DEPARTMENT : MECHANICAL ENGINEERING

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PREPARED BY : V V ANANTHA CHAKRAVARTHY

UNIT II : Metal Forming & Forging

Introduction

- Nature of plastic deformation
- Hot and cold working of metals
- Mechanics of metal forming
- Rolling: Principle
- Types of rolling mill and products,
- Roll passes, forces in rolling and power requirements

Extrusion: Basic extrusion process

- Extrusion process characteristics,
- Hot extrusion
- Cold extrusion,

- Wire drawing,
- Tube drawing.

- Principles of forging
- Tools and dies.
- Types of forging
- Smith forging
- Drop forging
- Forging hammers
- Rotary forging
- Forging defects

Sheet metal forming:

- Mechanics of sheet metal working
- Blanking
- Piercing

- Bending
- Stamping

Introduction Mechanical working of a metal

 Mechanical working of a metal is a simply plastic deformation performed to change the dimensions, properties and surface conditions with the help of mechanical pressure.

 Depending upon the temperature and strain rate, mechanical working may be either hot working or cold working, such that recovery process takes place simultaneously with the deformation.

  The plastic deformation of metal takes place due to two factors i.e. deformation by slip and deformation by twin formation.

Introduction Mechanical working of a metal

 During deformation the metal is said to flow, which is called as plastic flow of the metal and grain shapes are changed.

 If the deformation is carried out at higher temperatures, then the new grains start growing at the locations of internal stresses.

 When the temperature is sufficiently high, the grain growth is accelerated and continue still the metal comprises fully of new grains only.

Introduction Mechanical working of a metal

 This process of formation of new grains is called as recrystallisation and the corresponding temperature is the recrystallisation temperature of the metal. Recrystallisation temperature is the point which differentiates hot working and cold working.

 Mechanical working of metals above the recrystallisation temperature, but below the melting or burning point is known as hot working whereas; below the recrystallisation temperature, is known as cold working.

Plastic Deformation

– Any external or internal forces cause stresses in the material resulting into deformation.

– Deformation is of two basic types : o Elastic Deformation : o Plastic Deformation:

Plastic Deformation

Plastic deformation may occur by :

- Slip or
- Twinning or
- Both acting simultaneously

Plastic deformation is permanent and takes place when the applied stress level exceeds a certain limit known as yield stress.

Refer Fig. 4.1

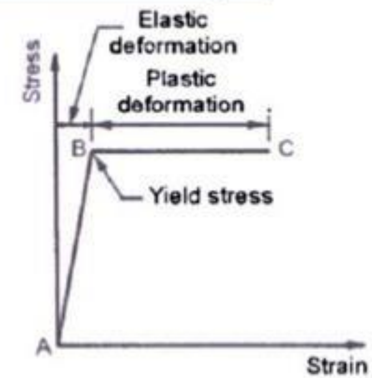


Fig. 4.1: Ideal plastic deformation preceded by ideal elastic deformation

phenomenon by which metals become harder and stronger during mechanical working or straining i.e. during plastic deformation of the metal.

- After initial work hardening or straining, more and more stress is required to further deform the material.
- E.g. During the operation of hammering a nail, quite often the nail bends. This bending of nail induces stress development inside the nail.

- The nail gets plastically deformed and work hardened or strained.
- Now if we try to straighten the nail, it requires more force than that required to bend it.
- Work hardening or Straining occurs below the re-crystallization temperature

Hot Working

- Hot working is accomplished at a temperature above the recrystallisation temperature but below the melting or the burning point of the metal, because above the melting or the burning point, the metal will burn and become unsuitable for use.

- Every metal has a characteristic hot working temperature range over which hot working may be performed. The upper limit of working temperature depends on composition of metal, prior deformation and impurities within the metal.

 The changes in structure from hot working improves mechanical properties such as ductility, toughness, resistance to shock and vibration, % elongation, % reduction in area, etc.

Hot Working

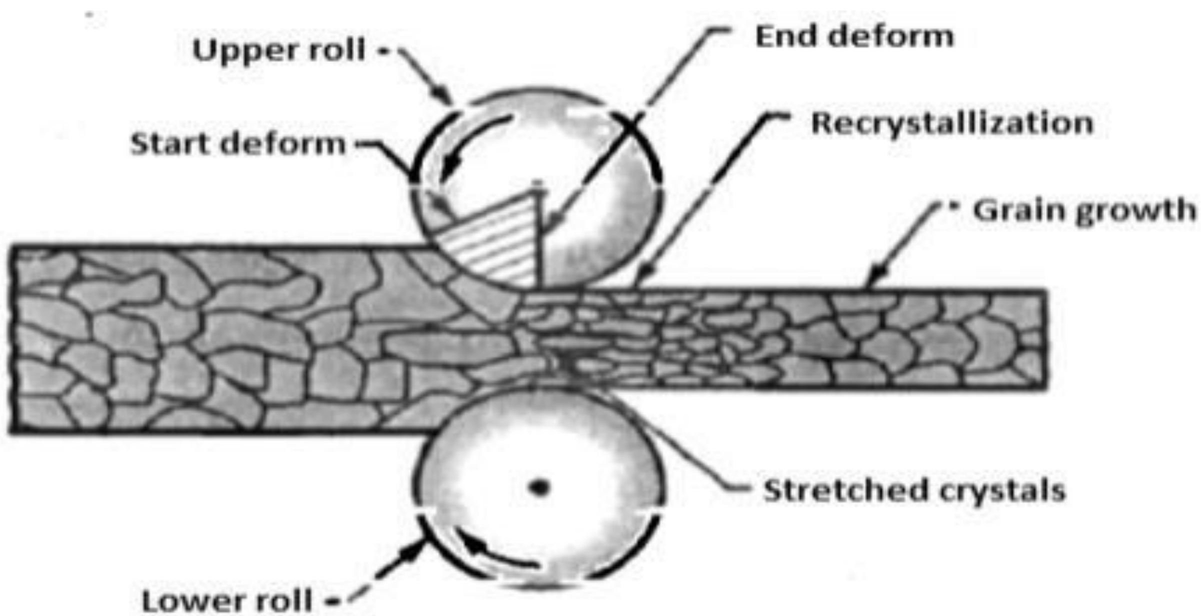
The principal hot working processes applied to various metals are as follows :

1. Hot rolling
2. Hot extrusion
3. Hot spinning 4. Roll piercing
5. Hot drawing

6. Hot forging .

1.Rolling:

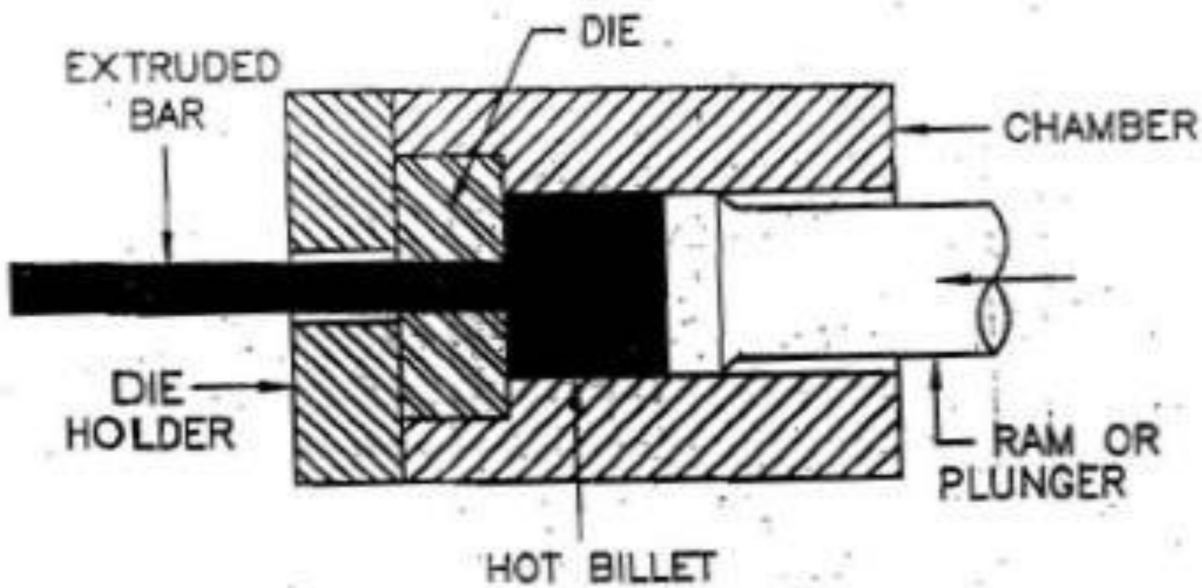
The plastic deformation of metal takes place as it passes through a pair of rolls rotating in opposite direction.



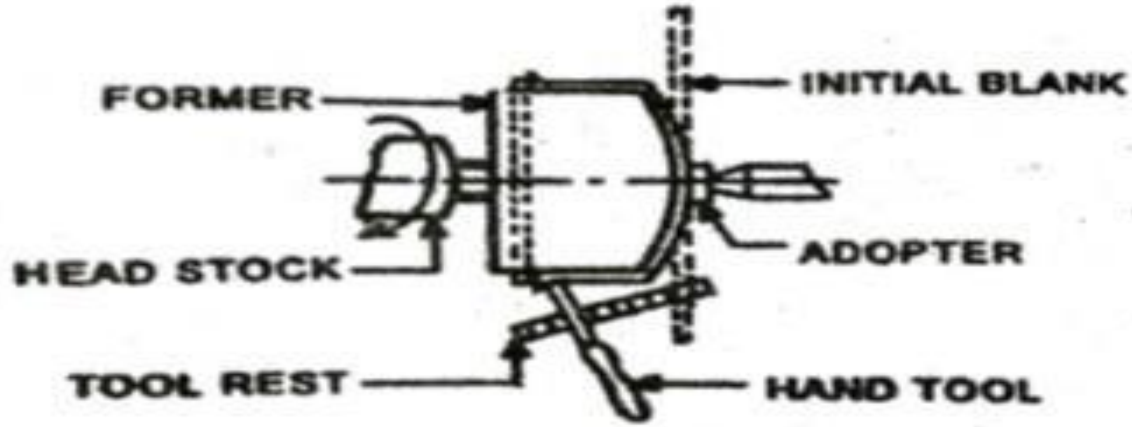
2. Extrusion:

In this the metal billet is heated to plastic state and placed in a container.

Ex: Tubes, cables, air craft parts etc.

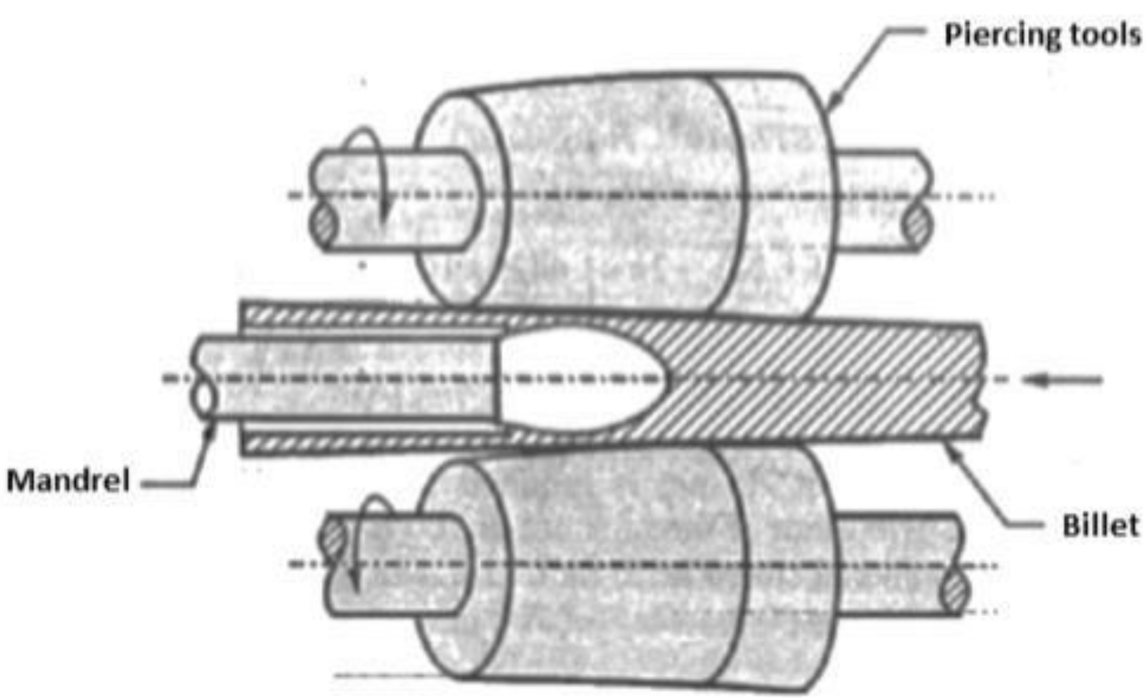


3. **Spinning:** It is the process of shaping thin sheets of metal by pressing against a rotating former.



4. piercing:

Hot piercing is used to produce seam less tubes.



5. Drawing or Cupping:

Drawing is the process of making a cup shaped parts from sheet metal blanks.

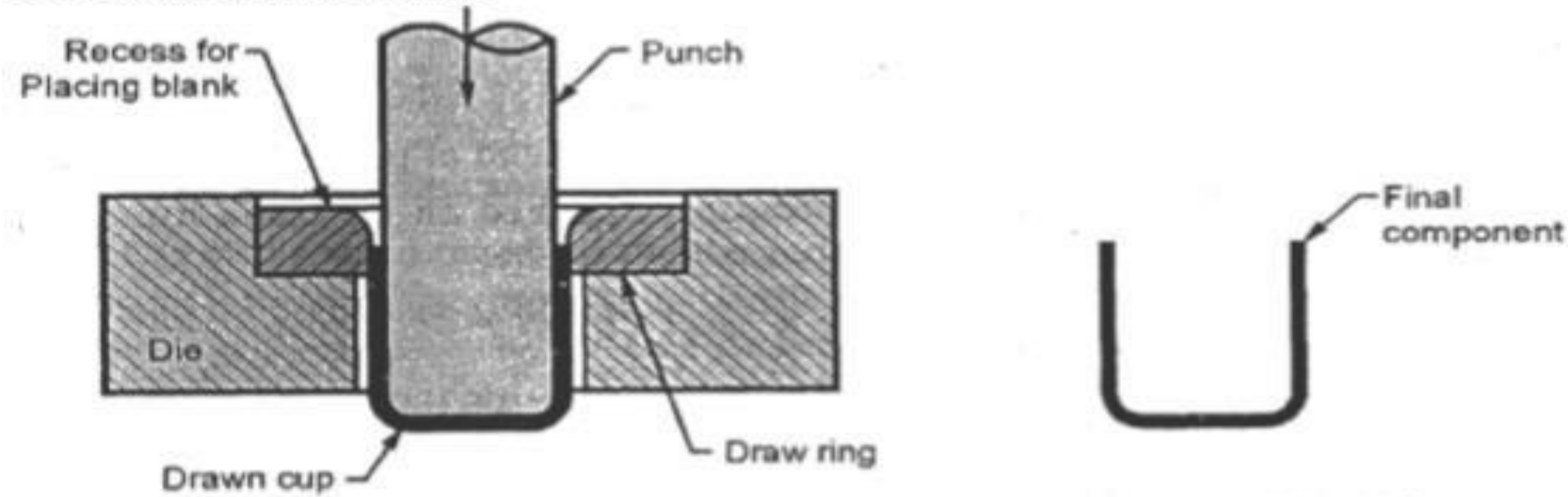
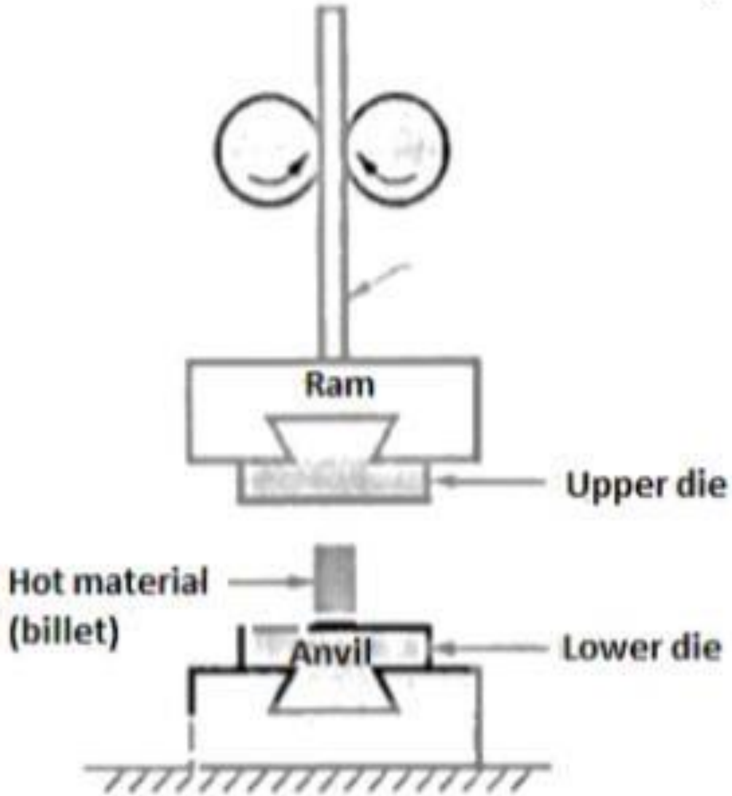
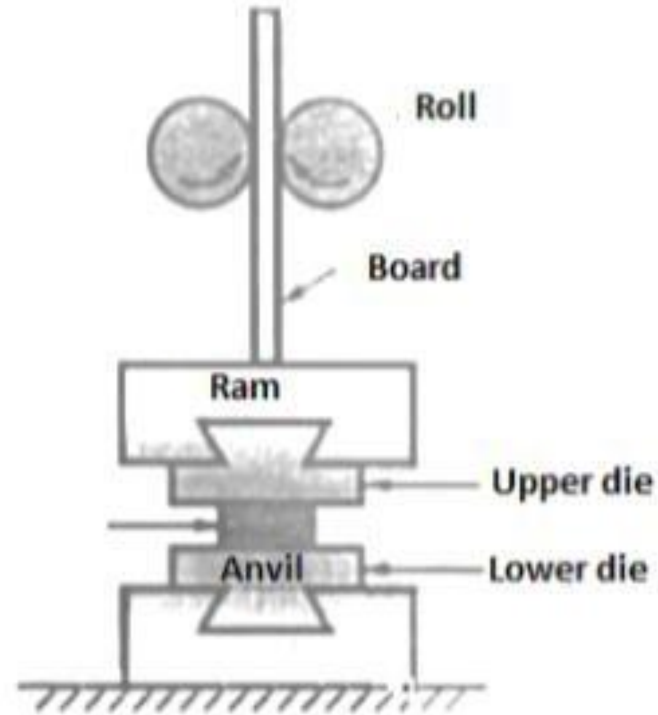


Fig. 5.17: Drawing

6.Forging

In this process, the work piece is compressed between the two opposing dies in order to produce the die shapes on the work piece





Advantages of Hot working process:

1.The grain structure is refined.

2. Less force is enough to shape the metal into desired shape.

3. Strength and hardness of metal decreases.

4. Porosity of metal eliminated.
5. Ductility and toughness increases.
6. Energy consumption is less.
7. Uni-directional fiber structure is obtained.
8. This process is easy and economical.
9. Larger deformation is possible with less force.

Dis-advantages of Hot working process:

1. At high temperature scales are formed, so poor surface finish.
2. Close tolerance cannot be maintained.
3. Tooling and handling costs are high.
4. Tool life is less due to work at high temperature.
5. The steel work piece loose carbon,

Cold Working

 The working of metals at temperatures below their recrystallisation temperature is called as cold working. – Most of the cold working processes are performed at room temperature.

 Unlike hot working, it distorts the grain structure and does not provide an appreciable reduction in size. – Cold working requires much higher pressure than hot working. If the material is more ductile, it can be more cold worked. Residual stresses are setup during the process, hence to neutralize these stresses a suitable heat treatment is required.

The principal methods of cold working are as follows :

1. Cold rolling
2. Cold drawing
3. Cold spinning

4. Stretch forming
5. Cold forging and swaging
6. Cold extrusion
7. Coining
8. Embossing
9. Cold bending
10. Reeding
11. Squeezing

1.Cold Rolling

 Cold rolling is used for producing bars of all shapes, rods, sheets and strips.

➢ Cold rolling is generally employed for providing a smooth and bright surface finish to the previously hot rolled steel. It is used to finish the hot rolled components, to close tolerances and improve their hardness and toughness.

- ➢ Before cold rolling, the hot rolled articles are cleaned through pickling and other operations.
- The same types of rolling mills, as in hot rolling, are used for cold rolling.
- The part being rolled is generally annealed and pickled before the final pass is made, so as to bring it to accurate size and obtain a perfectly clean surface.

2.Drawing:

It is the process to reduce the large diameter of metal in to required low diameter. In this die is used.

The metal is passed through the die, by applying
force the metal comes out from die.

3.Spinning:

It is the process of shaping thin sheet metal by pressing against the form which is rotation.
This process is suitable for soft metals.

4.**Stretch forming :**

Stretch forming strains the metal beyond elastic limit to give work piece a permanent set.
This prevents the metal from spring back

5.Cold forging

- For certain products like bolts, rivets, screws, pins, nails, etc. cold forging is also very common.
- It increases the strength which results from the strain hardening of the component.

6.Extrusion:

It is the process of pushing the billet of metal through an orifice in the die. The punch is passed on metal. Then the metal extruded into die shape

7. Coining (Squeezing):

 In coining operation, the metal having good plasticity and of proper size is placed within the punch and die and a tremendous pressure is applied on the blank from both ends. Refer Fig. 5.20.

7. Coining (Squeezing):

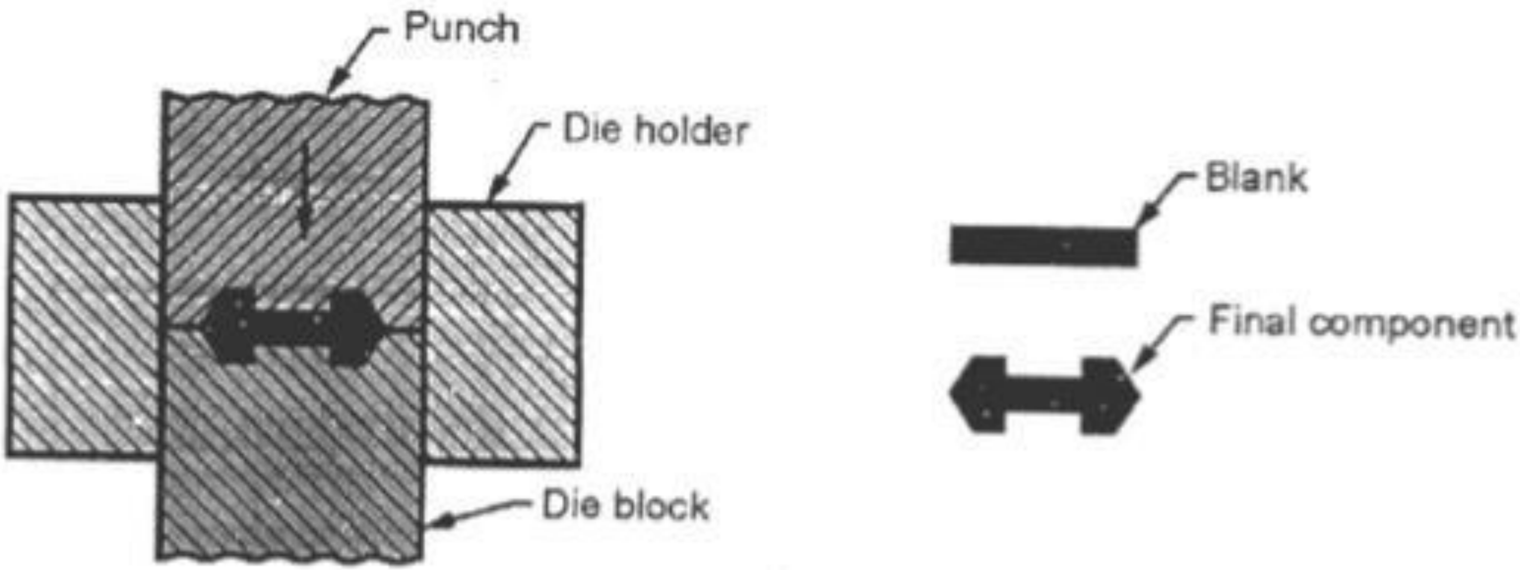


Fig. 5.20: Coining

 Under severe compressive loads, the metal flows in the cold state and fills up the cavity of the punch and die. – This operation is used .in the manufacturing of coins, medals, ornamental parts, etc.

Embossing

– With the help of this operation, specific shapes or figures are produced on the sheet metal.
– It is used for decorative purposes or giving details like names, trade marks specifications, etc. on the sheet metal. Refer Fig. 5.18.

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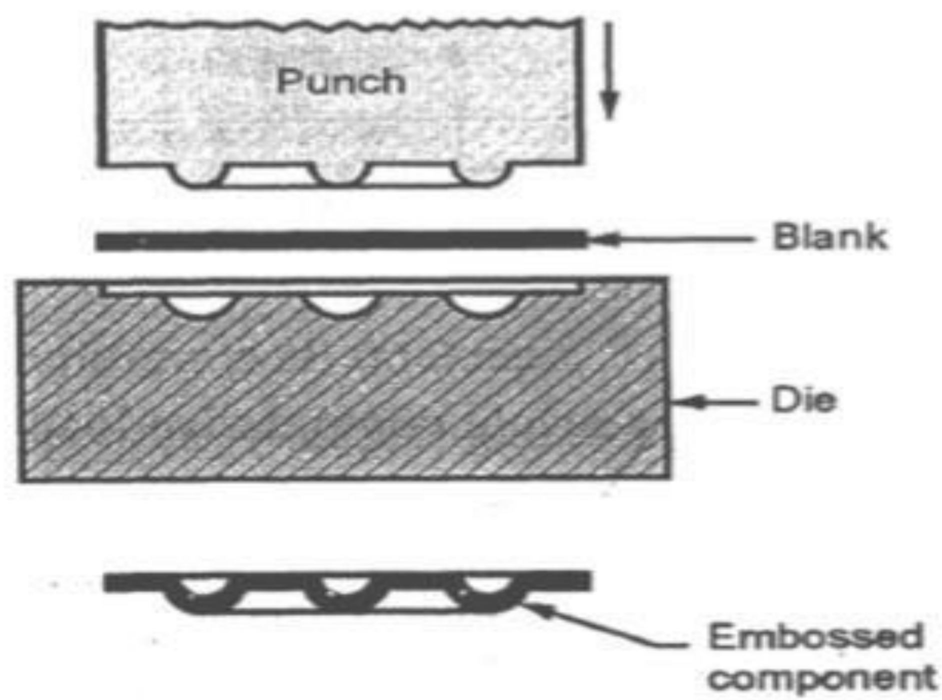


Fig. 5.18: Embossing

Bending

- It is a metal forming operation in which the straight metal sheet is transformed into a curve· form.
- In bending operations, the sheet metal is· subjected to both tensile and compressive stresses.
- During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.

The bending methods which are commonly used are as follows :

a. U-Bending b. V-bending c. Angle bending
d. Curling e. Roll bending
f. Bending in a 4-slide machine g. Edge bending

10.Reeding:

It is the process of intending large quantities of steel shots in to the surface of metal. This is done by air blast. By this indentation compressive stresses are developed at outer layer. Due to this the metal surface is slightly hardened

11.Squeezing:

It requires large amount pressure to get required shape. For this a cavityof die and punch are required.

Ex: bolts, screws, rivets.

Advantages of cold working process:

 Better dimensional control is possible because there is not much reduction in size.

 Surface finish of the component is better because no oxidation takes place during the process.

 Strength (tensile strength and yield strength) and hardness of metal are increased.

 It is an ideal method for increasing hardness of those metals which do not respond to the heat treatment.

Disadvantages of cold working process:

 Ductility of the metal is decreased during the process. Only ductile metals can be shaped through the cold working.

 Over-working of metal results in brittleness and it has to be annealed to remove this brittleness.

 To remove the residual stresses setup during the process, subsequent heat treatment is mostly required

Comparison between Hot Working and Cold Working

4.5.1 Comparison between Hot Working and Cold Working

Sr. No.	Hot working	Cold working
1.	Hot working is carried out above the recrystallisation temperature but below the melting point, hence deformation of metal and recovery takes place simultaneously.	Cold working is carried out below the recrystallisation temperature and as such there is not appreciable recovery of metal.
2.	During the process, residual stresses are not developed in the metal.	During the process, residual stresses are developed in the metal.
3.	Because of higher deformation temperature used, the stress required for deformation is less.	The stress required to cause deformation is much higher.
4.	Hot working refines metal grains,	Cold working leads to distortion of grains.

Comparison between Hot Working and Cold Working

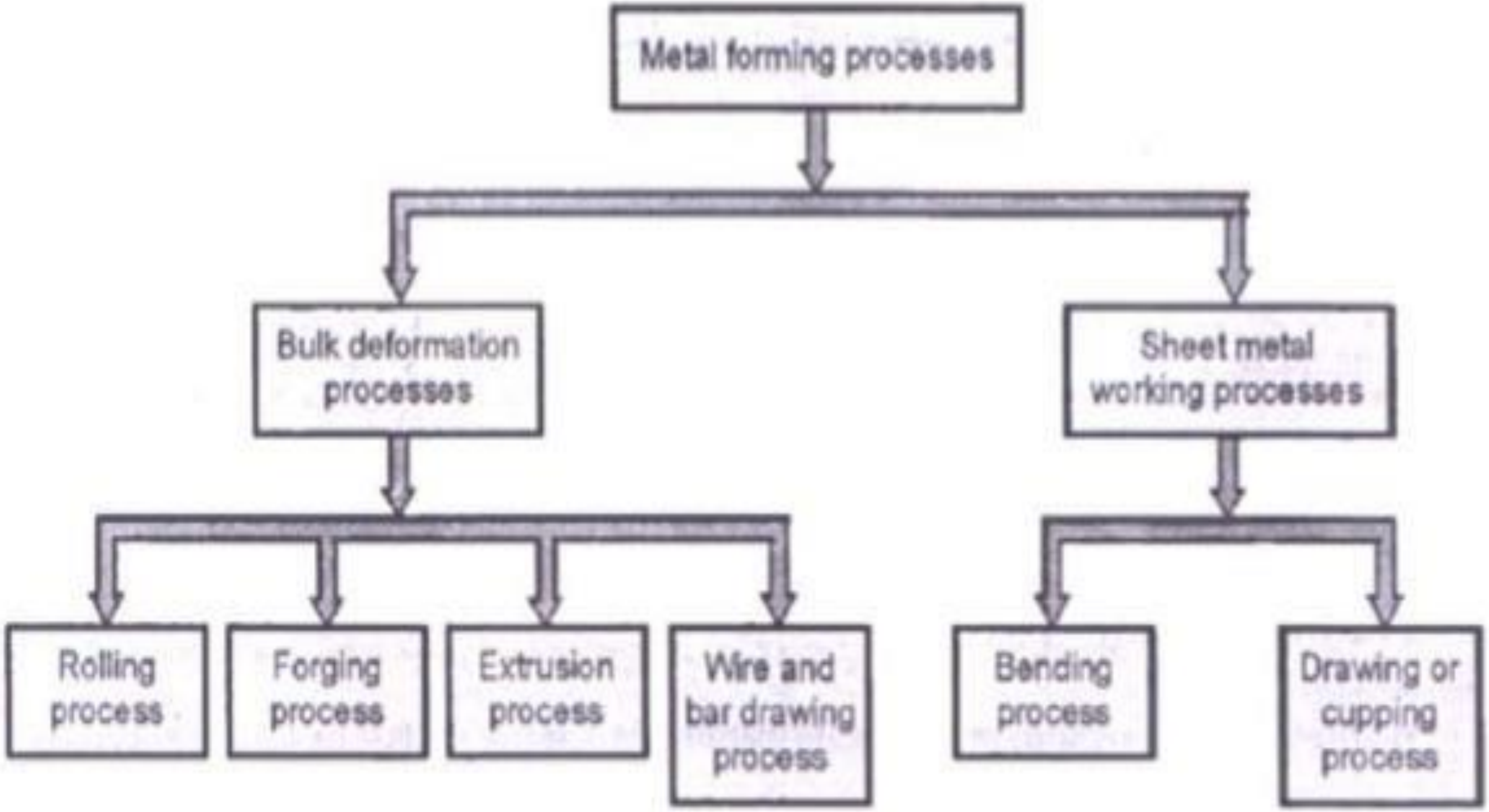
	resulting in improved mechanical properties.	
5.	No hardening of metal takes place.	Metal gets work hardened.
6.	If the process is properly performed, it does not affect ultimate tensile strength, hardness, corrosion and fatigue resistance of the metal.	It improves ultimate tensile strength, yield and fatigue strength but reduces corrosion resistance of the metal.
7.	It also improves some mechanical properties like impact strength and elongation	During the process, impact strength and elongation are reduced.
8.	Due to oxidation and scaling, poor surface finish is obtained.	Cold worked parts carry better surface finish.
9.	Close dimensional tolerances cannot be maintained.	Superior dimensional accuracy can be obtained.
10.	Hot working is most preferred where heavy deformation is required.	Cold working is preferred where work hardening is required.

Metal Forming

- ➢ Metal forming includes a large number of manufacturing processes in which plastic deformation property is used to change the shape and size of metal work pieces.
- During the process, for deformation purpose, a tool is used which is called as die. It applies stresses to the material to exceed the yield strength of the metal.
- ➢ Due to this the metal deforms into the shape of the die. Generally, the stresses applied to deform the metal plastically are compressive.

Metal Forming

- But, in some forming processes metal stretches, bends or shear stresses are also applied to the metal. For better forming of metal, the desirable properties of metal are low yield strength and high ductility.
- These properties are highly affected by the temperature. When the temperature of the metal is increased, its ductility increases and yield strength decreases.
- The other factors which affect the performance of metal forming process are, strain rate, friction, lubrication, etc.



Classification of metal forming processes Types of Rolling Mills

According to the number and arrangement of the rolls, rolling mills are classified as follow:

1. Two-high rolling mill

2. Three-high rolling mill
3. Four-high rolling mill
4. Tandem rolling mill
5. Cluster rolling mill
6. Planetary rolling mill
7. Universal rolling mill

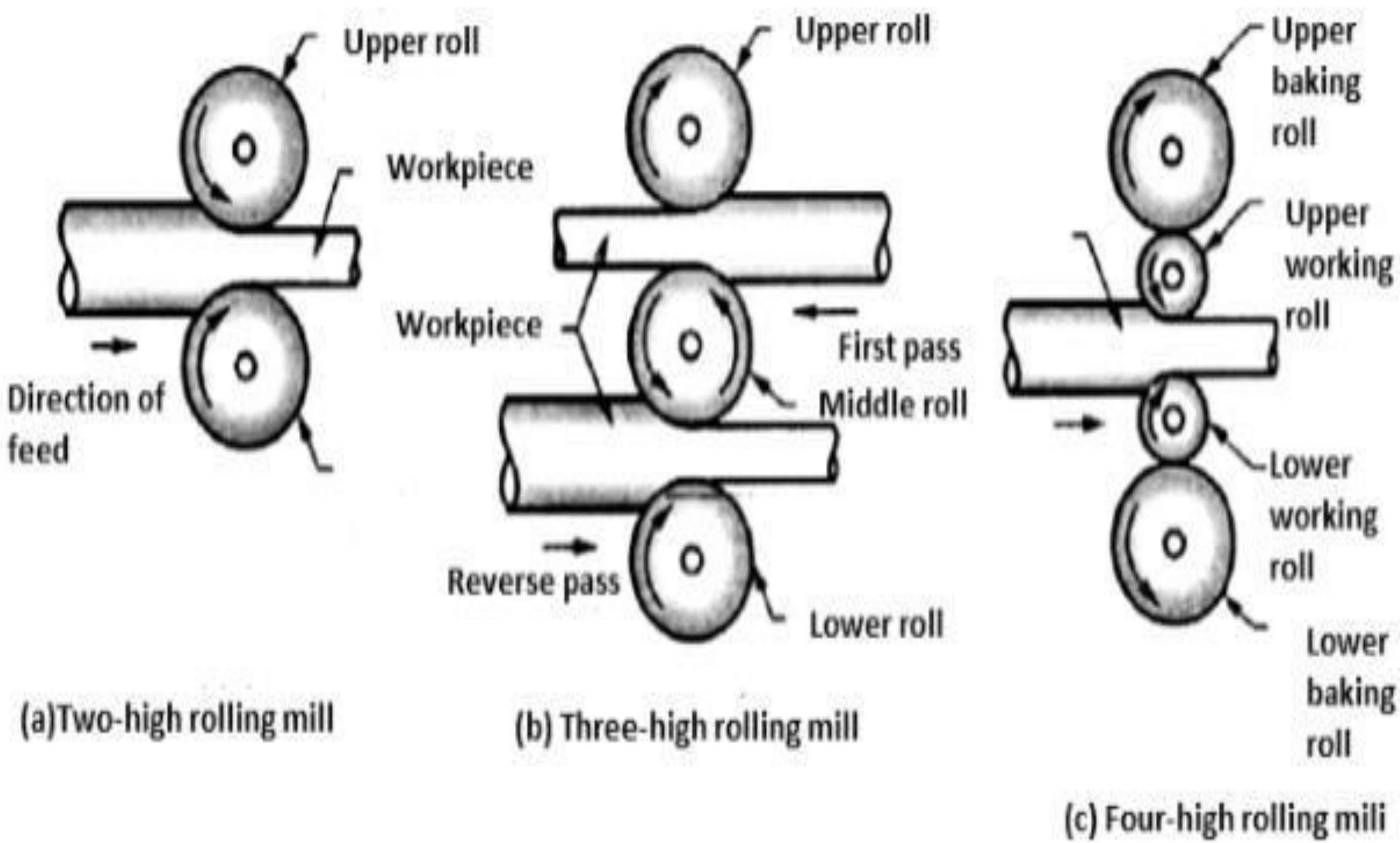


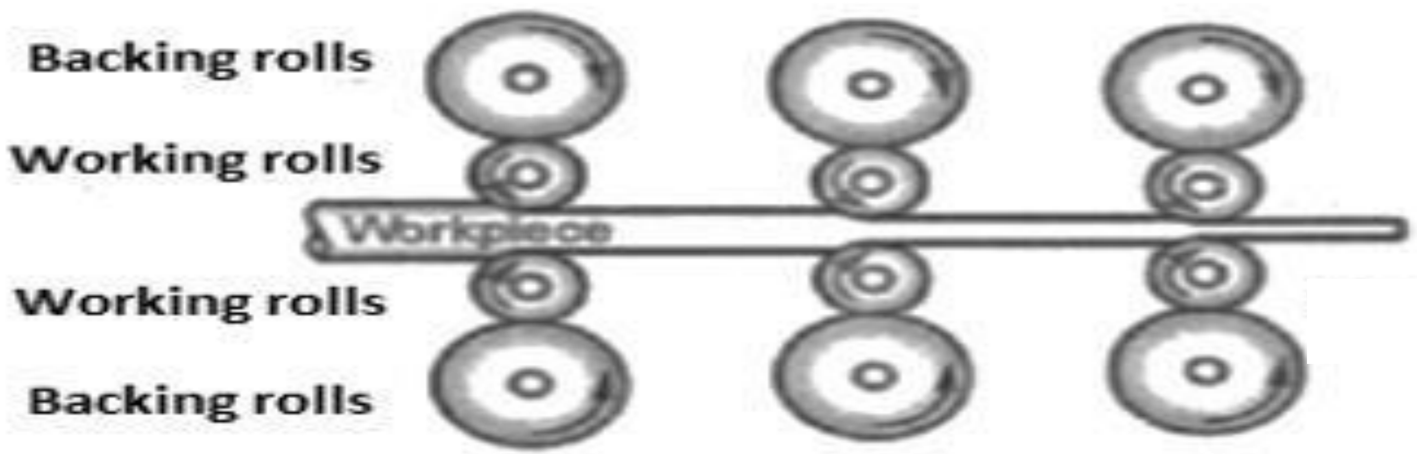
Fig. 4.8: Types of rolling mills

4. Tandem rolling mill:

 It is a set of two or three stands of rolls set in parallel alignment.

 This facilitates a continuous pass through each one successively without change of direction of the metal or pause in the rolling process.

 Fig. 4.8 (d) shows the tandem rolling mill.



(d) Tandem rolling mill

5. Cluster rolling mill:

 It is a special type of four-high rolling mill.

In this, each of the two working rolls is backed up by two or more of the larger backup rolls. Refer Fig. 4.8 (e). For rolling hard thin materials, it is necessary to employ work rolls of very small diameter but of considerable length. In such cases, adequate support of the working rolls can be obtained

6. Planetary rolling mill:

For the rolling arrangements requiring large reduction, a number of free rotating wheels are used instead of a single small roll.

Planetary mill consists of a pair of heavy backing rolls surrounded by a large number of planetary rolls. Refer Fig. 4.8 (f).

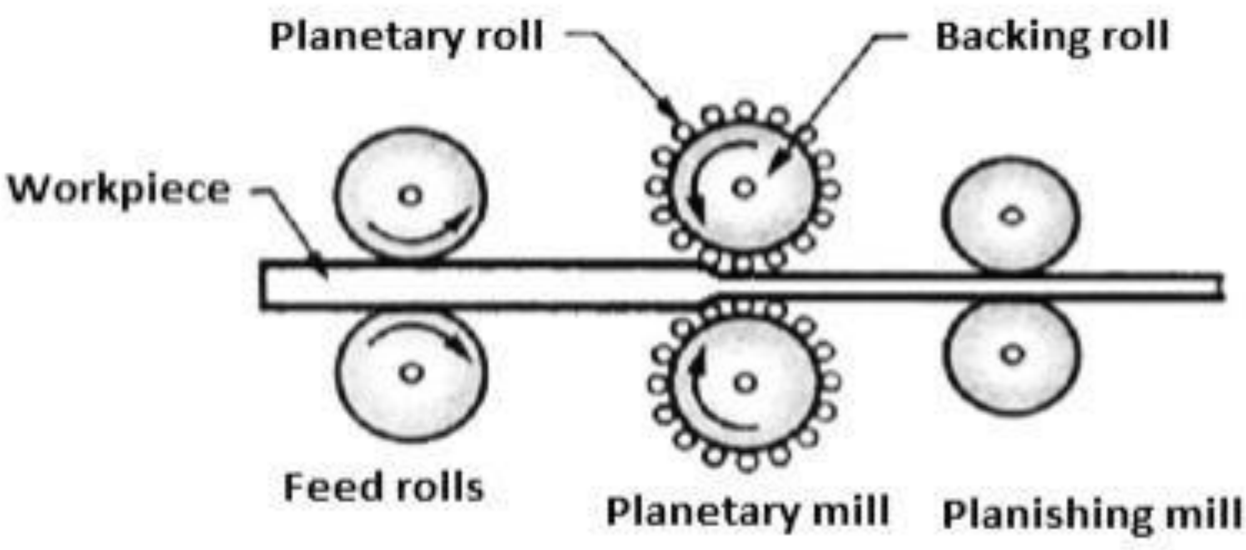


Fig. 4.8 (f): Planetary rolling mill

7. Universal rolling mill:

 In this type of rolling mill, the metal is reduced by both horizontal and vertical rolls. − Refer Fig. 4.15 (g).

 The vertical rolls are mounted either on one side or on both sides of horizontal roll stand which makes the edges of bar even and smooth.

 The horizontal rolls may be either two-high, three-high or four-high arrangement

Principle of Roll Pass

➢ In addition to flat rolling, different shapes can be produced by shape rolling.

➢ Straight and long structural shapes like solid bars of different cross-sections, channels, − I-beams, rails, etc. are produced by passing the stock through specially designed rolls.

 The shape cut into one roll is called as groove and the shape formed when the grooves of

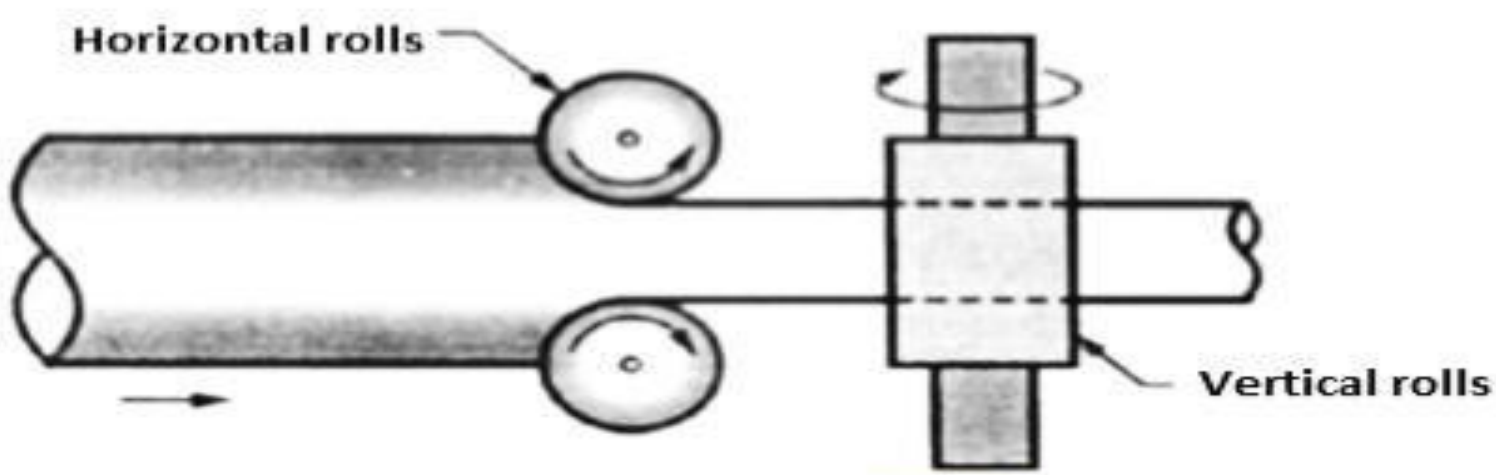


Fig. 4.8 (f): Universal rolling mill

the mating rolls are matched together is called as pass.

Principle of Roll Pass

- As the materials cross-section is to be reduced nonuniformly, the design of series of rolls requires considerable experience to avoid external and internal defects.
- By rolling the metal consequently through the passes, the initial square or rectangular cross section of the ingot (bloom or billet) can be gradually changed to produce a bar of final desired shape.
- As per the designation, passes are divided into the following three groups :

a. Roughing or breakdown or roll down passes

b. Leader passes

c. Finishing passes

Cold Rolling

- Cold rolling is used for producing bars of all shapes, rods, sheets and strips.
- Cold rolling is generally employed for providing a smooth and bright surface finish to the previously hot rolled steel. It is used to finish the hot rolled components, to close tolerances and improve their hardness and toughness. Before cold rolling, the hot rolled articles are cleaned through pickling and other operations.

The same types of rolling mills, as in hot rolling, are used for cold rolling. The part being rolled is generally annealed and pickled before the final pass is made, so as to bring it to accurate size and obtain a perfectly clean surface.

Comparison between Hot Rolling and Cold Rolling

Sr. No.	Hot rolling	Cold rolling
1.	Metal is fed into the rolls after being heated above recrystallisation temperature.	Metal is fed into the rolls when its temperature is below recrystallisation temperature.
2.	Hot rolled metal does not show work hardening effect.	Cold rolled metal shows work hardening effect.
3.	Coefficient of friction between the rolls and stock is higher.	Coefficient of friction between rolls and stock is relatively lower.
4.	Heavy reduction is cross-sectional area is possible.	Heavy reduction in cross-sectional area is not possible.
5.	Close dimensional tolerances cannot be obtained.	Section dimensions can be finished to close tolerances.
6.	Very thin sections cannot be obtained.	Aluminum foils up to 0.02 mm can be made.
7.	Poor surface finish with scale on it.	Smooth and oxide free surface can be obtained.
8.	Roll radius is larger.	Roll radius is smaller.

Extrusion

 Extrusion is a compression process in which the work metal is forced to flow through a small opening which is called as die to produce a required cross-sectional shape. The extrusion process is similar to squeezing toothpaste or cream from a tube.

 Almost any solid or hollow cross-section may be produced by extrusion process.

 As the geometry of the die remains same during the operation, extruded parts have the same cross-section. During the process, a heated cylindrical billet is placed in the container and it is forced out through a steel die with the help of a ram or plunger.

Extrusion

 The products made by extrusion process are tubes, rods, railings for sliding doors, structural and architectural shapes, door and window frames, etc.

 Extrusion process is suitable for the non-ferrous alloys, steel alloys, non-ferrous metals, stainless steel, etc. Extrusion process is carried out on horizontal hydraulic press machines which are rated from 250 to 5500 tonnes in capacity.

Extrusion process is classified as follows :

1. According to physical configuration

a. Direct (Forward) extrusion

b. Indirect (Backward) extrusion

2. According to working temperature

a.Hot extrusion

b. Cold extrusion

Direct Extrusion

- Direct or forward hot extrusion is most widely used and the maximum numbers of extruded parts are produced by this method.
- Fig. 4.28 shows the direct extrusion process in which the raw material is a billet.
- A billet is heated to its forging temperature and fed into the machine chamber.
- Pressure is applied to the billet with the help of ram or plunger which forces the material through the die.
- The length of extruded part will depend on the billet size and cross-section of the die.

Direct Extrusion

- The extruded part is then cut to the required length. As the ram approaches the die, a small portion of billet remains which cannot be forced through the die opening. This extra portion is known as butt which is separated from the product at the end.
- When the billet is forced to flow through the die opening, there is friction between the work piece and chamber walls.

- This friction is overcome by providing additional ram force.

This is the major problem with this process.

- To overcome this problem oxide layer is provided on the billet or dummy block is used between the ram and billet.

Direct Extrusion

- Direct extrusion process is also used to produce hollow or semi-hollow sections.
- To produce hollow sections, by direct extrusion process, a mandrel is used. Refer Fig. 4.28
- When the billet is compressed, the material is forced to flow through the gap between the mandrel and die opening.

