal milling machines on some salient features.

Answer : May/June-13, (R09), Q5(a)

Horizontal Milling Machine	Vertical Milling Machine	Universal Milling Machine
1. The spindle horizontal and parallel to the workpiece.	1. The spindle is vertical and perpendicular to the workpiece.	1. The spindle is horizontal and parallel to the workpiece.
2. Cutter can not be moved up and down.	2. Cutter can be moved up and down.	2. Cutter can not be moved up and down.
3. Cutter is mounted on the arbor.	3. Cutter is directly mounted on the spindle.	3. Cutter is mounted on the arbor.
4. Spindle cannot be tilted.	4. Spindle can be tilted for angular cutting.	4. Spindle cannot be tilted.
5. Table can not be swivelled.	5. Table can not be swivelled.	5. Table can be swivelled and the work is fed at an angle to the spindle.
6. It is used for heavier machining operations such as plain milling, form milling gang milling, etc.	6. It is used for machining operations such as slot milling T-slot milling, angular milling, etc.	6. It is used for tool room works and special machining operations such as production of helical grooves and helical gears etc.

Q42. Explain in detail various operations performed on milling machine.

Answer : Nov./Dec.-17, (R15), Q8(b)

Various operations performed on a milling machine are as follows,

1. **Plain Milling**

This operation is performed by using a plain milling cutter. In this operation, the axis of rotation of cutter is parallel to the horizontal surface. In order to perform this operation, the cutter and work are properly mounted, proper feed, speed and depth of cut are adjusted.

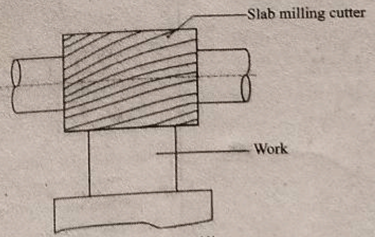


Figure (1)

2. **Face Milling**

In this machining process the axis of rotation of cutter is perpendicular to the work surface and is performed using a face milling cutter.

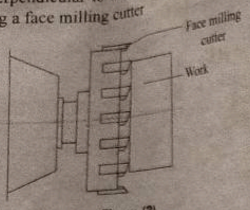


Figure (2)

3. **Side Milling**

In this operation flat vertical surfaces are produced by using a side milling cutter. The depth of cut is given by vertical feed screw.

4. **Straddle Milling**

This is the combination of plain and side milling where the side and plain milling cutters are mounted on arbor and distance between them is adjusted by using collars. This operation is mainly intended to produce square or hexagonal surfaces.

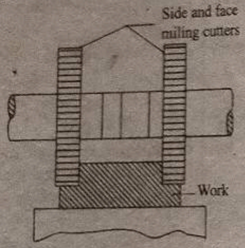


Figure (3)

5. **Angular Milling**

In this operation angular milling cutters of either one side or double side are used to produce angular surfaces. The included angle of the angular surface depends on the type and shape of the angular cutter.

Example: Cutting of V blocks.

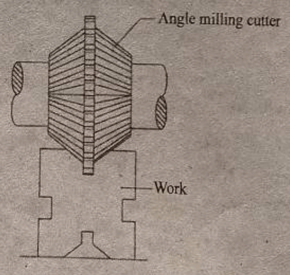


Figure (4)

6. **Gang Milling**

In this operation series of milling cutters of different or same diameter are mounted on the arbor and the work is fed simultaneously against all the cutters by feeding the table. This operation is mainly employed for mass production and the cutting speed is determined on the basis of the cutter with the largest diameter.

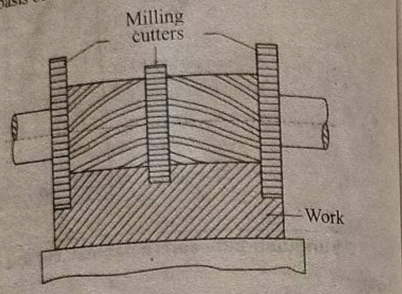


Figure (5)

7. **Form Milling**

In this operation form milling cutters like concave, convex or any other shaped are used to produce irregular contours on the workpiece. The cutting speed of the form milling is less compared to plain milling.

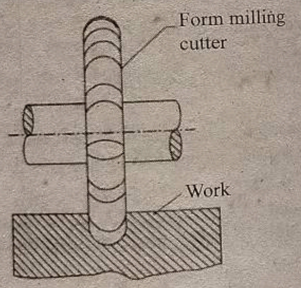


Figure (6)

Q43. Explain upmilling and down milling operation?

Answer :

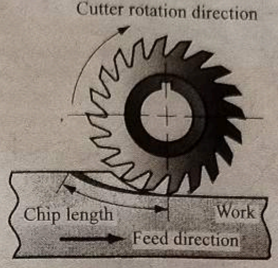
Milling processes are classified into two types. They are,

1. Upmilling or conventional milling process
2. Down milling or climb milling process

1. **Up Milling or Conventional Milling**

It is the process of removing metal by a milling cutter which rotates in opposite direction to the direction of workpiece movement (i.e., feed). It is milling against the feed. In this method of milling, cutting action takes place when the cutter moves upwards.

The schematic diagram representing this milling process is shown in below figure.

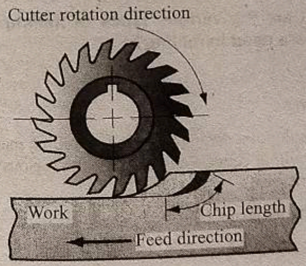


Figure

As shown in figure at the beginning of the cutting action,the chip thickness is minimum and it reaches to maximum at the end. In this milling, the cutting force acts upwards. Thus, there is a tendency to lift the work as the cutter teeth exit the material. During milling operation, the chips will accumulate in front of the cutter. These chips interfere with the cutting action, thus, the machined surface is not smooth .

2. **Down milling or Climb Milling**

In this method of milling, the milling cutter rotates in the same direction of the travel of the workpiece. In this method, cutting action takes place when the cutter moves downward. This method is also called as "In down milling" or 'In cut milling'. It is milling with feed. The schematic representation of this method of milling is shown in below figure.



Figure

As shown in figure, at the beginning of the cutting action, the chip thickness is maximum and it decreases to minimum at the end. In this milling, the cutting force acts in downward direction. Thus, there is a tendency to press the work against the milling machine table. This helps in damping of the workpiece (i.e., there is vibrations or chatter in workpiece). Hence, it gives better surface finish.

Q44. Differentiate between up milling and down milling and explain their applications.

Answer : Nov./Dec.-17, (R15), Q8(a)

Difference between Up Milling and Down Milling

For answer refer Unit-III, Q4.

Applications of Up milling

1. Up milling is used for machining sandy surfaces and flame cut surfaces.
2. Scaly surfaces can be machined using up milling method.
3. If there is any considerable variation in the quantity of a specimen that has to be machined, then upmilling is preferred.

Applications of Down Milling

Down milling is generally used for sawing, grooving, slotting, keyway cutting, etc. It is used for cutting materials like aluminium and aluminium alloys. It is also used to permit formation of thin chips with carbide and cast alloy cutters.

Q45. What is the principle of working of milling machines? How do you classify the milling machine?

Answer : Nov./Dec.-16, (R13), Q8(b)

Working Principle of Milling Machine

For answer refer Unit-III, Q1.

Classification of Milling Machine

For answer refer Unit-III, Q33.

3.1.2 Geometry of Milling Cutters

Q46. With the help of neat sketch explain the different elements in a plain milling cutter?

May/June-19, (R16), Q6(a)

OR

Explain the geometry of milling cutters with sketches.

Nov./Dec.-18, (R16), Q7(a)

OR

Give the tool geometry of milling cutters with neat sketches.

May/June-13, (R09), Q5(b)

OR

With the help of neat sketch, explain the geometry of milling cutter.

Answer : [Model Paper-III, Q6(a) | Nov./Dec.-17, (R15), Q9(b)]

Tool geometry of Milling Cutters

The geometry of milling cutters includes four angles such as radial rake angle, axial rake angle, radial relief angle and axial relief angle. Generally, these angles are considered for three types of milling cutters like face mills, end mills, side and slot mills.

When angles of milling cutter are compared with the angels of single point cutting tool, axial rake angle of milling cutter is similar to back rake angle of single point tool. Where as, radial rake angle of milling cutter is similar to side rake angle of single point tool.

Radial Rake Angle

The angle measured between the side face and the radial plane passing through the cutter axis is referred as radial rake angle. It can be positive or negative.

Due to positive rake angle, the cutting edge becomes weak or may break also. Negative rake angle makes the cutting edge more stronger. The radial rake angle depends on the type of material of workpiece and tool.

Axial Rake Angle

It is the cutting edge inclination with respect to cutter axis. It also gives the direction of chip flow. It can be positive or negative.

Positive axial rake angle removes the chips away from the cut, when rake nose of cutter contacts with the workpiece. While negative axial rake angle traverse the chips along the direction of workpiece. It also makes the cutting edge more stronger.

Mostly negative axial rake angle is applied in carbide cutters.

Approach Angle

The angle measured between the plane normal to axial cutter and the plane tangent to the surface of revolution of the cutting edge is referred as approach angle. The value of approach angle is different for different types of milling cutters.

Milling cutter	Approach angle
End mills	90°
Shoulder mills	90°
Face mills	45°, 60°, 75°

For a given feed, chip thickness increases with the increase in approach angle. Due to this, productivity also increases.

Side Clearance Angle

The angle measured between the cut surface and the clearance flank on the cutter is referred as side clearance angle.

The cutting edges become weak at higher clearance, but less wear and tear occurs. Its value depends on end mill diameter.

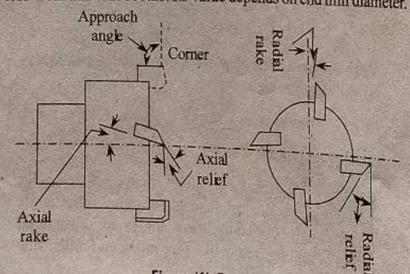


Figure (1): Face Mills

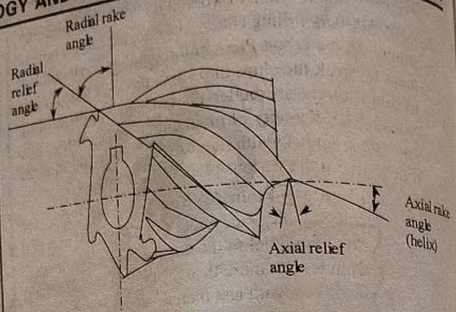


Figure (2): End Mills

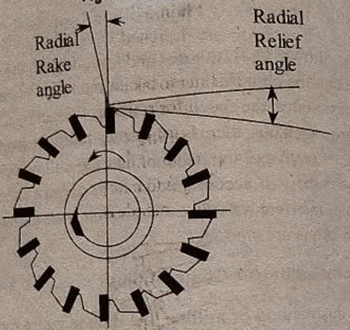


Figure (3): Side and Slot Mills

Q47. Draw sketches of any five types of milling cutters and explain them briefly.

Nov.-10, Set-4, Q5(a)

OR

What are the various types of milling cutters that are used in milling?

Answer :

Milling Cutter

The multipoint cutting tool used in milling machines is known as a milling cutter. Following are the various types of milling cutters used.

1. Plain milling cutters
2. Side milling cutters
3. Metal slitting saw
4. Angle milling cutter
5. T-slot cutter.

1. Plain Milling Cutters

These are cylindrical in shape with teeth (cutting edges) on the periphery as shown in the figure. They are used for machining flat surfaces parallel to the axis of spindle rotation. Based on the size, the cutting edges may be straight or helical. If the width of the cutter is more i.e.,

greater than the width of work, it is called as a slab cutter or cylindrical milling cutter. They have a central hole to mount on the arbor. Plain milling cutters have notched teeth to break the chips into small pieces. Helical plain milling cutters are better than straight plain milling cutters. The diameter of plain cutter ranges from 16 to 160 mm whereas width ranges from 20 to 160 mm the following are the various plain milling cutters.

(i) **Light Duty Plain Milling Cutters:** These are designed with a face width of less than 20 mm and teeth are parallel to the axis of the cutter. In case of cutters with more than 20 mm face width then, helical teeth with less than 25 degrees helix angle are on the periphery.

(ii) **Heavy Duty Plain Milling Cutters:** the tooth of these tools are designed with helix angle ranging from 25-45 degrees and less number of teeth. This enables the cutter to take deeper cuts. These cutters are mainly used for rough cuts.

(iii) **Helical Plain Milling Cutter:** These cutters are provided with teeth of helix angle greater than 45 degrees, enabling it to make smooth and light cuts. These are mainly intended for profile making.

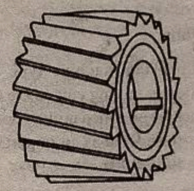


Figure (1): Plain milling cutter

2. Side Milling Cutters: These cutters are similar to plain milling cutters but these have cutting edges on one or both sides of the periphery. These are mainly used for removing material from sides of the work. There are different types of side milling cutters like face and side milling cutter, half side milling cutter, staggered teeth side milling cutter and interlocked side milling cutter. Based on the requirement, appropriate milling cutters are used. Following are the types of side milling cutters.

(i) **Plain Side Milling Cutter:** these cutters have straight teeth on the circumference and on both sides of the cutter and multiple cutters of this kind are mounted on the arbor to machine various faces simultaneously.

(ii) **Staggered Teeth Milling Cutter:** these cutters are designed in such a way that the alternating teeth are oriented with opposite helix angle these are used for producing narrow slots, keyways etc.

(iii) **Half Side Milling Cutter:** These cutters are similar to the plain side milling cutter but the only difference is straight or helical teeth are present on the single face of the cutter along with teeth on its periphery.

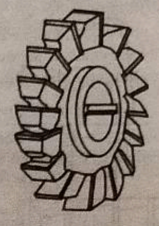


Figure (2): Side milling cutter

3. Metal Slitting Saw

It is designed for cutting narrow, deep slots and for parting off operations. The teeth are cut on the periphery of the cutter. The width of the cutter is short and the outside diameter of the cutter is up to 200mm and width of the cutter ranges from 0.75mm to 7mm. The side of the cutter is relieved so that the sides of the cutter do not touch the work.

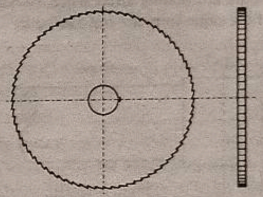


Figure (3)

4. Angle Milling Cutter

The teeth of the angle milling cutter are oriented at an angle instead of being parallel. These are mainly used for machining inclined surfaces, bevels and helical grooves. There are two types of angle milling cutter – Single angle milling cutter and double angle milling cutter.

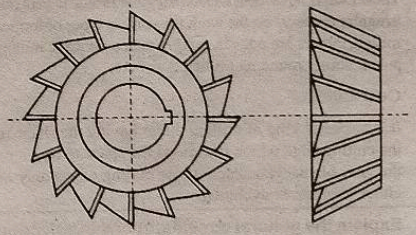


Figure (4)

5. T-Slot Cutter

It is a special form tool where teeth are provided on the periphery and both sides of the tool. These are specially designed for making T-slots. For making T-slots, firstly, a plain slot is cut using an end milling cutter then the T slot cutter is fed from the slot.

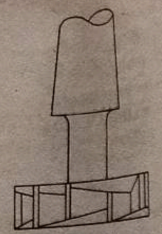


Figure (5)

6. **Woodruff Key Slot Milling Cutter**

These are small standard milling cutters either with straight or staggered teeth and are similar to plain milling cutters but are only intended to cut woodruff key slots.

7. **Fly Cutter**

It is a single point form tool is mounted on an arbor. These type of tools are mainly used when standard milling cutters of the same form are not available.

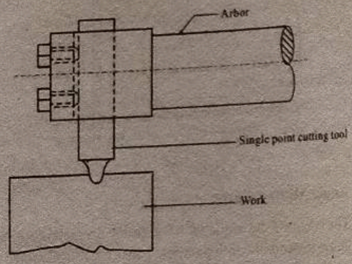


Figure (6)

8. **Formed Milling Cutter**

These cutters have teeth with an irregular profile to generate irregular contours on the work the various types of formed milling cutters are convex milling cutter, concave milling cutter, corner rounding milling cutter etc.

9. **Gear Cutter**

It is a special kind of milling cutter having the shape of the cutting edge which is same as the space to be cut on the gear blank. The shape of the cutting edges may be either involute or cycloidal.

Q48. Explain the general considerations in selection of milling cutters. How do you calculate the number of teeth on milling cutters?

May/June-12, Set-1, Q5

OR

Explain the factors to be considered while selecting a milling cutter.

Nov.-15, (R13), Q9(b)

Answer :

General Considerations in Selection of Milling Cutters

Selection of milling cutter is important, in specifying the rate of productivity. General considerations in selection of milling cutters are as follows.

1. Type of operation
2. Type of machine
3. Type of component
4. Rake angle
5. Finish required
6. Speed, feed and depth of cut.

1. **Type of Operation**

For different types of operations, various milling cutters are used. Selection of the cutter should be done carefully, which may otherwise effect the production rate.

Example

T-slot milling can be performed only with T-slot milling cutter.

2. **Type of Machine**

Depending upon the machine type and method of mounting, different milling cutters are used. Therefore, the type of machine on which milling operation is carried out should be considered as an important parameter in selection of milling cutter.

3. **Type of Workpiece**

Type of component to be machined on milling machine is important, while selecting the cutter. The factors to be included are material, size, shape, thickness of material to be removed, etc. The workpiece material should be always softer than that of cutter material.

4. **Rake Angle**

It specifies the expected life of the cutter. For carbide cutters, the axial rake angle should be negative. It traverses the chips along the direction of workpiece, which makes the cutting edge more stronger.

5. **Finishing Required**

The degree of finish required for the component completely depends on the selection of the milling cutter. The surface finish primarily depends upon the type of cutter used for machining.

6. **Speed, Feed and Depth of Cut**

Speed, feed and depth of cut plays an important role in machining process. The cutting speed, feed and depth of cut of milling cutter should be selected, based on the mechanical and material properties.

Calculation of Number of Teeth on Milling Cutter

In milling operation, the working conditions vary from one milling cutter to another. Thus, for different milling cutters, the number of teeth also varies. The number of teeth can be determined as,

For fluted and relieved cutter,

$$Z = 2.75\sqrt{D} - 5.8$$

Where,

Z – Number of teeth

D – Diameter of cutter in mm.

For fairly coarse teeth over 66 mm diameter, $Z = \frac{D}{12} + 8$

For inserted blade face milling cutter,

$$\text{Number of Blades} = \frac{\text{Circumference of cutter}}{\text{Required blade spacing}}$$

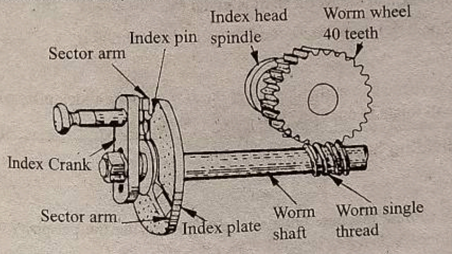
3.1.3 Methods of Indexing

Q49. Explain briefly about indexing.

Answer :

Indexing is the method of dividing the periphery of workpiece into equal number of divisions. Indexing is performed by using dividing head. The workpiece is driven by main spindle of dividing head by means of three-jaw chuck or centres.

The arrangement of indexing mechanism is in such a way that the axis of headstock centre and tailstock centre are perpendicular to the machine spindle. A 40 tooth worm wheel is held in the spindle and it is driven by a single threaded worm. An index crank and an index pin are attached at end of worm shaft. Index plate has equally spaced holes and index pin is made to fit into any hole of index plate as per the requirement.



Figure

The index crank rotates the workpiece by means of handle. As the worm consists of 40 teeth, the gear ratio is 40 : 1. The gear ratio specifies that one complete revolution of workpiece is obtained by 40 turns of the crank for every 40 turns of index crank, spindle completes one revolution.

Similarly, for every 20 turns of, index crank, spindle completes half revolution i.e., one turn of index crank rotates spindle by $\frac{1}{40}$ th of a turn. Index plates are used for more than 40 divisions. The angle by which the index crank is turned is determined by the sector arms.

The following are the various methods of indexing.

1. Direct indexing
2. Plain /simple indexing
3. Compound indexing
4. Differential indexing.

Q50. What is indexing? Explain some common methods of indexing in milling machines.

Dec.-19, (R16), Q6(a)

OR

Distinguish between simple, compound and differential indexing methods.

Nov./Dec.-13, (R09), Q5(b)

OR

Compare and contract compound and differential indexing?

Answer : [Model Paper-I, Q6(b) | May/June-19, (R16), Q7(b)]

Indexing

Indexing is a process used for cutting slots, grooves etc., which are to be spaced equally around the circumference of a blank. Hence, identical multiple operations are performed on one or more workpieces, which are rotated through required set-angle (indexing) each time, to present a new position and thus repeating the same process.

Methods of Indexing

1. **Simple Indexing**

In this indexing, more than one index plate is used. These plates have different number of holes because of which range of indexing is increased. The universal dividing head is used for indexing. Dividing head spindle is rotated by turning the index crank.

The index plate is fixed in position by lock pin then spindle is rotated which is keyed to the worm shaft. To obtain 'N' number of divisions on the job, the number of turns through which index crank must be rotated is $\frac{40}{N}$.

$\therefore$ Index crank movement $= \frac{40}{N}$

Where,

N – Number of divisions required on workpiece.

For 10 divisions on the work the crank will make,

$$\frac{40}{10} = 4 \text{ turns}$$

i.e., 4 turns for each division.

This method is used for divisions that could not be indexed be direct indexing.

2. **Compound Indexing**

This indexing involves two separate indexing movements and is done in two stages.

(i) Rotating crank through certain angle in one direction, keeping index plate fixed.

(ii) Turning indexing plate and crank both in same or reverse direction, thus adding or subtracting movement from obtained movement in first stage.

For example, a 27 teeth gear is to be cut i.e., 27 divisions are to be made, then the rotation required for one tooth spacing is $\frac{40}{27}$ which may be given as $\frac{2}{3}+\frac{22}{27}$ or $\frac{12}{18}+\frac{22}{27}$

Thus, worm will be rotated by 12 holes of 18 holes circle, with the help of crank and then index plate is rotated by 22 holes of 27 holes circle.

3. **Differential Indexing**

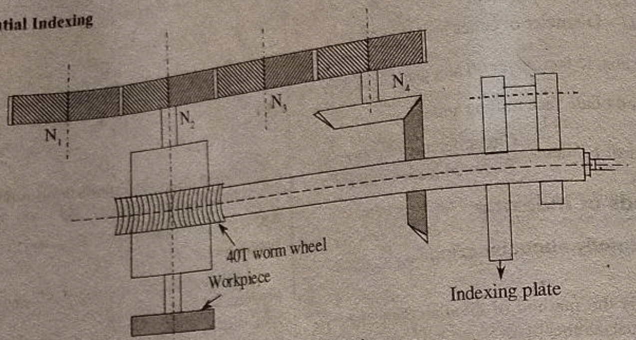


Figure: Differential Indexing

The differential indexing method overcomes the drawbacks of simple indexing, by providing simultaneous movement of the index plate, even when the crank is rotated. In this type of indexing, additional gears are incorporated, between the indexing plate and spindle of dividing head. During indexing, the motion of index plate takes place by a set of gears, which obtain their motion from the worm wheel. At every indexing position, the actual movement of the crank can be increased or decreased, according to the desired index movement of the spindle. Hence, this type of indexing is considered to be an automatic method of performing compound indexing.

Let 'N' be the number of divisions to be indexed and 'n' be the number greater or lesser than N. Then, the relation to determine the change of gears, when placed between the spindle and the worm shaft is given by,

$$\frac{\text{Driver}}{\text{Driven}} = \frac{40}{n} \times (n-N) \text{ and crank movement, } T = \frac{40}{n}$$

The difference between 'n' and 'N' causes the index plate to rotate in a particular direction. If $n > N$, the index plate will rotate in the direction of the crank and if $n < N$, the plate will rotate in opposite direction to crank.

Q51. What is dividing head. Explain various types of dividing heads.

Answer :

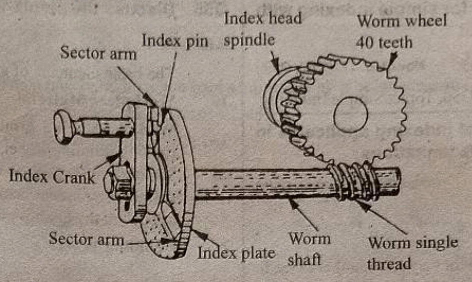
Dividing head or indexing head in an attachment used on milling machine table to accurately divide the periphery of components for grooving or fluting, gear cutting, the cutting of splines, squares or hexagons, etc.

The dividing heads are of three types,

1. Plain dividing head
2. Universal dividing head
3. Optical dividing head

1. **Plain Dividing Head**

The arrangement of indexing mechanism is in such a way that the axis of headstock centre and tailstock centre are perpendicular to the machine spindle. A 40 tooth worm wheel is held in the spindle and it is driven by a single threaded worm. An index crank and an index pin are attached at end of worm shaft. Index plate has equally spaced holes and index pin is made to fit into any hole of index plate as per the requirement.



Figure

The index crank rotates the workpiece by means of handle. As the worm consists of 40 teeth, the gear ratio is 40 : 1. The gear ratio specifies that one complete revolution of workpiece is obtained by 40 turns of the crank for every 40 turns of index crank, spindle completes one revolution.

Similarly for every 20 turns of, index crank, spindle completes half revolution i.e., one turn of index crank rotates spindle by $\frac{1}{40}$ th of a turn. Index plates are used for more than 40 divisions. The angle by which the index crank is turned is determined by the sector arms.

2. **Universal Dividing Head**

Universal dividing head is highly preferred due to the limitations of plain dividing head.

It is operated by means of hand or a gear drive depending upon the operation performed. It can be used for simple, compound and differential indexing methods. It works on the same principle as that of other types of dividing heads.

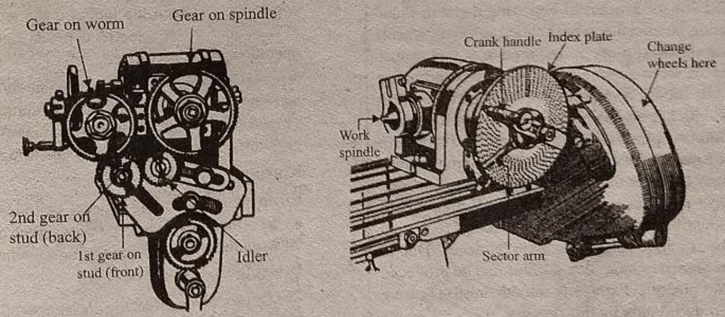
The universal dividing head mainly consists of two parts. They are,

(i) **Head Stock**

It carries both driving and dividing mechanisms.

(ii) **Tail Stock**

It is mounted with the back centre, for work that has to be supported between centres, when being milled.



Figure

3. **Optical Dividing Head**

This dividing head is mostly used for high precision operations, when the error in angular settings is limited to 0.25 minute of arc. This type of dividing head should have a highly accurate dial, and an eyepiece of an optical system is built into the head to read the values on dial. This dividing head is completely free from pitch and backlash errors. Single start worm and 40 teeth worm wheel is the only gear combination used in this dividing head and these gears are only used to rotate the spindle and not for any other dividing purposes.

Q52. Explain the procedure for simple indexing with an example.

Nov./Dec.-17, (R15), Q9(a)

Answer :

For answer refer Unit-III, Q50, Topic: Simple Indexing.

Q53. Explain the methods of indexing applicable in milling machine and its limitations.

Nov./Dec.-18, (R16), Q6(b)

Answer:

1. **Direct Indexing**

   For answer refer Unit-III, Q8.

   Limitations: It can be used for very less number of teeth. The obtained index ratio should be a definite number, else indexing is not possible.

2. **Simple Indexing**

   For answer refer Unit-III, Q50, Topic: Simple Indexing.

   Limitation: It can not be used to cut wide range of teeth on the gear.

3. **Compound Indexing**

   For answer refer Unit-III, Q50, Topic: Compound Indexing.

   Limitation: It is a complicated process in actual practice.

4. **Differential Indexing**

   For answer refer Unit-III, Q50, Topic: Differential Indexing.

3.2 GRINDING MACHINES

3.2.1 Theory of Grinding

Q54. Why is grinding so important in modern production? Explain.

Dec.-11, Set-4, Q1(b)

Answer :

Grinding is defined as the process of removing metal in small quantities, by using an abrasive wheel called grinding wheel. In order to bring the workpiece to required size and shape, to obtain quality of work surface and dimensional accuracy grinding process is used. The metal removal is carried out in small quantities, which bring the machining process to desired accuracy. The microscopic examination of removed chips are similar to that of machined metal chips. The unique surface finish and accuracy in size is obtained by the grinding process. This process, also removes material in a small area where machining is impossible. It is an efficient method of removing material from the machine parts, which are hardened. Due to high hardness of abrasives, complex profiles can be produced with extremely low pressure. Extremely smooth finish at bearing surface can be produced only by this process.

Applications of Grinding

1. It is used for sharpening the cutting tools.
2. It is used for grinding threads.
3. It is used for machining hard surface, which are difficult to machine by HSS and carbide tools.
4. It is used for rapid stock removal from the workpiece.

Q55. Discuss the elements of grinding.

Answer :

The basic elements of a grinding process include,

1. **Workpiece Material**

   Workpiece being ground is firmly held against the rotating grinding wheel, to remove the unwanted metal. Various parameters of workpiece such as shape, size, stiffness, hardness, chemical and thermal properties have impact on the quality of grinding.

2. **Grinding Wheel**

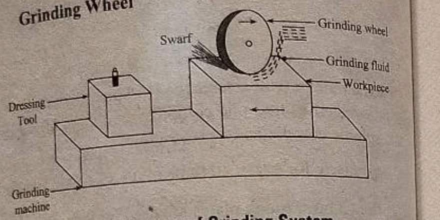


Figure: Elements of Grinding System

   It is the cutting tool, made up of abrasive materials which should be harder than the workpiece material. The grinding wheel should possess the following properties for better accuracy and surface finish,

   (i) High hardness and stiffness
   (ii) Low heat sensitivity
   (iii) High wear resistance
   (iv) Better grain size
   (v) Good structure of bond
   (vi) Highly resistant to thermal and chemical effects.

3. **Grinding Machine**

   The machine structure provides the static and dynamic constraints between the tool and the workpiece. Type of machines to be selected depends upon the type of operations to be performed.

   A perfectly designed grinding machine should experience less vibrations and provide high accuracy movements. Thus, the specification, design and manufacturing of the grinding machine, influence its performance.

4. **Kinematics**

   Kinematics of grinding process includes the geometry and motions governing the movement or engagement between the workpiece and grinding wheel.

5. **Dressing Conditions**

   The factors which affect the dressing conditions are type of tool, cooling medium, lubrication, speed and feed, maintenance, etc.

6. **Grinding Fluid (Coolant)**

   Grinding fluid is used to reduce the wheel wear, cool the workpiece and flush away the swarf (fine chips and abrasive particles). Flow rate, velocity, pressure, physical, chemical and thermal properties of grinding fluid affects its effectiveness.

Q56. What are the merits and demerits of grinding.

Answer :

Merits

1. It can be employed for materials, which are too hard to machine by other processes.
2. Better surface finish and smooth surfaces can be obtained.
3. The pressure required during grinding process is less.
4. Complex profiles can be produced accurately.
5. The grinding wheels have self sharpening property.
6. High cutting speeds can be employed.
7. High material removal rate.
8. The abrasives can sustain at high temperatures.
9. High dimensional accuracy up to ± 0.02 mm can be obtained.

Demerits

1. High cost of tool, power and labour is required.
2. The value of the operation lies in the quality of finish obtained and accuracy of the product, but not in the amount of material removed.
3. The time taken in removing a certain quantity of stock through grinding operation is more.
4. The grinding wheels wear out more quickly than other types of cutting tools.
5. Incorrect grinding leads to glazing and clogging.

3.2.2 Classification of Grinding Machines

Q57. What are surface grinding machines, explain various surface grinding machines.

Nov./Dec.-17, (R15), Q10(a)

Answer :

Surface grinding is a finishing process, in which a small amount of metal is removed from the surface, in the form of powder, by using a grinding wheel. The grinding wheel consists of abrasive particles, which acts like cutting edges. This process is generally used for producing flat work surfaces with very high degree of surface finish and smoothness.

During the process, an abrasive bonded grinding wheel is fed over the workpiece located on the table which has reciprocating or rotary motion. As the grinding wheel is rotated, the abrasive particles perform finishing operation, by cutting small amounts of material. The supply of coolant ensures cooling of working interface and removal of chips from the surface.

The grinding machines used for this operation are known as surface grinding machines or surface grinders.

Based on the spindle arrangement, surface grinders are classified into two types.

1. Surface grinder with horizontal spindle
2. Surface grinder with vertical spindle.

1. **Surface Grinder with Horizontal Spindle Machine**

   In this type, the grinding wheel is mounted on horizontal spindle. The periphery or face of the grinding wheel is in contact with the work material. The work is placed on table, to which required motion is provided and the grinding wheel is given rotary motion. This surface grinding involves traverse grinding and plunge grinding. In traverse grinding, feed motion is the reciprocation on of the work table (traverse feed). Whereas, in plunge grinding, feed motion is in vertical direction (in feed) by moving wheel head down the column, i.e., moving the grinding wheel down to the table.

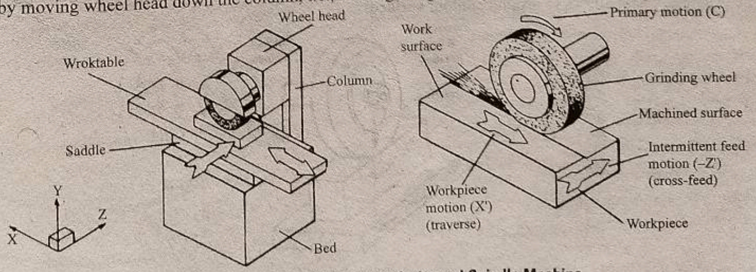
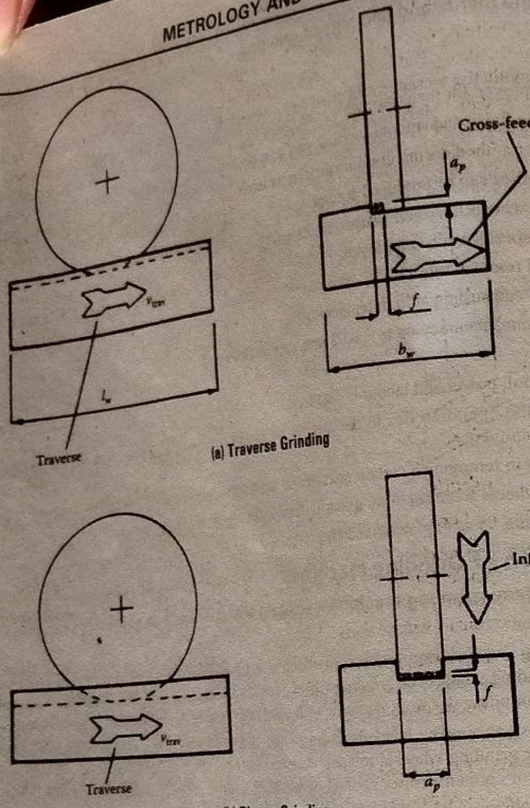


Figure (1): Surface Grinder with Horizontal Spindle Machine



(a) Traverse Grinding

(b) Plunge Grinding

Figure (2)

Based on table motion, these grinder are classified into two types.

(i) Horizontal Spindle with Reciprocating Table

The work table has reciprocating motion and the grinding wheel is placed on horizontal spindle. This is the most common process and the grinding is performed in straight paths. Depth of cut is controlled by raising or lowering the wheel head. The size of these grinders ranges from a small machine that can grind an area of 4 × 8 inches to large machines that can grind an area of 6 × 16 ft or more. Good accuracy and surface finish is obtained by this type of grinding. Special shaping of the grinding wheel allows to ground contour surfaces.

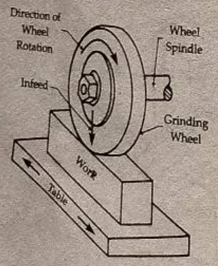


Figure (3)

(ii) Horizontal Spindle with Rotary Table

The work table has rotary motion on which the workpieces to be ground are mounted. The face of the wheel is brought into contact with the workpiece to perform grinding operation. It is used for round and flat parts. The table can also be tilted to pefrom special grinding operations such as hollow grinding of the sides of a circular saw. The principle of operation is similar to facing in lathe.

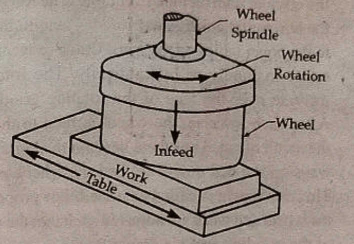


Figure (4)

2. Surface Grinding on Vertical Spindle Machine

In this type of grinding machine, the grinding wheel is mounted on vertical spindle. The face of the grinding wheel is in contact with the workpiece. Thus, in this process workpiece is in more contact with grinding wheel.

These grinding machines have high metal removal rate, and large flat surfaces can be ground easily. Based on table motion, these grinding machines can be classified into two types.

(i) Vertical Spindle Reciprocating Table

This process is similar to face milling where, the face of grinding wheel removes material. The work is clamped on the reciprocating table with the help of magnetic check or fixture. A cup shaped grinding wheel is used, which rotates about vertical axis against the work surface. The longitudinal and cross feeds are given through the table. The face or side of the grinding wheel involves in grinding action. The depth of cut is given by lowering the wheel head. This process is used for grinding flat surfaces on medium sized works such as narrow castings, bed ways of lathe.

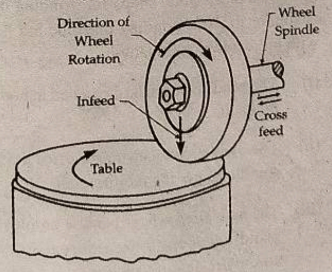


Figure (5)

(ii) Vertical Spindle Rotary Motion

The grinding wheel is mounted on vertical spindle and the work is clamped on the rotary table with the help of magnetic chuck. The grinding wheel rotates about its fixed axis and can be fed only along its axis. When the grinding wheel is brought in contact with the workpiece mounted on rotaring table, grinding action is performed and material is removed. As both the work and grinding wheel are in rotating motion, this process is best suited for large castings. Large amount of material is removed in a single pass. A single large workpiece or a number of small workpieces can be grind at a time.

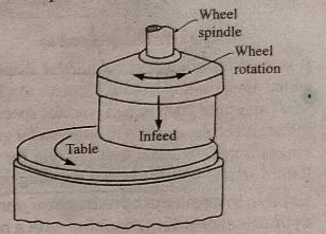


Figure (6)

Q58. Sketch and explain three methods of cylindrical grinding.

Answer : [Model Paper-III, Q6(b) | Nov./Dec.-12, (R09), Q6(b)]

Cylindrical grinding is the basic grinding process in which the workpice is held in between the centres and is rotated at high speeds. The grinding wheel is also rotated about its own axis and is fed against the workpiece. In cylindrical grinding, there are two types of grinding operations. They are,

1. Traverse grinding
2. Plunge grinding.

1. Traverse Cylindrical Grinding

During the process, the work reciprocates and the wheel is fed into the workpiece. This operation produces cylindrical shapes longer than the width of the grinding wheel.

The traverse cylindrical grinding machine is similar to the of centre lathe. The grading motor is driven at a speed suitable for grinding operation. The workpiece is held between the centres and is rotated at a lower speed than grinding wheel speed. The feed is provided by the movement of grinding wheel head.

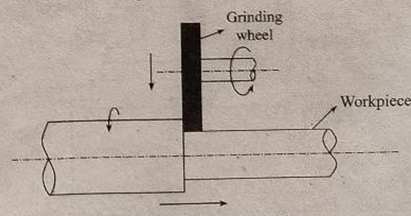


Figure (1): Traverse Grinding

2. **Plunge-Centre Type Grinding**

In plunge grinding, the workpiece is rotated between the centres in a fixed position and the wheel is fed against the workpiece, till the desired diameter is obtained. The length of the cylindrical shape produced is equal to the width of grinding wheel.

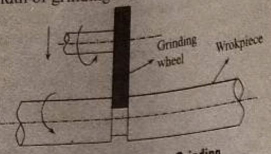


Figure (2): Plunge Grinding

It is used for producing cylindrical shapes and is best suited for grinding of cranks, with a wheel speed of 1500 m.p.m to 2000 m.p.m (surface speed in meter per minute). The depth of cut to be given for grinding wheel ranges from 0.025 mm to 0.125 mm for roughing and 0.0125 mm to 0.0625 mm for finishing operation.

Q59. Explain in detail the construction and working of cylindrical grinding machine with a neat sketch?

May/June-19, (R16), Q6(b)

OR

Explain any two types of cylindrical grinding machines.

Answer :

Classification of Cylindrical Grinding

1. Plain cylindrical grinders
2. Universal cylindrical grinders
3. Centreless grinders.

1. **Plain Cylindrical Grinders**

A plain cylindrical grinder consists of the following main parts,

(i) Head stock
(ii) Tailstock
(iii) Upper table
(iv) Lower table
(v) Guide ways
(vi) Wheel head.

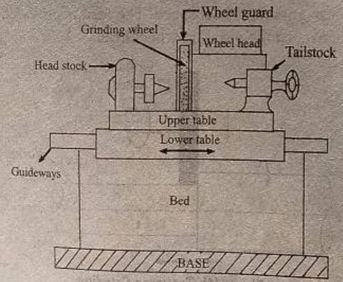


Figure: Plain Cylindrical Grinder

In plain cylindrical grinders, the workpiece is placed between the centres by keeping the headstock stationary and adjusting the tailstock manually or hydraulically. Tailstock and headstock can be moved along the table depending on the type of work. Plain cylindrical grinder consists of an upper table, which incorporates a tailstock, headstock and the workpiece. The upper table can be swivelled horizontally for about 10° an either side along the circular path on the lower table. The lower table over the horizontal guideways provides longitudinal traverse to the upper table and the work. Table movement is done either manually or hydraulically. The rotating work traverse over the face of the rotating grinding wheel. After each traverse, the wheel is feed to the work for the depth of cut. The wheel head on the horizontal cross ways on the bed moves to feed the wheel to the work. This movement is called as infeed. For proper stability, the wheel and work are adjusted such that the orientation of the grinding force is downwards.

2. **Universal Cylindrical Grinders**

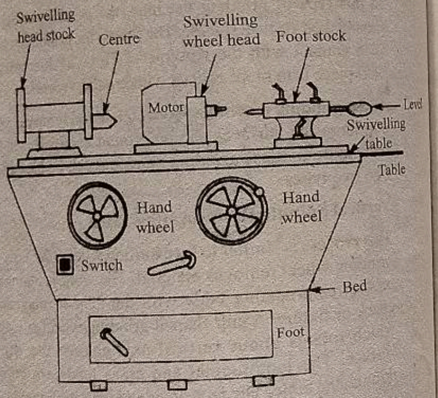


Figure: Universal Cylindrical Grinding Machine

Universal grinding machines are most commonly used machines in machine shops for grinding operations. It is similar to plain grinding machine but it is equipped with more additional features.

(i) The headstock can be swivelled in horizontal plane by itself.

(ii) The swivelled headstock carries a dead (or) live spindle as per the requirement.

(iii) The swivelled wheel head is employed for taper grinding operations, internal grinding. Semi automatic feature makes it as a chucking type grinding machine.

Q60. With the help of sketch explain external centerless grinding and internal centerless grinding.

Answer :

Centreless grinding is one of the methods of grinding which is widely used for finishing the components that are difficult to mount and rotate in between centres. There are two methods of centreless grinding which are,

1. External centreless grinding
2. Internal centreless grinding.

1. **External Centreless Grinding**

This method of grinding is especially used for finishing exterior cylindrical, tapered and formed surfaces. The equipment consists of grinding wheel, work rest and regulating wheel. The work is positioned in between the centres and is supported by work rest. The work rest along with regulating wheel apply force on the work against the grinding wheel. The axial feed of the work is achieved by tilting the regulating wheel by 2 to 10 degrees with respect to horizontal.

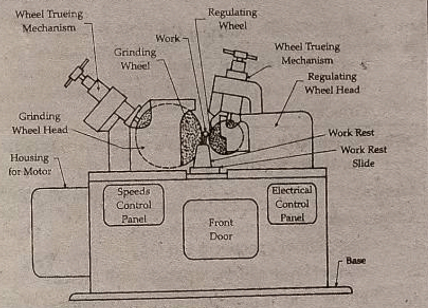


Figure (1)

External centreless grinding can be performed by the following three methods,

(i) Through feed grinding
(ii) In feed grinding
(iii) End feed grinding.

(i) **Through Feed Grinding**

In this method of grinding, the centre of workpiece is above the line joining the centres of grinding wheel and regulating wheels. The velocity component ($V \cos \alpha$) helps to feed the workpiece and the grinding wheel rotates in such a manner, that it pushes the workpiece down for through feed. This method is used for straight cylindrical objects.

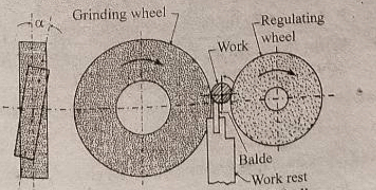


Figure (2): Through Feed Centreless Grinding

(ii) **In Feed Grinding**

In this method, the width of grinding wheels is more than the length of the job. The regulating wheel is withdrawn for placing of workpiece on work rest and is moved back to its initial position. This method is mostly used for grinding formed components.

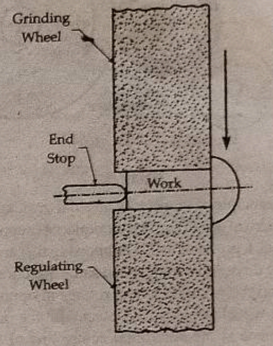


Figure (3): In Feed Centreless Grinding

(iii) **End Feed Grinding**

In this method, the feed of the workpiece is provided from side of the wheels in longitudinal direction. The profile of grinding wheel or regulating wheel or both are made tapered. The grinding is completed, when the workpiece touches the end stop which is on other side. It is used for grinding spherical and tapered jobs.

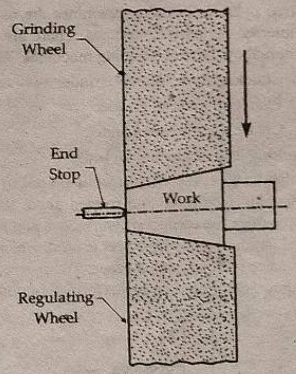


Figure (4): End Feed Centreless Grinding

2. **Internal Centreless Grinding**

It is used for grinding internal surfaces of relatively long workpieces. It eliminates the need for centre holes, drivers and other fixtures, required to hold the workpiece.

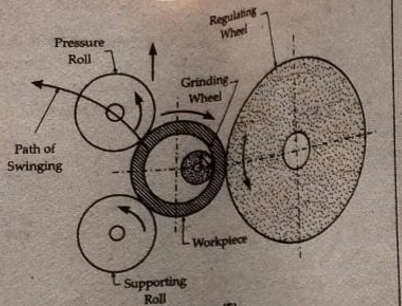


Figure (5)

The principle of centreless internal grinding is similar to external cylindrical grinding. The workpiece is supported between three rolls, i.e., a pressure roll, a supporting roll and a regulating wheel. All the three rolls rotate in the same direction, whereas the workpiece and the grinding wheel rotates in opposite direction. The grinding wheel remains in contact with the internal surface of the workpiece at the horizontal centre line of the regulating wheel. This ensures uniform wall thickness and concentricity of internal hole with the external surface of workpiece.

Q61. Explain with neat sketch,

(i) Centreless grinding

(ii) Internal grinding.

Answer : Nov.-15, (R13), Q11(b)

(i) **Centreless Grinding**

For answer refer Unit-III, Q60.

(ii) **Internal Grinding**

Internal cylinder grinding machines are used to finish the internal cylindrical surfaces. There are three types of internal cylindrical grinding machines. They are

1. Chucking type internal grinder
2. Planetary internal grinder
3. Centreless internal grinder.

1. **Chucking Type Internal Grinder**

In this machine, the workpiece is placed in a chuck or a magnetic face plate and rotated about its own axis. This enables the contact of workpiece and the grinding wheel. A small grinding wheel is used, which grinds the workpiece with its outer surface. Transverse and plunge grinding operations can be performed on this machine.

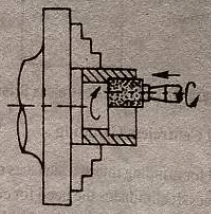


Figure (1)

2. **Planetary Internal Grinder**

These are used to grind internal cylindrical holes of large, irregular shapes and heavy works. In this type, the workpiece is stationary, where the grinding wheel is given rotary and planetary motions i.e., the grinding wheel axis moves along the axis of the hole. The longitudinal movement can be obtained by either forward and backward movement of the slide or by movement of the wheel spindle. These are high speed grinders as they consists of smaller grinding wheels.

