MANUFACTURING PROCESSES

(M–SCHEME)

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Manufacturing Processes

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Preface

This book on **MANUFACTURING PROCESSES** has been written to cover the latest revised syllabus for the Polytechnic college students of III Semester Mechanical, Automobile, and Production Engineering.

All the topics in this book are written in simple and constructive manner with suitable examples and neat sketches. I assure that the review questions added at the end of each chapter will be more helpful to the students while preparing for the examination.

I acknowledge my gratitude with thanks to **M/s. KAL PATHIPPAGAM** for their kind encouragement to bring out this book in time. The author would be very glad and thankful to receive any comments and constructive suggestions for the improvement of this book.

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All the best...

32032 - MANUFACTURING PROCESSES
DETAILED SYLLABUS

Unit - I : Foundry Technology

Patterns: Definition – types of pattern – solid piece – split piece - loose piece – match plate - sweep - skeleton – segmental – shell – pattern materials – pattern allowances.

Moulding: Moulding sand – constituents – types – properties of moulding sand – moulding sand preparation – moulding tools - moulding boxes – types of moulds – green sand mould – dry sand mould – loam mould – methods of moulding – moulding machines – jolting – squeezing – sand slinger construction and working principle.

Cores: Essential qualities of core – materials – core sand preparation – core binders – core boxes - CO_2 process core making – types of core.

Metallurgy :– Introduction - Iron-carbon diagram.

Melting furnaces: Blast furnace – Cupola furnace – crucible furnace – types – pit furnace – coke fired – oil fired – electric furnace – types – direct arc – indirect arc – induction furnace – working principles.

Casting: Shell mould casting – investment casting – pressure die casting – hot chamber die casting – cold chamber die casting – gravity die casting – centrifugal casting – continuous casting - defects in casting – causes and remedies.

Unit - II : Welding Technology

Arc Welding: Definition – arc welding equipment – electrode types – filler and flux materials - arc welding methods – metal arc - Metal Inert gas (MIG) - Tungsten inert gas (TIG) - Submerged arc - Electro slag welding – resistance welding – spot welding – butt welding – seam welding – Plasma arc welding – Thermit welding – Electron beam welding – Laser beam welding – friction welding – ultrasonic welding – Induction welding - working principle – applications – advantages and disadvantages.

Gas welding: Oxy-acetylene welding – advantages - limitations - gas welding equipment - Three types of flames – welding techniques – filler rods. – Flame cutting – soldering – brazing – difference between soldering and brazing. Types of welded joints – merits and demerits of welded joints – inspection and testing of welded joints – destructive and nondestructive types of tests – magnetic particle test – radiographic and ultrasonic test - defects in welding – causes and remedies.

Unit - III : Forming Technology

Forging: Hot working, cold working – advantages of hot working and cold working– hot working operations – rolling, forging, smith forging, drop forging, upset forging, press forging – roll forging.

Press Working: Types of presses - mechanical and hydraulic presses - press tools and accessories - press working operations - bending operations - angle bending -

channel bending – curling – drawing - shearing operations - blanking, piercing, trimming – notching – lancing.

Powder Metallurgy: Methods of manufacturing metal powders – atomization, reduction and electrolysis deposition – compacting – sintering – sizing – infiltration – mechanical properties of parts made by powder metallurgy – design rules for the power metallurgy process.

Unit - IV : Theory of metal cutting: Introduction – orthogonal cutting – oblique cutting - single point cutting tool – nomenclature – types of chips – chip breakers – cutting tool materials – properties – tool wears – factors affecting tool life – cutting fluids – functions – properties of cutting fluid.

Centre Lathe: Introduction - specifications – simple sketch – principal parts – head stock – back geared type – all geared type – feed mechanism - tumbler gear mechanism – quick change gear box – apron mechanism – work holding device – three jaw chuck – four jaw chuck – centres - faceplate – mandrel – steadyrest – follower rest – machining operations done on lathe - straight turning – step turning - taper turning methods: form tool – tailstock set over method – compound rest method – taper turning attachment – knurling - Thread cutting – Facing – Boring – chamfering –grooving – parting-off – eccentric turning - cutting speed – feed - depth of cut - metal removal rate.

Semi-Automatic Lathes: Types of semi-automatic lathes – capstan and turret lathes – Geneva indexing mechanism – bar feeding mechanism - difference between turret and capstan – work holding devices – tool holders.

Unit - V : Drilling and Metrology

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Metrology: Definition – need of inspection – precision – accuracy – sensitivity - magnification – repeatability – calibration – comparator – Advantages – requirements – mechanical comparator – optical comparator – electrical comparator – pneumatic comparator – Principles – advantages and disadvantages.

Measuring instruments: Construction and principles only - Steel rule – Callipers: outside calliper – inside calliper – jenny calliper – Combination set – Feeler gauge – Pitch screw gauge – Vernier calliper – Digital calliper – Vernier height gauge – Micrometer – Inside micrometer – Thread micrometer – Slip gauges – requirement – Indian standard – care and use - Sine bar – types – uses – limitations – Working principle of clinometers, autocollimator, angle dekkor.

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Unit – I

FOUNDRY TECHNOLOGY

1.1 Introduction

Various manufacturing processes are available for producing a component with required shape. Casting is one of the processes used for making component of complicated shapes in large numbers. The parts obtained by pouring the molten metal into the mould cavity and solidification are known as castings. The processes of making required shape in moulding sand with the help of a pattern is known as moulding. The cavity produced by moulding is known as mould or mould cavity. The place where moulding, melting and casting are done is known as foundry.

1.2 Pattern - Definition

Pattern is the model of casting. It is made of wood, metal or plastics. Mould is produced in moulding sand by using pattern.

1.2.1 Types of patterns

The following types of pattern are generally used in foundry.

1) Solid piece pattern	2) Split piece pattern
3) Loose pirce pattern	4) Match plate pattern
5) Sweep pattern	6) Skeleton pattern
7) Segmental pattern	8) Shell pattern

1) Solid piece or Single piece pattern

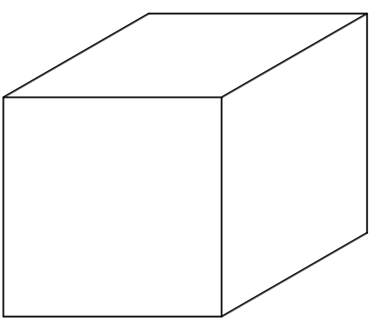


Fig.1.1 Solid piece pattern

The pattern made of single piece without joints is known as solid pattern. This pattern is used for making small castings with simple shape. Solid pattern can be easily removed from the moulding sand.

2) Split piece pattern

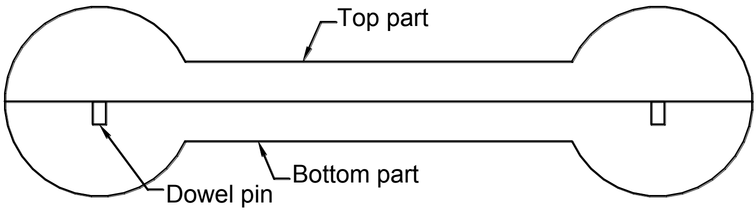


Fig.1.2 Split piece pattern

Some patterns cannot be removed from the mould, if they are made in single piece. So split patterns are used in that time. Split pattern is usually made of two parts. One part will make the lower half of the mould and the other part will make the upper half of the mould. These two parts are fitted correctly by dowel pins. Split pattern made in three or four parts is used for producing symmetrical castings such as cylinders, spindles, pipes, shafts, etc.

3) Loose piece pattern

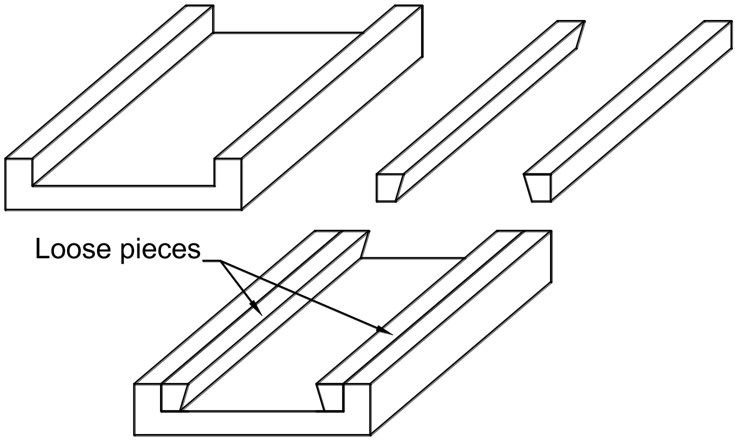


Fig.1.3 Loose piece pattern

Some patterns cannot be removed from the mould as single piece. So loose piece patterns are used with the solid pattern for the easy removal. After moulding, the solid pattern is removed first. Then the loose pieces are removed without damaging the mould. This pattern is used for producing complicated castings of large size.

4) Match plate pattern

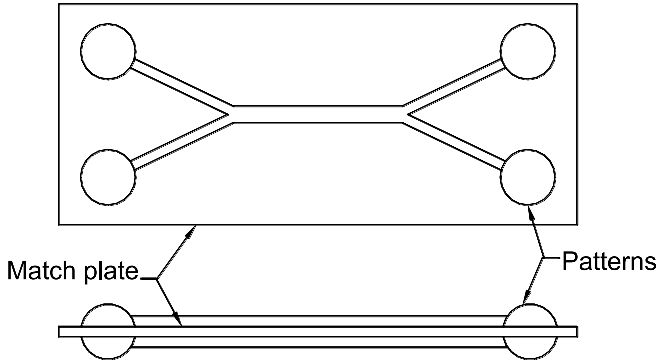


Fig.1.4 Match plate pattern

This pattern has a match plate made of aluminium. Split metal patterns are fitted on both sides of the match plate. One half of the pattern is fitted on one side of the match plate. The other half is fitted directly opposite on the other side of the match plate. Number of patterns can be fitted on the match plate in the same way. Patterns for runners and gates are fitted at the bottom of the match plate.

Match plate patterns are used in machine moulding. These patterns are suitable for producing small and accurate castings in large numbers.

5) Sweep pattern

It has a sweep board which rotates about a central axis. The sweep board is made to a shape similar to half the size and shape of the required casting. This is called sweep pattern. The pattern is placed in a moulding box. The box is filled with moulding sand and ramming is done.

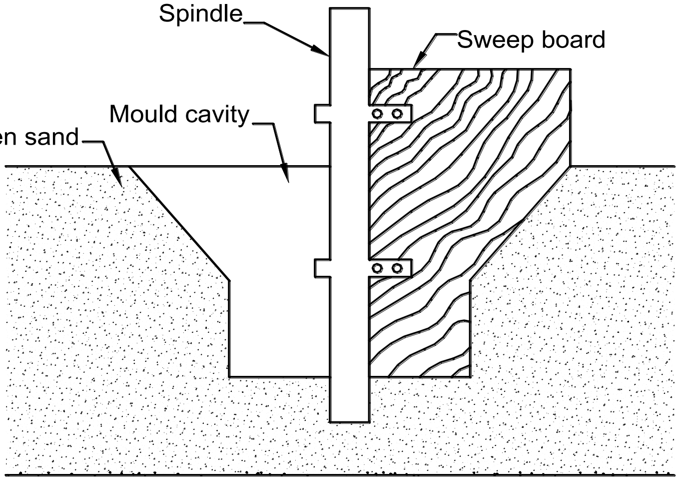


Fig.1.5 Sweep pattern

The required mould cavity is made by removing the sand when the pattern is rotated about its axis. Large size solid patterns are avoided by using sweep pattern. Sweep pattern is used for producing large size symmetrical and circular castings.

6) Skeleton pattern

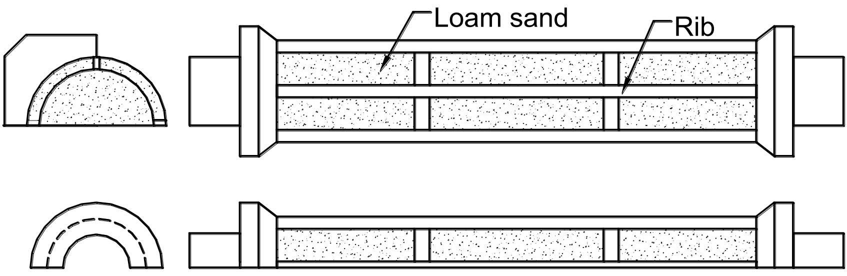


Fig.1.6 Skeleton pattern

More amount of wood is required for making patterns to produce large size castings. So skeleton pattern is used instead of a solid pattern. First, frame work of required shape is constructed by using ribs and wooden frames. This frame work is filled with loam sand. The excess sand is removed by using a strickle board. Now the pattern of required shape is obtained. Skeleton pattern is used for producing water pipes, pipe bends, valve bodies, etc.

7) Segmental pattern

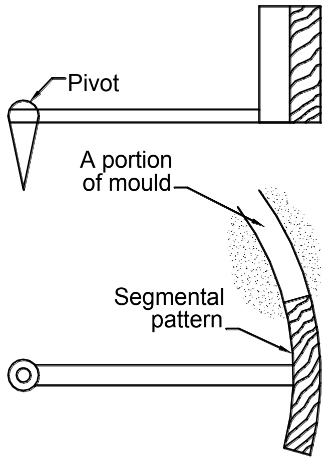


Fig.1.7 Segmental pattern

This is also known as part pattern. This pattern is used for making circular moulds. This pattern is a segment of a circular pattern. First, a vertical spindle is fixed at the centre of the mould box. The pattern is fitted to the spindle with the help of a pivot. Moulding sand is filled around the outer surface and inner surface of the pattern. After ramming, the pattern is removed to form a segment of mould. Similarly, a number of segments are formed to make a complete mould. Segmental pattern is used for producing circular castings such as rings, wheel rims, etc.

8) Shell pattern

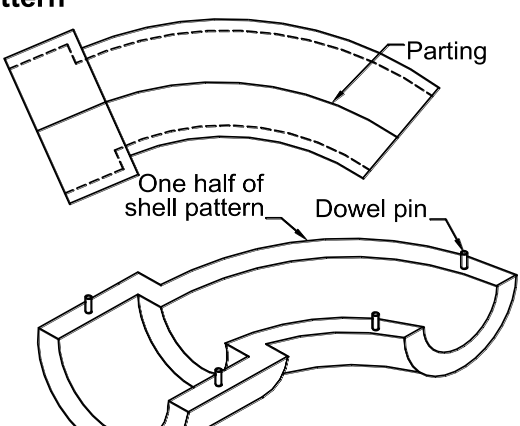


Fig.1.8 Shell pattern

Shell pattern is a thin hollow pattern. These are metal patterns made in two halves and joined correctly by dowel pins. The outside shape of the pattern is used for making the mould and the inside surface is used for making core. Shell patterns are used for producing large pipe fittings, short bends, etc.

1.2.2 Pattern Materials

The following pattern materials are used for making patterns.

1) Wood 2) Metal 3) Plaster 4) Plastic 5) Wax

1) Wood

Wood is widely used for making pattern. Generally pattern is made from teak wood, mahogany, pine and rose wood. The surface finish and life can be increased by applying metal coating on the wood pattern.

Advantages

1) Wood is cheap and easily available.
2) It is easy to cut for making required shape.
3) It can be easily handled as it is light weight.

Disadvantages

1) Wood is affected by moisture. So change in shape may occur.
2) It is easily worn out and hence it cannot be used for mass production.
3) It is not suitable for machine moulding.

2) Metal

Metal pattern is used for producing large number of castings. Metal pattern is made by using a master pattern made of wood. Cast iron, brass, aluminium and white metal are commonly used for pattern making. Aluminium is the best metal for pattern making. Brass is suitable for small size patterns. White metal can be used for making patterns of complicated shapes.

Advantages

1) Metal pattern is strong. The life and dimensional accuracy of the metal pattern is more.
2) Change in shape does not occur due to moisture.

3) It can be used in machine moulding.
4) It is suitable for mass production.
5) Metal surface can be finished smoothly and hence very good impression of the pattern can be obtained in the mould.

Disadvantages

1) Metal patterns are heavier and costlier.
2) Machining of metal pattern is difficult.
3) Master pattern is required.
4) It is difficult to repair.

3) Plaster

The gypsum cement is known as plaster. Plaster pattern is made by pouring the mixture of plaster and water into the mould prepared by using a master pattern. It is used for making small patterns and core boxes.

Advantages

1) It is easy to make complicated shapes.
2) It has high compressive strength.
3) It is cheaper.
4) It can be easily worked.

Disadvantages

1) Plaster cannot be used for large size patterns.

4) Plastics

Plastic patterns are produced from a master pattern made of wood. Both thermo setting plastics and thermo plastics are used. Pattern made of thermo setting plastic is used for producing large number of castings. Pattern made of thermo plastic is used for producing less number of castings.

Advantages

1) It has light weight but strong.
2) The cost is less.
3) It is not affected by moisture.
4) It has good wear resistance.
5) The dimensional accuracy is more.

5) Wax

Wax patterns are produced from paraffin wax, shellac wax and bees wax. The liquefied wax is injected into a split die. Then the die is cooled and the wax pattern is taken out.

Advantages

1) Patterns with accurate shape can be made.
2) The moulds prepared by wax pattern has smooth surface.
3) It is suitable for investing casting.

1.2.3 Factors for selecting pattern materials

Selection of pattern material depends upon the following factors.

1) Number of castings to be produced.
2) Quality of the casting.
3) Size and shape of the casting.
4) The method of moulding and casting.
5) Required surface finishing of casting.
6) Required accuracy of casting.

1.2.4 Pattern allowances

Patterns are not made to correct size of the required casting. They are made slightly larger than the required casting. This extra dimension given to the pattern is called allowance. Pattern allowances are given to compensate the metal shrinkage, to avoid metal distortion, to withdraw the pattern easily from the mould.

The following pattern allowances are given.

1) Shrinkage allowance
2) Machining allowance
3) Draft allowance
4) Distortion allowance
5) Rapping allowance

1) Shrinkage allowance or contraction allowance

The molten metal in the mould will cool and become solid. The metal will shrink and reduce in size during cooling. The pattern is made larger than the required size of the casting to compensate this metal shrinkage. This is called shrinkage allowance. The shrinkage allowances given for various metals are:

Cast iron – 10mm / metre, Steel –15 mm / metre
Brass - 14mm / metre, Aluminium –18 mm / metre

2) Machining or finishing allowance

Machining is done on the castings to remove excess metal and to get smooth surface finish. The pattern is made larger than the required size of the casting for this purpose. This extra size given to the pattern is called machining allowance. A machining allowance of 3 mm is given for ferrous metals like iron and steel. A machining allowance of 1.5 mm is given for non-ferrous metals like aluminium and brass.

3) Draft allowance

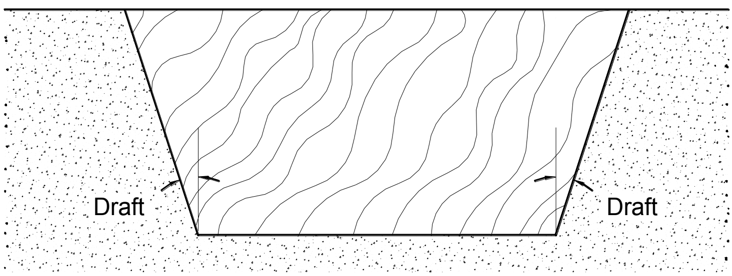


Fig.1.9 Draft allowance

The edges of the mould may be damaged when the pattern is removed from the mould. This can be avoided by making the vertical surfaces of the pattern with slight taper. This taper is called draft allowance. It may be expressed in degrees or in mm. Generally, a draft allowance of 3 mm / metre is given.

4) Distortion or camber allowance

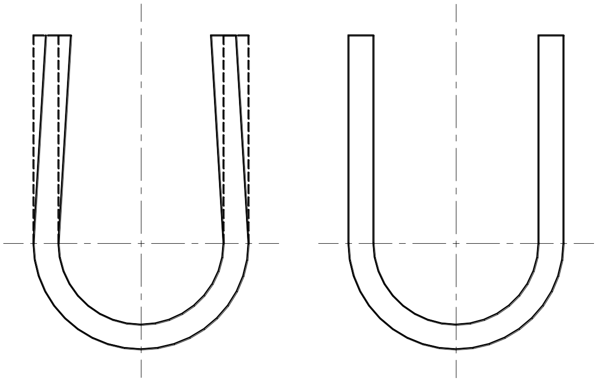


Fig.1.10 Distortion allowance

The shape of some castings may be distorted during cooling. It depends upon the size, shape and thickness of the casting. To avoid this distortions, the pattern is made with slight bent in the opposite direction. For example, a 'U' shaped casting may distort and the ends become diverged. To avoid this, the ends are slightly bent towards the opposite direction. Due to this, the ends become correct shape after cooling.

5) Rapping or shake allowance

The pattern is shaked from side to side before removing it from the mould. Due to this, the mould cavity may become larger. So the pattern is made slightly smaller. This negative allowance given to the pattern is called rapping allowance.

1.3 Moulding

The process of making mould is called moulding. It includes filling of moulding sand around the pattern, ramming, removing the pattern, making runner, riser, gate and vent holes.

1.4 Moulding sand

Moulding sand is an important material in foundry. It can withstand the high temperature of molten metal. It does not react with molten metal. It permits the gases and air to escape from the mould when the molten metal is poured. Due to these properties of moulding sand, it is used for casting.

1.4.1 Constituents of moulding

Moulding sand has the following ingredients.

1) Sand 2) Binder 3) Additive

1) Sand

Sand contains silica, clay and moisture. Sand has 80 to 90% silica which gives refractoriness. Sand contains 5 to 20% clay which gives binding strength. 2 to 3% of water is added with the sand to give moisture.

2) Binder

Binder is added with the moulding sand to obtain cohesiveness. Binder binds the sand particles together and give strength to the mould. The following three types of binders are used.

a) ***Clay type binders :*** Bentonite, kalvanite are clay type binders.

b) ***Organic binders :*** Wood, resin, linseed oil, dextrin and molasses are organic binders.

c) ***Inorganic binders :*** Portland cement and sodium silicate are inorganic binders.

3) Additives

Additives are added with the moulding sand to improve the properties like strength, permeability and refractoriness. The following three types of additives are used.

a) ***Reducing agents :*** This type of additives prevent the formation of oxides. They fill up the fine pores in the mould surface. This improves the surface finish of the casting. Coal dust, fuel oil and sea coal are some reducing agents.

b) ***Fibrous material :*** This type of additives prevent the formation of dry surface on the mould. It improves the collapsibility of mould. Wood flour, straw, cow dung, asbestos and saw dust are some fibrous materials.

c) ***Special additives :*** Some special additives are added to improve the dry strength and collapsibility of mould. These additives also prevent quick drying of the mould. Dextrin and molasses are some special additives.

1.4.2 Classification of moulding sand

Moulding sand are classified as follows:

1) Natural sand 2) Synthetic sand 3) Special sand

1) Natural sand or green sand

Natural sand is available at river beds. It contains 80 to 90% silica, 5 to 10% alumina or clay and small amount of lime and magnesia.

Application

Natural sand is used to make castings in ferrous and non-ferrous metals.

Advantages

1) It is easily available.
2) It is cheap.
3) It has grains of various shapes and sizes.

Disadvantages

1) It may be fused with molten metal.
2) It has high expansion rate.

2) Synthetic sand

Synthetic sand is prepared to obtain required properties by adding some ingredients with the natural sand. Bentonite, water, iron oxide, calcium and magnesium are mixed with the natural sand.

Application

Synthetic sand is used in machine moulding and high pressure moulding.

Advantages

1) It is easy to mould.
2) It has high refractoriness.
3) The properties can be controlled easily.
4) Less amount of binder is sufficient.

3) Special sand

Special sands are prepared to obtain specific properties such as refractoriness, high heat conductivity and low expansion. Good quality castings with fine surface finish can be produced by using special sands. The most widely used special sands are given below.

a) ***Olivine sand :*** It is in green colour. It has medium refractoriness. It is used for producing non-ferrous castings of complicated shapes.

b) ***Zircon sand :*** It is in cream colour. It has high heat conductivity, good refractoriness and high density. It is used for making cores required for brass and bronze castings.

c) ***Chromite sand :*** It has high heat conductivity and good refractoriness. It is used in chilled castings. It is also used as facing sand.

1.4.3 Types of moulding sand

The following are the different types of moulding sand.

1) Green sand 2) Dry sand 3) Loam sand
4) Facing sand 5) Parting sand 6) Core sand

1) Green sand

Green sand is in moist condition. It is a mixture of silica sand with 18 to 30% clay and 6 to 8% water. Green sand mould is used for making small and medium size castings.

2) Dry sand

Moulding sand which is dried or heated after making the mould is called dry sand. Casting defects such as blow holes will not occur, as dry sand does not contain moisture. Dry sand mould is used for producing large castings.

3) Loam sand

Loam sand has up to 50% clay. Loam sand becomes hard when it is dried. Large castings are made by using loam sand mould.

4) Facing sand

Facing sand contains fine silica sand, clay and coal dust. Facing sand is filled around the mould cavity about 20 to 30 mm thick. As it comes in direct contact with molten metal, it should have high strength and refractoriness.

5) Parting sand

Parting sand does not contain clay. It prevents the sticking of green sand to the pattern. It separates the sand in cope and drag boxes without sticking each other.

6) Core sand

Core sand is obtained by mixing silica sand with core oil. It is used for making core.

1.4.4 Properties of moulding sand

A good moulding sand should have the following properties.

1) Porosity 2) Plasticity 3) Adhesiveness
4) Cohesiveness 5) Refractoriness 6) Collapsibility

1) Porosity or permeability

It is the property of moulding sand by which the sand permits steam and gases to escape through it. If the steam and gases are not removed, casting defects such as blow holes may occur. Porosity depends upon the shape and size of the mould sand grains.

2) Plasticity or flowability

It is the property by which the moulding sand gets the shape of the pattern and retains the shape. Due to this property, the correct shape is obtained in the mould. This property depends upon the clay and moisture content of the mould sand.

3) Adhesiveness

This is the property by which the moulding sand particles stick to other materials. Due to this property, the moulding sand sticks to the sides of the moulding boxes. The moulding sand does not fall down when the moulding box is lifted up.

4) Cohesiveness

This is the property of moulding sand by which the sand particles stick together. Due to this property, the mould remains strong.

5) Refractoriness

This is the property of moulding sand to withstand high temperature of molten metal. Moulding sand mixed with quartz has high refractoriness. Sand mixed with iron oxide, calcium and sodium has low refractoriness. The required refractoriness of sand depends upon the metal used for casting.

6) Collapsibility

This is the property of moulding sand by which it collapses easily. The size of the casting will reduce during cooling. Accordingly, the mould collapses and prevents the formation of cracks in the casting.

1.4.5 Moulding sand preparation

Moulding sand is prepared by the following steps.

1) Mixing of sand 2) Tempering of sand 3) Conditioning of sand

1) Mixing of sand

Moulding sand is thoroughly mixed with clay, lime, magnesia, potash, cow dung, coal dust and water so that all the ingredients are distributed uniformly. Shovel is used for mixing when small quantity of sand is required. A machine called muller is used for mixing when large quantity of sand is required. Before mixing, the unwanted materials like nails, fins, etc. should be removed by using magnetic separator and screens.

2) Tempering of sand

Tempering is the process of adding sufficient water to the sand. When the muller is used for mixing, water is sprayed over the sand so that it is uniformly distributed throughout the sand.

3) Conditioning of sand

Conditioning is the process of distributing the binder uniformly throughout the sand. Sand mixed in mulller is separated into individual particles by using air blaster. This increases the flowability of sand and thus become suitable for ramming.

1.5 Moulding tools

The following moulding tools are used in the foundry.

1) Shovel

Shovel has a broad metal blade with long wooden handle. It is used for mixing and transferring the moulding sand in to moulding box.

2) Riddle

It has a circular or square wooden frame with a wire mesh at the bottom. It is used to clean the moulding sand by removing unwanted materials like nails, metal chips, stones, etc.

3) Rammer

Rammer is used for packing or ramming the moulding sand in the moulding box. It is made of wood or cast iron. It has a butt end and a peen end. The butt end is in cylindrical shape and the peen end is in wedge shape.

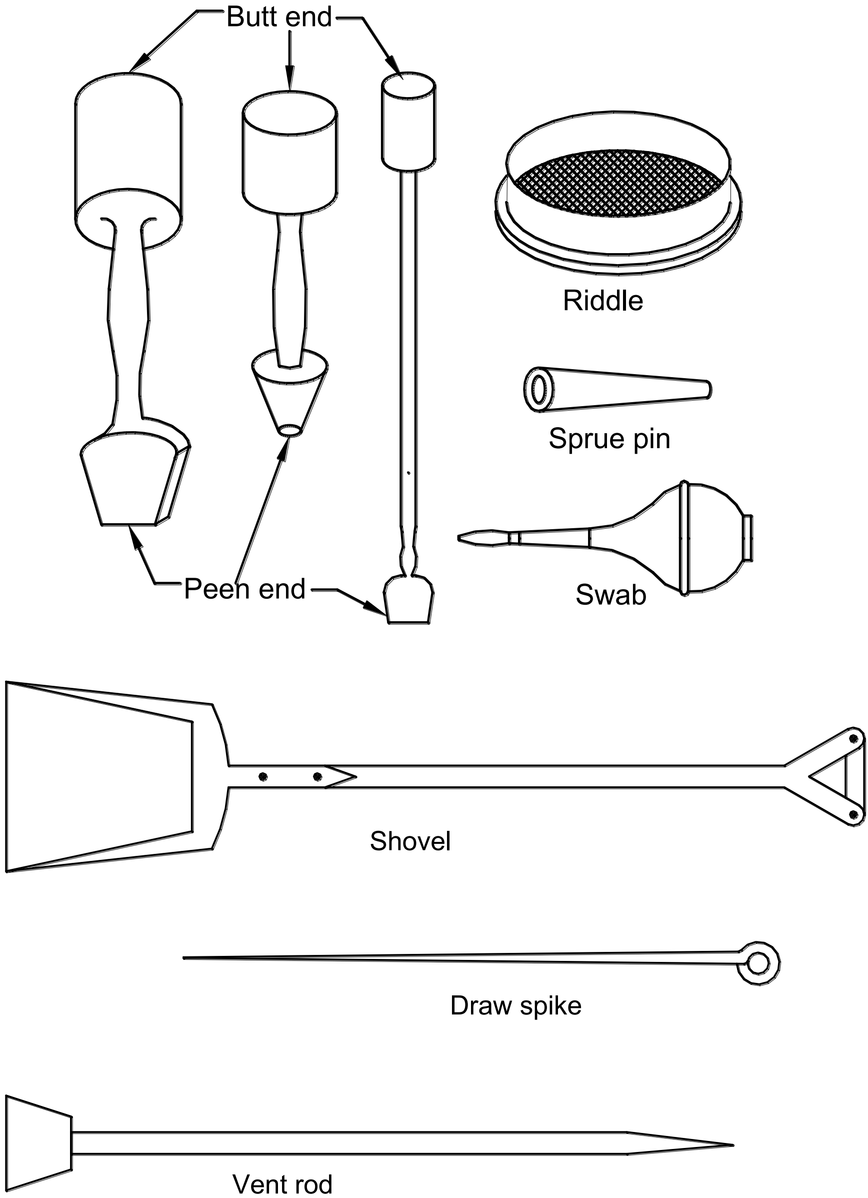


Fig.1.11 Moulding tools

4) Trowel

It has a metal blade fitted with a wooden handle. It is used to smoothen the mould surface and to repair the damaged portions of the mould. The end of the blade has square or round shape.

5) Slick

It has two spoon like blades at the ends. It is used for finishing mould surfaces and for repairing the round corners of the mould.

6) Lifter

It is a long steel plate with a twisted and bent end. It is available with various lengths and widths. It is used to remove the loose sand from the mould and to repair the broken surfaces of the mould.

7) Strike off bar

It is a wood or metal piece with straight edges. It is used for removing excess sand from the mould after ramming. This gives a leveled surface .

8) Sprue pin

It is a cone shaped wooden piece. It is used for making holes for runner and riser in the mould. Sprue pins of different sizes are used for different sizes of mould.

9) Bellows

Bellows are used for blowing off loose sand particles from the mould.

10) Swab

It is a small brush. It is used for applying small amount of water around the pattern before removing it from the mould. It is also used to give coating on the mould surface.

11) Gate cutter

It is a steel piece with bent end. It is used for cutting gate in the mould. Gate connects the runner hole and the mould cavity.

12) Draw spike

Draw spike is a long steel rod with a pointed or threaded end. The other end has a ring shaped head. It is used for removing the pattern from the mould.

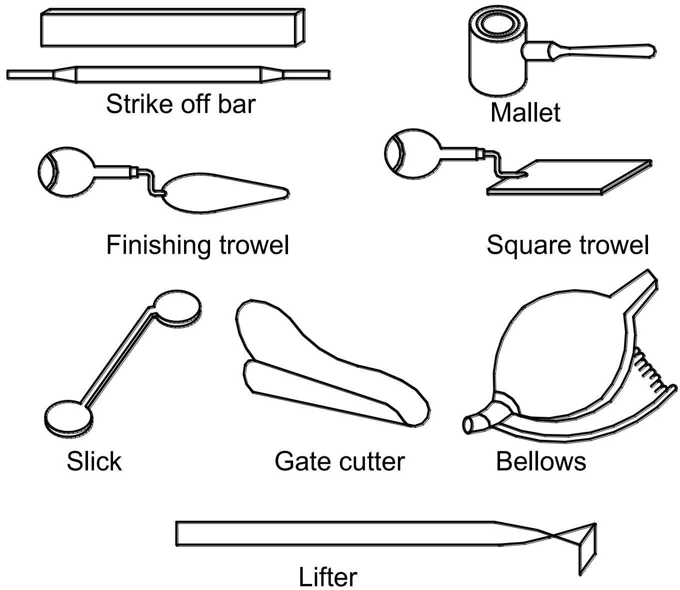


Fig.1.12 Moulding tools

13) Vent rod

It is a long thin steel wire with handle. It is used for making small holes on the mould. During casting, the steam and gases escape through these holes.

14) Mallet

It is a hammer made of wood. It is used to fix the draw spike into the pattern by hammering.

1.6 Moulding boxes

It is also called as moulding flask. Moulding box is used to prepare sand mould. It is a frame made of wood or metal. It is box with both the bottom and top surfaces are opened. If the moulding is done with two boxes, the upper box is called cope and the lower box is called drag. The two boxes are aligned correctly with the help of dowel pin. If the moulding is done with three boxes, the middle box is called cheek.

The two types of moulding flasks are:

1) Snap flask 2) Tight or box flask

1) Snap Flask

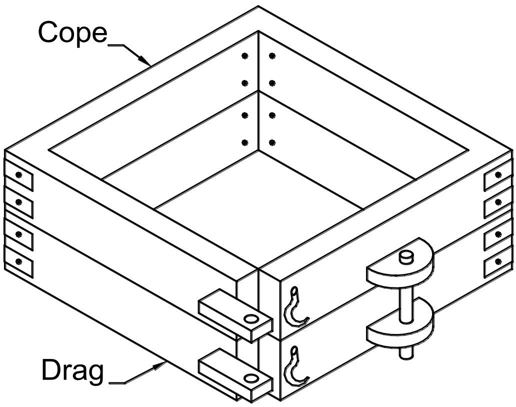


Fig.1.13 Snap flask

It is used for preparing small size moulds in large numbers. It has made with hinges and locks to open the flask easily after moulding. Number of moulds can be prepared by using one moulding box.

2) Tight or box flask

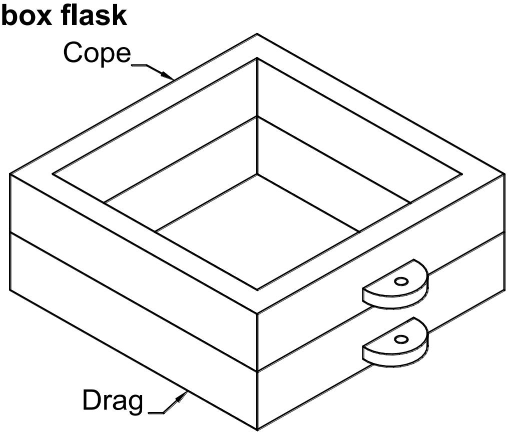


Fig.1.14 Box flask

It is used to prepare small and medium size moulds. The box cannot be separated from the mould after moulding. So it is also called permanent flask.

1.7 Gating system

Gating system consists of pouring cup, sprue, runner, gate and riser.

- **Pouring cup:** It is the funnel shaped portion on the top of the sprue hole. Molten metal is poured easily through this cup.

- **Sprue:** It is the hole which connects the pouring cup to the runner. Molten metal passes through the sprue to the runner

- **Runner:** Runner supplies molten metal from sprue to different gates.

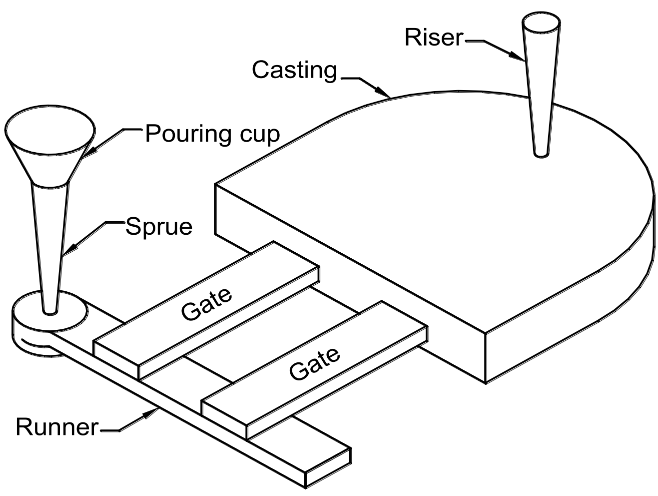


Fig.1.15 Gating system

- **Gate:** it connects the runner and the mould. Molten metal enters the mould through the gate.

- **Riser:** It is a hole in the cope portion. After the mould is filled up, the molten metal rises into the riser. It supplies molten metal to the mould during shrinkage of casting and thus correct size casting can be obtained.

1.8 Types of mould

The moulds are classified as :

- ***Temporary moulds :*** These moulds are destroyed at the time of removing casting from them. *Example : Sand moulds.*
- ***Permanent moulds :*** These moulds are used repeatedly. They are not destroyed after the removal of casting. *Example : Metallic moulds*.

The commonly used types of moulds are :

1) Green sand mould 2) Dry sand mould
3) Skin - dry sand mould 4) Loam mould
5) Metal mould

1) ***Green sand mould :*** It is the mould made with green sand. A green sand mould consists of a mixture of silica sand, clay and water. The sand is called "green" because of moisture present.

2) ***Dry sand mould :*** It is the sand mould made with a sand that does not require moisture to develop strength. The binder and additives provide the strength. A strong mould is obtained after heating the prepared mould in an oven.

3) ***Skin-dry sand mould :*** It is the sand mould with dry sand facing and a green sand backing. After the mould is prepared, it is partly dried around the cavity.

4) ***Loam sand mould :*** It is the sand mould made with loam sand. Loam sand consists of silica sand, fire clay and graphite. It requires large space. It is suitable only for a single casting of large size.

5) Metal moulds : These are permanent type of moulds used in die casting. Metal moulds are suitable in the casting of low-melting temperature alloys.

1.9 Methods of moulding

The following are the various types of moulding.

1) Green sand moulding 2) Dry sand moulding 3) Loam moulding
4) Bench moulding 5) Floor moulding. 6) Pit moulding
7) Sweep moulding 8) Plate moulding 9) Machine moulding

1.9.1 Green sand moulding

The process of making mould by using green sand is called green sand moulding. After the mould is prepared, the molten metal is poured into the mould for producing casting.

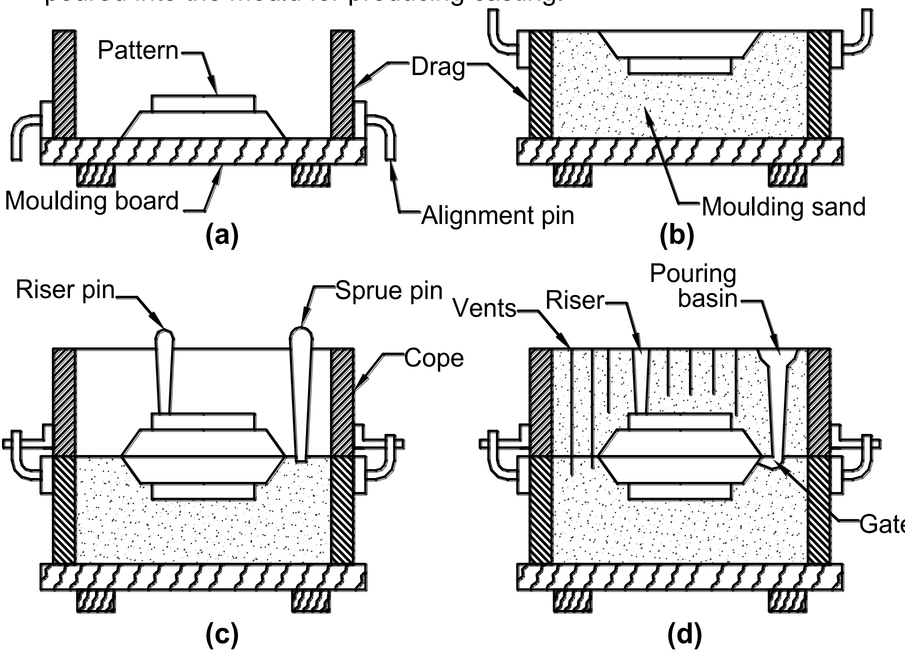


Fig.1.16 Green sand moulding

The following is the step by step procedure of making green sand mould using a split pattern.

1) One half of the pattern is placed on the moulding board.
2) Drag box is placed upside down on the board and parting sand is sprinkled over the pattern. (Refer figure.1.16)
3) 20 mm layer of facing sand is filed around the pattern. Then green sand is filled in the box.
4) Ramming is done uniformly by using rammer.
5) Excess sand is removed and leveled by strike off bar.
6) Vent holes are made. The box is tilted upside down.

7) The cope box and another half of the pattern are placed correctly. Parting sand is sprayed over the pattern.

8) The runner pin and riser pin are placed in the cope box at correct position. Then facing sand and moulding sand are filled.

9) Ramming is done uniformly. Vent holes are made.

10) Runner pin and riser pin are removed and pouring cup is made.

11) Cope and drag boxes are separated so as to remove the pattern.

12) Draw spike is driven into pattern pieces and shaken lightly in all direction. Then pattern pieces are withdrawn slowly.

13) Runner and gate are cut in drag portion.

14) Core is placed in the mould if necessary.

15) The cope and drag boxed are assembled in correct position and weight is placed over the cope. Now molten metal can be poured in this mould for producing casting.

Application

Green sand moulds are used for producing small and medium sized castings. It can be used for all types castings of ferrous and non-ferrous alloys.

Advantages

1) Cost is less
2) More flexibility
3) Less distortion
4) Less time consuming
5) Less danger of hot tears

Disadvantages

1) Sand control is more critical
2) More intricate castings cannot be made
3) It is not very strong
4) It may be damaged during handling
5) Less dimensional accuracy and surface finish.
6) It cannot be stored for a longer time.

1.9.2 Dry sand moulding

Dry sand mould is obtained after heating the green sand mould. The procedure for making dry sand mould is same as that of green sand mould. The large moulds are heated by oxy-acetylene flame. Small moulds are heated in ovens.

Application

Dry sand moulds are used for producing large castings like engine cylinders, engine blocks and mill rolls.

Advantages

1) It is stronger than green sand mould.
2) It is not damaged while handling.
3) More dimensional accuracy.
4) Smooth surface finish can be obtained.
5) Casting defects like blow holes will not occur.

Disadvantages

1) It requires heating.
2) More time is needed.
3) Cost is more.

1.9.3 Loam moulding

The cost of pattern and moulding box for producing large castings are more. So loam sand moulding is used. It does not require solid pattern and moulding box. Loam sand consists of silica, clay (50%) and fire clay. Loam mould is prepared by using loam sand.

First, a rough frame work is made by using bricks and iron pieces. Then the loam sand is applied over the frame work. The required mould is prepared by using suitable sweep pattern or skeleton pattern. This loam mould can be used after drying.

Applications of loam moulding

Loam mould is used for producing large castings like cylinders, bells, gears and machine parts.

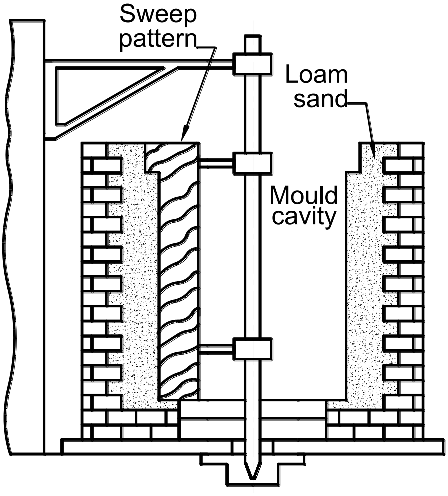


Fig.1.17 Loam moulding

Advantages of loam moulding

1) Good surface finish can be obtained.
2) It does not require moulding box.
3) Accurate castings can be produced.

Disadvantages of loam moulding

1) It requires more time.
2) It is not suitable for small castings.
3) Skilled labour is required.

1.9.4 Bench moulding

Bench moulding is carried out on a bench. The moulding bench is suitably designed for keeping moulding sand, tools, cores and moulding box on it. Both green sand and dry sand mould can be prepared. It is suitable for preparing small and less weight moulds.

1.9.5 Floor moulding

Handling of medium and large size casting is difficult. For producing large castings, mould is prepared on the foundry floor itself. The molten metal is poured into the mould for producing castings. Both green sand and dry sand mould can be prepared by this method.

1.9.6 Pit moulding

Pit moulding is used for producing castings which cannot be produced in moulding box. In this method, a pit is formed in the foundry floor. Pit acts as the drag portion of the mould. Cope part is made separately and placed over the pit at floor level. The sides are constructed with refractory bricks. Vent pipe is provided in the pit to allow gases to escape. Moulding sand is filled into the pit. Mould cavity is formed by using sweep pattern.

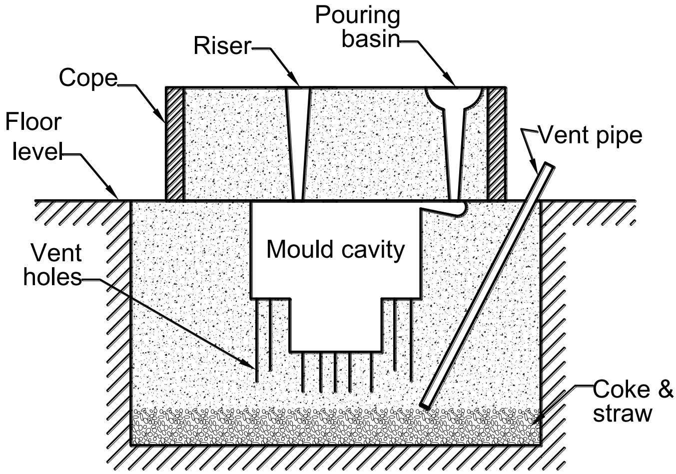


Fig.1.18 Pit moulding

1.9.7 Sweep moulding

Preparing mould using sweep pattern is known as sweep moulding. It is used for producing symmetrical shaped castings. Sand is filled in the box and rammed evenly. Mould is formed by rotating a sweep pattern. This method is suitable for producing large and medium size castings.

1.9.8 Plate moulding

Preparing mould using match plate is known as plate moulding. Number of patterns can be placed in a match plate. Patterns for runner and gate are placed at the bottom of the plate. Match plate patterns are used in machine moulding. It is suitable for producing small and accurate castings in large numbers.

1.9.9 Machine moulding

Hand moulding is a slow process. It is suitable only for producing less number of castings. Ramming may not be done uniformly during moulding. Due to this, production time is increased. So machine moulding is best suitable for producing large number of similar castings. Accurate and better quality moulds can be prepared at faster rate by using machine moulding. The production cost is also reduced.

Ramming the moulding sand, tilting the moulding box and removing the pattern from the mould are done by moulding machine. Generally, the following types of moulding machines are used.

1) Squeezer machine
    a) *Top squeezer machine*
    b) *Bottom squeezer machine*
2) Jolt machine
3) Sand slinger

1) Squeezer machine

In a squeezing machine, the sand in the moulding box is squeezed between the table and squeezer head.

a) Top squeezer machine

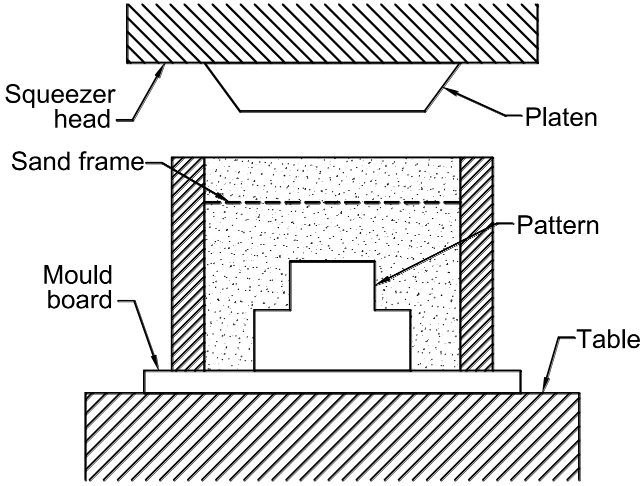


Fig.1.19 Top squeezer machine

A moulding board and moulding box are placed on the table. The pattern is placed inside the moulding box. The sand frame is placed on the upper side of the box. Moulding sand is filled up in the box. The table is lifted up by using a table lifting mechanism. The platen in the squeezer head slightly presses the sand. The table comes to the starting position after the squeezing is over.

This machine is suitable for small moulds. In this method, the sand is rammed more densely on the top of the mould than around the pattern.

b) Bottom squeezer machine

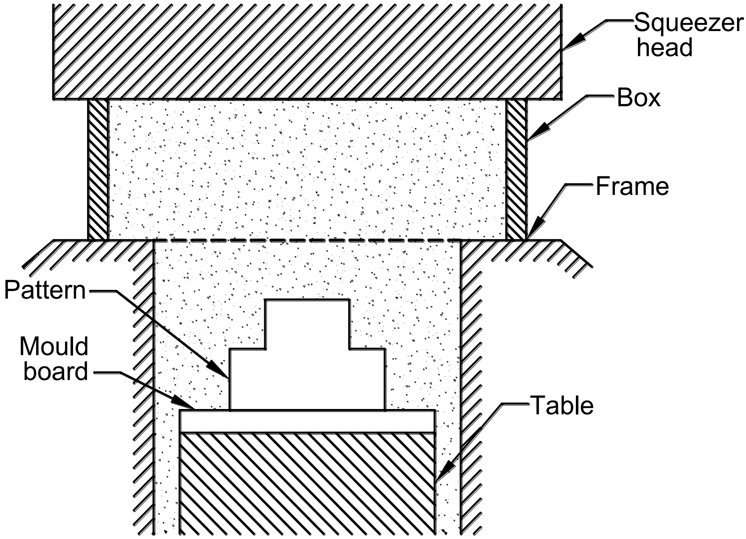


Fig.1.20 Bottom squeezer machine

In this method, the moulding board is placed on the table. The pattern is placed on the board. The moulding box is placed on a frame and filled with sand. The table is lifted up by using a lift mechanism. The moulding sand in the box is squeezed between the squeezer head and table. The table returns to the bottom position after squeezing is over.

2) Jolt machine

In this machine, the pattern is placed in the moulding box on the table. The box is filled up with sand. The table is raised by a plunger when compressed air enters under the plunger. After the table is raised up to 80 mm, the air escapes through the opening. Now the table is dropped suddenly. Due to this, the sand around the pattern is rammed evenly. Springs are used to reduce the vibrations of table and noise. Cope and drag boxes are rammed separately in this machine. Then the two boxes are assembled to form a complete mould.

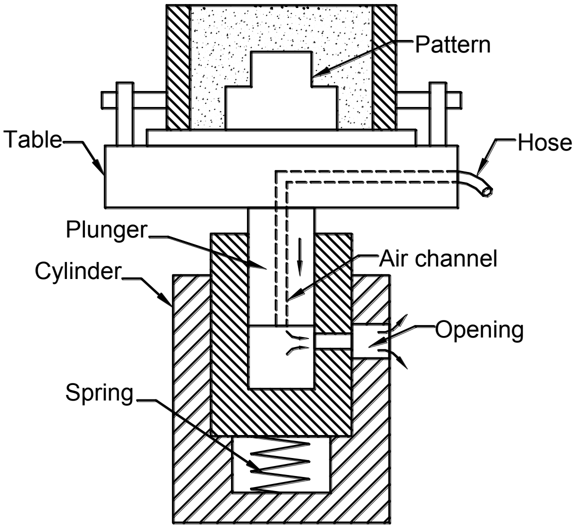


Fig.1.21 Jolt machine

3) Sand slinger

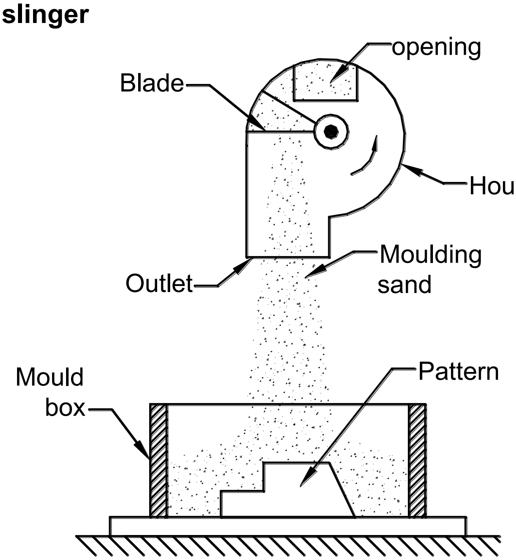


Fig.1.22 Sand slinger

In this machine, the sand is thrown into the moulding box with high velocity by an impeller. The impeller blades rotate at high speed. The sand from the conveyor bucket is thrown into the moulding box with high velocity (500 Kg/min.) through these blades. So the sand gets rammed evenly around the pattern. The density of the sand is controlled by the speed of the impeller. Ramming is done uniformly in this machine. This machine is suitable for preparing large and medium size moulds. Ramming is quick and the initial cost is more.

1.10 Cores

Core

Core is used to make hollow or a hole in a casting. It is made with core sand. The shape of the core is similar to the required cavity in the casting. Core is placed in the mould and is removed after casting.

Core print

A projection made in the pattern is called core print. It is used to form a core seat in the mould. The core is correctly seated in this seat.

1.10.1 Essential qualities of core

When the molten metal is poured into the mould, it fills around the core. Therefore, the core sand should have the following properties.

1) It should have high refractoriness to withstand the high temperature of the molten metal.
2) It should have good permeability to allow the steam and gases to escape easily.
3) The core should have enough strength and hardness to withstand the high pressure of molten metal.
4) The core must have good stability so as to keep the cavity in correct shape. It should not expand or shrink due to the temperature of the molten metal.
5) It should have good collapsibility for easy removal of sand from the casting.

1.10.2 Core Sands

Core sand is the mixture of silica sand and binder. The core sand is heated to obtain required strength. Sand having clay above 5% is not suitable for producing core. Sand with sharp grains will bind together and form a strong core. Sand with rounded grains will have good permeability. The suitable core sand is used according to the size of the core and the temperature of the molten metal.

1.10.3 Core binders

Binders are added with the core sand to bind the sand grains together. They also give strength and hardness to the core and prevent moisture absorption. Generally, the following binders are used.

1) Oil binders

Linseed oil is used as oil binder. This oil forms a thin film around the sand grains. When the core is heated, the oil gets hardened and makes the sand grain to bind together.

2) Water soluble binders

Starch, dextrin are used as water soluble binders after mixing with small amount of water. This binder is added with the core sand. The core gets hardened when it is heated.

3) Resin binders

Phenol formaldehyde and urea are used as resin binders. These binders are added with the core sand to give strength, to reduce the formation of gas and to give collapsibility.

1.10.4 Core boxes

The box used for making core is called core box. It is made of wood or metal. The following types of core boxes are used according to the shape of required core.

1) Half core box
2) Dump core box
3) Split core box
4) Strickle core box
5) Gang core box

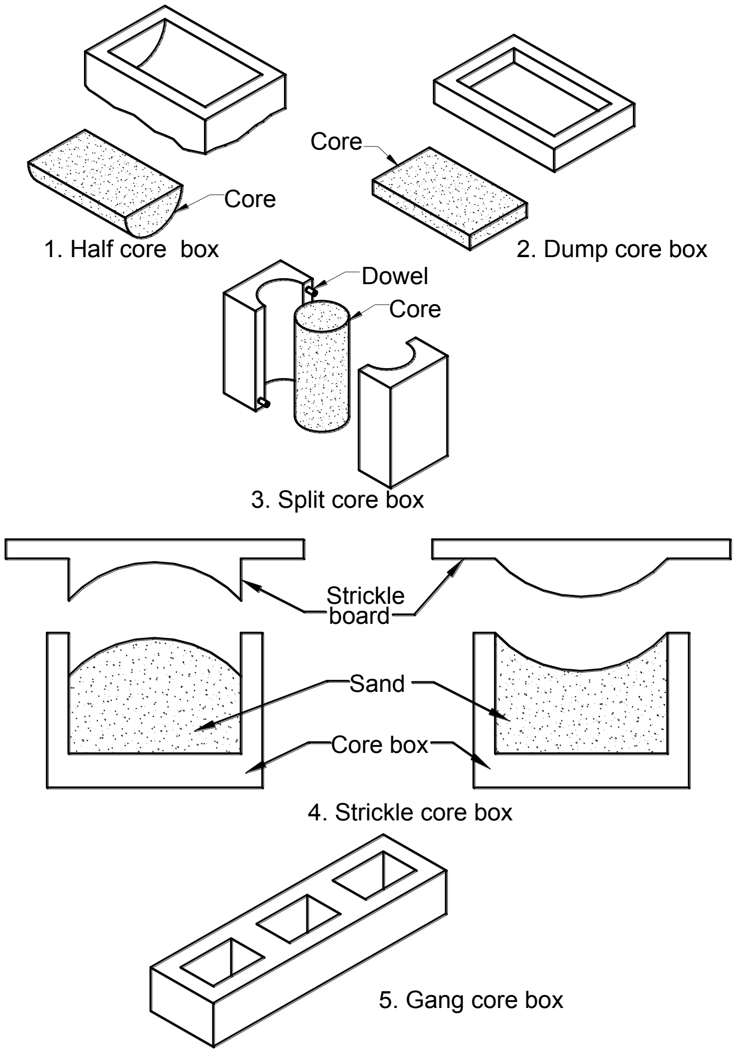


Fig.1.23 Core boxes

1) Half core box

Half core box is used to prepare half portion of a symmetrical core. Two half portions are baked and pasted to form a full core.

2) Dump core box

It resembles half core box. Dump core box is used to prepare a full core. Square and rectangular shaped cores are prepared by using this core box.

3) Split core box

This box has two similar half portions. The two portions are assembled correctly by using dowel pins. After ramming the sand, the box is splitted. Then the full core is removed.

4) Strickle core box

it is used to prepare cores having irregular shapes. The box is filled up with core sand and ramming is done. The core with required shape is obtained after removing the sand by using a strickle board. The strickle board has required shape of the core.

5) Gang core box

Gang core box is used to prepare number of cores at a time. Number of cores equal to the number of core cavities in the core box can be prepared by using this box.

1.10.5 Core making

Core is prepared by the following steps.

1) Core sand preparation   2) Core moulding

3) Baking   4) Core finishing

1) Core sand preparation

The ingredients like binder and additives are thoroughly mixed with core sand. This will give uniform strength to the core. The mixing is generally done in roller mill or core mixer.

2) Core moulding

Core is prepared by using core box. The core sand is filled in the core box and ramming is done. Then the core box is split to remove the core. Now the core is called green sand core. It is not strong. Steel rods are placed inside the large size cores to give more strength. Core is prepared by hand or machine.

3) Core baking

The cores are placed in an oven and heated to temperature of 15^{o}C to 400^{o}C. Moisture in the core is removed during heating. Also, the binder hardens and gives strength to the core. The cores are classified according to the type of binder and the size or core.

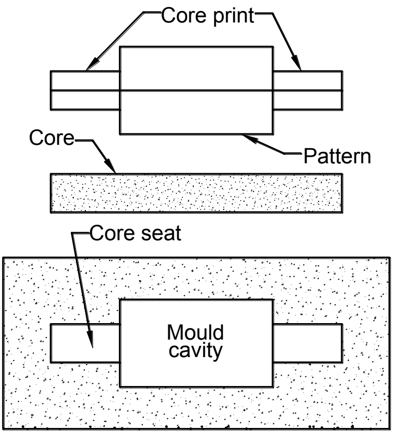


Fig.1.24 Core making

4) Finishing

After baking the core, the rough surfaces and unwanted projections are removed by filing. Silica or graphite powder is coated on the surface of finished core. This will prevent the metal penetration into the core. Also it gives smooth surface to the casting.

1.10.6 CO_2 process of core making

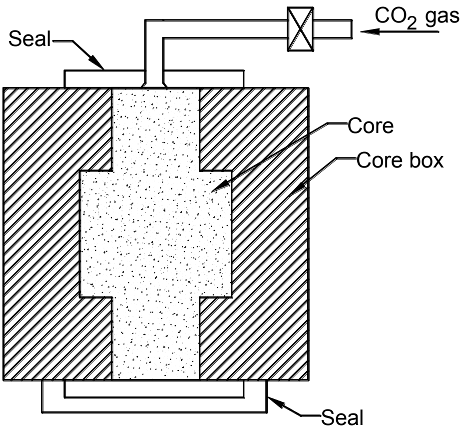


Fig.1.25 CO_2 process of core making

In this process, the core is prepared and hardened simultaneously. The core sand is mixed with sodium silicate binder. Also additives like wood flour or graphite may be added with the core sand. This mixture is thoroughly mixed in a sand muller. The core sand is filled up in the core box and rammed. Then CO_2 gas is passed through the core for 30 seconds at a pressure of 1.5Kg / cm^2. This is called gassing.

CO_2 reacts with sodium silicate to form silica gel. As this silica gel is very hard, the core becomes very hard. Now the core can be used immediately.

Advantages

1) Core is very hard.
2) Baking is not necessary.
3) It is simple and very quick process.
4) The core can be stored for long use.

Disadvantages

1) The core sand cannot be reused.
2) The cost of binder is high.
3) This process requires special additives.

1.10.7 Types of cores

The following are the various types of cores.

1) Green sand core	2) Horizontal core
3) Vertical core	4) Balanced core
5) Hanging core	6) Drop core

1) Green sand core

When the core is prepared in the mould by using the pattern itself, then it is called green sand core. Core box and core sand are not needed for producing this core. The core is prepared by the moulding sand. This core is suitable only for vertical openings.

2) Horizontal core

This core is held horizontally in the mould. It is usually in cylindrical shape. Both the ends of the core are seated in core seat. Horizontal core is most widely used.

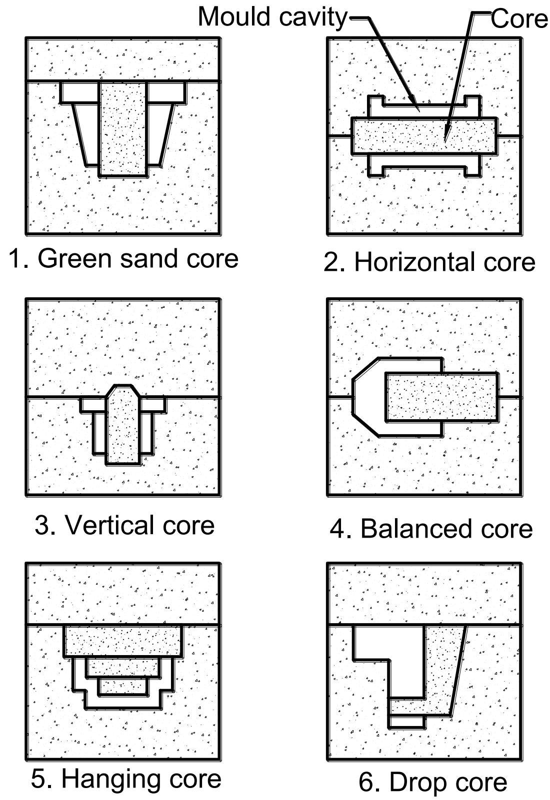


Fig.1.26 Types of cores

3) Vertical core

This core is placed vertically in the mould. The ends of the core are supported in the seats provided at the cope and drag. Major portion of the core rests in drag.

4) Balanced core

One end of this core alone is placed in the mould cavity. The other end is supported in the long core seat provided in the mould. It is placed horizontally. This core can be used to provide hole at the one end of the casting.

5) Hanging core

This core is supported only in the cope and hangs vertically. It has no support in the drag. There is a hole provided in the core for pouring the molten metal. It is also called as cover core.

6) Drop core or wing core

Drop core is used to provide hole which is below or above the centre line of casting. The core is prepared so that it can be conveniently held in the mould. It may also be called as tail core or chain core.

1.10.8 Core ovens

The following ovens are used for heating the cores to obtained required strength.

1) Batch type ovens
2) Continuous type ovens
30 Dielectric type ovens

1) Batch type ovens

Small cores of different sizes can be held in batches and heated simultaneously in this oven. This type of oven has rack or shelf for placing cores. The oven can be fired by using coal, oil or gas.

2) Continuous type ovens

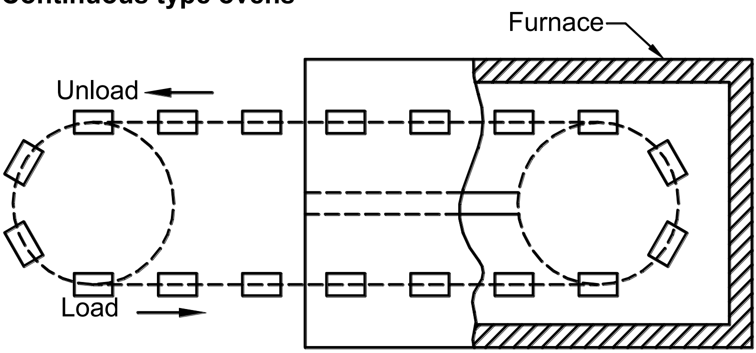


Fig.1.27 Continuous type oven

In this type of oven, the cores are continuously loaded and heated. At on side of the oven, cores are loaded on the conveyor. The cores are heated when the conveyor moves very slowly inside the oven. The cores are unloaded at the other side of the oven. The heating time can be controlled by varying the speed of conveyor. The heating is done by using gas, oil or electricity. This oven is suitable for mass production.

3) Dielectric baking ovens

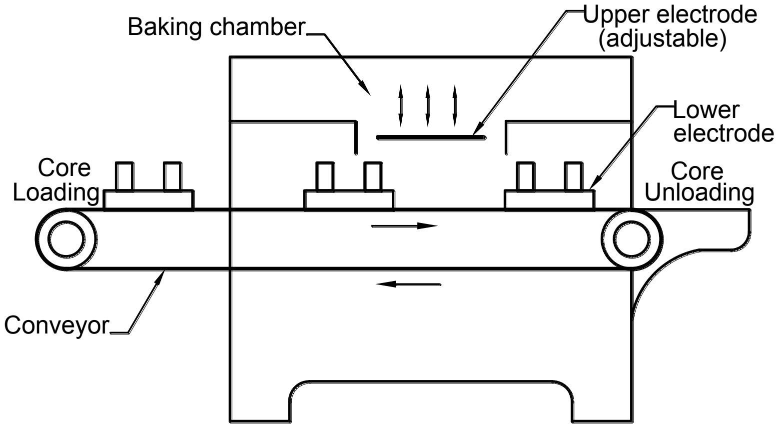


Fig.1.28 Dielectric baking oven

This type of oven is used for heating cores very quickly. The cores are placed on the conveyor and moved between the two parallel electrodes. An aluminium plate acts as upper electrode and the conveyor acts as lower electrode. When A.C supply is given to the electrode, high heat is produced and the cores are heated uniformly.

