



UNESCO-NIGERIA TECHNICAL &  
VOCATIONAL EDUCATION  
REVITALISATION PROJECT-PHASE II



## NATIONAL DIPLOMA IN MECHANICAL ENGINEERING TECHNOLOGY



## MACHINE TOOLS TECHNOLOGY AND PRACTICE

COURSE CODE: MEC123

YEAR I- SEMESTER 2

THEORY

Version 1: December 2008



## TABLE OF CONTENTS

### WEEK 1: THEORY OF METAL CUTTING

- 1.1 Introduction
- 1.2 Mechanics of cutting
- 1.3 The action of cutting tools
- 1.4 Exercises

### WEEK 2:

- 1.5 Chip formation
- 1.6 Discontinuous chip
- 1.7 Continuous with built up edge
- 1.8 Continuous chip
- 1.9 cutting temperature
- 1.10 Cutting fluids
- 1.11 Types of cutting fluids
- 1.12 Economic advantages of cutting fluids
- 1.13 Exercises

### WEEK 3:

- 2.0 Cutting tool materials
- 2.1 Introduction
- 2.2 High carbon steel
- 2.3 High speed steel
- 2.4 Satellite
- 2.5 Cemented or tungsten carbides
- 2.6 Ceramics
- 2.7 Diamond
- 2.8 Exercises

### WEEK 4

- 3.0 Lathe machines
- 3.1 Introduction
- 3.2 Capstan and turret lathe (production lathe)
- 3.3 Engine lathe
- 3.4 Bench lathe
- 3.5 Speed lathe
- 3.6 Gap-bed lathe
- 3.7 Tool room lathe
- 3.8 Lathe parts
- 3.9 Safety precautions
- 3.10 Exercises

### WEEK 5

- 3.11 Lathe operations
- 3.12 Exercises

### WEEK 6

3.13 Lathe accessories

3.14 Exercises

### **WEEK 7**

3.15 Taper turning using attachments

3.16 Cutting taper with tailstock off-set

3.17 Cutting taper with compound rest method

3.18 Exercises

### **WEEK 8**

4.0 Shaping machine

4.1 Introduction

4.2 Main parts of shaping machine

4.3 Shaping machine driving mechanism

4.4 Action of the shaping machine

4.5 Feed mechanism

4.6 Exercises

### **WEEK 9**

4.7 Cutting speed

4.8 Tool holding in shaping machine

4.9 Tool head clapper box

4.10 Holding the work

4.11 Machining vertical and angular faces

4.12 Shaping tools

4.13 Safety precautions

4.14 Exercises

### **WEEK 10**

5.0 Milling machine

5.1 Introduction

5.2 Types of milling machines

5.3 Types of milling cutters

5.4 Face milling cutters

5.5 Construction of milling cutters

5.6 Cutter materials

5.7 Cutting speeds, feeds and depths of cut

5.8 Exercises

### **WEEK 11**

5.9 Dividing heads

5.10 Types of dividing head

5.11 Methods of indexing

5.12 Milling operations

5.13 Exercises

### **WEEK 12**

6.0 Grinding machines

6.1 Introduction

6.2 Types of grinding machines

6.3 Grinding and safety instructions

6.4 Exercises

**WEEK 13**

- 6.5 Surface grinder
- 6.6 Introduction
- 6.7 Mounting of grinding wheel
- 6.8 Exercises

**WEEK 14**

- 6.9 Truing and dressing a grinding wheel
- 6.10 Safety precautions
- 6.11 Grinding a flat surface
- 6.12 Exercises

**WEEK 15**

- 6.13 Precautions to be observed when mounting a grinding wheel
- 6.14 Characteristic terms used in grinding
- 6.15 Grinding faults
- 6.16 Thermal effect of grinding
- 6.17 Trouble shooting in grinding
- 6.18 Exercises

**MACHINE TOOLS TECHNOLOGY & PRACTICE COURSE OUTLINE**

<b>Subject</b>	Machine Tools Technology & practice
<b>Year</b>	1
<b>Semester</b>	2
<b>Course Code</b>	MEC 123
<b>Credit Hours</b>	6
<b>Theoretical</b>	2
<b>Practical</b>	4

**OUTCOMES**

On completion of this module, the students should be able to;

- Understand cutting action in machining operation.
- understand the importance of cutting fluid in machining operation.
- Know various types of lathes, their functions and operations.
- Understand the features, functions and uses of shaping machines.
- Understand the features, functions and uses of milling machines.
- Know the features, functions and use of grinding machines.

## Week 1

**SPECIFIC LEARNING OUTCOME:** At the end of this week the students should be able to;

- Explain the theory of metal cutting
- Define forces acting at a tool point
- Sketch a diagram of forces acting at tool point
- Relate the tool angles to cutting efficiency.

### 1.0 Theory of metal cutting

#### Introduction

In the workshop, most of the shaping involves cutting the metal. The usual conception of cutting involves tearing the substance apart with a thin knife edge or wedge. When the cut is taken the chip presses heavily on the tool some distance back from the extreme point.

The pressure of the tool on the chip tears the chip from the body of the metal as illustrated in the diagram below, this tear continues along a generated crack.

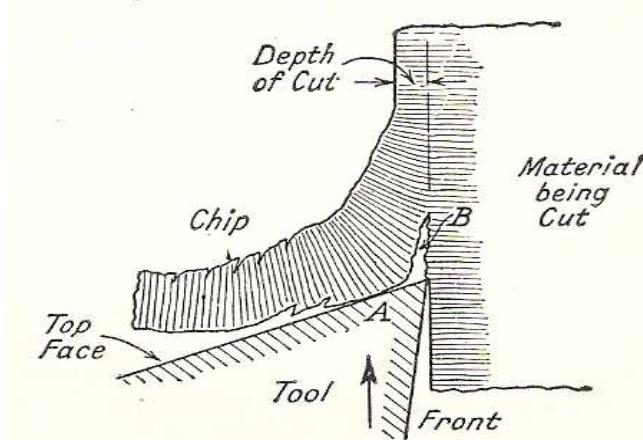


Fig 1.0 Metal cutting action

At the same time the chip suffers severe pressure and shearing force, being sheared and compressed up to a much shorter length by the time it leaves the tool. The surface of the work is left in a torn and rough condition; it is at this point that the extreme tip of the tool does its work by trimming off the irregularities and leaving the surface in a reasonably smooth condition.

## 1.1 MECHANICS OF CUTTING

Cutting is divided into two namely Oblique and Orthogonal. Oblique cutting occurs when turning along a bar with a straight roughing tool, the chip coming off at some angle. While orthogonal cutting takes place when a cut is being taken by a knife tool fed along perpendicular to its straight cutting edge. The resultant chip, in orthogonal cutting is the continuous chip.

## 1.2 THE ACTION OF CUTTING TOOLS

### Forces Acting at Cutting Tool Points

In order to determine the magnitude of the forces acting on a lathe tool a dynamometer is used. It is essentially an instrument designed to measure energy. It thus measures the forces acting on the point of

a lathe tool.

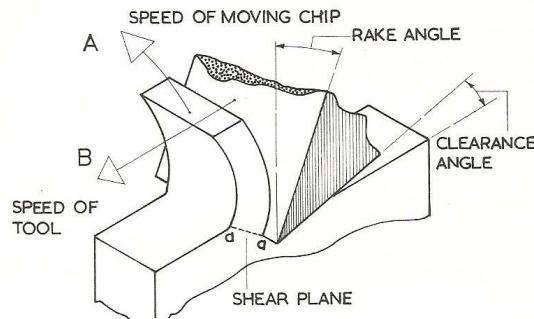


Fig. 1.1 Orthogonal

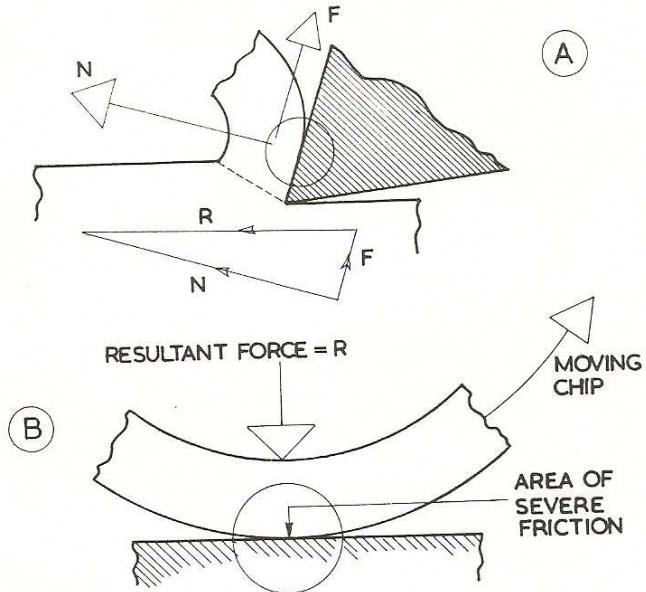


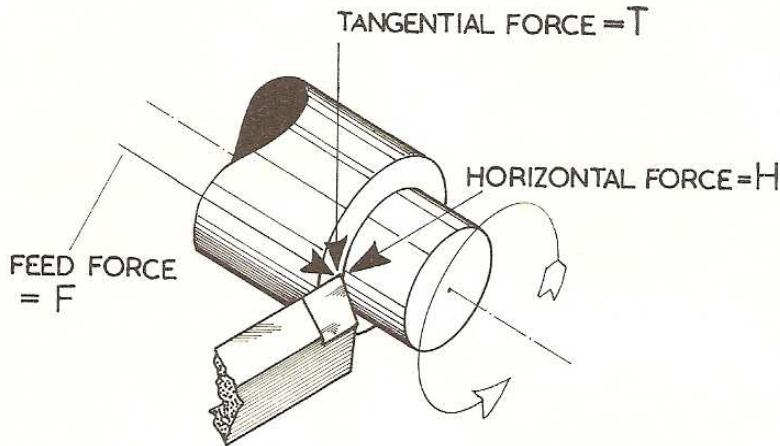
Fig 1.2 Forces acting at cutting tool point

The above diagram is representative of shaping, planing, milling and turning, or for that matter of all metal cutting using the wedge principle.

Two movements can be seen; the movement or speed of tool in the direction of the arrow B, and the movement or speed of the sheared chip in the indicated by the arrow A. Thus the tool exerts a force on the metal, resulting in the partial shear of the metal along a shear plane “a O: The chip is of a fairly ductile metal allowing considerable elongation of the chip under the force executed by the cutting tool.

The force exerted by the tool is at  $90^\circ$  or normal to the tool face (N).

The force exerted by the moving chip is parallel to the tool face (F). R is the resultant of these two forces and this is the force that leads to tool wear and failure, because the high frictional effect of the fast moving ship on the tool face.



**Fig 1.3 Forces at lathe tool point**

The above represents the forces that act on the lathe cutting tool tip. The greatest of these forces is the tangential force  $T$ . It can be considered as being equivalent to the force present in the turning moment of the work.

$$\text{Torque} = \text{Force} \times \text{Radius}$$

To calculate the power required to machine a cylindrical work on the torque ( $No$ ) = Force (x) x radius of job (m).

$$\rho = 2\pi NT \text{ (Watts)}$$

Where  $N$  = rows/s

$T$  = Toque in Nm

## Exercises

Question one.

Describe a typical experiment that could be carried out to determine the effect of rake angle on high speed steel lathe tool on:

- power consumed
- Pressure on tool point..

Question two.

Briefly explain the three forces acting at a tool point using a simplified diagram.

## **Week 2**

### **SPECIFIC LEARNING OUTCOME**

- List the types of chip formation
- Sketch diagrams of chips
- List factors affecting chip formation.
- Relate tool angles with cutting efficiency.
- Explain how heat is generated during cutting
- List common types of cutting fluids.
- Outline the characteristics of cutting fluids.

## **2.0 CHIP FORMATION**

### **Introduction**

Depending on the circumstances surrounding the cut that is being taken, the formation of chip may belong to one of the three different categories. These are:

1. Discontinuous chip
2. Continuous chip with an unbroken compressed layer adjacent to the tool face and;
3. Continuous chip with a built up edge adjacent to the tool face.

### **2.1 DISCONTINUOUS CHIP**

This is formed by a series of ruptures occurring approximately

Perpendicular to the tool face, each chip element passing off along the face of the tool.

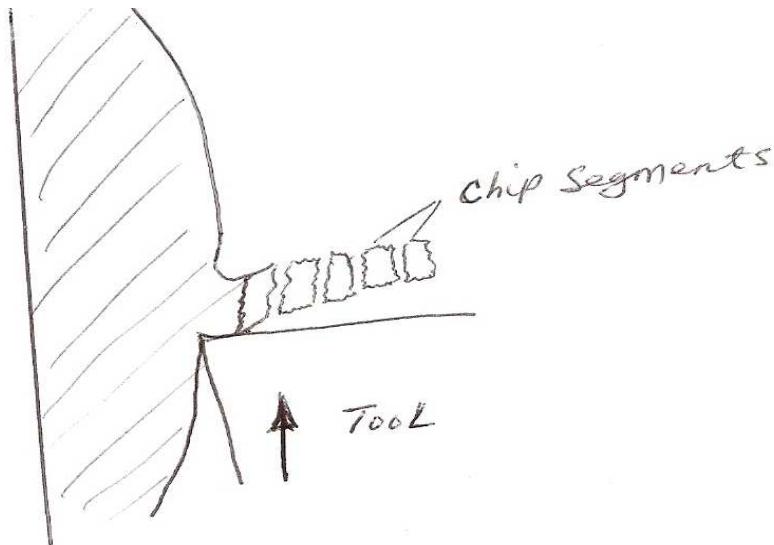


Fig 2.0. Discontinuous chip formation

Chips of this type are formed when any of the following conditions exist:

- i. brittle material
- ii. Low cutting speed
- iii. Large chip thickness
- iv. Small rake angle

## 2.2 CONTINUOUS CHIP WITH BUILT UP EDGE

This may occur when cutting soft ductile materials under conditions which promote molecular bonding between the tool face and the compressed layer of chip in contact with it.

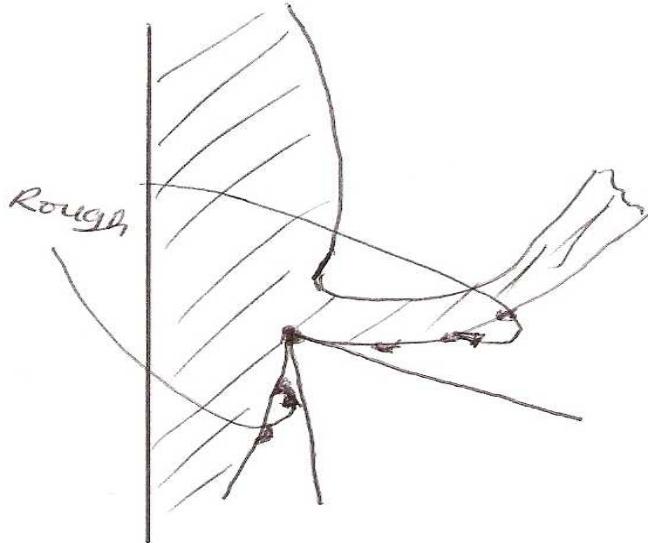


Fig 2.1. Continuous chip formation with built up edge

Below are the factors leading to such conditions?

- i. Ductile material
- ii. Inefficient cutting fluid
- iii. Affinity between tool and chip material
- iv. High pressure and friction at tool face.

As the cutting action goes on, a compressed layer of the metal become welded to the tool face near the cutting edge and gradually becomes built up by the addition of more particles of metal. This increases in size and become more unstable until a point is reached where it is torn off the tool, some fragments of it escaping with the chip and some adhering to the work.

The building up and breaking down takes place at a very rapid rate (usually so many times/second) so that the adhesion of these portions on the work price causes a roughness of finish. Also with chip of this type the portions of the built up edge remaining on the chip may generally be seen. Often at the end of the cut the built up edge remains attached to the tool.

When a tool is operating with a built up edge, a short distance back from the cutting edge, the wear takes the form of a cratering of the tool face, caused by the extreme abrasion of the chip. This crater eventually results to the break down of the edge coupled with high temperature. A suitable cutting fluid destroys the built up edge formation giving a continuous chip only. Also how cutting temperature help prevent built up edge.

### 2.3 CONTINUOUS CHIP

When a ductile material is being machined, and when the resistance to sliding on the tool face has been made small by such means as polishing, providing large rake angle, or using a suitable cutting lubricant etc the successive ruptures giving a discontinuous chip will not occur and by a readjustment of material flow, the chip will leave the tool in a continuous ribbon with its under face in contact with the rake surface of the tool.

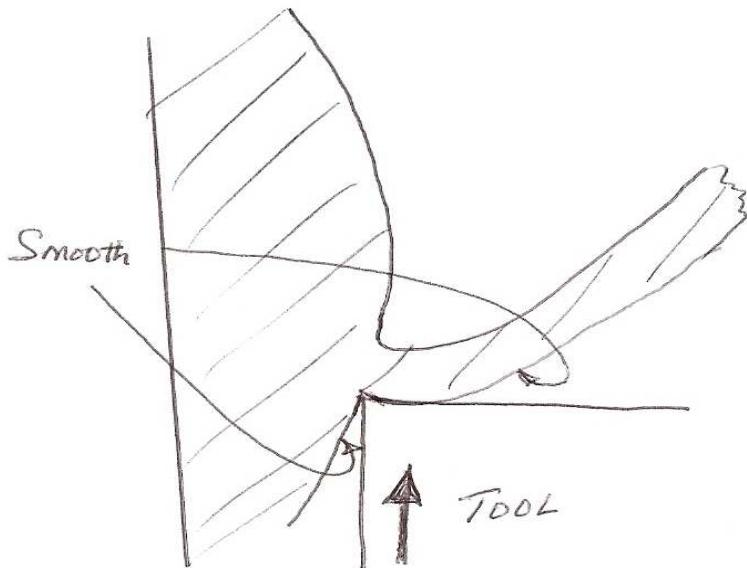


Fig 2.2 Continuous chip

The characteristics of this type of chip is its polished under face. Conditions that lead to the formation of a continuous chip are as follows:

- i. Ductile material
- ii. Small chip thickness

- iii. High cutting speed
- iv. Large rake angle
- v. Minimum friction of chip on tool face achieved by
  - a) Polished tool face
  - b) Use of efficient cutting fluid
  - c) Use of tool material with low coefficient of friction.

Vi Realization of most suitable cutting temperature.

Good surface finish is essential with continuous chip condition, also lower tool pressures and heat generation.

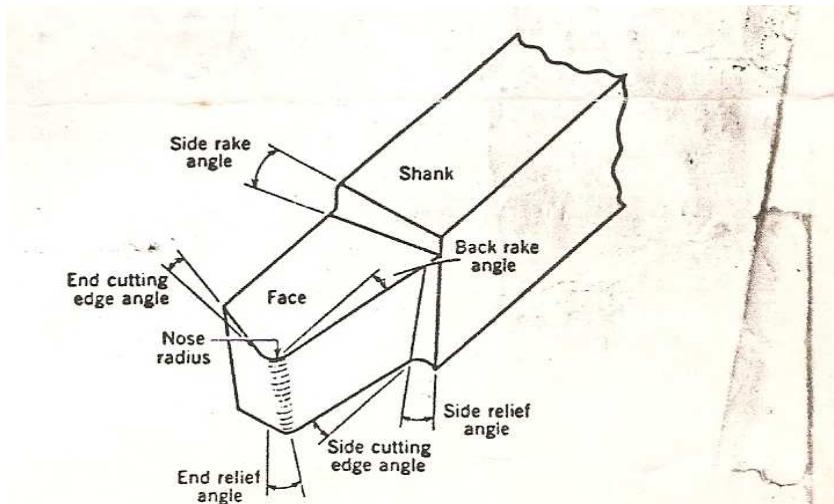


Fig 2.3 Cutting tool nomenclature

## 2.4 THE RAKE ANGLE

The rake angle of a cutting tool is the angle or inclination of tool breast or cutting to a line drawn perpendicular to the path or feed of the tool.

Generally the softer the metal the greater the rake angle, although grey cast iron and brass are exceptions to this rule.

The table below gives an indication of the rake angle and the machinability of various materials.

<i>Material</i>	<i>Rake angle</i>	<i>Machinability</i>
Grey cast iron	0°-10°	Brittle
Brass	0°-6°	Brittle
Tool steel	8°-12°	Fairly ductile
Mild steel	15°-20°	Ductile
Copper	35°-40°	Very ductile
Aluminium	35°-40°	Very ductile
Perspex	40°-50°	Extremely ductile

Table 1. Rake angle and machinability index for various materials

## 2.5 Clearance angle

The purpose of a clearance angle is to reduce the energy required to shear the metal, by removal or reduction of friction arising from the rubbing action between the tool and the work.

## 2.6 CUTTING TEMPERATURE

With every cutting operation there is an associated cutting temperature. This may be instantaneous as in the case of a punch or chisel or it may be sustained as when cutting on the lathe. This could be seen practically when one touches a chip that has just left a tool face or from the burning of swarf by heat. The instantaneous temperature at the edge of a chisel may be as much as 500°C.

A thermocouple is used to measure the quantity of heat generated at the tool tip (or during cutting). The temperature measured by the thermocouple is that at the point of contact between the chip and the tools, and is the maximum cutting temperature.

Below is a graph showing the maximum cutting temperature against cutting speed for a certain cutting operation.