This results in tubular cross-section.

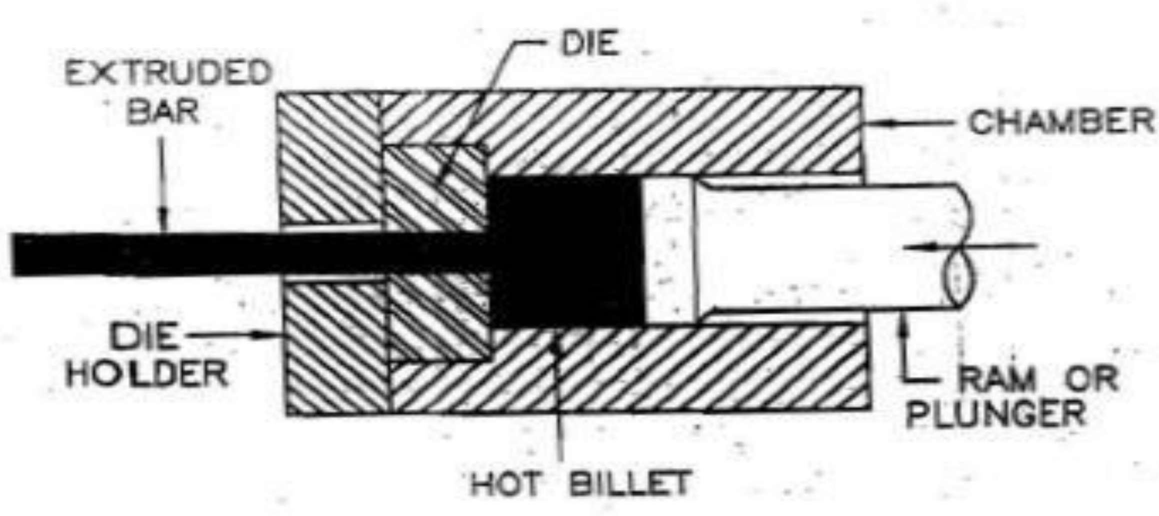


Fig. 4.28: Direct extrusion

Indirect Extrusion

□ Indirect extrusion is also called as backward extrusion. □ In this type, the ram or plunger used is hollow and as it presses the billet against the back wall of the closed chamber, the metal is extruded back into the plunger. Refer Fig. 4.29.

□ □ It involves no friction between the metal billet and the chamber because the billet does not move inside the chamber. As compared to direct extrusion, less total force is required in this method.

□ But the equipment used is mechanically complicated in order to support the passage of the extruded shape through the center of the hollow ram.

Indirect Extrusion

□ Indirect extrusion is also used to solid as well as hollow components. For producing solid parts ram is hollow whereas for producing hollow parts ram is solid.

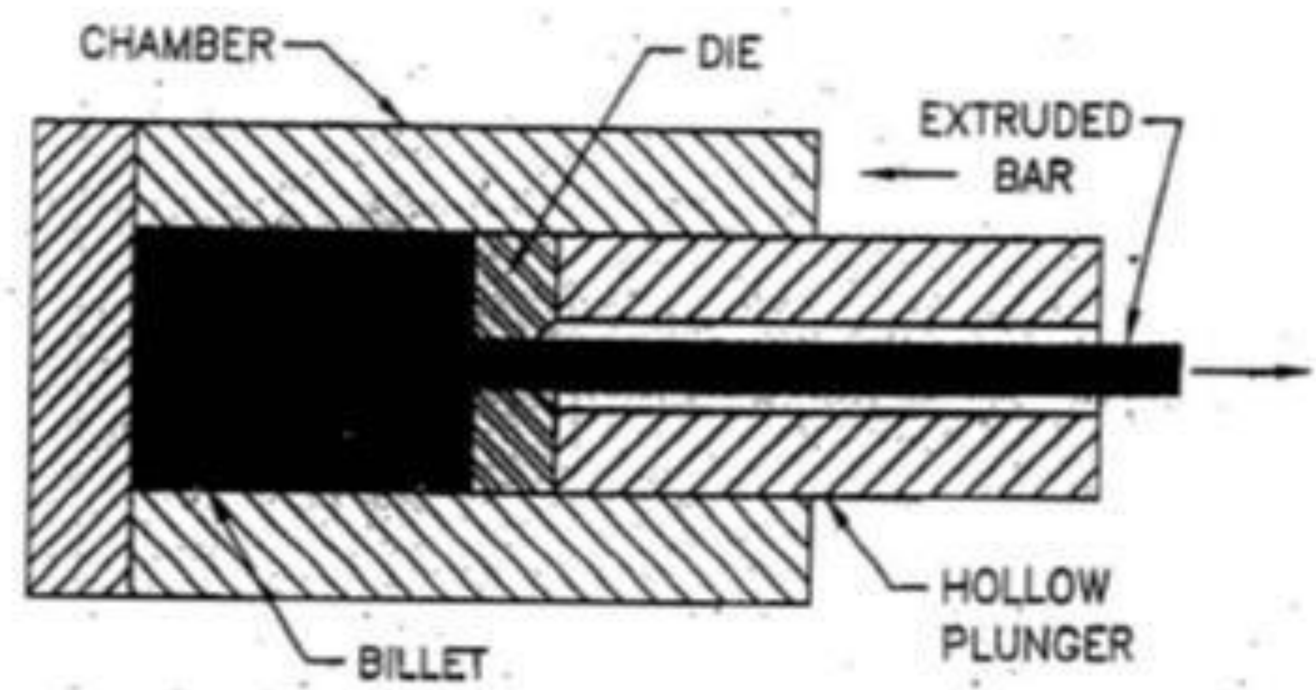


Fig. 4.29 : Indirect or backward or reverse extrusion

Cold Extrusion (Impact Extrusion)

 The most common cold extrusion process is impact extrusion.

 Various daily use products such as tubes for shaving creams, tooth paste and paints, condenser cans and such other thin walled products are impact extruded. The raw material is in slug form which have been turned from a bar or punched from a strip.

 By using punch and dies, the operation is performed. The slug is placed in the die and struck from top by the punch operating at high pressure and speed. Refer Fig. 4.30. The metal flows up along the surface of the punch, forming a cup shaped component

Cold Extrusion (Impact Extrusion)

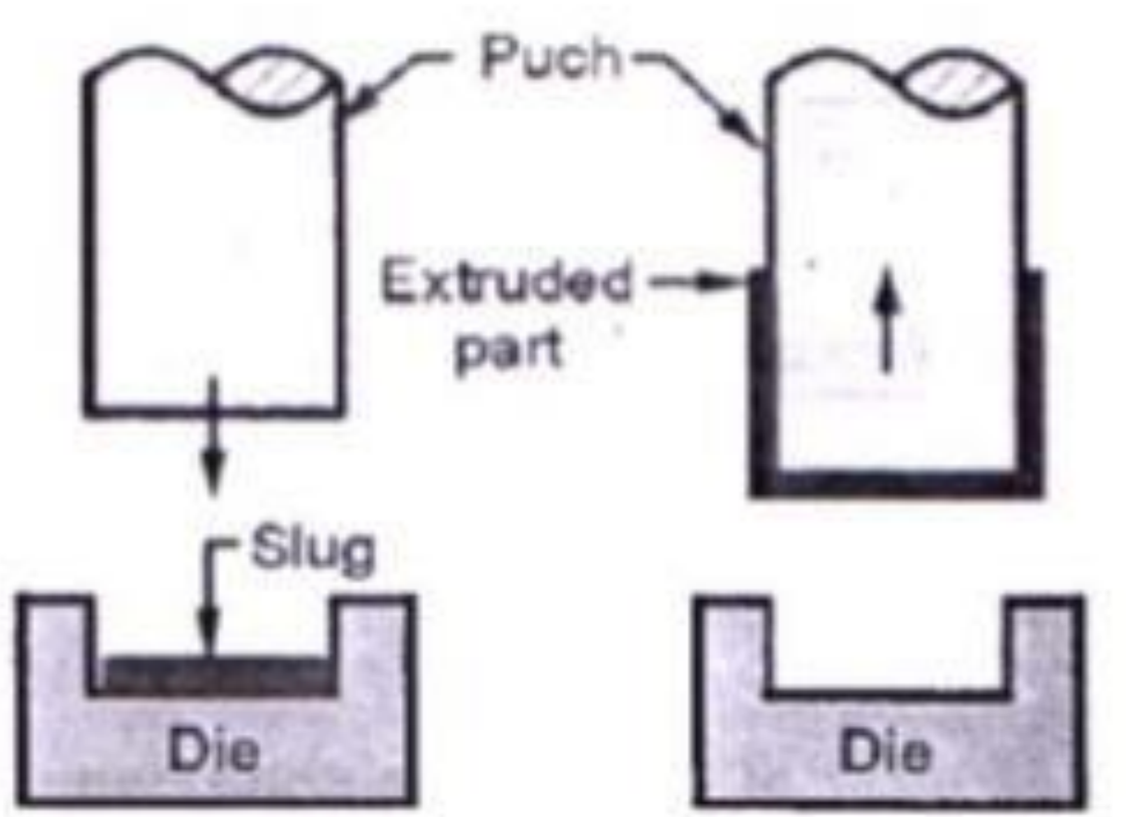


Fig. 4.30: Principle of impact extrusion

Cold Extrusion (Impact Extrusion)

 When the punch moves up, to separate the component from the punch compressed air is used.

- At the same time, a fresh slug is fed into the die.

The rate of production is fairly high i.e. 60 components per minute.

- This process is used only for soft and ductile materials such as lead, tin, aluminum, zinc and some of their alloys. The main advantages of this process are its speed, product uniformity and no wastage.

Hydrostatic Extrusion

In this type of extrusion process, the billet is surrounded by a working fluid which is pressurised by the ram to apply the extrusion force.

In this process, hydraulic fluid remains between the billet and the chamber walls hence eliminating the contact between them. Also, it avoids the friction between the metal billet and the walls of the chamber.

Fig. 4.31 shows the working principle of hydrostatic extrusion.

Due to absence of wall friction, extrusion of very long billets or even wires and large reductions can be taken.

Hydrostatic Extrusion

 During the process, the ram does not directly act on the billet, instead of that, it acts on the hydraulic fluid which forces the billet through the die and produces the extrusions. The materials which cannot be extruded successfully by conventional methods can be extruded by this process.

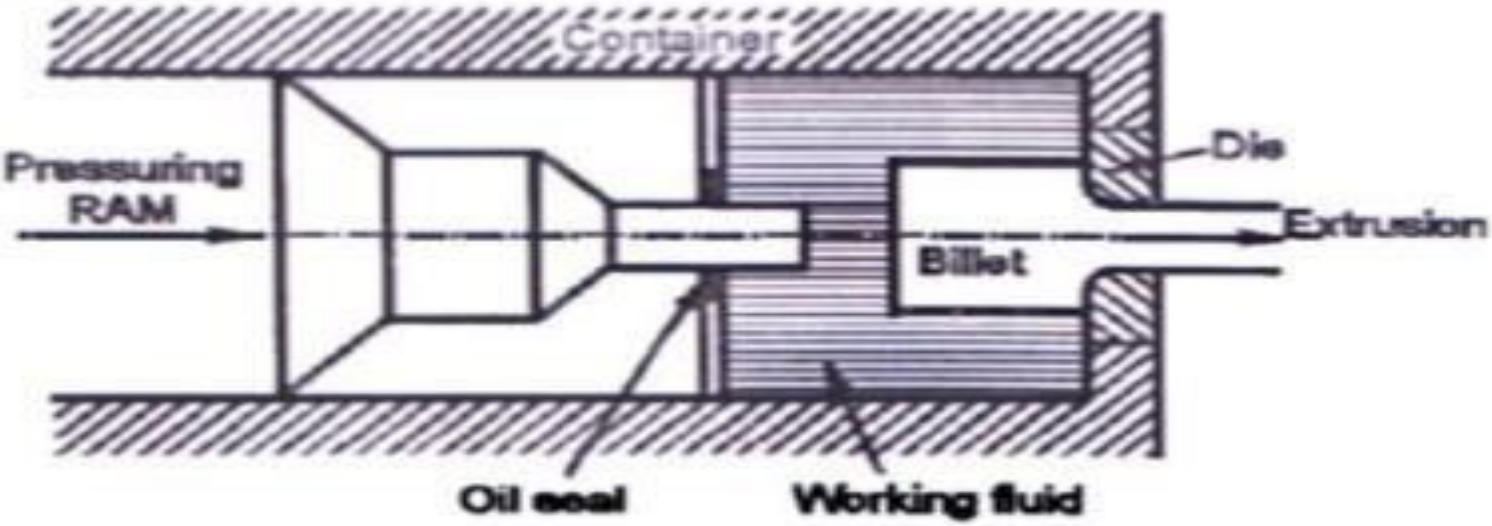


Fig. 4.31: Hydrostatic extrusion

Defects in Extrusion

Following are the three basic categories of extrusion defects : i. Center cracking ii. Surface cracking

iii. Piping defect

i. Center cracking

- It is commonly called as internal breakage, cheveron cracking, arrowhead fracture and center burst.
- As the work piece is being extruded from the die, stresses in the work break the material.
- It causes cracks to form along the central axis of extruded part.
- This defect occurs due to difference in metal flow of central region and outer region.

Defects in Extrusion ii.Surface cracking

- In surface cracking, excessive stresses on the surface of the extruded part cause the breakage on the surface. Refer Fig. 4.60.
- These cracks usually occur along the grain boundaries. – Surface cracking occurs due to high extrusion temperature, friction and speed.

iii. Piping defect

- Piping defect is commonly called as tail pipe or fish tailing defect and occurs during direct extrusion at the end opposite to the die.
- Piping defects results due to improper metal flow during the extrusion operation.
- A funnel shaped void of material at the end of the work is seen in this defect.

Wire Drawing

 Drawing is an operation in which the cross-section of a bar, rod or wire is reduced by pulling it through a die opening. The general features of the drawing process are similar to extrusion. But the difference is that, in drawing the work piece is pulled through the die whereas in extrusion work piece is pushed through the die.

- During the process, tensile as well as compressive stresses are produced in the material.
- The main difference between the bar drawing and wire drawing is the stock size(work piece size). Bar drawing is used for large diameter (bar and rod) stock whereas wire drawing is used for small diameter stock

Wire Drawing

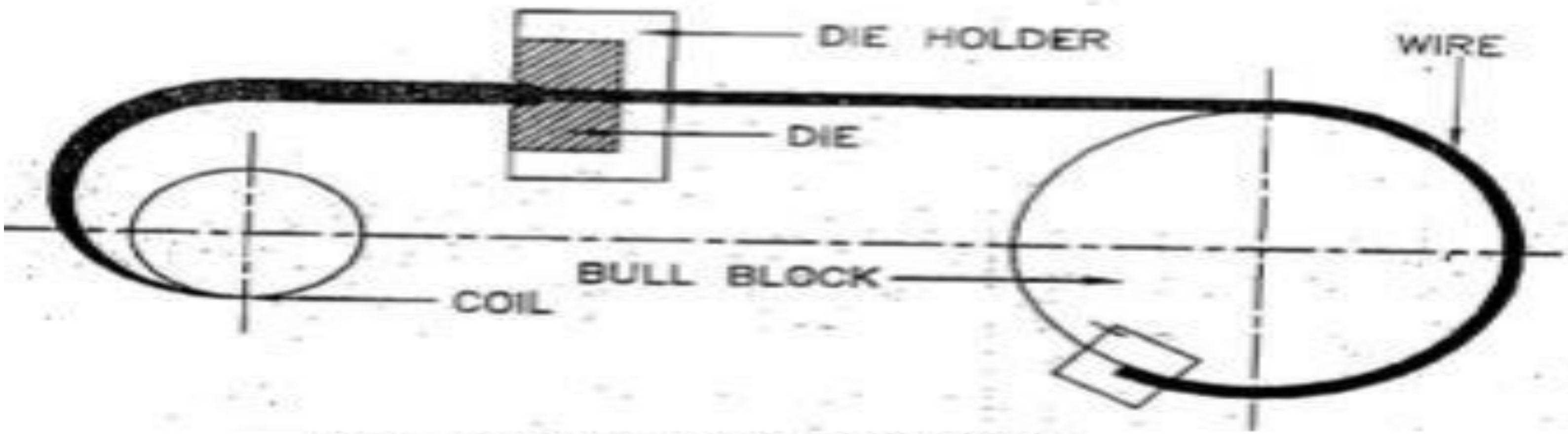


Fig. 4.32(a) : Wire drawing

 Wire sizes upto 0.03 mm can be drawn by wire drawing process.

 The process consists of pulling the hot drawn bar or rod through a die of which the bore size is similar to the finished product size. Depending upon the material to be drawn and the amount of reduction required, total drawing can be accomplished in a single die or in a series of successive dies.

Wire Drawing

□□ One end of the rod to be drawn into wire is made pointed, entered through the die and gripped at the other end by using tongs

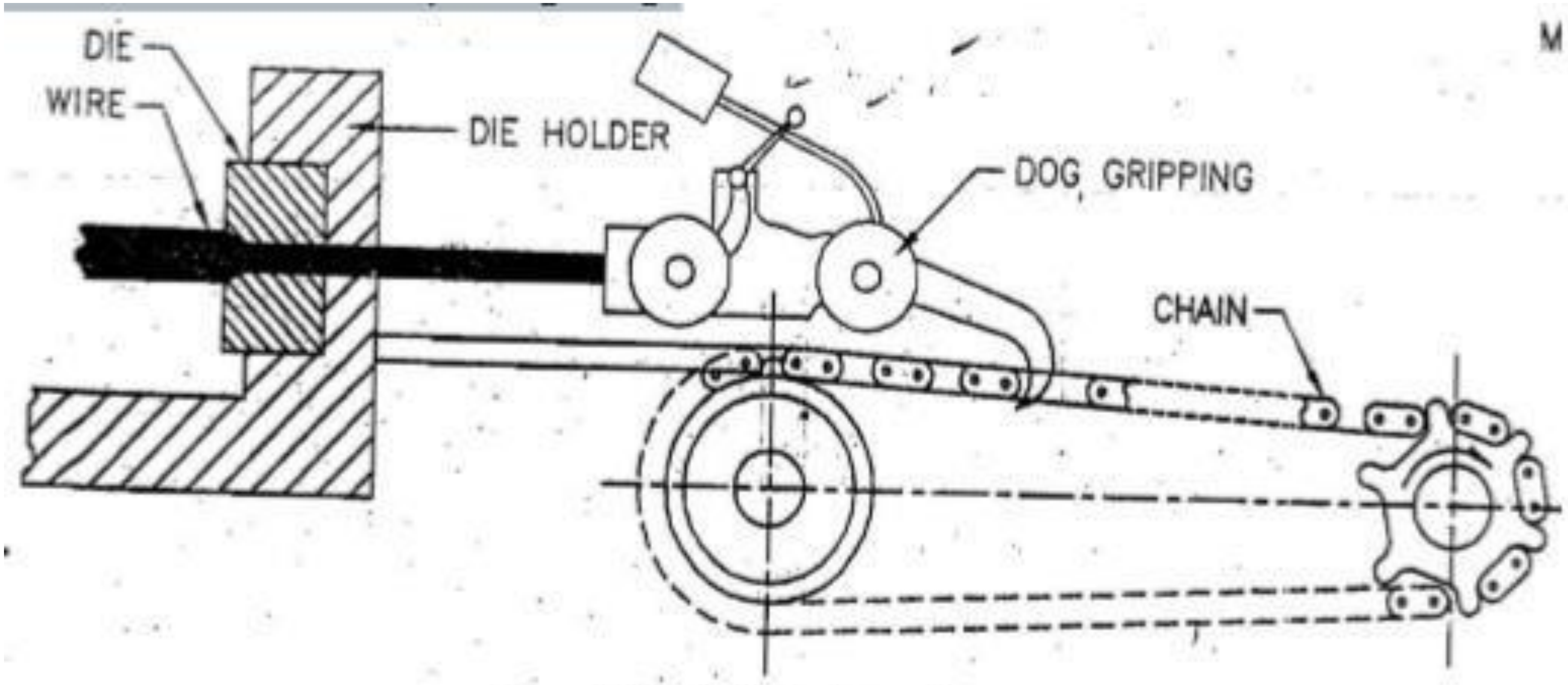


Fig. 4.32(b): Wire drawing

Wire Drawing

□□ After pulling a certain length, this end is wound to a reel or draw pulley.

□ When the pulley or reel is rotated, the rod is pulled through the die and its diameter reduces.

□ Refer Fig. 4.32 (a) & (b)

 The die is made of highly wear resistant material.

 Generally, tungsten carbide is used for die making.

 The die made of tungsten carbide is suitably supported in a die holder which is made of mild steel or brass.

Tube Drawing

 As the initial tubing has been produced by other processes like extrusion, drawing can be used to reduce the diameter or wall thickness of seamless tubes and pipes.

 Tube drawing can be carried out either with mandrel or without mandrel

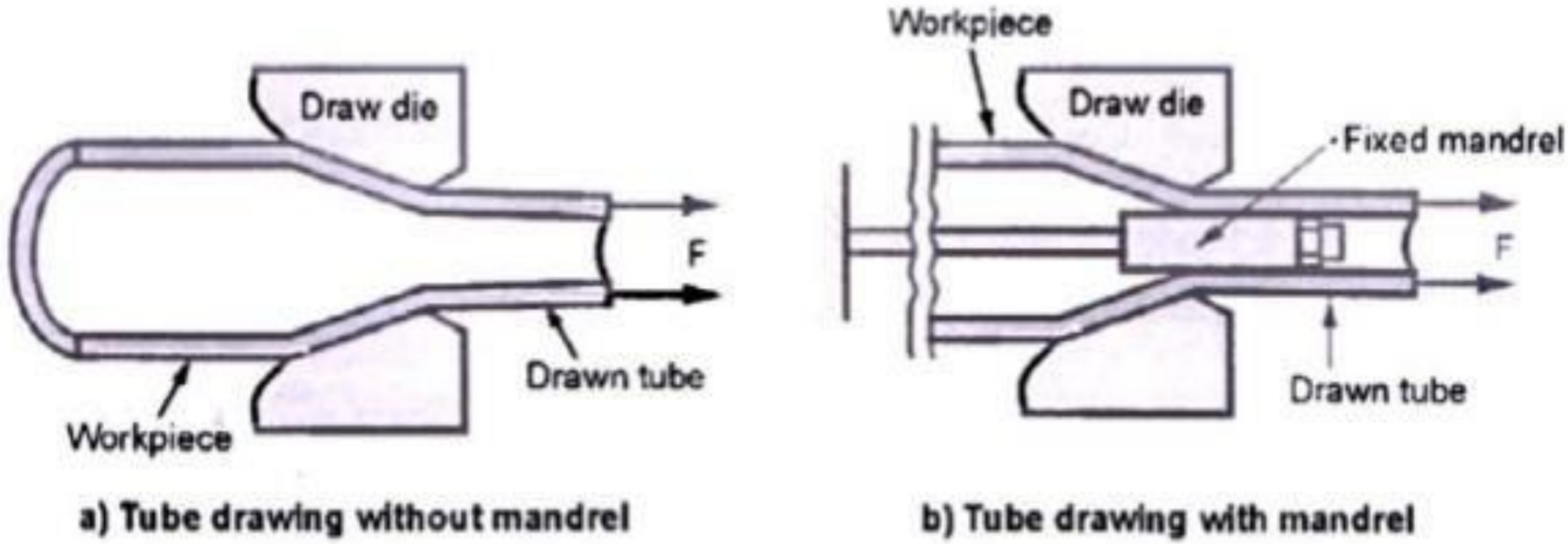


Fig. 4.33: Tube drawing

Tube Drawing

 The simplest method of producing tubes and pipes is shown in Fig. 4.65 (a) in which mandrel is not used. This method is also called as tube sinking.

➢ In tube sinking method there is no control over the inner diameter and wall thickness of tube.

 To overcome this drawback, mandrels are used in the process

➢ Fig. 4.33(b) shows tube drawing with mandrel. In this method, mandrel is fixed and attached to a long support bar to produce inside diameter and wall thickness during the process.

DEPARTMENT : MECHANICAL ENGINEERING

YEAR & SEM : II-I SEM

SUBJECT : MANUFACTURING PROCESS

SUBJECT CODE : (19A03301T)

PREPARED BY : V V ANANTHA CHAKRAVARTHY

UNIT III : Metal Joining Processes

- Classification of welding processes,
- Types of welding
- Welded joints and V-I characteristics,
- Arc welding,
- Weld bead geometry
- Submerged arc welding. applications, advantages and disadvantages
- Gas tungsten. applications, advantages and disadvantages Gas metal arc welding applications. applications, advantages and disadvantages
- Fabrication processes

- Heat affected zones in welding
- soldering
- Types of soldering and their applications
- brazing
- Types of brazing and their applications
- Types and their applications
- Welding defects
- Causes and remedies

Welding :

Welding is a process of joining similar

metals by application of heat with or without application of pressure and additional of filler material.

Welding joints different metals/alloys. In

welding heat is supplied either electrically or by means of a gas torch.

Advantages

- Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.) Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.

 Large number of metals and alloys both similar and dissimilar can be joined by welding.

- General welding equipment is not very costly.

- Portable welding equipment can be easily made available.

 Welding permits considerable freedom in design. Welding can join welding jobs through spots, as continuous pressure tight seams, end to-end and in a number of other configurations.

- Welding can also be mechanized.

Disadvantages

 It results in residual stresses and distortion of the work pieces.

 Welded joint needs stress relieving and heat treatment. Welding gives out harmful radiations (light), fumes and spatter.

- Jigs, and fixtures may also be needed to hold and position the parts to be welded
- Edges preparation of the welding jobs are required before welding

 Skilled welder is required for production of good welding Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

Types of welding

There are two types of welding: 1) Plastic welding

2) Fusion welding

1) Plastic welding (Pressure welding)

2)Fusion welding (Non-pressure)

Classification of welding

1.Gas welding

a. Oxy-acetylene

b. Air-acetylene

c. Oxy-hydrogen

2. Arc welding

a. Carbon arc welding

b. Plasma arc welding

c. Submerged arc welding

d. Metal arc

e. Electro-slag

f. Flux-cored

g. Gas-metal arc(MIG)

h. Gas-tungsten arc (TIG)

i. Atomic-hydrogen arc

Classification of welding 3. Resistance welding

a. Butt

b. Projection

c. Spot

d. Percussion

e. Seam

4. Thermit welding

5. Solid state welding

a. Friction

b. Explosive

c. Ultrasonic

d.Diffusion

6. Newer welding (Radiant Energy welding)

a. Electro-beam

b. Laser

Gas welding

A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen) mixture is usually referred as ‘gas welding’.

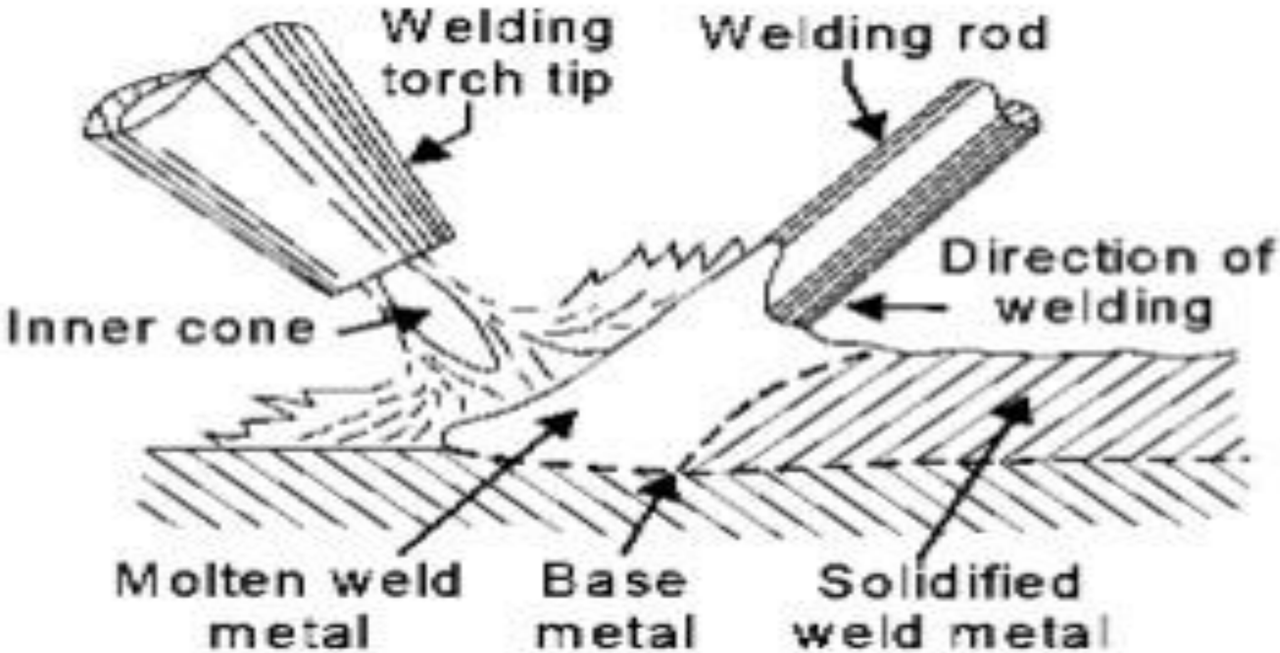


Figure 3.1 Gas welding

Gas welding

 The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal.

 The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature

  Oxy-acetylene flame is themost versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases.

Oxy-acetylene welding

  In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.

 The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and nonferrous metals in common use.

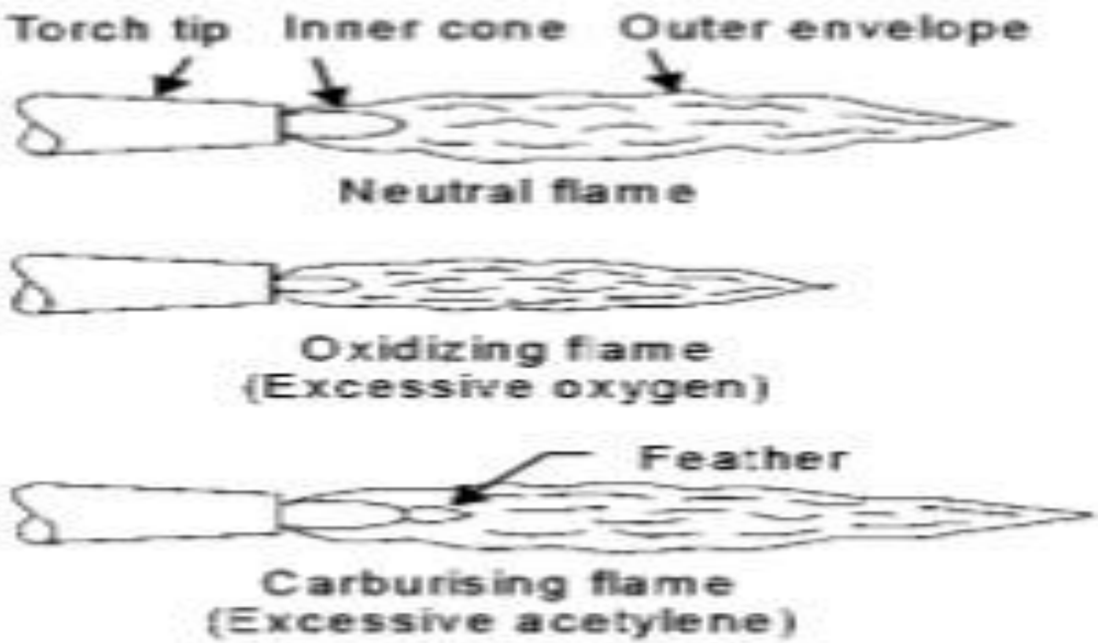
 A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

Types of flame

a. Neutral flame

b. Carburizing flame

c. Oxidizing flame



- *Figure 3.2 Oxy-Acetylene gas flames*

Design of Welded Joint:

The details of a joint, which includes both the geometry and the required dimensions, are called the joint design.

Just what type of joint design is

best suited for a particular job depends on many factors. Although welded joints are designed primarily to meet strength and safety requirements, there are other factors that must be considered.

Design of Welded Joint:

- A few of these factors areas follows: Whether the load will be in tension or compression and whether bending, fatigue, or impact stresses will be applied
- How a load will be applied; that is, whether the load will be steady, sudden, or variable
- The direction of the load as applied to the joint
- The cost of preparing the joint

- Another consideration that must be made is the ratio of the strength of the joint compared to the strength of the base metal.
- This ratio is called joint efficiency.
- An efficient joint is one that is just as strong as the base metal.

Design of Welded Joint:

- Normally, the joint design is determined by a designer or engineer and is included in the project plans and specifications.
- Even so, understanding the joint design for a weld enables you to produce better welds. Earlier in this chapter,
- We discussed the five basic types of welded joints—butt, corner, tee, lap, and edge. While there are many variations, every joint you weld will be one of these basic types.
- Now, we will consider some of the variations of the welded joint designs and the efficiency of the joints.

Design of Welded Joint:

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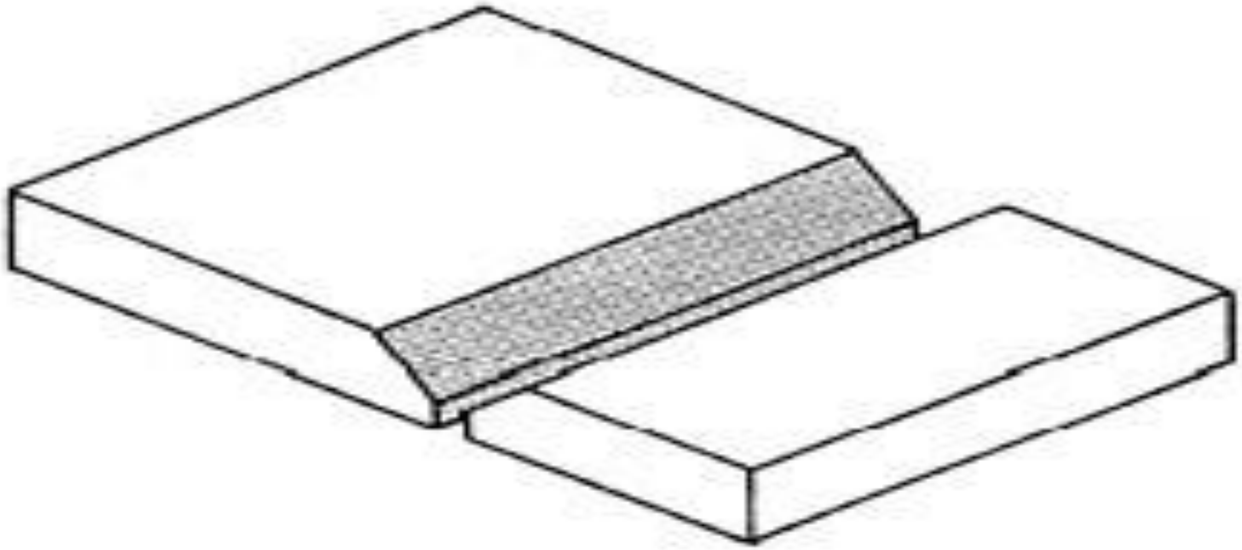
- Now, we will consider some of the variations of the welded joint designs and the efficiency of the joints.

1 BUTT JOINTS



Figure—Butt joints.

1 .BUTT JOINTS:

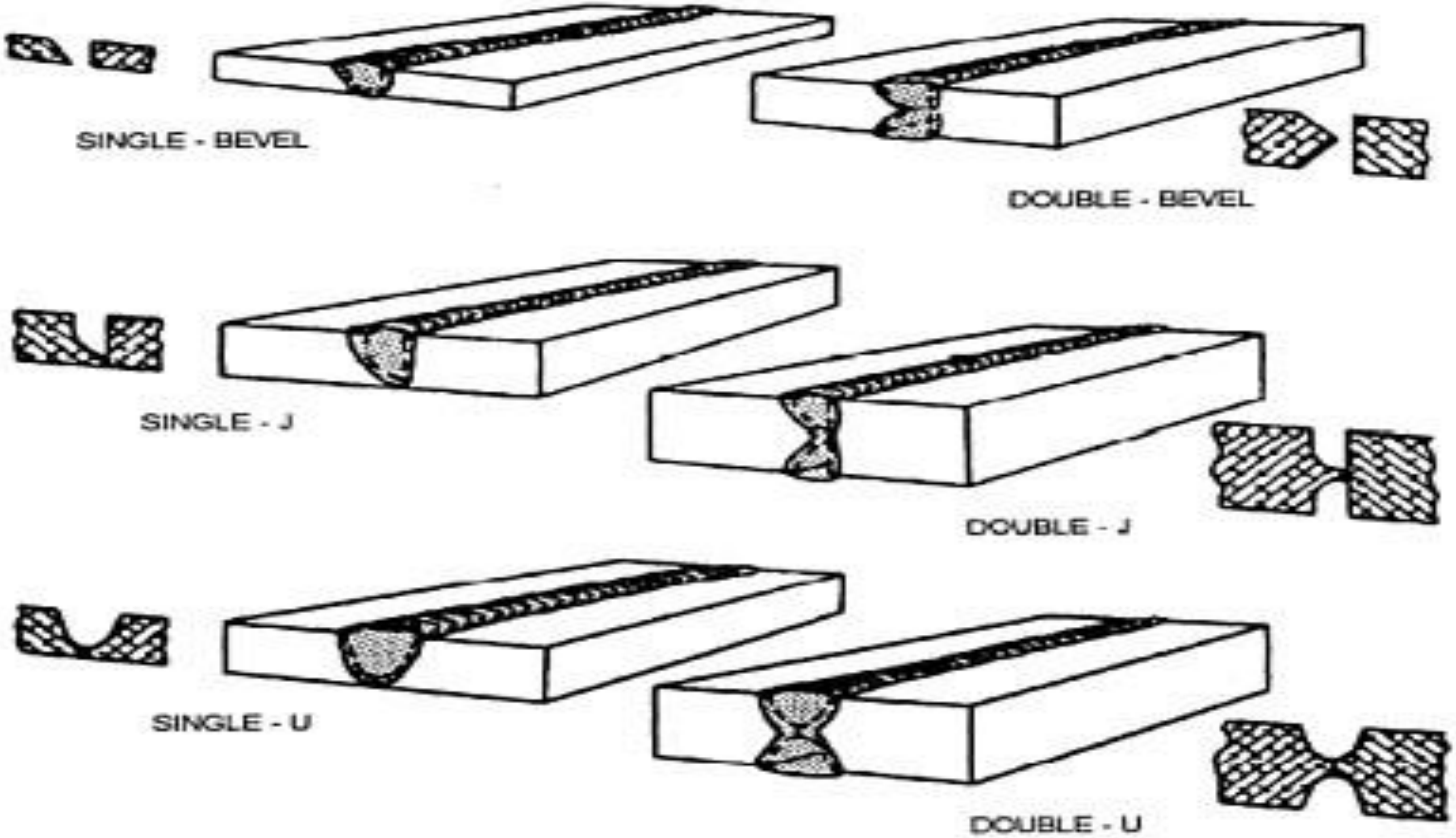
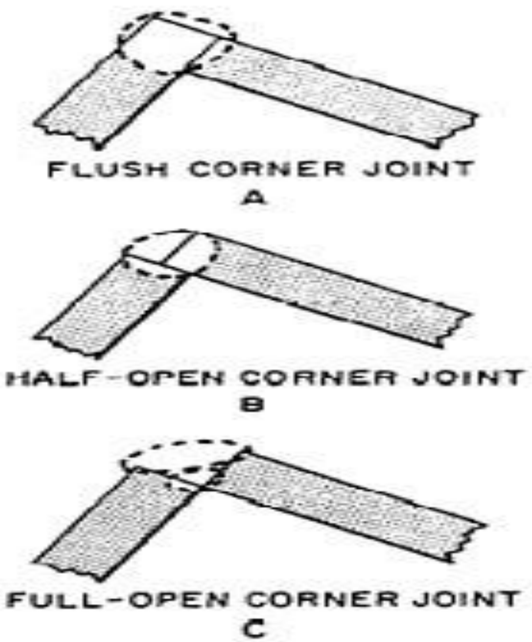
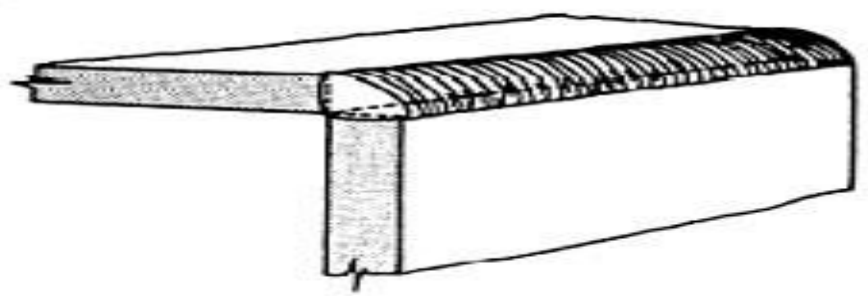

SINGLE - BEVEL
DOUBLE - BEVEL
SINGLE - J
DOUBLE - J
SINGLE - U
DOUBLE - U

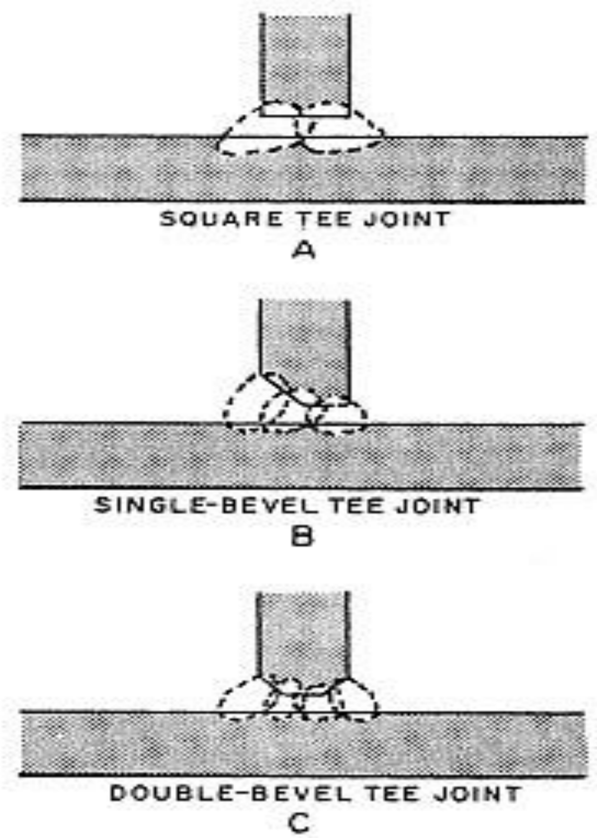
Figure —Additiona1 types of groove welds.

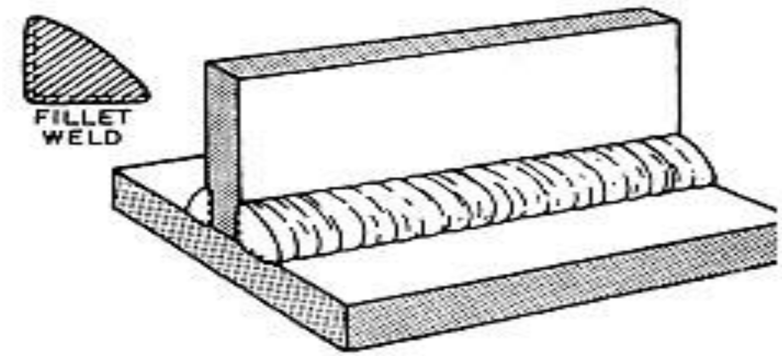
CORNER JOINTS:



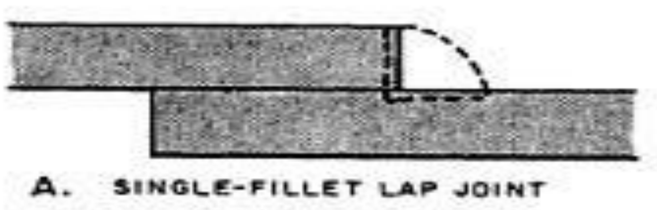


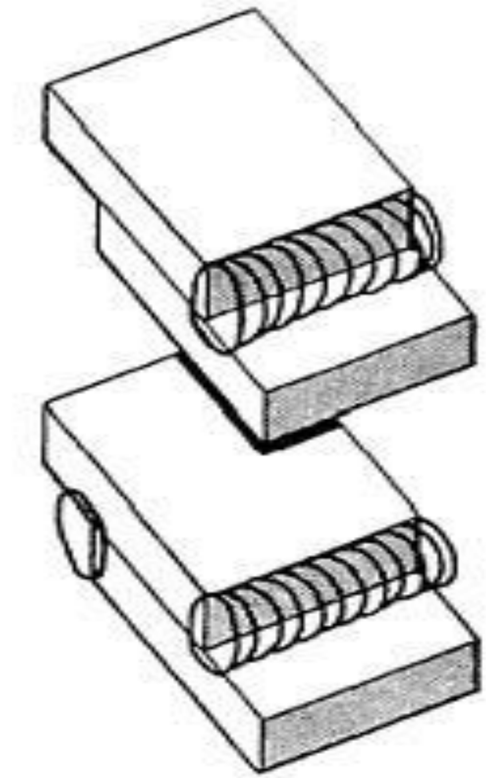
TEE JOINTS:


SQUARE TEE JOINT
A
SINGLE-BEVEL TEE JOINT
B
DOUBLE-BEVEL TEE JOINT
C


FILLET
WELD

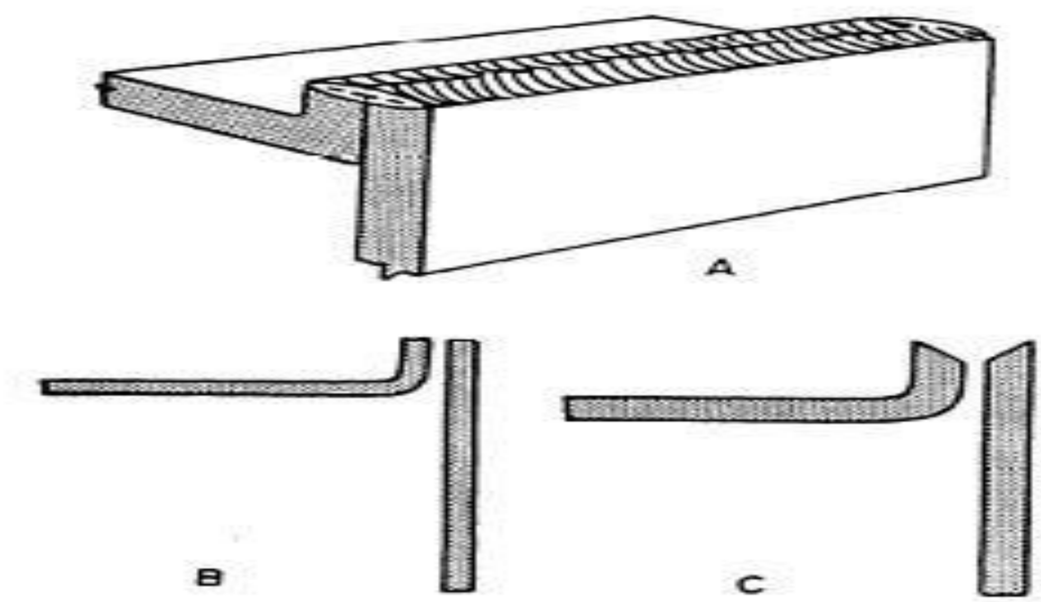
LAP JOINTS:





5 EDGE JOINTS:

The flanged edge joint is suitable for plate 1/4 inch or less in thickness and can only sustain light loads. Edge preparation for this joint may be done, as shown in either views B or C.



Figure—Flanged edge Joints.

Position of welding

a.Horizontal welding

b.Vertical welding

c.Overhead welding

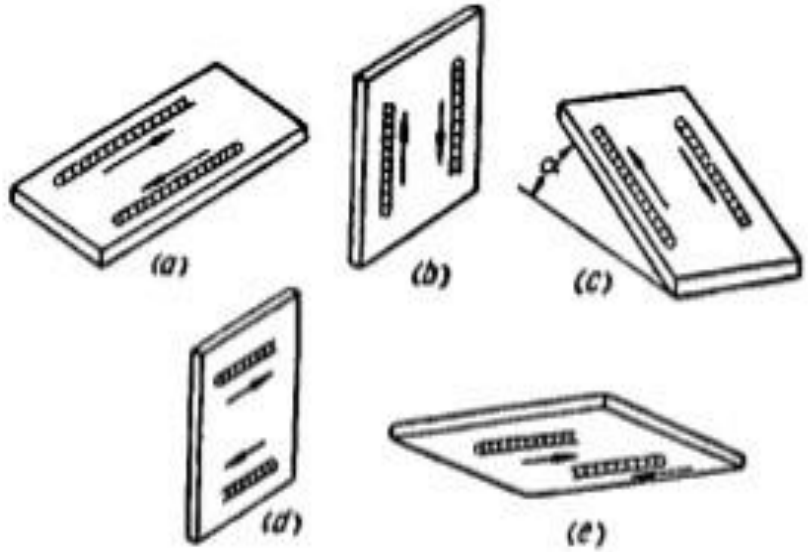


Figure 3.3 Position of welding

(a)Horizontal welding (b) Vertical welding (c) Inclined welding (d) Horizontal welding in vertical direction (e) overhead welding

Techniques of welding

a.Leftward (Forward) welding technique

b.Rightward (Backward) welding technique

c.Vertical welding

a.Leftward (Forward) welding technique

 In this technique, the welder holds welding torch in his right hand and filler rod in left hand.

 The welding flame is directed from right to left as shown in figure

 The welding torch should be given a small sideways movement and the filler rod should be moved steadily without sideways movement.

  The welding torch held at 60^0 to 70^0 to the weld plane and the filler rod at 30^o to 40^0.