1.11 Metallurgy - Introduction

Metallurgy is a branch of materials science and engineering that studies the physical and chemical behavior of metallic elements, their intermetallic compounds, and their mixtures. Heat treatment is the process of modifying the required properties of metal and metal alloys. The required properties can be improved by the metal and metal alloys to different temperature and cooling at specific rate.

For example, the crystal structure of steel gets changed when heating. The micro structure of steel depends upon carbon content, temperature and rate of cooling. The properties of steel will be modified according to the micro structure.

1.11.1 Iron - Carbon equilibrium diagram

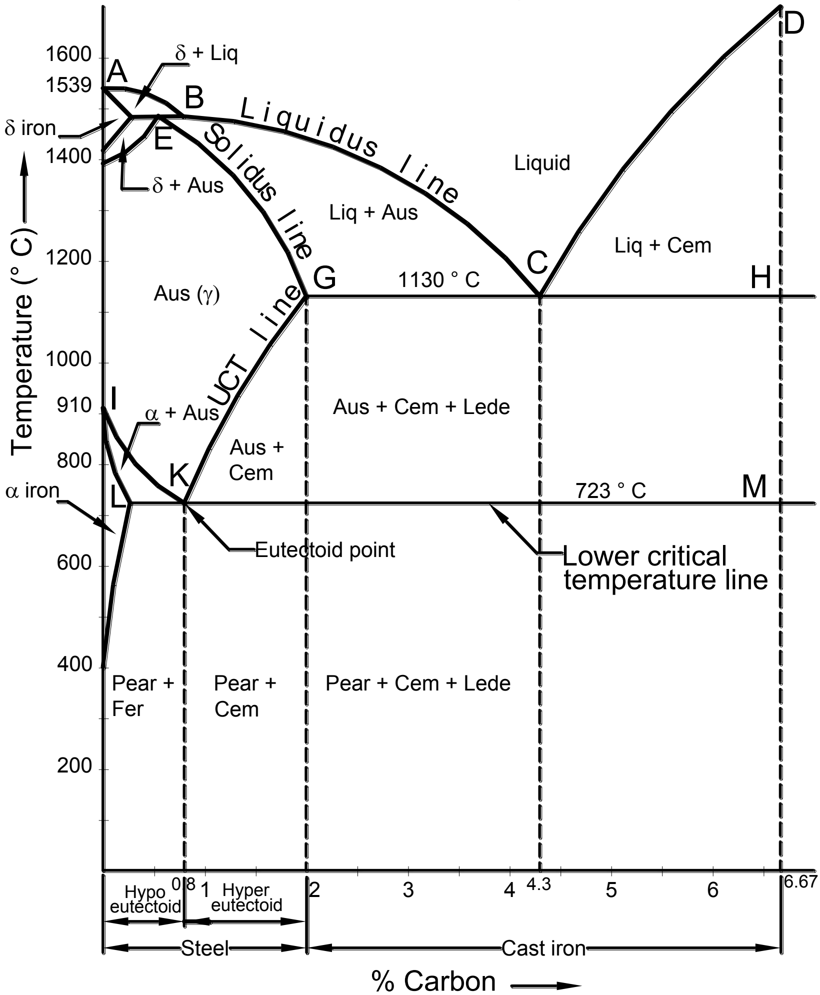


Fig.1.29 Iron-Carbon equilibrium diagram

Iron – carbon equilibrium diagram is the graphical representation of the phase changes undergone by iron with respect to the carbon content and temperature on cooling or heating. This diagram is very much used to identify the suitable metal alloys for different heat treatment processes, carbon content and required temperature for the process. This diagram is drawn by taking the carbon content in X-axis and temperature in Y-axis.

Description of the diagram

The line ABCD is known as liquidus line. Iron exists in liquid state at temperature above this line. The pure iron starts to solidify at the point A (1530ºC). As the line goes gradually downwards from A to C, it is understood that the solidification temperature decreases when the carbon content increases.

The point C represents the solidification temperature of iron (1130ºC) with 4.3% carbon. The line CD shows that the solidification temperature increases when the carbon content increases above 4.3%.

The line AGCH is known as solidus line. Iron exists in solid state at temperature below this line.

The diagram is divided into two parts based on the carbon content. The part up to 2% carbon is called steel range and the part with more than 2% carbon is known as cast iron range.

Steel containing carbon less than 0.8% is called *hypo eutectoid steel.* Steel containing carbon exactly 0.8% is called *eutectoid steel*. Steel containing carbon from 0.8% to 2% is called *hyper eutectoid steel.*

Moreover, steel containing less than 0.2% is called low carbon steel. Steel with 0.2% to 0.8% carbon is called medium carbon steel and with 0.8% to 2% carbon is called high carbon steel.

Critical temperatures

The temperature at which the micro structure of metal starts changing is called critical temperature. When the molten metal is cooled, the temperature at which the micro structure of metal starts changing is known as *Upper Critical Temperature (UCT*). The temperature at which the micro structure is completely changed is known as *Lower Critical Temperature (LCT).* The line LKM (723ºC) is known as Lower Critical Temperature line. The lower and upper critical temperature of eutectoid steel which contains 0.8% carbon are same (point K).

1.11.2 Structure transformation in steel

Let us consider two types of steel having 0.4% carbon and 1.2% carbon. In the figure, the points t_1 and t_2 are the LCT and UCT of steel with 0.4% carbon respectively. Steel is in austenite structure above the temperature t_2. Austenite is converted into ferrite at the temperature t_2. Ferrite is converted into pearlite at the temperature t_1. Steel exists as a mixture of pearlite and ferrite below the temperature t_1.

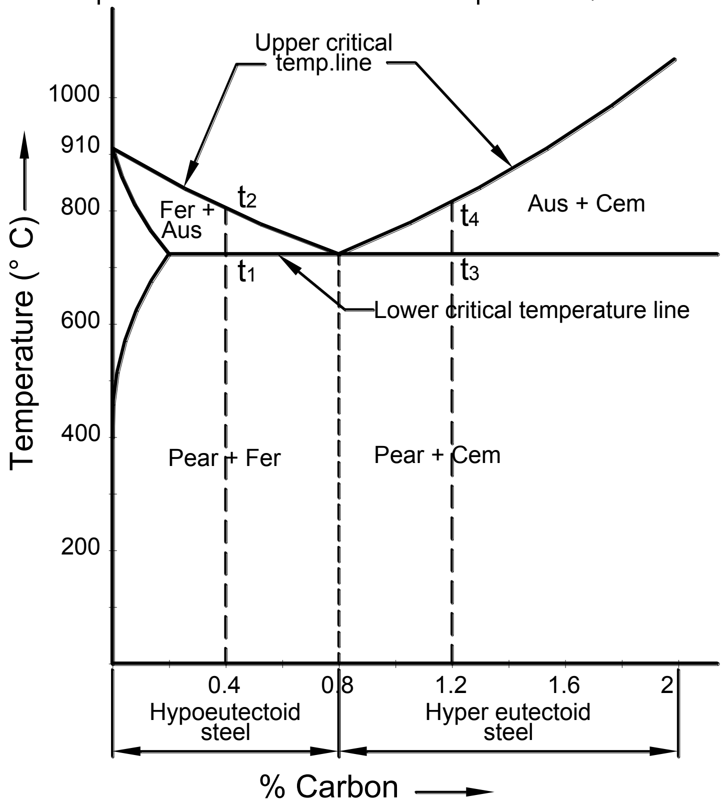


Fig.1.30 Structure transformation in steel

t_3 and t_4 are the LCT and UCT of steel with 1.2% carbon respectively. This type of steel is in austenite structure above the temperature t_4. It is converted into cementite at the temperature t_4. Cementite is converted into pearlite at the temperature t_3. Steel exists as a mixture of austenite and cementite in between these two temperature. Steel exists as a mixture of pearlite and ferrite below the temperature t_3.

1.12 Melting furnaces

The furnace is used for melting the metal by heating it to a temperature above its melting point. The furnace can be fired by using coal, oil, gas and electricity. According to the size and type of metal to be melted, the following different furnaces are used.

1) Blast furnace
2) Cupola furnace
3) Crucible furnace
   i) Pit type furnace
   ii) Coke fired stationary furnace
   iii) Oil fired tilting furnace
4) Electric furnace
   i) Direct arc furnace
   ii) Indirect arc furnace
   iii) Induction furnace

1.12.1 Blast furnace

Blast furnace is used to chemically reduce and convert iron oxides in iron ore into molten pig iron by smelting process.

Construction

The Blast Furnace is a large steel structure about 30 metres height. It is lined with refractory firebricks that can withstand temperatures upto 2000^{o}C. The bottom of the furnace has a thick plate. A tap hole is provided for taking out the molten metal. A slag hole is provided at the opposite side just above the tap hole.

Water cooled copper nozzles, called tuyers, are provided near the base to supply a blast of pre-heated air for heating the charge. A stackhouse is provided at the top of the furnace to store the raw materials. A hopper is used to control and charge the raw materials into the furnace. Pipes are provided at the top for the hot gases to exit.

Preparation

Iron making in the furnace usually continues for about ten years before the furnace linings have to be renewed. The furnace is cleaned by removing the slag and unwanted material. The broken bricks inside the furnace are repaired. The bottom plate is fitted. The tap hole and slag hole are formed. The furnace is dried thoroughly before firing.

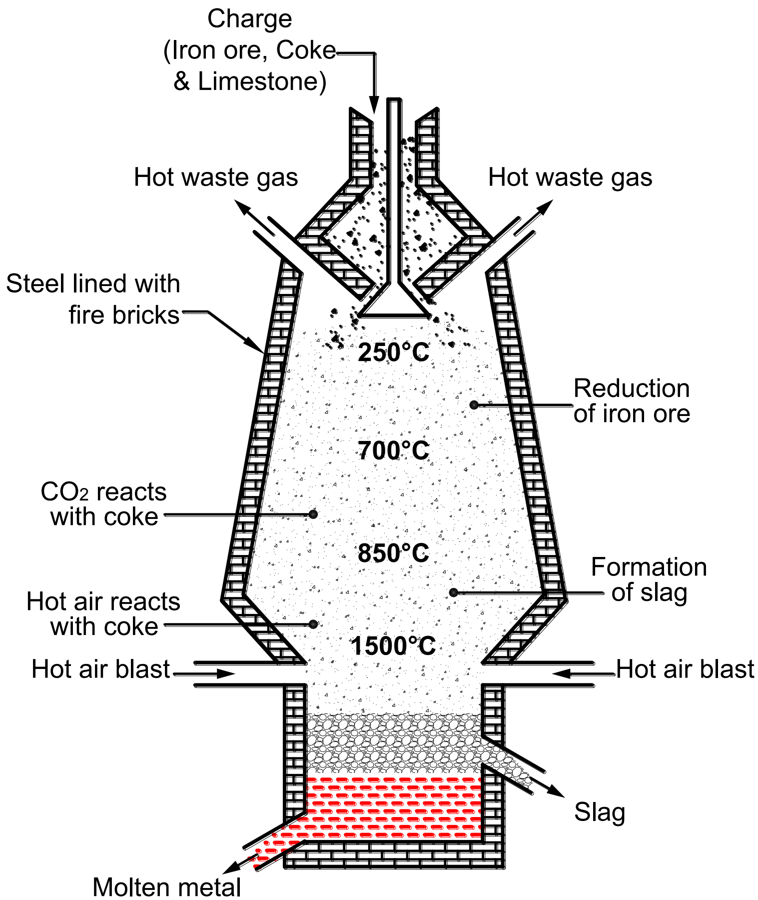


Fig.1.31 Blast furnace

Operation

The raw material containing coke, lime stone flux and iron ore (iron oxide) are charged into the furnace through hopper in a precise filling order. The hot blast air is directed into the furnace through tuyers near the base.

The hot air burns the coke and maintains a very high temperature. The reaction between air and coke generates carbon monoxide. This gas reduces the iron oxide in the ore to iron.

$$\text{Iron oxide} + \text{Carbon monoxide} \rightarrow \text{Iron} + \text{Carbon dioxide}$$

$$Fe_2O_3 + 3\,CO \rightarrow 2\,Fe + 3\,CO_2$$

At high temperature, lime stone (calcium carbonate) decomposes into calcium oxide. This oxide reacts with acidic impurities (silica, alumina, magnesia, calcia, etc) to form slag.

$$\text{Calcium carbonate (lime stone)} \rightarrow \text{Calcium oxide} + \text{Carbon dioxide}$$

$$CaCO_3 \rightarrow CaO + CO_2$$

$$\text{Calcium oxide} + \text{Silica (sand)} \rightarrow \text{Calcium silicate (slag)}$$

$$CaO + SiO_2 \rightarrow CaSiO_3$$

The slag floats to the surface of the molten pig iron. The liquid slag and molten iron are drained from the furnace at regular intervals. The hot gases from the furnace can be reused to heat up the blast air.

Application

Blast furnace is used to produce pig iron from iron ore. Pig iron is used as raw material in the production of cast iron and steel.

Advantages

1) High volume production rate
2) Low operating cost
3) Low maintenance cost
4) It can be operated for a longer time.

Disadvantages

1) High metal oxidation rates
2) Low efficiency
3) Larger floor requirements

1.12.2 Cupola furnace (Melting of cast iron)

Construction

Cupola furnace is used for melting cast iron. It is a hollow cylindrical shell made of steel plate. The inner side of the furnace is constructed with refractory bricks and lined with fire clay. The cupola is supported by cast iron columns which are mounted in the concrete. The bottom of the cupola has a thick plate. A sand bed with slopping is prepared over the bottom door so that the molten metal flow easily.

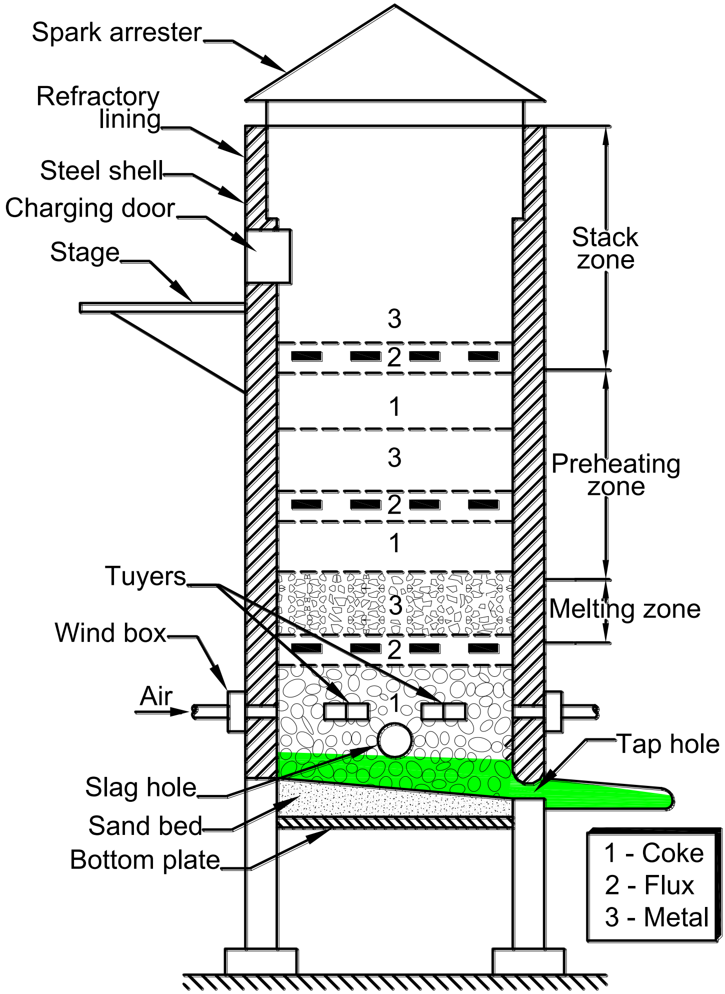


Fig.1.32 Cupola furnace

A tap hole is provided for taking out the molten metal. The tap hole is closed by a clay plug. The slag hole is provided at the opposite side just above the tap hole. Air for combustion of fuel is sent through the openings called tuyers. A wind box is provided to blow the air into the furnace. A charging door and platform is provided for charging metal and fuel into the furnace.

Preparation

The cupola is cleaned by removing the slag and unwanted material. The broken bricks inside the cupola are repaired. The bottom plate is fitted. Sand bottom is prepared with sloping towards tap hole. The tap hole and slag hole are formed. The cupola is dried thoroughly before firing.

Operation

Firing : Wooden pieces are placed on the sand bed and fired. Now air is supplied into the furnace. When the wood pieces start burning, coke is charged slowly in step by step. When the coke starts burning, more coke is added up to the tuyers openings. When the coke bed is burnt for half an hour, the charging can be done.

Charging : Pig iron, iron scrap and flux are charged into the furnace one by one through the charging door. The ratio of iron to coke is 10:1. The lime stone is added as flux to remove the slag. The ratio of iron to lime stone is 25:1.

Melting : The iron is heated for about 45 minutes by blowing the air slowly. Then the air is supplied at high speed. Within minutes, the metal is melted and collected at the sand bed. The slag will be tapped out through the slag hole. The tap hole is opened and the molten metal is filled in a ladle. Then the molten metal is poured into the mould for producing casting.

Advantages

1) The furnace is in simple construction.
2) The initial cost is low.
3) Less floor space is sufficient.
4) Operation and maintenance of furnace is easy.
5) The furnace can be operated for long time

1.12.3 Crucible furnace (Melting of non-ferrous metals)

Crucible furnaces are used for melting non-ferrous metals. In this furnace, the metal is melted without mixing to the fuel. The capacities varies from 30 Kg to 150 Kg.

Types of crucible furnaces :

The following types of crucible furnaces are available.

1) Pit furnace
2) Coke fired stationary furnace
3) Oil fired tilting furnace

1) Pit furnace

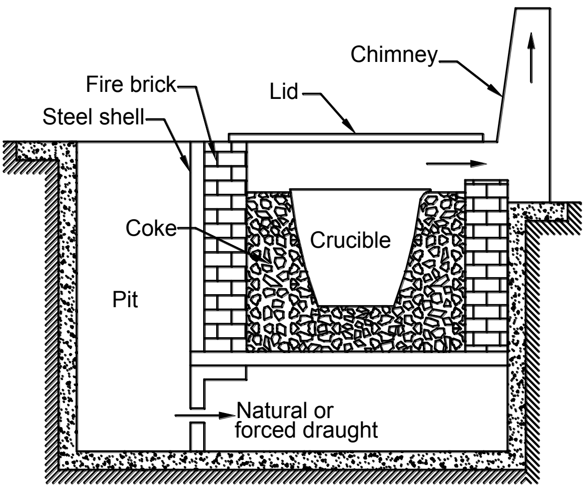


Fig.1.33 Pit furnace

In this furnace, the crucible is placed in a pit below the floor level. The air required for burning the fuel is supplied by natural or forced draft. Grate and ash pit are provided at the bottom of the furnace. The inside of furnace is built with fire bricks.

The metal to be melted is placed in the crucible. Coke is packed around the crucible and fired. After the metal is melted, the crucible is lifted out by using tongs. Then the molten metal is poured into the mould for producing castings.

2) Coke fired stationary furnace

This furnace is used for melting non-ferrous metals in small quantities. This type of furnace is erected above the floor level. The crucible is placed in a chamber which is built with fire bricks. A blower is provided to supply required air for burning of fuel.

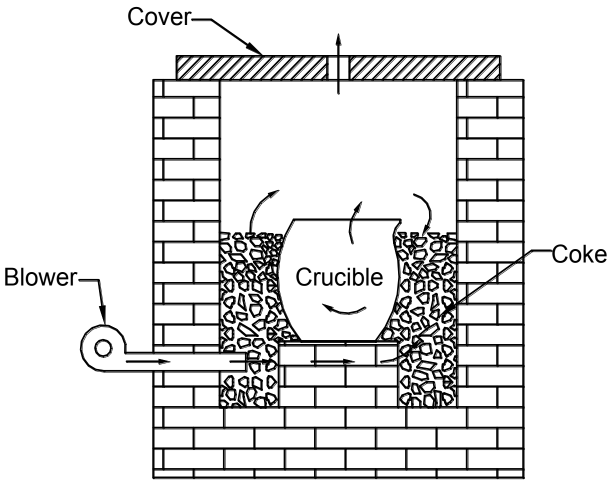


Fig.1.34 Coke fired stationary furnace

The metal to be melted is placed in the crucible. Coke is packed around the crucible and fired. After the metal is melted, the crucible is lifted out by using tongs. Then the molten metal is poured into the mould for producing castings.

3) Oil fired tilting furnace

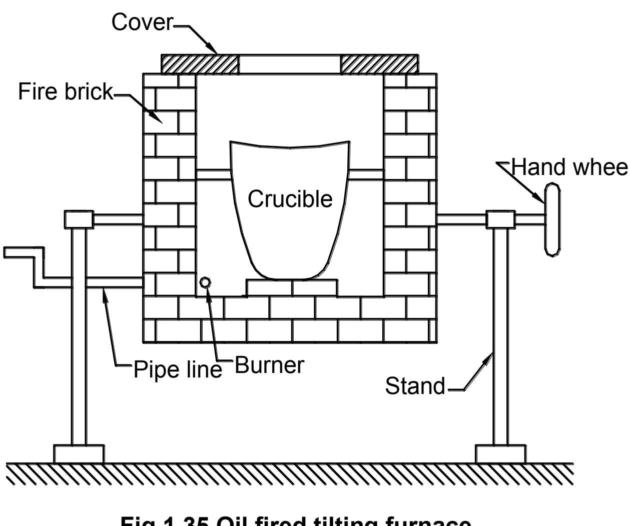


Fig.1.35 Oil fired tilting furnace

This furnace is supported by two stands above the floor level. The crucible is placed in a chamber which is built with fire bricks. The furnace can be tilted by a geared hand wheel for pouring the molten metal. Kerosene or waste oil required for burning is kept at a height of 6m. air and oil are supplied to the burner through a nozzle with sufficient pressure. The crucible is heated by burning the oil. This furnace is used for melting non-ferrous metals in small quantities.

Advantages

1) The rate of melting is high.
2) The furnace can be easily stopped whenever needed.
3) The temperature can be controlled easily.
4) Less floor space is sufficient.

1.12.4 Electric furnaces (Melting of steel)

The following types of electric furnaces are available.

1) Direct arc furnace
2) Indirect arc furnace
3) Induction furnace

1) Direct arc furnace

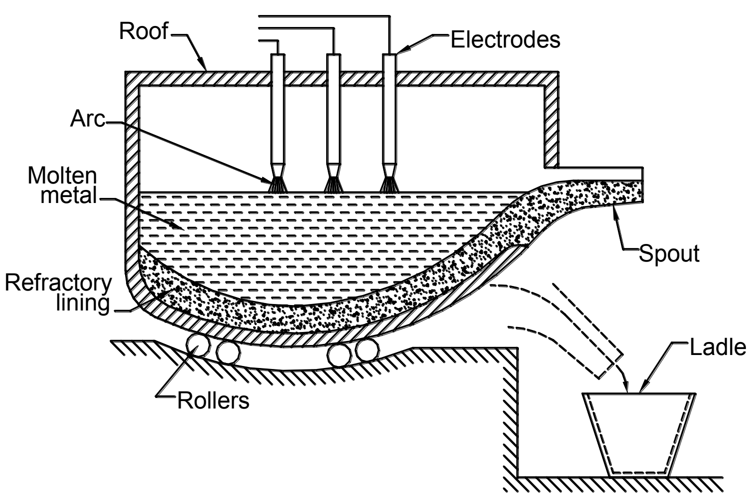


Fig.1.36 Direct arc furnace

This furnace is made of steel and has a spherical bottom. The inside is lined with fire bricks. A roof is provided at the top. Three movable graphite electrodes are provided in the roof. There is a charging door for charging the raw material and a spout for pouring out the molten metal. The furnace can be tilted with the help of rollers fitted at the bottom.

Steel scarp and pig iron are charged through the charging door. When the power supply is given, electric arcs are produced between the electrodes and metal. The metal is melted by the high temperature of arc. The furnace is tilted and molten metal is poured into the ladle. The height of the electrodes are automatically adjusted so as to produce the arc continuously. The capacity of the furnace is 80 tons.

Application

This furnace is used for melting steel and alloy steels.

Advantages

1) Very pure metal can be obtained.
2) Thermal efficiency of the furnace is high.
3) Steel can be directly obtained form pig iron and steel scrap.

2) Indirect arc furnace

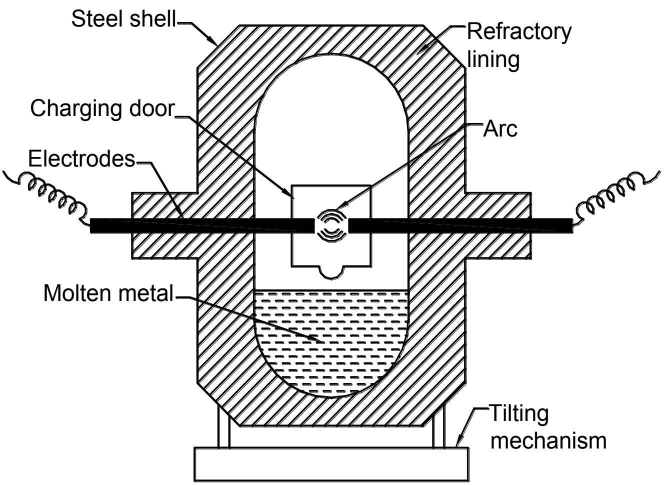


Fig.1.37 Indirect arc furnace

In this furnace, the metal do not contact with the electrodes and arc. Hence it is called indirect arc furnace. The furnace is a steel shell lined with refractory material. Two electrodes are provided directly opposite to each other. Charging door is provided at the middle of the furnace.

Pig iron and steel scrap is charged through the charging door. When power supply is given, an electric arc is produced between the electrodes. The metal is melted by the high temperature of arc. The furnace is tilted by a tilting mechanism and the molten metal is poured into the ladle.

Application

This furnace is used for melting steel, copper and copper alloys.

Advantages

1) Metal composition is uniform.
2) Metal oxide is not formed.
3) Charging and pouring out of metal is easy.

3) Induction furnace

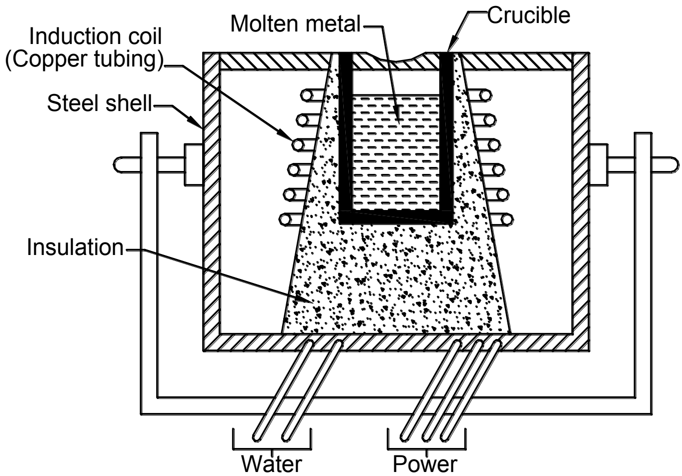


Fig.1.38 Induction furnace

In this furnace, a refractory crucible is placed inside a steel shell. A copper tube coil is placed around the crucible. The shell is cooled by circulating water through these tubes. An insulation is provided between the copper tube and crucible.

This furnace is working in transformer principle. The copper tube acts as primary coil and the metal to be melted in the crucible acts as a secondary coil. An alternate current is passed through the primary coil. This induces eddy current in the secondary coil (metal to be melted). The metal is melted by the high heat generated due to the eddy current. The molten metal is poured into the ladle by tilting the crucible. High frequency current of 500Hz to 2500Hz is passed in this furnace. The capacity of the furnace is up to 10 tons.

Application

This furnace is used for melting steel and alloy steels.

Advantages

1) No electrodes are needed.
2) It is a fast process.
3) Very pure metal can be obtained.

Advantages of electric furnaces

1) High temperature (2000°C) can be generated.
2) The temperature can be controlled easily.
3) Metal is melted at fast rate.
4) Thermal efficiency is high.
5) The metal will not be affected by air and impurities.
6) Chromium and nickel can be added to steel.

1.13 Casting

Casting is obtained by pouring the molten metal into the mould and allowing it to solidify. This process includes melting of the metal, pouring the metal into the mould and solidification. The casting gets the shape of mould cavity.

The following casting processes are available.

1) Sand casting
2) Gravity die casting
3) Pressure die casting
   i) Hot chamber die casting
   ii) Cold chamber die casting
4) Centrifugal casting
5) Continuous casting
6) Chilled casting
7) Malleable casting
8) Shell mould casting
9) Investment casting

1.13.1 Sand casting

In sand casting, after the molten metal is solidified, the casting is removed by destroying the mould. When the green sand mould is used, it is called green sand casting. It is used to produce small and medium size castings. When the dry sand mould is used, it is called dry sand casting. Large castings can be produced by this method. Defects like blow holes will not occur in this casting. Only one casting is produced by using a sand mould. The mould cannot be reused. Production cost and time will be more in this process.

1.13.2 Gravity die casting

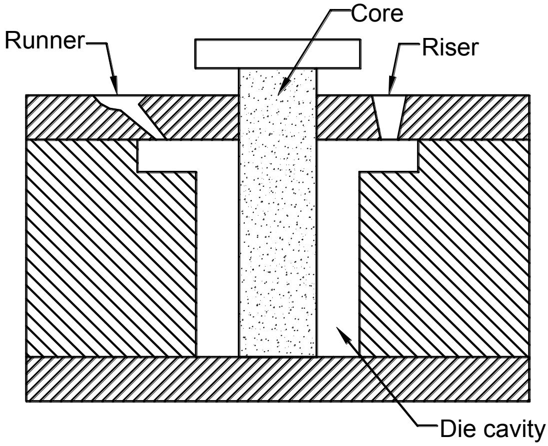


Fig.1.39 Gravity die casting

It is also called as permanent mould casting. Sand moulds are destroyed to obtain casting. The sand mould cannot be reused. So permanent moulds are used for producing large number of castings. Permanent mould is made by using heat resisting cast iron, alloy steel or graphite.

Permanent moulds are made of several parts for easy removal of castings. Pouring cup, runner and riser are provided in the upper part of mould. After placing the core, the parts of mould are assembled correctly. The mould or die cavity is coated with refractory material. When the molten metal is poured, it fills into the die due to the gravity. The core should be removed before the metal starts solidifying. After the metal is solidified, the die is split and the casting is removed.

Application

This method is used for producing carburetor body, hydraulic brake cylinder, etc.

Advantages

1) It is a fast process.
2) Closer dimensional accuracy can be achieved.
3) Good surface finish can be obtained.
4) Castings without defects can be obtained.
5) Less floor space is sufficient.
6) Production cost is less

Disadvantages

1) The cost of die is more.
2) It is not suitable for producing complicated castings.
3) Removal of casting is difficult.
4) It is suitable only for mass production.

1.13.3 Pressure die casting

When the molten metal is forced into a die under pressure for producing casting, it is called pressure die casting. The die is made of two parts. One part is stationary and the other is movable. The permanent mould made of metal is called die. This method is suitable for casting lead, magnesium, tin, zinc, brass, etc.

The two types of die casting are:

1) Hot chamber die casting
2) Cold chamber die casting

1) Hot chamber die casting

In this machine, heating chamber is provided for melting the metal. This chamber is heated by a burner. A goose neck vessel (injector) is submerged in the molten metal. A plunger is provided at the top of goose neck vessel. When the plunger moves upward, the molten metal flows into the vessel through a port.

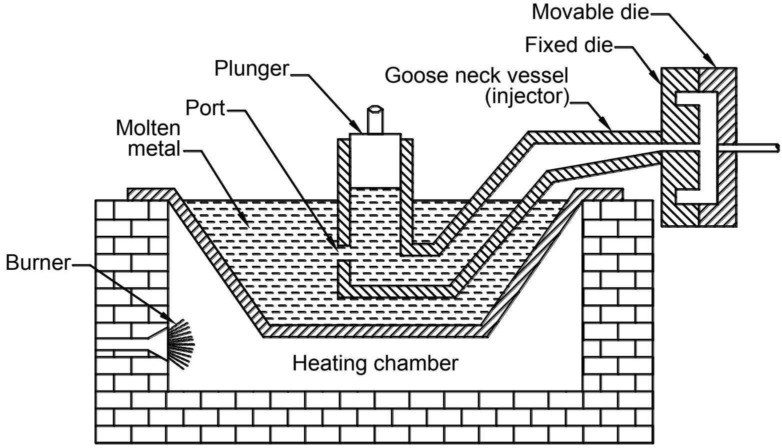


Fig.1.40 Hot chamber die casting

When the plunger moves downward, the molten metal is forced into the die under pressure (15 MN/m^2). As the die is water cooled, the molten metal will solidify immediately. Then the movable die is moved and the casting is removed by ejectors. The plunger and movable die are actuated hydraulically.

2) Cold chamber die casting

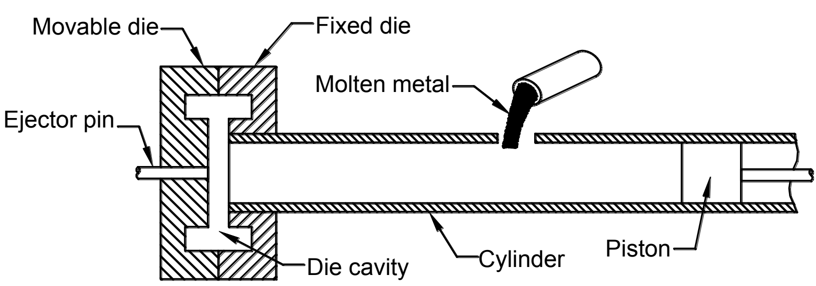


Fig.1.41 Cold chamber die casting

In this machine, heating chamber is not provided. The metal is melted separately in the furnace and brought to the machine by ladles. The horizontal plunger and movable die are actuated by hydraulic means. The molten metal is poured into the cylinder. When the plunger moves towards left, the molten metal is forced into the die under pressure. As the die is water cooled, the molten metal will solidify immediately. Then the movable die is moved and the casting is removed by ejectors.

Application of pressure die casting

Carburetor body, crank case, fuel pump parts, sound horn and wiper can be produced by pressure die casting. It can also be used for producing toys, cameras, clocks and washing machine parts.

Advantages of pressure die casting

1) Very high rate of production.
2) It is suitable for mass production.
3) Good surface finish can be obtained.
4) Very accurate castings can be produced.
5) The die has long life.
6) Less floor space is sufficient.
7) Thin castings can also be produced.
8) Casting defects are less.
9) Metal wastage is low.

Disadvantages

1) The cost of the die is high.
2) It is not suitable for large castings.
3) It is suitable only for mass production.

1.13.4 Centrifugal casting

In centrifugal casting, a rotating metal mould is mounted on a trolley. Rails are provided to move trolley. The molten metal is poured into the mould through a long spout. The mould is rotated as well as moved axially. Due to centrifugal force, the molten metal is thrown away from the centre and deposits uniformly on the walls of the mould. The outside of the mould is cooled by water. So the molten metal solidifies immediately.

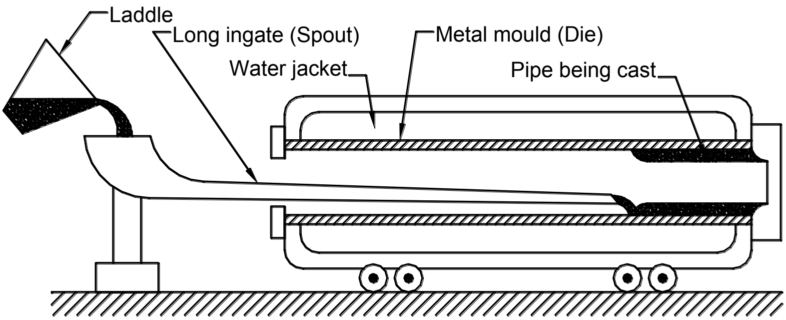


Fig.1.42 Centrifugal casting

The mould may be rotated about a horizontal axis or vertical axis. The casting is removed after splitting the mould. Hollow castings can be produced in this method without using core. This method is used for producing cylindrical and symmetrical castings.

Application

The castings like water pipes, gun barrels, fly wheel, bush bearings, gears, brake drum etc. are produced by centrifugal casting.

Advantages

1) High rate of production.
2) Closer dimensional accuracy can be obtained.
3) Thin castings can be produced.
4) Core is not required.
5) Casting defects are less.

Disadvantages

1) It is suitable only for symmetrical castings.
2) The cost of equipment is high.
3) Skilled labour is required.
4) Risk of accident is more.

1.13.5 Continuous casting (ASARCO Process)

In this process, castings are produced by pouring the molten metal continuously in to a vertical mould. The mould is made of brass or graphite. This method is suitable for brass, bronze, copper and aluminium.

The metal is melted in a furnace which is just above the mould. The molten metal continuously flows into the vertical mould (die) through a valve. The mould is water cooled. So the molten metal solidifies immediately. Two rollers are provided to pull the casting. A saw below the roller cuts the casting to pieces of required length.

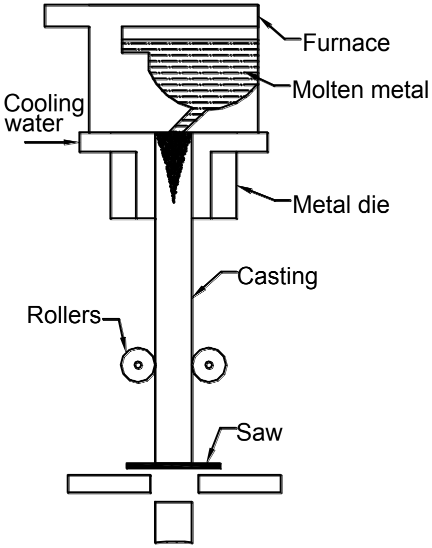


Fig.1.43 Continuous casting

Application

Large bars or rods having round, square and hexagonal cross section can be produced. Also, this method is used for producing pipes, slabs and flats.

Advantages

1) Good surface finish can be achieved.
2) As this process is automatic, rate of production is high.
3) Labour cost is less.

Disadvantages

1) The cost equipment and mould is high.
2) The cost of operation and maintenance is also high.

1.13.6 Chilled casting

Cooling a metal surface quickly is called chilling. This gives a hard and wear resistant surface. Chills (small metal chips) are placed in the mould to cool the surface rapidly. Chills are placed on the outside of the mould where the surface of the casting are to be hardened.

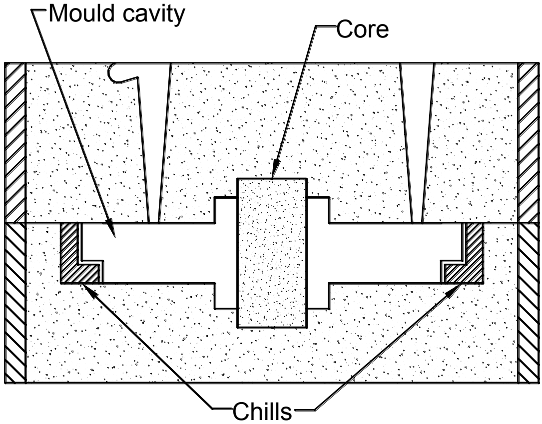


Fig.1.44 Chilled casting

The molten metal around the chill cools faster. Due to the rapid cooling, the free carbon in casting becomes hard iron carbide. Core chills are placed in the mould for hardening the inner surface of casting.

Application

This method is used for producing railway brake shoes, wheel rims, crusher jaws, machine slide ways, etc.

1.13.7 Malleable casting

Hard castings cannot be easily machined. The toughness and strength of such castings are poor. To improve these properties, annealing should be done. This gives soft casting. The castings are placed in steel box and filled with sand. They are heated to about 900°C and maintained at the same temperature for 3 to 4 days. Then they are slowly cooled to room temperature at the rate of 10°C per hour. During this annealing process, iron carbide in the casting becomes free carbon. These are called malleable castings. They have high tensile strength and good machinability.

Application

Malleable casting is used for producing wagon wheel hub, door hinges, pipe fittings, locks, levers, cranks, and textile machine parts.

1.13.8 Shell mould casting

Shell mould casting is the modification of sand casting in which a relatively thin shell forms the mould cavity. It is used for producing precise castings which are not required for further machining.

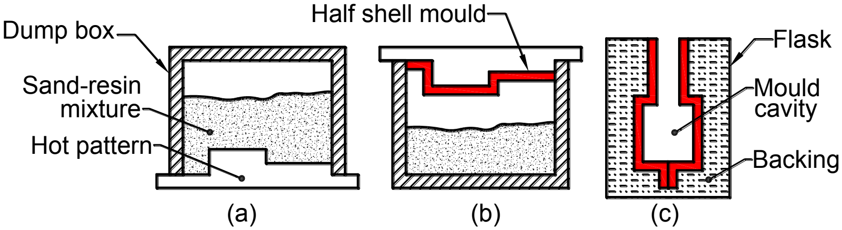


Fig.1.45 Shell mould casting

The mould material (investing material) consist of phenolic-resin mixed with dry silica sand in the presence of alcohol. The pattern material is made of grey cast iron, aluminium or brass. It is machined accurately with good surface finish.

The shell mould casting process involves the following steps :

1) The pattern is heated to about 200 – 300°C.
2) Silica sand and resin mixture is dumped over the pattern surface.
3) The resin is melted and hardened due the heat on the pattern surface. The resin binds the sand grains very closely and firmly within 20 – 30 seconds over the pattern. This time duration is called dwell time.
4) Now a layer of sand-resin mixture adheres to the pattern. Thus a shell of about 6 mm thickness is formed. The thickness of shell is controlled by dwelling time. The thickness depends upon the weight of molten metal to be poured into the shell cavity.

5) The dump box is then rotated upside down so that the loose and unaffected sand grains to fall down.

6) The shell mould with pattern is then heated in an oven to about 250 – 350^{o}C for 15 – 60 seconds. This time is called curing time. Now the shell mould becomes rigid.

7) Then the pattern is ejected by means of ejector pins mounted on the pattern.

8) Now one-half of the mould is prepared. The second half is also prepared in the similar way. The two halves are clamped to make a complete shell mould cavity.

9) The molten metal is poured into the mould cavity and allowed to cool.

10) After solidification, the shells are broken up and the castings is separated.

Applications

Shell mould casting process is used to produce mechanical parts that require high levels of precision, such as cylinder head, connecting rods, gear housings, brake drums, cams, cam shafts, pistons, piston rings, engine block water jackets, etc.

Advantages

1) A high precise castings is produced.
2) A very smooth surface finish can be obtained.
3) The cost for cleaning and machining is reduced.
4) The production rate is high.
5) The moulds can be stored until required.
6) Complex shapes can be produced easily.
7) Less skilled labour is required.
8) The process can be automated easily.

Disadvantages

1) The cost of metal patterns and other equipment is high.
2) The resin binder is more expensive than other binders.
3) The size of casting is limited.
4) It is suitable only for specific metals.

1.13.9 Investment casting

The investment casting process is also known as precision casting process or lost wax casting process. The term investment refers to the layer of refractory material covering the pattern while making the mould. The castings produced by this method have very smooth surfaces and high dimensional accuracy.

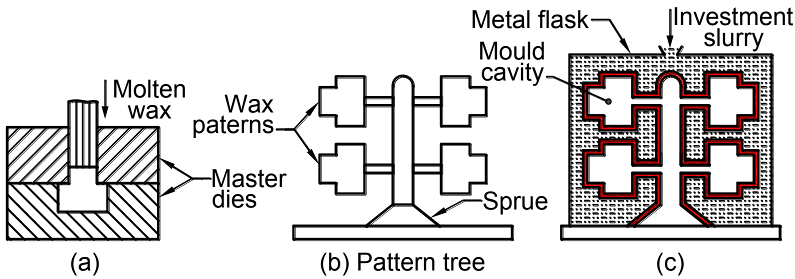


Fig.1.46 Investment casting

The investment casting process involves the following steps :

1) The master dies in the form of pattern are made from metal by machining the cavities.

2) The two hales of the master die are clamped together. The molten wax or plastic is injected into the die cavity under pressure. After solidification the pattern is removed from the die.

3) A number of small wax patterns are assembled together to a wax gating system with a central sprue. This assembly is called pattern tree. This increases the process productivity.

4) The pattern tree is dipped into investment slurry. The slurry is made by mixing fine silica sand with ethyl silicate or gypsum solution. After the primary coating is dried, a final investment layer of less expensive slurry is applied around the patterns.

5) The finished mould is dried in air and heated to a temperature of 90°C to 150°C. The wax patterns melt and run out of the sprue. Thus mould cavities are formed.

6) Then the molten metal is poured into the mould cavities. After the metal is solidified, the mould is broken up and casting is removed.

Advantages

1) High dimensional accuracy can be obtained.
2) Extremely smooth surface finish can be obtained.
3) Intricate details can be produced.
4) More than one castings can be made at a time.
5) Castings of non-machinable alloys can be produced.
6) Undercut and other complex shapes can be made.

Disadvantages

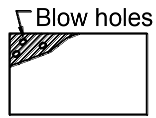
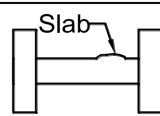
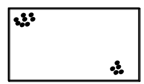
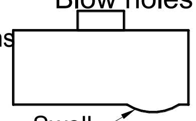
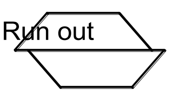
1) The process is expensive.
2) Not suitable for large size castings.
3) The mould cannot be reused.
4) Use and location of holes in the mould is difficult.

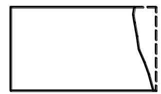
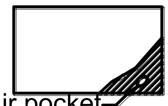
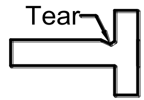
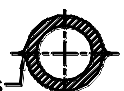
Applications

Investment casting process is used to produce the following :

- Costume Jewellery.
- Parts for computers and electronics equipment.
- Parts for aerospace industry, machine tools and accessories.
- Nozzles, buckets, vanes and blades for gas turbines.
- Radar wave guides, etc.

1.14 Defects in castings – causes and remedies

Defect		Causes	Remedies
1) Blow holes: Holes produced in the castings when the steam and gases are not come out.		**1.** Excessive moisture in the sand. **2.** Hard ramming. **3.** Less number of vent holes	**1.** Moisture content in the sand should be controlled. **2.** Ramming should be done properly. **3.** Sufficient vent holes should be provided.
2) Slabs: Unwanted projections in the casting		**1.** Uneven ramming. **2.** Dropping down of part of mould	**1.** Ramming should be done properly. **2.** The molten metal should be poured slowly.
3) Honey combing: Small cavities on the surface of casting.		**1.** Improper pouring of molten metal. **2.** Faulty gating.	**1.** The molten metal should be poured properly. **2.** Correct gating should be provided.
4) Swells: Enlargement of casting surface.		**1.** Slow ramming. **2.** Pouring the metal very quickly. **3.** Mould no supported properly.	**1.** Ramming should be done correctly. **2.** The metal should be poured properly. **3.** Sufficient support should be provided for mould.
5) Shifts: Misalignment of casting sections.		**1.** Misalignment of pattern pieces. **2.** Misalignment of cope and drag boxes. **3.** Misalignment of core.	**1.** Pattern pieces should be aligned properly. **2.** Drag and cope boxes should be placed correctly. **3.** The core should be seated at the correct place.

Defect		Causes Swab	Remedies
6) Cold shuts: Incomplete filling of mould cavity.		1. Pouring the metal at low temperature. Tear 2. Improper gating. 3. Pouring the metal slowly. Air pocket	1. The metal should be poured at correct temperature. 2. Proper gating should be provided. 3. The metal should be poured properly.
7) Internal air pockets: Small holes inside the casting. Fins		1. Pouring the boiling metal. 2. Pouring the metal very quickly.	1. The metal should be poured at correct temperature. 2. The metal should be poured properly.
8) Hot tears: Internal or external dis-continuity in the casting.	Run out 	1. Sudden change in section of casting. 2. No fillets in the corners. 3. Pouring the metal at low temperature.	1. The pattern design should be improved. 2. Fillets should be provided at the corners. 3. The metal should be poured at correct temperature.
9) Fins: Thin projection on parting line.		1. Misalignment of core in the mould. 2. Improper clamping of moulding box.	1. The core should be correctly placed. 2. The moulding box should be clamped correctly.
10) Run out: Leakage of metal from the mould.		1. Faulty moulding. 2. Faulty moulding box. 3. Pattern too large for the box.	1. The moulding should be done properly. 2. The correct size moulding box should be used. 3. The suitable size pattern should be used.

Review Questions

5 marks questions

1) State the various factors considered for selecting the pattern materials.
2) List out the various types of pattern and explain any two of them.
3) Name the common pattern materials and state their advantages.
4) State the different pattern allowances used while making patterns and explain the needs.
5) Classify the moulding sand.
6) State the properties of moulding sand.
7) Briefly explain the sand additives used in moulding.
8) How the mould sand is prepared?
9) Describe any four moulding tools with sketches.
10) Briefly explain various types of moulding boxes.
11) What are the ingredients of moulding sand? State the purpose of using each.
12) Define moulding and casting.
13) Briefly explain the various types of moulds.
14) List out the methods of moulding.
15) What is loam moulding?
16) What is core? State the function of a core print?
17) What are the requirements of a good core?
18) Describe the various types of core boxes used.
19) Describe the CO_2 process of core making.
20) Describe the different types of cores used.
21) Briefly explain pressure die casting.
22) Describe briefly the hot chamber die casting.
23) State the advantages of die casting.
24) Describe briefly the centrifugal casting.
25) Describe briefly the chilled casting.
26) Describe briefly the malleable casting process.

10 marks questions

1) Enumerate the properties of moulding sand and explain any five of it in detail.
2) With neat sketches describe the uses of different tools used in moulding.
3) With suitable sketches, describe the step by step procedure of making a green sand mould using a split pattern.
4) Explain the complete procedure of dry sand moulding with an example.
5) State the different machine moulding process. Explain any one.
6) Briefly explain the following: a) Core sands b) Core binders
7) Briefly explain the procedure for core making.
8) Describe the iron – carbon equilibrium diagram with simple sketch.
9) Explain the construction and working of blast furnace with neat sketch.
10) Draw a simple cross section view of a cupola and explain briefly the operation of cupola.
11) Explain the construction and working of any one type of crucible furnace.
12) Sketch and explain the operation of induction furnace. State its advantages.
13) Describe the process of die casting with a neat sketch.
14) Describe the cold chamber die casting process with a neat sketch.
15) With a neat diagram explain any one method of centrifugal casting process. State the advantages and applications of centrifugal casting.
16) Describe continuous casting process with a neat sketch.
17) Explain the process of shell mould casting with neat sketch.
18) Describe the investment casting process with a neat sketch.
19) What are the defects that occur in castings? State their causes and remedies.

Unit – II

WELDING TECHNOLOGY

2.1 Welding

Welding is the process of joining similar or different metal by heating. Welding can be done with or without the application of pressure. It can be done with or without the addition of filler metal. During welding, the edges of metal pieces are either melted or brought to plastic stage. Welding gives a permanent joint. Welding is used in the fabrication of automobile bodies, air craft, machine frames, boilers, ship building, railway wagons, etc.

2.1.1 Types of welding

The following are the two types of welding processes.

1) Plastic welding or pressure welding,
2) Fusion welding or non – pressure welding.

Plastic welding or pressure welding

In this type of welding, the metal pieces are heated to plastic stage and joined by applying sufficient pressure.

Example : Electric resistance welding.

Fusion welding

In this type of welding, the metal pieces are melted and joined with the help of filler material without applying pressure.

Example : Electric arc welding, gas welding.

2.2 Arc welding or metal arc welding

Arc welding is the process of joining two work pieces by melting their edges by an electric arc. An electric arc is produced when there is a small air gap (2 to 4 mm) between two conductors. The work piece acts as one conductor and the electrode acts as another conductor. When the current is passed, an electric arc having temperature 4000°C to 7000°C is produced between the work piece and electrode. The edges of work pieces and the electrode are melted by this high temperature.

WELDING

- **Arc welding**
  1. Carbon arc
  2. Metal arc
  3. Metal inert gas
  4. Tungsten inert gas
  5. Atomic hydrogen arc
  6. Plasma arc
  7. Submerged arc
  8. Electro slag
- **Gas welding**
  1. Oxy-acetylene
  2. Air- acetylene
  3. Oxy-hydrogen
- **Resistance welding**
  1. Butt
  2. Spot
  3. Seam
  4. Projection
  5. Percussion
- **Related processes**
  1. Oxygen cutting
  2. Flame cutting
  3. Arc cutting
  4. Hard facing
  5. Bronze welding
  6. Soldering
  7. Brazing
- **Thermit welding**
- **Solid state welding**
  1. Friction
  2. Ultrasonic
  3. Diffusion
  4. Explosive
- **Modern Welding**
  1. Electron beam
  2. Laser beam

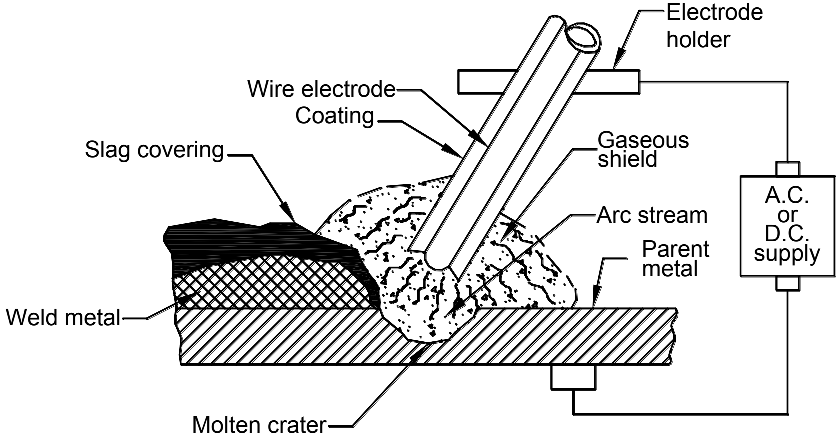


Fig.2.1 Arc welding

The melted metal pieces are joined together and cooled to give permanent joint (weld). The electrode supplies additional filler material into the joint. The current is supplied by a transformer or a generator.

2.2.1 Arc welding equipments

The following equipments are needed for arc welding.

1) Welding generator(D.C) or transformer(A.C)
2) Electrode holder
3) Electrode
4) Welding cables
5) Earthing clamps
6) Protective shield
7) Gloves
8) Apron
9) Chipping hammer
10) Wire brush

Power sources : D.C arc welding machines are D.C. generators driven by an electric motor. D.C welding is mostly used for heavy work. A.C. welding machines are transformers for stepping down the main supply voltage and current suitable for arc welding. A.C. welding sets are used for all types of fabrication works.

Electrode holder : The electrode holder connects to the welding cable and conducts the welding current to the electrode. The insulated handle is used to guide the electrode over the weld joint. Electrode holders are available in different sizes.

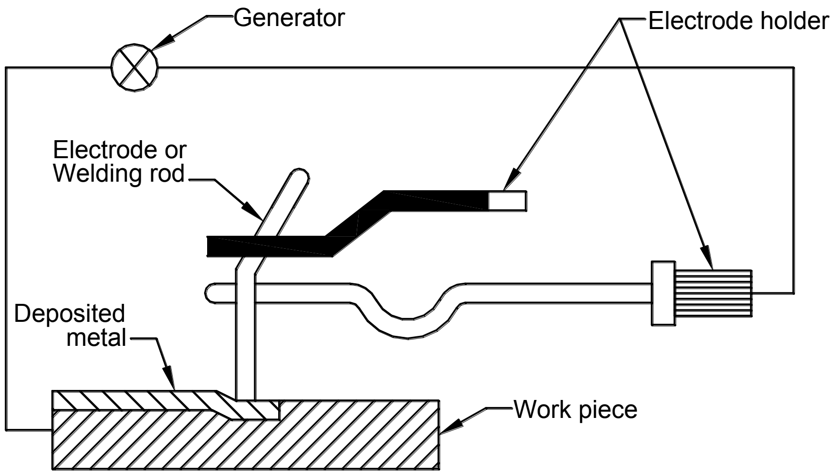


Fig.2.2 Arc welding equipments

Electrodes : In arc welding, an electrode is used to conduct current through a workpiece to fuse two pieces together. Depending upon the process, the electrode is either consumable or non-consumable. Bare, fluxed and heavy coated electrodes are the common types of electrodes.

Welding cables : The cables must be very flexible and have a tough heat-resistant insulation. Cable connections must be soldered or well crimped to assure low electrical resistance. The thickness of the cable must be sufficient to carry the welding current with a minimum of voltage drop.

Earthing clamp : The Earthing clamp is used to connect the earth cable to the work piece. It may be connected directly to the work or to the table upon which the work is positioned.

Safety equipment : Safety equipments like protective shield, gloves and apron are used to protect from ultraviolet and infrared radiations.

Cleaning equipment : Wire brush is used to clean the surface of workpiece. Chipping hammer is used to remove the weld beads after welding.

2.2.2 Types of electrodes

Generally, welding electrodes are classified as follows :

i) Non-consumable electrodes

ii) Consumable electrodes.

✦ *Non-consumable electrodes* are made of carbon, graphite or tungsten. As the electrodes are not consumed during welding, the filler material is added separately. They are used in TIG and atomic hydrogen welding.

✦ *Consumable electrodes* provide the filler material also. During welding, they melt and supply the filler material. The following types of consumable electrodes are available.

1) ***Bare electrodes:*** They are not coated with flux.
2) ***Lightly coated electrodes:*** A light layer of flux is coated on the electrodes.
3) ***Heavily coated electrodes:*** Flux is coated on the electrodes to a thickness of 1 mm to 3 mm.

2.2.3 Functions of flux

The functions of flux coating in electrodes are :

1) It provides a protective gaseous atmosphere to prevent the molten metal to react with oxygen and nitrogen in the air.
2) It provides a protective slag over hot metal to prevent from rapid cooling.
3) It removes oxides and other impurities from the molten metal.
4) It reduces spatter of weld metal.
5) It acts as deoxidizer.
6) It increases the deposition efficiency.

2.2.4 Filler and flux materials

Filler materials

In arc welding, the filler material melts at the high temperature and fills the gap between the base metals. The filler material may be made of various metals, but it should have same composition as the base metals. The consumable electrode provides the filler material also.

Flux materials

The commonly used flux materials are :

- ✦ *Slag forming ingredients :* Asbestos, mica, silica, fluorspar, titanium dioxide, magnesium carbonate, calcium carbonate, etc.
- ✦ *Arc stabilising ingredients :* Potassium silicate, calcium oxide, magnesium oxide, feldspar, etc.
- ✦ *Deoxidizing ingredients :* Cellulose, dolo-mite, starch, dextrin, wood flour, graphite, aluminium, etc.
- ✦ *Binding materials :* Sodium silicate, pottasium silicate, etc.

2.3 Arc welding methods

The commonly used arc welding methods are :

1) Metal arc welding
2) Metal Inert Gas (MIG) welding
3) Tungsten Inert Gas (TIG) Welding
4) Submerged arc welding
5) Electro slag welding

2.3.1 Metal arc welding

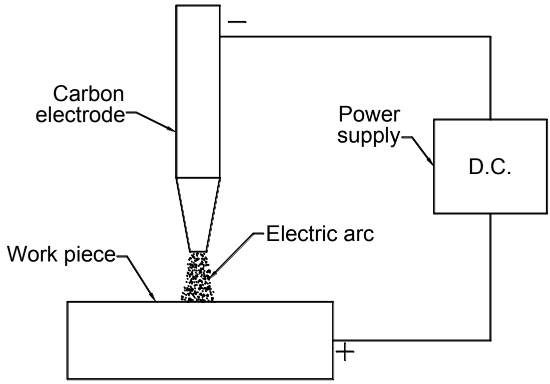


Fig.2.3 Carbon arc welding

In this method, welding is done by using carbon electrode and D.C. power supply. The electrode is connected to negative (-ve) terminal and work piece is connected to positive (+ve) terminal. When the D.C. supply is given, the work piece is heated more than the electrode by the electric arc. So the edges of work pieces are heated and joined together. Then it is cooled to form weld.

Application

Steel sheets, copper alloys, brass, aluminium and bronze can be welded by this method.

Advantages

1) Both ferrous and non-ferrous metals can be welded.
2) The temperature can be controlled easily.
3) Production of electric arc is very easy.

2.3.2 Metal Inert Gas (MIG) Welding

In this type of arc welding, the consumable electrode is supplied continuously. This electrode is used as filler metal and to produce arc. When D.C. supply is given, an electric arc is produced between the consumable electrode and the work piece. An inert gas like argon or helium is passed at the welding place through nozzle. The inert gas produces a gas shield around the electric arc. This prevents the molten metal to react with atmospheric air. The edges of the work pieces are melted by the electric arc and joined together to give weld.

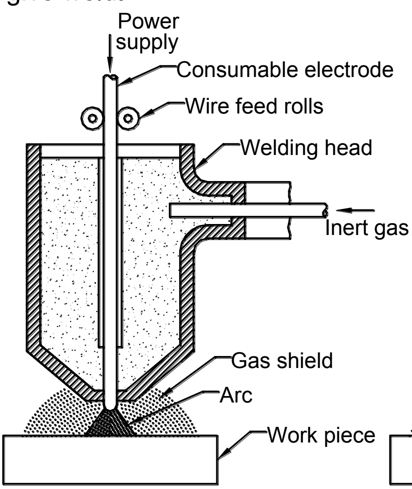


Fig.2.4 MIG welding

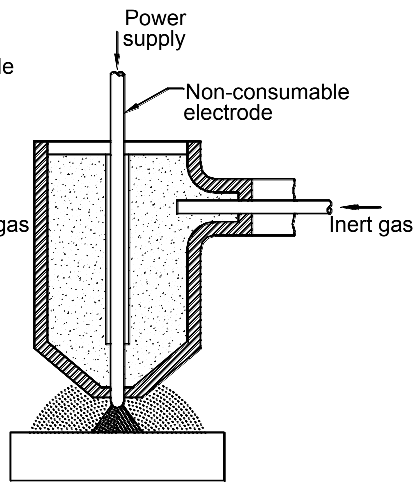


Fig.2.5 TIG welding

Application

Aluminium, stainless steel, magnesium and nickel alloys can be welded by this method.

Advantages

1) No flux is needed.
2) Welding speed is high.
3) Quality welding joint can be obtained.
4) Non-ferrous metals can also be welded.

2.3.3 Tungsten Inert Gas (TIG) Welding

This method is similar to MIG welding. Non-consumable tungsten electrode is used. It produces only electric arc. It cannot be used as filler metal. The tungsten electrode is fixed in an electrode holder. When power supply is given, an electric arc is produced between the tungsten electrode and the work piece. An inert gas like argon or helium is passed at the welding place through a nozzle. The inert gas produces a gas shield around the electric arc. This prevents the molten metal to react with atmospheric air. The edges of work pieces are melted by the electric arc and joined together to give weld. The electrode will not be melted during welding.

Application

Aluminium, cast iron, steel and magnesium can be welded by this method.

Advantages

1) No flux is needed.
2) Welding speed is high.
3) Quality welding joint can be obtained.
4) Both ferrous and non-ferrous metal can be welded.

2.3.4 Submerged arc welding

In this type of arc welding, a bare electrode is continuously supplied. An electric arc is produced between the electrode and the work piece. Flux powder is continuously supplied in front of the welding area. The arc, molten metal and the end of the electrode are completely submerged by the flux powder. So the arc and welding cannot be seen. This prevents the molten metal to react with atmospheric air and gives defects free weld. The fused flux forms slag with the impurities and deposits on the weld. So the metal is cooled slowly to form welded joint. Electrode and flux are continuously supplied by an automatic mechanism.

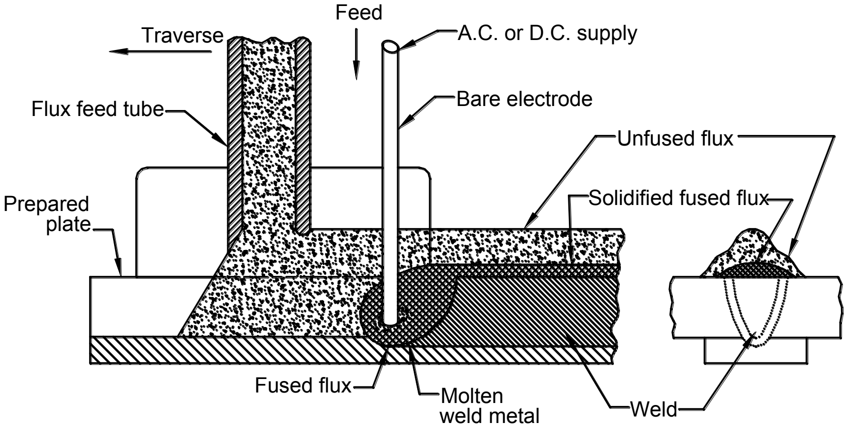


Fig.2.6 Submerged arc welding

Application

It is used for welding low carbon steel and alloy steel. It is also used for welding in fabrication of pressure vessel and boiler.

Advantages

1) Welding speed is high.
2) Good quality welding joint is obtained.
3) Work pieces with more thickness and length can be easily welded.
4) It is a safe process.

Disadvantages

1) It is difficult to guide the electrode as the weld cannot be seen.
2) It cannot be used for welding in vertical and inclined position.

2.3.5 Electro slag welding

Electro slag welding is a process of joining two thick metal plates by the heat generated when electric current is passed through molten slag. The work pieces to be welded are held on the bottom plate with uniform gap between them and tack welded. Two sliding plates are fitted on both sides of the work pieces. The flux is filled in the gap between the work pieces and the sliding plates. The electrode is held in this gap.

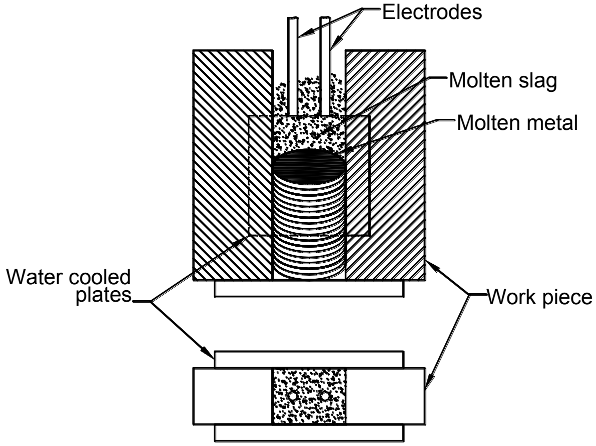


Fig.2.7 Electro slag welding

When the power supply is given to the work piece and electrode, an electric arc is produced between the flux and electrode. The flux melts and a slag of 2 to 3 mm thick is formed. Then the arc stops. Now the current passes from the electrode to the work piece directly through the slag. The slag gives high resistance to the current. This produces high heat (1900^{o}C).

The electrode and the edges of work pieces are melted by this heat and then weld is formed. The electrode and the slides are moved upwards at a specified speed by a driving mechanism. The slag always remains at the top of the molten metal and prevents the atmospheric reaction.

Application

Boiler plate, turbine shaft, stainless steel and carbon steel can be welded by this method.

Advantages

1) Welding speed is high.
2) No edge preparation is needed.
3) Weld without pores can be obtained.
4) Thick plates can be welded in single pass.
5) Strong welding joint can be obtained.

Disadvantages

1) It is not suitable for welding thin metals.
2) Butt welding only can be done.

2.4 Resistance welding

In resistance welding, the metal is heated to plastic stage due to the heat generated by the electric resistance. Then weld is formed by applying pressure. Two copper electrodes are connected to an A.C, transformer. The metal to be welded are held in between the electrodes. When the current is passed, very high resistance is developed at the metal joint. The metals are heated to plastic stage due to the heat generated by this resistance. The mechanical, air or hydraulic pressure is applied to form weld.