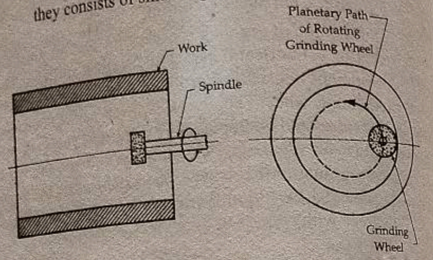


Figure (2)

3. **Centreless Internal Grinder**

For answer refer Unit-III, Q60, Topic: Internal Centreless Grinding.

Q62. State the advantages and limitations of centreless grinding?

Answer : Nov./Dec.-13, (R09), Q6(b)

Advantages

1. Less skill of operator is required.
2. Control on size of the work is much easier.
3. Productivity is high compared to cylindrical grinding.
4. The principle can be used for both external and internal grinding.
5. No deflection of work.
6. It provides rigid support to the work.
7. A true floating condition is obtained during the process.
8. Less grinding stock is needed.
9. Less maintenance is required.

Limitations

1. Work with several diameters is difficult to handle.
2. Work with flats and keyways cannot be ground.
3. Time consumed in changing centreless grinder to grind different sizes is more.
4. It is used only for large size production.

Q63. What is meant by centerless grinding? State its advantages and limitations of it.

Answer : Nov./Dec.-17, (R15), Q11(b)

For answer refer Unit-III, Q60.

Advantages and Limitations of Centreless Grinding

For answer refer Unit-III, Q62.

Q64. Sketch and explain the three methods of external cylindrical centreless grinding.

Answer : Nov.-15, (R13), Q10(a)

For answer refer Unit-III, Q60, Topic: External Centreless Grinding.

Q65. Differentiate between traverse and plunge grinding.

Answer : Nov.-15, (R13), Q11(a)

For answer refer Unit-III, Q58, Topics: Traverse Cylindrical Grinding and Plunge-centre Type Grinding.

3.2.3 Types of Abrasives – Bonds, Selection of a Grinding Wheel

Q66. Describe grinding wheel structure with a neat sketch.

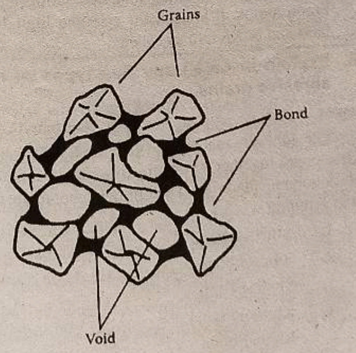
Nov./Dec.-17, (R15), Q10(b)

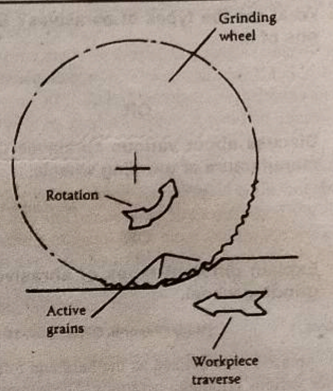
OR

Describe a grinding wheel structure with the help of a neat sketch and state different abrasive materials used in it.

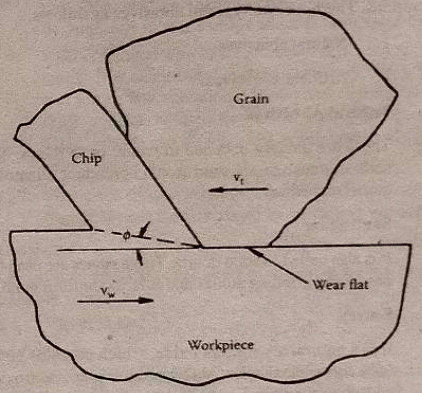
Answer : [Model Paper-I, Q7(a) | Nov.-10. Set-1, Q8(b)]

Grinding wheel is a multipoint cutting tool consists of a large number of abrasive particles, called grains. These abrasives are held together firmly by means of a bond. The cutting action of the grinding wheel is similar to that of milling cutter, but the only difference is that, the cutting points are irregularly shaped and distributed over the active face (the face that involves in cutting action) in a random fashion. Compared to other traditional machining operations, the cutting speeds are significantly higher in grinding operation. The grains on wheel surface, which involve in cutting operation are called active grains. During surface grinding operation, each active grain removes small amount of material in the form of chips of gradually increasing thickness, which is similar to the action of tooth on slab milling cutter.





Figures



Figure

Even though,the grains are irregular in shape, there is sufficient interference, plowing action between the each active grain and the work surface being grind. Here, each active grain behaves like a small cutting tool with a large negative rake angle of about – 60° or larger. Due to which, the shear angle is very small during the removal of chips.

Due to the plowing action, the active grains are subjected progressive wear, and forms worn areas on the active grains. As the grinding operation continues, the more number of worn areas will form on the grains. The interference or friction increases, which results in increase in force acting on the grain. This force gradually increases and becomes large enough to either tear the worn grain from the wheel and expose a new unworn grain or to fracture the worn grain to produce new cutting edges. Thus, the grinding wheel has a self sharpening characteristic before the worn grain torn from the wheel or fracture.

If the wheel becomes grazed, 'dressing' should be done with a diamond tipped tool to remove or fracture the worn grains at wheel surface, thus a new and sharpened cutting surface is generated.

Q67. What are the types of abrasives? Explain any one of it.

Nov./Dec.-16, (R16), Q7(b)

OR

Discuss about various abrasives used in the manufacture of grinding wheels.

May/June-12, Set-3, Q3(b)

OR

Explain different types of abrasives used in grinding wheel.

[Model Paper-II, Q7(a) | Nov.-15, (R13), Q10(b)]

Answer :

Abrasives are defined as the hard and tough materials used for various grinding operations. These consists of small particles, which possess sharp edges, useful for cutting operations. There are two types of abrasives as follows,

1. Natural abrasives
2. Artificial abrasives.

1. Natural Abrasives

These are directly obtained in nature or in mines. The natural abrasives are sand stone, corundum, diamond, garnet and emery.

(i) Sand Stone

It is also called as solid quartz. These stones are used for producing grinding stones and it lacks uniform bond.

(ii) Emery

It is a natural aluminium oxide, which contains 50%-60% crystalline alumina (Al_2O_3) and remaining is iron oxide and other impurities. Emery, because of variations in natural bond, is not suitable for grinding work.

(iii) Corundum

It contains 75%-90% crystalline alumina and the remaining is iron oxide. It is harder and possess better abrasive action than sand stone.

(iv) Diamond

It is the hardest abrasive material. The wheels made of diamond are useful for cemented-carbide tools. They have very rapid cutting ability, slow wear and free cutting action. Natural diamond grains cannot be readily used and leads to fracture. When diamonds are used as abrasive material, very little heat is generated.

(v) Garnet

These are used in the form of coated abrasive, which is a cloth or paper, on which abrasive grains are cemented. These are used for machine grinding in the form of disc or belt.

2. Artificial Abrasives

These are also called as synthetic abrasives and are manufactured by various process under controlled conditions. These are harder and have greater toughness than other natural abrasives, except diamond. The quality and composition of abrasive particles is easily controlled. The various artificial abrasives are as follows,

(i) Silicon Carbide (SiC)

The important contents of silicon carbide are silica, sand and coke. To this, saw dust is added to make porous mixture and then it is put in an electric furnace. The formed resultant mass is crystalline in nature and is crushed and graded to particle size. There are two types of silicon carbide abrasives, i.e., green silicon carbide and blue-black carbide, which contains 97% silicon carbide and 95% silicon carbide respectively.

It has high hardness and sharpness but it is brittle as compared to aluminium oxide. It is used to grind specific materials, because of its grain fracturing properties. The grinding wheels made from this abrasive are used for grinding brass, grey cast iron, bronze, copper, aluminium, etc.

(ii) Boron Carbide (B_4C)

It is produced from boric acid and coke at very high temperatures, in an electric furnace and is harder than silicon carbide. It is used in stick form to dress grinding wheels for carrying out lapping operations on very hard materials such as hardened steel, etc.

(iii) Aluminium Oxide (Al_2O_3)

It is the most commonly used grinding abrasive. It is prepared by refining bauxite mixed with coke and iron burning. The resultant mixture is crushed and screened into grit size. The wheels made from this abrasive may be black, pink, grey or white. The wheels of these types of abrasives are tough and shock resistant. They are used for grinding materials like carbon steels, wrought iron, malleable iron, tough bronze and alloy steels.

(iv) Cubic Boron Nitride

It is the second hardest abrasive. It has a tight network of interlocking and alternating nitrogen and boron atoms. It is used for grinding high speed steel, hard and tough tool steels etc.

Q68. Explain in detail any five types of bonds of abrasive grains.

May/June-12, Set-4, Q2(a)

Answer :

The adhesive materials which are used for holding the abrasive grains together for an effective cutting action are called bonds or bonding materials. The following bonds are commonly used in grinding wheels.

1. Vitrified bond
2. Silicate bond
3. Shellac bond
4. Resinoid bond
5. Rubber bond.

1. Vitrified Bond

It is made of clay or feldspar and is denoted by *V*. The clay and water are mixed with abrasive grains and the mixture is moulded to form the wheel. It is then baked in a furnace to a temperature of about 1250°C to develop required structural strength. As burning proceeds, clay fuses and forms porcelain that holds the grains together. The wheels are then cooled slowly, to avoid thermal cracking. Then, they are finished to size, inspected for dimensional accuracy and tested for defects. Since, vitrified bond wheels are baked at high temperatures, they can withstand high temperature generated during the actual process. The bond is used in about 75% of the wheels manufactured.

Vitrified bonded wheels has high strength, porosity and does not easily clog and also not affected by water, acid, oils or ordinary metal cutting conditions. A high rate of metal removal is possible with this bond. It breaks down readily on the wheel to expose new grains, during the grinding operation. These wheels are generally operated at 1950 m/min or below.

Vitrified bonded wheels are brittle and possess low bending strength and low impact strength.

2. Silicate Bond

It is made from silicate soda and is mixed with abrasives grains. The mixture is moulded to wheel shape and then baked in a furnace at a temperature of 260°C for several days. A silicate bond is denoted by *S*. These wheels are less sensitive to shock and not as strong as vitrified bond and therefore releases the abrasive grains more readily.

Silicate bond is affected by moisture and alkaline solutions. These wheels are suitable for the grinding, where the heat generation is minimum and is mainly used for making large wheels.

3. Shellac Bond

It is also called as elastic bond. Shellac is mixed with abrasives in a heated container and is shaped in a heated mould. The shaped wheels are then baked at 150°C for several hours. These wheels are denoted by *E*.

Shellac wheels are comparatively easy to manufacture and are capable of producing high finishes on cam shaft and mill rolls. They are produced at less temperature (120°C–150°C) than vitrified bond. Shellac wheels possess high elasticity and considerable strength. These wheels also possess a high degree of safety and the other applications of these wheels include sharpening of saws, knives and fettling of castings.

Shellac wheels are not suitable for heavy duty applications and wheels of bigger diameter cannot be produced.

4. Resinoid Bond

These are made from synthetic resins (Bakelite) mixed with abrasive grains. The mixture is heated in a mould at about 200°C. At this temperature, resin sets and holds the abrasive grains together. A resinoid bonded wheel is designated as *B*.

Resinoid wheels are more flexible and can run at high speeds (2900 m/min) than vitrified bond wheels. They cut easily and removes the stock quickly. They are used for cutting of metal bars, tubes and for the work which needs a very high surface finish. These wheels becomes soft on prolonged exposure to water or water based cutting fluids.

5. Rubber Bond

These wheels are made from pure rubber and abrasives. The abrasive grains are mixed with pure rubber and sulphur and deformed into sheets. The wheels are cut out of the sheet and then heated in a mould to vulcanize the rubber. A rubber bonded wheel is designated by *R*.

Rubber bonded wheels are strongest of all and are also tough. It is suitable for making extremely thin wheels and for cutting operations. They produce high surface finish and can be used for finishing ball bearing races. These wheels can also be used as regulating wheels in centreless grinding.

Q69. What are the advantages and disadvantages of the different bonds used in grinding wheel?

Answer : Nov./Dec.-16, (R13), Q11(b)

Advantages and Disadvantages of different bonds used in grinding wheel

1. Vitrified Bond

Advantages

1. Provides high strength and porosity to grinding wheel.
2. It do not easily clog and also not affected by water, acid, oils or ordinary metal cutting conditions.
3. High rate of metal removal is possible.

Disadvantages

1. Possibility of thermal distrortion of the vitrified bonded wheels is high.
2. Vitrified bonded wheels cannot tolerate extreme working conditions.
3. Time taken in the production of wheel by this bond is more.
4. Vitrified bonded wheels can be employed upto the speed of 2000 m/min.

2. Silicate bond

Advantages

1. Suitable for production of large wheels
2. Highly efficient wheels can be produced
3. Time taken for wheel production is comparatively low.
4. Free cutting action can be obtained by silicate bonded wheels.

Disadvantages

1. It is less sensitive to shock.
2. It is not as strong as vitrified bond.
3. Wear in the silicate bonded wheels is high.

3. Shellac bond

Advantages

1. Shellac bonded wheels possess high elasticity and considerable strength.
2. These wheels possess high degree of safety.

Disadvantages

1. Shellac wheels are not suitable for heavy duty application
2. Wheels of bigger diameter cannot be produced

4. Resinoid bond

Advantages

1. Resinoid wheels are more flexible and can run at high speeds.
2. Easier cutting and rapid stock removal are obtained by these wheels.
3. Suitable for cutting of metal bars, tubes and for the work which needs a very high surface finish.

Disadvantage

Resinoid wheels become soft on prolonged exposure to water or water based cutting fluids.

5. Rubber bond

Advantages

1. Rubber bonded wheels are strongest of all and are also tough.
2. These produce high surface finish and can be used for finishing ball bearing races.
3. Rubber bonded wheels can also be used as regulating wheels in centreless grinding.

Disadvantage

Heat resistance of rubber bonded wheels is low.

Q70. How is the abrasive selected for a grinding operation? Indicate the reasons for selection.

Answer :

Factors

The various factors to be considered in selection of abrasives for grinding operations are as follows,

1. The amount of stock to be ground and hardness of material.
2. The amount of stock to be ground and surface finish desired.
3. Compulsory requirement of grinding operation in such critical grinding conditions.
4. The speed of the grinding wheel depends on the type of abrasive used.
5. Whether the operation is dry or wet.
6. Surface area in contact with grinding wheel.

Consideration for these six factors are given as follows,

1. Aluminium oxide Al_2O_3 abrasives are used to ground steel, alloy steel and high speed steel (HSS). Silicon carbide (SiC) abrasives are used to grind aluminium, brass and cast iron. Silicon carbide wheels or diamond wheels are used for grinding carbide tools. For grinding softer material, coarser grits and softer grades of abrasives are used. Fine grits and softer graded abrasives are used for grinding hard material.
2. By using a coarse grit abrasives rapid stock removal with ordinary finish is obtained and by using fine grits abrasives low stock removal with high finish is desired.
3. Tough abrasive grinding wheels are used under severe conditions, whereas friable abrasives are used for fine finishing.
4. Wheels under maximum speeds have low strength and tougher or act hard at slower speeds.
5. Wet grinding provides cleaning and cooling of wheel and work and increases the life of the wheel. Coarser abrasive of softer grades are used to ground large area under contact i.e., in internal grinding operation. Fine and harder wheels are used to ground small areas in contact.

Reasons

The reasons for selection of these abrasives are,

(i) **Fracture Resistance**

It is the ability of the abrasive particle to resist cracking or breaking under load.

(ii) **Penetration Hardness**

It is the ability of the abrasive to cut or scratch a softer material.

(iii) **Wear Resistance**

It is the ability of the abrasive grain to retain its sharpness after cutting.

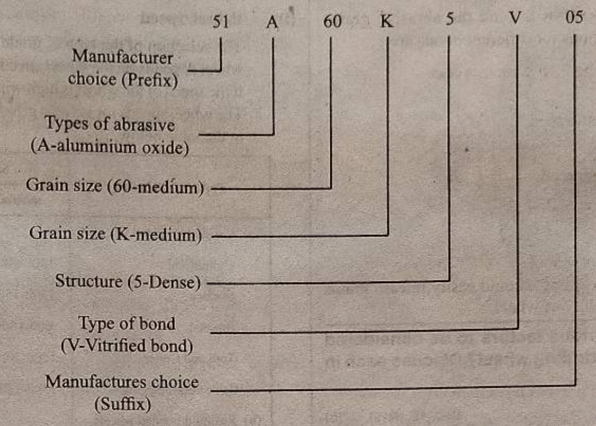
Q71. Explain the specification of grinding wheels.

Answer :

Marking system followed in case of grinding wheel is established by Indian Standards Institute. It provides a uniform system of marking grinding wheel. This system consist of six symbols which represents the following parameters.

1. Abrasive type
2. Grain size
3. Grade
4. Structure
5. Bond type
6. Manufacturer record.

An example of standard marking is given below,



Figure

1. Types of Abrasives

There are two types of abrasives. They are,

(i) Natural abrasive

(ii) Artificial abrasive.

Abrasive have high hardness, high toughness, heat resistance, friability, etc. Artificial abrasive such as Silicon Carbide (SiC), boron carbide, Aluminium Oxide (Al_2O_3), cubic boron nitride are used extensively, because their properties can be easily controlled. Aluminium oxide is the best abrasive for grinding steel, soft bronze and malleable iron. Aluminium oxide is designated by '*A*' and silicon carbide is represented by '*C*'.

2. Grain Size

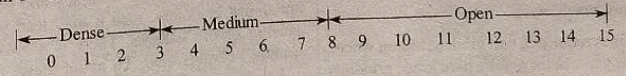
The size of the grain is an important element or factor which influence the functioning of grinding wheel. The rate at which metal is removed and also quality of ground workpiece, depends on grain size of abrasive material. Grain size ranging from 220 to 600 are used for very high surface finish.

3. Grade

It is defined as the capability of the bond to hold the abrasive particles. If a bond easily loses the abrasive particles then it is termed as soft else termed as hard. The words soft and hard specify the hardness of bond but not the hardness of abrasive particles. In all bonds and processes, the grade is specified by uppercase alphabets i.e., A to Z softest grades are represented by A and hardest grades are represented by Z the table shows the categories of grades and their representations.

4. Structure

It represents the spacing between the abrasive grains. The binding material and grains do not occupy whole volume of grinding wheel. There are spaces between grains, which are called as pores. If structure is denser i.e., if more grains are present per unit volume, then the wheel is harder and more durable. Open structured wheels, which contains fewer grains per unit volume, are used for high stock removal and hence increases efficiency of cutting. Structures are denoted by numbers from 0 – 15. The lower numbers indicates a dense structure and higher numbers indicates an open structure.



Figure

5. **Type of Bond**

The function of bond is to bind the abrasive grains together. The notations for different bonds are,

- V – Vitrified
- B – Resinoid
- BF – Resinoid reinforced
- R – Rubber
- RF – Rubber reinforced
- E – Shellac
- S – Silicate
- Mg – Magnesia

The bond must be strong, should easily release grains and increase durability of wheel.

Q72. What are the various factors to be considered in selection of grinding wheel? Discuss each in detail.

Dec.-19, (R16), Q7(b)

OR

Write about cutting action of a grinding wheel and state the factors effecting wheel selection.

Answer : [Model Paper-III, Q7(a) | May/June-12, Set-4, Q2(b)]

Cutting Action of Grinding Wheel

For answer refer Unit-III, Q66.

Factors Affecting the Wheel Selection

1. **Constant Factors**

(i) **Material to be ground**

Based on the material of the component being ground, type of abrasive, grain size, grade, structure and bond are selected.

(a) Materials with high tensile strength are ground with aluminium oxide whereas materials with low tensile strength are ground with silicon carbide.

(b) Soft ductile materials are ground with coarse grains while hard and brittle materials are ground with fine grains.

(ii) **Amount of material to be removed**

Coarse grains are used for rapid stock removal with the moderate finish while fine grains are used for low stock removal with fine finishing.

(iii) **Area of contact**

Coarse and softer wheels are used for a larger area of contact while harder and fine wheels are used for a small area of contact.

(iv) **Type of grinding machine**

The rigid machines requires a soft grade grinding wheel whereas light duty machines require hard grade grinding wheels.

2. **Variable Factors**

(i) **Wheel Speed**

The selection of the type of grade and bond of a grinding wheel depends on the wheel speed. Softer wheels are used if the speed of the wheel is high with respect to work speed. The wheel speeds for various grinding operations is shown in the table below.

Types of Grinding	Surface Speed	
	m/min	ft/min
(a) Vitrified bounded wheels		
Cylindrical	1500-2000	5000-6500
Surface	1200-1500	4000-5000
Internal	600-1800	2000-6000
Tool and Cutter	1500-2000	5000-6500
Centreless snagging	1500-1800	5000-6500
(b) Resinoid bonded wheels		
Snagging	2000-3000	6500-9500

(ii) **Work Speed**

In most of the cases the work speed with respect to wheel speed is used to determine the wheel hardness. In order to work at higher work speeds, the material should be proportionally harder. The approximate surface speeds for grinding various materials are shown in the table below.

Work Material	Surface Speed in m/min	
	Roughing Cut	Finishing Cut
Cast iron	60	120
Aluminium	30	60
Soft steel	9	15
Hard steel	20	30

(iii) **The condition of the machine**

The working condition of a grinding machine will have an influence on the grade of grinding wheel to be used on that particular machine. If the machine has a loose spindle and unstable foundations harder grinding wheels must be used and in case of a proper working condition of the machine softer grinding wheels are used.

Q73. Write short notes on balancing of grinding wheels.

Answer :

Balancing of Grinding Wheel

Grinding wheels rotate at very high speeds and if not balanced properly, may cause vibrations, which results in waviness errors, low accuracy and poor surface finish. If imbalance is excess, then it may lead to wheel breakdown causing severe hazards. There is a possibility of damaging spindle bearings also. To avoid these, there are two ways of balancing a grinding wheel, they are static balancing and dynamic balancing.

1. **Static Balancing**

In this method, wheel is removed from the machine and balancing is performed on it, with the help of an arbor. Following are the steps for static balancing.

(i) Balancing weights are withdrawn and wheel is placed on a balancing stand.

(ii) Then, the wheel is rotated, so that it comes to rest with its heavier part at the botton.

(iii) Mark the heavier part and insert weights at equal distances from the mark and above the horizontal.

(iv) Rotate the wheel again and if the wheel stops at the same marked point, then displace the weights closer.

(v) If the wheel stops rotating at a point opposite to the marked point, then weights are displaced apart.

(vi) Following the above procedure, wheel can be balanced, such that it does not stop at the same point.

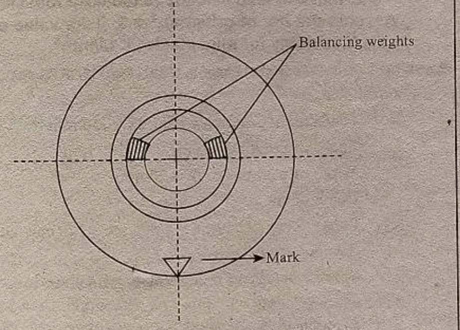


Figure (1): Static Balancing

2. **Dynamic Balancing**

In modern grinding machines, balancing devices are employed, which enables dynamic balancing of wheels. In this, balancing operation can be performed, while the wheel is in motion on the grinder. Higher accuracies can be achieved, by using this method.

Mounting of Grinding Wheel

It is an important criteria in grinding process. It should be carried out carefully as the wheel rotates at high speeds. Improper mounting of the wheel may lead to severe accidents. Two flanges are mounted on either sides of grinding wheel. The outer flange is keyed to the spindle, whereas inner flange is loosely fitted. The flanges and the grinding wheel are tightened by a nut, as shown in figure (2).

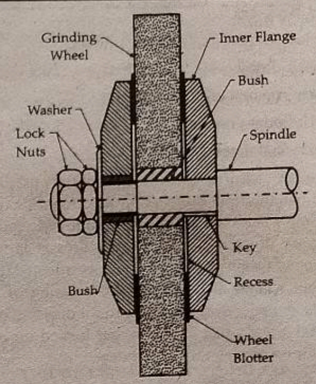


Figure (2): Mounting of Grinding Wheel

Points to be Considered During Mounting

1. Ensure that the wheel is balanced, before mounting.
2. Inspect the wheel flatness on its either sides.
3. The grinding wheel should be fitted easily on the spindle, without applying much force.
4. The lead bush should not be projected beyond the wheel face.
5. The size of flanges on either sides of wheel must be equal.
6. The wheel diameter should be atleast twice the diameter of flange.
7. The flanges must be rigidly keyed.
8. Flanges should have sufficient clearance on either sides of grinding wheel.
9. Thick compressive washers should be used in between the wheel and the flanges.
10. The nut should be tightened firmly, to hold the wheel.
11. After mounting, the wheel should be run idle for sometime.
12. The working speed should be properly selected.
13. Lubrication should be done periodically to ensure maximum safety.

Q74. Describe the dressing in grinding.

OR

What are common devices used for dressing of grinding wheels? Describe in brief.

Answer : Nov./Dec.-16, (R13), Q11(a)

Dressing of Grinding Wheels

It is the process of removing a thin layer of grinding surface, on which foreign materials are clogged between the grains. The process is carried out using different types of dressers, as follows.

1. Wheel dressers
2. Abrasive wheels dressers
3. Abrasive sticks
4. Diamond
5. Crush dressing fixtures.

1. **Wheel Dressers**

These are further classified as follows.

(i) Star dresser

(ii) Corrugated disc type dresser

(iii) Cylinder dresser

(iv) Locked dresser.

Among all, star dresser in most commonly used dresser, which has multiple dressers on its circumference. The grinding wheel is rotated and is moved against the stationary dresser. Generally, star dresser is used for dressing of rough grinding wheels, corrugated disc type dressing wheels are used for the dressing of smooth wheels, cylinder dressers are used for dressing of brittle material wheels like cast iron and locked dressers are used for rough cylindrical grinders.

2. **Abrasive Wheel Dressers**

Dressing of grinding wheel using these dressers can be done by both hand and machine. The silicon carbide grains present in the wheel acts as the dressing tools. These are mostly used for dressing of grinding wheels which are used for grinding of pistons and where degree of finish is high.

3. **Abrasive Sticks**

These are used for dressing of thin grinding wheels, and also for pre-dressing operation before dressing of wheels with costly tools like diamond.

4. **Diamond**

For dressing of wheels with diamond, a tool holder is used to hold the diamond tool, the tool holder makes an angle of 12° to 16° with the horizontal axis of grinding wheel, while dressing. Coolant is supplied during this process to avoid fracture or drop out of diamond.

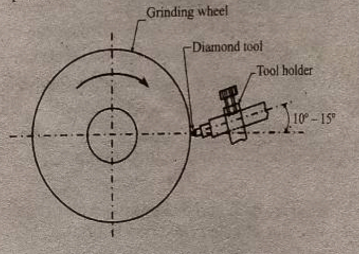


Figure: Dressing Grinding Wheels

Wheel Truing

In this process, the cutting face of the grinding wheel is restored by the removal of the abrasive material from the cutting face and sides of the wheel. This operation is performed to make the periphery of the wheel concentric with its axis. The sides of wheel are made true and for recovering the lost shape of its sides.

Truing and dressing operations are performed with the same tools, but for different purposes. The method of truing a grinding wheel uses diamond tool and produces many grains with flat surfaces.

Q75. How the grinding wheel is selected for a particular job?

Nov./Dec.-16, (R13), Q10(a)

Answer :

For answer refer Unit-III, Q72, Topic: Factors affecting the wheel selection.

Q76. Which materials are used in the manufacture of grinding wheels? What properties they impart to the wheel?

Nov./Dec.-16, (R13), Q10(b)

Answer :

For answer refer Unit-III, Q67 and Q68.

Q77. Enumerate different types of abrasives used and How do you specify a grinding wheel?

May/June-19, (R16), Q7(a)

Answer :

Types of Abrasives

For answer refer Unit-III, Q67.

Specification of Grinding Wheel

For answer refer Unit-III, Q71.

Q78. Calculate the grinding force in surface grinding operation using grinding wheel of 250 mm diameter, rotating at 2500 rpm. The work piece is of mild steel having width of 20 mm. depth of cut = 0.05 mm and feed velocity of table = 2 mm/sec. Assume the no. of grits/mm² = 3. Take value of specific energy for mild steel = 1.4J/mm³.

[Model Paper-II, Q6(b) | Dec.-19, (R16), Q6(b)]

Answer :

Given that,

Diameter of grinding wheel, $D = 250$ mm

Speed of grinding wheel, $N = 2500$ rpm

Width of workpiece, $W = 20$ mm

Depth of cut, $d = 0.05$ mm

Feed velocity of table, $v = 2$ mm/sec = 120 mm/min

Number of grits/mm², $\rho = 3$

Specific energy of mild steel, $u = 1.4$ J/mm³

For surface grinding,

Material removal rate is given by,

$$MRR = W \times v \times d$$

$$= 20 \times 120 \times 0.05$$

$$= 120 \text{ mm}^3/\text{min}$$

$$= 2 \text{ mm}^3/\text{sec}$$

Peripheral velocity of grinding wheel is given as,

$$V = \frac{\pi DN}{1000}$$

$$= \frac{\pi \times 250 \times 2500}{1000}$$

$$= 1963.495 \text{ m/min}$$

Total grinding force is given by,

$$F_{grinding} = u \times \frac{MRR}{V}$$

$$= 1.4 \times \frac{120}{1963.495}$$

$$\therefore \; F_{grinding} = 0.085 \text{ N}$$

3.3 LAPPING, HONING AND BROACHING MACHINES – COMPARISON AND CONSTRUCTIONAL FEATURES – MACHINING TIME CALCULATIONS

3.3.1 Lapping

Q79. What is lapping? Write in detail any three types of lapping techniques.

[Model Paper-I, Q7(b) | Nov./Dec.-12, (R09), Q7(b) | Nov.-10, Set-4, Q2(a)]

Answer :

Lapping is a finishing process used to improve the surface finish and dimensional accuracy or to obtain a perfect contact between two mating surfaces. It is a process of removing surface roughness tool marks, surface cracks from grinding, slight distortions and other minor defects from previous operations. This process is extensively used for the finishing of gauge blocks and flats. In this process, a layer of fine abrasive particles suspended in liquid is held between the work and lap. Commonly used abrasives are iron oxide, corundum, emery, chromium oxide, etc.

Lapping is mostly done by means of lapping quills or shoes called laps which are rubbed against the work with some pressure. The laps may be made of any material, soft enough to receive and retain abrasive grains. Thus, the lap is charged with abrasives. The common materials for laps are soft cast iron, brass, copper, lead or soft steel. Graphite in cast iron serves to hold the abrasive particles and provide lubricating effect.

These abrasive grains are responsible for the cutting action. The metal is cut similar to the grinding operation when relative motion is provided between the workpiece and the lap. All these grains are not of same size, thus not all the grains are embedded or charged into the lap and these not embedded or loose grains roll and slide between the workpiece and the lap and removes some material. But, the embedded grains are responsible for large amount of material removal, and the workpiece after lapping conforms to the shape of the lap.

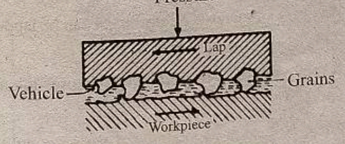


Figure: Lapping Process

Lapping can be performed manually by hand or by specially designed machines.

The three important types of lapping techniques are,

1. Hand lapping for flat work
2. Hand lapping for external cylindrical work or ring lapping
3. Machine lapping

1. **Hand Lapping for Flat Work**

For answer refer Unit-III, Q80, Topic: Hand Lapping

2. **Hand Lapping for External Cylindrical Work (Ring Lapping)**

For answer refer Unit-III, Q81.

3. **Machine Lapping**

For answer refer Unit-III, Q80, Topic: Machine Lapping

Q80. List out various lapping methods. Briefly explain them.

Answer :

The various lapping methods are,

1. Hand lapping
2. Machine lapping.

1. **Hand Lapping**

In this lapping method, either the workpiece or the lap is held by hand and the other one is rotated irregularly with the second hand. Due to this motion of the workpiece or lap, the abrading action takes place between the two surfaces in contact. Here, the lap is also flat similar to the surface plate, and some grooves are cut on its surface to collect the excessive abrasives and chips.

This method is most commonly used for lapping press work dies, dies and metal moulds used for casting, limit gauges, surface plates, valve seats, engine valves, gauge blocks, piston rings, etc.

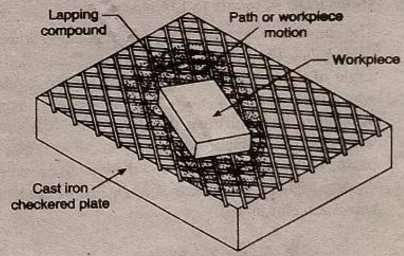


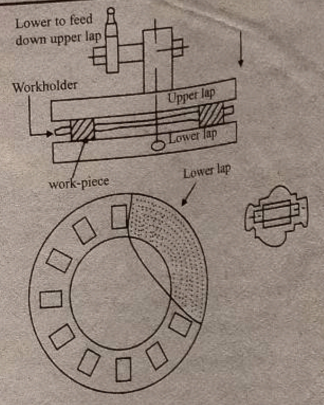
Figure : Hand Lapping

2. **Machine Lapping**

This method of lapping used for obtaining highly finished surfaces on races and ball bearings, crank shafts, spray nozzle, injector pump, etc. Some of the common lapping machines are,

(i) **Vertical Spindle Lapping Machine**

This machine consists of two laps mounted on two vertical spindles such that the laps surfaces are opposing each other. The job/work is placed in between two opposed laps and finishing operation is performed. The pressure is applied by gravity on upper lap. This machine is used for lapping both flat and round surfaces.

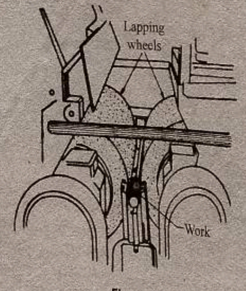


Figure

(ii) Centreless Lapping Machine

This machine construction is similar to centre less grinding machine, and the only difference is that, in centre less lapping machine, the abrasive lapping wheel and regulating wheels are much wider than the grinding wheels. Due to which the workpiece remain in abrading contact for longer time and receive finer finish. The lapping wheel speed varies from 175 m/min to 650 m /min depending upon the degree of surface finish and rate of production. The speed of regulating wheel varies from 70 m/min to 175 m/min.

The spindles of lapping wheel and regulating wheel are not parallel. The axis of lapping spindle is swivelled to an angle of about 4° in vertical direction, and the regulating wheel is about an angle of 1° – 3° in opposite direction. When the wheels are trued, they form an hourglass shape, which causes a wraparound effect on the workpice as it passes between the wheels, and the wheels are come in contact with the workpiece at angle. Thus, the lapping marks are eliminated.



Figure

This machine is used for lapping piston pins, shafts and bearing races.

3. Abrasive Belt Lapping Machine

In this machine, a high speed continuous moving belt with abrasive is used for lapping operation. These machines are used for lapping crank shaft and pins, etc.

Q81. Explain in details how hand lapping is carried out for external cylindrical work.

Answer :

Hand Lapping for External Cylindrical Work

In this method of lapping, the cylindrical work to be lapped is held in a lathe chuck. A lapping ring or external lap is split by a saw cut and can be closed and tightened by one or more screwes. The internal surface of the lap is provided with grooves which can be charged with abrasive particles such as aluminium oxide, silicon carbides, etc. The size of the lap diameter is slightly shorter than the work. The lapping tool or ring lap is held with hand and is made to reciprocate over the surface of workpiece. The abrasive and vehicle are fed through the slot, due to the rubbing action of abrasives, the metal is removed from the cylindrical workpiece.

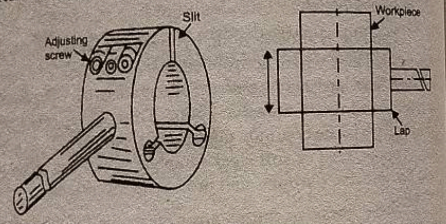


Figure: Hand Lapping

Q82. Write the advantages, disadvantages and applications of lapping.

Answer :

Advantages

(i) It can produce very close tolerances and extremely high surface finish, greater uniformity and optical flatness.

(ii) Any type of material of any shape can be lapped, if it is flat.

(iii) It removes errors in gears which causes the noise and undue wear.

(iv) Since no heat is generated and parts are not clamped, there is no warping effect.

(v) It removes burrs left in previous process, and no burrs are produced.

Disadvantages

(i) Flatness, surface finish and polished surface are not obtained all at the same time and in equal quantities.

(ii) Amount of material removed is limited.

(iii) Cost of lapping operation is very high.

Applications

Applications of lapping is found in,

(i) Machine bearings such as ball and roller bearings.

(ii) Bushes of jigs and fixtures

(iii) Tappet valves and valve seats

(iv) Diesel engine injectors

(v) Oil burner parts

(vi) Surface plates

(vii) Holes and pins

(viii) Measuring instruments like slip gauges, plug gauges, etc.

Q83. What characteristics of the work piece are improved by lapping process?

Answer : May/June-12, Set-1, Q6(b)

The characteristics of workpiece which are improved by lapping process are,

1. Geometrical accuracy is improved.
2. High dimensional accuracy is obtained.
3. The job possess a refined surface finish.
4. There is a closed fitting between the mating parts.
5. The minor surface imperfections in shape are corrected.
6. The workpiece does not possess distorted parts, due to no heat generation and no clamping.
7. Any burrs present on the workpiece are removed by this operation.

Q84. List out the lapping parameters and explain them.

Answer :

Lapping Parameters

The lapping parameters are,

(i) Grain size

(ii) Lapping speed

(iii) Lapping pressure

(iv) Lapping allowance.

Surface finish achieved in a lapping process is tabualted below,

Abrasive Used	Grain Size	Surface Finish, mm
SiC	220, 320, 400, 500 600, 800	0.75 - 1.00, 0.64 - 0.75, 0.46 - 0.64, 0.38 - 0.46, 0.25 - 0.38, 0.13 - 0.25
Al_2O_3	400, 800, 900	0.08 - 0.13, 0.05 - 0.08, 0.03 - 0.08

The material removed depends upon the lapping speed. Higher lapping speeds are required for higher lapping allowance. The lapping pressure is low for soft materials and it is around 0.01 to 0.03 MPa and for hard materials it is around 0.7 MPa. The lapping allowance depends upon the previous operation caused and the material hardness.

Q85. List the product applications of lapping process.

Answer : Nov.-15, (R13), Q8(b)

For answer refer Unit-III, Q82, Topic: Applications.

3.3.2 Honing

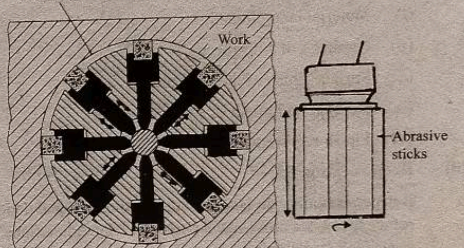
Q86. Explain clearly a honing tool with neat sketch.

OR

Describe in detail about honing tools.

Answer : Nov./Dec.-16, (R13), Q8(a)

Honing tool is an expanding mandrel on which abrasive sticks are mounted. The tool rotates and reciprocates simultaneously inside the stationary hole being honed and removes the metal.



The common abrasives used for honing are silicon carbide, aluminium oxide (Al_2O_3), diamond or CBN, etc.

1. **Silicon Carbide**

   Used for honing cast iron and non ferrous metals.

2. **Aluminium oxide**

   Used for honing steels.

3. **Diamond**

   Used for honing ceramics or hard carbides.

Q87. How honing is done? How does it differ from lapping? Discuss.

Answer :

Honing

Honing is a process of removing metal from a workpiece by means of a rotating tool called hone which reciprocates inside the workpiece. It is generally a wet process and is called a finishing process which is used for finishing internal cylindrical surface. It is used to correct irregularities and to develop a particular texture. It is performed at slow speed which reduces the heat and pressure resulting in excellent size and metallurgical control of the workpiece. It is used for the purpose of limited stock removal and attainment of surface finish. It can correct some out of roughness, taper and axial distortion. It can be used for hard surfaces and the surface finish obtained will be 0.05 mm. This process cannot be used for perpendicularity or hole location.

Difference between Lapping and Honing

	Lapping		Honing
1.	Used to improve surface finish.	1.	Used to finish internal cylindrical surface.
2.	It removes only thin layers of 0.005 to 0.01 mm.	2.	It removes layers upto 0.0025 mm.
3.	Requires skilled and experienced labour.	3.	Does not required skilled labour.
4.	Any material of any shape can be lapped.	4.	It is used for internal cylindrical surfaces only.
5.	It is costly.	5.	It requires less cost.

Q88. List out honing parameters and explain them.

[May/June-12, Set-2, Q1(a) | Nov.-10, Set-3, Q3(a)]

Answer :

The various honing parameters are as follows.

(i) Spindle Speed

It mainly depends upon the diameter of the bore to be honed. The following factors govern the spindle speed,

(i) Material being honed

(ii) Hardness of workpiece

(iii) Surface finish of the workpiece.

(iv) Number and width of stones in a tool.

(v) Finish requirements after honing process

(ii) Reciprocating Speed

It depends mainly on length of the honing tool and depth of the bore and is expressed in m/min. The reciprocating speed, rotary speed and cross-hatch angle are related functions. Hence, by keeping rotation constant, the cross hatch angle can be controlled by varying reciprocating speed. The finish requirements of the job is significantly influenced by reciprocating speed. It the reciprocating speed is high, the dressing action of honing tool is much higher, which result in a rough finish on the job.

(iii) Cross-hatch Angle

This angle obtained on a honed surface, depends upon the ratio of reciprocating speed to the speed of rotation.

The below formula is used for calculating the cross hatch angle.

$$\tan \alpha = \frac{\text{Reciprocating speed (m/min)}}{\text{Rotary speed (m/min)}}$$

Cross-hatch angle = 2α

If, Reciprocating speed = Rotating speed, $2\alpha = 90°$

If, Reciprocating speed < Rotating speed, $2\alpha < 90°$

(iv) Honing Pressure

Honing process uses a wide range of pressures depending upon the finish requirements to obtain higher material removal rates and better performance. Honing is mostly depends on the rate of feed out than by gauge pressure. If the pressure is insufficient, it results in lower rates of metal removal. Whereas, the excessive pressure leads to a very frequent break down of abrasives, which results in rough surface finish. Thus, the tooling cost and machine down time increases for frequent interchange of the stones.

Q89. With the help of a neat diagram, explain the honing process.

Nov.-15, (R13), Q9(a)

Answer :

For answer refer Unit-III, Q87, Topic: Honing and Q86.

Q90. Explain the difference between lapping and grinding.

Nov./Dec.-16, (R13), Q9(b)

Answer :

For answer refer Unit-III, Q98, Topics : Lapping and Grinding.

3.3.3 Broaching

Q91. Give the complete classifications of broaching machines.

Answer :

[Model Paper-II, Q7(b) | Nov./Dec.-12, (R09), Q7(a) | May/June-12, Set-2, Q1(b) | Nov.-10, Set-3, Q3(b)]

Broaching machines are classified into different types as follows.

1. Horizontal broaching machines (Pull or Push type broaching machines)
   - (i) Based on the type of drive used.
     - (a) Mechanically operated broaching machine.
     - (b) Hydraulically operated broaching machine.
     - (c) Electrochemically operated machine using rack and pinion drive.
   - (ii) Based on the type of operation
     - (a) Surface broaching machine
     - (b) Internal broaching machine
2. Vertical machines (Pull-up, Pull-down, or push -down type broaching machines)
   - (i) Based on the type of operation
     - (a) Surface broaching machine.
     - (b) Internal broaching machine.
   - (ii) Based on the type of drive used (Operate on hydraulic system).
3. Special design broaching machines
   - (i) Rotary table continuous machine.
   - (ii) Horizontal continuous machine.

Q92. Discuss the continuous type of broaching machine.

May/June-12, Set-4, Q5(b)

Answer :

Continuous broaching machines are highly productive machines and are used for mass production. The process used in these machines is continuous broaching method. Generally, in this method, the tool is fixed at desired position and workpiece makes the contact with the tool. These broaching machines are of two types. They are,

1. Horizontal continuous broaching machine
2. Rotary table continuous machine.

1. Horizontal Continuous Broaching Machine

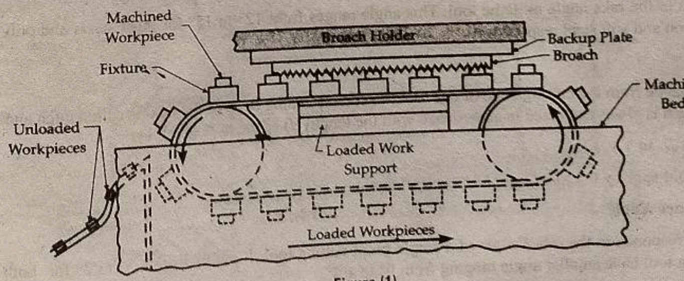


Figure (1)

In these machines, the workpieces are placed on fixtures, which are carried away by continuous chain, which is mounted on two rotating sprockets. The workpieces are loaded from one side of the machine and are unloaded from the otherside of the machine. The broach is held in horizontal position and the arrangement is in such a way, that the projection of teeth is opposite to the direction of the workpieces.

2. **Rotary Table Continuous Machine**

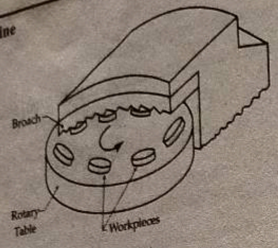


Figure (2)

In this type of machines, the workpieces are fixed on the rotary table, by means of a magnetic holder. The rotary table rotates continuously about vertical axis, and workpieces are broached by the broach.

Q93. Write factors which contribute to increased production rates of broaching.

May/June-12, Set-4, Q5(a)

Answer :

The factors which increases the production rates in broaching process are,

1. Different machining operations such as roughing, finishing, etc., can be accomplished in a single pass of tool.
2. The broaching operation is faster than any other machining operations with better surface finish.
3. Interchangeability of components is carried out at a faster rate.
4. The cutting forces provides the clamping of the component and holds it firmly, hence reducing the production time.
5. A broach tool tends to draw the cutting fluid (coolant) into the cut, thus the fluid can be easily applied, wherever required.
6. Higher tolerance limit of about ± 0.0001 mm (or 1 micron) can be obtained.
7. Due to longer life of cutting tool, the time required for frequent changing of tool is saved and hence increases the productivity.

Q94. How is a broaching tool specified?

Nov.-10, Set-2, Q1(b)

Answer :

The broach tool specifications are,

1. **Land**

   The top portion of the tool is called land and in most cases ground to have slight clearance.

   An average land of 0.005" on throughing teeth and 0.01" to 0.03" gradually increasing through finishers.

2. **Rake/Face Angle**

   It corresponds to the rake angle on lathe tool. This angle ranges from 12° to 15° for most steels and only 6° and 20° in case of cast iron and soft steel respectively.

3. **Pitch**

   The linear distance from the cutting edge of one tooth to corresponding edge of the next is called pitch and is represented by 'p'. The pitch is always selected in accordance with the length (l) of the hole given by,

   $(p = 1.25\sqrt{l}$ to $1.5\sqrt{l})$

   The pitch should vary by 0.2 to 0.3 mm after several teeth.

4. **Relief/Clearance Angle**

   This angle corresponds to the relief angle of a single point cutting tool. It varies from 1.5° to 2° for both cast iron and steel. Finishing tool have smaller angle ranging from 0° to 1.5°.

5. Rise per tooth is of the order of 0.025 to 0.16 mm
6. The cut per tooth ranges from 0.15 mm to 0.01 mm
7. Cutting speed varies from 0.1 to 0.4 m/sec

Q95. How push broaches differ from pull broach?

Answer :

Push Broach	Pull Broach
1. Push broach is pushed through work, during broaching operation.	1. Pull broach is pulled through work, during broaching operation.
2. This broach bends under compressive load, during cutting operation.	2. This broach does not bend, during cutting operation.
3. It has less number of teeth.	3. It has more number of teeth.
4. This broach is shorter in size.	4. This broach is longer in size.
5. It is used for short length workpieces.	5. It is used for long length workpieces.
6. It is designed to remove less amount of material in one stroke.	6. It is designed to remove more amount of material in one stroke.

Q96. Write the expression for cutting speed in broaching operation.

Answer :

In broaching operation, the cutting speed depends upon the material of workpiece, tool life, production rate and surface finish required. The broaching speed varies from 2 m/min to 15m/min. The cutting speed is given by the below equation,

$$V_c = \frac{Ck_1}{T^x s^y} \text{ m/min}$$

Where,

C – Coefficient depends on the processing conditions ($C = 12$)

T – Life of broach

s – Depth of cut/tooth, mm

x, y – Two exponents of value 0.62

k_1 – Constant depends on broach material ($C = 1$ to 1.45)

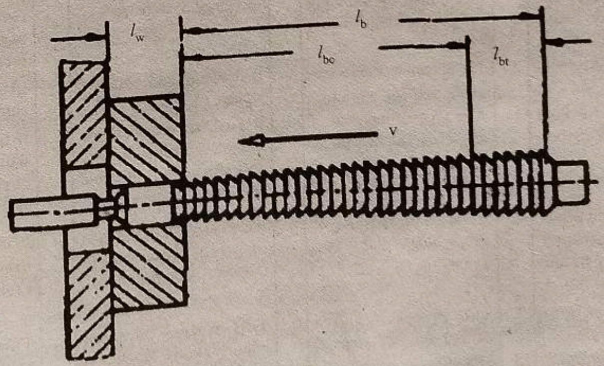
For steel castings and forgings, $V_c = 6 - 10$ m/min

For cast iron, brass and aluminium, $V_c = 12$ m/min

Q97. Explain how the length and machining timing of a broach are determined.