Techniques of welding

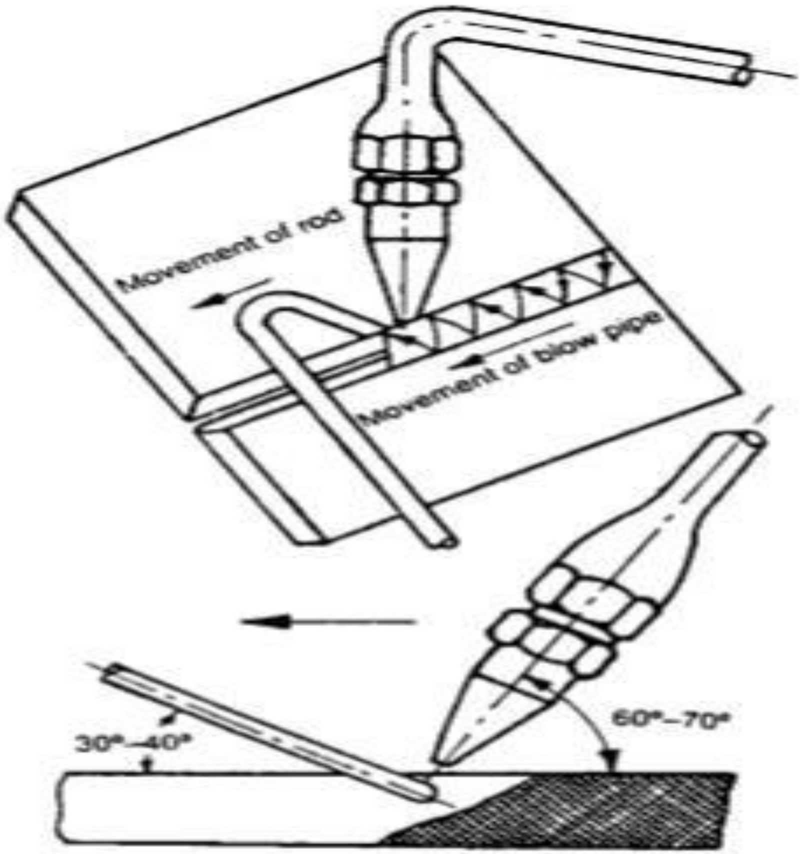


Figure 3.4 Left ward welding

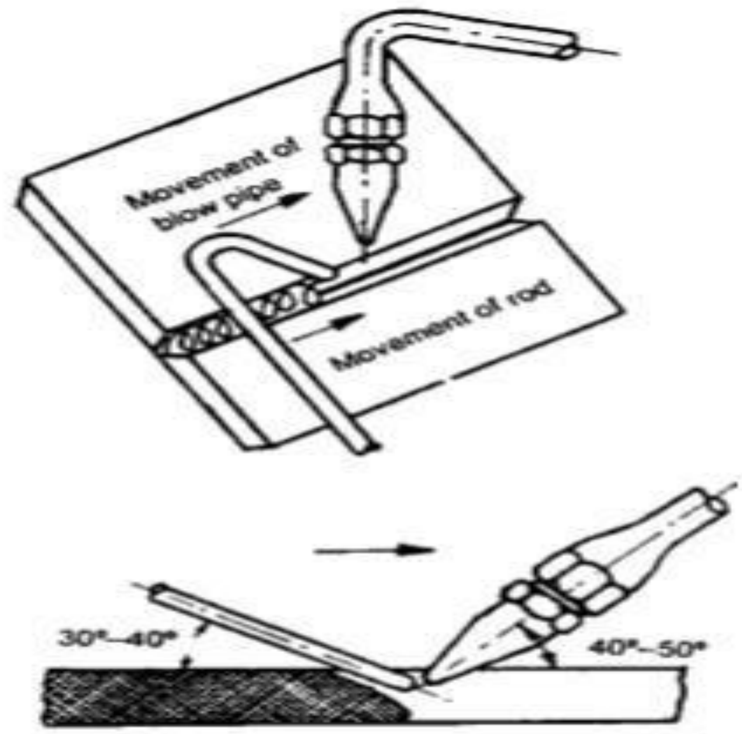


Figure 3.5 Right ward welding

Techniques of welding

b.Rightward (Backward) welding technique

 In this technique, the welder holds welding torch in his left hand and filler rod in right hand.

  The welding flame is directed from left right to as shown in figure

 The welding torch has no lateral movement.

 The welding torch held at $40^0$to$50^0$to the weld plane and the filler rod at 30^0to40^0.

Techniques of welding

 The method is more advantageous for plate thickness of 6 mm and above.

 In this, the welder starts at the bottom of the welded joint and gives oscillating movement to the welding torch which points slightly upwards.

 It can be done by one or two operator.

Vertical welding

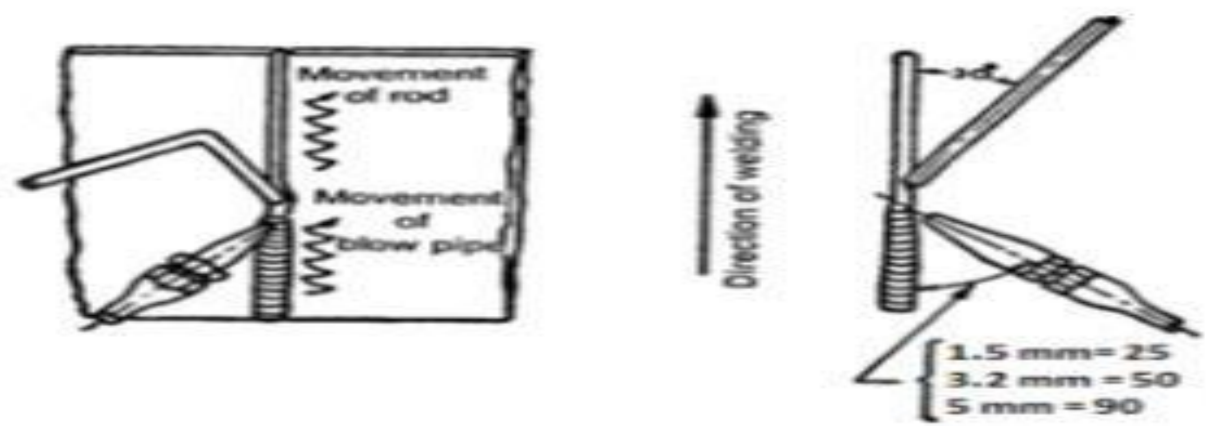


Figure 3.6 vertical welding

 In case of single operator technique, the angle between the welding torch and plate increases as the plate thickness increases.

Welding Equipment

a.Cylinder

b.Gas pressure regulators

c.Welding torch

d.Torch tips

e.Hose pipes

f.Goggles

g.Gloves

h.Spark lighter

i.Filler rods

j.Flux

Welding Equipment a.Cylinder

 Fragile discs and fusible plugs are usually provided in the cylinders valves in case it is subjected to danger.

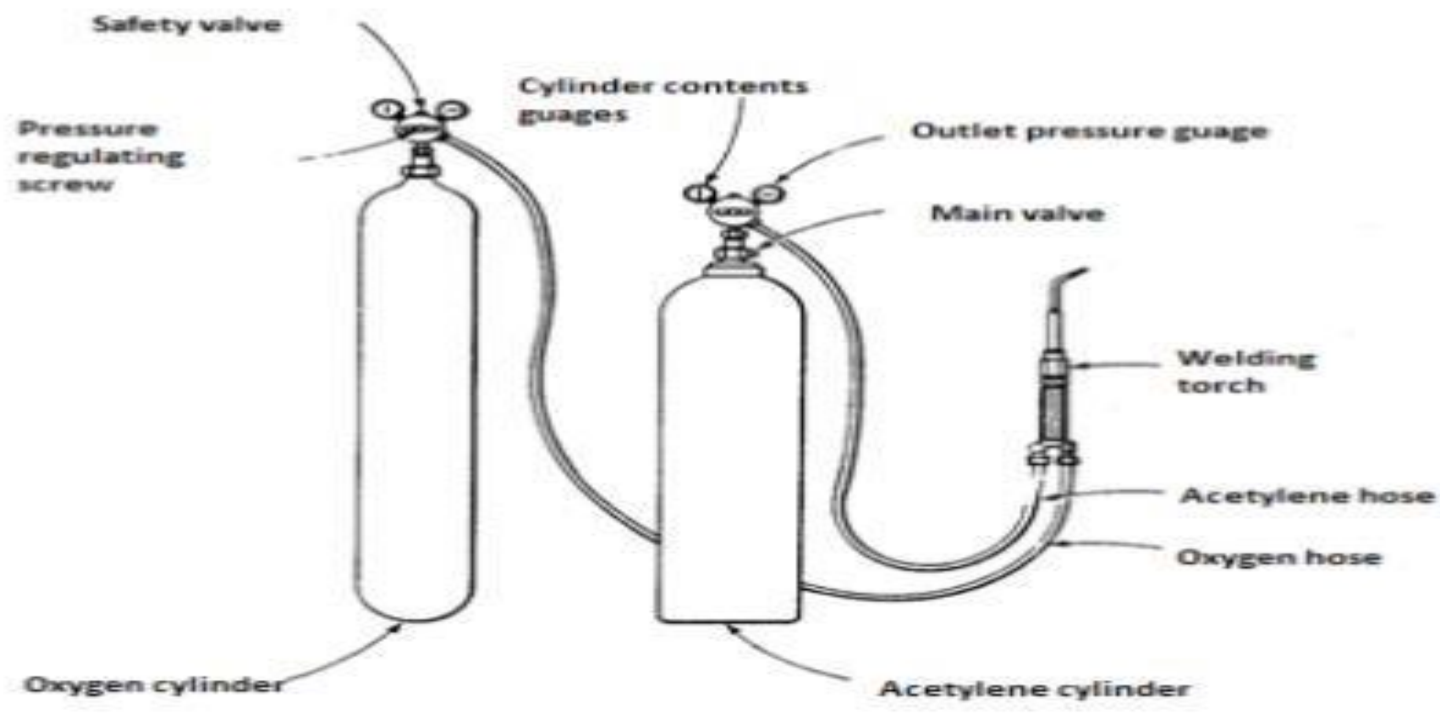


Figure 3.7 Oxy-Acetylene welding set

Welding Equipment Welding torch

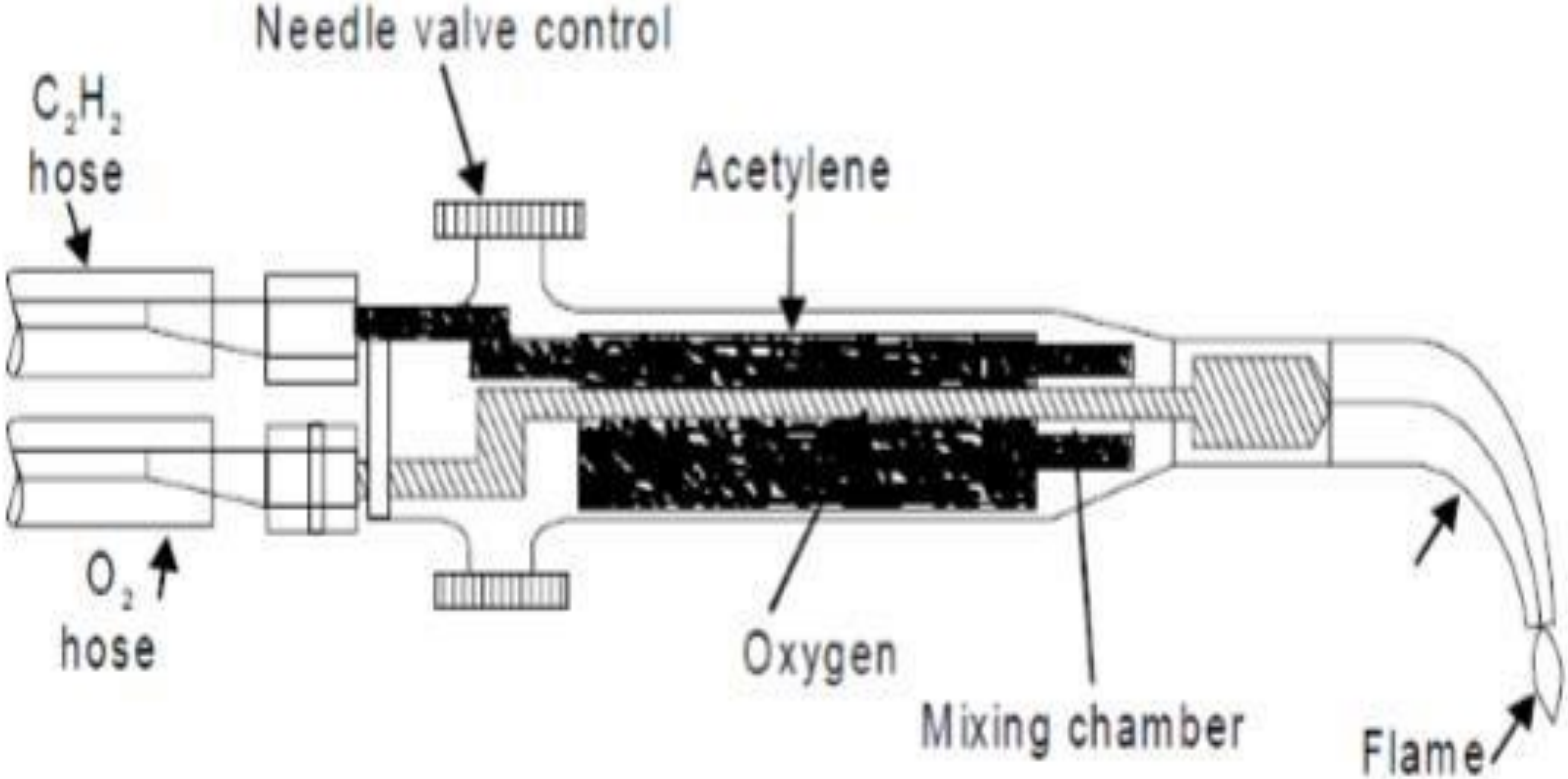


Figure 3.8 Welding torch

3.9Arc welding

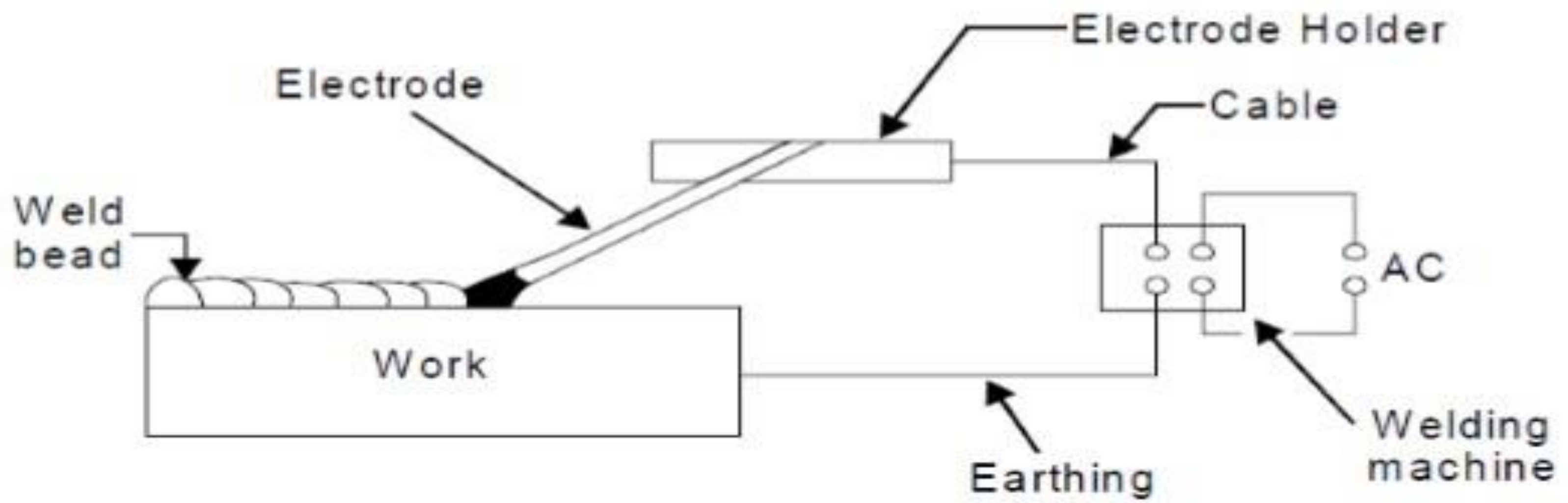


Figure 3.9 Arc Welding

9 Arc welding

 The process, in which an electric arc between an electrode and a work piece or between two electrodes is utilized to weld base metals, is called an arc welding process.

 The basic elements involved in arc welding process are shown in figure.

9 Arc welding

 Most of these processes use some shielding gas while others employ coatings or fluxes to prevent the weld pool from the surrounding atmosphere.

The various arc welding processes are: 1. Carbon Arc Welding

2. Shielded Metal Arc Welding
3. Gas Tungsten Arc Welding
4. Gas Metal Arc Welding
5. Plasma Arc Welding
6. Atomic Hydrogen Welding
7. Electro slag Welding

Carbon arc welding

Carbon arc welding

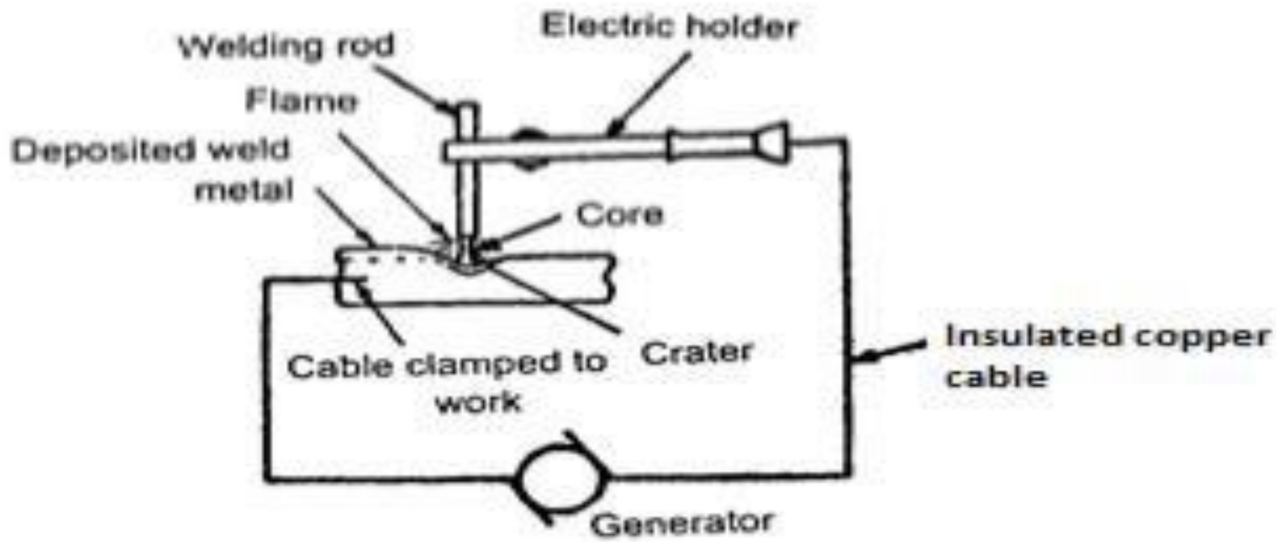


Figure 3.10 Carbon Arc Welding

- In this process, a pure graphite or baked carbon rod is used as a non-consumable electrode to create an electric arc between it and the work piece.

 The electric arc produces heat and weld can be made with or without the addition of filler material.

Carbon arc welding

Carbon arc welding may be classified as-

(1) Single electrode arc welding, and

(2) Twin carbon electrode arc welding

(1)Single electrode arc welding

- In single electrode arc welding, an electric arc is struck between a carbon electrode and the work piece. Welding may be carried out in air or in an inert atmosphere.
- Direct current straight polarity (DCSP) is preferred to restrict electrode disintegration and the amount of carbon going into the weld metal.
- This process is mainly used for providing heat source for brazing, braze welding, soldering and heat treating as well as for repairing iron and steel castings.

- It is also used for welding of galvanized steel and copper.

Carbon arc welding (2) Twin carbon electrode arc welding

- In twin carbon arc welding the arc struck between two carbon electrodes produces heatand welds the joint.
- The arc produced between these two electrodes heats the metal to the melting temperature and welds the joint after solidification.
- The power source used is AC(Alternating Current) to keep the electrodes at the same temperature.
- Twin-electrode carbon arc welding can be used for welding in any position. This process is mainly used for joining copper alloys to each other or to ferrous metal.
- It can also be used for welding aluminium,nickel, zinc and lead alloys.

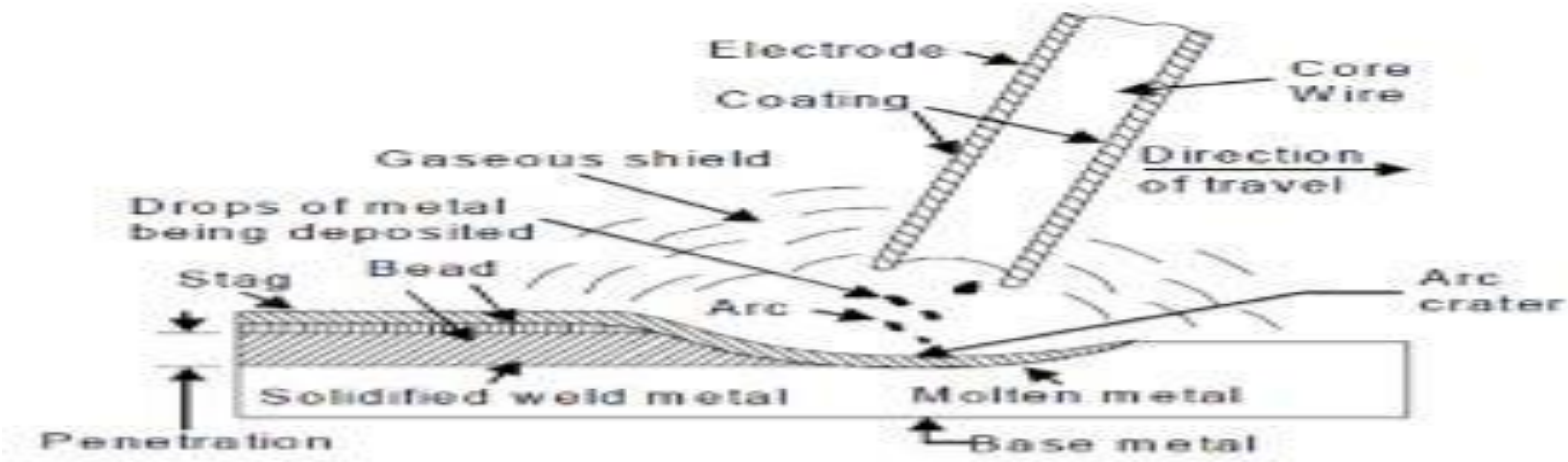


Figure 3.11 Shilded metal arc Welding

Shielded metal arc welding (SMAW)

 Shielded metal arc welding (SMAW) Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder.

 It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the workpiece.

Advantages of Shielded Metal Arc Welding (SMAW)

- Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest   weld quality.

- MMAW is the simplest of all the arc welding. This welding process finds innumerable applications, because of the availability of a wide variety of electrodes.

 Big range of metals and their alloys can be welded easily. The process can be very well employed for hard facing and metal resistance etc

 Joints (e.g., between nozzles and shell in a pressure vessel) which because of their position are difficult to be welded by automatic welding machines can be easily accomplished by flux shielded metal arc welding.

 The MMAW welding equipment is portable and the cost is fairly low.

Dis advantages of Shielded Metal Arc Welding (SMAW)

 Due to flux coated electrodes, the chances of slag entrapment and other related defects are more as compared to MIG and TIG welding.

- Due to fumes and particles of slag, the arc and metal transfer is not very clear and thus welding control in this process is a bit difficult as compared to MIG welding.
- Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.

 In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weld is to be progressed with the next electrode. Unless properly cared, a defect (like slag inclusion or insufficient penetration) may occur at the place where welding is restarted with the new electrode

 The process uses stick electrodes and thus it is slower as compared to MIG welding

Applications of Shielded Metal Arc Welding (SMAW)

 Today, almost all the commonly employed metals and their alloys can be welded by this process. Shielded metal arc welding is used both as a fabrication process and for maintenance and repair jobs.

Submerged Arc Welding

 Schematic submerged arc welding process is shown in figure. In this welding process, a consumable bare electrode is used in combination with a flux feeder tube.

- The arc, end of the bare electrode and molten pool remain completely submerged under blanket of granular flux.
- The feed of electrode and tube is automatic and the welding is homogenous in structure. No pressure is applied for welding purposes.
- This process is used for welding low carbon steel,bronze, nickel and other non-ferrous materials.

Submerged Arc Welding

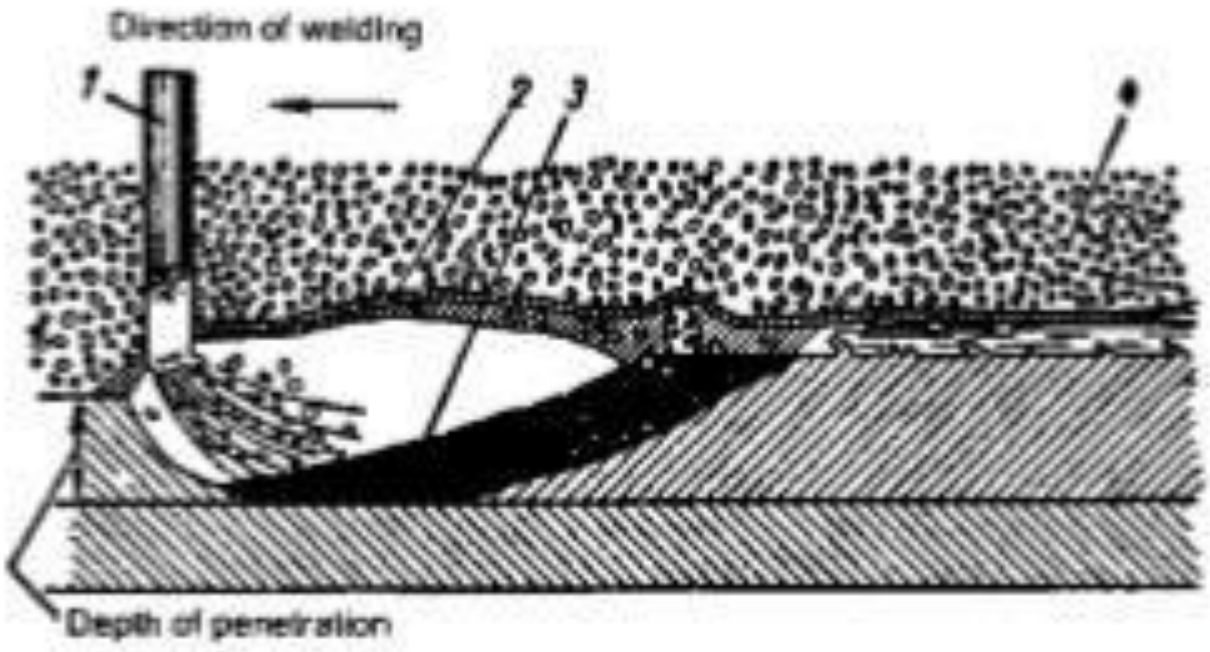


Figure 3.12 Submeged arc Welding

1 Electrode 2 envelope of flux 3 molten metal 4 flux

Gas Tungsten Arc Welding

- In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it.
- The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmosphericcontamination.

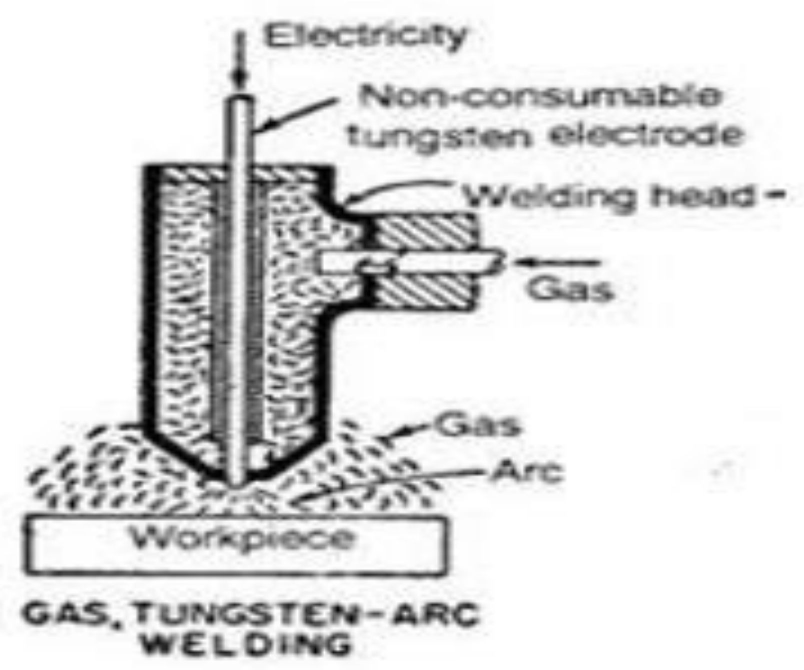


Figure 3.13 Tungusten inert gas arc welding

Gas Tungsten Arc Welding

 The shielding gases generally used are argon, helium or their mixtures. Typical tungsten inert gas welding setup is shown in figure.

 The electrode material may be tungsten, or tungsten alloy (thoriated tungsten orzirconiated tungsten).

 Alloy-tungsten electrodes possess higher current carrying capacity, produce a steadier arc as compared to pure tungsten electrodes and high resistance to

contamination. Electric power source

Gas Tungsten Arc Welding

 Both AC and DC power source can be used for TIG welding. DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas DC reverse polarity (DCRP) or AC is used for welding aluminum, magnesium or their alloys. DCRP removes oxide film on magnesium and aluminium Inert gases

The following inert gases are generally used in TIG welding: 1. Argon

2. Helium
3. Argon-helium mixtures
4. Argon-hydrogen mixtures

Gas Metal Arc Welding

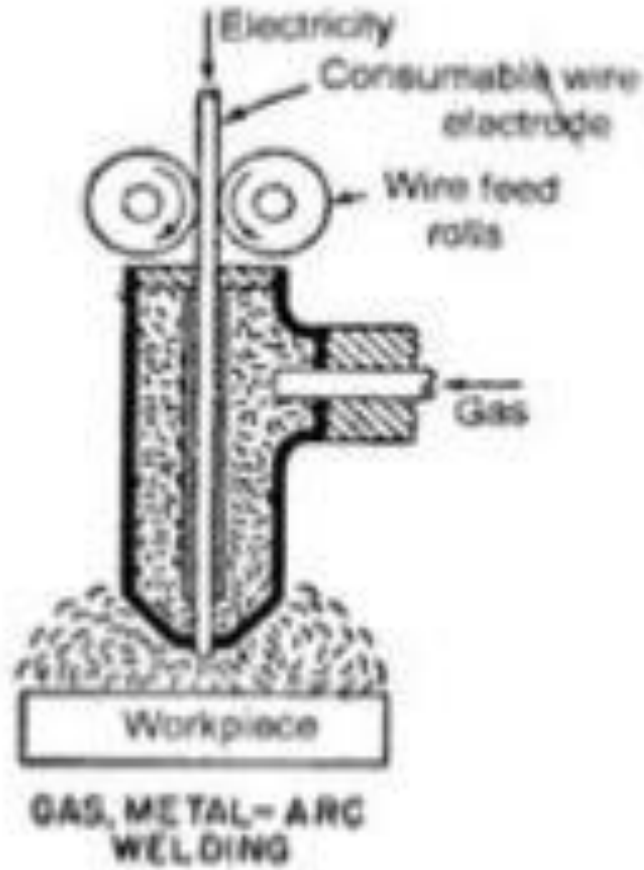


Figure 3.13Metal inert gas arc welding

Gas Metal Arc Welding

 Metal inert gas arc welding (MIG) or more appropriately called as gas metal arc weldingGMAW) utilizes a consumable electrode and hence, the term metal appears in the title.There are other gas shielded arc welding processes utilizing

  the consumable electrodes,such as flux cored arc welding (FCAW) all of which can be termed under MIG.

 Though gas tungsten arc welding (GTAW) can be used to weld all types of metals, it is more suitable for thin sheets. When thicker sheets are to be welded, the filler metal requirement makes GTAW difficult to use. In this situation, the GMAW comes handy.

Gas Metal Arc Welding

 The typical setup for GMAW or MIG welding process is shown in Fig. consumable electrode is in the form of a wire reel which is fed at a constant rate, through the feed rollers. The welding torch is connected to the gas supply cylinder which provides the necessary inert gas.

 The electrode and the work-piece are connected to the welding power supply. The power supplies are always of the constant voltage type only.

- The current from the welding machine is changed by the rate of feeding of the electrode wire.
- Normally DC arc welding machines are used for GMAW with electrode positive (DCRP).

Gas Metal Arc Welding

- The DCRP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer. - With DCSP, the arc becomes highly unstable and also results in a large spatter. But special electrodes having calcium and titanium oxide mixtures as coatings are found to be good for welding steel with DCSP.
- In the GMAW process, the filler metal is transferred from the electrode to the joint. Depending on the current and voltage used for a given electrode, the metal transfer is done in different ways.

Electrodes for arc welding

- An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between electrode and work piece.
- Welding electrodes are classified into following types

(1) Consumable Electrodes

(a) Bare Electrodes

(b) Coated Electrodes

(2) **Non-consumable Electrodes**

(a) Carbon or Graphite Electrodes

(b) Tungsten Electrodes

Electrodes for arc welding

 Consumable electrode is made of different metals and their alloys.

 The end of this electrode starts melting when arc is struck between the electrode and work piece.

 Thus consumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloy wire without any flux coating on them.

  Coated electrodes have flux coating which starts melting as soon as an electric arc is struck.

Resistance welding

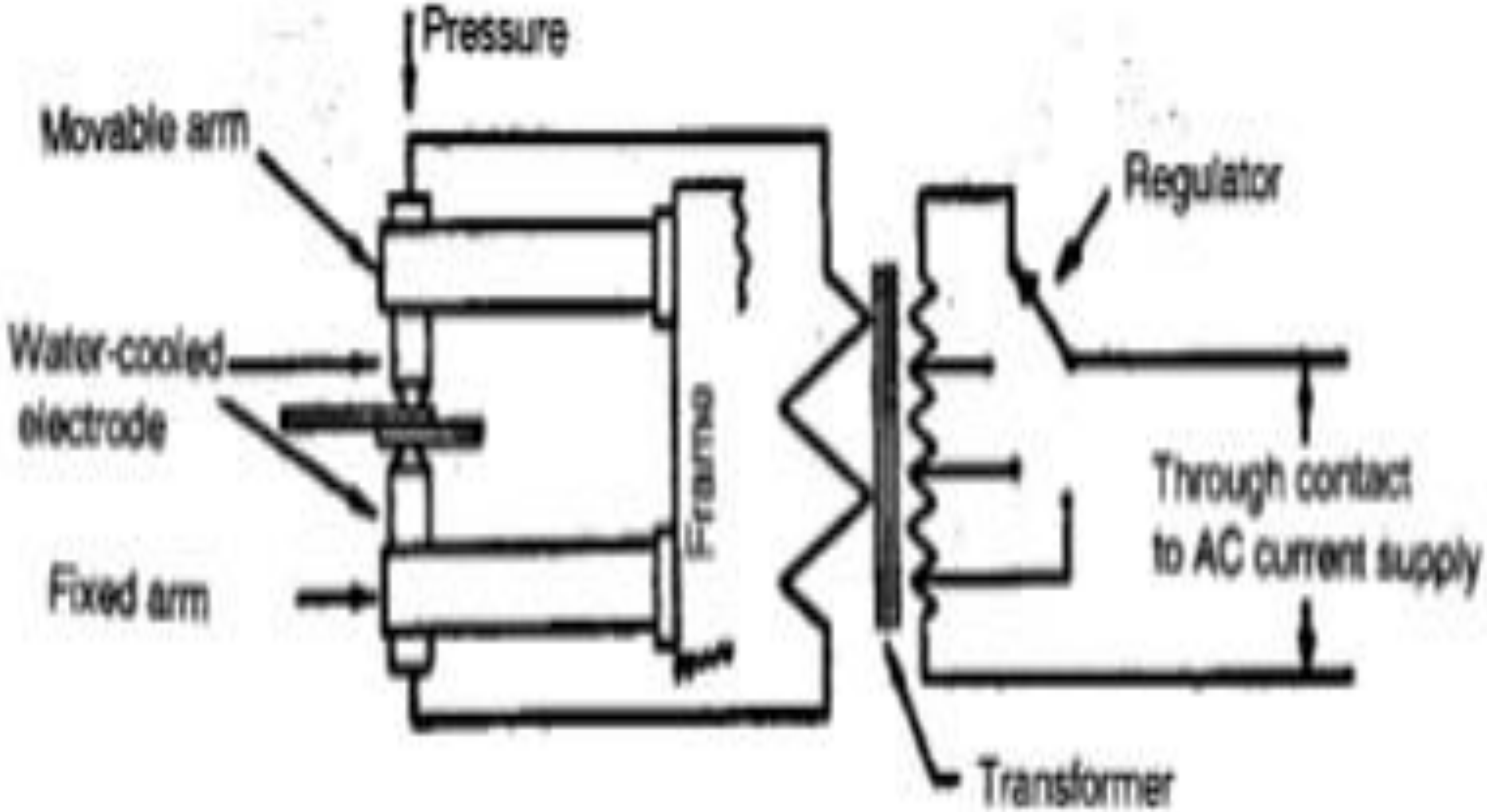
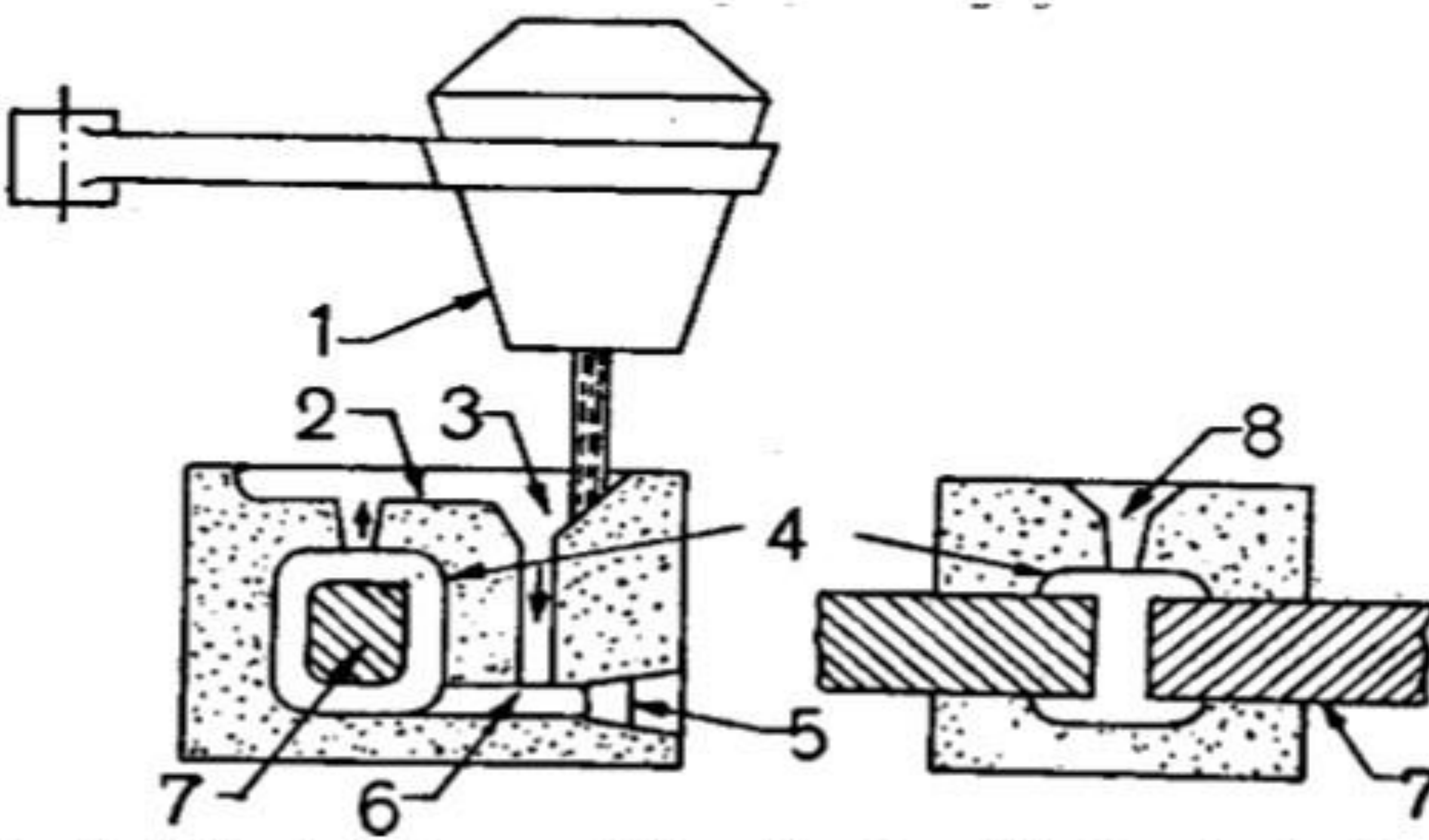


Figure 3.15Resistance welding

Thermit welding

Thermit welding



1. Crucible, 2. Slag basin 3. runner, 4. Wax pattern 5 sand plug 6. pre heating 7, work piece 8. Riser

Figure 3.16 Thermit welding

Thermit welding

 Heating is continued to raise the temperature Preheating is done before the liquid metal is poured into the mould.

- Burner is removed preheating gate is closed with sand.
- The superheated metal in crucible is poured into the mould surrounding the surfaces to be welded.

Temperature 3000^0C.

Solid state welding

 Inter atomic bonds may be established by bringing atoms of two surfaces in close enough proximity to assure adhesion.

 Relative movement of surface under pressure and controlled roughness are helpful Three methods

1. Diffusion

2. Ultrasonic
3. Friction

Figure 3.17 Diffusion welding

1.Diffusion welding Diffusion welding

 It is a process where heat is not necessary to produce fusion welds.

 Rather it needs two kinds of surfaces that come in contact under pressure.

1.Diffusion welding

- This pressure is applied for a period of hours
- In this process, although heating is not essential, if the temperature is raised, the diffusion rate will be cut sufficiently.
- The individual peaks and valleys which make up the roughness are deformed by the application increasing pressure
- At places, where the surface move together shear , the films diffused and metal to metal contact take place.
- After that the atoms are within the attractive force fields of each other, hence joint resembles a grain boundary

2.**Ultrasonic welding**

- It is a solid state welding where coalescence is produced by the application by the high frequency vibratory energy to the w/p as they are held together under pressure. The w/p to be joined are clamped together under a static normal force to their interface and oscillating shear stresses of ultrasonic frequencies are applied parallel to plan for one second. The combined of pressure and vibration cause movement of the metal molecules are welded together.

- The welding is accomplished in solid state, without applying external heat filler rod or high pressure.

- Time 0.5 to 2 sec

2.Ultrasonic welding

- Vibratory action breaks up moistures, oxide and other coatings
- Frequency 20000 to 60000 Hz
- Overlapping metals are joined
- Parts to be joined are clamped between welding tip and supporting member under low static pressure
- High frequency vibratory energy is then transmitted into the weld area for brief interval

 this process Produces a sound bond without an arc or melting weld metal and absent of filler metal or flux Thickness 0.38 to 2.5 mm.

3.Friction welding

- Frictional energy generated when two bodies slide on each other is transformed into heat when the rate of movement is high and heat is contained in narrow zone welding occurs.

 The components to be weld are held in an axial alignment.

 One component held in chucking spindle is rotate and accelerated

- The stationary component is held in movable clamp which is moved forward to come into pressure contact with the rotating component

3.Friction welding

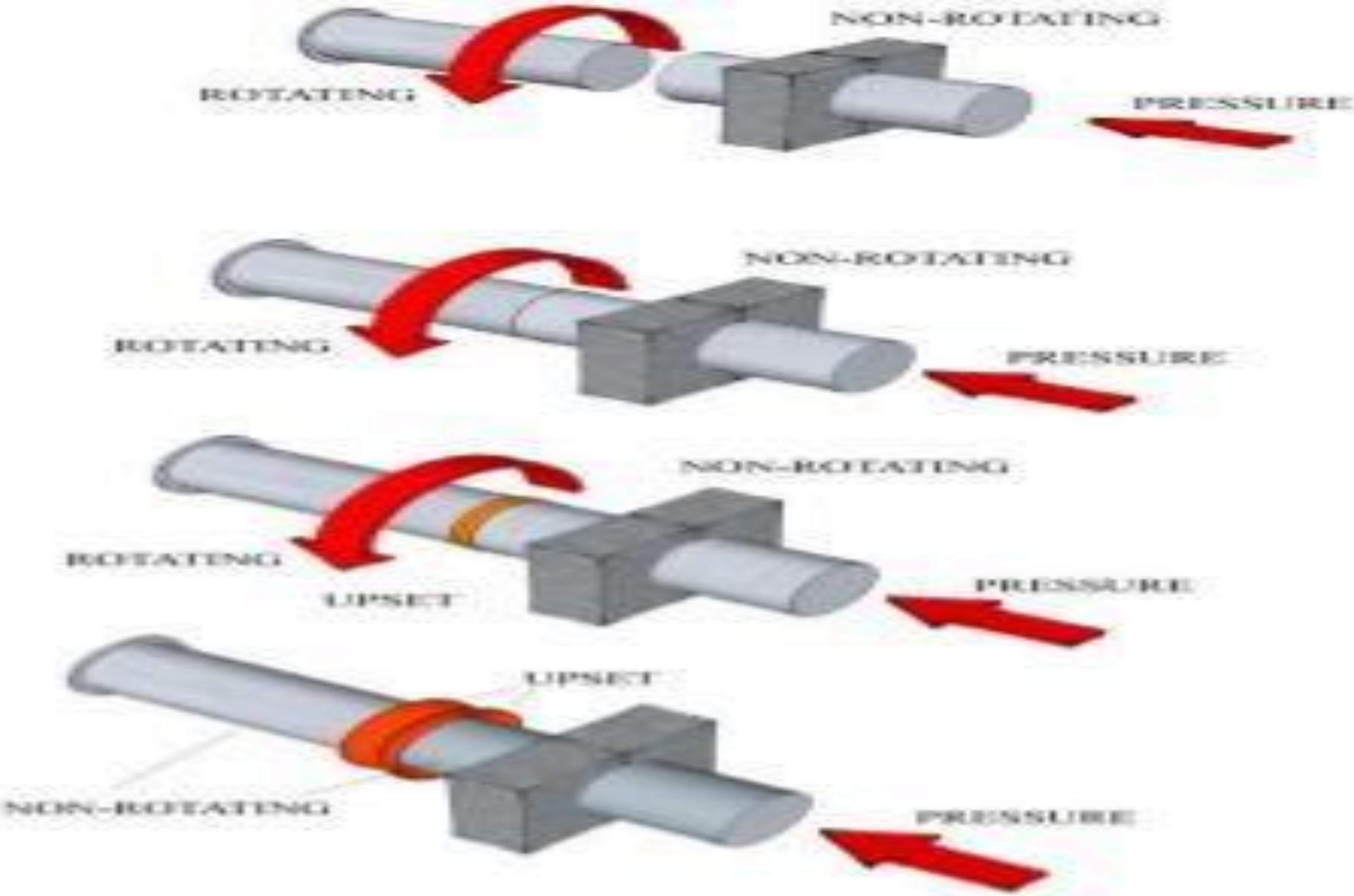


Figure 3.18 Friction welding

Electron beam welding

 Electron beam welding utilizes the energy from a fast moving beam of electrons focused on the work piece

 The electrons strike the metal surface which gives up kinetic energy almost completely into heat.

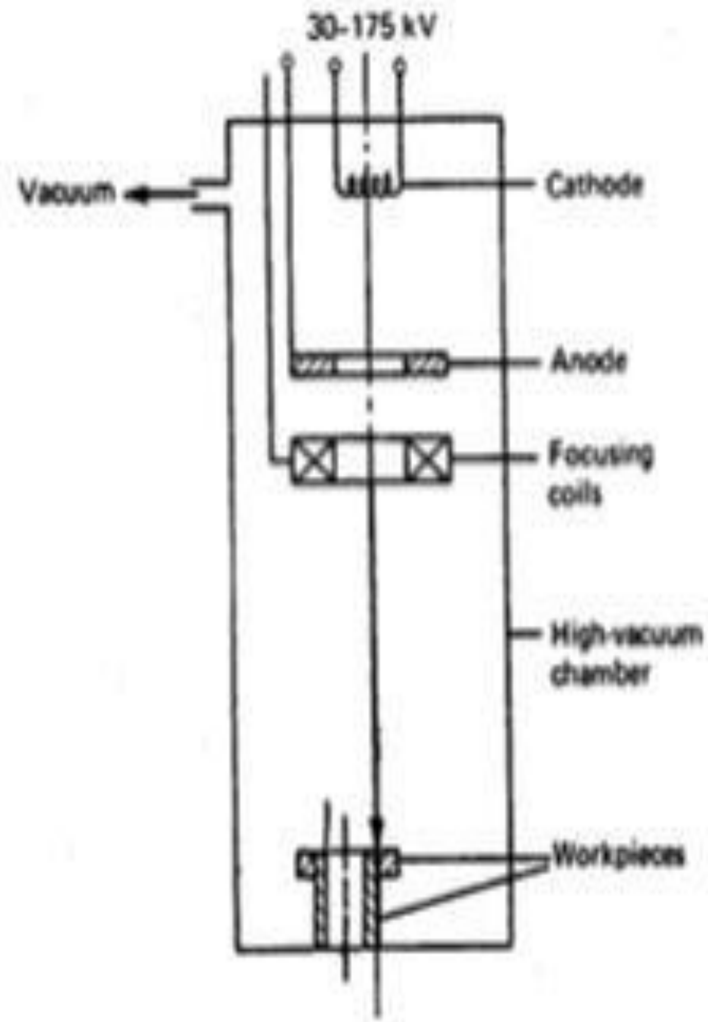
- In all types of electron beam machines, a tungsten filament which serves as cathode emits a mass of electron that are accelerated and focused 0.25 to 1 mm diameter of beam The heat is generated about 2500^0C.
- This is sufficient to melt and vaporize the work piece materials and thus fills a narrow weld gap even without filler rod
- It is Fusion welding process

Electron beam welding

 The high velocity electrons strike to the surface to be welded, their kinetic energy changes to thermal energy, hence causing w/p to be melt. The electrode beam is created in vacuum.