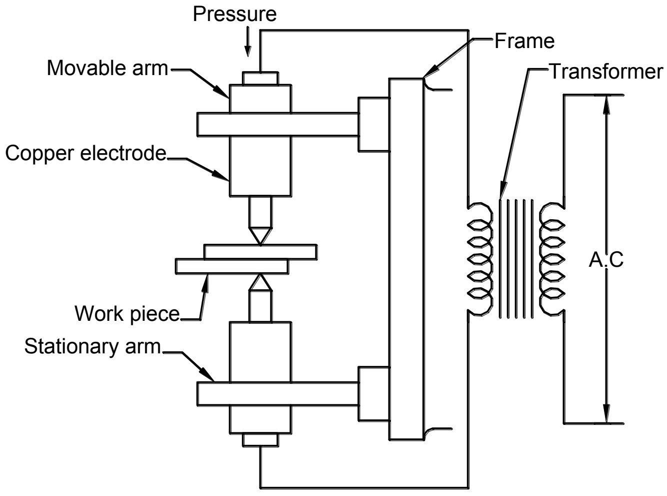


Fig.2.8 Resistance welding

Application

It is suitable for mass production. Sheet metals, wires, tubes, bars, boxes, cans and frames can be welded by this method.

The following are the types of resistance welding.

1) Spot welding 2) Butt welding
3) Seam welding 4) Projection welding

2.4.1 Spot welding

It is a type of resistance welding. Spot welding is the process of joining overlapping sheet metals by making weld at regular interval. The work pieces are held between two copper electrodes. The lower electrode is fixed and the upper electrode is movable. Low voltage and high ampere current is passed through the electrodes. High heat is generated due to the resistance developed at the place of contact of electrode and work piece. This place becomes plastic stage. Then pressure is given by the electrode to form strong weld. By this method, welding is done on the work piece at regular intervals.

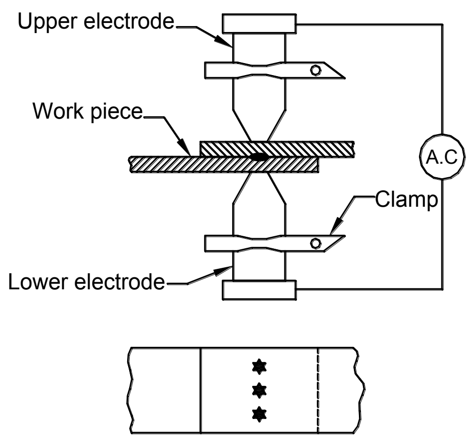


Fig.2.9 Spot welding

Application

Boxes, cans, automobile frames and air conditioners can be welded by spot welding. Spot welding can be done on the metal sheets of thickness up to 12 mm.

2.4.2 Butt welding

It is a type of resistance welding. There are two types of butt welding. They are upset butt welding and flash butt welding.

1) Upset butt welding

In this method, the metals to be welded are clamped in copper jaws so that there is a light contact at the ends of metals. When the current is passed through the jaws, high resistance is developed at the contact. This produces high heat and the ends of metal becomes plastic stage. When pressure is given by moving the jaws, the ends of metals are upset and strong weld is formed.

Application

Bar, rod, wire, tube and pipe can be welded by this method.

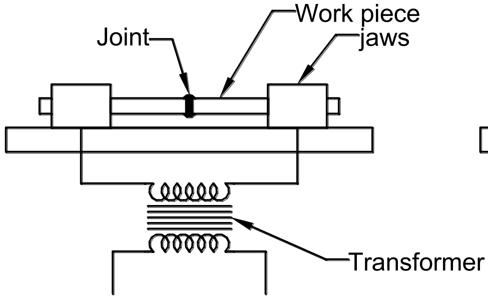


Fig.2.10 Upset butt welding

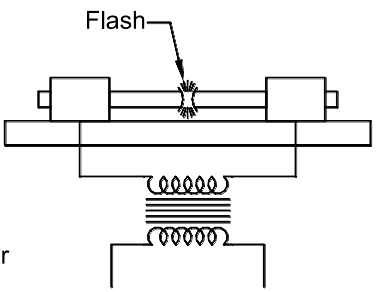


Fig.2.11 Flash butt welding

2) Flash butt welding

In this method, the metals to be welded are clamped in jaws so that there is a small air gap between the ends of metals. When the current is passed through the jaws, a flash or arc is produced between the ends. The ends become plastic state due to the temperature of arc. When pressure is given by moving the jaws, the ends of metals are joined and strong weld is formed. There is no welding rod, gas or flux is needed for this welding.

Application

Flash butt welding is used for welding automobile body, axles and frames.

Advantages

1) It is a fast process.
2) The cost is less.
3) Different metals can be welded.

2.4.3 Seam welding

It is a type of resistance welding. Seam welding is a process of making weld continuously between two overlapping sheet metals. The work pieces are held between two rotating wheel electrodes.

When the current is passed through the electrodes, high heat is produced on the work piece due to the resistance developed. At the same time, pressure is applied by the wheels to form continuous weld in a straight line.

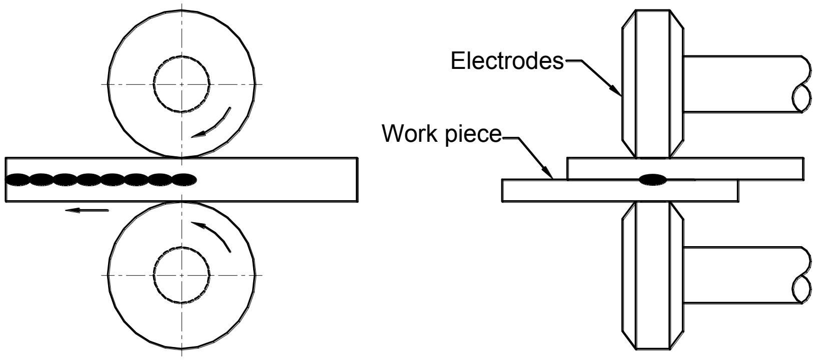


Fig.2.12 Seam welding

Application

Seam welding is used for welding radiators, drums, leak proof tanks, automobile silencers, etc.

2.5 Plasma arc welding

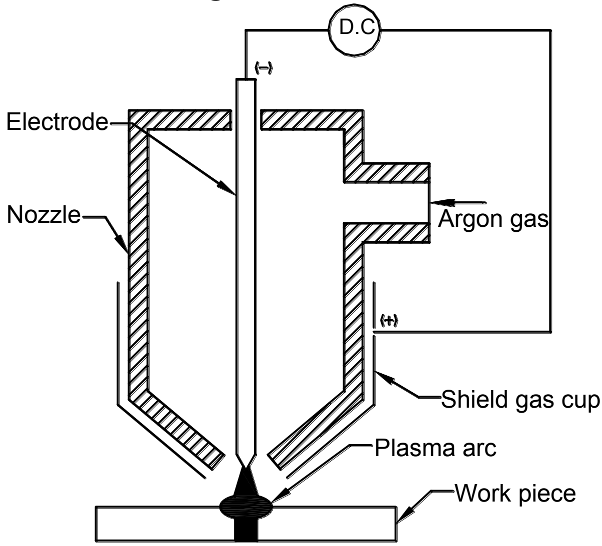


Fig.2.13 Plasma arc welding

In this method, the high heat produced by an ionized gas jet called plasma is used for joining work pieces together. This equipment has gas chamber with a copper nozzle at the bottom. It is cooled by water.

A tungsten electrode is held vertically in the gas chamber. The nozzle is connected to positive terminal and the electrode is connected to negative terminal of D.C. supply. When power supply is given, an electric arc is produced between the nozzle and the electrode. Argon gas is supplied through the nozzle. The gas gets ionized due to the temperature of electric arc. This ionized gas is called plasma.

The high temperature (1400°C) plasma is directed on the work piece for melting and to form weld. Another inert gas (helium) supplied around the nozzle produces gas shield. This prevents the molten metal to react with atmospheric air.

Application

Stainless steel, carbon steel, monel metal, titanium, copper, brass, etc. can be welded by this method.

Advantages

1) All metals can be welded by this method.
2) No filler rod is needed.
3) Welding speed is high.
4) Work pieces with more thickness can also be welded.
5) High quality welding joint can be obtained.

Disadvantages

1) Automatic control is necessary.
2) It is not suitable for welding short lengths.
3) The ultra violet and infra red radiations produced by the plasma will affect the health of operator.
4) Initial cost is high.

2.6 Thermit welding

It is a non-pressure welding. In this method, welding is done by pouring molten thermit steel around the parts to be welded. Thermit steel is a mixture of aluminium powder and iron oxide (1:3). The mixture is placed in a crucible and barium peroxide is added with it. When the mixture is ignited, thermit reaction takes place. This gives a molten thermit steel of 300ºC within 30 seconds.

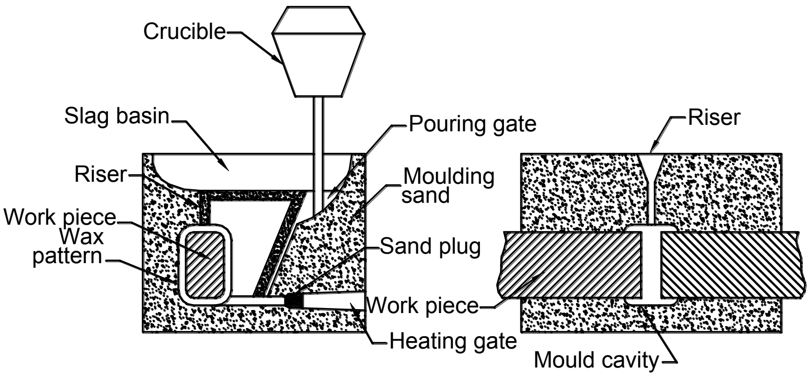


Fig.2.14 Thermit welding

The work piece to be joined are kept in a moulding box and wax pattern is placed between them. Moulding sand is filled and rammed around the wax pattern. Runner, riser and preheating gate are made. When a flame is introduced through the preheating gate, the wax pattern is melted and a mould cavity is formed. Then the preheating gate is closed by a sand core. The liquid thermit steel from the crucible is poured into the mould cavity between the work pieces. The molten metal is slowly cooled to form a strong weld.

Application

Thermit welding is used for joining heavy parts, rails, pipes, shafts, cables and worn out machine frames.

Advantages

1) It is very portable process.
2) Low set-up cost.
3) High skill is not required.
4) No external power is needed.
5) Thick sections can be welded.

Disadvantages

1) Low deposition rate.
2) Metals with low melting point cannot be welded.
3) Thin metals cannot be joined.
4) High level of fume.
5) It has slag inclusion.

2.7 Electron beam welding

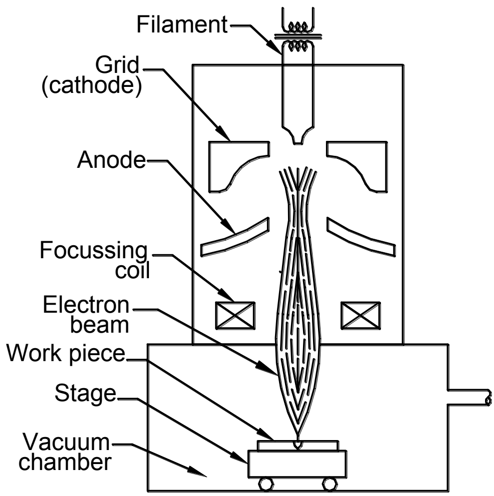


Fig.2.15 Electron beam welding

In this method, welding is done by the heat produced when the high velocity electron beams are focused on the object. Free electrons are released when a tungsten filament is heated to hig temperature (up to 2000ºC) in a high vacuum chamber by a high voltage current. The electrons are converted into a beam (0.25 mm to 1 mm dia.) by means of a control grid, anode and focusing coils. This beam is focused on the work piece to be welded. The kinetic energy of electron beam is converted into heat energy. The work piece is melted due to the high temperature (about 2500ºC) and weld is formed.

Generally electron beam welding is done in a vacuum chamber. So oxidation is prevented and high quality weld is obtained.

Application

1) It is used for welding automobile and aero plane parts.
2) It is used for welding high temperature metals like tungsten, molybdenum and tantalum.
3) Pressure vessel and turbine parts can be welded.

Advantages

1) Dissimilar metals can be welded.
2) Thin and heavy work pieces can be welded.
3) It is a fast process.
4) No distortion occurs.
5) Good quality weld can be obtained.
6) The temperature can be controlled easily.

Disadvantages

1) The cost of equipment is high.
2) High skilled labour is needed.
3) The size of the work piece is restricted as the welding is done in a vacuum chamber.

2.8 Laser beam welding

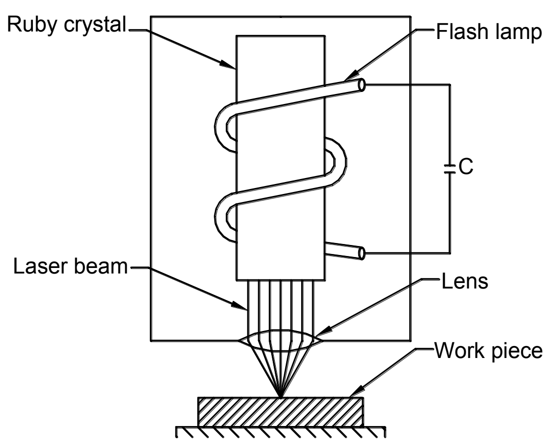


Fig.2.16 Laser beam welding

In this method, welding is done using the heat generated by a laser beam. LASER means Light Amplification by Stimulated Emission of Radiation. It is a beam of light having a single wave length. When this beam is focused at a very small spot on the work piece, high heat is produced and the metal gets welded.

The equipment has a ruby crystal. This crystal is held inside a 1000W flash lamp coil. Xenon gas is filled in the flash lamp. When power supply is given, the flash lamp gives out high intensity light. The ruby crystal is stimulated by this light and emits the laser beams. The beam is focused on the required spot in the work piece. This spot is melted by the high heat and welded. This process is controlled automatically. The diameter of laser beam is about 0.005 mm. It is possible to make weld with a micron size diameter. So it is also called as micro welding.

Application

1) It is used for making weld in aerospace and electronic industries.
2) Nickel, copper, titanium, zirconium and silver can be welded.
3) Object which is sealed in a glass container can also be welded.
4) It is also used for welding glass, plastic and quartz.

Advantages

1) The temperature can be controlled easily.
2) Welding can be accurately done.
3) No distortion occurs.
4) Heat treated components can be welded without affecting its properties.
5) The weld is not affected by oxidation.

Disadvantages

1) The cost of equipment is high.
2) High skilled labour is needed.
3) The power consumption is more.

2.9 Friction welding

In this method, welding is done by the heat developed due to the mechanical friction between two surfaces. The cylindrical work pieces to be joined are aligned axially. One part is fitted stationary in a fixture. Another part is fitted in a chuck and rotated at high speed (12000 rpm). The rotating part is axially moved to touch the another part. Welding takes place by the high heat developed due to the friction between the two surfaces. Now the rotation of work piece is stopped. The same pressure is maintained until the welding is completed.

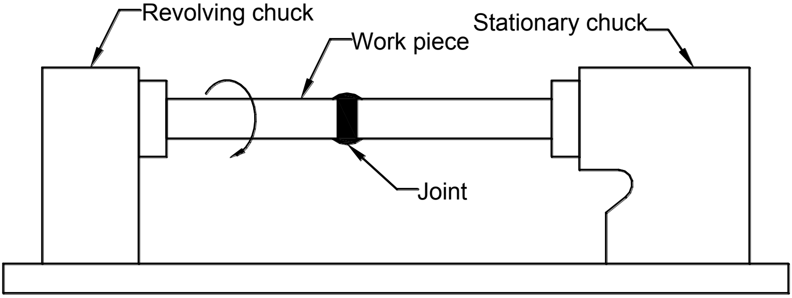


Fig.2.17 Friction welding

Application

Friction welding is used for welding aero engine parts and gas turbine shafts. It is also used for welding pinions to shafts, rods to yokes, flanges to pipes, etc.

Advantages

1) The initial cost is low.
2) Dissimilar metals can be welded.
3) It is a simple and fast process.
4) High quality weld can be obtained.
5) The power consumption is less.
6) The distortion is less.

Disadvantages

1) It is only suitable for circular butt weld.
2) The welded work piece should be finished.

2.10 Ultrasonic welding

In this method, welding is done by applying light pressure and high frequency vibrations. A frequency converter converts the low frequency (50Hz) current into high frequency current (20000Hz). This current passes to the transducer. The transducer converts the high frequency current into mechanical vibrations (ultrasonic vibrations). These vibrations are transmitted to the welding tip through a coupling system. The parts to be welded are held in close contact between welding tip and anvil by applying light pressure. When power supply is given, the welding tip vibrates and heats the parts to be welded. After reaching plastic stage, the parts are welded due to the inter atomic bond.

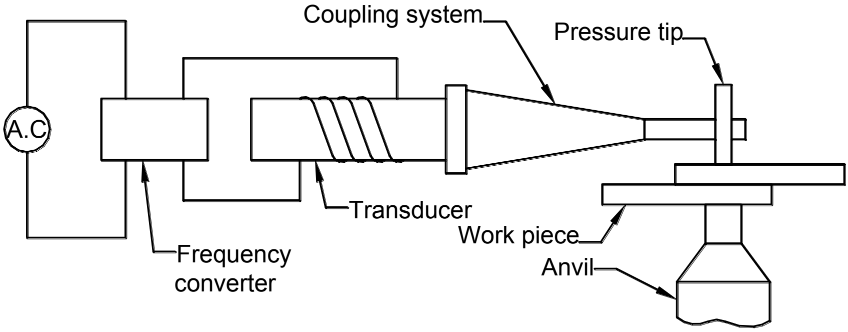


Fig.2.18 Ultrasonic welding

Application

1) It is used for welding metals up to 3 mm thick.
2) Thin sheets can be joined with thick sheets.
3) Electrical and electronic components can be welded.
4) Plastic components can also be joined.
5) It is used for welding in nuclear reactor and aircraft parts.

Advantages

1) Dissimilar metals can be welded easily.
2) It is a fast process.
3) No distortion occurs.
4) Filler rod and flux are not needed.
5) Non-metals can also be joined.

Disadvantages

1) The cost of equipment is high.
2) It is not suitable for welding thick metals.

2.11 Induction welding

Induction welding is a welding process in which an electromagnetic induction is used to heat the parts to be welded. An induction coil is placed around the edges of the workpieces to be joined. A high frequency current is passed through the coil. This current generates a high frequency electromagnetic field around the edges of the workpieces.

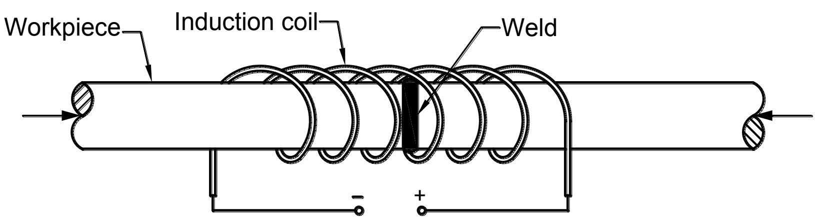


Fig.2.19 Induction welding

A high degree of heat is rapidly generated due to the resistance of the workpiece material to this current flow. When the temperature of the workpieces reaches the welding stage, they are welded with or without the use of pressure. Induction welding is mainly suitable for materials of low electrical conductivity.

Nonmagnetic materials, such as plastics, can be induction-welded by placing them with metallic compounds, called *susceptors*. The susceptors absorb the electromagnetic energy from the induction coil and become hot. The heat is transferred to the plastics material by thermal conduction.

Applications

Induction welding is used for butt and seam welding of pipe, sealing containers and fabrication of various structural members.

Advantages

1) It is a very fast process.
2) No physical contact and less maintenance.
3) Dissimilar metals can be joined.
4) Non-metals can also be welded.
5) The process can be automated easily.

Disadvantages

1) The cost of equipment is high.
2) It is not suitable for welding thick metals.

2.12 Gas welding (Oxy-acetylene welding)

In gas welding, a gas flame is used for melting the edges of work pieces to be joined. Gas welding is a process of joining metals by the heat of the flame formed when oxygen burns with another gas (acetylene). In this method, welding is done by using filler rod without applying pressure. One of the gases (acetylene) used for producing fame is flammable. Another gas (oxygen) induces the burning of inflammable gas. The temperature of flame produced by oxy-acetylene gases is 3200ºC .

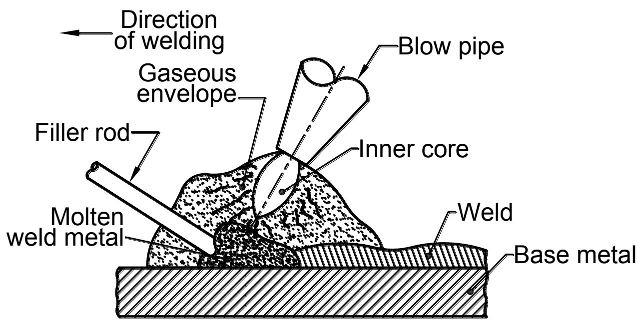


Fig.2.20 Gas welding

The two gases are mixed at required proportion in the welding torch and flame is produced in the tip of the torch. The edges of work pieces and the filler rod are melted by the heat of the flame and weld is formed. The oxidation is prevented by using flux during welding. Work pieces having thickness 2 mm to 50 mm can be welded by using this method.

The filler rod supplies the additional metal needed during gas welding. The filler rod is melted by the gas flame and weld is formed with the metal. The filler rod material depends upon the metals to be welded. The diameter of filler rod depends upon the thickness of the work pieces. Generally the following gases are used to produce flame in gas welding.

1) Oxygen – acetylene 2) Oxygen – hydrogen 3) Air - acetylene

Advantages

1) The flame temperature can be controlled easily.
2) The cost of welding equipment is less.
3) The maintenance cost is low,
4) The amount of filler metal deposit can be easily controlled.
5) It can also be used in the places where electricity is not available.
6) Thin metal sheets can also be welded.

Disadvantages

1) It is a slow process.
2) It is not suitable for welding thick plates.
3) The strength of welded joint is less.

2.12.1 Gas welding equipments

The following are the equipments used in gas welding.

1) Gas cylinders 2) Pressure regulators 3) Pressure gauges
4) Hoses 5) Welding torch

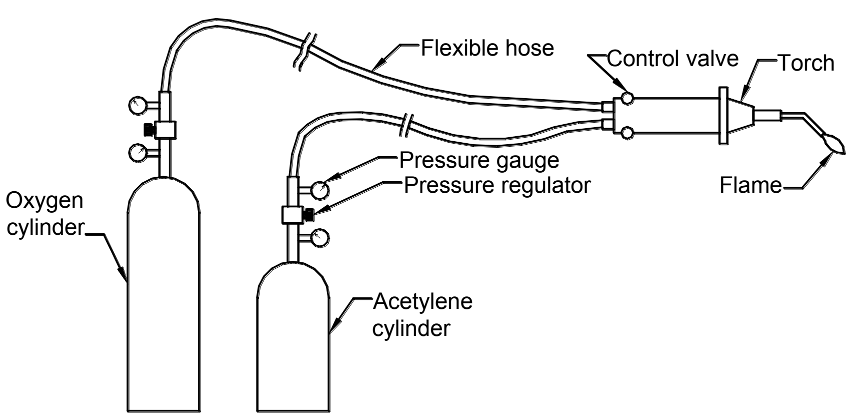


Fig.2.21 Gas welding equipments

1) Gas cylinders

Oxygen and acetylene gases used in gas welding are stored in separate cylinders. The cylinder painted with black colour has oxygen at a pressure of 125 Kg / cm^2. The cylinder painted with maroon colour has acetylene at a pressure of 16 Kg / cm^2.

2) Pressure regulators

There is one pressure regulator fitted on each cylinder to control the working pressure of oxygen and acetylene. The working pressure varies according to the thickness of work pieces to be welded. Generally the working pressure of oxygen is about 1 Kg/cm^2 and the working pressure of acetylene is about 0.14 Kg/cm^2

3. Pressure gauges

There are two pressure gauges are fitted in the regulators of each cylinder. They indicate the cylinder pressure and the working pressure.

4. Hoses

The gas from cylinder regulator passes to the welding torch through a long hose. The hose for oxygen is in black colour and for acetylene is in red colour.

5. Welding torch

The oxygen and acetylene gases from the hose are mixed at the mixing chamber of welding torch. The amount of oxygen and acetylene can be controlled by the control valves to obtain suitable gas flame. The tip of the welding torch can be changed for welding work pieces of different thickness.

2.12.2 Types of flames

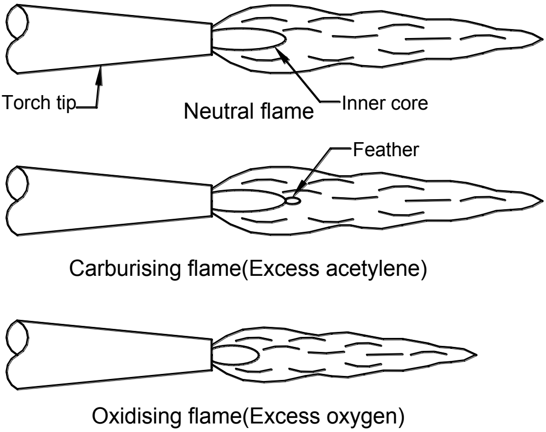


Fig.2.22 Types of flames

The following three types of flames can be obtained by varying the ratio of oxygen and acetylene.

1) Neutral flame
2) Carburising flame
3) Oxidising flame

1) Neutral flame

The neutral flame is produced when equal quantity of oxygen and acetylene gases are used. The temperature of this flame is about 3200^{o}C. The neutral flame has two zones. One is a sharp bright inner cone and another one is a bluish outer cone. This flame is widely used because the chemical effect on the heated metal is less.

Application

Neutral flame is used for welding steel, cast iron, aluminium, copper and stainless steel.

2) Carburising flame or reducing flame

Carburising flame is produced when the quantity of acetylene is more than oxygen. This flame has three zones. They are bright inner cone, white intermediate feather cone and bluish outer cone.

Application

Carburising flame is used for welding steel, alloy steels, non-ferrous metals, nickel and monel metal.

3) Oxidising flame

Oxidising flame is produced when the quantity of oxygen is more than acetylene. This flame has two zones. They are bright inner cone and sharp bright outer cone.

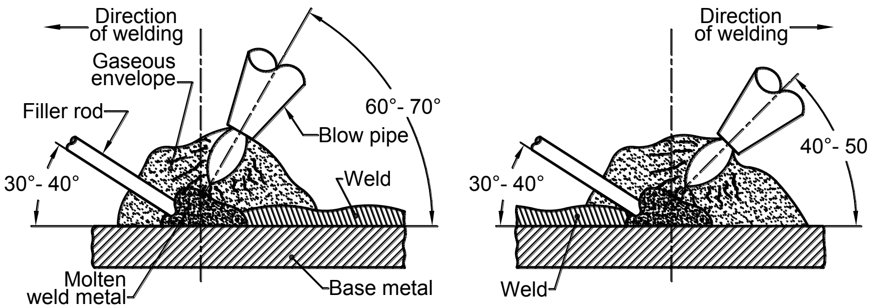
Application

Oxidising flame is used for welding brass, bronze, manganese and steel.

2.12.3 Welding techniques

In oxy-acetylene welding, the following two techniques are commonly used :

1) Leftward or forward or forehand welding technique
2) Rightward or backward or backhand welding technique



(a) Leftward welding **(b) Rightward welding**

Fig.2.23 Welding techniques

1) Leftward welding technique

In leftward welding technique, the torch flame progresses from right to left. The blow pipe is kept at an angle of $60^o – 70^o$ to the surface of the work. The filler rod is held at and angle of $30^o – 40^o$. The blowpipe is steadily moved in forward direction with a slight side ways movement. The filler rod is moved progressively along the joint. In this method, the plate edges immediately ahead of the molten pool is preheated.

As the flame moves away from the just welded portion of the joint, cooling starts immediately. Hence, this technique is restricted to welding of workpieces upto 5 mm thick. Vertical joints are welded by this technique.

2) Rightward welding technique

In rightward welding technique, the torch flame progresses from left to right. The blow pipe is moved steadily without any lateral movement. The filler rod is moved progressively with a slight circular movement.

In this method, the torch flame is directed towards the completed weld. Due to this, the weld is kept hot for a longer time. This results in a narrow and deeper weld. Hence, this technique is used for welding thick workpieces. Vertical and overhead welding are done by this technique.

Advantages of rightward technique

1) Rightward technique is faster by 20 to 25% than leftward technique.
2) The mechanical properties of weld are improved due to the annealing effect.
3) This technique consumes less gas and filler material.
4) The amount of distortion is minimum.

2.12.4 Filler rods and fluxes

Filler rods

In gas welding process, the welding rod or wire is used as filler material. The filler rod should have a chemical composition similar to that of base metals. The welding rods are available in different diameter ranging from 0.3 to 12 mm.

Welding rod diameter, $d = \frac{t}{2} + 1$ (mm),

where, t = Thickness of base plate (mm).

Some typical compositions of welding rods for gas welding are :

Material to be welded	Welding rod composition
Low Carbon steel	0.08%C, 0.36%Mn, 0.13%Cr, 0.013%Ni, 0.20%P
Manganese steel	0.14%C, 0.12%Si, 0.81%Mn, 0.25%Ni
Chromium steel	0.24%C, 0.21%Si, 0.42%Mnh, 0.96%Cr, 0.17%Ni, 0.35%S

Fluxes

- ✦ Fluxes are generally used in the gas welding of non-ferrous metals, cast iron and stainless steel. Fluxes must melt at a lower temperatures than the base metals.
- ✦ Gas welding fluxes are composed of boric acid, soda ash and small amount of other compounds such as sodium chloride, ammonium sulphate and iron oxide.

2.12.5 Flame cutting

In this method, the metal is heated by an oxy-acetylene flame and cut by passing oxygen jet. The end of welding torch has a big hole at its centre and four small holes around the big hole. Oxygen and acetylene mixture is passed through the small holes. Oxygen is passed through the big hole. The metal is preheated to its kindling temperature by the oxy-acetylene flame. In this high temperature, the metal reacts with oxygen and forms weak metal oxide. Now oxygen jet is passed through the torch to remove the metal oxide. Thus the metal is cut.

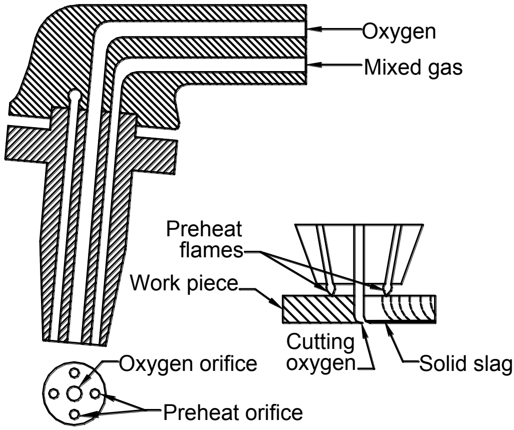


Fig.2.24 Flame cutting

Application

Steel and iron plates having thickness up to 100 mm can be cut by this method.

2.12.6 Comparison of arc welding and gas welding

	Arc welding	Gas welding
1)	The heat is obtained form electric arc (4000ºC)	The heat is obtained from gas flame (2300ºC)
2)	Electrode is used as filler rod.	Separate filler material is used.
3)	The strength of welding joint is more.	The strength of welding joint is less.
4)	This is a non-pressure fusion welding method.	It is also a non-pressure fusion welding method.
5)	The filler metal should be same as work piece metal.	The filler metal and work piece metal need not be same.
6)	Brazing and soldering cannot be done.	Brazing and soldering can also be done.

2.13 Soldering

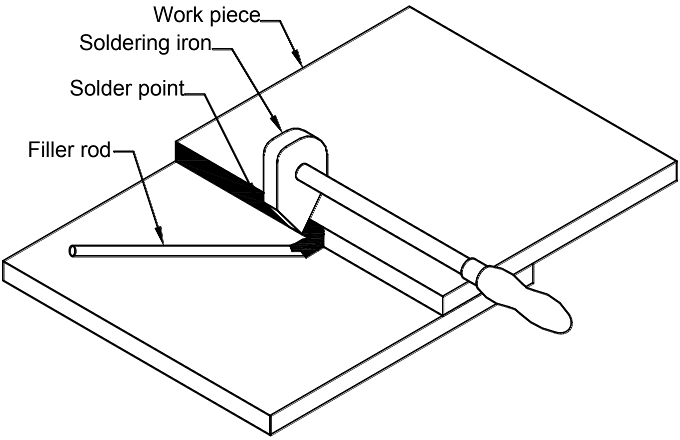


Fig.2.25 Soldering

Soldering is the process of joining two similar or dissimilar metals by using a low melting alloy called solder. Solder is an alloy of tin and lead. It melts at low temperature (150ºC to 350ºC). The edges are not melted in this method.

First the edges to be joined are prepared and cleaned thoroughly. The parts are arranged in correct position. A flux like zinc chloride is applied at the edges to prevent oxidation. A welding torch or electric soldering iron is used for heating the work piece and melting the solder. The molten solder fills the edges to be joined. Then joint is formed after solidification.

Application

The soldering is used in the following work :

1) Connections in wireless set, T.V. sets, etc.
2) Wiring joints in electrical connections, battery and other terminals.
3) Radiator brass tubes for motor car.
4) Copper tubing carrying liquid fuel, gas or air used in engines.
5) Drain water pipes.

Advantages

1) Low cost.
2) The equipment is simple and cheap.

3) Effective sealing in fabrication.
4) The properties of base metal are not affected.
5) Dissimilar metals can be joined.

Disadvantages

1) The joints are weaker.
2) It is not suitable for joining thick metals.
3) Joints are damaged under high temperature.

2.14 Brazing

Brazing is similar to soldering. It is the process of joining two similar or dissimilar metals by using a high melting alloy called spelter. Spelter is a mixture of copper and zinc alloy. The melting temperature of spelter (600ºC) is lower than the melting temperature of work piece. The edges of work pieces are not melted in this method.

First the edges are prepared by filing or grinding. Flux (borax) is applied and the work pieces are assembled in correct position. The work pieces are heated to a temperature below its melting point. The filler rod (spelter) is placed at the joint and heated by welding torch. The molten filler metal fills the edges to be joined. Then joint is formed after solidification.

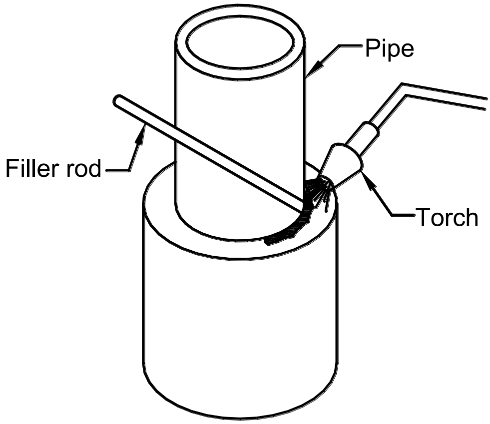


Fig.2.26 Brazing

Brazing is classified as follows depending upon the method of heating.

1) Torch brazing   2) Dip brazing
3) Furnace brazing   4) Induction brazing

Application

Brazing can be done in brass, bronze, copper, steel and stainless steel. Brazing is used in radiator works, joining pipes with drums and tanks, joining carbide tips on tool shank, etc.

Advantages

1) Thin metals can be joined.
2) It is a fast process.
3) Different metals can be joined.
4) Metals of different thickness can be joined easily.
5) No distortion occurs.

Disadvantages

1) It is not suitable for joining thick metals.
2) The cost is more.
3) The strength of joint is less.

2.15 Difference between soldering and brazing

	Soldering	Brazing
1)	Solder is used as filler material.	Spelter is used as filler material.
2)	The melting temperature of filler metal is low (150 - 350°C).	The melting temperature of filler metal is high (about 600°C)
3)	Heating of workpiece is not required.	Workpieces are heated below their melting point.
4)	The strength of joint is low.	The strength of joint is better than soldering.
5)	The cost is low.	The cost is more.
6)	Less skilled is required.	High skill is required.

2.16 Types of welded joints

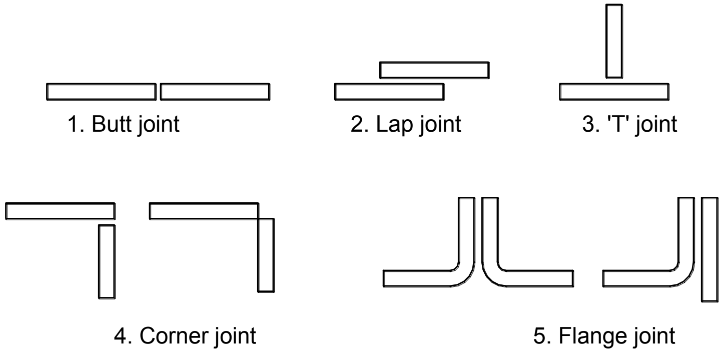


Fig.2.27 Types of welded joints

The following are the important types of weld joints.

1) Butt joint 2) Lap joint 3) 'T' joint

4) Corner joint 5) Flange joint

1) Butt joint

In this type, the plates to be welded are arranged so that the edges are in contact or closer to each other. For more than 5 mm thickness, the edges of plates are prepared to V or U shape before welding.

2) Lap joint

The plates to be joined are placed one over the other. In lap joint, the edge of one plate is welded to the surface of the other plate. The types of lap joints are single lap joint and double lap joint.

3) 'T' joint

In 'T' joint, the plates to be welded are placed at 90º to each other ('T' shape). 'T' joint is used for welding plates having thickness more than 3 mm.

4) Corner joint

In this joint, the plates to be welded are placed at 90º to each other ('L' shape). Corner joint is used for welding boxes, cranks and frames.

5) Flange joint or edge joint

In this type of joint, the plates to be welded are placed parallel to each other. It is used in sheet metal works.

2.16.1 Merits and demerits of welded joints

Merits

1) Welding is a lightweight method of fabrication.
2) Good saving in material.
3) Low manufacturing cost.
4) Similar and dissimilar metals can be joined.
5) Greater strength.
6) It permits freedom in design.
7) Various types of joints like lap, butt, seam, end-to-end, etc can be welded.
8) Portable for indoor or outdoor use.
9) It is used to repair broken, worn or defective parts.

Demerits

1) Residual stresses are developed.
2) Distortion occurs in workpieces.
3) Heat of welding degrades base metal properties.
4) Welding defects, such as cracks, incomplete fusion, slag inclusion, etc. may occur.
5) It gives harmful radiations, fumes and spatter.
6) Jigs and fixtures are required.
7) High skilled labours are required.

2.17 Inspection and testing of welded joints

The strength and defects in welded joint are found out by conducting various test. The following are the two types of tests.

Testing of welded joints

1) Non-destructive Tests

i) Magnetic particle test
ii) X-ray test
iii) Ultrasonic test

2) Destructive Tests

i) Nick brake test
ii) Bend test
iii) Tensile test

1) Non-destructive test

In this method, test is conducted without destroying the welded joint.

2) Destructive test

In this method, test is conducted by destroying the welded joint. So the tested work piece cannot be used.

2.17.1 Non-destructive test

1) Magnetic particles test

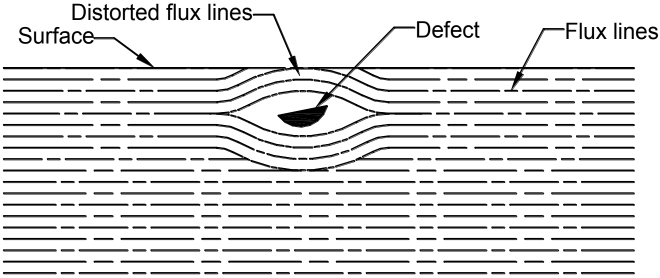


Fig.2.28 Magnetic particles test

Magnetic particle test is used to find out cracks and slag inclusions. The work piece is magnetized. Fine iron powder is sprayed over the surface of work piece. If there is a crack, magnetic poles will be formed at that place. The iron powder will be attracted more at that place and the crack is identified. This test is suitable only for ferrous metals.

2) X – ray test or radiographic test

X-ray test is used to fine out defects like porosity, blow holes and cavities. Generally X-rays can pass through the solid metals. In this method, the test piece is placed in front of X-ray tube. X-ray film is placed behind the test piece. The X-ray is passed through the test piece. If there is no defect, the image in the film will be uniform.

If there is any defect like porosity or blow holes, it will be shown in the film as bright spots. It is a fast method and the cost of test is high. The results of X-ray test can be stored as permanent records. X-rays affect the human health. So special precautions to be taken.

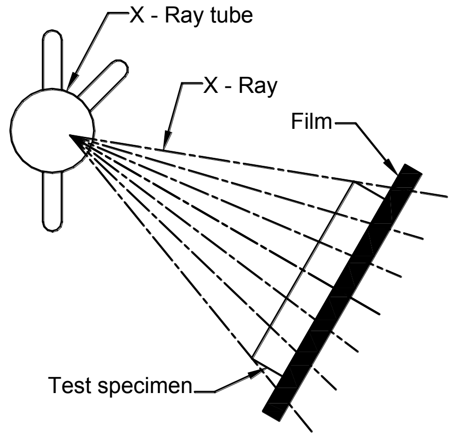


Fig.2.29 X- ray test

3) Ultrasonic test

This test is used to find out defects like cracks, blow holes and porosity by using ultrasonic waves. Ultrasonic waves are high frequency vibrations. In this method, the ultrasonic waves produced by a transducer are passed in to the test piece.

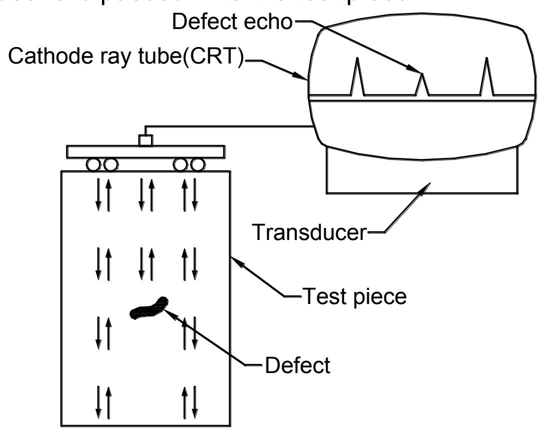


Fig.2.30 Ultrasonic test

If there is no defect, the waves will pass up to the bottom and come back. If there is a defect, the waves will be returned from that place. The returned waves are received by a receiver and converted into electric signals. This signal is projected into a CRT screen. By referring the signals, the size and place of defect in test piece is found out.

2.17.2 Destructive test

Nick break test

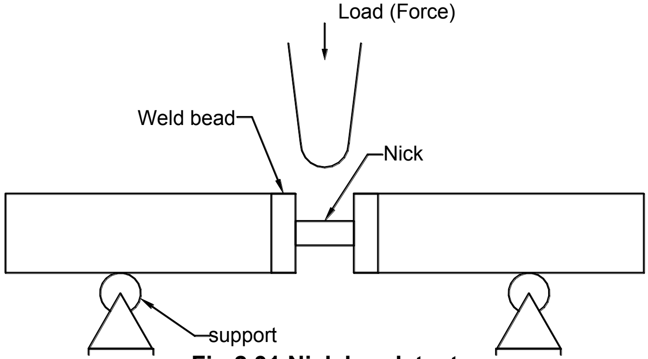


Fig.2.31 Nick break test

This test is used to find out defects like blow holes, flash eye and slag inclusion. A test piece of length 200 mm is used. Two slots of 6 mm depth are cut at the opposite sides of the welded portion. It is called nicking. The test piece is placed on two roller supports. The nicked portion of the test piece is broken by applying excessive force. The broken surface of the welded portion is inspected to find defects.

2.18 Defects in welding – Causes and remedies

	Defects	Causes	Remedies
1)	Incomplete fusion	Low current, high welding speed.	Proper welding condition should be set up.
2)	Slag inclusion	Improper flux coated electrode, metal oxide in the work piece.	Electrode with proper flux coating should be used. The work piece should be cleaned thoroughly.
3)	Porosity and blow holes	Moisture in the flux, stain in the work piece.	Dry electrode should be used. The work piece should be cleaned thoroughly.
4)	Cracks	Non-uniform heating and cooling.	Heating and cooling should be uniform.
5)	Undercut	High current, improper position of electrode.	Proper current setting should be done. The electrode should be positioned correctly.

Review Questions

5 marks questions

1) Define welding and classify the welding processes.
2) What is meant by arc welding? Mention the types of arc welding.
3) List out the equipments required for arc welding.
4) Explain the types of electrodes.
5) Give examples of filler flux materials.
6) State the principle of operation of resistance welding.
7) What are the differences between spot and seam welding?
8) Explain the principle of gas welding.
9) State the three types of oxy-acetylene flames and their uses.
10) List out the equipments required for oxy-acetylene welding and state their functions.
11) Briefly explain flame cutting.
12) Explain briefly the soldering process.
13) Briefly explain the brazing process.
14) Compare soldering and brazing with example.
15) Sketch the various types of welded joints.
16) Explain the ultrasonic test.
17) What are the common defects in welding?

10 Marks questions

1) With a neat sketch explain the arc welding process. What are the accessories needed for it?
2) Briefly explain the Metal Inert Gas arc welding. How does it differ from other metal arc welding processes?
3) Explain TIG welding process.
4) Explain the principle of operation of submerged arc welding process and state the advantages and applications of this welding process.
5) Write short notes on the following welding processes:
   a) Metal arc welding   b) Plasma arc welding
   c) Electro slag welding.
6) What is resistance welding? State the classification of resistance welding. Explain any one method.

7) Describe the following process:
   a)Spot welding b) Flash butt welding.
8) What is a thermit welding? What does a thermit mixture consist of? What reactions take place in thermit welding?
9) Explain the following welding processes:
   a)Friction welding b)Ultrasonic welding
10) With a neat sketch explain electron beam welding.
11) Explain the laser beam welding with a sketch.
12) With a neat sketch describe the gas welding process. List out the advantages of this process.
13) Explain the procedure followed for oxy-acetylene welding.
14) Explain the three types of welding flames obtained in oxy acetylene welding process. State the application of each flame.
15) Explain how flame cutting is done?
16) Name the various non-destructive testing methods used for welded joints. Explain any one method.
17) Discuss the common non-destructive tests for testing welded joints.
18) Explain the ultrasonic testing of the welded joints. Draw neat sketch to support your answer.
19) State the various defects found in welding. State their causes and remedies.

Unit – III

FORMING TECHNOLOGY

3.1 Introduction

Generally metals are formed to the required shape by hot working and cold working methods. These methods are also known as mechanical working or metal forming. In these methods, metal undergoes plastic deformation by means of an external force and gets the required shape.

3.2 Hot working

Hot working is the process of heating the metal above its recrystallization temperature to undergo plastic deformation and to get the required shape.

During heating, a change in grain structure of metal occurs to form new grains at particular temperature. This temperature is called recrystallization temperature. Generally, the recrystallization temperature of metal will be about 30 to 40% of it melting point.

Advantages of hot working

1) The toughness and ductility of metal can be improved.
2) The hardness due to the plastic deformation can be removed.
3) No internal stresses are produced in the metal.
4) Less amount of force is sufficient to deform the metal.
5) Defects like cracks, blow holes, porosity will not occur in the metal.
6) As the grain structure of metal is refined, the strength can be increased.
7) It is a quick and economical process.
8) All methods can be formed to required shape by this method.

Limitations of hot working

1) Poor surface finish due to oxidation or scale formation .
2) De-carburization takes place on the metal surface.
3) Less dimensional accuracy
4) High tooling cost
5) Handling of hot worked parts is difficult

3.3 Cold Working

Cold working of a metal is carried out below its recrystallisation temperature. Cold working involves plastic deformation of a metal, which results in strain hardening. It is widely applied as a forming process of making steel products using pressing and spinning.

Advantages of cold working

1) Mechanical properties are improved
2) Smooth surface finish can be easily produced.
3) Better dimensional accuracy is achieved.
4) Strength and hardness of the metal are increased
5) No formation of oxide
6) There is no possibility of decarburization of the surface
7) It is easier to handle cold parts.

Limitations of cold working

1) The ductility of metal is decreased
2) The grain structure is distorted.
3) Residual stresses are set up in the metal.
4) Strain hardening occurs.
5) Metal surfaces must be clean and scale free before cold working.
6) Greater force is required
7) Only small sized components can be produced.

3.4 Comparison of hot working and cold working

	Hot working	Cold working
1)	It is carried out above the recrystallisation temperature and below the melting point.	It is carried out below the recrystallisation temperature.
2)	No internal stresses are developed.	Internal or residual stresses are developed.
3)	The grain structure is refined.	The grain structure is distorted.
4)	Close tolerance cannot be maintained.	Better tolerance can be maintained.
5)	Poor surface finish is obtained.	Better surface finish can be obtained.

	Hot working	Cold working
6)	Less work hardening occurs.	High work hardening occurs.
7)	Lesser force is required.	Greater force is required.
8)	Components of any size can be produced.	Only small size components can be produced.
9)	Higher tooling cost.	Lesser tooling cost.
10)	Handling of parts is difficult.	Handling of parts is easy.

3.5 Hot working operations

The following are the important hot working processes.

1) Rolling 2) Forging 3) Swaging
4) Extrusion 5) Drawing 6) Hot spinning

3.6 Hot rolling

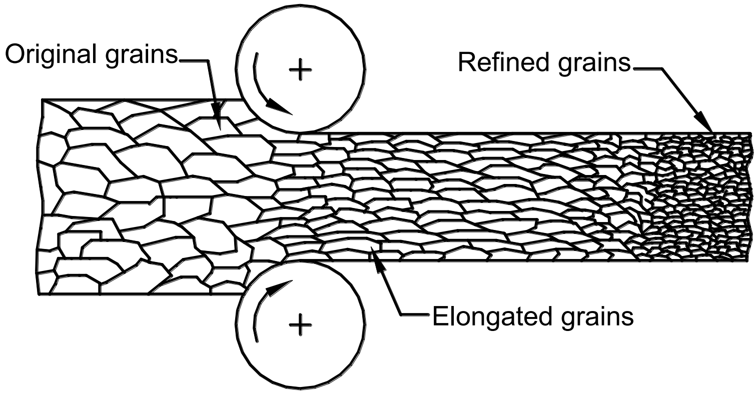


Fig.3.1 Hot rolling

Rolling is a process of forming metal to the required shape by passing it between rotating rolls. When the metal to be rolled is heated above its recrystallization temperature, it is called hot rolling. The periphery of the roll is made to the required shape. When the metal passes between the rolls, plastic deformation of metal occurs due to the high compressive stress. The metal grains elongate in the direction of rolling. So the cross section of metal is reduced and the length is increased. Hot rolling is done by using two or three sets of roll mills. Rolling is done progressively until the required shape is obtained.

By hot rolling, the metal can be formed into sheets, plates, rounds, I-sections, T-sections, channels, angles and many other shapes. The casting got from foundry shop is called *ingot*. First the heated ingots are rolled to obtain semi-finished shapes like bloom, billet and slab. I-section, T-section, channels and angles are formed by hot rolling the blooms. Rounds, squares and wires are obtained from billet. Plates and sheets are obtained from slab.

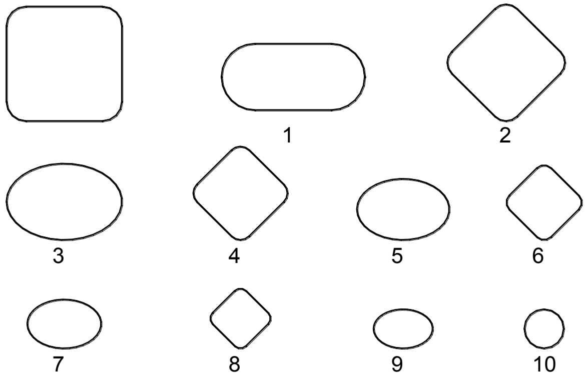


Fig.3.2 Number of passes to produce a bar

As shown in the figure, the billet is passed between the rolls several times to form into round rod.

3.7 Forging

Forging is a process of forming the metal into the required shape by compressive or impact force. When the process is carried out above the recrystallization temperature of metal, it is called hot forging. Connecting rod, crank shaft, etc. can be produced by this method.

Classification of forging

1) Smith forging
   a) Hand forging b) Power forging
2) Impression die forging
   a) Drop forging b) Upset forging
3) Roll forging
4) Swaging

3.7.1 Hammer forging or smith forging

It is also called as flat die forging and open die forging. Smith forging can be done manually or by power. The accuracy of forgings are depend upon the skill of the worker. Generally smith forging is used for rough work.

Hand forging

In this method, the heated metal is held over an anvil with the help of tongs. The metal is hammered several times by using a hammer to form into required shape. Hand forging is used for producing less number of small size forgings.

Power forging

In this method, power hammer or power press is used for forging. The heated metal is hammered several times by using a power hammer to form into required shape. The power hammer may be operated hydraulically or pneumatically. Power forging is used for producing medium and large size forgings.

Smith forging operations

1) Upsetting 2) Drawing down 3) Setting down 4) Swaging
5) Bending 6) Punching 7) Welding

1) Upsetting

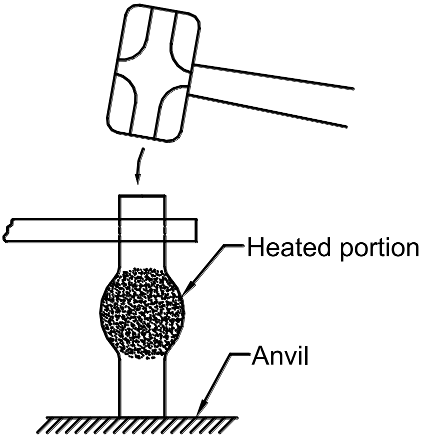


Fig.3.3 Upsetting

This is the process of increasing the cross section of heated work piece by reducing the length. The portion where upsetting is to be done is heated and the end of the work piece is hammered. Now the length is reduced and the cross section is increased.

2) Drawing down

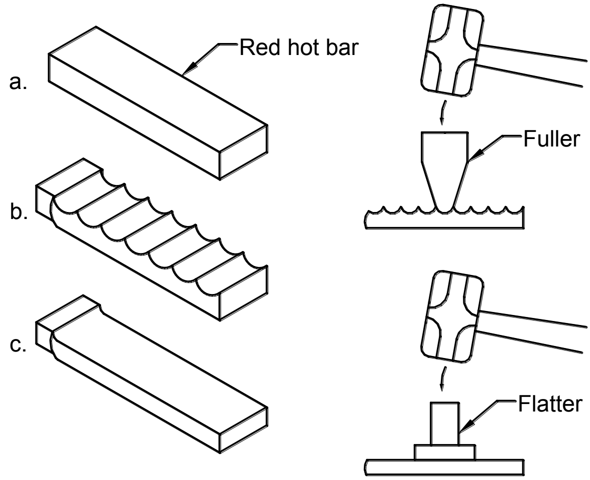


Fig.3.4 Drawing down

This is the process of increasing the length of the heated work piece by reducing the cross section. The work piece is heated and held between the fullers. When the work piece is hammered, the length is increased and the cross section is reduced.

3) Setting down

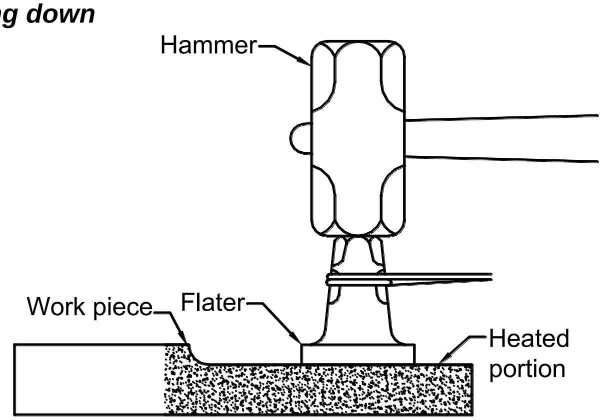


Fig.3.5 Setting down

Setting down is a process similar to drawing down. In this method, a flatter is used instead of fuller for reducing the cross section at particular portion of work piece.

4) Swaging

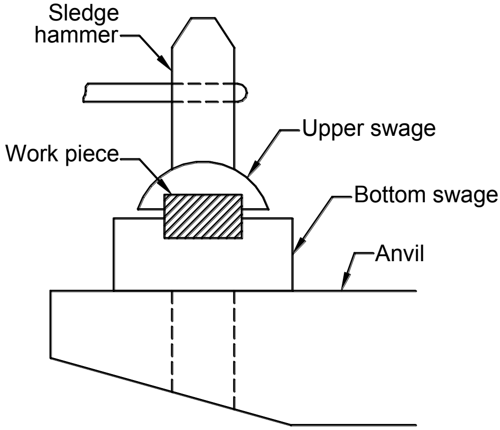


Fig.3.6 Swaging

Swaging is the process of increasing the length of heated metal and to form the cross section to the required shape. The work piece is heated and held between the swage blocks. Then the work piece is hammered to form the required shape. In this method, the work piece can be formed into round, square and hexagonal shapes.

5) Bending

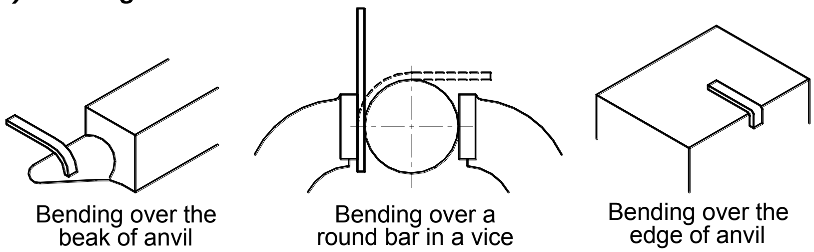


Fig.3.7 Bending

It is the process of forming the work piece into required angle or circular. The sharp cornered bend can be made by hammering the metal over the edge of the anvil. The work piece is held over the beak of the anvil and hammered to form circular bends.

6) Punching

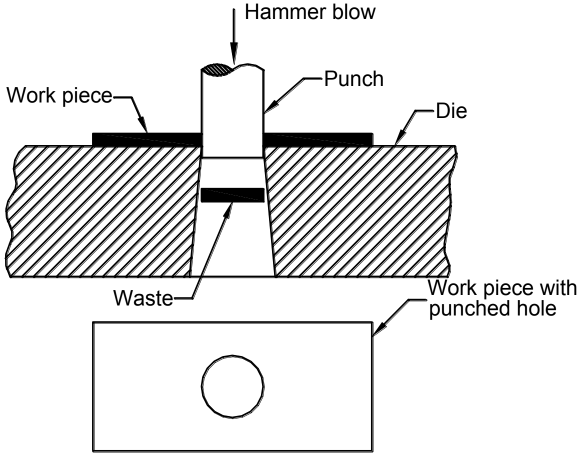


Fig.3.8 Punching

Punching is the process of making holes in the heated work piece. The work piece is held over the hole in the anvil. The punch is correctly placed on the work piece and hammered to produce hole.

7) Forge welding

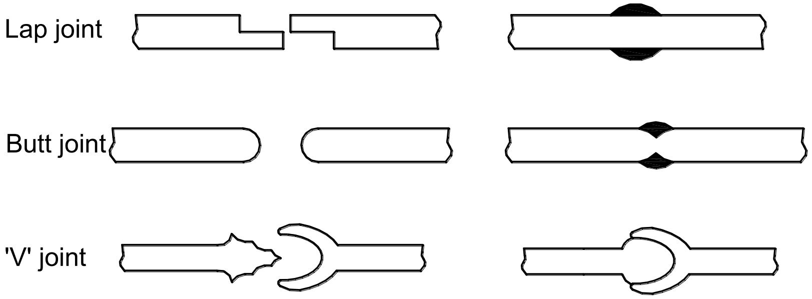


Fig.3.9 Forge welding

It is the process of joining two ends of heated work pieces by hammering. The part to be welded are cleaned thoroughly and the edges are prepared for the required joint. Flux can be applied at the ends of work pieces to avoid oxidation. The ends are heated and held in correct position. Then the two parts are hammered together to get the required joint. The various joints made by forge welding are shown in the figure.

3.7.2 Drop forging

Drop forging is the process of making the heated metal into required shape by placing it between two closed dies and pressing with the help of power hammer. The lower die is fitted on the anvil and the upper die is fitted with the ram. The heated metal is placed over the lower die. When the ram falls down, the heated metal fills the die cavities due to the impact force of the upper die. Thus the required shape is obtained. Power hammers like gravity hammer, power drop hammer and air lift hammer are used.

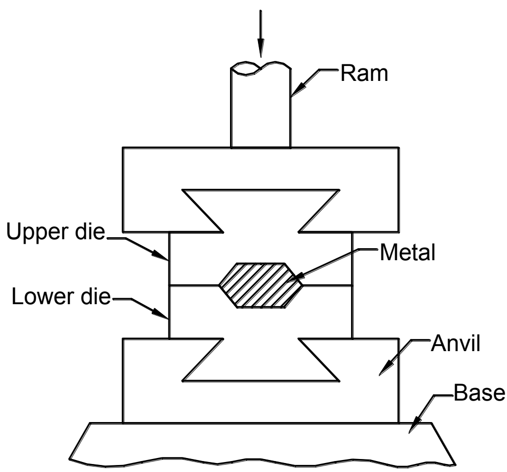


Fig.3.10 Drop forging

Components with simple shapes are forged in single operation. Components with complicated shapes are forged in several steps. Roughing die, semi finishing die and finishing die are used for such operations.

Application

Crank, crank shaft, connecting rod, levers, camshaft, etc. can be produced by drop forging.

Advantages

1) It is suitable for mass production.
2) The strength of the component is high.
3) Less material wastage.

Disadvantages

1) Large anvil and strong foundation are needed.
2) More noise and vibration.
3) The die may wear our quickly.

3.7.3 Upset forging or machine forging

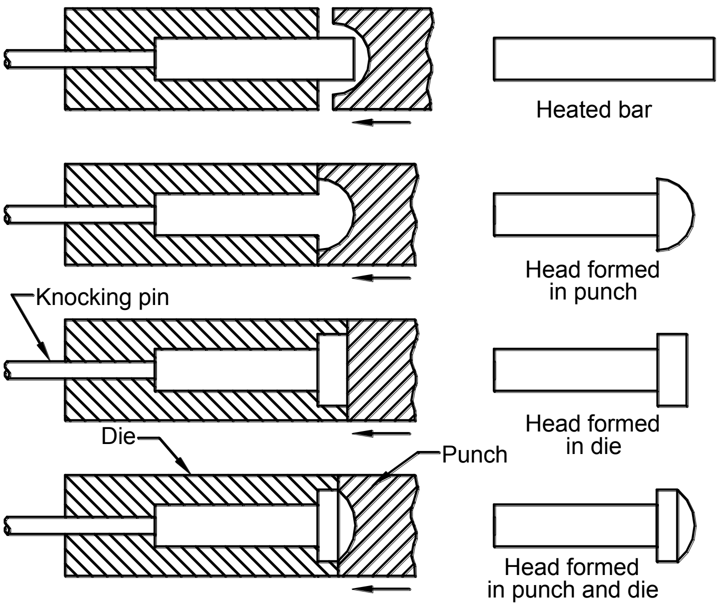


Fig.3.11 Upset forging

Upset forging is the process of making rivet head, hexagonal head, etc. at the end of heated work piece. In this process, the length is reduced and the cross section at the end is increased. As it is done in a press forging machine, it is also called as machine forging.

This machine has a fixed die, movable punch and knock out pin. The end of the work piece is heated and held in the fixed die. When the punch is pressed, the end of the work piece gets the shape of the punch. The knock out pin push out the work piece. The shape to be formed at the end of the work piece will be in the punch or in die or in both.

Some forging machine has a fixed die, movable die, movable punch, knock out pin and stop. The end of the work piece is heated and placed between the two dies. The length of the work piece is controlled by the stop. The movable die is moved to hold the work piece. The stop goes to its idle position. The punch is moved and pressed against the end of the work piece. Now the end of the work piece gets the shape of the die or punch or punch and die. The punch and movable die go back to initial position and the work piece is removed.

Application

Upset forging is used to produce bolt head, rivet head, collars, cylindrical pin, flanges, etc.

Advantages

1) It is suitable for mass production.
2) The size of the work piece is accurate.
3) The strength of the component is improved.

3.7.4 Press forging

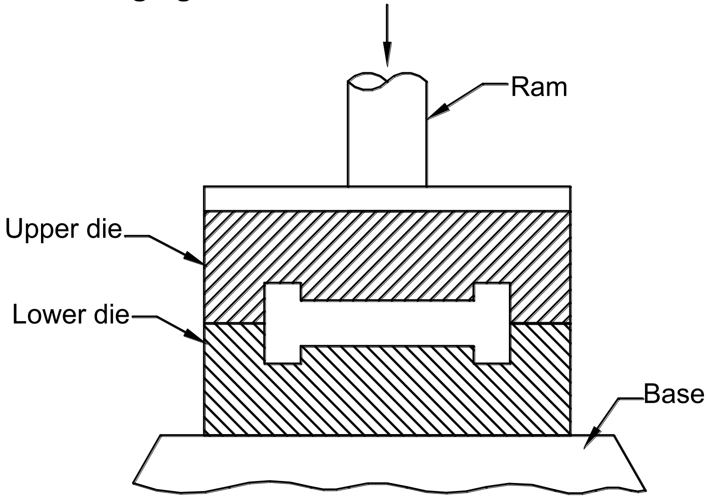


Fig.3.12 Press forging

In this process, the metal heated to plastic stage is pressed between two closed dies by using a power press to get required shape. The half of the required shape is made in the lower die and another half is made in the upper die. The lower die is fitted on the anvil and the upper die is fitted to a ram. The heated metal is placed over the lower die. When the ram falls down, the upper die presses the metal slowly and uniformly. Now the metal flows and fills up the die cavities to get required shape. Mechanical and hydraulic press can be used.

Application

Press forging can be used to produce symmetrical shaped objects such as coins, bolts, rivets, nuts, etc.

Advantages

1) The components can be made in single working stroke.
2) The production time is less.
3) Good surface finish can be obtained.
4) Less noise and vibration.
5) The density of work piece will be uniform.

Comparison of drop forging and press forging

	Drop forging	Press forging
1)	The work piece gets the required shape by impact force.	The work piece gets the required shape by uniform pressure
2)	Power hammer is used.	Power press is used.
3)	Vibration and noise are more.	Vibration and noise are less.
4)	The density of work piece is not uniform.	The density of work piece is uniform.
5)	It is a slow process.	It is a fast process.
6)	Several die sets are required to produce a component with complicated shape.	One die set is sufficient to produce a component with complicated shape.

3.7.5 Roll forging

In plain rolling, components with uniform cross section are produced. Roll forging is a process of producing components with varying cross sections by pressing the heated work piece between two rotating rolls.

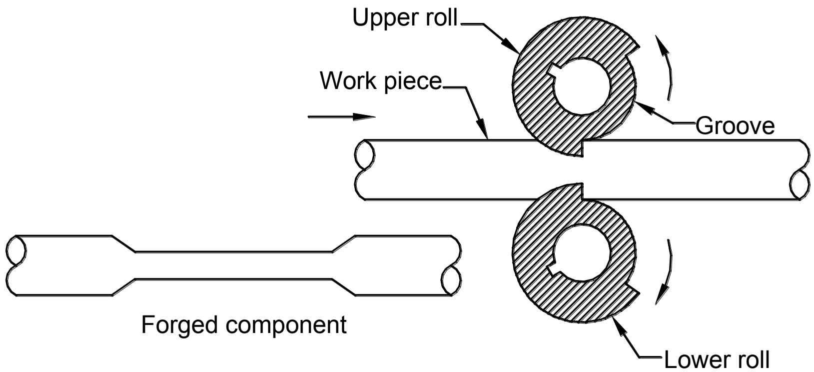


Fig.3.13 Roll forging

The periphery of the rolls used in this method will not be round. According to the required shape of the component, the rolls have grooves of different radii. When the heated work piece passes between the rolls, it gets the shape of the grooves in the roll. Thus the varying cross section is obtained in the component. In this process, the cross section or work piece is decreased and the length is increased.

Application

Automobile axles, levers, leaf springs, tapered tube are produced by roll forging.

3.8 Press working

In press working, the sheet metal is pressed in a press to get the required shape. Press is a machine used for pressing or cutting the metal to get required shape by applying mechanical force or pressure. The press used during cold working and hot working are called cold working press and hot working press respectively. The press is used for producing finished products from sheet metal at fast rate. So it is suitable for mass production.

3.9 Specification of press

1) Capacity of press in tons
2) Maximum stroke length of ram
3) Die space
4) Type of frame
5) Type of drive
6) Number of slides
7) Weight and floor area.