May/June-13, (R09), Q7(b)

Answer :



Figure

2. **Rotary Table Continuous Machine**

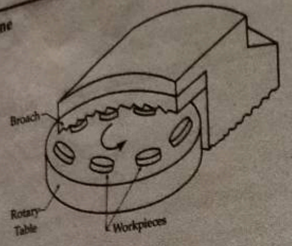


Figure (2)

In this type of machines, the workpieces are fixed on the rotary table, by means of a magnetic holder. The rotary table rotates continuously about vertical axis, and workpieces are broached by the broach.

Q93. Write factors which contribute to increased production rates of broaching. May/June-12, Set-4, Q5(a)

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3. Interchangeability of components is carried out at a faster rate.
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5. A broach tool tends to draw the cutting fluid (coolant) into the cut, thus the fluid can be easily applied, wherever required.
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7. Due to longer life of cutting tool, the time required for frequent changing of tool is saved and hence increases the productivity.

Q94. How is a broaching tool specified? Nov.-10, Set-2, Q1(b)

Answer :

The broach tool specifications are,

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   The top portion of the tool is called land and in most cases ground to have slight clearance.

   An average land of 0.005" on throughing teeth and 0.01" to 0.03" gradually increasing through finishers.

2. **Rake/Face Angle**

   It corresponds to the rake angle on lathe tool. This angle ranges from 12° to 15° for most steels and only 6° and 20° in case of cast iron and soft steel respectively.

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Q95. ...

Answer ...

				Pull Broach
1.	Push broa... broaching o...			Pull broach is pulled through w... broaching operation.
2.	This broach be... ...ssive load, during cutting operation.	2.		This broach does not bend, d... operation.
3.	It has less number of teeth.	3.		It has more number of teeth.
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Where,

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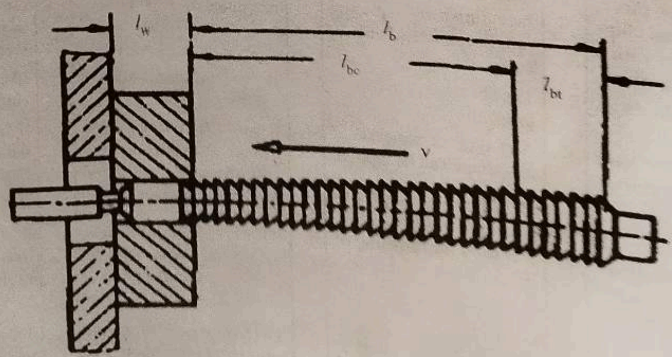
k_1 – Constant depends on broach material ($C = 1$ to 1.45)

For steel castings and forgings, $V_c = 6 - 10$ m/min

For cast iron, brass and aluminium, $V_c = 12$ m/min

Q97. Explain how the length and machining timing of a broach are determined. May/June-13, (R09), Q7(b)

Answer :



Figure

As shown in figure,

l_w – Length of the workpiece surface in mm

l_b – Length of broach in mm

l_a – Length of approach (10 – 20 mm)

l_o – Length of overrun (10 – 20 mm)

l_{bc} – Cutting length of broach

l_{fb} – Finishing length of broach

The length of broach travel is given by,

$L_m = (l_w + l_b + l_a + l_o)$ mm

$\therefore$ Length of broach, $l_b = l_{bc} + l_{fb} = Z_c P_{cb} + Z_f P_{fb}$

Where,

Z_c and Z_f – Number of cutting and finishing teeth

P_{cb} and P_{fb} – Pitch of cutting and finishing teeth

Machining Time

The machining time depends on effective length of broach and it is expressed as,

$$\text{Machining time, } T_m = \frac{\text{Effective length of broach}}{\text{Cutting speed}}$$

$$= \left(\frac{l_w + l_b}{V_C}\right)$$

Where,

l_w – Workpiece length

l_b – Broach length.

V_c – Cutting speed of broach

Q98. Give a comparison of grinding machine with lapping, honing and broaching machines.

[Model Paper-III, Q7(b) | Nov.-10, Set-1, Q6]

Answer :

The comparison of grinding with respect to lapping, honing and broaching machines,

	Grinding		Lapping		Honing		Broaching
1.	It is a process of removing metal from a work-piece, in the form of small chips by abrasive action with a revolving grinding wheel.	1.	It is an abrading process, used to improve the surface finish by reducing roughness irregularities, etc.	1.	It is an abrading process used for finishing previously machined of surfaces.	1.	It is the metal removing process, in which metal is removed by push or pull of the cutting tool called broach.
2.	It employs, abrasives in bonded form.	2.	The abrasives used are in loose form.	2.	It uses bonded abrasive stones.	2.	Broaching tool is used for cutting the metal.
3.	Generally, used for hard metals like high carbon steels.	3.	Any type of material of any shape can be lapped.	3.	It is used for plastic, silver, brass, aluminium, and cast iron to hard steel and cemented carbides.	3.	It is applied on surfaces which do not have any obstruction.
4.	It is generally used where a high degree of accuracy is required i.e., of the order of 0.3 to 0.5 μm.	4.	It is used for finishing of gauge blocks and flats.	4.	It is used for the correction of irregularities and to develop particular texture.	4.	It is used on straight or irregular surfaces either externally or internally.
5.	This process requires highly skilled operator.	5.	This process requires skilled and experienced labour.	5.	This process does not require skilled labour.	5.	This process requires moderate skilled operator.

IMPORTANT QUESTIONS

Q1. Write a short notes on the following,

(a) Omniversal milling machine

(b) Rise and fall type milling machine

(c) Tracer controlled milling machine. [redacted]

Q2. Sketch and describe a vertical milling machine. Refer Unit-III, Q38

Q3. Sketch and explain the working of plain column and knee type milling machine. [redacted]

Q4. Distinguish between horizontal, vertical and universal milling machines on some salient features. [redacted]

Q5. Explain in detail various operations performed on milling machine. [redacted]

Q6. What is the principle of working of milling machines? How do you classify the milling machine? [redacted]

Q7. With the help of neat sketch explain the different elements in a plain milling cutter? [redacted]

Q8. Draw sketches of any five types of milling cutters and explain them briefly. [redacted]

Q9. Explain the general considerations in selection of milling cutters. How do you calculate the number of teeth on milling cutters? [redacted]

Q10. What is indexing? Explain some common methods of indexing in milling machines. [redacted]

Q11. Explain the procedure for simple indexing with an example. [redacted]

Q12. Explain the methods of indexing applicable in milling machine and its limitations. [redacted]

Q13. Why is grinding so important in modern production? Explain. [redacted]

Q14. What are surface grinding machines, explain various surface grinding machines. [redacted]

Q15. Sketch and explain three methods of cylindrical grinding. [redacted]

Q16. Explain in detail the construction and working of cylindrical grinding machine with a neat sketch? [redacted]

Q17. Explain with neat sketch,

(i) Centreless grinding

(ii) Internal grinding. [redacted]

Q18. State the advantages and limitations of centreless grinding? [redacted]

Q19. What is meant by centerless grinding? State its advantages and limitations of it. [redacted]

Q20. Sketch and explain the three methods of external cylindrical centre less grinding. [redacted]

Q21. Differentiate between traverse and plunge grinding. [redacted]

Q22. Describe grinding wheel structure with a neat sketch. [redacted]

Q23. What are the types of abrasives? Explain any one of it. [redacted]

Q24. Explain in detail any five types of bonds of abrasive grains. [redacted]

Q25. What are the advantages and disadvantages of the different bonds used in grinding wheel? [redacted]

Q26. What are the various factors to be considered in selection of grinding wheel? Discuss each in detail. [redacted]

Q27. Describe the dressing in grinding. Refer Unit-III, Q74

Q28. How the grinding wheel is selected for a particular job? Refer Unit-III, Q75

Q29. Enumerate different types of abrasives used and How do you specify a grinding wheel? Refer Unit-III, Q77

Q30. Calculate the grinding force in surface grinding operation using grinding wheel of 250 mm diameter, rotating at 2500 rpm. The work piece is of mild steel having width of 20 mm. depth of cut = 0.05 mm and feed velocity of table = 2 mm/sec. Assume the no. of grits/mm^2 = 3. Take value of specific energy for mild steel = 1.4J/mm^3. Refer Unit-III, Q78

Q31. What is lapping? Write in detail any three types of lapping techniques. Refer Unit-III, Q79

Q32. What characteristics of the work piece are improved by lapping process? Refer Unit-III, Q83

Q33. List the product applications of lapping process. Refer Unit-III, Q85

Q34. Explain clearly a honing tool with neat sketch. Refer Unit-III, Q86

Q35. List out honing parameters and explain them. Refer Unit-III, Q88

Q36. With the help of a neat diagram, explain the honing process. Refer Unit-III, Q89

Q37. Give the complete classifications of broaching machines. Refer Unit-III, Q91

Q38. Discuss the continuous type of broaching machine. Refer Unit-III, Q92

Q39. Write factors which contribute to increased production rates of broaching. Refer Unit-III, Q93

Q40. Explain how the length and machining timing of a broach are determined. Refer Unit-III, Q97

Q41. Give a comparison of grinding machine with lapping, honing and broaching machines. Refer Unit-III, Q98

UNIT 4

LIMITS, FITS, TOLERANCES AND MEASUREMENT OF FLATNESS

Syllabus

Limits, fits and tolerances – Types of Fits, Unilateral and Bilateral tolerance system, Hole and Shaft basis system. Interchangeability and Selective assembly.

Limit Gauges : Taylor's principle, Design of GO and NO GO gauges, Measurement of angles using Bevel protractor and Sine bar. Measurement of flatness using Straight edges, Surface plates, Optical flat and Auto collimator.

LEARNING OBJECTIVES

On the completion of this unit, the student shall be able to understand the following concepts,

- Types of fits
- Unilateral and bilateral system
- Hole and Shaft basis system
- Interchangeability and selective assembly
- Design of GO and NO-GO gauges
- Measurement of angles by Sine bar and Bevel protractor
- Flatness measurement by straight edges and surface plate
- Optical flat and Autocollimator

INTRODUCTION

The word 'Metrology' is derived from Greek words, Metro (measurement) and Logy (science). Hence, it is defined as science of measurement, which deals with determining the unknown quantities by comparing it with the predetermined standards or by using various measuring instruments. The quantities that are measured may be mechanical, electrical, chemical, optical, physical etc.

In practice, it is impossible to manufacture a component to exact size repeatedly. Therefore, it is logical to consider the variations in the dimensions of the part as being acceptable, if its size is known to lie between a maximum and minimum limit. This difference between the size limits is called tolerance.

GO gauge and NO GO gauge, which inspect the upper and lower limits of the workpiece. Based on the form of surface to be tested, limit gauges are classified as, Plug gauge, Snap gauge, Ring gauge.

Angular measurement involves in measuring the inclination between surfaces. Precise angular measuring instruments help in navigation of ships and aeroplanes, also for determining the approximate distance between stars and planets. The instruments that measure angles include sine bar, angle gauges, autocollimator, clinometers, etc. Selection of instrument depends upon the type of component and accuracy required.

Flatness can be measured by using straight edges, surface plates, optical flat and autocollimator. Based on the type of surface and degree of accuracy required, the instrument is selected for measurement.

PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. Define the term metrology as applied to engineering industry.

Answer :

Metrology is derived from a Greek word, which means "the science of measurements". It deals with the measurement of length, angles and other quantities, that can be expressed in linear and angular terms. It is concerned with the methods and estimation of accuracy of measurements.

Metrology plays a vital role in the field of engineering for designing and manufacturing of various engineering products. It is used for measuring the size, shape, etc. The products obtained should be with in the limits of the specification with dimensional accuracy. In order to improve the process of manufacturing, it is required to develop the means of measurement, which gives the correct meaning to the quantity measured.

Q2. State the uses of metrology.

Answer :

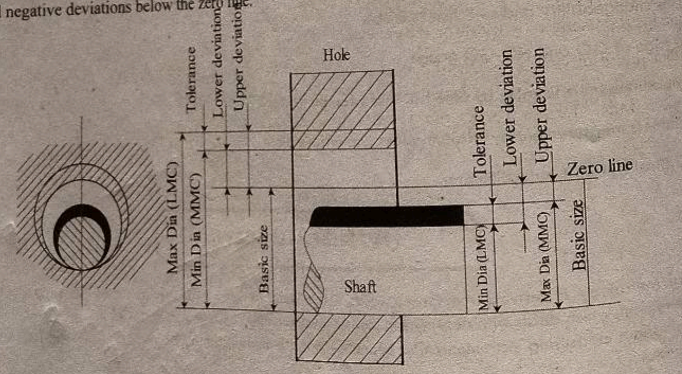
Uses of Metrology

1. It is a basis for length and angle measurement.
2. It is used in manufacturing, inspection processes and error measurement.
3. It forms a basis for units of measurements and its standards.
4. It is employed in various fields such as medical, industrial, agricultural, environmental, etc.

Q3. Define the term zero line.

Answer :

Zero line (datum line) is defined as the horizontal straight line, drawn for representing the basic size. The deviations in the graphical representation of limits and fits are shown with respect to the zero line. The positive deviations are represented above the zero line and negative deviations below the zero line.



(LMC) – Least Material Condition
(MMC) – Max Material Condition

Figure: Limits and Fits

Q4. What are the advantages and disadvantages of unilateral and bilateral dimensioning system?

Answer :

Unilateral Dimensioning System

Advantages

1. It is the most easiest and simplest method to find the deviations.
2. It can standardize the 'GO' gauge ends, without any difficulty.
3. While machining the mating parts, the tolerance under this system facilitates the operator to a higher extent.

Disadvantages

In this system, few components are rejected due to the crossing of working limits.

Bilateral Dimensioning System

Advantages

This system is used in mass production, as the setting of machine for basic size is the main criteria.

Disadvantages

1. Variation in tolerances, does not retain the same fit and it has to vary the basic size of one or both of mating components.
2. The components in bilateral system are rejected, when they are within the working limits and are accepted when they are outside the working limits.

Q5. Define Tolerance? Classify different types of tolerances?

Answer : [May/June-19, (R16), Q1(g) | Model Paper-I, Q1(g)]

The difference between the upper limit and lower limit of a dimension is known as tolerance.

It is also defined as the maximum permissible variation in a dimension.

The tolerance is of two types.

1. Unilateral tolerance
2. Bilateral tolerance.

Q6. Explain the need for the use of tolerance. Dec.-19, (R16), Q1(g)

OR

What is the need for tolerance? Nov./Dec.-16, (R15), Q1(a)

OR

Why it is necessary to give tolerance in engineering dimensions.

Answer : [Nov./Dec.-16, (R13), Q1(b) | Model Paper-II, Q1(g)]

Tolerance

It is impossible to make any part to an exact size. When working to a high degree of accuracy, the amount of error that can be tolerated is represented by limits on the drawing.

Consider figure in which a shaft of diameter 40.00 mm is to be obtained. This is called the basic or nominal diameter. The shaft is accepted, if its diameter lies between 40.00 ± 0.05 = 40.05 mm and 39.95 mm. The dimension 40.05 mm is called the upper limit and the dimension 39.95 mm is called lower limit. The difference between the upper and lower limits is called tolerance.

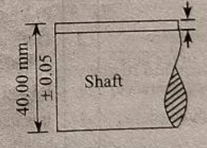


Figure: Tolerance

Need for Tolerance

Tolerances are employed due to the unexpectable human failure and limitations followed by the machines, that avoid complete ideal construction of the specimen. To carry on the material productivity and ease the assembly of components, a normal deviation from the actual size of the specimen is required.

The actual need of tolerance is to allow deviations within the limits of the specified dimensions in the design. Tolerance values can be selected based on standardization, manufacturing equipment and various machining processes.

Q7. Why is unilateral tolerance preferred over bilateral tolerance? Explain in detail. Nov./Dec.-16, (R13), Q1(a)

Answer :

Unilateral tolerance system is the system, in which the dimensions of the part are varied only in one direction, it may be over or under the basic size dimension, as shown in figure. Thus, the variation may be either positive or negative.

Example: $30^{+0.04}_{+0.01}, 30^{-0.04}_{-0.01}, 30^{+0.04}_{-0.00}$

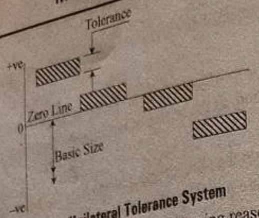


Figure: Unilateral Tolerance System

This system is used in interchangeable manufacture, due to the following reasons,

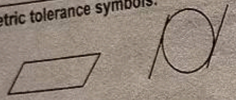
(i) It is simple and easy to find deviations.

(ii) 'Go' gauge end can be standardized, as the holes and shafts of different tolerance grades have the same lower and upper limits respectively.

(iii) It assists the operator, when machining is to be done. The operator machines hole to lower limit and shaft to upper limit so that the components can be machined further, to avoid rejection.

This system is preferred over the bilateral system because, in this system the tolerance can be revised without affecting the allowance or clearance i.e., without changing the type of fit.

Q8. Interpret the following geometric tolerance symbols.



Answer :

Symbol	Geometric Characteristics
▱	Flatness
⌭	Cylindricity

Q9. Enumerate the difference between tolerance and allowance.

Answer :

Allowance	Tolerance
1. It is provided on the dimensions of any mating part in order to get the required fit type.	1. It is provided on a dimension of a part, because it is not possible to make exact specified dimension of a part.
2. Allowance is calculated as the difference between the higher limit of the shaft and lower limit of the hole.	2. Difference between higher and lower limits of dimension of part is the tolerance.
3. It may be negative (interference) or positive (clearance).	3. It is an exact value.
4. It is the prescribed difference between the dimensions of hole and shaft or any two mating parts.	4. It is the permissible variation in the dimension of a part.

Q10. Define fit? Classify different types of fits? May/June-19, (R16), Q1

OR

What are types of fits? Nov./Dec.-18, (R16), Q1

Answer:

Fit is defined as the degree of looseness or tightness among two mating components, so as to assemble together and perform a specific function. A fit gives the relationship between two mating parts, i.e., shaft and hole which are assembled in accordance with their sizes. It can either provide a fixed joint or a movable joint.

Example: If the pulley is placed on the shaft, it forms a fixed type of joint. Whereas, when the shaft runs in a bearing, then there exists a relative motion between them, forming a movable joint.

Different types of fits are,

1. Clearance fit
2. Transition fit and
3. Interference fit.

Q11. Draw the limit diagram for clearance fit.

Answer :

Limit Diagram for Clearance Fit

In clearance fit, it is essential that, the lower limit of hole should be greater than the higher limit of shaft.

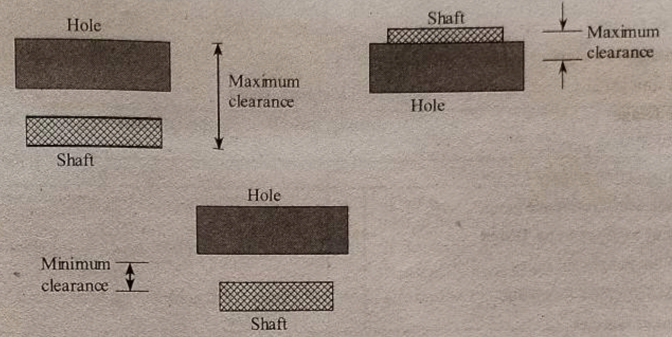


Figure: Line Diagram for Clearance fit

Q12. Define the term interchangeability.

Answer :

Interchangeability is a system of mass production, in which large number of mating parts are produced. In conventional method, single operator was confined with number of units and assemble it, which used to take long time and was not economical. So, to reduce the cost and time, mass production system was developed. In most production systems, the components are produced in one or more batches, by different operations on different machines.

Q13. What are the limitations of interchangeable assembly? [Nov./Dec.-17, (R15), Q1(b) | Model Paper-III, Q1(g)]

Answer :

Limitations of Interchangeable Assembly

1. In an assembly of a machine component, if one of the parts is found to be defective, then it is required to check with the assembly manual to find out the group in which this defective part is located and replace it with a spare part.
2. Deviation in the size of a component occurs, when the fit between two mating parts is highly focussed instead of the basic size of the components.

Q14. How selective assembly can increase the number of acceptable components.

Answer :

A selective assembly can increase the number of acceptable components, by increasing the tolerance limit to twice for both shafts and holes. In this method, the tolerance of assembly are tight although the components are made with wide tolerances. The components are divided mainly into two classes according to their sizes and dimensions. Thus, small shafts are mated with small holes whereas large shafts with large holes respectively.

Q15. Distinguish between measuring instrument and Gauge. [Nov./Dec.-16, (R13), Q1(c) | Nov.-15, (R13), Q1(a)]

Answer :

Measuring Instrument	Gauge
1. It determines the actual dimensions of a component	1. It compares the actual dimensions of a component with standard dimensions.
2. It consists of a graduated or calibrated scale, for indicating the dimension.	2. It does not consists of any scale.
3. Adjustment is required.	3. No adjustment is required to use.
4. It is not preferred, in case of mass production.	4. It is preferred in case of mass production.
5. Time taken for measurement is more	5. Time taken for measurement is less.

Q16. Give the classification of plain limit gauges.

Answer :

Plain limit gauges are used to check holes and shafts which do not have threads, and are classified based on the follow parameters,

1. **Type of Gauge**
   (i) Standard gauges
   (ii) Limit gauges.
2. **Their Usage**
   (i) Workshop gauges
   (ii) Inspection gauges
   (iii) Master or reference gauges.
3. **Form of Surface to be Tested**
   (i) Plug gauges for holes
   (ii) Snap guages for shafts.
4. **Design of Gauges**
   (i) Single limit guages
   (ii) Double limit guages
   (iii) Single ended gauges
   (iv) Double ended gauges
   (v) Fixed and adjustable gauges.

Q17. Comment about the corollaries for Taylor's principles of gauge design. Nov./Dec-17, (R15), Q

Answer :

Willium Taylor explains the relation between verifying the exact dimensions of a component and verifying the differ elements or geometric features of a dimension.

Corollaries for Taylor's Principle of Gauge Design

1. 'GO' and 'NO GO' gauges must be designed such that, they should check the maximum material condition and minim material conditions of a component respectively.
2. The 'GO' gauge should check the related dimensions like roundness, size, location, etc., simultaneously. Whereas, N GO' gauge should check only one feature of a dimension at a time.

Q18. What are the essential considerations in selection of materials for gauges?

Answer :

The essential considerations, while selecting a material for gauge are,

1. Hard enough to resist wear and tear.
2. Stable and resists change in shape and size over a time period.
3. High resistance to corrosion.
4. Machinability to obtain required shape with desired accuracy and finish.
5. Low coefficient of thermal expansion and low thermal conductivity

Q19. Write short notes on combined limit gauges. April/May-12, Set-3

Answer :

The plug gauge combined with GO and NO GO dimensions to check both upper and lower limits of work, is know combined limit gauge. It is usually used for gauging cylindrical holes. This gauge is formed by arranging a spherical ended ga of equal diameter as that of lower limit of hole. A spherical projection (P), as shown in figure, is provided at the outer edg spherical member. The distance between the spherical projection to its diametrically opposite side is equal to maximum lim dimension.

For measuring the hole for minimum limit (i.e., Go-position), the gauge inserted into the hole with gauge handle par to axis of hole, whereas, for measuring maximum limit (i.e., NO GO position), the gauge should be tilted such that sphe projection is normal (perpendicular) to hole.

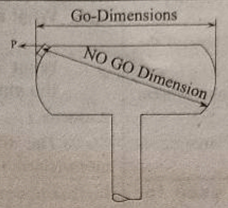


Figure: Combined Limit Gauge

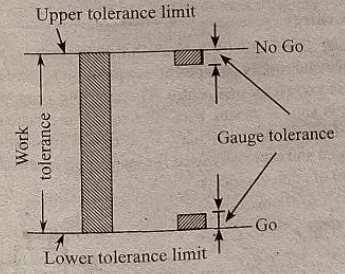
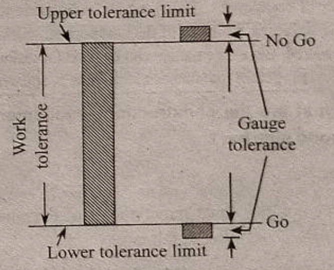
Q20. Differentiate between standard gauge and limit gauge.

Answer :

	Standard Gauge		Limit Gauge
1.	It is a replica of mating part of component to be checked.	1.	It has upper and lower limits of the dimensions of part to be checked.
2.	It is not suitable for checking interference fits.	2.	It is suitable for checking interference fits.
3.	It is rarely used in industries.	3.	It is widely used in industries.
4.	**Example :** A shaft used for checking dimensions of bush.	4.	**Example :** Plug gauges used for checking holes.

Q21. Differentiate between workshop gauges and inspection gauges.

Answer :

	Workshop Gauges		Inspection Gauges
1.	Workshop gauges are used by an operator.	1.	Inspection gauges are used by an inspector.
2.	These gauges are used during the manufacturing process.	2.	These gauges are used for the final inspection of the parts.
3.	In this case, tolerances are arranged within the work tolerance limits.	3.	In this case, tolerances are arranged outside the work tolerance limits.
4.	The limits provided on workshop gauges are within the limits of parts which are being inspected, as shown in below figure.  Figure	4.	The limits provided on inspection gauges are slightly higher than the workshop gauges, as shown in below figure.  Figure

Q22. What are the advantages and limitations of gauges? Nov./Dec-17, (R15), Q4(b)

Answer :

Advantages of Gauges

1. Checking of product wether it is in specified limits or not, can be done very fastly.
2. Since the dependence on operator skill is very less in gauging, errors due operator judgement does not affect the result.
3. It is possible to check more then one dimension at a time, the properties like roundness, taper can be verified at a time.
4. Gauges are economical than measuring instruments and consume less time for measurement.

Limitations of Gauges

1. It is impossible to know the exact dimensions of the product.
2. Accuracy of gauges is affected due to continuous wear and tear of the gauges with time.
3. Manufacture and maintenance of gauges of large size is very difficult.

Q23. Name the various instruments used for measuring angles.

Answer :

The various instruments used for measuring angles are illustrated below,

1. Protractors
   (a) Vernier bevel protractor
   (b) Optical bevel protractor
   (c) Dial bevel protractor.
2. Angle gauges
3. Clinometers
4. Optical instruments
   (a) Angle dekkor
   (b) Auto collimator
5. Sine bars
6. Sine tables
7. Sine centre
8. Spirit level
9. Plain index centre

Q24. Discuss about the Bevel protractor. Where it is used?

Answer: Nov./Dec.-18, (R16), Q1(h)

Bevel protractor is used to measure angle between the two faces of component. The fixed and adjustable measuring blades are set along the faces of the component, whose angle is to be measured. Bevel protractors can be used for testing various geometrical properties like flatness, straightness, squareness, etc.

Q25. What are the construction requirements of a good sine bar?

Answer:

The constructional requirements of the sine bar for accurate measurement are as follows,

1. The diameters of the two rollers should be same.
2. The distance between centres of rollers should be precisely known.
3. The rollers must be parallel to each other.
4. The top surface of sine bar must posses high degree of the flatness.
5. The two rollers should have cylindricity.

Q26. What are the sources of error in sine bars?

OR

What are the chances of occurrence of error in the sine bar?

Answer : Nov.-15, (R13), Q1

The different sources of error in sine bar while measurement of angles are,

1. Error in central distance of rollers.
2. Error caused due to inappropriate combination of slip gauges used for measurement.
3. Unequal roller size and cylindricity error in rollers.
4. Flatness error in upper surface of sine bar.
5. Parallelism error between surface of gauge and roller axes plane.

Q27. What are the limitations of sine bar?

Answer:

The following are the limitations of sine bar,

1. A small error in the sine bar leads to larger angular error.
2. The part size which is to be inspected is limited. This is due to size of the sine bar.
3. It is physically difficult to hold in correct position.
4. It is best suited to measure angles less than 15° and as the measuring angle increases, it becomes inaccurate.
5. It cannot be used to measure angles above 45°
6. The body of the sine bar obstructs the gauge block stack even if released.
7. Accuracy decreases, as the length increases.

Q28. Write about sine centres and sine tables.

Answer :

Sine Centres

A sine bar with a block holding centres, which are adjusted and rigidly clamped at any position to guide the work piece is known as sine centre. The working principle of sine centre is similar to sine bars. The rollers are fastened firmly to the body without any play. Upto 60° of inclination can be measured and especially used for inspecting centres (male and female) of conical objects.

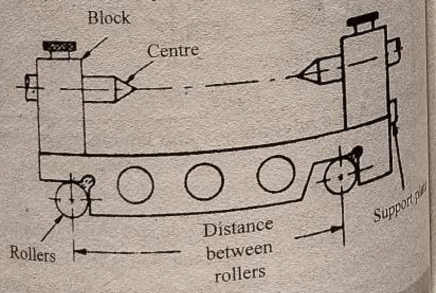


Figure: Sine Centre

Sine Tables

A sine table is a modified form of sine bar. The working principle is same as that of sine bar. It is made rigid to withstand large works. Sine table can be lowered or elevated to any heights and swing from 0° to 90° corresponding to hinged end. The further development of sine table is formed as compound sine table, whose axes of tilt are positioned at right angles to each other. The two tables are mounted on a common base. The compound table used for measuring compound angles, by revolving individual sine tables in two planes at perpendicular each other and positioning corresponding to each other. Sine tables are also used for linear and radial measurements.

Q29. Differentiate between flat and smooth surface.

Answer : [Nov./Dec.-17, (R15), Q1(e) | Model Paper-I, Q1(h)]

It is impossible to produce a surface which is absolutely flat and smooth. The surfaces obtained by various machining processes can be either smooth or flat. The difference between a flat and a smooth surface can be explained by below figures.

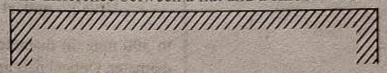


Figure (1)

Figure (1) represents the surface which is theoretically smooth and flat.

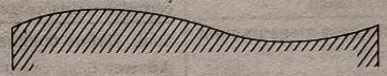


Figure (2)

Figure (2) shows a surface which is smooth but it is not a flat surface.

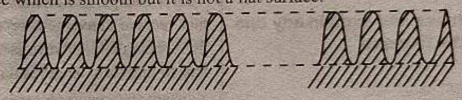


Figure (3)

The surface in figure (3) is said to be flat but not smooth.

The variations in the surface textures of above figures are completely caused by the changes in wavelengths. Hence variation in wavelength is the important parameter to measure the degree of roughness of a surface.

Q30. Distinguish between straightness and flatness.

Answer :

Distinguishes between Straightness and Flatness

Straightness	Flatness
1. The shortest distance measured between the two points on the plane is known as straightness.	1. The minimum distance measured between the two parallel planes is known as flatness.
2. It can be indicated by the normal distance between the two straight lines.	2. It can be indicated by symbol '▱'.
3. Straightness of planes can be checked, by using devices like straight edge, dial indicator, autocollimator, etc.	3. Flatness of surfaces, can be checked by measuring the actual deviation from true planes at various points.

Q31. Given the symbolic representation of flatness of surface.

Answer : Nov./Dec.-17, (R15), Q1(f)

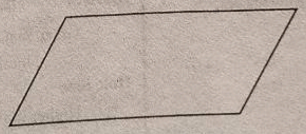


Figure : Symbol of Flatness

Q32. List out the methods of measuring flatness and straightness.

Answer :

The various methods of measuring flatness are,

1. Sprit level method
2. Laser beam method
3. Interference method
4. Autocollimator method and
5. The liquid wedge method

The various methods of measuring straightness are,

1. The wedge method
2. Spirit level method
3. Autocollimator method
4. Beam comparator and
5. Comparison with surface of liquid.

Q33. Explain the procedure for flatness measurement on surface table.

[Dec.-11, Set-3,Q4(b) | Model Paper-II, Q1(h)]

OR

What is meant by flatness and explain any one method to measure the flatness.

Answer :

Flatness is defined as the distance between the two parallel planes containing the surface. It is a geometrical quality of a perfect plane. It is determined by measuring the actual deviation from the planes at different points. The symbol for flatness is ▱.

Flatness Measurement by Surface Plate

1. It is used to test the flatness of a surface.
2. It acts as a datum plane for measuring or comparing vertical distances.
3. It is used as reference for mounting comparators, sine bars, slip gauge blocks, vernier height gauges, etc.
4. The surface plate has good rigidity and it is a high quality casting.
5. To inspect the flatness, the top of surface plate is applied with a thin layer of red lead and oil and the workpiece surface is placed over it. If the surface is flat, red spot will be visible all over the surface.

Q34. Classify optical measuring instruments and flat surface measuring instruments.

Answer :

The various optical measuring instruments are,

(a) Tool maker's microscope
(b) Collimators
(c) Optical projectors
(d) Optical flats and
(e) Interferometers.

The various flat surface measuring instruments are,

(a) Straight edges
(b) Surface plate
(c) Spirit level
(d) Optical flat and
(e) Autocollimator.

Q35. What is optical flat?

Answer : [Nov./Dec.-16, (R13), Q1(e) | Model Paper-III, Q1(h)]

Optical flat provides precision and accuracy in the measurement of flatness.

Usually, optical flats are cylindrical pieces of 25 mm to 300 mm in diameter and of thickness about $\frac{1}{6}$ th of the diameter. Optical flats are made up of transparent materials such as quartz, glass, sapphire, etc. The quartz optical flats are widely used because of its hardness, low coefficient of expansion, high corrosion resistance and longer life.

Q36. Define collimator.

Answer :

Collimator is defined as an optical instrument developed from telescope. Collimators are the assemblies of optical lenses that receive convergent or divergent light rays as input and deliver parallel light rays as output. These are used in testing of lens to find local length and in other meterological uses, where a distant (far away) object is needed at a known location.

Q37. Write the applications of autocollimator.

Answer :

Autocollimator has following applications,

1. It is used for measuring straightness and flatness of surfaces.
2. For evaluating the squareness and parallelism of components.
3. Autocollimator combined with polygons is used for precise angular indexing.
4. Autocollimator is also used in machine tool adjustment.
5. With the aid of master angles, it is used for comparative measurement of components.
6. To measure small linear dimensions.

Q38. In an assembly of two parts of 50 mm nominal diameter the lower deviation of the hole is zero and upper deviation is 5 microns while that of the shaft is –8 and –4 microns respectively. Estimate the allowance and type of fit.

Answer : [May/June-19, (R16), Q8(a) | Nov./Dec.-12, (R09), Q1(b)]

Given that,

Nominal diameter of parts, $d = 50$ mm

Hole Size

Higher limit of hole $= 50 + 0.005 = 50.005$ mm

Lower limit of hole $= 50 - 0.000 = 50.000$ mm

Shaft Size

Higher limit of shaft $= 50 - 0.008 = 49.992$ mm

Lower limit of shaft $= 50 - 0.004 = 49.996$ mm

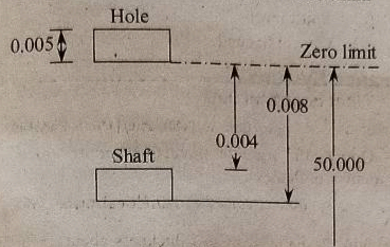


Figure: Hole and Shaft Assembly

$\therefore$ Minimum allowance = Lower limit of hole – Higher limit of shaft

$= 50.000 - 49.992$

$= 0.008$ mm

Since, lower limit of hole and higher limit of shaft is considered, there will be an interference. Therefore, it is a transition fit.

Q39. Find the values of allowance, and tolerances for hole and shaft assembly for the following dimensions of mating parts,

Hole : $25^{+0.05}_{+0.00}$ Shaft : $25^{-0.02}_{-0.05}$

Answer : Dec.-10, Set-3, Q1(b)

Given that,

Hole : $25^{+0.05}_{+0.00}$

Shaft : $25^{-0.02}_{-0.05}$

For Hole

Tolerance = Higher limit – Lower limit

$= 25 + 0.05 - 25 + 0.00$

$= 25.05 - 25$

$= 0.05$ mm

For Shaft

Tolerance = Higher limit – Lower limit

$= 25 - 0.02 - 25 - 0.05$

$= 24.98 - 24.95$

$= 0.03$ mm

Allowance

Allowance = Lower limit of hole – Higher limit of shaft

$= 25.00 - 24.98$

$\therefore$ Allowance $= 0.02$ mm.

Q40. A 200 mm sine bar is to be set up to an angle of 25°. Determine the slip gauges needed from 87 pieces set.

Answer :

Given that,

Distance between rollers, $L = 200$ mm

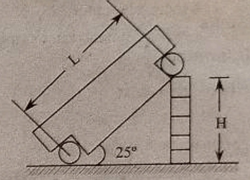
Angle, $\theta = 25°$

The slip gauge combination needed to setup an angle is given by formula,

$H = L \sin\theta$

$= 200 \sin 25°$

$\therefore H = 84.524$ mm



Figure

Hence, minimum number of slip gauges required to build up height, H = 84.524 mm from 87 pieces set is as follows,

1. 1.004
2. 1.520
3. 2.000
4. 80.000

Therefore, minimum number of slip gauges required is 4.

Q41. The angle of wedge shaped block is being checked with 200 mm sine bar. With slip gauges of 26.867 mm height at one end of sine bar, the dial gauge readings at each end of the workpiece vary by 0.06 mm, the gauge block end being low. If the workpiece is 30 mm long what should be the next height of the gauge block? Also calculate the angle of the work piece.

Answer :

Given that,

Length of the sine bar, $L = 200$ mm

Height of the slip gauges, $H = 26.867$ mm

Length of the workpiece = 30 mm

Therefore, the required increase in gauge block length,

$\frac{0.06}{30} \times 200 = 0.4$ mm

Hence, the next height of the gauge block,

$H = 26.867 + 0.4 = 27.267$ mm

And, the required angle of the workpiece is,

$\sin\theta = \frac{H}{L}$

$= \frac{27.267}{200}$

$\sin\theta = 0.136$

$\theta = \sin^{-1}(0.136)$

$\therefore \theta = 7.835°$

PART-B ESSAY QUESTIONS WITH SOLUTIONS

4.1 LIMITS, FITS AND TOLERANCES

4.1.1 Types of Fits – Unilateral and Bilateral Tolerance System

Q42. Define the terms,

(i) Allowance

(ii) Limits

(iii) Tolerance

(iv) Fits.

Dec.-10, Set-4, Q1(a)

Answer :

(i) **Allowance**

The prescribed difference between the dimensions of two mating parts (i.e, holes and shaft) for any type of fit is known as allowance.

Maximum allowance = Higher limit of hole – Lower limit of shaft

Minimum allowance = Higher limit of shaft – Lower limit of hole

The allowance may be positive or negative.

Thus, the allowance is positive for clearance fit and negative for interference fit as shown in below figure.

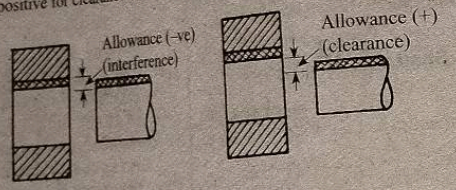


Figure (2): Negative Allowance

(ii) **Limits**

Limits are defined as the permissible variation in dimension, to account for variability. Usually in mass production, large number of components are to be made by different operators on different machines. Hence, it is impossible to make components with exact dimensions. The difference in dimensions vary from machine to machine, operator to operator and quality of the components. The limits of a size are the maximum and minimum permissible sizes of the component.

(iii) **Tolerance**

The difference between upper limit and lower limit is known as Tolerance. In the figure below, the diameter of shaft is 40.00 ± 0.05 – 40.00 mm which is known as the basic or nominal diameter. The shaft is accepted, if its diameter lies between 40.00 ± 0.05 mm and 39.95 mm. The dimension 40.05 mm is called the upper limit and the dimension 39.95 mm is called lower limit and the difference between these limits is called tolerance.

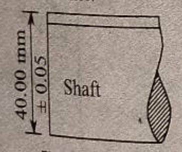


Figure: Tolerance

(iv) **Fits**

It is defined as the degree of looseness or tightness among two mating components, so as to assemble together and perform a specific function. A fit gives the relationship between two mating parts, i.e., shaft and hole which are assembled in accordance with their sizes. It can either provide a fixed joint or a movable joint.

Example: If the pulley is placed on the shaft, it forms a fixed type of joint. Whereas, when the shaft runs in a bearing, then there exists a relative motion between them forming a movable joint.

Depending upon the tolerance between the mating parts, fits can be classified into three basic types. They are,

1. Clearance fit
2. Transition fit and
3. Interference fit.

Q43. Draw the conventional diagram of limits and fits and explain the terms,

(i) Basic size

(ii) Upper deviation

(iii) Lower deviation

(iv) Fundamental deviation.

Dec.-10, Set-3, Q1(a)

Answer :

Conventional Diagram of Fits

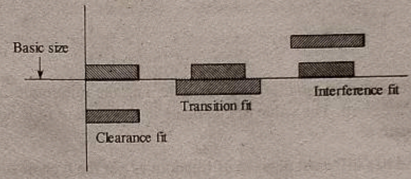


Figure (1) : Types of Fits

Conventional Diagram of Limits

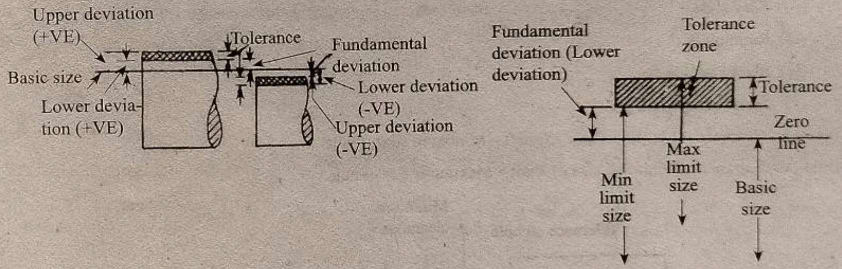


Figure (2): Limits

(i) **Basic Size**

It is the standard size of a part, in relation to which all limits of variation of size are determined. It is also known as nominal size of a part or dimension. The basic size is specified for both shaft and hole is same. It is the designed size obtained by calculation for strength.

(ii) **Upper Deviation**

It is the difference between the maximum limit of size and the corresponding basic size. It is a positive quantity, when the maximum limit of size is greater than the basic size, and negative when the maximum limit of size is less than the basic size.

(iii) **Lower Deviation**

It is the difference between the minimum limit of size and the corresponding basic size. It is positive, when the minimum limit of size is greater than the basic size, and negative when the minimum limit of size is less than the basic size.

(iv) **Fundamental Deviation**

It is the deviation, either upper or lower deviation, nearest to the zero line for a hole or a shaft. It fixes the position of the tolerance zone, in relation to the zero line.

4. What are the different types of fits and explain with neat sketches? Nov./Dec.-16, (R13), Q3(a)

OR

Define fit. What are the conditions of types of fits? Nov.-15, (R13), Q1(b)

OR

Define fit. State different types of fits and explain each of them with suitable sketches and examples. [May-10, Set-4, Q2 | Model Paper-I, Q8(a)]

nswer :

Fit is defined as the degree of tightness or looseness between two mating parts to perform a specific function in an assembly. fit can be either a movable joint or a fixed joint.

ype of Fits

Depending upon the clearance (i.e., positive, zero or negative), the fits are classified as,

1. Clearance fit
2. Interference fit.
3. Transition fit

1. Clearance Fit

In this fit, the diameter of shaft is always smaller than the hole, i.e., the minimum diameter of hole is greater than the largest permissible diameter of the shaft. The value of clearance in this type of fit is positive, i.e., the difference between the sizes of hole and shaft is positive.

The shaft can rotate or slide, and has different degrees of freedom as per the type of function served by the fit.

The most common fits of clearance type are,

(i) Slide fit
(ii) Easy slide
(iii) Running fit
(iv) Slack running fit
(v) Loose running fit.

Maximum clearance = Maximum size of shaft – Minimum size of hole.

Minimum clearance = Minimum size of shaft – Maximum size of hole

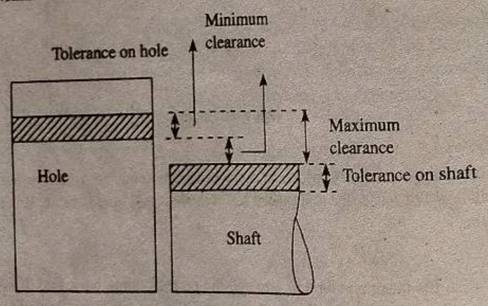


Figure : Clearance Fit

2. Interference Fit

In this type of fit, the minimum permissible diameter of the shaft is larger than the maximum allowable diameter of the hole. As the diameter of shaft is larger than the diameter of hole, the hole and shaft are intended to be attached permanently as a solid component.

Interference fits are classified as force fit, tight fit and heavy force and shrink fit.

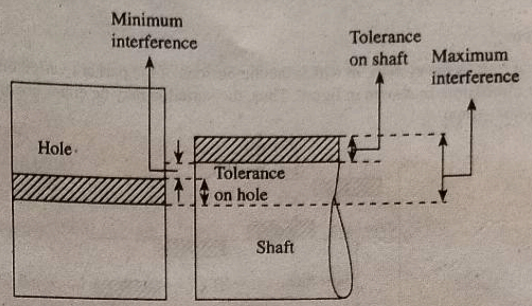


Figure : Interference Fit

Maximum interference = Minimum size of hole ± Maximum size of shaft

Minimum clearance = Maximum size of hole ± Minimum size of shaft.

3. Transition Fit

Transition fit is obtained, when the diameter of the largest allowable hole is greater than diameter of smallest shaft but the smallest hole is smaller than the largest shaft. Thus there is a small positive or negative clearance between the shaft and hole members.

They are of two types,

(i) Wringing fit and
(ii) Push fit.

In this type of fit the tolerance zones of the hole and shaft overlap completely or part

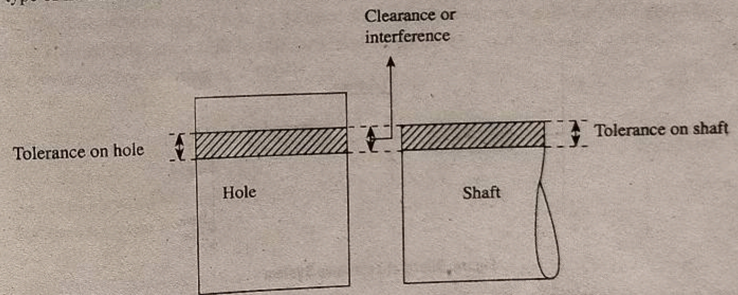


Figure : Transition Fit

Q45. Compare and contrast unilateral and bilateral tolerance system. Dec.-19, (R16), Q8(b)

OR

What is the difference between Unilateral tolerance and Bilateral tolerance? Which is the most suitable tolerance method and why? Nov.-15, (R13), Q3(a)

OR

Explain the unilateral and bilateral systems of writing tolerances with suitable examples. Which system is preferred in interchangeable manufacturing? Why? [Dec.-10, Set-1, Q1(a) | Model Paper-II, Q8(a)]

OR

Explain unilateral system and bilateral system of tolerances.

Nov./Dec.-17, (R15), Q3(b)

Answer :

Unilateral Tolerance System

Unilateral tolerance system is the system, in which the dimensions of the part are varied only in one direction, it may be over or under the basic size dimension, as shown in figure. Thus, the variation may be either positive or negative.

Example: $30^{+0.04}_{+0.01}, 30^{-0.04}_{-0.01}, 30^{+0.04}_{-0.00}$

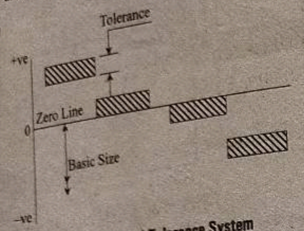


Figure: Unilateral Tolerance System

This system is used in interchangeable manufacture, due to the following reasons,

(i) It is simple and easy to find deviations.

(ii) 'Go' gauge end can be standardized, as the holes and shafts of different tolerance grades have the same lower and upper limits respectively.

(iii) It assists the operator, when machining is to be done. The operator machines hole to lower limit and shaft to upper limit, so that components can be machined further, to avoid rejection.

Bilateral Tolerance System

It is the system, in which the variation in the dimension is allowed on both sides of the basic size, i.e., the variation on either side of the basic size may not be equal. Thus, the variation will be both positive and negative.

The examples of this system are,

$20^{\pm 0.02}$, $20^{+0.02}_{-0.01}$, etc.

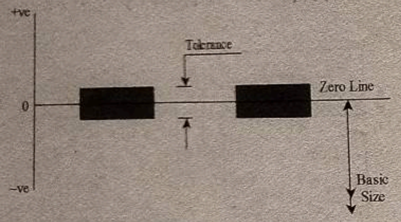


Figure: Bilateral Tolerance System

This system is useful for positioning of a hole. In this system, the machine setting is done for the basic size, hence it is used in mass production.