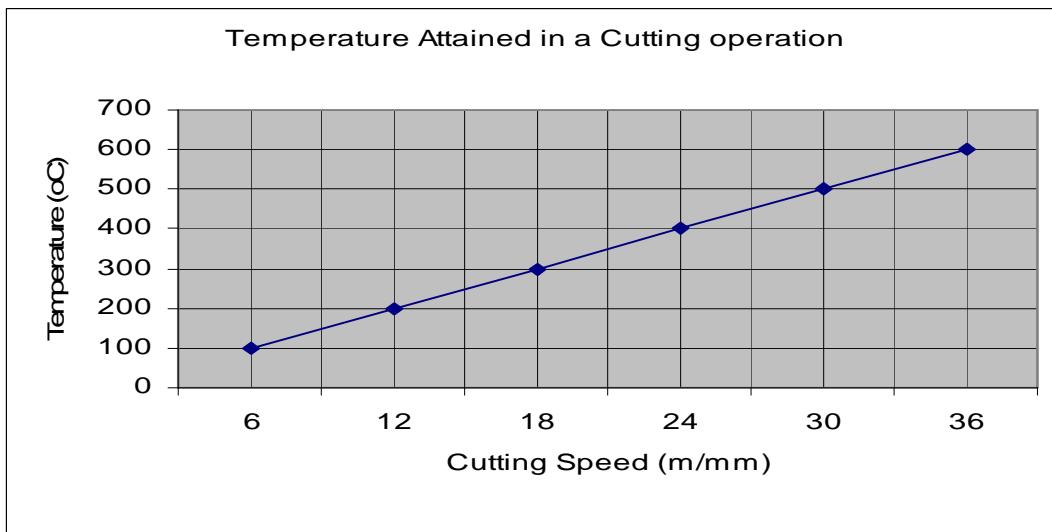


Fig 2.4. Temperature attained in a cutting operation

## 2.7 CUTTING FLUIDS

Cutting is accompanied with two major effects, these are friction and heat. Considering the tool life and quantity of finish, it is necessary to apply a cutting fluid to the operation of cutting, where primary function includes:

- a) To carry away heat and
- b) Provide lubrication where the chip bears at the tool face

Secondary functions performed by cutting fluids are

- c) To flush away swarf and keep the cutting zone clear and
- d) to protect the newly machined surface from rusting.

In any particular operation the choice as to whether heat removal or lubrication is the more important function and the dependent determination as to the most suitable fluid is often a problem of some complexity, but there are certain fairly well-defined principles for guidance.

In addition to its property of cooling and lubrication, it is desirable for cutting fluids to possess the following properties:

- a) Stability under heat or prolonged exposure. (Heat or exposure may cause some oils to decompose or oxidize with the liberation of fatty acids which may cause ill effects to

work and to machine tools. Other oils may tend to become gummy and when in this condition will obstruct the feed pipes of a cooling system.

- b) When applied to the heated cutting point, the oil should not fume or smoke unduly. (This can be reduced by employing oil with a reasonably high flash point not less than 200°C, and ensuring a copious flow of oil).
- c) The cutting fluid should not contaminate the lubricating oil employed else where on the machine.
- d) At no stage in its condition should the fluid be injurious to the skin of operator or open wounds. (For this reason, an antiseptic is often added)

Before any fluid is considered for a particular use, the following should be taken into account. Whether

- a) To cool
- b) To cool and lubricate
- c) To lubricate mainly, or
- d) To minimize adhesion between chip and tool.

In any operation the heat generated is imparted to the chip, the tool and the work piece in various proportions according to the class of operation.

## 2.8 TYPES OF CUTTING FLUIDS

	<b>Group</b>	<b>Composition</b>	<b>Props &amp; Uses</b>
a.	Soluble oils	Blends of oils and an emulsifier mixed with H <sub>2</sub> O 92-10% concentration)	Low in lubricating value. High capacity for carrying away heat.
	Clear soluble oil	Aqueous solutions of chemicals further diluted. used chemicals; N <sub>a</sub> NO <sub>3</sub> & triethanol amine).	
b.	Extreme pressure (e.p) soluble oil	Soluble oil with an e.p additive e.g. sulphur chlorine or both.	Superior in lubricating value to (a) above.

c.	Straight oils	Mineral or fatty (lard, sperm, olive, neat's-foot and rape) Other chemically unstable. used alone or compounded.	High lubricating value.
d.	Sulphurised e.p oils	Oils under (e) with sulphur, zinc oxide or other addition (- 2-8% S).	Medium coolants. Better lubes. than "c" process pressure resisting pumps and minimize welding of chip on tool (iron sulphide film formed at high temperature).
e.	Sulpho-chlorinated (e.p) oils	Mineral and fatty oil blends with sulphur and chlorine additives	More efficient than (d) and suitable for the most arduous cutting condition. Highly resistant to chip-tool weldment
g.	Gases	Compressed air, oil mist, carbon dioxide	Limited cooling power high chip dispersal.

Table 2. Types of cutting fluids

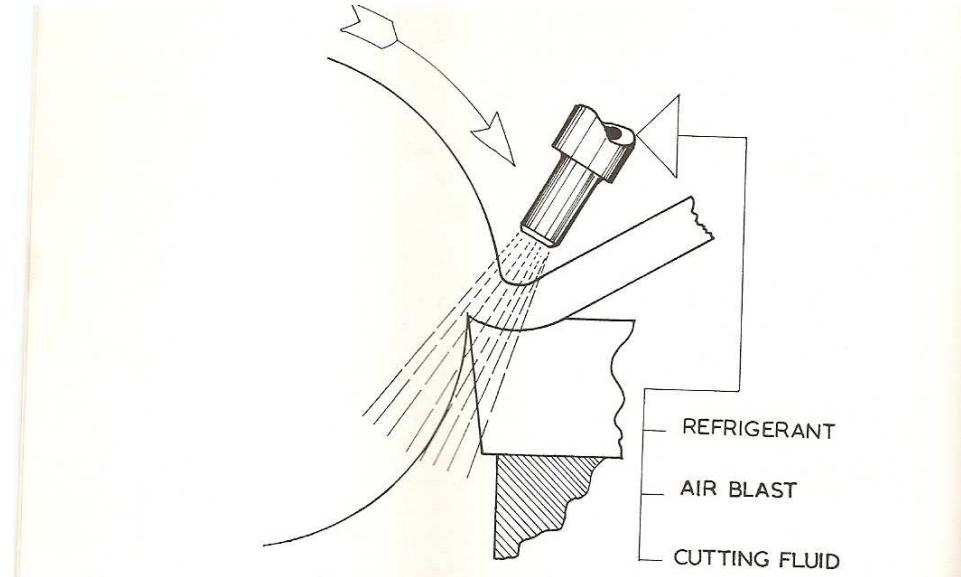


Fig. 2.5. Application of cutting fluid

## **2.9 ECONOMIC ADVANTAGES OF CUTTING FLUIDS**

1. Reduction of tool cost – By reducing tool wear, thus reducing replacements and time for reshaping and resetting.
2. Increased speed of production – Because of 1 above and increasing the attainable rate of machinery.
3. Reduction in labour cost – By reducing idle time, while resharpening and resetting.
4. Reduction of power cost – By reducing the coefficient of friction
5. Help in stabilizing the size of the finished part (product).

### **Exercises**

Question one.

List three types of chip formation and in each case give four reasons that could lead to such a chip formation.

Question two.

What are the primary functions of cutting fluids? List four economic advantages of cutting fluids.

Question three.

Why is it necessary to prevent the formation of “built-up” edge?

## **Week 3**

**Specific learning outcomes;** At the end of this week the student should be able

to:

- Out line the properties of cutting tool materials.
  - List common types of cutting tool materials.
  - Outline the constituents of cutting tool materials
- 

### **3.0 CUTTING TOOL MATERIALS**

#### **Introduction**

The most important factor in cutting tool efficiency is the material from which the tool is made. Correct design and accurate rake and clearance angles amount to nothing if the tool material is unable to stand up to the cutting conditions. All cutting tool materials must possess the following two properties.

- i. Hardness
- ii. Toughness

the approximate temperature of a metal chip sheared by a cutting tool under conditions of efficient machinery is 500°C, although the use of lubricant and coolants may reduce the temperature.

The common types of cutting tool materials available include:

#### **1. High Carbon Steel**

This has a relatively high carbon content which means that it has low hardness fig at 500°C. This steel loses hardness rapidly when it is taken to temperatures in excess of 220°C. At 350°C to be precise the steel has almost reverted to its normal hardness value. This is a serious limitation on the one of HCS as a cutting tool material. It

cannot be used where high machinery speeds are required, such as those used in the machinery of worm wheel. It is however conveniently suitable for cutting tools not likely to be subjected to unable friction leading to a rise in temperature, such as cold chisels, punches, files, scribes.

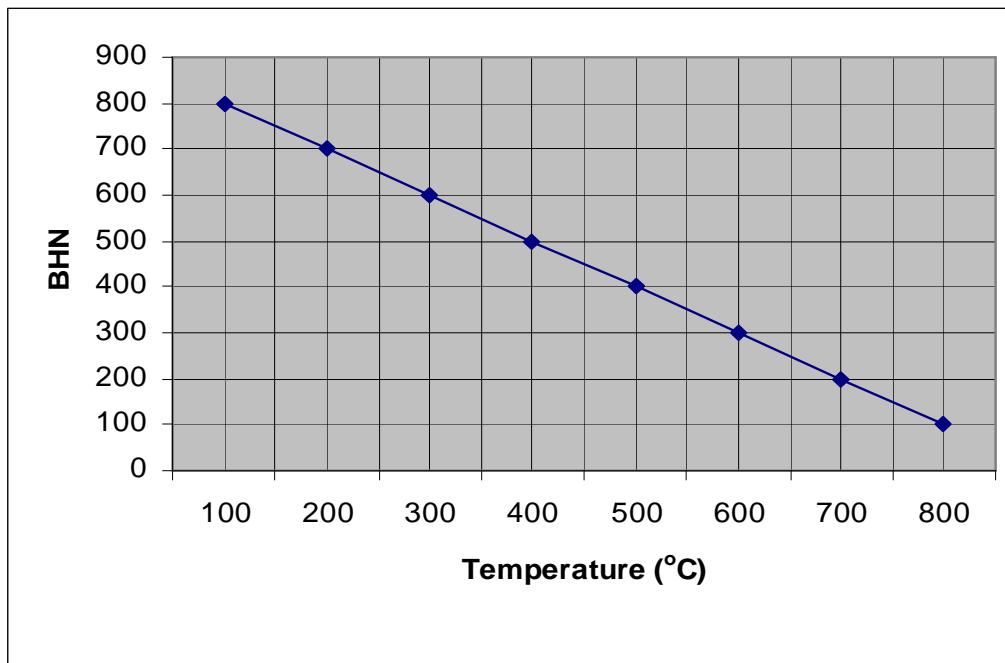


Fig. 3.0 Temperature vs hardness plot.

Fig.10. above shows the effect of temperature rise on the hardness of (hardened) HCS.

## 2. HIGH SPEED STEEL (HSS)

The hardness of this steel increases between 400°C and 550°C. This is quite unlike the behaviour of HCS and it is clear that the friction involved when machining at high speeds will not affect the hardness values of hardened HSS. HSS posses the quality of red hardness; that is to say it has ability to retain its hardness value even when the swart is leaving the parent metal at red heat.

This steel is a very expensive metal (steel), simply put its cost is ten times the cost of HCS. It is used in the production of cutting tools like, drills, reamers, and milling cutters. Due to its high cost it is sometimes welded to cheaper and triangular material

if the need arises, thus providing not only cheaper tool but also one that is more likely to stand up to cutting conditions.

### **3. STELLITE**

Stellite is the trade name of a special material. It is a non ferrous alloy containing high proportion of cobalt, chromium and tungsten. It is harder than HSS. When poured in liquid state from an electric furnace satellite is self hardening, thus a satellite carting allowed to cool in air has a Rockwell hardness value of 62 on the C scale.

This inherent hardening property allows the use of satellite as a hard facing metal, available for electrodes to be used in arc welding process.

Satellite is used as inserts for large diameter milling cutter, this is much better proposition than milling a large diameter milling cutter from HSS. Apart from the high cost of solid high speed milling cutter, there is a considerable with of cracking or distortion during heat treatment process, not to mention the possibility of tool breakage when in use. The inserted tool type milling cutter using stellite teeth is an efficient and reliable multi-point cutting tool, the high tensile strength of stellite allows the inserted blades to stand up to the considerable stress involved.

### **4. CEMENTED OR TUNGSTEN CARBIDES**

This is an unexceptionally hard material, it is however brittle as such it is being used as a tip, necessary segmented and brazed to a Carbon steel shank and employed as a lathe tools. It can be alloyed with elements like tantalum and titanium which gives it excellent steel cutting properties and a long tool life.

### **5. CERAMICS**

Ceramics posses a higher hardness value than tungsten carbon at a temperature of 500°C, but its more brittle. It is chemically inert, with a low coefficient of friction and low heat conductivity, a ceramic tipped tool has very high metal removal rate,

together with the ability to produce a good finish. The life of a ceramic tipped tool is high even when working at maximum speeds and produces surfaces with very close dimensional tolerance.

## 6. DIAMOND

Tools tipped with diamond are used for high grades machinery of hard metals and often plastics which blunt H.S.S. tools very quickly. For preparation of diamond tools, selected brown and black diamonds are cut and lapped to a suitable shape and mounted in holders.

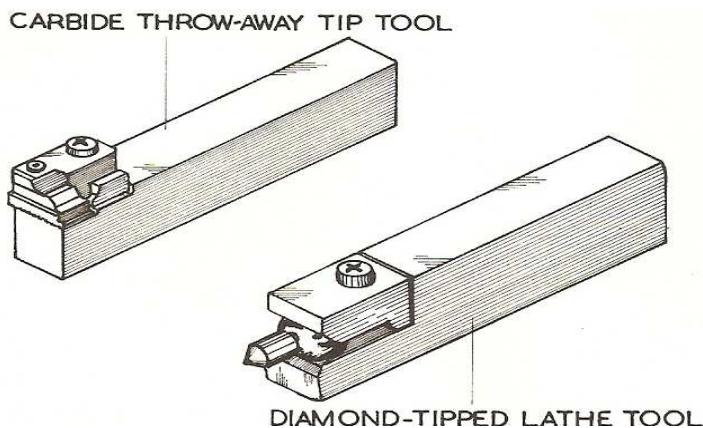


Fig 3.1 Throw away tipped Cutting tool holders

Diamonds tools accommodate cutting speeds up to 300 m/min and under ideal conditions the tool will give very long life.

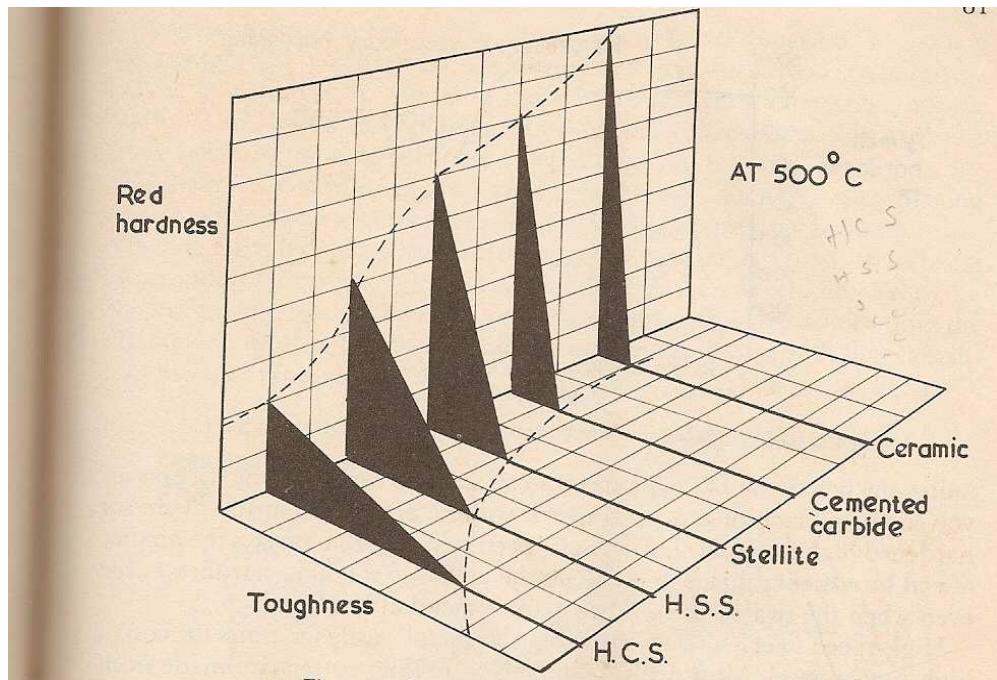
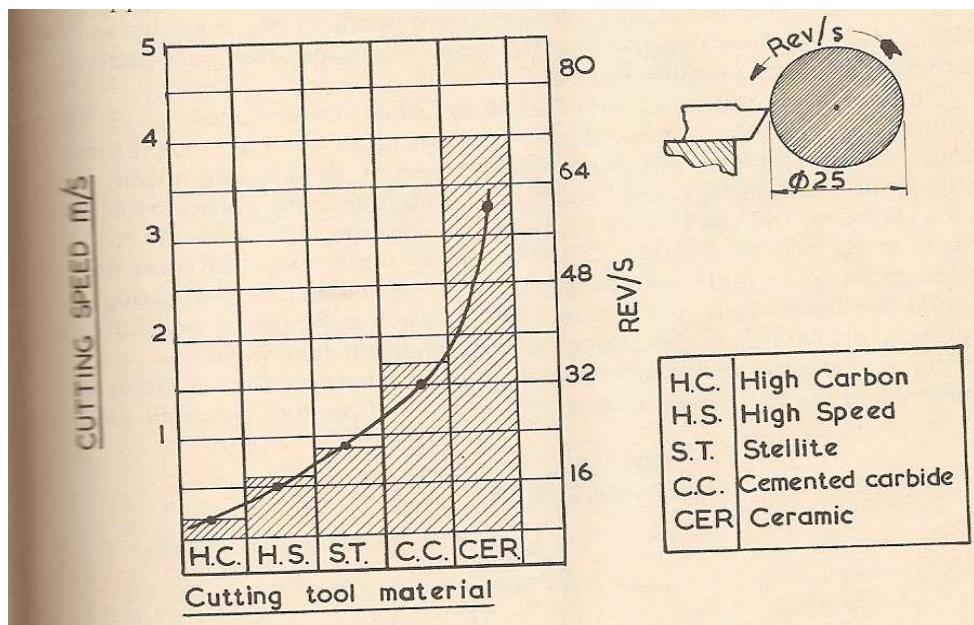


Fig. 3.2. Relative comparison of toughness and red hardness of cutting tool materials.



Cutting tool materials and cutting speeds.

**Exercises:**

Question one.

Explain why high carbon steel is not used as a material for making milling cutters.

Question two.

Why are the cemented carbides always used as a material for tipping tools? Make a neat sketch of carbide tipped lathe tool.

Question three.

List five cutting tool materials in ascending order of their red hardness.

Question four.

Explain the following terms, Red hardness, toughness, hardness.

## **Week 4**

**Specific learning outcomes;** At the end of this week the student should be able

to:

- Describe the main types of lathes and their accessories.
- List the necessary precautions to be observed while working on the lathe.
- List main lathe parts.

### **4.0 Lathe machines**

#### **Introduction**

The Lathe machine is the most important of all machine tools. Many other types of machines have been developed from the principle of the lathe. A lathe has made possible the building of electric motors automobiles, aircraft and a host of other kind of machines.

The lathe is basically a machine for generating cylindrical forms; it is in fact however, much more than this being a readily adaptable piece of mechanism which can be used to perform numerous other machining operations in addition to its basic functions.

#### 4.1 TYPES OF LATHE

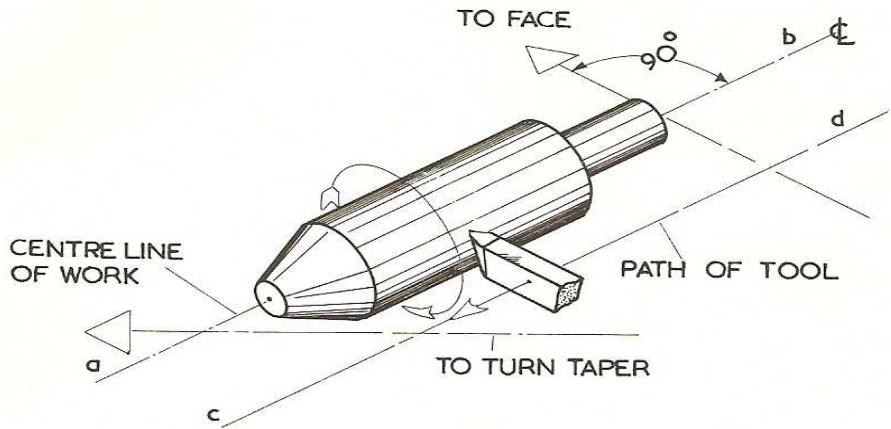


Fig. 7.2 Generating on the lathe

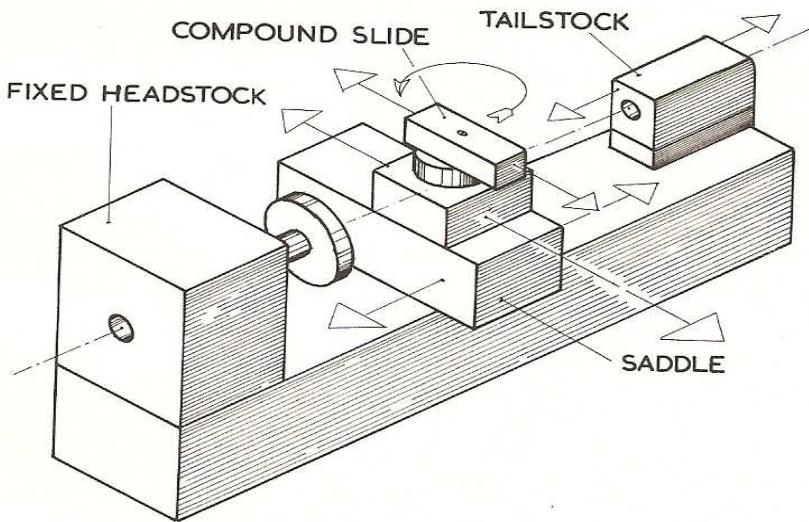


Fig 4.0 Schematic diagram of a typical lathe machine

Lathes are classified according to their swings, swing A being the largest diameter that can be rotated over the bed, and the minimum distance between lathe centres swing B.