3.10 Types of presses

3.10.1 Hand press or ball press

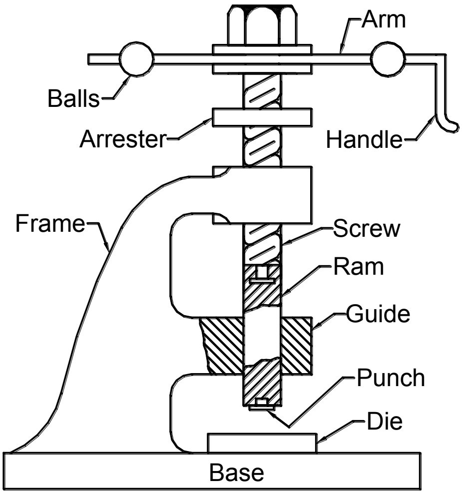


Fig.3.14 Hand press

This press has a C shaped frame integral with the base. A nut with long screw is fitted in the frame. An arm with balls on both side is fitted at the one end of the screw. Ram is fitted at the another end. It slides in the guides of frame.

The punch is fitted at the end of the ram. The die is fitted on the base. The work piece is placed between the punch and die. When the arm is rotated by hand, ram moves downwards. The work piece is pressed and required shape is formed. Arrester is used to adjust the stroke length.

3.10.2 Types of frames

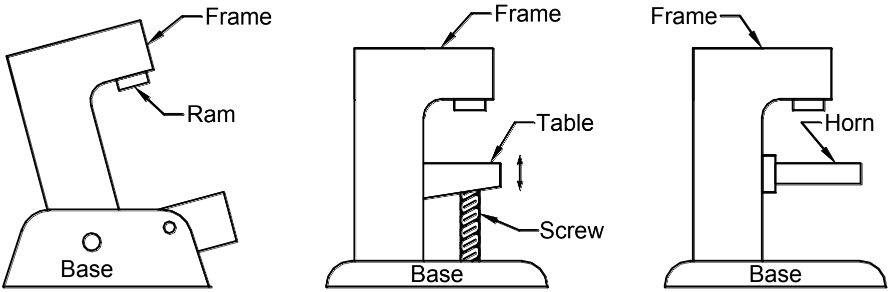
Presses with various frames are used according to the size and shape of the work piece.

1) Open Back Inclinable press or OBI press

The frame of this press is pivoted in the base. So the frame can be tilted to any required angle. The components will slide down through a gap in the frame due to gravity.

2) Adjustable press or knee press

The bed of the press can be vertically moved by using an elevating screw. The bed is suitably adjusted according to the height of die and work piece. This press will not be strong.



(a) Inclined press (b) Adjustable press (c) Horn press

Fig.3.15 Types of presses

3) Horn press

This press has a cylindrical projection known as horn from the machine frame. The horn supports cylindrical work pieces. The horns can be changed according to the size of the work piece.

4) Straight side press

This press has two vertical frames mounted on the base. The two frames are connected by a crown at the top. This press is suitable for heavy duty works as it is very strong.

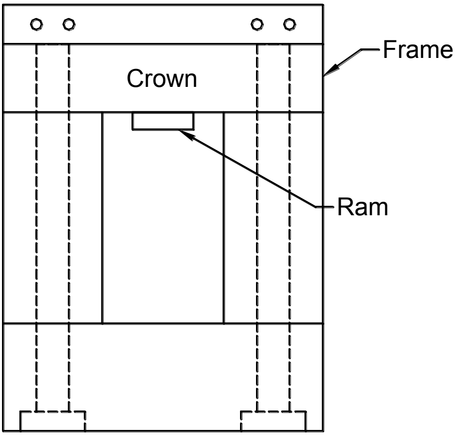


Fig.3.16 Straight side press

5) Pillar type press or open frame press

This press has a square base. Four pillars are fitted over the base. The pillars are connected in a crown at the top. This press is operated by hydraulic drive.

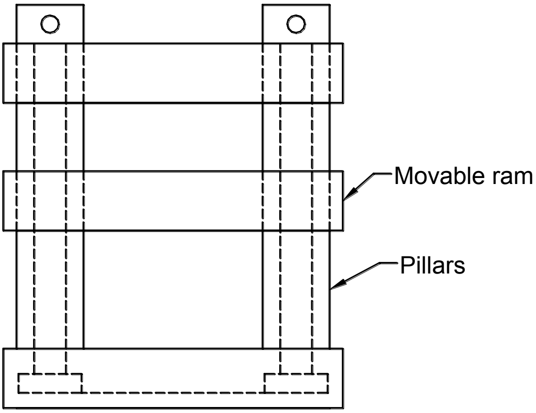


Fig.3.17 Pillar type press

3.10.3 Mechanical press

The important parts of mechanical press are explained below.

1) Base

It supports the press. Bed and frame are fitted over the base.

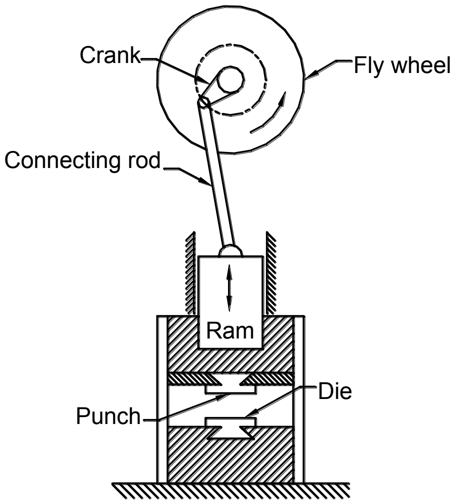


Fig.3.18 Mechanical press

2) Frame

It houses the driving mechanism. The ram slides over the guide ways provided in the frame.

3) Bolster plate

It is a heavy plate fitted over the bed. Die assembly is fitted on the bolster plate.

4) Driving mechanism

Crank and connecting rod drive is generally used in mechanical press. Ram is connected to the crank through connecting rod. When crank shaft rotates, ram slides up and down.

5) Fly wheel

It is a large wheel fitted at the end of driving shaft. It stores the energy during idle stroke and gives the energy to deform the work piece during working stroke.

6) Punch

Punch is fitted in the punch holder. The punch holder is fitted at the bottom of ram. The punch moves up and down along with the ram.

7) Die

Die is fitted in the stationary die holder on the bolster plate.

Working principle

Suitable punch and die are fitted in the press. Work piece is held between the punch and die. Crank shaft is rotated by a motor. Crank and connecting rod drive converts the rotary motion into reciprocating motion. So the ram moves up and down. When the ram moves down, it presses the work piece and required operation is performed. Different die and punch set are used in the press for various operations.

3.10.4 Hydraulic press

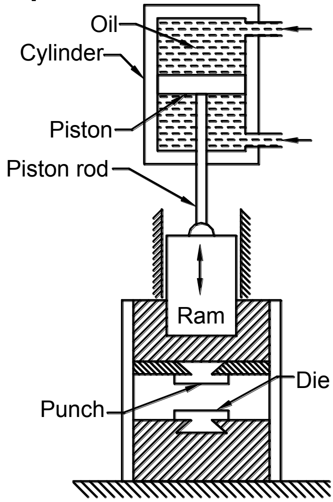


Fig.3.19 Hydraulic press

This type of press is operated by hydraulic drive. The piston in the hydraulic cylinder moves up and down. The piston is connected to the ram through a piston rod. When the piston moves, the ram slides up and down on the guide ways. Valves are provided to control the flow of oil into the cylinder.

Punch and die are fitted in the press and aligned correctly. Work piece is held between the punch and die. The high pressure oil is supplied into the cylinder at the top of the piston. So the piston moves the ram downwards. The punch fitted to the ram presses the work piece and required operation is performed. At the end of the working stroke, oil is supplied at the bottom of the piston. So the piston moves the ram upwards.

Advantages of hydraulic press

1) High pressure and force can be obtained.
2) The required pressure to table ram can be controlled easily.
3) The pressure is uniform.
4) The movement of ram is uniform.
5) Noiseless and smooth operation take place.

3.10.5 Types of drive

Driving mechanism gives the reciprocating motion of ram. The following drives are used according to required load and stroke length of ram.

1) Eccentric drive

An eccentric is made integral with the driving shaft. One end of the connecting rod is connected to the eccentric and the another end is connected to the ram. When the driving shaft rotates with the eccentric, the ram moves up and down. This type of drive is used for shorter stroke lengths.

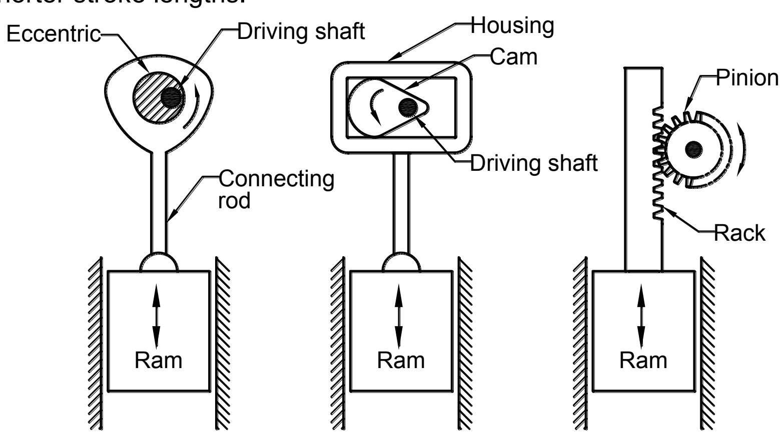


Fig.3.20 Types of drive

2) Cam drive

In this drive, the driving shaft has a cam. One end of the connecting rod is connected to the cam and the another end is connected to the ram. When the driving shaft rotates with cam, it actuates the ram to move up and down. Cam drive is used for short stroke length.

3) Rack and pinion drive

In this drive, the ram is connected to a long rack. A pinion is meshed with the rack. When pinion rotates, the ram moves downwards. After the end of stroke, the pinion is made to rotate in opposite direction. So the ram moves upwards. This drive is used for long stroke length.

3.11 Press tools

Die and punch are called press tools. These two are always used together. Die is the lower part of the press tool. It is clamped stationary on the bolster plate of the press. The die has a cavity to receive the punch.

Punch is the upper part of the press tool. It is fitted to the lower end of the ram. The punch slides with the ram and is pressed into the die cavity. Die and punch must be perfectly aligned.

High speed steel (HSS), satellite and cementite carbide are used for making dies and punches.

3.11.1 Press or die accessories

Press accessories are used to perform operation quickly and easily in a press. They are used to easily remove the finished product and to locate the blank exactly between the punch and die. The following are the various press accessories used.

1) Stops 2) Pilots 3) Strippers
4) Knock outs 5) Pressure pads.

1) Stops

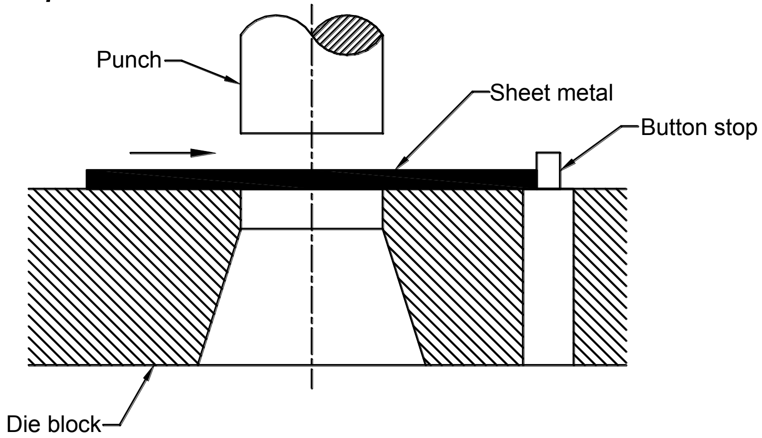


Fig.3.21 Stop

Stops are used to stop the sheet metal at the correct length. This prevents the wastage of material and reduces the scrap. The stops are made in the form of button, lever or pin.

2) Pilots

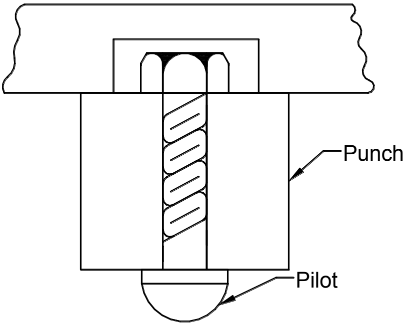


Fig.3.22 Pilot

Pilot is fitted at the lower end of the punch. Pilot is used to exactly locate the hole which is already pierced in the blank.

3) Strippers

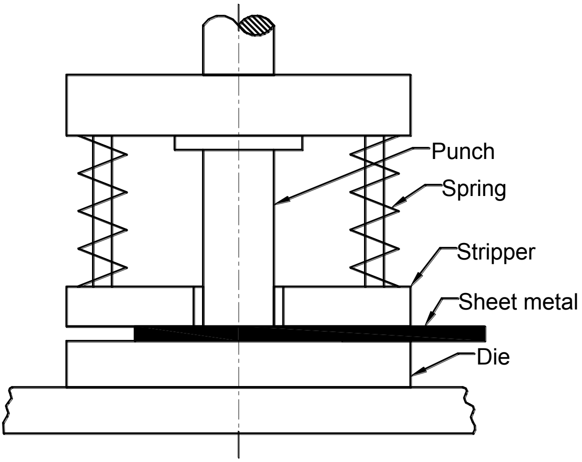


Fig.3.23 Stripper

Stripper is used to remove the work piece from the punch or die after the end of blanking or piercing operation. It may be of fixed type and spring operated type. Fixed strippers are attached to the die block. The spring operated stripper travel up and down along with the punch.

4) Knock outs

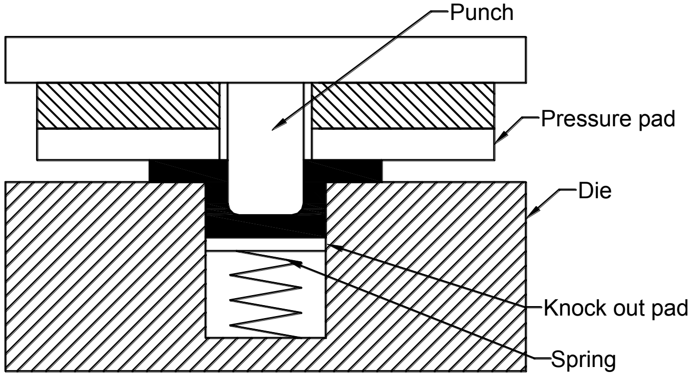


Fig.3.24 Knock out

Knock out is used to kick out the products which cannot fall through the die opening after the end of drawing operation. It works with the help of spring action or air pressure.

5) Pressure pads

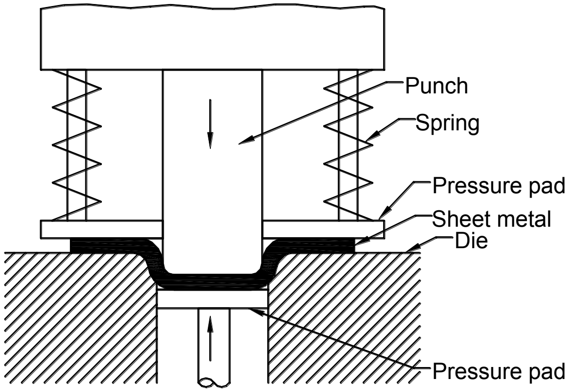


Fig.3.25 Pressure pad

It is used to hold the sheet metal at correct position by applying sufficient pressure. The pressure may be applied by spring, pneumatic or hydraulic means. When the punch moves downward, the springs are pressed and hence holds the sheet metal with pressure. So the metal between the punch and die is drawn uniformly to required shape. One more pressure pad is used to maintain the flat surface at the bottom of the cup.

3.12 Types of dies

Dies

Based on operation	Based on construction
1. Shearing dies	1. Simple dies
2. Drawing dies	2. Progressive dies
3. Squeezing dies	3. Compound dies
4. Bending dies	4. Combination dies
	5. Inverted dies

3.12.1 Simple die or plain die

Only one operation can be performed in a simple die at each stroke of the ram. Cutting dies, bending dies and punching dies are some simple dies. The cost of simple die is less. It has simple construction.

3.12.2 Progressive die

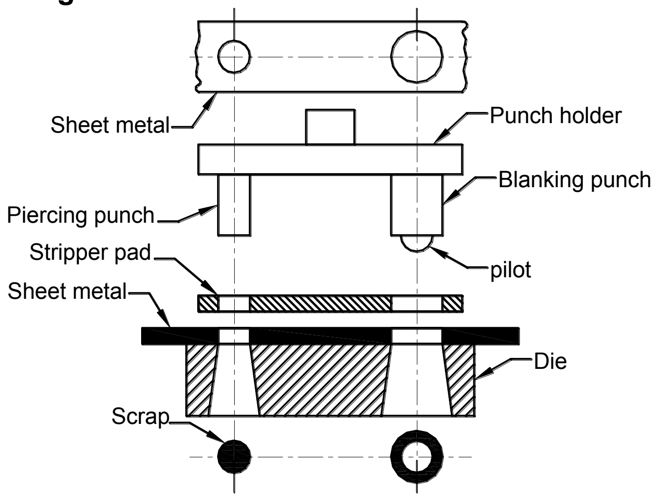


Fig.3.26 Progressive die

In this die, two or more operations can be performed one after another every time the ram moves down. The work piece is moved through a series of work stations to perform various operations. The distance between the work stations will be same. One finished product can be obtained in each stroke of the ram. In the production of washer, piercing and blanking operations are done progressively.

Piercing punch and blanking punch are fitted in the punch holder. Piercing die and blanking die are fitted in the die holder. The sheet metal is fed into the die where a hole is pierced in the first stroke of the ram. When ram moves upward, the sheet metal is moved to the next work station. Stop pins are used to stop the sheet metal at correct length. In the next stroke of the ram, the pilot enters the pierced hole and locate the job correctly. Now blanking operation is performed. At the same time, piercing operation for the next washer is performed in the first work station. Thus in each stroke of the ram, piercing and blanking operation are performed at different work stations.

Advantages

1) The production time is less.
2) Production rate is high. So it is suitable for mass production.
3) Various operations can be performed in a sheet metal.

Disadvantages

1) The design of die is complicated.
2) Thin sheet metals may be bent during cutting.

3.12.3 Compound die

In this die, two or more operations can be performed in one stroke of the ram at a single work station. Generally cutting operations are performed in this die. Piercing and blanking operations are performed in a single stroke for the production of washer using compound die.

In this die, piercing and blanking punch are fitted opposite to each other. The blanking punch acts as a piercing die. Angular clearance should be provided in the piercing die for the scrap to fall down. Piercing and blanking operations are performed when the ram moves downward. When the ram moves upward, the knock out rod ejects the washer.

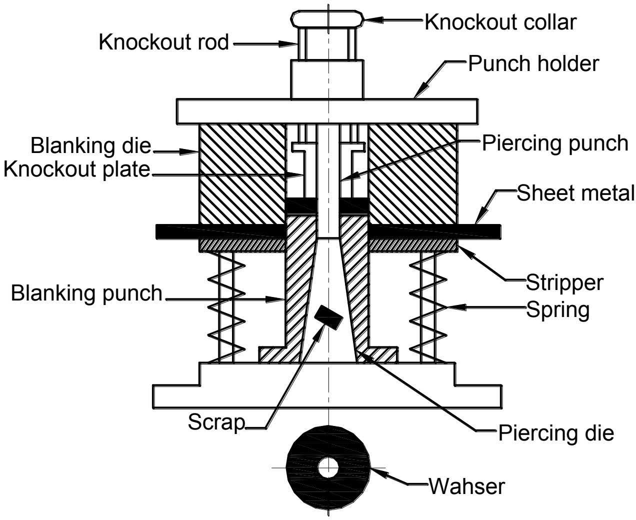


Fig.3.27 Compound die

Advantages

1) Two or more operations can be performed in single die.
2) The products can be made accurately.
3) Production time is less.

Disadvantages

1) The cost of die is more.
2) The design of die is complicated.

3.12.4 Combination die

In this die, a cutting and a non-cutting operation can be performed simultaneously in a single work station when the ram moves downward. Any one cutting operation like blanking, piercing, trimming or cut-off and any one non-cutting operation like bending or drawing can be performed in a single work station. The combination die used for marking up is shown in the figure.

The blanking punch in the punch holder acts as a drawing die also. When ram moves downward, blanking punch cuts the sheet metal. When the ram moves downward further, the blank is pressed between the drawing punch and die to form the required shape.

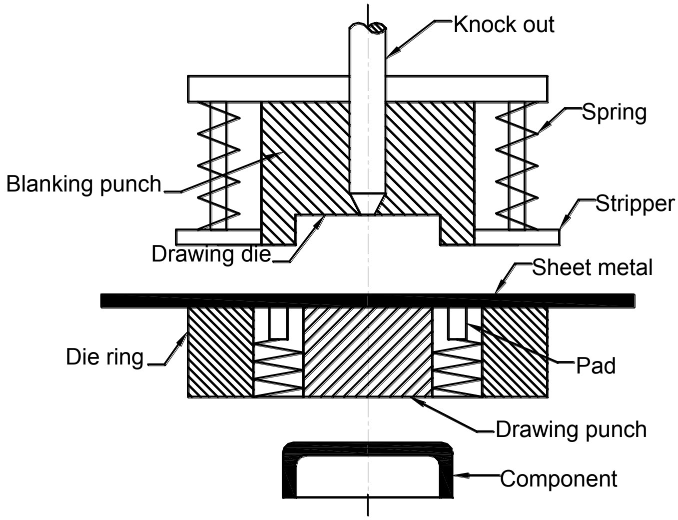


Fig.3.28 Combination die

Advantages

1) Two operations can be performed in a single work station.
2) Production time less.
3) Components can be produced accurately.

Disadvantages

1) The design of die is complicated.
2) The cost of the die is more.

3.12.5 Inverted die

Generally die is fitted in the die holder and punch is fitted in the punch holder. In some times, this arrangement may be changed. In an inverted die, punch is fitted in the die holder and die is fitted in the punch holder.

When ram moves downward, the blank is cut from the sheet metal. This blank is forced into the die opening by the punch to get required shape. The knock out and stripper springs are compressed. When the ram moves upward, the stripper spring releases and ejects the blank form the punch. Then the knock out spring releases and pushes out the blank or product.

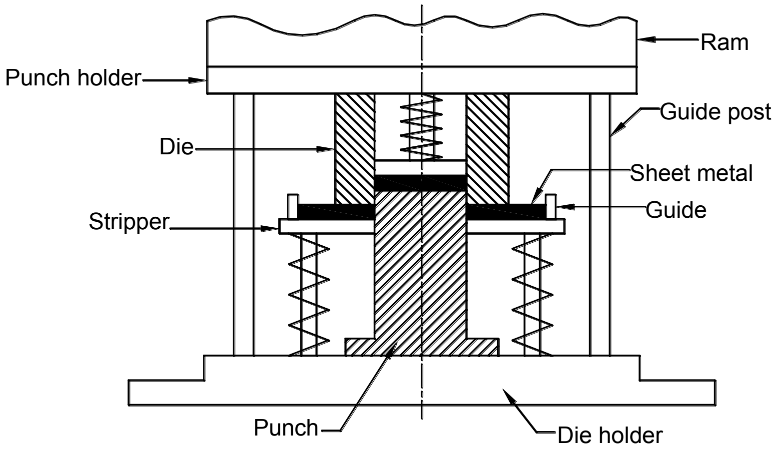


Fig.3.29 Inverted die

In this die, the punch is fitted in the die holder remains stationary. The die fitted to the punch holder moves up and down along with the ram.

Advantages

1) Thin sheet metal does not bend during operation.
2) Heavy blanks can be produced.

Disadvantages

1) The cost of die is more.
2) The design of die is complicated.

3.13 Press working operations

3.13.1 Bending operations

Bending is the process of making the metal sheet into a shape or required angle by plastically deforming the metal. Bending can be done in ductile material by using die and punch or rolls. The surface area of the metal will not be changed after bending.

1) Angle bending

Angle bending is the process of bending a sheet metal to small angle. The die and punch are shaped to required angle. The sheet metal is placed between the die and punch.

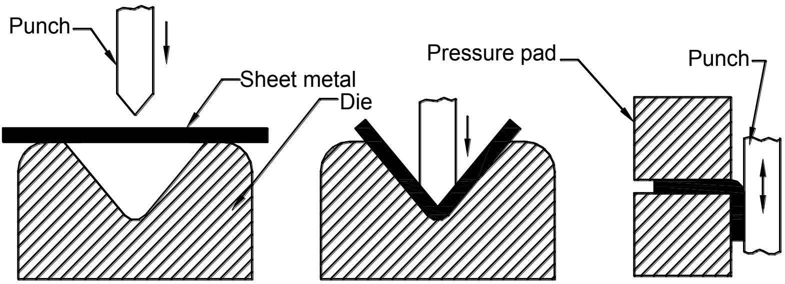


Fig.3.30 Angle bending

When the punch moves downward and presses the sheet metal, the sheet metal is bent according to the shape of die and punch. A small amount of spring back will occur after bending. To overcome this, required allowance should be given in the die.

2) Channel bending

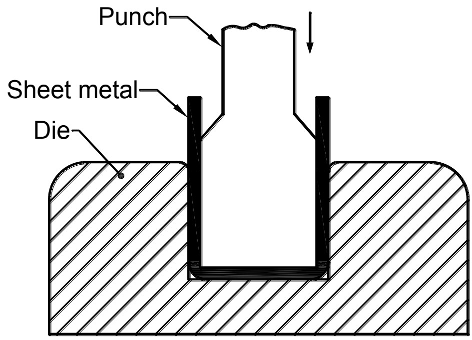


Fig.3.31 Channel bending

Channel bending is the operation of bending a sheet metal in to a channel. The die and punch are formed to required shape and size of channel. The sheet metal is placed between the die and punch. When the punch moves downward and presses the sheet metal, the sheet metal is bent according to the shape of die and punch. Thus channels of required size and shape are formed.

3) Curling

Curling is the operation of bending the edges of the sheet metal into circular form. The sharp edges are avoided by curling. It also strengthens the edges.

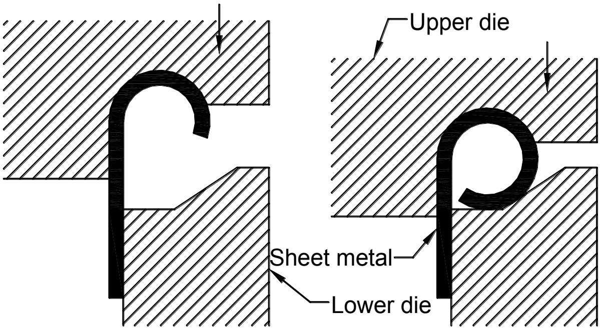


Fig.3.32 Curling

The sheet metal is placed between the copper die (punch) and lower die. The lower die is held stationary. The upper die is shaped to required form at its end. When the upper die moves down, the edge of the work piece is curled and strengthened. Thus curling operation is done in the edges of sheet metal.

4) Drawing

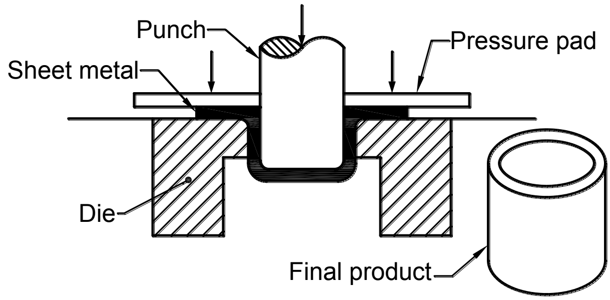


Fig.3.33 Drawing

Drawing is the operation of forming a sheet metal into hollow shape like a cup. If the depth of cup is upto half its diameter, the process is called "*shallow drawing*". If the depth of cup is more than its diamter, it is called as "*deep drawing*".

The die has a cavity in the external shape of the part. The sheet metal blank is held on the die. A blank holder or pressure pad is provided on the blank to avoid buckling or wrinkling of sheet metal. When the punch moves downward, it draws or streches the sheet metal into the die cavity. Due to the tensile forces applied to the sheet, it plastically deforms into a cup-shaped part. The portion of the sheet metal clamped under the blank holder may form a flange around the part that can be trimmed off.

Examples of parts made by drawing include automotive bodies, fuel tanks, cans, cups, bottle caps, kitchen sinks, pots, pans, etc.

5) Seaming

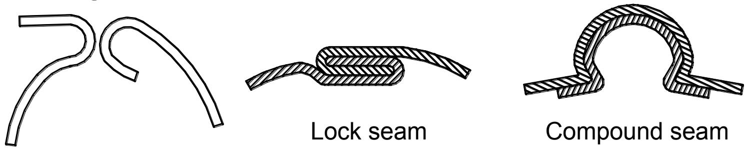


Fig.3.34 Seaming

Seaming is the process of inter locking sheet metals. First, the edges of sheet metal are folded as shown in the figure. Then the edges are inter locked and pressed in rollers to get seam joint. Two types of seam joint are available. They are lock seam and compound seam. Lock seam is used for light joints and compound seam is used for strong and tight joint. Seam joint is done in drums, cans, tins and boxes.

3.13.2 Shearing operations

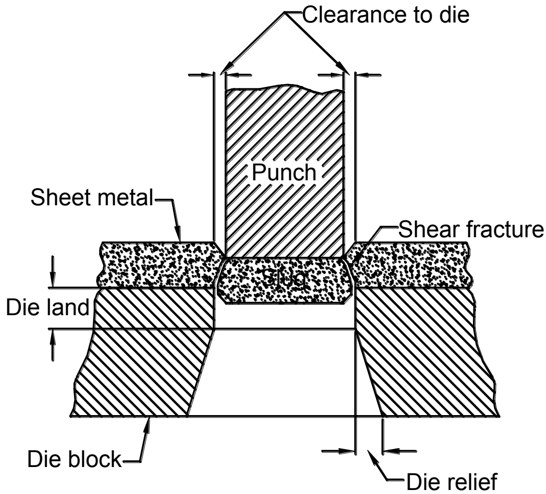


Fig.3.35 Shearing

Shearing is an operation of cutting the sheet metal in punch and die. The sheet metal is placed between the punch and die. When the punch moves down, it is pressed in the die opening. Sufficient clearance should be provided between the punch and die. By this high pressure, high stress is developed in a small area between the cutting edges of punch and die. This causes the plastic deformation of metal. When the stress exceeds the ultimate strength of the metal, fracture takes place. When the punch continues to move down, the metal under the punch is completely cut off and drops down though the die opening.

1) Blanking

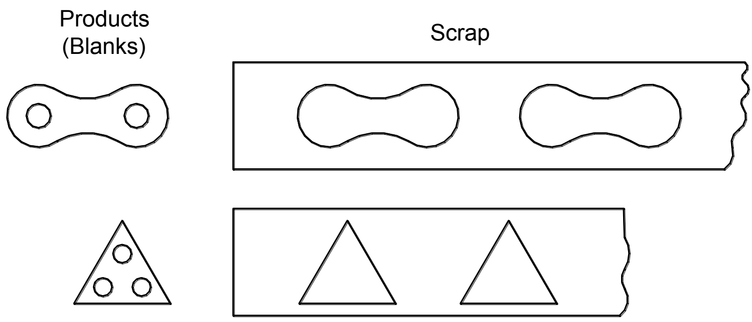


Fig.3.36 Blanking

Blanking is the operation of cutting the sheet metal into required shape by using die and punch. The metal drops down through the die opening is the required product (blank). The sheet metal left on the die is the scrap. The die has the shape and size of required blank. Clearance is given to the punch. So the size of the punch will be smaller than the die.

2) Punching or piercing

Punching is an operation of cutting circular holes in a sheet metal by using a punch and die. The punch has the shape and size of required hole. Clearance is given to the die. The sheet metal is placed between the punch and die. When the punch moves down, hole is pierced. The metal drops down through the die opening is the scrap. The stripper is fitted to prevent the sheet metal from sticking and lifting of sheet metal along the punch. Stop is used to stop the sheet metal at required length.

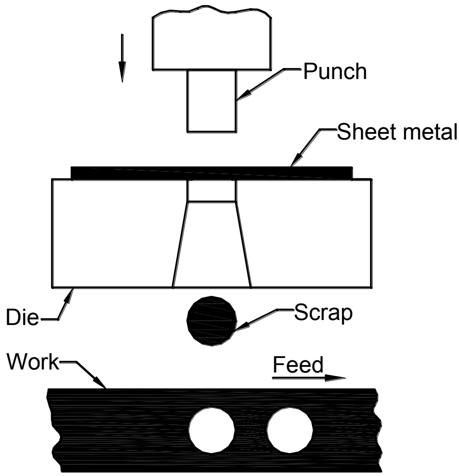


Fig.3.37 Punching

3) Cutting off

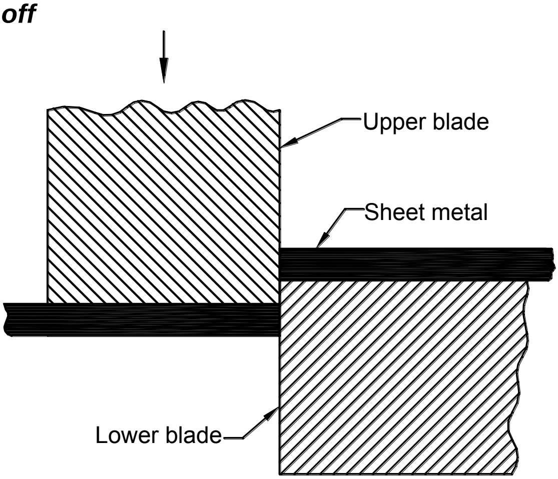


Fig.3.38 Cutting off

Cutting off is an operation of cutting a sheet metal into pieces of required length. The lower blade is fitted in the machine frame and the upper blade is fitted in the ram. Clearance is given between the cutting edges of blades. It varies according to the thickness of work piece. The work piece is held between the blades. When upper blade moves down, the sheet metal is cut off. There is no scrap in cutting operation.

4) Trimming

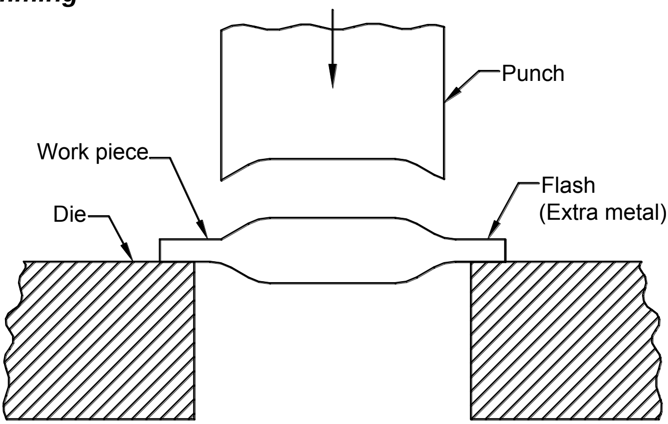


Fig.3.39 Trimming

It is an operation of finishing the work piece by removing the unwanted projections. The work piece is placed on the die. When the punch moves down, it cuts and removes the unwanted portions from the work piece. During drawing operations, impressions are formed on the area gripped by the pressure pad. This portion is removed by trimming.

5) Notching

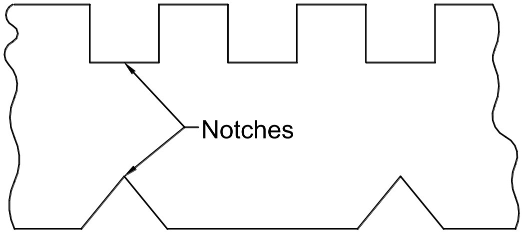


Fig.3.40 Notching

Notching is the operation of cutting small notches at the edge of the sheet metal. Suitable die and punch are used according to the shape of notch to be cut.

6) Slitting

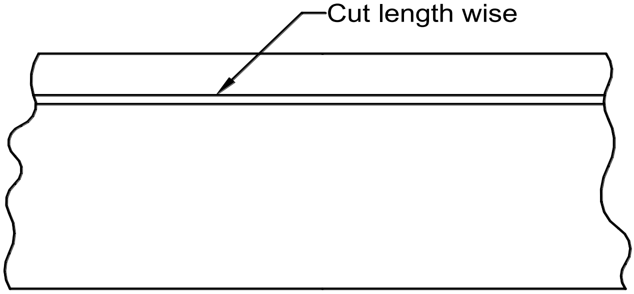


Fig.3.41 Slitting

Slitting is the operation of cutting a sheet metal in straight line to required length. It is done along the length of the sheet metal. The sheet metal is placed between the slitting die and punch and cut to required length.

7) Lancing

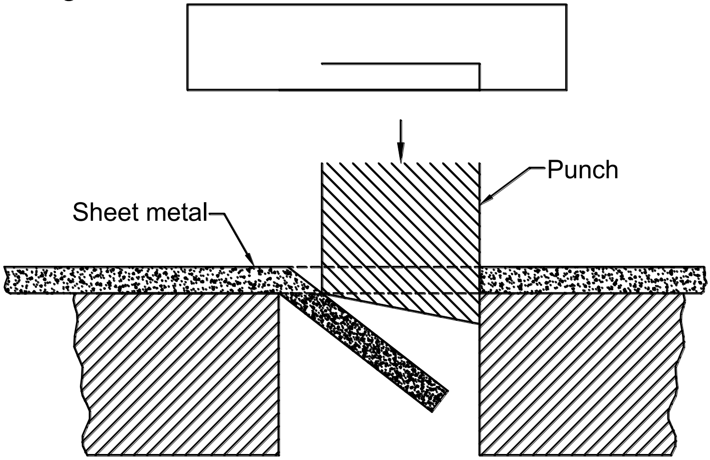


Fig.3.42 Lancing

Lancing is the operation of cutting a sheet metal through a small length and bending it. The sheet metal is placed between the punch and die. When the punch moves down, the blade cuts the sheet metal to required length. When the punch moves further, the cut portion is bent to required angle.

8) Shaving

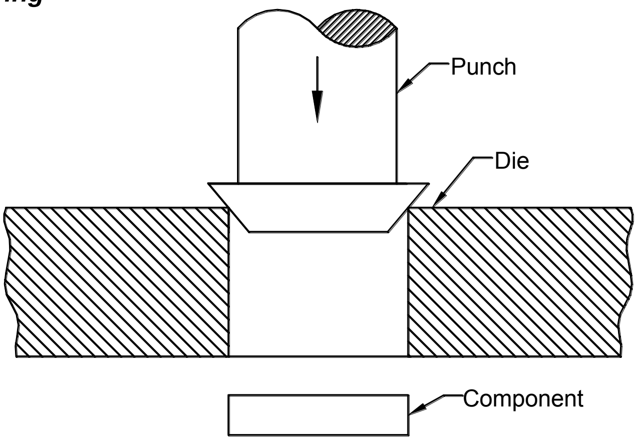


Fig.3.43 Shaving

Shaving is the operation of finishing the components made in sheet metal operations by removing the burrs and irregularities. The component is placed between the die and punch. When the punch moves downward, the burrs and irregular edges in the component are cut and finished.

3.14 POWDER METALLURGY

Generally components are manufactured to required size and shape by machining, casting, hot working and cold working processes. Some times, metals and non-metals cannot be combined and is not possible to produce components with required properties by these methods. Some metals cannot be machined to required shape. Some metals cannot be alloyed together. As some metal has high melting point, it cannot be easily melted and cast.

The above disadvantages are overcome by a special process called powder metallurgy. First the metal and non-metal powders are prepared and mixed together to required proportions. The mixed powder is pressed into a die to get required shape. Then it is hardened by sintering (heating). Thus metal and non-metal powders are mixed at required proportions and components are made with required properties and shape.

3.15 Manufacturing procedure

Powder metallurgy is the process of making components with required properties and shape by mixing metal and non-metal powders.

Powder metal products are manufactured by tie following procedure.

1) Manufacturing of metal powder
2) Blending or mixing
3) Pressing or compacting
4) Sintering
5) Finishing and sizing

3.15.1 Manufacture of metal powder

Powder of various metals are prepared by the following methods.

1) Atomization
2) Electrolytic deposition
3) Chemical reduction
4) Machining
5) Shotting
6) Milling
7) Grinding

1) Atomization

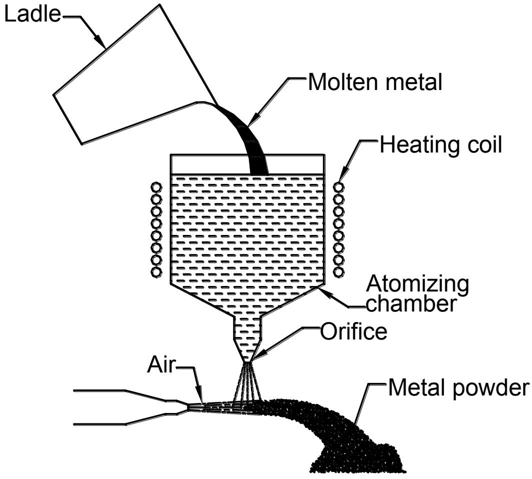


Fig. 3.44 Atomization

In this process, the molten metal is poured into the atomizing chamber. The molten metal comes out through an orifice provided at the bottom of the chamber. Heating coils are provided around the chamber to maintain the temperature of molten metal.

A steam of high pressure water or air or inert gas is passed through a nozzle against the molten metal coming out of orifice. This makes the metal into finely divided particles (powder) and solidify. The metal powder is collected when falls down. This method is used for producing powder of metals having low melting point such as aluminium, lead and zinc.

The size of the particle depends upon the following factors.

1) The temperature of molten metal.
2) Pressure and temperature of atomizing water or air or gas.
3) Design or orifice and nozzle.

Advantages

1) Particles with any required size can be obtained.
2) The size of all particles are uniform.
3) The production rate is high.

2) Electrolytic deposition

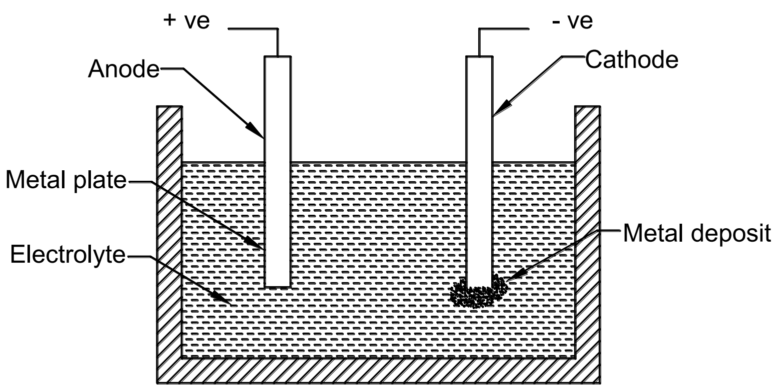


Fig.3.45 Electrolytic deposition

It is similar to electroplating process. In this method, the metal to be powdered acts as anode (+ve) and the metal on which the powder is to be deposited acts as cathode (-ve). The two metals are dipped into an electrolyte. When D.C. supply is given, the metal from the anode gets deposited on the cathode like sponge. Then the metal powder is separated.

Suitable electrolyte should be used in this method. Electrolyte is a salt solution of metal to be powdered. Copper sulphate solution is used as electrolyte to produce copper powder. Here, copper plate acts and anode and aluminium plate acts as cathode.

Metals powders of copper, iron, silver and zinc can be produced by this method.

Advantages

1) Pure powder can be obtained.
2) The powder will have good moulding properties.

Disadvantages

1) It is a slow process.
2) The operating cost is high.

3) Chemical reduction or reduction of oxides

In this method, metal powders can be produced by reducing the metal oxides. For example, tungsten oxide powder is prepared first to produce tungsten powder. This powder is heated to a temperature below its melting point in hydrogen atmosphere. Tungsten oxide is reduced to tungsten by hydrogen in the form of spongy mass.

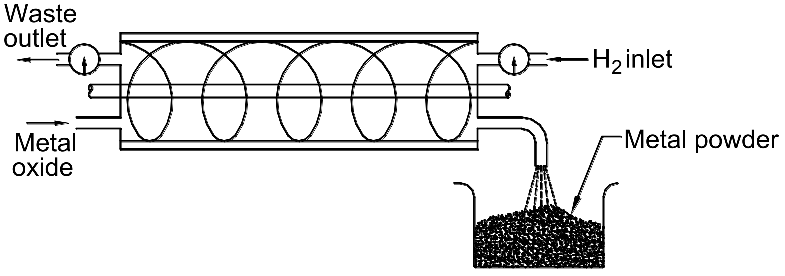


Fig.3.46 Chemical reduction

This method is suitable for producing powders of metals having high melting point such as tungsten and molybdenum. Hydrogen or carbon monoxide is used as reducing agent.

Advantages

1) The metal powder is soft.
2) Compacting can be done easily.
3) Production rate is high.

Disadvantages

1) It is suitable only for metals which can be reduced easily.
2) The metal oxides should be pure.

3.15.2 Blending or mixing

Blending or mixing is the process of combining metal and non-metal powders with correct proportions to get required properties. The particles are uniformly distributed during mixing by using machine. Mixing should be done only for correct duration. The friction between die and component during pressing can be reduced by adding lubricants like graphite powder.

3.15.3 Compacting or pressing

Pressing or compacting is the process of pressing the mixed metal powder into a die to get required size and shape. It is also called as briquetting.

The following can be achieve by pressing.

i) The component remains strong without breaking when handling.
ii) Required density of component can be obtained.
iii) Bonding between the particles is improved.

The following are the two types of pressing.

1) Cold pressing 2) Hot pressing

1) Cold pressing

Mechanical or hydraulic press is used for cold pressing. In this method, the mixed powder is filled in the die cavity and pressed between upper and lower punch. Thus required shape is obtained. The finished metal compact is ejected from the die by the lower punch. The component obtained by cold pressing is called green compact.

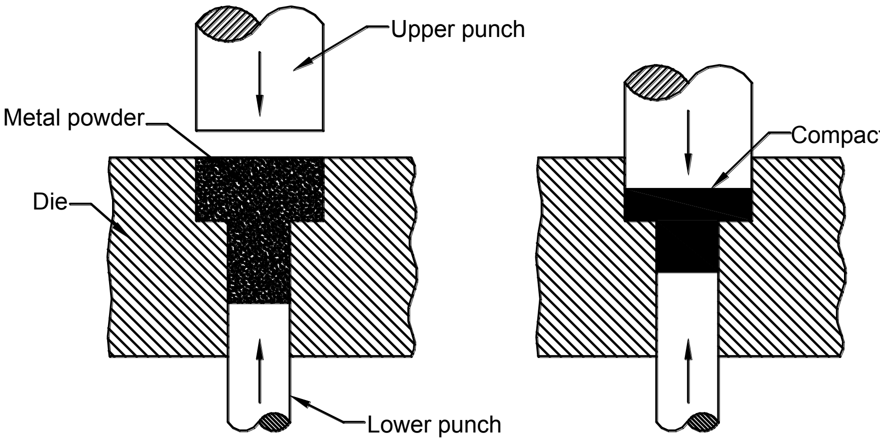


Fig.3.47 Cold pressing

2) Hot pressing

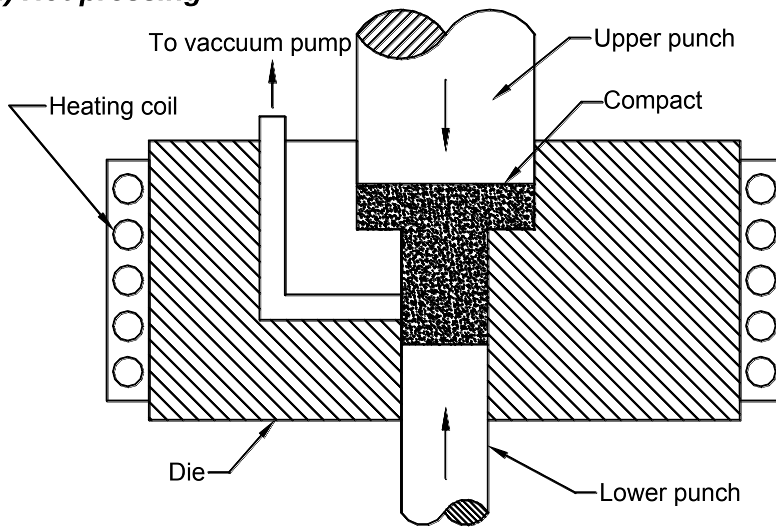


Fig.3.48 Hot pressing

The metal powders of hard materials like diamond and tungsten carbide cannot be pressed by cold pressing. These metal powders can be pressed by using hot pressing to make the component. The mixed metal powder is filled in the die cavity. The die is made of steel or graphite. Steel dies are used when temperature is below 1000ºC and graphite dies are used when the temperature is above 1000ºC. The metal powder is heated to above its recrystalization temperature by the heating coils provided around the die. At the same time, the metal powder is pressed by the upper and lower punch. Hot pressing is done in vacuum or in an inert gas atmosphere. This is to avoid oxidation of metal at high temperature. In hot pressing, heating (sintering) and pressing take place at the same time.

Advantages

1) Components having high strength and hardness can be obtained.
2) Low compacting pressure is sufficient.
3) No lubricant is required.
4) Components with high density can be obtained.
5) Production rate is high as heating and pressing take place at the same time.

Disadvantages

1) The cost of the die is high.
2) The life of die is less as it wears out quickly.

3.15.4 Sintering

Sintering is the process of heating the green compact just below the melting point of its base metal in an controlled atmosphere. Sintering process is affected by the temperature, time and atmosphere. During sintering, the particles of green compact are fused together. This gives required strength, hardness and properties to the component. Sintering is done in vacuum or inert gas atmosphere.

The sintering temperature and time varies according to the type of metal powder and required properties. When the compact is heated to sufficient time, the metal particle bind together to give high tensile strength. The size of the components change during sintering. Generally green compact made of iron and brass is reduced in size by sintering. The green compact made of bronze is increased in size.

Sintering furnace

The sintering furnace is divided into three zones viz. heating zone, soaking zone and cooling zone. Thermo couples are provided in each zone to control the temperature. The furnace is heated by heating coils. Controlled atmosphere is created by passing hydrogen gas into the furnace. Trays are placed over a wire mesh belt conveyor. Green compacts are placed in trays and passed into the furnace.

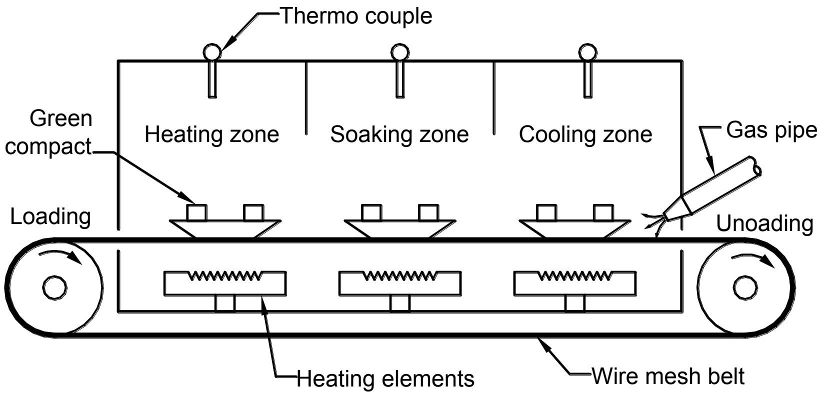


Fig.3.49 Sintering furnace

The green compacts are warmed in the heating zone. In soaking zone, the compacts are heated to sintering temperature. Then the compacts are cooled in cooling zone. The sintering time can be controlled by varying the speed of the conveyor.

3.15.5 Secondary operations or finishing operations

The powder metal products can be used directly after sintering. The following finishing operations are done if more surface finish and accuracy are required.

1) Sizing or coining	2) Infiltration	3) Impregnation
4) Machining	5) Heat treatment	6) Metal coating

1) Sizing or coining

In this method, the sintered component is held in a die and pressed under high pressure. Due to this, a small amount of plastic flow occurs. The component gets the correct size and shape. The strength and density of component is improved by reducing the gap between the particles.

2) Infiltration

Infiltration is the process of filling the pores in the sintered component by using an another molten metal having low melting point. The work piece is covered with the infiltrant metal as thin sheet or powder and kept in a furnace. The infiltrant metal is heated to its melting point. The molten metal fills the pores in the work piece by capillary action.

The strength, hardness and density of the component can be increased by infiltration. Infiltration in iron products are done by using copper. Copper and silver are used as infiltrants in tungsten products.

3.16 Advantages of powder metallurgy

1) High dimensional accuracy, shape and surface finish can be obtained.
2) No material wastage.
3) The product with required density and porosity can be obtained.
4) Components with required properties can be produced by combining metal and non-metal.
5) The rate of production is high.
6) It is suitable for mass production.
7) No skilled labour is required.
8) Components with complicated shapes can be produced easily.
9) The life of the product is high.
10) Components with high hardness can be made easily.

3.17 Disadvantages / Limitations of powder metallurgy

1) It is not economical for small scale production.
2) The cost of equipments and die are high.
3) Large components cannot be produced.
4) The density is not uniform throughout the component.
5) When powder is stored, it may be wasted by oxidation.
6) The broken parts cannot be rejoined.
7) Explosion may occurs while handling some metal powders.
8) The health of operator may be affected.
9) Good physical properties of components cannot be obtained.
10) The time for producing metal powder is more.

3.18 Applications of powder metallurgy

Powder metallurgy is used for producing the following products.

1) Self lubricating bearing, filters and oil pump gears.
2) Hardened carbide tips and wire drawing dies.
3) Tungsten filament wire used in electric bulbs, radio valves and X-ray tubes.
4) Cathode, anode and control grids.
5) Heavy duty electrical contacts.
6) Automobile clutch plate, brake lining and motor brushes.
7) Small gears, cam, lever, piston ring and magnets.
8) Nozzles used in rockets and missiles.
9) Welding electrodes.
10) Refractories.

3.19 Mechanical properties of parts made by powder metallurgy

1) Strength

The structure is not fibrous as the powder grains are only bonded together. So the products have low tensile strength.

2) Hardness

The hardness of the powder metal component is less due to the pores present in it. The hardness will not be uniform as the density varies at different locations.

3) Ductility

The powder metal component has low ductility as the structure is porous. The ductility can be increased by the hot pressing and sintering.

4) Dampness

Powder metal components have good damping properties. So they can absorb vibrations.

3.20 Design rules for powder metallurgy

1) Small holes (less than 2mm diameter) should be avoided.
2) Sudden changes in thickness should be avoided.
3) Narrow and deep sections should be avoided.
4) Holes should not be provided in the direction of pressing.
5) Shape of the component should allow easy ejection from the die. Sharp corners should be avoided in the work piece.
6) Threads, knurling and under cuts should not be formed by compacting.

Review Questions

5 marks questions

1) Define hot working and name the hot working operations.
2) State the advantages of hot working.
3) What is rolling? Briefly explain hot rolling.
4) State the different forging operations.
5) Briefly describe roll forging operation. State its applications.
6) How is a power press specified?
7) List out the driving mechanisms used in presses? Explain any one in detail.
8) What are the advantages of hydraulic press over mechanical press?
9) Write short notes on press tools.
10) List out various types of dies used in press.
11) Distinguish between blanking and punching operation.
12) Explain any three shearing operations.
13) What is powder metallurgy? Give a few industrial applications
14) What is the principle involved in manufacture by powder metallurgy? (Hint: Manufacturing procedure of powder metallurgy)
15) Explain the uses and advantages of powder metallurgy.
16) Describe the atomization process in the manufacture of metal powders.
17) Explain electrolytic deposition

18) Explain how powders are compacted?
19) Explain cold and hot compaction of powders.
20) Explain the sintering process.
21) What is meant by infiltration?
22) Name the few components manufactured by powder metallurgy process.
23) Explain the design rules for the powder metallurgy process.
24) Explain mechanical properties of parts made by powder metallurgy process.

10 Marks Questions

1) Explain the process of press forging. State its advantages.
2) Explain the following forging operations:
   a) Upset forging c) Roll forging
   b) Drop forging d) Swaging.
3) Write short notes on the following smith forging operations:
   a) Upsetting c) Punching
   b) Bending d) Setting down.
4) How are presses classified? Sketch and explain the working of ball press.
5) What are the types of frames used in presses? Explain any two of them with sketches.
6) Explain the working of a mechanical press with any one driving mechanism.
7) Explain the hydraulic press with sketch.
8) Briefly explain the following accessories in a die set.
   a) Stripper b) Pressure pad c) Knock out d) Pilot e) Stop
9) What is compound die? Explain its working with a neat sketch
10) Explain a combination die set with a sketch.
11) Sketch and explain a simple progressive die set.
12) Explain an inverted die with neat sketch.
13) Explain the following operations with sketches.
   a) Blanking b) Trimming c) Cutting off
14) Explain the following operations with sketches.
   a) Punching b) Lancing c) Drawing

15) Explain the following bending operations:

a) Angle bending b) Seaming c) Curling.

16) State the various methods of manufacturing metal powders and explain any one method in detail.

17) Explain the step by step procedure to manufacture parts by powder metallurgy process.

18) Explain the method of manufacturing metal powder by reduction of oxides.

19) Describe the process of compacting and sintering of metal powders.

20) Explain briefly the working of sintering furnace with neat sketch.

Unit – IV

THEORY OF METAL CUTTING, CENTRE LATHE & SEMI – AUTOMATIC LATHE

4.1 Metal cutting - Introduction

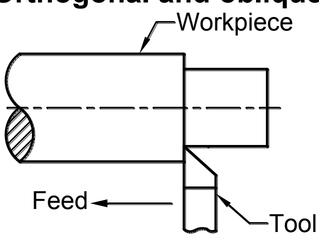
The manufacturing processes used for producing a component is generally divided into two groups. They are

1) Non-cutting shaping process
2) Cutting shaping process

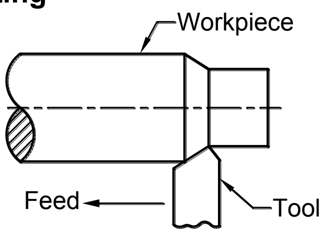
In non cutting shaping process, the required shape is formed in the work piece by the application of heat, pressure or both. There is no chip formation in this method. This group includes operations like forging, drawing, spinning, rolling, extrusion, etc.

In cutting shaping process, the required shape is obtained in the work piece by removing material form the work piece in the form of chips. This group includes operations like turning, boring, milling, drilling, shaping, broaching, etc. Metal cutting is done by using a single point cutting tool or multipoint cutting tool.

4.2 Orthogonal and oblique cutting



(a) Orthogonal cutting



(b) Oblique cutting

Fig.4.1 Orthogonal and oblique cutting

In *orthogonal cutting,* the cutting edge of the tool is perpendicular to the direction of tool feed or work feed. The forces acting at the cutting edge can be represented by two mutually perpendicular coordinates. Hence it is also called as *two dimensional cutting*.

In *oblique cutting* , the cutting edge of the tool is inclined at an acute angle with the direction of tool feed or work feed. The forces acting at the cutting edge can be represented by three mutually perpendicular coordinates. Hence it is also called as *three dimensional cutting*.

The differences between orthogonal and oblique cutting are tabulated below :

	Orthogonal cutting	**Oblique Cutting**
1)	The cutting edge of the tool is perpendicular to the direction of feed motion.	The cutting edge of the tool is inclined to the direction of feed motion.
2)	The direction of chip flow velocity is perpendicular to the cutting edge of tool.	The direction of chip flow velocity is at an angle to the cutting edge of tool.
3)	The chips flow over the tool.	The chips flow along the sideways.
4)	Cutting force and thrust forces are acting at the cutting edge.	Cutting force, radial force and thrust forces are acting at the cutting edge.
5)	The cutting edge is larger than cutting width.	The cutting edge may or may not be larger than cutting width.
6)	High heat concentration at cutting region.	Less heat concentration at cutting region.
7)	Tool life is less.	Tool life is more.
8)	Poor surface finish on workpiece.	Good surface finish on workpiece.
9)	Operations include grooving, parting, slotting, pipe cutting, etc.	Operations include drilling, grinding, milling, turning in lathe, etc.

4.3 Lathe tools

Single point cutting tool has one cutting edge. Shank of the tool can be easily fitted in the tool post. Cylindrical or flat work pieces can be machined by using single point tool.

The important tools used in lathe are shown in the figure.

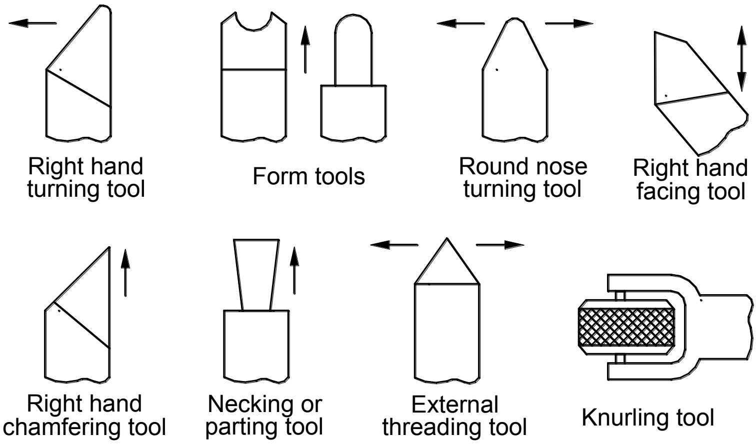


Fig.4.2 Lathe tools

4.3.1 Nomenclature of single point cutting tool

Naming the various parts and angles of a cutting tool is known as nomenclature of cutting tool.

The important parts of a single point cutting tool are as follows.

1) ***Shank:*** It is the body of the tool which is not ground.

2) ***Face:*** It is a tapered surface in front of the shank. The chips slides over the face.

3) ***Flank:*** It is the tool surface facing the work piece. There are two flanks namely end flank and side flank.

4) ***Base:*** It is bottom surface of the shank.

5) ***Cutting edge:*** It is the edge formed by the intersection of face and flank. There are two cutting edges namely end cutting edge and side cutting edge.

6) ***Nose:*** It is the junction of side cutting edge and end cutting edge.

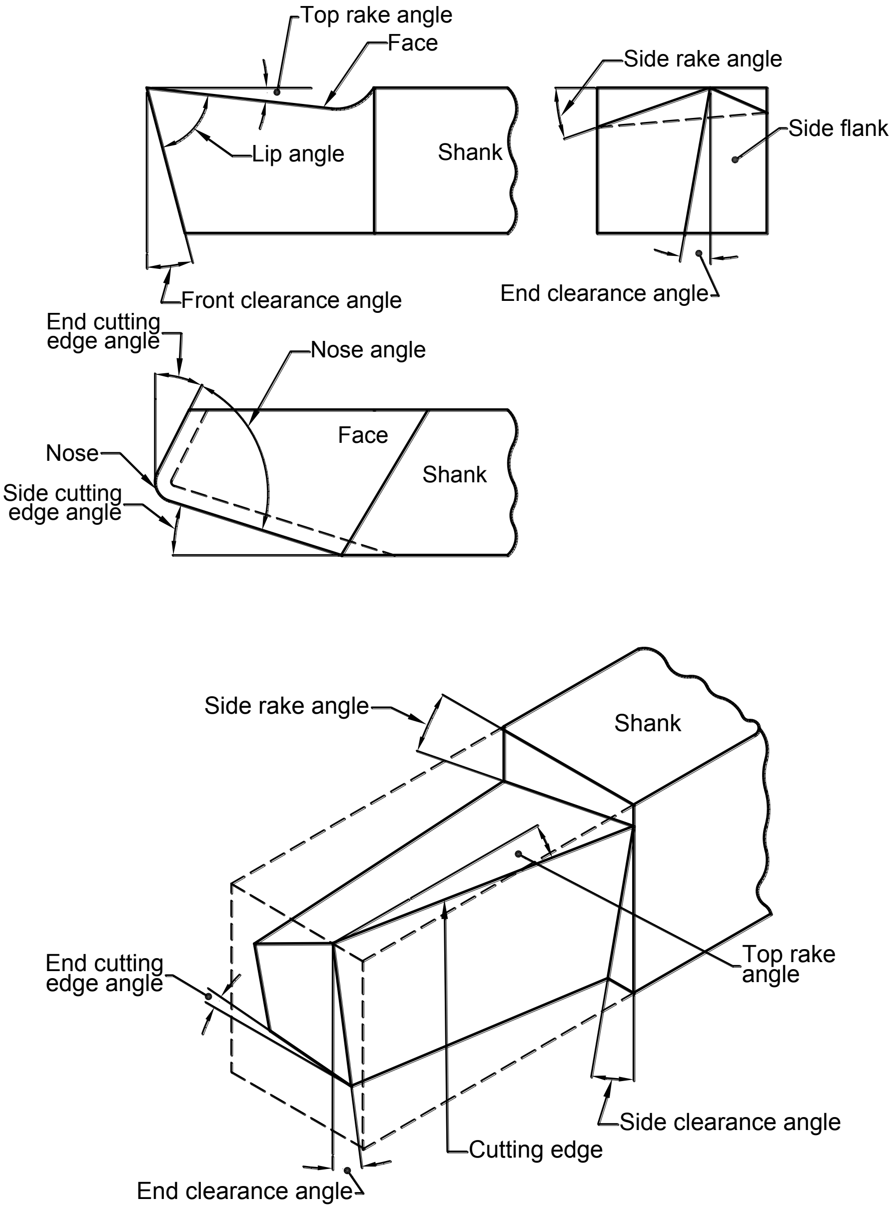


Fig.4.3 Nomenclature of a single point tool

The important angles of single point cutting tool are as follows.

1) Top rake angle

This is the angle of slope formed on the face towards the shank from the cutting edge. If the slope is downwards from the cutting edge, it is called positive rake. If the slope is upwards from the cutting edge, it is called negative rake. If there is no slope, it is called zero rake.

2) Side rake angle

This is the angle of slope formed from the cutting edge towards the side (width) of the face. The rake angle helps easy flow of chips.

3) Clearance angle or relief angle

This is the angle of the slope formed downwards from the cutting edge. This prevents the rubbing of the work piece on the tool.

Side clearance angle : It is the angle of slope formed downwards at the side of the tool.

End clearance angle : It is the angle of slope formed downwards at the front of the tool.

4) Cutting edge angle

There are two cutting edge angles namely side cutting edge angle and end cutting edge angle.

Side cutting edge angle: It is the angle made by the side cutting edge with the tool axis.

End cutting edge angle : It is the angle made by the end cutting edge with the tool width.

5) Lip angle or cutting angle

It is the angle between face and end surface. The strength of the tool depends on this angle.

6) Nose angle

It is the angle between the side cutting edge and end cutting edge.

4.4 Types of chips

During the cutting operation of work piece by using a turning tool, the metal is removed in the form of chips. The chips are of three types.

1) Continuous chips

These are metal chips formed during machining in the form of a long continuous ribbon. Continuous chips are formed while machining ductile material at high cutting speed with low feed.

2) Discontinuous or segmental chips

These chips are produced during machining in the form of small pieces without any continuity. Discontinuous chips are formed while machining brittle materials like cast iron, bronze, etc.

3) Chip with built-up edge

During the formation of continuous chips, a small piece of chip is welding at the cutting edge of the tool due to the high pressure and high temperature. This is known as built up edge. The cutting action is decreased and rough surface is produced on the work piece.

4.4.1 Chip breakers

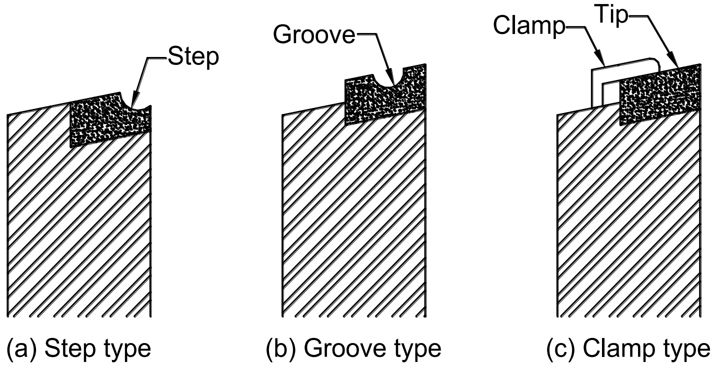


Fig.4.4 Chip breakers

Chip breakers are used to break the long continuous chips formed during machining into small pieces. Continuous chips will affect the tool, work piece, machine and operator. It is difficult to remove these chips. So the chips should be broken into small pieces. Chip breaker is necessary in automatic and high speed machines.