  If welding is done in such vacuum, then there is no need of electrodes, gases, filler metal that contaminates the weld.

Laser beam welding



.Figure 3.18 Electron Beam welding

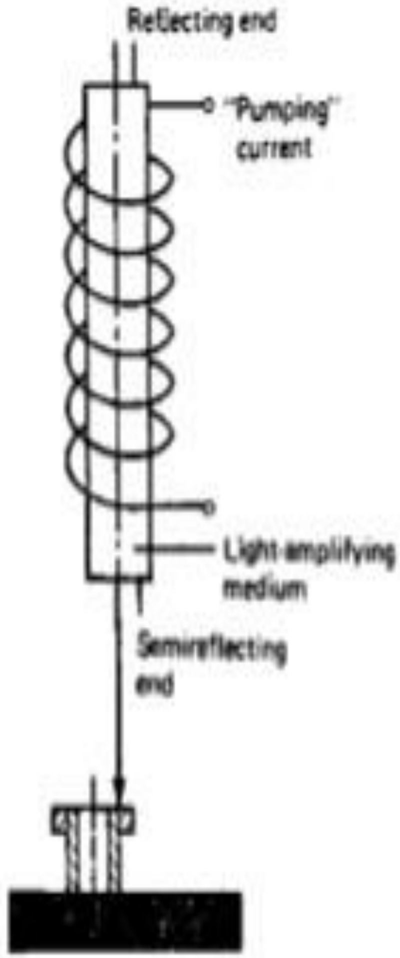


Figure 3.20 Laser Beam welding

 This means that many welds can now be made without electrode arrangement required for vacuum electrode

 Laser is a device for concentrating light waves are identical and parallel Laser is device for concentrating light waves into narrowly defined highly intense beam that can import energy on a small area for producing fusion welding.

Defects in welding

1. Lack of Penetration
2. Lack of Fusion
3. Porosity
4. During the welding process
5. Slag Inclusion

6. Undercuts

1. Lack of Penetration

It is the failure of the filler metal to penetrate into the joint. It is due to

a. Inadequate de-slagging

b. Incorrect edge penetration

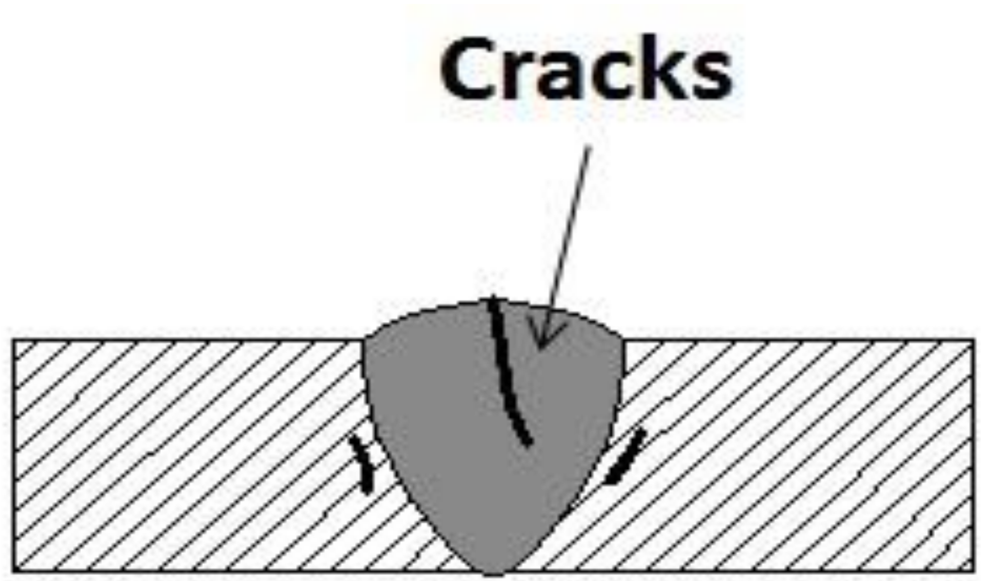
c. Incorrect welding technique.

Defects in welding

1. Weld Crack
2. Porosity
3. Undercut
4. Incomplete Fusion

5. Incomplete Penetration
6. Slag Inclusion
7. Spatter

Defects in welding 1.Weld Crack



Defects in welding 1.Weld Crack

Causes of Weld Crack :

a. Use of hydrogen when welding ferrous metals.

b. Residual stress caused by the solidification shrinkage.

c. Base metal contamination.

d. High welding speed but low current.

e. No preheat before starting welding.

f. Poor joint design.

g. A high content of sulfur and carbon in the metal.

Defects in welding 1.Weld Crack Remedies:

a. Preheat the metal as required.

b. Provide proper cooling of the weld area.

c. Use proper joint design.

d. Remove impurities.

e. Use appropriate metal.

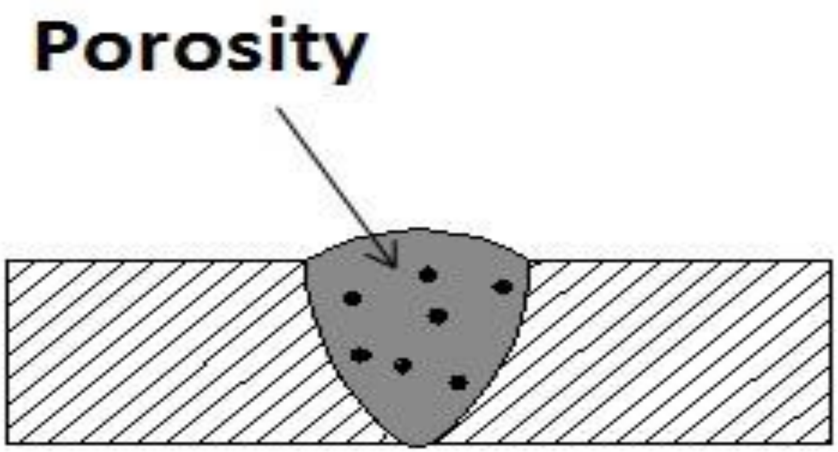
f. Make sure to weld a sufficient sectional area.

g. Use proper welding speed and amperage current.

h. To prevent crater cracks make sure that the crater is properly filled.

Defects in welding 2.Porosity

Porosity occurs as a result of weld metal contamination. The trapped gases create a bubble-filled weld that becomes weak and can with time



collapse.

Defects in welding 2. Causes of porosity:

a. Inadequate electrode deoxidant.

b. Using a longer arc.

c. The presence of moisture.

d. Improper gas shield.

e. Incorrect surface treatment.

f. Use of too high gas flow.

g. Contaminated surface.

h. Presence of rust, paint, grease or oil.

2.Porosity Remedies:

a. Clean the materials before you begin welding.

b. Use dry electrodes and materials.

c. Use correct arc distance.

d. Check the gas flow meter and make sure that it's optimized as required with proper with pressure and flow settings.

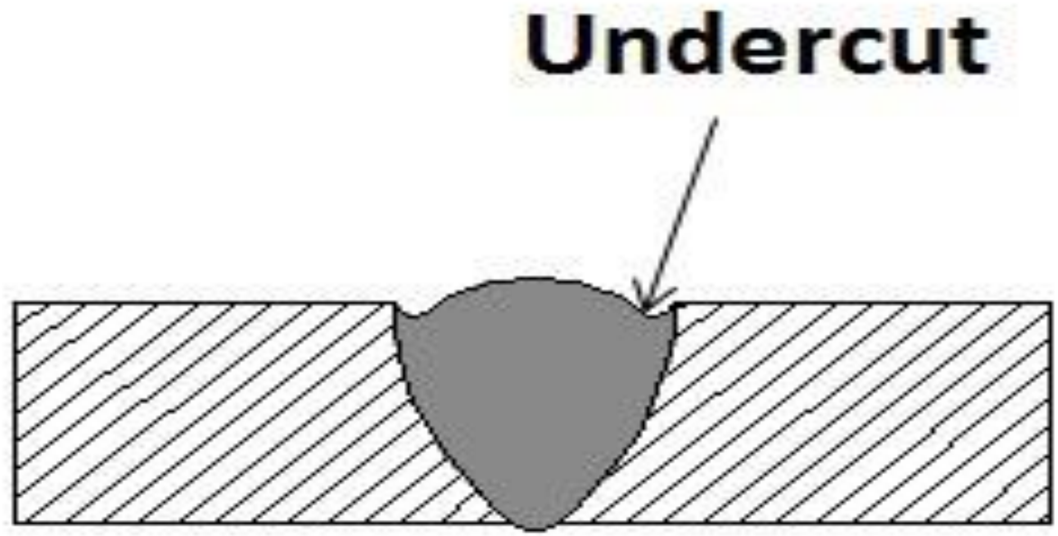
e. Reduce arc travel speed, which will allow the gases to escape.

f. Use the right electrodes.

g. Use a proper weld technique.

3.Undercut

This welding imperfection is the groove formation at the weld toe, reducing the cross-sectional thickness of the base metal. The result is the weakened weld and work piece.



3.Undercut: Causes:

a. Too high weld current.

b. Too fast weld speed.

c. The use of an incorrect angle, which will direct more heat to free edges.

d. The electrode is too large.

e. Incorrect usage of gas shielding.

f. Incorrect filler metal.

g. Poor weld technique.

3.Undercut:

Remedies:

a. Use proper electrode angle.

b. Reduce the arc length.

c. Reduce the electrode's travel speed, but it also shouldn't be too slow.

d. Choose shielding gas with the correct composition for the material type you'll be welding.

e. Use of proper electrode angle, with more heat directed towards thicker components.

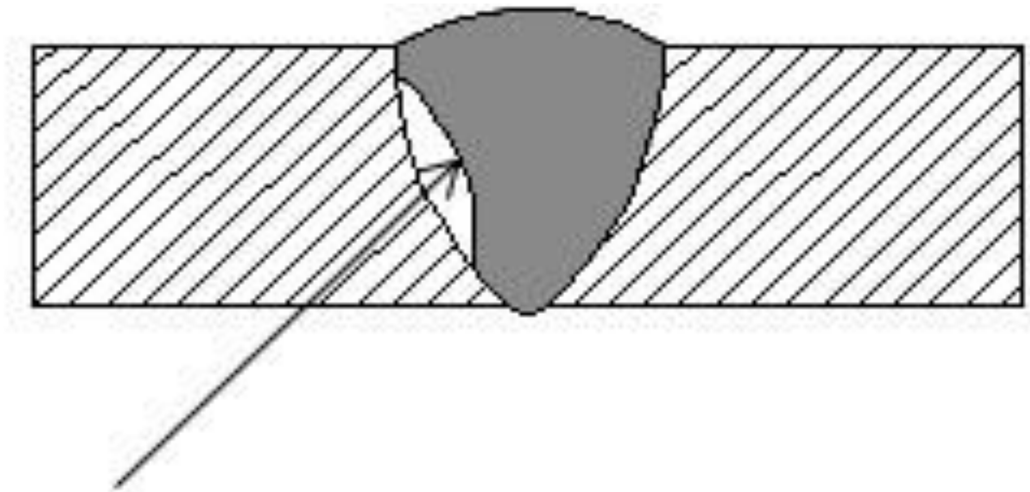
f. Use of proper current, reducing it when approaching thinner areas and free edges.

g. Choose a correct welding technique that doesn't involve excessive weaving.

h. Use the multi pass technique

4.Incomplete Fusion

This type of welding defect occurs when there's a lack of proper fusion between the base metal and the weld metal. It can also appear between adjoining weld beads. This creates a gap in the joint that is not filled with molten metal.



Incomplete Fusion

4.Incomplete Fusion Causes:

a. Low heat input.

b. Surface contamination.

c. Electrode angle is incorrect.

d. The electrode diameter is incorrect for the material thickness you’re welding.

e. Travel speed is too fast.

f. The weld pool is too large and it runs ahead of the arc.

4.Incomplete Fusion Remedies:

a. Use a sufficiently high welding current with the appropriate arc voltage.

b. Before you begin welding, clean the metal.

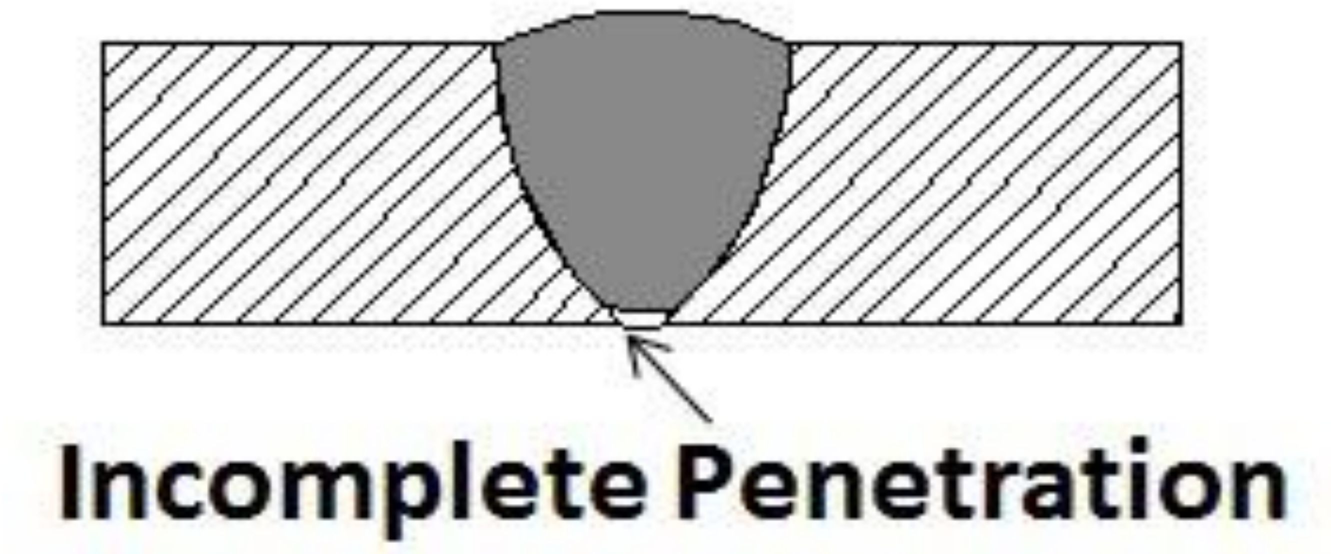
c. Avoid molten pool from flooding the arc.

d. Use correct electrode diameter and angle.

e. Reduce deposition rate.

5.Incomplete Penetration

Incomplete penetration occurs when the groove of the metal is not filled completely, meaning the weld metal doesn’t fully extend through the joint thickness.



5.Incomplete Penetration

Causes:

a. There was too much space between the metal you're welding together.

b. You’re moving the bead too quickly, which doesn’t allow enough metal to be deposited in the joint.

c. You’re using a too low amperage setting, which results in the current not being strong enough to properly melt the metal.

d. Large electrode diameter.

e. Misalignment.

f. Improper joint.

5.Incomplete Penetration Remedies:

a. Use proper joint geometry.

b. Use a properly sized electrode.

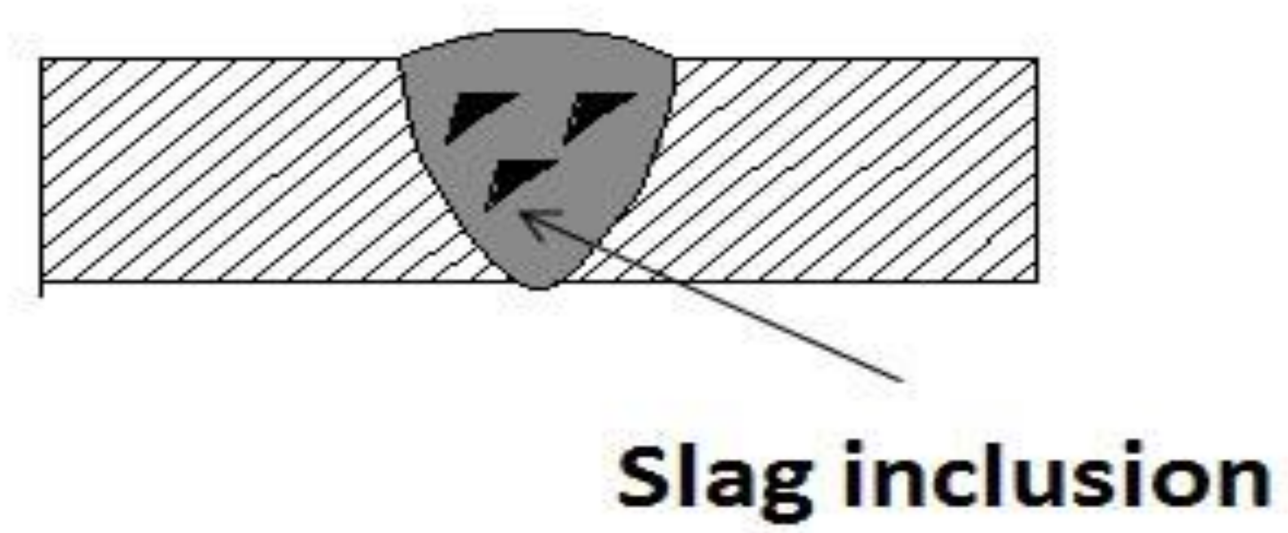
c. Reduce arc travel speed.

d. Choose proper welding current.

e. Check for proper alignment.

6.Slag Inclusion

Slag inclusion is one of the welding defects that are usually easily visible in the weld. Slag is a vitreous material that occurs as a byproduct of stick welding, flux-cored arc welding and submerged arc welding. Is can occur when the flux, which is the solid shielding material used when welding, melts in the weld or on the surface of the weld zone.



6.Slag Inclusion Causes:

a. Improper cleaning.

b. The weld speed is too fast.

c. Not cleaning the weld pass before starting a new one.

d. Incorrect welding angle.

e. The weld pool cools down too fast.

Welding current is too low.

Remedies:

Increase current density.

Reduce rapid cooling.

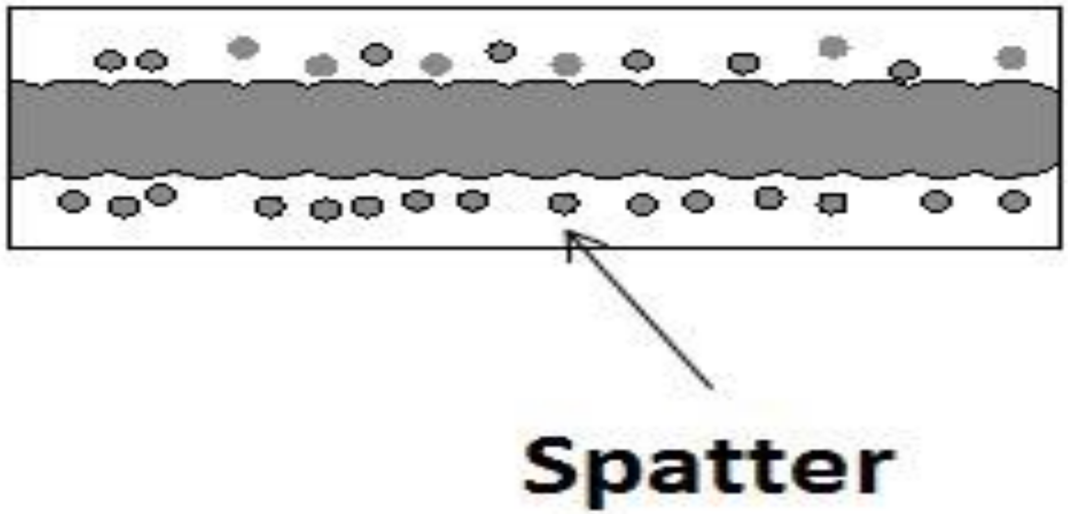
Adjust the electrode angle.

Remove any slag from the previous bead.

Adjust the welding speed.

7.Spatter

Spatter occurs when small particles from the weld attach themselves to the surrounding surface. It’s an especially common occurrence in gas metal arc welding. No matter how hard you try, it can't be completely eliminated. However, there are a few ways you can keep it to a



minimum.

7.Spatter Causes:

a. The running amperage is too high.

b. Voltage setting is too low.

c. The work angle of the electrode is too steep.

d. The surface is contaminated.

e. The arc is too long.

f. Incorrect polarity.

g. Erratic wire feeding.

7.Spatter Remedies:

a. Clean surfaces prior to welding.

b. Reduce the arc length.

c. Adjust the weld current.

d. Increase the electrode angle.

e. Use proper polarity.

f. Make sure you don’t have any feeding issues.

Heat-affected zone:

The heat-affected zone (HAZ) is the area of base material, either a metal or a thermoplastic which is not melted and has had its microstructure and properties altered by welding or heat intensive cutting operations.

The heat from the welding process and

subsequent re-cooling causes this change from the weld interface to the termination of the sensitizing temperature in the base metal.

The extent and magnitude of property

change depends primarily on the base material, the weld filler metal, and the amount and concentration of heat input by the welding process.

Heat-affected zone:

The thermal diffusivity of the base material plays a large role—if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small.

Alternatively, a low diffusivity leads to slower cooling and a larger HAZ.

The amount of heat input during

the welding process also plays an important role as well, as processes like ox fuel welding use high heat input and increase the size of the HAZ. Processes like laser beam welding and electron beam welding give a highly concentrated, limited amount of heat, resulting in a small HAZ.

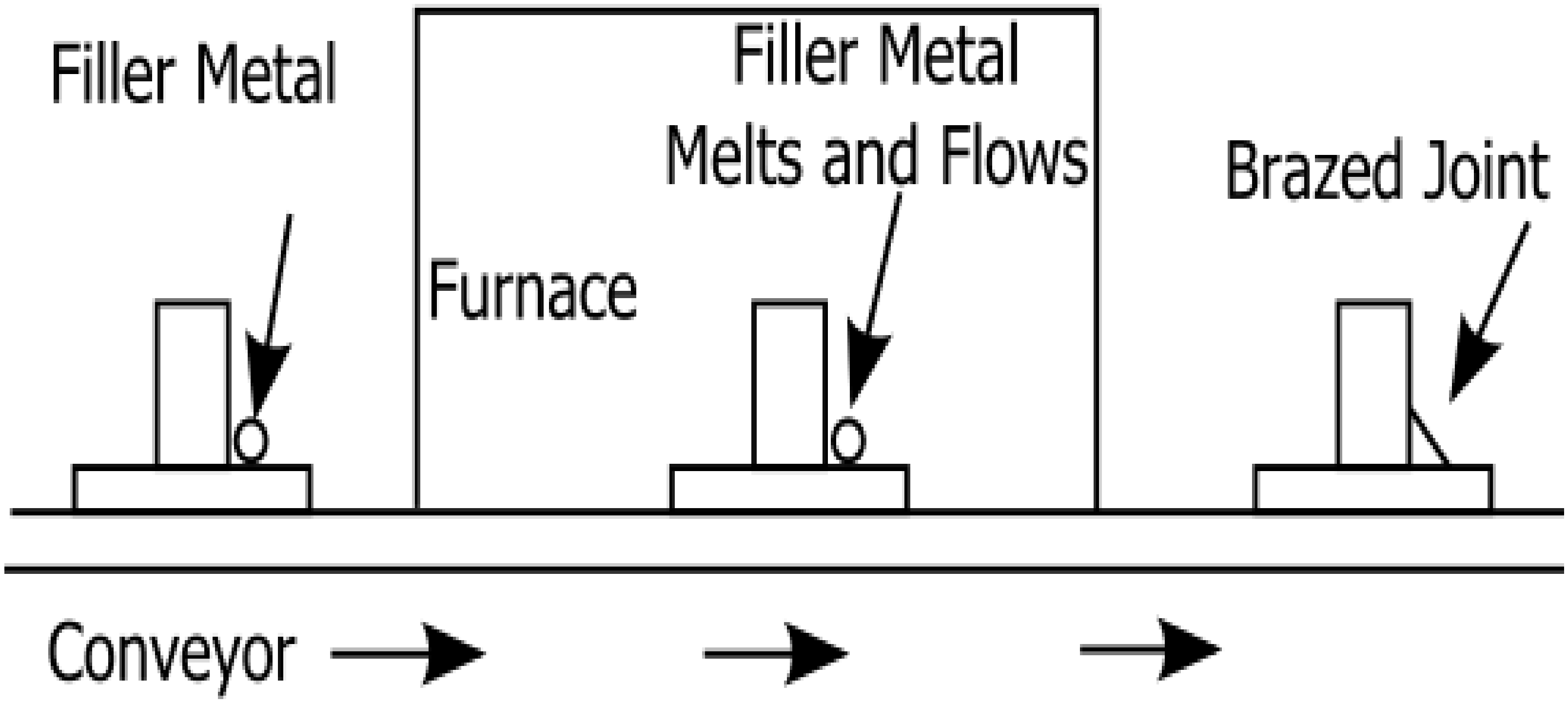
Brazing:

- Brazing is a metal joining process whereby a filler metal is heated above melting point and distributed between two or more close fitting parts by capillary action.

- In brazing, metallic parts are joined by joined by a nonferrous filler metal or alloy.

- Brazing involves the melting of comparatively low melting point filler material against the base metal pieces to be joined while they are clean and free from oxides, oil grease, etc.

Brazing:



Brazing:

The molten filler material

1. Wets the base metal surfaces
2. Spreads along the joint by capillary action
3. Adheres and solidifies to from the brazed joint.

Brazing gives much stronger joint compare to soldering.

Filler material used in this processes are generally two types

1. Copper based alloy
2. Silver based alloy

Brazing:

The parts to be joined by brazing are carefully cleaned, the flux applied and the parts clamped in position for joining.

Borax is generally used as flux.

The parts to be joined are to be heated to a temperature above the melting point of the spelter, and molten spelter is allowed to flow by capillary action into the space between the parts and to cool slowly.

Brazing:

Advantages

- In brazing dissimilar metals or non-metals can be joined.
- Complicated component can also be brazed at low cost.
- It is suitable for mass production.
- Brazing produces clean joint.
- Brazing does not melt the base metal which allows much close control over the tolerances.

Brazing:

Disadvantages :

- Strength of brazed joints can be damaged under high service temperature.
- Strength of the brazed joints is less compare to welded joints.
- Filler metals used in this process are costly.

- The joint color is different than that of base metal which creates an aesthetic disadvantage.

Application:

Brazing is applicable to cast and wrought iron, steel, Cu, Al, Mg and their alloys.

Soldering

- Soldering is a method of joining two or more pieces of metal by means of a fusible alloy or metal, called solder, applied in molten state.

 Solders are essentially alloys of lead and tin. To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmium and silver in various proportions. Solders are essentially alloys of lead and tin.

- To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmium and silver in various proportions. Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering.

Soldering:

Advantages :

- By soldering various dissimilar metals can be joined.

It is simple and low cost method.

- Work piece with different thickness can be joined. The joined formed in the soldering, do not require machining.

 Soldering is a low temperature process; hence there is no change in the properties of metals.

Soldering:

Disadvantages

 The soldered joints are not suitable for high temperature service because of the low melting temperatures of the filler metals used. The soldering joints also need to be cleaned meticulously to provide chemically clean surfaces to obtain a proper bond.

- Corrosion resistance of solder joint is less.

Adhesive bonding:

- Adhesive bonding is the process of joining materials by using adhesives.
- In this processes surface preparation is done so that the adhesive applied on the surface which is free from foreign particles.
- A low viscosity primer is then applied in one or more coats by spraying and brushing.
- After primer is dried, the adhesive is applied.
- After that assembly of adhesive coated components is done.

Application :

- Assembly of electronic components
- Joints in wire
- Joints in sheet metal objects like food cans.

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DEPARTMENT : MECHANICAL ENGINEERING

YEAR & SEM : II-I SEM

SUBJECT : MANUFACTURING PROCESS

SUBJECT CODE : (19A03301T)

PREPARED BY : V V ANANTHA CHAKRAVARTHY

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

- Types of plastics
- Plastics properties and their applications
- ➢ Processing of plastics
- ➢ Extrusion of plastics
- Transfer molding and compression molding
- Injection molding
- Thermoforming
- Rotational molding and blow molding

Ceramics: Classification of ceramic materials, properties and their application,

- ➢ Ceramic powder preparation;
- ➢ Processing of ceramic parts:

- Pressing,
- Casting,
- Sintering;
- Secondary processing of ceramics:
- Coatings,
- Finishing.

Powder Metallurgy: Principle, manufacture of powders, steps involved.

Plastic:

- Plastic is the general common term for a wide range of synthetic or semi synthetic organic amorphous solid materials suitable for the manufacture of industrial products.
- Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs

Types of Plastics

Plastics can be divided into two major categories:

A.Thermoset or thermosetting plastics:

Once cooled and hardened, these plastics retain their shapes and cannot return to their original form. They are hard and durable. Thermosets can be used for auto parts, aircraft parts and tires.

Examples include polyurethanes, polyesters, epoxy resins and phenolic resins.

B.Thermoplastics:

Less rigid than thermosets, thermoplastics can soften upon heating and return to their original form. They are easily molded and extruded into films, fibers and packaging.

Examples include polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC).

A. Thermoset or Thermosetting Plastics:

1. Polyurethane Plastics 2. Epoxy 3. Phenolic **B.Thermoplastics :**

1.Vinyl Plastics 2.Polyacrylics Plastics 3.Polyvinyl Chloride

4.Polyethylene Terephthalate (PETE)

5.High Density Polyethylene (HDPE)

6.Polyvinyl Chloride (PVC)

7.Low Density Polyethylene (LDPE)

8.Polypropylene (PP)

9.Polystyrene (PS)

Symbol	Type of Plastic	Properties	Common Uses	Recycled In
	PET Polyethylene Terephthalate	Clear, tough solvent resistant, barrier to gas and moisture, softens at around 80°C	Soft drink and water bottles, salad domes, biscuit trays, salad dressing and peanut butter containers	Pillow and sleeping bag filling, clothing, soft drink bottles carpet
	PE-HD High Density Polyethylene (HDPE)	Hard to semi-flexible, resistant to chemicals and moisture, waxy surface, opaque, softens at around 75°C, easily colored, processed and formed	Crinkly shopping bags, freezer bags, milk bottles, ice cream containers, juice bottles, shampoo, chemical and detergent bottles, buckets, rigid agricultural pipe, milk crates	Recycling bins, compost bins, buckets, detergent containers, posts, fencing, pipes
	PVC Unplasticised Polyvinyl Chloride PVC-U	Strong, tough, can be clear, can be solvent welded, softens at around 80°C	Cosmetic containers, electrical conduit, plumbing pipes and fittings, blister packs, wall cladding, roof sheeting, bottles	Flooring, film and sheets, cables, speed bumps, packaging, binders, mud flaps and mats
	Plasticised Polyvinyl Chloride PCV-P	Flexible, clear, elastic, can be solvent welded	garden hose, shoe soles, cable sheathing, blood bags and tubing, watch straps	

Characteristics of Plastics:

- Mechanical properties:
- Thermal properties
- Chemical properties:
- Electric properties
- Physical properties

Materials for Processing Plastics :

Most Plastic resins have to be
combined, compounded, or otherwise chemically treated with processing materials before they are ready for processing.

One of the following additions are usually employed;

1. Plasticizers
2. Fillers
3. Catalyst
4. Initiators
5. Dyes and Pigments

Plastic Processes:

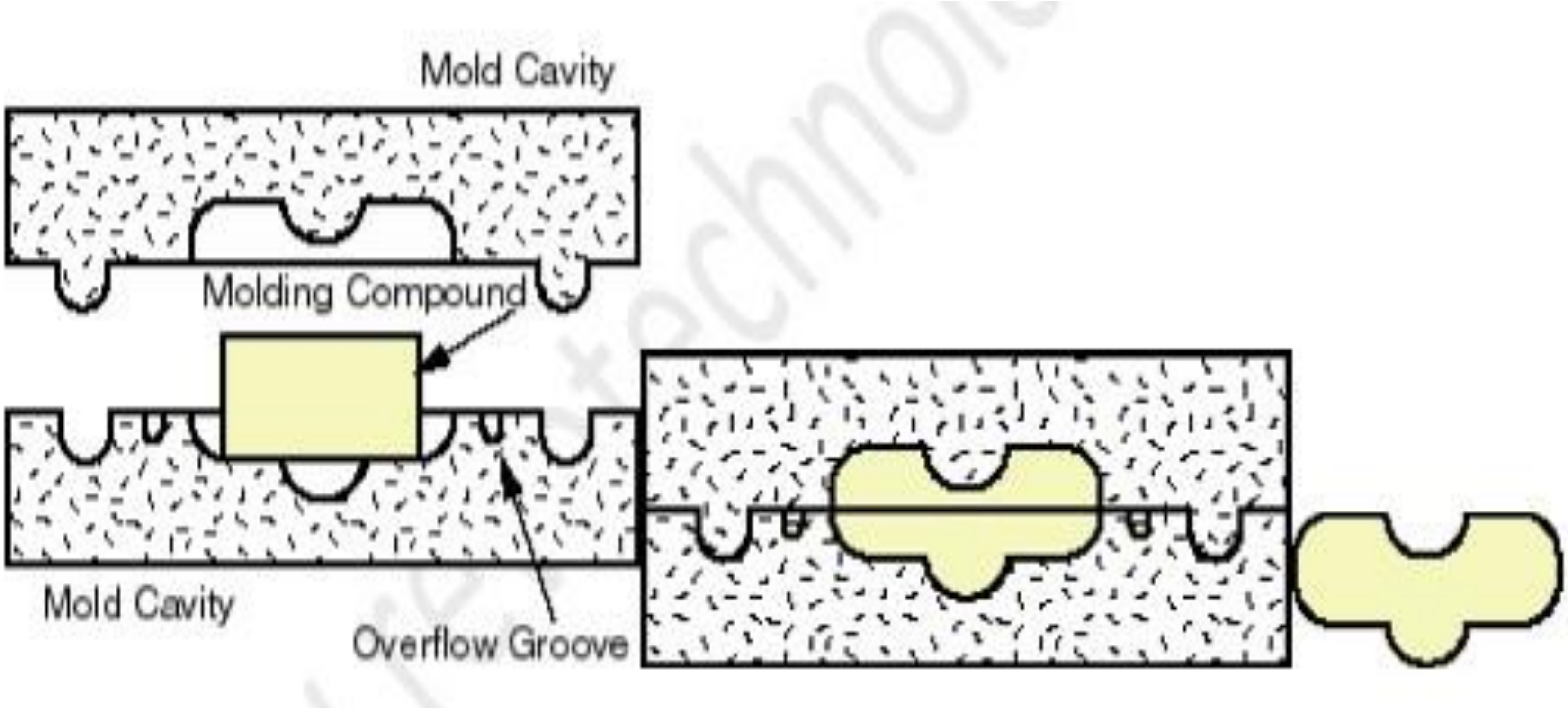
1. Moulding Process
2. Calendering Process
3. Thermoforming
4. Casting
5. Fabrication Process

1. Moulding Processes:

i.Compression Moulding ii. Transfer Moulding iii.Injection Moulding iv. Jet Moulding Extrusion

i.Compression molding: Compression molding is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured.

i.Compression molding:



i.Compression molding:

Common plastics used in compression molding processes include:

- Polyester
- Polyimide (PI)
- Polyamide-imide (PAI)
- Polyphenylene Sulfide (PPS)
- Polyetheretherketone (PEEK)
- Fiber reinforced plastics

Compression molding Principle of working:

- The compression molding starts, with an allotted amount of plastic or gelatin placed over or inserted into a mold. Afterward the material is heated to a pliable state in and by the mold.
- Shortly there after the hydraulic press compresses the pliable plastic against the mold, resulting in a perfectly molded piece, retaining the shape of the inside surface of the mold. After the hydraulic press releases, an ejector pin in the bottom of the mold quickly ejects the finish piece out of the mold and then the process is finished.
- Also depending on the type of plunger used in the press there will or won't be excess material on the mold.

Factors affecting Compression Moulding:

- Amount of material
- Heating time and technique
- Force applied to the mold
- Cooling time and technique

Disadvantages of Compression Moulding

 Production speed is not up to injection molding standards Limited largely to flat or moderately curved parts with no undercuts

 Less-than-ideal product consistency

Advantages of Compression Moulding:

 Low initial setup costs

  Fast setup time

 Capable of large size parts beyond the capacity of extrusion techniques

 Allows intricate parts

 Good surface finish (in general)

 Wastes relatively little material

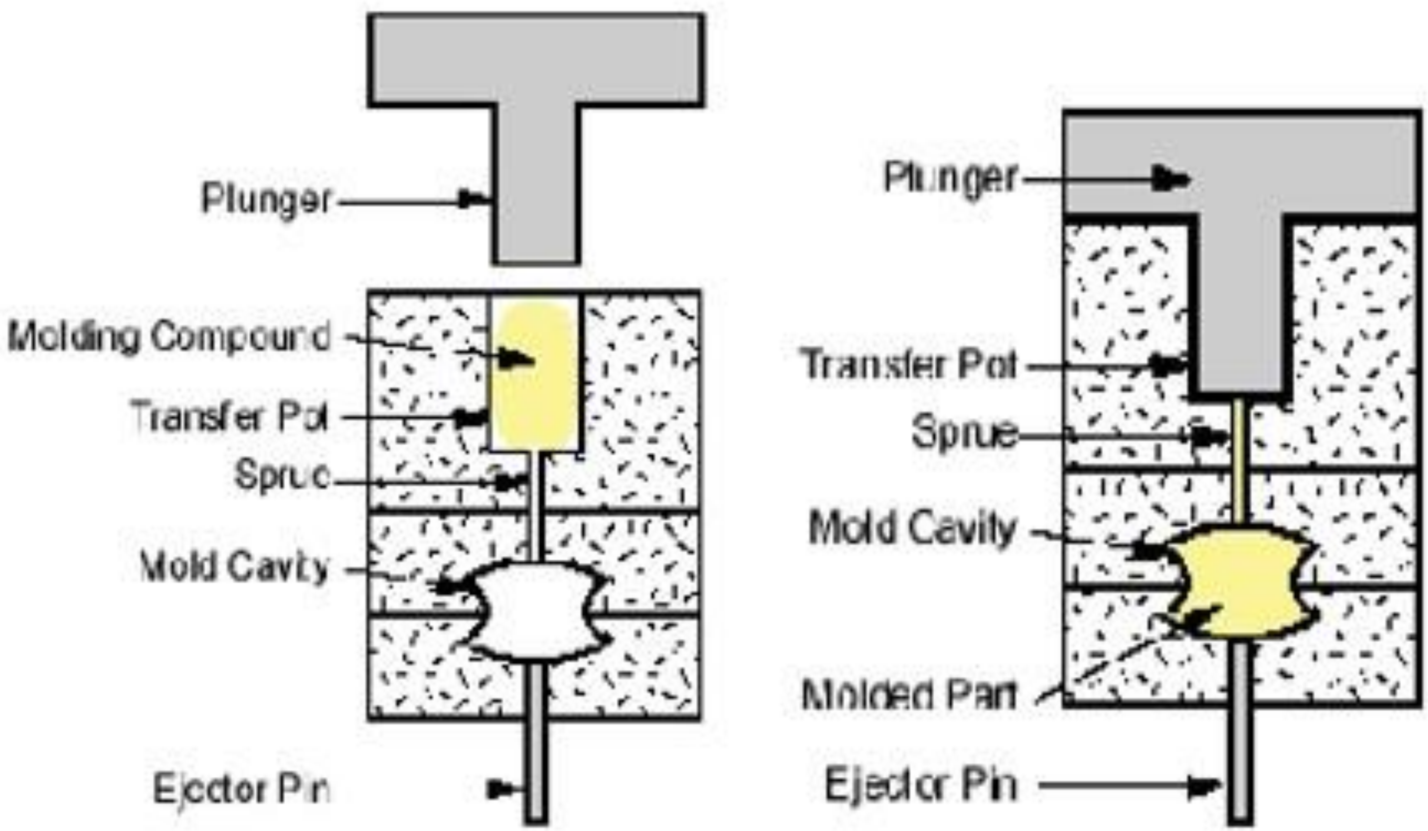
 Can apply to composite thermoplastics with unidirectional tapes, woven fabrics, randomly orientated fiber mat or chopped strand

 Compression molding produces fewer knit lines and less fiber-length degradation than injection molding.

ii.Transfer molding:

- Transfer molding is similar to compression molding in that a carefully calculated, pre-measured amount of uncured molding compound is used for the molding process.
- The difference is, instead of loading the polymer into an open mold, the plastic material is preheated and loaded into a holding champers called the pot.
- The material is then forced/transferred into the preheated mold cavity by a hydraulic plunger through a channel called sprue. The mold remains closed until the material inside is cured.

ii.Transfer molding:



ii.Transfer molding:

Process in Transfer molding:

1.The pre-heated, uncured molding compound is placed in the transfer pot.

2.A hydraulically powered plunger pushes the molding compound through the sprue(s) into the preheated mold cavity. The mold remains closed until the material inside is cured (thermosets) or cooled (thermoplastics).

3.The mold is split to free the product, with the help of the ejector pins.

4.The flash and sprue material is trimmed off.

Plastic used in this Process:

- Epoxy
- Polyester (Unsaturated)
- Phenol-formaldehyde Plastic (PF, Phenolic)
- Silicone rubber (SI)

Advantages:

- Product consistency better than compression molding, allowing tighter tolerance and more intricate parts
- Production speed higher than compression molding
- Fast setup time and lower setup costs than injection molding
- Lower maintenance costs than injection molding
- Ideal for plastic parts with metal inserts

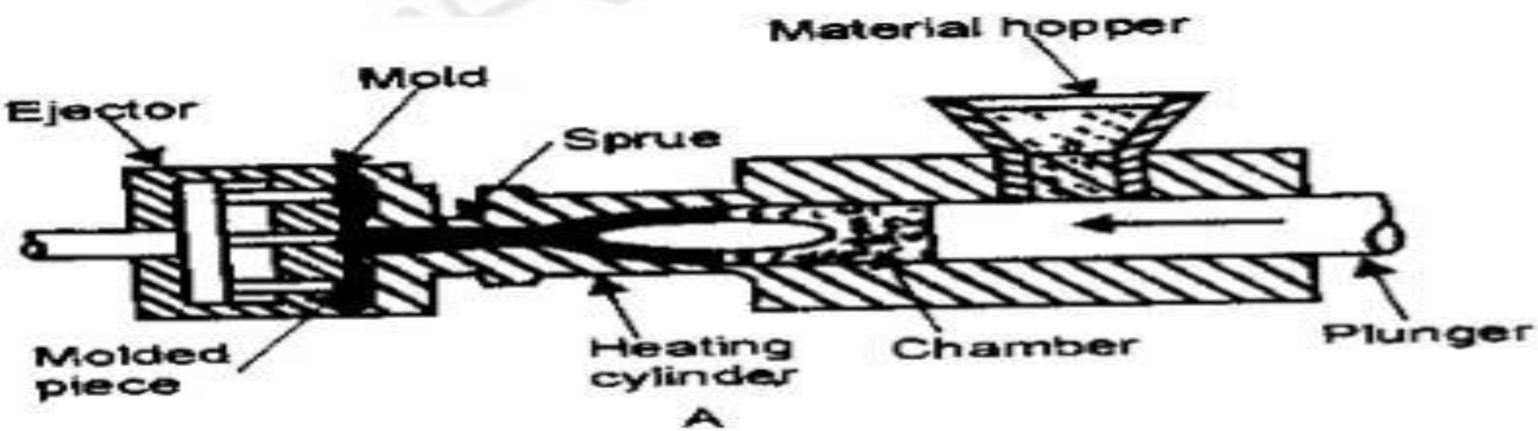
Disadvantages:

- Wastes more material than compression molding (scraps of thermosets are not re-useable).
- Production speed lower than injection molding

iii.Injection molding:

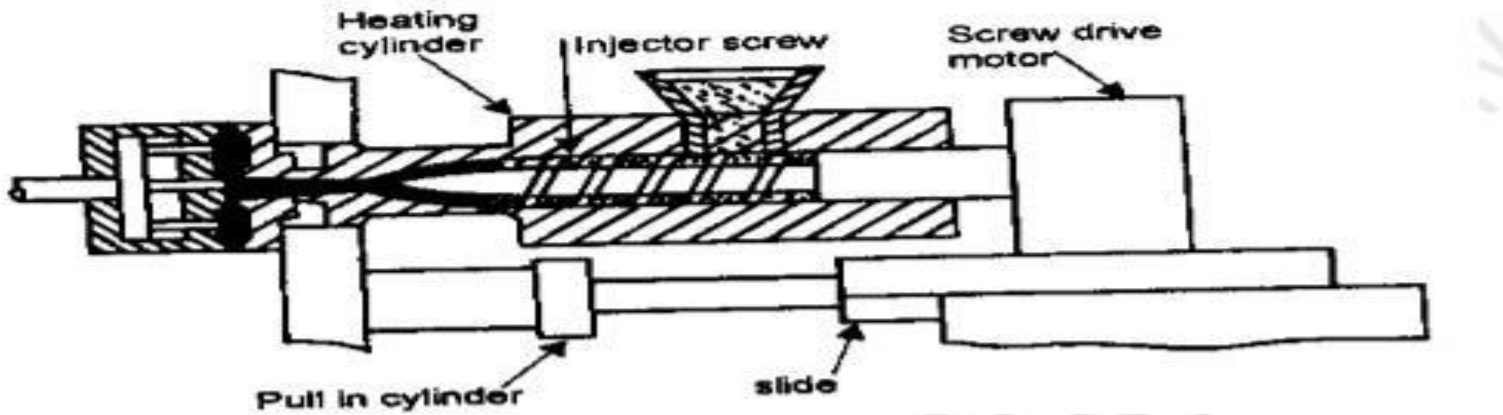
- Injection molding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials.
- Material is fed into a heated barrel, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the mold cavity.

Conventional Single Stage Plunger Type

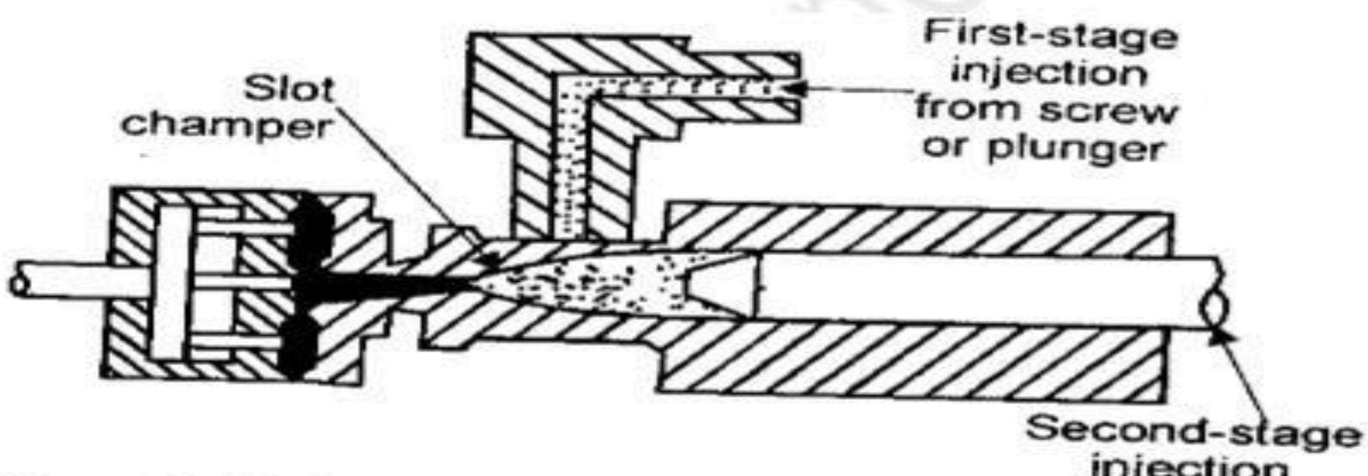


iii.Injection molding:

Single Stage Reciprocating Screw Type



Two stage plunger or Screw plasticiser type



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iii.Process of Injection Moulding:

 The process start with feeding plastic pellets in the hopper above the heating cylinder of the machine.

- The resin falls into and is pushed along the heated tube by reciprocating screw until a sufficient volume of melted plastic available

 This may take from 10 Sec to 6 min.

 The entire screw is then plunged forward to force the plastic into the mould.

 Each shot may produce one or several parts, depending on the die used.

 The ram is held under pressure for a few seconds so that the moulded part can solidify.

- It then retracts slightly, and the mould open Knockout pins eject the moulded piece.