Many types of lathes are available, some being designed for repetition work e.g. the automatic, capstan and turret lathes. Some are designed for special purposes, e.g. the brass finishing lathe – used exclusively for that one metal whilst the spinning lathe is used in producing bowl forms from that metal.

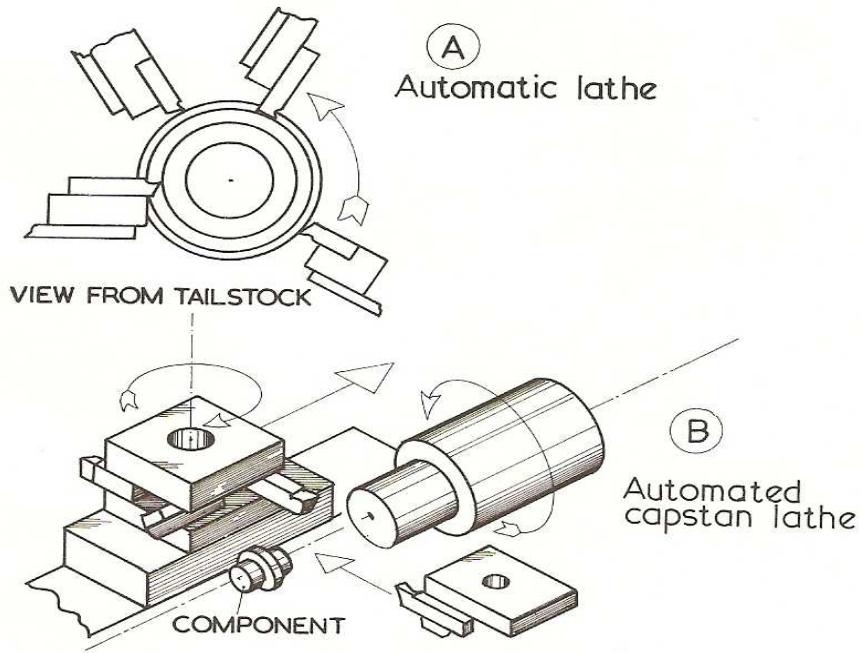


Fig 4.1 Schematic diagram of an automatic lathe

### - Capstan and Turret Lathes (Production Lathes)

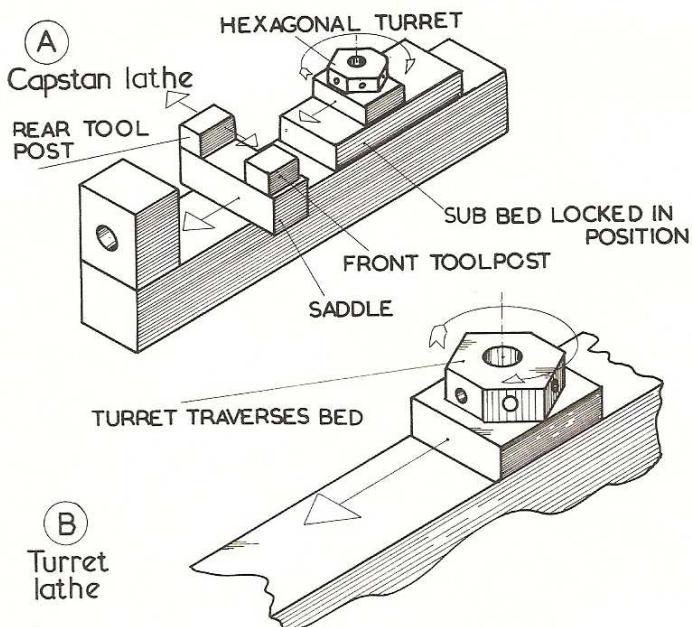


Fig 4.2 Schematic diagram of capstan and turret lathes

Capstan and turret lathes are developments of centre lathe. During the process of machining a job on the centre lathe, considerable time is taken in changing and setting tools. On a turret lathe this is largely obviated by the incorporation of facilities for carrying eight or more tools, each of which may be brought into position for operating on the work. This feature, together with the system of trips and steps with which the machine is provided, enables large quantities of identical turned parts to be produced in a maximum time frame.

The other feature of these machining is the capstan, or turret a six sided block (like a large hexagon nut) which is mounted on the bed and to each face of which tools may be attached. The turret of the turret lathe is mounted on a saddle which slides directly on the bed in the same way as a lathe saddle.

Other production lathes includes all of the following:

- (i) Single spindle automatic lathe
- (ii) NC lathes

They are employed when large number of duplicate parts has to be produced.

### **-Engine Lathes**

These include the bench, speed, tool room and gap bed lathes and are available in various sizes.

#### **-Bench Lathe**

This is a small lathe which can be mounted on a bench or cabinet. They are generally small in size and used for light machining on small work process.



Fig 4.3 Tool room lathe

### - Speed Lathe

This can be mounted on a bench or cabinet, it is noted for fast setup and changeover work, ease of operation and low maintenance. Speed lathes are used for light machining operations, turning, polishing and finishing on small precision work.

### - The Gap-Bed Lathe

It has a motion of the bed below the face plate which can be removed to increase the maximum work diameter that can be revolved.

### - The Tool Room Lathe

This is equipped with special attachments and accessories to allow a variety of precision operations to be performed. It is generally used to produce tools and gages which are used in tool and die work. The size of an engine lathe is determined by the maximum diameter of work which may be revolved or swing over the bed. The length of a lathe is stated by the length of the bed.

The average metric lathe used in school shops may have a 230-330mm swing and have a bed length of from 500-300mm in length. All lathes regardless of design or size are beneficially the same. They provide:

- 1) A support for the lathe accessories or the work piece
- 2) A way of holding and revolving the work piece
- 3) A means of holding and moving the cutting tool

## 4.2 LATHE PARTS

### 1) The Bed

A heavy rugged casting made to support the working parts of the lathe.

### 2) The Head Stock

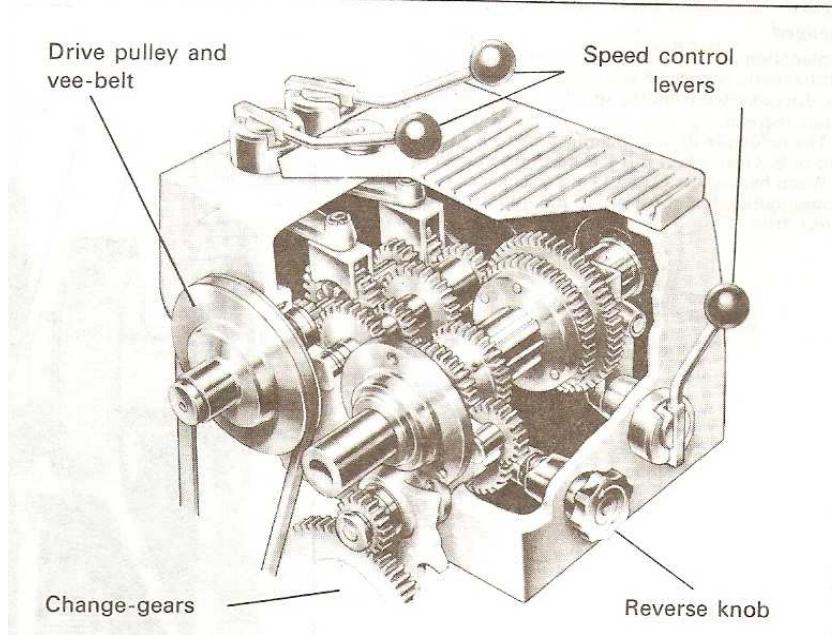


Fig 4.4 The lathe head stock

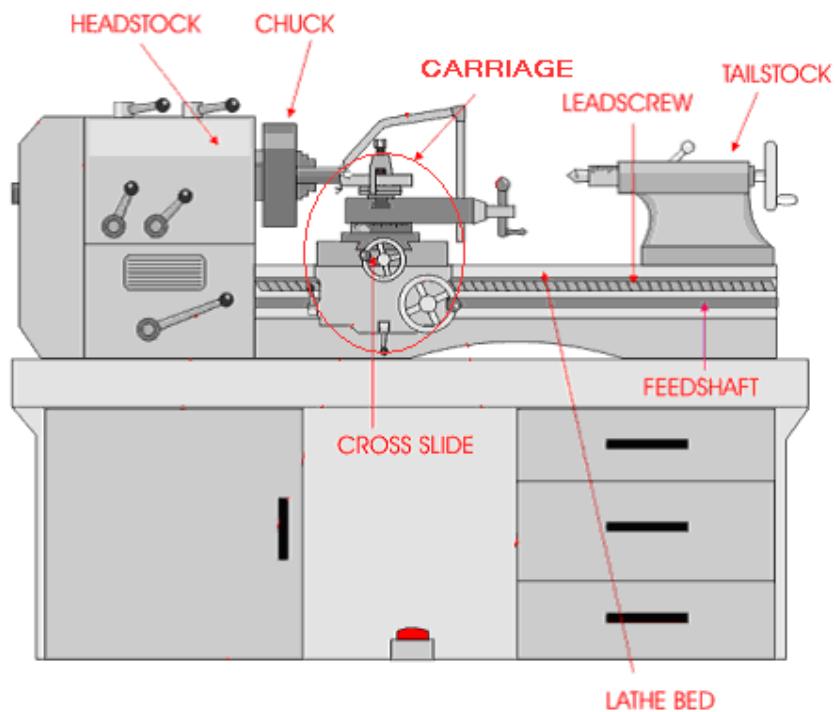


Fig4.5 lathe parts

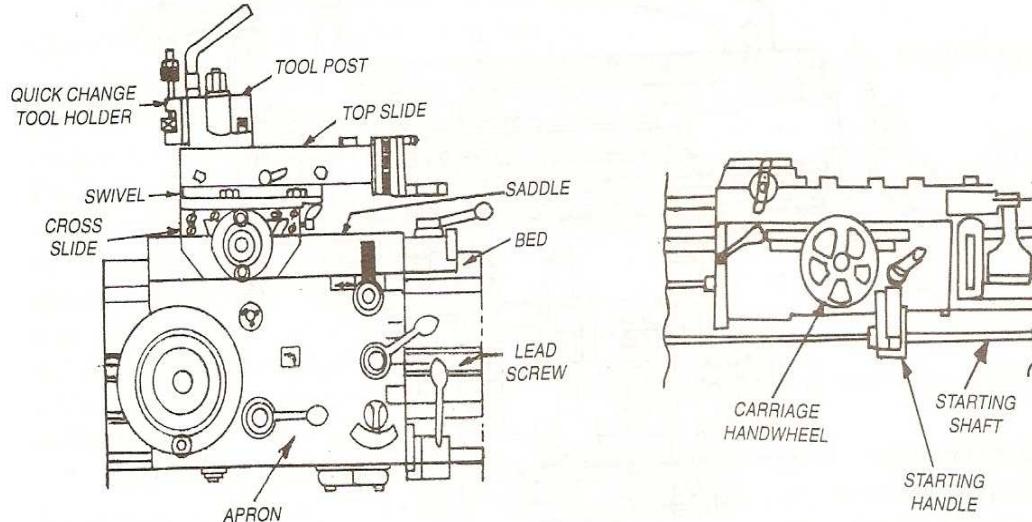
This is located at the left hand side of the bed. The head stock spindle is a hollow cylindrical shaft supported by bearings provides a drive from the motor to work holding devices.

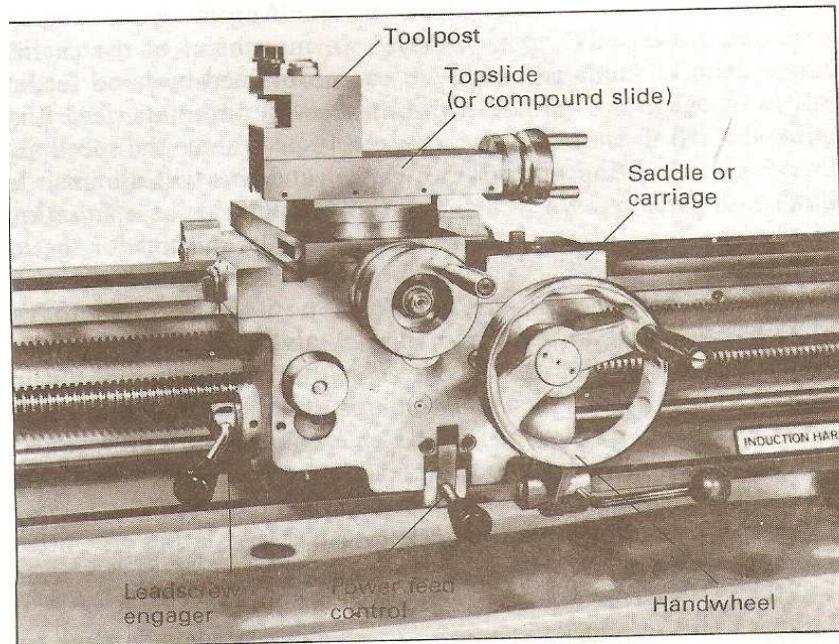
Head stock spindles are driven by a set of gears in the head stock.

### 3) Quick Change Gear Box

This contains a number of different sized gears, provides the feed rod and lead screw with various speeds for turning and thread cutting operation. The feed rod and lead screw provide a drive for the carriage when either automatic feed lever or split-met lever is engaged.

### 4) Carriage





**Fig 4.6 The lathe carriage**

The carriage supports the cutting tool and is used to move it along the bed of the lathe for turning operations; it consists of three main parts:

- a) **The Saddle:** A “H” shaped casting mounted on the top of lathe ways, supports the cross slide.

- b) **The Cross Slide:** This provides the cross movement for the cutting tool. The compound rest supports the cutting tool.

They are provided with a graduated collar to make accurate settings possible for cutting tools.

- c) **The Apron**

This is fastened to the saddle and houses the feeding mechanisms, which provide and automatic feed to the carriage.

## 5) Tailstock

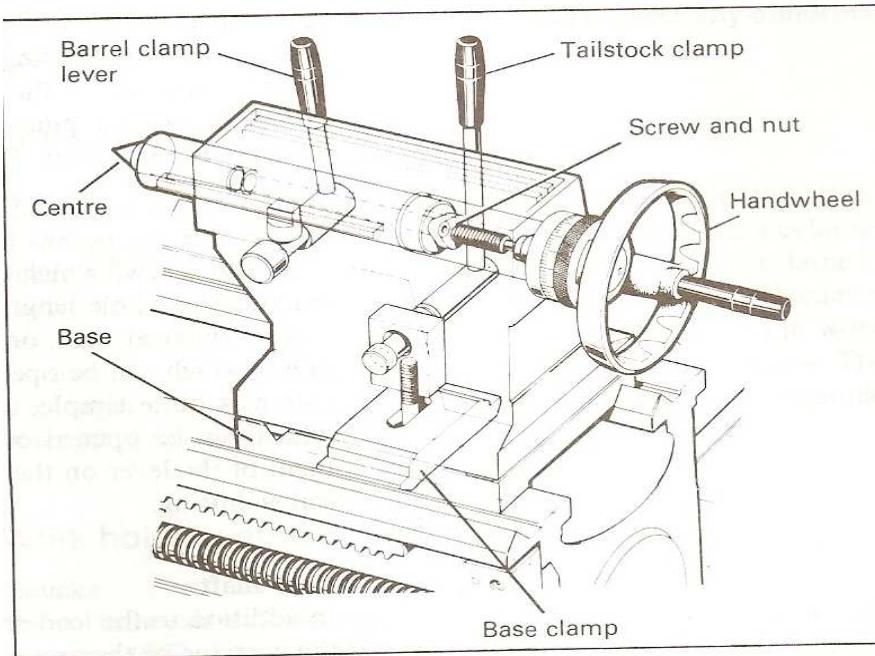


Fig 4.7 Lathe tail stock

This is made up of two units. The top half can be adjusted on the base by two adjusting screws for aligning the dead and live centres for parallel turning. The screws can be used for offsetting the tail stock for taper turning between centres.

## 6) The Feed Shaft

This is situated in the front of the lathe lying parallel with the lead screw used mainly to engage the carriage for auto-feeds.

### 4.4 Safety Precautions to be observed when working on the lathe.

A lathe can be very dangerous if not handled proper, even though it is equipped with various safety guards. Below are some of the important safety regulation which should be observed:

- 1) Always wear the approved safety working dress
- 2) Never attempt to run a lathe until you are familiar with its operation
- 3) Never wear rings or watches when operating lathe

- 4) Always stop the lathe before taking measurements
- 5) Always use a brush to remove chips. Do not use bare hands
- 6) Before mounting or removing accessories, always sheet off the power supply to the motor.
- 7) Do not take heavy cuts on long slender pieces. It could cause the work to bend and fly out of the machine.
- 8) Do not lean on the machine, but stand erect.
- 9) Keep the floor free of grease and oil, which could cause dangerous falls.

#### **4.5 Exercises.**

Question one

List four types of lathe machines, and how is the size of lathe stated?

Question two.

What is the main difference between a turret lathe and a centre lathe?

Question three

List five parts of the lathe carriage.

Question four

Identify the parts labeled on the fig 4.8 below.

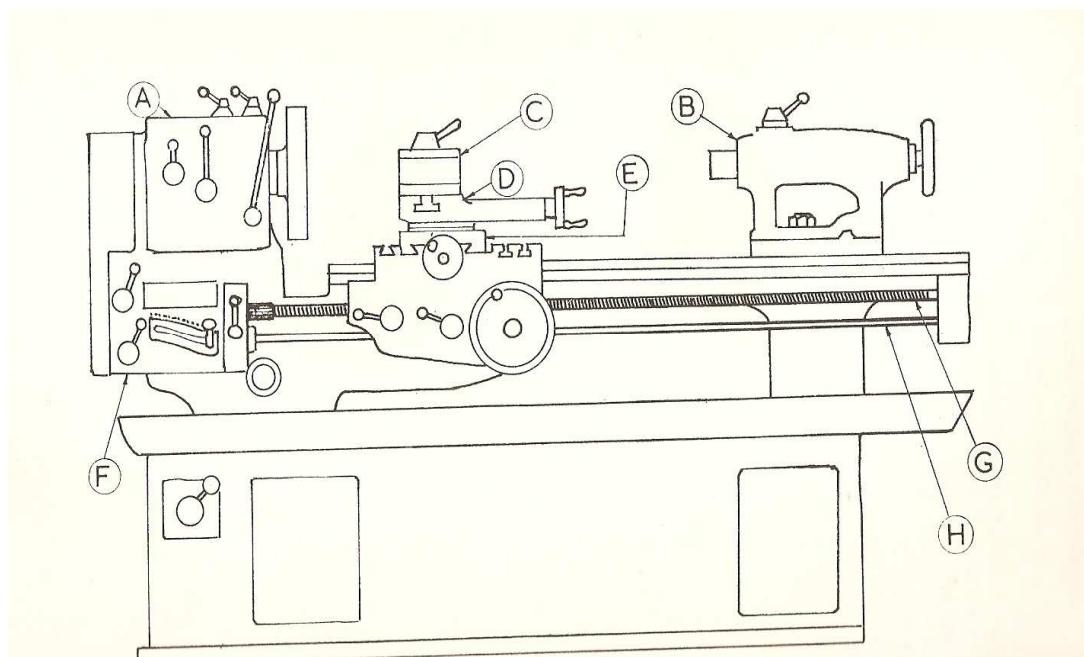


Fig 4.8 A centre lathe

## WEEK 5

**Specific learning outcomes;** At the end of this week the student should be able to:

-List and explain the following lathe operations.

-Facing

-Parallel turning

- Taper Turning

- Screw Cutting

- Boring

- Knurling

- Drilling

-Parting, etc.

### 5.1 Lathe Operations

#### 1) Facing



Fig 5.0 Work piece held in a three jaw chuck.



Fig 5.1 Facing in progress.

This is a process of machining the end or face to produce a smooth, flat surface which is square with the axis of the work. Facing is carried out for the following reasons:

- i) To square the end surface
- ii) To have an accurate surface from which measurement could be taken
- iii) To reduce work to the required length

Cutting is carried out at right angle to the axis of the work.