Unilateral tolerance system is preferred over the bilateral system because, in this system the tolerance can be revised without affecting the allowance or clearance, i.e., without changing the type of fit.

Q46. Calculate the tolerances, fundamental deviations and limits of size for the shaft designated as 40 H8/f7. Standard tolerance for IT 7 is 16i and IT 8 is 25i. Where 'i' is the standard tolerance unit. Upper deviation for 'f' shaft is – 5.5D$^{0.41}$, 40 mm lies in the diameter range 30–50 mm.

Answer :

Given that,

Hole and shaft pair = 40H8/f7

Basic size = 40mm.

Standard tolerances, IT7 = 16i

IT8 = 25i

Upper deviation for shaft, 'f' = – 5.5D$^{0.41}$

Range of diameter = 30 mm to 50 mm

Since, the basic size of shaft ranges from 30 to 50 mm, the geometric mean diameter is,

$\therefore$ D = $\sqrt{30\times 50}$ = 38.729 mm

Standard tolerance unit,

$$i = 0.45\sqrt[3]{D} + 0.001D$$
$$= 0.45\sqrt[3]{38.729} + 0.001\,(38.729)$$
$$= 1.56 \text{ microns} = 0.001561 \text{ mm}$$

For Shaft

Upper deviation or fundamental deviation = –5.5 D$^{0.41}$

= – 5.5 (38.729)$^{0.41}$

= – 24.629 microns = – 0.0246 mm

Standard tolerance for grade of IT 8 = 25 i

= 25×0.001561 = 0.03902 mm

Maximum limit of shaft = Basic size + Fundamental deviation

= 40 + (– 0.0246) mm = 39.975 mm

Minimum limit of shaft = Maximum size – Standard tolerance

= 39.975 – 0.03902 = 39.935 mm.

Tolerance of shaft = Maximum limit – Minimum limit

= 39.975 – 39.935 = 0.04 mm

Q47. Calculate the limits for a hole shaft pair designated 25 H8/d9. Show graphically the disposition of tolerance zones with reference to the zero line. The lower deviation for a H type hole is zero. 25 mm lies in the diameter range 18 mm to 30 mm. Standard tolerance for IT 8 is 25 i and I'T 9 is 40i, where 'i' is the standard tolerance unit in microns and is given as i(μm) = 0.45$\sqrt[3]{D}$ +0.001D, (D is in mm). The upper deviation for 'd' shaft is – 16D$^{0.44}$.

Answer :

Given that,

Hole shaft pair = 25 H8/d9

Range of diameter = 18 mm to 30 mm

Standard tolerance for IT8 = 25i

for IT9 = 40i

Since, the range of basic size is 18 to 30 mm,

Geometric mean diameter, D = $\sqrt{18\times 30}$

$\therefore$ D = 23.23 mm

Standard tolerance unit,

$$i = 0.45\sqrt[3]{D} + 0.001D$$
$$= 0.45\,(23.23)^{\frac{1}{3}} + 0.001 \times 23.23$$
$$= 1.30 \text{ microns} = 0.0013 \text{ mm}$$

For Hole

For grade '8' of hole (H8), standard tolerance = 25 i = 25 × 0.0013 = 0.0325 mm

Lower deviation of hole(H) is zero

$\therefore$ Minimum size of hole = 25 mm

Maximum size of hole = 25 + 0.0325 = 25.0325 mm

Limits of hole = $25^{+0.0325}_{+0.000}$

r Shaft

For shaft (d), upper deviation $= -16D^{0.44}$

$= -16 \times (23.23)^{0.44} = -63.853$ microns $= -0.063$ mm

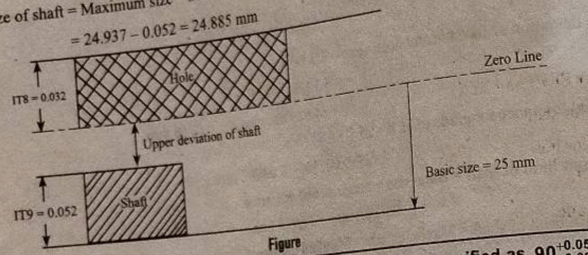
For grade '9' of shaft, standard tolerance $= 40i = 40 \times 0.0013 = 0.052$ mm

Maximum size of shaft = Basic size + Fundamental deviation

$= 25 - 0.063 = 24.937$ mm

Minimum size of shaft = Maximum size − Standard tolerance of shaft

$= 24.937 - 0.052 = 24.885$ mm



Figure

Q48. The hole and shaft assembly of 90 mm nominal size has tolerances specified as $90^{+0.05}_{-0.00}$ mm for hole and $90^{-0.03}_{+0.05}$ mm for shaft. Determine,

(i) Maximum and minimum clearance (interference) attainable

(ii) Allowance

(iii) Hole and shaft tolerances

(iv) Fundamental deviation

(v) MML for shaft and hole

(vi) Type of fit.

Sketch these values on a conventional diagram.

Answer :

Given that,

Nominal size $D = 90$ mm

Hole : $90^{+0.05}_{-0.00}$ mm

Shaft : $90^{-0.03}_{+0.05}$ mm

(i) **Maximum Clearance**

= Maximum size of hole − Minimum size of shaft

$= (90 + 0.05) - (90 - 0.03)$

$= 90.05 - 89.97 = 0.08$ mm

Minimum Clearance

= Minimum size of hole − Maximum size of shaft

$= (90 - 0.00) - (90 + 0.05)$

$= -0.05$ mm

(ii) **Allowance**

= Minimum size of hole − Maximum size of shaft

$= 90.00 - 90.05$

$= -0.05$ mm

(iii) **Tolerance on Hole**

$= (90 + 0.05) - (90 - 0.00)$

$= 0.05$ mm

Tolerance on Shaft

$= (90 + 0.05) - (90 - 0.03)$

$= 0.08$ mm

(iv) **Fundamental Deviation (i)**

$$i = 0.45\,(D)^{\frac{1}{3}} + 0.001\,D$$

$$= 0.45\,(90)^{\frac{1}{3}} + 0.001 \times 90$$

$$= 2.1066 \text{ microns}$$

(v) **MML for Shaft and Hole**

MML for shaft = 90.05 mm

MML for hole = 90.00 mm

(vi) **Type of Fit**

Since the allowance is negative, it is an interference fit.

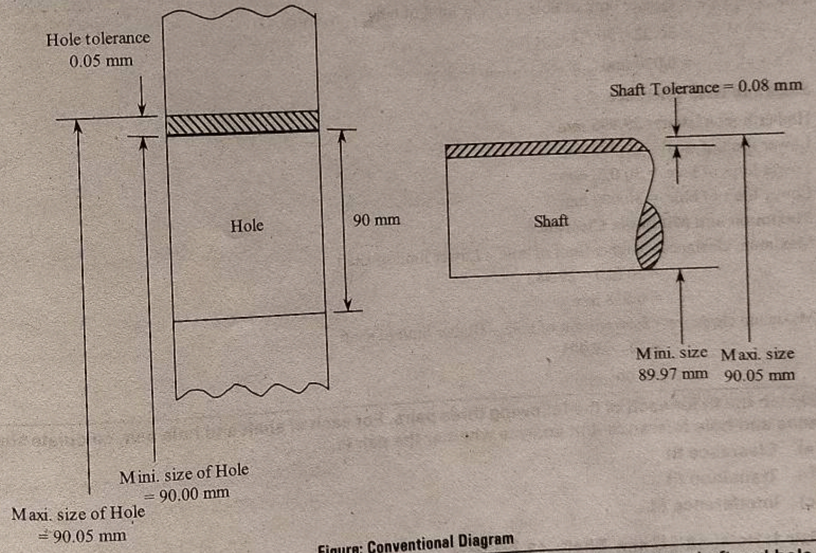


Figure: Conventional Diagram

Q49. In a limit system, the following limits are specified to give clearance between a shaft and hole.

Shaft : $30^{-0.005}_{-0.018}$ mmϕ

Hole : $30^{-0.020}_{-0.000}$ mmϕ

Determine :

(i) Shaft and hole tolerance

(ii) The shaft and hole limits

(iii) The maximum and minimum clearance.

Nov./Dec.-17, (R15), Q3(a)

Answer :

Given that,

Shaft : $30^{-0.005}_{-0.018}$ mmϕ

Hole : $30^{+0.020}_{-0.000}$ mmϕ

Higher limit of shaft $= 30 - 0.005$

$= 29.995$ mm

Lower limit of shaft $= 30 - 0.018$

$= 29.982$ mm

Higher limit of hole $= 30 + 0.020$

$= 30.020$ mm

Lower limit of hole $= 30 - 0.000$

$= 30.00$ mm

(i) **Shaft and Hole Tolerance**

Shaft tolerance = Higher limit of shaft – Lower limit of shaft

$= 29.995 - 29.982$

$= 0.013$ mm

Hole tolerance = Higher limit of hole – Lower limit of hole

$= 30.02 - 30$

$= 0.020$ mm

(ii) **Shaft and Hole Tolerance**

Higher limit of shaft = 29.995 mm

Lower limit of shaft = 29.982 mm

Lower limit of hole = 30.020 mm

Lower limit of hole = 30.000 mm

(iii) **Maximum and Minimum Clearance**

Maximum clearance = Higher limit of hole – Lower limit of shaft

$= 30.020 - 29.982$

$= 0.038$ mm

Maximum clearance = Lower limit of hole – Higher limit of shaft

$= 30 - 29.995$

$= 0.005$ mm

Q50. Sketch the fit for each of the following three pairs. For each of shaft and hole pair, calculate shaft tolerance and hole tolerance and analyze whether the pair is,

(a) Clearance fit

(b) Transition fit

(c) Interference fit.

Pair 1: Hole: $18^{+0.50}_{+0.00}$ mm Shaft: $18^{-0.02}_{+0.005}$ mm

Pair 2: Hole: $20^{+0.25}_{+0.00}$ mm Shaft: $20^{+0.05}_{+0.0005}$ mm

Answer :

Given that,

Pair 1: Hole: $18^{+0.50}_{+0.00}$ mm Shaft: $18^{-0.02}_{+0.005}$ mm

For Hole

Higher limit of hole = 18.50 mm

Lower limit of hole = 18.00 mm

$\therefore$ Hole tolerance = Higher limit of hole – Lower limit of hole

$= 18.50 - 18.00$

$= 0.50$ mm

For Shaft

Higher limit of shaft $= 18 - 0.02 = 17.98$ mm

Lower limit of shaft $= 18 + 0.005 = 18.005$ mm

Shaft tolerance = Higher limit of shaft – Lower limit of shaft

$= 17.98 - 18.005$

$= -0.025$ mm

Considering higher limit of hole with higher limit of shaft,

Allowance $= 18.50 - 17.98$

$= 0.52$ mm (clearance fit)

Considering lower limit of hole with higher limit of shaft,

Allowance $= 18.00 - 17.98$

$= 0.02$ mm (clearance fit)

$\therefore$ The type of fit is clearance fit.

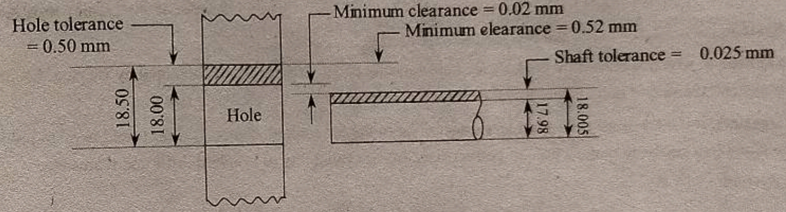


Figure (1): Clearance Fit

Pair 2: Hole: $20^{+0.25}_{+0.00}$ mm Shaft: $20^{+0.05}_{+0.0005}$ mm

For Hole

Higher limit of hole $= 20 + 0.25 = 20.25$ mm

Lower limit of hole $= 20 + 0.00 = 20.00$ mm

$\therefore$ Tolerance $= 20.25 - 20.00$

$= 0.25$ mm

For Shaft

Higher limit of shaft $= 20 + 0.05 = 20.05$ mm

Lower limit of shaft $= 20 + 0.0005 = 20.0005$ mm

$\therefore$ Tolerance $= 20.05 - 20.0005$

$= 0.0495$ mm

Considering higher limit of hole with higher limit of shaft,

Allowance $= 20.25 - 20.05$

$= 0.2$ mm (clearance fit)

Considering lower limit of hole with higher limit of shaft, then,

Allowance $= 20.00 - 20.05$

$= -0.05$ mm (interference fit)

$\therefore$ The fit is of the transition type.

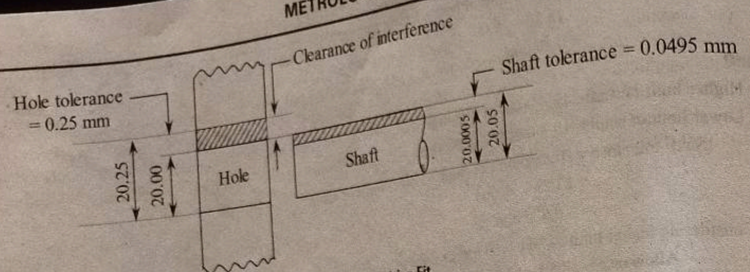


Figure (2): Transition Fit

4.1.2 Hole and Shaft Basis System

Q51. Differentiate between hole basis system and shaft basis system.

[Dec.-19, (R16), Q1(h) | May/June-13, (R09), Q1(b) | Dec.-11, Set-2, Q3(b)]

OR

Explain Hole basis system and shaft basis system.

[Nov./Dec.-18, (R16), Q9(b) | Model Paper-III, Q8(a)]

Answer :

Hole Basis System

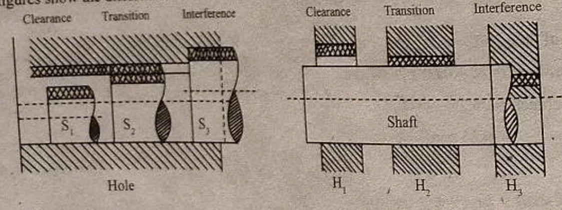
It is a system, in which the limits on the hole are kept constant and a series of fits are obtained by varying the limits on the shafts. In this system, the size of hole, where lower deviation is zero is assumed as the basic size.

In this system, it is easy to vary the shaft sizes, according to the fit required. Hence, it is preferred in mass production, as it is convenient and less costly, to make a hole of correct size, due to availability of standard drills and reams etc.

Shaft Basis System

It is a system, in which the limits on the shaft are kept constant and a series of fits are obtained, by varying the limits on the holes. In this system, the upper deviation of shaft is zero.

Following figures show the differences between hole based system and shaft based system.



Figure

Q52. Write short notes on converting a hole based fit into an equivalent shaft based fit.

May-10, Set-1, Q7(b)

Answer :

Hole basis system is employed for most general applications and some times shaft basis system is also used for design of fits. From Indian Standard (IS) system, the equivalent conversion of hole basis into shaft basis or vice versa are readily available as standards.

For clearance fit, the conversion of hole basis system equivalent to shaft basis system, for the size upto 500 mm is given as,

$$H7 - d8 = D8 - h7$$

$$H7 - f6 = F7 - h3$$

$$H11 - c11 = c11 - h11$$

The conversion for transition and interference fits is made if the tolerance grade for the shaft is same as that hole or one grade finer. Generally, for transition and interference fits with large total tolerance, grade of tolerance, used is same for both shaft and hole. Therefore, this is done for transition fits, J, K, M, N in grades above $IT8$, and for interference fits, P to ZC above $IT\,7$.

If the total tolerance on interference and transition fit is not very large, one finer grade of tolerance is used for hole, than on the shaft. Thus, the value of 'Δ' is used to calculate the deviations of holes in conversion of hole basis to shaft basis system.

Consider an example of conversion of hole basis fit, i.e., H7 – p6 into shaft basis fit P7 – h6 for the size of 25 mm. Therefore, the upper limit (ES) for the hole is given as,

$$P7 = ei(p) + \Delta$$

For 25 mm size, the fundamental deviation for 'p' can be taken from IS : 919 tables as – 22 microns. For grade of IT7, the value of deviation is 8 microns.

$$\therefore \text{ES } (P7) = -22 + 8 = -14 \text{ microns} = -0.014 \text{ mm}$$

Q53. Convert hole based fit Equivalent to the shaft based fit with neat sketch,

(i) 25 H_8c_7

(ii) 30 H_5n_9.

Nov.-15, (R13), Q2(b)

Answer :

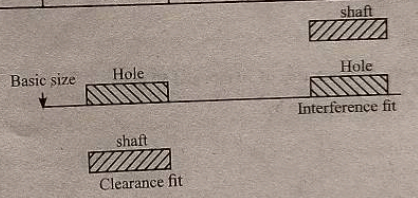
(i) **25 H_8c_7**

The equivalent system i.e., shaft basis system of this fit is "25C_8h_7". Hence, the given fit is clearance fit.

(ii) **30 H_5n_9**

The equivalent system i.e., shaft basis system of this fit is 30 N_5h_9. Hence, the given fit is interference fit.

S.No	Hole Basis	Shaft Basis	Type of Fit
1.	25 H_8c_7	25C_8h_7	Clearance fit
2.	30 H_5n_9	30 N_5n_9	Interference fit



Figure

Q54. A 50 mm diameter shaft is made to rotate in the bush. The tolerances for both shaft and bush are 0.050 mm. Determine the dimension of the shaft and the bush to give a maximum clearance of 0.075 mm with the hole basis system.

[Dec.-10, Set-1, Q1(b) | Model Paper-I, Q8(b)]

Answer :

Given that,

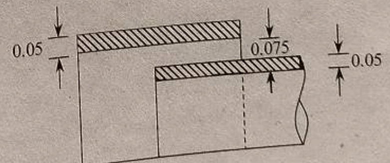
Tolerance for shaft = 0.050 mm

Tolerance for bush = 0.050 mm

Diameter of shaft = 50 mm

In a hole basis system, lower deviation of hole is zero.

$\therefore$ Lower limit of hole = 50 mm



Figure

For Hole

Tolerance = Higher limit of hole – Lower limit of hole

∴ Higher limit of hole = Lower limit + Tolerance

$= 50.00 + 0.050$

$= 50.050$ mm

For Shaft

Allowance = Lower limit of hole – Higher Limit of shaft

∴ Higher limit of shaft = Lower limit of hole – Allowance

$= 50.00 - 0.075$

$= 49.925$ mm

Tolerance = Higher limit of shaft – Lower limit of shaft.

∴ Lower limit of shaft = Higher limit of shaft – Tolerance

$= 49.925 - 0.050$

$= 49.875$ mm.

Q55. A shaft with a nominal size of 42 mm is fitted with an inner ring. The fitting condition is K5/h6.

(i) Determine the type of fit between the shaft and the hole.

(ii) Mention, whether it is a hole-based or a shaft-based.

Nov./Dec.-16, (R13), Q3(b)

Answer :

Given that,

Nominal size = 42 mm

Therefore, 42 mm lies between diameter step of 30 mm and 50 mm

The geometric mean diameter is given by,

$D = \sqrt{30 \times 50}$

$= 38.729$ mm

Standard tolerance unit,

$i = 0.45\ D^{\frac{1}{3}} + 0.001\ D$

$= 0.45\ (38.729)^{\frac{1}{3}} + 0.001\ (38.729)$

$= 0.45\ (3.38) + 0.001\ (38.729)$

$= 1.5224 + 0.03872$

∴ $i = 1.56112$ microns

Tolerance grade for hole, $K5$

$IT5 = 7i$

$= 7 \times 1.56112$

$= 10.928$ microns

$= 0.011$ mm

Tolerance grade for shaft, $h6$

$IT6 = 10i$

$= 10 \times 1.56112$

$= 15.611$ microns

$= 0.016$ mm

Maximum size of shaft = 42 mm

Minimum size of shaft = $42 - 0.016 = 41.984$ mm

Minimum size of hole = 42 mm

Maximum size of hole = $42 + 0.011 = 42.011$ mm

Minimum clearance = Minimum size of hole – Maximum size of shaft

$= 42 - 42$

$= 0$

(i) Therefore, K5/h6 is a transition fit.

(ii) It is shaft based fit.

4.1.3 Interchangeability And Selective Assembly

Q56. How does selective assembly differ from an interchangeability with reference to manufacturing?

May-10, Set-2, Q5(b)

OR

Explain the principle of selective assembly and interchangeability in detail.

Nov.-15, (R13), Q2(a)

OR

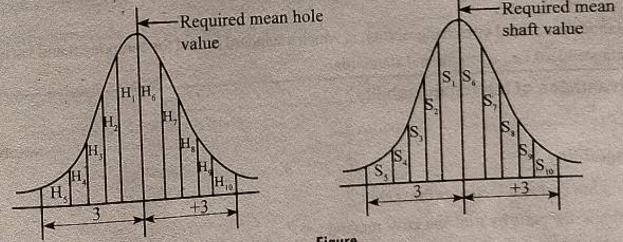
Explain briefly the difference between the interchangeable manufacturing and selective assembly.

Nov./Dec.-16, (R13), Q2(b)

Answer :

Selective Assembly :

The need of the consumer is not only the quality, precision and trouble-free products, but also the availability of products at economical prices. This is possible by automatic gauging for selective assembly. In this system, the parts are manufactured to wider tolerances and the products produced are classified into various groups, according to their sizes by automatic gauging. Classification is made for formatting the parts and only similar groups are assembled together.



Figure

If hole and shaft are to be produced within a tolerance of 0.02 mm and both are in the curve of normal distribution, then automatic gauging divides them into parts with a 0.002 mm limit for selective assembly of individual parts. Consider an example of piston with cylinder, whose size is 60 mm and the clearance of 0.12 mm is required for the assembly. Let the tolerance on bore and piston to be 0.04 mm. Then,

Dimension of bore diameter is $60^{\pm 0.02}$ mm and,

Dimension of piston is $59.88^{\pm 0.02}$ mm

The pistons and bores may be selected to give the clearance of 0.12 mm as given below,

Cylinder bore	59.98	60.00	60.02
Piston	59.86	59.88	59.90

...terchangeability

Interchangeability is a system of mass production, in which large number of mating parts are produced. In conventional ...ethod, single operator was confined with number of units and assemble it, which used to take long time and was not economical. ...o, to reduce the cost and time, mass production system was developed. In most production systems, the components are produced ...n one or more batches, by different operations on different machines.

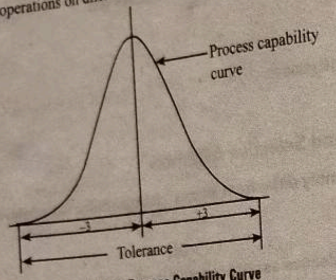


Figure : Process Capability Curve

When this system is applied, a component is selected randomly with any other component. This system ensures reduced cost and increased output.

In this system, operator is concerned with a specific work repeatedly. The other work is taken care by operators of other batch, thus saving the time and simultaneously all the operations can be completed within a specified time. With the help of this method, parts which are worn or defected can be removed, replaced and assembled by other part very easily and the cost of maintenance is reduced and time required for it also reduced. Interchangeability can be applied only when certain standards are followed. The required fit is obtained by two ways. They are,

1. Full or universal interchangeability
2. Selective assembly.

The mostly used method is universal interchangeability, in which a standard is used for component and various manufacturing units are converted into one standard i.e., international standards.

Q57. What are the advantages of interchangeability?

Answer : Nov./Dec.-16, (R13), Q2(a)

Advantages of Interchangeability

1. It reduces the production cost and increases the output.
2. It eliminates assembling the parts by trial and error method.
3. Worn out and defective parts can be easily replaced.
4. It is possible to produce mating parts at different places by different operators.
5. As there is a division of labour, the operator performs same operations number of times and becomes specialized in that particular operation, thus improving quality and saving the time for operations.
6. Maintenance cost and shut down period is reduced.

Q58. Explain the concept of selective assembly. Discuss its significance in manufacturing.

Answer : May-10, Set-2, Q5(a)

For answer refer Unit-IV, Q56, Topic: Selective Assembly.

Significance of Selective Assembly in Manufacturing

1. It is the best and cheapest method in manufacturing.
2. It reduces manufacturing cost and gives high quality in assembly.

3. It reduces the scrap rate in manufacturing.
4. It produces tight tolerance of assembly, although the components are made with wide tolerances.
5. It reduces machining cost and defective assemblies.
6. It increases the efficiency of fit, without reducing the tolerance zone of component.

Q59. Describe principal features of the Indian standard system of limits and fits for plain work.

Nov./Dec.-17, (R15), Q2

OR

"Indian Deviation and 18 grades of Tolerances". Explain the statement in detail.

Answer :

In India, the Indian Standard (IS 919– 1993) is used for system of limits and fits. This system comprises of 20 different grades of fundamental tolerances (or grades of standard tolerance or grades of accuracy of manufacture), and 28 types of standard deviations. These standard deviations are indicated by letters (i.e., for holes: capital letters *A* to *ZC* and for shafts: Small letters *a* to *zc*)in diameter steps upto 500 mm. The designations of 28 deviations are represented as follows.

For holes: *A,B,C,CD, D,E, EF,F,G,H,I,J, JS,K,M,N, P,R,S,T,U,V, X, Y,Z, ZA, ZB, ZC*, and letters *I,L,O,Q* and *W* are not used.

For shafts: Small letters from *a* to *zc* is used.

By selecting the suitable combination of fundamental tolerances and fundamental deviations, a number of different fits ranging from extreme interference to those of extreme clearance are obtained. All fits can be obtained except very exceptional engineering requirements such as very coarse work to fine gauge manufacturing applications.

Generally, a unilateral hole basis system is recommended, but if necessary, bilateral shaft basis system also used.

For the convenience, the part is described with basics size, and the maximum and minimum limits are determined by its deviation from the basic size.

4.2 LIMIT GAUGES

4.2.1 Taylor's Principle, Design of GO and NO GO Gauges

Q60. What are the symbols of various geometrical characteristics.

Answer :

The following are the symbols of various geometrical characteristics.

Geometrical Characteristics	Symbol
Straightness	—
Flatness	▱
Cylindricity	⌭
Roundness	○
Angularity	∠
Parallelism	//

Perpendicularity	⊥
Profile of line	⌒
Profile of surface	⌓
Position	⌖
Symmetry	≡
Concentricity	◎

Q61. State and explain the Taylor's principle of gauge design with neat sketch of Plug gauge and Snap gauges?

May/June-19, (R16), Q9(b)

OR

Explain the Taytor's principle applied in limits.

Nov./Dec.-18, (R16), Q8(a)

OR

State the Taylor's principle for the design of limit gauges.

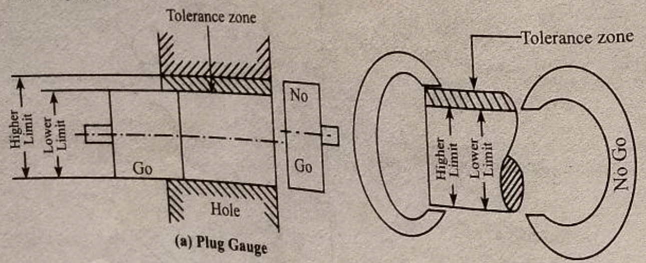
[Nov./Dec.-16, (R13), Q4(a) | Model Paper-II, Q8(b)]

Answer :

According to this principle, 'GO' gauge is designed to check the maximum material condition and 'NO GO' gauge is designed to check minimum material condition. The difference between 'GO' and NO GO' gauge sizes is equal to the tolerance of hole or shaft. Go gauges should ensure the checking of all the dimensions (location, size, roundness) in one pass, and NO GO gauge should check only one element of feature in a single pass.

In a plug gauge, the GO gauge corresponds to the lower limit of hole and NO GO gauge corresponds to the higher limit of the hole while in a snap gauge, the GO gauge indicates the higher limit of shaft and NO GO gauge indicates the lower limit of shaft.

The length of GO plug gauge should be equal to the length of hole, so that possible required dimensions such as diameter, alignability, straightness can be checked. The length of NO GO plug gauge is short compared to GO plug gauge and it measures the variation in the shape of hole.



Figure

Q62. Discuss in detail about the various types of limit gauges with neat diagram.

Answer :

Gauges are inspection tools, to check the measurement of manufactured components. They are used to inspect the size of component is within the specified limits or not.

Limit Gauges: These are used in industries. It has GO gauge and NO GO gauge, which inspect the upper limit and lower limit of the workpiece. The materials used are high carbon steel and alloy tool steels. GO gauges inspect the maximum material limit (MML) and NO GO gauges inspects minimum material limit (LML) of shaft and hole.Limit gauges are also used for checking interference of fits.

	GO gauge (MML)	NO-GO gauge (LML)
Hole	Lower limit	Upper limit
Shaft	Upper limit	Lower limit

Based on the form of surface to be tested, limit gauges are classified as follows,

1. Plug gauge
2. Snap gauge
3. Ring gauge.

1. **Plug Gauge:** Plug gauges are used to check the holes, in which 'GO' gauge is the size of the lower limit of the hole and the 'NO GO' gauge corresponds to the higher limit of hole. Generally, these gauges are made up of suitable wear-resisting steel and the handles can be made of any suitable steel. The commonly used various types of plug gauges are.

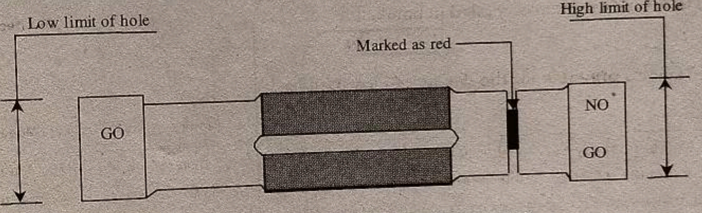
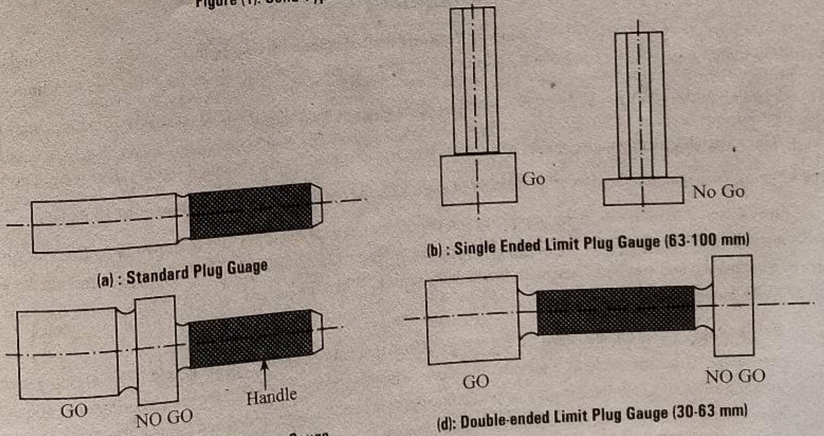


Figure (1): Solid Type Plain Plug Gauge (upto 10mm)



(a) : Standard Plug Guage

(b) : Single Ended Limit Plug Gauge (63-100 mm)

(a) : Progressive Limit Plug Gauge

(d): Double-ended Limit Plug Gauge (30-63 mm)

Figure (2): Types of Plug Gauges

Snap Gauge: These gauges are used for gauging shafts, spindles i.e., used for checking external diameters. The 'GO' snap gauge corresponds to the maximum material limit of the shaft, while the 'NO GO' gauge corresponds to the minimum material limit. Snap gauges are of three types.

(i) Single ended progressive type gauge

(ii) Double-ended gauge

(iii) Adjustable snap gauge.

Single ended gauges are non-adjustable gauges and the suitable for work size of 100-250 mm. Double ended gauges are easy and convenient to use for works of size 3-100mm. The gauging surfaces of the snap gauge is hardened and suitably grounded and lapped.

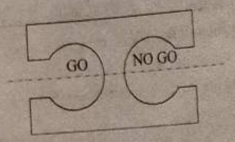


Figure (3) : Double Ended Snap Gauge

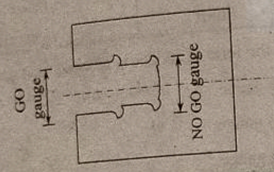


Figure (4) : Single End Progressive Gauge

Adjustable Snap Gauge

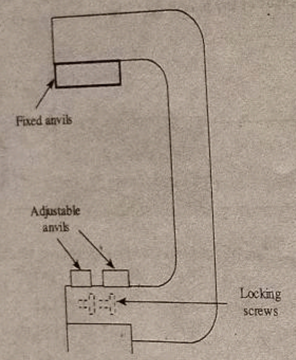


Figure (5) : Adjustable Snap Gauge

The adjustable snap gauge consists of a frame, which is designed for the structural rigidity, less weight and balance. This type of gauges are manufactured in large number of sizes with the openings that ranges from $\frac{1}{4}$ to 12 inches.

It consists of fixed anvils at the upper end and adjustable anvils at the lower end as shown in figure. The surfaces of these anvils are hard chrome plated, for reducing the errors due to wear. The adjustable anvils at the lower end can be adjusted to the desired dimensions and can be locked with the locking screws. When the gauges consists of two anvils, they are called as GO and NO-GO gauges.

3. **Ring Gauge:** These are also used for checking external diameter. The GO ring gauge and NO-GO ring gauge are designed separately. These are made of wear resisting steels. The gauging surface is stabilized with a heat treatment process and then grounded and lapped. The gauging surface is hardened to a hardness of about 720 H.V. The hole of size corresponding to the diameter of component. The range of gauge varies from 3-70 mm in 10 steps and 70-250 mm in 17 steps. Ring gauge is provided with a

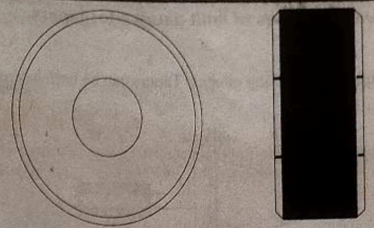


Figure (6) : Ring Gauge

The other types of limit gauges are as follows:

Combined Limit Gauge: The plug gauge combined with GO and NO GO dimensions to check both upper and lower limits of work, is known as combined limit gauge. It is usually used for gauging cylindrical holes. This gauge is formed by arranging a spherical ended gauge of equal diameter as lower limit of hole. A spherical projection (P), as shown in figure, is provided at the outer edge of spherical member. The distance between the spherical projection to its diametrically opposite side is equal to maximum limit of dimension.

For measuring the hole for minimum limit (i.e., GO-position), the gauge is inserted into the hole such that it is parallel to the axis of hole, whereas, for measuring maximum limit (i.e., NO GO position), the gauge should be tilted such that spherical projection is normal (perpendicular) to the hole.

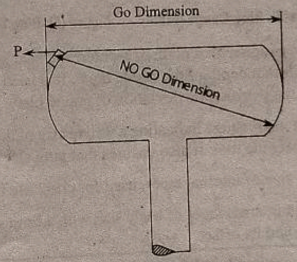


Figure (7) : Combined Limit Gauge

Position Gauges: Position gauges are used to inspect the location of different features on workpiece with respect to the reference surface, such as, distance of a hole, distance between the holes etc. Many types of position gauges are designed depending on the shape of the workpiece. Position gauges are designed based on two methods,

(i) Principle of sighting

(ii) Method of feel.

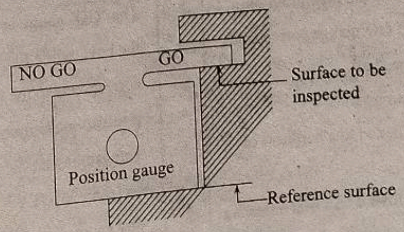
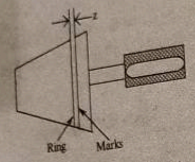


Figure (8) : Position Gauge

Q63. Enumerate and explicate various types of limit gauges for tapers.

Answer :

A taper is measured by using taper plug and ring gauges. Tapers can be both internal as well as external. The various types of limit gauges for tapers are,



Figure(1): Plug Gauge (Plain)

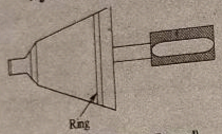
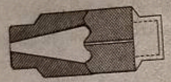


Figure (2): Plug Gauge (Tanged)



Figure(3): Ring Gauge (Plain)

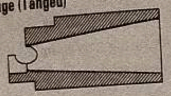


Figure (4): Ring Gauge (Tanged)

Plug Gauge (Plain): It is a full form 'GO' gauge with a plain or tapered end shank. It has two rings, one ring marked on gauge plane and another ring to represent the minimum depth of the inside taper. It is used for checking internal taper of corresponding size. The distance between the rings (z) is the permissible deviation of gauge plane position.

Plug Gauge (Tanged): It is also a full form 'GO' gauge indicating a virtual size of the shank of basic size having a tang employed to verify the internal tapers or sockets of machine tool. It also ensures that tang slot should be able to accept the tang.

Ring Gauge (Plain): It indicates the basic size of internal taper, used for checking the taper of tapped or plain end shank.

Ring Gauge (Tanged): It corresponds to an internal taper of basic size with a limit step, which checks the length of shank from gauge plane and effect of thickness of tang and its offset.

Q64. Compare between ring and plug gauges?

Answer :

	Ring Gauges		Plug Gauges
1.	It is used for gauging shafts, spindles, etc.	1.	It is used to check the holes.
2.	It is designed as 'GO' and 'NO GO' ring gauges.	2.	It is designed in two ways i.e., 'GO' and 'NO GO' plug gauges.
3.	The GO gauge corresponds to the maximum limit of the shaft, while the 'NO GO' gauge corresponds to the minimum limit of the shaft.	3.	The 'GO' gauge is the size of the lower limit of the hole, while the 'NO GO' plug gauge corresponds to the higher limit of hole.
4.	It is made up of wear resisting steels.	4.	It is also made up of wear resisting steels.
5.	The gauging surface is hardened to a hardness of about 720 H.V.	5.	The gauging surface is hardened to about or less than 750 H.V.
6.	The gauging surface is stabilized with a heat treatment process and then grounded and lapped.	6.	The gauging surface is stabilized, grounded and lapped.

Q65. What are the common materials used for gauges?

Answer :

The common materials used for gauges are as follows,

High Carbon Steels

Generally gauges are made of cast steel which are hardened with oil or water. Gauge plates and silver steels are made by using this material. Oil hardening is mostly used, to avoid cracking of material. Plug gauges of different sizes are made of different steels, such as,

Guages of diameter 15-32 mm – Made of cast steel.

Guages of smaller diameter – Made of silver steels.

Guages of bigger diameter – Made of case hardening steels.

During hardening process, the steel is heated to 730°C and subjected to quenching in water. A temperature of 200°C (tempering temperature) should be retained for about 7 to 10 hrs for stability and reduced brittleness.

Mild Steel

Gauges made of mild steel are commonly subjected to case hardening process. They are heat treated either by carburising or cyaniding process. Minimum depth of case hardening should be done about 0.75 mm, in order to permit for grinding and finishing. The gauge is maintained at a temperature range of 150°C to 160°C for about 5 hrs and followed by slow cooling, to reduce the inner stresses. Mild steel possess good machinability and is available at low cost.

Oil Hardened Steel

It is used in the mass production of gauges. Gauges made of this steel are surfaced with the carbide at contact points, to increase the gauge life.

Plated Gauges

Chromium plating is done, which helps in making the surface of gauge hard and wear and corrosion resistant. While manufacturing a gauge, it is machined, plated, grounded and lapped to desired size. The coating thickness is about 0.2 to 0.3 mm. Chromium plating is also done to recover the worn gauged.

To inspect the work materials like aluminium, etc., which possess abrasive action, gauges with stellite ribs are used.

Cast Irons

These are used in manufacturing gauges of large sized bodies. The working faces are made of tool steel or cemented carbide. A closed grain structure of iron, free from blow holes, is used. This iron is mades table to relieve the stresses, due to casting and then subjected to final machining.

Glass

The gauges made of glass are used in least cases due to their brittle nature. They are resistant to corrosion and abrasion and have low thermal expansion.

Invar

It consists of 36% nickel, having low coefficient of expansion i.e., less than 1×10^{-6}/°C, but it is not used for long periods.

Elinvar

It has 42% nickel with coefficient of expansion as 8×10^{-6}/°C and is more suitable than invar.

Q66. Elucidate terms, gauge tolerance and wear allowance as assignable to limit gauges.

Answer :

Gauge Tolerance or Manufacturing Tolerance: Generally, gauges can not be manufactured to exact sizes. Also, some variations in size cannot be eliminated due to imperfections in the process, skills of worker etc. Therefore, some allowance must be provided while manufacturing gauges.

The gauge tolerance is also called as gauge maker's tolerance. Basically, the gauge tolerance should be kept as small as possible, but this will increase the cost of manufacturing the gauges. There is no accepted policy for standard policy gauge tolerance. Generally, gauge tolerance on limit gauges, is 10% of work tolerance, on inspection is generally 5% of work tolerance and on reference or master gauge, it is 10% of work tolerance.

Wear Allowance: Due to constant rubbing of the measuring surfaces of GO gauges against the surface of the work piece, wearing is enhanced on the measuring surface of gauges. As a result, the original size of gauge varies. The size of 'GO plug' gauge is reduced due to wear and that of ring or snap gauge is increased. Hence, a wear allowance is provided to the gauges in the direction opposite to that of the wear. In case of GO plug gauges wear allowance is added, whereas in ring or snap gauges, it is subtracted. For 'NO GO' gauges, wear allowance is not provided as they are not subjected to much wear as GO gauges. Wear allowance is usually taken as 5% of work tolerance. Wear allowance is applied to a normal GO gauge diameter before gauge tolerance is applied. According to British standards, wear allowance is provided, when the work tolerance is greater than 0.09 mm.

Q67. What are the advantages and limitations of GO and NO GO gauges?

May/June-19, (R16), Q8(b)

Answer :

Advantages of Limit Gauges

1. These are portable and requires no power supply.
2. More than one dimension can be checked in a single pass of gauge.
3. Inspection is done at a faster rate.
4. Various dimensions of the components can be controlled.
5. Operation can be performed by a semi-skilled labour
6. Work is carried out with high flexibility.

Disadvantages of Limit Gauges

1. These do not specify the exact size of the component
2. These are difficult to manufacture with close (fine) tolerances.
3. Due to the wear and tear, the accuracy of the gauges is effected.
4. These are economical, if used for only similar products.

Uses of Limit Gauges

1. Mostly employed in mass production
2. Plug gauge – checks hole dimensions
3. Snap gauge – checks shaft dimensions
4. Taper gauge – inspects the taper dimensions
5. Thread gauge – checks the threading of the part
6. Profile gauge – checks the form or contour of the part.

Q68. Write a short note on the various aspects for deciding the limits on the limit gauges.

Nov./Dec.-16, (R13), Q4(b)

Answer :

The various aspects considered for deciding the limits on limit gauges are as follows,

1. Cost of production
2. Gauge tolerance and
3. Gauge wear

1. Cost of Production

The cost of production of a gauge increases with increase in accuracy to which gauge is manufactured. Therefore, high accuracy should be maintained only wherever it is necessary.

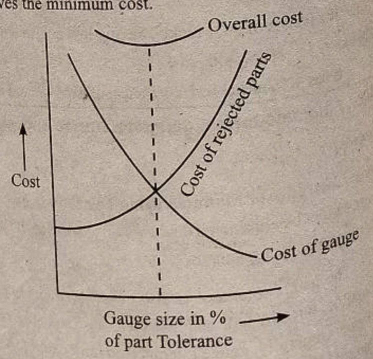
2. Gauge Tolerance

An attempt to manufacture a fixed size gauge to an exact dimension involves higher costs. The variation on gauge dimension may be restricted to small values, but, an allowable amount of tolerance is necessarily provided on gauge.

3. Gauge Wear

Suitable provisions are given for gauge wear as it is unavoidable. The GO and NO-GO gauges undergoes wear, but wear in GO-Gange is higher. Wear is permissible to certain extent but excessive wear results in rejection of components which are above the minimum metal conditions. Thus, it is required to set, gauge wear limit which is economical.

The below graph shows the method to find the variation which gives the minimum cost.



Figure

Q69. Design the general type of GO and NO-GO gauge for components having 20H7/f8 fit. i (microns) = 0.45 (D 1/3) +0.001 D, upper deviation of "f" shaft = –5.5 $D^{0.41}$, 20 mm falls from the diameter step of 18-30, IT7 = 16i, IT8 = 25i, wear allowance = 10% of gauge tolerance.

[Nov./Dec.-16, (R13), Q5 | Model Paper-III, Q8(b)]

Answer :

Given that,

Designation of fit = 20 H7/f8

Basic size = 20 mm

Standard tolerance, IT7 = 16 i

IT8 = 25 i

Upper deviation to shaft = – 5.5 $D^{0.41}$

Wear allowance = 10% of gauge tolerance

The range of diameter is 18 mm to 30 mm.

$\therefore D = \sqrt{18 \times 30} = 23.23$ mm

The standard tolerance unit (i) is given as,

$i = 0.45\,(D)^{1/3} + 0.001\,D$

$= 0.45\,(23.23)^{1/3} 0.001\,(23.23)$

$= 1.30$ microns

$\therefore\ i = 0.0013$ mm

For Hole

Tolerance grade, IT7 = 16 i

$= 16 \times 0.0013 = 0.0208$ mm

Lower deviation of hole (H) = 0

$\therefore$ Limits of hole $= 20^{+0.0208}_{+0.000}$

Gauge tolerance = 10% of standard tolerance of hole (work tolerance)

$= 0.1 \times 0.0208 = 0.00208$ mm

$\therefore$ Wear allowance = 10% of gauge tolerance

$= 0.1 \times 0.00208 = 0.000208$ mm

For Shaft

Tolerance grade, IT8 = 25 i

$= 25 \times 0.0013 = 0.0325$ mm

Upper deviation of shaft $= -5.5D^{0.41}$

$= -5.5\,(23.23)^{0.41}$

$= -19.932$ microns $= -0.01972$ mm

Maximum limit of shaft = Basic size + Upper deviation

$= 20 + (-0.01972) = 19.980$ mm

Minimum limit of shaft = Basic size + Upper deviation – Tolerance grade

= Maximum limit of shaft – Tolerance grade

$= 19.980 - 0.0325 = 19.9475$ mm

$\therefore$ Limits of shaft $= 20^{-0.02}_{-0.053}$

Gauge tolerance $= 10\%$ standard tolerance of shaft

$= 0.1 \times 0.0325 = 0.00325$ mm

Wear allowance $= 10\%$ of gauge tolerance

$= 0.1 \times 0.00325 = 0.000325$ mm.

Gauge Limits for Hole (Plug Gauge)

For Go gauge :

Upper limit $= 2 + 0.00208 + 0.000208 = 20.00228$ mm

Lower limit $= 20 + 0.00208 = 20.00208$ mm

$\therefore$ Limits of hole $= 20^{+0.00228}_{+0.00208}$

For NO GO gauge :

Upper limit $= 20.0208 + 0.00208 = 20.0228$ mm

Lower limit $= 20.0208 + 0.000 = 20.0208$ mm

$\therefore$ Limits of hole $= 20^{+0.0228}_{+0.0208}$

Gauge Limits for Shaft (Ring Gauge)

For GO gauge :

Upper limit $= 19.980 - 0.000325 = 19.979$ mm

Lower limit $= 19.980 - 0.00325 - 0.000325 = 19.976$ mm

$\therefore$ Limits $= 20^{-0.021}_{-0.024}$

For NO GO gauge :

Upper limit $= 19.947 - 0.000 = 19.947$ mm

Lower limit $= 19.947 - 0.00325 = 19.943$ mm

$\therefore$ Limits $= 20^{-0.053}_{-0.057}$

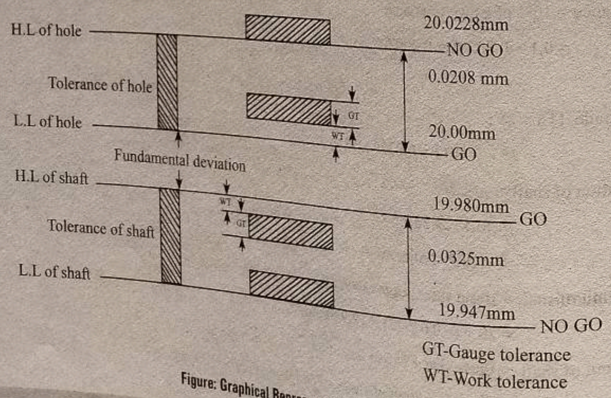


Figure: Graphical Representation of Tolerance

Q70. Shafts of 75 ± 0.02 mm diameter are to be checked by the help of GO and NO-GO ring gauges. Design the Gauge, sketch it and show GO size and NO-GO size dimensions. Assume normal wear allowance and Gauge maker's tolerance.