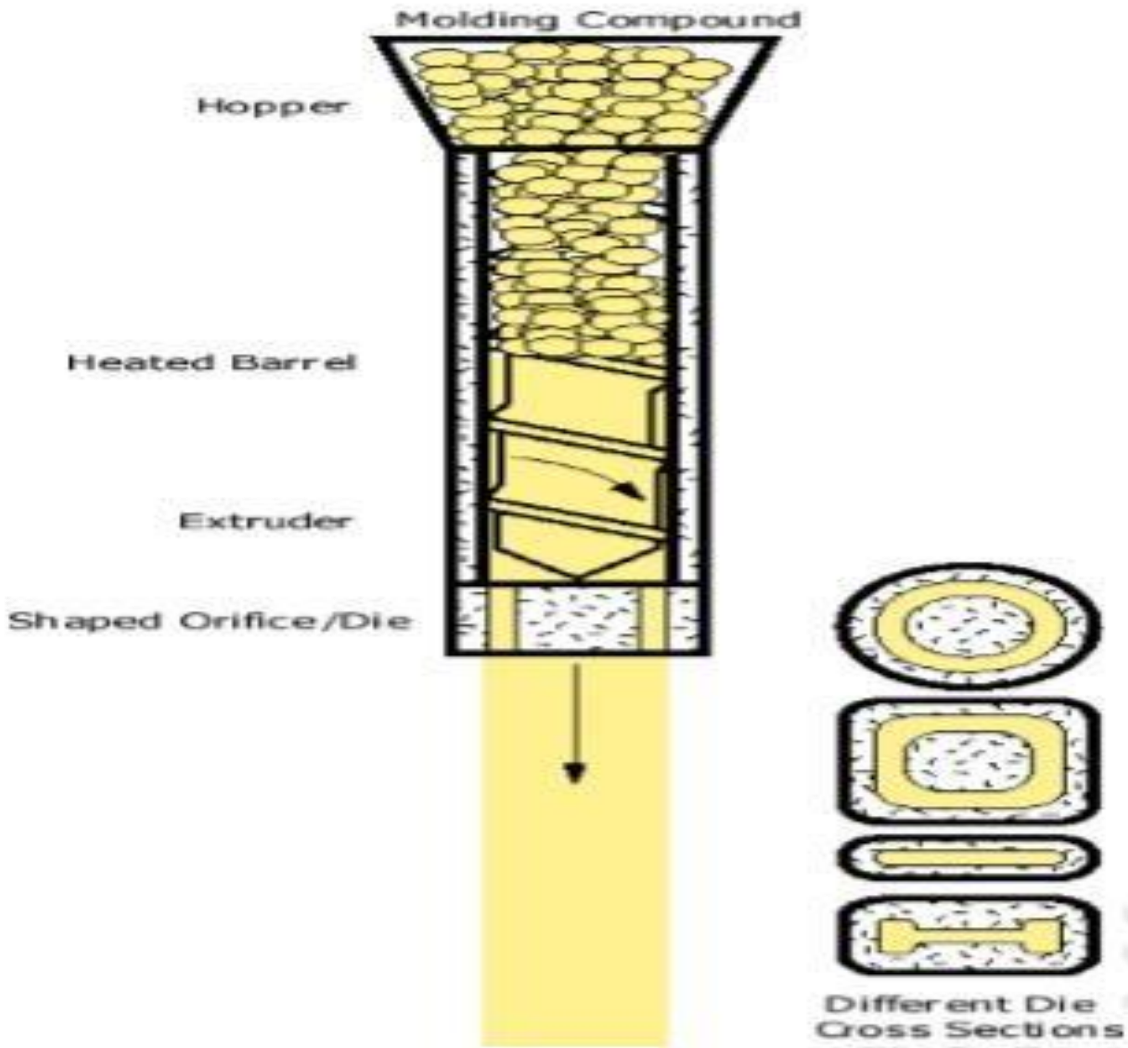
Applications of Process of Injection Moulding:

- Milk cartons,
- Packaging
- Bottle caps
- Automotive dashboards
- Pocket combs
- And most other plastic products available today.

iv.Extrusion Moulding:

- Extrusion is one of the most widely used manufacturing processes across many industries. Essentially, it is not much different from squeezing tooth paste out of the tube.
- Anything that is long with a consistent cross section is probably made by extrusion.
- Common examples are spaghetti, candy canes, chewing gums, drinking straws, plumbing pipes, door insulation seals, optical fibers, and steel or aluminum Ibeams.

iv.Extrusion Moulding:



iv.Extrusion Moulding Process:

- The plastic extrusion molding process usually begins with a thermoplastic in the form of pelletsorgranules.

- They are usually stored in a hopper (a funnel-shaped receptacle) before they are delivered to a heated barrel.
- The molten plastic is then forced through a shaped orifice, usually a custom steel die with shape of the cross section of the

intended part, forming a tube-like or rod-like continuous work piece.

- Cooling of the work piece should be as even as possible.

Plastics used in Extrusion Moulding Process:

- Acrylonitrile Butadiene Styrene (ABS)
- Acrylic
- Polycarbonate (PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polyester
- Polystyrene (PS)
- Polyvinylchloride (PVC)

Extrusion Moulding Process:

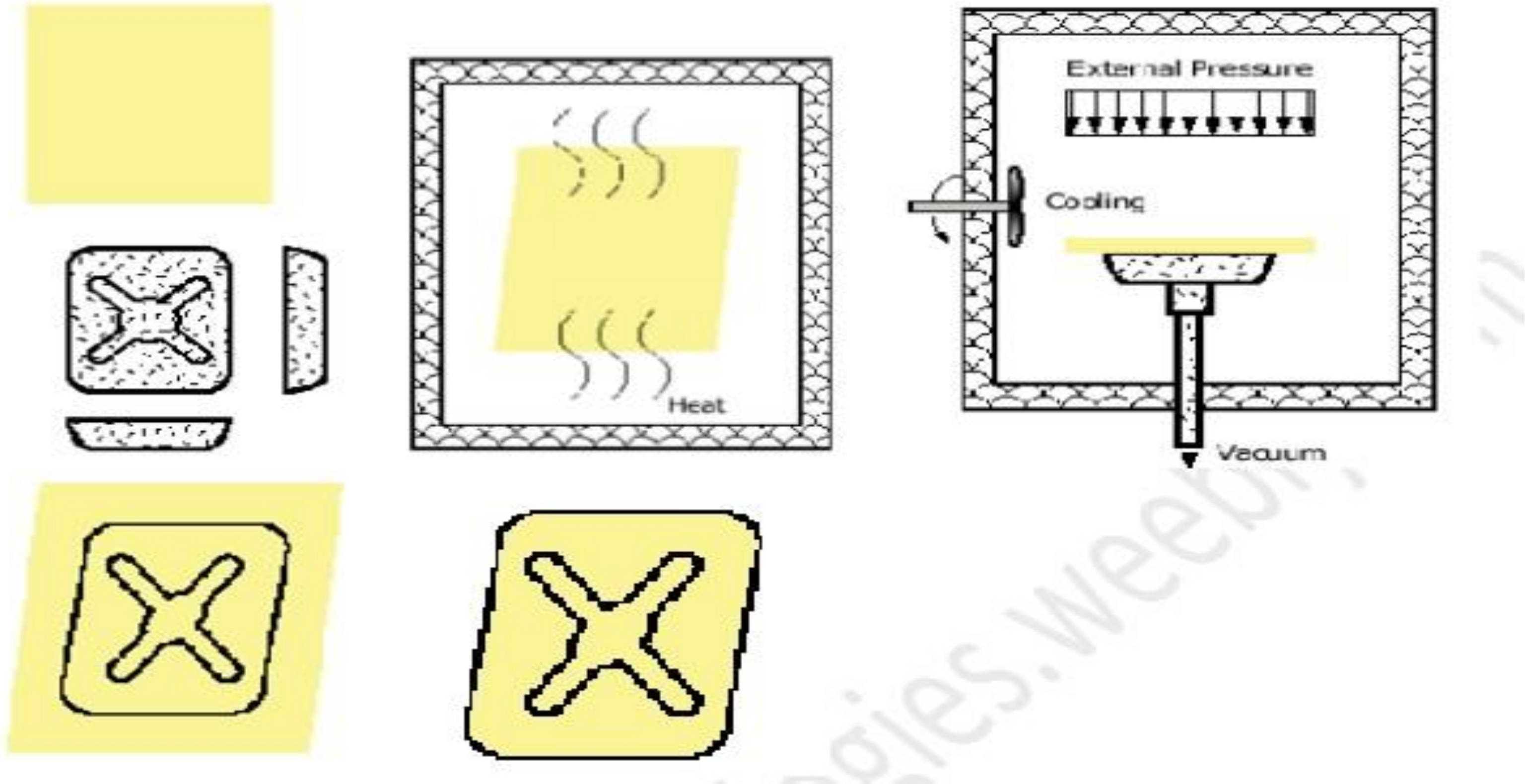
Advantages

- Low initial setup costs
- Fast setup time
- Low production costs

Disadvantages

- Moderate production speed
- Average precision
- Limited to parts with a uniform cross section

V.Thermoforming Process:



Plastics used inThermoforming process:

- Acrylonitrile Butadiene Styrene (ABS)
- Acrylic Polycarbonate (PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polystyrene (PS)
- Polyvinylchloride (PVC)

Thermoforming Process

Advantages

- Low initial setup costs
- Fast setup time
- Low production costs
- Less thermal stresses than injection molding and compression molding
- More details and better cosmetics than rotational-molded products

Disadvantages

- Geometries limited to thin shells or shallow shapes
- One side of the product can be precisely controlled by the mold dimensions while the other side can not.

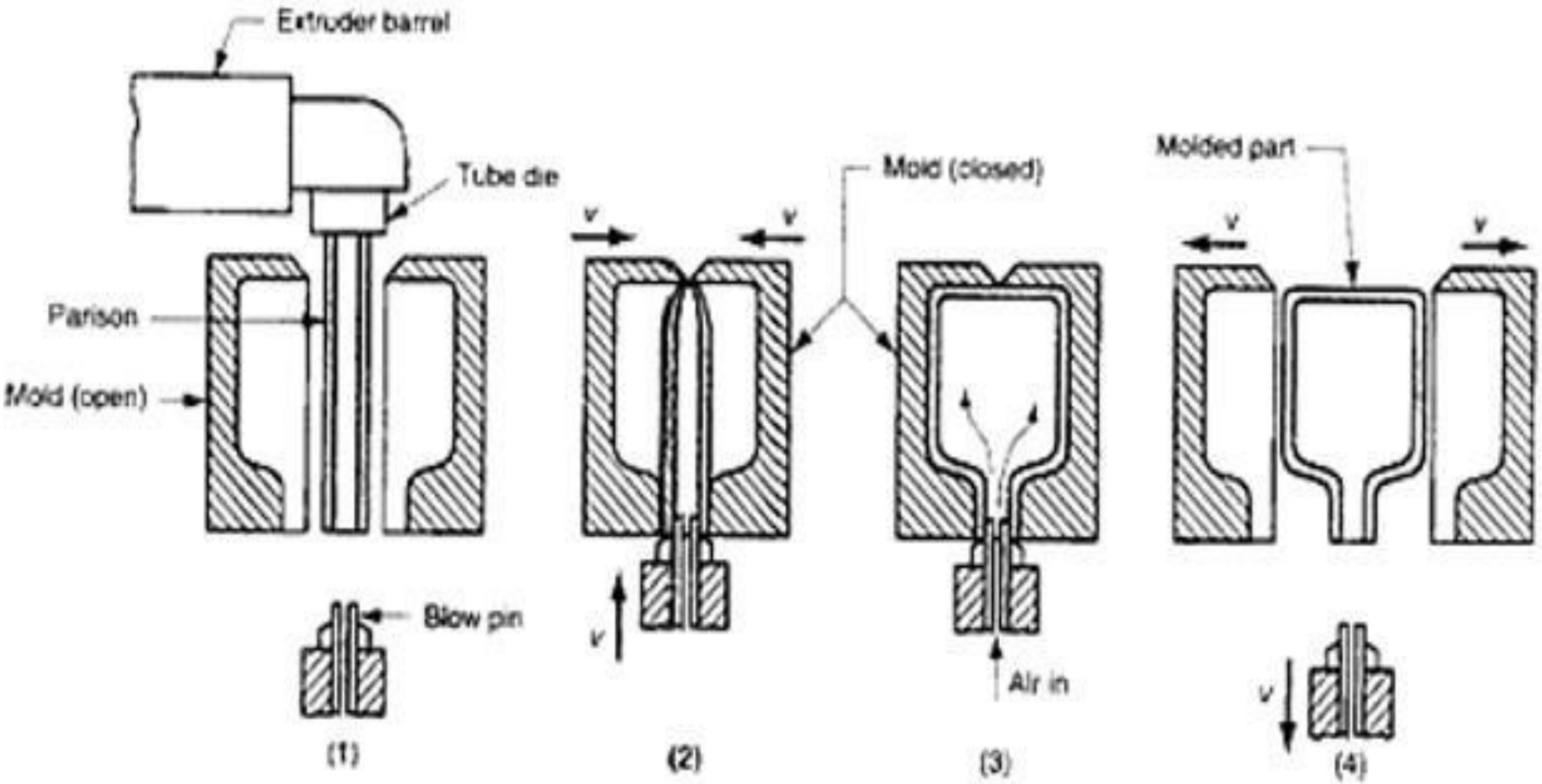
VII.Blow Moulding:

Blow molding, also known as blow forming, is a manufacturing process by which hollow plastic parts are formed. It is a process used to produce hollow objects from thermoplastic.

In general, there are three main types of blow molding:

VII.i. Extrusion Blow Molding, VII.ii. Injection Blow Molding, And VII.iii. Stretch Blow Molding.

Extrusion Blow Molding:



Extrusion Blow Molding:

Extrusion Blow molding allows for a wide variety of container shapes, sizes and neck openings, as well as the production of handle-ware. Some extrusion machines can produce 300 to 350 bottles per hour. Extrusion blown containers can also have their gram weights adjusted through an extremely wide range, Extrusion blow molds are generally much less expensive than injection blow molds and can be produced in a much shorter period of time.

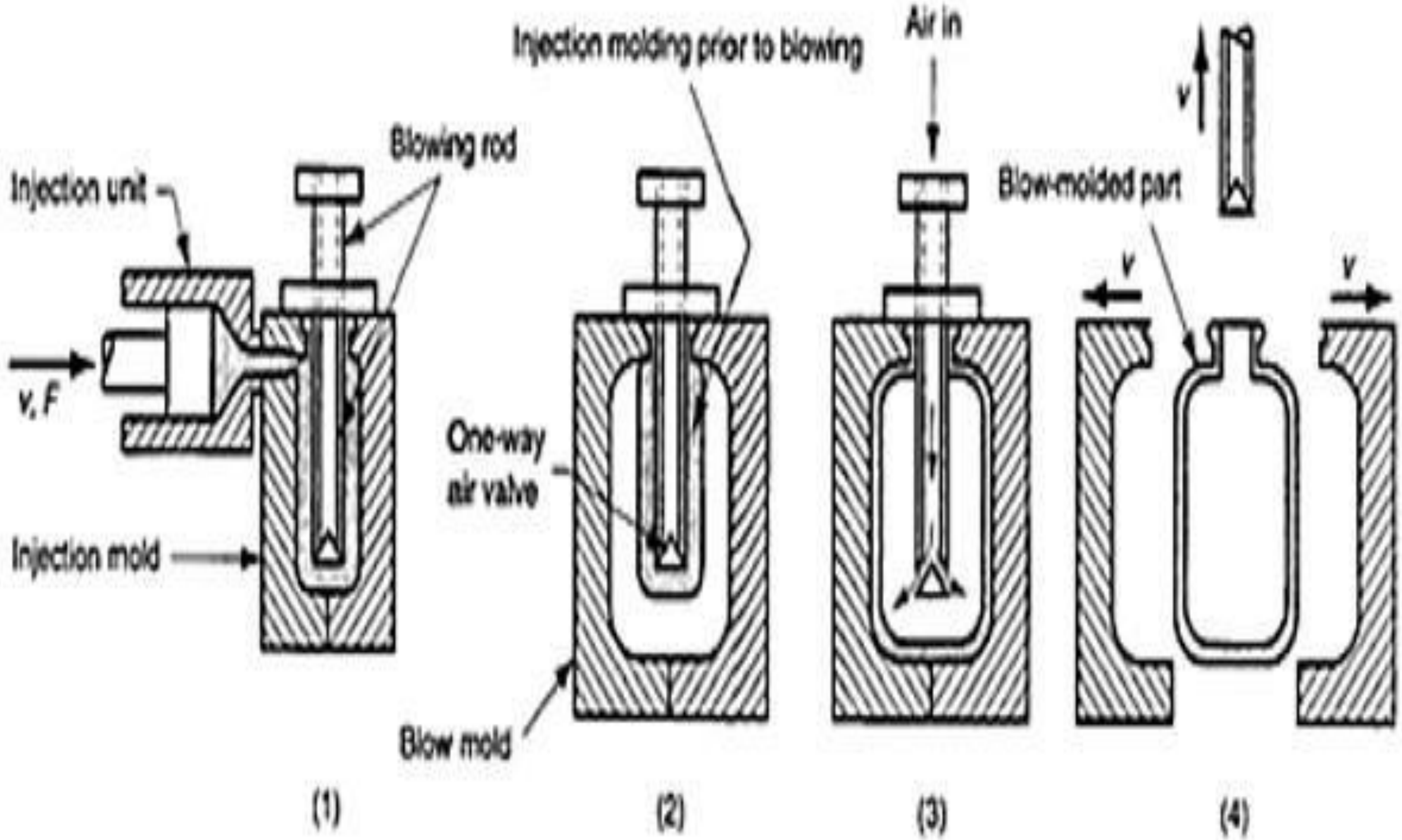
Advantages of extrusion blow molding

- high rate of production,
- low tooling cost, and a vast majority of machine manufactures. Some disadvantages usually include a high scrap rate, a limited control over wall thickness, and some difficulty of trimming away excess plastic.

Disadvantages

- include a high scrap rate,
- a limited control over wall thickness,
- and some difficulty of trimming away excess plastic.

VII.II.Injection Blow Molding:



Injection unit
Blowing rod
Injection molding prior to blowing
Air in
Blow-molded part
v
v, F
One-way
air valve
Injection mold
Blow mold
(1)
(2)
(3)
(4)

VII.II.Injection Blow Molding:

Injection molding can be broken down into three stages. The first stage is where the melted plastic is injected into a split steel mold cavity from the screw extruder.

 The mold produces a perform parison which resembles a test tube with a screw finish on the top.

 The perform is then transferred on a core rod to the second part of the injection blow molding stage. The perform is then placed inside another cold and usually aluminum blow mold cavity. Air is then injected through the core rod till the perform takes the shape of the cavity. While still on the core rod, the container is then transferred to a desired location for the third stage, where it is ejected from the machine.

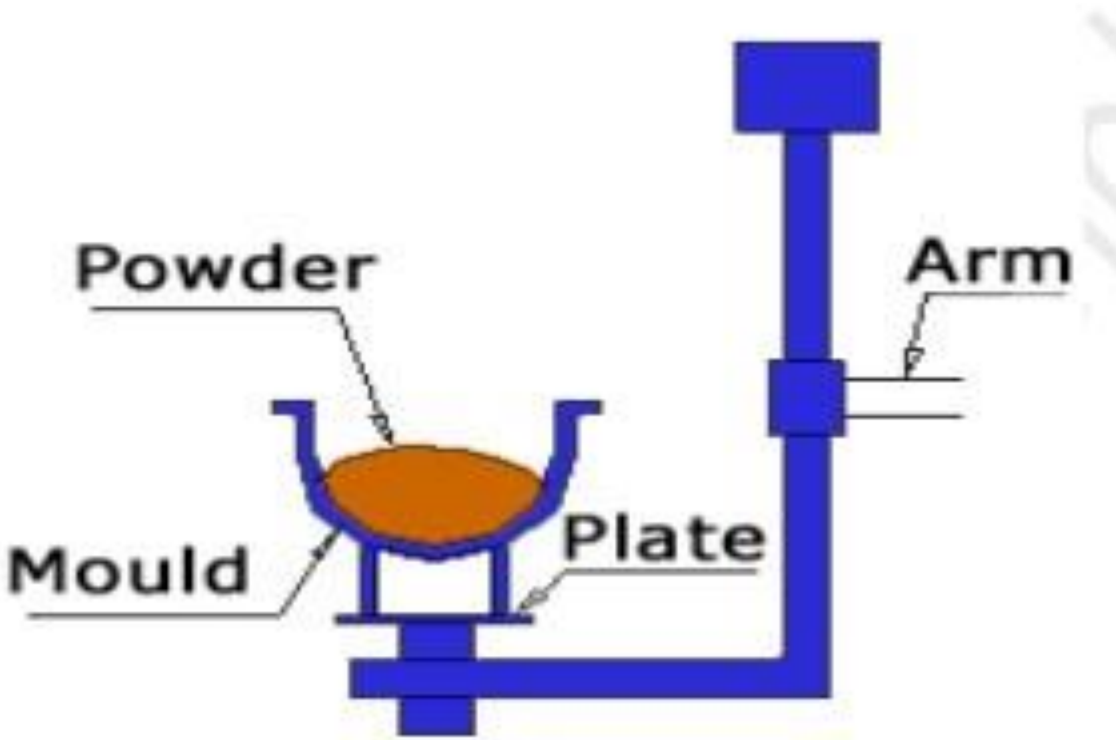
VII.III.Stretch Blow Moulding :

 Stretch blow molding is best known for producing PET bottles commonly used for water, juice and a variety of other products. Stretch blow molding has been used since the early 1970's especially for packaging detergent, and has grown in existence with the primary use for making carbonated beverage bottles.

 One of the major advantages of stretch blow molding is the ability to stretch the perform in both the hoop direction and the axial direction. This biaxial stretching of material increases the tensile strength, barrier properties, drop impact, clarity, and top load in the container. With these increases it is usually possible to reduce the overall weight in a container by 10 to 15 percent less then when producing a container in another way

VIII.Rotation Moulding :

Rotational molding or moulding is a versatile process for creating many kinds of mostly hollow items, typically of plastic. The phrase is often shortened to rotomolding or rotomoulding.



VIII.Rotation Moulding :

1. **Mould charging:** A predetermined charge of cold plastic powder is placed in one half of a cold mould, which is then closed
2. **Mould rotation and heating:** The arm with the mould is then inserted into the oven, where the plastic is warmed up to the right melting temperature. The mould is rotated biaxial in this heated oven. Thus, the plastic powder inside the mould starts to melt and coat the inside surface of the mould. The rotation of the mould continues until all plastic powder has melted and is evenly divided inside the mould.

VIII.Rotation Moulding :

3. **Mould cooling:** As the biaxial rotation continues, the arm with the mould is transferred to a cooled environment. There, air, water or a combination of both is used to cool the mould and the molten plastic. The cooling process continues until the plastic has solidified and the plastic product maintains its form.
4. **De-moulding of the final product:** After the cooling, the rotational arm is transferred to the load and unload station. The mould is opened and the product is de-moulded. When the product is de-moulded, the mould can be charged again with powder and the process can start all over again.

VIII. Advantages of Rotation Moulding :

 Rotational molding offers design advantages over other molding processes.

 With proper design, parts assembled from several pieces can be molded as one part, eliminating high fabrication costs. The process also has inherent design strengths, such as consistent wall thickness and strong outside corners that are virtually stress free.

 For additional strength, reinforcing ribs can be designed into the part. Along with being designed into the part, they can be added to the mold.

VIII. Limitations of Rotation Moulding :

 Rotationally molded parts have to follow some restrictions that are different from other plastic processes.

 As it is a low pressure process, sometimes designers face hard to reach areas in the mold. Good quality powder may help overcome some situations, but usually the designers have to keep in mind that it is not possible to make some sharp threads used in injection molded goods.

 Some products based on polyethylene can be put in the mold before filling it with the main material. This can help to avoid holes that otherwise would appear in some areas. This could be also achieved using molds with movable sections another limitation lies in the molds themselves.

VIII. Limitations of Rotation Moulding :

 Unlike other processes where only the product needs to be cooled before being removed, with rotational molding the entire mold must be cooled.

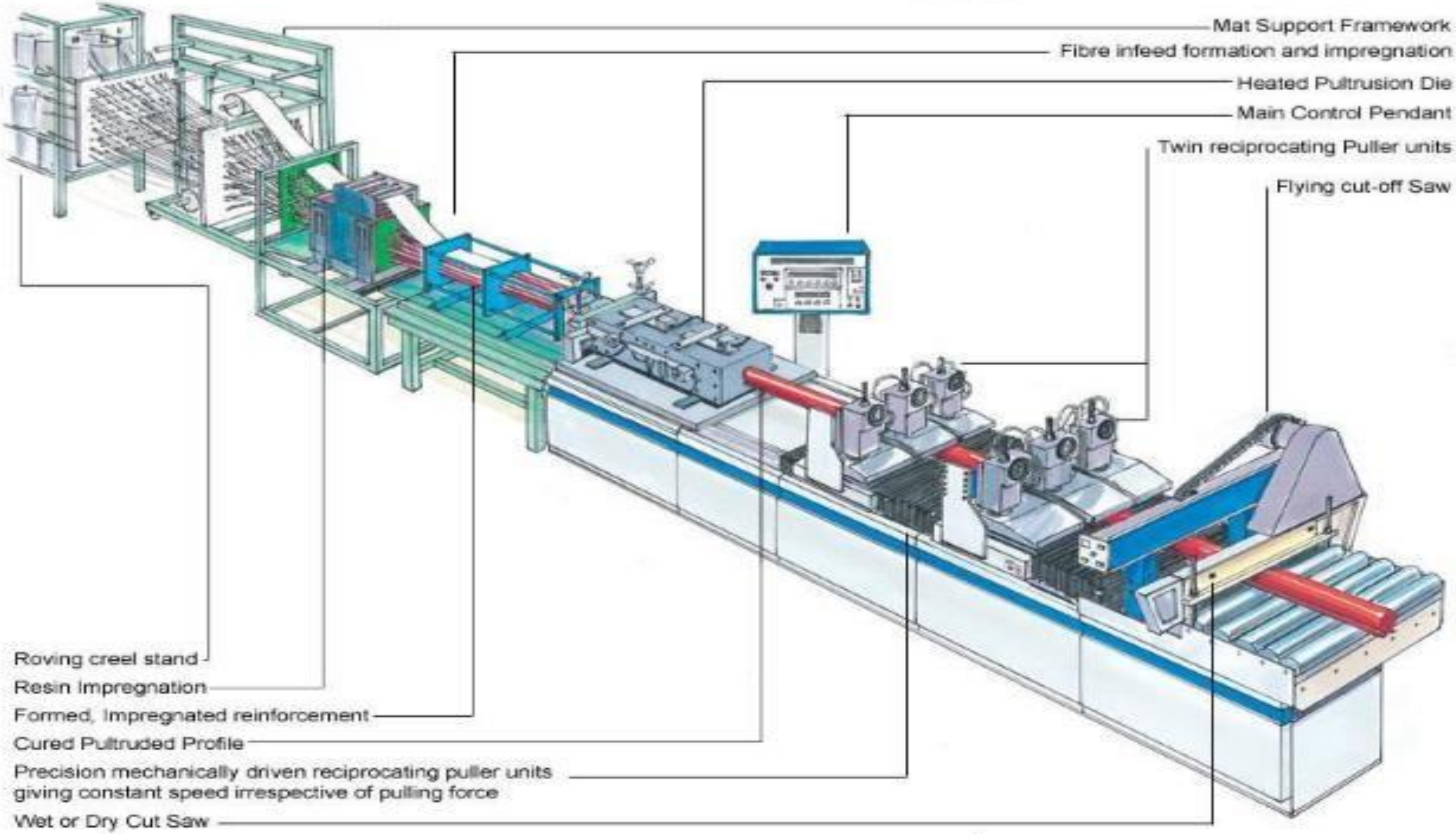
 While water cooling processes are possible, there is still a significant down time of the mold. Additionally, this increases both financial and environmental costs.

 Some plastics will degrade with the long heating cycles or in the process of turning them into a powder to be melted.

IX.Laminating:

In most cases, a hot laminator is used to seal the pouch and bind the layers together so that your document is laminated. The actual pouch consists of pockets of laminating film into which the item to be laminated is placed.

Laminating

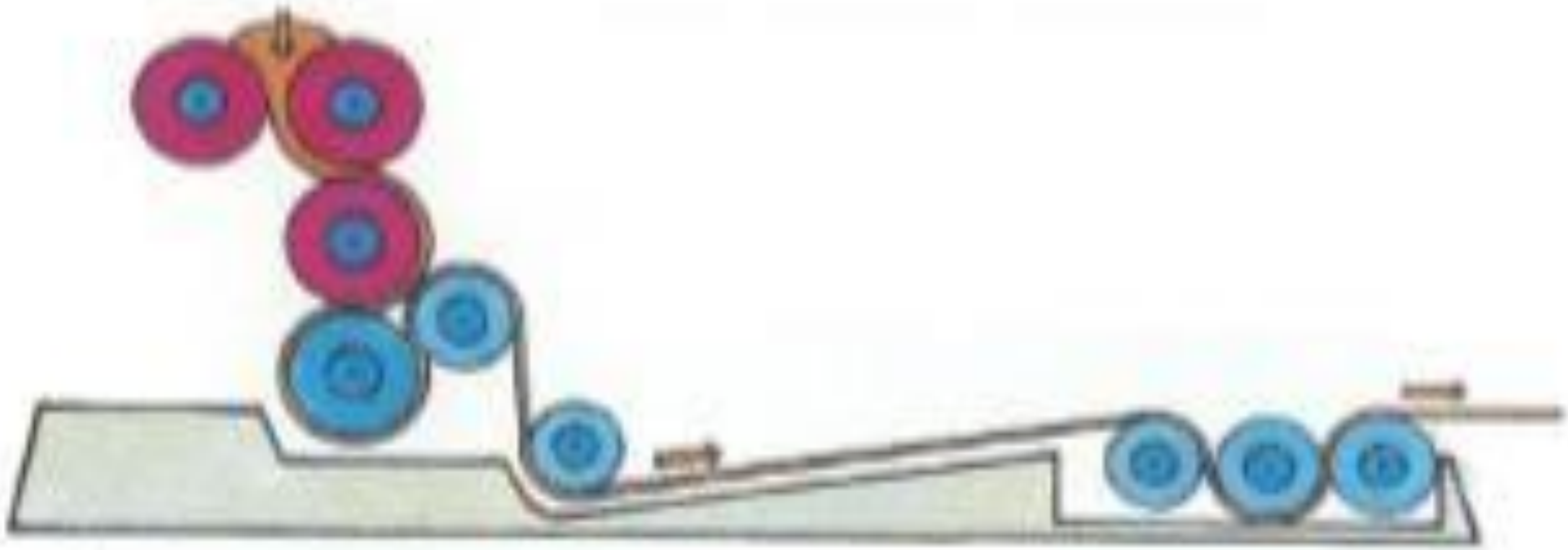


Mat Support Framework
Fibre infeed formation and impregnation
Heated Pultrusion Die
Main Control Pendant
Twin reciprocating Puller units
Flying cut-off Saw
Roving creel stand
Resin Impregnation
Formed, Impregnated reinforcement
Cured Pultruded Profile
Precision mechanically driven reciprocating puller units giving constant speed irrespective of pulling force
Wet or Dry Cut Saw

X.Calendaring:

- A PVC blend is pre-gelatinised and then kneaded to form a viscous material. It is laminated through a series of cylinders and transformed into a continuous sheet, which is cooled and then rolled up. The sheets may be monooriented during the process.
- As with extrusion, calendaring is a continuous process Calendaring is a finishing process used on cloth where fabric is folded in half and passed under rollers at high temperatures and pressures.
- Calendaring is used on fabrics such as moiré to produce its watered effect and also on cambric and some types of sateen's.

X.Calendaring:



X.Calendaring:

 In preparation for calendaring, the fabric is folded lengthwise with the front side, or face, inside, and stitched together along the edges.

 The fabric can be folded together at full width, however this isn't done as often as it is more difficult.

 The fabric is then run through rollers that polish the surface and make the fabric smoother and more lustrous.

 High temperatures and pressure are used as well. Fabrics that go through the calendaring process feel thin, glossy and papery.

Ceramics:

Ceramics are compounds of metallic and nonmetallic elements. The term ceramics (from the Greek words keramos, meaning “potter’s clay,” and keramikos, meaning “clay products”)refers both to the material and to the ceramic product itself. Because of the large number of possible combinations of elements, a wide variety of ceramics now is available for abroad range of consumer and industrial applications.

Raw Materials:

Among the oldest of the raw materials used for making ceramics is clay, which has a fine-grained sheet like structure. The most common example is kaolinite (from Kaoling, a hill in China), a white clay consisting of silicate of aluminum with alternating weakly bonded layers of silicon and aluminum ions.

When added to kaolinite, water attaches itself to the layers (adsorption). This makes the layers slippery and gives wet clay both its well-known softness and the plastic properties (hydro plasticity) that make it formable.

Raw Materials:

Other major raw materials for ceramics that are found in nature are flint (a rock composed of very fine grained silica,) and feldspar (a group of crystalline minerals consisting of aluminum silicates and potassium, calcium, or sodium).

Porcelain is a white ceramic composed of kaolin, quartz, and feldspar; its largest use is in appliances and kitchen and bath ware. In their natural state, these raw materials generally contain impurities of various kinds, which have to be removed prior to further processing of the materials into useful products with reliable performance.

Types and General Characteristics of Ceramics	
Type	**General characteristics**
Oxide ceramics	
Alumina	High hardness and moderate strength; most widely used ceramic; cutting tools; abrasives; electrical and thermal insulation.
Zirconia	High strength and toughness; thermal expansion close to cast iron; suitable for high-temperature applications.
Carbides	
Tungsten carbide	Hardness, strength, and wear resistance depend on cobalt binder content; commonly used for dies and cutting tools.
Titanium carbide	Not as tough as tungsten carbide; has nickel and molybdenum as the binder; used as cutting tools.
Silicon carbide	High-temperature strength and wear resistance; used for heat engines and as abrasives.
Nitrides	
Cubic boron nitride	Second-hardest substance known, after diamond; used as abrasives and cutting tools.
Titanium nitride	Gold in color; used as coatings because of low frictional characteristics.
Silicon nitride	High resistance to creep and thermal shock; used in high-temperature applications.
Sialon	Consists of silicon nitrides and other oxides and carbides; used as cutting tools.
Cermets	Consist of oxides, carbides, and nitrides; used in high-temperature applications.
Silica	High-temperature resistance; quartz exhibits piezoelectric effect; silicates containing various oxides are used in high-temperature nonstructural applications.
Glasses	Contain at least 50 percent silica; amorphous structures; several types available with a wide range of mechanical and physical properties.
Glass ceramics	Have a high crystalline component to their structure; good thermal-shock resistance and strong.
Graphite	Crystalline form of carbon; high electrical and thermal conductivity; good thermal-shock resistance.
Diamond	Hardest substance known; available as single crystal or in polycrystalline form; used as cutting tools and abrasives and as dies for fine wire drawing.
Carbon nanotubes	Unique crystalline form of graphite, with high electrical and thermal conductivity; under investigation for MEMS and microelectronics applications and in composite materials.

Properties of Various Ceramics at Room Temperature

Material	Symbol	Transverse rupture strength (MPa)	Compressive strength (MPa)	Elastic modulus (GPa)	Hardness (HK)	Poisson's ratio, ν	Density (kg/m^3)
Aluminum oxide	Al_2O_3	140–240	1000–2900	310–410	2000–3000	0.26	4000–4500
Cubic boron nitride	cBN	725	7000	850	4000–5000	—	3480
Diamond	—	1400	7000	830–1000	7000–8000	—	3500
Silica, fused	SiO_2	—	1300	70	550	0.25	—
Silicon carbide	SiC	100–750	700–3500	240–480	2100–3000	0.14	3100
Silicon nitride	Si_3N_4	480–600	—	300–310	2000–2500	0.24	3300
Titanium carbide	TiC	1400–1900	3100–3850	310–410	1800–3200	—	5500–5800
Tungsten carbide	WC	1030–2600	4100–5900	520–700	1800–2400	—	10,000–15,000
Partially stabilized zirconia	PSZ	620	—	200	1100	0.30	5800

Ceramics Applications:

- Applications of Ceramics have numerous consumer and industrial applications.
- Various types of ceramics are used in the electrical and electronics industries, because they have high electrical resistivity, high dielectric strength (voltage required for electrical breakdown per unit thickness), and magnetic properties suitable for such applications as magnets for speakers.
- The capability of ceramics to maintain their strength and stiffness at elevated temperatures makes them very attractive for high-temperature applications.

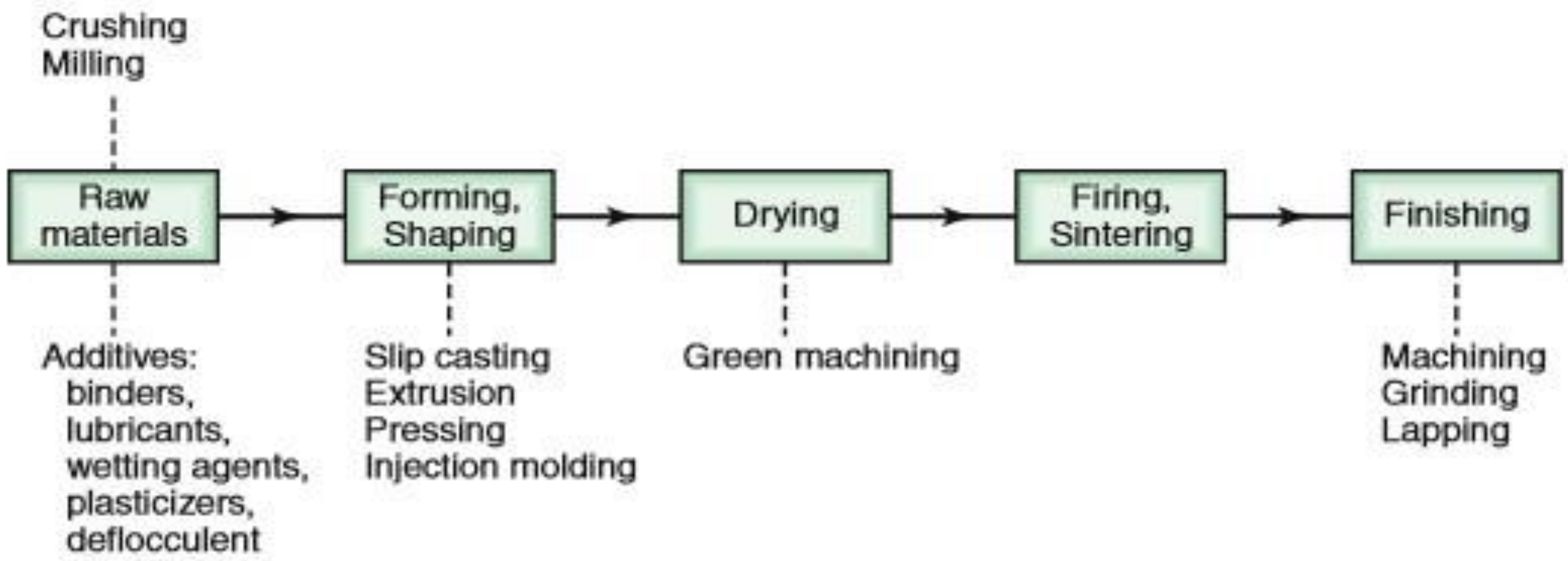
Ceramics Applications:

- The higher operating temperatures made possible by the use of ceramic components mean more efficient combustion of fuel and reduction of emissions in automobiles.
- Currently, internal combustion engines are only about 30% efficient, but with the use of ceramic components, the operating performance can be improved by at least 30%.
- Ceramics that are being used successfully, especially in automotive gas-turbine engine

components (such as rotors), are silicon nitride, silicon carbide, and partially stabilized zirconium.

Ceramics Applications:

- Other attractive properties of ceramics are their low density and high elastic modulus. They enable product weight to be reduced and allow the inertial forces generated by moving parts to be lower.
- Ceramic turbochargers, for example, are about 40% lighter than conventional ones. High-speed components for machine tools also are candidates for ceramics.
- Furthermore, the high elastic modulus of ceramics makes them attractive for improving the stiffness of machines, while reducing the weight.
- Their high resistance to wear makes them suitable for applications such as cylinder liners, bushings, seals, bearings, and liners for gun barrels.
- Coating metal with ceramics is another application, often done to reduce wear, prevent corrosion, or provide a thermal barrier.



Shaping processes for ceramics:

i.Casting:

The most common casting process is slip casting (also called drain casting), as illustrated in Fig. A slip is a suspension of colloidal (small particles that do not settle) ceramic particles in an immiscible liquid (insoluble in each other), which is generally water. The slip is poured into a porous mold, typically made of plaster of pairs. Molds also may consist of several components.

(a) (b) (c) (d) (e)

The slip must have sufficient fluidity and low enough viscosity to flow easily into the mold, much like the importance of fluidity of molten metals in casting operations as described in Section 10.3. Pouring the slip must be done properly, as air entrapment can be a significant problem during casting.

i.Casting:

- After the mold has absorbed some of the water from the outer layers of the suspension, it is inverted and the remaining suspension is poured out.
- The product is a hollow object, as in the slush casting of metals described in Section 11.4.3.
- The top of the part is then trimmed (note the trimming tool in Fig. 18.3d), the mold is opened, and the part is removed. Large and complex parts (such as plumbing ware, art objects, and dinnerware) can be made by slip casting.
- Although mold and equipment costs are low, dimensional control is poor and the production rate is low.

i.Casting:

- In some applications, components of the product (such as handles for cups and pitchers) are made separately and then joined, using the slip as an adhesive.
- Molds also may consist of multiple components
- For solid-ceramic parts, the slip is supplied continuously into the mold to replenish the absorbed water; otherwise, the part will shrink. At this stage, the part is described as either a soft solid or semi rigid.
- The higher the concentration of solids in the slip,the less water has to be removed.

i.Casting: .

- The part removed from the mold is referred to as a green part

and is associated with the light-green tint in decorative ceramic slip casts at this stage.

 While the ceramic parts are still green, they may be machined to produce certain features or to give dimensional accuracy to the parts.
 Because of the delicate nature of the green compacts, however, machining usually is done manually or with simple tools. For example, the flashing in a slip casting may be removed gently with a fine wire brush, or holes can be drilled in the mold.

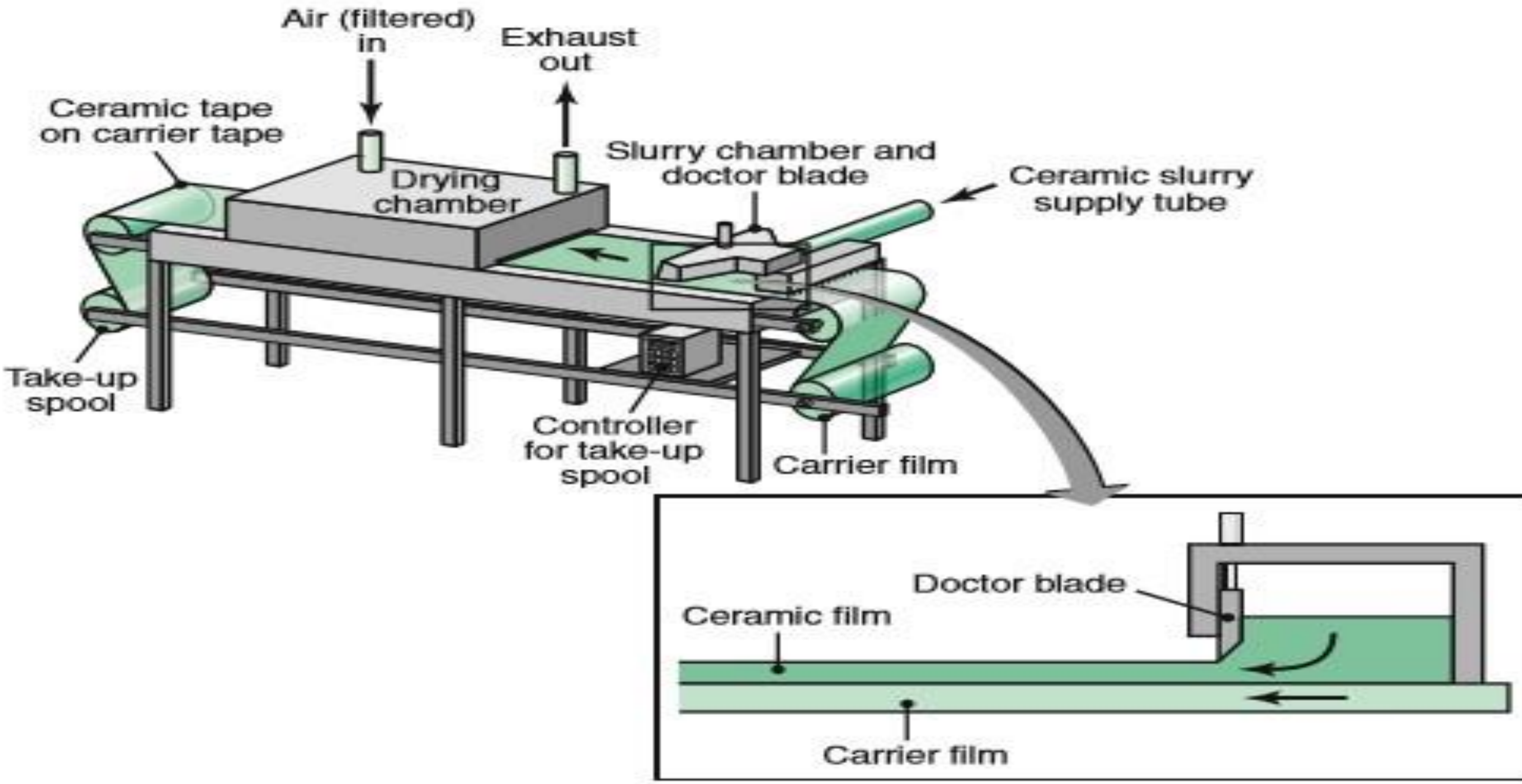
- Detailed work (such as the tapping of threads) generally is not done on green compacts because war page (due to firing) makes such machining not viable.

ii.Plastic Forming:

- Plastic forming (also called soft, wet, or hydro plastic forming) can be carried out by various methods, such as extrusion, injection molding, or molding and jiggering (Fig. 18.5).

 Plastic forming tends to orient the layered structure of clay along the direction of material flow and, hence, tends to cause anisotropic behavior of the material both in subsequent processing and in the final properties of the ceramic product.
 In extrusion, the clay mixture (containing 20 to 30% water) is forced through a die opening by a screw-type piece of equipment.

ii. Plastic Forming:


Air (filtered)
in
Exhaust
out
Ceramic tape
on carrier tape
Drying
chamber
Slurry chamber and
doctor blade
Ceramic slurry
supply tube
Take-up
spool
Controller
for take-up
spool
Carrier film
Doctor blade
Ceramic film
Carrier film

Production of ceramic sheets through the doctor-blade process.

ii.Plastic Forming:

- The cross section of the extruded product is constant, and there are limitations to wall thickness for hollow extrusions. The extruded products may be subjected to additional shaping operations. Tooling costs are low, and production rates are high.

iii.**Pressing:**

- Dry Pressing. This is a technique similar to powder-metal compaction, as described in Section 17.3.
- Dry pressing is used for relatively simple shapes, such as white ware, refractoriness for furnaces, and abrasive products. The moisture content of the mixture generally is below 4%, but it may be as high as 12%.
- Organic and inorganic binders (such as stearic acid, wax, starch, and polyvinyl alcohol) usually are added to the mixture; these additives also act as lubricants.
- This process has the same high production rates and close control of dimensional tolerances as does powder metallurgy.

iii.**Pressing:**

The recommended maximum ratio is 2:1. Several methods may be used to minimize density variations, including

(a) proper design of tooling,

(b) vibratory pressing and impact forming (particularly for nuclear-reactor fuel elements), and (c) isostatic pressing.

iii.a.Wet Pressing:

In wet pressing, the part is formed in a mold while under high pressure in a hydraulic or mechanical press. This process generally is used to make intricate shapes. Moisture content usually ranges from 10 to 15%. Production rates are high; however,

(a) part size is limited,

(b) dimensional control is difficult to achieve because of shrinkage during drying, and

(c) tooling costs can be high

iii.b. Isostatic Pressing:

Used extensively in powder metallurgy, isostatic pressing also is used for ceramics in order to obtain a uniform density distribution throughout the part during compaction. For example, automotive spark-plug insulators are made by this method at room temperature, while silicon-nitride vanes for high-temperature applications (see Fig. 8.1) are made by hot isostatic pressing.

iii.c. Jiggering:

A series of steps is needed to make ceramic plates. First, clay slugs are extruded and formed into a bat over a plaster mold.

Then they are jiggered on a rotating mold (see Fig. 18.5b). Jiggering is a motion in which the clay bat is formed by means of templates or rollers. The part then is dried and fired. The jiggering process is confined to axisymmetric parts and has limited dimensional accuracy. The operation is automated for improved productivity.

iii.c. Jiggering:

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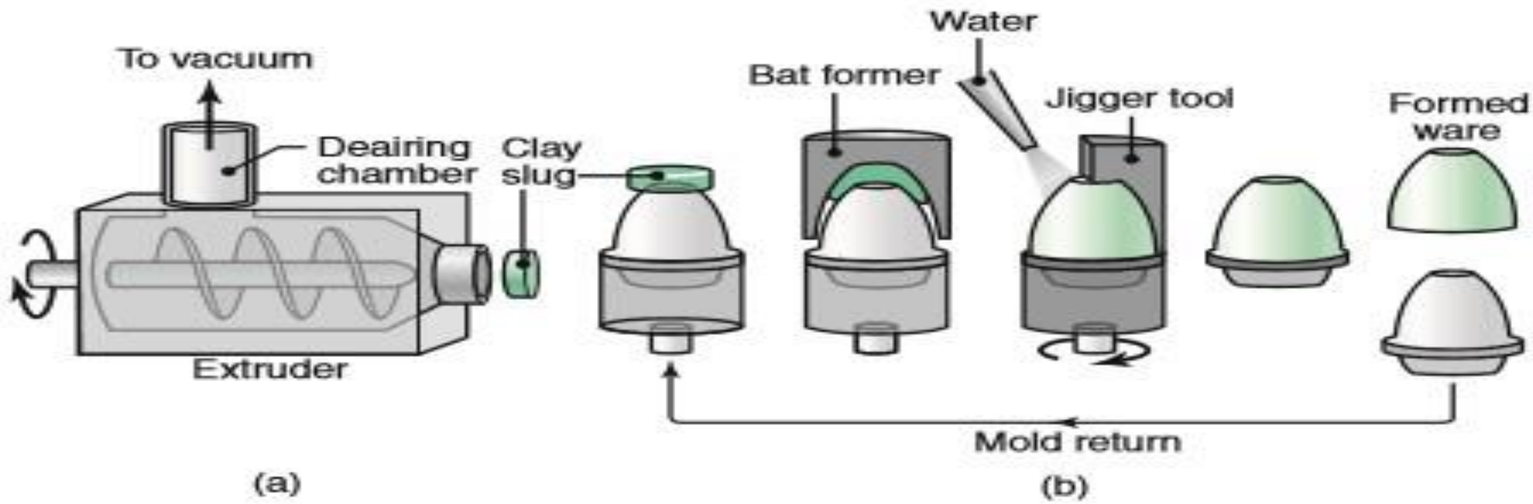


iii.d.Injection Molding:

- Injection molding is used extensively for the precision forming of ceramics in high-technology applications, such as for rocket-engine components.
- The raw materials mixed with abider ,such as a thermo plastic polymer(polypropylene, low-density polyethylene, or ethylene vinyl acetate) or wax.
- The binder usually is removed by pyrolysis (inducing chemical changes by heat); the part is then sintered by firing.
- The injection-molding process can produce thin sections [typically less than 10 to 15 mm (0.4 to 0.6 in.) thick] from most engineering ceramics, such as alumina, zirconium, silicon nitride, silicon carbide, and salon. Thicker sections require careful control of the materials used and of the processing parameters in order to avoid defects, such as internal voids and cracks—especially those due to shrinkage.

iii.e.Hot Pressing:

- In this process (also called pressure sintering), the pressure and the heat are applied simultaneously, thereby reducing porosity and making the part denser and stronger.
- Graphite commonly is used as a punch and die material, and protective atmospheres usually are employed during pressing. Hot isostatic pressing (Section 17.3.2) also may be used,

particularly to improve shape accuracy and the quality of high-technology ceramics, such as silicon carbide and silicon nitride.