The following three types of chip breakers are available.

1) Step type

The chips are broken into small pieces by a step provided in the tool face behind the cutting edge.

2) Groove type

The chips are broken into small pieces by a groove provided in the tool face behind the cutting edge.

3) Clamp type

A thin chip breaker is clamped on the tool face. The chips are broken into small pieces by this.

4.5 Cutting tool materials

The following cutting tool materials are used for producing tools.

1) Carbon steel
2) Alloy carbon steel
3) High Speed Steel (H.S.S)
4) Stellites
5) Carbides
6) Ceramics
7) Diamond

1) Carbon steel

a) Medium carbon steel

It contains 0.2 to 0.8% carbon. It has high strength and medium hardness. It is used for making cutting tools like chisel, hack saw, etc.

b) High carbon steel

It contains 0.8 to 1.2% carbon. It has low heat resistance and high wear resistance. It can be easily forged and hardened. It is used for making cutting tools operated at low speed such as turning tool, drill, taps, files, etc.

2) Alloy carbon steel

Alloy carbon steel is obtained by adding up to 5% of other elements with carbon steel. The properties of tool material can be improved by adding alloying elements like chromium, vanadium, tungsten, molybdenum, etc.

Alloying elements and its effects

1.	**Nickel**	:	Toughness, hardness and corrosion resistance are increased.
2.	**Chromium**	:	Toughness, hardness and corrosion resistance are increased.
3.	**Tungsten**	:	Hot hardness is increased.
4.	**Cobalt**	:	Toughness, hardness thermal resistance and magnetic properties are improved.
5.	**Vanadium**	:	Toughness, hardness and wear resistance are increased.
6.	**Molybdenum**	:	Hardness, wear resistance and thermal resistance are increased.
7.	**Manganese**	:	Strength, hardness and toughness are increased.

3) High Speed Steel (H.S.S)

This type of steel contains up to 0.8% carbon. Tungsten, molybdenum, cobalt, chromium and vanadium are added with this steel. This tool steel effectively cut materials at high speed also. The cutting speed is 2 to 3 times higher than the carbon steel. It can retain its hardness up to 900°C. Drills, turning tools, broaches, taps, dies and milling cutter can be produced by using this steel. The following three types of H.S.S are available.

a) Tungsten high speed steel
b) Molybdenum high speed steel
c) Cobalt high speed steel

a) Tungsten high speed steel

It contains 18% tungsten, 4% chromium, 1% vanadium and 0.75% carbon. It is also called as 18-4-1 HSS. It is used for producing drill bits, milling cutters, lathe, planer and shaper tools.

b) Molybdenum high speed steel

This type of steel contains 6% molybdenum, 5% tungsten, 4% chromium, 2% vanadium. It has high toughness and cutting ability.

c) Cobalt high speed steel

It contains 12% cobalt, 20% tungsten, 4% chromium, 2% vanadium. It is also called as super high speed steel. It is used for producing planer tools, milling cutters and lathe tools.

4) Stellites

It is a non-ferrous cast alloy. It contains 45% chromium, 15% tungsten and 2% carbon. It cannot be forged as it is so brittle. It can retain its hardness up to 1000ºC. The cutting speed is 2 times more than the high speed steel. Small tip of stellite is brazed to the tool shank. Stellites are used to produce tools for cutting rubber and plastics.

5) Carbides

Tungsten carbide is produced by mixing 6% carbon with 94% tungsten powder and heating at 1500ºC. Tungsten carbide is mixed with cobalt and pressed at high pressure to form as blocks. It is cut and ground to required shape and then sintered at high temperature. A type of carbide tip has 82% tungsten, 10% titanium carbide and 8% cobalt. This carbide tips are brazed in the tool shank. It can withstand temperature up to 1000ºC. The cutting speed is 6 times more than the cutting speed of H.S.S. Heavy support must be provided to avoid cracking as it so brittle. It is used for machining hard materials like cast iron, bronze and hard steel.

6) Ceramics

It consists of aluminium oxide. Aluminium oxide powder is pressed in moulds at high pressure and sintering is done at 2200ºC. Ceramic tips are clamped in the tool shank. It has high hot hardness, compressive strength and brittleness. It can withstand temperature up to 1200ºC. No coolant is required for this tool. The cutting speed is 40 times more than the cutting speed of H.S.S. It is used to produce single point cutting tools for machining plastics and cast iron.

7) Diamond

It is the hardest cutting material. The cutting speed is 50 times more than the cutting speed of H.S.S. It can withstand temperature up to 1250ºC. Diamond tipped tools are used for machining very hard materials like abrasive wheels, glass, plastics, and ceramics.

4.5.1 Properties of cutting tool materials

The cutting tool material should have the following properties.

1) The hardness of tool material must be more than the hardness of work material even at high temperature.
2) The tool material should have high wear resistance.
3) It should have high toughness to withstand shock and vibration.
4) The friction between the tool and work piece should be minimum.
5) The cost of tool material will be low.

4.6 Tool life and tool wears

Tool life is defined as the time between two successive grinding of tool or it is the period during which the tool cuts the metal satisfactorily. A tool cannot cut effectively for long period of time. Tool failure of cutting tool occurs gradually after certain period due to the following reasons.

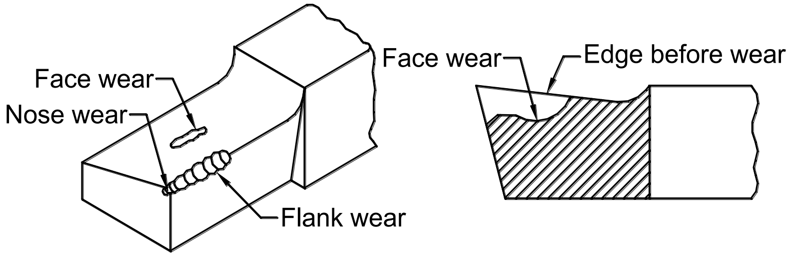


Fig.4.5 Tool wear

1) Face wear or crater wear

The tool face wears gradually due to the pressure of the sliding chips.

2) Flank wear or edge wear

The flank portion behind the cutting edge wears out gradually due to the friction and abrasion between the tool and work piece. It reduces the clearance in the tool and gives poor surface finish on the work piece.

3) Nose wear

When the tool nose is rough, the friction between the tool and work piece will be high. This generates high heat in the tool. So the tool nose wears out quickly.

4) Loss of hardness

The hardness of the tool gets reduced due to the high temperature developed during metal cutting and the tool becomes soft. So the tool cannot cut effectively. When tool failure occurs, regrinding is done on the tool and reused.

4.7 Factors affecting tool life

The life of the cutting tool is affected by the following factors.

1) Cutting speed	2) Feed	3) Depth of cut
4) Tool geometry	5) Tool material	6) Cutting fluid
7) Work material	8) Rigidity of work, tool and machine.	

1) Cutting speed

The length of chip cut by a tool from a rotating work piece in one minute is called cutting speed.

$$\textbf{Cutting speed,}\ \ V = \frac{\pi D n}{1000}\ \textbf{m/min}$$

Where, D – Diameter of work piece (mm)

n – Rotating speed of work piece (rpm)

It is an important factor affecting the tool life. When the cutting speed increased, temperature of tool increases. Due to this, the hardness of tool decreases and the tool flank wears out quickly. So tool life is decreased due to high cutting speed. The tool life will be increased at low cutting speed.

The relation between the cutting speed and tool life is expressed by Taylor's formula.

$$V\,T^n = C$$

Where, V – Cutting speed (m / min)

T – Tool life (min)

n – A value depends upon the tool and work piece.

(For machining mild steel work pieces using HSS tool, n= 0.1; when using carbide tool, n = 0.2 to 0.25)

C – A constant

2) Feed

Feed is the distance moved by the tool per revolution of the work piece. For particular speed, if the feed is very low, the area of chips slide over the tool face is increased and the tool wears out. At the same time, if more feed is given, the cutting force on the tool is increased. This also reduces the tool life. So correct feed should be given for increasing the tool life.

3) Depth of cut

Depth of cut is the thickness of metal removed from the work piece when the cutting tool is moved once. For particular cutting speed, if the depth of cut is more, the cutting force on the tool is increased. This reduces the tool life as the tool wears out quickly. So correct depth of cut should be given for increasing the tool life.

4) Tool geometry

Large rake angle reduces the cross section of tool. Due to this, the area of the tool which transfer the heat is reduced. So the tool is heated more and wears out easily. Correct rake angle should be provided for increasing tool life. The tool life can be increased by increasing the nose radius.

5) Tool material

The life of tool depends on the properties of tool material. High speed steel (HSS) tools have more life than carbon steel tools. Carbide tools have more life than HSS tools.

6) Cutting fluid

The tool life can be increased by using correct cutting fluids. The cutting fluid carries away the heat generated during machining and keeps the tool, chips and work piece cool. It also reduces the friction between the tool and chips. So tool life is increased.

7) Work material

The life of tool depends upon the physical and chemical properties of work piece material. Tool life will be more when machining soft materials than hard materials.

8) Rigidity of work, tool and machine

A tool rigidly fitted in the machine will have more life than a tool fitted under vibrating conditions. When the work piece is held with sufficient grip, the tool life is increased.

4.8 Cutting fluids

Cutting fluid is a type of coolant and lubricant used in metal working processes to increase the performance of machining. The commonly used cutting fluids are soluble oils, kerosene base oil, mineral oil, synthetic coolants, sulphonated oils, water base emulsion, etc. They may be made from petroleum distillates, animal fats, plant oils, water, air, or other raw ingredients.

4.8.1 Functions of cutting fluid

The following are the functions of a cutting fluid:

1) To cool the tool and work piece.
2) To conduct the heat generated in cutting away from the cutting zone.
3) To decrease adhesion between chip and tool.
4) To reduce the friction and wear.
5) To wash away the chips and keep the cutting region free.
6) To prevent corrosion on machine parts, work piece and tool.
7) To decrease wear and tear of the tool and hence to increase the tool life.
8) To provide a good surface finish on the work piece.
9) To improve machinability and to reduce machining forces.

4.8.2 Properties of cutting fluid

The following are the desirable properties of a good cutting fluid:

1) High thermal conductivity for cooling.
2) Low viscosity for free flow.
3) Good lubricating qualities.
4) High flash point to prevent fire hazard.
5) Must not produce a gummy or solid precipitate at ordinary working temperatures.
6) Be stable against oxidation.
7) Must not promote corrosion or discolouration of the work material.
8) Should not produce unpleasant odour on continued use.
9) Must not cause skin irritation or contamination.

4.9 LATHE - Introduction

Generally, lathe is an important basic machine for all types of machines. All the machine tools available nowadays are developed on the basis of lathe. Lathe is used for removing metal from cylindrical work piece to get required shape and size. The work piece is held in the lathe and rotated about its axis. The single point cutting tool is moved parallel to the axis of work piece to produce cylindrical surface.

4.9.1 Types of lathe

The various types of lathe are classified as follows according to the size, design and purpose of use.

1) Speed lathe
2) Engine lathe or Centre lathe
3) Bench lathe
4) Tool room lathe
5) Semi automatic lathe
6) Automatic lathe
7) Special purpose lathe

1) Speed lathe

In this type of lathe, head stock, tail stock and tool post are mounted on the bed. It has no gear box, carriage and lead screw. So it is used for simple operations like wood turning, polishing, etc. As the spindle of this lathe rotates at high speed, it is called as speed lathe.

2) Engine lathe or centre lathe

In early days this type of lathe is driven by using a steam engine. So it is called as engine lathe. In this type of lathe, head stock, tail stock and carriage are mounted on the bed. It has lead screw, feed rod and charge gears. So different feed and speed can be obtained in this lathe. Engine lathes are widely used. By using engine lathe, operations like facing, turning, drilling, reaming, boring, knurling, thread cutting, grooving, etc. Can be performed.

3) Bench lathe

It is a small size lathe mounted on a bench. It has all the parts and mechanisms as in an engine lathe. Small size products can be produced in this lathe.

4) Tool room lathe

It is a very accurate lathe used in tool rooms. It is designed for producing tools, dies and gauges more accurately and precisely. It has different feed and speed. The cost of the lathe is high.

5) Semi automatic lathe

Capstan lathe and turret lathe are the two types of Semi automatic lathe. This type of lathe has an hexagonal turret capable of holding 6 tools instead of tail stock. Four tools can be fitted in front tool post and one tool can be fitted in rear tool post of this machine. The tools required for producing a job are preset according to the sequence of operation. So the tool setting time is reduced and production rate is increased.

6) Automatic lathe

In this type of lathe, all the operations from loading to unloading are done automatically. The different movements are automatically controlled by the various cams provided in the cam shaft of the lathe.

7) Special purpose lathe

This type of lathe is specially designed for specified operation. This lathe can be used for producing jobs which cannot be easily produced is centre lathe.

Gap bed lathe

In this lathe, a portion of bed near the head stock is removed. So work piece with large diameter can be machined easily.

Duplicating lathe or copying lathe

In this lathe, a tracer moves on a master piece. It is connected to the cutting tool through pneumatic or mechanical devices. The tracer movement is transmitted to the tool and the shape of master piece is formed in the work piece.

4.10 Specifications of a lathe

The important specifications of a lather are given below.

1) Length of bed
2) Width of bed
3) Height of centres over the bed
4) Distance between centres
5) Swing diameter over the bed
6) Swing diameter over the carriage
7) Maximum diameter of hole through spindle
8) Power of the motor
9) Number of spindle speeds
10) Mode of drive
11) Lead screw details
12) Weight and floor space required.

4.11 Principal parts of a centre lathe

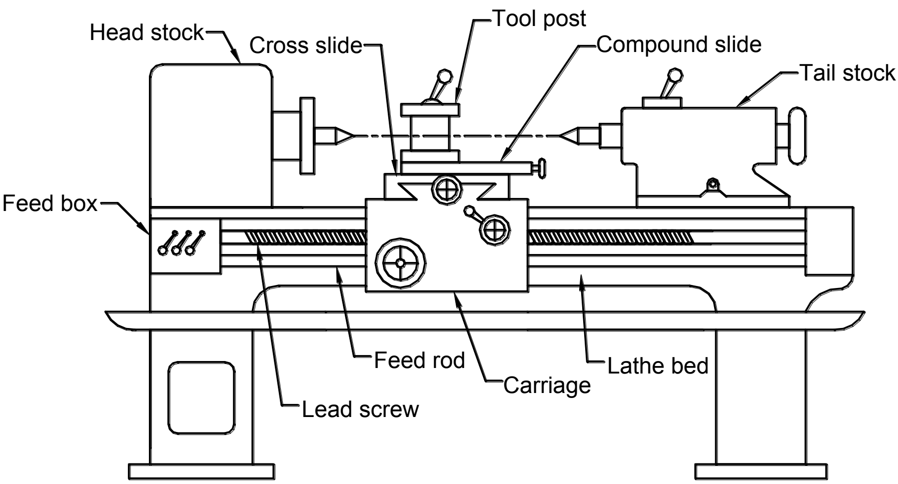


Fig.4.6 Simple sketch of a centre lathe

A lathe has the following principal parts.

1) Bed 2) Head stock
3) Carriage 4) Tail stock
   i) Saddle
   ii) Cross slide
   iii) Compound rest
   iv) Tool post
   v) Apron

4.11.1 Bed

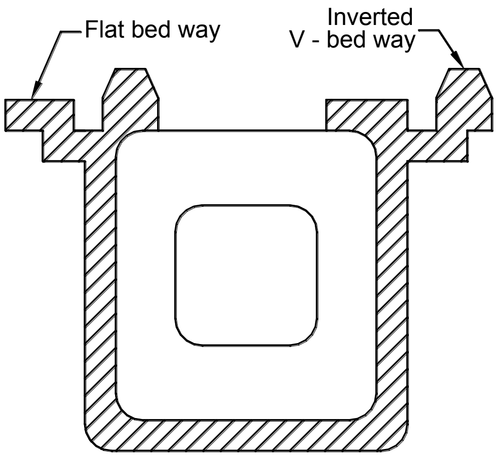


Fig.4.7 Lathe bed

The lathe bed is made strongly with cast iron. It withstands the cutting force and vibrations. The head stock is mounted on the left, the tail stock at the right and the carriage in the middle of bed. The carriage and tail stock move over the flat or 'V' shaped guide ways on the bed.

4.11.2 Head stock

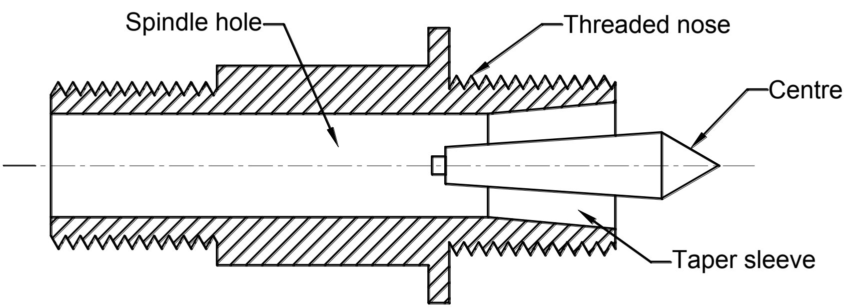


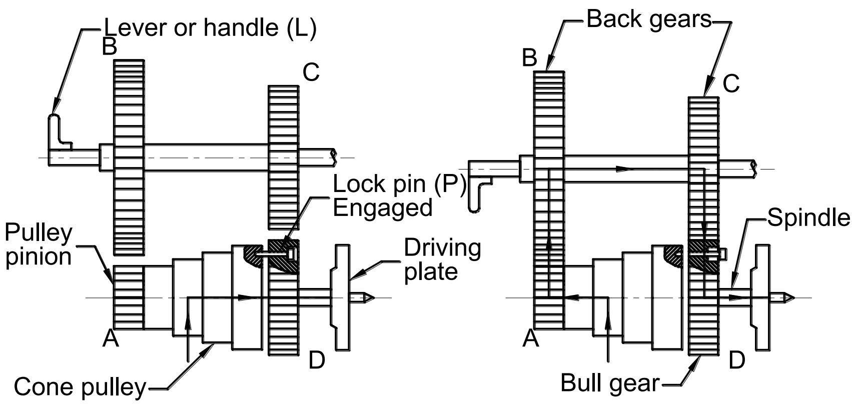
Fig.4.8 Head stock spindle

The head stock with a hollow spindle is mounted on the bed. Chuck or face plate can be fitted in the threaded spindle nose. Driving and speed changing mechanisms are provided in the head stock. The following are the two types of head stock.

1) Back geared head stock
2) All geared head stock

1) Back geared head stock

In this type of head stock, spindle speed is reduced by a back gear arrangement. Gear A is connected to the step cone pulley and bull gear D is connected to the spindle. Gear A will rotate when the cone pulley rotates. Back gears Band C are fitted in the back shaft. The back gears B and C can be engaged or disengaged to the gears A and D with the help of lever or handle (L).



(a) Back gear not engaged **(b) Back gear engaged**

Fig.4.9 Back geared head stock

Direct or fast speed

When the bull gear lock pin (P) is engaged, the cone pulley, gear A and bull gear D will rotate together. So four fast speed can be obtained. Now the back gears are in disengaged position.

Indirect or slow speed

The lock pin (P) is disengaged. Back gears B and C are meshed with gears A and D by shifting the lever (L). Now the power is transmitted from gear A to spindle through gear B, C and D as shown in the figure. As gear B is larger than A, the speed will be reduced at B. Gears B and C will have the same speed. As gear D is larger than gear C, the speed will be further reduced. Thus four slow speeds can be obtained by engaging back gears.

2) All geared head stock

In this type of head stock, the spindle is rotated by a motor through gears. In this arrangement the gears G_1, G_2, G_3, are mounted on the splined shaft and get power from the driving pulley. Gears G_4, G_5 and G_6 are permanently fixed in the intermediate shaft. Gears G_7, G_8 and G_9 are fitted on the splined head stock spindle and can be moved axially.

Gears G_1, G_2, G_3 and gears G_7, G_8, G_9 can be moved with the help of levers and engaged with the gears G_4, G_5, G_6 respectively. So 9 different gear combinations can be obtained and thus 9 different spindle speeds can be obtained.

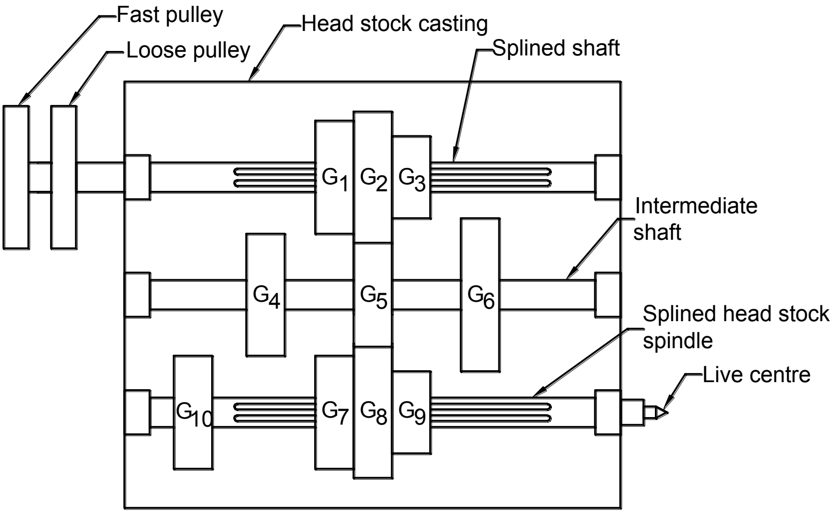


Fig.4.10 All geared head stock

The gear combinations for 9 different spindle speeds are as follows.

1) $\frac{G_1 \times G_4}{G_4 \times G_7}$ 2) $\frac{G_2 \times G_4}{G_5 \times G_7}$ 3) $\frac{G_3 \times G_4}{G_6 \times G_7}$

4) $\frac{G_1 \times G_5}{G_4 \times G_8}$ 5) $\frac{G_2 \times G_5}{G_5 \times G_8}$ 6) $\frac{G_3 \times G_5}{G_6 \times G_8}$

7) $\frac{G_1 \times G_6}{G_4 \times G_9}$ 8) $\frac{G_2 \times G_6}{G_5 \times G_9}$ 9) $\frac{G_3 \times G_6}{G_6 \times G_9}$

4.11.3 Carriage

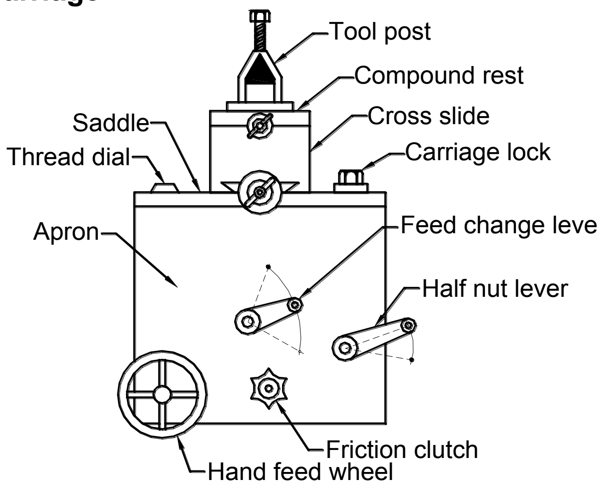


Fig.4.11 Carriage

Carriage moves on the guide ways of lathe bed parallel to the spindle axis. The carriage is used for giving various movements to the tool. It can be moved by hand or by power. Saddle, cross slide, compound rest, tool post and apron are mounted on the carriage.

1) Saddle

It is a 'H' shaped casting. Saddle slides over the guide ways of bed. Cross slide, compound rest and tool post are mounted over the saddle.

2) Cross slide

It is mounted over the saddle. It moves perpendicular to the lathe axis. The cross slide can be moved by hand or by power. Compound rest and tool post are mounted on the cross slide.

3) Compound rest or compound slide

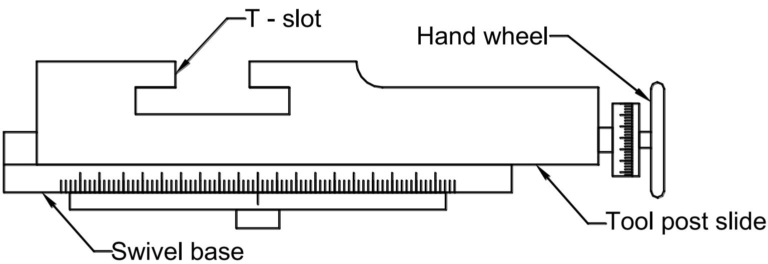


Fig.4.12 Compound rest

It is fitted on the cross slide. Compound rest has a swivel base graduated with degrees. The swivel base can be tilted to any required angle. Compound rest is used during taper turning. Hand feed only can be given. There is no power feed for compound rest.

4) Tool post

Tool post is fitted in the T-slots provided on the compound rest. The tool is clamped in the tool post. The following four types of tool posts are used in lathe.

i) Single screw tool post
ii) Open side tool post
iii) Four bolt tool post
iv) Four way tool post

Single screw tool post

One tool can be fitted in single screw tool post with the help of clamping screw. The tool can be adjusted to required height by placing on a convex rocker. The convex rocker rests over a concave ring.

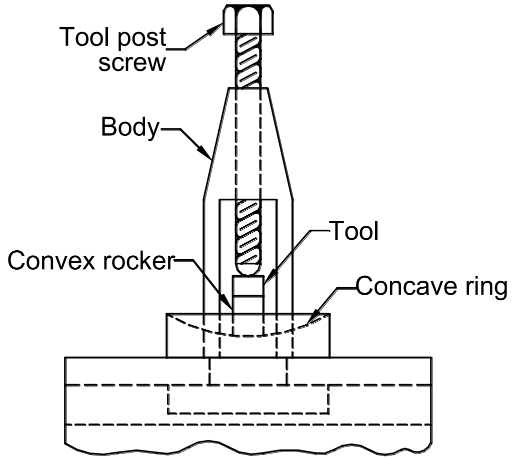


Fig.4.13 Single Screw tool post

Open side tool post

In this tool post, the tool can be held in position by two set screws. The height of the tool can be adjusted by placing packing strips. The tool post can be tilted to any required position by loosening the clamping bolt.

Four bolt tool post

In this tool post, two tools can be held in position by using straps and four bolts. The height of tool is adjusted by placing parallel strips. This tool post is used in heavy duty lathes.

Four way tool post

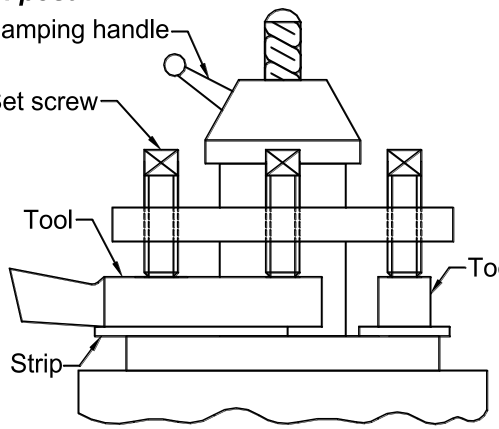


Fig.4.14 Four way tool post

This tool post has a square block. Four tools can be fitted on four sides of the block by sing screws. By loosening the clamp, each tool can be tilted by any required angle and set. The height of tool is adjusted by placing parallel strips.

Generally, the tool in a tool post can be moved as follows.

i) **Longitudinal feed**: Parallel to lathe axis.

ii) **Cross feed**: Perpendicular to lathe axis.

iii) **Angular feed**: Inclined at specified angle to lathe axis.

5) Apron

Apron is fitted with the saddle and hangs in front of the carriage. The carriage movement is controlled by the gears, levers and clutches provided in the apron. The carriage can be moved parallel to lathe axis by hand wheel. Thread cutting operation can be performed by engaging the half nut lever in the apron with the lead screw.

4.11.4 Tail Stock

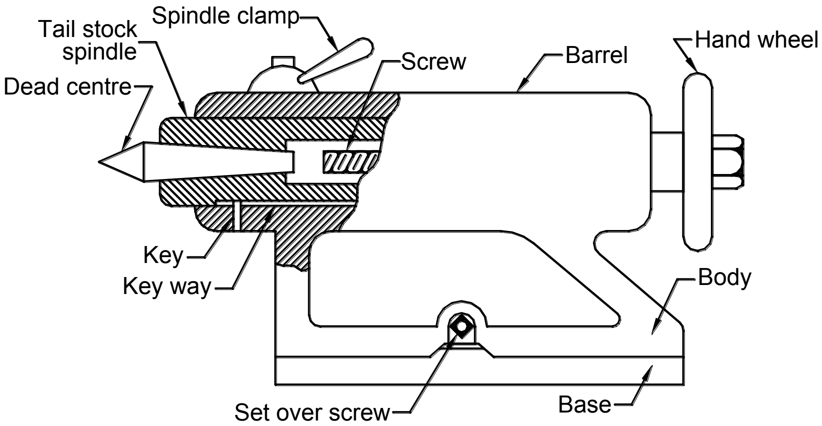


Fig.4.15 Tail stock

The tail stock is mounted at the right side of the lathe bed. It can be moved over the guide ways on the bed and positioned at any required place. The barrel in the tail stock has a hollow spindle. The spindle can be moved axially by rotating the hand wheel connected with a screw. Dead centre or tools like drill bit can be fitted in the tapered hole provided at front of the spindle. The spindle can be clamped in position by the spindle clamp.

The hand wheel is rotated in anti-clockwise direction to remove the dead centre or the tool. Now the spindle is drawn in and the end of screw pushes out the dead centre or tool.

The tail stock can be moved crosswise by loosening the set over screw.

Functions of tail stock

1) It supports the right end of the work piece.
2) Cutting tools like drill bit, reamer and tap can be fitted in the tail stock spindle to perform drilling, reaming and tapping operations.
3) The tail stock can be moved crosswise and taper turning can be done using set over method.

4.12 Feed mechanism

The movement of tool with respect to the work piece is called feed. The following feeds can be given to a lathe tool.

1) Longitudinal feed
2) Cross feed
3) Angular feed

The movement of tool parallel to lathe axis is known as *longitudinal feed.* This feed can be given by moving the carriage.

The movement of tool perpendicular to lathe axis is known as *cross feed.* This feed can be given by moving the cross slide.

When the tool is moved at an angle to the lathe axis, the movement is called *angular feed.* This feed can be given by moving the compound slide after swiveling it at required angle.

The above three types of feed can be given by hand. Angular feed cannot be given automatically. The longitudinal and cross feed can be given automatically. For giving automatic feed, the power from head stock spindle is transmitted to the carriage through the following units.

1) Tumbler gear mechanism
2) Quick change gear box
3) Apron mechanism

4.12.1 Tumbler gear mechanism

Tumbler gear mechanism is used to change the direction of rotation of lead screw and feed rod.

The spindle gear (A) always rotates in clockwise direction. Gears B and C are tumbler gears. One of these tumbler gears (B or C) can be engaged with the spindle gear (A) at a time. The tumbler gears (B and C) and stud gear (D) are fitted in a bracket. Gear C and D are always engaged. The lever (L) in the bracket can be positioned upward, middle or downward position. Stud gear D is connected to lead screw gear through intermediate gears.

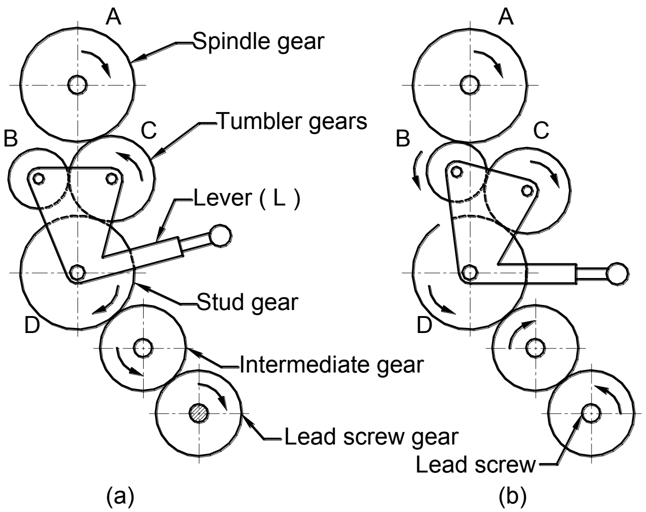


Fig.4.16 Tumbler gear mechanism

As shown in the fig.4.16(a), when the lever (L) is in upward position, tumbler gear C meshes with spindle gear A. Now the power is transmitted from the spindle gear (A) to lead screw through tumbler gear C, stud gear D and intermediate gears. Lead screw rotates in clockwise direction i.e. direction of rotation of spindle. The carriage moves towards the head stock. This arrangement is used for right hand thread cutting.

As shown in fig.4.16(b), when the lever (L) is in downward position, tumbler gear B meshes with spindle gear (A). Now the lead screw rotates in anti-clockwise direction. The carriage moves towards the tail stock. This arrangement is used for left hand thread cutting. Thus automatic feed is obtained by tumbler gear mechanism.

When the lever (L) is in middle (neutral) position, tumbler gears are not engaged with spindle gear. So automatic feed cannot be given. Only hand feed is given to the carriage.

4.12.2 Quick change gear box

The power is transmitted from spindle gear to shaft A through tumbler gear and change gears. 6 cone gears are keyed to shaft A. So shaft B can get 6 different speeds from shaft A by using a sliding gear. Shaft B is connected to shaft C through 3 cone gears. So shaft C can rotate with 6 x 3 = 18 different speeds.

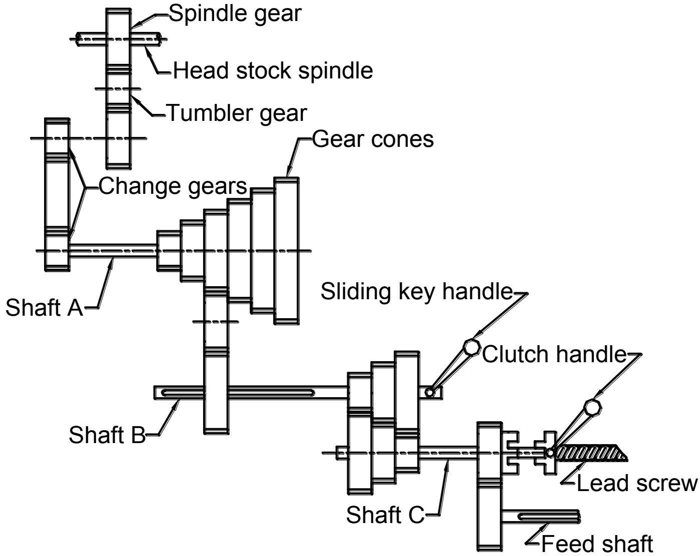


Fig.4.17 Quick change gear box

The rotation of shaft C is transmitted to lead screw and feed rod through a clutch. Quick change gear box is used for automatic feed and thread cutting operations.

4.12.3 Apron mechanism

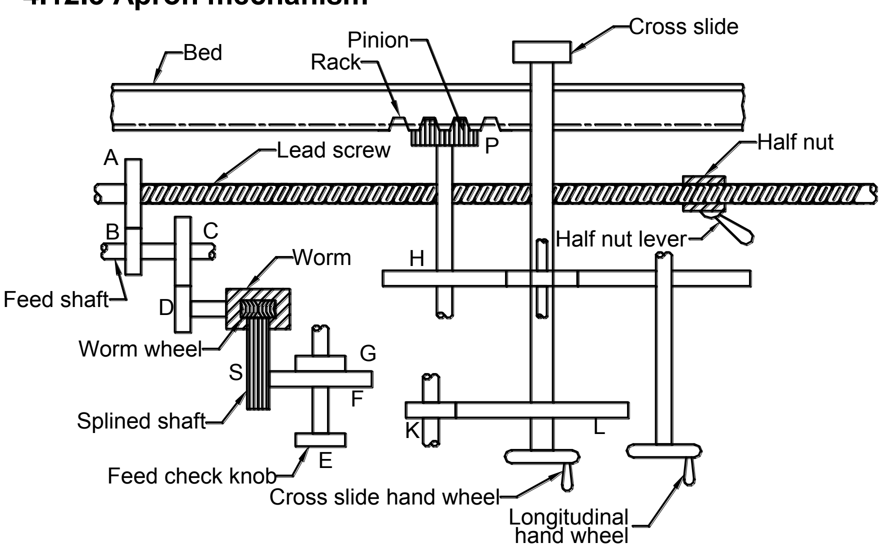


Fig.4.18 Apron mechanism

When the spindle gear rotates, the lead screw and feed rod will rotate through tumbler gears. The rotation of lead screw is transmitted to worm wheel through gears A, B, C and D. As the splined shaft (S) engaged with the worm wheel rotates, gears F and G will be always rotating. The feed check knob (E) can be positioned in push in, neutral and pull out positions. When the feed check knob (E) is in neutral position, cross feed and longitudinal feed can be given manually by rotating the hand wheel. Thread cutting can also be done by engaging the half nut lever.

Automatic longitudinal feed

When the feed check knob (E) is in push in position, gear G meshes with gear H. Now the rotation is transmitted to the rack and pinion (P) and automatic longitudinal feed is obtained.

Automatic cross feed

When the feed check knob (E) is in push out position, gear F meshes with gear K. Now the rotation is transmitted to the gear L and automatic cross feed is obtained.

4.13 Work holding devices

The devices used for holding the work pieces with grip are called work holding devices. The following work holding devices are used in lathe.

1) Chucks	2) Centres
3) Face plate	4) Mandrel
5) Steady rest	6) Follower rest
7) Angle plate	8) Carrier or dog
9) Catch plate or driving plate	10) Fixture

Centres, catch plate and carrier, face plate, angle plate and mandrel are also called as lathe accessories.

4.13.1 Chucks

Work pieces of short lengths, large diameter and irregular shapes can be held in chucks.

The following three type of chucks are available.

1) Three jaw self centering chuck
2) Four jaw independent chuck
3) Magnetic chuck

1) Three jaw self centering chuck

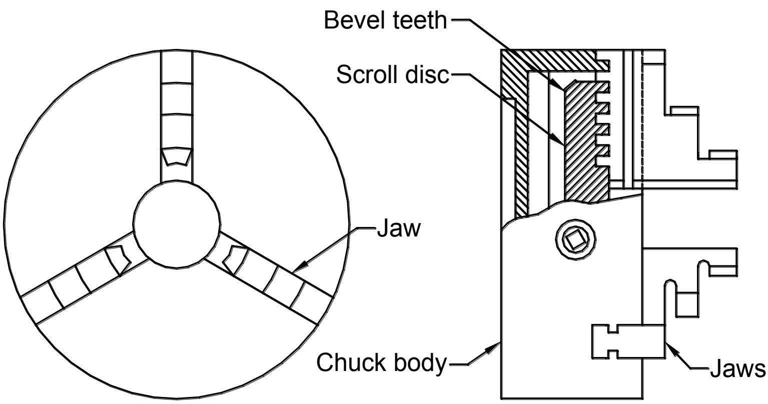


Fig.4.19 Three jaw chuck

This chuck has three jaws. All the jaws can be moved equal distance the same time through a bevel pinion and scroll disc by operating a chuck key. So the work piece held between these jaws can be centered automatically and quickly.

2) Four jaw independent chuck

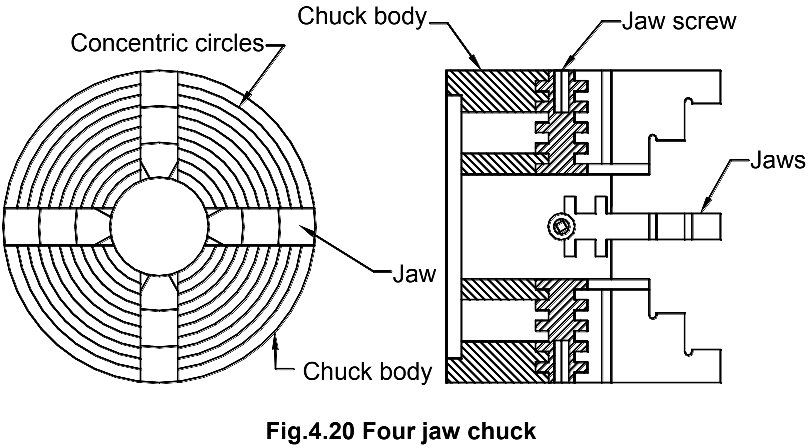


Fig.4.20 Four jaw chuck

This chuck has four jaws. Each jaw can be independently moved by using a chuck key. So it is called as independent chuck. Irregular work piece can be held in this chuck by moving each jaw to required distance. The work piece can be quickly centered by referring the concentric circles inscribed on the face of the chuck.

3) Magnetic chuck

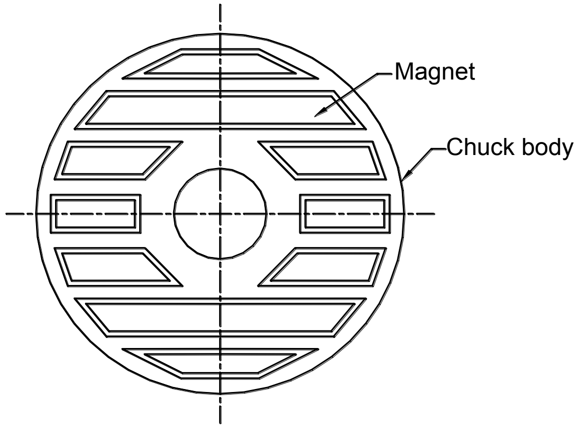


Fig.4.21 Magnetic chuck

This chuck is used for holding thin work pieces having magnetic properties. The pressure of jaws on the work piece is avoided by using this chuck. The chuck gets magnetic power from an electro magnet.

4.13.2 Centres

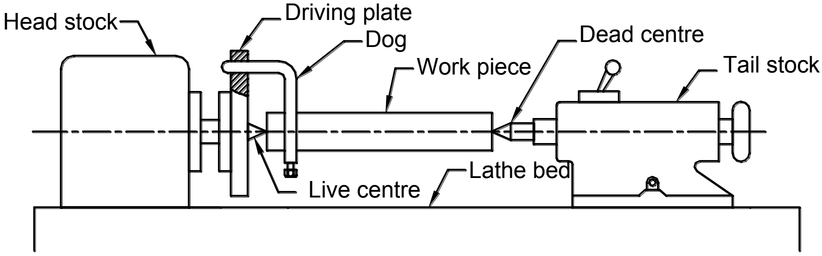


Fig.4.22 Work held between centres

Generally long work pieces are held between two centres. Live centre is fitted in the head stock and dead centre is fitted in the tail stock. The live centre rotates with the work piece. The dead centre supports the right end of the work piece. Dog or carrier is fitted around the work piece and the tail portion is attached with the catch plate. When the spindle rotates, the work piece is rotated through catch plate and dog.

Types of lathe centres

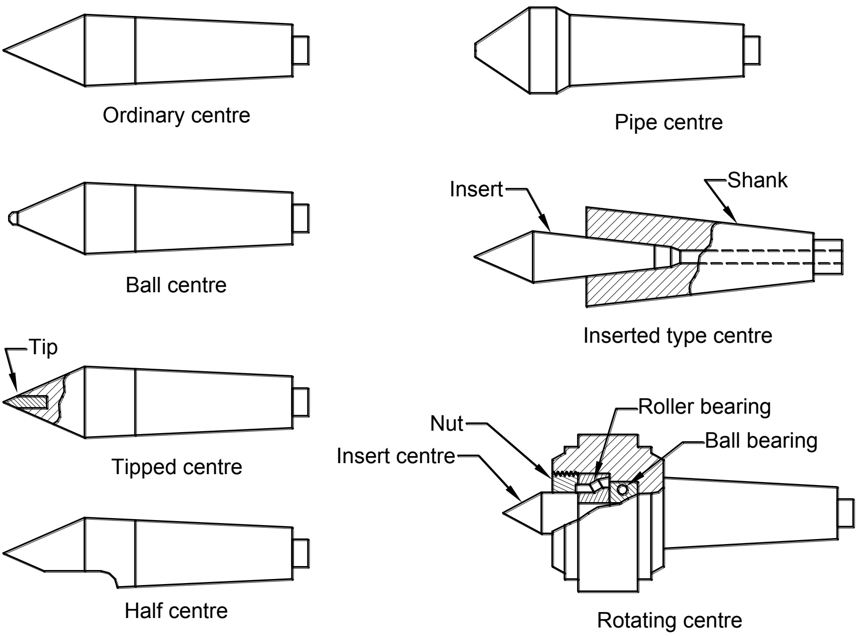


Fig.4.23 Lathe centres

Lathe centre is a hardened steel piece. It has More taper shank at the end and a conical taper of 60° at the another end. The centre in the main spindle is called live centre and the centre in the tail stock is called dead centre. It is used to support the work piece and withstand the force developed during machining.

Generally the following centres are used in lathe.

1) Ordinary centre 2) Ball centre
3) Tipped centre 4) Half centre
5) Pipe centre 6) Inserted centre
7) Rotating centre

1) **Ordinary centre:** Ordinary centre is used for general works.

2) **Ball centre:** Ball centre is used for taper turning by set over method.

3) **Tipped centre:** In this centre, a hard alloy tip is brazed at the conical end. This tip has high wear resistance.

4) **Half centre:** In this centre, half of the conical end is cut off. Facing operation can be easily done by fitting the half centre in the tail stock.

5) **Pipe centre**: This centre is used for supporting the end of a pipe.

6) **Inserted centre:** This centre is made of high speed steel. When the insert is worn out, the insert alone can be replaced instead of the whole centre.

7) **Rotating centre**: This centre is used for supporting heavy work which rotates at high speed. This centre is fitted in the tail stock and revolves on bearings to reduce friction. So it is also called as frictionless centre.

4.13.3 Face plate

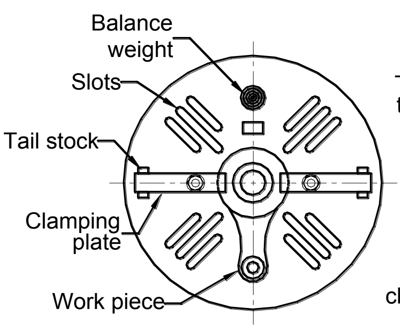


Fig.4.24 Face plate

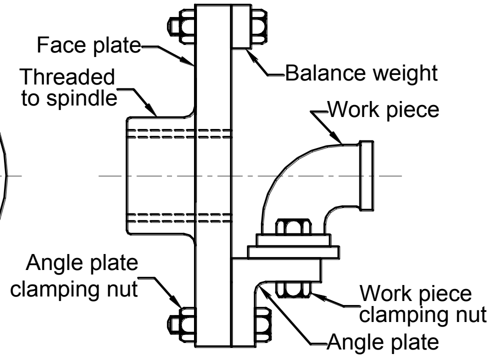


Fig. 4.25 Angle plate and face plate

It is a circular plate having threaded bore. It is screwed to the lather spindle. Slots and holes are provided on the face of the face plate. The work piece is clamped in the face plate by using T-bolts and nuts. Face plate is used for holding irregular work pieces which cannot be easily held in chuck.

4.13.4 Angle plate

Angle plate has two accurately machined faces at right angles. Slots and holes are provided on each face. The work piece is clamped on one face of the angle plate by using bolts and nuts. The other face is clamped to the face plate. Balancing weight is attached with the face plate for uniform rotation of work piece.

4.13.5 Mandrel

Mandrel is a device used for holding hollow work pieces between the centres. The hole on both sides of the mandrel fits in to the live centre and dead centre. The work piece rotates with the mandrel. The following mandrels are used in lathe.

1) Plain mandrel
2) Step mandrel
3) Collar mandrel
4) Screwed mandrel
5) Cone mandrel
6) Gang mandrel
7) Expansion mandrel

Plain mandrel

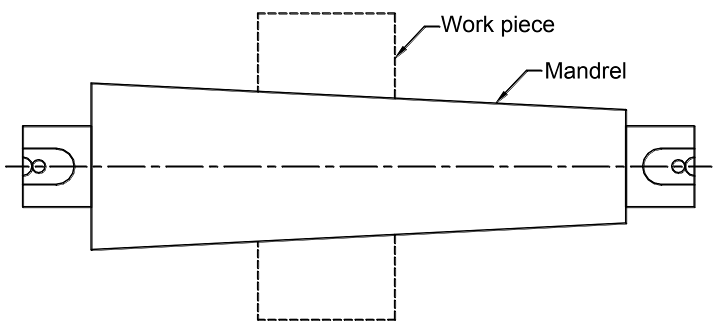


Fig.4.26 Plain mandrel

It is a commonly used mandrel. It is also known as solid mandrel. The body of the mandrel has a slight taper for gripping the work piece. The length of mandrel varies from 55 mm to 430 mm. Different mandrels are used for work pieces with different bore diameters.

4.13.6 Steady rest

While turning long workpiece on lathe, the cutting tool tends to vibrate and bend the workpiece due to large cutting force. The workpiece also provides a springing action and large bending moment due to its own weight. This results in failure of cutting tool and improper machining. To avoid such problems, the workpiece should be supported in the middle. This extra support can be provided by a steady rest or centre rest.

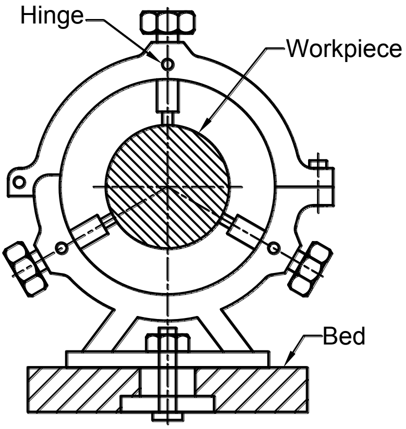


Fig.4.27 Steady rest

The steady rest is mounted on the lathe bed. It consists of a frame and three adjustable jaws which support the workpiece. The jaws have supports called quills on which the workpiece rotates. A bearing surface must be provided for the steady rest jaws. The bearing surface is usually machined directly on the workpiece. The over arm containing the top jaw can be unfastened so that identical pieces can be removed and replaced without adjusting the jaws. The functions include :

- to prevent springing or deflection of long and flexible work piece
- to provide support for the workpiece to give heavy cuts
- to support workpiece for drilling, boring, or internal threading

4.13.7 Follower rest

While machining a long flexible shaft of small diameter on lathe, the shaft tends to bend and vibrate. To avoid this, the shaft should be supported very close to the cutting edge of the tool. A follower rest is used for this purpose. It is attached to the saddle of the lathe carriage. It travels along with (follows) the tool throughout the operation.

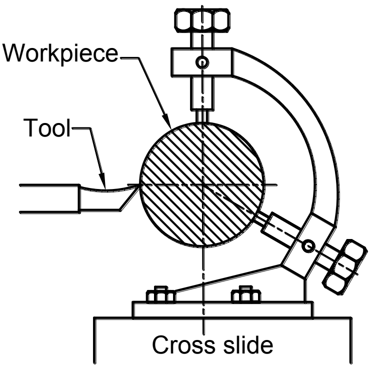
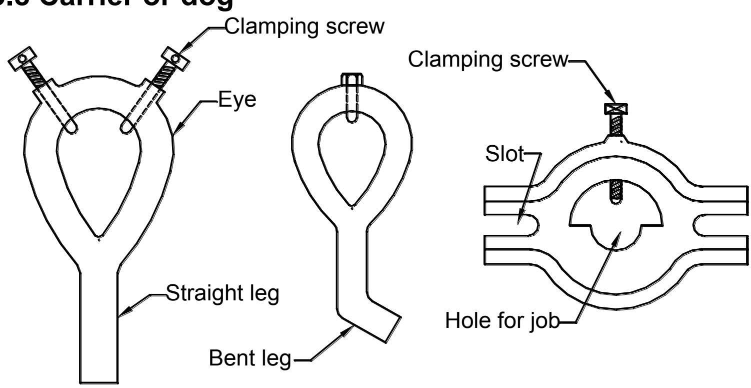


Fig.4.28 Follower rest

The upper jaw prevents the work piece from climbing the cutting tool. The lower jaw prevents the workpiece from springing away from the cutting tool. The jaws have supports called quills on which the workpiece rotates. The jaws are adjusted to accommodate the shaft exactly at centre. The follower rest is often used for making threads on long flexible shafts.

4.13.8 Carrier or dog



(a) Straight leg carrier (b) Bent leg carrier (c) Double slotted carrier
(a) Straight leg carrier (b) Bent leg carrier (c) Double slotted carrier

Fig.4.29 Lathe carrier

Carrier or dog is used to transmit the rotation of catch plate to the work piece held between two centres. One end of the work piece is clamped at the eye portion of the dog. The leg portion of the dog is fitted with the projecting pin in the catch plate.

4.13.9 Catch plate or driving plate

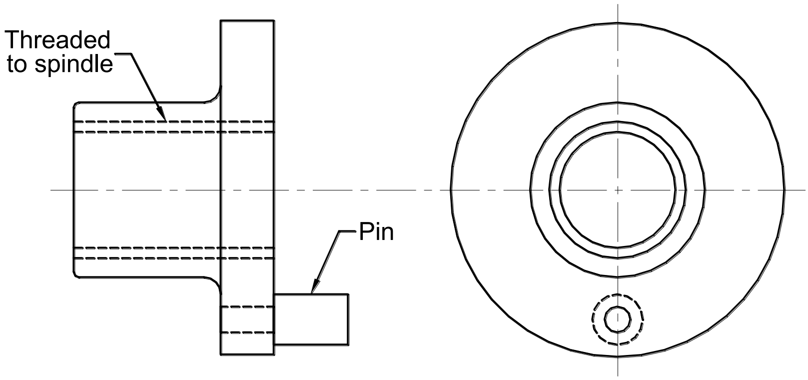


Fig.4.30 Catch plate

Catch plate is a circular cast iron plate having threaded bore. It can be screwed to the lathe spindle. Catch plate has a projecting pin. Work piece gets the drive from this pin through dog. Thus catch plate rotates the work piece held between two centres through the dog.

4.13.10 Turning Fixture

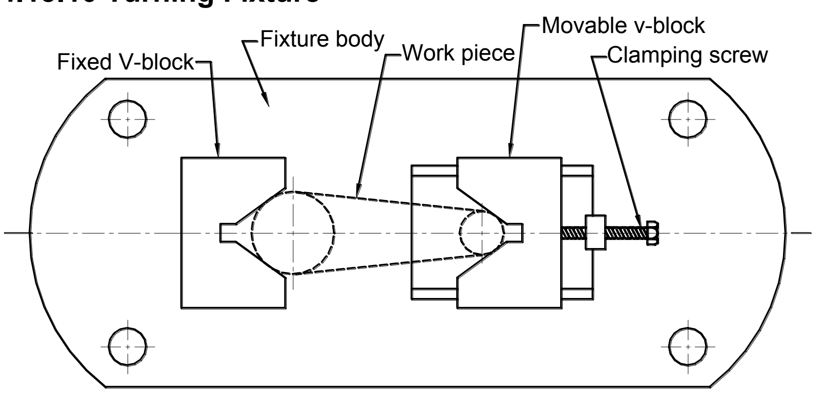


Fig.4.31 Turning fixture

Turning fixture is used for holding work pieces which cannot be held by using chuck, face plate, etc. A fixture is specially designed for holding a particular work piece. V-blocks, step blocks, angle plates, bolts & clamps and levers are provided in the turning fixture.

Functions of turning fixture

1) It accurately locates the work piece.
2) It holds the work piece with grip during machining.
3) Loading, unloading and clamping time is very much reduced by using fixture.
4) Marking on the work piece is not required. So it is suitable for mass production.

Turning fixture is fitted in the face plate. The work piece is easily held between the fixed and movable v-blocks.

4.14 Machining operations done on lathe

The following important operations are generally done on a lathe.

1) Straight turning	2) Step turning
3) Facing	4) Chamfering
5) Grooving	6) Parting off
7) Knurling	8) Forming
9) Eccentric turning	10) Drilling
11) Reaming	12) Boring
13) Taper turning	14) Thread cutting

1) Straight turning

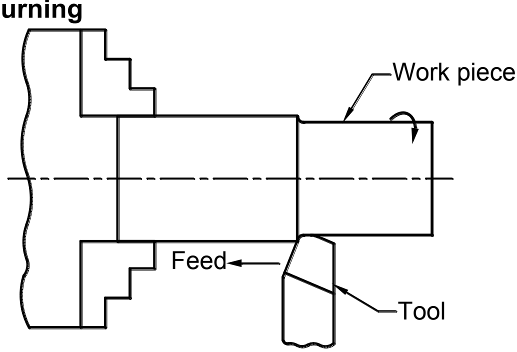


Fig.4.32 Straight turning

Cylindrical components can be produced in straight turning. The work piece is held in the chuck or in between the centres and rotated about the lathe axis. Turning tool is fitted correctly in the tool post. Depth of cut is given by moving the cross slide. The feed is given to the turning tool by moving the carriage parallel to the lathe axis.

For rough turning, the feed (0.3 to 1. mm / rev.) and depth of cut (2 to 5 mm) will be more. The spindle speed will be low. For finish turning, the feed (0.1 to 0.3 mm / rev.) and depth of cut (0.5 to 1 mm) will be less. The spindle speed will be high.

2) Step turning

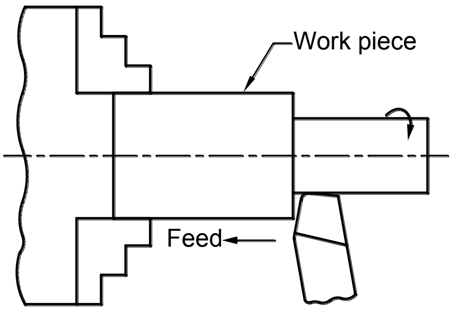


Fig.4.33 Step turning

Turning of different diameters in a work piece is called ***step turning.*** The work piece is held in the chuck and rotated about the lathe axis. Turning tool is fitted correctly in the tool post. Depth of cut is given by moving the cross slide. The feed is given to the turning tool by moving the carriage parallel to the lathe axis.

Using straight turning operation, the first step with maximum diameter is produced for the given length. Similarly the adjacent steps with required diameter and length can be produced.

3) Facing

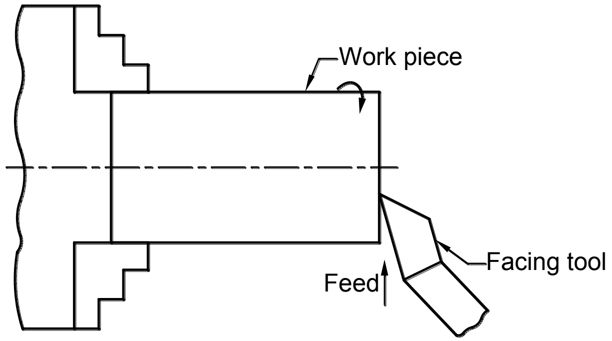


Fig.4.34 Facing

Machining the ends of work piece for producing flat surface is called facing. Work piece is held in the chuck or in between centres and rotated about lathe axis. The facing tool is moved towards the centre of work piece perpendicular to the lathe axis. Hand feed or automatic feed can be given.

4) Chamfering

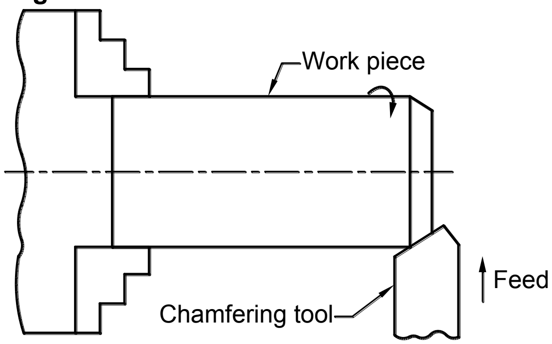


Fig.4.35 Chamfering

Machining the ends of the work piece for removing the sharp edge and producing a beveled edge by using chamfering tool is called chamfering. Generally chamfering is done after turning, drilling, boring and thread cutting operation. The work piece is held in the chuck and rotated about lathe axis. The chamfer tool is fitted in the tool post and moved perpendicular to the lathe axis.

5) Grooving

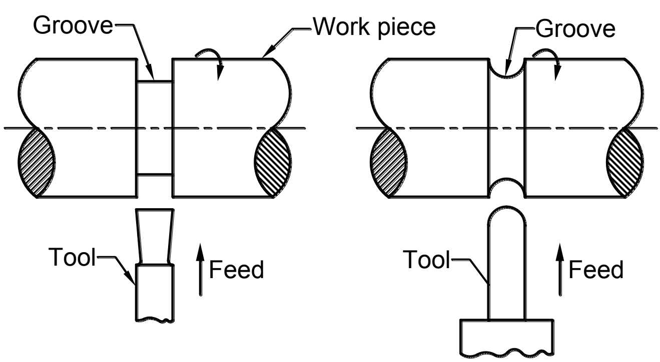


Fig.4.36 Grooving

It is also called as *undercutting* and *recessing*. Grooving is generally done at the end of the threaded portion. Work piece is held in the chuck and rotated about the lathe axis. The grooving tool is fed perpendicular to the lathe axis and undercutting of required depth can be done on the work piece. The carriage must be locked during this operation.

6) Parting off

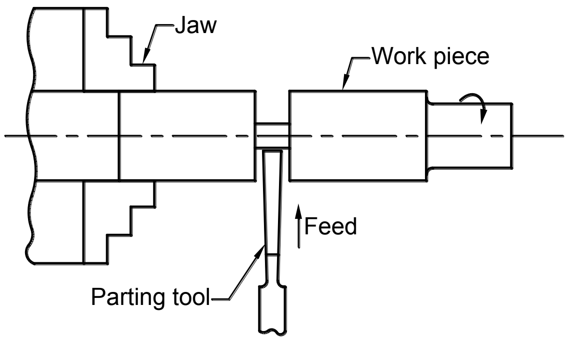


Fig.4.37 Parting off

Parting off is the operation of cutting and removing the work piece after the work piece is machined to required size and shape. The work piece is held in the chuck and rotated about the lathe axis at low speed. The parting tool is fed towards the centre of work piece perpendicular to the lathe axis. Carriage is locked during parting off operation.

7) Knurling

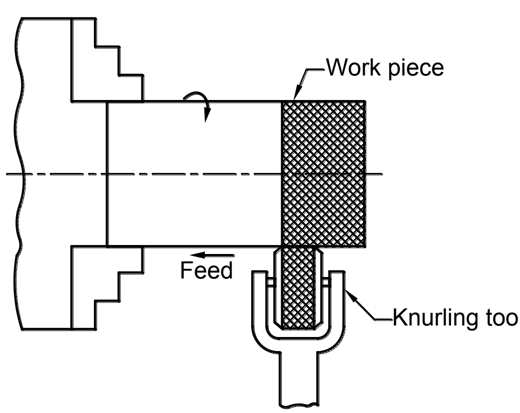


Fig.4.38 Knurling

Knurling is an operation used for providing good gripping surface on the work piece. Generally this surface will be in diamond shape. The knurling tool has two hardened steel rollers. The teeth cut on the roller surface may be fine, medium or coarse. The work piece is held in the chuck and rotated about lathe axis. The knurling tool is fitted in the tool post. It is pressed against the rotating work piece and moved parallel to the lathe axis. The pattern on the knurling tool is produced on the work piece surface. The work piece should be rotated at low speed. The diameter of work piece is slightly increased during knurling.

8) Forming

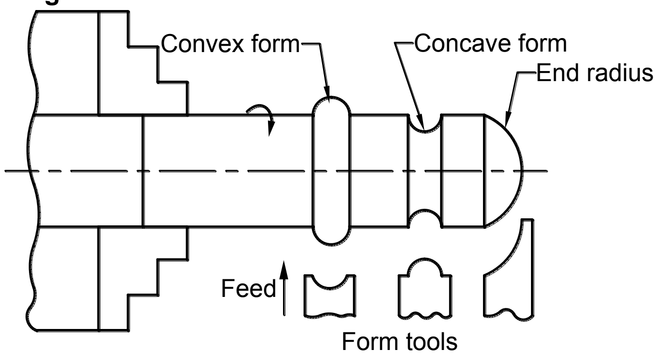


Fig.4.39 Forming

Forming is an operation of producing concave, convex and irregular shapes in the work piece by using a form tool. The cutting edge of the tool is formed to the required shape by grinding. The form tool is fed towards the work piece perpendicular to the lathe axis.

9) Eccentric turning

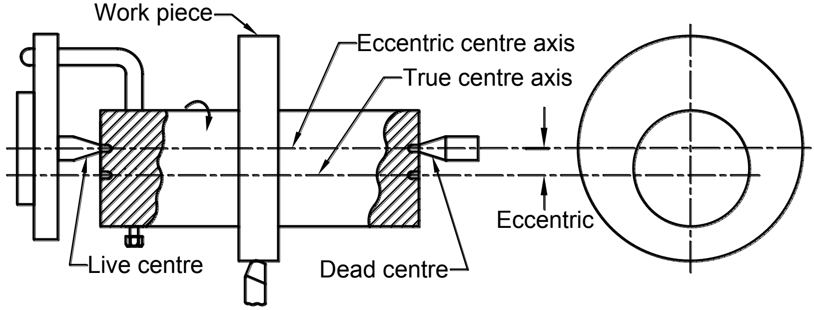


Fig.4.40 Eccentric turning

Eccentric turning is an operation performed on a work piece with different centres. It is used for turning crank shafts and eccentric. Before eccentric turning, two sets of holes are drilled at the ends of the work piece. First the work piece is held in its true centre axis and turning is done. Then it is held in the eccentric centre axis and turning is done for required length.

10) Drilling

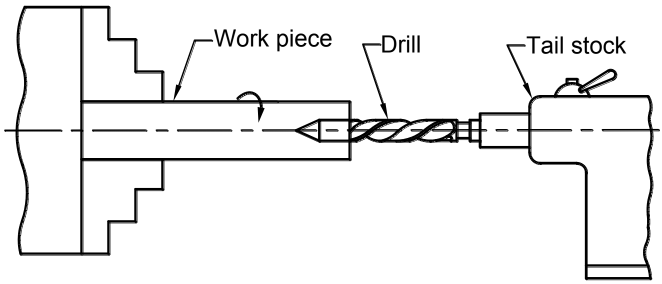


Fig.4.41 Drilling

Making holes in the work piece is called drilling. The work piece is held in chuck or face plate and rotated about the lathe axis. Drill bit is fitted directly in the tail stock spindle or by using drill chuck or socket. The tail stock is moved over the bed and clamped near the work piece. The drill bit is fed against the rotating work piece by rotating the tail stock hand wheel. Coolant is used during drilling operation. The tail stock spindle has markings to the length of drilled hole.

11) Reaming

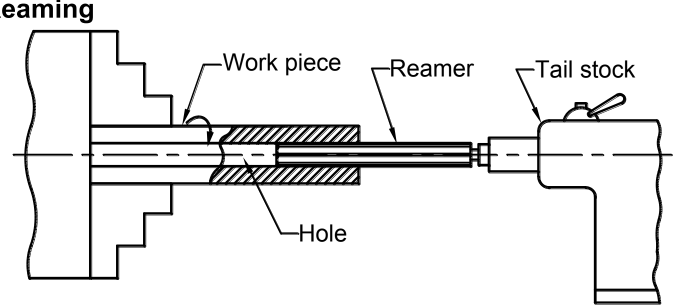


Fig.4.42 Reaming

Reaming is the process of finishing the drilled hole to correct size and shape. Reamer is fitted in the tail stock spindle. It is fed against the rotating work piece for finishing the hole.

12) Boring

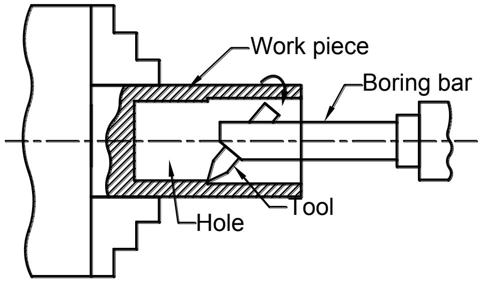


Fig.4.43 Boring

Enlarging the already drilled hole is called boring. The work piece is held in the chuck or face plate and rotated about the lathe axis. The boring tool is fitted in the tool post. The depth of cut is given by moving the cross slide. Boring is done by moving the carriage parallel to the lathe axis.