Answer : Nov.-15, (R13), Q5(b)

Given that,

Diameter of shaft $= 75 \pm 0.02$ mm

Maximum size of shaft $= 75 + 0.02 = 75.02$ mm

Minimum size of shaft $= 75 - 0.02 = 74.98$ mm

Tolerance = maximum size – minimum size

$= 75.02 - 74.98 = 0.04$ mm

Gauge maker's tolerance = 10% of work tolerance

$= 0.1 \times 0.04 = 0.004$ mm

Wear allowance $= 0.1 \times 0.004 = 0.0004$ mm

Go Gauge:

H.L $= 75.02 - 0.0004 = 75.0196$ mm

L.L $= 75.02 - 0.0004 - 0.004 = 75.0156$ mm

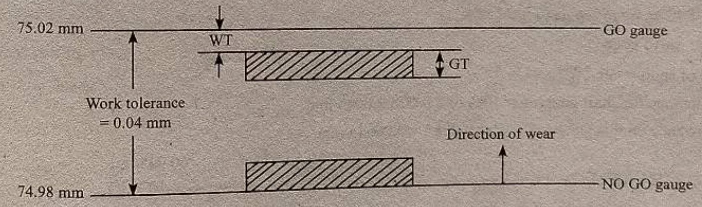
$\therefore$ Limits of gauge $= 75^{-0.0196}_{-0.0156}$

No-Go Guage

H.L $= 74.98 - 0.000 = 74.980$ mm

L.L $= 74.98 - 0.004 = 74.976$ mm

$\therefore$ Limits of gauge $= 74^{-0.980}_{+0.976} = 75^{-0.020}_{-0.024}$



Figure

Q71. A hole and shaft system had the following dimensions:

60 H 8 /c 8

The multiplier of grade 8 is 25.

The fundamental deviation for 'C' shaft is – (9.5 + 0.8 D).

The diameter slip is 50 – 80.

Design the suitable 'GO' and 'NO-GO' gauges for shaft and hole.

Answer : Dec.-19, (R16), Q9

Given that,

Basic size = 60 mm

Diameter range = 50 mm to 80 mm

Geometric mean diameter, $D = \sqrt{50 \times 80} = 63.24$ mm

Standard tolerance unit, $i = 0.45\,(D)^{\frac{1}{3}} + 0.001\,D$

$= 0.45\,(63.24)^{\frac{1}{3}} + 0.001(63.24)$

$= 1.8560$ microns

$= 0.0018$ mm

The multiplier of grade 8 = 25

Fundamental deviation for shaft 'C' $= -(9.5 + 0.8\,D)$

For Hole

For hole (H), fundamental deviation is zero.

$\therefore$ Minimum size of the hole = 60 mm.

Tolerance grade, $IT8 = 25i = 25 \times 0.0018 = 0.045$ mm

$\therefore$ Maximum size of hole $= 60 + 0.045 = 60.045$ mm

$\therefore$ Limits of hole $= 60^{+0.045}_{+0.000}$

Gauge tolerance for hole gauging = 10%. of 0.045 = 0.0045 mm

Wear allowance on this gauge = 10%. of 0.0045 = 0.00045 mm

For Shaft

Tolerance grade, $IT8 = 25i = 25 \times 0.0018 = 0.045$ mm

Fundamental deviation $= -(9.5 + 0.8\,D)$

$= -(9.5 + 0.8\,(63.24))$

$= -60.092$ microns

$= -0.06092$ mm

H.L of shaft = Basic size + Fundamental deviation

$= 60 + (-0.060092)$

$= 59.9399$

L.L of shaft = H.L of shaft − Tolerance of shaft

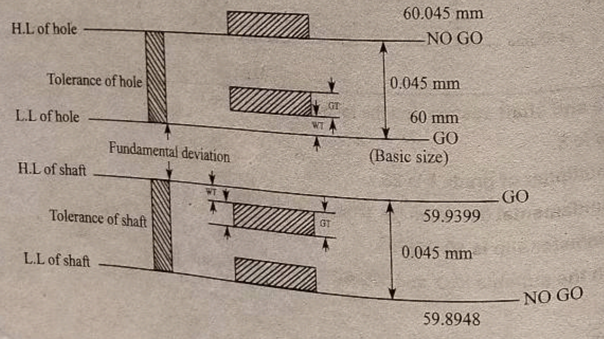
$= 59.9399 - 0.045$

$= 59.8949$

$\therefore$ Limits of shaft $= 60^{-0.0601}_{-0.1051}$

Gauge tolerance for shaft gauging = 10% of 0.045 = 0.0045 mm

Wear allowance on this gauge = 10% of 0.0045 = 0.00045 mm



WT-Wear tolerance

GT-Gauge tolerance

Figure

Gauge Limits for Hole (i.e., Plug Gauge)

For Go Gauge

Upper Limit $= 60 + 0.0045 + 0.0004 = 60.0049$ mm

Lower Limit $= 60 + 0.0004 = 60.0004$ mm

$\therefore$ Limits $= 60^{+0.0049}_{+0.045}$

For No Go Gauge

No Go Gauge $= 60.045^{+0.0045}_{-0.0000}$ mm

Gauge Limits for Shaft (i.e., Ring Gauge)

Go Gauge :

Upper limit $= 59.9399 - 0.0045 - 0.0004$

$= 59.935$ mm

Lower Limit $= 59.9399 - 0.0004$

$= 59.9395$

$\therefore$ Go Gauge $= 59.9395^{-0.0045}_{-0.000}$

$= 60^{-0.065}_{-0.0605}$

No Go Gauge :

Upper limit $= 59.8949 - 0.000$

$= 59.8949$

Lower Limit $= 59.8949 - 0.0045$

$= 59.8904$ mm

No Go Gauge $= 59.8949 - 0.0045 - 0.1051$

$= 60^{-0.1051}_{-0.1096}$

4.2.2 Measurement of Angles, Using Bevel Protractor and Sine Bar

Q72. Explain the construction and working of a bevel protractor.

Answer : [Nov./Dec.-17, (R15), Q4(a) | May/June-13, (R09), Q2(b)]

Construction

A bevel protractor is an angle measuring instrument, consisting of the following parts as shown in figure.

1. A fixed measuring blade
2. An adjustable blade
3. Body and
4. Turret.

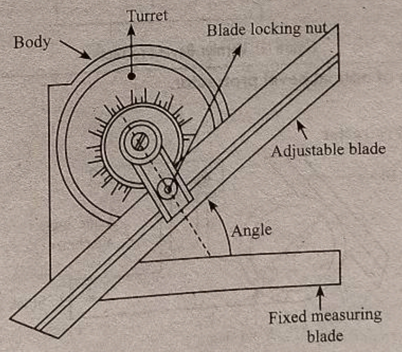


Figure: Bevel Protector

Working

A bevel protractor is used to measure angle between the two faces of a component. The fixed measuring blade and the adjustable blade is set along the faces of the component whose angle is to be measured, as shown in figure. The blades are then locked by a locking nut, to tighten the component for accurate measurement. The body consists of a circular scale and extends to form one of the blades. The circular scale can measure angles upto 360 degrees. The adjustable blade also slides and can be locked at any position along its length, to the rotating turret mounted on the body. Thus, accurate angular measurements of any component can be easily done by a bevel protractor.

Q73. Explain about vernier bevel protractor.

Answer :

The vernier principle is also applied in angular measurements. It is an instrument used to measure angle to an accuracy of 5 minutes (5') or 1/12 of one degree. The vernier protractor includes number of attachments, that make it possible far wide range of measurements.

The main scale is graduated in degrees. On some instruments, this scale is on the body of the instrument itself while on other instruments the graduations are on the rotating turret. The vernier scale has 24 divisions, 12 divisions are on each side of the zero index line. The 24 vernier scale divisions are numbered from 60 to 0 and 0 to 60, as shown in figure (1). Each vernier scale graduation represents 5' i.e., least count of the instrument is 5'.

In angular measurements, it is important to read vernier scale reading. When the angle is an exact degree, the index line on the vernier scale, coincides with graduation on the main scale. However, if the angle is more than an exact number of degrees, the fractional value (in 5' increments) is read on the vernier scale.

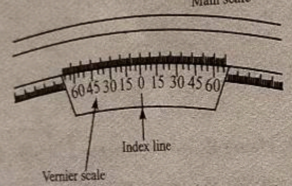


Figure (1): Vernier Scale

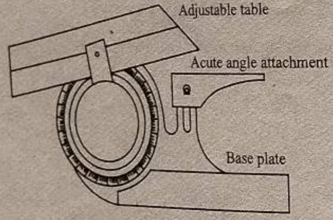


Figure (2): Vernier Bevel Protractor

Q74. Explain the construction of optical bevel protractor.

Answer :

Construction of an Optical Bevel Protractor

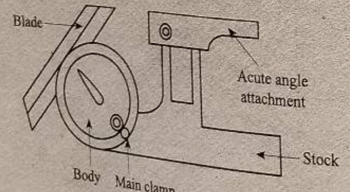


Figure: Optical Bevel Protractor

The main components of optical bevel protractor are,

1. **Body:** The body of an optical bevel protractor should be flat on its back, without any projections on it. It should be noted that, while placing the back of bevel protractor on the surface plate there should be no visible rock present on it. The flatness of the body and stock's working edge is tested, by checking the squareness of blade with respect to stock, by setting the blade at an angle of 90°.

2. **Stock:** The stock of protractor should be designed such that its working edge should be straight. The length and thickness of the working edge is about 90 mm and 7 mm. Any small variation in its straightness causes the formation of concavity, which will be available in the highest order of 0.01 mm.

3. **Blade:** The length of the protractor varies from 150 mm to 300 mm. The width and thickness of blade is 3 mm and 2 mm. It can be rotated at an angle of 45° and 60° along with an accuracy of 5 minutes. The straightness and parallelism of working edge is designed upto 0.02 mm and 0.03 mm, along the entire length of blade, i.e., 300 mm. The blade can be moved in the reverse direction throughout its length and can be able to clamp in any direction.

4. **Acute Angle Attachment:** This attachment is easily fitted into the body and can be clamped in any direction. The flatness of working edge should be in the range of 0.005 mm and it should be parallel to the stock's working edge.

Q75. Explain how the measurements are made with optical bevel protractor.

Answer :

Optical bevel protractor is a modified form of vernier bevel protractor. This instrument consists of glass circle, adjustable blade, working edge, etc., as shown in figure. The glass circle is fitted inside the main body and is divided into ten intervals through the circumference of 360°. A small microscope is incorporated on a rotating member to view the circular graduations. The adjustable blade is attached to rotating member and aids to record readings.

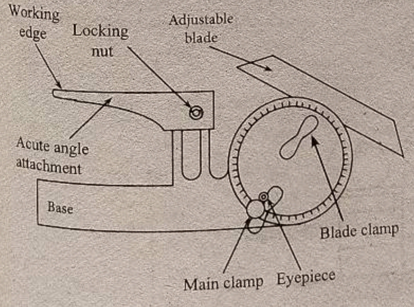


Figure: Optical Bevel Protractor

It can be used for wide range of applications. The general use is the angle measurement. The fixed and adjustable blades are set along the faces of the component whose angle is to be measured. The blades are locked by locking nut, to tighten the component for accurate measurement. The adjustable blade also slides and can be locked at any position along its length.

Optical bevel protractor comprises of a lens in the form of an eye piece for easy reading of protractor divisions. It can be also used for measuring flatness, acute angles, and checking the geometrical properties of the materials. The accuracy of the optical bevel protractor is upto 2 minutes.

Q76. Explain the use of sine bar for setting a component for a given angle.

Dec.-19, (R16), Q8(a)

OR

Explain the in detail the working of sine bar and what are its limitations? May/June-19, (R16), Q9(a)

OR

Describe the measuring method by using sine bar. Nov./Dec.-18, (R16), Q9(a)

OR

Discuss the construction, working principle, and applications of any one angular displacement measuring instrument.

Answer : Model Paper-I, Q9(a)

Sine bar is an angular measuring instrument. It is made of high chromium corrosion resistant steel, high carbon. It is hardened, grounded and stabilised. Sine bar consists of steel following parts,

1. Rollers
2. Steel bar
3. Slip gauges
4. Surface plate.

The rollers are made of same diameter and are attached at each end of bar so that their axis are parallel to each other. The slip gauges are used with sine bar and are arranged based on the angle to be measured.

Principle: The operating principle of sine bar is based on trigonometric laws.

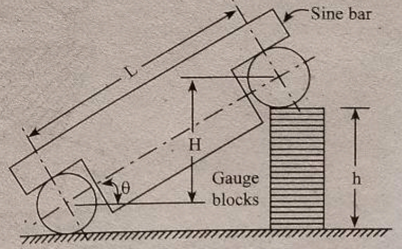


Figure (1): Principle of Sine Bar

In order to set a given angle, one roller is placed on the surface plate, and the other roller is placed over the slip gauges. Let 'H' be the height of the slip gauges and 'L' be the distance between the centres of steel rollers. Then,

$$\sin\theta = \frac{H}{L}$$

$$\theta = \sin^{-1}\left(\frac{H}{L}\right)$$

Thus, angle is measured by indirect method as a function of trigonometric sine. Due to this, the instrument is known as sine bar.

Applications of Sine Bar

1. **Locating Any Work to a Given Angle**

Let 'L' be the length of the sine bar and the surface plate is assumed to be flat and horizontal. As it consists of two rollers, at each end of the sine bar one roller, is placed on the surface plate and the other roller is placed over the slip gauges, as shown in figure (2).

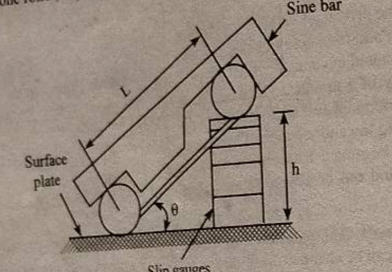


Figure (2)

Where,

H – Height of the slip gauges

θ – The angle at which sine bar is set

L – The distance between centre of the rollers.

For accurate results, rollers should be placed on slip gauges of height H_1 and H_2 respectively.

$$\therefore \sin\theta = \frac{H_2 - H_1}{L}$$

2. **Checking Unknown Angles, when the Component is of Small Size**

Initially, the angle is measured with the help of a bevel protractor. Then, sine bar is set up at desired angle and slip gauges are placed under the second roller. The component which is to be checked is placed over the surface of sine bar, with a dial gauge placed on it, as shown in figure (3).

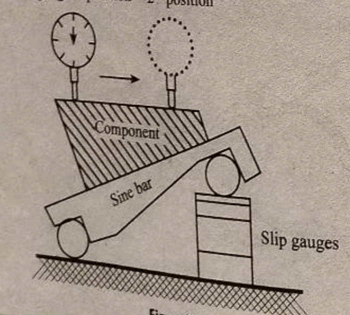


Figure (3)

Therefore, the angle of component can be calculated as,

$$\theta = \sin^{-1}\left(\frac{H}{L}\right)$$

3. **Checking of Unknown Angles, when the Component is of Large Size**

During measurement, the sine bar is placed on the component which is to be checked, and while the component is placed over the surface plate, as shown in figure (4).

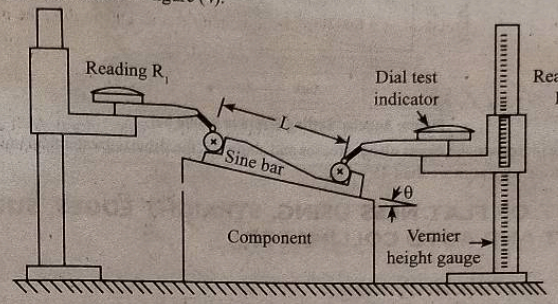


Figure (4)

The height above the rollers can be measured with the help of vernier height gauge, with dial test indicator mounted on the anvil. The the angle of component is by,

$$\theta = \sin^{-1}\left(\frac{H}{L}\right)$$

Where,

H – Difference in heights

L – Distance between the roller centres.

Limitations of Sine Bar

For answer refer Unit-IV, Q 27.

Q77. Explicate reasons for not to use sine bar for measuring angles more than 45°.

OR

Why sine bar is not suitable for measuring angles for more than 45°?

Nov.-15, (R13), Q1(d)

Answer :

The relationship between the angular setting accuracy ($d\theta$) and any error present in the combination of slip gauges (dH) or the spacing of the rollers (dL) can be obtained by differentiating the equation $\sin\theta = H/L$

$\sin\theta = H/L$

$\therefore$ By differentiation,

$$\cos\theta . d\theta = \frac{LdH - HdL}{L^2}$$

$$= \frac{dH}{L} - \frac{HdL}{L^2} = \frac{dH}{H} \times \frac{H}{L} - \frac{HdL}{L^2}$$

$$= \frac{dH}{H}\sin\theta - \frac{dL}{L}\sin\theta$$

$$= \sin\theta\left[\frac{dH}{H} - \frac{dL}{L}\right]$$

$$\therefore \quad d\theta = \tan\theta\left[\frac{dH}{H} - \frac{dL}{L}\right]$$

Thus, any error in spacing of rollers or combination of slip gauges is the function of the tangent of the angle 'θ'.

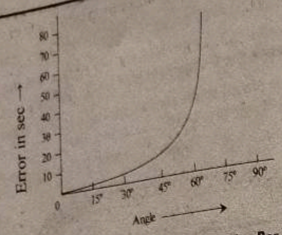


Figure: Angular Setting Errors in a Sine Bar

Therefore, as the angle increases, the errors also increases and above 45° the value is greater than unity. Hence, it is preferable not to use sine bar for measuring angles more than 45°.

4.3 MEASUREMENT OF FLAT NESS USING, STRAIGHT EDGES, SURFACE PLATES, OPTICAL FLAT AND AUTO COLLIMATOR

Q78. Enunciate,

(a) Flatness

(b) Straightness

Answer :

(a) **Flatness**

It is defined as the distance between the two parallel planes containing the surface. It is a geometrical quality of a perfect plane.

Flatness is determined by measuring the actual deviation from true planes at different points. The various methods of flatness testing are,

1. Spirit level method
2. Beam comparator
3. Auto collimator
4. Laser beam
5. Interference method.

The symbol for flatness is '▱' and in drawings flatness symbol with tolerance is mentioned as, | ▱ | 0.04 |.

(b) **Straightness**

The normal distance between the two straight lines indicates the straightness of the plane. Straightness can be checked, by using a straight edge, dial indicator or autocollimator. The guideways of lathe are made straight, in order to move the tool in straight path for making cylindrical surfaces.

Q79. What are the methods used for measuring the flatness and explain with neat sketches.

Answer : [Nov./Dec.-16, (R13), Q6 | Model Paper-II, Q9(a)]

1. **Flatness Comparators:** A beam comparator is used to measure the flatness of a surface. This method is highly accurate and rapid. The principle of checking the flatness involves in comparison of surface to be tested with a straight edge or a master plate, whose size is larger or similar than the test surface.

Since, there is no necessity for the master plate to be accurate, its flatness error must be known, for consideration during flatness testing.

Generally, a beam comparator instrument consists of a light beam body with three supports, where one support is fixed and is provided at the centre. The other two supports that are adjustable and are placed at the ends of the beam. Another supporting foot is also provided to prevent the falling or rolling of the beam over the surface. At the central part of the beam a sensitive dial indicator is fixed, in such a way that the line of action of plunger is same as that of the adjustable supports.

The flatness of a surface is checked multiple times and for each turn, the length of the movable feet (supports) are adjusted at various points on the surface and flatness is checked. Initially the readings are noted from the dial indicator by keeping the instrument over a reference master plate and then on the test surface and the process is repeated. Thus, the flatness error is known, when there exists a difference between the readings of master plate and test surface.

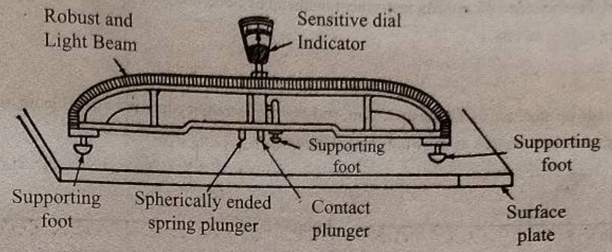


Figure (1): Beam Comparator

2. **Liquid Method:** In liquid method, the flatness testing is done by comparing the test surface with a liquid surface, which serves as a standard reference. This method is very quick and accurate. It is also suitable for checking the flatness of large work surfaces.

Mercury or dilute soda solution is filled in two cylinders which are connected at the base with a tube made up of rubber. These two cylinders are provided with micrometers, which are placed vertically over them, as shown in figure. To check the flatness, one cylinder is positioned at the centre of the surface and fixed. The other movable cylinder is positioned at various points over the test surface.

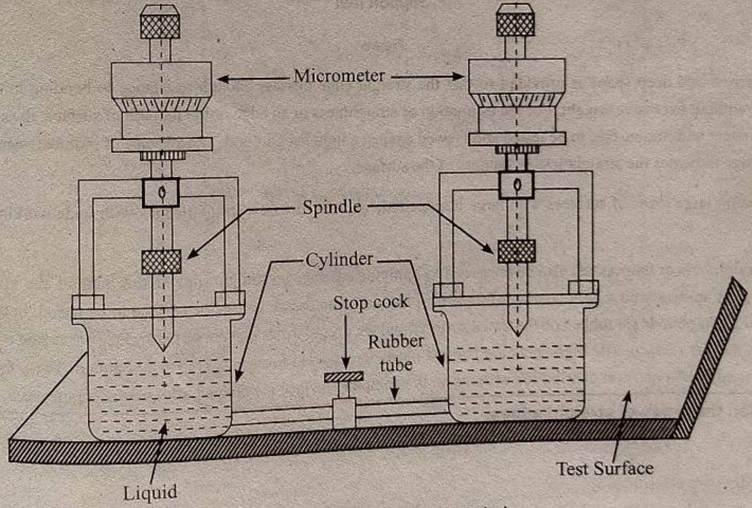


Figure (2) : Liquid Comparison Method

Then, by moving the spindles, till they touch the liquid surface, readings are noted for each position.

Thus, the error in flatness at each position can be known from the difference in two micrometer readings. It is necessary to check that there are no air bubbles present in the tube, while testing flatness. To restrict the flow of liquid from movable cylinder to fixed cylinder during testing, a stop cock is equipped in the tubing, as shown in figure (2).

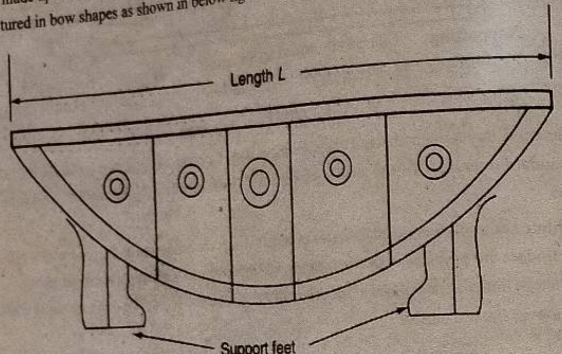
Q80. Explain briefly how straight edges are used for checking straightness or flatness

Answer :

For checking straightness or flatness, the straight edges are used in conjunction with surface plates and spirit levels. It is a narrow or thin, deep and flat-sectioned measuring instrument made up of steels and cast irons. The length of straight edges varies from several millimeters to few meters.

For Example

Straight edges made up steel are available up to 2 m, and cast iron straight edges are available up to 3 m. These are ribbed heavily and manufactured in bow shapes as shown in below figure.



Figure

The narrow and deep shape is provided so that the straight edge possess enough resistance to bending in the plane of measurement without excessive weight. For the estimation of straightness of an edge or the flatness of surface, the straight edge is placed in contact with the surface to be tested and viewed against a light background. The absence of light between the surface and straight edge indicates the straightness or flatness of the surface.

For testing large areas of surfaces with large intermediate gaps or recesses, straight edges with wide working edges are used.

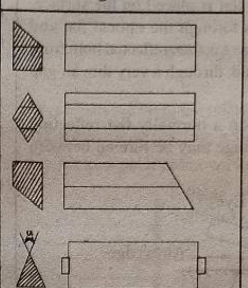
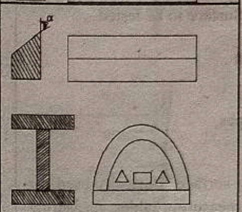
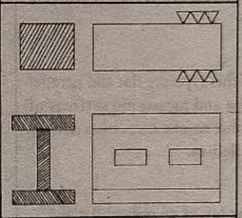
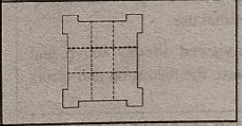
The straightness or flatness can also be measured by applying coatings on straight edge. In this method, the working edge of straight edge is applied with a light coating of Prussian blue, and then drawn across the surface to be tested. In this way, the trace of marking compounds are rubbed on the tested surfaces and the irregularities present on the surface are coated with different densities than the flat surface. The high spots are painted more densely and low spots are partly painted. Then, the surface is scraped or ground until a uniform distribution of spots on the complete surface is obtained after subsequent tests.

Q81. Mention the types of straight edges.

Answer :

The straight edges are classified as,

1. Tool maker's straight edges
2. Angle straight edges
3. Wide-edge straight edges
4. Box straight edge.

Type	Figure
Toolmaker's straight edges	
Angle straight edges	
Wide-edge straight edges	
Box straight edges	

Figure

Q82. Explain optical flat types and its limitations. Nov./Dec.-16, (R13), Q7(a)

OR

With a neat sketch explain the working of optical flat. Nov./Dec.-16, (R13), Q7(b)

OR

What is optical flat? What are their types? State the limitations of optical flat.

[Nov.-15, (R13) Q6(a) | Dec.-10, Set-4, Q3(a) | Model Paper-III, Q9(a)]

Answer :

Optical Flat

Optical flat provides precision and accuracy in the measurement of flatness.

Usually optical flats are cylindrical pieces of 25 mm to 300 mm in diameter and of thickness about $\frac{1}{6}$ th of the diameter. Optical flats are made up of transparent materials such as quartz, glass, sapphire, etc. The quartz optical flats are wieldy used because of its hardness, low coefficient of expansion, high corrosion resistance and longer life.

... are flat and parallel ... measuring surfaces of ... similar measuring devices ...

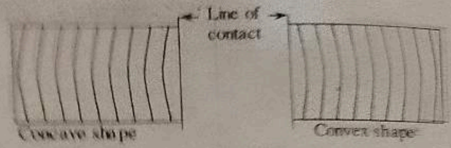
... the lay of an optical flat and to ... optimal use.

... viewed directly above, and ... cause the distortion and errors

... flat and monochromatic light ... to determine whether the ... flat or curved.

If the surface of testpiece is not flat, then the fringe pattern of alternate bands are curve shaped and circular bands are observed at the point of contact with a central bright spot.

To find whether the surface is convex or concave shape, the surface of testpiece is pressed with the finger at the edge tip. Thus, circular bands are disturbed and fringes gets closed, therefore the surface is convex shape. If circular bands are not disturbed by light pressure at the edge tip, then pressure is applied at the center of surface. Thus, the number of circular bands are reduced and move apart from the edge tip, this shows that surface is concave shape.



Figure

Q84. What is the difficulty in using the optical flat alone? How do you overcome this difficulty in the interferometer?

Answer : Nov./Dec.-17, (R15), Q7(b)

Limitations of Optical Flat

1. It is not easy to control the lay of an optical flat and to orient the fringes to its optimal use.
2. The fringe pattern is not viewed directly above, and resulting obliquity can cause distortion and errors in viewing.

An interferometer overcomes these problems, by means of refined arrangements. In interferometers, the lay of the optical flat can be controlled, and fringes can be oriented to the best advantages. An arrangement is provided so that it is possible to view the fringes directly from top and above the fringes.

Q85. With neat sketch explain the working principle of auto collimator. Nov-15, (R13), Q6(b)

OR

Explain the optical system of an auto collimater used for examination of plane surfaces. May-10, Set-1, Q8(b)

OR

Explain with a neat sketches, the principle and working of an auto collimator and also list its applications.

OR

Explain the construction and working principle of an autocollimator with a neat diagram.

Answer : Model Paper-I, Q9(b)

Autocollimeter is an optical instrument, which performs the functions of both optical tools (collimator and telescope). It is used for determining small angles with high degree of accuracy. Also it is used for checking straightness, flatness and parallelism.

Basic Working Principle

Autocollimator works on the principle that if a beam of light is projected on plane reflector which is perpendicular to the optical axis, the beam is reflected back along the same path as illustrated in figure (1). But, a slight change in the position of the plane reflector, will change the path of the light beam and is focused at a new point as shown in figure (2).

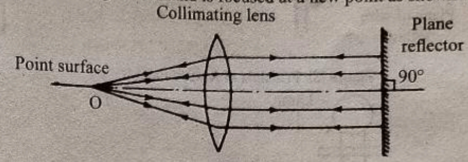


Figure (1)

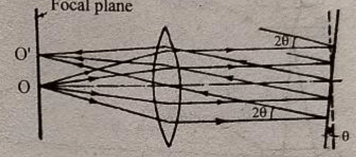


Figure (2)

The distance from OO' is given as,

$x = 2.\phi.f$

Where,

θ = Angle of inclination of the plane reflector.

f = Focal length.

Construction and Working

An autocollimator is equipped with the following components.

1. Cross line graticule at focal plane
2. Beam splitter
3. Objective lens
4. Plane reflector
5. Measuring/setting graticule.

Since, autocollimator is the combination of the telescope and collimator, it works on the principles of both the tools.

As Collimator: Initially, the light from the light source (lamp) illuminates the cross line graticule which is placed at the focal plane of objective lensor collimator lens and the diverged light rays from the graticule reaches the beam splitter, where they are reflected on to the objective. The light rays turn into parallel steam and projects onto the plane reflector, which is exactly perpendicular to the optical axis.

As Telescope: The parallel stream of light rays, which incident on the reflector are deflected back, where they intersect with the plane of target graticule. They, the light rays reaches the eyepiece through the beam splitter. This part of working of autocollimator illustrates a telescope.

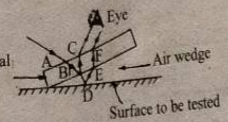
When the plane reflector is not perpendicular to the optical axis (i.e., if rotated about an angle, θ) the stream of light rays also deflect at a certain angle, equal to the twice the angle of tilt. And the distance between two focus points (i.e., O and O').

$x = 2.\phi.f$

Thus, the distance between the two focus points (OO') is directly proportional to the tilt angle of the reflector.

Generally, it is used for checking the flatness of a surface. To check the flatness the optical flat is placed on the surface. The monochromatic light passes through the optical flat and strikes the workpiece. The light wave is then reflected both from optical flat and surface being tested, through a very thin air gap between the two surfaces.

If an optical flat is laid on a normally flat reflecting surface, a wedge shaped air passage may be formed between the surfaces.



Figure

Types of Optical Flats

Optical flats are of two types,

Type A

It has single flat working surface. Basically used for testing the flatness of precision measuring tables, measuring surfaces of flats, slip gauges, etc.

Type B

Both working surfaces of this type are flat and parallel to each other. It is used for testing and measuring surfaces of anvils, meters, micrometers, and other similar measuring devices used for testing flatness and parallelism.

Limitations of Optical Flat

1. It is not easy to control the lay of an optical flat and to orient the fringes to its optimal use.
2. The fringe pattern is not viewed directly above, and resulting obliquity can cause the distortion and errors in viewing.

Q83. By using optical flat and monochromatic light explain the procedure to determine whether the given surface is flat or curved.

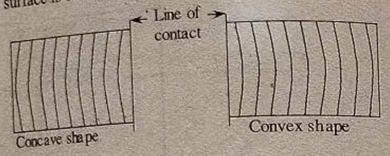
Answer : May-10, Set-2, Q7(a)

The surface to be tested is placed under an optical flat and a monochromatic light is illuminated on the optical flat Therefore, interference fringes are observed. The interference fringes are alternate bands (i.e., dark and bright) and are formed by a thin layer of air gap between the bottom surface of an optical flat and top surface of testpiece.

When the surface of test piece is perfectly flat, then the fringe pattern of alternative bands are dark, straight, parallel and equispaced on the surface. At this point, if light pressure is applied at any edge of surface, then no changes occurred in the fringe pattern.

If the surface of testpiece is not flat, then the fringe pattern of alternate bands are curve shaped and circular bands are observed at the point of contact with a central bright spot.

To find whether the surface is convex or concave shape, the surface of testpiece is pressed with the finger at the edge tip. Thus, circular bands are disturbed and fringes gets closed, therefore the surface is convex shape. If circular bands are not disturbed by light pressure at the edge tip, then pressure is applied at the center of surface. Thus, the number of circular bands are reduced and move apart from the edge tip, this shows that surface is concave shape.



Figure

Q84. What is the difficulty in using the optical flat alone? How do you overcome this difficulty in the interferometer?

Answer : Nov./Dec.-17, (R15), Q7(b)

Limitations of Optical Flat

1. It is not easy to control the lay of an optical flat and to orient the fringes to its optimal use.
2. The fringe pattern is not viewed directly above, and resulting obliquity can cause distortion and errors in viewing.

An interferometer overcomes these problems, by means of refined arrangements. In interferometers, the lay of the optical flat can be controlled, and fringes can be oriented to the best advantages. An arrangement is provided so that it is possible to view the fringes directly from top and above the fringes.

Q85. With neat sketch explain the working principle of auto collimator. Nov-15, (R13), Q6(b)

OR

Explain the optical system of an auto collimater used for examination of plane surfaces. May-10, Set-1, Q8(b)

OR

Explain with a neat sketches, the principle and working of an auto collimator and also list its applications.

OR

Explain the construction and working principle of an autocollimator with a neat diagram.

Answer : Model Paper-I, Q9(b)

Autocollimeter is an optical instrument, which performs the functions of both optical tools (collimator and telescope). It is used for determining small angles with high degree of accuracy. Also it is used for checking straightness, flatness and parallelism.

Basic Working Principle

Autocollimator works on the principle that if a beam of light is projected on plane reflector which is perpendicular to the optical axis, the beam is reflected back along the same path as illustrated in figure (1). But, a slight change in the position of the plane reflector, will change the path of the light beam and is focused at a new point as shown in figure (2).

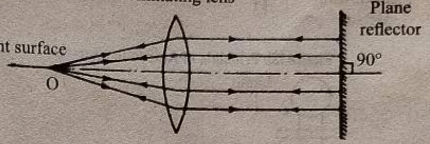


Figure (1)

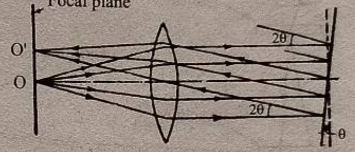


Figure (2)

The distance from OO' is given as,

$x = 2.\phi.f$

Where,

θ = Angle of inclination of the plane reflector.

f = Focal length.

Construction and Working

An autocollimator is equipped with the following components.

1. Cross line graticule at focal plane
2. Beam splitter
3. Objective lens
4. Plane reflector
5. Measuring/setting graticule,

Since, autocollimator is the combination of the telescope and collimator, it works on the principles of both the tools.

As Collimator: Initially, the light from the light source (lamp) illuminates the cross line graticule which is placed at the focal plane of objective lensor collimator lens and the diverged light rays from the graticule reaches the beam splitter, where they are reflected on to the objective. The light rays turn into parallel steam and projects onto the plane reflector, which is exactly perpendicular to the optical axis.

As Telescope: The parallel stream of light rays, which incident on the reflector are deflected back, where they intersect with the plane of target graticule. They, the light rays reaches the eyepiece through the beam splitter. This part of working of autocollimator illustrates a telescope.

When the plane reflector is not perpendicular to the optical axis (i.e., if rotated about an angle, θ) the stream of light rays also deflect at a certain angle, equal to the twice the angle of tilt. And the distance between two focus points (i.e., O and O').

$x = 2.\phi.f$

Thus, the distance between the two focus points (OO') is directly proportional to the tilt angle of the reflector.

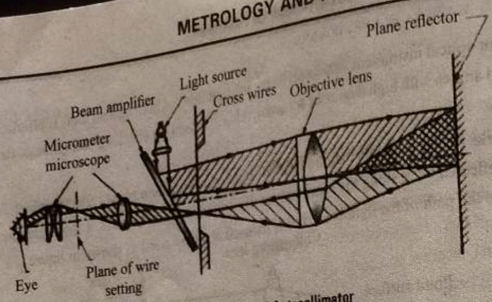


Figure (3): Principle of Autocollimator

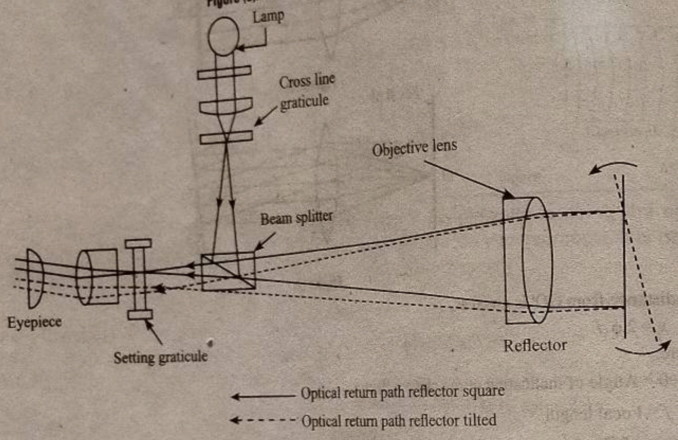


Figure (4): Line Diagram of Autocollimator

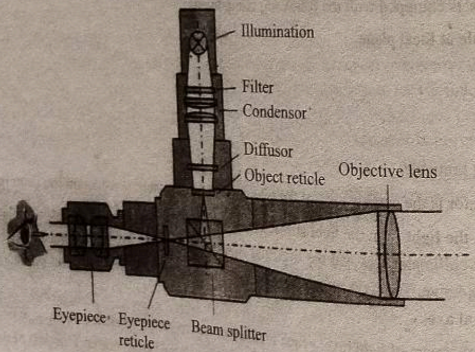


Figure (5): Visual Autocollimator

Characteristics of Autocollimator

1. Any other equipment is not required for focusing.
2. It does not respond to any external factors, except to the tilt of the reflector.
3. High repeatability can be achieved, when the autocollimator and target remain unchanged.

Factors Affecting the Performance of Autocollimator

Among many factors, focal length (f) and effective aperture of objective lens are the two factors which affect the performance of autocollimator. Sensitivity, angular measurement range and displacement of graticule image are dependent on the focal length, whereas working distance (distance between autocollimator and reflector) is regulated by the aperture of objective lens. For more working distance, large reflector must be used.

Disadvantages of Autocollimator

1. The designing of autocollimator is complicated.
2. The final readings are altered due to the air in between the reflector and autocollimator.
3. The flatness and reflectivity of the plane reflector also leads to errors.

Applications

1. It is used for measuring straightness and flatness of surfaces.
2. For evaluating the squareness and parallelism of components.
3. Autocollimator combined with polygons is used for precise angular indexing.
4. Autocollimator is also used in machine tool adjustments.
5. With the aid of master angles, it is used for comparative measurement of components.
6. To measure small linear dimensions.

Q86. Discuss the method of testing the straightness by spirit level and auto collimator.

Answer : [Nov./Dec.-17, (R15), Q7(a) | Model Paper-II, Q9(b)]

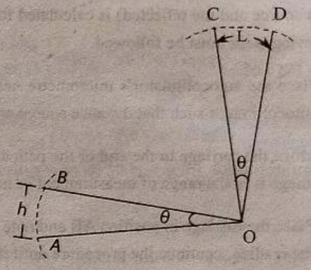
Spirit level mainly comprises of an enclosed glass tube which is attached to a cast iron base. The inner surface of the tube is finished to a large radius convex shape. This radius of curvature of the tube affects the precision or sensitivity of the spirit level. The upper surface of the tube is graduated with a scale. A small bubble of air or vapour is formed inside the tube by filling it with ether or alcohol.

Working Principle

It indicates the flatness of the surface with the position of the bubble i.e., if the spirit level is kept on a horizontal surface, the bubble settles at the middle of the scale. This is because the bubble tends to settle at the highest point in the tube and the centre point is its highest point.

When it is moved by an angle, the bubble starts moving along the tube by a distance through its radius with respect to the angle made by the base.

Figure represents two positions of the base of spirit level i.e., OA and OB and respective bubble positions C and D.



Figure

Consider,

θ – Small angle through which the base is tilted.

l – Distance travelled by the bubble.

h – Difference in heights between the ends of the base

L – Base length

R – Radius of curvature of the tube

Then,

$$l = R\theta \quad \text{... (1)}$$

And, $h = L\theta$

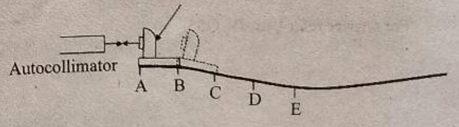
$$\theta = \frac{h}{L} \quad \text{... (2)}$$

From equations (1) and (2),

$$l = h.\frac{R}{L}$$

Thus, sensitivity of spirit level depends upon the length of bubble, internal radius of the tube and the radius of curvature.

2. **Autocollimator**



Figure

Measurement of Straightness

Consider a path ABCDE as shown in the figure. Initially, the reflector is placed on the carriage and is positioned on the path AB. Then the carriage is allowed to move to successive positions BC, CD etc. The gap between the points A, B, C... etc is equal to the length of the carriage which is equal to 50mm. If the path is not straight, the carriage will tilt at an angle. This angle is determined by the autocollimator and the difference in height of the two ends or extremes of the carriage (or distance between the point source and the reflected) is calculated for every position of the carriage. In order to check the straightness of the path the following steps must be followed.

1. Place the autocollimator's micrometre nearby carriage to measure vertical displacements. Then adjust the base of the autocollimator such that distance source and reflected image is nearly zero.
2. Move the carriage to the end of the path and check the reflected image through the eyepiece to ensure that the reflected image is in the range of measurement or not. If it is not in range then make fine levelling to the collimator.
3. Place the carriage in position AB and note the reading of autocollimator. Then move the carriage to position BC and take the reading, continue the procedure until the carriage reaches the end of the path.
4. Repeat the same in reverse direction i.e., moving the carriage from the end position to initial position.
5. Determine the average of readings at each position.

Q87. Bring out the importance and utility of straight edge and surface plate in laboratories.

Answer : [Nov./Dec.-17, (R15), Q6(b) | Model Paper-III, Q9(b)]

Straight Edge

For answer refer Unit-IV, Q80.

Surface Plate

For answer refer Unit-IV, Q33.

Surface plate forms the basis of a measurement. These are widely used in workshops and metrological laboratories, where inspection is carried out.

Q88. Describe a method used to check the flatness of a surface plate.

Answer : Nov.-15, (R13), Q5(a)

For answer refer Unit-IV, Q79. Topic: Flatness Comparators.

Q89. Explain the principle of optical flat and auto collimator.

Answer: Nov./Dec.-18, (R16), Q8(b)

Optical Flat

For answer refer Unit-IV, Q82, Topic: Optical Flat.

Autocollimator

For answer refer Unit-IV, Q85.

EXERCISE QUESTIONS

Q1. Calculate the dimensions of plug and ring gauges to control the production of 50 n m shaft and hole pair of H_7d_8 as per I.S. specification. The following assumptions may be made: 50 mm lies in diameter step of 30 and 50 mm and the upper deviation for 'd' shaft is given by $-16D^{0.44}$ and lower deviation for hole H is zero. Tolerance factor i (microns): $0.45\sqrt[3]{D} + 0.001D$ and IT6 = 10i and above IT6 grade the tolerance magnitude is multiplied by 10 at each fifth step.

[Plug Gauge:

'Go' Gauge: $\left.\begin{matrix}50.000\\50.0025\end{matrix}\right\}$ mm 'No Go' Gauge: $\left.\begin{matrix}50.0248\\50.0273\end{matrix}\right\}$ mm

Ring Gauge: Dimensions for

'Go' Gauge: $\left.\begin{matrix}49.9161\\49.9200\end{matrix}\right\}$ mm 'No Go' Gauge: $\left.\begin{matrix}49.8770\\49.8809\end{matrix}\right\}$ mm

Q2. Determine the dimensions and tolerances of shaft and hole having size of 30 H_7 / h_8 fit. Also determine the allowance (i.e. minimum clearance) and maximum clearance.

[Minimum size of hole = 30.0000 mm

Maximum size of hole = 30.0021 mm

Minimum size of shaft = 29.9967 mm

Maximum size of shaft = 30.0000 mm

Minimum clearance = 0

Maximum clearance = 0.0054 mm]

Q3. Design a workshop type progressive type Go-Not-Go plug gauge suitable for 25H7, with the following information:

(i) 25 mm lies in the diameter step of 18-30 mm.

(II) $i = 0.45\sqrt[3]{D} + 0.001\,D$

(iii) IT 7 = 16i.

[Go gauge : $25^{+0.0021}_{+0.000}$

No-Go gauge : $25^{+0.021}_{+0.0189}$]

IMPORTANT QUESTIONS

Q1. Define the terms,

(i) Allowance

(ii) Limits

(iii) Tolerance

(iv) Fits. Refer Unit-IV, Q42

Q2. Draw the conventional diagram of limits and fits and explain the terms,

(i) Basic size

(ii) Upper deviation

(iii) Lower deviation

(iv) Fundamental deviation. Refer Unit-IV, Q43

Q3. What are the different types of fits and explain with neat sketches? Refer Unit-IV, Q44

Q4. Compare and contrast unilateral and bilateral tolerance system. Refer Unit-IV, Q45

In a limit system, the following limits are specified to give clearance between a shaft and hole.

Shaft : $30^{-0.005}_{-0.018}$ mmϕ

Hole : $30^{-0.020}_{-0.000}$ mmϕ

Determine :

(i) Shaft and hole tolerance

(ii) The shaft and hole limits

(iii) The maximum and minimum clearance. **Refer Unit-IV, Q49**

Q6. Differentiate between hole basis system and shaft basis system. **Refer Unit-IV, Q51**

Q7. Write short notes on converting a hole based fit into an equivalent shaft based fit. **Refer Unit-IV, Q52**

Q8. Convert hole based fit Equivalent to the shaft based fit with neat sketch,

(i) 25 H_8c_7

(ii) 30 H_5n_9. **Refer Unit-IV, Q53**

Q9. A 50 mm diameter shaft is made to rotate in the bush. The tolerances for both shaft and bush are 0.050 mm. Determine the dimension of the shaft and the bush to give a maximum clearance of 0.075 mm with the hole basis system. **Refer Unit-IV, Q54**

Q10. A shaft with a nominal size of 42 mm is fitted with an inner ring. The fitting condition is K5/h6.

(i) Determine the type of fit between the shaft and the hole.

(ii) Mention, whether it is a hole-based or a shaft-based. **Refer Unit-IV, Q55**

Q11. How does selective assembly differ from an interchangeability with reference to manufacturing? **Refer Unit-IV, Q56**

Q12. What are the advantages of interchangeability? **Refer Unit-IV, Q57**

Q13. Explain the concept of selective assembly. Discuss its significance in manufacturing. **Refer Unit-IV, Q58**

Q14. Describe principal features of the Indian standard system of limits and fits for plain work. **Refer Unit-IV, Q59**

Q15. State and explain the Taylor's principle of gauge design with neat sketch of Plug gauge and Snap gauges? **Refer Unit-IV, Q61**

Q16. What are the advantages and limitations of GO and NO GO gauges? **Refer Unit-IV, Q67**

Q17. Write a short note on the various aspects for deciding the limits on the limit gauges. **Refer Unit-IV, Q68**

Q18. Design the general type of GO and NO-GO gauge for components having 20H7/f8 fit. i = 0.45 (D 1/3) +0.001 D, upper deviation of "f" shaft = –5.5 $D^{0.41}$, 20 mm falls from the diameter step of 18-30, IT7 = 16i, IT8 = 25i, wear allowance = 10% of gauge tolerance. **Refer Unit-IV, Q69**

Q19. Shafts of 75 ± 0.02 mm diameter are to be checked by the help of GO and NO-GO ring gauges. Design the Gauge, sketch it and show GO size and NO-GO size dimensions. Assume normal wear allowance and Gauge maker's tolerance. **Refer Unit-IV, Q70**

Q20. A hole and shaft system had the following dimensions: 60 H 8 /c 8

The multiplier of grade 8 is 25.

The fundamental deviation for 'C' shaft is – (9.5 + 0.8 D).

The diameter slip is 50 – 80.

Design the suitable 'GO' and 'NO-GO' gauges for shaft and hole. **Refer Unit-IV, Q71**

Q21. Explain the construction and working of a bevel protractor. **Refer Unit-IV, Q72**

Q22. Explain the in detail the working of sine bar and what are its limitations? **Refer Unit-IV, Q76**

Q23. Explicate reasons for not to use sine bar for measuring angles more than 45°. **Refer Unit-IV, Q77**

Q24. What are the methods used for measuring the flatness and explain with neat sketches. **Refer Unit-IV, Q79**

Q25. Explain optical flat types and its limitations. **Refer Unit-IV, Q82**

Q26. By using optical flat and monochromatic light explain the procedure to determine whether the given surface is flat or curved. **Refer Unit-IV, Q83**

Q27. What is the difficulty in using the optical flat alone? How do you overcome this difficulty in the interferometer? **Refer Unit-IV, Q84**

Q28. With neat sketch explain the working principle of auto collimator. **Refer Unit-IV, Q85**

Q29. Discuss the method of testing the straightness by spirit level and auto collimator. **Refer Unit-IV, Q86**

Q30. Bring out the importance and utility of straight edge and surface plate in laboratories. **Refer Unit-IV, Q87**

Q31. Describe a method used to check the flatness of a surface plate. **Refer Unit-IV, Q88**

Q32. Explain the principle of optical flat and auto collimator. **Refer Unit-IV, Q89**

UNIT 5

METROLOGY OF SURFACE FINISH AND MACHINE TOOLS

Syllabus

Surface Roughness Measurement : Roughness, Waviness, CLA, RMS, R_z Values. Methods of measurement of surface finish, Talysurf. Screw thread measurement, Gear measurement. Machine tool alignment tests on Lathe, Milling and Drilling machines. Coordinate measuring machines : Types and Applications of CMM.