- Glass-encapsulated HIP processing has been shown to be effective for this purpose.

iv.Drying:

- Drying is a critical stage because of the tendency for the part to warp or crack from variations in moisture content and in thickness. Control of atmospheric humidity and of ambient temperature is important in order to reduce warping and cracking.

➢ Loss of moisture during drying causes shrinkage of the part by as much as 20% from the original, moist size (Fig. 18.6). In a humid environment, the evaporation rate is low, and consequently, the moisture gradient across the thickness of the part is lower than that in a dry environment.

- This low moisture gradient, in turn, prevents a large, uneven gradient in shrinkage from the surface to the interior during drying.

 A ceramic part that has been shaped by any of the methods described thus far is in the green state. The part can be machined in order to bring it closer to a near net shape. Although the green part should be handled carefully, machining it is not particularly difficult, because of its relative softness.

V.Firing(also called sintering):

involves heating the part to an elevated temperature in
a controlled environment. Some shrinkage occurs during firing. Firing gives the ceramic part its strength and hardness.

This improvement in properties results from

(a) the development of a strong bond between the complex oxide particles in the ceramic and

(b) reduced porosity. A more recent technology (although not yet commercialized) involves the microwave sintering of ceramics in furnaces operating at more than 2 GHz. Its cost-effectiveness depends on the availability of inexpensive furnace insulation.

VI.Finishing Operations

Because firing causes dimensional changes, additional operations may be performed to

(a) give the ceramic part its final shape,

(b) improve its surface finish and dimensional tolerances, and

(c) remove any surface flaws. Although they are hard and brittle, major advances have been made in producing machinable ceramics and grindable ceramics,thusenablingtheproductionofceramiccomponent swithhighdimensional accuracy and agood surface finish. An example is silicon carbide, which can be machined into final shapes from sintered blanks.

The finishing processes employed can be one or more of the following operations:

1. Grinding (using a diamond wheel)
2. Lapping and honing
3. Ultrasonic machining
4. Drilling (using a diamond-coated drill)
5. Electrical-discharge machining
6. Laser-beam machining

The finishing processes employed can be one or more of the following operations:

- Process selection is an important consideration because of the brittle nature of most ceramics and the additional costs involved in some of these processes.
- The effect of the finishing operation on the properties of the product also must be considered.
- For instance, because of notch sensitivity, the finer the finish, the higher the part's strength and load-carrying capacity— particularly its fatigue strength
- Ceramic parts also may undergo static fatigue, as described for glass.

- To improve their appearance and strength and to make them impermeable, ceramic products often are coated with a glaze or enamel, which forms a glassy coating after firing

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

Powder Metallurgy

4.1. DEFINITION

Powder metallurgy *is defined as the art of making objects by the heat treatment of compressed metallic powders.*

"Powder metallurgy" includes the blending and mixing of powders, pressing or compacting powder into an appropriate shape, sintering the pressed-powder compact, and perhaps final sizing or finishing of the product to meet specified dimensional tolerances.

The process is applicable to a single metal powder, to mixtures of metals and non-metals. The operation of pressing may be carried out at ordinary or elevated temperatures depending upon the composition and properties desired in the product.

Advantages of Powder Metallurgy

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

Advantages :

The advantages of powder metallurgy are :

1. Such parts which have special properties can be produced which otherwise cannot be obtained.
2. Machining operations are eliminated.
3. Scrap losses are reduced and often results in lower unit cost for a given part in comparison to any other production method.
4. Metals and alloys can be mixed together in any proportion which is difficult and sometimes not possible by melting.
5. Metals and non-metals can be mixed together in any proportion.
6. There is better control of composition and structure of the component by this process.
7. Articles of any desired porosity can be manufactured.
8. Super-hard cutting bits, which can never be manufactured by any other methods are made by powder metallurgy, *e.g.*, sintered carbides, satellites.
9. This process is suitable for mass production because the stroke of the pressing or compacting consists of a press at a speed of 60 strokes/minute.
10. Antifriction alloy strips made by powder metallurgy can be made to adhere on a strong alloy backing piece.
11. The process is very economical and the loss of material is lesser as compared to other processes.
12. Diamond impregnated tools for cutting porcelain, glass and tungsten carbides are made possible only by powder metallurgy.

Disadvantages of Powder Metallurgy

Disadvantages/Limitations :

The process has the following *disadvantages/limitations :*

1. Owing to the fairly high compacting pressures required to press the powder, the wear on the dies is high.
2. Due to high rate of wear of dies, high costs for dies and presses the method is rendered uneconomical particularly for small runs.
3. Since the compacted parts must be ejected from the die without fracture, therefore, the shapes that may be made by this method are limited.
4. Equipments required are very costly.
5. A completely dense product is not possible without heating the product after pressing operation.
6. The physical properties obtained by this process are lower than those obtained by other processes.
7. In the low melting powders like tin, zinc and cadmium, sometimes certain thermal difficulties appear.
8. Pressed and sintered powder can approximately achieve the properties of the wrought alloy but at the cost of increased production cost.
9. The intricate shapes cannot be made by compacting since metal powders cannot flow like fluid under compact load.
10. The products are of small size because for large size bigger equipments and tools would be necessary involving very heavy investment.
11. Many metal powders are explosive at room temperature.
12. A few metals cannot be compressed because they have a tendency to cold-weld to the walls of the die causing wear on the die.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

Applications of Powder Metallurgy

APPLICATIONS OF POWDER METALLURGY

Powder metallurgy has the following present day *applications* :

1. Porous and graphite containing metal bearings.
2. Electrical contacts consisting of a current and heat-conducting matrix in which are embedded wear resisting particles.
3. Tungsten wires.
4. Rotors of gear pump.
5. Diamond impregnated tools.
6. Magnetic materials.
7. Refractory metal composites.
8. Metal to glass seals.
9. Motor brushes.
10. Metallic filters.
11. Metallic coatings.
12. Babitted bearings for automobiles.
13. Cemented carbides.
14. Friction materials.

MANUFACTURE OF PARTS BY POWDER METALLURGY

The manufacture of parts by powder metallurgy involve the following *steps* :

1. Production of metal powders.
2. Blending powders.
3. Pressing or compacting of metal powders.
4. Sintering.
5. Finishing operations.

4.4.1. Production of Metal Powders

The methods of powder production are :

1. Atomising
2. Gaseous reduction
3. Electrolysis process
4. Carbonyl process
5. Stamp and ball mills
6. Granulation process
7. Mechanical alloying
8. Other methods.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

1. **Atomising process.** In this process the molten metal is forced through an orifice into a stream of high-velocity air, steam or inert gas. This causes extremely rapid cooling and disintegration into a very fine powder.
   - The use of this process is usually *limited to metals* with low melting point.
2. **Gaseous reduction.** This process consists of grinding the metallic oxide to a finely divided state and then *reducing* it by hydrogen or carbonmonoxide.
   - It is employed for metals such as *iron*, *tungsten* and *copper* (whose melting points are near or above 1100°C).
3. **Electrolysis process.** In this process of producing powders the conditions of electrode position are controlled in such a way that a soft spongy deposit is formed ; which is then pulverised to form the powder. The particle size can be varied over a wide range by varying the electrolyte composition and various electrical parameters.
   - The powders of copper, iron and other metals are made by this process.
4. **Carbonyl process.** This process is based upon the fact that a number of metals can react with carbon monoxide to form what are known as *carbonyls*. For example, the iron carbonyl is made from iron reduced from ferric oxide. Carbon monoxide at a pressure of 48–200 bar is then passed over heated iron. The resulting carbonyl is decomposed by heating to a temperature of 200°C to 300°C.
   - This process yields powders of high purity but entails a heavy cost.

5. **Stamp and ball mills.** These are mechanical methods which produce a relatively coarse powder. The ball mill is employed for brittle materials while stamp mill for more ductile materials.

- The cost is usually high, and the powders produced by these methods are usually treated to remove the cold work-hardening received in the process.

6. **Granulation process.** This process consists in the formation of an oxide film on individual particles when a bath of metal is stirred in contact with air.

- This process produces a relatively coarse powder with a high percentage of oxide.

7. **Mechanical alloying.** In this method, powders of two or more pure metals are mixed in a ball mill. Under the impact of the hard balls, the powders repeatedly fracture and weld together by diffusion, forming alloy powders.

8. **Other methods.** Other, less commonly used methods include :

   (i) ***Precipitation*** *from a chemical solution.*

   (ii) *Production of fine metals by* ***machining.***

   (iii) ***Vapour condensation.***

- New developments include techniques based on high temperature *extractive metallurgical processes*. Metal powders are being produced using high temperature processing techniques based on :

— The reaction of volatile halides with liquid metals ;

— The controlled reduction and reduction/carburization of solid oxides.

- Recent developments include the production of ***nanopowders*** of various metals such as copper, aluminium, iron and titanium. When the metals are subjected to large plastic deformation at stress levels of 5500 MN/m^2, their particle size is reduced, and the material becomes pore free and thus possesses enhanced properties.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

4.4.2. Blending of Metal Powders

The process of blending (mixing) powders is carried out for the following *purposes* :

(*i*) To obtain *uniformity* (since the powders made by various processes may have different sizes and shapes).

(*ii*) To *impart special physical and mechanical properties and characteristics* to the powder metallurgy product.

(*iii*) Addition of lubricants (*e.g.*, stearic acid, zinc stearate in proportion of 0.25 to 0.5% by weight) to the powders improve the flow characteristics of the powders. Such blends result in reduced friction between the metal particles, improved flow of powder metals into the dies, and longer die life.

- In order to avoid contamination and deterioration, powder mixing must be carried out under controlled conditions.
- The metal powders like aluminium, magnesium, titanium, zirconium, and thorium powders are *explosive* owing to their *high surface area to volume ratio* consequently, a great case must be exercised during their blending, storage and handling.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

4.4.3. Pressing or Compaction of Metal Powders

The principal object of pressing or compacting is to effect cold-pressure welds between th particles so that some cohesion is conferred, this is usually measured by the strength of the gree compact and is termed the *green strength*.

Compacting exercises the following *effects* :

(*i*) Reduces voids between powder particles and increases density of the compact.

(*ii*) Produces adhesion and cold welding of the powder and sufficient green strength.

(*iii*) Plastically deforms the powder to allow recrystallisation during subsequent heating.

(*iv*) Plastically deforms the powder to increase the contact areas between the powder part cles, increasing green strength and facilitating subsequent sintering.

- *Pressing or compacting* is carried out by pouring a measured amount of the metal powder into the die cavity and then compacting the metal powder into coherent mass by means of one or more plungers (Fig. 4.1). Compressing from both top and bottom (Fig. 4.2) of the compact is better than compressing from the top only (Fig. 4.1), as pressure distribution and porosity distribution are more uniform.

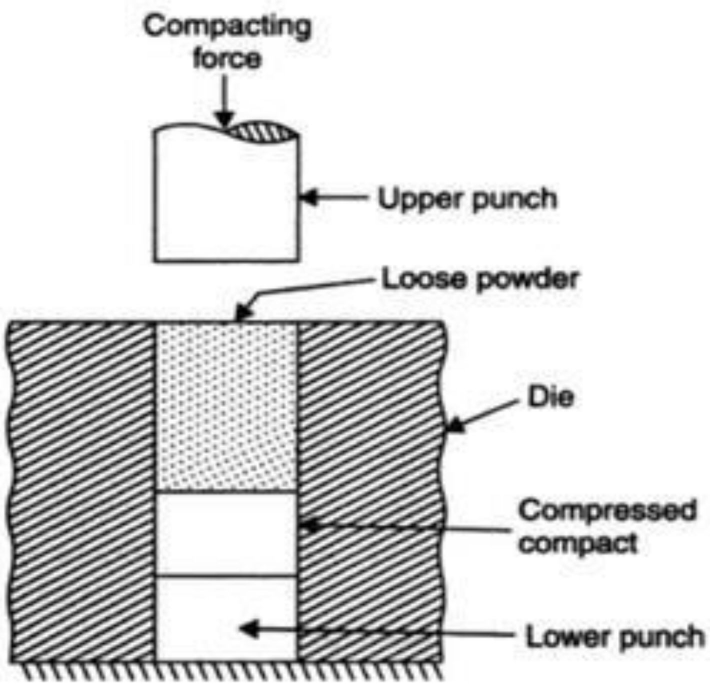


Fig. 4.1. Pressing or compacting by one or more plungers.

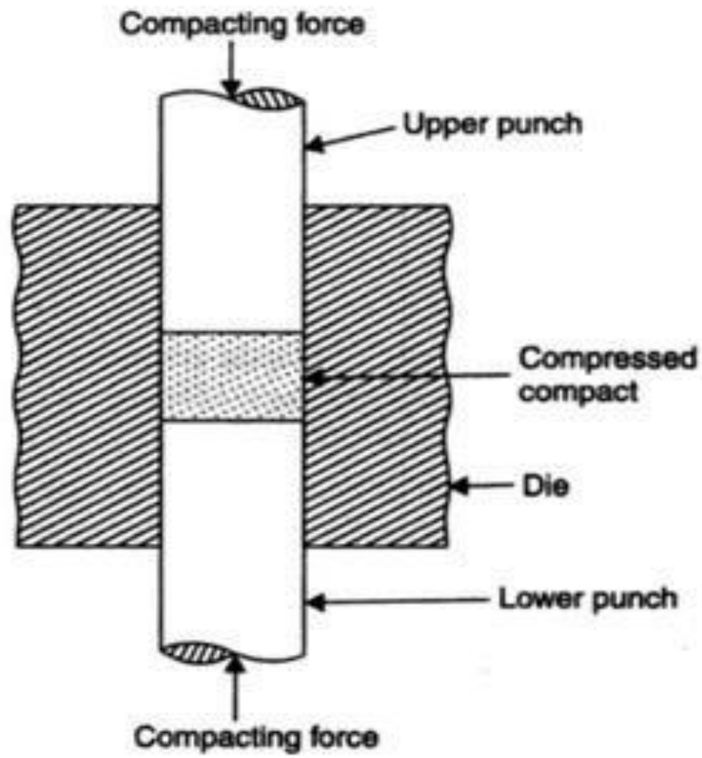


Fig. 4.2. Pressing or compacting from top and bottom.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy

— To improve uniformity of pressure and porosity through the piece the use of lubricants graphite, strearatex and zinc, aluminium and lithium strearate is made. Bond strength between particles is affected by the area of contact and by the cleanliness of particles (oxide layers being common sources of difficulty).

— The *compacting pressure required depends on the characteristics and shape of the particles, the methods of blending, and the lubrication.* The pressure required for pressing metal powders range from 70 MN/m^2 for aluminium to 800 MN/m^2 for high-density iron parts.

- In compacting powders in steel dies at room temperatures pressures from 7.5 to 37.5 (sometimes 150) kN/cm^2 are employed. Mechanical presses are employed for 500 kN and hydraulic presses for higher pressures. The moulding of small parts at great speeds and at relatively low pressures can be best accomplished in the mechanical press. However, large parts and parts to be moulded at higher pressures are best moulded in hydraulic presses.

— Extremely hard powders are slower and more difficult to press ; some organic binder is usually required to hold the hard particles together after pressing until the heat of sintering creates atomic bonds and promotes welding.

— In hot pressing if the powder is heated to proper temperature the pressure for complete densification is only 150 to 300 bar. Hot pressing requires a die material having appreciable high strength. Since even sturdy dies (made of graphite) usually sustain only one operation, therefore, *hot pressing is limited to the manufacture of articles of costly metals.*

4.4.4. Sintering

Sintering *means the heating of pressed compact to below the melting temperature of any constituent of the compact, or atleast below the melting temperature of all principal constituents of the compact*. Such heating facilitates *bonding action* between the individual powder particles and *increases the strength of the compact*. Heating is carried out *in a controlled, inert or reducing atmosphere, or in vacuum to prevent oxidation.*

— Prior to sintering, the compact is brittle, and its strength, known *as green strength* is low. The nature and strength of the bond between the particles, and hence of sintered product, depend on the *mechanism of diffusion plastic flow, evaporation of volatile materials in the compact, recrystallization, grain growth, and pure shrinkage.*

During the sintering process bonding of the individual powder particles takes places in any of the following three ways :

(*i*) Melting of a minor constituent ;

(*ii*) Diffusion ;

(*iii*) Mechanical bonding.

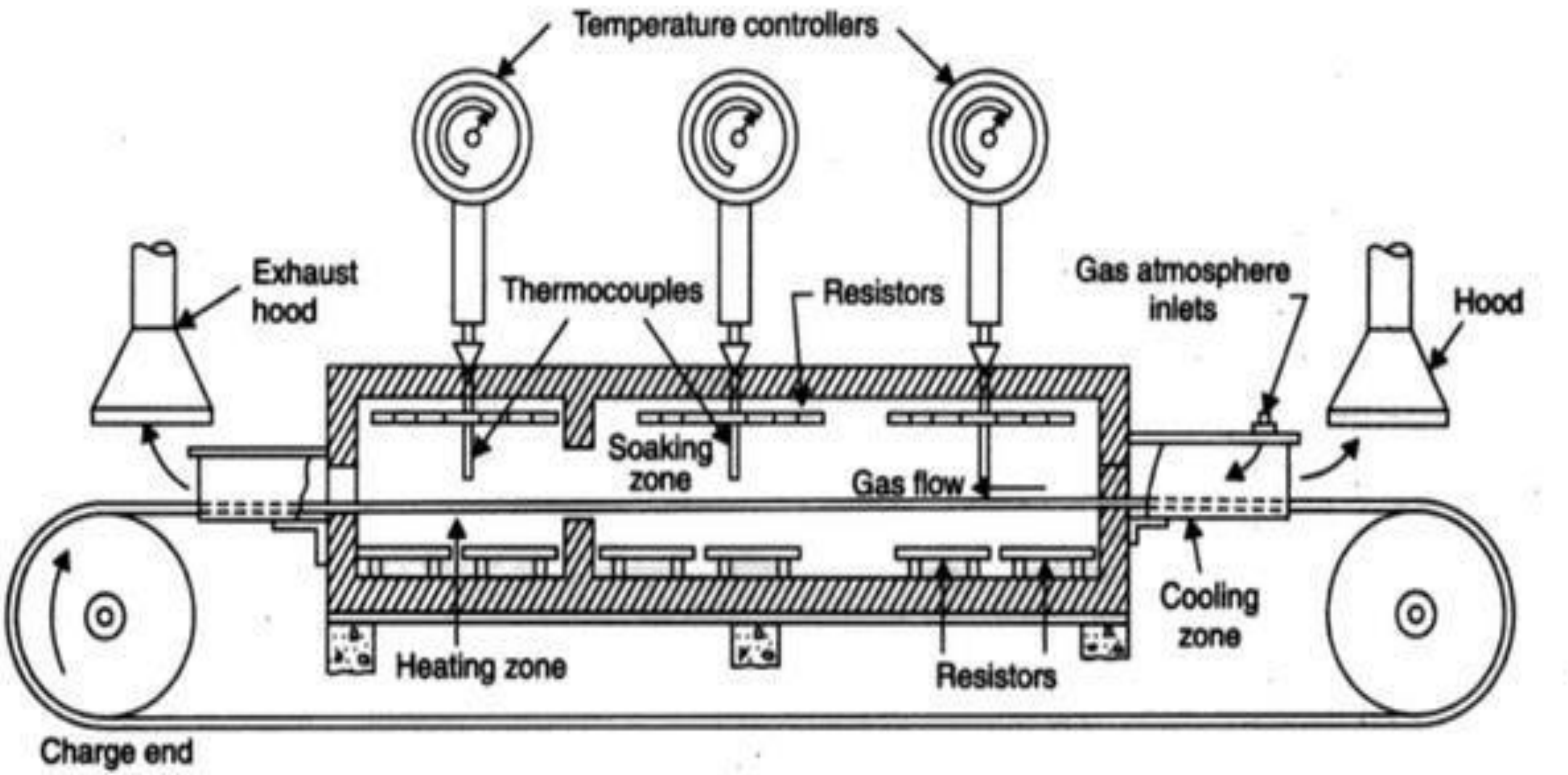
The important factors which control sintering are : (*a*) *temperature*, (*b*) *time, and* (*c*) *furnace atmosphere*. The sintering temperatures used vary with the compressive loads used, the type of powders, and strength required of the finished part.

— Aluminium and aluminium alloys can be sintered at temperatures from 350° to 500°C for periods upto 24 hours.

— Copper and copper alloys can be sintered at temperatures ranging from 700°C to temperatures that may melt one of the constituent metals.

— Compacts of iron powders are usually sintered at temperatures from 1000°C to 1200°C for approximately half an hour.

UNIT IV : Plastic Processing, Ceramics and Powder Metallurgy



Sintering furnace

DEPARTMENT : MECHANICAL ENGINEERING

YEAR & SEM : II-I SEM

SUBJECT : MANUFACTURING PROCESS

SUBJECT CODE : (19A03301T)

PREPARED BY : V V ANANTHA CHAKRAVARTHY

UNIT V : Unconventional Machining Processes

- Principles and process parameters electro-chemical machining (ECM)
- Principles and process parameters Laser beam machining (LBM)
- Principles and process parameters plasma arc machining (PAM)
- Principles and process parameters electron beam machining of Abrasive jet machining (AJM)
- Principles and process parameters water jet machining
- Principles and process parameters ultrasonic machining Principle and processes parameters Electrical discharge machining (EDM)

INTRODUCTION:

In conventional machining processes, metal is removed by using some sort of tool which is harder than the work piece and it is subjected to wear.

- In this process, tool and work piece are in direct contact with each other.

- In other words, the conventional machining processes involve removal of metal by compression shear chip formation.

Disadvantages of conventional machining processes:-

- In conventional machining , metal is removed by chip formation which is an expensive and difficult process.
- Removal of these chips and their disposal and recycling is a very tedious procedure , involving energy and money.
- Very large cutting forces are involved in this process. so, proper holding of the work piece is most important.

Disadvantages of conventional machining processes:-

- Due to the large cutting forces and large amount of heat generated between the tool and the work piece interface, undesirable deformation and residual stresses are developed in the work piece.
- It is not possible to produce chips by conventional machining process for delicate components like semi conductor.

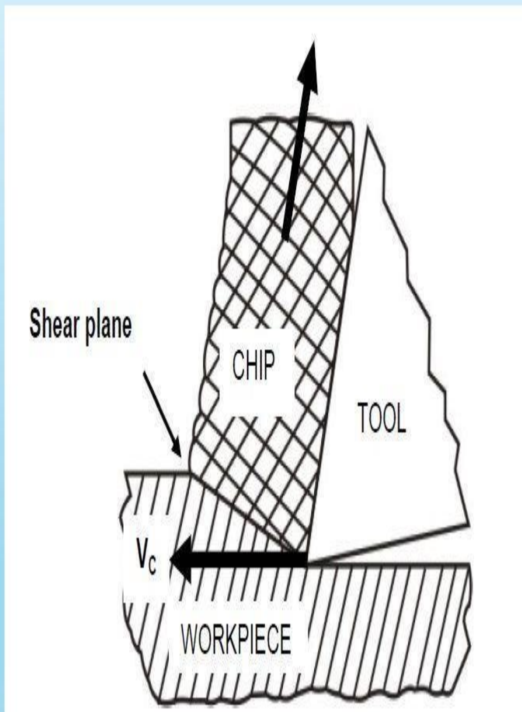
TO OVERCOME THESE ALL DIFFICULTIES WE ARE GOING FOR UNCONVENTIONAL MACHINING PROCESS.

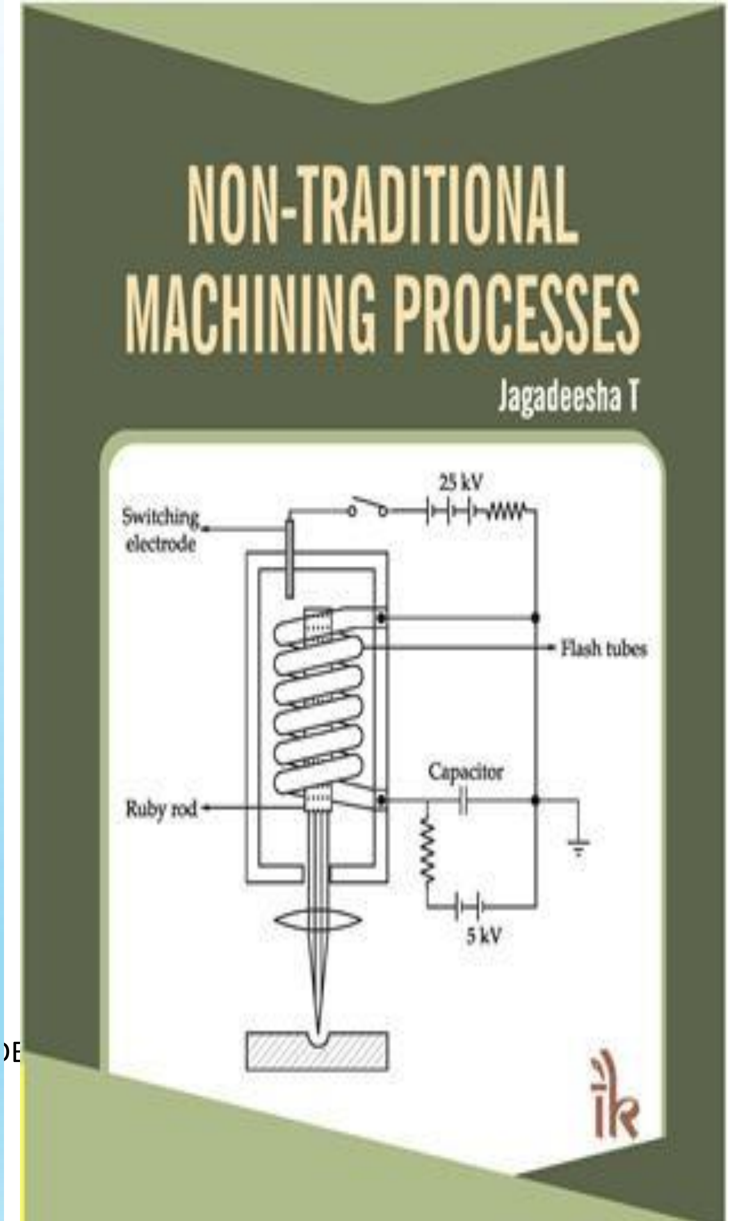
The unconventional machining:

- The unconventional machining processes do not employ a conventional or traditional tool for metal removal, instead they directly **utilize some form of energy** for metal machining.

- In this process, there is no direct physical contact between the tool and the work piece. There fore the tool material need not be harder than the work piece material as in conventional machining.

CONVENTIONAL MACHINING PROCESS





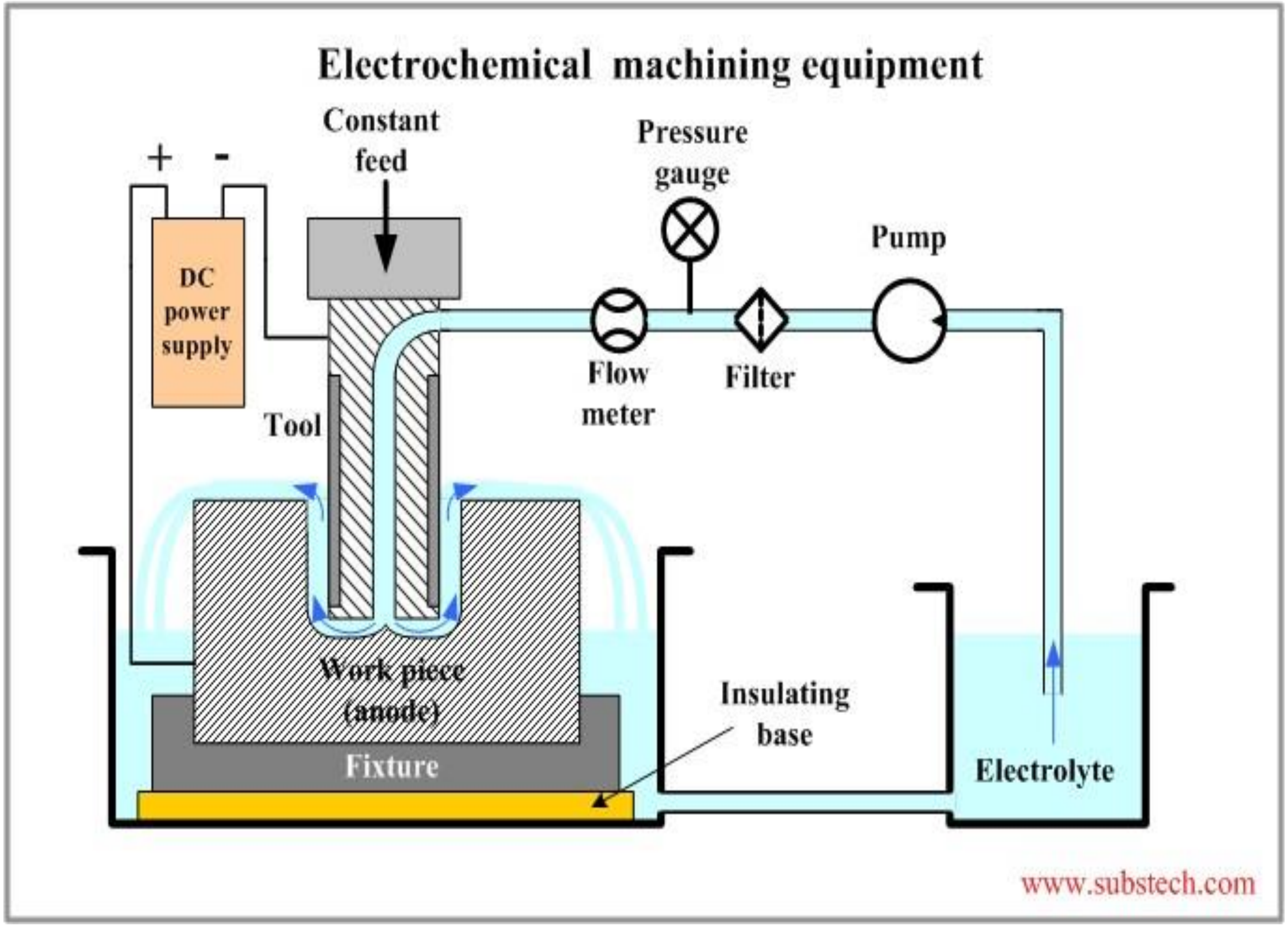
INTRODUCTION:-

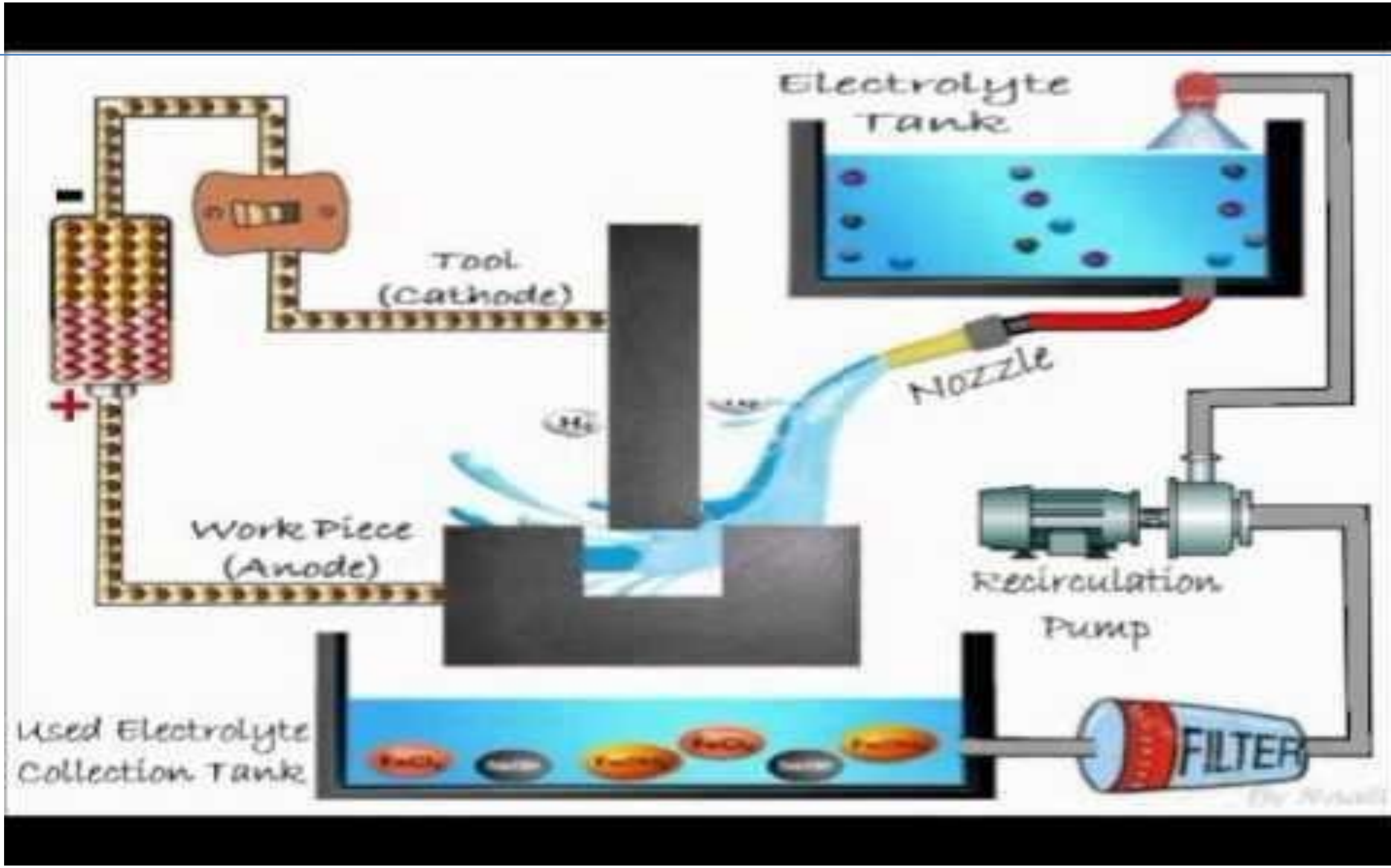
Electro-chemical machining (ECM): In electro chemical energy methods, material is removed by ion displacement of the work piece material in contact with a chemical solution.

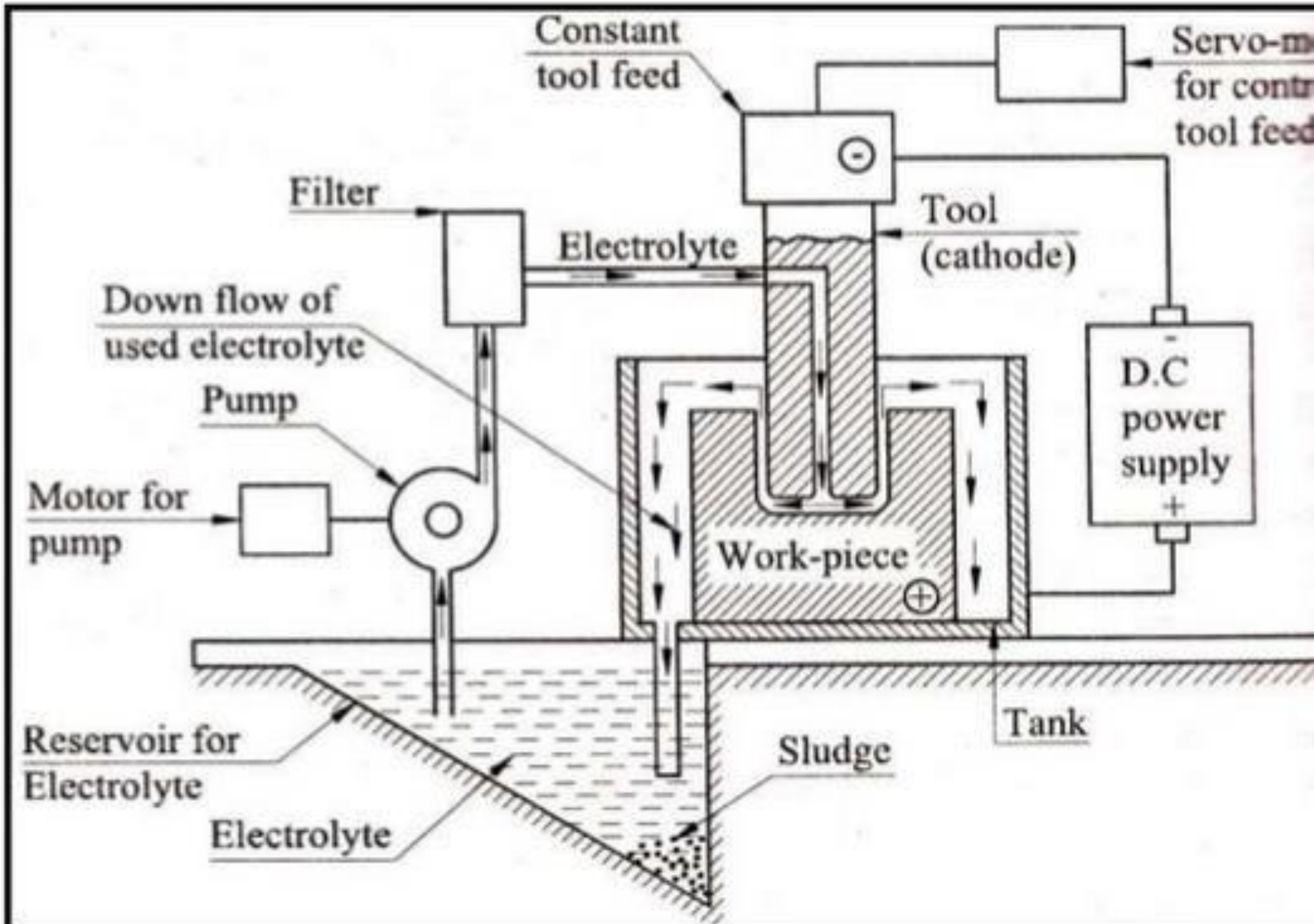
PRINCIPLE:-

This process is based on the principle of faraday's law of electrolysis which may be stated as follows

- The first law states that the amount of any material dissolved or deposited, is proportional to the quantity of electricity passed.
- The second law proposes that the amount of change produced in the material is proportional to its electrochemical equivalent of the material.


Electrochemical machining equipment
Constant feed
Pressure gauge
+
-
DC power supply
Pump
Flow meter
Filter
Tool
Work piece (anode)
Insulating base
Fixture
Electrolyte
www.substech.com


Electrolyte Tank
Tool (Cathode)
Nozzle
Work Piece (Anode)
Recirculation Pump
Used Electrolyte Collection Tank
FILTER


Constant
tool feed
Filter
Electrolyte
Tool
(cathode)
Down flow of
used electrolyte
Pump
Motor for
pump
D.C
power
supply
Work-piece
Tank
Sludge
Reservoir for
Electrolyte
Electrolyte

CONSTRUCTION:-

 The schematic arrangement of ECM process is shown in fig.

 It consist of work piece, tool ,servomotor for controlled tool feed , D.C power supply, electrolyte, pump, motor for pump, filter for incoming electrolyte and reservoir for electrolyte.

 A shaped tool (electrode) is used in this process, which is connected to negative terminal (cathode) and the work piece is connected to positive terminal (anode). The tools used in this process should be made up of the materials which have enough thermal and electrical conductivity , high chemical resistance to electrolyte and adequate stiffness and machinability.

 The widely used tool materials are stainless steel, titanium, brass and copper.

•The tool is of hollow tabular type as shown in fig . And an electrolyte is circulated between the work and tool.

•Most widely used electrolyte in this process is sodium nitrate solution . Sodium chloride solution in water is a good alternative but it is more corrosive than the former. Some other chemicals used in this process are sodium hydroxide , sodium sulphate , sodium fluoride , potassium nitrate and potassium chloride.

•Servomotor is used for controlling the tool feed and the filter is used to remove the dust particles from the electrolytic fluid.

WORKING:-

•The tool and work piece are held close to each other with a very small gap (0.05 to 0.5mm) between them by using servomotor.

•The electrolyte from the reservoir is pumped at high pressure and flows through the gap between the work piece and tool at a velocity of 30 to 60 m/s.

•A mild D.C voltage about 5 to 30 volts is applied between the tool and work piece.

- Due to the applied voltage , the current flows through the electrolyte with positively charged ions and negatively charged ions. The positive ions move towards the tool (cathode) while negative ions move towards workpiece (anode).
- The electro chemical reaction takes place due to this flow of ions and it causes the removal of metal from the work piece in the form of sludge.

Advantage of ECM

Advantages:

1. MRR is not dependent on mechanical or physical properties of WP.
2. No surface damage, no burr, low tool wear,
3. **High MRR** for hard-to machine materials
4. Hard to soft materials made of conductive material can be m/ced.
5. Cutting tool can be made from soft material.
6. **Low** heat generated during process.
7. No cutting forces.
8. Excellent surface finish.

Disadvantages:

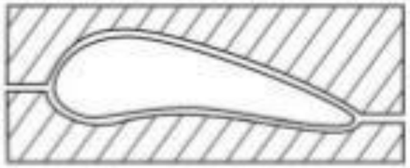
1. Since ECM depends on atomic weight & valency of work material therefore work material should be **electrically conductive**.
2. Low machining accuracy due to its wider machining gap.

Applications of ECM

Application:

1. ECM can machine any electrically conductive work material irrespective of their hardness, strength or even thermal properties.
2. Moreover as ECM leads to atomic level dissolution, the surface finish is excellent with almost stress free machined surface and without any thermal damage so **fragile and thin** section can be machined.
3. ECM is used for : Die sinking, Profiling and contouring, Trepanning , Grinding , Drilling , Micro-machining etc.

Die sinking



3D Profiling

ECM Process Parameter:

- Voltage: 4 to 30 V
- Current: 50 to 40000 A
- MRR: 1600 mm^3/min
- Surface Finish: 0.1-2.5 μm (CLA)
- Gap: 0.025 to 0.75 mm

Properties of Electrolyte:

Electrolyte provides several functions like complete the circuit, Remove material from cutting region by pressure, Carry away heat to be generated.

- High thermal and Electrical Conductivity
- Low viscosity
- Cheaper and Available
- Non corrosive and Non toxic
- Chemically Stable at process temperature.

LASER BEAM MACHINING

INTRODUCTION:-

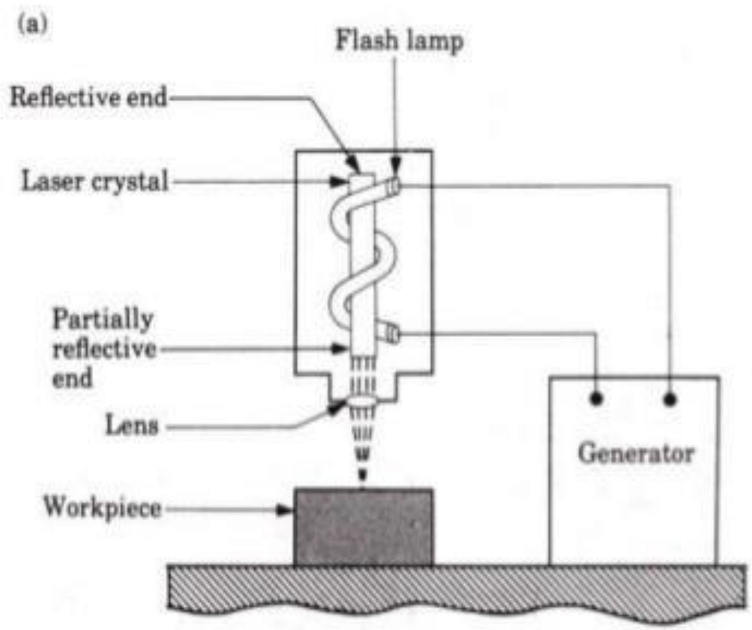
Recent researches in solid state physics have revealed a new device known as "LASER" which means " light amplification by stimulated emission of radiation" . It produces a powerful, monochromatic, collimated beam of light in which the waves are coherent.

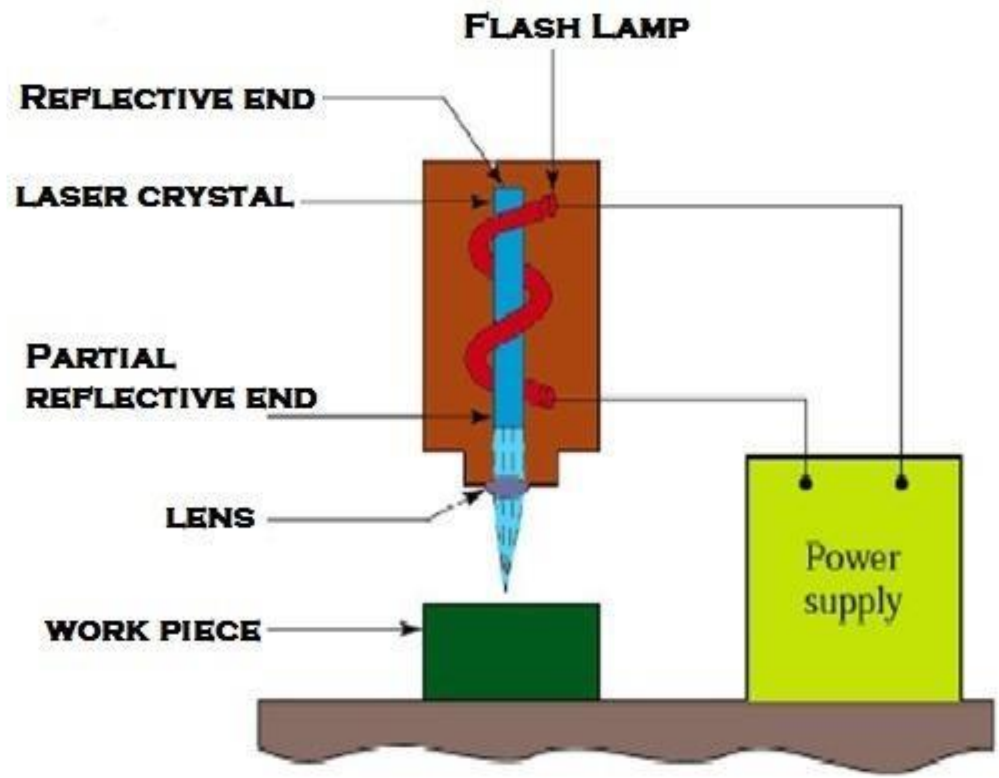
Like the electron beam , the laser beam is also used for drilling micro holes up to 25 micro meter and for cutting very narrow slots , with dimensional accuracy +- 0.025 mm . It is very costly method and can be employed only when it is not feasible to machine a work piece through other methods.

PRINCIPLE OF LASER BEAM MACHINING:-

In laser beam machining process , laser beam (a powerful, monochromatic , collimated beam of light) is focused on the work piece by means of lens to give extremely high energy density to melt and vaporise the work material.

Laser Beam Machining





LASER BEAM MACHINING PROCESS

CONSTRUCTION:-

- The schematic arrangement of laser beam machining process is shown in fig.
- These are several types of lasers used for different purposes. Eg , solid state laser , gas laser, liquid laser and semiconductor laser. In general , only the solid state lasers can provide the required power levels**.**
- **Themo**st commonly used solid state laser is ruby laser. It is the first successful laser achieved by maiman in 1960. it consists of ruby rod surrounded by a flash tube.
- Synthetic ruby consists of a crystal of aluminum oxide in which a few of the aluminum atoms are replaced by chromium atoms. Chromium atoms have the property of absorbing green light.
- The end surfaces of the ruby rod is made reflective by mirrors. One end of the ruby rod is highly reflective and the other end is partially reflective.

- The flash tube is called the pump and it surrounds the ruby rod in the form of spiral as shown in fig. this tube is filled with xenon, argon or krypton gas.
- Since the ruby rod becomes less efficient at high temperatures, it is continuously cooled with water, air or liquid nitrogen.
- Since the laser beam has no effect on aluminum , the work piece to be machined is placed on the aluminum work table.

WORKING:-

- The xenon or argon gas present in the flash tube is fired by discharging a large capacitor through it. The electric power of 250 to 1000 watts may be needed for this operation.
- This optical energy i.e, light energy from the flash tube is passed in to the ruby rod.

- The chromium atoms in the ruby rod are thus excited to high energy levels. The excited atoms are highly unstable in the higher energy levels and it emits energy (photons) when they return to the original levels.
- The emitted photons in the axis of ruby rod are allowed to pass back and forth millions of times in the ruby with the help of mirror at the two ends . The emitted photons other than the axis, will escape out of rod.
- The chain reaction is started and a powerful coherent beam of red light is obtained.
- This powerful beam of red light goes out of the partially reflective mirror at one end of the ruby rod.
- This highly amplified beam of light is focused through a lens , which converges it to a chosen point on the workpiece.

- This high intensity converged laser beam , when falls on the work piece , melts and vapourise the work piece material.
- The laser head is traversed over the work material by manually adjusting the control panel and an operator can visually inspect the machining process.
- The actual profile is obtained from a linked mechanism , made to copy the master drawing or actual profile placed on near –by bench.

LBM Process parameters:

- Voltage: 4500 V
- Pulse duration: 100 microsecond
- MRR: 0.1 mm^3/min
- Surface Finish: 0.5-1.2 μm (CLA)

APPLICATION of LBM:

- LASER drilling
- LASER metal cutting
- LASER welding

ADVANTAGE of LBM:

- Small, complex and micro sized holes.
- No direct contact between tool and work.
- Accuracy is high and doesn't require filler material.
- Dissimilar material can easily welded.
- Automated easily.