## 2) Turning (Parallel)

This is cutting along the work parallel to work axis. This results in the reduction of

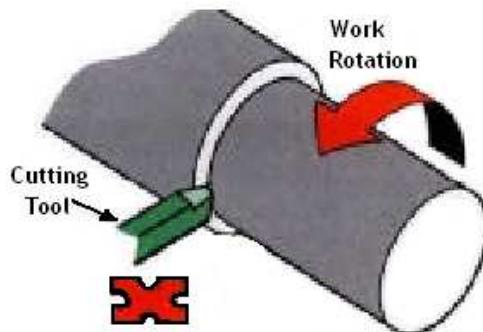


Fig 5.2 Parallel turning action

the diameter of the work and production of a curved surface. In order to produce a parallel diameter, the head stock and tail stock centres must be in line.

### **3) Taper Turning**

A taper may be defined as a uniform increase or decrease in the diameter of a piece of work measured along its length. Tapers provide a fast and accurate means of aligning machine parts and holding cutting tools.

Tapers can be cut on a lathe by using the attachment, off-setting the tail stock, and setting the compound rest to the angle of the taper.

### **4) Screw Cutting**

The process of producing screw threads, internal or external on the lathe by the use of a screw cutting tool.

To cut a thread on the lathe, taps and dies could be used easily as well as the screw cutting tool.

### **5) Boring**

This is a process of enlarging and tracing a drilled or cored hole with a single point cutting tool. Boring is also used to finish an off size hole for which no drill or reamer is available.

### **6) Knurling**

This is a process of impressing a diamond shaped or straight indentation on the surface of the work. the purpose of which is to improve the appearance of the work and to provide a better grip. It is done by firing a knurling tool containing a set of hardened cylindrical patterned rolls against the surface of revolving work.

Knurling tools have a heat treated body held in the tool part and a set of hardened rolls mounted in a moveable head. It is fed 90° to the work axis.

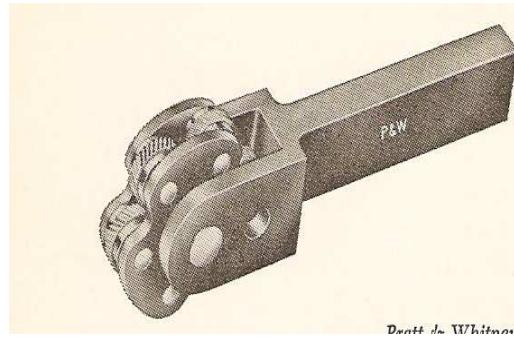


Fig 5.3 Knurling tool

## 7) Drilling



Fig 5.4 Drilling on the lathe

Work held in a chuck can be drilled quickly and accurately in a lathe. The drill held in a drill chuck or in the tail stock spindle, is brought against the revolving work by turning the tail stock hand wheel.

Other lathe operations include:

Counter boring, reaming, parting etc.



Fig 5.5 Parting tool.

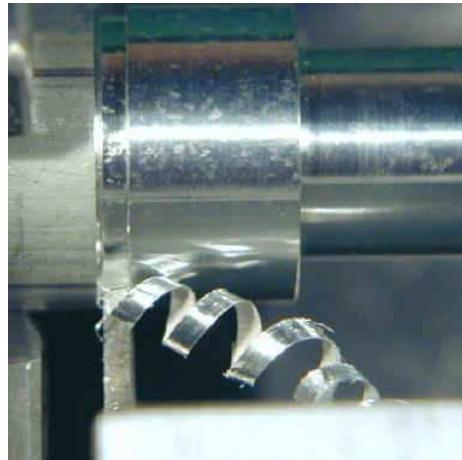


Fig5.6 Parting in progress

Name of Operation	External Turning
Straight Turning	
Face Turning	
Taper Turning	

Thread Cutting

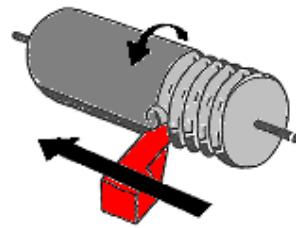


Fig 5.7 Some lathe operations.

## 5.2 Exercises

Question one

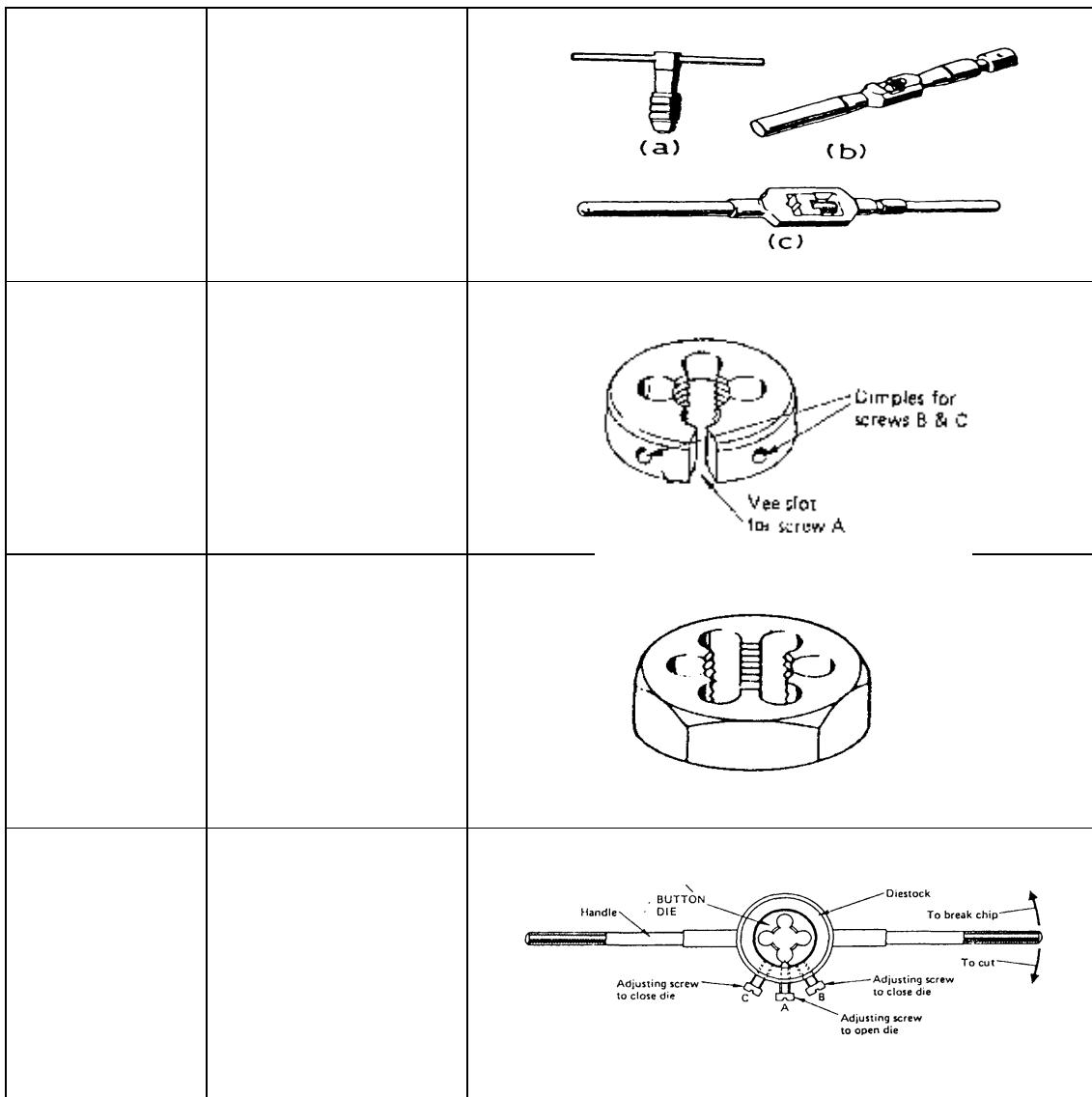
State three reasons why facing is carried out.

Question two

Find the rpm required to machine a piece of cast iron 50.8mm in diameter, using a high speed steel cutting tool.

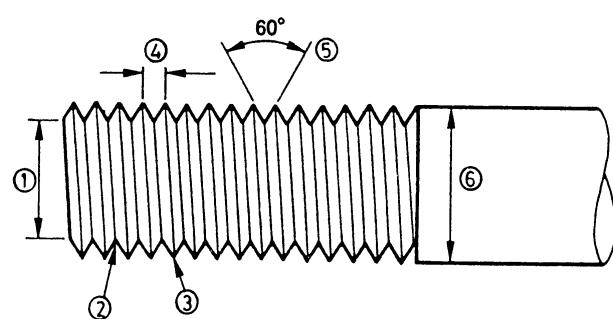
3) Complete the following table:

Tool name	use	drawing
		A technical line drawing of a tap tool. It features a long, tapered shank with a helical fluted cutting edge. At the end of the shank, there is a square-shaped tap body with a central hole and a small slot for coolant or debris. The drawing is oriented horizontally.



2) The following figure shows a thread form, label the numbered parts.

Name: .....	
No.	Parts name
1	
2	
3	
4	
5	
6	



3) What is meant by: M 30x3?

M: .....

30: .....

3: .....

4) Name three turning operations and draw two of them

1- .....

2- .....

3- .....

## WEEK 6

**Specific learning outcomes;** ; At the end of this week the student should be able to:

- Identify and use work holding devices on the lathe and its accessories.

### 6.0 Lathe Accessories

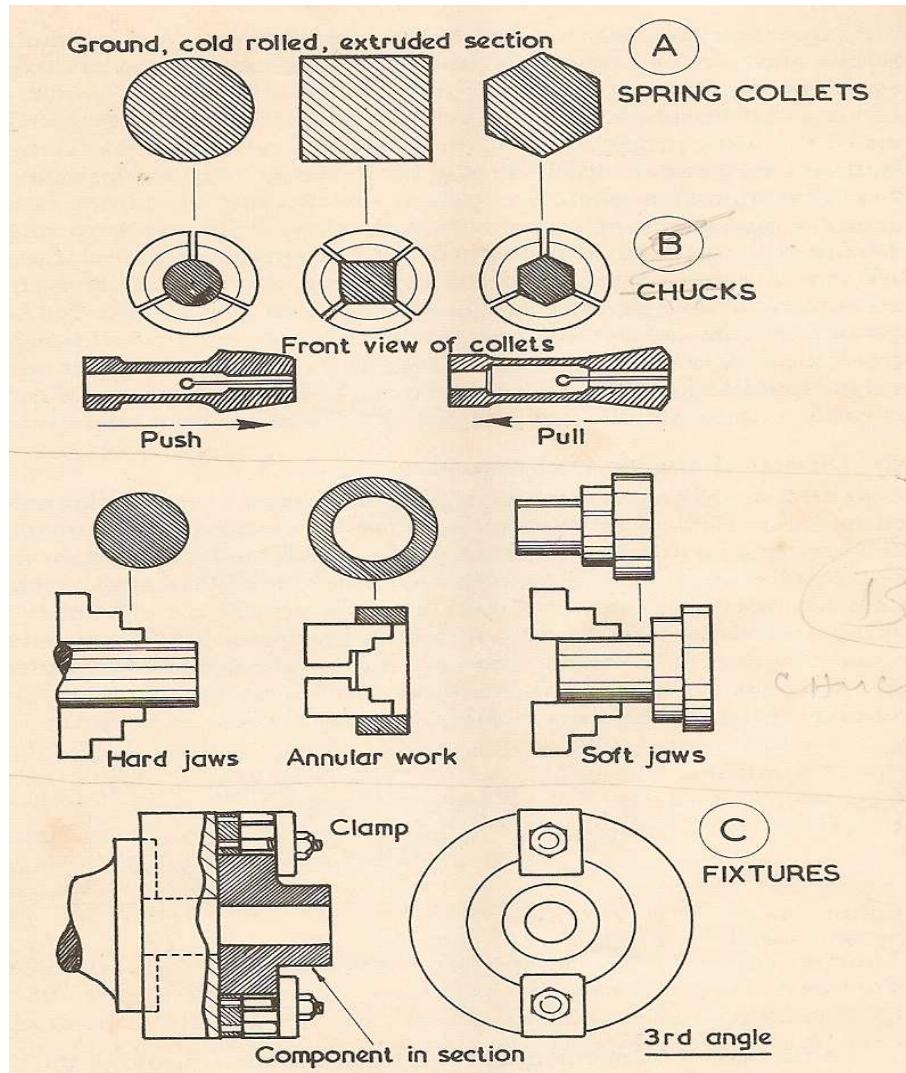


Fig 6.0 Some work holding devices on the capstan lathe

## 1) Steady Rest (Fixed Steady)

This is used to support long, slender work and prevent it from springing while being machined between centres. It may also be used when it is necessary to perform a machining operation on the end of a work piece which is held in a chuck. It is fastened to the lathe bed and its three jaws are adjusted to the surface of the work to provide a supporting bearing. The jaws are made of soft material such as brass to prevent damage to the work surface.

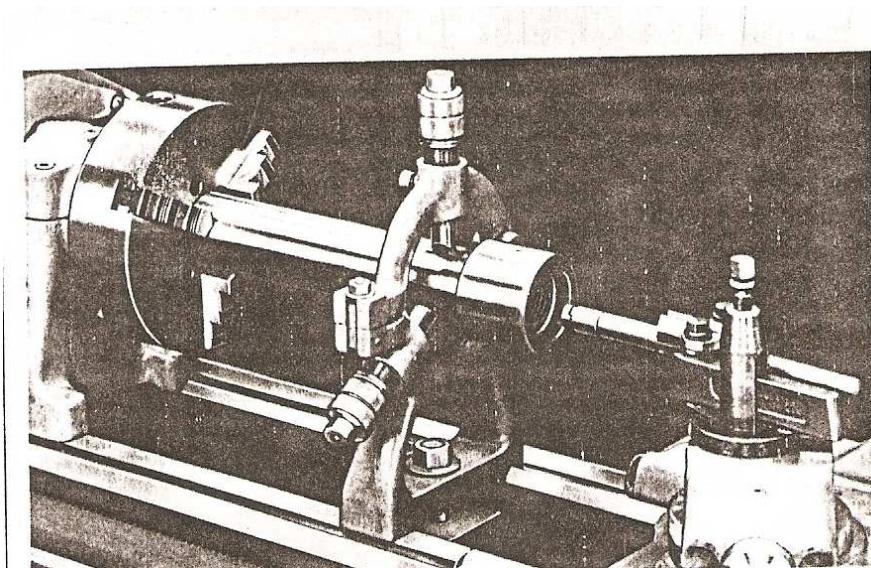


Fig 6.1 Fixed steady in use.

## 2) Follower Rest (Traveling Steady)

This is mounted on the saddle and moves along with the carriage to prevent work from springing up and away from the cutting tool. The follower rest positioned immediately behind the cutting tool can be used to support long work for operations such as thread cutting.

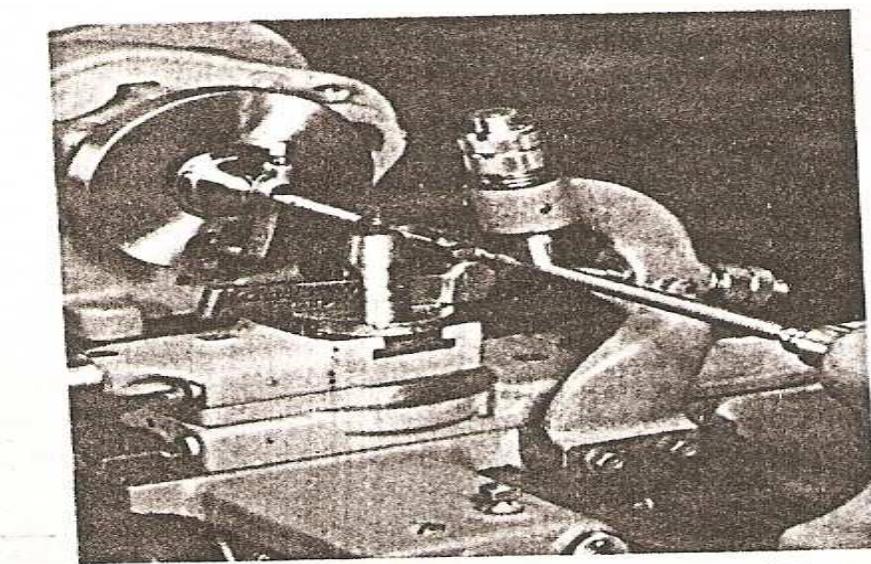


Fig 6.2 Traveling steady in use.

Other lathe accessories include mandrels, lathe dogs, chucks, drive plate, face plates, collets, etc.

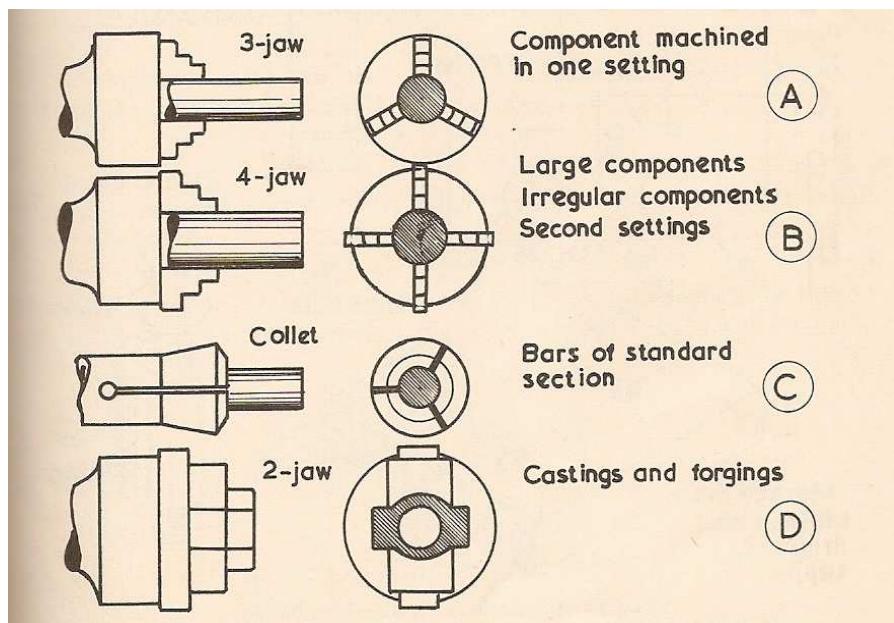


Fig 6.3 Lathe work holding devices.

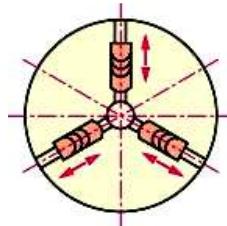
## 6.2 Work Holding Methods

The following are the normal methods of work holding on the center lathe

- Between centers:

The work piece is located between the centers and is driven by the catch plate and carrier.

b) The three-jaw chuck:



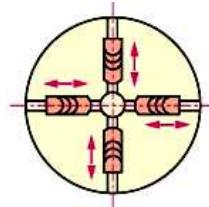
It's used for holding a short cylindrical or hexagonal work pieces for normal cutting.

Fig 6.4 Three jaw chuck

c) The four-jaw chuck:

i. Self-centering chuck

It is used for the chucking of short cylindrical or octagonal work pieces for light cuts.



ii. Independent chuck

Each jaw works independently from the others. It is used to chuck irregular shaped work pieces or for heavy cuts.

Fig 6.5 Four jaw chuck

### 6.3 Exercises

Question one

What is the function of the following lathe accessories?

- follower rest
- fixed steady

Question two

What is the difference between a three jaw chuck and a four jaw chuck?

## WEEK 7

**Specific learning outcomes;** At the end of this week the student should be able to:

-Explain and carry out taper turning on the lathe.

### 7.0 Taper turning using taper turning attachments

This is confined to external tapers only. The attachment is bolted at the back of the lathe and has guide bar which may be set to the desired angle of taper. As the carriage moves along the bed length, a slide over bar causes the tool to move in and out according to the setting of the bar. The taper setting of the bar is duplicated on the work. The main advantage of this system is that the lathe centres are kept in alignment, and same taper may be turned on numerous pieces even if they vary in length.

The procedures for cutting a taper using either a plain or telescopic taper attachment are as follows:

- 1) Clean and oil the guide bar
- 2) Loosen the guide bar locks nuts so as to free it on the base plate
- 3) By adjusting the locking screws, offset the end of the guide bar in the required amount.
- 4) Tighten the guide bar lock nuts
- 5) Swivel the compound rest so that it is about  $30^\circ$  to the cross slide.
- 6) Set the cutting tool to centre and tighten the tool part securely
- 7) Mount the work in the lathe and mark length to be tapered.
- 8) Feed the cutting tool in until it is about 6.35mm from the  $\varnothing$  of the work.
- 9) Remove the binding screw which connects the cross slide and the cross feed screw nut.
- 10) Use the binding screw to connect the cross slide extension to the sliding block.

- 11) Insert a plug in the hole where the binding screw was removed to keep clips from damaging the cross feed screw.
- 12) Move the carriage till the cutting tool clears the right hand end of the work by about 12.7mm.
- 13) Take a light trial cut for about 1.58mm and check the  $\text{Ø}^\circ$  for size.

## **7.1 Cutting Taper with Tail Stock Offset**

This is usually employed when a lathe is not equipped with a taper turning attachment and work is mounted between centres. The tail stock centre must be moved out of line with the head stock centre enough to produce the desired taper. Since the tail stock can be offset by a small amount only, the range of tapers that can be cut by this method is limited.

To Offset the Tail Stock

- 1) Calculate the amount the tail stock must be offset to cut the desired taper.

$$T.O = \text{tpf} \times 0.1/24 \quad \text{where: O.L = over all length of work}$$

tpf = taper/foot

T.O = Tail stock offset

Or

$$T.O = \frac{D - d}{2 \times T.L.} \times O.L. \quad D = \text{Large diameter}$$

d = small diameter

T.L. = Length of taper

O.L = over all length of work

- 2) Loosen the tailstock clamp nut
- 3) Loosen one tail stock adjusting screw and tighten the opposite one until the tailstock offset is correct
- 4) Tighten the adjusting screw that was loosened and recheck the offset with a rule.