LEARNING OBJECTIVES

On the completion of this unit, the student shall be able to understand the following concepts,

- Roughness and Waviness
- Measurement of CLA, RMS and Rz values
- Methods of surface finish measurement
- Measurement of gear parameters
- Alignment tests on Lathe, Milling and Drilling machines
- Working principle and Types of CMM

INTRODUCTION

In any manufacturing industry, dimensional control is an important factor to achieve quality and reliability in the service. Dimensional accuracy of any product depends upon its form or geometrical shape. Form of a machine component plays a vital role in their functionality, especially in case of mating parts. Form measurement includes measurement of straightness, flatness, roundness, cylindricity, squareness, etc. It also includes checking the form of threads and gear teeth, etc. For form measurement, various inspection methods and instruments (from basic to sophisticate level) are available.

Geometric accuracy significantly influences the product quality and precision to be maintained during the service life of a machine tool. Machine tool metrology is the distinct field of metrology, primarily deals with geometric tests (alignment) of machine tools under static and dynamic conditions. Geometric tests are carried out to check the grade of manufacturing machine tools under static and dynamic conditions. Alignment tests check the accuracy describing the degree of accuracy with which a machine tool has been assembled. Alignment tests check the relationship between various elements such as forms and positions of machine-tool parts and displacement relative to one another, when the machine tool is unloaded.

PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. Write about surface roughness.

Answer :

The surfaces which are produced by using different processes will have irregularities and imperfections on it. The irregularities are in the form of succession of peaks and valleys, which varies in their heights and spacing. These irregularities are termed as surface roughness, surface finish or surface texture.

Generally, the cutting processes such as lapping and honing produces an irregular and multidirectional texture, whereas the finishing processes such as grinding have an irregular unidirectional texture. The other cutting processes such as turning, boring, shaping, etc., produces a unidirectional texture.

Q2. Describe the importance of surface roughness? [Nov./Dec.-18, (R16), Q1(l) | Model Paper-I, Q1(i)]

Answer:

Surface roughness plays a vital role in the performance of machine components. The components mainly fail due to high stress concentration produced by surface irregularities in the form of sharp corners. The properties of the components which are affected by surface roughness are appearance, hardness, friction, lubrication, absorption capacity, resistance to wear, fatigue and corrosion, etc.

In some cases, the surface roughness is useful because it possesses good bearing condition, which helps in lubrication between two mating components. Hence, for different applications, the surface roughness may be advantageous or disadvantageous. In any manufacturing process, it is difficult to produce an absolute smooth surface or same surface texture on all the components.

Q3. How is surface roughness assessed?

Answer :

The following three methods are used for assessing the surface roughness.

1. Peak to valley height method
2. The average roughness method
3. Form factor or bearing curve method.

Q4. State the various factors affecting on surface texture in detail? May/June-19, (R16), Q10(a)

OR

What are the factors affecting surface roughness?

Answer :

Factors Affecting Surface Roughness

1. Type of workpiece material.
2. Properties of cutting tool such as material, type, sharpness, etc.
3. Vibrations occurring in the system.
4. Type of machining process employed.
5. Type of coolant used.
6. Cutting speed, feed and depth of cut.
7. Rigidity of the system which comprises of machine tool, cutting tool and work material.

Q5. Differentiate between roughness and waviness. Dec.-19, (R16), Q1(i)

OR

Distinguish between surface roughness and surface waviness? May/June-19, (R16), Q11(a)

OR

Explain the terms Roughness, Waviness and Lay.

Answer : [Nov.-15, (R13), Q1(h) | Model Paper-II, Q1(i)]

Roughness

The roughness is defined as the surface irregularities whose wavelength is small. It is also called as primary texture. These irregularities are produced due to the direct action of the cutting parameters such as the shape of tool, tool feed rate and the other disturbances such as friction, wear or corrosion on the material.

These irregularities include third and fourth order irregularities and micro-geometrical errors.

For micro errors, $\frac{l_r}{h_r} < 50$

Where,

l_r – Length along the surface

h_r – Deviation of surface from the ideal surface

Waveness

The surface irregularities of significantly higher wavelength of a periodic character are called waviness or secondary texture. These irregularities arise due to the inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work which is acted upon by cutting forces and vibrations of machine tool, etc.

These irregularities include first and second order irregularities and macro-geometrical errors.

For macro-geometrical errors, $\frac{l_w}{h_w} < 50$

Where,

l_w – Length along the surface

h_w – Deviation of surface from ideal surface.

Lay

It indicates the direction of surface pattern produced by the tool marks or scratches. The lay can be defined based on the method of production.

Q6. Show the schematic representation of roughness on machined components.

Answer :

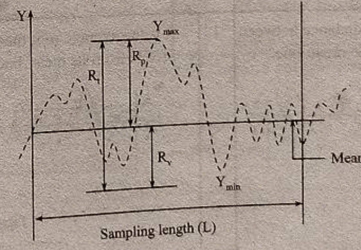


Figure: Schematic Representation of Roughness on Machined Component

Where,

R_t – Maximum peak to valley height

R_p – Maximum peak to mean height

R_v – Mean to valley height.

Q7. Define traverse length.

Answer :

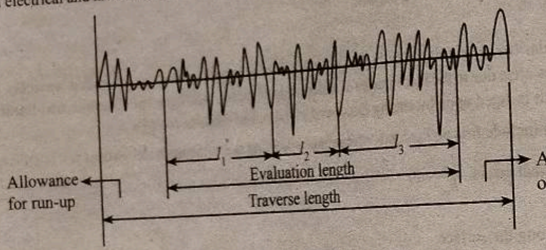
Traverse length is defined as the overall length traversed by the stylus while evaluating the surface texture of a component. It is equal to the sum of the pre-travel, evaluation length and post travel length. Traverse length consists of more than one sampling length.

Q8. Is assessment length greater/lesser than traverse length in surface finish measurement? Why?

Answer :

The total length in the direction of x-axis over which surface finish is evaluated on the work piece is called as assessment length. Sometimes, it is referred as evaluation length. Generally assessment length is divided into 5 equal parts known as sampling lengths, for determining roughness and waviness profiles on workpiece.

Generally assessment length is less than traverse length because traverse length also include the run-up and over travel allowances, which are added at both the ends of assessment length. Allowances are added, to remove the effects of filter edges together with electrical and mechanical transients from the measurement.



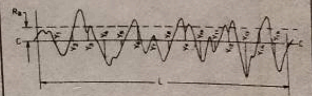
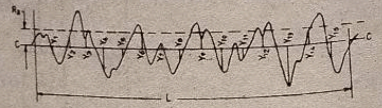
Figure

Q9. What do you mean by RMS and CLA? May/June-19, (R16), Q1(i)

OR

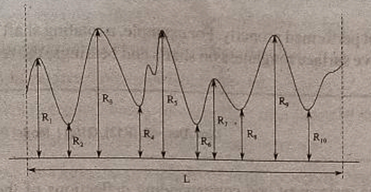
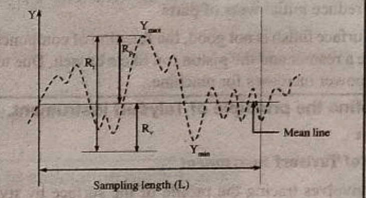
Distinguish between CLA and RMS method.

Answer : [Nov.-15, (R13), Q1(g) | Model Paper-III, Q1(i)]

	CLA Method		RMS Method
1.	It is the arithmetic mean of the distance between the points on the profile from the mean line.  Figure	1.	It is the average root mean square of deviation Y of the profile from its mean line within the sampling length,  Figure
2.	$R_a = \frac{Y_1+Y_2+Y_3+Y_4+...Y_n}{L}$ Where, n – Number of ordinates i the sampling length L.	2.	R_q or RMS $= \sqrt{\frac{Y_1^2+Y_2^2+Y_3^2+...+Y_n^2}{n}}$ Where, n – Number of ordinates in the sampling length L
3.	It is also known as arithmetic average or arithmetic mean deviation	3.	It is also known as roughness average or geometric mean.

Q10. What is the difference between R_z and R_t?

Answer :

	R_Z		R_t
1.	R_z is ten point peak to valley average height.	1.	R_t is maximum peak to valley height.
2.	It is the simplest method used to measure the total depth of the surface roughness. This is the average difference between the five highest peaks and the five deepest valleys over a sampling length, measured parallel to the direction of the profile.	2.	It is the sum of highest peak and lowest valley.
3.	 Figure	3.	 Figure
4.	Formula: $R_z = \frac{1}{5}[(R_1+R_3+R_5+R_7+R_9) - (R_2+R_4+R_6+R_8+R_{10})]$	4.	Formula: $R_t = R_P + R_V$.

Q11. Differentiate between direct and indirect method of measurement of surface roughness.

Answer :

Direct and Indirect Methods of Roughness Measurement

	Direct Method of Measurement of Roughness		Indirect Method of Measurement of Roughness
1.	This method enables to determine a numerical value of the surface finish of any surface.	1.	In this method, the surface texture is measured by comparison methods.
2.	It is a reliable method.	2.	Not reliable and causes errors in result.
3.	It operates on electrical principles.	3.	It operates on comparison principles.
4.	All instruments used are stylus probe type of instruments.	4.	Examples: Touch inspection, visual inspection, scratch inspection, etc.

Q12. What are the disadvantages of direct method of surface roughness measurement?

Answer :

1. In these methods, the machine process should be interrupted.
2. The sharp diamond stylus produces mico-scratches on the surface.
3. Errors in measurement occur, due to surface waviness.

Q13. Write a note on the adverse effects of poor surface finish. Nov./Dec.-17, (R15), Q1(g)

Answer :

The Effects of Poor Surface Finish

1. Wear resistance of the surface reduces.
2. Reduced service life of the parts.
3. Low fatigue resistance.
4. Corrosion resistance of the surface is less.
5. Close dimensional tolerances cannot be achieved.

Q14. What are the reasons for controlling the surface texture? Nov./Dec.-16, (R13), Q1(h)

OR

State reasons for controlling the surface finish.

Answer :

Following are the important reasons for controlling the surface finish,

1. To minimize the frictional wear of parts.
2. For improving the service life of the parts.
3. Minimising corrosion by reducing in depth of irregularities.
4. For improving the fatigue resistance.
5. For having a close dimensional tolerance on the components.
6. For good appearance.
7. To reduce initial wear of parts
8. If surface finish is not good, the function of component can not performed properly. For example, a rotating shaft may work like a reamer and the piston rod like a broach. Due to excessive surface roughness on shafts and bearings, the requirement of power increases for machine.

Q15. Define the principle of Talysurf instrument. [Nov./Dec.-16, (R13), Q1(g) | Model Paper-I, Q1(j)]

Answer :

Principle of Taylsurf Instrument

It involves tracing the profile of the surface by stylus of the instrument and corresponding deflections of the stylus is converted into change in electric current.

Q16. What are the merits of Tomlinson surface recorder and Talysurf machine?

Answer :

Merits of Tomlinson Surface Recorder

1. It is economical.
2. The results of this instrument maintains desired accuracy.
3. It gives reliable results.

Merits of Talysurf Machine

1. The response of machine is more rapid and accurate.
2. Magnifications can be obtained electrically and therefore for the analysis of surface texture parameters, the output of the instrument can be based on micro-processor.
3. From the talysurf trace, average waviness of surface texture, quantitative estimates of maximum roughness can be easily evaluated.

Q17. Name the common instruments and methods used for screw thread measurement.

Answer : May/June-12, (R09), Q5(b)

The various screw thread parameters measured in metrology and the corresponding instruments required for measurement are tabulated below.

S.No.	Parameter	Instruments and Methods
1.	Major diameter	Ordinary microscope, bench microscope.
2.	Minor diameter	Floating carriage diameter measuring machine and two V-Pieces.
3.	Minor diameter of internal thread	Taper parallels, rollers and slip gauges.
4.	Effective diameter	Thread micrometer, two or three wire methods.
5.	Effective diameter of internal thread	Horizontal comparator with detachable small ball ended stylii
6.	Thread angle and profile	Vernier protractor, NPL protractor, optical profile projector, pin measurement
7.	Pitch	Tool makers microscope, screw pitch gauge, pitch measuring machine.

Q18. What is a drunken thread? Explain.

Answer : Nov./Dec.-17, (R15), Q1(j)

Drunken thread is defined as the thread which has irregular pitch. The movement of helix in one complete revolution of thread is erratic or irregular. It is a special case of periodic error in pitch measurement. The periodic error is repeated at the intervals of single pitch. The measurement of pitch parallel to the axis of thread will be accurate and correct, but the error occurs due to improper cut of true helix on the thread (i.e., helix is curve in drunken thread instead of straight). This type of error will not effect the thread to a great extent in working, except in case of very large size threads. It is complex to find this type of errors.

Q19. What is the effect of pitch error on effective diameter?

Answer : [May/June-12, Set-2, Q6(b) | Model Paper-II, Q1(j)]

The important effects of pitch errors on the effective diameter are as follows,

1. It increases the effective diameter of screw or bolt.
2. It decreases the effective diameter of nut.
3. The clearance is considerably reduced.
4. It will not screw easily into a perfect ring gauge of same nominal size.
5. Interference between mating threads increases.

Q20. How is Taylor's principle of limit gauging applicable in estimating pitch errors?

Answer :

According to the Taylor's principle, the GO and NO GO gauge is designed to check geometrical features, size of component and only one dimension respectively. Hence, the GO gauge is made to the full length and maximum diameter of screw thread, whereas NO GO gauges are made to check major and effective diameter of screw thread. Thus, pitch errors causing reduction in effective diameter and inaccurate results are also eliminated.

Q21. What are progressive errors in screw threads?

Answer : Nov.-15, (R13), Q1(i)

Progressive error occurs due to the incorrect tool-work velocity ratio. It may also be caused by using an inappropriate (or) incorrect gear train between work and tool lead screw. For example, When producing a metric thread with an inch pitch lead screw with no translatory gear, progressive pitch errors may occur.

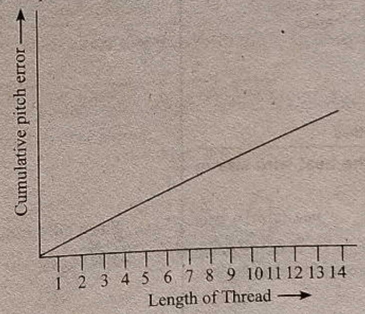


Figure: Progressive Pitch Error

Q22. Write about the measurement of major diameter of external threads using ordinary micrometer.

Answer :

An ordinary micrometer is the simplest type among all the micrometers and it is quite suitable for measuring the major diameter of screw thread. Generally, the micrometers are used as comparators. It is first adjusted for the appropriate cylindrical size (S) and is slightly similar to the size (D) of major diameter. This setting is known as "gauge setting". After taking the reading as R_1, the micrometer is adjusted on the major diameter of thread and readings are noted as R_2.

Then, the major diameter is calculated as,

$$D = S \pm (R_1 - R_2)$$

Where,

D – Major diameter of screw thread

S – Size of the setting gauge

R_1 – Micrometer reading on setting gauge

R_2 – Micrometer reading on thread.

Q23. Write short notes on one wire method of measuring effective diameter of thread?

Answer :

In one wire method, effective diameter is measured by placing one wire between two threads at one side and the anvil of the measuring micrometer, which contacts the crests on the other side. Initially, the micrometer reading d_1 is noted on a standard gauge whose dimension is approximately same as to be obtained by this method. The setting gauge is then replaced by thread under test. Let this reading be d_2. Then, the effective diameter is given as,

$$D = \pm (d_1 - d_2).$$

Where, D – Size of setting gauge.

If $d_2 > d_1$, + ve sign is used

If $d_2 < d_1$, – ve sign is used

This method is used for measuring effective diameter of counter pitch threads, during manufacturing of threads.

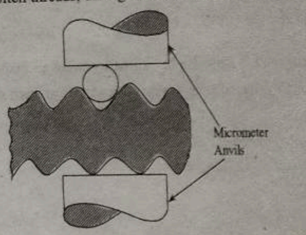


Figure: One Wire Method

Q24. Derive an expression for the best wire size in screw threads.

Answer : Nov.-15, (R13), Q1(j)

If there is no error in the thread angle, the diameter of the wire where it touches the flank of the thread exactly on the pitch line is called as best wire.

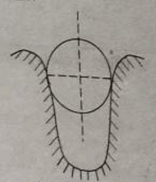


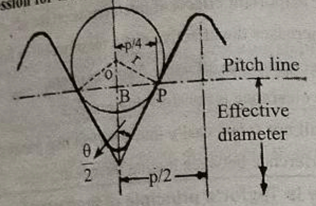
Figure: Best Wire

The inspection of the effective diameter from a reading over such wires is independent of any error in the thread angle.

The best wire sizes are as follows,

S.No.	Form of Thread	"Best Wire" Diameter
1.	B.A	0.546 p
2.	Metric and American	0.577 p
3.	Whitworth	0.564 p

Expression for the Size of the Best Wire



Figure

From the figure,

θ – Angle of thread

OP – Radius of the wire (r)

d – Size of the best wire.

p – Pitch of the thread.

Consider Δ OPB,

$$\sin\left(90 - \frac{\theta}{2}\right) = \frac{PB}{OB}$$

$$OB = \frac{PB}{\sin\left(90 - \frac{\theta}{2}\right)}$$

$$OB = \frac{PB}{\cos\frac{\theta}{2}} = PB \sec \theta/2$$

$$r = PB \sec\frac{\theta}{2} \quad \text{... (1)}$$

Since, $OB = r$, diameter of wire $= 2r$

∴ Size of best wire diameter, $d = 2r$

$$d = 2\,PB \sec \theta/2$$

(∵ from equation (1))

Also,

$$PB = \frac{p}{4} \quad \text{... (2)}$$

∴ Best wire size, $d = \frac{2p}{4} \sec\frac{\theta}{2}$ (∵ from equation (2))

$$\therefore d = \frac{p}{2}\sec\frac{\theta}{2}$$

Q25. Differentiate between simple and virtual effective diameter of a screw thread.

Answer :

Differences between Simple and Virtual Effective Diameter of a Screw Thread

	Simple Effective Diameter		Virtual Effective Diameter
1.	It is the diameter of an imaginary cylinder, which is co-axial with the axis of the screw.	1.	It is the pitch diameter of the enveloping thread of perfect pitch, lead and flank angles with full depth for mating.
2.	The width of spaces are equal on a perfect thread.	2.	The width of spaces vary according to the thread parameters.
3.	Crests and roots are uncleared.	3.	Crest and roots of mating parts are cleared.
4.	No errors are considered.	4.	Errors in pitch and angle of thread are considered.
5.	It specifies the quality of fit between the screw and nut.	5.	It specifies the screw thread gauge.

Q26. Write about checking of thread form and angle by optical projection method.

Answer :

Checking the Thread Form and Angle by Optical Projection

This method is limited to external threads only because internal threads cannot be projected. The member projectors are equipped with various work holding fixtures, the projection lamp and the lenses situated on the top of the cabinet with the screen at front. The light rays from the lens are directed downwards into the cabinet and finally to the screen by a system of mirrors and prisms.

On the ground glass screen, enlarged images of the screw thread form will appear on which the template or drawing is made to scale equal to the magnification of the levis. Finally, the two forms ideal and actual (projected) are compared.

Q27. Write short notes on thread gauges.

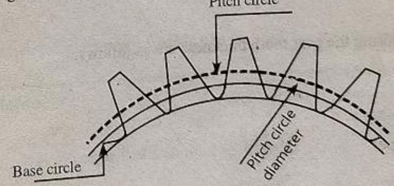
Answer :

Thread gauges are broadly classified as checking and reference gauges. The checking gauges or setting gauges are used for checking the size of a component, whereas the reference or working gauges are used for inspection of manufactured products and enables acceptance or rejection of a component. Gauges have different accuracy based on the tolerance provided. Examples of thread gauges are plug gauges, snap gauges, comparators, etc.

Q28. Explain base circle, pitch circle, pitch circle diameter with the help of figure.

Answer :

Base Circle: It is the circle, which produce the involute curve of the tooth profile. Generally, base circles exist only in involute gears. The base circle is fixed on the gear and cannot be altered.



Figure

Pitch Circle: It is an imaginary circle represented by dotted line as shown in figure. It is possible to select unlimited number of pitch circles, each one is related to its own pressure angle.

Pitch Circle Diameter: It is the most important diameter of gears which is generated by performing pure rolling action and it has the same motion as a toothed gear wheel.

Q29. What is gear pitch?

Answer :

Gear pitch is the distance measured from the origin of the involute on the tooth to the origin of a similar involute on the next tooth on the base circle. It is also called as base pitch.

$$\text{Base pitch} = \frac{\text{Base circumference}}{\text{Number of teeth}}$$

$$= \frac{\pi \times \text{Diameter of base circle}}{N}$$

$$= \frac{\pi \times D\cos\phi}{N}$$

$$= \pi.m \cos\phi$$

Where, m – Module

ϕ – Pressure angle.

Q30. Enumerate various gear parameters measured in metrology lab and corresponding instruments required for measurement.

Answer :

The various gear parameters measured in metrology lab and the corresponding instruments required for measurement are shown in below table.

S.No.	Gear Parameter	Corresponding Instrument
1.	Run out	Gear eccentricity tester.
2.	Pitch	Portable hand-held instrument.
3.	Profile	Involute measuring machine.
4.	Lead	Lead checking instruments.
5.	Back lash	Comparator.
6.	Tooth thickness	Gear tooth vernier calliper.
7.	Concentricity	Dial gauge.
8.	Alignment	Parallel bar.
9.	Composite errors	Master gear.

Q31 . What are the various methods used for measuring the gear tooth thickness?

Answer :

The various methods of measuring the gear tooth thickness are as follows,

1. Constant chord method
2. Base tangent method
3. Using gear tooth vernier calliper
4. Using dimension over pins.

Q32. Explain the reasons for inspecting gear tooth elements.

Answer :

The gear tooth elements are inspected for the purpose of obtaining higher efficiency and better accuracy of gears. It is essential to inspect the arrangement of shafts, gears and bearings before use. Precision has a great effect on smoothness of operation, freedom from noise and life span. Hence, it is necessary to inspect and measure the gears accurately before use.

Q33. Distinguish the comparator and gauge.

Answer : Nov./Dec.-16, (R13), Q1(i)

	Gauge		Comparator
1.	It is used to check the dimensions whether they are in the specified limits or not.	1.	It compares the dimensions of a part with the working standards.
2.	No magnification system is provided in gauges.	2.	The readings can be magnified by means of a suitable arrangement.
3.	Measurements are noted so rapidly and accuretely thus it is used for mass production.	3.	It can also be used for mass production, as it consumes less time for compression.

Q34. What is Coordinate measuring machine?

Answer: Nov./Dec.-18, (R16), Q1(j)

Coordinate measuring machine (CMM) is one of the most essential equipment used in the contact type inspection process of parts. It is a flexible measuring machine widely used in manufacturing industries for post production inspection of components.

Q35. List out the various components of CMM.

Answer :

The various components of CMM are as follows,

1. Movable probe head
2. Sensing probe
3. Rigid mechanical structure
4. Table with holding fixture
5. Displacement transducer
6. Control unit
7. Drive system unit
8. Computer system with integrated software.

Q36. Write the features of CMM.

Answer :

Features of CMM

1. In CMMs all systematic errors are fed to an integrated computer Thus, an error compensation is built up into the software.
2. All CMMs are provided with a dedicated computer with a friendly software.
3. Temperature gradients in the machine is compensated by a computer interfaced with the thermocouples. Thus, the accuracy and repeatability of machine is higher.
4. By using CMMs with dedicated computers, a 3–D object can be measured from variable datums. This is possible by three–axis programming.
5. Due to high flexibility and simple programming, CMMs can be used for any measuring requirement within the capacity of machine.

Q37. Give the classification CMMs.

Answer : [Nov./Dec.-17, (R15), Q1(i) | Model Paper-III, Q1(j)]

Based on their construction, CMMs are classified into following types,

1. Cantilever type
2. Bridge type
   (i) Moving bridge
   (ii) Fixed bridge.
3. Column type
4. Horizontal arm type
5. Gantry type.

Q38. What are the advantages and applications of cantilever type CMM?

Answer :

Advantages of Cantilever Type CMM

1. Good accessibility.
2. Less weight.
3. Less measuring errors.
4. Convenient access to worktable.
5. More number of parts can be measured.
6. Measurement of large components.

Applications

1. Inspection of gauges and standard parts.
2. Air craft and ship building areas.
3. Inspection of cast iron and steel in automotive industries.

Q39. What are touch trigger probes?

Answer :

Touch trigger probes are measuring devices in Coordinate Measuring Machine (CMM). The main elements are,

1. Probe head
2. Probe
3. Stylus.

The probe head is mounted on moving axes of CMM. The tip of probe is in contact with surface of workpiece. An electronic signal is generated due to the difference in contact resistance between probe and work. The contact is ensured by providing a LED light and an audible signal. These probes work on the 'three-leg principle.'

Q40. What are the various accessories used in CMM?

Answer :

CMM is provided with two accessories to increase its performance during inspection.

1. **Environment Enclosure:** It acts as casing for CMM, which protects it from the contaminated air, dust and other particulates present in factory environment.
2. **Automatic Temperature Compensation:** All tolerances and dimensions on drawings are considered at 20°C. But the actual temperatures are much higher than the standard value. Thus, an automatic temperature compensation arrangement is employed for compensating temperature gradient between workpiece and CMM.

   CMM software converts the measurement information at working temperature into standard temperature (i.e, 20°C). It is a working computer controlled accessory best suited for shop floor use.

Q41. List any four possible causes of error in CMM.

Answer :

Various Causes/Sources of Errors in CMM

1. Misalignment of table and probes.
2. Imperfect geometric shape of the table.
3. Degree of runout of CMM probes.
4. Perpendicularity errors caused during the vertical movement of the probes.
5. Errors in displaying the output on the digital system.

Q42. What is meant by "qualifying the tip" in CMMS?

Answer :

Qualifying is the calibration of stylus tip by using standard sphere, gauge blocks or plain setting rings. It is done by contacting the each stylus tip with the standard or reference sphere. In order to consider all probing directions, sphere is preferred in most case. During the qualification, stylus tip diameters and distance between the centres of each stylus is determined by CMM software. For each stylus tip, twenty five to fifty touch points are needed for accurate qualification.

Q43. Write the applications of coordinate measuring machines? May/June-19, (R16), Q1(j)

OR

List out the applications of CMMs. Dec.-19, (R16), Q1(j)

OR

List out the different applications of CMM.

Answer :

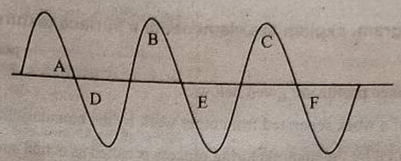
Applications of CMM

1. Used in machine tool, automobile, electronics, space applications and used for development of new products and construction of prototype.
2. Used for the testing and inspection of gauges, tools and test equipment.
3. Used for determining dimensional accuracy of the bought in components and to check the quality of supplied components.
4. 100% inspection and documentation of space and aircraft safety components are carried out by using CMMs.
5. Used for sorting tasks to achieve optimum pairing of components with tolerance limits.
6. Used to check the dimensional accuracy of NC machine produced jobs.

Q44. A rectilinear pen recording of a diamond turned surface is shown in figure. The sampling length used was 0.8 mm and the V/H magnification ratio was 5000/100.

A	B	C	D	E	F
60	115	96	92	109	70

Calculate the R_a.



Figure

Answer : [May/June-12, Set-4, Q8(b) | Nov./Dec.-17, (R15), Q9(b)]

Given that,

Sampling length = 0.8 mm

Vertical magnification = 5000

Horizontal magnification = 100

Areas above mean line	60	115	96
Areas below mean line	92	109	70

$$R_a = \frac{\text{Sum of areas}}{\text{Sampling length}} \times \frac{1}{\text{Horizontal magnification}} \times \frac{1000}{\text{Vertical magnification}}$$

$$= \frac{(60+115+96+92+109+70)}{0.8} \times \frac{1}{100} \times \frac{1000}{5000}$$

$$\therefore \quad R_a = 1.355 \text{ cm}$$

Q45. Calculate C.L.A and R.M.S roughness values for the following data,
Number of peaks and valleys : 10
Peaks : 40, 42, 40, 41, 42.
Valleys : 25, 22, 22, 24, 23.

Answer :

Given that,

Number of peaks and valleys, $n = 10$

Centre Line Average Value (C.L.A)

C.L.A (or) R_a Value,

$$= \frac{Y_1 + Y_2 + ... + Y_n}{n}$$

$$= \frac{40+42+40+41+42+25+22+22+24+23}{10} = \frac{321}{10} = 32.1 \text{ microns}$$

Root Mean Square Value (R.M.S)

R.M.S value of roughness,

$$R_q = \sqrt{\frac{Y_1^2 + Y_2^2 + ... + Y_n^2}{n}}$$

$$= \sqrt{\frac{(40)^2+(42)^2+(40)^2+(41)^2+(42)^2+(25)^2+(22)^2+(22)^2+(24)^2+(23)^2}{10}}$$

$$= \sqrt{\frac{11107}{10}} = \sqrt{1110.7}$$

$= 33.327$ microns.

PART-B ESSAY QUESTIONS WITH SOLUTIONS

5.1 SURFACE ROUGHNESS MEASUREMENT

5.1.1 Roughness and Waviness

Q46. With the help of neat diagram, explain the elements of a surface texture.

[May/June-12, Set-1, Q4(a) | Model Paper-I, Q9(a)]

Answer :

The components of surface profile are given below,

Surface: It is the enclosed portion of a work separated from other work by the boundary line.

Actual Surface: The surface generated by the manufacturing process is called as actual surface.

Nominal Surface: It is the theoretical, imaginary perfect surface obtained by calculating the mean of peaks and valleys on the surface.

Profile: It is defined as the shape of the surface.

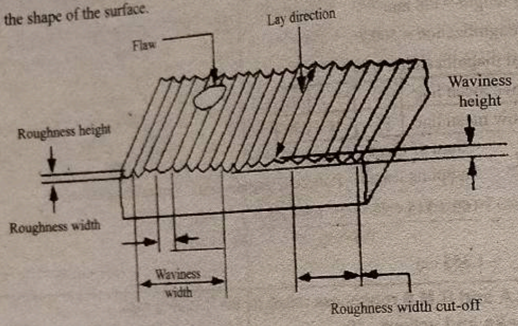


Figure: Elements of Surface Roughness

Roughness (Primary Texture): It indicates very fine irregularities on the surface. These irregularities are of third and fourth order.

Roughness Height: It is the mean deviation of real surface along normal direction from the imaginary surface. It is expressed in micrometers.

Roughness Width: The distance between adjacent peaks or valleys parallel to normal surface is called roughness width.

Roughness Width Cut-off: The maximum roughness width involved in the evaluation of roughness height. It is expressed in centimeters.

Roughness width cut-off > Roughness width.

Waviness (Secondary Texture): The irregularities on the surface whose space length is more than roughness is termed as waviness. It is also named as macro geometrical errors. These irregularities are of first and second order. Improper positioning of centers, shocks or vibrations, deflections of work and machine, warping, etc, results in waviness.

Effective Profile: The real surface generated by the instrument is referred as effective profile.

Flaws: These are the forms of irregularities on surface such as scratches, cracks, etc. These irregularities occur randomly and can be identified using penetrating die.

Lay: It indicates the direction of surface pattern produced by the tool scratches. The lay can be defined based on the method of production.

Surface Texture: The presence of irregularities on the nominal surface, forming a different patterns such as, waviness, roughness, lays and flaws is called surface texture.

Sampling Length: The specific length of the profile considered to determine the irregularities is defined as sampling length. It is also termed as cut-off length. It can be evaluated in the direction similar to that of profile. This length depends on the type of profile

Importance of Surface Finish Measurement: The surface finish is measured for evaluating the performance of machine tools. The components mainly fail due to high stress concentration produced by surface irregularities in form of sharp corners. Surface finish affects the properties of components like appearance, hardness, wear and fatigue resistance, etc. In some cases, surface roughness is important, as it imparts good bearing characteristics to the components.

Q47. Explain the Roughness parameters and Roughness Profiles.

Answer: Nov./Dec.-18, (R16), Q11(b)

Roughness Parameters

For answer refer Unit-V, Q50.

Roughness Profiles

Roughness (or) R-profile

The roughness is defined as the surface irregularities whose wavelength is small. It is also called as primary texture. These irregularities are produced due to the direct action of the cutting parameters such as the shape of tool, tool feed rate and the other disturbances such as friction, wear or corrosion on the material.

These irregularities include third and fourth order irregularities and micro-geometrical errors.

For micro errors, $\frac{l_r}{h_r} < 50$

Where,

l_r – Length along the surface

h_r – Deviation of surface from the ideal surface

Waviness or , W-profile

For answer refer Unit-V, Q5, Topic: Waviness.

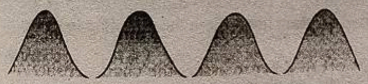


Figure : Secondary texture (waviness)

Form

It is the surface profile obtained by reflecting the irregularities due to waviness and roughness.

Figure: Form

Q48. What are the various orders of geometrical irregularities on surface? How these are classified. Nov./Dec.-13 (R09), Q4(a)

OR

It is not possible to produce perfectly smooth surface? Justify the statement.

Answer : Nov.-15, (R13) Q8(b)

When a material is machined by any chip removal process, a perfectly finished surface cannot be obtained, since it is practically impossible to design any machine to the ideal conditions. Hence, the surface will have some irregularities. These geometrical irregularities can be classified into four categories. They are,

1. First order
2. Second order
3. Third order
4. Fourth order

1. First order

The first order irregularities are caused due to inaccuracies present in the machine tool itself, i.e., inaccuracies such as lack of straightness of guideways on which the tool post is moving. The irregularities of this category include the surface irregularities resulted due to deformation of work which is subjected to the cutting forces and the self weight of the material.

2. Second order

This category includes the irregularities such as chatter marks caused due to any kind of vibrations.

3. Third order

Even though, the machine is perfect and completely free from vibrations, it will not produce a perfectly finished surface, and there will be some irregularities, arised by the machining itself due to characteristic of the process. This category also includes the feed marks of the cutting tool.

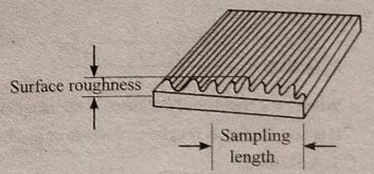
4. Fourth order

This category includes the irregularities formed due to the rupture of material during the separation of the chip.

Q49. Explain the importance of sampling length in surface roughness measurement.

Answer : May/June-12, Set-4, Q8(a)

Sampling length is defined as length over which the parameter to be measured is significant consisting the desired and relevant information.



Figure

Sampling length is also called as roughness width cut-off. This is the maximum length of surface roughness or irregularities, included in the measurement of roughness width. It is measured in parallel direction with respect to the profile of irregularities.

Depending upon the various finishing processes, it varies from 0.08 mm to 25 mm. However, most commonly used sampling length is 0.8 mm. This is a very simple and reliable method of measuring surface roughness. It is obtained by dividing the data into equal sample lengths in surface roughness.

Importance of Sampling Length: Sampling length plays a prominent role in surface roughness measurement, as the better statistical analysis of the surface depends upon it. A very small sampling length shows only the unrepresentative micro roughness, whereas too large sampling length results in distorted waviness of the surface. It should be long enough to hold some even feed rate cycles and the drift should be filtered out caused by the wavelength. For different operations, different sampling lengths are used as per the standards. When sampling length is not specified, it is considered as 0.8 mm for most of the finishing operations.

5.1.2 C.L.A, R.M.S, R_z Values

Q50. Describe various methods of numerical assessment of surface finish.

Answer :

The numerical assessment is performed to indicate the degree of smoothness or roughness.

1. Maximum peak to valley height of roughness
2. Root mean square value (R.M.S value)
3. Centre line average method (C.L.A value)
4. Ten point Height Method

1. **Peak to Valley Height Method**

This is the most simple and commonly used method for measuring the roughness, but it does not satisfy the complete definition of roughness.

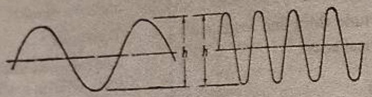


Figure (1)

As shown in figure, in the both the cases, the maximum peak to valley height is same, but the frequencies of irregularities are different. The roughness in second case is more than the first case. Since this is the simple method, it is best suited where it is desired to control the cost of finishing for checking the rough machining. This method is very advantageous, where the properties such as fatigue resistance is influenced by surface condition, and where it is necessary to clear the surface of irregularities left by previous operation.

2. **Root Mean Square Method**

It is the average root mean square of deviation Y of the profile from its mean line with in the sampling length,

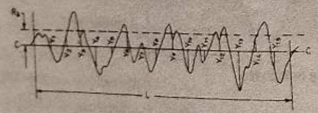


Figure: (2)

$$R_q \text{ or } RMS = \sqrt{\frac{Y_1^2 + Y_2^2 + Y_3^2 + ... + Y_n^2}{n}}$$

Where, n – Number of ordinates in the sampling length L.

It is also known as roughness average or geometric mean.

3. **C.L.A Method**

The surface roughness is measured by determining average deviation from the nominal surface. C.L.A or Arithmetic mean deviation (R_a) may be defined as the average height from a mean line, neglecting the arithmetic signs of the ordinates.

$$\text{C.L.A value} = Y_1 + Y_2 + Y_3 + ... + Y_n = \frac{1}{n}\sum_{i=1}^{n} Y_i$$

Where, n is the number of ordinates in the sampling length L.

By using planimeter area of any curve can be found easily. Then,

$$\text{C.L.A value or } R_a = \frac{A_1 + A_2 + A_3 + ... + A_n}{L} = \frac{\Sigma A}{L}$$

C.L.A value should be expressed in microns.

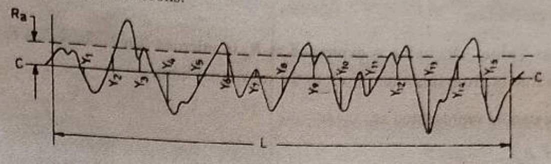


Figure (3)

4. **Ten Point Height Method**

It is the simplest method used to measure the total depth of the surface roughness. The amount of surface roughness is indicated by the average difference between the five highest peaks and the five lowest valleys of the surface texture within the sampling length measured from a line parallel to the mean line and not crossing the profile.

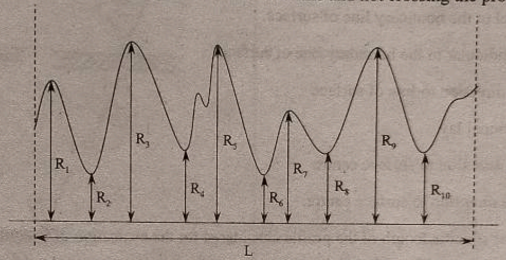


Figure (4)

The roughness value is given by,

$$R_Z = \frac{1}{5}(R_1 + R_3 + R_5 + R_7 + R_9) - (R_2 + R_4 + R_6 + R_8 + R_{10})]$$

Q51. How is surface finish indicated in an engineering drawing? What are the various elements indicated in the symbol?

Answer :

Surface Finish: The components or parts which are manufactured by different production processes will have irregularities and imperfections on its surface. These surface irregularities are in the form of hills and valleys, which varies in their height and spacing. In an engineering drawing, surface finish is indicated by the following symbol,

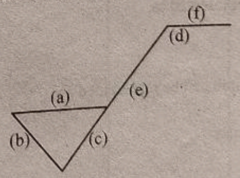


Figure: Symbol of Surface Finish

The various elements indicated in the symbol are,

a – Roughness value

b – Machining allowance

c – Direction of lay

d – Sampling length

e – Other roughness values

f – Method of production.

1. **Surface Roughness Value:** The value is expressed as R_a in microns (μm). The value represents the ranges, from zero to the stated value or from minimum limit to the maximum limit.

   The limits of value can be represented as,

   $R_{a_{16.0}}^{8.0}$ or $R_a^{8.0-16.0}$

2. **Machining Allowance:** It is the amount of material that can be removed from the manufactured part to obtain desired surface texture.

3. **Direction of Lay:** It indicates the direction of tool or scratch marks produced on the surface during production process. The lay can be defined based on the method of production. Different symbols used to specify lay direction are,

   // – Lay is parallel to the boundary line of surface.

   ⊥ – Lay is perpendicular to the boundary line of surface

   X – Angular lay direction to line of surface

   M – Multi-directional lay

   C – Circular lay direction to surface centre

   R – Lay in radial direction to surface centre.

4. **Sampling Length:** The specific length of the profile considered for the evaluation of irregularities is known as sampling length. It is also known as cut-off length and depends on type of production process by which the surface is produced.

5. **Other Roughness Values:** These are other important values specified on the symbol, if needed. They represent additional information of the profile.

6. **Method of Production:** It indicates the manufacturing process involved. The method of production can be milling, casting, grinding or hot working process.

Q52. As per ISI specification how many roughness grades are specified? Draw the roughness symbol for each grade and indicate its roughness value.

Answer :

Representation of Surface Roughness

1. The limits of surface roughness can be represented as,

   $R_{a_{16.0}}^{8.0}$ or $R_a^{8.0-16.0}$

2. The surface roughness and sampling length can be represented as,

   R_a 8.0 (2.5)

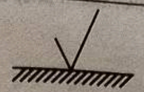
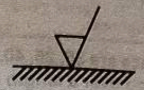
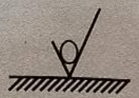
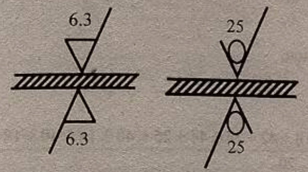
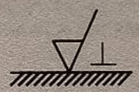
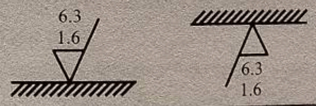
   Where,

   Sampling length is 2.5 mm

3. The surface roughness and lay can be stated as,

   R_a 1.6 lay Circular

However, the surface roughness can be represented as shown in below table.

Symbol	Explanation
	Surface obtained by a manufacturing process (turning, milling)
	Material removal method is needed for the surface
	Material removal method is prohibited for the surface
	R_a upper limits
	Grain direction
	R_a upper and lower limits

The recommended series of preferred roughness values and corresponding roughness grade numbers to be used when specifying surface roughness on drawings are given in the following table, as per ISI Specifications.

Roughness Values (R_a) (μm)	Roughness Grade Number	IS Roughness Symbol
50	N 12	~
25	N 11	∇
12.5	N 10	
6.3	N 9	∇∇
3.2	N 8	
1.6	N 7	
0.8	N 6	∇∇∇
0.4	N 5	
0.2	N 4	
0.1	N 3	∇∇∇∇
0.05	N 2	
0.025	N 1	

Q53. State the possible causes of each of the various types of irregularities found in surface texture. Show how surfaces having the same numerical assessment may have different properties and texture.

[Nov./Dec.-17 (R15), Q8(a) | Model Paper-II, Q9(a)]

Answer :

Causes of Various Types of Irregularities of Surface Finish

For answer refer Unit-V, Q48.

Surfaces Having Same Numerical Assessment Have Different Properties and Texture

For answer refer Unit-V, Q50, Topic: Maximum Peak to Valley Height of Roughness.

Q54. The heights of peak and valleys of 20 Successive points on a surface are 35, 25, 40, 22, 37, 19, 41, 21, 42, 18, 42, 24, 44, 25, 40,18,40,18,39, 21 microns respectively, measured over a length of 20 mm. Determine CLA and RMS values of roughness surface.

Dec.-19 (R16), Q10(a)

Answer :

Given that,

Number of successive points, $n = 20$

(i) **CLA Value (R_a)**

Centre Line Average (CLA) value is given by the following equation,

$$R_a = \frac{Y_1 + Y_2 + ... + Y_n}{n}$$

$$= \frac{35+25+40+22+37+19+41+21+42+18+42+24+44+25+40+18+40+18+39+21}{20}$$

$$= \frac{611}{20}$$

$$= 30.55 \text{ microns}$$

$\therefore$ CLA or R_a = 30.55 microns

(ii) **Root Mean Square (RMS) Value**

RMS value is given by the following equation,

$$= \sqrt{\frac{Y_1^2 + Y_2^2 + Y_3^2 + ... + Y_n^2}{n}}$$

$$= \sqrt{\frac{35^2+25^2+40^2+22^2+37^2+19^2+41^2+21^2+42^2+18^2+42^2+24^2+44^2+25^2+40^2+18^2+40^2+18^2+39^2+21^2}{20}}$$

$$\sqrt{\frac{20585}{20}}$$

$$= \frac{143.47}{4.472}$$

= 32.082 microns

$\therefore$ RMS value = 32.082 microns

Q55. In the measurement of roughness, the heights of 16 successive peaks and troughs were measured from a datum and are 18, 42, 25, 35, 22, 36, 18, 42, 22, 32, 24, 36, 16, 38, 23, 40 microns. If these measurements were obtained over a length of 30 mm, determine the following values,

(i) R_a

(ii) R_z

(iii) R.M.S.

Answer :

Given that,

Number of peaks and troughs, $n = 16$

(i) **Centre Line Average Method (R_a)**

$$R_a = \frac{Y_1 + Y_2 + ... + Y_n}{n}$$

$$= \frac{18+42+25+35+22+36+18+42+22+32+24+36+16+38+23+40}{16}$$

$\therefore$ R_a = 29.312 microns

(ii) **Average Peak to Valley Height (R_z)**

$$R_z = \frac{[R_1 + R_3 + R_5 + R_7 + R_9] - [R_2 + R_4 + R_6 + R_8 + R_{10}]}{5}$$ [$\because$ By ten point height method]

$$= \frac{[42+40+38+36+35] - [16+18+22+24+25]}{5}$$

$\therefore$ R_z = 17.2 microns

(iii) **R.M.S. Value**

$$= \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + y_4^2 + ... + y_n^2}{n}}$$

$$= \sqrt{\frac{18^2+42^2+25^2+35^2+22^2+36^2+18^2+42^2+22^2+32^2+24^2+36^2+16^2+38^2+23^2+40^2}{16}}$$

$\therefore$ R.M.S = 30.634 microns.

Q56. The heights of peak and valleys of 22 Successive points on a surface are 32, 28, 41, 24, 35, 19, 31, 21, 40, 18, 44, 24, 41, 25, 40, 26, 35, 18, 40, 18, 39, 21 microns respectively, measured over a length of 20 mm. Determine CLA and RMS values of roughness surface.

Answer : **[Dec.-11, Set-3, Q8(b) | Model Paper-III, Q10(b)]**

Given that,

Number of successive points, $n = 22$

(i) **CLA Value (R_a)**

Centre Line Average (CLA) value is given by the following equation,

$$R_a = \frac{Y_1 + Y_2 + ...Y_n}{n}$$

$$= \frac{32+28+41+24+35+19+31+21+40+18+44+24+41+25+40+26+35+18+40+18+39+21}{22}$$

$$= \frac{660}{22}$$

$\therefore$ CLA or R_a = 30 microns

(ii) **Root Mean Square (RMS) Value**

RMS value is given by following equation,

$$\text{R.M.S or } R_q = \sqrt{\frac{Y_1^2 + Y_2^2 + Y_3^2 + ... + Y_n^2}{n}}$$

$$= \sqrt{\frac{32^2+28^2+41^2+24^2+35^2+19^2+31^2+21^2+40^2+18^2+44^2+24^2+41^2+25^2+40^2+26^2+35^2+18^2+40^2+18^2+39^2+21^2}{22}}$$

$$= \sqrt{\frac{21506}{22}}$$

$\therefore$ RMS value = 31.266 microns

5.1.3 Methods of Measurement of Surface Finish, Talysurf

Q57. State and explain the methods of measuring primary texture of a surface?

May/June-19, (R16), Q10(b)

OR

What are the inspection methods used for measurement of surface finish. Explain in detail.

Nov./Dec.-16, (R13), Q9

Answer :

The methods used to measure surface finish or texture are broadly classified into two types. They are,

1. Inspection methods
2. Direct instrument method.

1. **Inspection Method:** In this measurement method, the surface is assessed by observation, tested and compared with a known roughness value. The required surface finish is obtained by similar machining processes, performed on specimen.

The different methods of surface finish measurement with reference to inspection by comparison are,

(i) Visual inspection
(ii) Touch inspection
(iii) Microscopic inspection
(iv) Scratch inspection
(v) Micro-interferometer
(vi) Surface photographs
(vii) Wallace surface dynamometer
(viii) Reflected light intensity.

(i) **Visual Inspection:** The method in which the inspection of surface is done by a naked eye is called as visual inspection. This method is generally used to inspect rougher surfaces. More accurate results can be obtained with the help of illuminated magnifiers.

(ii) **Touch Inspection:** This method can simply define which surface is more rough. It is a simple touch inspection method in which a fingertip is moved along the surface with 25 mm per second speed. This can inspect small irregularities of 0.01 mm. A modification of it enables using a table tennis ball, which is subjected over the surface to be detected. The main defect of this method is that, the degree of surface roughness cannot be assessed and also minute flaws cannot be inspected.