13) Taper turning

Taper turning is an operation of producing conical surface on the work piece. Taper turning is done in the following methods.

a) Form tool method
b) Compound rest method
c) Tail stock set over method
d) Taper turning attachment method
e) By combining longitudinal and cross feed

a) Form tool method

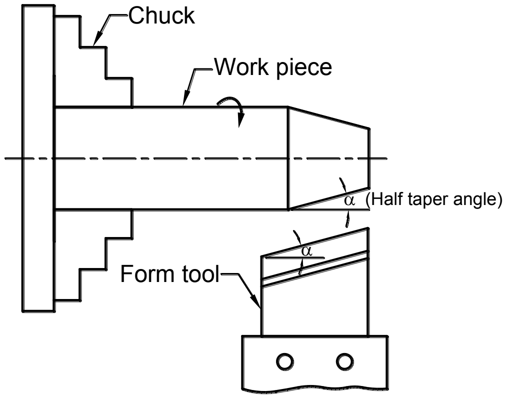


Fig.4.44 Form tool method

In this method, the tool is formed to required taper angle by grinding. Form tool is fitted in the tool post. Taper turning is done by moving the form tool perpendicular to the lathe axis. In this method, the length of taper will be smaller than the length of cutting edge of tool. So taper of short length can only be produced by this method.

b) Compound rest method

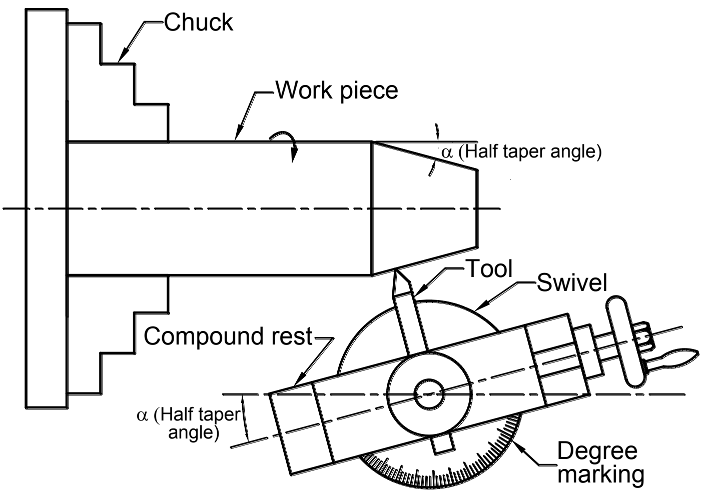


Fig.4.45 Compound rest method

In this method, the tool is fed at an angle to the lathe axis against the rotating work piece and taper turning is done.

The compound rest is mounted on a circular base graduated in degrees. The circular base can be tilted and fitted at an angle equal to half taper angle. The tool is fed at an angle to the lathe axis by rotating the hand wheel in the compound rest. Hand feed only can be given to the tool.

$$\textbf{Half taper angle, } \boldsymbol{\alpha = tan^{-1}\left(\frac{D-d}{2l}\right)}$$

D – Large diameter of taper

d – Small diameter of taper

l – length of taper

c) Tail stock set over method

$$\textbf{Set over, } S = L \times \left(\frac{D-d}{2l}\right)$$

D – Large diameter of taper

d – Small diameter of taper

L – Length of work piece

l – length of taper

If taper turning is done on entire length of the work piece,

$$\textbf{Set over, } S = \left(\frac{D-d}{2}\right)$$

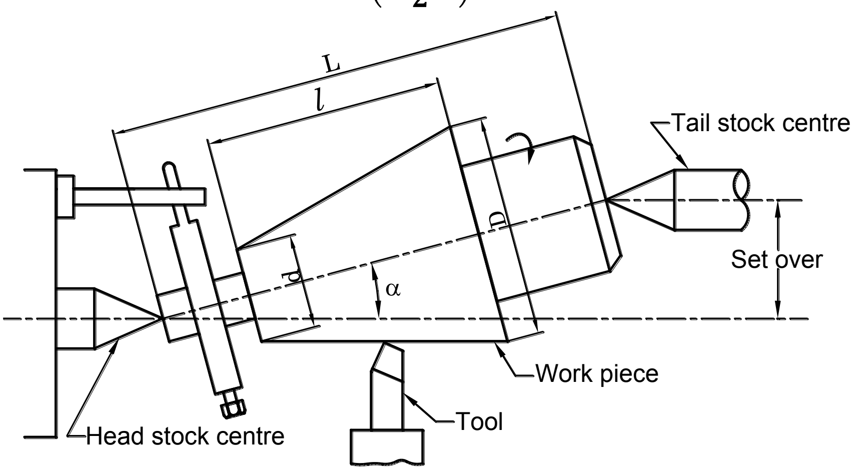


Fig.4.46 Tail stock set over method

The tail stock can be moved crosswise by loosening the set over screw. The distance by which the tail stock is to be moved from the lathe centre is known as set over. The work piece is held between the dead centre and live centre. Now the axis of work piece is tilted at an angle from the lathe axis. The tool is fed over the rotating work piece parallel the lathe axis for producing taper. This method is used for turning very small tapers on long work pieces.

d) Taper turning attachment method

This attachment is fitted by a bracket at the back of the lathe bed. There is a guide bar graduated in degrees. It can be swiveled and fitted to any required angle to lathe axis. The guide bar has a guide block. It is connected to the cross slide.

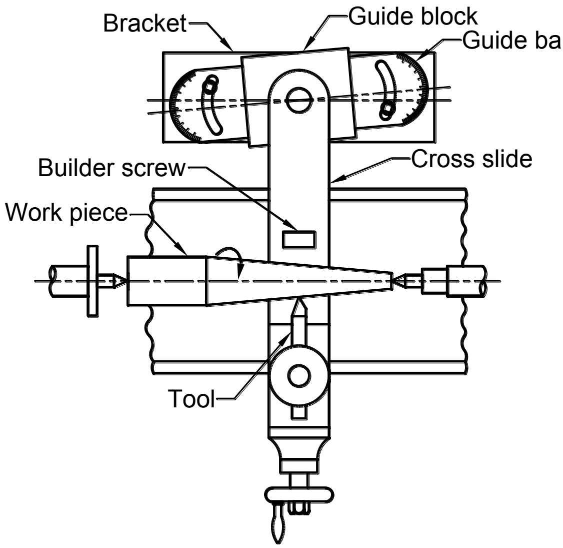


Fig.4.47 Taper turning attachment method

The cross slide is made to move along with the guide block by removing the binder screw. The work piece is held in the chuck and rotated about the lathe axis. When longitudinal feed is given to the tool, the tool will move at an angle to lathe axis as the guide block moves at an angle on the guide bar. Depth of cut is given by moving the compound rest perpendicular to the lathe axis.

Steep taper, long taper and internal taper can be produced by taper turning attachment.

$$\textbf{Half taper angle,}\ \boldsymbol{\alpha = tan^{-1}\left(\frac{D-d}{2l}\right)}$$

D – Large diameter of taper
d – Small diameter of taper
l – length of taper

e) By combining longitudinal and cross feed

Taper turning can be done by giving longitudinal and cross feed to the tool at the same time. Accurate taper cannot be produced by this method. This method requires a skilled operator.

14) Thread cutting

Producing 'V' shaped and square shaped helical grooves on the cylindrical work piece is called thread cutting. Thread cutting on the surface of cylindrical job is called external thread cutting. Thread cutting in the inner surface of a hole is called internal thread cutting or tapping. External thread cutting is done by using die or cutting tool. Internal thread cutting is done by using tap or cutting tool.

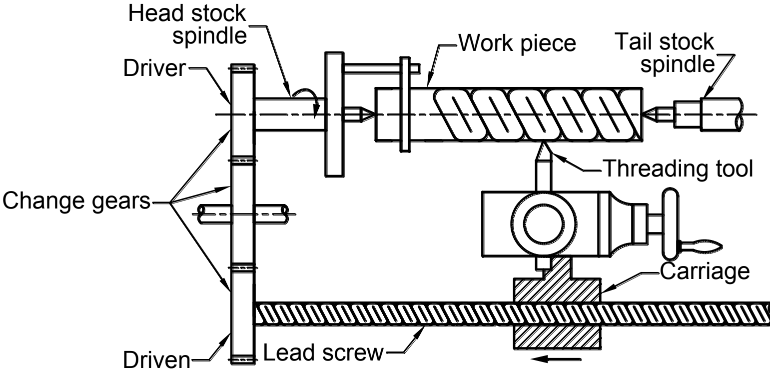


Fig.4.48 Thread cutting

Lead screw is connected to the main spindle through change gears. The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the work piece. The change gears should have specific gear ratio so that the speed of lead screw and main spindle are same. Threading tool is correctly fitted into the tool post and depth of cut is given. The lead screw is engaged with the carriage by the half nut. Now the tool is automatically moved in longitudinal direction and thread cutting is done.

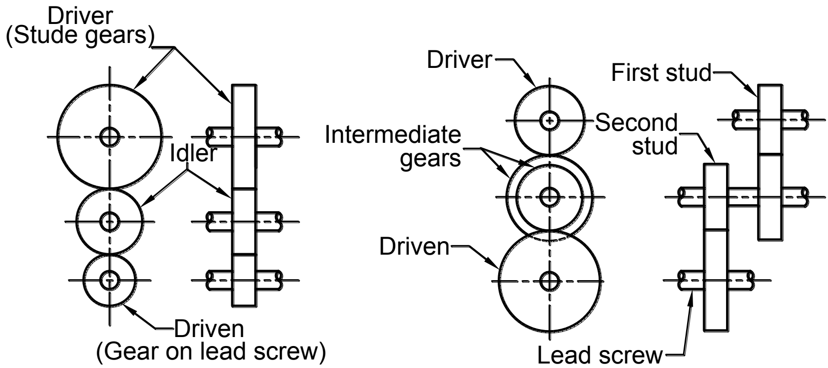
For cutting threads of various pitch, the speed of lead screw should be changed by meshing suitable change gears. The gear ratio of change gears is calculated as follows.

$$\textbf{Gear ratio} = \frac{\text{Driver teeth}}{\text{Driven teeth}}$$

$$= \frac{\text{spindle gear teeth}}{\text{Leads crew gear teeth}}$$

$$= \frac{\textbf{Pitch of the work}}{\textbf{Pitch of the lead screw}}$$

Generally, the change gears supplied with lathe have teeth from 20 to 120 in steps of 5. Simple gear train or compound gear train is used for getting required gear ratio of change gears.



(a) Simple gear train **(b) Compound gear train**

Fig.4.49 Gear train

While cutting right hand threads, the lead screw rotates in the same direction of the spindle. Tool (carriage) moves towards the head stock. While cutting left hand threads, the lead screw rotates in a direction opposite to the spindle. Tool (carriage) moves towards tail stock.

4.15 Cutting speed, feed, depth of cut and metal removal rate

1) Cutting speed (V_c)

The length of chip cut by a tool from a rotating work piece in one minute is called cutting speed.

$$\textit{Cutting speed, } V_c = \frac{\pi D N}{1000} \text{ (m / min)}$$

Where, D – Diameter of work piece (mm),

N – Rotating speed of work piece (rpm)

2) Feed (*f*)

Feed is the distance moved by the tool per revolution of the work piece. It is expressed in *mm / revolution*. Feed is given by,

$$\textit{Feed}, f = \frac{L}{N \times T_m}$$

where, L – Length of cut (mm)

N – Rotating speed of work piece (rpm)

T_m – Machining time / Cutting time (min)

For particular speed, if the feed is very low, the area of chips slide over the tool face is increased and the tool wears out. At the same time, if more feed is given, the cutting force on the tool is increased. This also reduces the tool life. So correct feed should be given for increasing the tool life.

3) Depth of cut (*t*)

Depth of cut is the thickness of metal removed from the work piece when the cutting tool is moved once. Depth of cut is given by,

$$\textit{Depth of cut}, t = \frac{D_i - D_f}{2}$$

Where, D_i – Initial diameter of the workpiece

D_f – Final diameter of the workpiece

For particular cutting speed, if the depth of cut is more, the cutting force on the tool is increased. This reduces the tool life as the tool wears out quickly. So correct depth of cut should be given for increasing the tool life.

4) Metal Removal Rate (or) Material Removal Rate (MRR)

The metal removal rate (MRR) can be defined as the volume of material removed per unit time. It is used to calculate the time required to remove specified quantity of material from the work piece. It is given by,

$$MRR = \textit{Cutting speed} \times \textit{Feed} \times \textit{Depth of cut}$$

$$MRR = V_c \times f \times t = \frac{\pi DN}{1000} \times f \times t \ \ (\text{mm}^3/\text{min})$$

Where, D – Diameter of work piece (mm),

n – Rotating speed of work piece (rpm)

f – feed (mm/rev)

t – Depth of cut (mm)

4.16 SEMI AUTOMATIC LATHE

In semi automatic lathes, loading, unloading and bringing the tool to machining position are done manually. All other operations are done automatically.

4.16.1 Types of semi automatic lathe

The following types of semi automatic lathes are available

1) Capstan lathe or ram type lathe
2) Turret lathe or saddle type lathe

4.17 Capstan and turret lathe

The capstan or turret lathe has the following parts.

1) Bed
2) Head Stock
3) Cross slide
4) Turret head and saddle
5) Preset stops

An hexagonal turret is mounted in capstan or turret lathe instead of tailstock. Six tools can be preset in the turret.

4.17.1 Bed

Bed is made of cast iron. It is designed so as to withstand heavy load and vibrations. Head stock is mounted on the one end of bed. At the another end, turret saddle is mounted. Guide ways are provided on the saddle for the movement of turret.

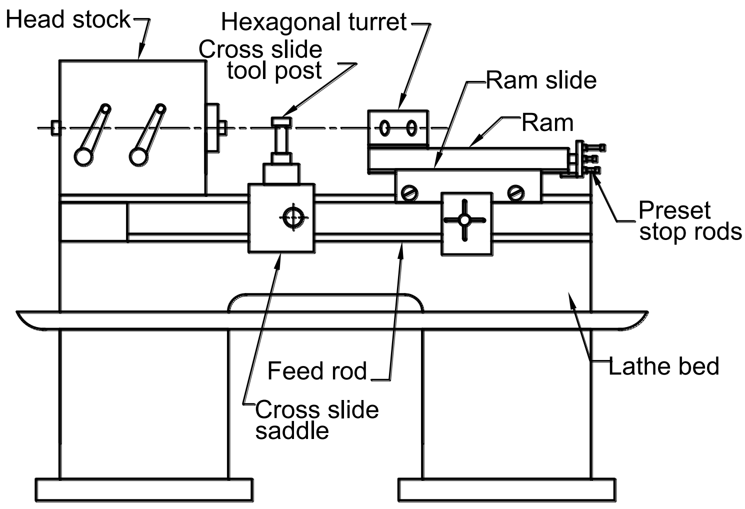


Fig.4.50 Capstan lathe

4.17.2 Head Stock

Capstan or turret lathe has one of the following head stock.

1) Step cone pulley head stock
2) Electric motor driven head stock
3) All geared head stock

In step cone pulley head stock, a pulley with three or four steps is fitted to the head stock to get various speeds. The drive from the counter shaft is transmitted to the main spindle through the step cone pulley with the help of belts.

In electric motor driven head stock, the main spindle is directly fitted to the variable speed motor shaft. Various speeds are obtained by the regulator in the motor.

All geared head stock is driven by a constant speed motor. The power from the motor shaft is transmitted to the gear box through V-belts. Various spindle speeds are obtained by changing the position of levers in the gear box. This type of head stock is suitable for heavy duty and smooth operation.

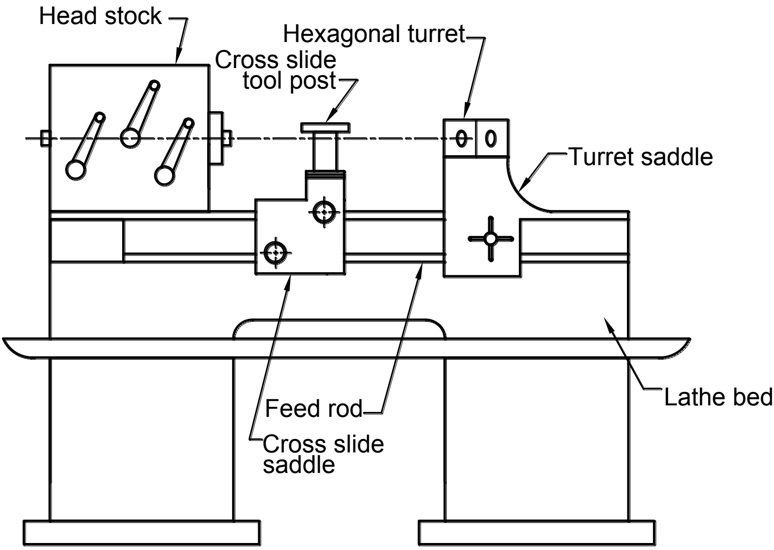


Fig.4.51 Turret lathe

4.17.3 Cross Slide

The cross slide is mounted between the head stock and turret head. It can be moved parallel and perpendicular to the spindle axis. The cross slide has two tool posts mounted at its front side and rear side. Four tools can be fitted in the front tool post and one tool can be fitted in rear tool post. The square turret is indexed through 90^{o} to bring the various tools in to working positions.

Generally the tools used for facing, forming and chamfering operations are fitted in the front tool post. Parting or cutting off tool is fitted upside down in the rear tool post.

4.17.4 Turret Head and saddle

Turret head is an hexagonal block in which six tools can be fitted at a time. It can be indexed about a vertical axis. Tool holders are fitted in threaded holes on each face of the turret. After the end of each operation, turret head is moved back to the starting position. By the time, the turret head is automatically indexed through 60^{o} to bring the next tool to the working position. This is done by using turret indexing mechanism.

The turret head of a capstan lathe is mounted on a ram. The ram slides over the saddle. During machining, the saddle is clamped at required place. In turret lathe, the turret and saddle are combined together and slides on the guide ways of bed. There is no ram in turret lathe.

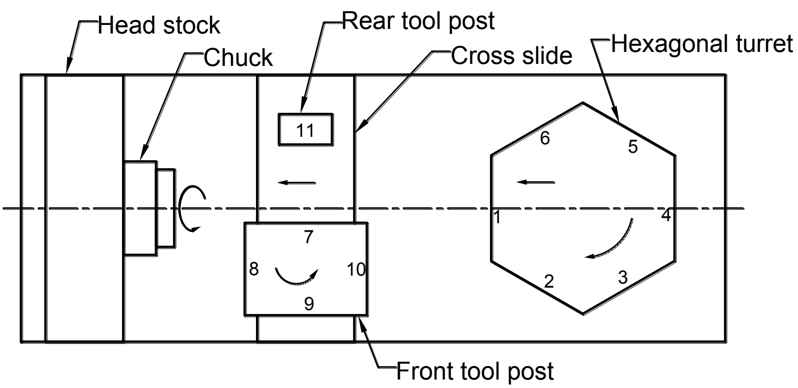


Fig.4.52 Simple sketch of capstan / turret lathe

At least 11 tools can be fitted at a time in capstan or turret lathe. Six tools are held on the turret faces. Four tools are held in front square tool post and one parting off tool is held in the rear tool post.

4.17.5 Preset stops or feed stop rods

Six adjustable stops are provided in turret head to control the length of travel of six tools. When the turret head is indexed, the adjustable stops also get indexed and come to the control position. The turret movement required for a particular tool is preset by the adjustable stop.

4.18 Working principle of turret and capstan lathe

The tools required for drilling, reaming, boring, turning and knurling operations are fitted in the hexagonal turret. The tools required for turning, facing, forming and under cut operations are fitted in the front tool post in the sequence of operations. The parting off tool is fitted upside down in the rear tool post. The movement of front and rear tool post can be controlled by preset stops.

The cylindrical or hexagonal shaped bar stocks are held in the turret lathe with the help of collet or jaw chucks. The bar stock is moved to the machining position by automatic bar feeding mechanism. The bar stop in the turret controls the amount of bar stock to be moved.

The turret head and tool post are moved according to the sequence of operations. The turret head is moved to the left during machining. After the end of each operation, turret head is moved back to the starting position. By the time, the turret head is automatically indexed though 60^{o} to bring the next tool to the working position. At the same time, the six adjustable stops in the turret head are also indexed to bring them into position. After all the operations are completed, the job is cut and removed from the bar stock by using the parting off tool in rear tool post.

4.18.1 Geneva mechanism or turret indexing mechanism

A small vertical spindle is fixed on the turret saddle. The turret head is mounted at the top of the spindle. A circular index plate having 6 slots, a bevel gear and a ratchet wheel are mounted on the same spindle. A spring actuated plunger in the saddle locks the index plate. A projecting pin is fitted in the plunger. A spring actuated cam and an indexing pawl are fitted to the lathe bed. A shaft is provided to set the distance of turret movement. This shaft has a bevel pinion at one end and a circular plate with the adjustable stops at the another end.

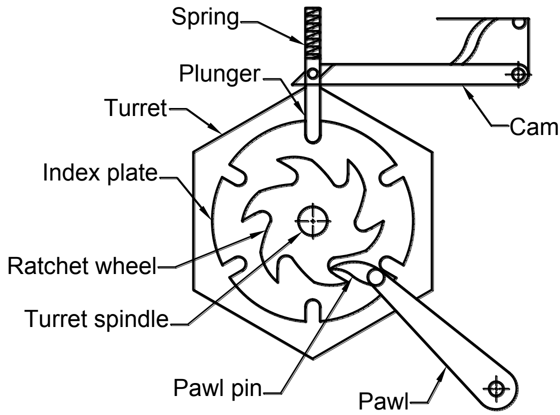


Fig.4.53 Turret indexing mechanism

When the turret is moved backward after the end of an operation, the projecting pin in the plunger slides over the sloping surface of the cam. So the plunger is released from the slot of the index plate. Now the indexing pawl engage with the ratchet teeth and turns the index plate and turret through 60^{o} ($^{1}/_{6}$ turn). The projecting pin drops out of the cam and hence the plunger locks the index plate at the next slot. When the turret rotates, the bevel gear and bevel pinion also rotate. This rotates the circular plate for indexing the preset stops.

4.18.2 Bar feeding mechanism

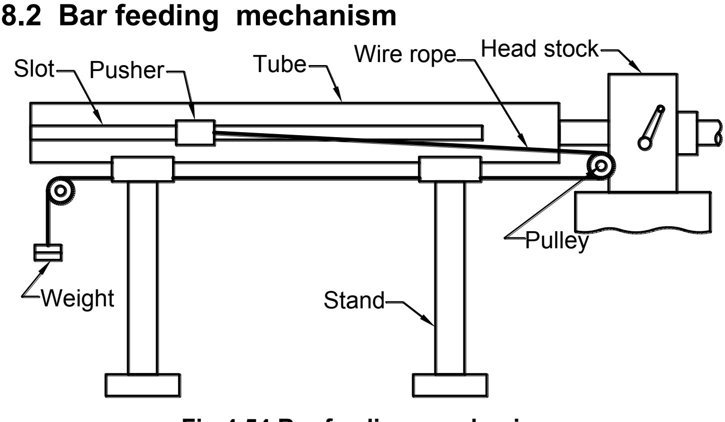


Fig.4.54 Bar feeding mechanism

In turret and capstan lathes, the bar stock is fed automatically by bar feeding mechanism. In this mechanism, a slotted tube is provided at the back side of the head stock. It is supported with stands. A pusher slides along the slot. There is a wire rope connecting two pulleys. One end of the rope is connected to the pusher and the other end is connected to the dead weight.

The bar stock is inserted in to the collet fitted with the head stock spindle. The pusher always presses the one end of the bar stock due to the pressure of dead weight. When the collet is opened, the bar stock is fed forward by the pressure of pusher. The bar stock is moved till it touches the bar stop fitted in the turret. Then the collet lever is operated for gripping the bar stock. Thus the bar stock is fed automatically without stopping the machine.

4.19 Difference between centre lathe and capstan / turret lathe

	Centre lathe	Capstan / Turret lathe
1)	It is a manually operated lathe	It is a semi automatic lathe
2)	It has only one tool post	Front and rear tool posts are available
3)	It has tail stock	It has turret head instead of tail stock
4)	Only one tool can be fitted in the tail stock	Six different tools can be fitted in the turret head
5)	Number of speeds is less	Number of speeds is more
6)	Tool changing time is more	Tool changing time is less
7)	The machine should be stopped for changing tool	Tool can be changed without stopping the machine
8)	It is not suitable for mass production	It is suitable for mass production
9)	No feed stops to control the tool	The tools are controlled by feed stops
10)	The tool is centered manually after changing the tool	The tool is centered automatically
11)	Only one operation is done at a time	More than one operation can be done at a time

4.20 Difference between capstan lathe and turret lathe

	Capstan lathe	Turret lathe
1)	It is a light duty machine	It is a heavy duty machine
2)	The turret head is mounted on the ram and the ram is mounted on the saddle	The turret head is directly mounted on the saddle and the saddle slides over the bed ways
3)	The saddle will not be moved during machining	The saddle is moved along with the turret head during machining
4)	The lengthwise movement of turret is less	The lengthwise movement of turret is more
5)	Short work pieces only can be machined	Long work pieces can be machined
6)	It is easy to move the turret head as it slides over the ram	It is difficult to move the turret head along with saddle
7)	The turret head cannot be moved crosswise	The turret head can be moved crosswise in some turret lathes.
8)	As the construction of lathe is not rigid, heavy cut cannot be given	As the construction of lathe is rigid, heavy cut can be given
9)	It is used for machining work pieces up to 60mm diameter	It is used for machining work pieces up to 200mm diameter
10)	Collet is used to hold the work piece	Jaw chuck is used to hold the work piece

4.21 Work holding devices

The work holding devices are used to hold the work piece firmly. The following work holding devices are used in capstan and turret lathes.

Work holding devices

Collets
1) Draw back collet
2) Push out collet
3) Dead length collet

Jaw chucks
1) Two jaw chuck
2) Three jaw chuck
3) Four jaw chuck
4) Air operated chuck

Fixtures

4.21.1 Collet or collet chuck

A collet is a cylindrical steel bush with a taper nose. It is used in capstan and turret lathes for holding the bar stock. The three equally spaced slits provided on the taper nose give spring action. The bore of the collet may be circular or hexagonal depending upon the shape of the work piece. The work piece is set quickly with accurate centering. The following three types of collets are available.

i) Draw back collet   ii) Push out collet   iii) Dead length collet

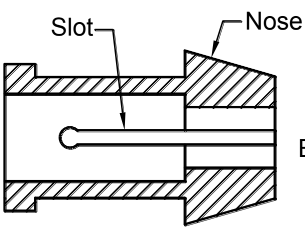


Fig.4.55 Collet

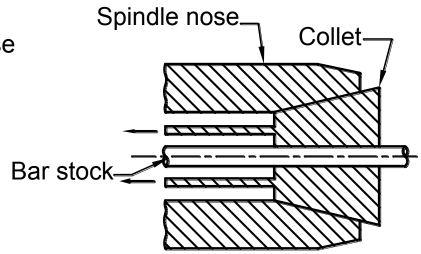


Fig.4.56 Draw back collet

i) Draw back collet or draw in collet

In this type, the collet nose and spindle nose are tapered towards the left. The thrust tube in the back end of the collet can be moved by a lever. When the collet moves forward, the collet jaws are opened. When the collet is pulled back, the taper nose of the collet moves in to the spindle taper. This makes the collet jaws to close in and grip the bar stock. In this collet, the bar stock is slightly drawn inwards while gripping.

ii) Push out collet

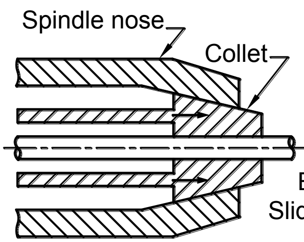


Fig.4.57 Push out collet

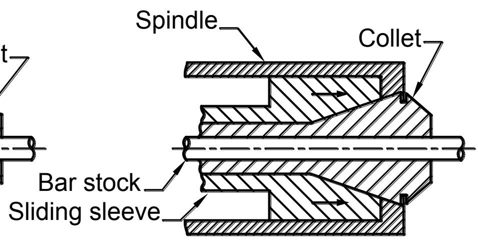


Fig.4.58 Dead length collet

In this type, the collet nose and spindle nose are tapered towards the right. When the collet is moved forward, the taper nose of the collet moves in to the spindle taper. This makes the collet jaws to close in and grip the bar stock. In this collet, the bar stock is fed till it touches the bar stop. This ensures the correct length of bar stock.

iii) Dead length collet

In this type of collet, a sliding sleeve tapered towards left is held between the spindle and the collet. It fits correctly in to taper of collet nose. When the sliding sleeve is moved towards left by the thrust tube, it makes the collet nose to close in and grip the bar stock. The bar stock is fed to the correct length as the collet is stationary.

4.21.2 Jaw chucks

Jaw chucks are generally used for holding heavy, large and irregular shaped work pieces. The following types of jaw chucks are available.

1) Two jaw chuck
2) Three jaw chuck
3) Four jaw chuck
4) Air operated chuck.

1) Two jaw chuck

It is a self centering chuck having two jaws. Irregular work pieces can be held in this chuck with the help of special work holding devices.

2) Three jaw chuck

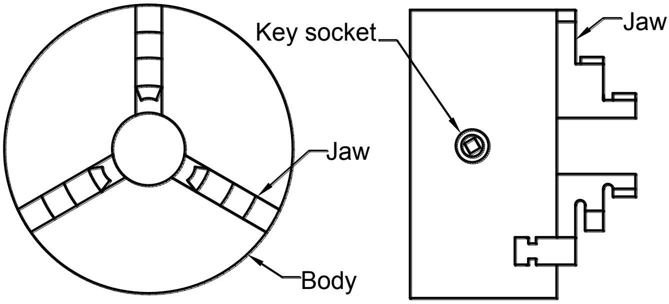


Fig.4.59 Three jaw chuck

This chuck is also known as self centering chuck or universal chuck. There are three jaws in this chuck which move in radial direction. The three jaws are simultaneously moved towards the centre of the chuck with the help of a single chuck key. The bar stock held between these jaws is gripped at the centre position. This type of chuck is used for holding cylindrical or hexagonal bar stock.

3) Four jaw chuck

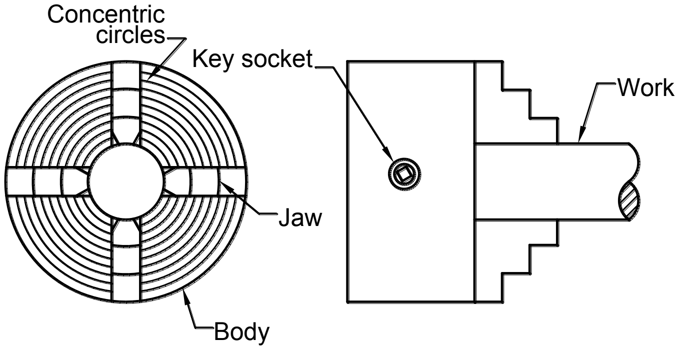


Fig.4.60 Four jaw chuck

The four jaws in this chuck can be independently moved in radial direction. So it is also known as four jaw independent chuck. This type of chucks are used for holding square, cylindrical and irregular shaped work pieces. The work piece can be easily centered with reference to the concentric circles in the chuck face.

4) Air operated or pneumatic chuck

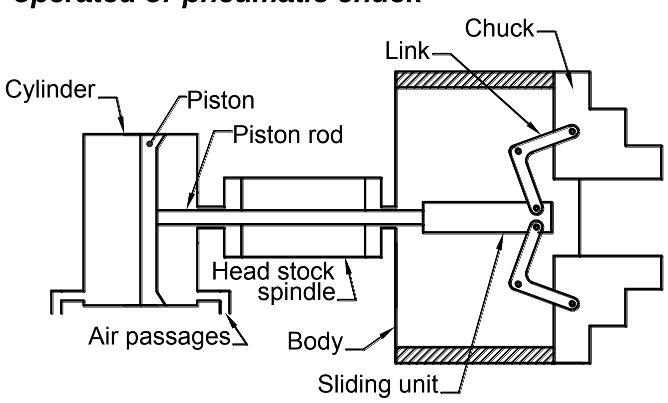


Fig.4.61 Air operated chuck

This type of chuck has two jaws which are operated by compressed air. A cylinder with piston is fitted at the back of the head stock. The piston rod is connected to the jaws through links. When the compressed air is passed in to the cylinder at the right side of the piston, the piston moves to the left. Now the jaws connected to the piston rod close in and grip the bar stock. When the compressed air passes at the left side of the piston, the jaws are opened to release the bar stock. The air supply is controlled by an hand operated valve.

4.21.3 Fixture

Fixture is a special work holding device used for mass production. It is used for holding work pieces which cannot be easily held by other work holding devices. Fixture holds the work pieces quickly and accurately. The time required for loading, locating, clamping and unloading are very much reduced by using fixture.

4.22 Tool holding devices

Tool holding device is used to hold the cutting tool firmly. The following tool holders are used in capstan and turret lathes to fix the various tools.

1) Straight cutter tool holder
2) Adjustable angle cutter tool holder
3) Multiple cutter tool holder
4) Offset cutter tool holder
5) Sliding tool holder
6) Knee tool holder
7) Flange tool holder
8) Roller steady box tool holder
9) Combination tool holder
10) Self opening die holder
11) Collapsible tap.

1) Straight cutter tool holder

One tool can be fixed in this tool holder perpendicular to the shank axis. The tool bit is fixed in the holder by means of set screws. Generally, the tools used for turning, facing, boring and chamfering operation are held in this tool holder.

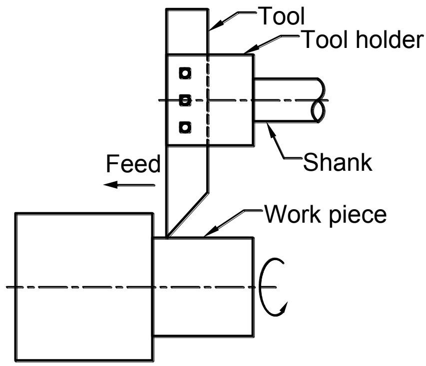


Fig.4.62 Straight cutter tool holder

2) Adjustable angle cutter tool holder

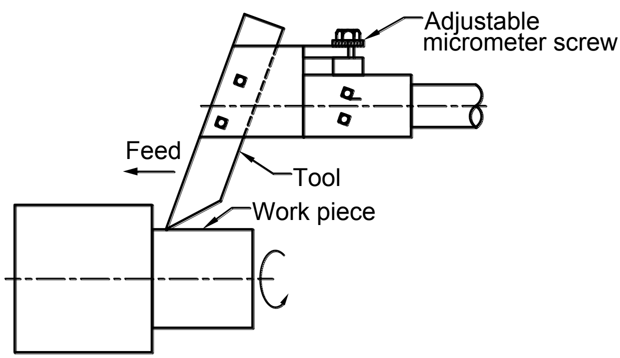


Fig.4.63 Adjustable angle cutter tool holder

This tool holder has an angular slot. The tool is fitted into this slot by means of set screws. The tool can be accurately set with the help of adjustable micrometer screws. As the tool is inclined, the operation can be done close to the jaws or to the shoulder of work piece.

3) Multiple cutter tool holder

In this tool holder, two or more cutting tools can be fitted and more than one operations can be performed at a time. This reduces the machining time.

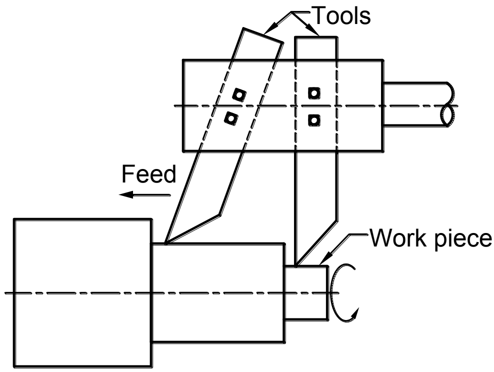


Fig.4.64 Multiple cutter tool holder

4) Offset cutter tool holder

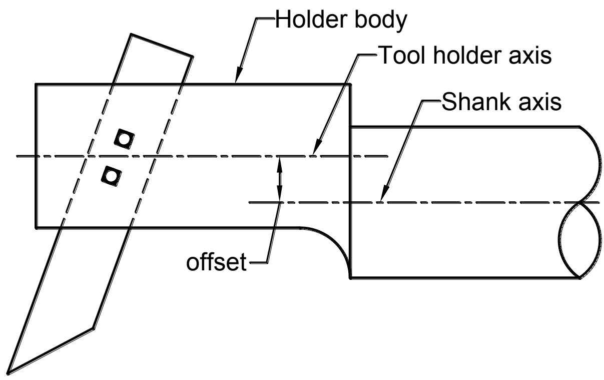


Fig.4.65 Offset cutter tool holder

In this type of tool holder, the holder body is offset with the shank axis. Large diameter work pieces can be machined by using this tool holder.

5) Sliding tool holder

This tool holder has a vertical slide which can be adjusted up and down. This slide can be accurately adjusted with the help of a micrometer fitted with the hand wheel. The slide has two holes to fit two tools. Drill, reamer or boring bar can be held in the lower hole. Turning or facing tool can be fitted in the upper hole.

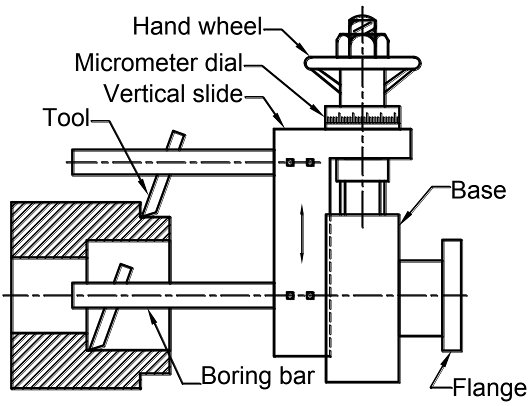


Fig.4.66 Sliding tool holder

6) Knee tool holder

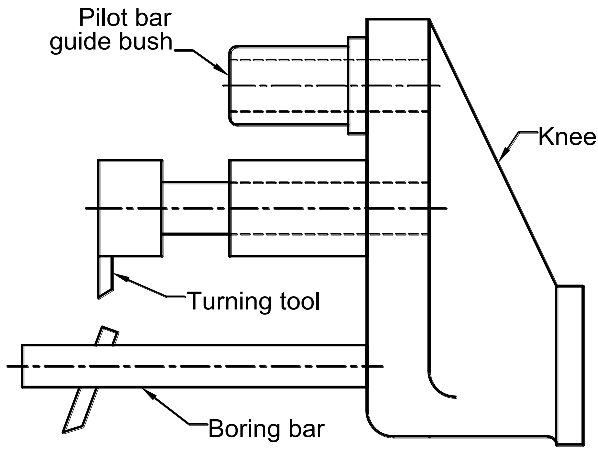


Fig.4.67 Knee tool holder

The knee of this tool holder has three holes. The centre of lower hole is aligned with the lathe axis. Drill and boring tools can be fitted in this hole. Turning tool is fitted in the middle hole. Guide bush fits in to the upper hole.

7) Flange tool holder

This tool holder has cylindrical bore. Drill, reamer or boring bar can be fitted in this bore with the help of socket. The flange can be directly bolted to the turret face.

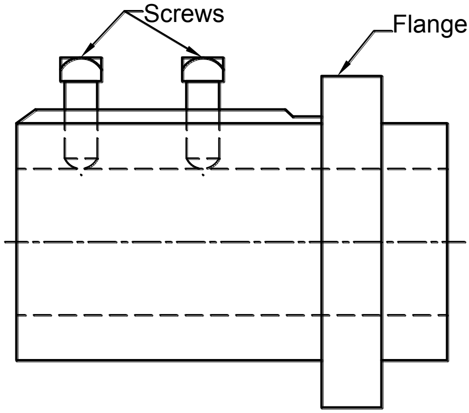


Fig.4.68 Flange tool holder

8) Roller steady box tool holder

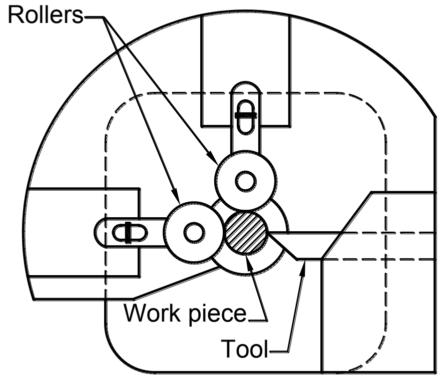


Fig.4.69 Roller steady box tool holder

In this tool holder, two rollers are provided in the opposite side of the cutter. This gives support for work piece during machining. Hence heavy cut can be given. Good surface finish is obtained by the burnishing action of the roller. The rollers can be adjusted to suit the diameter of the work piece.

9) Combination tool holder

In this tool holder, a number of turning tools and a boring bar can be fitted and the machining is done at a same time. The tool holder is directly fitted to the turret head. The guide bush fits into the pilot bar of head stock. This gives additional support during machining.

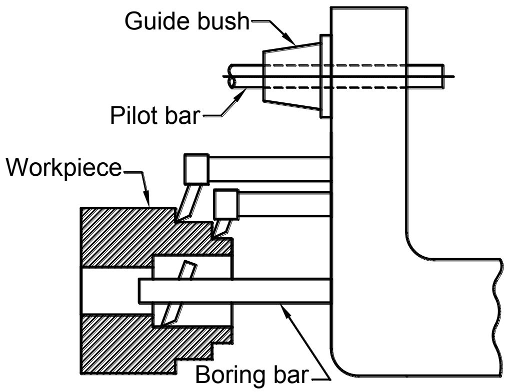


Fig.4.70 Combination tool holder

10) Self opening die holder

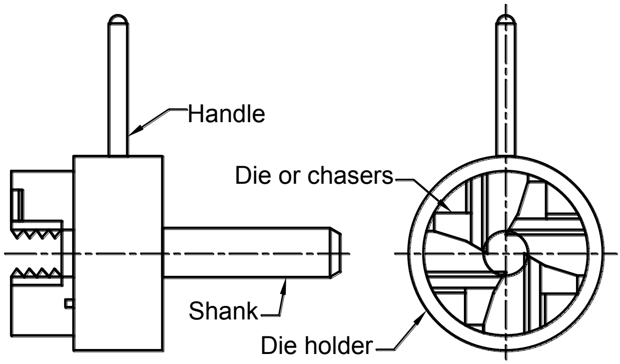


Fig.4.71 Self opening die holder

Self opening die holder is used for cutting external threads accurately on the work pieces for required length. The die holder has four thread cutting blades called chaser or die. After the required length of thread is cut, the movement of die holder is stopped by the stop fitted in the rear tool post. Now the tripper pin in the die holder actuates the tripping mechanism. This mechanism releases the chasers radially outward from the work piece. The die holder can be moved back to the starting position. So, it is not necessary to stop or reverse the spindle. Hence the production time is considerably reduced.

11) Collapsible tap

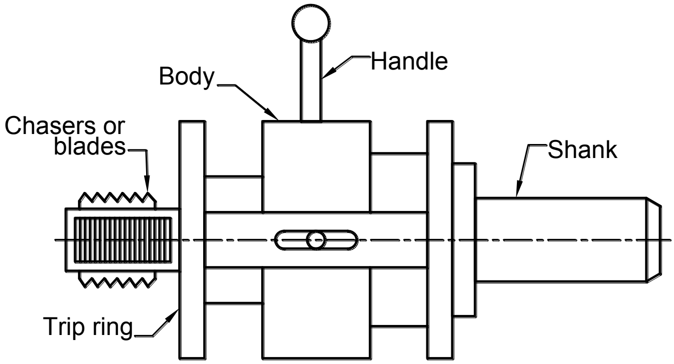


Fig.4.72 Collapsible tap

Collapsible tap is used for cutting internal threads accurately on the work piece for required length. The shank of the tap fits in to the tool holder. Plunger with blades or chasers is fitted to the collapsible tap body. After the required length of internal thread is cut, the handle is operated. This releases the chasers radially inwards and reduces the tap diameter. Now the tap can be withdrawn without reversing or stopping the machine.

12) Bar stop or work stop

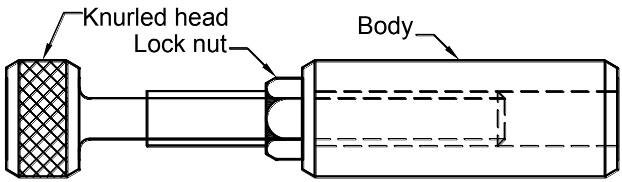


Fig.4.73 Bar stop

The correct length of bar stock to be machined is controlled by the bar stop. The bar stop can be fitted to a holder in the turret head. It has a cylindrical body with threaded hole. A knurled head screw is fitted in the threaded hole. The length of the stop is adjusted by screwing the thread. Then it is locked by a lock nut in position.

Review Questions

5 marks questions

1) What are the desired properties of cutting tool material?
2) What are the different materials used for manufacturing cutting tool? State their applications.
3) Discuss the composition and properties of H.S.S cutting tool.
4) What are the principal cutting angles of a single point lathe tool? Draw and indicate the angles.
5) What is the function of chip breaker?
6) What are the defects you find in the work piece if the tool is not set properly?
7) What is tool life? Write the equation for determining the tool life.
8) Explain briefly, about any two factors that influence the tool life.
9) Name the different types of lathe and explain any one type briefly.
10) How do you specify the size of lathe?
11) Draw the sketch of a centre lathe and indicate the parts.
12) Sketch and explain the back gear mechanism in a lathe
13) How is tail stock useful in a lathe?
14) Name the types of lathe tool posts and briefly explain any one.
15) Sketch the carriage mechanism of a lathe and label the parts.
16) How automatic longitudinal feed is given in a lathe?
17) Sketch any one work holding device for lathe.
18) Sketch and explain the working of three jaw chuck.
19) Sketch the mechanism of a four jaw chuck and explain.
20) Explain face plates.
21) What are the methods used to support and drive work pieces in a lathe? Explain any one method.
22) List out the accessories used in a lathe. Write the specific application of any two.
23) Name the types of lathe centres. Sketch a half centre.

24) Compare steady rest with follower rest.

25) Explain knurling with a sketch.

26) Explain the principle of thread cutting in a lathe.

27) What are the different methods of taper turning? Explain any one method.

28) Explain cutting speed for lathe work.

29) Compare a capstan and turret lathe.

30) Distinguish between engine lathe and turret lathe

31) What are the advantages of semi automatic lathe?

32) Sketch a turret indexing mechanism of a lathe.

33) What are the types of collet chucks used in semi automatic lathe?

34) Explain a draw back collet with a neat sketch.

35) Explain an air operated chuck with a sketch.

36) Name any five tool holders used in semi automatic lathes.

37) Sketch and explain an adjustable angle cutter tool holder.

38) Sketch and explain combination tool holder

39) Sketch a self opening die head and name the parts

40) Draw a sketch of collapsible tap and name the parts.

41) Draw a neat sketch of bar stop and describe its functions

10 Marks questions

1) Discuss about various cutting tool materials.

2) Describe with a sketch the nomenclature of single point cutting tool.

3) What are chip breakers? Briefly describe any three types.

4) Define cutting speed and feed. What are the factors considered in determining the speeds and feeds?

5) Define tool life. What are the factors affecting the tool life?

6) Draw a neat sketch of a lathe and explain the functions of each part.

7) Describe a back geared head stock with a neat sketch.

8) What are the types of head stock used in lathe? Explain the working of all geared head stock in lathe.

9) What is the importance of carriage in a lathe? Explain with a sketch.

10) Draw and describe tumbler gear mechanism.

11) Draw and explain apron mechanism of a lathe.

12) By means of a neat sketch explain the function and working of a quick change gear box.

13) What are the various work holding devices used in lathe? Explain any two of them with simple sketches.

14) List out the various machining operations done on a lathe. Explain any two of them with sketch.

15) What are the methods of taper turning in a lathe? Explain any one method with a sketch.

16) Draw and describe the taper turning by setting over the tail stock in a lathe.

17) Sketch and explain a milling attachment for lathe.

18) Explain the working of tool post grinder in a lathe.

19) With a neat sketch explain the principal parts of capstan lathe.

20) With the help of a neat sketch describe the working of a turret lathe.

21) Explain with a neat sketch, the working of a bar feeding mechanism of an automatic lathe.

22) Briefly give an account of differences between turret and capstan lathe.

23) With a sketch, explain any two work holding devices for a capstan lathe.

24) With a sketch, explain any two tool holding devices for a turret lathe.

25) Explain the following:

    (i) Flange tool holder (ii) Knee tool holder.

26) Explain the self opening die head with the help of a neat sketch.

27) With the help of a neat sketch explain the working of a collapsible tap used in turret and capstan lathes

Unit – V

DRILLING AND METROLOGY

5.1 Introduction

Drilling is the process of producing circular holes in a work piece. The machine used for this operation is called drilling machine and the tool is called drill or drill bit. The hole is produced by giving axial movement to the rotating drill against the work piece.

5.2 Types of drills

The following are the types of drills used for producing holes.

1) Flat drill or spade drill
2) Straight fluted drill
3) Twist drill
4) Oil tube drill

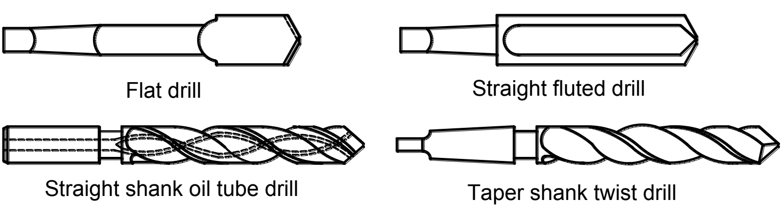


Fig.5.1 Types of drill

1) Flat drill

It has 'V' shaped flat cutting edge. The cutting angle varies from 90^{o} to 120^{o}. The cutting edge is made from a round tool steel by forging. The clearance of 3^{o} to 8^{o} is given to the cutting edge. It is generally used for drilling wood, brass and plastic materials. As it can not produce accurate holes, it is not mostly used.

2) Straight fluted drill

In this drill, the flute is made straight. There is no passage for the chips to escape during drilling by using this drill. So, nowadays it is not widely used. This drill is used for drilling soft materials and thin sheet metals.

3) Twist drill

This type of drill is most widely used nowadays. The drill has a cylindrical body on which helical flutes are cut. It has cone shaped cutting edge at the end of the flute. This drill is made of HSS or carbon steel with various sizes. Generally, twist drill up to 12mm have straight shank and longer size have taper shank.

4) Oil tube drill

This is a type of twist drill having two holes along the flute up to the cutting edge. Coolant passes through these holes for cooling the cutting edge during drilling. Compressed air can also be passed through the holes to remove the chips easily.

5.3 Twist drill nomenclature

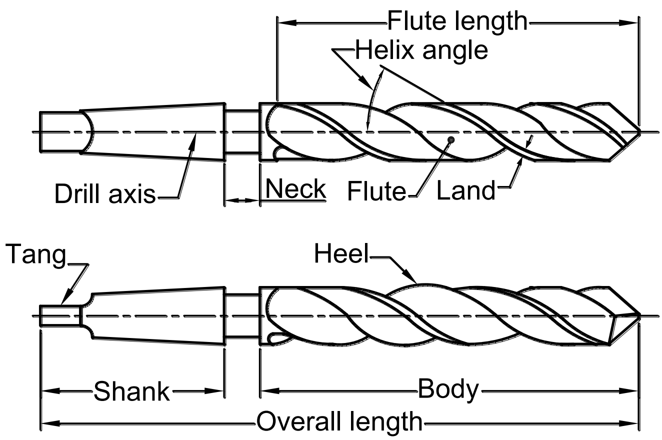


Fig.5.2 Nomenclature of twist drill

The various parts of the commonly used twist drill are shown in the figure.

1) Tang : It is the flattened end of taper shank. It correctly fits in to the spindle slot and gives rotation to the drill bit.

2) Shank: It is a part that fits into the machine spindle or any other tool holding device. The shank may be straight or tapered. Generally shank with Morse taper is used.

3) Neck: It is the portion between the body and the shank. The diameter of the neck is less than the diameter of the body. The size and other details of the drill are marked on the neck.

4) Body : It is the main part of the drill. It has the following parts.

a) Flutes : These are helical grooves cut on the body. The function of flutes are:

i) to form cutting edge
ii) to make curling chips
iii) to give passage for escaping chips
iv) to allow the coolant to reach the cutting edge

b) Land or Margin : It is a narrow surface on the edge of the flute. The size of the drill is measured across the lands at the point end. The drill bit is aligned with the help of land.

c) Heel : It is another edge of the flute.

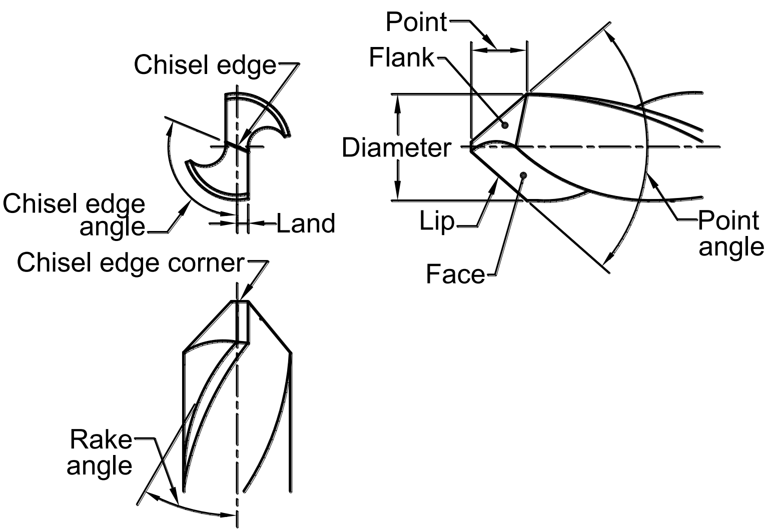


Fig.5.3 Nomenclature twist of drill

5) Point : The cone shaped end of the drill is called point. The point has the following parts.

a) Flank : It is the slant surface of the cone shaped end.

b) Lip or cutting edge : It is formed by the intersection of flank and face. It is actually the cutting edge of drill. The cutting edges are ground as they are equally inclined at 59^{o} with the drill axis.

c) Face : It is the portion of the flute surface adjacent to the lip. The chips impinges on the face.

d) Chisel edge or dead center : The chisel edge is formed by the intersection of flanks. It acts like a flat drill and cuts a small hole in the work piece. Then the cutting edges remove further metal to make the hole with required size.

6. Important drill angles

a) Point angle : It is the angle between the cutting edges(lips). It is usually 118°. Drill bit with large point angle is used for drilling hard materials.

b) Rake angle or Helix angle : It is the angle of inclination of helical groove with the drill axis. It is usually from 30° to 45°.

c) Chisel edge angle : It is the obtuse angle between the chisel edge and lip. It is generally from 120° to 135°.

5.4. Types of drilling machines

The different types of drilling machines are

1) Portable drilling machine
2) Bench type - sensitive drilling machine
3) Floor type - upright drilling machine
4) Radial drilling machine
   (i) Plain type (ii) Semi universal type (iii) Universal type
5) Gang drilling machine
6) Multi spindle drilling machine
7) Deep hole drilling machine
   (i) Vertical type (ii) Horizontal type

5.4.1 Portable drilling machine

This is a small and compact machine, it can be easily taken to a required places. It is used for drilling holes up to 12mm diameter in large work pieces. It is run by an electric motor or pneumatic power with high speed. Feed is given by hand.

5.4.2. Bench type – sensitive drilling machine

This is a light duty high speed drilling machine mounted on a bench. It is used for drilling holes from 1.5mm to 15mm diameter. Feed is given only by hand. So the operator can sense the travel of the drill. Hence it is called as sensitive drilling machine. The important parts are explained below.

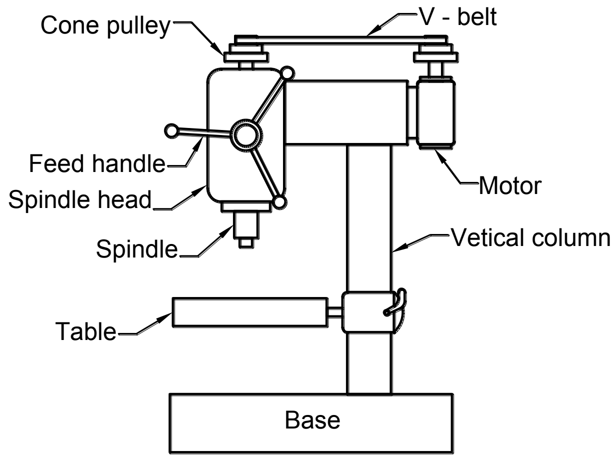


Fig.5.4 Sensitive drilling machine

1) Base

The base is mounted on the bench. It supports the column and other parts of the machine.

2) Column

It is a cylindrical post mounted vertically on the base. It supports the table, spindle head and driving mechanism.

3) Table

The rectangular or circular table is fitted with the column. T-slots are provided on the table for holding the work piece. The table can be moved up and down and fitted at any position on the column. It can be swiveled about the column.

4) Spindle head

At the top of the column, a motor is fitted on one side. The spindle head is fitted on the other side. The motor drives the spindle through a V-belt and step cone pulley. The spindle speed can be changed by shifting the V-belt to different pulleys. It is possible to obtain six different spindle speeds from 50 rpm to 2000 rpm.

5.4.3. Floor type – upright drilling machine

It is a heavy duty drilling machine mounted on the floor. It can be used for drilling holes up to 25mm diameter. The important parts are explained below.

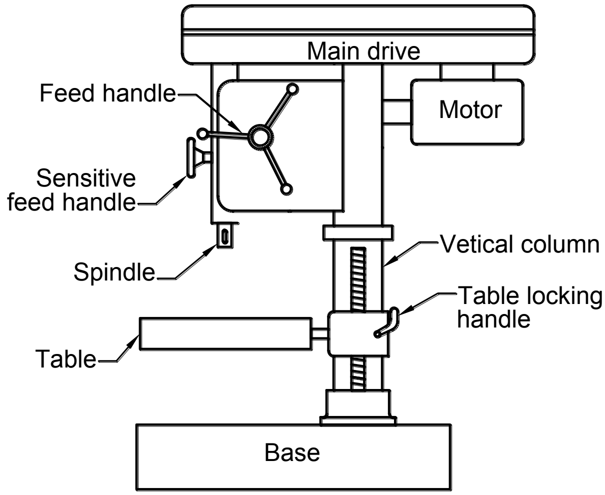


Fig.5.5 Upright drilling machine

1) Base

The base is mounted on the floor. It supports other parts of the drilling machine. The top surface of the base is machined accurately. T-slots are provided for holding large work pieces.

2) Column

It is mounted vertically on the base. It is also called as upright. It supports the table, spindle head and driving mechanism. It is designed so as to withstand heavy cutting forces.

3) Table

The rectangular or circular table is fitted to the column. T-slots are provided on the table to hold work pieces. The table can be moved up and down along the column. It can be rotated about its own axis. It can also be adjusted radially towards or away from the column.

4) Spindle head

At the top of the column, a motor is fitted on one side. The spindle head is fitted on the other side. The motor drives the spindle through V-belt and step cone pulley. The spindle can run at different speeds from 75 rpm to 3500 rpm. The lower end of the spindle has Morse taper to hold the drill bit or drill chuck. Sensitive hand feed and quick traverse feed are available in this machine. The quick traverse feed is used to bring down the drill quickly to the hole location and to withdraw after drilling.

5.4.4 Radial drilling machine

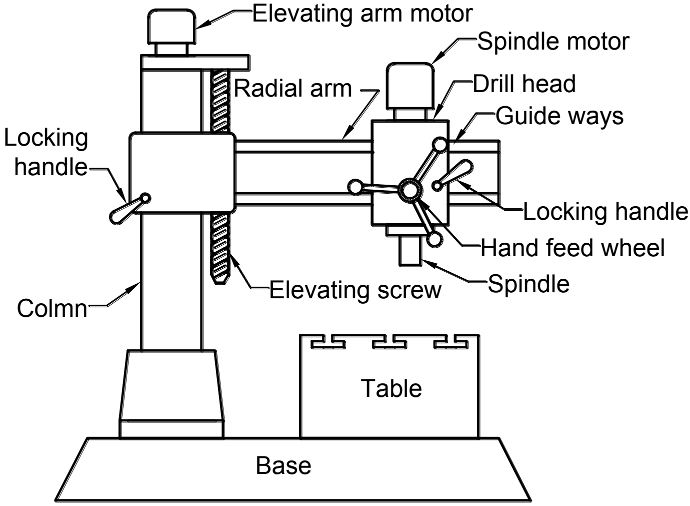


Fig.5.6 Radial drilling machine

This is the most widely used drilling machine. It can be used for drilling holes in heavy and large work pieces. The important parts are explained below.

1) Base

It is a large rectangular casting. The top surface of base is machined accurately. T-slots are provided on the base for holding large work pieces. The table is fitted at one end. It supports a column at the another end.

2) Table

It is fitted on the base. It has T-slots to hold work pieces.

3) Column

It is a cylindrical hollow casting mounted on the base. A radial arm is fitted perpendicular to the column. The radial arm can be moved up and down by an elevating screw which is driven by a motor.

4) Radial arm

It is a heavy casting mounted perpendicular to the column. It has horizontal guide ways for the movement of spindle head. The radial arm can be adjusted vertically along the column according to the height of work piece. It can be rotated about the column.

5) Spindle head

The spindle head is mounted on the radial arm. It has a motor in the top to drive the spindle. It has a gear box to get different speeds and feeds for spindle. The spindle head can be moved along the guide ways on the radial arm. The lower end of the spindle has Morse taper to hold the drill or drill chuck.

Types of radial drilling machine.

(a) Plain radial drilling machine :

In this machine, the following adjustments can be done.

1) Up and down movement of radial arm.
2) Circular movement of radial arm about the column.
3) Radial movement of spindle head along the radial arm.

(b) Semi universal radial drilling machine

In this machine, the above said three adjustments are available. In addition, the spindle head can be tilted about an axis perpendicular to the radial arm. This adjustment helps to produce holes on angular surfaces of work pieces.

(c) Universal drilling machine

In this machine, the above said four adjustments are available. In addition, the radial arm can be tilted about a horizontal axis perpendicular to the column. This adjustment is used for drilling holes in work pieces at any angle.

5.4.5 Gang drilling machine

Gang drilling machine is used to perform a series of operations in a work piece one by one. It has a long common table and a base. Many spindle heads are placed separately on the table side by side. Each spindle head has individual motor. The speed and feed of the spindles are controlled independently by the motor.

The tools for different operations are held in the spindles. The work piece is held in the table and brought under the first spindle. After the operation is finished, the work piece is moved to next spindle. Now the operation is performed on the second spindle. At the same time, operation is performed by the first spindle in another work piece. Thus drilling, boring, reaming and tapping can be done one after another.

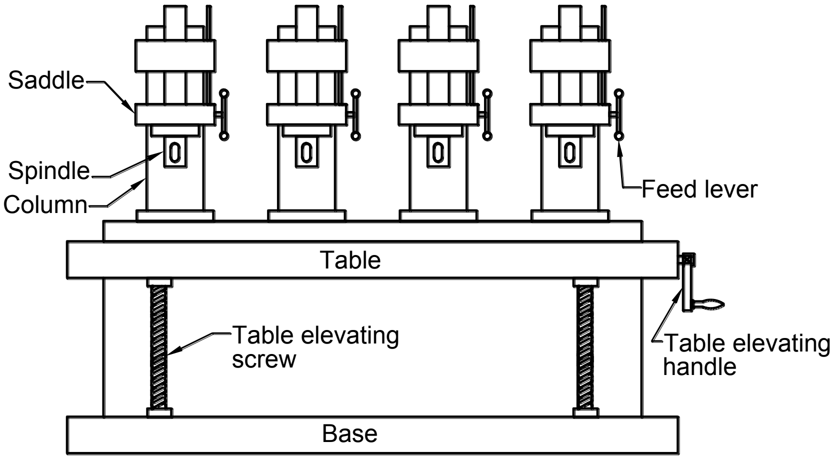


Fig.5.7 Gang drilling machine

5.4.6 Multi spindle drilling machine

Multi spindle drilling machine is used to perform the same operation at various locations in a work piece. In this machine, several spindles are fitted at required distances. All the spindles are driven by a single motor. The drive is transmitted to the spindles through a set of gears. All the spindles are fed towards the work piece at the same time. The feed can be given by raising the table or by lowering the spindle head. By using this machine, number of holes can be drilled on the parts like pipe flange, pipe housing, etc.

5.5 Specification of drilling machine

The important specifications of a drilling machine are given below.

1) Type of drilling machine.
2) The maximum diameter of the drill that the machine can hold.
3) The maximum size of the work piece that can be fitted on the machine.
4) Size of the table.
5) Maximum spindle movement.
6) Number of spindle speed and feed.
7) Net weight of the drilling machine.
8) Power of the motor.
9) Floor area.

5.6 Principle of operation in drilling

The spindle head has a hollow cylindrical shaped part called quil. The quil has a rack cut on its outer surface. The quil can be moved up and down by engaging pinion with the rack. The revolving spindle is held inside the quil with bearing supports.

So the quil can be moved up and down while the spindle rotates. The spindle has a long key way at its upper end. A bevel gear connected with the spindle can slide on these guide ways. This arrangement allows the bevel gear to transmit the drive to the spindle, while the spindle moves up and down.

The lower end of the spindle has a hole with Morse taper to hold the drill bit or sleeve. The taper shank fits in to the taper hole to get positive drive. The work piece is fitted on the table by using suitable work holding device. The drilling is performed on the work piece by feeding the spindle manually or automatic.

5.7 Feed mechanism

Hand feed or automatic feed can be given to the spindle.

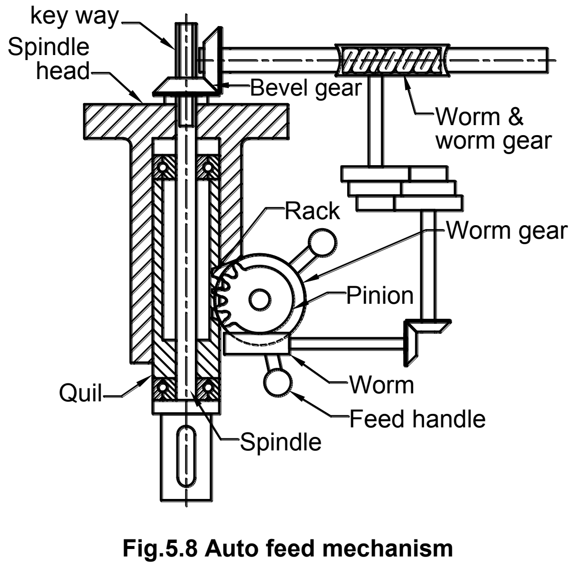


Fig.5.8 Auto feed mechanism

1) Hand feed

A pinion meshes with the rack on the quil. A worm gear is connected with the pinion. Hand feed handle is engaged with this set up to move the spindle up and down manually.

2) Automatic feed

The hand feed handle is disengaged. The worm gear meshes with a worm. The worm is connected to a feed gear box through a set of bevel gears. The gear box gets power from the main shaft. When the worm rotates, the worm gear rotates. Now the pinion also rotates and the quil is moved up and down. Thus automatic feed is given to the spindle.

The speed of the worm shaft can be changed by engaging two different gears in the gear box. This changes the amount of feed of the spindle.

5.8. Cutting speed and feed

1) Cutting speed

The peripheral speed of the drill is called cutting speed. It is expressed in the unit m/min.

$$\text{Cutting speed, } V = \frac{\pi DN}{1000} \text{ m/min}$$

Where, d – diameter of drill (mm)

N – Spindle speed (rpm)

The cutting speed for various work piece material are given in the following table.

Work piece material	Cutting speed (m/min)	
	HSS drill	Carbon steel drill
Mild steel	24 – 45	9 –17
Stainless steel	18 – 21	7 –11
Cast iron	21 – 30	9 –15
Copper	18 – 30	7 –15
Aluminium & Alloys	60 – 90	24 – 45
Brass & Bronze	60 – 90	24 – 45

2) Feed

The feed of the drill is the lengthwise movement of the drill for one revolution of the spindle. It is expressed in the unit mm/revolution or mm/min. Cutting speed and feed depend upon the following factors:

1) Work piece material
2) Cutting tool material
3) Required surface finish
4) Type of cutting fluid
5) Rigidity of the machine and work holding device

5.9 Methods of holding drill bit

The following are the methods used for holding drill bits having straight shank and taper shank.