- 5)      Correct the setting if necessary and then tighten the tailstock clamp nut.

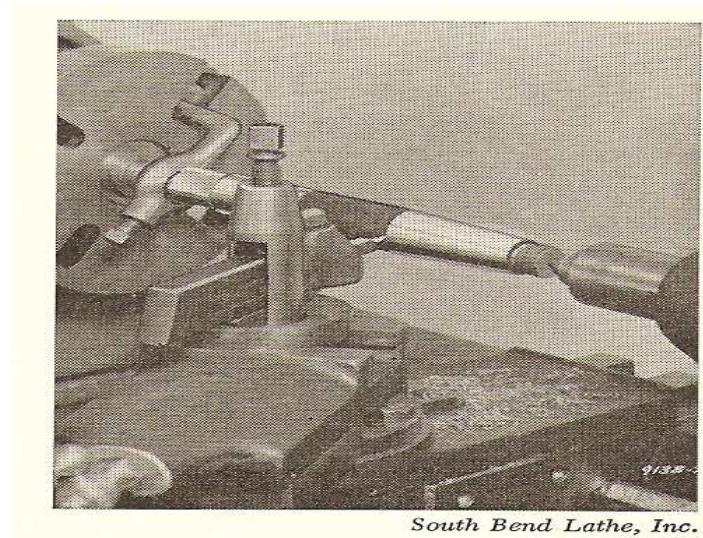


Fig 7.0 a Machining a taper with the tailstock offset.

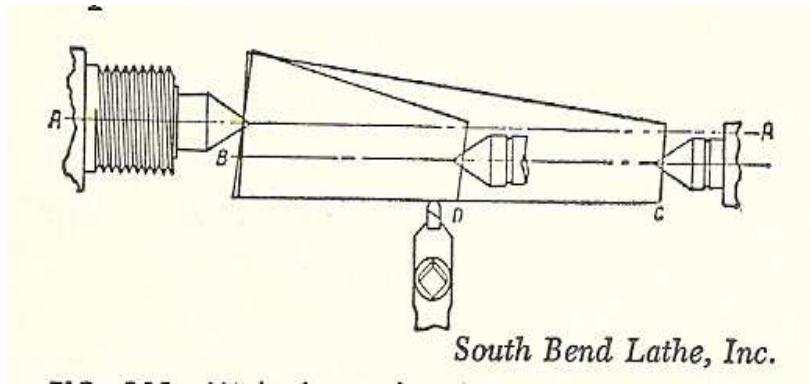


Fig 7.0 b Machining a taper with the tailstock offset.

### Cutting Taper with the Compound Rest Method

The compound rest is used to cut short, steep tapers that are given in degrees on work mounted in a chuck or between centres. The compound rest must be set to the required angle, then the cutting tool advanced along taper using compound rest feed handle.

This method is employed for internal tapers.

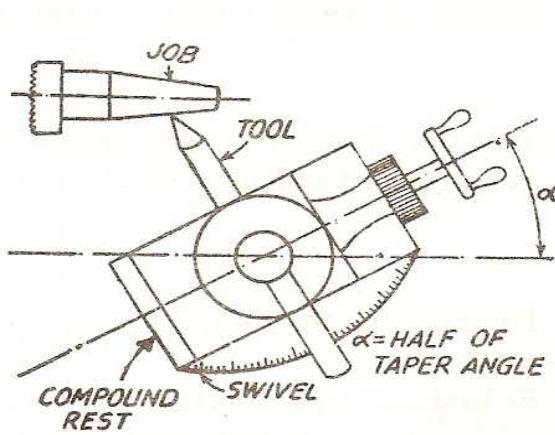


Fig 7.1 Cutting taper with the compound rest swiveled.

## 7.4 Exercises

Question one

Find the angle at which the compound rest must be set to turn taper on a work piece having a length of 200mm, larger diameter 45mm and smaller diameter 30mm.

Question two

When does it become necessary to cut tapers using the tail stock offset method?

Question three

What is the main advantage of cutting taper with a taper turning attachment?

## Week 8

### Shaping machines

#### Specific learning objectives;

- a. Describe main types of the shapers
- b. List the various parts of a shaper
- c. Describe the different shaper operations
- d. List safety precautions necessary while working on the shaping machine.
- e. Carry out practices on the shaper

## 4.0 SHAPING MACHINE

### 4.1 Introduction

The shaping machine is used for producing flat surfaces. It is more compact and cheaper than a milling machine and it is often speedier, particularly when operating on small work. The shaping machine is frequently used for toughing out casting since sand or hard spots may damage the teeth of a milling cutter.

### 4.2 THE MAIN PARTS OF THE SHAPING MACHINE:

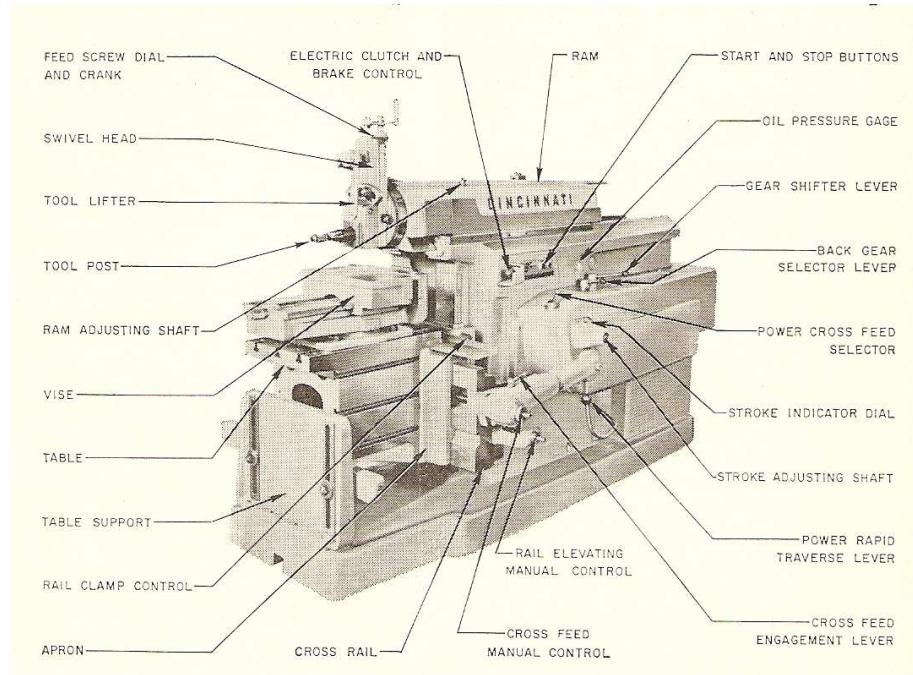


Fig. 21 Parts of a shaping machine

### 4.3 THE SHAPING MACHINE DRIVING MECHANISM

This is shown in Fig 22.

The slotted link converts the circular motion of bull gear into the straight line motion of the ram Fig.5.2 shows that the cutting stroke, and the mechanism is described as a quick return mechanism.

194 Part 4 Craft theory

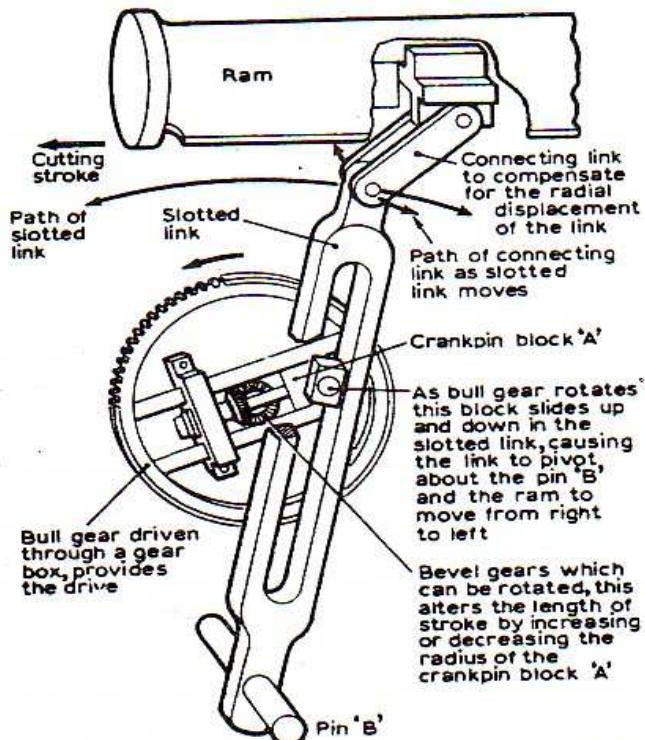


Fig 22 the shaping machine driving mechanism

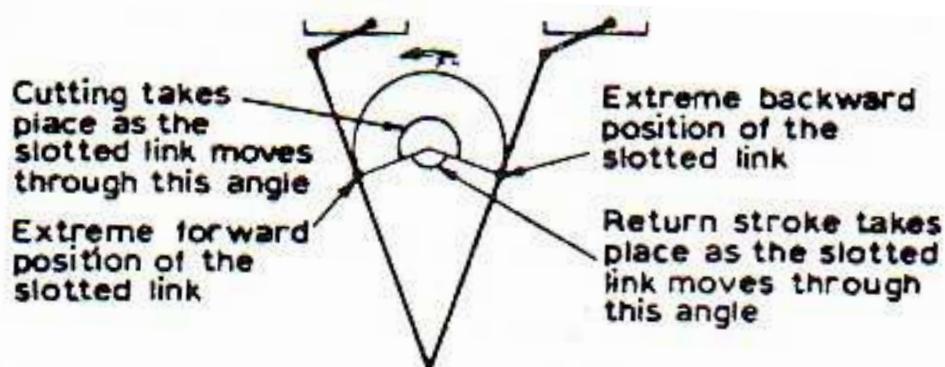


Fig 23 Quick return mechanism

#### 4.4 THE ACTION OF THE SHAPING MACHINE

Figure 5.4 shows how a flat surface is produced on the shaping machine. It will be seen that the tool movement and the work movement are perpendicular to each other. The work is moved a short distance during the return stroke and the amount of work movement is called the feed. This is usually quoted in mm per stroke (e.g 0.25mm per stroke)

In setting for horizontal work the length of the stroke should be regulated so that it is about 20mm longer than the work. About 12mm of this additional length should be at the start of the work. When machine a rectangular block it is more economical in time if the block is set so that the tool moves parallel to the longest side because less time is taken during the return strokes.

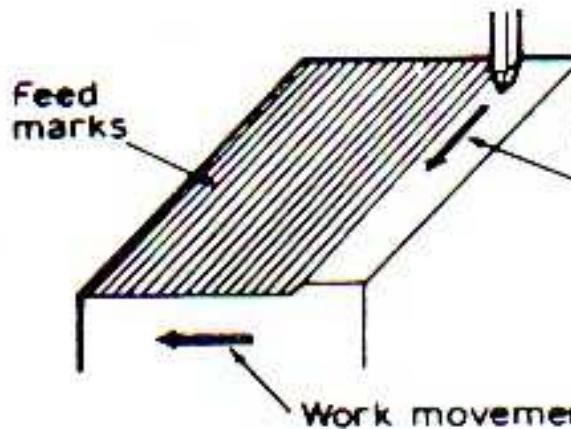


Fig24 the action of a shaping machine

#### 4.5 THE FEED MECHANISM

The feed of the sharper table and the way in which it is obtained varies with different makes of machines. It is not so important to have such a large selection of feeds as it is with the centre lathe and milling machine. The feed is selected according to the finish required –a very coarse feed being used for finishing cuts. Fig 5.5 shows the feed mechanism.

The table feed depends upon the number of feed on the ratchet wheel and the pitch of the thread on the feed shaft. If the ratchet wheel has 40 teeth and the feed shaft thread has a pitch of 6mm, then 1 revolution of the ratchet wheel moves the feed shaft through 6mm. this means that if the pawl moves one tooth at a time the table feed will be  $6/40 = 0.15\text{mm per stroke}$ . If the feed is set so that the pawl moves three teeth at a time the table feed will be  $3 \times 0.15 = 0.45\text{mm per stroke}$ .

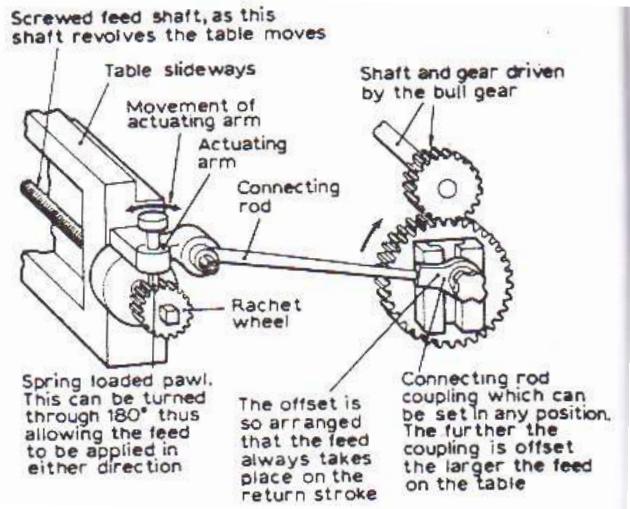


Fig.25 The shaping machine feed mechanisms

#### 4.6 Exercises

- 1 Explain why the return stroke of the shaping machine ram is made to take place in less time than the cutting stroke.
- 2 What is the purpose of the head slide of a shaping machine?
- 3 Make a simple outline diagram of a shaping machine, clearly indicating the following features:  
A Ram  
B head slide,  
C table  
D tool post and clapper box
- 4 Explain why shaper tool of stronger section than lathe tools.

## WEEK 9

### 4.7 CUTTING SPEEDS

The shaping machine has a reciprocating motion and the tool travel at different speed for every part of the ram movement. The cutting speed obtained depends on both the gear box setting and the length of stroke. With a particular gear-box setting the cutting speeds alters if the length of the stroke is changed. The cutting speeds quoted is always the average cutting speeds which can be calculated from the formula

Average cutting speed in meters per minute

= length of stroked in meters/tie in minutes taken by the cutting stroke

#### EXAMPLE

During a shaping operation the length of the cutting stroke is 500mm and the machine makes 30 cutting speed.

Solution

Length of stroke = 500mm =0.5m

Time taken for one cutting stroke = 1/30 mm

Average cutting speed =  $0.5 \div 1/30 = 0.5 \times 30/1$

### 4.8 TOOL HOLDING IN SHAPING MACHINE

The sliding head of the shaping machine is illustrated in figures 5.6

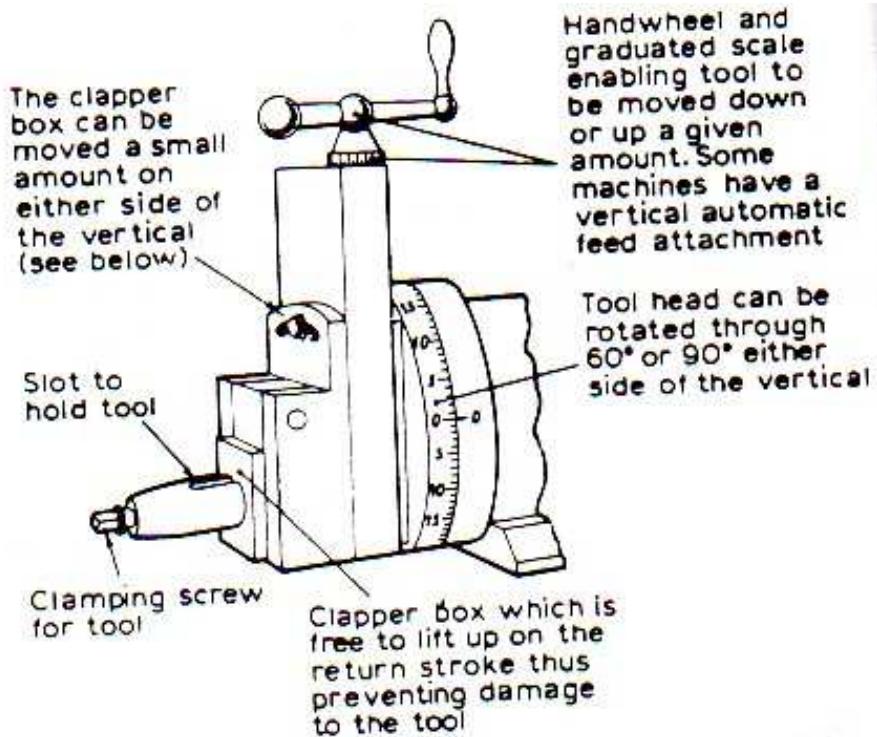


Fig26The sliding head of the shaping machine

#### 4.9 TOOL HEAD AND CLAPPER BOX

Figures 5 7 shows the tool head and clapper box is set when shaping a horizontal surface. This position prevents the tool from digging in and also enables the tool to swing away from the work on the return stroke.



Fig.27 tool head and clapper box

#### **4.10 HOLDING THE WORK**

Except for castings and work of irregular shape, the machine vice is used for holding the work. The jaw pieces of the vice are usually left soft and hence they can be cleaned up if they become damaged. Castings etc, can be clamped to the table in the usual way by using bolts and settings pieces.

Fig 5.8 shows the work being held in the machine vice. Notice how the main cutting force is resisted by the fixed jaw of the vice.

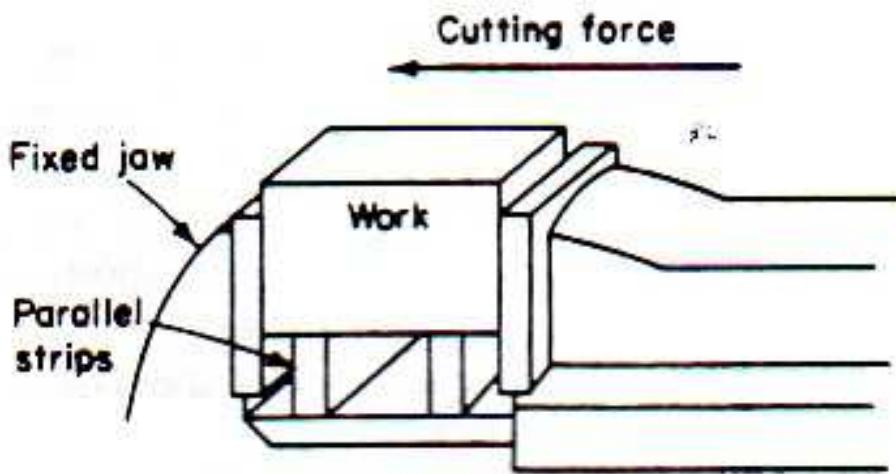


Fig 28 Work held in the machine vice

#### **4.11 MACHINING VERTICAL AND ANGULAR FACES**

The methods are shown in figures 29 and 30

## MACHINING VERTICAL FACE

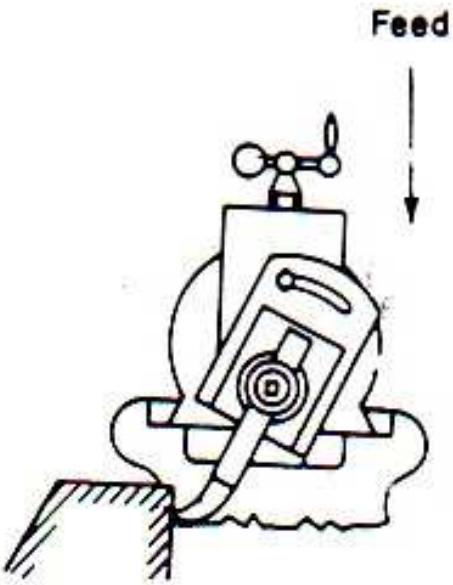


Fig29 Machining a vertical face

## MACHINING AN ANGULAR FACE

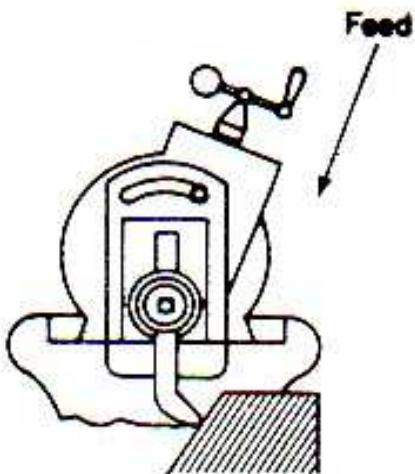
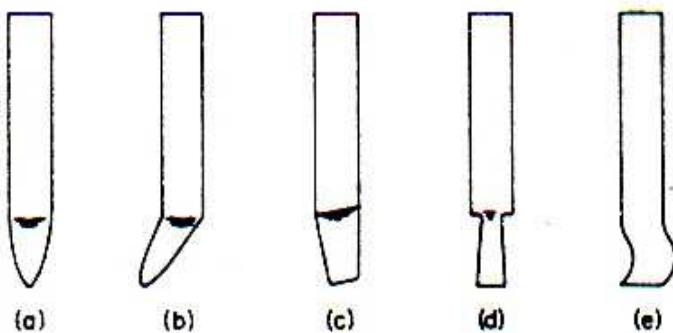


Fig30 Machining an angular face

#### 4.12 SHAPING TOOLS



- (a) Round-nosed roughing tool
- (b) Cranked tool
- (c) Straight-nosed roughing tool
- (d) Slotting tool
- (e) Swan-necked finishing tool

Fig 31 Shaping machine tools

#### SHAPING MACHINE TOOLS

- a. round nosed roughing tools
- b. cranked tool
- c. straight nosed roughing tool
- d. slotting tool
- e. swan-necked finishing tool

The tools used in shaping machine are similar to those used on a lathe but the shanks are generally stronger so that they can withstand the shock which occurred at the beginning of each cutting stroke.