(iii) **Microscopic Inspection:** In this method, a microscope is used to inspect the surface roughness or texture. Initially, the finished surface is placed under microscope and compared with the standard surface. This method is considered to be the best method for examining the surface roughness. But, only a small portion of surface is detected at a time. Hence, several readings are required to get an average value.

(iv) **Scratch Inspection:** In this method, a softer material such as lead, babbit or plastic is used to detect the surface finish. The material is rubbed over the surface to be inspected. Since, it carries the impression of scratches on the surface, it can be easily visualized.

(v) **Micro-Interferometer:** In this method, a monochromatic source of light is used to detect the surface texture. The light ray is passed through the optical flat, which is placed on the surface to be detected. Then, with the help of microscope, the scratches in the form of interference lines or bands are inspected. In this method, the depth of defect is measured in fraction of bands.

(vi) **Surface Photographs:** The magnified photographs of the surface to be inspected are taken by using different types of illumination. Example: By using vertical illumination, defects such as scratches and irregularities appear as dark spots and flat portion of the surface appears as bright area.

(vii) **Wallace Surface Dynamometer:** It is a friction meter that consists of a pendulum in which testing shoes are clamped to the surface to be detected and a predefined spring pressure is applied. Initially, the pendulum is lifted and then allowed to swing over the surface. If the result is smooth, then there will be less friction and pendulum swings for a long time. It is the direct measurement of surface roughness.

(viii) **Reflected Light Intensity:** In this method, a beam of light is initially projected on the surface to be inspected. Then with the help of photocell, these reflected light intensities in different directions are measured. Thus, the readings from the surface are then calibrated by a suitable method.

2. **Direct Instrument Method:** In this method, a numerical value for surface is obtained, by using instruments of stylus probe type, which operates on electrical principles.

Stylus is an instrument, used to measure and record surface roughness. The most commonly used stylus is a diamond stylus. The use of phonograph needles is less, due to large size and heavy load. Some of the stylus are cone shaped with an included angle of 90° and radius of tip being 4 to 12 μm. A popular stylus with truncated pyramid is shown in the following figure.

Depending upon the dimensions of stylus, load is applied on it. The load on it ranges upto force of 70 N. The area of contact of stylus is too small.

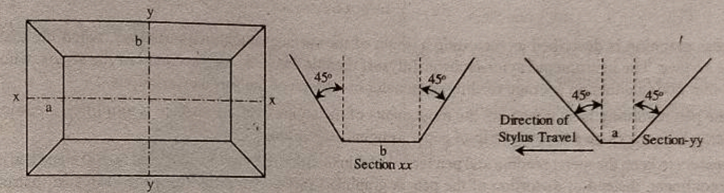


Figure: Stylus

Q58. Explain the principle, the function and operation of a stylus type surface texture measuring instrument.

Nov./Dec.-17, (R15), Q8(b)

OR

Explain typical set up using which the measurement of surface finish of a surface is carried out.

Nov.-15, (R13), Q9(a)

OR

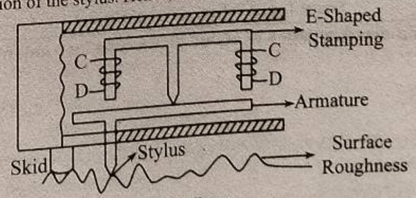
Describe with a neat sketch the construction, principle and operation of talysurf surface meter.

[Nov./Dec.-13, (R09), Q4(b) | Model Paper-III, Q9(a)]

Answer :

Taylor-Hobson Talysurf is a stylus and skid type of instrument used to measure surface roughness by electronic principle. This electronic means is more rapid and accurate as compared to other surface meter. It consists of a sharply pointed diamond stylus in a measuring head. The stylus has 0.002 mm tip radius and skid traverses the surface by a driving motor.

In this type of instrument, the stylus traces the profile of the surface and deflections of the stylus is converted into change in electric current. The armature is pivoted about the centre of E-shaped stamping, which has two coils. These two coils forms an oscillator, which is purely a electronic mean. As the armature is pivoted, any deflection of the stylus causes the air gap to change and thus, the amplitude of the current flowing in the coil is modulated. The output is then demodulated, such that the current is directly proportional to the deflection of the stylus. Hence, surface roughness is effectively measured by this electronic system.



Figure

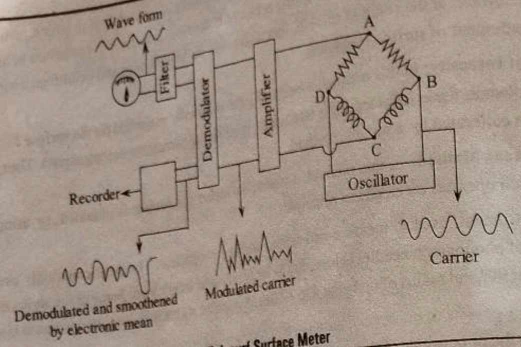


Figure: Talysurf Surface Meter

Q59. Describe roughness graphing using Talysurf.

Answer :

Roughness graphing is described as recording a graph of the surface roughness variations, when the diamond stylus is moved over the surface. The instrument Taylor-Hobson Talysurf records the static displacement of the stylus, whose tip radius is of about 0.002 mm giving either an average reading on a meter or a graph of the surface variations.

When the pen recording is switched on, the movements of the stylus over the surface is amplified electrically and fed to the pen recorder, which traces on a moving strip of paper, roughness graphing.

It is necessary to keep the meter reading and pen record within their limits between 1000.and 50000 electrical magnifications. The record is rectilinear, instead of distortion of the pen. A graphical surface variation record by Talysurf instrument is shown below,

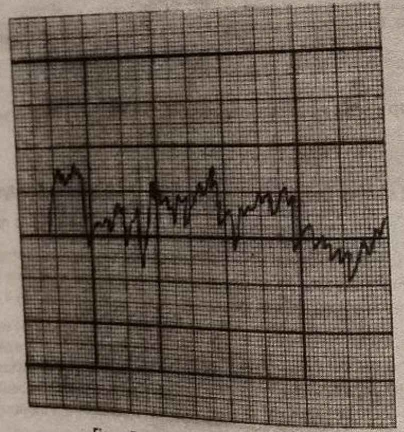


Figure: Typical Talysurf Graphical Record

Q60. Write the advantages and disadvantages of stylus probe type instrument used for surface roughness measurement.

Answer : May-10, Set-4, Q8(a)

Advantages

1. Any roughness parameter is measured by the generated electric signal.
2. Measures surface finish of deep bores.
3. Provides direct measurement of surface quality.

4. The tomlinson surface meter is an economical instrument.
5. Provides highly reliable results.
6. Measurement is rapid and accurate.

Disadvantages

1. Initial cost is high.
2. The construction is massive and complicated.
3. It is relatively undurable.
4. For surfaces having waviness, the instrument shows error.
5. Measurement of surface waviness is limited to a section of a surface.
6. Skilled operators are required to operate the instrument.

5.2 SCREW THREAD MEASUREMENT

Q61. "Explain the nomenclature of screw thread with the help of a neat sketch.

Answer : Dec.-11, Set-1, Q1(a)

Nomenclature of Screw Thread

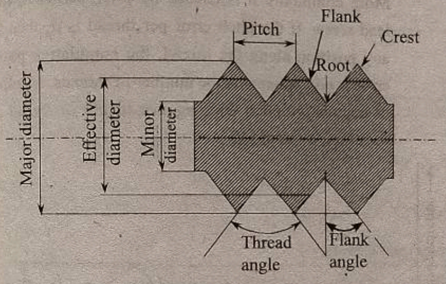


Figure: Screw Thread Elements

Various elements of screw thread are as follows,

1. Major diameter
2. Minor diameter
3. Effective diameter
4. Pitch
5. Crest
6. Root
7. Flank
8. Threaded angle
9. Flank angle.

1. **Major Diameter:** It is also called as external diameter, outside diameter, core diameter or full diameter of external thread. It is the diameter of an ideal coaxial cylinder which touches the crests and roots of an external and internal thread respectively.
2. **Minor Diameter:** It is also called as core diameter or root diameter. It is the diameter of an ideal coaxial cylinder, which touches the crests on internal thread and roots on external thread.
3. **Effective Diameter:** It is also called as pitch diameter. It is the diameter of an ideal coaxial cylinder, which intersects the flanks. So that space width is equal.
4. **Pitch:** The distance measured between two consecutive crests or two consecutive troughs, when measured parallel to the axis of the threads is called pitch.
5. **Crest:** Crest is the principal part of thread. It is the top surface of thread, which is connected by two sides of thread.
6. **Root:** The bottom side of the groove formed by two adjacent sides of thread is termed as root. It is the lowest point in the thread.
7. **Flank:** The surface which joins the crest and the root is known as flank, i.e., it is the straight surface between crest and root.
8. **Thread Angle:** The angle measured between two flanks or slopes of a thread in an axial plane is known as thread angle. It is also called included angle.
9. **Flank Angle:** The angle between the flank or slope of a thread perpendicular to thread axis is known as flank angle. It is usually equal to half of the thread angle.

Q62. What are the sources of errors in screw threads? Explain.

Answer : Dec.-11, Set-3, Q6(b)

1. Improper ratio between velocities of tool and workpiece.
2. Error in pitch of the screw of the machine, used for thread cutting.
3. Due to lack of squareness of the lead screw, it causes the lead screw to move forward and backward once in each revolution.
4. Incorrect selection of gear on gear train between lead screw and workpiece.
5. Error in guideways of saddle.
6. Placing the gears eccentrically between the spindle and lead screw.
7. Faulty teeth on the gears.
8. Variations in the length results in progressive pitch errors.

Q63. What is a drunken thread? Explain in detail.

Dec.-19, (R16), Q11(a)

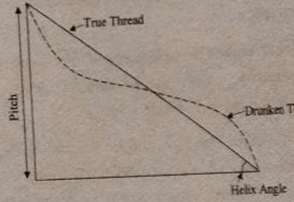
OR

What is meant by drunken thread? What troubles does it present in finding the pitch of the thread?

swer : May-10, Set-1, Q5(a)

Drunken thread is defined as the thread which has irregular pitch. The movement of helix in one complete revolution of thread is erratic (or) irregular. It is a special case of periodic error in pitch measurement. The periodic error is repeated at the intervals of single pitch. The measurement of pitch parallel to the axis of thread will be accurate and correct, but the error occurs due to improper cut of true helix on the thread (i.e., helix is curve in drunken thread instead of straight). This type of error will not effect the thread to a great extent in working, except in case of very large size threads. It is complex to find this type of errors.

The drunken thread can be seen, when the screw thread is considered on inclined plane, wound around the cylinder and true thread is unwound from the cylinder, as shown in figure.



Figure

Q64. Explain different pitch errors observed in threads.

Answer : May/June-12, Set-2, Q6(a)

If a screw thread is generated by a single point cutting tool, it's pitch depends on the following.

1. The ratio of linear velocity of the tool and angular velocity of the work should be correct.
2. The above ratio should be constant.

If these conditions are not satisfied, then pitch errors will occur. It causes the total length of thread engaged, to be too large or too small and this error in overall length of thread is called the cumulative pitch error. It can be obtained either by,

1. Measuring individual thread to thread errors and adding them.
2. Measuring the total length of thread, from a datum, at each thread and subtracting from the nominal value.

The following two types of pitch errors are observed in screw threads.

1. **Progressive Pitch Error:** This occurs due to the incorrect tool-work velocity ratio. It may also be caused by using an inappropriate (or) incorrect gear train between work and tool lead screw.

For example, When producing a metric thread with an inch pitch lead screw with no translatory gear, progressive pitch errors may occur.

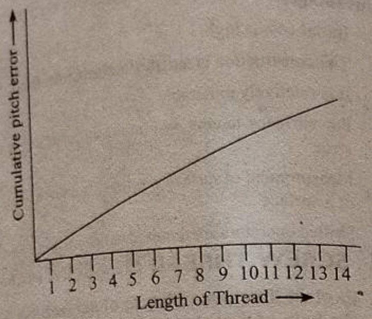


Figure (1): Progressive Pitch Error

More commonly it is caused by pitch errors in the lead screw. If the pitch error per thread is d_p then at any position along the thread, the cumulative pitch error is nd_p, where n is the number of threads. A graph of cumulative pitch error against length of thread is therefore, a straight line.

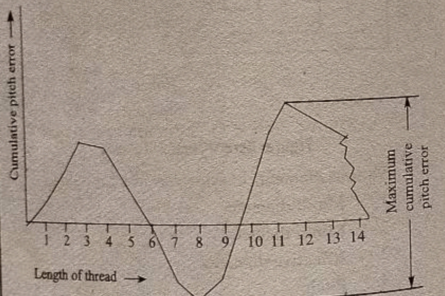


Figure (2): Periodic Pitch Error

2. **Periodic Pitch Error:** This type of error occurs due to varying tool-work velocity ratio. It may also be caused by pitch errors in gears, connecting the work and lead screw or by an axial movement of the lead screw, due to worn thrust faces. These errors are cyclic in nature. i.e., repeated at regular intervals.

A graph of cumulative pitch error will thus be of approximately sinusoidal form as shown in figure (2), and the maximum cumulative pitch error will be the total error between the maximum peak and valley within the length of thread engaged.

Q65. Describe an experiment to determine the pitch errors of a lead screw. Nov./Dec.-17, (R15), Q10(b)

OR

Explain a method of measuring errors in the pitch of a screw thread. Nov.-15, (R13), Q10(a)

OR

With the help of suitable sketches describe the pitch measuring machine for a thread gauge.

Answer : [May/June-12, Set-4, Q4(b) | Model Paper-I, Q9(b)]

The method of measurement of pitch of the thread by using this machine is simple and accurate comparatively. The thread to be measured is held in between the centres of the machine. A stylus of appropriate size according to the pitch type is placed in the frame of indicator unit, such that it contacts the flanks at positions nearer to the line of pitch. During measurement, the indicator unit is moved over the thread. This indicator unit supports the stylus and is actuated by means of a micrometer. The stylus, when moving over the thread profile, falls in and out of each screw thread. When, the stylus is at mid-position of each thread, the indicator shows zero reading. At this position, the reading from micrometer is obtained. Thus, different readings are taken for different threads, which gives the error in pitch of screw thread. The pitch errors obtained are very small i.e., within 0.002 mm.

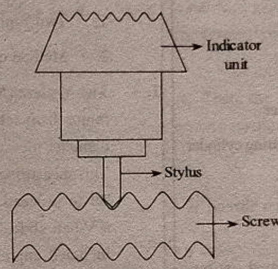


Figure: Line Diagram of Pitch Measuring Machine

Q66. Explain about bench micrometer for measuring major diameter of threads.

Answer :

Bench micrometer is an instrument designed by N. P. L (National Physical Laboratory) to determine the major diameter of threads. N.P.L has designed this instrument by eliminating the following drawbacks in normal hand micrometer.

1. Variable pressures at anvils caused by hand tightening, which results in errors due to compression.
2. Errors caused by pitch error in the micrometer.

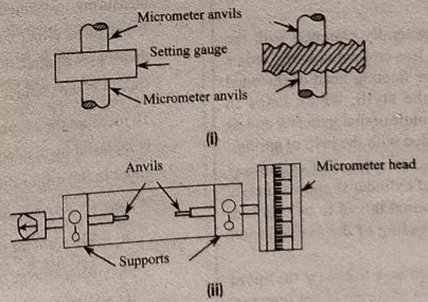


Figure: Bench Micrometer

In this instrument, instead of fixed anvil a fiducial dicator is used to determine every measurement at constant essure and instead of holding work piece between centres, ork is held by hand, as workpiece centers are not true with iameter of threads. Errors like pitch errors, zero errors are liminated by using this instrument as comparator. A calibrated etting cylinder is used as a standard for comparing with major diameter of work piece. The difference between the diameters of setting cylinder and workpiece threads must be minimum.

During the measurement, the setting cylinder is fixed between anvils and the diameter of setting cylinder is noted, then the diameter of workpiece is measured by placing it in between anvils at same fiducial indicator reading.

The major diameter of thread is measured by,

$$D_{major} = D_1 + (R_2 - R_1)$$

Where,

D_{major} – Major diameter of thread

D_1 – Diameter of setting cylinder

R_1 – Micrometer reading when setting cylinder is measured

R_2 – Micrometer reading when thread is measured.

This measurement procedure is performed various times at various positions on thread, to determine taperness and if measurements are taken at different angular positions on thread, ovality can be detected.

Q67. Explain how to measure major diameter of internal threads.

Answer :

The major diameter of internal threads can be measured by using an instrument known as threaded comparator. This comparator consists of Stylus, Floating head, Dial indicator, Spindle and Spring.

Threaded comparator is generally clamped with the ball ended stylus, whose radius is less compared to the radius of thread root to be measured. The floating head of threaded comparator is fixed to one of the stylii, which helps in maintaining the contact with the spindle of dial indicator and its motion against indicator is controlled with the help of spring.

The comparator is arranged to a level of cylindrical reference standard. The diameter of cylinder is approximately equal to the major diameter of internal thread to be checked. After checking the diameter, the reading of the dial indicator may be noted.

The floating head is then taken back to engage the tips of stylii. This action is taken at the root of spring under pressure. Hence, the next reading is noted.

The measurement of external threads is easier compared to the internal threads, as the components of internal threads are hidden and complicated to approach.

Let,

D – Diameter of standard gauge

R_1 – Reading of dial indicator

R_2 – Thread reading.

Then,

Major diameter of internal threads is given as,

$$D \pm (R_2 - R_1)$$

Q68. Name and describe various methods of measuring the minor diameter of an external thread.

Answer : May/June-12, Set-4, Q4(a)

The methods used for the measurement of minor diameter of the thread are,

1. Two V-pieces method
2. Method of projecting the thread on the screen.

1. **Two V-pieces Method:** This is the method of measuring minor diameter of a V-screw thread by floating carriage diameter measuring machine with two small V-pieces. This measuring machine is mounted on a carriage and set to proceed perpendicularly to the center axis by a V-ball slide. The ends of V-pieces have radius and included angles less than the root radius and thread angles respectively.

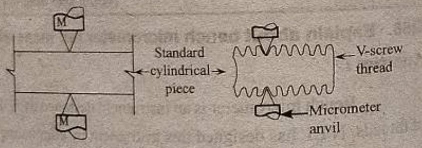


Figure: Measurement of Minor Diameter

The thread is placed in between the centers of the measuring instrument. Note the reading by placing the V-pieces on either side of the threaded workpiece with their bases against the to micrometer anvil, such that it should make contact with the root of thread.

To measure the second reading, the threaded workpiece is replaced by a standard cylindrical gauge of diameter equal to the minor diameter of the screw.

Where,

R_1 – Micrometer reading of standard gauge

R_2 – Micrometer reading of threaded workpiece

D – Diameter of standard gauge.

The minor diameter of thread is given by $D \pm (R_2 - R_1)$.

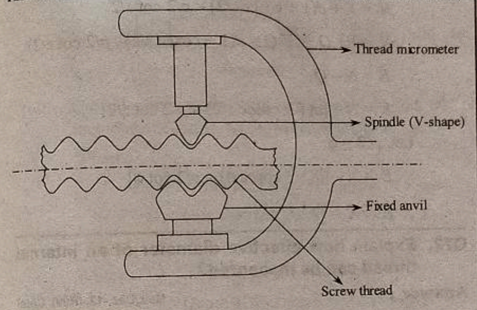
At various positions, the readings are noted to detect the taper and ovality of threaded workpiece.

2. **Method of Projecting the Thread on the Screen**

When the threads of the workpieces are very sharp and possess negligible radius at the root, then the minor diameter is measured by projecting the thread form on a screen and comparing with the standards.

Q69. Describe an exclusive method for effective diameter measurement which shows variation in drunken thread.

Answer : May-10, Set-1, Q5(b)



Figure

Thread Micrometer

1. Thread micrometer is used to measure the effective diameter or pitch diameter of the screw thread and it shows the variation in drunken thread.
2. It is identical to an ordinary micrometer, but provided with special feeler or contact points.
3. One end of the micrometer has a spindle, which is formed in v-shape and the other end has a fixed anvil with corresponding recess. Both the spindle and anvil are fitted between the two thread flanks.

Method of Measurement

1. Before using the micrometer, the zero error is measured, by keeping the spindle and anvil in contact.
2. Then, the screw is placed between the spindle and the anvil, such that the angle of point and the thread flanks are in contact with the screw thread.
3. Then, the readings from the micrometer are obtained.
4. As the major diameter is measured on one side and the minor diameter on other side, the effective diameter of screw thread is determined.
5. The value obtained should be similar to the value obtained from the relation:

   Pitch diameter (or) Effective diameter $= D - 0.6403\,P$ (For whitworth thread)

   Where, P – Pitch

   D – Outer diameter.
6. The major limitation of thread micrometer is that, it shows errors due to helix angle, if it is not set to a standard gauge, before the measurement.

Q70. Describe with neat sketches two wire method of measuring the effective diameter of a screw threads.

Answer : [Dec.-10, Set-3, Q5(a) | Model Paper-II, Q9(b)]

Two Wire Method: The effective diameter of the screw thread can be measured by placing two wires of equal diameter between the flanks of the two adjacent threads as shown in figure (2) and measuring distance between these wires.

In this method, wires of appropriate size are placed on a standard gauge whose dimensions are approximately same as the screw thread.

Assume that, the micrometer reading over standard is R_1. Then, the standard is replaced by the screw thread and the second reading R_2 is taken.

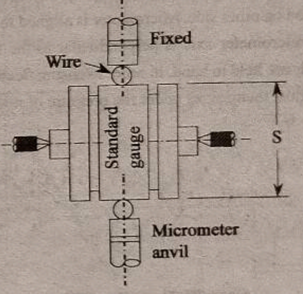


Figure (1): First Operation

Where,

S – Diameter of standard

T – Diameter between the wires

E – Effective diameter of screw.

Therefore, $E = T + P$

$$T = S - (R_1 - R_2)$$

But, P is a constant for different threads, which is based on wire diameter and thread pitch.

$\therefore$ $P = 0.9605\,p - 1.1657\,d$ for witworth threads, and

$P = 0.866\,p - d$ for metric threads.

Where,

p – pitch of the thread

d – Wire diameter.

Two wire method is normally used where high accuracy is not so concerned and is performed on the diameter measuring machine.

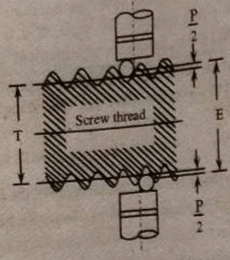


Figure (2): Second Operation

Q71. Elucidate the measurement of effective diameter by three wire method.

Answer :

Three wire method is also called as three rod method. Three wire method is the accurate method for measuring the effective diameter of the threads. In this method, three wires or rods of given diameter are employed. i.e., two rods on one side and one rod on other side. Micrometer is aligned in such a way that, the micrometer axis is perpendicular to the thread axis. These rods are held in hand, in order to ensure flexibility of the rods to adjust themselves under the pressure of micrometer.

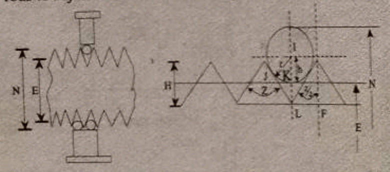


Figure (1): Three Wire Method

Where,

E – Effective diameter

N – Distance between wires

r – Radius of rods

d – Wire diameter

h – Height of the centre from effective diameter.

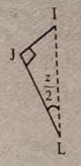


Figure (2)

From the figure,

$$IL = IJ \operatorname{cosec} z/2$$

$$H = LF \cot z/2 = p/2 \cot z/2 \qquad (\because p = \text{pitch})$$

$$KL = H/2 = p/4 \cot z/2$$

$$h = IL - KL$$

Distance between rods,

$$N = E + 2h + 2r$$

$$= E + 2(r \operatorname{cosec} z/2 - p/4 \cot z/2) + 2r$$

$$= E + 2r\,(1 + \operatorname{cosec} z/2) - p/2 \cot z/2$$

$$N = E + d(1 + \operatorname{cosec} z/2) - p/2 \cot z/2$$

$$N = E + Q \quad (\because Q = d(1 + \operatorname{cosec} z/2) - p/2 \cot z/2)$$

$$\therefore E = N - Q$$

$$E = N - [d(1 + \operatorname{cosec} z/2) - p/2 \cot z/2]$$

Let, $z/2 = \phi$

$$E = N - [d(1 + \operatorname{cosec} \phi) - p/2 \cot \phi]$$

$$\therefore E = N - Q$$

Q72. Explain how effective diameter of an internal thread can be measured? Nov./Dec.-12, (R09), Q6(a)

Answer :

Various Instruments are used to measure the effective diameter of internal threads. A thread comparator is most commonly used for measurement of effective diameter of internal threads.

Measurement by Thread Comparator

(i) A thread comparator consists of a pair of ball tips, which engages with the thread flanks and measures the effective diameter only. The ball tip on the right side is attached to the measuring jaw end, which is clamped to the floating head in the sliding bracket (B).

(ii) A dial indicator is used with its spindle is in contact with extension of the floating head, and the movement of floating head towards the indicator is restricted by using a spring.

(iii) The left side ball tip is carried by the fixed end (A) and is adjusted using a fine screw, to set the gauge to the reference standard.

(iv) The dial indicator is set to zero corresponding to this reference.

(v) The floating head is moved back to insert the ball tips in the workpiece internal threads. It is then released to permit the tips to contact with thread flanks under spring pressure. The indicator gives the deviation from nominal size or reference size to which the gauge is set.

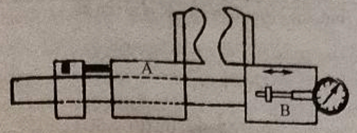


Figure (a)

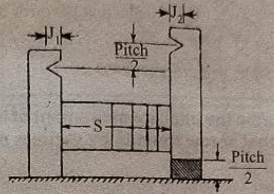


Figure (b)

(vi) Consider two workpieces with V-jaws having 60° of included vee-angle, as shown in figure (b).

Where,

J_1, J_2 – Depths from face to vertex points of V-jaw.

S – Distance between the workpieces.

$$\therefore \quad S = X + y - Z$$

Where, X – Mean effective Diameter

y – Depth of the thread between two vertex points of V - jaws.

The value 'y' depends on the included angle of thread.

For 55° angle, $y = 0.9605\,p$

For 60° angle, $y = 0.866\,p$

$$\therefore \quad Z = J_1 + J_2$$

Where,

Z – constant for the end gauge pieces

p – pitch

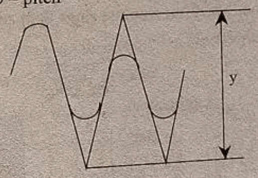


Figure (c)

(vii) The slips assembled are set in a holder with a slip equal to half the pitch, beneath one end piece to compensate for the helix angle. The size of ball tips for various threads is given as,

For threads from,

4 – 7 t.p.i — 0.095 inch diameter ball is used

7 – 12 t.p.i — 0.060 inch diameter ball is used

12 – 20 t.p.i — 0.035 inch diameter ball is used.

Where, t.p.i is threads per inch.

Q73. What is the 'best wire size'? Derive an expression for the diameter of terms of the pitch and angle of the thread.

Answer :

If there is no error in the thread angle, the diameter of the wire where it touches the flank of the thread exactly on the pitch line is called as best wire.

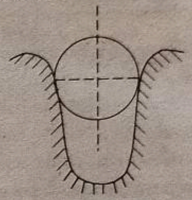


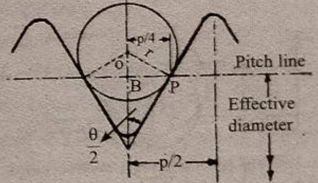
Figure: Best Wire

The inspection of the effective diameter from a reading over such wires is independent of any error in the thread angle.

The best wire sizes are as follows,

S.No.	Form of Thread	"Best Wire" Diameter
1.	B.A	0.546 p
2.	Metric and American	0.577 p
3.	Whitworth	0.564 p

Expression for the Size of the Best Wire



Figure

From the figure,

θ – Angle of thread

OP – Radius of the wire (r)

d – Size of the best wire.

p – Pitch of the thread.

Consider Δ OPB,

$$\sin\left(90 - \frac{\theta}{2}\right) = \frac{PB}{OB}$$

$$OB = \frac{PB}{\sin\left(90 - \frac{\theta}{2}\right)}$$

$$OB = \frac{PB}{\cos\frac{\theta}{2}} = PB \sec \theta/2$$

$$r = PB \sec\frac{\theta}{2} \quad \text{... (1)}$$

Since, $OB = r$, diameter of wire $= 2r$

$\therefore$ Size of best wire diameter, $d = 2r$

$$d = 2\,PB \sec \theta/2$$

($\because$ from equation (1))

Also,

$$PB = \frac{p}{4} \quad \text{... (2)}$$

$\therefore$ Best wire size, $d = \frac{2p}{4} \sec \frac{\theta}{2}$ ($\because$ from equation (2))

$$\therefore d = \frac{p}{2} \sec\frac{\theta}{2}$$

Q74. Elucidate measurement method of thread angle by two ball method.

May-10, Set-3, Q6(a)

Answer :

It is a simple method employed for the measurement of thread angle by using two unequal balls. The included angle can be checked with the help of diameter measuring machine with diameters D_1 and D_2 measured over the wires of diameters d_1 and d_2 as shown in figure.

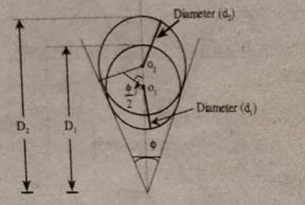


Figure: Measurement of Included Angle by Two Ball Method

Thus, an included angle can be obtained as,

$$\sin\frac{\phi}{2} = \frac{d_2 - d_1}{(D_2 - D_1) - (d_2 - d_1)}$$

Let, the distance between two centres O_1 and O_2 is 'C'.

i.e., $\frac{1}{2}(D_2 - D_1 - d_2 + d_1) = C$

Difference in radii of wires is given by,

$$r = \frac{1}{2}(d_2 - d_1)$$

And, the error in angle 'ϕ' is given as,

$$\delta\phi = \frac{2}{C\sqrt{C^2 - r^2}} - (C.\delta r - r.\delta C)$$

$$= \frac{2}{C\sqrt{C^2 - r^2}}\,[C.(0) - r.\delta C]$$

[$\because$ Neglecting the error δr i.e., $\delta r = 0$]

$$\therefore \delta\phi = \frac{-2r.\delta C}{C\sqrt{C^2 - r^2}} \text{ radians}$$

Q75. Describe the pitch measurement of internal and external screw threads by various methods.

Answer :

The pitch measurement of internal and external screw threads by various methods are as follows,

Pitch Measurement of Internal Screw Threads

1. Pitch measuring machine
2. Tool maker's microscope.

Pitch Measurement of External Screw Threads

1. Zeiss pitch or lead measuring instrument
2. Screw measuring machine
3. Microscope method and
4. Matrix pitch measuring machine.

Pitch Measuring Machine: By using an adapter, the pitch of an internal screw thread can be measured. This adapter consists of a bar which can be placed into the ring gauge. The end of bar consists of a stylus, which engages with the internal thread profile of ring gauge. Ring gauge is held on a face plate or chuck of the machine, which incorporate rings upto several sizes, as shown in the figure (1).

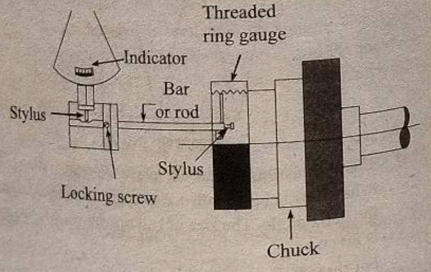


Figure (1): Measurement of Pitch of an Internal Thread

A special surface place is required with a dial indicator and slip gauges, for very large rings. And, micrometer is used to measure the movement of the stylus.

Microscope Method: It is more accurate method, used to measure the pitch of external screw thread using goniometric microscope . It consists of two reticules, which are aligned to thread slopes and point of intersection of these is taken as reference for measurement, as shown in the figure (2).

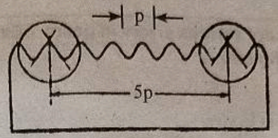


Figure (2): Measurement of Pitch of an External Screw Thread

Micrometer microscope is used for the reading of movement of carriage. The accuracy of this instrument is 0.001 mm and for angle measurement it is 10 sec of arc.

Zeiss Pitch or Lead Measuring Instrument: It is less accurate method, used to measure the pitch of external threads. It consists of two ball points, employed to effective surface of the thread. These points are held parallel to axis of thread by a special arrangement. With the help of micrometer gauge, the instrument is set to zero prior to measurement. Thus, the instrument shows the pitch deviation from standard values, when applied to thread.

Screw Measuring Machine: By using screw measuring machine, pitch of external screw threads can be easily measured. It consists of series of threads with non-uniform pitch. The pitch is the one which aligns perfectly with thread being tested. Therefore, the accuracy of measurement is based on sight.

Q76. Explain any three thread gauges to measure screw threads.

Answer :

The following three types of thread gauges are used for measurement of screw threads.

1. **Plug Screw Gauges:** Plug gauges are used for gauging internal threads. It is made to the minimum dimensions of internal threads, to ensure accurate inspection. The different elements of threads such as major diameter, minor diameter, effective diameter, etc., being checked, and also defines the form of thread, angle and pitch. Generally, NO GO gauge is used for gauging major, minor and effective diameter. For gauging parallel internal screw threads, different gauges are used. i.e., GO gauge to check the tolerance on minor diameter and minimum effective diameter, whereas the NO GO gauge to check the tolerance and maximum effective diameter, these gauges are generally made up of special steel followed by hardening.

2. **Ring Screw Gauge:** These gauges are used for gauging bolts during production. It is provided with a system of limits to check the dimensions of the part. A thread ring gauge may be used to check the pitch diameter, major diameter, etc. By using ring gauges, the lead errors of thread can be easily determined. A special precaution must be taken to avoid excessive pressure on gauge, while checking five or more threads.

3. **Calliper Gauges:** Calliper gauges are similar to gap gauges with threads provided on anvils. The front anvils with full thread form acts as GO gauge to check the threads below the upper size limit. The screw with correct effective diameter and pitch errors will not pass through GO anvils, whereas eliminating pitch error by reduction in effective diameter enables the screw to pass through GO as well as NO GO anvils. This leads to rejection of screw threads.

Q77. Describe the screw thread measurement with sketch.

Answer: [Nov./Dec.-18, (R16), Q10(b) | Model Paper-III, Q9(b)]

The various screw thread parameters measured are,

1. Major diameter
2. Minor diameter
3. Effective diameter
4. Thread angle
5. Pitch.

Methods for Effective Diameter Measurement

For answer refer Unit-V, Q69.

Q78. With neat sketch, discuss the gear tooth nomenclature by indicating the different parts.

Answer:

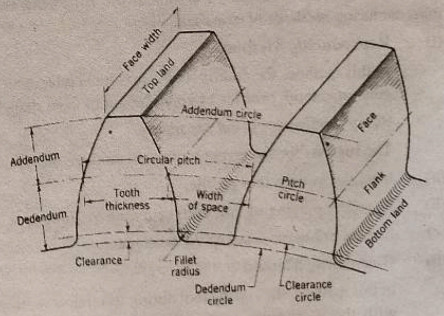


Figure: Gear Geometry

omenclature of Gear Tooth

. **Face of the Tooth:** The surface of the gear tooth above the pitch surface is referred as the face of the tooth.

. **Flank of the Tooth:** The gear tooth surface below the pitch surface is called as flank of the tooth.

3. **Top Land:** It is the top surface of the gear tooth.

4. **Bottom Land:** It is the bottom surface in between the teeth of the gear.

5. **Addendum:** The radial distance of a tooth from the pitch circle to the top edge of the tooth is called as addendum.

6. **Dedendum:** The radial distance between the pitch circle and the bottom edge of the tooth is known as dedendum.

7. **Tooth Thickness:** The width of the tooth measured along the pitch circle is known as tooth thickness.

8. **Space Width:** It is the width of space measured along the pitch circle between two adjacent teeth.

9 **Face Width:** The width of gear tooth measured along the axis of gear.

10. **Circular Pitch:** The distance measured on the circumference of pitch circle from one point on the tooth to the corresponding point on the adjacent tooth. Mathematically, it is given as,

$$P_c = \frac{\pi D}{T}$$

Where,

D – Diameter of pitch circle

T – Number of teeth.

Q79. State the various sources of errors in manufacturing gears.

Answer :

The various sources of errors in the following two manufacturing methods of gears are,

(i) **Reproducing Method**

In this method, the cutting tool is involute cutter, which generates tooth profiles by reproducing its own shape. Every tooth space is cut separately.

The reasons for the errors by this method are due to

(a) Irregular cutting tool profile.

(b) Improper placing of tool corresponding to workpiece.

(c) Inappropriate indexing of the workpiece.

(ii) **Generating Method**

In this method, the cutting tool during its relative motion with the workpiece simultaneously generates tooth profiles.

The reasons for the errors by this method are,

(a) Manufacturing errors of cutting tools.

(b) Due to improper relative positioning of workpiece and tool.

(c) Errors in relative motion between the workpiece and cutting tool.

Q80. What are various errors in gears ? Explain with neat figures.

Answer :

Various Errors in Gears

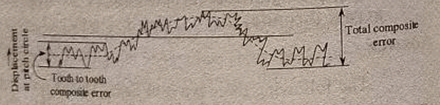
1. **Adjacent pitch error:** It is the difference between the actual pitch and theoretical pitch. $(P_a - P_{th})$

2. **Cumulative pitch error :** It is difference of actual and theoretical lengths, between corresponding flanks of teeth which are non adjacent.

3. **Profile error :** When the actual profile and design profile coincide at the common circle, the maximum deviation of any point on the actual profile in direction normal to the design profile is called profile error.

4. **Tooth to tooth composite error (single flank) :** When a gear and master gear are meshed only through a single tooth on each gear, and rotated through a distance equal to one pitch. Then the extent of variation in their displacement at the pitch circle is called tooth to tooth composite error.

5. **Total composite errors (single flank) :** When a gear and master gear are meshed only throug a single tooth on each gear and given one complete revolution. Then the extent of variation in their displacement at the pitch circle is called total compsite error.



Figure

6. **Tooth to tooth composite error (double flank) :** When a gear and a master gear in mesh is moved through a distance equal to one pich. Then, the extent of deviation in the minimum centre distance between them is called tooth to tooth composite error.

7. **Tooth composite error (double flank) :** When a gear and a master gear in mesh is given one complete revolution. Then, it is the extent of deviation in the minimum centre distance between them.

8. **Tooth thickness error :** It is difference between the actual tooth thickness to theoretical tooth thickness, measured along the reference surface.

9. **Cyclic error :** It is an error that repeats for every revolution of the gear under test.

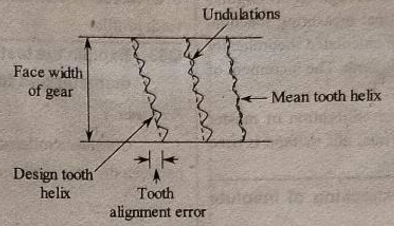
10. **Periodic error :** It is an error that occurs at regular intervals and independent of number of gear revolutions.

11. **Run out :** It is the complete extent of error or reading, shown by a fixed gauge, when its feeler rests on a surface that is given rotary motion only.

12. **Radial run out :** The run- out measured along the plane, which is perpendicular to the rotational axis of gear, is called as radial run-out.

13. **Eccentricity :** Half of the radial run-out is called eccentricity.

14. **Axial run-out :** The run-out measured on the plane, which is parallel to and at certain distance from rotational axis is called axial run-out or wobble.



Figure

15. **Undulation :** The departure of the actual tooth surface from the theoretical surface at regular intervals is called as undulation.

16. **Undulation height :** It is the distance measured between the parallel planes, that consists of the crests and the troughs of the gear tooth undulation.

17. **Undulation wavelength :** In an undulation, the distance measured from a point on a crest to a point on adjacent crest is called undulation wavelength.

18. **Tooth alignment error :** It is the distance of a point on the actual tooth trace, measured from the theoretical tooth trace, which passes through a reference point on that gear tooth.

Q81. Explain with the help of sketches, the different methods used in checking of profile of gear.

Answer :

The various methods used in checking of profile of the gear are,

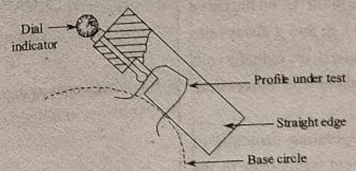
1. **Optical Projection Method**

This method is not a direct measuring method. The gear profile to be tested is magnified by optical system and displayed on the screen and compared with the master profile. Any deviation of profile from master profile is noted.

It is simple and best suited for testing gears of small precise instruments.

2. **By using Involute Measuring Machine**

The equipments required to check the profile of the gear by this method are straight edge, dial gauge, mandrel and ground circular disc of diameter equal to the base circle of gear being tested.

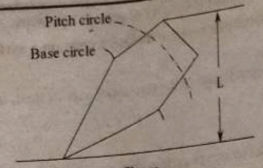


Figure

The gear to be tested and a ground circular disc are mounted on the mandrel. The straight edge is in contact with the base circle of disc and feeler of dial gauge with tooth profile respectively. The straight edge slides over the disc without slip, while the disc and gear are rotated. Dial gauge indicates the deviation of tooth profile from the true profile. This method is less time consuming and possess accuracy of about 0.001 mm.

3. **Tooth Displacement Method**

This method uses a dividing head and a vertical measuring machine (height gauge), to check the profile of large gears.



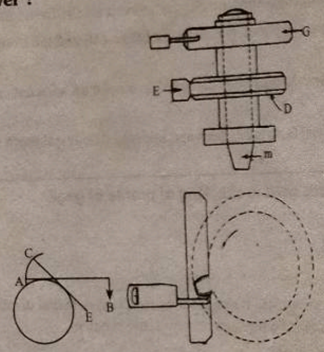
Figure

The gear under test is rotated through small angular increments. The readings of the vertical measuring machine are compared with the values that are calculated theoretically at above 5 to 10 points along the tooth flank. The increment of angular settings may be decided by trial.

This method is best suited for calibration of master involute, but very time consuming. Thus, this method is used only for very precision components.

Q82. Describe the method of checking of involute shape of gear.

Answer :



Figure

As shown in figure, point 'A' represents the straight edge end, that rolls on the base circle diameter cylinder without any slip, to trace the involute curve. The point 'C' on the curve represents the position of straight edge CE, and it always lies tangential to the base cylinder. Conversely, if the cylinder rolls along the straight edge CE, then the fixed point 'C' moves in an involute path 'CA'.

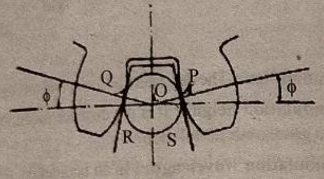
In order to understand the operating principle of involute tester, consider an arrangement equivalent to the straight edge, rolling on the edge of a disc as shown in figure. The gear (G) to be tested is mounted on the mandrel 'M', which is carrying a ground disc (D) of diameter equal to the base circle diameter of gear. The straight edge (E) is mounted on the slide of the instrument such that it should be in contact with the base circle disc.

Thus, when the straight edge is moving along the slide, the gear and base circle disc are rotated without any slip. Any point on the straight edge traces an involute profile with respect to the base circle. When the top of an indicator is placed in the plane of the straight edge, such that it touches the tooth flank, it records the deviations of the tooth profile with reference to the standard involute profile. Instead of indicators, sensing element of a recorder is used for making the permanent records of gear teeth profiles.

Q83. Explain the test plug method for checking pitch diameter and tooth spacing.

Answer :

Consider a roller along with a rack tooth, which is placed between the gear tooth spacing as shown in the figure.



Figure

From the figure, it can be seen that the sides of the rack meet with the gear teeth at points P and Q. Let 'O' be the pitch point or centre of roller and rack tooth has an empty space encloses with its outline. Then, the radius 'OP' and 'OQ' will fit and coincide the rack space at points P and Q as they travel in a direction perpendicular to the rack sides. Hence the roller will rest towards the gear teeth at P and Q and its centre will lies on pitch circle.

Consider triangle OQR,

$$OR = \frac{\text{Circular pitch}}{4}$$

$$OR = \frac{\pi}{4}.m$$

$$\therefore\ OQ = OR \cos\phi$$

$$= \frac{\pi}{4}.m\ \cos\phi$$

Diameter of roller or plug $= 2 \times OQ$

$$= 2 \times \frac{\pi}{4}.m\ \cos\phi$$

$$= \frac{\pi}{2} m \cos\phi$$

The diameter of plug will remain same for all gears having the same pitch and pressure angle.

The accuracy of spacing over a number of teeth can be determined by calculating the angle subtended to the centre and relating this value with the obtaining value (of chordal check of plug).

5.3 GEAR MEASUREMENT

Q84. Describe with the help of a neat sketch the working of gear tooth vernier calliper.

Nov./Dec.-13, (R09), Q6(b)

OR

With a neat diagram explain how gear tooth thickness is measured using a gear tooth vernier caliper.

Answer : Model Paper-I, Q10(a)

Gear Tooth Vernier Calliper: Gear tooth vernier calliper is an instrument used to measure the gear tooth thickness at pitch line. Chordal thickness and the distance between the top of the teeth and the chord.

Construction: The gear tooth vernier calliper consists of two perpendicular vernier arms or tongues. Both these arms are engraved with main scale and vernier scale. The horizontal scale is used for the measurement of depth (i.e., distance from the top of the gear to the chordal addendum). The vertical scale is used to measure the thickness of tooth at pitch line or chordal thickness. Each arm is adjusted independently by adjusting the screw. Figure (1) illustrates the construction of gear tooth vernier caliper.

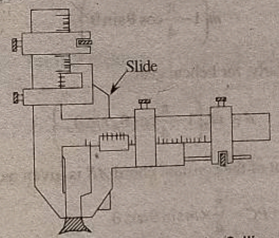


Figure (1) : Gear Tooth Vernier Calliper

The values measured by this instrument are compared with analytical values. Least count of the instrument limits the accuracy of measurements, and instrument should be calibrated at regular intervals, as the wearing takes place on the jaws due to continuous usage.

Consider a gear tooth on which measured values of chordal thickness (w) and chordal addendum are shown in figure (2).

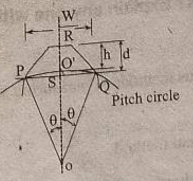


Figure (2)

From the figure, it can be observed that 'w' is equal to the length of the chord PSQ and tooth thickness is equal to the arc distance $PO'Q$. The distance 'd' is slightly greater than addendum O', i.e., 'h' and therefore 'w' is called as chordal thickness and 'd' is called as chordal addendum.

$$\therefore\ w = PQ = 2PS$$

and $\angle POS = \theta = \dfrac{360^\circ}{4T}$

Where,

T – Number of teeth

$$w = 2PS = 2 \times PO \sin\theta$$

Since, PO = Radius of the pitch circle (R)

And, $\theta = \dfrac{360^\circ}{4T}$

$$\therefore\ w = 2R\sin\left(\frac{360^\circ}{4T}\right) \quad \text{... (1)}$$

Also, module 'm' $= \dfrac{\text{Pitch circle diameter}}{\text{Number of teeth}}$

$$= \frac{2R}{T}$$

$$\therefore\ R = \frac{Tm}{2}$$

By substituting the value of 'R' in equation (1),

$$w = 2.\frac{Tm}{2}.\sin\left(\frac{360^\circ}{4T}\right)$$

$$= T.m.\sin\left(\frac{90^\circ}{T}\right) \quad \text{... (2)}$$

From figure,

$$OR = OO' + \text{Addendum}$$

$$= R + m$$

And, $d = OR - OS$

$$d = (R+m) - R\cos\theta \qquad [\because\ OS = R\cos\theta]$$

$$= \frac{Tm}{2} + m - \frac{Tm}{2}\cos\left(\frac{90^\circ}{T}\right) \qquad \left[\because R = \frac{Tm}{2} \text{ and } \theta = \frac{90^\circ}{T}\right]$$

$$\therefore\ d = \frac{Tm}{2}\left[1 + \frac{2}{T} - \cos\left(\frac{90^\circ}{T}\right)\right]$$

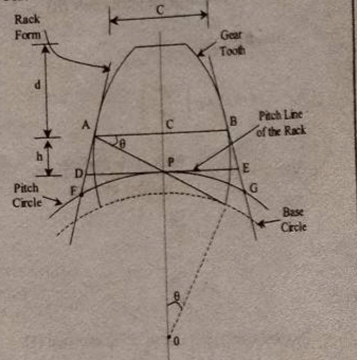
Q85. Explicate gear metrology of spur gears with reference to tooth thickness by constant chord method.

Answer :

Constant Chord Method

It is very difficult to measure a large member of gears set with different number of teeth, because it involves numerous calculations and is time-consuming. Hence, to overcome such difficulties, a constant chord method is used.

In this method, the constant chord is the chord between the points at which the tooth profile touches the basic rack of the system, where the tangents to the flank lie at the pressure angle to the tooth centre line. The geometry is shown in the figure below and AB is shown as constant chord.



Figure

Then the value of constant chord AB and its depth can be calculated as follows.