DISADVANTAGE:

- It can't be used to drill deep holes.
- Highly reflective material can't be effectively machined.
- Initial investment is high.
- Safety must be followed strictly and skilled operator required.

PLASMA ARC MACHINING:-

INTRODUCTION:-

Solids , liquids and gases are the three familiar state of matter. In general when solid is heated, it turns to liquids and the liquids eventually become gases. When a gas is heated to sufficiently high temperature , the atoms (molecules) are spit in to free electrons and ions. The dynamical properties of this gas of free electrons and ions are sufficiently different from the normal unionizes gas. So, it can be considered a fourth state of matter , and is given a new name , PLASMA in other words, when a following gas is heated to a sufficiently high temperature of the order of 11000oc to 28000oc ,it becomes partially ionized and it is known as PLASMA. This is a mixture of free electrons , positively charged ions and neutral atoms. This plasma is used for metal removing process.

WORKING PRINCIPLE:-

In plasma arc machining process, material is removed by directing a high velocity jet of high

temperature

(11,000oc to 28,000 oc) ionized gas on the work piece . This temperature plasma jet melts the material of the work

piece.

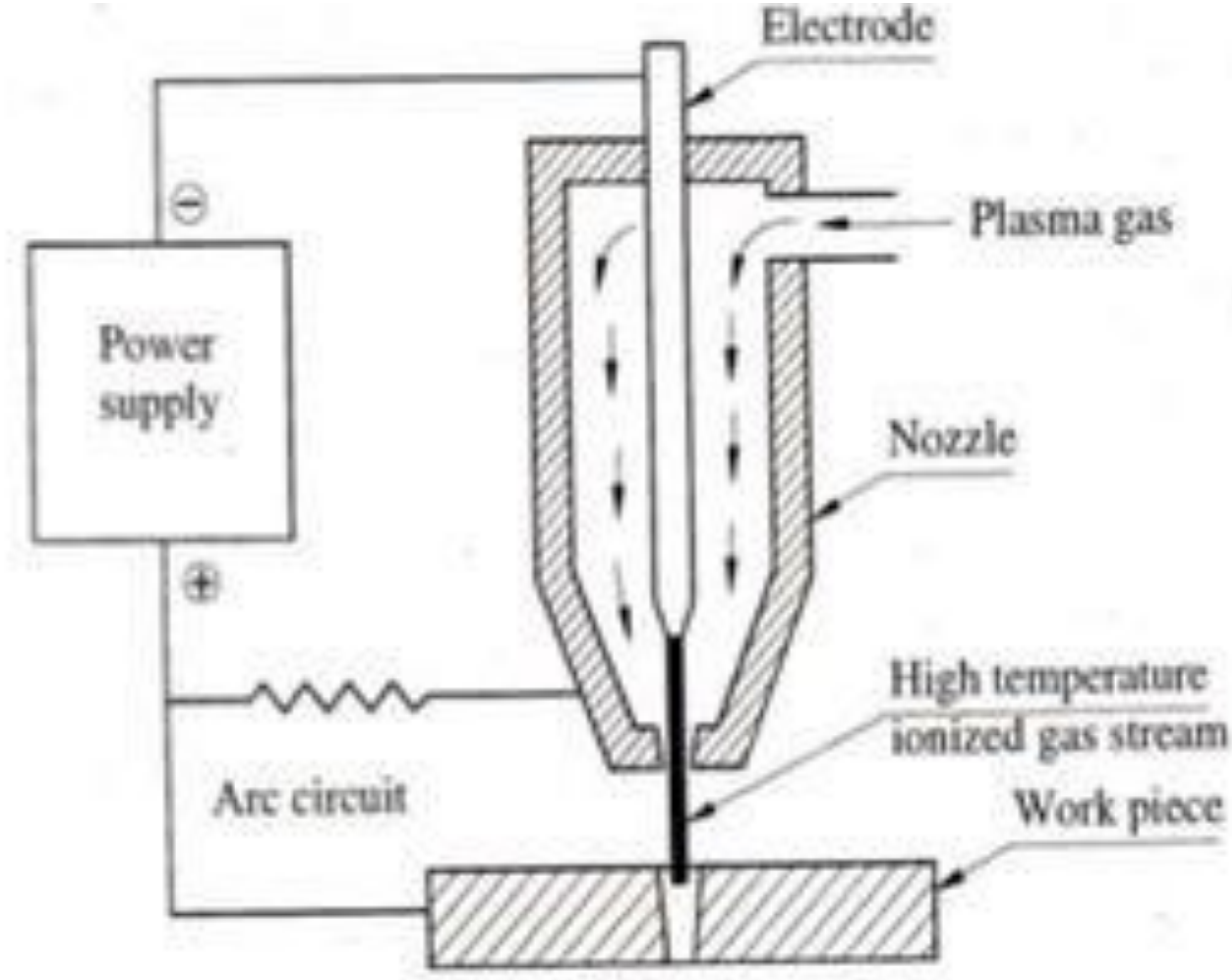

Electrode
Plasma gas
Power supply
Nozzle
High temperature ionized gas stream
Arc circuit
Work piece

Fig. Schematic arrangement of PAM CONSTRUCTION:-

- The schematic arrangement of plasma arc machining is shown in fig.
- The plasma arc cutting torch carries a tungsten electrode fitted in a small chamber.
- This electrode is connected to the negative terminal of a DC power supply. So it acts as a cathode.
- The positive terminal of a D.C power supply is connected to the nozzle formed near the bottom of the chamber. So , nozzle act as anode.
- A small passage is provided on one side of the torch for supplying gas in to the chamber.
- Since there is a water circulation around the torch, the electrode and the nozzle remains water cooled.

WORKING:-

- When a D.C power is given to the circuit, a strong arc is produced between the electrode (cathode) and the nozzle (anode).
- A gas usually hydrogen(H_2) or Nitrogen (N_2) is passed in to the chamber.
- This gas is heated to a sufficiently high temperature of the order of 11,000oc to 28,000 oc by using an electric arc produced between the electrode and the nozzle.
- In this high temperature, the gases are ionized and large amount of thermal energy is liberated.
- This high velocity and high temperature ionized gas (plasma) is directed on the work piece surface through nozzle.
- This plasma jet melts the metal of the work piece and the high velocity gas stream effectively blows the molten metal away.
- The heating of work piece material is not due to any chemical

reaction, but due to the continuous attack of plasma on the work piece material. So, it can be subjected to chemical reaction.

PAM Process Parameter:

- Voltage: 30-250 V
- Current: Up to 600 A
- Power: 2-200 KW
- Velocity of plasma jet: 500 m/s
- MRR: 1,50,000 mm^3/min

Advantages:

- Any electrically conductive material machined regardless it's hardness.
- Doesn't require any surface preparation.
- It has high cutting rate.

Disadvantage:

- Power consumption is very high.
- High equipment cost.
- It produced tapered surface.
- Noise protection is required.

Applications

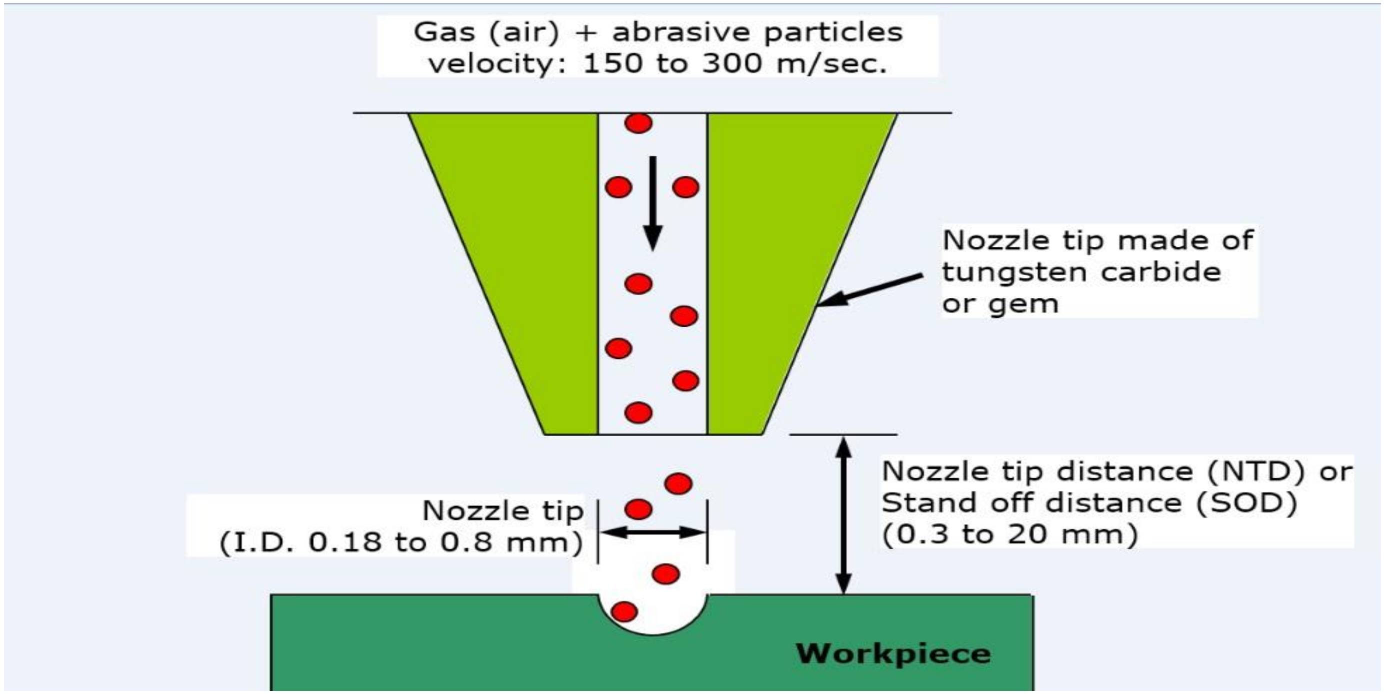
- In tube mill application.
- Welding cryogenic, aerospace and high temperature corrosion resistant alloys.
- Welding steel rocket motor cases.

INTRODUCTION:-

In mechanical energy methods ,the material is removed mechanical erosion of the work piece material.

PRINCIPLE OF AJM:-

In abrasive jet machining process, a high speed stream of abrasive particles mixed with high pressure air or gas are injected through nozzle on the work piece to be machined.


Gas (air) + abrasive particles
velocity: 150 to 300 m/sec.
Nozzle tip made of
tungsten carbide
or gem
Nozzle tip distance (NTD) or
Stand off distance (SOD)
(0.3 to 20 mm)
Nozzle tip
(I.D. 0.18 to 0.8 mm)
Workpiece

CONSTRUCTION AND WORKING OF AJM:

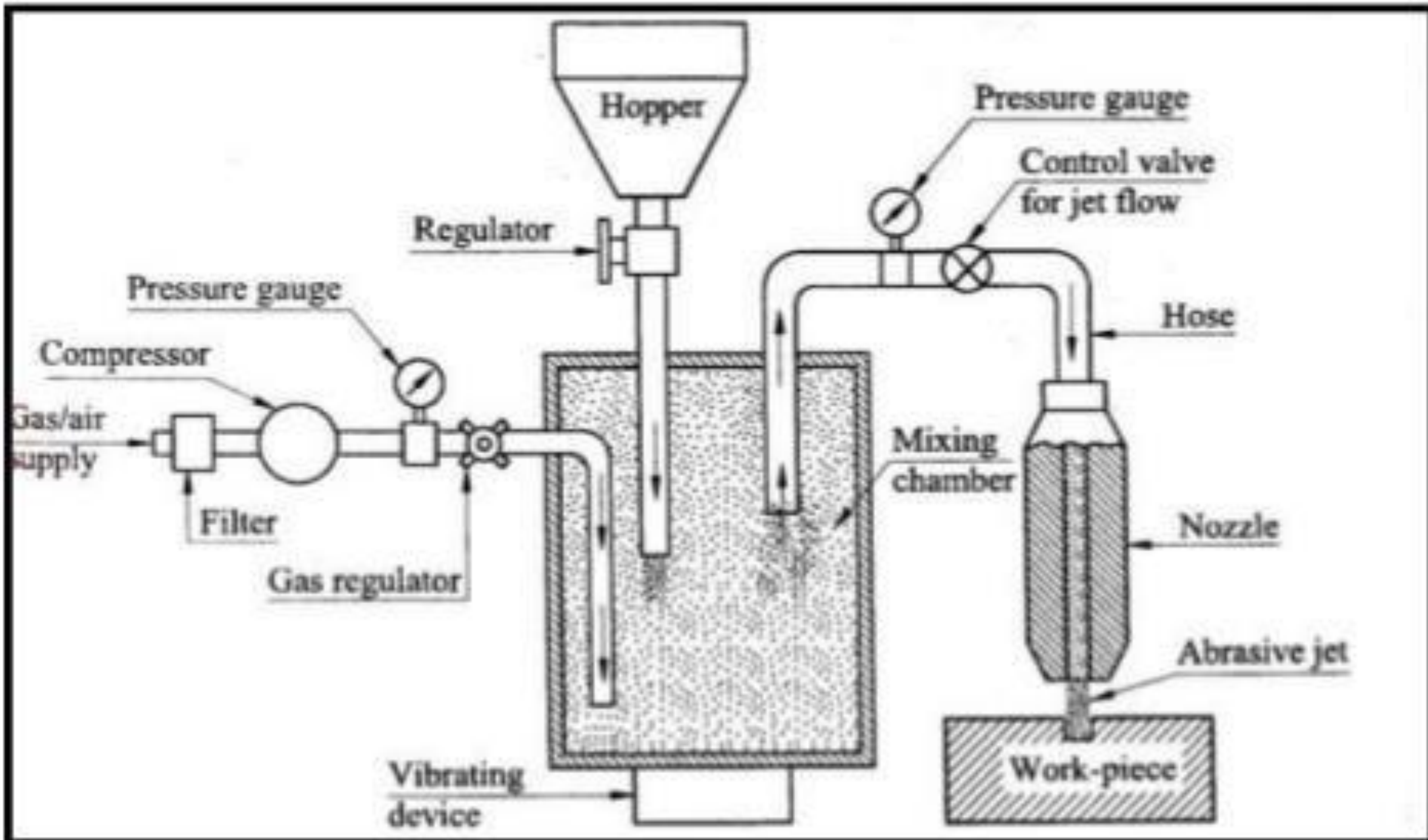
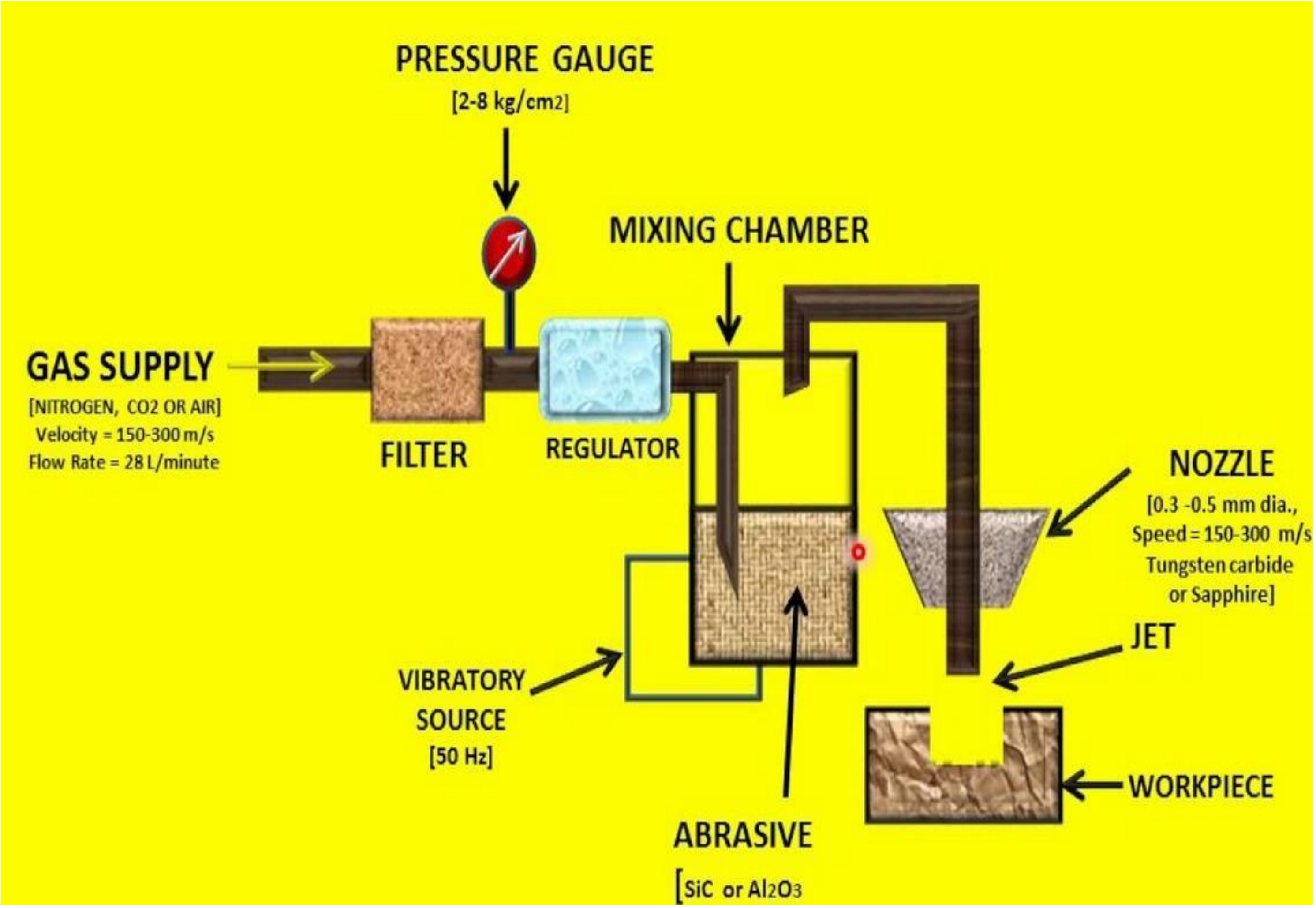


Fig : Arrangements of abrasive jet machining


PRESSURE GAUGE
[2-8 kg/cm2]
MIXING CHAMBER
GAS SUPPLY
[NITROGEN, CO2 OR AIR]
Velocity = 150-300 m/s
Flow Rate = 28 L/minute
FILTER
REGULATOR
NOZZLE
[0.3 -0.5 mm dia.,
Speed = 150-300 m/s
Tungsten carbide
or Sapphire]
JET
VIBRATORY
SOURCE
[50 Hz]
WORKPIECE
ABRASIVE
[SiC or Al2O3

CONSTRUCTION:-

The schematic arrangements of abrasive jet machine is shown in fig

It consists of mixing chamber, nozzle, pressure gauge, hopper, filter, compressor, vibrating device, regulator, etc.

- The gases generally used in this process are nitrogen, carbon dioxide or compressed air.
- The various abrasive particles used in this process are aluminum oxide, silicon carbide, glass powder, dolomite and specially prepared sodium bicarbonate.
- Aluminum oxide(Al203) is general purpose abrasive and it used in sizes of 10, 25, and 50 micron. Silicon carbide (Sic) is used for faster cutting on extremely hard materials. It is used in sizes of 25 and 50 microns. Dolomite of 200 grit size is found suitable for light cleaning and etching. Glass powder of diameter 0.30 to 0.60 mm are used for light polishing and deburring.
- As the nozzle is subjected to a great degree of abrasion wear , it is made up of hard materials such as tungsten carbide, synthetic sapphire(ceramics), etc ., to reduce the wear rate.

 Nozzles made of tungsten carbide have an average life of 12 to 20 hours , where as synthetic sapphire nozzle have an average life of 300 hours . Nozzle tip clearance from work is kept at a distance of 0.25 to 0.75 mm.

 The abrasive powder feed rate is controlled by the amplitude of the vibration of mixing chamber. A pressure regulator controls the gas or air flow and pressure. To control the size and shape of the cut , either the work piece or the nozzle is moved by a well designed mechanism such as cam mechanism , pantograph mechanism, etc.

WORKING:-

- Dry air or gas (N_2 or CO_2) is entered in to the compressor through a filter where the pressure of air or gas increased.
- The pressure of the air varies from 2 kg/cm2 to 8kg/cm2.

- Compressed air or high pressure gas is supplied to the mixing chamber through a pipe line. This pipe line carries a pressure gauge and a regulator to control the air or gas and its pressure.
- The fine abrasive particles are collected in the hopper and fed into the mixing chamber. A regulator is incorporated in the line to control the flow of abrasive particles.
- The mixture of pressurized air and abrasive particles from the mixing chamber flows in to the nozzle at a considerable speed.
- Nozzle is used to increase the speed of the abrasive particles and it is increased up to 300 m/s.
- This high speed stream of abrasive particles from the nozzle, impact the work piece to be machined. Due to repeated impacts , small chips of material get loosened and a fresh surface is exposed.
- a vibrator is fixed at the bottom of the mixing chamber. When it vibrates, the amplitude of the vibrations controls the flow of abrasive particles.

•This process is widely used for machining hard and brittle materials, non metallic materials (germanium, glass ,ceramics and mica) of thin sections. This process is capable of performing drilling, cutting,

deburring ,etching and cleaning the surfaces.

METAL REMOVAL RATE PROCESS PARAMETERS:-

The metal removal rate depends upon the following parameters.

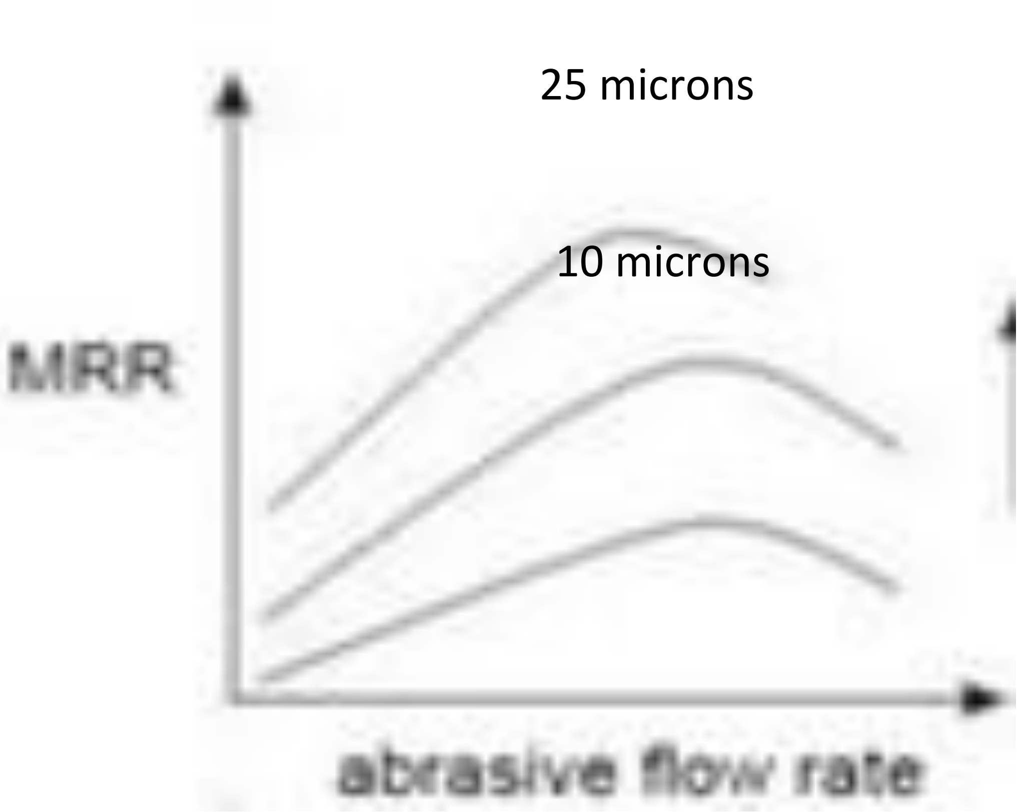
1. Mass flow rate
2. Abrasive grain size
3. Gas pressure

4. Velocity of abrasive particles

5. Mixing ratio

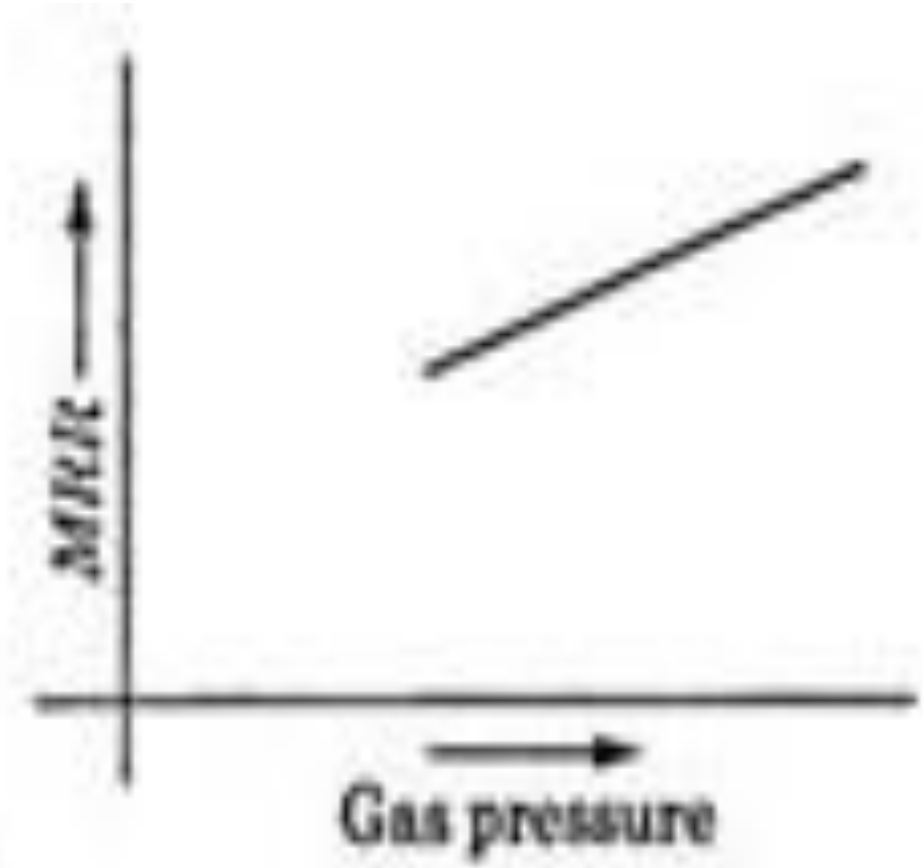
6. Nozzle tip clearance.

Grain size 50 microns



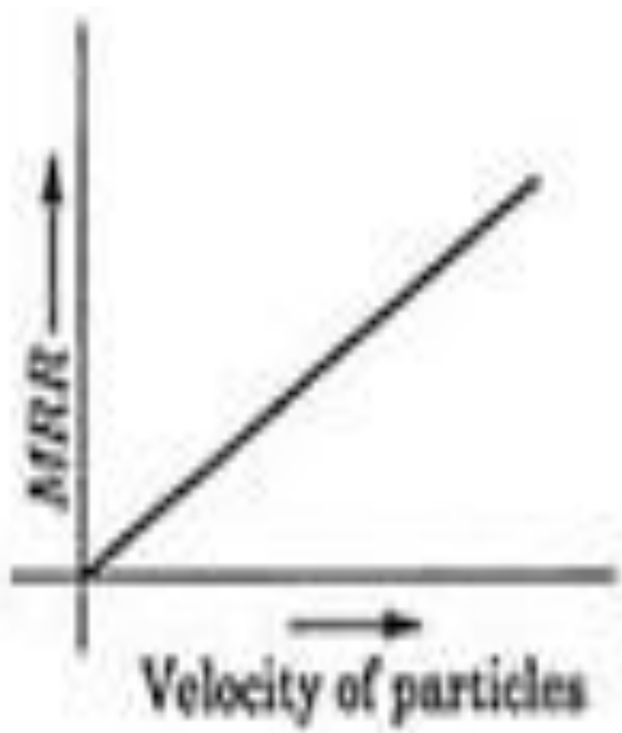
3. GAS PRESSURE:-

The metal removal rate increases with increase in gas or air pressure as shown in fig



4. VELOCITY OF ABRASIVE PARTICLES:-

The metal removal rate increases with the increase of velocity of abrasive particles as shown in fig.

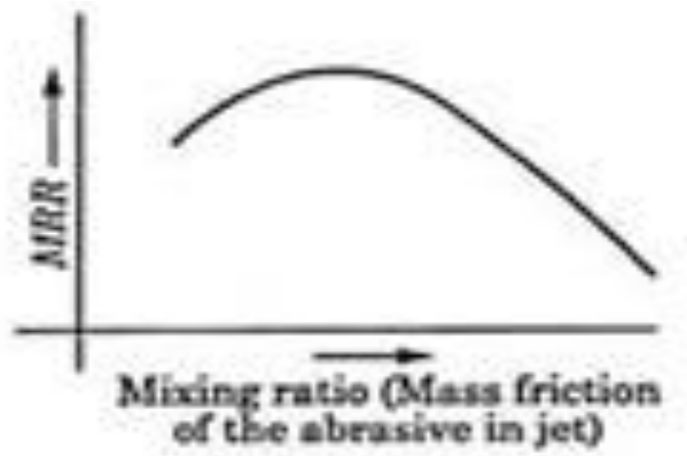


5. MIXING RATIO:-

Mixing ratio is defined as the ratio of mass flow rate of abrasive to the mass flow rate of gas.

mixing ratio= mass flow rate of abrasive/mass flow rate of gas

metal removal rate first increases with the increase of mixing ratio up to certain limit after

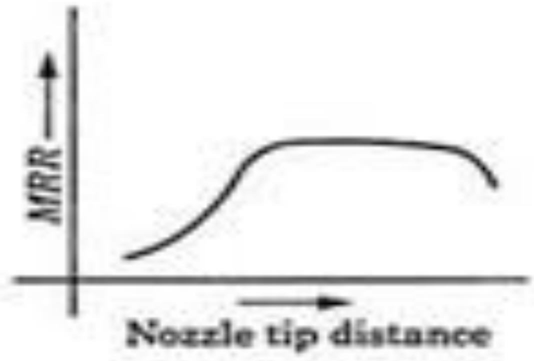


that it decreases gradually as shown in fig.

6. NOZZLE TIP CLEARNCE OR STAND OFF DISTANCE:-

The distance between the nozzle tip and the work piece has great influence on the diameter of cut , its shape, size and also on the rate of material removal.

The material removal rate first increases with the increase of tip clearance from work piece up to a certain limit after that it remains unchanged for a certain tip clearance and then decreases gradually as shown in fig



ADVANTAGES

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- It has the capability of cutting holes of intricate shape in hard materials.
- Thin sections of hard & brittle materials like germanium, mica, silicon, glass and ceramics can be machined.
- Process is free from chatter and vibration as there is no contact between the tool and work piece.
- Abrasive jet machining process creates localized forces and generates lesser heat than the conventional machining processes.
- The power consumption in abrasive jet machining process is considerably low.

TA

DISADVANTAGES

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- The accuracy of cutting is hampered by tapering of hole due to unavoidable flaring of abrasive jet.
- Abrasive powders cannot be reused as the sharp edges are worn and smaller particles can clog the nozzle.
- The mixing chamber and the nozzle are the two critical components and they need to be changed very frequently because of the wear.
- Material removal rate in abrasive jet machining process is rather low(around 15 mm^3/min for glass).

OTA

APPLICATIONS

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- AJM is useful in manufacture of electronic devices. Micro-machining of brittle objects.
- Making of nylon and Teflon parts, permanent marking on rubber stencils, cutting titanium foils.
- Cutting of optical fibers without altering its wavelength is one of the most important applications of this process.
- Deburring of some critical zones in the machined parts.
- Cutting, drilling and frosting of precision optical lenses.
- Cutting and etching of inaccessible areas and internal surfaces can be done.
- Reproducing designs on a glass surface with the help of rubber or copper masks.

- <u>Characteristics of AJM:</u>

Work material → hard and brittle materials like glass,ceramics,mica.

Abrasive → Al_2O_3,Silicon carbide, Glass powder
Dolomite

Size of abrasive → around 25μm

Flow rate → 2-20g/min

Medium → N_2 (or) CO_2 (or) air

Velocity → 125-300m/s

Pressure → 2 to 8 kg/cm2

Nozzle material → tungsten carbide or synthetic sapphire

Life of nozzle → tungsten carbide (12 to 20 hours)
sapphire (300hours)

Gap → 0.25-0.75mm

Tolerance → ±0.05mm

Machining operation → drilling,cutting,cleaning etc

INTRODUCTION:-

water jet machining process is an extension of abrasive jet machining process. In this process , high pressure and high velocity stream of water is used to cut the relatively soft and non-metallic materials like paper boards,wood,plastics, rubber, fiber glass , leather, etc.

PRINCIPLE:when the high velocity of water jet comes out of the nozzle and strikes the material , its kinetic energy is converted into pressure energy including high stresses in the work material. When this induced stress exceeds the ultimate shear stress of the material, small chips of the material get loosened and fresh surface is exposed.

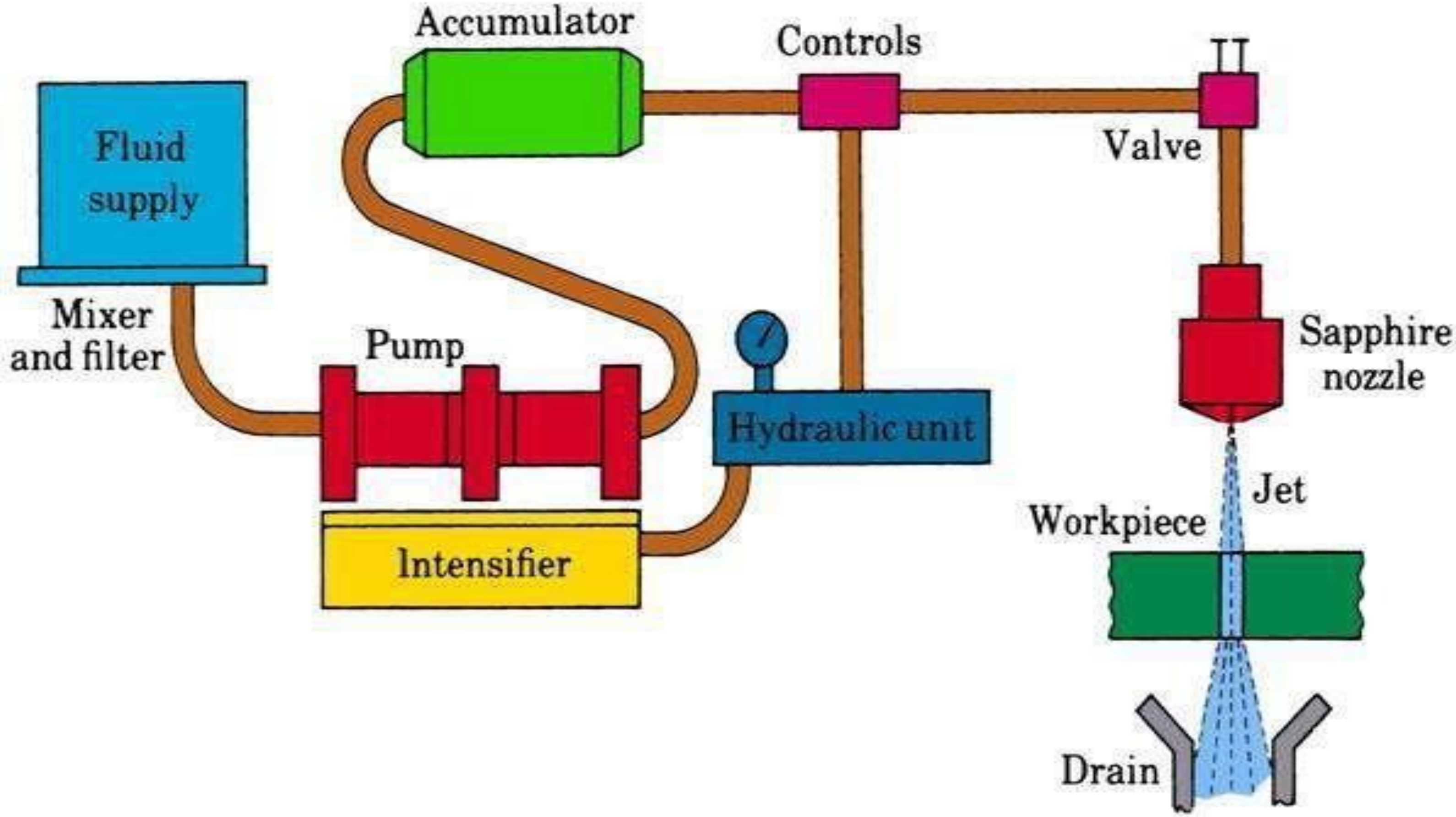


Fig : schematic diagram of WJM

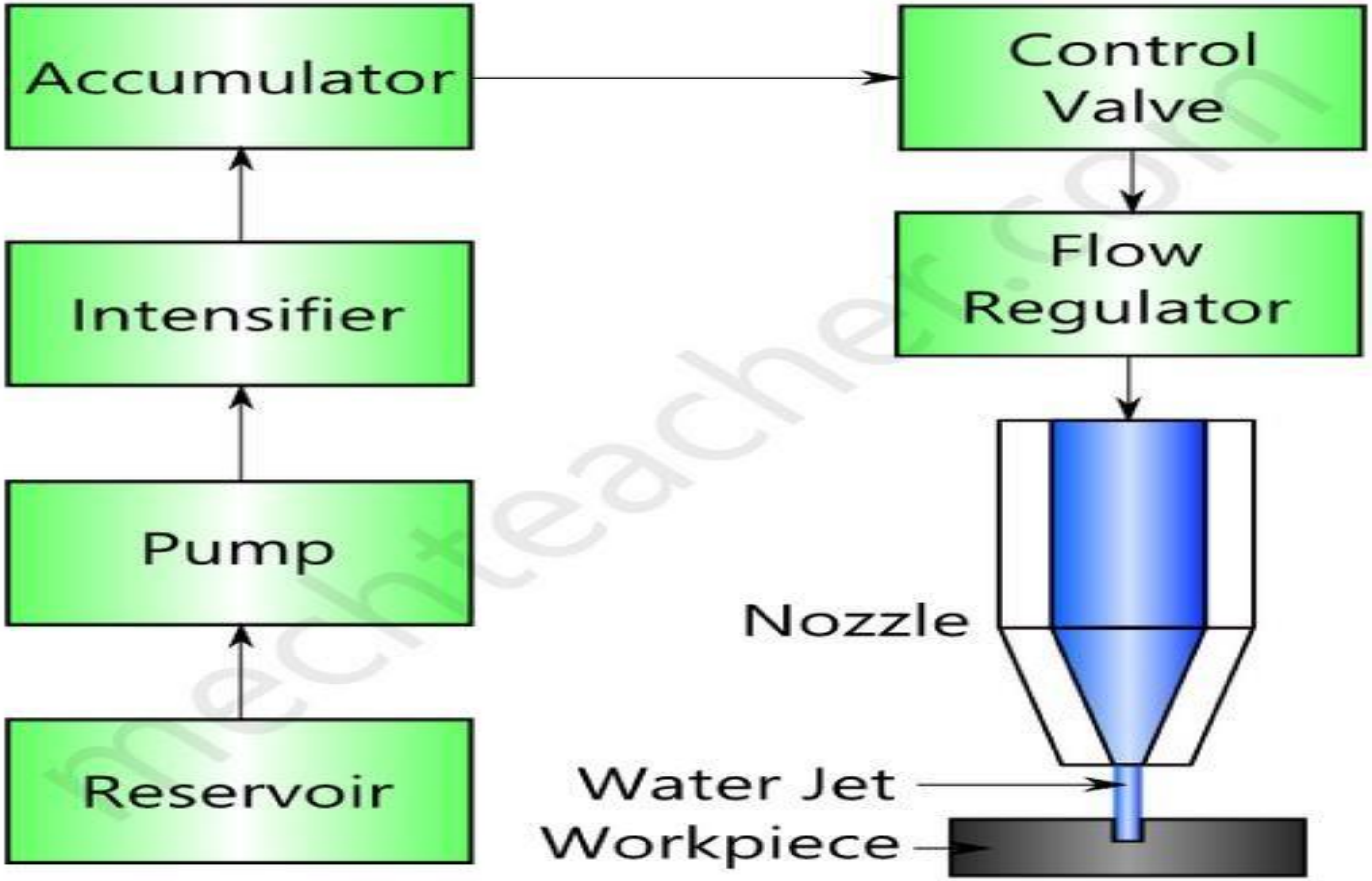


Fig : schematic diagram of WJM

Construction of Water Jet Machining (WJM):

The apparatus of water jet machining consists of the following components:

1.Reservoir: It is used for storing water that is to be used in the machining operation.

2.Pump: It pumps the water from the reservoir.

3.Intensifier: It is connected to the pump. It pressurizes the water acquired from the pump to a desired level. in the range of 1500 to 4000 N/mm2.

4.Accumulator: It is used for temporarily storing the pressurized water. It is connected to the flow regulator through a control valve.

5.Control Valve: It controls the direction and pressure of pressurized water that is to be supplied to the nozzle.

6.Flow regulator: It is used to regulate the flow of water.

7.Nozzle: It renders the pressurized water as a water jet at high velocity. The exit diameter of the nozzle is in the range of 0.05 to 0.35 mm and the exit velocity of the water jet from the nozzle varies up to 920 m/s.

Working of Water Jet Machining (WJM):

- Water from the reservoir is pumped to the intensifier using a hydraulic pump.
- The intensifier increases the pressure of the water to the required level. Usually, the water is pressurized to 200 to 400 Map.
- Pressurized water is then sent to the accumulator. The accumulator temporarily stores the pressurized water.
- Pressurized water then enters the nozzle by passing through the control valve and flow regulator.
- Control valve controls the direction of water and limits the pressure of water under permissible limits.
- Flow regulator regulates and controls the flow rate of water.
- Pressurized water finally enters the nozzle. Here, it expands with a tremendous increase in its kinetic energy. High velocity water jet is produced by the nozzle.

•When this water jet strikes the work piece, stresses are induced. These stresses are used to remove material from the work piece.

•The water used in water jet machining may or may not be used with stabilizers. Stabilizers are substances that improve the quality of water jet by preventing its fragmentation.

PROCESS PARAMETERS:-

The following process parameters are needed to utilize the WJM process successfully.

1. Material removal rate
2. Geometry and surface finish of work material.
3. Wear rate of the nozzle.

MATERIAL REMOVAL RATE:-

in water jet machining process, material removal rate is directly proportional to the reactive force(F) of the jet.

$MRR \alpha F$

$MRR \alpha mix$

Where m=mass flow rate, and v=jet velocity.

Mass flow rate depends on nozzle diameter (d) and fluid pressure (p). Jet velocity depends on fluid pressure.

MRR αd αP

Stand-off distance is the distance between the nozzle tip and the surface of the material being machined.

When MRR increases , the SOD also increases up to a certain limit after that it remains unchanged for a certain tip distances and then falls gradually.

2. GEAOMETRY AND SURFACE FINISH OF WORK MATERIAL:-

Geometry and surface finish of work material mainly depends upon the following parameters.

- Nozzle design,
- Jet velocity,
- Cutting speed,
- Depth of cut, and
- Properties of the material to be machined.

3. WEAR RATE OF THE NOZZLE:-

Nozzle wear rate depends up on the following factors.

 Hardness of the nozzle material,

 Pressure of the jet,

 Velocity of the jet, Nozzle design.

ADVANTAGES OF WATER JET MACHINING (WJM):

1.Water jet machining is a relatively fast process.
2.It prevents the formation of heat affected zones on the work piece.
3.It automatically cleans the surface of the work piece.
4.WJM has excellent precision. Tolerances of the order of ±0.005" can be obtained.
5.It does not produce any hazardous gas.
6.It is eco-friendly.

Disadvantages of Water Jet Machining:

•Only soft materials can be machined.

- Very thick materials cannot be easily machined.
- Initial investment is high.

Applications of Water Jet Machining:

- Water jet machining is used to cut thin non-metallic sheets.
- It is used to cut rubber, wood, ceramics and many other soft materials.
- It is used for machining circuit boards.
- It is used in food industry.

CHARCTERISTICS OF WJM

TOOL	WATER OR WATER WITH ADDITIVES

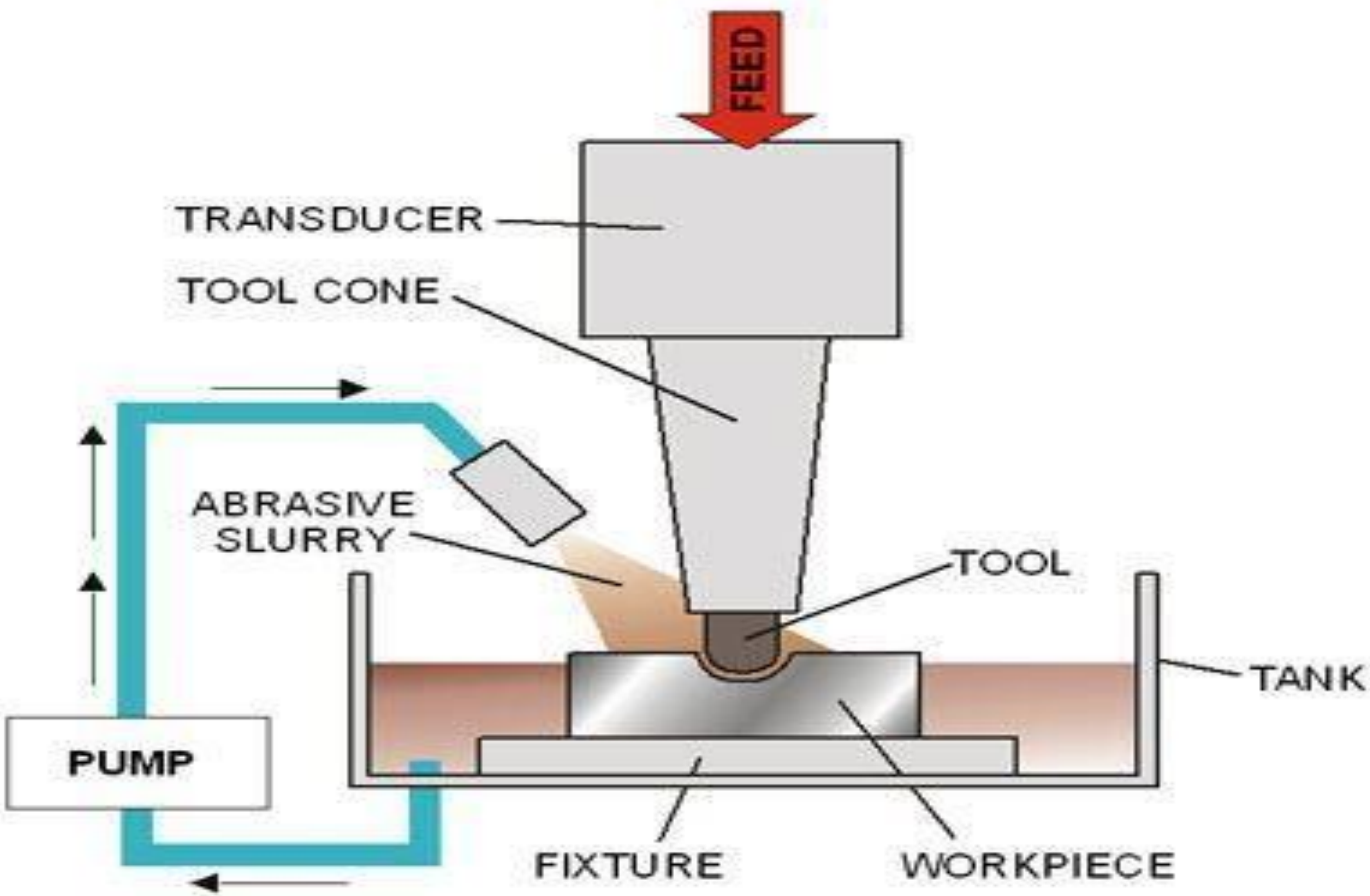
ADDITIVES	GLYCERIN,POLYETHYLENE OXIDE
PRESSURE OF WATER	100 TO 1000 MPA
MASS FLOW RATE	8 LIT/MIN
POWER	45KW
METAL REMOVAL RATE	0.6 MM3/S
FEED RATE	1-4 mm/s
NOZZLE MATERIAL	TUNSTEN CARBIDE,SYNTHETIC SAPPHIRE
STAND OFF DISTANCE	2 TO 50 mm

INTRODUCTION:-

Ultrasonic machining is one kind of grinding method. It is also known as ultrasonic grinding or impact grinding. The term ultrasonic refers to waves of high frequency. Human ear can hear the sound waves between 20hz to 20khz. This range is known as audible range. The sound waves which have frequencies less than the audible range are called infrasonic waves. The sound waves having frequencies above the audible range are known as ultrasonic waves. The ultra sonic machining process is suitable only for hard and brittle materials like carbides, glass, ceramics, silicon, precious stones,germanium,titanium,tungsten,tool steels, die steels, etc.

PRINCIPLE OF USM:-

In this machining method, a slurry of small abrasive particles are forced against the work piece by means of a vibrating tool and it causes the removal of metal from the work piece in the form of extremely small chips.