#### 4.13 SAFETY PRECAUTION WHEN USING SHAPING MACHINE

- i. Before starting a shaping machine make sure that the work and tool are securely held.
- ii. Always stop the machine before taking any measurement
- iii. Wear goggles when cutting brittle materials like brass and cast iron.

#### 4.14 Exercises

- 1 Describe the operation of cutting T-slots on a shaper
- 2 What parts of a shaper are used to set the position of the stroke?
- 3 Why is it important to set the position of stroke after the length has been set?
- 4 Why must the ram lock always be tightened before the shaper is started?

## **WEEK 10**

### **5.0 MILLING MACHINES**

#### **5.1 Introduction**

Milling machine may be defined as a machining process for removing excess material from a work piece with a rotating cutting tool. Milling process involves simultaneous rotary cutter and usually linear (sometimes) motion of the work, with the work fed against the cutter. Milling process is used for producing flat, contoured or helical surfaces, for cutting threads and toothed gears and for making helical grooves.

Milling machines were basically developed to machine flat surfaces but the present milling machines can make the machine flat, contoured and helical surfaces, cut gears and do other various jobs. Milling machine is one of the useful and necessary machine tools found in the workshop.

Milling machine are designed to hold and rotate milling cutter or cutters, hold the work piece and feed the work piece to the milling in one of several directions.

#### **5.2 TYPES OF MILLING MACHINES**

Milling machines can be divided or classified in different ways;

(a) According to the axis of the spindle of the machine we have,

(1)Horizontal milling machine with horizontal spindle.

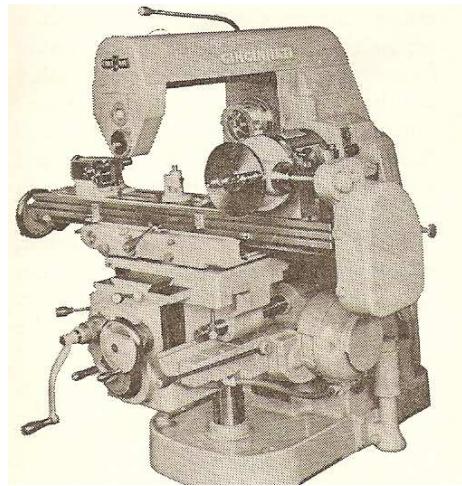


Fig 32 Horizontal milling machine

(2)Vertical milling machine with vertical spindle.

(B)According to the purpose of the milling machine.

(1)General purpose milling machine.

(2)Production milling machine.

(3)Special purpose milling machine .

### **GENERAL PURPOSE MILLING MACHINE**

---

The most common type of milling machine in this category are the column

and knee type models which are all single spindle machines .The various

Models under this category are...

(!)Plain (Horizontal spindle)

(2)Universal (Horizontal spindle with swivel table .

(3)Ominiversal (Horizontal spindle with swivel table and swivel knee).

(4) Vertical spindle

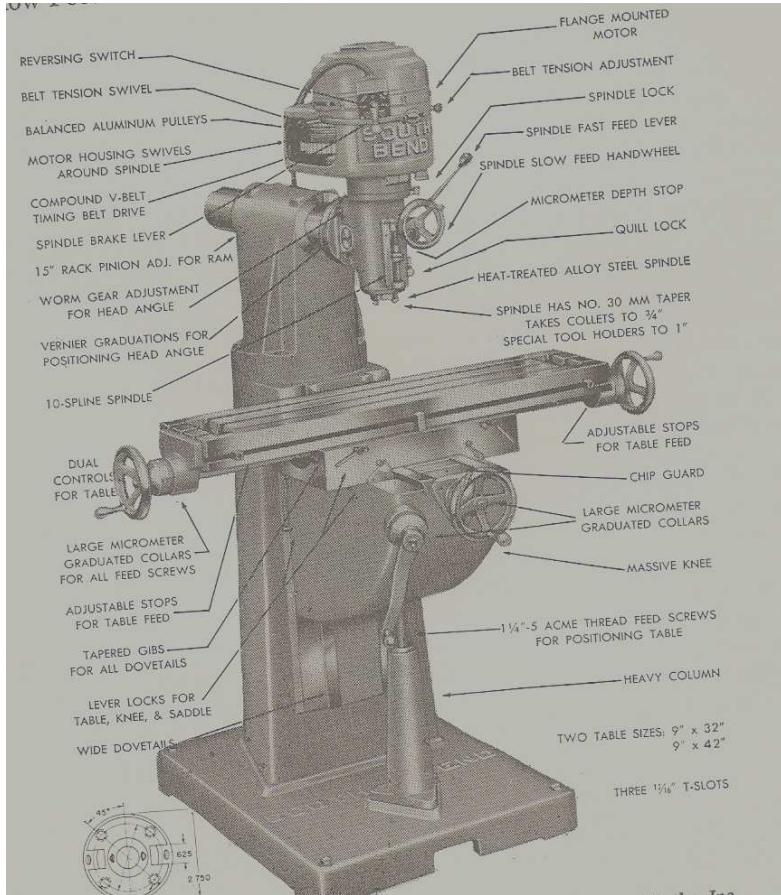


Fig 33 Light duty vertical milling machine

#### PLAIN COLUMN AND KNEE TYPE MILLING MACHINES

---

This machine is called by this name because the spindle (the part that rotates) is fixed in the column. A block diagram of the machine is shown in the figure 6.1

### 5.3 TYPES OF MILLING CUTTERS

#### 5.4 FACE MILLING CUTTERS

Face milling cutters, with teeth on the end face are used for machining large, flat surfaces .The cutter may be mounted to an arbor.

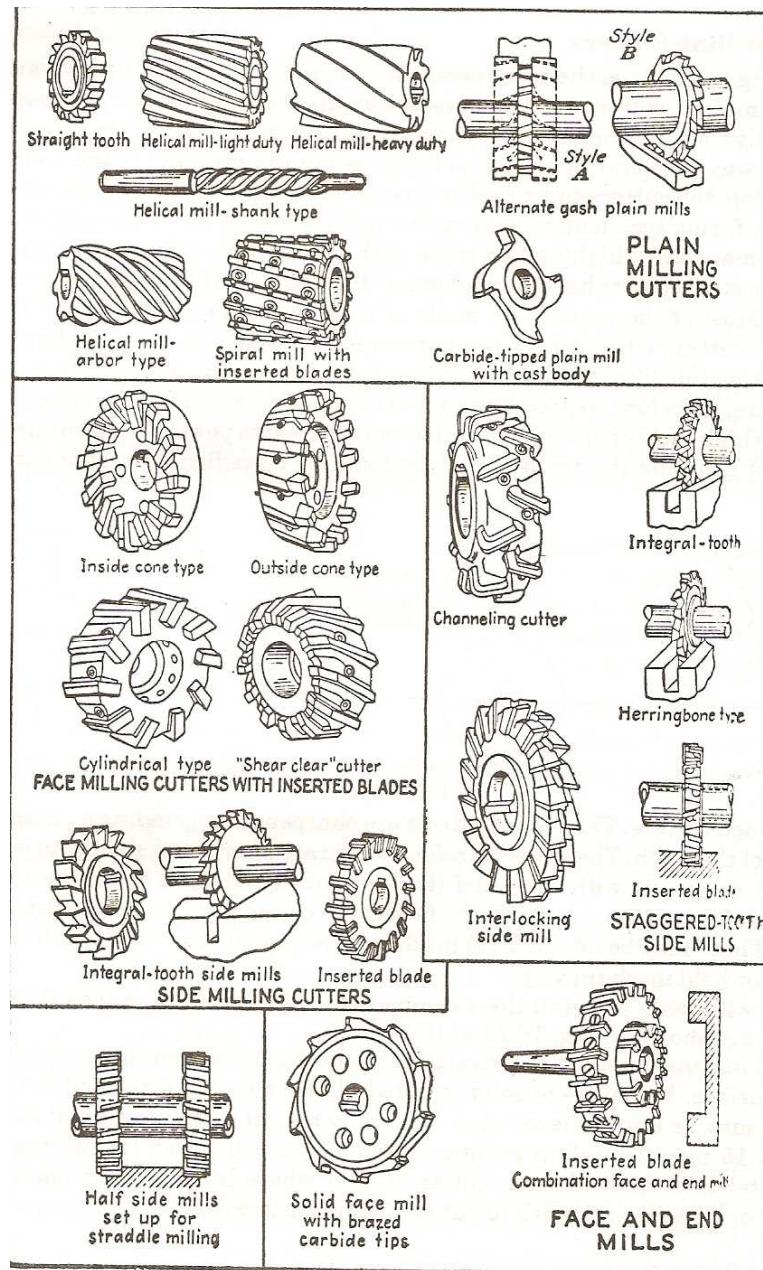


Fig 34 Different types of milling cutters

#### 5.5 CONSTRUCTION OF MILLING CUTTERS.

The milling cutters may be solid, carbide tipped solid cutters and inserted blade cutters with H.S.S or carbide tipped blades, the body being of constructional steel .

The advantages of carbide tipped cutters (either solid or inserted blade type) are:

1. Their high production capacity.
2. The high quality of the surfaces they produce.
3. Elimination of grinding operation in some cases, the possibility of machining hardened steels and the reduction in machining costs that their use leads to .

Due to these advantages, they have been successfully applied in metal cutting industry where they have replaced many solid cutters of tool steels.

### **5.6 CUTTER MATERIALS**

General purpose solid milling cutters are common made of H.S.S some cutters are tungsten carbide teeth which may be brazed on the type of the teeth or individually inserted and held in the body of the cutter by some mechanical means .Carbide tipped cutters are especially adapted to heavy cuts and increased cutting speeds .

### **5.7 CUTTING SPEEDS, FEEDS AND DEPTHS OF CUTS**

Since the milling cutter is a multiple point cutter, the feed may be given as.

Feed per rev; mm/rev,  $f_t$ =feed per tooth ,mmxN of cutter teeth .

; feed per min .

$Fe = f_t \times N$

Or  $F(mm/min) = fe \times N$

Where  $fe$ =feed rate per tooth, mm

$N$ =number of cutter teeth.

For H.S.S.plain milling cutters.

$Fe=0.05\text{to }0.6\text{mm/tooth}$

For milling steel  $=0.1\text{to }0.8\text{mm/tooth}$

For milling c.i.

The r.p.m of the cutter is obtained as,

$N=1000xv/VD$

D is the cutter diameter in mm

V is the cutter speed in mm/min

Material being cut Brass C.I Bronze Hard c. steel Hard alloy steel Al

V.mpm 45-60 21-30 24-45

15-18 9- 18 150 -300degrees.

#### TABLE 6.1 CUTTING SPEED H.S.S CUTTERS.

The cutting with carbide tools can be as high as five times the cutting speed for H.S.S tools.

Depth of cut

=3to 8mm for roughing

=0.5 to 1.5 mm for finishing.

#### EXAMPLE 6.1

A Slot is to be milled by a side and face milling cutter with 10 teeth and of diameter 150mm.The cutting speed is 50m/min and feed is 0.25mm/tooth .Determine the table feed in mm min.

#### SOLUTION.

Given, n=10

V=50 m/min

Diameter of cutter =150mm

Feed, fe =0.25mm/tooth

Now table feed, F,mm/min =fexnxN

N=RPM of the cutter

= $1000 \times V / VxD = 1000 \times 50 / V \times 150 = 106$  r.p.m.

; F= $0.25 \times 10 \times 106 = 265$ mm/min.

### Example 6.2

A steel work piece is to be milled .Metal removed rate is 30cmcube /min .Depth of cut is 5mm and width of cut is 100mm.Find the table feed.

**SOLUTION;**

Now , metal removal rate, MRR is given as ;

MRR=Depth of cut x width of cut x rate of feed .

;  $30 \times 10 \text{cube} = 5 \times 100 \times F$

; Rate of feed (Table of feed)

$F=60 \text{mm/min.}$

### 5.8 Exercises and quiz

**QUESTION 1**

What precaution is essential in mounting gang cutters in milling operation.

**ANSWER 1**

Gang cutters must be grouped so that cutters having opposite helix angles are placed alternatively side by side. It must also be ensured that the cutting edges engaging steps or shoulders permit of free disposal of the cuttings.

**QUESTION 2**

Why certain milling cutters are provided with flutes.

**ANSWER 2**

Certain milling cutters are provided with spiral flutes for the following reasons:

- (i) A number of flutes on the cutter ensure that at all times in a revolution of the some cutting is occurring;
- (ii) Have the effect of reducing the vibratory nature of milling;
- (iii) Eliminate axial backlash in the arbour by preventing an axial component of force to load thrust bearings.

## WEEK 11

### 5.9 DIVIDING HEADS

An important function and use of milling machines is for cutting slots ,grooves etc which are to be equally spaced around the circumference of a blank ,for example gear cutting ,ratchet wheels ,milling cutter blank reamers etc .This necessitates holding of the blanks (work piece ) and rotating it the exact amount for each grooves or slot to be cut .

This process is known as “Indexing “.The dividing head is the device used for this purpose .It is lined and bolted to the machine table so that the axis passing through the head stock center and tailstock center is at right angle to the spindle axis of the machine .The head stock of the dividing stock consists especially of the spindle to which is keyed 40 tooth worm wheel .A single threaded worm meshes with this wheel .The worm spindle projects from the front of the head and has a crank and handle attached .The head spindle is bored with a taper hole and is also screwed on its end .The work piece is mounted between centers ,one inserted into the dividing head spindle and the other into the tails stock of the head .The work piece may also be mounted on a mandrel between these centers .A clock may be mounted on the spindle nose for having short work pieces having no center holes.

The work piece is rotated by turning the index crank by means of handle .Since the gear ratio of worm and worm wheel is 40:1,it takes 40turns of the crank to rotate the spindle and hence the work piece through one complete revolution .Thus one turn of the crank rotates the work  $1/4^{\text{th}}$  of a turn .If division other than factors of 40 are required “Index plates are used” An indexing plate has several circle of holes (each circle containing a different number of holes ) and is mounted on the worm shaft .A pin on the crank can be adjusted to a radius such that it will fit in any desired circle of holes .By using different circles of holes and indexing plates ,any fractional

Part of turn of the index crank can be obtained .The sector arm on the front of the index plate, determine the angle through which the index crank is turned for indexing .

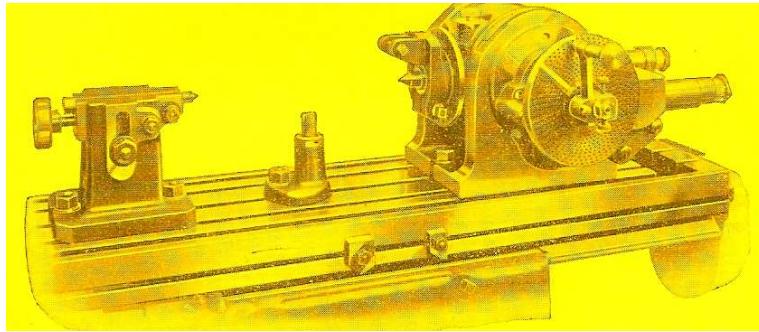


Fig 35 Universal dividing head and tailstock

### 5.10 TYPES OF DIVIDING HEADS

The various dividing heads used with milling machine are :

1. PLAIN: A Plain dividing heads has a fixed spindle axis and the spindle rotates only about a horizontal axis.
2. UNIVERSAL: In these models, the spindle can be rotated at different angle in the vertical plane from horizontal to vertical .A universal dividing heads performs the following functions.
  - !.Indexes the work piece.
  - !!..Imparts a continuous rotary motion to the work piece for milling helical grooves (Flutes of drills, reamers, milling cutters etc)
  - !!!.Soften the work piece in a given inclined position in reference to the table.

### 3. OPTICAL

These models are used for high precision angular sifting of the work piece with respect to the cutter .For reading the angles, an optical system is built into the dividing head.

### 5.11 METHOD OF INDEXING

The various methods of indexing are:

1. DIRECT INDEXING: In direct indexing, the index plate is directly mounted on the dividing head spindle. The intermediate use of worm and worm wheel is avoided.

For indexing, the index pin is pulled out on a hole the work on the index plate are rotated the desired number of holes and the pin is engaged .Both plain and universal head can be used in this manner .Direct indexing is the most rapid method of indexing, but fraction of the complete turn of the spindle are limited to those available with the index plate .

With a standard indexing plate having 24holes , all factors of 24 can indexed that is the work can be divided into 2,3,4,6,8,12and 24 parts .

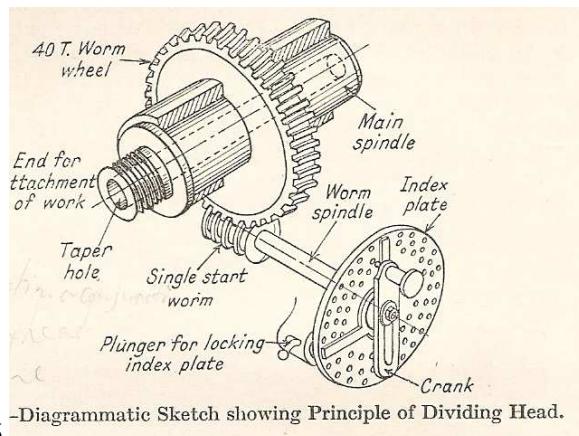


Fig 36

## 2. SIMPLE INDEXING

In a simple or plain indexing ,an index plate selected for the particular application is fitted on the worm shaft and locked through a locking pin .To index the work through any required angle ,the index crank pin is withdrawn from a hole in the index plate .The spindle and hence the work is indexed through the required angle by turning the index crank through a calculated number of whole revolutions and holes on one of the hole circles ,after which the index pin is relocated in the required hole .

If the number of the divisions on the job circumference (that is number of indexing) needed is Z, than the number of turns that the crank must be rotated for each indexing can be found from the formula.

$$N=40/Z$$

Dividing head are usually furnished with a set of three index plates having six concentric hole circles with different numbers of equally spaced holes on each hole circle .A typical set has the following number of holes .

Plate No.I 15, 16, 17, 18, 19,20holes

Plate No II 21, 23, 27, 29, 31,33holes

Plates NoIII 37, 39, 41, 43, 47,49holes

EXAMPLE Z=16

$$N=40/16=2.8/16$$

That is for each indexing we need two complete rotations of the crank plus 8 more holes on the 16 holes.

Circle of plate 1

Example let Z=45

$$N=40/45=8/9=8/9 \times 2/2=16/18$$

We will employ index plate I and use hole circle with 18 holes . For each indexing the crank will rotate through 16 holes .

### 3. COMPOUND INDEXING

When none of the index plates has a hole circle which would enable the work to be divided by simple indexing method ,more involved method are employed .one method is “compound indexing”. The compound indexing is achieved in two stages ,by using two different hole circles of one index plate .

(!)By a movement of the crank in the usual way as in simple indexing, say n 1 holes in hole circle N1, with the lock pin engaged in circle N2 of the index plate.

(!!)By adding and subtracting a further movement by rotating the crank and the index plate together forward or backward ,through n2 spaces in the N2 circle (by disengaging the locking pin of the index plate so that it is free to turn ).

The procedure is explained below:

Let  $Z$ =number of divisions needed on the work.

; Crank rotations for each indexing  $=40/Z$

Since this can not be obtained by simple indexing .it is achieved by compound indexing.

Therefore, addition or subtraction of the two movements given above should be equal to  $40/Z$ . This is done as explained below:

(!)Write  $Z$  above and 40 below a straight line and factorize them.

(!!)Select two numbers representing two hole circles in the same plate .Write these numbers below 40 and factorize them .Write their difference above and factorize it .These whole numbers are to be chosen in such a manner that all the factors above the line get cancelled out with factors below the line .

Let these whole numbers be  $N_1$  and  $N_2$

(!!!)Let  $N_1$  be the number of holes to be indexed in  $N_1$  hole circle and  $N_2$  the number of holes to be indexed in  $N_2$  hole circle.

Then,  $N_1/N_1+N_2/n_2 =40/Z$

From here  $n_1$  and  $n_2$  are found by trial and error .Then the total indexing will be:

$N_1$  holes in  $n_1$  hole circle by rotation of the crank + $_n_2$  holes  $N_2$  hole circle by rotating the crank and index plate together.

Example 6.3

Let  $Z=87$

Steps

(!) $87=29\times 3/40=2\times 2\times 2\times 5$

(!!)Let  $N_1=29$ and  $N_2=33$

:  $4=2\times 2$

$$87=29 \times 3$$

$$40=2 \times 2 \times 2 \times 5$$

$$29=29 \times 1$$

$$33=11 \times 3$$

Since all factors above the line get cancelled out, therefore, selection of  $n_1$  and  $N_2$  is correct.

(!!!) Now indexing equation is:

$$N_1/29 + n_2/33 = 40/87$$

$$\text{OR} \quad 33n_1 + 29n_2 = 440$$

By trial and error  $n_1 = 23$

$$N_2 = 11 \text{ with minus sign}$$

That is  $33 \times 23 - 29 \times 11 = 440$

: Indexing equation will be:

$$23/29 - 11/33 = 40/87$$

That is, movement of the crank by 23 holes in 29 holes circle forwards and movement of crank and index plate both by 11 holes in 33 holes circle backwards.