1) Fitting directly in the spindle

The end of the drilling machine spindle has a Morse taper of 1:20. The taper shank of the drill also has the Morse taper. The drill shank is correctly fitted in to the spindle taper. The tang of the drill fits in to a slot at the end of spindle taper to get positive drive. A tapered wedge called drift is forced in to the slot to remove the drill from the spindle.

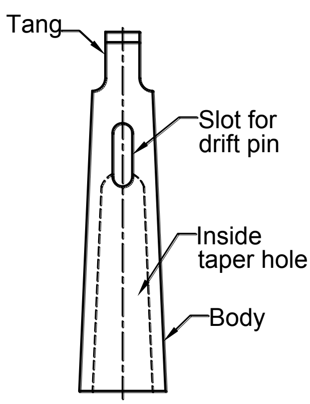


Fig.5.9 Drill sleeve

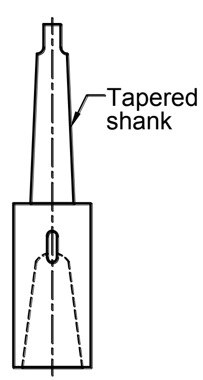


Fig.5.10 Drill Socket

2) Sleeve

If the taper shank of the drill is smaller than the spindle taper, a sleeve can be used. The outside taper of the sleeve fits in to the tapered hole on the spindle. A drill can be held in the inside taper of the sleeve. Sleeves of different sizes are used to hold the drills having different taper shanks.

3) Socket

If the taper shank of the drill is larger than the spindle taper, a socket can be used. The outside taper of the socket fits in to the tapered hole of the spindle. The inside taper of the socket is larger than spindle taper. So a drill of bigger size can be fitted in to the socket.

4) Drill Chuck

Drill chuck is used for holding drills having straight shank. Drill chuck has a taper shank that fits correctly in to the tapered hole of the spindle. A commonly used self centering chuck is shown in the figure.

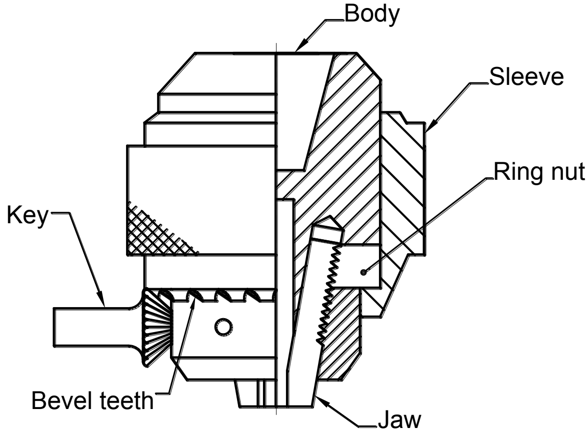


Fig.5.11 Drill chuck

The chuck has three jaws. A ring nut is meshed with the threads at the back of the jaws. The ring nut is connected to a sleeve. This sleeve has bevel teeth on its peripheral surface. When the sleeve rotates, the ring nut also rotates. This makes the jaws to move towards or away from the centre. Thus the jaws grip the drill which is held between them. The sleeve can be rotated by using a key having bevel teeth.

5.10. Drilling machine operations

The following operations can be performed in a drilling machine.

1) Drilling	2) Reming	3) Boring
4) Counter boring	5) Counter sinking	6) Spot facing
7) Tapping		

1) Drilling

Drilling is the operation of producing round hole on the work piece by using a drill bit. The centre of the hole is located and marked by using centre punch. The drill of correct size is fitted in the spindle. The rotating drill is pressed at the centre point marked on the work piece. The cutting edge of the drill removes the metal as curling chips. The internal surface of the drilled hole will be rough. Due to the vibration in the drill, the size of the hole is slightly larger than the size of the drill. When the hole is drilled to full depth of the work piece, it is called through hole. When the hole is drilled to certain depth of the work piece, then it is called blind holes.

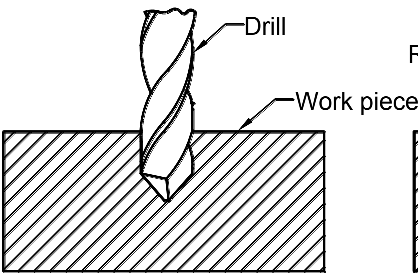


Fig.5.12 Drilling

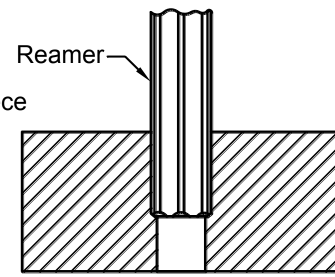


Fig.5.13 Reaming

2) Reaming

The process of finishing the already drilled hole is called reaming. A tool with multiple cutting edge called reamer is used for this operation. It removes less amount (0.375mm) of metal. In reaming, the spindle speed is reduced to half the speed during drilling. Generally automatic feed is used for reaming.

3) Boring

Boring is the process of enlarging the already drilled hole by a single point cutting tool. When the suitable larger size drill is not available, boring is done to enlarge the small hole. The tool is fitted in to the boring bar. The boring bar has a taper shank that fits in to the spindle. When the spindle moves down, the cutting tool cuts the metal to produce the hole of required size. The spindle speed should be reduced in boring.

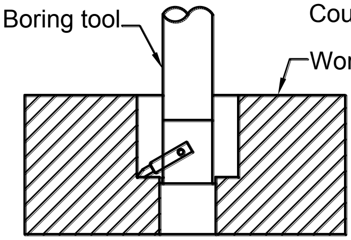


Fig.5.14 Boring

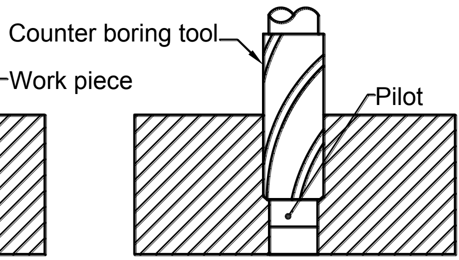


Fig.5.15 Counter boring

4) Counter boring

Counter boring is the process of enlarging the end of a hole cylindrically. This enlarged portion is to accommodate the heads of bolts, studs and pins. A tool known as counter bore is used for this operation. The tool has taper shank to fit in to the spindle. It carries a pilot at the end to guide the tool correctly into the hole during operation. The spindle speed should be slightly less than that of drilling.

5) Counter sinking

Counter sinking is the process of producing a conical enlargement at the end of a hole. This is done to seat the counter sink heads of the screws and rivets. A tool with conical cutting edge known as counter sink is used for this operation. The included angle of standard counter sinking tools are 60^{o}, 82^{o} and 90^{o}. The cutting speed is slightly less than that of drilling.

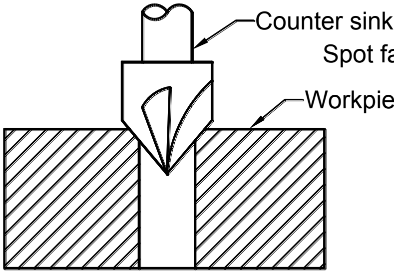


Fig.5.16 Counter sinking

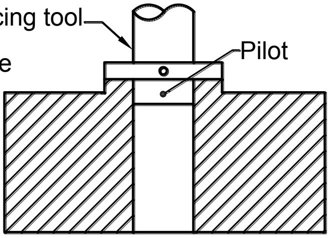


Fig.5.17 Spot facing

6) Spot facing

It is the process of producing a smooth and flat surface around a hole. Spot facing is done to provide a true seat for screw head, nut, washer, etc. A pilot is provided at the end of spot facing tool to guide the tool correctly in to the hole.

7) Tapping

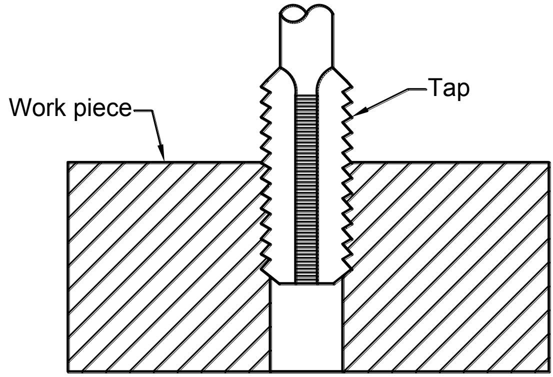


Fig.5.18 Tapping

Tapping is the process of cutting internal threads in a hole by using a tool called tap. A tap has cutting edge in the form of threads. A hole is drilled before tapping. The drilled hole will be smaller than the tap size. When the tap is screwed in to the hole, it removes the metal and cuts internal threads.

5.11. Deep hole drilling.

Deep hole drilling is used to drill deep holes in the parts like crank shaft, cam shaft, rifle barrel, etc. The drill used for this operation is shown in the figure.

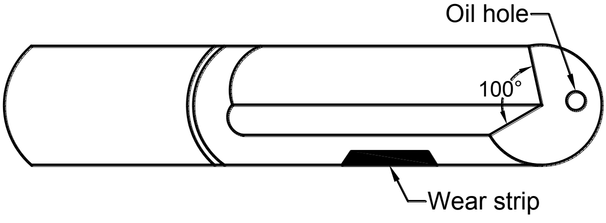


Fig.5.19 Deep hole drill

It has a 'V' flute of 100^{o} included angle along its length. The extended lip of the flute cuts the metal. Cutting fluid is supplied through a long hole in the drill body. The long work piece is supported at various points to prevent deflection. The drill is fed against the rotating work piece to produce hole. In some machines, both the drill and work piece are rotated. The drill is withdrawn often to remove the chips.

5.12 Micro drills or miniature drills

The drills used for producing small holes are called micro drills or miniature drills. Generally, the diameter of the drill will be form 0.1mm to 3mm. The length may be about 40 to 60 times of the diameter. As it is smaller and longer, it should be supported to prevent from breaking and bending. The drill is held in a chuck or a collet. The speed and feed should be carefully selected so that the drill is not over loaded. Generally hand feed is given for this drills.

5.13. Regrinding of drill

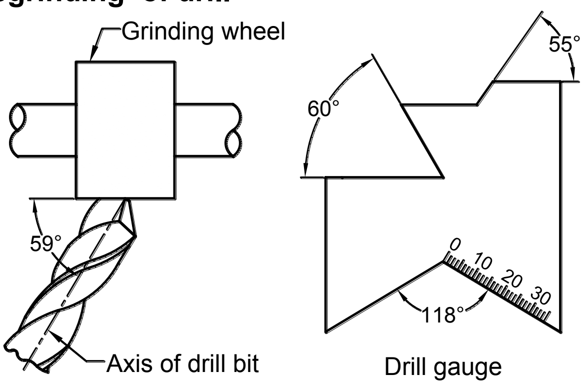


Fig.5.20 Regrinding of drill

The cutting edge of the drill becomes dull on use and requires regrinding. If it is used without regrinding, it will be over heated and may break. During grinding, the axis of the drill is inclined to 59^{o} with the wheel face. Thus the point angle of 118^{o} is obtained. The lip of the drill is slowly rotated during grinding. The length and slope of the lip should be equal on both sides. Special drill grinders are used for grinding drills of size greater than 10mm. After grinding, the point angle, chisel edge angle and lip length of the drill are checked by using drill gauge.

5.14 Metrology

Metrology is a branch of science which deals with measurements and measuring instruments. When checking the quality of a product, it is necessary to measure the size of the product. The quality of a product depends upon the shape, correct size and surface finish. Various measuring instruments are used to measure these characteristics.

Vernier caliper, micrometer, etc. are used to for measuring the exact dimension of the products. The instruments used to check whether the size of the product is within the specified limits are known as limit gauges. Some instruments compares the size of a component with the known standards to find the deviations. These are called comparators.

5.15 Inspection

Inspection is necessary to check all materials, products, and components parts at various stages during manufacturing, assembly, packaging and installation. It is the quality assurance method that compares materials, products or processes with established standards.

Need of inspection

The inspection is needed for the following purposes:

1) To ensure the correctness of materials and components with the established standards.
2) To meet the interchangeability of manufacture.
3) To produce components with acceptable quality levels.
4) To reduce scrap and wastages.
5) To purchase good quality of raw materials, tools and equipment.
6) To reduce the rejection percentage of products.
7) To judge the possibility of rework of defective parts.

5.16 Metrological terms

1) Accuracy

Accuracy is the closeness of agreement between the measured value and the true value. Accuracy is an important quality of a mesuring instrument. As the exact measurement of a true value is difficult, a set of observations are made and the mean value is taken as the true value.

Example : Let a micrometer measures a part dimension as 10 mm. If the selected accuracy is ± 0.01mm, then the true dimension may lie between 9.99 mm to 10.01 mm. Thus, the accuracy of the micrometer is ± 0.01mm means that the results obtained by the micrometer are inaccurate between ± 0.01mm.

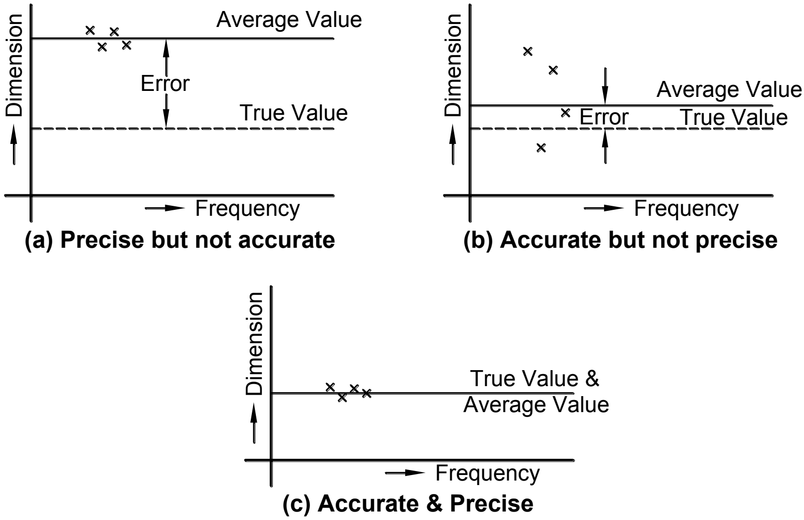


Fig. 5.21 Accuracy and Precision

2) Precision

Precision is the closeness of agreement between independent test results obtained under specified conditions. Precision refers to a group of measurements rather than a single measurement. If an instrument is not precise, it will give different results for same dimension when measured again and again.

It indicates the degree of repeatability in the measuring process. A numerical measure of a precision is the standard deviation of the frequency distribution of the values obtained from repeated measurements. For the right level of precision, the measuring device must be ten times more precise than the specified tolerance. For example, if the tolerance to be measured is ± 0.01mm, the measuring device must have a precision of ± 0.001mm. The relation between precision and accuracy is shown in the figure.

3) Error

Error of a measuring instrument is the difference between the value measured by the instrument and true value of the corresponding input.

4) Magnification

In order to measure small difference in dimensions, the movement of the measuring tip in contact with the work piece must be magnified. The output signal from a measuring instrument is to be magnified many times to make it more readable. Magnification may be achieved by mechanical, electrical, optical, pneumatic principle or a combination of these.

5) Repeatability

Repeatability is the quality of a measuring instrument to give the same result when measuring a component using the same method in the same conditions by the same operator.

6) Resolution

Resolution is the smallest change of the measured quantity which changes the indication of a measuring instrument.

7) Sensitivity

Sensitivity of the instrument denotes the smallest change in the value of the measured variable to which the instrument responds. It also denotes the maximum change in an input signal that will not initiate a response on the output.

8) Calibration

The process of periodic checking against measuring instruments and standards of high accuracy is called as calibration. The following are the requirement of a good calibration system.

1) The measuring equipment in measuring system should be capable of desired accuracy and precision
2) Calibration should be carried out using measurement systems having adequate accuracy, stability and range.
3) All the test and measuring equipment should be securely and durably labeled.
4) Test and measuring equipment should be calibrated at periodic intervals with desired accuracy and quality.
5) Records should be maintained for all the test and measuring equipment included in the calibration system.

5.17 Comparators

Comparators are devices used to compare the size of the component with a standard size. The actual size of the component cannot be measured directly by using comparators. The deviation in the size of component only can be measured.

Requirements of a comparator

The following are the requirements of a good comparator :

1) The scale used in the instrument should be linear and have a wide range of acceptability for measurement
2) There should not be any backlash and lag between the movement of the parts.
3) The instrument must be precise and accurate.
4) The indication method should be clear.
5) The indicator should be constant in its return to zero.
6) The design and construction of the comparator should be strong.
7) The measuring pressure should be uniform for all similar measuring cycles.
8) The comparator must possess maximum compensation for temperature effects.

5.18 Classification of comparators

All comparators have a magnifying device. According to the mechanism used for magnification, the comparators are classified as follows.

1) Mechanical comparator
2) Electrical comparator
3) Pneumatic comparator
4) Optical comparator

5.18.1 Mechanical comparator

A dial gauge is used as a mechanical comparators. It has a work table. A vertical stand is fitted on the table. The dial gauge can be fitted at required height in the stand by a screw.

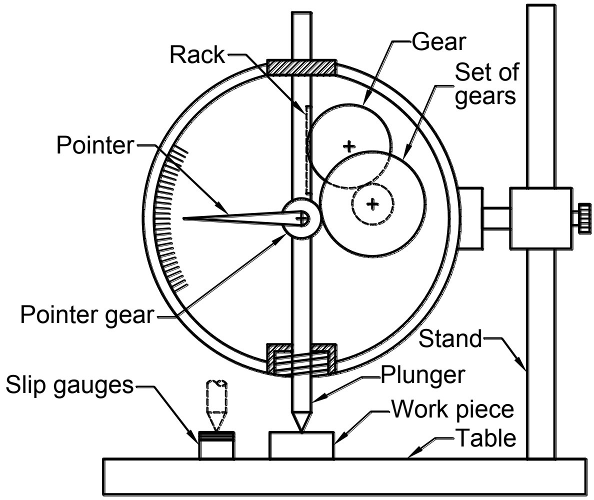


Fig.5.22 Mechanical comparator

The dial gauge has a spring actuated plunger. The plunger has rack teeth cut on its periphery. A gear is engaged with the rack. Two more gears are attached with the gear as shown in the figure. A small gear connected with the pointer is independently hinged. It is not connected with the plunger. Even a small movement of the plunger is magnified by this gear arrangement and shown by the point. Each division in the dial scale is equal to 0.01 mm.

First, slip gauges are built up to required size of component to be checked. The slip gauge blocks are placed under the plunger of dial gauge. The pointer is adjusted to zero. Then the slip gauges are removed and the work piece is placed under the plunger. If there is any deviation in the size of work piece, it will be indicated by the pointer.

Advantages of mechanical comparator

1) It is cheaper in comparison to the other comparators.
2) It has linear scale, which is easily readable.
3) It is compact and robust in construction.
4) It is easily handled.
5) It does not require any external supply such as electricity, air, etc.
6) It is suitable for ordinary workshops.

Disadvantages of mechanical comparator

1) The friction is more due to more moving parts, and hence the accuracy is less.
2) Any slackness in moving part reduces the accuracy considerably.
3) The more inertia in the mechanism causes the instrument to be sensitive to vibration.
4) The range of the instrument is limited as the pointer moves over a fixed scale.
5) Error due to parallax may occur.

5.18.2 Electrical comparator

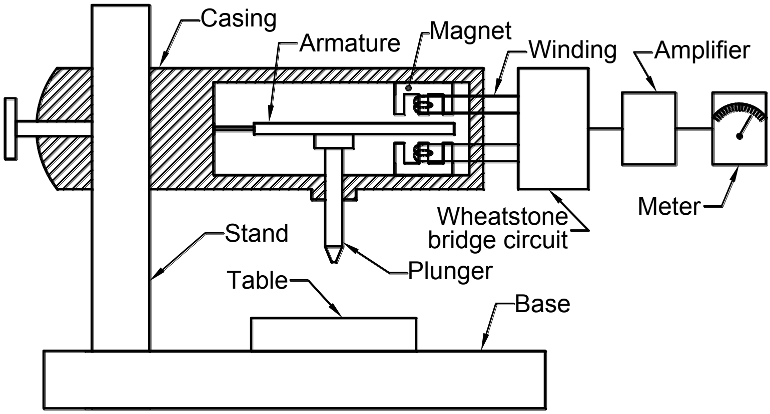


Fig.5.23 Electrical comparator

This comparator has a solid base. A vertical post is mounted on its one end. A casing is fitted horizontally to the vertical post. The casing can be moved vertically and locked at required position. An armature made of iron is hinged at one end of casing. Two electro magnets are placed on both sides of armature at equal distances. A plunger is fitted vertically to the armature. The coils wound on electromagnets are connected to a wheatstone bridge circuit.

First, a specimen of correct size is placed between the plunger and the table. The resistance of the circuit is adjusted so that the meter indicates zero reading. Then the specimen is removed, and the work piece to be checked is placed under the plunger.

If there is any variation in the size of work piece, the plunger moves up and down. So the armature also moves up and down. This changes the distance between the armature and electromagnets. So the wheatstone bridge circuit will become unbalanced. This causes change in current flowing through the circuit. This current is amplified by an amplifier and shown by the meter. The accuracy of electrical comparator is 0.001 mm.

Advantage of electrical comparator

1) It has very less number of moving parts.
2) The magnification is comparatively high.
3) It can be used for various ranges.
4) It has very light pointer mechanism and hence not sensitive to vibrations.
5) It has a compact construction.

Disadvantages of electrical comparator

1) The fluctuation in electrical supply may affect the accuracy.
2) Heating of coils in the measuring unit may cause zero drift and change the calibration.
3) It is comparatively more expensive.
4) The range of measurement is limited.

5.18.3 Pneumatic comparator

This comparator has a water tank fitted with a manometer. A calibrated scale is fitted vertically at the side of the manometer. A dip tube is immersed in the water tank. Restriction chamber is provided at he top of the dip tube. The lower end of the dip tube is opened. The upper end is connected to a flexible pipe through a control orifice. The top of the manometer tube is connected to the flexible pipe. A measuring head is connected at the end of flexible pipe.

Compressed air is passed into the dip tube through restriction chamber. The velocity of air is reduced in the restriction chamber and the air enters into the flexible pipe through control orifice. From the flexible pipe, the air passes to the measuring head and escapes through the holes on the measuring head.

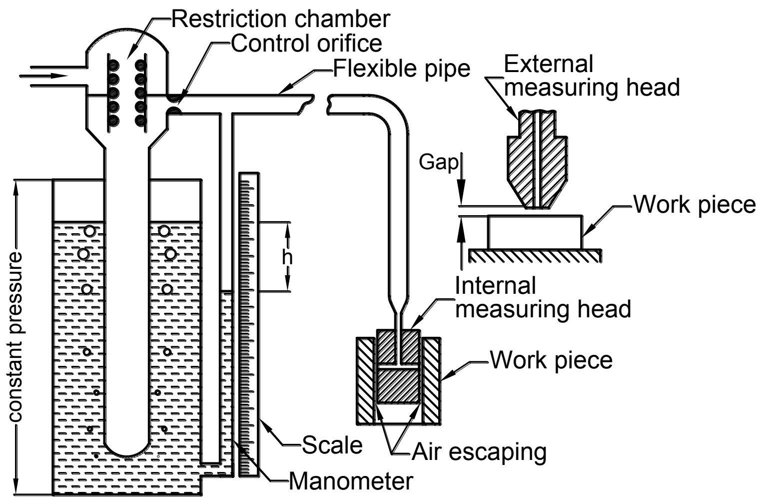


Fig.5.24 Pneumatic comparator

When the air flows freely through the measuring head, the water levels in the manometer and in the tank will be same. If there is some restriction to the flow of air, there will be a pressure difference between the flexible pipe and the dip tube due to the back pressure. This pressure difference is shown by the variation of water level in the manometer.

a) Internal measurement

For checking the size of hole, internal measuring head is connected to the flexible pipe. It is in cylindrical shape. Two holes are provided at its sides through which air can escape. First, the measuring head is introduced into the hole of standard specimen or in a ring gauge. The level of water in the manometer is marked as zero. Then the measuring head is introduced in the hole of work piece to be checked. When the size of hole is smaller, the restriction for air flow will be more. So the water level in the manometer will fall down from the zero reading. When the size of hole is larger, the restriction for air flow will be less. So the water level in manometer will rise above the zero reading. The deviation can be found out with an accuracy of 0.001 mm by using this method.

b) External measurement

External measuring head is connected to the flexible pipe to check the thickness and height of components. Slip gauge blocks are built up to required size and kept under the measuring head. The zero reading in the manometer is noted. Then the slip gauges are removed and the work piece is placed under the measuring head. The gap between the work piece and measuring head varies according to the variations in the size of work piece. This variation is indicated by the water level in the manometer.

Advantages of pneumatic comparator

1) No wear takes place on the gauging devices.
2) Accuracy is more due to less friction and less inertia.
3) Higher magnification can be obtained.
4) Components with very small dimensions can be checked accurately.
5) The indicating instrument can be kept remote from the measuring unit.
6) A very small measuring pressure is sufficient.

Disadvantages of pneumatic comparator

1) The scale is generally not uniform.
2) Very high magnification is required to avoid meniscus errors.
3) Various gauging heads are needed for different dimensions.
4) It requires a number of auxiliary equipment.
5) Handling of equipment is difficult.

5.18.4 Optical Comparator

In this comparator, a plunger is connected to a lever which is hinged at one end. The displacement of plunger is magnified through these lever. A mirror is fitted at an angle at the end of the lever. A bulb is fitted at a certain distance above the mirror. The light rays from the bulb are reflected by the mirror and fall on the screen opposite to the mirror. A calibrated scale is provided on the screen.

First, the slip gauge of required size are built up and placed between the plunger and the table. Now the point where the beam of light falls on the screen is noted as zero reading. Then the slip gauges are removed and the work piece to be checked is placed under the plunger.

If there is any deviation in the size of work piece, the plunger will move up and down. This makes the lever to tilt the mirror. Now the beam of light reflected from the mirror falls on the screen at another point. From this, the deviation in the size of work piece is determined accurately.

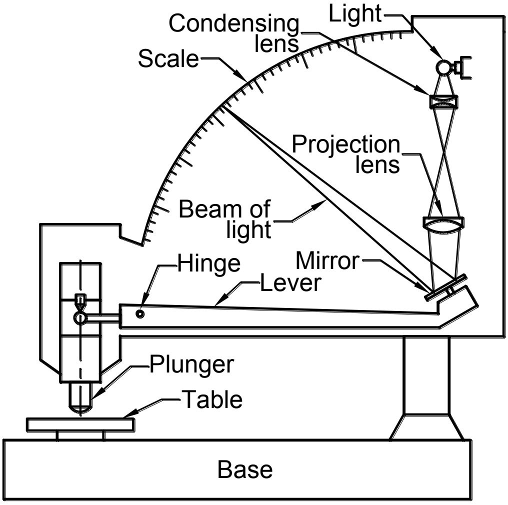


Fig.5.25 Optical comparator

Optical comparator is used for checking gear teeth, screw thread, cutting tools, needles, etc.

Advantages of optical comparator

1) Very high magnification can be obtained.
2) It has less number of moving parts.
3) The accuracy is higher.
4) The range of instrument is high.
5) No parallax error occurs.
6) The weight is comparatively less.

Disadvantages of optical comparator

1) It has large construction.
2) The cost of equipment is more.
3) Heat from the lamp, transformer, etc. may cause the settings to drift.
4) A dark room is needed.
5) It is not convenient for continuous use as it viewed through the microscope.

5.19 Measuring Instruments

5.19.1 Steel rule

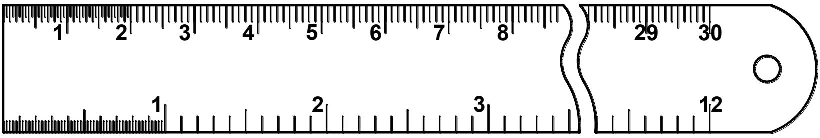


Fig. 5.26 Steel rule

This is also called as scale. It is simplest and most common measuring instruments used to measure length. It consists of a strip of hardened steel having line graduations etched or engraved at interval of fraction. The scale can be graduated on one side or both sides with different units of measurement. The scales are available in the sizes of 150 mm, 300 mm, 600 mm and 1000 mm. This is not accurate measuring device. It can be used in general measurement in foundry, steel factories, fabrication works, etc.

5.19.2 Calipers

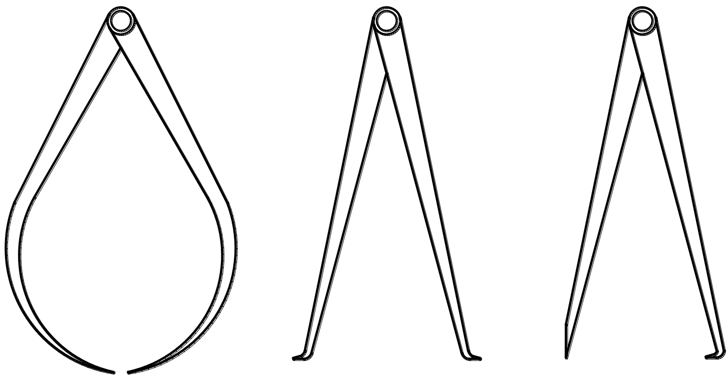


Fig. 5.27 Calipers

Calipers are generally used to measure the size or to transfer a dimension to a work piece. The commonly used calipers are :

1) Outside caliper 2) Inside caliper 3) Outside spring caliper
4) Inside spring caliper 5) Jenny or Odd leg caliper

Outside caliper has two-curved legs bent inwards. It is used to measure outside dimensions like diameter, thickness, etc. with the help of steel rule. The two legs are joined stiff at the hinge of the legs.

Inside calipers has two straight legs bent outwards. It is used to measure the inside dimensions of holes, shoulders, parallel surface, etc. The accurate measurements can be easily adjusted in the screw controlled spring calipers.

The odd leg caliper is used for scribing parallel lines about a straight edge of the work piece. It is alos used to find the centre of a cylindrical work.

5.19.3 Combination set

This is the most adaptable and widely used non-precision instrument in layout and inspection work. The combination set consists of scale, squaring head, protractor and centre head. Groove is cut along the length of the heavy scale. The sliding squaring head is fitted in this groove. One surface of the squaring head is always perpendicular to the scale. It can be adjusted and placed in any position by a locking bolt and nut. The squaring head also contains a spirit level which is used to test the surfaces for parallelism.

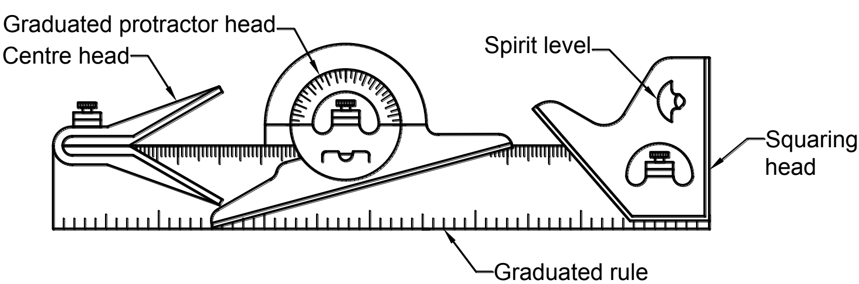


Fig. 5.28 Combination set

The graduated protractor mounted on the scale is used for laying out dovetails and angles in the work pieces. It can be moved and locked in any position. The height and depth measurements can be done with the combination of squaring head and scale. The centre head attachment is used with the scale to locate the centre of bar stock.

5.19.4 Feeler gauges

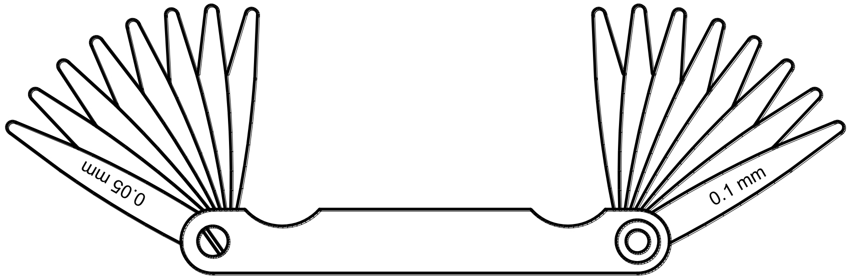


Fig.5.29 Feeler gauges

Feeler gauges are used to measure the gap between two parallel flat faces. It is also called as thickness gauges. A feeler gauge consists of a narrow strip of sheet steel with specified thickness. There are many gauges of different thickness assembled together to a common hinge. They can be brought into use independently. These are called feeler gauges because the user can feel its correctness by himself.

Feeler gauges generally comprise of a series of gauging bladed of different grades and thickness from 0.003 mm to 1 mm. assembled in protective sheath. Generally these blades are available in overall length of 100 mm. These are wide at heel and taper in outer part. These are hinged in a sheath on a screw and nut on both sides. The sheath is designed to fully protect the blades when not in use.

The correct size of the gap can be determined by inserting a number of gauges one after another. While measuring, the blade should not slide easily. At the same time it should not be forced in the clearance. One or more gauges can be used together to get the desired value.

Applications of feeler gauges :

1) It is used to measure the clearance between the tool and work piece in the machines.
2) It is used in automobiles for adjusting the spark plug clearance correctly.
3) It is used to measure the clearance between piston and cylinder.
4) It is used for measuring the clearance between the guide and guide ways in machines.

5.19.5 Fillet and radius gauge

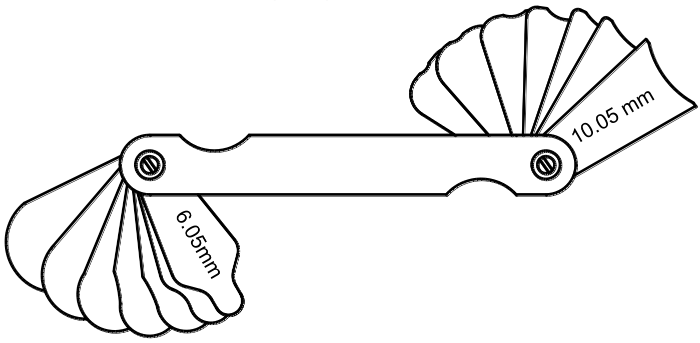


Fig. 5.30 Fillet and radius gauge

Fillet and radius gauge consists of a metal case containing a number of steel blades in it. The fillet and radius gauges are made in thin strong strips curved to different radii at end. One set of blades, mounted on one end of the case carries concave end faces. The other set at the other end of the case, carries convex end formations. The radii of the curvatures of the end formations are of different dimensions.

It is highly useful for measuring and checking the inside and outside radii of fillets and other round surfaces.

5.19.6 Pitch screw gauge

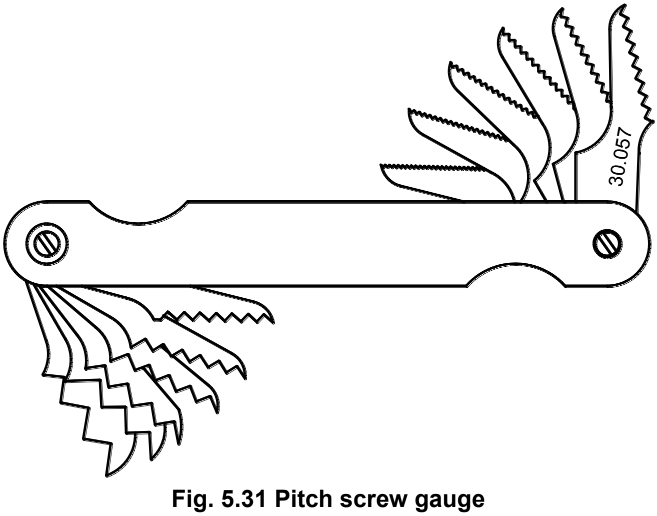


Fig. 5.31 Pitch screw gauge

Pitch screw gauge is a very effective and accurate instrument used to identify or check the pitch of the threads on different threaded items. It consists of a case made of metal carrying a large number of blades or threaded strips. They have teeth of different pitches cut on their edges. The corresponding pitch value is marked on the surfaces.

For checking the pitch value, different blades are applied on the threads one after another. The pitch value can be directly read from the marking on the exactly meshing blade surface. This gauge can be used to measure both external and internal threads. The free ends of the blades are made narrow for entering easily into the threaded holes.

5.19.7 Vernier caliper

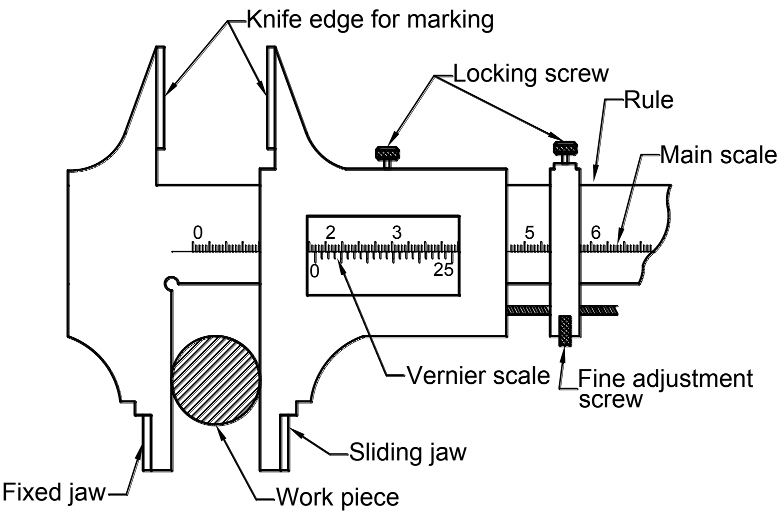


Fig.5.32 Vernier caliper

Length, width, depth, outside diameter and inside diameter of a component can be measured by using vernier caliper. The accuracy of vernier caliper is 0.02 mm.

Vernier caliper has a main beam called rule. It is graduated in millimeters. It has a fixed jaw at one end. There is a vernier head with a sliding jaw. It has a vernier scale marked on it. The sliding jaw slides over the rule and can be locked in any position by using locking screws. A fine adjustment screw is fitted in the vernier head. The inside face of fixed and sliding jaw are parallel with each other.

For measuring the outside diameter, the work piece is placed between the two jaws. The sliding jaw is moved and made to touch the work piece correctly. The vernier head is locked by tightening the locking screw. The sliding jaw can be minutely adjusted to touch the work piece exactly by using fine adjustment screw. Then main scale and vernier scale readings are noted.

Reading

The length of one main scale division is 0.5 mm. The length of 25 divisions in the vernier scale equal to 12 mm. So length of one vernier scale division = 12 / 25 = 0.48 mm.

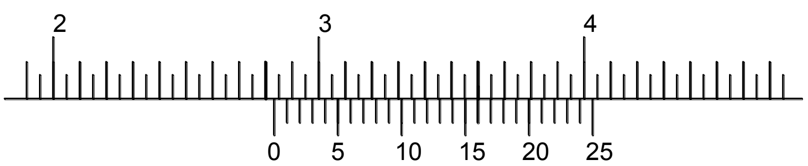
Least count = Length of one main scale division –
Length of one vernier scale division
= 0.50 – 0.48 = **0.02** mm

In some vernier calipers, the length of one main scale division will be 1 mm. The length of 50 divisions in vernier scale is 49 mm. So length of one vernier scale division = 49 / 50 = 0.98 mm.

Least count = Length of one main scale division –
Length of one vernier scale division

= 1.00 – 0.98 = **0.02** mm

While reading the vernier, the main scale reading just before the zero line of vernier is noted. Then the vernier scale division which exactly coincides with any one of the main scale division is noted. This number is multiplied by the least count and added with the main scale reading. This is the correct reading of the work piece.



Reading = 28 + (16 x 0.02) = 28.32 mm

Fig.5.33 Reading of vernier

For example, as shown in the figure,

Main scale reading	= 28 mm
Vernier scale coincidence	= 16 divisions
Vernier scale reading	= 16 x 0.02 = 0.32 mm
Correct reading	= 28 + 0.32 = **28.32** mm.

Digital vernier caliper

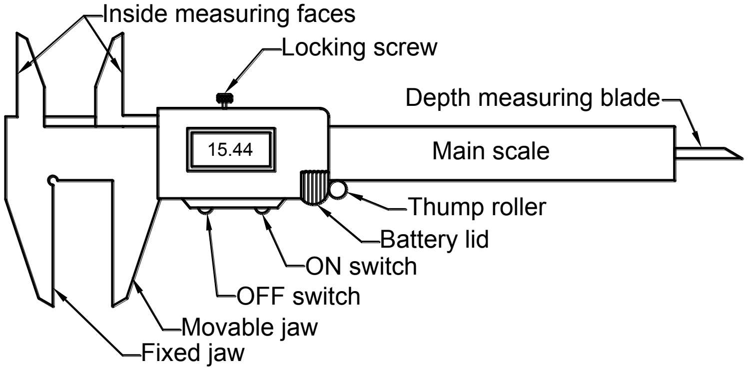


Fig.5.34 Digital vernier caliper

This vernier caliper has all the parts same as in ordinary vernier caliper. In this vernier, the reading are shown directly in liquid crystal display (LCD). It works with the help of small battery fitted in it. The accuracy of instrument is 0.01 mm. The readings can be taken in millimeter or in inches. This instrument is also used to find the deviation between the dimensions of the component and a standard dimension.

5.19.8 Vernier height gauge

Vernier height gauge is used to measure the height of the work piece and to mark the specified dimension exactly on the work piece. The accuracy of this instrument is 0.02 mm. The dimensions are measured after placing the work piece and the height gauge on a surface plate.

It has a solid base made of steel. A vertical beam is mounted over the base. Main scale is graduated in the beam. A slider slides up and down along the beam. Vernier scale is graduated in the slider.

The slider can be moved and locked in any position using a clamping screw. The slider can be adjusted accurately using a fine adjustment screw. A measuring jaw is fitted with the slider. A scriber is clamped with the measuring jaw.

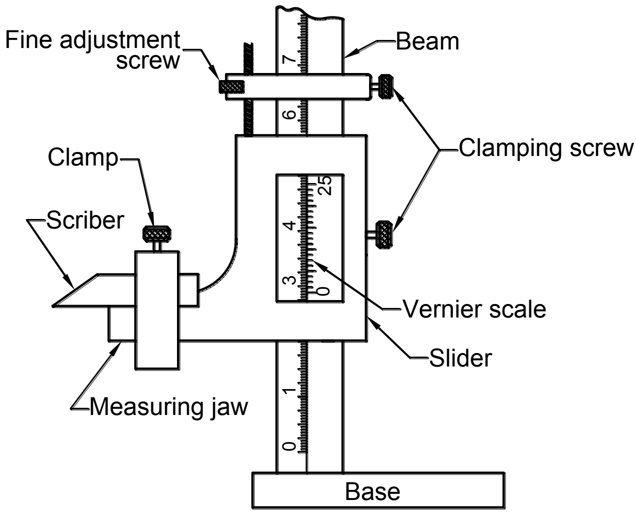


Fig.5.35 Vernier height gauge

For measuring the height of work piece, it is placed on the surface plate. The slider is adjusted so that the lower face of the slider touches the top surface of the work piece. Then main scale and vernier scale readings are noted. The least count of vernier is 0.02 mm.

Correct reading = Main Scale Reading + (Vernier Scale Coincidence x Least Count)

With this reading, the height of the base block given with the height gauge is added to determine the actual height of the work piece.

Actual height of work piece = MSR+(VSC x LC)+Height of base block

5.19.9 Gear tooth vernier

Gear tooth vernier is used to measure the chordal thickness of a gear tooth. Chordal thickness is the thickness of a gear tooth at which the pitch circle passes through it. This vernier has a horizontal slide and a vertical slide. The slides can be independently moved. Main scale and vernier scale graduations are marked in both slides.

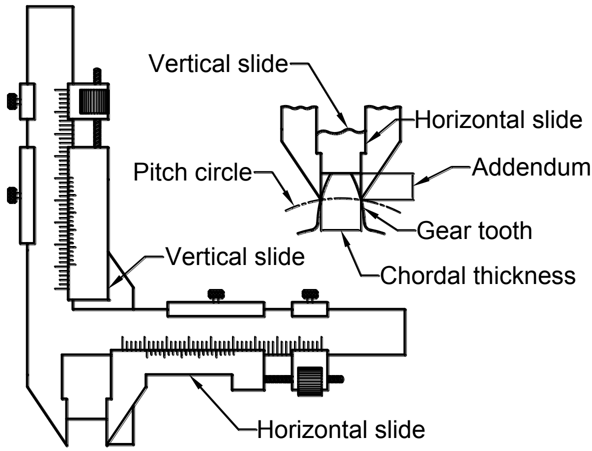


Fig.5.36 Gear tooth vernier

First, the addendum of gear tooth is found out by using the following formula.

$$\boldsymbol{Addendum = m\left[\frac{z}{2}\left(1 - cos\left(\frac{90}{z}\right) + 1\ \right)\right]}$$

Where, $\boldsymbol{m}$ = Module of the gear

$\boldsymbol{z}$ = Number of teeth

Addendum is the linear distance from the top surface of the tooth to the pitch circle.

First, the vertical slide is moved up to the calculated value of addendum and locked. The vertical slide is made to rest on the top of the gear tooth. The horizontal slide is adjusted to touch the side of gear tooth. Now the reading noted from the horizontal scale is the value of chordal thickness.

5.19.10 Micrometer

The micrometer is used to measure length, width, thickness and diameter of small and medium size components. The outside micrometer used for measuring external dimensions is shown in the figure.

It has a 'C' shaped frame made of steel. An anvil is fitted at the left end and a barrel is fitted at the right end of frame. The main scale is graduated on the barrel. The barrel has a bore with threads of 0.5 mm pitch. A screw of 0.5 mm pitch passes through this bore. The spindle is fitted in the left end and the thimble is fitted at the right end of the screw. Thimble is tubular cover. When thimble is rotated, spindle moves as the screw rotates. Vernier scale is graduated in the beveled edge at the left end of the thimble. Ratchet is fitted at the right end of thimble. The ratchet will slip when the pressure on the screw exceeds a certain limits.

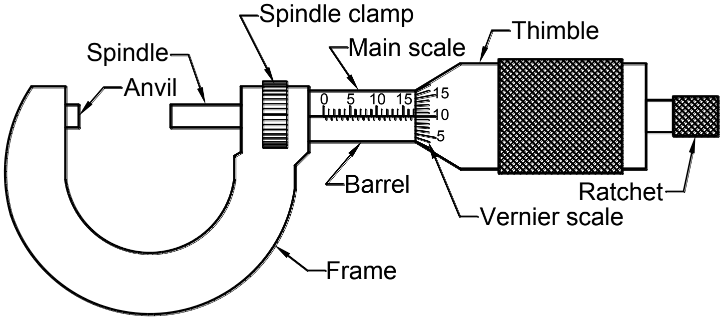


Fig.5.37 Micrometer

A clamp is provided at the right end of ‘C’ frame. The spindle can be locked at any position by using the clamp.

For measuring the dimension, the work piece is placed between the spindle and anvil. The ratchet is screwed until the spindle face touches the work piece. Then the spindle is clamped. Main scale and vernier scale readings are noted.

Reading

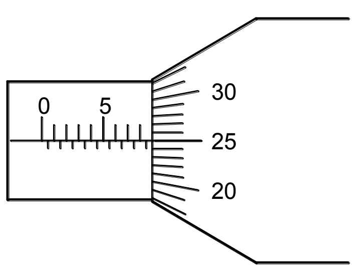


Fig.5.38 Reading of micrometer

The value of one main scale division is 0.5 mm. Spindle moves 0.5 mm for one complete rotation of thimble. Thimble is divided into 50 equal divisions. So value of one vernier scale division = 0.5 / 50 = 0.01 mm

Dimension of component = Main scale reading + (vernier scale division coinciding with the datum line x 0.01 mm)

For example, as shown in the figure,

Dimension of component = 8.50 + (25 x 0.01)
= 8.50 + 0.25
= **8.75** mm

5.19.11 Inside micrometer

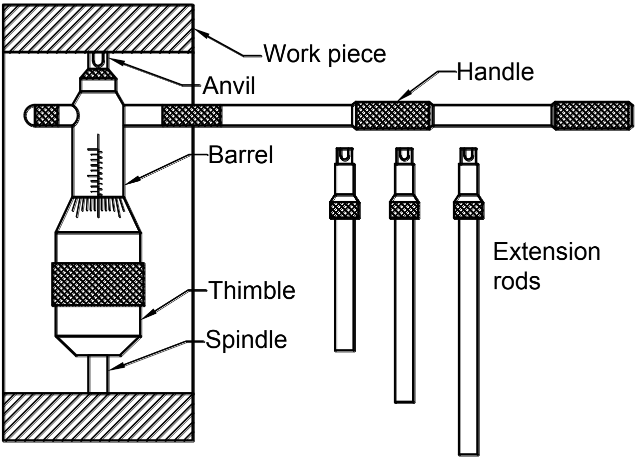


Fig.5.39 Inside micrometer

Inside micrometer is used to measure the inside diameter of a hole. It works on the same principle as the outside micrometer. The dimensions above 50 mm only can be measured by this instrument. It has an anvil at one end and a spindle at the another end. The spindle moves when the thimble is rotated. A long handle is provided to insert the micrometer into hole.

The spindle can be moved to the maximum of 13 mm. So this micrometer is directly used for measuring the dimensions from 50 mm to 63 mm. For measuring larger dimensions, the anvil is removed and suitable extension rod is fitted. The extension rods of 25, 50, 100, 150, 200 and 600 mm are available. The accuracy of this micrometer is 0.01 mm.

5.19.12 Depth micrometer

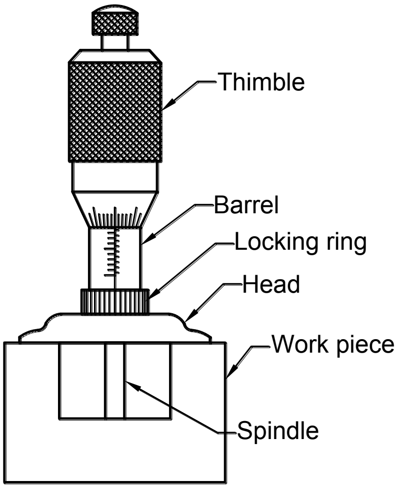


Fig.5.40 Depth micrometer

Depth micrometer is used to measure the depth of blind holes, slots and grooves. The method of measuring is similar to the outside micrometer. It has a head. The spindle moves through the head. This instrument can be used only in the places where suitable seating is available for the head.

The head is correctly placed on the top of the hole whose depth is to be measured. When thimble is rotated, spindle moves inside the hole. After the spindle touches the bottom of the hole, it is locked. Then the micrometer is taken out and the reading is noted. The main scale divisions are graduated in decreasing order from the bottom to top. Extension rods of various sizes can be used for measuring large depths.

5.19.13 Thread micrometer

Thread micrometer is used for measuring the pitch diameter of a thread accurately. The construction is similar to external micrometer. The spindle has a conical end and the anvil has a ‘V’ shaped end. The conical point and V shaped anvil have the same shape as the thread to be measured. Different sets of conical points and V shaped anvils are used for measuring different threads.

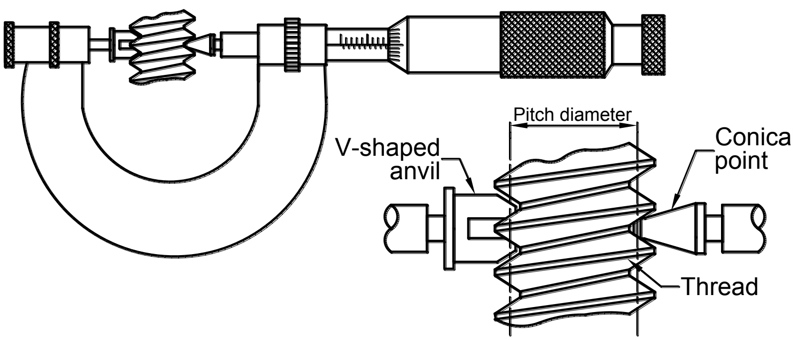


Fig.5.41 Thread micrometer

The thread to be measured is placed between the spindle and anvil. The spindle is moved to touch the flank of the thread. Now the reading taken from the micrometer is the pitch diameter of the thread.

Three wire method

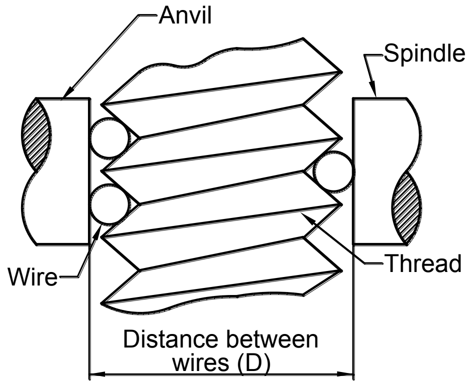


Fig.5.42 Three wire method

This method is used for measuring pitch circle diameter accurately. In this method, an ordinary micrometer and three wires of same diameter are used. These wires are made of hardened steel and finished by lapping. The correct size of wire is selected according to the size of thread to be measured.

As shown in the figure, two wires are placed in one side of thread and one wire is placed at the other side of thread. The micrometer anvil and spindle are adjusted to touch the wires on the both sides. Now the reading in micrometer (D) is noted.

Then the pitch diameter of thread is calculated by using the following formula.

$$\boldsymbol{Pitch\ diameter = D - d\left[1 + sin\ \left(\frac{\alpha}{2}\right)\right]}$$

Where, D = Distance between the wires

d = Diameter of wire

α = Included angle of thread

5.19.14 Slip gauges

Slip gauges are precision gauge blocks used for measuring linear dimensions. They are in the shape of cuboids. They are made of hardened alloy steel and the surfaces are finished by lapping. They have various thickness. The length of all slip gauges are same and the width of all slip gauges are same.

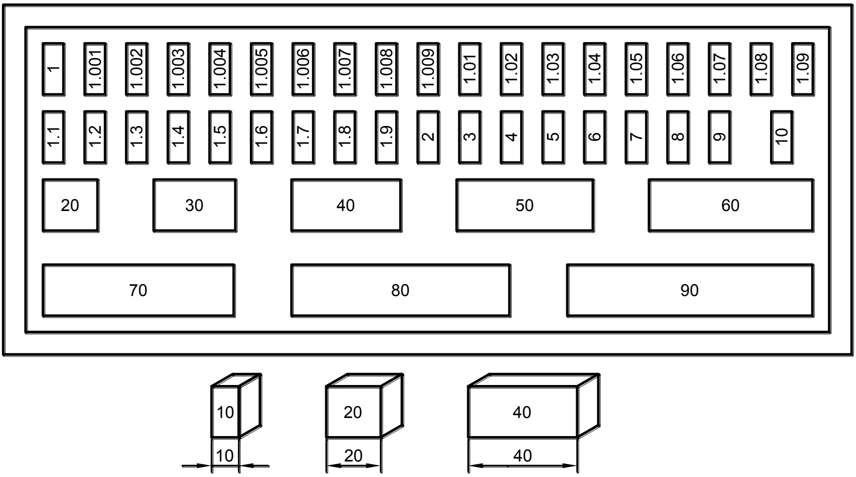


Fig.5.43 Slip gauges

One or more slip gauges are used to build up required dimension. Slip gauges are placed one over another and combined by wringing. The two gauges will stick together due to the adhesion between the two highly finished surfaces.

A normal set of slip gauges has 45 pieces. The thickness of gauge blocks will be from 1 mm to 90 mm. The size of each block is marked on it. Different sets of slip gauges having 27, 33, 87, 112 and 165 pieces are available.

Requirements of slip gagues

The following are the basic requirements of slip gauges:

1) The end faces of the gauges must be flat and parallel to each other.
2) All the adjacent faces must be perfectly square to each other.
3) They must possess high degree of surface finish.
4) The actual size must be within tolerances.
5) The edges must be deburrred.

Indian standard on slip gauges (IS:2984-1966)

Slip gauges are graded according to their accuracy as *Grade 0, Grade I & Grade II.*

- *Grade II* is intended for use in workshops during actual production of components, tools and gauges.
- *Grade I* is of higher accuracy for use in inspection departments.
- *Grade 0* is used in laboratories and standard rooms for periodic calibration of Grade I and Grade II gauges.

M-87 set of slip gauges:

Range	Steps	No. of pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9
1.0005	--	1
Total		**87**

M-112 set of slip gauges:

Range	Steps	No. of pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 24.5	0.5	49
25, 50, 75, 100	25	4
1.0005	--	1
Total		**112**

Care of slip gauges

The following care should be taken for slip gagues to maintain their accuracy for a long period.

1) The gauges should not be left in the wrung condition when not in use.
2) Before the use of slip gauges, they must be properly cleaned to remove dust and grease traces.
3) The slip gauges should be kept in their case when not in use.
4) Do not break the wring after use. Slide one gauge over the other to separate them.
5) Slip gagues should be used in an atmosphere free from dust.
6) The blocks are not to be used again immediately after separating them.
7) A thin layer of good quality grease should be applied on their faces before they are kept in their case.

Uses of slip gauges

The following are the uses of slip gagues :

1) Slip gagues are used in metrology laboratory, tool room and machine shop for the calibration of precison measuring instruments.
2) Slip gagues are used in setting sine bars for establishing angles.
3) They are used to set other measuring instruments such as snap gauges.
4) They are used to check comparators and optical inspection devices.
5) They are used as auxiliary measuring system on milling machine.

5.19.15 Bevel protractor

Bevel protractor is used for measuring angle between two adjacent surfaces with an accuracy of 5 minutes. This instrument has a rectangular stock beam integral with a circular disc. This circular disc is pivoted at the centre of another circular dial. Main scale is graduated on the circular dial.

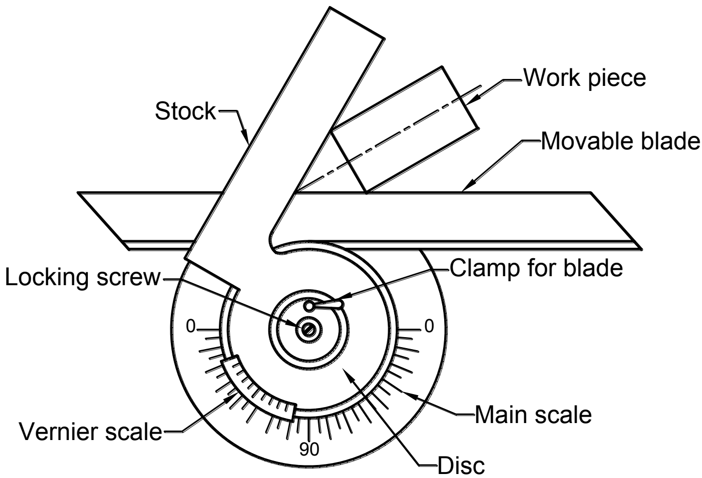


Fig.5.44 Bevel protractor

A vernier scale is fitted to the disc. A movable blade is fitted in the groove of circular dial. This blade is suitably adjusted and clamped. A locking screw is provided to lock the circular disc with the dial. The stock can be tilted to any angle with respect to the movable blade.

Reading

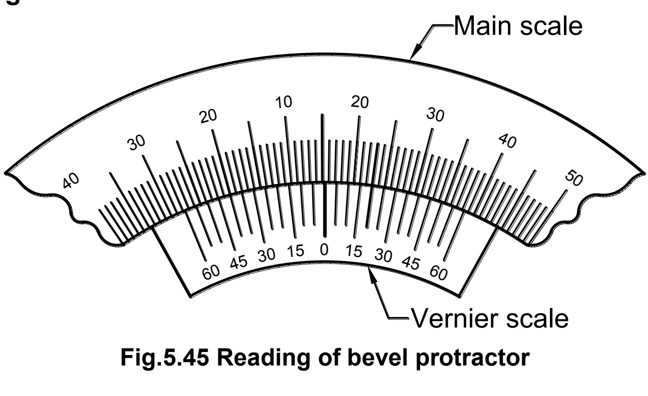


Fig.5.45 Reading of bevel protractor

The value of one main scale division is equal to 1°. Vernier scale is divided into 12 equal parts. The value of 12 vernier scale division is equal to 23°.

So, the value of one vernier scale division $= \dfrac{23°}{12}$

Least count = 2 Main scale division – 1 vernier scale division

$$= 2° - \left(\frac{23°}{12}\right)$$

$$= \frac{1°}{12} = \frac{60 \text{ minutes}}{12} = \mathbf{5\ minutes}$$

As shown in the figure,

Main scale reading	= 15°
Vernier scale coincidence	= 4 divisions
Vernier scale reading	= 4 x 5 = 20 minutes
Actual reading	= Main scale reading + Vernier scale reading
	= 15 + 20 Minutes = **15° 20'**

5.19.16 Sine bar

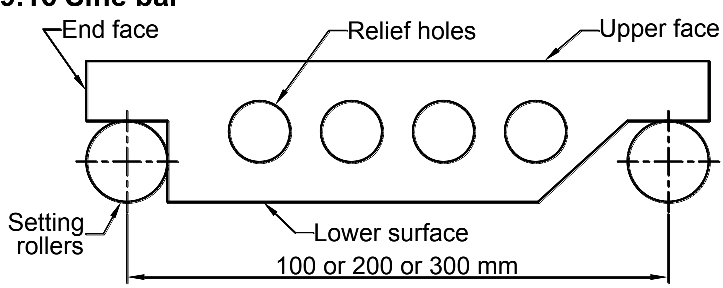


Fig.5.46 Sine bar

Sine bar is used for measuring angles accurately. It is a rectangular beam made of steel. All the surface of sine bar are finished by lapping. Two rollers of equal diameter are fitted at both the ends of sine bar. The size of the sine bar is specified by the distance between the centres of these two rollers. The size varies from 100 mm to 300 mm. The line drawn between the centres of two rollers will be parallel with the top and bottom surface of the sine bar.

Types of sine bar

The following are the types of sine bar :

1) Sine centre 2) Sine table 3) Compound sine table

1) Sine centre

Sine centers are used for mounting conical work pieces which cannot be held on a simple sine bar. Sine center consists of a selfcontained sine bar hinged at one roller and mounted on its own datum surface. The top surface of the bar is provided with clamps and centers to hold the conical work pieces. It cannot measures the angle more than 45 degrees

2) Sine table or sine plate

A sine table or sine plate is a large and wide sine bar. It is equipped with a mechanism for locking it in place after positioning. It is used to hold workpieces during measurement.

3) Compound sine table

It is used to measure compound angles of large workpieces. In this case, two sine tables are mounted one over the other at right angles. The tables can be twisted to get the required alignment.

Uses of sine bar

1) Measuring unknown angle

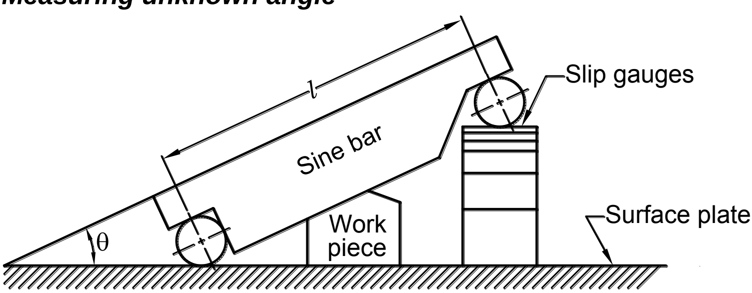


Fig.5.47 Uses of sine bar

The figure shows an arrangement for measuring the angle of the tapered surface of a work piece by using sine bar and slip gauges.

The work piece is placed on a surface plate. The bottom surface of the sine bar is placed over the tapered surface of the work piece. One roller of the sine bar rests on the surface plate. Slip gauges are built up between the another roller and the surface plate. The slip gauges are built up so that there is no gap between the sine bar and work piece surface. The total height of slip gauge is added.

From the figure,

Length of sine bar = l

Height of slip gauge block = h

$$\boldsymbol{Sin\ \theta = \frac{h}{l}}$$

By using the above formula, the taper angle $\boldsymbol{\theta}$ can be calculated.

2) Setting up known angle

From the sine principle $sin\ \theta = \frac{h}{l}$, the height h can be calculated by knowing the values of θ and l. One of the rollers of the sine bar is placed on the surface plate. The other roller is placed on the slip gauges of height h. Now the sine bar is inclined at an dangle of θ. Thus a workpiece can be set to any required angle.

3) Checking of unknown angles of heavy component

When components are heavy and difficult to place on the sine bar, then the sine bar is placed on the component. The height of both rollers from the horizontal reference surface are measured by a vernier height gauge. A dial test gauge is used along with the vernier height gauge for accurate measurement.

Let, h_1= Height of the lower roller, and

h_2= Height of the upper roller

Then the angle of inclination of the workpiece can be calculated with the forumula,

$$\boldsymbol{Sin\ \theta = \frac{h_2 - h_1}{l}}$$

Limitations of sine bar (Disadvantages of sine bar)

The following are the limitations of sine bar

1) The accuracy of sine bars is limited by measurement of center distance between the two precision rollers.
2) It cannot be used as a primary standard for angle measurements.
3) Sine principle is fairly reliable at angles less than 15°, but becomes inaccurate as the angle increases.
4) Sine bar becomes impractical and inaccurate as the angle exceeds 45°.

5.19.17 Clinometer

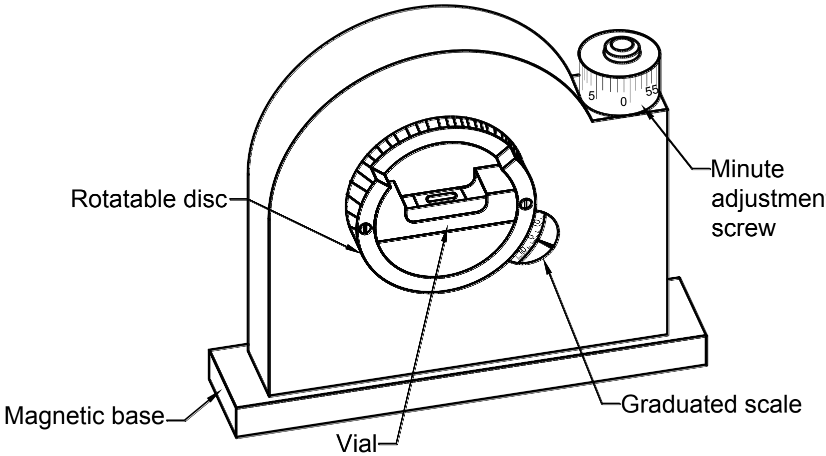


Fig. 5.48 Clinometer

A clinometer is a special case of application of spirit level for measuring the inclinations in the vertical plane in relation to the horizontal plane. The main functional element of a clinometer is the sensitive vial mounted on a rotatable disc. Vial is a closed glass tube of accurate size in a spirit level, which is used for storing the liquid. It is graduated in linear scale and the bubble moves inside it. Vial carries a graduated ring with its horizontal axis supported in the housing of the instrument.

The bubble of the vial is in its centre position, when the clinometer is placed on a horizontal surface and the scale of the rotatable disc is at zero position. If the clinometer is placed on an inclined surface, the bubble deviates from the centre. It can be brought to the centre by rotating the disc. The rotation of the disc can be read on the scale. It represents the deviation of the surface over which the clinometer is placed from the horizontal plane.

A number of commercially available clinometers with various designs are available. They differ in their sensitivity and measuring accuracy. Sensitivity and measuring accuracy of modern clinometers can be compared with any other high precision measuring instruments. Clinometers with 1 minutes graduations are available.

Applications

The following two categories of measurement are possible with clinometer :

a) *Measurement of an inclined plane with respect to a horizontal plane :* This is done by placing the instrument on the surface to be measured and rotating graduated disc to produce zero inclination on the bubble. The scale value of the disc position will be equal to the angle of incline.

b) *Measurement of the relative position of two mutually inclined surfaces :* This is done by placing the clinometer on each of the surface in turn, and taking the readings with respect to the horizontal. The difference of both the readings will indicate the angular value of the relative incline.