From the figure,

$$PD = PF = \text{arc } PF$$

$$= \frac{1}{4} \times \text{Circular pitch}$$

$$= \frac{1}{4} \times \frac{\pi \times \text{Pitch circle diameter}}{N}$$

$$= \frac{\pi}{4} \times m$$

Since, AP is the line tangential to base circle, $\angle CAP = \theta$,

$\therefore$ From triangle, APD

$$AP = PD \cos\theta$$

$$AP = \left(\frac{\pi}{4}\right) m \cos\theta \left[\because PD = \frac{\pi}{4} \times m\right]$$

From triangle, PCA

$$AC = AP\cos\theta$$

$$= \frac{\pi}{4} m \cos\theta \times \cos\theta$$

$$= \frac{\pi}{4} m \cos^2\theta$$

$$\therefore \quad 2AC = 2 \times \frac{\pi}{4} m \cos^2\theta$$

$$= \frac{\pi}{2} m \cos^2\theta$$

But, $2AC = C$ (Constant chord)

For helical gear, $C = \frac{\pi}{2} m_n \cos^2\theta_n$

Where,

m_n – Normal module

θ_n – Normal pressure angle.

And, $PC = AP \sin\theta$

$$= \frac{\pi}{4} \times m \cos\theta . \sin\theta$$

$$\therefore \quad d = m - \frac{\pi}{4} \times m \cos\theta . \sin\theta \qquad [\because \text{Addendum} = d + PC]$$

$$= m\left(1 - \frac{\pi}{4}\cos\theta \sin\theta\right)$$

Similarly, for helical gear,

$$d = m_n\left(1 - \frac{\pi}{4}\cos\theta_n \sin\theta_n\right)$$

Height of the constant chord AB is given as,

$$h = PC = \frac{\pi}{4} \times m \sin\theta \cos\theta$$

$$= \frac{\pi}{4} \times m \times \frac{2}{2} \sin\theta \cos\theta$$

$$\therefore \quad h = \frac{\pi}{8} \times m \sin 2\theta \qquad [\because \sin 2\theta = 2\sin\theta\cos\theta]$$

Q86. Suggest and explain a method to check the root thickness of gear teeth. Dec.-19, (R16), Q11(b)

OR

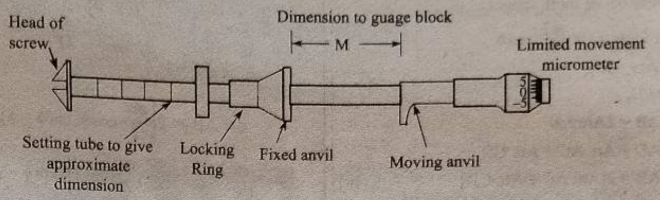
What are the various gear tooth measuring methods? Explain any one with simple sketch.

Answer :

The various methods of measuring gear tooth thickness are as follows,

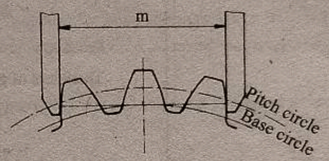
1. Base tangent method
2. Constant chord method.

Base Tangent Method: It measures the gear tooth thickness with higher accuracy. It uses either a micrometer with flanged anvils or the David Brown tangent comparator as shown in the figure.



Figure(1): David Brown Tangent Comparator

This comparator comprises of a fixed anvil and a movable anvil. On the side of a moving anvil, there is a micrometer which possess a very fine limited movement on both sides of the zero setting. With the help of distant pieces or gauge blocks, the base tangent length is adjusted in the comparator. The distance of fixed anvil is adjusted at a required place from head of screw with the aid of spacing collars.



Figure(2)

Expression for Tooth Thickness of Gear: Consider a tangent ABC, which is rolled back and forth over the base circle as shown in figure (3). The measurements along opposed involutes is constant.

$$M = AC = A_1C_1 = A_2C_2 = \text{Arc } A_oB_o$$

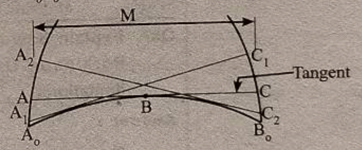


Figure (3)

When the measuring faces are parallel to each other or present on opposed faces of the involutes, their position is not important. The true involute of gear tooth is at the pitch point of gear. The number of teeth required for the measurement are obtained from databook. The required measurement is done at the base circle of the gear.

From figure (3),

$$M = \text{arc } AB + \text{arc } BC \qquad \text{.... (i)}$$

Where,

Arc AB – Tooth thickness

Arc BC – $S \times$ Base pitch

Angular pitch, $P_\theta = \frac{2\pi}{T}$ radians

Base pitch, $P_b = \frac{2\pi}{T} \times r_b$

Where,

T – Number of teeth

S – Number of tooth spaces

Base circle radius, $r_b = \frac{mT}{2}\cos\phi$

Determination of Arc AB

From figure (3),

Arc AB = 2Arc AD

Arc AD = Arc AC + Arc CD

Arc AB = 2[Arc AC + Arc CD] ... (ii)

Arc AC = r_b(invϕ)

Where,

inv ϕ – Involute function of an angle

It is the angle between involute radius to the origin and radius to the intercept of generator with involute.

$$\frac{AB}{OB} = (\phi + \text{inv}\phi) \text{ radians}$$

Arc AB = Arc BC

$$\therefore \frac{BC}{OB} = (\phi + \text{inv}\phi) \text{ radians}$$

$$\tan\phi = \phi + \text{inv}\phi$$

$$\text{inv}\phi = (\tan\phi - \phi) \text{ radians}$$

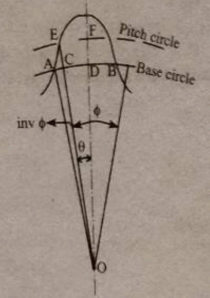


Figure (4) : Gear Tooth Thickness by Base Tangent Method

Therefore,

$$\text{Arc AC} = \frac{MT}{2}\cos\phi(\tan\phi - \phi)$$

$$\text{Arc EF} = r_p \cdot \theta$$

$$\text{Arc CD} = r_b \cdot \theta$$

$$\theta = \frac{Arc\ EF}{r_p}$$

$$= \frac{\frac{1}{4}(\pi m)}{\frac{mT}{2}}$$

$$= \frac{1}{4}(\pi m) \times \frac{1}{mT}$$

$$\theta = \frac{\pi}{2T}$$

$$\text{Arc CD} = r_b \cdot \theta$$

$$= \frac{mT}{2}\cos\phi \times \frac{\pi}{2T}$$

From equation (ii),

$$\text{Arc AB} = 2\left[\frac{mT}{2}\cos\phi(\tan\phi - \phi) + \frac{mT}{2}\cos\phi\left(\frac{\pi}{2T}\right)\right]$$

$$= 2 \times \frac{mT}{2}\cos\phi\left[(\tan\phi - \phi) + \frac{\pi}{2T}\right]$$

$$\text{Arc AB} = mT\cos\phi\left[(\tan\phi - \phi) + \frac{\pi}{2T}\right]$$

Determination of Arc BC

$$\text{Arc BC} = P_b \cdot S$$

$$= \frac{2\pi}{T} \times \frac{mT}{2} \times \cos\phi \times S$$

$$= mT\cos\phi\left[\frac{\pi S}{T}\right]$$

From equation (i)

Thickness of gear teeth,

$$M = \text{Arc AB} + \text{Arc BC}$$

$$= mT\cos\phi\left[(\tan\phi - \phi) + \frac{\pi}{2} + \frac{\pi S}{T}\right]$$

Where,

m – Module

T – Number of teeth

ϕ – Pressure angle in radians

M – Base tangent

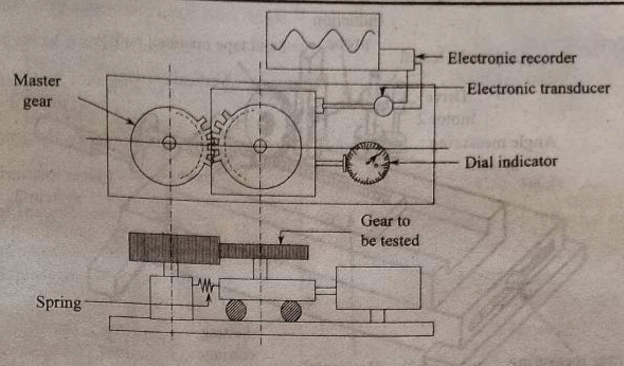
Q87. Explain how a gear can be checked using Parkinson Gear Tester also mention its limitations.

Answer :

Parkinson gear tester is the instrument used to test the gears for their tooth shape, profile, eccentricity, etc.

Construction

1. It consists of a master or standard gear and a gear to be tested. Both are fixed on two seperate spindles, so that they can rotate in mesh with negligible clearance.
2. The master gear spindle can be moved along the table and clamped in any required position. The other spindle is free to move on rollers.
3. The axial distance between the two spindles must be equal to the distance between the gear centres. A scale is fixed on one carriage and vernier on other carriage, allowing the measuring distance to be within the limit of 0.025 mm.

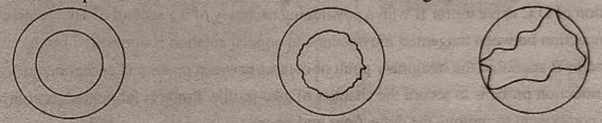


Figure(1): Parkinson Gear Tester

4. Any irregularites in tooth shape, pitch, concentricity, etc, causes changes in center distance.

Working Principle: A master gear is fixed on the stationary vertical spindle and gear to be tested is mounted on other spindle over movable carriage. These gears are held in contact by using spring pressure. The dial indicator indicates the irregularities, when both the gears are in rotation. An electric recorder is used to record the irregularities in the gear, which generates wave form of circular or rectangular charts.

Figure (2) shows the reproduction of charts with reduced scale and magnified errors.



Figure(2)

Advantages

1. It detects poor tooth form caused due to worn or inaccurate cutting tool.
2. It detects pitch circle eccentricity which results due to inaccurate centering of the gear blank prior to tooth cutting.

Disadvantages

1. Gears of diameters only upto 300 mm can be tested.
2. Accuracy is $\pm$ 0.001 mm.
3. Highly sensitive to cumulative position errors.
4. Testing can be done by using reference gear or master gear only.
5. Errors are not clearly determined.

Q88. Explain about automatic gear measuring machine with neat sketch.

Answer :

Automatic gear measuring machine is used for through measurement of gears only in one automatic cycle. The gear which is to be tested is mounted on the shaft consisting angle measuring system. The involute inspection of gear is carried out by fixing the base circle to an accuracy of 1 micron using a digital counter by the movement of setting carriage.

The linear measuring system as show in figure, measures the movement of setting carriage. The microprocessor in the machine with the help of linear measuring system B, drives probe head tangentially across the desired length of area. The tangential axis have a resolution of 0.1 micron.

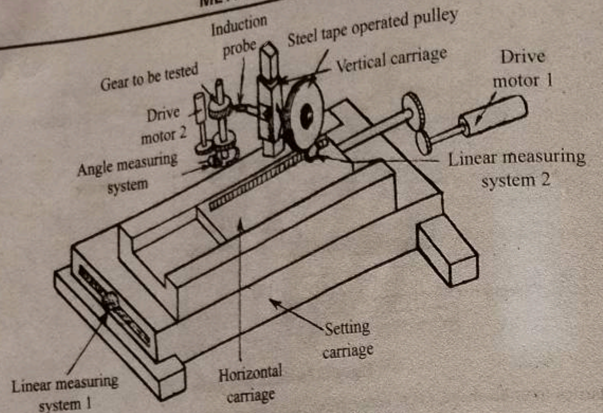


Figure: Automatic Gear Measuring Machine

The drive system A drives the horizontal carriage and the movement of this carriage is measured by linear measuring system B. The vertical carriage is mounted on the horizontal carriage. The probe on vertical carriage is driven by drive motor A by the action of steel tape pulley. The vertical carriage can also move back and forth in the axial direction of gear. This machine provides a provision to connect or disconnect the drive with vertical column.

The angular resolution of D.C drive motor B with a positioning accuracy of 0.5 second of arc, controls the radial rotation of the component. The connection between tangential movement and angular rotation is controlled by the microprocessor. This is done by altering drive motor B such that the imaginary point of contact between probe and component travels the true path of involute. The function of induction probe is to record the changes of gear profile. Probe is fabricated as compact as possible and always placed close to the component to remove the deflections and errors.

5.4 ALIGNMENT TESTS

5.4.1 Machine Tool Alignment Tests on Lathe

Q89. What are the various alignment tests performed on lathe.

Answer :

1. Levelling of the machine.
2. True running of locating cylinder of main spindle.
3. Axial slip of main spindle and true running of shoulder face of spindle Nose.
4. True running of headstock centre.
5. Parallelism of the main spindle to saddle movement.
6. True running of taper socket in main spindle.
7. Parallelism of tailstock guideways with the movement of carriage.
8. Movement of upper slide parallel with main spindle in vertical plane.
9. Parallelism of tailstock sleeve to saddle movement.
10. Parallelism of tailstock sleeve taper socket to saddle movement.
11. Alignment of both the centres in vertical plane.
12. Pitch accuracy of lead screw.
13. Alignment of lead screw bearings with respect to each other.
14. Axial slip of lead screw.

Q90. Discuss the following alignment tests on a lathe,

(i) Test for level of installation

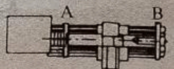
(ii) True running of locating cylinder of main spindle

(iii) True running of taper socket in main spindle.

Answer :

(i) **Test for Level of Installation**

It is essential that, a machine to be installed truly in both longitudinal and transverse directions.



Figure

Measuring Instruments

Spirit level, gauge block which can fit the guide ways of the lathe bed.

Procedure

During testing, the gauge block with spirit level is placed on the bed ways on the front position, back position and in the crosswise direction. The position of the bubble in spirit level is checked and the readings are recorded.

Permissible Error

(i) On front guide ways : 0.02 mm/meter convexity

(ii) On rear guide ways : 0.01 to 0.02 mm/meter convexity

(iii) Straightness of the slide ways (for machines with 3 m turning length is measured by measuring taught wire and microscope or long straight edge).

(iv) Tail stock guide ways are parallel with the movement (0.02 mm/m) of carriage.

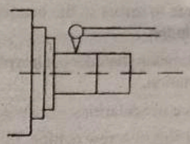
(v) No twist is allowed.

The error in level of machine tool installation can be corrected by placing wedges at suitable points under the support feet or pads of the machine.

(ii) **True Running of Locating Cylinder of Main Spindle**

To locate the chuck or face plate, a locating cylinder is used. The locating surface is cylindrical, but not threaded one, since heads worn out soon. For true running of face plate, it is essential that locating cylinder must run truly.

The dial indicator is fixed to the carriage or to the fixed member such that the feeler of the indicator touches the locating surface. The surface is then rotated on its axis and indicator should not show any movement of needle.



Figure

(iii) **True Running of Taper Socket in Main Spindle**

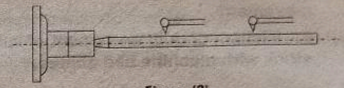


Figure (2)

An eccentric and tapered jobs will be produced, when the axis of tapered hole of the socket is not concentric with the main spindle axis.

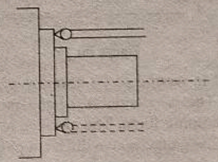
To test the true running of taper socket, a mandrel is fitted into the tapered hole and readings are noted at two extremes of mandrel, by means of a dial indicator.

Q91. Explain about the test axial slip of main spindle and true running of shoulder face of spindle nose on lathe?

Answer :

Axial play is an important and necessary freedom of spindle movement in axial direction so that the seizing of spindle by heating is prevented. The spindle is supported between two bearings, and the temperature rises, due to running of spindle, which leads to thermal expansion of spindle. If no axial play is allowed, the spindle may try to bend.

Thus, there is no adverse effect of axial play, if the direction of cutting forces remains the same. If the direction of cutting forces changes, error might occur due to movement of spindle in both directions. Therefore, it is suitable to cut threads in one direction only. Axial slip is the axial spindle movement, which causes the similar problem as that of axial play, and is caused due to the error in manufacturing.



Figure

To check this manufacturing error, the feeler of the dial gauge rests on the face of the locating spindle shoulder and the dial gauge holder is clamped to the bed. Then the locating cylinder is rotated and change in readings are noted down. Generally, the readings are recorded at two diametrically opposite points. The overall error indicated by the movement of pointer includes following sources of errors.

(i) Axial slip due to errors in the bearings supporting the locating cylinder.

(ii) The face of locating shoulder not in a plane perpendicular to axis of rotation.

(iii) The front face irregularities.

Due to axial slip in screw cutting, the pitch will not be uniform due to periodic movement of the spindle.

Q92. Describe the following alignment tests on a lathe,

(i) Parallelism of tail stock sleeve to saddle movement

(ii) Parallelism of quill movement of lathe tail stock with machine bed guides.

Answer :

(i) Parallelism of Tail Stock Sleeve to Saddle Movement

For this test, a dial indicator is fixed on the tool post and the plunger is pressed against the sleeves first in vertical and then in horizontal plane as shown in below figure.

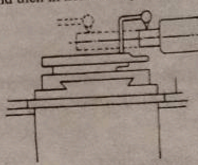


Figure (i)

As the carriage moves along the full length of the sleeves, the deviations are obtained by the dial indicator. Therefore, in vertical plane, the tailstock sleeve should rise towards the free end and in horizontal plane, it should be inclined towards the tool pressure.

(ii) Parallelism of Quill Movement of Lathe Tail Stock with Machine Bed Guides

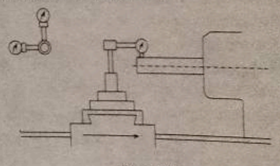


Figure (ii)

The quill is wound to its extreme position and then clamped. This is essential as the quill position is affected by the clamping force. The carriage is traversed along with the dial gauge in two different positions.

The end of the quill should rise by an amount not exceeding 0.02 mm and should be inclined forward by not more than 0.01 mm.

Q93. Briefly discuss the following test on a lathe,

(a) Parallelism of tailstock guideways with the movement of carriage.

(b) Parallelism of main spindle to saddle movement.

Answer :

(a) Parallelism of Tailstock Guideways with the Movement of Carriage

For turning of the job which is held between head stock and tailstock centre, the job axis must coincide with the tailstock centre, which otherwise results in taper turning.

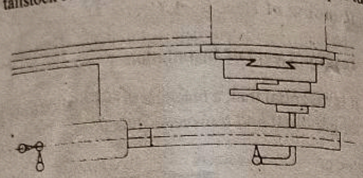


Figure (1)

To check the parallelism of tailstock guideways in both horizontal and vertical planes, a block is placed on the guideways and the feeler is held on the horizontal and vertical surfaces of the block. The dial indicator is held in the carriage and it is moved. Any error is indicated by the pointer of indicator.

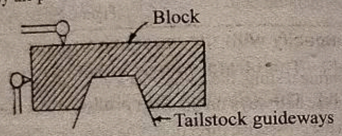


Figure (2)

(b) Parallelism of the Main Spindle to Saddle Movement

The mandrel which is used for this test must be proportioned such that its overhang does not produce significant sag, or else the sag should be calculated and accounted for. If not, the changes in reading is recorded by pointer is completely due to deflection of the indicator mounting in different positions, and is very difficult to detect the false deflections from the true variations.

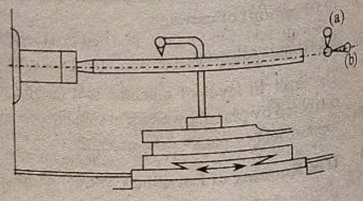


Figure (3)

A tapered surface is generated, when the axis of the spindle is not parallel to bed in horizontal direction. Similarly, a hyperboloid surface is generated, when the spindle axis is not parallel to bed in vertical direction. For this test, a mandrel having a concentric taper shank which closely fits into the spindle nose taper is used. It is fitted in the taper socket of the spindle.

The feeler of the dial indicator is pressed on the mandrel and the carriage is moved. In vertical plane, the mandrel should rise towards the free end, in order to counteract the weight of mandrel and job. But for counteracting cutting forces, it should be lowered towards free end. In horizontal plane, mandrel should be inclined in a direction opposite to the direction, of tool pressure.

Q94. Explain the alignment test on lathe for true running of headstock center.

Answer :

True Running of Headstock Centre

Measuring instrument required is dial gauge.

Test Procedure

This alignment test is very important, in order to rotate the workpiece with the head stock centre or live centre. If this alignment is not accurate, eccentricity will be caused while turning a workpiece. For testing this error, the feeler of the dial indicator is pressed against the tapered surface of the live centre and the main spindle is rotated. The deviation indicted by the dial gauge indicator gives the trueness of the live centre.

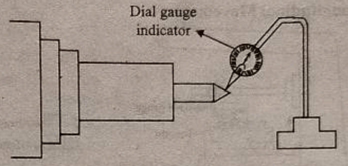


Figure: Alignment Test for True Running of Headstock Centre

Q95. Specify with the diagrams how two of the following tests would be carried out on a centre lathe?

(i) The straightness of the bed horizontally and vertically.

(ii) The spindle axis parallel to the bed in both the horizontal and vertical panes.

Answer : [Nov.-15, (R13), Q11(b) | Model Paper-II, Q10(a)]

(i) The Straightness of the Bed Horizontally and Vertically

For answer refer Unit-V, Q90, Topic: Test for Level of Installation.

(ii) The Spindle Axis Parallel to the bed in both the Horizontal and Vertical Planes

For answer refer, Unit-V, Q93, Topic: Parallelism of Main Spindle to Saddle Movement.

5.4.2 Alignment Tests on Milling and Drilling Machines

Q96. Describe any three alignment tests on milling machine.

Answer :

Tests on Column

(a) To check column ways squareness with table and front to rear inclination.

(b) Side inclination

During test, the table is adjusted in its central-position and on its surface, a square with an arm of about 300 mm length is fixed and a dial gauge is attached to the spindle mandrel, such that its feeler rests on the arm of the surface near the bottom edge. The reading of the dial gauge is observed, and another reading should be noted by moving the table about 300 mm upwards.

The difference in readings is the indication of the error in perpendicularity of the table and knee support. The test is performed for two positions of the square, i.e., in first position the dial gauge touches the square in front and in second position, it faces the side of the square (90° to the first position). Any considerable error in column-ways sequences, the surfaces produced will not be square with the table surface.

True Running of Internal Taper

For this test, first the table is set in its main position longitudinally, and mandrel of length 300 mm is fixed in the spindle taper. On the machine table, a dial gauge is set, and the feeler is adjusted to touch the lower surface of the mandrel. Then the mandrel is rotated by means of the spindle and the dial gauge readings are noted at two points. The first point is at the location nearest to the spindle nose and the second point is at about 300 mm from the first point.

The cross slide of the machine is operated to shift the dial gauge position form A to B at the bottom of the end of mandrel. The following two errors may arise during the test,

1. The spindle axis and the taper axis may not be parallel,
2. Eccentricity of taper hole.

Due to above errors, there may be vibrations in machine tool and also results in poor surface finish.

Table Surface Parallel with Arbor Rising Towards Overarm

In horizontal milling machines, during the operation, the table tends to incline in the downward direction, due to the weight of the work and cutting pressure, while the arbor tends to deflect in upward direction. Parallelism between table face and spindle axis can be tested, by placing a dial gauge on the table. A mandrel of length 300 mm is fixed in the spindle taper. The feeler is adjusted, such that it touches the mandrel on its lower surface. By keeping the mended in position, the readings at the maximum travel of the table are obtained. In this test, the table remains stationary and the dial gauge is moved.

Due to this error, the surface generated by milling is not square to the machine bed and cross ways.

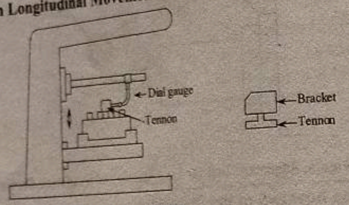
Q97. Discuss the following tests on milling machine,

(a) Central T-slots parallel with longitudinal movement

(b) Centre T-slot square with the arbor

Answer :

(a) Central T-slots Parallel with Longitudinal Movement



Figure

Parallelism of central T-slots with table longitudinal movement can be checked, by using the dial gauge and bracket of length 150 mm with a tennon block which enters the T-slot.

Procedure

(i) A dial gauge is fixed on the spindle, whose feeler is adjusted to touch the upper surface of the bracket.

(ii) Tennon is held stationary by hand, while table is given the longitudinal movement, which causes tennon to slide along in the T-slot. Thus, the effects of local errors are eliminated.

(iii) Any deviation in parallelism causing deflection of dial gauge is noted.

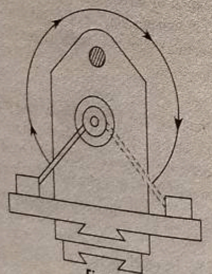
This error causes non-uniform depth of cuts, as work is inclined according to the inclination of slots.

The permissible error is,

Error	Table Longitudinal Movement
0.04 mm	600 mm
0.05 mm	600 mm – 1000 mm

(b) Centre T-slot Square with the Arbor

If the central T – Slots are not perpendicular to the arbor, the keyway cut on the machine will not be parallel to the axis of the job.



Figure

Procedure

(i) The table is positioned in the mid portion of its longitudinal movement.

(ii) The tennon block of length 160 mm is inserted into the T-slot.

(iii) The dial gauge is mounted on the mandrel, such that the feeler is touching the vertical surface of the bracket.

(iv) When the tennon block is near one end of the table, note the readings from dial gauge.

(v) Then turn over the dial gauge, and note the reading at the other end of the table by moving the tennon block.

Q98. Explain the following alignment tests on a milling machine,

(i) Cutter spindle axial slip or float

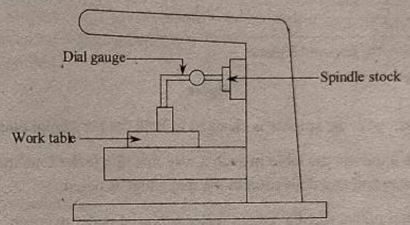
(ii) Eccentricity of external diameter

(iii) Overarm parallel with spindle

Answer :

Alignment Tests on a Milling Machine

(i) Cutter Spindle Axial Slip or Float



Figure

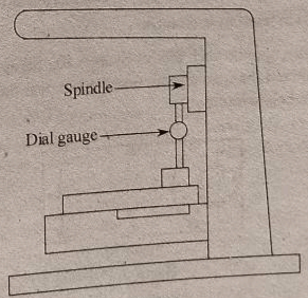
Axial play is defined as the axial spindle motion which may occur repeatedly in each revolution.

It is due to effect of manufacturing errors, such as error in bearing on which spindle is supported, spindle face irregularities, perpendicularity error in face of locating shoulder.

For testing the axial slip, dial gauge used. The dial gauge holder is fixed on the table such that the feeler touches the face of the locating shoulder. Any deflection shown by the dial gauge when the machine spindle is rotated, is noted. This test has to be done at two different points, which are diametrically opposite to each other(180° apart) on the collar of the spindle, because dial gauge will not show any deflection if the feeler touches at the same point. The permissible axial slip is 0.01 mm.

Due to these errors in cutting spirals, the pitch will not be constant and the pitch helix also irregular.

(ii) Eccentricity of External Diameter



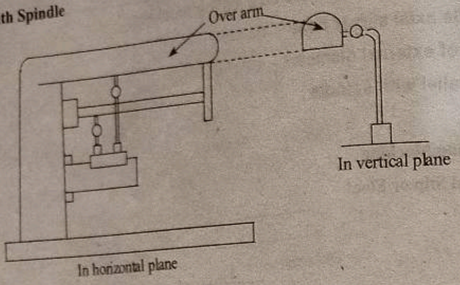
Figure

It is defined as misalignment of the spindle centre axis with the hole axis, in which it is located.

This test uses a dial gauge to measure the deviation, which is clamped on table and the feeler rests on the cylindrical surface of the locating shoulder. The locating shoulder is allowed to rotate and any deflection shown by dial gauge is recorded, which gives the error.

Eccentricity of external diameter causes vibration in machine tool and the cutter will float sidways and cut over or under size, and varying depth of cut should not exceed 0.01 mm.

(iii) Overarm Parallel with Spindle



Figure

The parallelism of the overarm with the spindle is checked in both the horizontal plane and vertical plane.

For this test, the dial gauge is fixed on the table in such a way that, the feeler touches under the diametral surface of the mandrel. The table is moved cross wise and any deflection in the dial gauge is noted.

To check the error in horizontal plane, the dial gauge feeler is placed under overarm. Then the table is moved crosswise and dial gauge reading is noted. Then, compare two sets of the readings.

To check the error in vertical plane, compare the readings on mandrel and side of overarm. The permissible error in horizontal and vertical plane is 0.025 mm/300 mm.

Q99. Explain alignment tests on a radial drilling machine.

Answer :

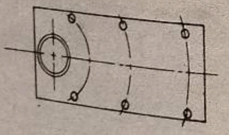
Various tests performed on a radial drilling machine are:

1. **Saddle Movement Parallel to the Bases Plate**

   During the test, the plunger bearing (or) feeler of the dial gauge, which is attached to the spindle, is placed on the surface of base plate. By moving the saddle along the arm, different readings are obtained, which shows the error. The error obtained gives the deviation from parallelism with base plate should be on inclination upword towards the column, The permissible error is limited to 0.16 mm/m.

2. **Checking the Parallelism of the Arm itself as it Rotates**

   In this test, a dial gauge is fixed to the spindle such that its plunger bearing is on the surface of the base plate. Then the arm is rotated slowly on the column and the readings are noted down near the edge of the base plate, with its saddle in three different positions as shown in below figure.



Figure

The permissible error for this test is limited to 0.16 mm per meter.

Q100. Explain the alignment test for determining the total deflection in pillar type drilling machine.

Answer :

Alignment Test to Determine the Total Deflection in Pillar Type Drilling Machine

The instruments required for total deflection test are dial indicator for measuring deflection and dynamometer or load gauge for measuring load on the spindle.

Steps in Performing Total Deflection Test

1. The drill head and machine table are positioned, such that they align with their center axis.
2. Dynamometer is mounted on table, exactly below the drill head.
3. Dial gauge is fixed on table and arranged, such that its feeler is touching the lower machined surface part and spindle stock.
4. Then, machine spindle is loaded with the help of dynamometer (load gauge) and corresponding deflection shown by dial indicator is recorded.

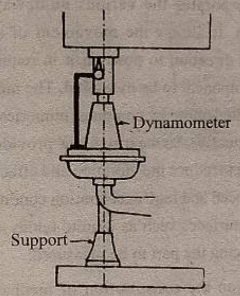


Figure: Total Deflection Test Arrangement

Q101. Describe the following alignment tests on a pillar drilling machine,

(a) Parallelism of the spindle axis with its vertical movement

(b) Flatness of clamping surface of table.

Answer :

(a) Parallelism of the Spindle Axis with its Vertical Movement

In this test, a test mandrel is fitted into the tapered hole of the spindle. A dial gauge is fixed on the work table, such that the feeler is touching the mandrel surface. By moving the spindle up and down from the mid position the readings are noted down. The test is performed in two planes (A) and (B), which are perpendicular to each other. The permissible errors in both the planes are limited to 0.03 mm/100 mm and 0.05 mm/300 mm depending upon the taper size.

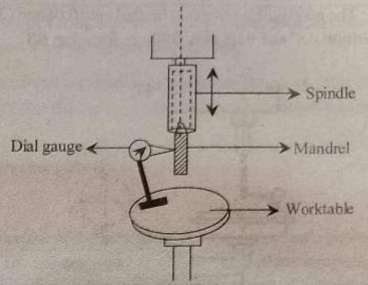


Figure: Parallelism of Spindle Axis with its Vertical Movement

(b) Flatness of Clamping Surface of Table

In this test, a straight edge is used to measure the flatness, by placing it on the two gauge blocks on base plate in different positions. The error is recorded by inserting feeler gauges and it is limited to 0.1mm/ 1000 mm clamping surface. It should be noted that the clamping surface must be concave in shape.

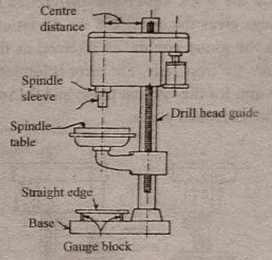


Figure: Flatness of Clamping Surface of Table

Q102. Describe the following alignment tests on a pillar drilling machine.

(a) Squareness of the spindle axis with table

(b) Perpendicularity of drill guide to the table.

Answer :

(a) Squareness of the Spindle Axis with Table

During this test, the straight edge is placed on the work table, in positions *AA'* and *BB'*. The work table is arranged in the middle positoin of its vertical travel. The spindle has a tapered hole, into which the dial gauge is mounted with its feeler is touching the straight edge surface at point A. The readings are noted from the dial indicator. Then, by rotating the spindle by 180°, the dial gauge feeler is made to touch the straight edge at point *A'* and again the readings are noted. The error is calculated by the difference of two readings. Similarly, another two readings are taken when the straight edge is placed perpendicular to the arm in a position *BB*. Variations are observed when the lower end of the spindle inclining towards the column.

The permissible errors are limited upto 0.08mm / 300mm for position *AA'* and 0.05 mm/ 300mm for setup *BB'*.

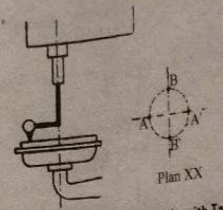


Figure: Squareness of Spindle Axis with Table

(b) Perpendicularity of Drill Guide to the Table

This test is performed in two planes, one which is vertical passing through spindle and column axes, and the other is perpendicular to it. During the test, perpendicularity is measured by using frame level. The two readings are noted when frame level is placed on the guide column and on the work table. The difference between two readings gives the error, and the deviation is observed when the guide column is inclined at the upper end towards the front only. The error is limited to 0.25 mm/ 1000 mm for the vertical plane and 0.15mm/1000 mm for the horizontal plane.

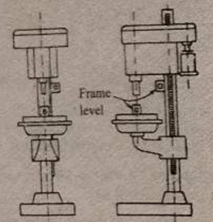


Figure: Perpendicular of Drill Guide to the Table

Q103. Explain in detail the alignment test performed on milling machine? May/June-19, (R16), Q11(b)

OR

Explain various alignment tests to be conducted on milling machine.

Answer : [Dec.-19, (R16), Q10(b) | Model Paper-III, Q10(a)]

For answer refer Unit-IV, Q96, Q97 and Q98.

Q104. Explain the machine tool alignment test on drilling machine. Nov./Dec.-18, (R16), Q11(a)

OR

Describe various alignment tests to be conducted on drilling machines.

Answer : Nov./Dec.-17, (R15), Q11(a)

For answer refer Unit-V, Q100 and Q101.

5.5 COORDINATE MEASURING MACHINES : TYPES AND APPLICATIONS OF CMM

Q105. Describe briefly Coordinating Measuring Machine (CMM).

Answer : Nov./Dec.-16, (R13), Q11(a)

Coordinate measuring machine (CMM) is one of the most important equipment used in the contact type inspection process of parts. It is a flexible measuring machine widely used in manufacturing industries for post production inspection of components. The basic elements of CMM are as follows,

1. Rigid mechanical structure
2. Probing system
3. Control unit
4. CMM software.

1. **Rigid Mechanical Structure :** It is a rigid structure and serves as a main operating unit of CMM, where it incorporates the various guideways and probing system. It allows the movement of sensor probe in X-Y-Z direction to position it in required position on the component to be measured. The movements can be controlled either by computer numerical control (CNC) or manually. Air bearings are provided for the line motion to reduce the vibration and effects caused during high speed and high acceleration conditions. Thermally stable surfaces such as granite tables are used as base for placing the part to be measured.

   Based on the construction of mechanical structure different of CMMs are available. They are,
   1. Cantilever type
   2. Bridge type
   3. Column type
   4. Horizontal arm type
   5. Gantry type.

2. **Probing System :** The measuring head of the CMM is incorporated with the touch trigger probes to record the coordinates (x,y,z) of the points where the probe touches the component to be measured. The stem of the probe is made of tungsten, steel, ceramics and titanium whereas the tip of the probe is made of ruby, silicon nitride and zirconia. These probes are faster and accurate in measurement. For non-contact type measurements, opto-electronic sensors are used instead of touch trigger probes.

3. **Control Unit :** It controls the positioning of probe and movements of various spindles in x-y-z directions. It collects data in the form of measured point sets, which is an input for CMM software for further calculations.

4. **CMM Software :** It is the operating system of CMM. It consists of various types of application programs. This software enables the CMM to do required calculations on the point sets and this data is exchanged between the other equipment in the CMM.

   Based on the type of industry, number of application softwares are available.

Working

During its working, the sensing probe is made to contact with the surface of the part. Then, the three coordinate positions are marked with greater accuracy, by moving the probe in required direction. The accuracy may be of 2.6 + L / 300 micrometers, where 'L' indicates the measured length in mm. The movement of probe can be obtained either manually or by means of a programmable computer system. The coordinate data can be obtained from the computer, as CMM is monitored using a computer. This reduces the time of inspection process. The major disadvantage is that, it also leads to the wastage of time due to transportation of components for inspection, as CMMs are placed away from the production machines.

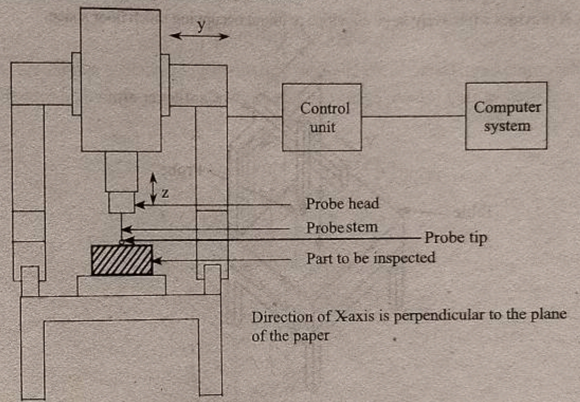


Figure: Coordinate Measuring Machine

Q106. Explain the different types of CMM controls.

Answer :

The different types of CMM controls are as follows,

1. Manual controlled CMM
2. Computer controlled CMM.

1. **Manual Controlled CMM:** In this type of CMM control, the measurement or inspection is done by moving the probe manually relative to the part surface along the axes. The probe moves by means of a sliding mechanism, which is designed to be smooth. This enables free movement of probe in *x*, *y* and *z* directions. The data obtained from measurement is recorded by the operator. Thus, the operator analyses and evaluates the data for results. Hence, this method is time consuming and less accurate, when compared to computer controlled CMM.

2. **Computer Controlled CMM:** In this type, CMM is directly operated by computer control such as CNC machines. In this, the probe movement relative to the part surface is automated by means of motor drive are controlled by means of programmed instructions in *x*, *y* and *z* directions. The computer system with integrated software processes and evaluates the data. The data related to measurement is recorded by this computer. The results are stored in this system as to recall, when it is required. Hence, the use of computer makes this method simple, less time consuming and highly accurate.

However, the CMMs are also controlled by implementation of features of both the above methods in combination.

Q107. Write a short note on different types of coordinate measuring machines.

OR

Explain the structure of various types of coordinate measuring machines with neat sketch.

[Nov.-15, (R13), Q11(a) | Model Paper-I, Q10(b)]

Answer :

The following are the basic Coordinate Measuring Machines (CMMs).

1. Cantilever type
2. Bridge type
3. Column type
4. Horizontal arm type
5. Gantry type.

1. **Cantilever Type :** In this, a vertical probe moves in z-axis, carried by a cantilever arm that moves in y-axis, which can also move in x-axis (laterally). It provides a relatively large envelope ,without occupying much floor space.

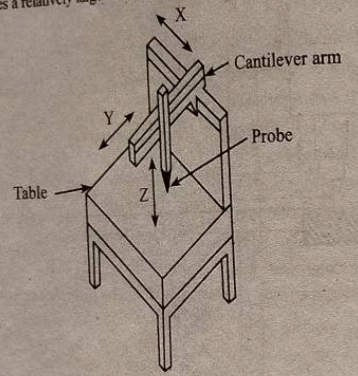
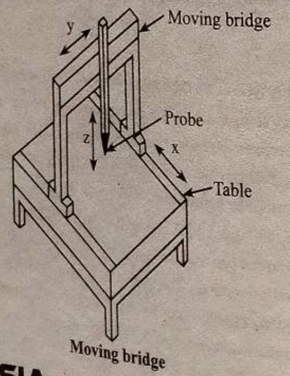


Figure (1) : Cantilever Type

2. **Bridge Type :** It is similar to the cantilever type. It has a support for outer ends of the y-axis beam on the base. The bridge construction adds rigidity to the machine. The bridge can be either fixed or movable. This type of configuration provides superior accuracy in measurement, making it useful for gauge room applications and mass production inspection.



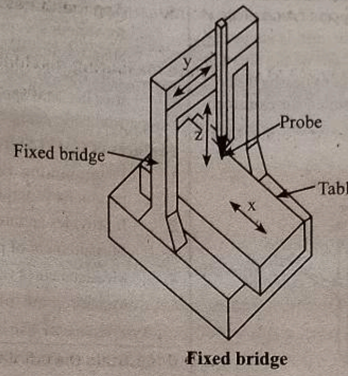


Figure (2): Bridge Type

3. **Column Type:** Its construction is similar to jig borer and it is named as "universal measuring machine" instead of a CMM. Its construction provides high rigidity and accuracy and used in gauge rooms rather inspection.

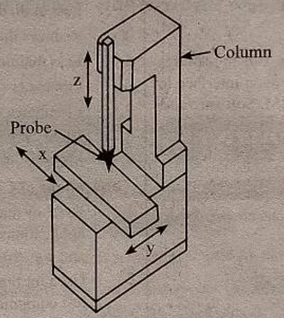


Figure (3): Column Type

4. **Horizontal Arm Type:** It is referred as a layout machine. It has a moving arm and the probe is carried along the y-axis. Its construction provides a large, unobstructed work area, which is suitable for very large work pieces. In one variation, it is also called a "fixed arm type" CMM.

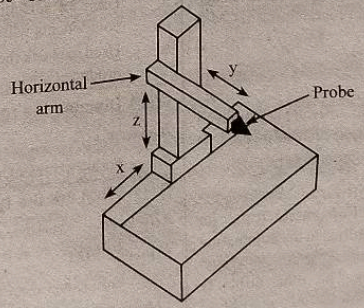


Figure (4): Horizontal Arm Type

5. **Gantry Type:** In this type, the support of workpiece is independent of the x and y-axes. The arm is supported by four vertical columns. This setup allows the operator to walk along the workpiece and remains nearby the area of inspection. This construction is suited for extremely large workpieces.

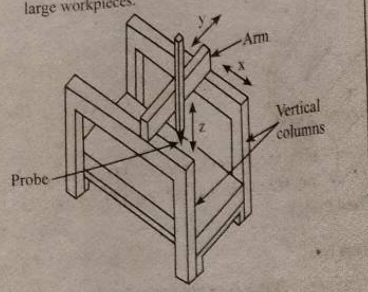


Figure (5): Gantry Type

Q108. Explain briefly about CMM software.

Answer :

CMM software is a set of programs and procedures to operate the CMM. These programs provide an interface to the accessories and other components of CMM. Software also allows the communication and data exchange between various equipment of CMM. The following are the various types of CMM software.

1. **Core software:** It is the basic software required to operate CMM. The basic functions of core software are as follows,
   1. Calibration of probe
   2. Development of a part coordinate system
   3. Feature construction
   4. Tolerance analysis.
2. **Programming Software:** This software helps in programming of the CMM. It enhances the operator interface. It assists the operator by providing an expert system for development of a program. Even though, software is not necessary to run the CMM, it is needed to increase the usability of CMM. Programming of CMM is of two types. They are,
   1. On-line programming
   2. Off-line programming.
3. **Post - Inspection Software:** This software is employed for the process after the inspection of workpiece. It is used to analyze the data obtained by the inspection.
4. **Reverse Engineering:** This software is used for the construction of computer model of measured part by digitization. There are two difficulties in the automation of reverse engineering. One is manual digitization, which is required for complex surfaces. The other difficulty is processing of large number of measured point sets on CAD/CAM system.
5. **Application Specific Software:** This software is developed for various specific applications. Some of the applications are inspection of gear, checking of automobile bodies, etc. This type of software is also developed for accessories used in CMM applications like probe changing, rotary and worktables and part handling equipment.

Features of CMM Software

1. Programming time of similar parts is reduced by parameter programming.
2. It provides an interface to the CAD software.
3. Measurement of plane and spatial curves.
4. Measurement of various types of gears (spur, helical, bevel)
5. Measurement of various parameters of prismatic components like diameter, lengths, geometrical errors.

Q109. State the advantages and applications of CMM.

Answer : Nov./Dec.-16, (R13), Q10(b)

Advantages of CMM

1. It saves time and maintains consistency in the process.
2. High degree of accuracy can be obtained.
3. Less skilled operators are required for the inspection.
4. Reduces the setting up and fixing time.
5. Less maintenance is required.
6. Process is simple and reliable.
7. Eliminates the human errors.
8. Highly precise and reduce inspection time.
9. More flexible compared to conventional machines.

Applications of CMM

1. Used in machine tool, automobile, electronics, space applications and used for development of new products and construction of prototype.
2. Used for the testing and inspection of gauges, tools and test equipment.
3. Used for determining dimensional accuracy of the bought in components and to check the quality of supplied components.
4. 100% inspection and documentation of space and aircraft safety components are carried out by using CMMs.
5. Used for sorting tasks to achieve optimum pairing of components with tolerance limits.
6. Used to check the dimensional accuracy of NC machine produced jobs.

Q110. Discuss the role of CMMs in industry?

Answer : Nov./Dec.-17, (R15), Q11(b)

For answer refer Unit-V, Q109, Topic: Applications of CMM.

Q111. What are the types and applications of CMM?

Answer: [Nov./Dec.-18, (R16), Q10(a) | Model Paper-II, Q10(b)]

Type of CMM

For answer refer Unit- V, Q107.

Applications of CMM

For answer refer Unit-V, Q109, Topic: Applications.

EXERCISE QUESTIONS

Q1. Calculate the CLA (Ra) value of a surface for which the sampling length was 0.8 mm The graph was drawn to a vertical magnification of 10000 and a horizontal magnification of 100, and the areas above and below the datum line were:

Above:	150	80	170	40 mm^2
Below:	80	60	150	120 mm^2

[C.L.A or R_A = 1.06 μm]

Q2. Calculate the C.L.A. value of a surface for the following data:

The sampling length is 0.8 mm, the graph is drawn to a vertical magnification of 15000 and horizontal magnification of 100 and the areas above and below the datum line are 160, 90, 180, 50 mm2 and 95, .65, 170, 150 mm^2 respectively.

[C.L.A = 0.8 μm]

Q3. In the measurement of surface roughness, heights of 20 successive peaks and valleys measured from a datum are as follows: 45,25, 40, 25, 35, 16, 40, 22,25, 34, 25, 40, 20, 36,28, 18, 20, 25,30, 38. If these measurements were made over a length of 20 mm, determine the C.LA and RMS values of the surface.

[CLA = 29.35 μm

RMS value = 930.96 μm]

IMPORTANT QUESTIONS

Q1. With the help of neat diagram, explain the elements of a surface texture. Refer Unit-V, Q46

Q2. Explain the Roughness parameters and Roughness profiles. Refer Unit-V, Q47

Q3. What are the various orders of geometrical irregularities on surface? How these are classified. Refer Unit-V, Q48

Q4. Explain the importance of sampling length in surface roughness measurement. Refer Unit-V, Q49

Q5. State the possible causes of each of the various types of irregularities found in surface texture. Show how surfaces having the same numerical assessment may have different properties and texture. Refer Unit-V, Q53

Q6. The heights of peak and valleys of 20 Successive points on a surface are 35, 25, 40, 22, 37, 19, 41, 21, 42, 18, 42, 24, 44, 25, 40,18,40,18,39, 21 microns respectively, measured over a length of 20 mm. Determine CLA and RMS values of roughness surface. Refer Unit-V, Q54

Q7. The heights of peak and valleys of 22 Successive points on a surface are 32, 28, 41, 24, 35, 19, 31, 21, 40, 18, 44, 24, 41, 25, 40, 26, 35, 18, 40, 18, 39, 21 microns respectively, measured over a length of 20 mm. Determine CLA and RMS values of roughness surface. Refer Unit-V, Q56

Q8. State and explain the methods of measuring primary texture of a surface? Refer Unit-V, Q57

Q9. Explain the principle, the function and operation of a stylus type surface texture measuring instrument. Refer Unit-V, Q58

Q10. Write the advantages and disadvantages of stylus probe type instrument used for surface roughness measurement. Refer Unit-V, Q60

Q11. Explain the nomenclature of screw thread with the help of a neat sketch. Refer Unit-V, Q61

Q12. What are the sources of errors in screw threads? Explain. Refer Unit-V, Q62

Q13. What is a drunken thread? Explain in detail. Refer Unit-V, Q63

Q14. Describe an experiment to determine the pitch errors of a lead screw. Refer Unit-V, Q65

Q15. Name and describe various methods of measuring the minor diameter of an external thread. Refer Unit-V, Q68

Q16. Describe an exclusive method for effective diameter measurement which shows variation in drunken thread. Refer Unit-V, Q69