NOTE: The method of compound indexing is little used today, as it has been replaced by differential indexing.

#### 4. DIFFERENTIAL INDEXING

Differential indexing in reality is an automatic method of doing compound indexing. It is achieved in a single step as compared to two stages needed in compound indexing.

In differential indexing, the index plate is connected to the head stock spindle by means of a gear train. The figure below shows one such design where  $Z_1, Z_2, Z_3$  and  $Z_4$  are interchangeable gears. During indexing, the index plate rotates in rotation to the crank movement. For this the locking pin which kept the index plate locked while doing simple indexing, is disengaged. As the index plate is turned for indexing, rotating the spindle

through worm and worm gear, the index plate will receive power through the change gears ,equal bevel gears and the sleeves ,and will rotate slowly .The index plate can rotate either in the same directions or in opposite direction to the index crank (by gear train design)

Indexing is performed in the same manner as that for simple indexing except that the location of the hole from which the index pin is turned will move slightly during indexing .The required movement of the index plate is calculated and taken care of by the gear train.

Differential indexing is thus more straight forward and so has wider application as compared to compound indexing.

#### PROCEDURE

Let  $Z$ = number of divisions required to be indexed for one complete revolution of the spindle and hence the work piece .

$K$ =A number very nearly equal to  $Z$  and which can be used in simple indexing method .

: Number of crank turns for each simple indexing.

$$N=40/K$$

: Number of crank turns needed for  $Z$  indexing,

$$N=40/K \times Z$$

But, we know that the crank must make only 40turns for the spindle (and hence the work )to turn through one complete circle. So

- (i) If  $N > 40$ , then  $(N - 40)$  turns have to be subtracted. This is achieved through the change gears so that while the spindle makes one turn, the Index plate makes  $(N - 40)$  turns in the opposite direction to that of the crank.
- (ii) If  $N < 40$ , then the Index plate should rotate  $(40 - N)$  turns in the same direction as that of the crank.

The gear ratio will be:

$$!=40/K (K-Z).$$

Thus, the movement of the index handle (crank) operates according to the principle of simple indexing and the gear ratio makes it possible to find gears which take care of residual divisions.

#### EXAMPLE 6.

: Do differential indexing for 93 divisions.

Solution  $=Z=93$

: Simple indexing  $=40/93$

It is clear from the available index plates, that 93 can be simple indexed, each indexing  $=40/90=4/9=8/18$ , that is ,8

: For 93 indexing

$$N=8/18 \times 93 = 41.1/3 \text{ turns of the crank.}$$

Since  $N > 40$ , the index plate must rotate  $4/3$  turns backwards, that is, in the opposite direction.

$$!=40/K (K-Z)=40/90 \times 3=4/3.$$

In the Brown and sharp dividing head ,the gears supplied are :  
24(2),28,32,40,44,48,56,64,72,86 and 100teeth.

:  $=4/3=32/24=\text{Drivers/Driven.}$

It is a simple gear train.

Example 6.5  $Z=127$

Let  $K=128$

Simple indexing  $=40/128=5/16$

:  $N=5/16 \times 127 = 39.11/16 \text{ turns of the crank.}$

Since  $N$  is  $< 40$ , therefore, the index plate must rotate  $[40-39.11/16]$ , that is  $5/16$  turns in the same direction as the crank, as the spindle completes one turn .

$$!=40/K(K-Z)=40/128 \times 1=5/16=5 \times 1/8 \times 2=40/64 \times 24/48=\text{Drivers/Driven}$$

It is a compound gear train.

Gears Z1 and Z3 are drivers and gears Z2 and Z4 are driven gears.

With this gear train and an indexing of 5 holes in a 16 hole circle, the 127 divisions would be obtained.

### RULE OF THUMB

(!) If  $(K-Z)$  is positive, the index plate must rotate in the same direction as that of the crank.

(!!) If  $(K-Z)$  is negative, the rotation of index plate is in opposite direction to that of the crank.

Example, 6.6. Let  $Z=153$

(!) Let  $K=155$

: Simple indexing  $=40/155=8/31$ , that is, 8 holes in 31 hole circle.

Change gears  $=40/K (K-Z)=40/155 \times 2=80/155=16/31$ .

It is clear that this gear ratio can be accommodated with the gears available .Therefore, choice of  $K=155$  is not correct.

(!!) Let  $K=150$

: For simple indexing  $=40/150=4/15$ , that is, 4 holes in 15 hole circle.

Change gears  $=40/K (K-Z)$

$$40/50 \times 3 = 12/15 = 2 \times 6/3 \times 5 = 32/48 \times 48/40 = \text{Drivers /Driven}$$

: Change gears:  $Z_1=32, Z_2=48, Z_3=48, Z_4=40$

(!!!) Another solution can also be obtained.

Now indexing of 153 divisions by.

Simple indexing  $=40/153=1/3.825$  which is approximately equal to  $7/27$ , that is 7 holes in a hole of circle 27 for each indexing.

Now , number of crank turns for 153 indexing

$$=7/27 \times 153 = 39.18/27$$

Which is less than 40 by  $9/27$  turns .Therefore the gear train must rotate the index plate in the same direction as the crank.

Change gears =Drivers /Driven =9/27=1/3 =24/72,

That is a simple train.

: For 153 divisions the indexing is: 7 hole in a 27 hole circle .Gear ratio 24/72 and the crank and the index plate rotating in the same direction.

NOTE: It is clear from above that for a given problem many solutions are possible .solution (!!!)Is better than (!! )as a simple gear train is needed .To avoid wastage of time if the gear ratio does not fit the available gears as in solution (!)above .The hole circle selected for approximate simple indexing should be a number whose factors are accommodated in the available gears ,For example, use hole circles of ,18,20,21,27 etc.

#### RULES OF THUMB FOR GEAR TRAINS.

- (a)If  $K > Z$  and the gear train is simple, than only one idler gear is to be used.
- (b)If  $K > Z$  and the gear train is compound, no idler gear is to be used.
- (c)If  $K < Z$  and the gear train is simple, than two idler gear is to be used.
- (d)If  $K < Z$  and the gear train is compound, than no idler gear is to be used.

#### (5) ANGULAR INDEXING

Angular indexing is used when it is necessary to cut grooves or slots subtending a given angle at the center of the circle upon which they are spaced.

We know that 40 turns of index crank will rotate the head spindle and hence the work piece through one revolution, that is 360degrees.

- : 1 turn of the crank =9degrees of the spindle
- : Turns of crank to give any angle =Angle required/9

EXAMPLE 6.7: Do angular indexing for 38degrees.

$$\text{Indexing} = 38/9 = 4.2/9 = 4.4/18.$$

That is, four complete turns of the crank and 4 holes in a 18 hole circle.

EXAMPLE 6.8: Do angular indexing for 51degrees 37i.

$$\text{Indexing} = 51 \frac{37i}{9} = 5 + 6\text{degrees} 37i/9\text{degrees} = 5 + 397i/540i.$$

Now no index plate is available with 540 hole circle .So, the exact indexing is not possible.

For approximate indexing, Let us convert the residual turn to a continual fraction.

397)540(1

397/

143)397(2

286/

111)143(1

111/

32)111(3

96/

15)32(2

30/2)15(7/14

1)2(2

2/0

: We can write the residual fraction as :

$$397/540 = 1 + 1/2 + 1\backslash 1 + 1/3 + 1/2 + 1/7 + 1/2$$

First fraction = 1/1

Second fraction = 1/1 + 1/2 = 1/3/2 = 2/3

Third fraction = 1/1 + 1/2 + 1/1 = 1/1 + 1/3 = 1/4/3 = 3/4

Fourth fraction = 1/1 + 1/2 + 1/1 + 1/3 = 1/1 + 1/2 + 1/4/3  
= 1/1 + 1/2 + 3/4 = 1/1 + 1/11/4 = 1/1 + 4/11 = 1/15/11 = 11/15 and so on .

All the fractions will be 1/1, 2/3, /3/4, /11/15, 25/34, 186/253, 397/540

Now with the available index plates ,the nearest indexing for the residual turn is 11/15,an error of 1i.

Now Cincinnati and Parkinson index plates have the following hole circles:

FIRST :24,25,28,30,34,37,38,39,41,42,43.

Second : 46,47,49,51,53,54,57,58,59,62,66.

Using the Cincinnati plate, the closest fraction to the residual fraction is 25134

: Angle will be  $=5.25/34 \times 9 = 51$  degrees,37i,3.9ii/17

That is an error of only 3.9ii/17in the angle.

This is well within the accuracy of the ordinary dividing heads.

## 5.12 MILLING OPERATIONS

### GANG MILLING

When two or more milling cutters are mounted on an arbor so that each cutter will produce its own distinctive surface as the workpiece is fed to it ,the operation is called “GANG MILLING”.

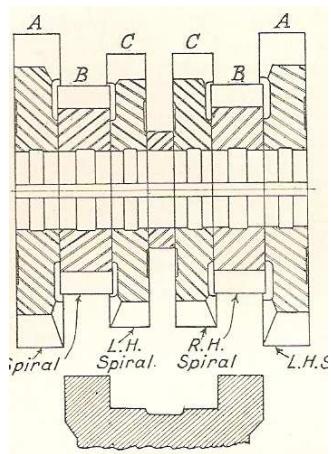


Fig 37 Gang milling

## STRADDLE MILLING

Is special form of gang milling in which side milling cutters are used to machine both sides of a work piece simultaneously?

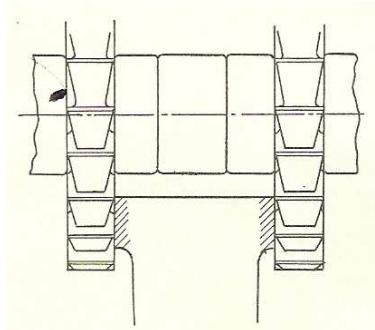


Fig 38 Straddle milling

**STRING MILLING:** Two or more work pieces are mounted on the milling machine table in a line ,so that they are successively fed to one or milling cutters .String milling results in a substantial reduction in handling time as it is overlapped by the machining time .

### 5.13 Exercises

- **QUESTION 1**

- (a) How one establishes whether the milling operation is up milling or down milling?
  - (a) When down milling is recommended?
  - (b) What is the essential difference between up and down milling?

**ANSWER 4**

- (a) By seeing the direction of feed relative to the direction of cutter, one can decide whether a milling operation is up or down milling. When the direction of feed opposes the direction of cutter rotation, it is called up milling. When the direction of feed is in the same direction as the cutter rotation, it is called down milling.
- (b) Down milling should be used only on milling machine provided with auto-backlash devices or on machine equipped with preloaded recirculating ball bearing table screws.
- (c) In up milling, the cutter tooth starts with a chip of zero thickness and end with a thick chip. The cuts start in clean metal and ends by lifting off the rough surface scale, thus increasing cutting tool life. Since the forces caused by the cutter on the work piece act in a direction that tends to pull the work piece out of the vice or fixture, the work piece must be fastened very securely. Further as up milling tends to push the work

piece away from the cutter, it eliminate backlash. It is recommended for softer and ductile metals and cast iron having hard surface. In down milling, the cutter tooth starts with a chip of maximum thickness and ends with a thin chip of zero thickness. Thus a scraping action is produced as the thinned edge of the chip is removed, resulting in a good surface finish. Since cutter tends to push the work down against the table, it is suited for cutting thin work pieces held in a vice or on a magnetic chuck. Further due to cut starting with of maximum thickness, the rubbing action is less and wear on cutting tool is also less

#### QUESTION 2

- (a) How one can feel confident that correct cutting angles have been used on a milling cutter?
- (b) What are the usual values of various angles for milling alloy steel, aluminium?

#### ANSWER 5

- (a) If correct cutting angles are ground on the tool, then curled chips will be produced.  
Otherwise the chips will be in the nature of needles, broken up or even powdered.

For milling any alloy steel, rake angle of  $5^\circ$  and clearance angle of  $2-3^\circ$  is provided. For aluminium, these angles are  $20-25^\circ$  and  $8^\circ$  respectively. As a general rule, harder the material, the smaller should be the cutting angles. The greater the helix angle, it should be the clearance angle which is also influenced by

#### WEEK 12

#### 6.0 GRINDING MACHINES

## 6.1 Introduction

Grinding operation is a method of machining work pieces by the use of a rotary abrasive tool, called “grinding wheel”. Such wheels are made of fine grains and abrasive materials held together by a bonding material, called a “bond”. Each individual and irregular shaped grains act as a cutting element (a single point cutting tool) The grinding operation can be :

- (i)Rough grinding or finishing (precision grinding)

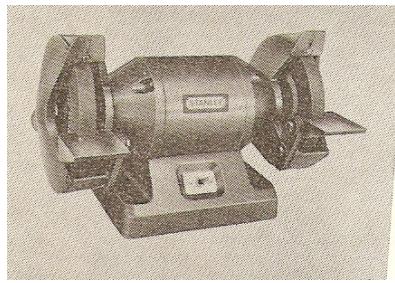
Rough grinding is a commonly used method for removing excess material from castings, forgings and burrs or as a method for removing or snagging thin fins, sharp corners, burrs or other unwanted projections from various shapes of work pieces.

## 6.2 TYPES OF GRINDING MACHINES

Grinding machines are classified as :

- (i) Cylindrical
- (ii) Internal
- (iii) Centre less
- (iv) Surface
- (v) Special grinding machines

A bench type grinder used for general purpose grinding and tool sharpening .This grinder consists of a motor with a double –end spindle on which the wheels are supported between flanges and are held by a nut at each end ,two grinding wheels (usually one for rough –and one for finish –grinding ),two rests to support the work



.Fig 38 Bench grinder

### 6.3 Grinding and Safety Instructions.

Safety glasses or an eye shield should be worn while operating a grinder.

The work rests should be adjusted leaving approximately 0.12mm clearance from the grinding wheel ,to prevent the work from jamming between the wheel and the rest and possibly causing an accident .Hold the work securely with the fingers well back and grind on the outside diameter or the face of the wheel only . Rotate round work on the rest to avoid grinding flat spots on it. When grinding flat work move it across the face of the wheel to avoid wearing a groove in the grinding wheel .Dip the work in water to to keep it cool .Do not wear gloves or hold the work with a cloth when grinding .Shut off the motor on the machine when your grinding has been completed .

Abrasives ,Natural .Grinding wheels are made from small particles of cutting materials called abrasives which are held together by a suitable adhesive called the bond .There are two general type of adhesives ,natural and manufactured . Natural abrasives, such as sandstone, emery, corundum and quartz, are mined, but owing to their variable hardness their use is limited.

Abrasives, Manufactured. One type of manufactured abrasive is silicon carbide which is made by mixing coke, sand, salt and sawdust in the correct proportions. After heating in an electric furnace the mixture is cooled, crushed and graded .Silicon carbide wheels are

recommended for grinding cast iron , brass, bronze, marble and granite. Another manufactured abrasive is aluminum oxide ,produced by fusing bauxite in an electric furnace .The hardness of wheels made from this material can be varied ,making them suitable for grinding all kinds of steel and other materials of high tensile strength .

### Abrasives

**Grain Size:** After cooling, the abrasive material is crushed and screened for manufacturing into grinding wheels. The commercial grain sizes are coarse range from 8 to 24, medium range from 30 to 60, and fine range from 70 to 120. The size s are obtained by using screens with a definite number of openings per mm.

**Bonds:** The adhesive material that holds the abrasive grains of a grinding wheel together is called the bond . The grade of hardness of a wheel depends upon the strength or holding power of the bond .A enlarged section of grinding wheel in fig .100 shows the grain ,bond and cutting action of a grinding wheel .The lines across the abrasive are the cleavage lines ,where the abrasive will break when it becomes dull .New sharp cutting edges will then be exposed providing grinding wheels with a self – sharpening action . A vitrified bond is used in approximately 75 percent of all grinding wheels .This is a strong bond which is not affected by water ,oils ,or changes in temperature .The abrasive and bond are mixed according to the hardness of the wheel required .The wheel is then molded into various shapes and heated

until it vitrifies .Finally it is trued ,bushed ,balanced ,and tested .Vitrified wheels are used for general purpose grinding .

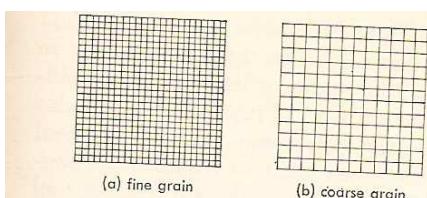


Fig. 39 Fine and coarse grain (Abrasives)

Silicate Bonded Wheels .silicate bonded wheels are more closely bonded than vitrified wheels and are made by a process known as tamping .The abrasive materials and bonds are thoroughly mixed and then tamped firmly into moulds . Only a short time in the heat is required to set the bond for this type of wheel. Silicate bonded wheels give excellent results for work such as tool grinding, knife sharpening, and surface grinding. Wheels over 914.4mm in diameter are usually made by the silicate process.

Rubber Bonded Wheels. Small elastic or rubber bonded wheels are made in moulds, larger wheels been formed under pressure. Elastic wheels are baked for only a short time similarly to silicate wheels. they have a high degree of elasticity ,resisting side pressure to a considerable extent .Elastic wheels may be run in water –caustic soda or dry .They have a very high factor of safety and give good results for light grinding operations ,such as small-tool grinding and roll grinding ;they may also be used for cutting off steel in place of a power hack-saw , especially hardened steel .All grinding wheels are tested before leaving the factory and should never be run at a higher speed than that recommended by the manufacturer .

Grain Spacing .The pieces of abrasive may be spaced according to the hardness of the grinding wheel required .Two wheel of the same abrasive, bond and grain size but with different spacing will cut differently .Less spacing gives a stronger wheel and more spacing gives a wheel that will break away and provide a better self –sharpening action . fig 4o a medium –and a wide spaced wheel .

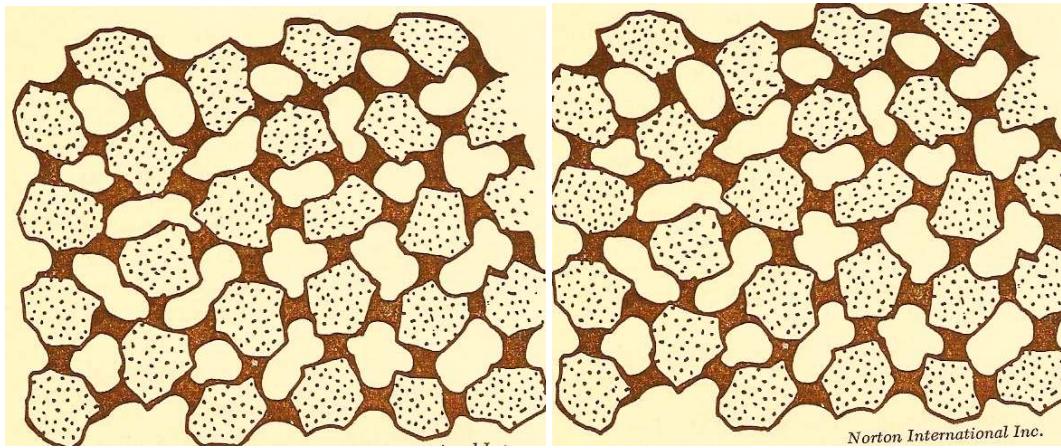


Fig 40 Medium and wide grain spacing

#### 6.4 Exercises

- **QUESTION 1**

- (c) How one establishes whether the milling operation is up milling or down milling?
- (d) When down milling is recommended?
- (e) What is the essential difference between up and down milling?

**ANSWER 4**

- (d) By seeing the direction of feed relative to the direction of cutter, one can decide whether a milling operation is up or down milling. When the direction of feed opposes the direction of cutter rotation, it is called up milling. When the direction of feed is in the same direction as the cutter rotation, it is called down milling.
- (e) Down milling should be used only on milling machine provided with auto-backlash devices or on machine equipped with preloaded recirculating ball bearing table screws.
- (f) In up milling, the cutter tooth starts with a chip of zero thickness and end with a thick chip. The cuts start in clean metal and ends by lifting off the rough surface scale, thus increasing cutting tool life. Since the forces caused by the cutter on the work piece act in a direction that tends to pull the work piece out of the vice or fixture, the work piece must be fastened very securely. Further as up milling tends to push the work piece away from the cutter, it eliminate backlash. It is recommended for softer and ductile metals and cast iron having hard surface. In down milling, the cutter tooth starts with a chip of maximum thickness and ends with a thin chip of zero thickness. Thus a scraping action is produced as the thinned edge of the chip is removed, resulting in a good surface finish. Since cutter tends to push the work down against the table, it is suited for cutting thin work pieces held in a vice or on a magnetic chuck. Further due to cut starting with of maximum thickness, the rubbing action is less and wear on cutting tool is also less

## QUESTION 2

- (a) How one can feel confident that correct cutting angles have been used on a milling cutter?
- (b) What are the usual values of various angles for milling alloy steel, aluminium?

## ANSWER 2

(b) If correct cutting angles are ground on the tool, then curled chips will be produced.

Otherwise the chips will be in the nature of needles, broken up or even powdered.

For milling any alloy steel, rake angle of  $5^\circ$  and clearance angle of  $2-3^\circ$  is provided. For aluminium, these angles are  $20-25^\circ$  and  $8^\circ$  respectively. As a general rule, harder the material, the smaller should be the cutting angles. The greater the helix angle, it should be the clearance angle which is also influenced by

## WEEK 13

### 6.5 SURFACE GRINDER

### 6.6 INTRODUCTION.

Surface grinders are used to produce smooth, accurate, flat surfaces and to finish-grind hardened steel parts .Fig 41(a) shows a typical production job of a number of gauge blocks being ground while held by a permanent magnet chuck.