5.19.18 Autocollimator

Principle of auto-collimation

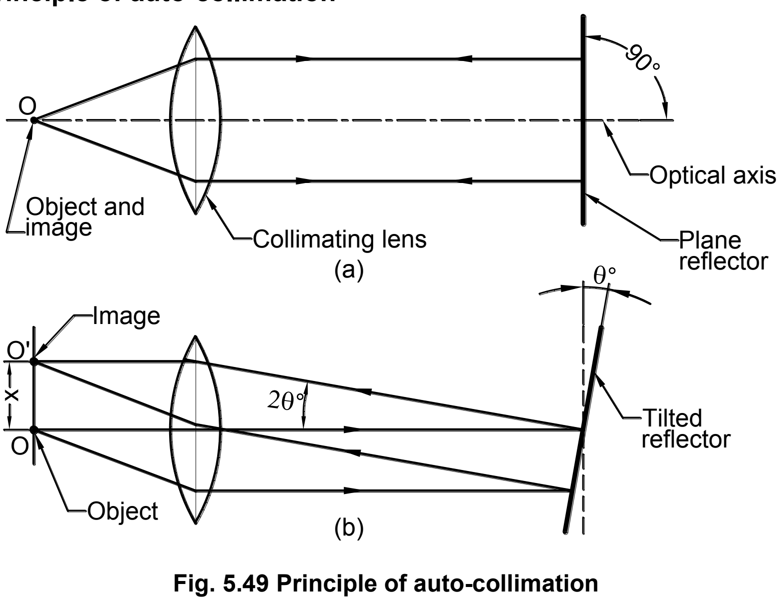


Fig. 5.49 Principle of auto-collimation

Let us imagine a converging lens with a point source of light O at its principle focus. When a beam of light strikes a flat reflecting surface, a part of the beam is absorbed and the other part is reflected back. If the angle of incidence is zero, i.e. incident rays fall perpendicular to the reflecting surface, the rays are reflected back along the same path and refocused at the point of origin. When the reflecting plane is tilted through a small angle $\theta°$, the reflected rays will be inclined at $2\theta°$ to the optical axis. These rays will be focused at a point in the focal plane with a distance x from the origin.

Now, from the diagram, $OO' = x = 2\theta f,$ where f is the focal length of the lens. Thus, by measuring the linear distance x, the inclination of the reflecting surface θ can be determined.

Working of autocollimator

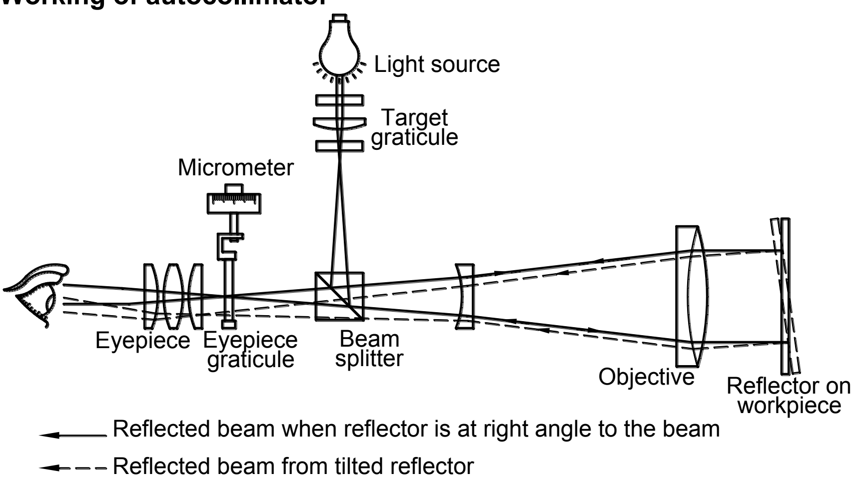


Fig. 5.50 Ray diagram of autocollimator

The surface of the work piece whose inclination is to be measured acts as the reflecting surface. The displacement x is measured by a precision microscope which is calibrated directly to read the values of inclination . The target wires are illuminated by the electric bulb and act as a source of light.

The image of the illuminated wires are projected onto the reflective surface of the work piece through a collimating lens system. The reflected image of the wires are returned back through the same lens system. The target wires and their reflected images are viewed simultaneously through a magnifying eyepiece.

Reading on eyepiece

The eyepiece contains an adjustable graticule engraved with setting lines and a scale. The scale is divided into minutes and half minutes. The setting lines are adjusted by the micrometer control until they coincide with the reflected image of the target wires. The scale is then read to the nearest minute plus the micrometer reading.

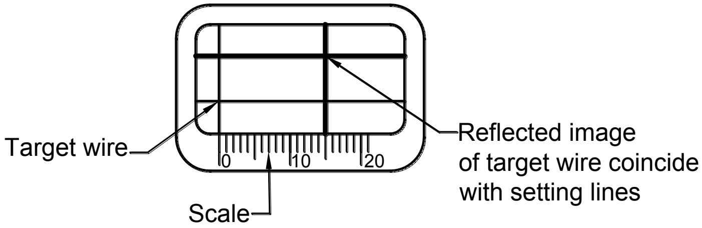


Fig. 5.51 Reading on eyepiece

Generally the divisions of the micrometer scale represent a 0.5 seconds. Autocollimators can accurately read up to 0.1 seconds and may be used for distance up to 30 meters.

5.19.19 Angle dekkor

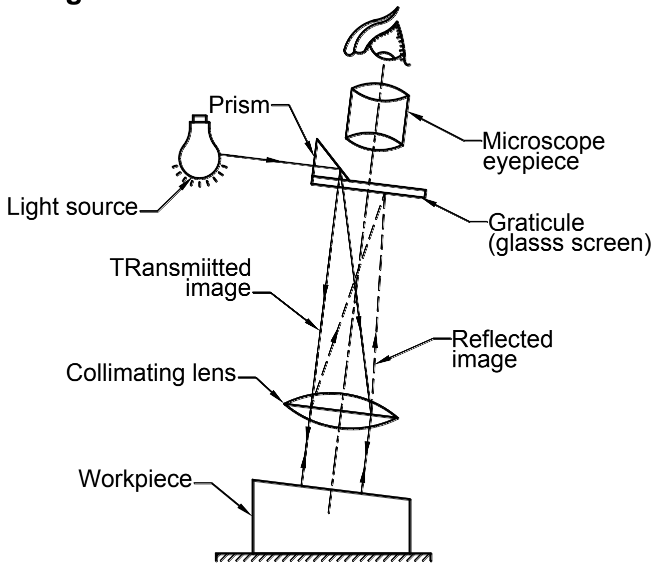


Fig. 5.52 Ray diagram of angle dekkor

Angle dekkor works on the principle of auto collimation. This instrument measures angle by comparing the reading from a standard, such as combination of angle gauges, and the reading from the work piece under test. Thus it acts as a comparator.

This optical system consists of a ground glass screen on which a fixed datum scale and a illuminated scale are engraved right angles to each other. The illuminated scale is engraved outside the view of the eyepiece. The magnifying eyepiece views both the fixed datum scale and the reflected image of illuminated scale at right angles to each other. The image does not fall across a simple datum line, but across a similar fixed scale at a right angle to the image. Thus the reading on the reflected scale measures angular deviation in one plane at $90°$ to the optical axis.

The reading on the fixed scale gives the deviation in a plane which is perpendicular to the former plane. This feature enables to measure angular errors in two planes at the same time. The whole optical system is enclosed in a tube which is mounted on an adjustable bracket.

Procedure to measure inclination angle

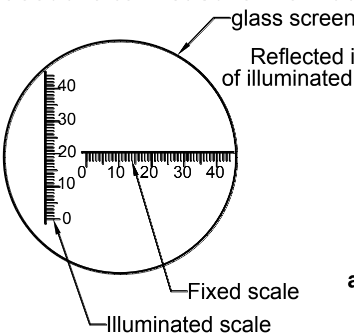


Fig. 5.53 Arrangement of scales in glass screen

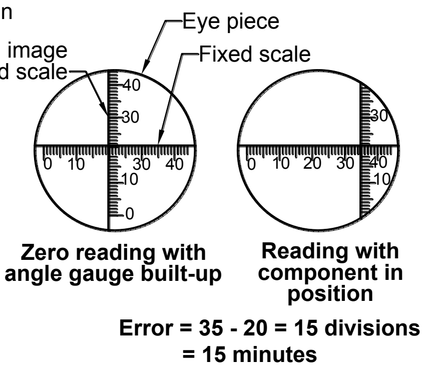


Fig. 5.54 Reading in the eyepiece

The angle of inclination of the work piece is measured roughly by an angle protractor. Then the angle is built up with the combination of angle gauges. This angle gauge set is placed below the telescoping tube of the angle dekkor. The zero reading is adjusted in the eyepiece with the help of special attachment. Then the angle gauge set is replaced by the work piece under test. The reflected image of the datum scale and illuminated scale shows the angular deviation of the work piece from the built up angle. The correct inclination angle of the work piece can be obtained by adding or subtracting the angular deviation with the built up angle.

Angle dekkor requires considerable skill to set and read accurately. It is a very useful instrument for wide range of angular measurement at short distances. Reading can be obtained to an accuracy of 0.2 minutes.

Review Questions

5 marks questions

1) Distinguish between a flat drill and twist drill
2) What is the purpose of a 'tang' in a twist drill?
3) Name the different types of drilling machines.
4) Distinguish between gang drilling and multispindle drilling machine.
5) Give the specifications of a drilling machine.
6) What are the methods of holding a drill bit in a drilling machine?
7) Differentiate between sleeve and socket.
8) Explain drill chuck with a sketch.
9) Name the different types of operations which are performed on a drilling machine.
10) Explain the counter sinking operation with a sketch.
11) With a neat sketch explain : (i) Spot facing (ii) counter boring.
12) How deep holes are drilled ?
13) Write short notes on regrinding of drill.
14) What is the need of inspection?
15) Define accuracy and precision.
16) Define the terms : Sensitivity, magnification, repeatability, calibration.
17) What is comparator? List out the various types of comparators.
18) What are the requirements for a good comparator?
19) Explain a simple mechanical comparator with sketch.
20) What are the advantages and disadvantages of mechanical comparator?

21) Explain the optical comparator with a sketch.
22) Briefly explain the types of calipers.
23) What are the uses of feeler gauge and pitch screw gauge?
24) Explain the principle of working of a vernier caliper.
25) Sketch and explain the working of vernier height gauge.
26) Explain the construction and working of depth micrometer.
27) Explain the use of an inside micrometer with example.
28) Briefly explain screw thread micrometer.
29) List out the care and uses of slip gauges.
30) Draw a line diagram of a bevel protractor and describe how angles are measured by using it.
31) What are the uses of sine bar? Give an example.
32) Explain the principle of auto-collimation.
33) Eplain the working principle of clinometer.

10 Marks questions

1) Draw a neat sketch of a twist drill bit and explain the various parts of the same.
2) Explain the principle of operation of a radial drilling machine.
3) Explain the multi spindle drilling machine with neat sketch.
4) Explain the auto feed mechanism of a drilling machine with neat sketch.
5) Explain the different operations which are performed on a drilling machine with neat sketches.
6) Explain the electrical comparator with neat sketch. List out the advantages and disadvantages.
7) Describe the working principle of pneumatic comparator with a neat sketch. What are the advantages and disadvantages?
8) Explain the construction and working of a gear tooth vernier.
9) Explain the three wire method of measuring the pitch diameter of a screw thread.
10) Explain the working principle of auto-collimator.
11) Explain the method of measuring angle using angle dekkor?

TWO & THREE MARKS Questions & Answers

Unit – I : FOUNDRY TECHNOLOGY

1. What is pattern?

Pattern is the model of casting. It is made of wood, metal or plastics. Mould is produced in moulding sand by using pattern.

2. What are the types of pattern?

1) Solid piece pattern
2) Split piece pattern
3) Loose piece pattern
4) Match plate pattern
5) Sweep pattern
6) Skeleton pattern
7) Segmental pattern
8) Shell pattern

3. What is the use of dowel pin?

Split pattern is usually made of two parts. One part will make the lower half of the mould and the other part will make the upper half of the mould. These two parts are fitted correctly by dowel pins.

4. What is the need of loose piece pattern?

Some patterns cannot be removed from the mould as single piece. So loose piece patterns are used with the solid pattern for the easy removal.

5. List out the various pattern materials.

1) Wood 2) Metal 3) Plaster 4) Plastic 5) Wax

6. What are the advantages of using wood as pattern material?

1) Wood is cheap and easily available.
2) It is easy to cut for making required shape.
3) It can be easily handled as it is light weight.

7. What are the advantages of using aluminium as pattern material?

1) Metal pattern is strong. The life and dimensional accuracy of the metal pattern is more.
2) Change in shape does not occur due to moisture.
3) It can be used in machine moulding.

4) It is suitable for mass production.
5) Metal surface can be finished smoothly and hence very good impression of the pattern can be obtained in the mould.

8. List out the factors for selecting pattern material.

1) Number of castings to be produced.
2) Quality of the casting.
3) Size and shape of the casting.
4) The method of moulding and casting.
5) Required surface finishing of casting.
6) Required accuracy of casting.

9. What are the pattern making allowances?

1) Shrinkage allowance
2) Machining allowance
3) Draft allowance
4) Distortion allowance
5) Rapping allowance

10. What is shrinkage allowance?

The molten metal in the mould will cool and become solid. The metal will shrink and reduce in size during cooling. The pattern is made larger than the required size of the casting to compensate this metal shrinkage. This is called shrinkage allowance.

11. What is draft allowance?

The edges of the mould may be damaged when the pattern is removed from the mould. This can be avoided by making the vertical surfaces of the pattern with slight taper. This taper is called draft allowance.

12. List out the various binders used in moulding sand? Give an example.

a) Clay type binders : Bentonite and kalvanite
b) Organic binders : Wood, resin, linseed oil and dextrin.
c) Inorganic binders : Portland cement and sodium silicate

13. List out the special sand used in moulding.

a) Olivine sand b) Zircon sand c) Chromite sand

14. What are the types of moulding sand?

1) Green sand 2) Dry sand 3) Loam sand
4) Facing sand 5) Parting sand 6) Core sand

15. List out the properties of moulding sand.

1) Porosity 2) Plasticity 3) Adhesiveness
4) Cohesiveness 5) Refractoriness 6) Collapsibility

16. List out the steps involved in preparation of moulding sand.

1)Mixing of sand 2)Tempering of sand 3)Conditioning of sand

17. List out the various moulding tools?

1) Shovel 2) Riddle 3) Rammer 4) Trowel
5) Slick 6) Lifter 7) Sprue pin 8) Strike off bar
9) Bellows 10) Swab 11) Gate cutter 12) Draw spike
13) Vent rod 14) Mallet

18. List out the uses of rammer, trowel and slick.

1) Rammer is used for packing or ramming the moulding sand in the moulding box.
2) Trowel is used to smoothen the mould surface and to repair the damaged portions of the mould.
3) Slick is used for finishing mould surfaces and for repairing the round corners of the mould.

19. Give the uses of lifter, sprue pin and strike off bar.

1) Lifter is used to remove the loose sand from the mould and to repair the broken surfaces of the mould.
2) Sprue pin is used for making holes for runner and riser in the mould.
3) Strike of bar is used for removing excess sand from the mould after ramming.

20. What are the uses of swab, gate cutter and draw spike?

1) It is used for applying small amount of water around the pattern before removing it from the mould.
2) It is used for cutting gate in the mould.
3) It is used for removing the pattern from the mould.

21. What are cope and drag?

If the moulding is done with two boxes, the upper box is called cope and the lower box is called drag. The two boxes are aligned correctly with the help of dowel pin

22. What are the elements in gating system?

1) Pouring cup 2) Sprue 3) Runner 5)Gate 6) Riser.

23. What is the function of riser?

After the mould is filled up, the molten metal rises into the riser. It supplies molten metal to the mould during shrinkage of casting and thus correct size casting can be obtained.

24. List out the types of mould.

1)Green sand mould 2)Dry sand mould 3)Skin - dry sand mould 4)Loam mould 5) Metal mould

25. What are the methods of moulding?

1) Green sand moulding 2) Dry sand moulding 3) Loam moulding 4) Bench moulding 5) Floor moulding. 6) Pit moulding 7) Sweep moulding 8) Plate moulding 9) Machine moulding

26. What are the advantages of dry sand moulding?

1) It is stronger than green sand mould.
2) It is not damaged while handling.
3) More dimensional accuracy.
4) Smooth surface finish can be obtained.
5) Casting defects like blow holes will not occur.

27. State the applications of loam moulding and pit moulding.

✦ Loam mould is used for producing large castings like cylinders, bells, gears and machine parts.

✦ Pit moulding is used for producing castings which cannot be produced in moulding box.

28. List out the types of moulding machines.

1) Squeezer machine
   a. *Top squeezer machine*
   b. *Bottom squeezer machine*
2) Jolt machine
3) Sand slinger

29. What is the use of core and core print?

- ✦ Core is used to make hollow or a hole in a casting.
- ✦ A projection made in the pattern is called core print. It is used to form a core seat in the mould. The core is correctly seated in this seat.

30. What are the essential qualities of core sand?

1) High refractoriness 2) Good permeability
3) Good stability 4) Good collapsibility
5) Sufficient strength and hardness

31. List out the core binders. Give an example.

1) Oil binders : Linseed oil
2) Water soluble binders : Starch and dextrin
3) Resin binders : Phenol formaldehyde and urea

32. List out the types of core boxes.

1) Half core box 4. Stickle core box
2. Dump core box 5. Gang core box
3. Split core box

33. List out the steps involved in core making.

1) Core sand preparation 2) Core moulding
3) Baking 4) Core finishing

34. What are the types of cores?

1) Green sand core 2) Horizontal core
3) Vertical core 4) Balanced core
5) Hanging core 6) Drop core

35. List out the ovens used for heating the core.

1) Batch type ovens
2) Continuous type ovens
3) Dielectric type ovens

36. What is iron-carbon equilibrium diagram?

Iron – carbon equilibrium diagram is the graphical representation of the phase changes undergone by iron with respect to the carbon content and temperature on cooling or heating. This diagram is drawn by taking the carbon content in X-axis and temperature in Y-axis.

37. What is hypo eutectoid steel and hyper eutectoid steel?

Steel containing carbon less than 0.8% is called *hypo eutectoid steel.* Steel containing carbon exactly 0.8% is called *eutectoid steel*. Steel containing carbon from 0.8% to 2% is called *hyper eutectoid steel.*

38. What is the use of blast furnace?

Blast furnace is used to chemically reduce and convert iron oxides in iron ore into molten pig iron by smelting process.

39. What is the purpose of adding flux during melting of metal?

At high temperature, the flux reacts with acidic impurities (silica, alumina, magnesia, calcia, etc) and forms slag. The slag floats to the surface of the molten metal and removed at regular intervals.

40. What are uses of tap hole and tuyers in cupola furnace?

- ✦ Tap hole is provided for taking out the molten metal.
- ✦ Air for combustion of fuel is sent through the openings called tuyers.

41. List out the furnaces used for melting non-ferrous metals.

1) Pit furnace
2) Coke fired stationary furnace
3) Oil fired tilting furnace

42. Mention the furnaces used for melting steel.

1) Direct arc furnace 2) Indirect arc furnace 3) Induction furnace

43. List out the various casting processes.

1) Sand casting
2) Gravity die casting
3) Pressure die casting
   i) Hot chamber die casting
   ii) Cold chamber die casting
4) Centrifugal casting
5) Continuous casting
6) Chilled casting
7) Malleable casting
8) Shell mould casting
9) Investment casting

44. What are the applications of pressure die casting?

Carburetor body, crank case, fuel pump parts, sound horn and wiper can be produced by pressure die casting. It can also be used for producing toys, cameras, clocks and washing machine parts.

45. What is the difference between hot chamber die casting and cold chamber die casting?

- ✦ In hot chamber die casting, heating chamber is provided for melting the metal. This chamber is heated by a burner.
- ✦ In cold chamber die casting, heating chamber is not provided. The metal is melted separately in the furnace and brought to the machine by ladles.

46. Mention the applications of centrifugal casting.

The castings like water pipes, gun barrels, fly wheel, bush bearings, gears, brake drum etc. are produced by centrifugal casting.

47. What is continuous casting? Give its applications.

- ✦ In this process, castings are produced by pouring the molten metal continuously in to a vertical mould.
- ✦ Large bars or rods having round, square and hexagonal cross section can be produced.

48. What are the applications of chilled casting and malleable casting?

- ✦ Chilled casting is used for producing railway brake shoes, wheel rims, crusher jaws, machine slide ways, etc.
- ✦ Malleable casting is used for producing wagon wheel hub, door hinges, pipe fittings, locks, levers, cranks, and textile machine parts.

49. What is shell mould casting? Give its applications.

- ✦ Shell mould casting is the modification of sand casting in which a relatively thin shell forms the mould cavity.
- ✦ it is used to produce cylinder head, connecting rods, gear housings, brake drums, cams, pistons, piston rings, etc.

50. What is investment in casting process? Give example.

- ✦ The term investment refers to the layer of refractory material covering the pattern while making the mould.
- ✦ *Example :* Phenolic-resin mixed with dry silica sand in the presence of alcohol.

51. List out the applications of investment casting.

- ✦ Costume Jewellery.
- ✦ Parts for computers and electronics equipment.
- ✦ Parts for aerospace industry and machine tools.
- ✦ Nozzles, buckets, vanes and blades for gas turbines.

52. List out the various defects in casting?

1) Blow holes 2) Slabs 3) Honey combing 4)Swells
5) Shifts 6) Cold shuts 7) Hot tears 8)Fins
9) Internal air pockets 10) Runout

45. What are the causes for blow holes?

1) Excessive moisture in the sand.
2) Hard ramming.
3) Less number of vent holes

46. What is swells and shift?

- ✦ Swells : Enlargement of casting surface.
- ✦ Shifts : Misalignment of casting sections.

47. What is cold shuts and hot tears?

- ✦ Cold shuts : Incomplete filling of mould cavity.
- ✦ Hot tears : Internal or external dis-continuity in the casting.

48. What is fins and run out?

- ✦ Fins : Thin projection on parting line.
- ✦ Run out : Leakage of metal from the mould.

Unit – II : WELDING TECHNOLOGY

1. Define welding. List out its uses.

- ✦ Welding is the process of joining similar or different metal by heating.
- ✦ Welding is used in the fabrication of automobile bodies, air craft, machine frames, boilers, ship building, railway wagons, etc.

2. What are the types of welding? Give example.

1) Plastic welding or pressure welding

   Example : Electric resistance welding.

2) Fusion welding or non – pressure welding.

   Example : Electric arc welding, gas welding.

3. List out the equipment needed for arc welding.

1) Welding generator(D.C) or transformer(A.C)
2) Electrode holder
3) Electrode
4) Welding cables
5) Earthing clamps
6) Protective shield
7) Gloves
8) Apron
9) Chipping hammer
10) Wire brush

4. What are the uses of electrode holder and earth clamp.

- ✦ The electrode holder connects to the welding cable and conducts the welding current to the electrode.
- ✦ The Earthing clamp is used to connect the earth cable to the work piece.

5. Name the two basic types of electrode?

1) Consumable electrode 2) Non-consumable electrode

6. What are the types of consumable electrodes?

1) *Bare electrodes:* They are not coated with flux.

2) *Lightly coated electrodes:* A light layer of flux is coated on the electrodes.

3) *Heavily coated electrodes:* Flux is coated on the electrodes to a thickness of 1 mm to 3 mm.

7. **State the functions of flux coating on a metal electrode.**

1) It provides a protective gaseous atmosphere to prevent the molten metal to react with oxygen and nitrogen in the air.
2) It provides a protective slag over hot metal to prevent from rapid cooling.
3) It removes oxides and other impurities from the molten metal.
4) It reduces spatter of weld metal.

8. **Give examples of flux materials.**

Asbestos, mica, silica, fluorspar, titanium dioxide, magnesium carbonate, calcium carbonate, feldspar, cellulose, dolo-mite, starch, dextrin, etc.

9. **List out the various methods of arc welding.**

1) Metal arc welding
2) Metal Inert Gas (MIG) welding
3) Tungsten Inert Gas (TIG) Welding
4) Submerged arc welding
5) Electro slag welding

10. **Give the expansion of MIG and TIG**

✦ MIG - Metal Inert Gas welding
✦ TIG - Tungsten Inert Gas welding

11. **State the difference between MIG and TIG welding.**

MIG welding	TIG welding
Consumable electrode is used	Non-consumable electrode is used.
Electrode is used as filler metal.	Filler metal is supplied separately.
Efficiency is more.	Efficiency is less.

12. **Write the applications of submerged arc welding.**

✦ Submerged arc welding is used for welding low carbon steel and alloy steel.

13. **What is electro slag welding? Give its applications.**

✦ Electro slag welding is a process of joining two thick metal plates by the heat generated when electric current is passed through molten slag.

- Boiler plate, turbine shaft, stainless steel and carbon steel can be welded by this method.

14. What is resistance welding? List out the types of resistance welding.

- In resistance welding, the metal is heated to plastic stage due to the heat generated by the electric resistance.
- The types of resistance welding are :
  1) Butt welding
  2) Spot welding
  3) Seam welding
  4) Projection welding

15. What is spot welding? Give its applications.

- Spot welding is a type of resistance welding which is used for joining overlapping sheet metals by making weld at regular interval.
- Boxes, cans, automobile frames and air conditioners can be welded by spot welding.

16. Give the difference between upset butt welding and flash butt welding.

- In upset butt welding, the metals to be welded are clamped in copper jaws so that there is a light contact at the ends of metals.
- In flash but welding, the metals to be welded are clamped in jaws so that there is a small air gap between the ends of metals.

17. What is seam welding? List out its applications.

- Seam welding is a process of making weld continuously between two overlapping sheet metals.
- Seam welding is used for welding radiators, drums, leak proof tanks, automobile silencers, etc.

18. What is plasma? List out the advantages of plasma arc welding.

- Ionised gas jet is called plasma. It produces high heat and is used for joining metal together.
- Advantages of plasma arc welding :
  1) All metals can be welded by this method.
  2) No filler rod is needed.
  3) Welding speed is high.
  4) High quality welding joint can be obtained.

19. **What is thermit? Give the applications of thermit welding.**

- ✦ Thermit steel is a mixture of aluminium powder and iron oxide in the ratio of 1:3.
- ✦ Thermit welding is used for joining heavy parts, rails, pipes, shafts, cables and worn out machine frames.

20. **What is the principle involved in electron beam welding? Give its applications.**

In this method, welding is done by the heat produced when the high velocity electron beams are focused on the object.

Application:

1) It is used for welding automobile and aero plane parts.
2) It is used for welding high temperature metals like tungsten, molybdenum and tantalum.
3) Pressure vessel and turbine parts can be welded.

21. **What is LASER? List out the advantages of laser beam welding.**

LASER means Light Amplification by Stimulated Emission of Radiation. It is a beam of light having a single wave length.

Advantages :

1) The temperature can be controlled easily.
2) Welding can be accurately done.
3) No distortion occurs.
4) Heat treated components can be welded without affecting its properties.
5) The weld is not affected by oxidation.

22. **List out the applications and advantages of friction welding.**

Applications:

Friction welding is used for welding aero engine parts and gas turbine shafts. It is also used for welding pinions to shafts, rods to yokes, flanges to pipes, etc.

Advantages :

1) The initial cost is low.
2) Dissimilar metals can be welded.
3) It is a simple and fast process.
4) High quality weld can be obtained.
5) The power consumption is less.

23. List out the applications of ultrasonic welding.

1) It is used for welding metals up to 3 mm thick.
2) Thin sheets can be joined with thick sheets.
3) Electrical and electronic components can be welded.
4) Plastic components can also be joined.
5) It is used for welding in nuclear reactor and aircraft parts.

24. What is the principle involved in induction welding? Give its applications.

✦ Induction welding is a welding process in which an electro magnetic induction is used to heat the parts to be welded.

✦ It is used for butt and seam welding of pipe, sealing containers and fabrication of various structural members.

25. What is gas welding? Name the gases used in gas welding.

✦ Gas welding is a process of joining metals by the heat of the flame formed when oxygen burns with another gas

✦ The following gases are used to produce flame in gas welding.

1) Oxygen – acetylene
2) Oxygen - hydrogen
3) Air- acetylene

26. List out the equipment need for gas welding.

1) Gas cylinders 2) Pressure regulators 3) Pressure gauges 4) Hoses 5) Welding torch

27. How do you differentiate oxygen and acetylene cylinders in gas welding?

The cylinder painted with black colour has oxygen. The cylinder painted with maroon colour has acetylene.

28. What is the function of a pressure regulator fixed on a gas cylinder?

The pressure regulator is used to control the working pressure of oxygen and acetylene.

29. What are the three types of flames in gas welding?

1) Neutral flame 2) Carburising flame 3) Oxidising flame

30. What is neutral flame? Give its application.

- ✦ The neutral flame is produced when equal quantity of oxygen and acetylene gases are used.
- ✦ Neutral flame is used for welding steel, cast iron, aluminium, copper and stainless steel.

31. When carburising flame is produced? State its applications.

- ✦ Carburising flame is produced when the quantity of acetylene is more than oxygen.
- ✦ Carburising flame is used for welding steel, alloy steels, non-ferrous metals, nickel and monel metal.

32. How oxidising flame is produced? List out its applications.

- ✦ Oxidising flame is produced when the quantity of oxygen is more than acetylene.
- ✦ Oxidising flame is used for welding brass, bronze, manganese and steel.

33. What are the two welding techniques?

1) Leftward or forward or forehand welding technique
2) Rightward or backward or backhand welding technique

34. Give the basic difference between two welding techniques.

- ✦ In leftward welding technique, the torch flame progresses from right to left.
- ✦ In rightward welding technique, the torch flame progresses from left to right.

35. What is filler rod? Give examples for flux used in gas welding.

- ✦ The welding rod or wire is used as filler rod. The filler rod should have a chemical composition similar to that of base metals.
- ✦ Gas welding fluxes are composed of boric acid, soda ash and small amount of other compounds such as sodium chloride, ammonium sulphate and iron oxide.

36. Give the applications of flame cutting.

Steel and iron plates having thickness up to 100 mm can be cut by this method.

37. Differentiate between soldering and brazing.

✦ Soldering is the process of joining two similar or dissimilar metals by using a low melting alloy called solder.

✦ Brazing is the process of joining two similar or dissimilar metals by using a high melting alloy called spelter.

38. What is solder and spelter?

✦ Solder is an alloy of tin and lead.

✦ Spelter is a mixture of copper and zinc alloy.

39. List out the types of brazing.

1) Torch brazing 2) Dip brazing
3) Furnace brazing 4) Induction brazing

40. What are the types of welded joints?

1) Butt joint 2) Lap joint 3) 'T' joint
4) Corner joint 5) Flange joint

41. List out the non-destructive and destructive methods for welded joints.

Non destructive testing methods :

i) Magnetic particle test ii) X-ray test iii) Ultrasonic test

Destructive testing methods :

i) Nick brake test ii) Bend test iii) Tensile test

42. What are the applications of magnetic particle test, X-ray test and ultrasonic test.

✦ Magnetic particle test is used to find out cracks and slag inclusions.

✦ X-ray test is used to fine out defects like porosity, blow holes and cavities.

✦ Ultrasonic test is used to find out defects like cracks, blow holes and porosity by using ultrasonic waves.

43. List out the various defects in welding.

1) Incomplete fusion 2) Slag inclusion 3) Crack
4) Undercut 5) Porosity and blow holes

Unit – III : FORMING TECHNOLOGY

1. Define : i) Hot working ii) Cold working

- ✦ Hot working is the process of heating the metal above its recrystallization temperature to undergo plastic deformation and to get the required shape.
- ✦ Cold working of a metal is carried out below its recrystallization temperature.

2. List out the advantages of hot working.

1) The toughness and ductility of metal can be improved.
2) No internal stresses are produced in the metal.
3) Less amount of force is sufficient to deform the metal.
4) Cracks, blow holes, porosity will not occur in the metal.
5) The strength can be increased.
6) It is a quick and economical process.

3. List out the limitations of hot working.

1) Poor surface finish due to oxidation or scale formation .
2) De-carburization takes place on the metal surface.
3) Less dimensional accuracy.
4) High tooling cost.
5) Handling of hot worked parts is difficult.

4. State the advantages of cold working?

1) Mechanical properties are improved
2) Smooth surface finish can be easily produced.
3) Better dimensional accuracy is achieved.
4) Strength and hardness of the metal are increased
5) No formation of oxide
6) It is easier to handle cold parts.

5. Mention the limitations of cold working.

1) The ductility of metal in decreased
2) The grain structure is distorted.
3) Residual stresses are set up in the metal.
4) Strain hardening occurs.
5) Greater force is required
6) Only small sized components can be produced.

6. **List out the various hot working operations.**

1) Rolling 2) Forging 3) Swaging
4) Extrusion 5) Drawing 6) Hot spinning

7. **What is rolling? Give its applications.**

- ✦ Rolling is a process of forming metal to the required shape by passing it between rotating rolls.
- ✦ By hot rolling, the metal can be formed into sheets, plates, rounds, I-sections, channels, angles and many other shapes.

8. **What is forging? Mention its applications.**

- ✦ Forging is a process of forming the metal into the required shape by compressive or impact force.
- ✦ Connecting rod, crank shaft, etc. can be produced by this method.

9. **Write down the classification of forging.**

1) Smith forging : *a) Hand forging b) Power forging*
2) Impression die forging : *a) Drop forging b) Upset forging*
3) Roll forging
4) Swaging

10. **List out the smith forging operations.**

1) Upsetting 2) Drawing down 3) Setting down 4) Swaging
5) Bending 6) Punching 7) Welding

11. **What is the difference between upsetting and drawing down.**

- ✦ Upsetting is the process of increasing the cross section of heated work piece by reducing the length.
- ✦ Drawing down is the process of increasing the length of the heated work piece by reducing the cross section.

12. **Define : Swaging and Bending**

- ✦ Swaging is the process of increasing the length of heated metal and to form the cross section to the required shape.
- ✦ Bending is the process of forming the work piece into required angle or circular.

13. What is drop forging? Give its applications.

- ✦ Drop forging is the process of making the heated metal into required shape by placing it between two closed dies and pressing with the help of power hammer.
- ✦ Crank, crank shaft, connecting rod, levers, camshaft, etc. can be produced by drop forging.

14. What are the applications and advantages of press forging.

Application

Press forging can be used to produce symmetrical shaped objects such as coins, bolts, rivets, nuts, etc.

Advantages

1) The components can be made in single working stroke.
2) The production time is less.
3) Good surface finish can be obtained.
4) Less noise and vibration.
5) The density of work piece will be uniform.

15. What is the difference between forging and roll forging?

- ✦ In plain rolling, components with uniform cross section are produced by compressive force.
- ✦ In roll forging, components with varying cross sections are produced by pressing the heated work piece between two rotating rolls.

16. Which are called press tools?

Die and punch are called press tools.

17. Write the specifications of a press.

1) Capacity of press in tons 2) Maximum stroke length of ram
3) Die space 4) Type of frame
5) Type of drive 6) Number of slides

18. Classify the presses based on the frames.

1) Open back inclinable press 2) Adjustable press
3) Horn press 4) Straight side press 5) Pillar type press

19. Mention the advantages of hydraulic press.

1) High pressure and force can be obtained.
2) The required pressure to table ram can be controlled easily.
3) The pressure is uniform.

4) The movement of ram is uniform.
5) Noiseless and smooth operation take place.

20. Mention the types of drives used in press.

1) Eccentric drive 2) Cam drive 3) Rack and pinion drive

21. Name the various press accessories.

1) Stops 2) Pilots 3) Strippers
4) Knock outs 5) Pressure pads.

22. What is the use of stops and pilots?

- ✦ Stops are used to stop the sheet metal at the correct length.
- ✦ Pilot is used to exactly locate the hole which is already pierced in the blank.

23. What is the application of strippers and knock out?

- ✦ Stripper is used to remove the work piece from the punch or die after the end of blanking or piercing operation.
- ✦ Knock out is used to kick out the products which cannot fall through the die opening after the end of drawing operation.

24. What is the purpose of providing pressure pads?

Pressure pad is used to hold the sheet metal at correct position by applying sufficient pressure.

25. Classify the dies based on construction.

1) Simple dies 2) Progressive dies 3) Compound dies
4) Combination dies 5) Inverted dies

26. What is progressive die?

In progressive die, two or more operations can be performed one after another every time the ram moves down.

27. State the difference between compound and combination dies.

- ✦ In compound die, two or more operations can be performed in one stroke of the ram at a single work station.
- ✦ In combination die, a cutting and a non-cutting operation can be performed simultaneously in a single work station when the ram moves downward.

28. What is inverted die?

In an inverted die, punch is fitted in the die holder and die is fitted in the punch holder.

29. List out the various bending operations performed in press.

1) Angle bending 2) Channel bending 3) Curling
4) Drawing 5) Seaming

30. Differentiate between channel bending and drawing.

- ✦ Channel bending is the operation of bending a sheet metal in to a channel.
- ✦ Drawing is the operation of forming a sheet metal into hollow shape like a cup.

31. Define : Curling and seaming?

- ✦ Curling is the operation of bending the edges of the sheet metal into circular form.
- ✦ Seaming is the process of inter locking sheet metals.

32. List out the various shearing operations.

1) Blanking 2) Piercing 3) Cutting off 4) Trimming
5) Notching 6) Slitting 7) Lancing 8) Shaving

33. Define : i) Blanking ii) Piercing.

- ✦ Blanking is the operation of cutting the sheet metal into required shape by using die and punch.
- ✦ Piercing is an operation of cutting circular holes in a sheet metal by using a punch and die.

34. Differentiate : i) Notching ii) Slitting

- ✦ Notching is the operation of cutting small notches at the edge of the sheet metal.
- ✦ Slitting is the operation of cutting a sheet metal in straight line to required length.

35. Define : a) Lancing b) Shaving

- ✦ Lancing is the operation of cutting a sheet metal through a small length and bending it.
- ✦ Shaving is the operation of finishing the components made in sheet metal operations by removing the burrs and irregularities.

36. What is powder metallurgy?

Powder metallurgy is the process of making components with required properties and shape by mixing metal and non-metal powders.

37. List out the step by step procedure of making products in powder metallurgy.

1) Manufacturing of metal powder 2) Blending or mixing
3) Pressing or compacting 4) Sintering
5) Finishing and sizing

38. What are the methods used for manufacturing metal powders?

1) Atomization 2) Electrolytic deposition
3) Chemical reduction 4) Machining
5) Shotting 6) Milling 7) Grinding

39. What are the applications of atomization and electrolytic deposition?

✦ Atomization is used for producing powder of metals having low melting point such as aluminium, lead and zinc.

✦ Metals powders of copper, iron, silver and zinc can be produced electrolytic deposition method.

40. Define : i) Blending ii) Sintering

✦ Blending or mixing is the process of combining metal and non-metal powders with correct proportions to get required properties.

✦ Sintering is the process of heating the green compact just below the melting point of its base metal in an controlled atmosphere.

41. What is compacting? List out the types of pressing.

✦ Pressing or compacting is the process of pressing the mixed metal powder into a die to get required size and shape. It is also called as briquetting.

✦ The types of pressing are :
1) Cold pressing 2) Hot pressing

42. List out the finishing operations in powder metallurgy.

1) Sizing or coining 2) Infiltration 3) Impregnation
4) Machining 5) Heat treatment 6) Metal coating.

43. What is infiltration? Give its advantages.

✦ Infiltration is the process of filling the pores in the sintered component by using an another molten metal having low melting point.

✦ The strength, hardness and density of the component can be increased by infiltration.

44. List out the advantages of powder metallurgy.

1) High dimensional accuracy and surface finish can be obtained.
2) No material wastage.
3) The product with required density and porosity can be obtained.
4) Components with required properties can be produced by combining metal and non-metal.
5) Components with complicated shapes can be produced easily.
6) Components with high hardness can be made easily.

45. List out the applications of powder metallurgy.

Powder metallurgy is used for producing the following products.

1) Self lubricating bearing, filters and oil pump gears.
2) Hardened carbide tips and wire drawing dies.
3) Tungsten filament wire used in electric bulbs, radio valves and X-ray tubes.
4) Cathode, anode and control grids.
5) Automobile clutch plate, brake lining and motor brushes.
6) Small gears, cam, lever, piston ring and magnets.

46. What are the design rules in powder metallurgy?

1) Small holes (less than 2mm diameter) should be avoided.
2) Sudden changes in thickness should be avoided.
3) Narrow and deep sections should be avoided.
4) Holes should not be provided in the direction of pressing.
5) Threads, knurling and under cuts should not be formed by compacting.

Unit – IV: THEORY OR METAL CUTTING, CENTRE LATHE & SEMI-AUTOMATIC LATHE

1. Differentiate between orthogonal and oblique cutting.

	Orthogonal cutting	Oblique Cutting
1)	The cutting edge of the tool is perpendicular to the direction of feed motion.	The cutting edge of the tool is inclined to the direction of feed motion.
2)	Cutting force and thrust forces are acting at the cutting edge.	Cutting force, radial force and thrust forces are acting at the cutting edge.
3)	The cutting edge is larger than cutting width.	The cutting edge may or may not be larger than cutting width.
4)	Tool life is less.	Tool life is more.

2. Give examples for orthogonal and oblique cutting processes.

Orthogona clutting : *Parting, slotting, pipe cutting, etc.*
Oblique cutting *: Drilling, grinding, milling, turning in lathe, etc.*

3. Define : i) Top rake angle ii) Side rake angle

✦ Top rake angle is the angle of slope formed on the face towards the shank from the cutting edge.

✦ Side rake angle is the angle of slope formed from the cutting edge towards the side (width) of the face.

4. What is clearance angle and lip angle?

✦ Clearance angle is the angle of the slope formed downwards from the cutting edge.

✦ Lip angle is the angle between face and end surface.

5. What are the cutting edge angles?

1) Side cutting edge angle 2) End cutting edge angle

6. **What is nose angle?**

   It is the angle between the side cutting edge and end cutting edge.

7. **What are the types of chips?**

   1) Continuous chips 2) Discontinuous chips
   3) Chip with built-up edge.

8. **What is the use of chip breaker?**

   Chip breakers are used to break the long continuous chips formed during machining into small pieces.

9. **What are the three types of chip breakers?**

   1) Step type 2) Groove type 3) Clamp type

10. **What are the materials used for producing cutting tools?**

    1) Carbon steel 2) Alloy carbon steel
    3) High Speed Steel (H.S.S) 4) Stellites
    5) Carbides 6) Ceramics
    7) Diamond

11. **Give the composition of 18-4-1 HSS and stellite.**

    ✦ 18-4-1 HSS represents tungsten high sped steel. It contains 18% tungsten, 4% chromium, 1% vanadium and 0.75% carbon.

    ✦ Stellite contains 45% chromium, 15% tungsten and 2% carbon.

12. **State the applications of HSS and stellite.**

    ✦ Drills, turning tools, broaches, taps, dies and milling cutters can be produced by using HSS.

    ✦ Stellites are used to produce tools for cutting rubber and plastics.

13. **Mention the tool material used for making drill bits.**

    High carbon steel and High Speed Steel.

14. **What is the use of ceramics and diamond as cutting tool material?**

    ✦ Ceramics is used to produce single point cutting tools for machining plastics and cast iron.

✦ Diamond tipped tools are used for machining very hard materials like abrasive wheels, glass, plastics, and ceramics.

15. What is tool life?

Tool life is defined as the time between two successive grinding of tool or it is the period during which the tool cuts the metal satisfactorily.

16. List out the properties of cutting tool material.

1) More hardness 2) High wear resistance
3) High toughness 4) Low cost

17. What the various tool wear?

1) Face wear or crater wear
2) Flank wear or edge wear
3) Nose wear

18. What are the factors affecting tool life?

1) Cutting speed	2) Feed	3) Depth of cut
4) Tool geometry	5) Tool material	6) Cutting fluid
7) Work material	8) Rigidity of work, tool and machine.	

19. Give the relationship between cutting speed and tool life.

$$\boldsymbol{V\,T^n = C}$$

Where, V – Cutting speed (m / min)
T – Tool life (min)
n – A value depends upon the tool and work piece.
C – A constant

20. Name the cutting fluids commonly used.

Soluble oils, kerosene base oil, mineral oil, synthetic coolants, sulphonated oils, water base emulsion, etc.

21. List out the functions of cutting fluids.

1) To cool the tool and work piece
2) To decrease adhesion between chip and tool
3) To reduce the friction and wear
4) To wash away the chips and keep the cutting region free
5) To prevent corrosion on machine parts, work piece and tool.
6) To decrease wear and tear of the tool

22. What are the desirable properties of cutting fluid?

1) High thermal conductivity for cooling.
2) Low viscosity for free flow.
3) Good lubricating qualities.
4) High flash point to prevent fire hazard.
5) Should not produce unpleasant odour on continued use.
6) Must not cause skin irritation or contamination.

23. List out the types of lathe.

1) Speed lathe
2) Engine lathe or Centre lathe
3) Bench lathe
4) Tool room lathe
5) Semi automatic lathe
6) Automatic lathe
7) Special purpose lathe

24. Write the important specifications of lathe.

1) Length of bed
2) Width of bed
3) Height of centres over the bed
4) Distance between centres
5) Swing diameter over the bed
6) Swing diameter over the carriage
7) Maximum diameter of hole through spindle
8) Number of spindle speeds

25. List out principal parts of a centre lathe.

1) Bed 2) Head stock 3) Carriage 4) Tail stock

26. What are the types of head stocks?

1) Back geared head stock 2) All geared head stock

27. Name the parts mounted on the carriage.

1) Saddle 2) Cross slide 3) Compound rest
4) Tool post 5) Apron

28. What is the use of compound rest?

Compound rest has a swivel base graduated with degrees. The swivel base can be tilted to any required angle. It is used during taper turning operation.

29. List out the types of tool posts.

i) Single screw tool post ii) Open side tool post

iii) Four bolt tool post iv) Four way tool post

30. What are the various feed given to lathe tool?

i) Longitudinal feed : Parallel to lathe axis.

ii) Cross feed : Perpendicular to lathe axis.

iii) Angular feed : Inclined at specified angle to lathe axis.

31. List out the functions of tail stock.

1) It supports the right end of the work piece.

2) Cutting tools like drill bit, reamer and tap can be fitted in the tail stock spindle to perform drilling, reaming and tapping operations.

3) The tail stock can be moved crosswise and taper turning can be done using set over method.

32. Name the types of feed given to lathe tool.

1) Longitudinal feed

2) Cross feed

3) Angular feed

33. Name the feed mechanisms in lathe.

1) Tumbler gear mechanism

2) Quick change gear box

3) Apron mechanism

34. What is the use of tumbler gear mechanism.

Tumbler gear mechanism is used to change the direction of rotation of lead screw and feed rod.

35. List out the various work holding devices used in lathe.

1) Chucks 2) Centres 3) Face plate

4) Mandrel 5) Steady rest 6) Follower rest

7) Angle plate 8) Carrier or dog 9) Catch plate

36. What are the types of chucks used in lathe.

1) Three jaw self centering chuck

2) Four jaw independent chuck

3) Magnetic chuck

37. What is live centre and dead centre. Give its uses.

- ✦ The centre in the main spindle is called live centre and the centre in the tail stock is called dead centre.
- ✦ It is used to support the work piece and withstand the force developed during machining.

38. List out the various lathe centres.

1) Ordinary centre 2) Ball centre 3) Tipped centre
4) Half centre 5) Pipe centre 6) Inserted centre
7) Rotating centre

39. What is face plate? Give its uses.

- ✦ Face plate is a circular plate having threaded bore.
- ✦ It is used for holding irregular work pieces which cannot be easily held in chuck.

40. What is mandrel? List out its types.

- ✦ Mandrel is a device used for holding hollow work pieces between the centres.
- ✦ The following mandrels are used in lathe:

1) Plain mandrel 2) Step mandrel 3) Collar mandrel
4) Screwed mandrel 5) Cone mandrel 6) Gang mandrel
7) Expansion mandrel

41. Compare steady rest and follower rest.

	Steady rest	Follower rest
1)	The steady rest is mounted on the lathe bed.	The follower rest is attached to the saddle of the lathe carriage.
2)	It is stationary.	It travels along with the tool.
3)	It has three adjustable jaws to support the workpiece.	It has two adjustable jaws to support the workpiece.
4)	A bearing surface must be provided on the workpiece for the jaws.	No such bearing surface is needed.

42. Mention the uses of carrier and catch plate.

- ✦ Carrier or dog is used to transmit the rotation of catch plate to the work piece held between two centres.

✦ Catch plate rotates the work piece held between two centres through the dog.

43. List out the various machining operations done on lathe.

1) Straight turning 2) Step turning 3) Facing
4) Chamfering 5) Grooving 6) Parting off
7) Knurling 8) Forming 9) Eccentric turning
10) Drilling 11) Reaming 12) Boring
13) Taper turning 14) Thread cutting

44. What is the basic difference between turning and facing?

✦ In turning, the feed is given to the tool by moving the carriage parallel to the lathe axis.

✦ In facing, the feed is given to the tool by moving the cross slide towards the centre of work piece perpendicular to the lathe axis.

45. What is chamfering and parting off?

✦ Machining the ends of the work piece for removing the sharp edge and producing a beveled edge is called chamfering.

✦ Parting off is the operation of cutting and removing the work piece after the work piece is machined to required size.

46. What is the purpose knurling?

Knurling is done for providing good gripping surface on the work piece. Generally this surface will be in diamond shape.

47. What is eccentric turning? Give its uses.

✦ Eccentric turning is an operation performed on a work piece with different centres.

✦ It is used for turning crank shafts and eccentric.

48. List out the methods of tape turning.

a) Form tool method
b) Compound rest method
c) Tail stock set over method
d) Taper turning attachment method
e) By combining longitudinal and cross feed

49. **Give the formula for calculating half taper angle.**

Half taper angle, $\boldsymbol{\alpha = tan^{-1}\left(\frac{D-d}{2l}\right)}$

D – Large diameter of taper

d – Small diameter of taper

l – length of taper

50. **Write down the formula for tail stock set over distance.**

$$\textbf{Set over, } \boldsymbol{S = L \times \left(\frac{D-d}{2l}\right)}$$

D – Large diameter of taper

d – Small diameter of taper

L – Length of work piece

l – length of taper

51. **How do you find the gear ratio for thread cutting in lathe.**

$$\text{Gear ratio} = \frac{\text{Pitch of the work}}{\text{Pitch of the lead screw}}$$

52. **What are rules for cutting LH and RH threads in lathe.**

- ✦ While cutting right hand threads, the lead screw rotates in the same direction of the spindle. Tool (carriage) moves towards the head stock.
- ✦ While cutting left hand threads, the lead screw rotates in a direction opposite to the spindle. Tool (carriage) moves towards tail stock.

53. **Define cutting speed. Write the formula for cutting speed.**

The length of chip cut by a tool from a rotating work piece in one minute is called cutting speed.

$$\textit{Cutting speed, } V_c = \frac{\pi DN}{1000} \ \textbf{(m / min)}$$

Where, $\boldsymbol{D}$ – Diameter of work piece (mm),

$\boldsymbol{N}$ – Rotating speed of work piece (rpm)

54. **Define : i) Feed ii) Depth of cut.**

- ✦ Feed is the distance moved by the tool per revolution of the work piece

$$\textit{Feed}, f = \frac{L}{N \times T_m}$$

where, L – Length of cut (mm)

N – Rotating speed of work piece (rpm)

T_m – Machining time / Cutting (min)

✦ Depth of cut is the thickness of metal removed from the work piece when the cutting tool is moved once.

$$Depth\ of\ cut, t = \frac{D_i - D_f}{2}$$

Where, D_i – Initial diameter of the workpiece

D_f – Final diameter of the workpiece

55. What is MRR?

The metal removal rate (MRR) can be defined as the volume of material removed per unit time.

$$MRR = Cutting\ speed \times Feed \times Depth\ of\ cut$$

$$MRR = V_c \times f \times t = \frac{\pi D n}{1000} \times f \times t \text{ (mm}^3\text{/min)}$$

Where, D – Diameter of work piece (mm),

n – Rotating speed of work piece (rpm)

f – feed (mm/rev)

t – Depth of cut (mm)

56. What is semi-automatic lathes. Give its types.

✦ In semi automatic lathes, loading, unloading and bringing the tool to machining position are done manually. All other operations are done automatically.

✦ The following types of semi automatic lathes are available

1) Capstan lathe or ram type lathe
2) Turret lathe or saddle type lathe

57. List out the principal parts in capston lathe.

1) Bed 2) Head Stock 3) Cross slide
4) Turret head and saddle 5) Preset stops

58. What is turret head?

Turret head is an hexagonal block in which six tools can be fitted at a time. It can be indexed about a vertical axis.

59. What is preset stops in turret lathe?

- ✦ Six adjustable stops are provided in turret head to control the length of travel of six tools.
- ✦ The turret movement required for a particular tool is preset by the adjustable stop.

60. What is the use of Geneva mechanism?

Geneva mechanism is used to rotate the index plate and the turret head through 60^{o} after each operation.

61. What is collet? List out its types.

- ✦ A collet is a cylindrical steel bush with a taper nose. It is used in capstan and turret lathes for holding the bar stock.
- ✦ The types of collets are :
  i) Draw back collet ii) Push out collet iii) Dead length collet

62. State the difference between draw back and push out collet.

- ✦ When the draw back collet moves forward, the collet jaws are opened.
- ✦ When the push out collet is moves forward, the taper nose of the collet moves in to the spindle taper

63. List out the various tool holding devices used in capstan and turret lathe.

1) Straight cutter tool holder 2) Adjustable angle cutter tool holder
3) Multiple cutter tool holder 4) Offset cutter tool holder
5) Sliding tool holder 6) Knee tool holder
7) Flange tool holder 8) Roller steady box tool holder
9) Combination tool holder 10) Self opening die holder
11) Collapsible tap.

64. What is self opening die and collapsible tap?

- ✦ Self opening die is used for cutting external threads accurately on the work pieces for required length.
- ✦ Collapsible tap is used for cutting internal threads accurately on the work piece for required length.

Unit – V: DRILLING & METROLOGY

1. What are the types of drills?

1) Flat drill or spade drill　　2) Straight fluted drill
3) Twist drill　　4) Oil tube drill

2. What is the purpose of oil hole in oil tube drill?

Coolant passes through these holes for cooling the cutting edge during drilling. Compressed air can also be passed through the holes to remove the chips easily.

3. State the functions of flutes in drill.

1) to form cutting edge
2) to make curling chips
3) to give passage for escaping chips
4) to allow the coolant to reach the cutting edge

4. Name the parts involved in point of drill bit.

1) Flank　　2) Lip or cutting edge
3) Face　　4) Chisel edge or dead centre

5. What are the values of important drill angles?

i) Point angle $=118^{o}$　　ii) Rake angle $=30^{o}$ to 45^{o}
iii) Chisel edge angle = 120^{o} to 135^{o}.

6. What are the types of radial drilling machine?

(i) Plain type　(ii) Semi universal type　(iii) Universal type

7. What are the principal movements in universal drilling machine?

1)Up and down movement of radial arm.
2)Circular movement of radial arm about the column.
3)Radial movement of spindle head along the radial arm.
4)The spindle head can be tilted about an axis perpendicular to the radial arm.
5)The radial arm can be tilted about a horizontal axis perpendicular to the column.

8. What is the difference between gang drilling and multi-spindle drilling machine?

✦ Gang drilling machine is used to perform a series of operations in a work piece one by one.

✦ Multi spindle drilling machine is used to perform the same operation at various locations in a work piece.

9. Write the specifications of drilling machine.

1)Maximum diameter of the drill that the machine can hold.
2)Maximum size of the work piece that can be fitted on the machine.
3)Size of the table.
4)Maximum spindle movement.
5)Number of spindle speed and feed.
6)Net weight of the drilling machine.

10. What is cutting speed in drilling?

The peripheral speed of the drill is called cutting speed. It is expressed in the unit m/min.

11. What are the methods of holding drill bits?

1) Fitting directly in the spindle
2) Using sleeve
3) Using socket
4) Using drill chuck

12. What is the use of sleeve in drilling?

If the taper shank of the drill is smaller than the spindle taper, a sleeve can be used.

13. What is the use of socket in drilling?

If the taper shank of the drill is larger than the spindle taper, a socket can be used.

14. What are the operations performed in drilling machine?

1) Drilling 2) Reming 3) Boring
4) Counter boring 5) Counter sinking 6) Spot facing
7) Tapping

15. Define counter boring.

Counter boring is the process of enlarging the end of a hole cylindrically.

16. What is counter sinking?

Counter sinking is the process of producing a conical enlargement at the end of a hole.

17. What is spot facing?

Spot facing is the process of producing a smooth and flat surface around a hole.

18. What is the use of deep hole drilling?

Deep hole drilling is used to drill deep holes in the parts like crank shaft, cam shaft, rifle barrel, etc.

19. What is miniature drills?

The drills used for producing small holes are called micro drills or miniature drills. Generally, the diameter of the drill will be form 0.1mm to 3mm.

20. What are the needs for inspection?

1) To ensure the correctness of materials and components with the established standards.
2) To meet the interchangeability of manufacture.
3) To produce components with acceptable quality levels.
4) To reduce scrap and wastages.
5) To purchase good quality of raw materials, tools and equipment.
6) To reduce the rejection percentage of products.
7) To judge the possibility of rework of defective parts.

21. Define : i) Accuracy ii) Precision

- Accuracy is the closeness of agreement between the measured value and the true value.
- Precision is the closeness of agreement between independent test results obtained under specified conditions.

22. What is the need of magnification?

In order to measure small difference in dimensions, the movement of the measuring tip in contact with the work piece must be magnified.

23. What is repeatability?

Repeatability is the quality of a measuring instrument to give the same result when measuring a component using the same method in the same conditions by the same operator.

24. Define : i) Resolution ii) Sensitivity

✦ Resolution is the smallest change of the measured quantity which changes the indication of a measuring instrument.

✦ Sensitivity of the instrument denotes the smallest change in the value of the measured variable to which the instrument responds.

25. What is calibration?

The process of periodic checking against measuring instruments and standards of high accuracy is called as calibration.

26. List out the requirements of a good comparator.

1) The scale used in the instrument should be linear.
2) There should not be any backlash and lag between the movement of the parts.
3) The instrument must be precise and accurate.
4) The indication method should be clear.
5) The indicator should be constant in its return to zero.

27. Classify the comparators.

1) Mechanical comparator
2) Electrical comparator
3) Pneumatic comparator
4) Optical comparator

28. What are the advantages of mechanical comparator?

✦ It is cheaper in comparison to the other comparators.
✦ It has linear scale, which is easily readable.
✦ It is compact and robust in construction.
✦ It is easily handled.
✦ It is suitable for ordinary workshops.

29. Write down the advantages of electrical comparator.

✦ It has very less number of moving parts.
✦ The magnification is comparatively high.
✦ It can be used for various ranges.
✦ It has a compact construction.

30. What are the limitations of pneumatic comparators?

- ✦ The scale is generally not uniform.
- ✦ Very high magnification is required to avoid meniscus errors.
- ✦ Various gauging heads are needed for different dimensions.
- ✦ It requires a number of auxiliary equipment.
- ✦ Handling of equipment is difficult.

31. What are the uses of optical comparator?

Optical comparator is used for checking gear teeth, screw thread, cutting tools, needles, etc.

32. List out the important measuring instruments.

1) Steel rule 2) Calipers 3) Combination set
4) Feeler gauge 5) Pitch screw gauge 6) Vernier caliper
7) Vernier height gauge 8) Micrometer 9) Thread micrometer

33. Mention the types of calipers.

1) Outside caliper 2) Inside caliper 3) Outside spring caliper
4) Inside spring caliper 5) Jenny or Odd leg caliper

34. What is combination set?

Combination set is the most adaptable and widely used non-precision instrument in layout and inspection work. The combination set consists of scale, squaring head, protractor and centre head.

35. List out the applications of feeler gauges.

1) It is used to measure the clearance between the tool and work piece in the machines.
2) It is used in automobiles for adjusting the spark plug clearance correctly.
3) It is used to measure the clearance between piston and cylinder.
4) It is used for measuring the clearance between the guide and guide ways in machines.

36. List the applications of radius gauges and pitch screw gauges.

- ✦ Radius gauge is useful for measuring and checking the inside and outside radii of fillets and other round surfaces.
- ✦ Pitch screw gauge is used to identify or check the pitch of the threads on different threaded items.

37. What is least count? How it is calculated in vernier caliper?

- ✦ Least count is the smallest value that can be measured by using an instrument.
- ✦ Least count = Length of one main scale division – Length of one vernier scale division

38. Give the uses of vernier height gauge and gear tooth vernier?

- ✦ Vernier height gauge is used to measure the height of the work piece and to mark the specified dimension exactly on the work piece.
- ✦ Gear tooth vernier is used to measure the chordal thickness of a gear tooth.

39. What is chordal thickness? Give the formula for addendum.

Chordal thickness is the thickness of a gear tooth at which the pitch circle passes through it.

$$\boldsymbol{Addendum = m\left[\frac{z}{2}\left(1 - cos\left(\frac{90}{z}\right) + 1\ \right)\right]}$$

Where, m = Module of the gear

z = Number of teeth

40. List out the types of micrometers.

1) Outside micrometer
2) Inside micrometer
3) Depth micrometer
4) Thread micrometer

41. What are the uses of inside micrometer and depth micrometer?

- ✦ Inside micrometer is used to measure the inside diameter of a hole.
- ✦ Depth micrometer is used to measure the depth of blind holes, slots and grooves.

42. What is the use of thread micrometer? Give the formula use in three wire method for pitch diameter.

Thread micrometer is used for measuring the pitch diameter of a thread accurately.

$$\boldsymbol{Pitch\ diameter = D - d\left[1 + sin\ \left(\frac{\alpha}{2}\right)\right]}$$

Where, D = Distance between the wires

d = Diameter of wire

α = Included angle of thread

43. What is slip gauges? Define wringing.

- ✦ Slip gauges are precision gauge blocks used for measuring linear dimensions.
- ✦ Wringing is the process of combining slip gauges by placing one over another with the help of adhesion between the two highly finished surfaces.

44. What are the requirements of slip gauges?

1) The end faces of the gauges must be flat and parallel to each other.
2) All the adjacent faces must be perfectly square to each other.
3) They must possess high degree of surface finish.
4) The actual size must be within tolerances.
5) The edges must be deburrred.

45. Classify the slip gauges.

- ✦ *Grade II* is intended for use in workshops during actual production of components, tools and gauges.
- ✦ *Grade I* is of higher accuracy for use in inspection departments.
- ✦ *Grade 0* is used in laboratories and standard rooms for periodic calibration of Grade I and Grade II gauges.

46. List out the uses of slip gauges.

1) Slip gauges are used for the calibration of precision measuring instruments.
2) Slip gauges are used in setting sine bars for establishing angles.
3) They are used to check comparators and optical inspection devices.
4) They are used as auxiliary measuring system on milling machine.

47. What are the types of sine bar?

1) Sine centre 2) Sine table 3) Compound sine table

48. Mention the uses of sine centre and compound sine table.

- ✦ Sine centers are used for mounting conical work pieces which cannot be held on a simple sine bar
- ✦ Compound sine table is used to measure compound angles of large work pieces.

49. What are the uses of sine bar?

- ✦ Measuring unknown angle.
- ✦ Setting up known angle.
- ✦ Checking of unknown angles of heavy component.

50. Write the limitations of sine bar.

1) The accuracy of sine bars is limited by measurement of center distance between the two precision rollers.
2) It cannot be used as a primary standard for angle measurements.
3) Sine principle is fairly reliable at angles less than 15^o, but becomes inaccurate as the angle increases.
4) Sine bar becomes impractical and inaccurate as the angle exceeds 45^o.

51. What is clinometer? Give its uses.

A clinometer is a special case of application of spirit level for measuring the inclinations

Uses :

1) It is used for the measurement of an inclined plane with respect to a horizontal plane
2) It is used for the measurement of the relative position of two mutually inclined surfaces :

52. What is vial?

Vial is a closed glass tube of accurate size in a spirit level, which is used for storing the liquid. It is graduated in linear scale and the bubble moves inside it.

53. What is the principle involved in autocollimator?

- ✦ When the reflecting plane is tilted through a small angle θ°, the reflected rays will be inclined at 2θ° to the optical axis.
- ✦ These rays will be focused at a point in the focal plane with a distance $x = 2\theta f$ from the origin, where f is the focal length of the lens.

54. How angles are measured in angle dekkor?

Angle dekkor measures angle by comparing the reading from a standard, such as combination of angle gauges, and the reading from the work piece under test. Thus it acts as a comparator.

32032 MANUFACTURING PROCESSES

MODEL QUESTION PAPER

Time: 3 Hrs   Max Marks : 75

[N.B: *(1) Answer any five questions in each PART – A and PART – B Q.No.8 in PART – A and 16 in PART – B are compulsory.*

(2) Answer division (a) or division (b) of each question in PART – C.

(3) Each question carries 2 marks in PART – A, 3 marks in PART – B and 10 marks in PART – C.]

PART - A

1. State any four types of pattern.
2. List out the various shearing operations in press working.
3. What is infiltration?
4. Give the composition of 18-4-1 HSS and Stellite.
5. What is eccentric turning?
6. What are the methods of holding drill bit?
7. Define precision and accuracy.
8. Name the two basic types of electrodes.

PART - B

9. What are the essential qualities of core?
10. State the three types of flames in gas welding and list out its uses.
11. Write down the differences between hot working and cold working.
12. Define : i) Blanking ii) Piercing
13. List out the principal parts of centre lathe.
14. List out the difference between turret and capstan lathe.
15. What are the principal movements in universal drilling machine?
16. What are the advantages and disadvantages of electrical comparator?

PART – C

17.(a) (i) What are the properties of good moulding sand?

(ii) Explain with a neat sketch CO_2 process of core making.

(Or)

(b) Describe the step by step procedure of making green sand mould with a neat sketch.

18.(a) (i) State the differences between gas welding and arc welding process.

(ii) Describe briefly X-ray test of welded joint.

(Or)

(b) (i) Explain the working of atomic hydrogen welding with a neat sketch.

(ii) Explain the laser beam welding process with a neat sketch.

19.(a) (i) Explain : a) Upset forging b) Swaging

(ii) Enumerate the advantages and disadvantages of powder metallurgy.

(Or)

(b) (i) With a neat sketch explain any two bending operations in press working.

(ii) Explain the atomisation process of metal powder manufacture with a neat sketch.

20.(a) With a neat sketch, explain the nomenclature of a single point cutting tool.

(Or)

(b) (i) List out the work holding devices used in lathe and explain any one device with a neat sketch.

(ii) Explain the turret indexing mechanism with a neat sketch.

21.(a) (i) Explain : a) Counter sinking b) Spot facing

(ii) Explain three wire method of measuring pitch diameter of a screw thread.

(Or)

(b) (i) Explain the working principle of pneumatic comparator with a neat sketch.

(ii) Explain the method of measuring angle using angle dekkor.

BOARD EXAMINATION QUESTION PAPER

OCTOBER – 2016

Time: 3 Hrs Max Marks : 75

***[N.B:** (1) Answer any five questions in each PART – A and PART – B Q.No.8 in PART – A and 16 in PART – B are compulsory.*

(2) Answer division (a) or division (b) of each question in PART – C.

(3) Each question carries 2 marks in PART – A, 3 marks in PART – B and 10 marks in PART – C.]

PART - A

1. Define pattern.
2. What is the use of core?
3. Name the two basic types of electrode.
4. Name any two non-destructive tests used in welding inspection.
5. Name the straight shank drill bit holding devices.
6. Name any two methods of metal powder manufacturing.
7. What is the use of mandrel in lathes?
8. What is cold working?

PART – B

9. Explain the draft allowance.
10. Explain the balanced core with a sketch.
11. State any three functions of flux coating on a metal electrode.
12. Describe the function of a pressure regulator fixed on a gas cylinder.
13. State any three advantages of cold working.
14. What is infiltration in powder metallurgy?
15. Compare the steady rest with follower rest.
16. Define the term precision and accuracy.
17. What are the advantages and disadvantages of electrical comparator?

PART – C

17.(a) With sketches explain the green sand moulding process.

(Or)

(b) Sketch and explain any three defects in castings.

18.(a) Sketch and explain any two types of resistance welding.

(Or)

(b) Sketch and explain the three types of gas flames.

19.(a) Explain any three press working operations with sketches.

(Or)

(b) Explain the various steps involved in powder metallurgy process.

20.(a) Sketch and explain the three types of chip breakers.

(Or)

(b) Sketch and explain the Geneva indexing mechanism.

21.(a) Explain any three drilling machine operations with sketches.

(Or)

(b) What is comparator? Sketch and explain the pneumatic comparator.