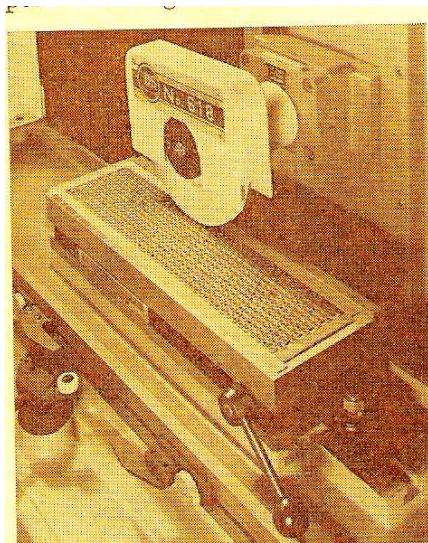


Fig.41(a) Showing a permanent magnet chuck.

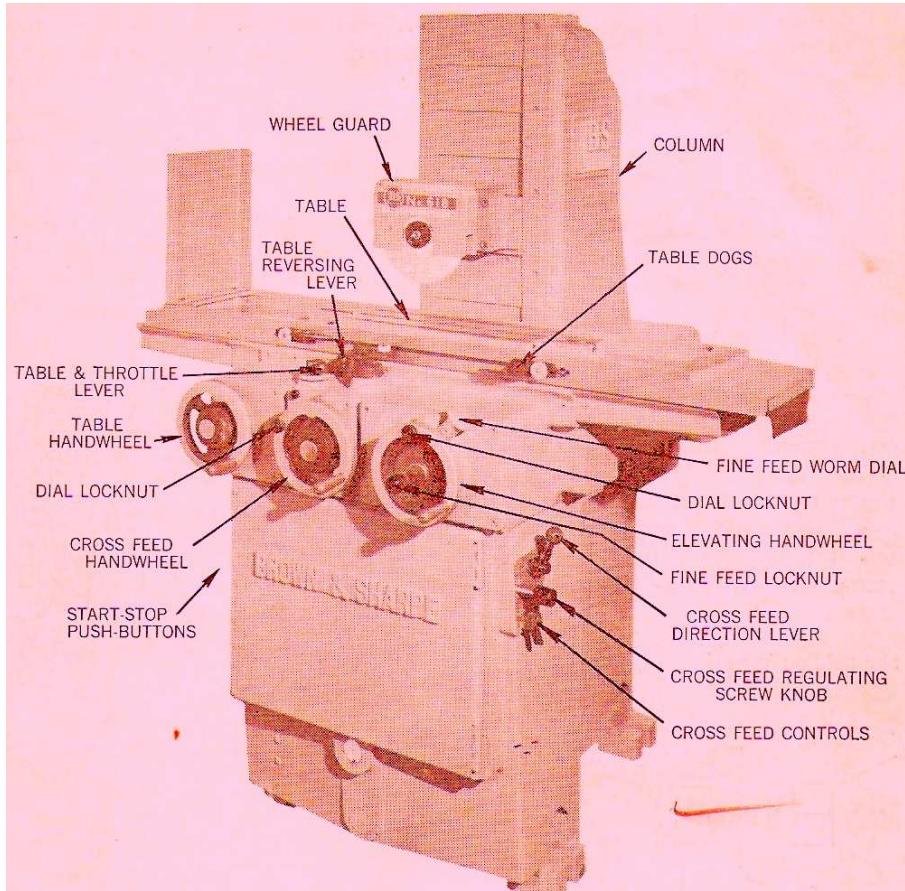


Fig 41(b) Surface Grinder.

The fig. above shows a surface grinder ,an average -size machine in general use .The machine shown has hand operated longitudinal and cross feeds . Some grinding machines have hydraulic power feeds which provide a wide range of surface speeds ,although they are controlled similarly to mechanical power feed machines .The principal part of a surface machine are as follows :

#### 6.7 MOUNTING OF GRINDING WHEEL.

The manufacturer and construction of grinding wheels has been discussed under abrasives .The size of the grinding wheel on the machine and similar machine is 177.8mm diameter x 12.7mm wide x31.7mm hole .The wheel guard must be removed to install a grinding wheel

Wheels on some machines are mounted directly on the spindle and are held between a flange on the spindle and a clamping nut. A grinding wheel mounted on a wheel sleeve which fits on the tapered spindle of the grinder. Other wise, the wheel is held as on a spindle without using a sleeve. The advantage of using a wheel sleeve is in changing from one type of wheel to another; the wheel and sleeve can be changed as a unit and will remain concentric, requiring only a minimum of truing. This saves the operator's time and extends the life of a grinding wheel.

To remove a wheel sleeve remove the nut fastening the sleeve to the spindle, screw a wheel puller into the wheel sleeve, and tighten the set screw which will loosen the wheel, .

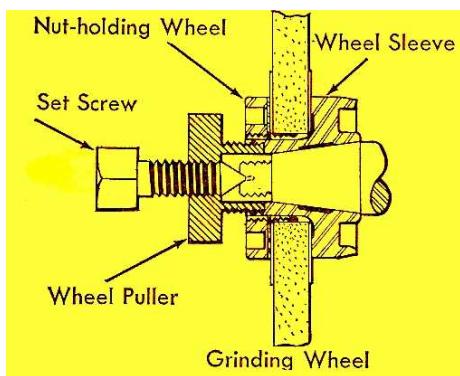


Fig 42 (a) Wheel puller being used to remove a sleeve.

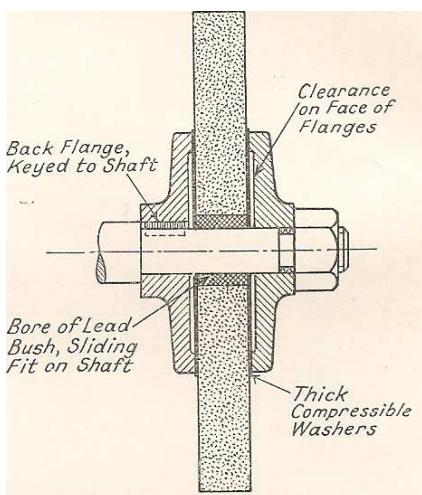


Fig.42(b) Method of mounting grinding wheel.

## 6.8 Exercises

### QUESTION 1

What are the various factors to be considered in selection of grinding wheel? Discuss each in detail.

Answer 1

The various factors are;

- (i) Material to be ground and its hardness,
- (ii) Stock to be ground and finish desired,
- (iii) Whether wet or dry operation,
- (iv) Wheel speed,
- (v) Area of grinding contact,
- (vi) Severity of grinding operation.

#### (i) MATERIAL.

The guideline for different materials is discussed below;

- Steel, alloy steel and HSS tool—use  $\text{Al}_2\text{O}_3$  abrasives.
- Cast iron, brass, aluminium—use Sic abrasives
- Carbide tools—use Sic or diamond wheels.
- Hard materials – use fine grit and softer grade. Fine grit will allow more particles to cut at a time and softer grade would keep wheel sharp by quick breaking of particles.
- Soft material—uses coarser grit and softer grade.

#### (ii) STOCK REMOVAL AND FINISH:

- (a) Rapid stock removal, ordinary finish—uses coarse grits.
- (A) High finish and low stock removal—use fine grits.

#### (iii) WET AND DRY OPERATION.

Wet grinding (using soluble oils, sulphurised oil and synthetic compounds) provides cooling and cleaning of work and wheel, and wheel life is also longer.

(iv) Wheel speed: Maximum speed is limited by the strength of the bond. Slower speed makes the wheel to act hard.

#### (v) Area of contact:

- (a) Larger area of contact (internal grinding)—use coarser softer grades.
- (b) Small contact—uses finer and harder wheels.

#### (vi) Severities of grinding operation:

- (f) Severe condition—uses tough abrasives.
- (g) Fine finishing cut—uses friable abrasives.

### QUESTION 2

What type of imperfections left in machining operation can be corrected by honing and what conditions can not be corrected by honing?

## ANSWER2

Honing operations can correct conditions like:

- (i) Taper,
- (ii) Out-of round,
- (iii) Barrel,
- (iv) Bell mouth,
- (v) Waviness,
- (vi) Boring marks,
- (vii) Undersize,
- (viii) Reamer chatter,
- (ix) Rainbow or banana shape,
- (x) Little misalignment in two holes in same plane.

Honing can not change the location of hole or correct sloped condition of a hole.

## 6.9 TRUING AND DRESSING A GRINDING WHEEL.

It is essential that a grinding wheel run perfectly true and without vibration .Grinding wheels on surface grinders and other precision grinders should be true with a diamond dresser When truing a wheel touch the rotating wheel against the diamond dresser and lower the wheel head about 0.127mm for a roughing cut ,using about a 0.635mm cross feed ; finish -dress the wheel with a 0.0254mm cut using a 0.254mm cross feed .The diamond should be held at an angle of approximately 10 degrees and should be turned every few days when in contact use so that it will wear evenly and keep sharp .

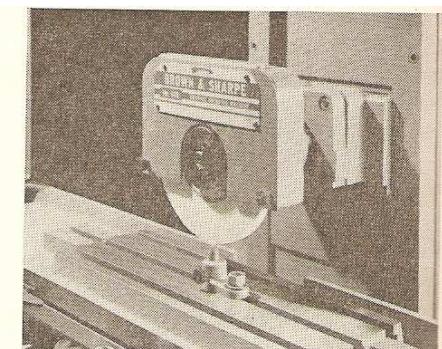


Fig 43 Truing a grinding wheel using a diamond dresser held in a wheel truing fixture

## 6.10 SAFETY PRECAUTIONS WHEN OPERATING A SURFACE GRINDER.

Grinding wheels are brittle and easily broken ; therefore they must be used very carefully .A grinding wheel should be examined for cracks before it is installed on a grinder .If a grinding wheel is hung on a pencil held in the hand and the side of the wheel is struck with a pencil ,a good wheel will have a clear ring while a cracked wheel will resound with a dull thud .

The wheel should be firmly mounted between wheel flanges and the guards installed .Safety glasses must be worn when operating a grinder . When starting a grinder do not stand directly in front of the wheel .The work must be rigidly fastened to the machine .When using a magnetic chuck test the work to see that it is held firmly before starting the machine .

Small-area work higher than 1 inch should be gripped in a vise. When moving the table take care not to strike the work against the wheel. Hands should not be placed near a rotating grinding wheel. Finally, stop the grinding wheel before removing the work from the machine.

**6.11 GRINDING A FLAT SURFACE** Fig 44(a) shows a flat surface being ground on a surface grinder. The work is held by a magnetic chuck. Magnetic chucks may be operated by direct current where conductor wires are used to power the chuck, or by permanent magnets. Permanent magnet-type chucks type are used on smaller equipment. To install the work on a permanent magnetic chuck use the handle to the left, thus disconnecting the magnets. Clean the top of the chuck and the bottom of the work to remove any dirt. Place the work on the chuck and move the handle to the right, thus connecting the magnets within the chuck holding the work.

Move the work under the grinding wheel by moving the table-and cross-feed handles. Slowly lower the wheel head by turning the vertical adjusting hand-wheel until the wheel just touches the work. Move the work toward the operator and clear of the wheel. For roughing cuts lower the wheel head 0.0508mm On a hand-feed machine move the cross-feed handle with the right hand until it just touches the work and move the table-feed handle the length of the work plus 12.7mm at each end of the stroke. The cross feed may be moved about 0.794 mm at each end of the cut. On finishing cuts the wheel head should be lowered about 0.0254mm and a 0.254mm cross feed taken.

On power-feed machines the table reverse dogs should be set longer than the work. The power table feed is engaged by turning the table throttle lever a quarter-turn to the right. To stop the table move the table throttle lever to the off position.

The power cross feed is adjustable for the amount of feed by adjusting the stops for setting the amount of power cross feed, as shown in Fig .44(b). A different amount of cross

feed may be made at each end of the stroke .To start the power cross- feed drive, turn the knob for engaging the power cross -feed drive clockwise about two turns. The direction of the cross feed may be selected by moving the cross-feed selector lever – The controls of grinders vary with each manufacturer.

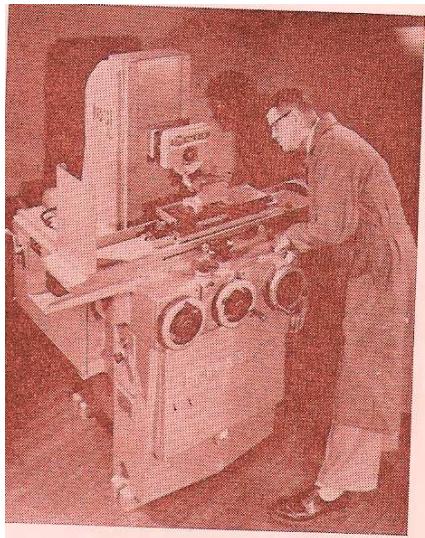


Fig.44(a) Grinding a flat surface on a surface grinder.

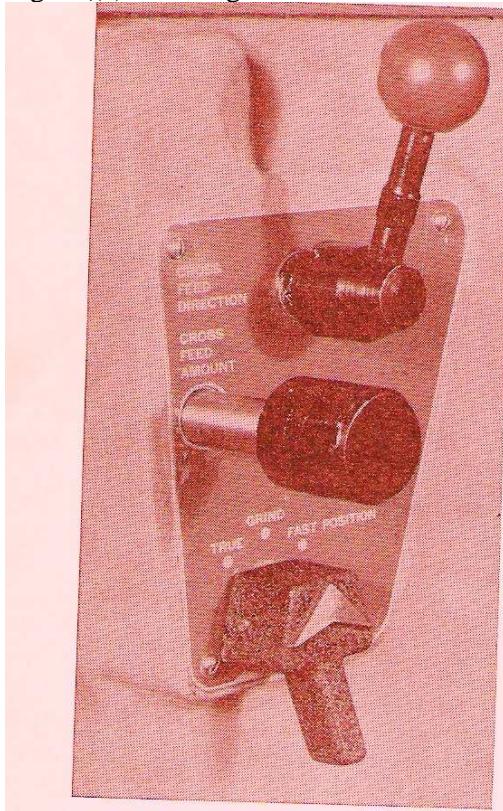


Fig.44 (b) cross feed controls

## 6.12 Exercises

### QUESTION 1

How it is that honing can correct irregularities but grinding can not?

#### ANSWER 1

Honing operation can correct irregularities because it uses rectangular grinding stones instead of circular grinding wheel, *e.i.* it uses a large contact area at slow speed. Further honing operation is free from problems like spindle deflection, difficulties in precise holding of work, and vibration in hardness of material.

#### QUESTION 2

Select a proper grinding wheel for cylindrical grinding of cast iron work piece. Finishing is desired.

#### ANSWER 2

The selection of proper grinding wheel involves suitable decision following five items:

Abrasive type. Since the material to be ground is cast iron (low tensile strength brittle material) use silicon carbide(C).

Grit size. Finish calls for fine grit size. Let us select intermediate value in the fine range of grit (70-180) *i.e.* 120.

Grade. Since area of contact in cylindrical grinding is less, it is preferable to use harder grade However for finish grinding softer grade is preferred. Therefore it is good to select medium grade, M.

Structure. For cylindrical grinding as while as finish grinding, a close order structure is more suited. So we can select 4.

Bond. For finish grinding, less heat generation and not very large wheel, we may select most popular vitrified (V) bond.

Thus wheel selected is

Code no.	Abrasive type	Grit size	Grade	Structure	Bond	Mfr record
Manufacturer's code to indicate exact type of abrasive	C	120	M	4	V	(Optional) And.C120 M4V.

### QUESTIONS AND ANSWERS ON GRINDING MACHINES.

1. How does the area of contact affect grinding wheel selection?
2. What is the difference between wheel dressing and wheel truing?
3. Describe vitrified, shellac, and resinous bonds.

## WEEK 15

### 6.13 PRECAUTION TO BE TAKEN BEFORE MOUNTING A GRINDING WHEEL

In the interest of satisfactory operation and safety, it is important that grinding wheels are mounted correctly on the machine and before mounting they should be examined for any defects:

1. The wheel should be first examined for any flaw or crack which, under stresses set up due to high speed of rotation, might lead to fracture of the wheel, thus causing serious accident.
2. Wheel Balance: Out-of-balance and out-of-round wheels results in vibrations and poor surface finish, faster wheel breakdown and sometimes even cause injury to the operator. To avoid the wheel is mounted at the centre of perfectly straight and round spindle; the assembly is then rested on level knife-edge ways. The test should be carried out after turning up the wheel face and mounting it on its spindle. If there is any unbalance, wheel will come to rest with its heavy side underneath. Error is rectified by cutting some of the lead from heavy side of bush. Other way is to adjust the position of the slotted weights provided in the rim of the flange.

3. The sides of the wheel and the flanges which clamp the wheel should be flat and bear evenly all the around.
4. The lead bushing should be an easy fit and no force be used.
5. The back fix flange should be keyed, shrunk or otherwise fixed to the spindle in order to transmit the power from the spindle to the wheel.
6. The nut should be tightened only just enough to hold the wheel. The undue tightness is unnecessary and not desirable.
7. The wheel speed chosen should be proper.
8. When wheel is mounted for the first time it should be made to run idle for some time.
9. Safety guard should always be used, so that in case of accident operator is not injured.
10. If possible, some proper lubricant should be used in grinding operation and while grinding cast iron job, dust collector should also be operated.

#### 6.14 CHARACTERISTIC TERMS USED IN GRINDING

*Grindability.* It is regarded as the property by which the metal can be removed easily, i.e. the removal of metal should be done as rapidly as possible consistent with less wheel wear, free of grinding cracks burns and securing good surface finish.

*SENSITIVITY.* It indicates the degree of susceptibility to surface cracking.

*FINISHABILITY.* It is regarded as the property by which a good surface finish can be obtained easily.

*GRINDING RATIO.* It is the quick method of evaluating the grinding wheel performance. Grinding operation remove metal very delicately, leaving a finished surface of superior dimensional accuracy and good surface texture. If it is carried out properly, there will be very less metallurgical damage due to the in pressure and temperature of the material being ground. The term grinding ratio is defined as the ratio between the volume of metal removed from the work piece to the wear of grinding wheel.

#### 6.15 GRINDING FAULTS

Two common faults due to incorrect choice of wheel or incorrect grinding condition are (i) loading and (ii) glazing.

#### LOADING

Loading occurs when spaces between the abrasives grains become clogged with particles of the metal being ground. As such grains do not project sufficiently to promote efficient cutting. It occurs due to grinding of soft metals with open structured wheel.

#### GLAZING.

Glazing is easily recognised by shiny appearance on the face of the wheel. It occurs due to abrasive grains becoming dull and not breaking away from the bond. This happens when the wheels are too hard for the material being ground. Glazing can be reduced by increasing wheel or work speed.

#### 6.16 THERMAL EFFECTS OF GRINDING

During the process of grinding a lot of heat is generated between the cutting tool and work piece. A major portion of the heat is dissipated in the work piece and the remaining is retained by the grinding wheel. Two thermal effects of grinding are:

1. *Effect on grinding wheel.* Due to the generation of heat, cracks are developed which are called grinding cracks. These cracks are perpendicular to the grinding marks.
  2. *Effects on work piece (a) Discoloration.* Oxidation of surfaces takes place at  $200^{\circ}$  producing oxide. These oxides have different colours unlike the parent metal. In other words, we can say that this leads to discolouration of work piece. The generation of heat is due to the dull grains which will lead to burning of surface.
- (b). Mechanical damage. Due to the sharpness of the grains, scratches are formed on the metallic surface.
- (c). Metallurgical damage. Due to generation of heat the brittle cracks are formed on the surface.
- (d). Chemical damage. Due to generation of heat chemical oxides are formed.

#### 6.17 TROUBLE SHOOTING IN GRINDING.

Various faults that could be encountered during grinding and various solutions to overcome them are given below:

- (i). Fast wheel wear. This can be taken care of by (a) using harder wheel, (b) increasing wheel speed, (c) reducing rate of traverse and work speed, and slightly decreasing the depth of cut.
- (ii) Wheel glazing. This occurs due to incorrect dressing, wrong wheel selection and using slow traverse and high work speed. It can be taken care of by keeping the wheel sharp, using softer wheel or coarser grit, reducing wheel speed and fast traverse, using greater depth of in-feed and increasing depth of cut.
- (iii). Chatter marks. This can be taken care of by (a) properly balancing the wheel, (b) using proper dressing tool, (c) using softer grade or coarser grit, (d) reducing machine vibrations by

checking bearings and foundations, and adjusting spindle bearings, (e) tightening pulley, (f) using suitable supports or clamps for large jobs.

(iv) Coarse finish. This could be due to using either too coarse wheel or too soft wheel.

#### 6.18 Exercises

(v) Wheel loading. This can be taken of by using softer or porous structure wheel; using sharper dresser, using a copious quantity of clean coolant. Irregular marks of different lengths and widths could occur due to dirty coolant. Deep irregular marks occur due to loose wheel flanges.

(vi) Overheating of work piece. This occurs due to wrong selection of wheel. To overcome it, softer wheel should be used and sufficient coolant used.

#### 6.18 Exercises

1. How does the area of contact affect grinding wheel selection?
  - a. What is the difference between wheel dressing and wheel truing?
2. Describe vitrified, shellac, and resinous bonds.