FEED
TRANSDUCER
TOOL CONE
ABRASIVE
SLURRY
TOOL
TANK
PUMP
FIXTURE
WORKPIECE

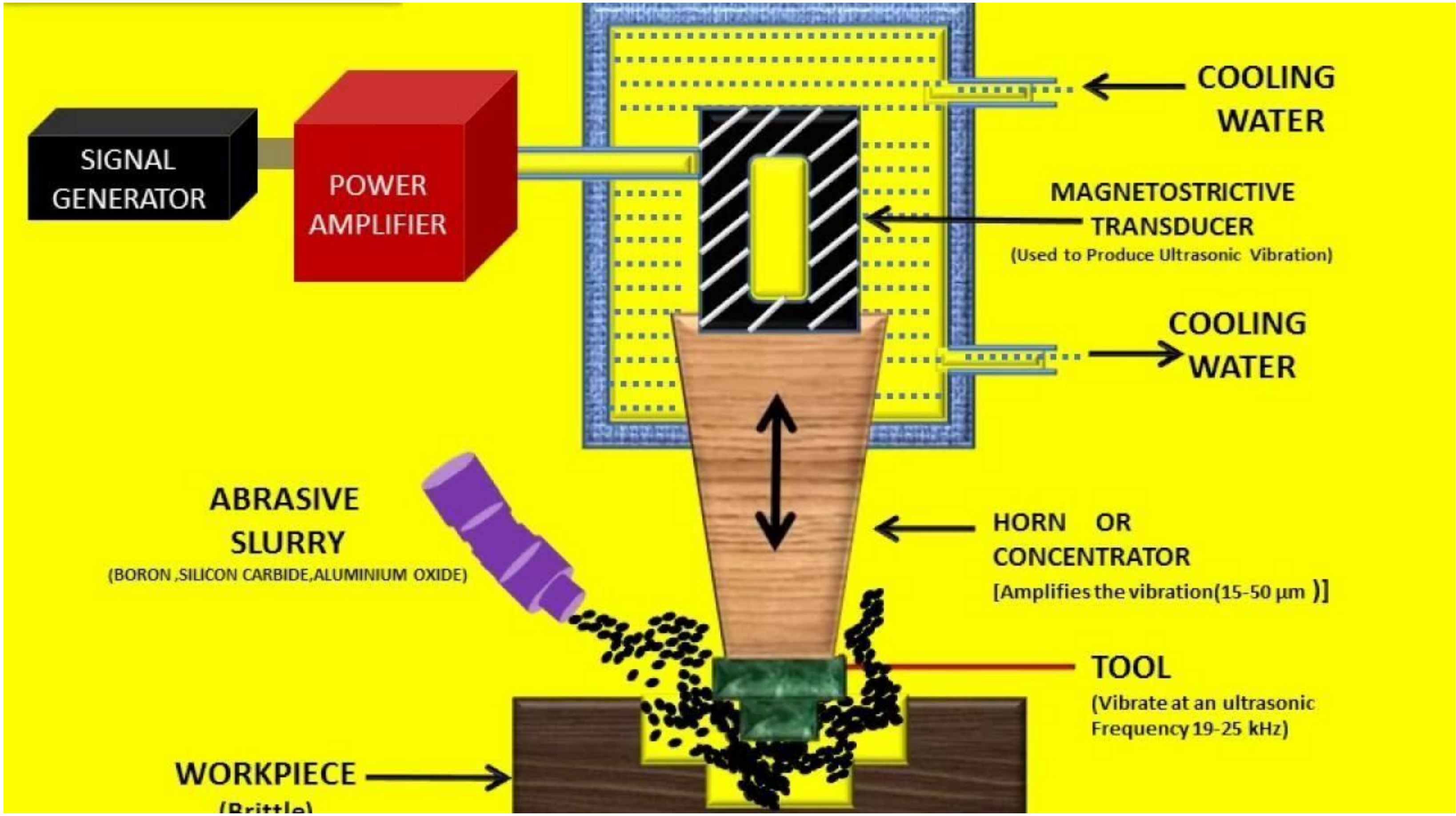

SIGNAL GENERATOR
POWER AMPLIFIER
COOLING WATER
MAGNETOSTRICTIVE TRANSDUCER
(Used to Produce Ultrasonic Vibration)
COOLING WATER
ABRASIVE SLURRY
(BORON ,SILICON CARBIDE,ALUMINIUM OXIDE)
HORN OR CONCENTRATOR
[Amplifies the vibration(15-50 µm)]
TOOL
(Vibrate at an ultrasonic Frequency 19-25 kHz)
WORKPIECE

Fig : arrangement of ultrasonic machining process

CONSTRUCTION:-

- It consists of abrasive slurry, work piece, fixture, table, cutting tool, circulating pump, reservoir, ultrasonic oscillator, leads, excitation coil, feed mechanism, ultrasonic transducer, transducer cone, connecting body and tool holder.
- The ultrasonic oscillator and amplifier also known as generator is used to convert the applied electrical energy at low frequency to high frequency.
- The transducer is made up of magnetosrictive material and it consists of a stack of nickel laminations that are wound with a coil.
- The function of the transducer is to convert the electrical energy in to mechanical energy.

 Generally tough and ductile tool material is used in this process. Low carbon steels and stainless steels are commonly used as tool materials.

 The tool is brazed, soldered or fastened mechanically to the transducer through a tool holder. Generally tool holder is of cylindrical or conical shape.

 The materials used for tool holders are titanium alloys, monel, aluminum,

stainless steel, etc.

 An abrasive slurry, usually a mixture of abrasive grains and water of definite proportion (20-30 percent), is made to flow under pressure through the gap between tool and work piece . The gap between the tool and work piece is of the order 0.02 to 0.1 mm.

 The most commonly used abrasives are boron carbides (b4c), silicon carbide(sic), aluminum oxide (al2o3), and diamond. Boron carbide is most commonly used abrasive slurry , since it has the fastest cutting abrasive property.

WORKING:-

 Electric power is given to ultrasonic oscillator and this oscillator converts the electrical energy at low frequency to high frequency(20khz).

 High frequency power (20khz) from oscillator is supplied to the transducer. The function of the transducer is to convert the electrical energy in to mechanical vibrations. The transducer is made up of magnetostrictive material, which is excited by flowing high frequency electric current and this results in the generation of mechanical vibrations. The vibrations are generated in the transducer of the order of 20khz to 30khz and hence ultrasonic waves are produced.

- These vibrations are then transmitted to the cutting tool through transducer cone, connecting body and tool holder. This makes the tool to vibrate in a longitudinal direction .
- Abrasive slurry is pumped from the reservoir and it is made to flow under pressure through the gap between tool and work piece.
- In an abrasive slurry, when the cutting tool vibrates at high frequency, it leads in the removal of metal from the work piece.
- The impact force arises out from the vibration of tool end and the flow of slurry through the work piece tool gap causes thousands of microscopic grains to remove the work piece material by abrasion.

 A refrigerated cooling system is used to cool the abrasive slurry to a temperature of 5 to 6 degree centigrade.

 The ultrasonic machining process is a copying process in which the shape of the cutting tool is same as that of the cavity produced.

PROCESS PARAMETERS:-

The various process parameters involved in USM methods are as follows:

1. Metal removal rate.
2. Tool material.
3. Tool wear rate.
4. Abrasive materials and abrasive slurry.

5. Surface finish.

6. Work material.

1. METAL REMOVAL RATE:-

- The material removal rate per unit time is inversely proportional to the cutting area of the tool. Boron carbide is the hardest material and has the highest metal removal rate.

- Wear ratio is defined as the ratio of volume of material removed from the work to volume of material eroded from tool.

  wear ratio=volume of material removed from the work/volume of material eroded from the tool.

- Material removal in USM is a very complex process and it depends on certain factors. They are:

1. Grain size of abrasive.
2. Abrasive materials.
3. Concentration of slurry.
4. Amplitude of vibration.
5. Frequency of ultra sonic waves.

1. GRAIN SIZE OF ABRASIVE:-

Material removal rate and surface finish are greatly influenced by grit or grain size of the abrasive.

Maximum rate in machining is attained when the grain size of the abrasive is comparable to the tool amplitude.

For rough work operation grit size of 200-400 are used and for finishing operation ,grit size of 800-1000 are used.

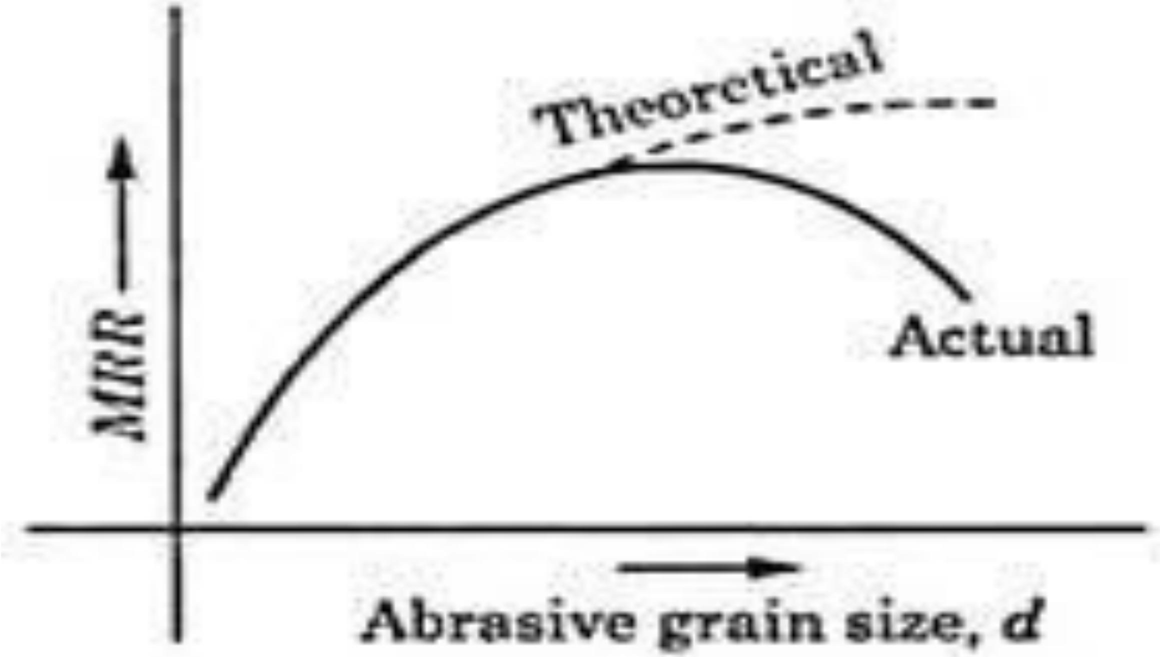


Fig. 10.48

2. ABRASIVE MATERIALS:

for effective machining, the abrasive materials should be replaced periodically since the dull abrasives stop the cutting action. the proper selection of abrasive particles depends on the type of material to be machined, hardness of the material, metal removal rate desired and the surface finish required.

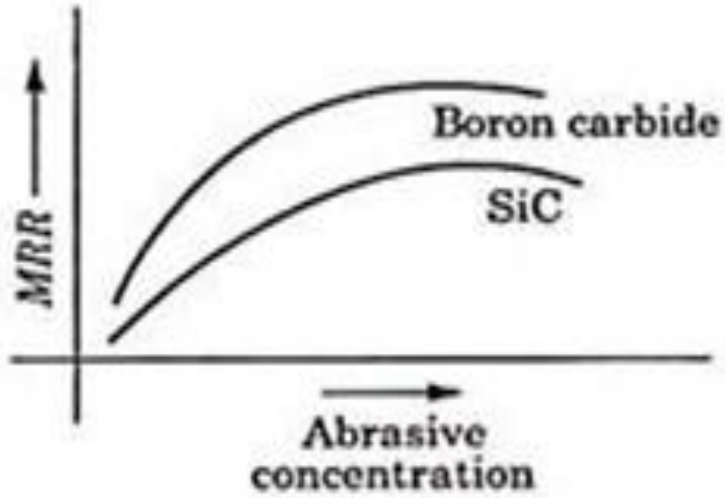
The most commonly used abrasives are boron carbide and silicon carbide which are used for machining tungsten carbide, die steel, etc.

Aluminum oxide is the softest abrasive and it is used for machining glass and ceramics.

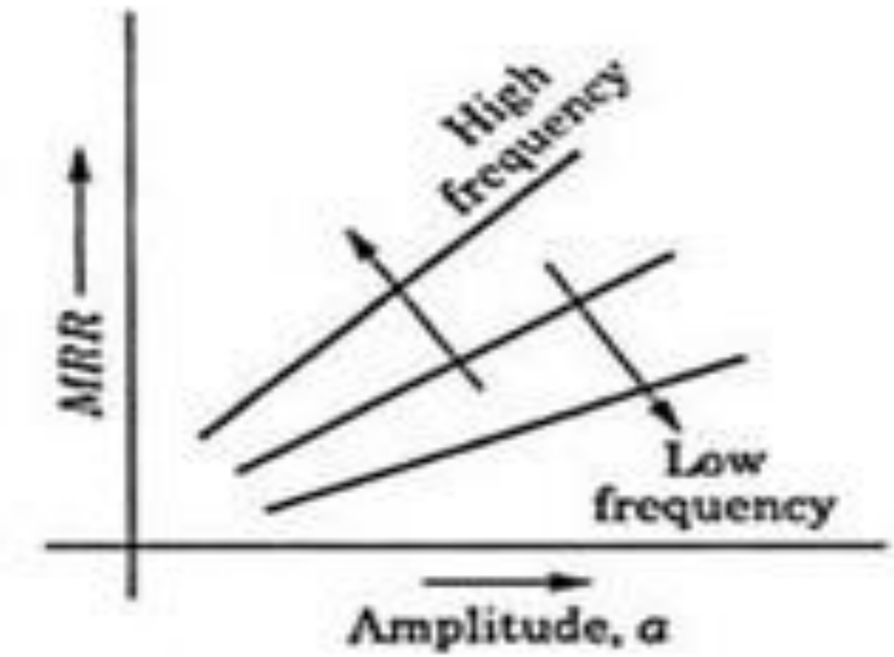
3. CONCENTRATION OF SLURRY:

an abrasive slurry, usually a mixture of abrasive grains and water of definite proportion(20-30 percent), is made to flow under pressure through the gap between tool and work piece.

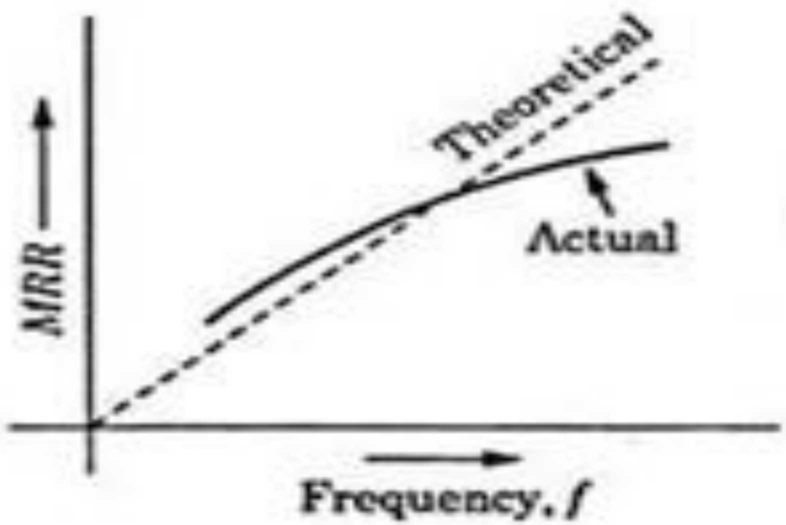
the fig shows how the material removal rate in ultrasonic machining process varies with slurry concentration.


Boron carbide
SiC
MRR
Abrasive
concentration

4. AMPLITUDE OF VIBRATION:metal removal rate in ultrasonic machining process increases with increasing amplitude of vibration which is shown in fig



5. FREQUENCY:ultrasonic wave frequency is directly proportional to the metal removal rate which is shown in fig



2. TOOL MATERIAL:generally , tough and ductile tool material is used in USM process. Low carbon steels and stainless steels are commonly used as tool materials. Since very long tools cause overstress, the tool should be short and rigid.

hollow tool can be made with wall thickness greater than 0.5 to 0.8

mm.

the USM process is a copying process in which the shape of the cutting tool is same as that of the cavity produced.

3. TOOL WEAR RATE:-

- Wear ratio is defined as the ratio of volume of material removed from the work to volume of material eroded from tool.

  wear ratio=volume of material removed from the work/volume of material eroded from the tool.

- The wear ratio is approximated to 1.5 : 1 for tungsten carbide (WC) work piece, 100:1 for glass , 50:1 for quartz , 75:1 for ceramics and 1:1 for hardened tool steel.

4. ABRASIVE MATERIALS AND ABRASIVE SLURRY:-

1	BORON CARBIDE(B4C)	2800	0.50-0.60
2	SILICON CARBIDE(SIC)	2450-2500	0.25-0.458

3	ALLUMINIUM OXIDE(AL2O3)	2000-2100	0.14-0 .16	the cutting power of differen t abrasive s are shown
4	DIAMOND	6500-7000	1	

in the table.

5. SURFACE FINISH:-

The maximum speed of penetration in soft and brittle materials such as soft ceramics are of the order of 200 mm/min.

Penetration rate is lower for hard and tough materials.

Accuracy of this process is plus or minus 0.006 mm and surface finish up to 0.02 to 0.8 micron value can be achieved.

6. WORK MATERIALS:-

Hard and brittle metals, non metals like glass , ceramics, etc, and semiconductors are used as work material in USM process.

Advantages of USM

- Machining any materials regardless of their conductivity
- USM apply to machining semi-conductor such as silicon, germanium etc.
- USM is suitable to precise machining brittle material.
- USM does not produce electric, thermal, chemical abnormal surface.
- Can drill circular or non-circular holes in very hard materials
- Less stress because of its non-thermal characteristics

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Disadvantages of USM

- **USM has low material removal rate. (3-15mm3/min)**
- **Tool wears fast in USM.**
- **Machining area and depth is restraint in USM.**

Applications

It is mainly used for

(1) drilling

(2) grinding,

(3) Profiling

(4) coining

(5) piercing of dies

(6) welding operations on all materials which can be treated suitably by abrasives.

(7) Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.

(8) Used for machining round, square, irregular shaped holes and surface impressions.

CHARCTERISTICS OF USM:-

METAL REMOVAL MECHANISM

ABRASIVE	BORON CARBIDE(B4C),SILICON CARBIODE (SIC),ALLUMINUM OXIDE (AL2O3) AND DIAMOND
ABRASIVE SLURRY	ABRASIVE GRAINS + WATER(20-30 PERCENT)
VIBRATION FREQUENCY	20 TO 30 KHZ
AMPLITUDE	25 TO 100 MICRONS

WEAR RATIO	1.5:1 FOR TUNGSTEN CARBIDE , 100:1 FOR GLASS , 50:1 FOR QUARTZ, 75:1 FOR CERAMICS AND 1:1 FOR TOOL STEEL.
WORK MATERIAL	TUNGSTEN CARBIDE,GERMANIUM,GLASS,CERAMICS, QUARTZ, TOOL STEEL ETC
TOOL MATERIAL	LOW CARBON STEELS, STAINLESS STEELS.
SURFACE FINISH	0.2 TO 0.7 MICRONS.

DEPARTMENT : MECHANICAL ENGINEERING

YEAR & SEM : II-I SEM

SUBJECT : MANUFACTURING PROCESS

SUBJECT CODE : (19A03301T)

PREPARED BY : V V ANANTHA CHAKRAVARTHY

UNIT I : Casting Processes

- Introduction to casting process
- Process steps
- Pattern: types, materials and allowance
- Cores: Types of cores, core prints
- Principles and design of gating system
- Solidification of casting: Concept
- Solidification of pure metal and alloy

UNIT I :Casting Processes

- Special casting processes
- Shell casting
- Investment casting
- Die casting
- Centrifugal casting

- Casting defects and remedies.

Introduction

- Beside above, all kinds of the future engineers must know the basic requirements of workshop activities in term of man, machine, material, methods, money and other infrastructure facilities needed to be positioned properly for optimal shop layouts or plant layout and other support services effectively adjusted or located in the industry or plant within a well-planned manufacturing organization

Importance of Manufacturing process

- Manufacturing is achieved through a proper planning and control system.
- It is classified as continuous production and intermittent production.
- Continuous production involves a continuous flow of material physically, leading to large quantities of finished good.
- Chemical processing, cigarette manufacturing and cement manufacturing are some of the industries employing continuous production.
- Also, sheets, wires, pipes, TV sets, motor cycles are examples of continuous production

Importance of Manufacturing process

- ➢ An intermitted production involves interrupted flow of material through the plant.
- Machine shops, welding shops, etc. are industries employing intermittent production.

- Manufacturing and tech **Importance of manufacturing towards technology development** are complementary to each other

- ➢ Growth in manufacturing enables increase availability of finish goods and its appliance in various sectors

. **Importance of manufacturing towards technology development**

- Such appliance leads to technology development of the industries which is then transferred to development of manufacturing technology.

- ➢ Growth of manufacturing is also referred to as an index of technology growth of a country

- ➢ Manufacturing provides availability of finish goods for technology application**.**

Importance of manufacturing towards social-economicdevelopment.

- Manufacturing is backbone of any economy. Manufacturing industries provides employment to hundreds of people.

- Before the industrial revolution, manufacturing was carried out in rural area, where household-based manufacturing was the trend.
  - Later government policy and entrepreneurs organized a number of manufacturing house hold in to a single enterprise producing goods at large scale

Importance of manufacturing towards social-economic development.

- It leads to development of industrialization and society.
- Manufacturing provides an opportunity for establishment of allied industries.
- It provides a boost to the services industry catering to the people employed.
- Manufacturing is considered as a wealth-producing sector of an economy.
- It provides important material supports for national infrastructure and for national defense.

Classification of Manufacturing Process

- For producing of products materials are needed. It is therefore important to know the characteristics of the available engineering materials.

- Raw materials used manufacturing of products, tools, machines and equipments in factories or industries are extracted from ores.
- The ores are suitably converted the metal into a molten form by reducing or refining processes in foundries. This molten metal is poured into moulds for providing commercial castings, called ingots.

Classification of Manufacturing Process

These forms of material supply are further subjected to various manufacturing processes for getting usable metal products of different shapes and sizes in various manufacturing shops.

- All these processes used in manufacturing concern for changing the ingots into usable products may be classified into six major groups as primary shaping processes, secondary machining processes, metal forming processes, joining processes, surface finishing processes and processes effecting change in properties. These are discussed as under.

Classification of Manufacturing Process

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machining processes, metal forming processes, joining processes, surface finishing processes and processes effecting change in properties. These are discussed as under.

1.Primary Shaping Processes

- Primary shaping processes are manufacturing of a product from an amorphous material.
- Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size.
- Castings need re-melting of scrap and defective ingots in cupola or in some other melting furnace and then pouring of the molten metal into sand or metallic moulds to obtain the castings. Thus the intricate shapes can be manufactured.

1.Primary Shaping Processes

Some of the important primary shaping processes is:

(1) Casting, (2) Powder metallurgy, (3) Plastic technology,
(4) Gas cutting, (5) Bending and (6) Forging.

2. Secondary or Machining Processes

Some of the common secondary or machining processes are:

(1) Turning, (2) Threading, (3) Knurling, (4) Milling, (5) Drilling, (6) Boring, (7) Planning, (8) Shaping, (9) Slotting, (10) Sawing, (11) Broaching, (12) Hobbing, (13) Grinding, (14) Gear cutting, (15) Thread cutting and (16) Unconventional machining processes namely machining with Numerical Control (NC) machines tools or Computer Numerical Control (CNC) machines tools using ECM, LBM, AJM, USM setups etc

3. Metal Forming Processes

Some of the important metals forming processes are: **Hot working Processes** (1) Forging, (2) Rolling, (3) Hot spinning, (4) Extrusion, (5) Hot drawing and (6) Hot spinning.

Cold working processes (1) Cold forging, (2) Cold rolling, (3) Cold heading, (4) Cold drawing, (5) Wire drawing, (6) Stretch forming, (7) Sheet metal working processes such as piercing, punching, lancing, notching, coining, squeezing, deep drawing, bending etc.

4. Joining Processes

Temporary joining of component scan be achieved by use of nuts, screws and bolts. Adhesives are also used to make temporary joints. Some of the important and common joining processes are: (1) Welding (plastic or fusion), (2) Brazing, (3) Soldering, (4) Riveting, (5) Screwing, (6) Press fitting, (7) Sintering, (8) Adhesive bonding, (9) Shrink fitting, (10) Explosive welding, (11) Diffusion welding, (12) Keys and cotters joints, (13) Coupling and (14) Nut and bolt joints.

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5. Surface Finishing Processes

Surface cleaning process also called as a surface finishing process.

Some of the commonly used surface finishing processes are:

(1) Honing, (2) Lapping, (3) Super finishing, (4) Belt grinding, (5) Polishing, (6) Tumbling, (7) Organic finishes, (8) Sanding, (9) deburring, (10) Electroplating, (11) Buffing,

(12) Metal spraying, (13) Painting, (14) Inorganic coating, (15) Anodizing, (16) Sheradising, (17) Parkerizing, (18) Galvanizing, (19) Plastic coating, (20) Metallic coating, (21) Anodizing and (22) Sand blasting.

6. Processes Effecting Change in Properties

Similarly the metal forming processes effect on the physical properties of work pieces similarly shot peening process, imparts fatigue resistance to work pieces.

A few such commonly used processes are given as under:

(1) Annealing, (2) Normalising, (3) Hardening,

(4) Case hardening, (5) Flame hardening, (6) Tempering, (7) Shot peeing, (8) Grain refining and (9) Age hardening. In addition, some allied manufacturing activities are also required to produce the finished product such as measurement and assembly.

Introduction to casting

□□ Casting or founding is the process of producing metal or alloy component parts.

□ The parts of desired shapes are produced by pouring the molten metal or alloy into a prepared mould and then allowing the metal or alloy to cool and solidify. □□ This solidified piece of metal or alloy is called as casting.

Steps Involved in Making a Casting

Following are the steps to be followed while making a sand casting:

1. Pattern making
2. Sand mixing and preparation
3. Core making
4. Melting
5. Pouring
6. Finishing
7. Testing

8. Heat treatment

9. Re-testing

Advantages of Metal Casting :

- Casting is one of the most versatile manufacturing processes.

 It provides the greatest freedom of design in terms of shape, size and quality of product.

- Casting provides uniform directional properties and better vibration damping capacity to the cast components.

 Complex and uneconomical shapes which are difficult to produce by other processes can be easily produced by casting process.

Advantages of Metal Casting :

- A product obtained by casting is one piece; hence there is no need of metal joining processes. Very heavy and bulky parts which are difficult to get fabricated, may be cast. It also produces machinable parts.

- Casting process can be mechanized and generally used for mass production of components.

Applications of Metal Casting:

A few applications of casting or cast components are given below :

- Transportation vehicles (in automobile engine and tractors)
- Machine tool structures
- Turbine vanes and power generators
- Mill housing
- Pump filter and valve
- Railway crossings and aircraft jet engine blades

Agricultural parts and sanitary fittings

- Construction, communication and atomic energy applications, etc.

Pattern Making

 A pattern is a mould forming tool in the hands of foundry men.

- A pattern is defined as a model or replica of the object to be cast.
- A pattern exactly resembles the casting to be made except for the various allowances.
- If one object has to be cast, then also pattern is required.
- It is a model or form around which sand is packed to give rise to a cavity called as mould cavity; in which molten metal is poured and the casting is produced.

The ways in which a pattern differ from a casting are as follows:

- A pattern is slightly larger than the casting because a pattern carries allowance to compensate. For metal shrinkage.
- Also, pattern carries allowances for machining so as to clean and finish the required surfaces.
- Pattern also has the necessary draft for its easy removal from the sand mass.

The ways in which a pattern differ from a casting are as follows :

- It carries additional projections, called as core prints, to produce seats for the cores.
- A pattern may not have holes and slots which a casting will have. Such holes and slots make a pattern complicated, hence can be drilled in the casting after it has been made.
- The material from which casting and pattern is made, is also different.

Functions of a Pattern

The main functions of a pattern are as follows :

- To prepare a mould cavity of appropriate shape and size for the purpose of making a casting.
- To produce seats for the cores in the mould in which cores can be placed, for producing cavity in the casting. Such seats in the mould are called as core prints.
- To establish the parting line and parting surfaces in the mould.
- To minimize casting defects.
- To help for positioning of a core before the moulding sand is rammed.
- It should minimize the overall casting cost.

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- It should minimize the overall casting cost.

Types of Patterns

The type of pattern to be used for a particular casting will depend on following factors :

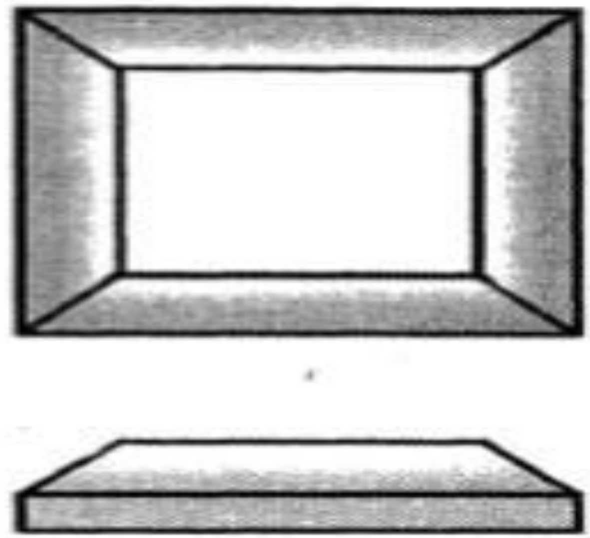
- Quantity of casting to be produced
- Size and shape of the casting
- Type of moulding method
- Design of casting.

The various types of patterns which are commonly used are as follows :

1. Single piece or solid pattern
2. Two piece or split pattern
3. Loose piece pattern
4. Cope and drag pattern
5. Gated pattern

6. Match plate pattern
7. Sweep pattern
8. Skeleton pattern
9. Segmental pattern
10. Follow board pattern
11. Lagged-up pattern

1. **Single piece or solid pattern**:
   – It is the simplest of all the patterns and it is made in one-piece and does not carry loose pieces or joints.

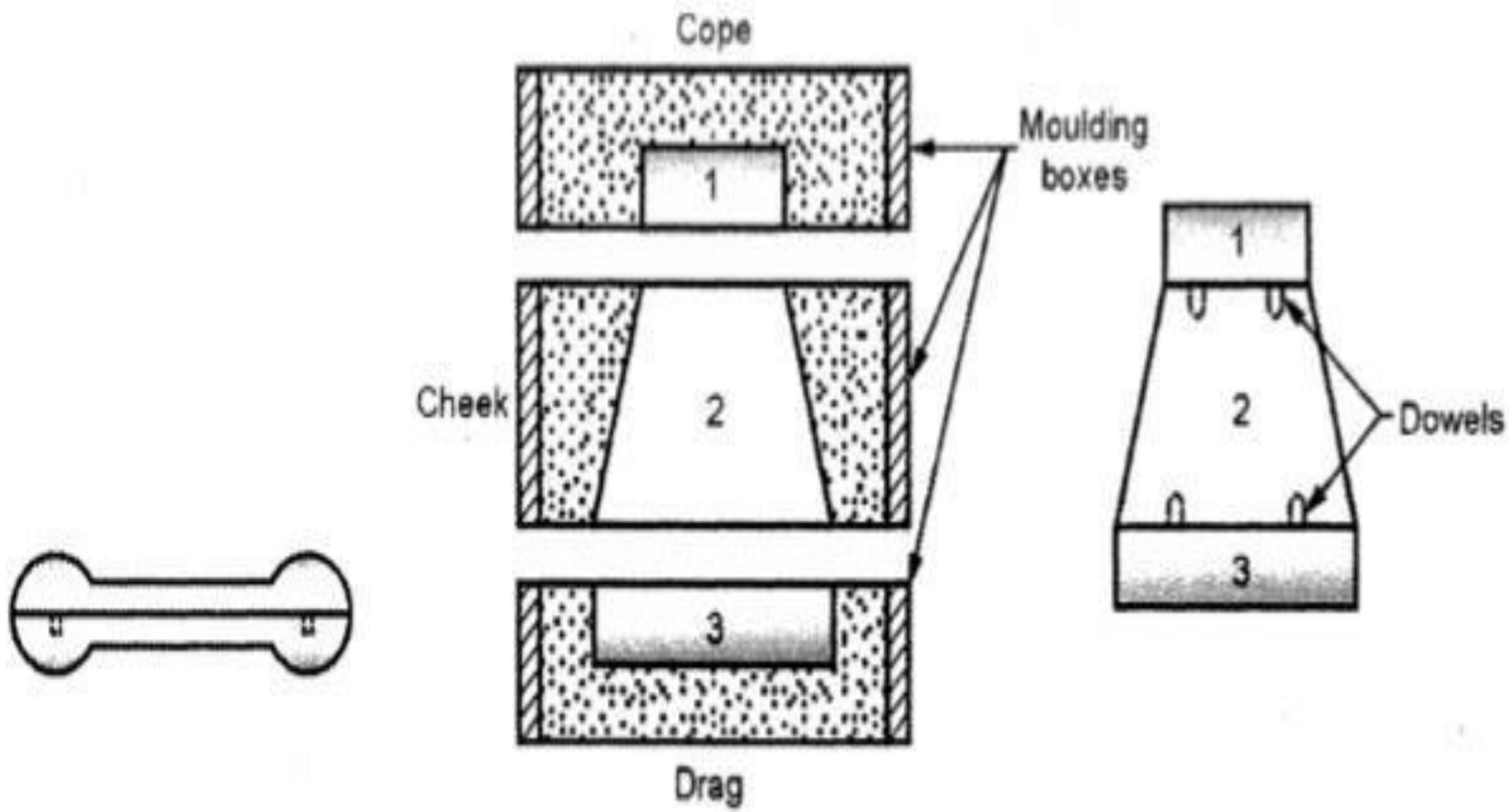


ig. 2.2: Single piece pattern

2. Two piece or split pattern :

 Patterns of complicated shape castings cannot be made in one-piece because of the difficulties associated with the moulding operations.

➢ Such patterns are made in two pieces, called as split pattern or two piece pattern.



(a) Split pattern

(b) Three piece pattern and its moulding arrangement

Fig. 2.3: Two piece pattern

3. Loose piece pattern :

 Some patterns embedded in the moulding sand cannot be withdrawn, hence such patterns are made with one or more loose pieces for their easy removal from the moulding box.

➢ These patterns are known as loose piece patterns.

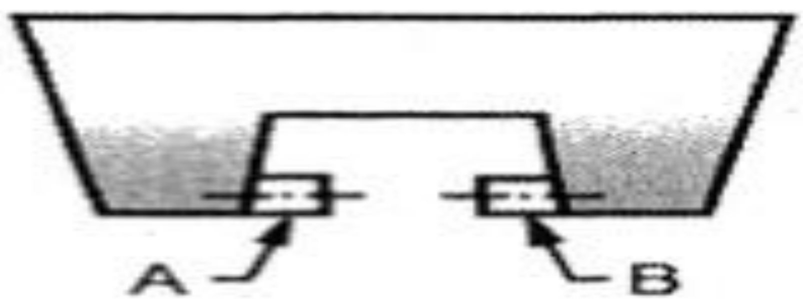


Fig. 2.4: Loose piece pattern

– Loose pieces like A and B as shown in Fig. 2.4 remain attached with the main body by using dowel pins.

– These patterns consume more time for moulding operation and require more labour work.

4. Cope and Drag pattern :

 It is another form of split pattern.

 The pattern is split about a suitable surface or line. Each half of the pattern is fixed to a separate plate and besides the pattern it has provision for moulding runner and gates.

 Each half of the pattern is moulded separately in a separate moulding box and then assembled for pouring.

 These patterns are used for producing large casting.

5. Gated pattern:

 To increase the strength and reduce the tendency to warp, gated patterns are generally made of metals.

 By using gated patterns number of casting can be made at a time, hence they are used in mass production system. The sections connecting various patterns serve as a runner and gates. Refer Fig. 2.5.

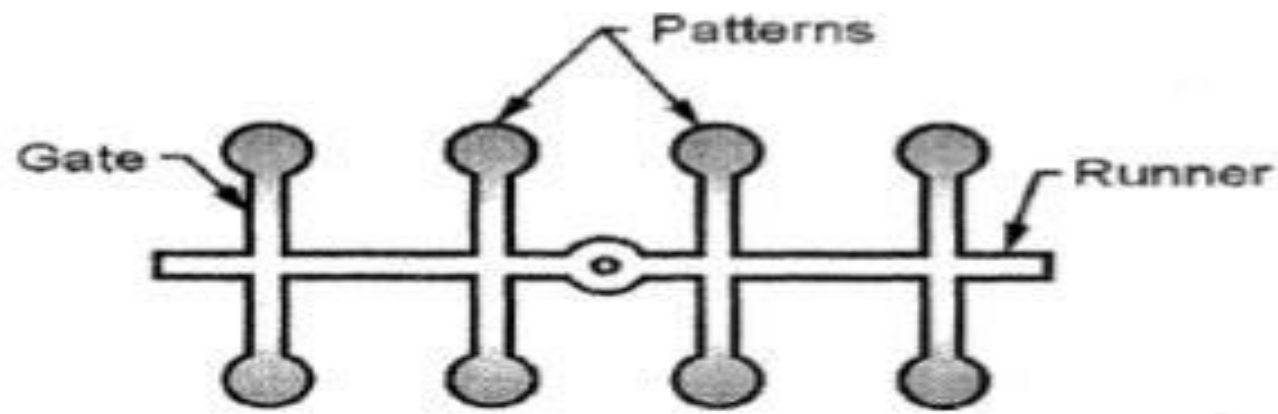


Fig. 2.5: Gated pattern

6. Match plate pattern :

 These patterns are made in two pieces i.e. one piece mounted on one side and the other on the other side of the plate, called as match plate.

 The plate may carry one pattern or group of patterns mounted in the same way on its two sides.

Refer Fig. 2.6.

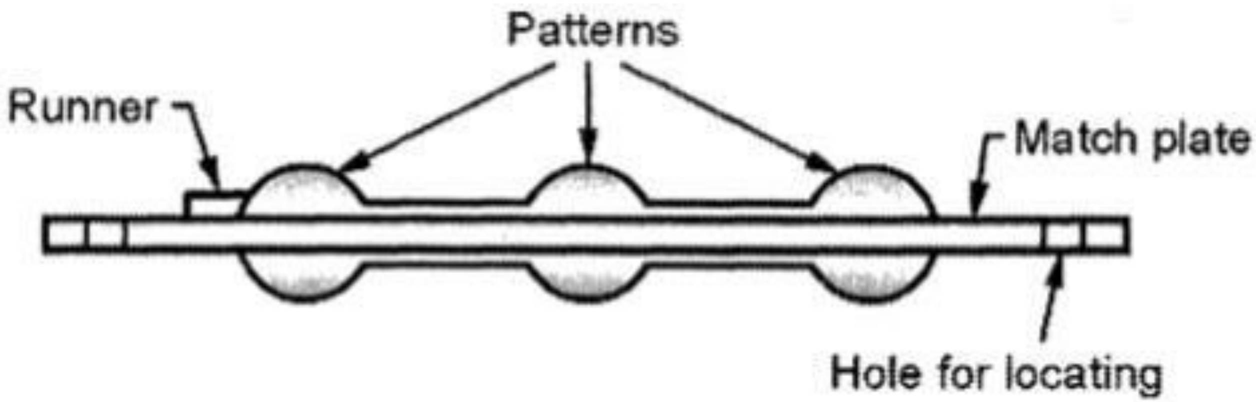


Fig. 2.6: Match plate pattern

7. Sweep pattern :

□□ Sweep pattern is just a form made on a wooden board which sweeps the casting shape into the sand all around the circumference.

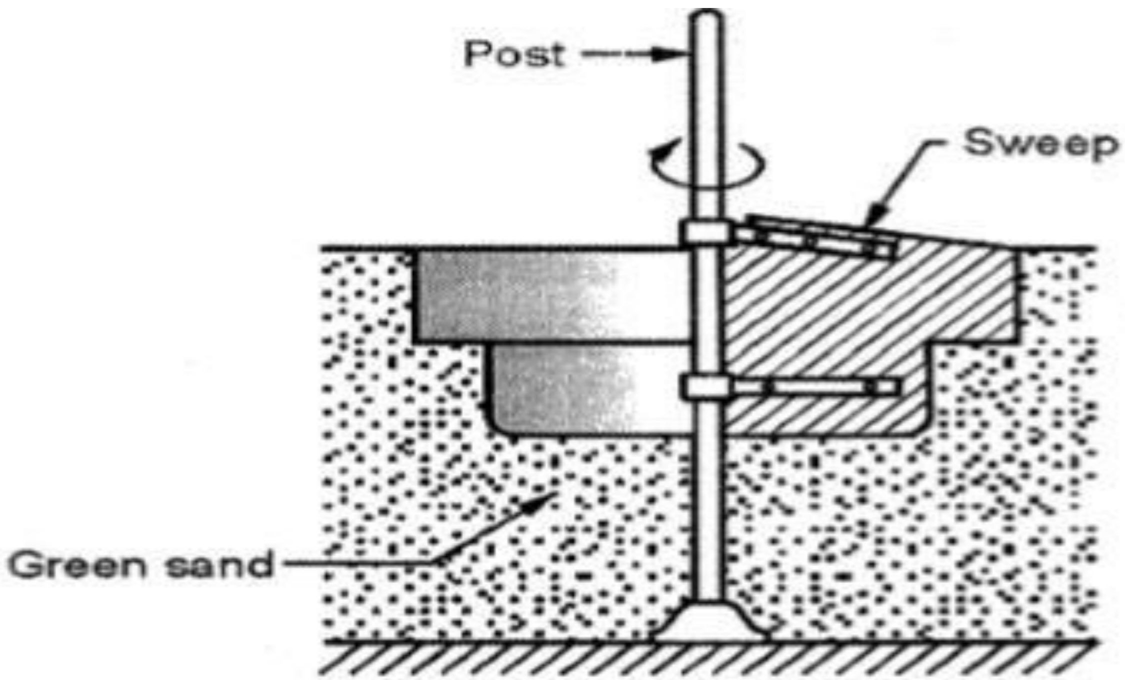


Fig. 2.7: Sweep pattern

8. Skeleton pattern :

– When the casting size is very large, but easy to shape and few are to be made, then it is not economical to make a large solid pattern of that size.

– In such cases, a pattern consisting of a wooden frame and strips is made which is called as skeleton pattern.

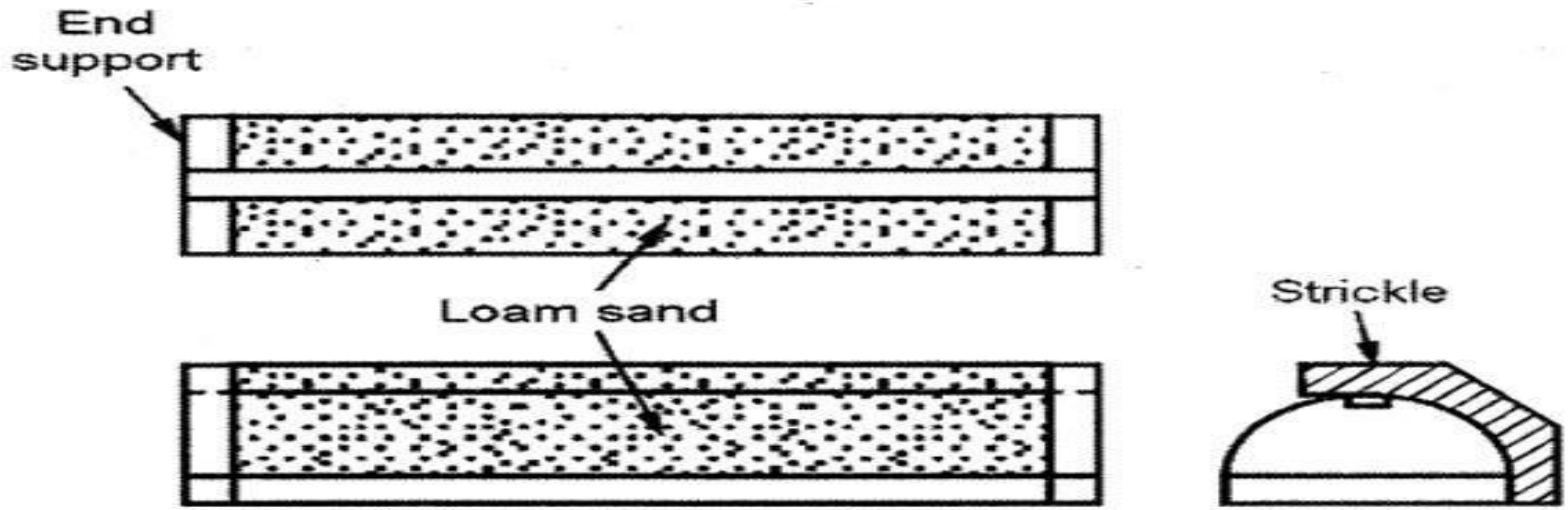


Fig. 2.8: Skeleton pattern

9. Segmental pattern :

- The working principle of segmental pattern is similar to sweep pattern.

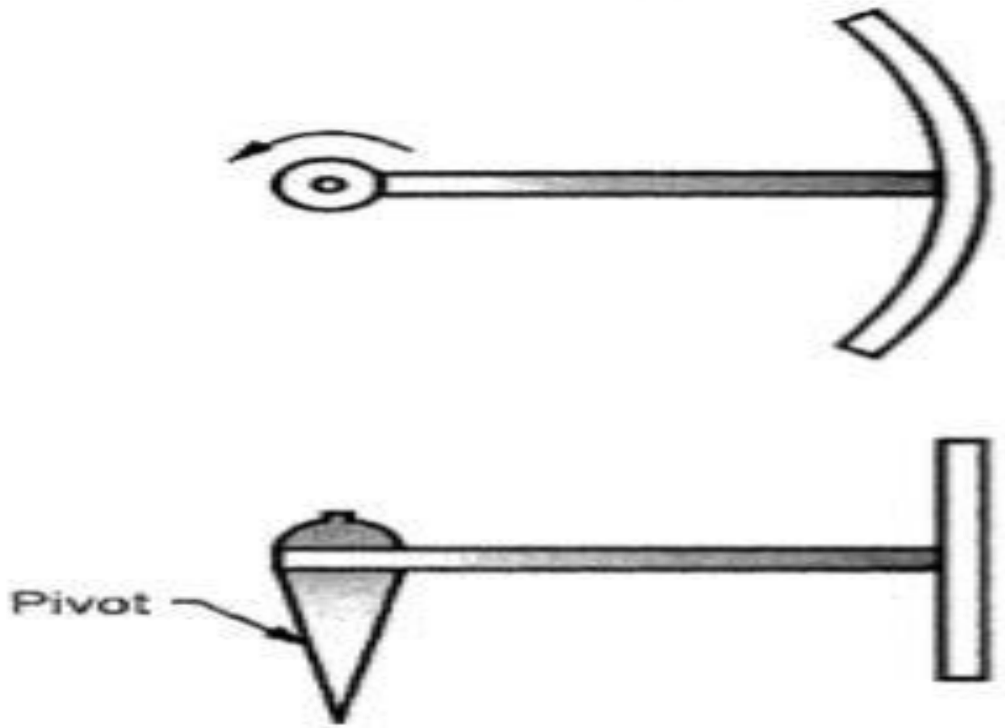


Fig. 2.9: Segmental pattern

10. Follow board pattern :

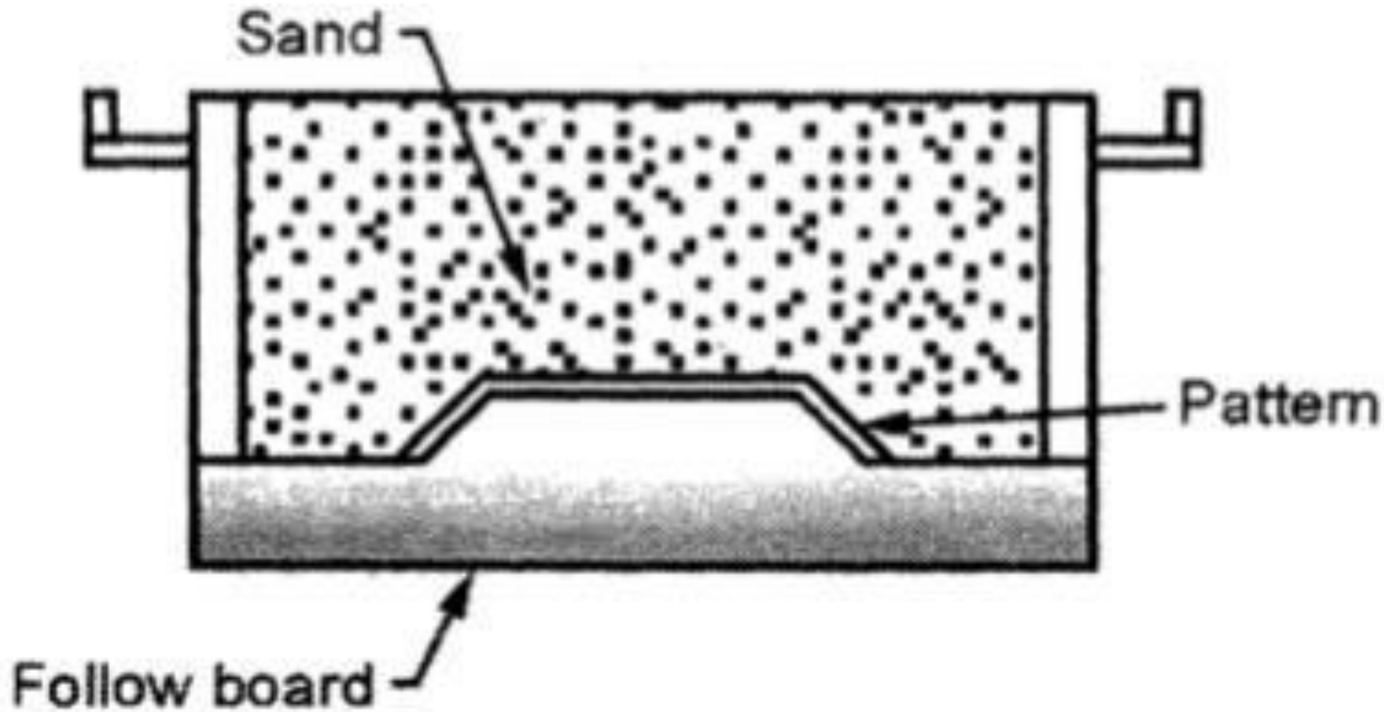


Fig. 2.10: Follow board pattern

11. Lagged-up pattern

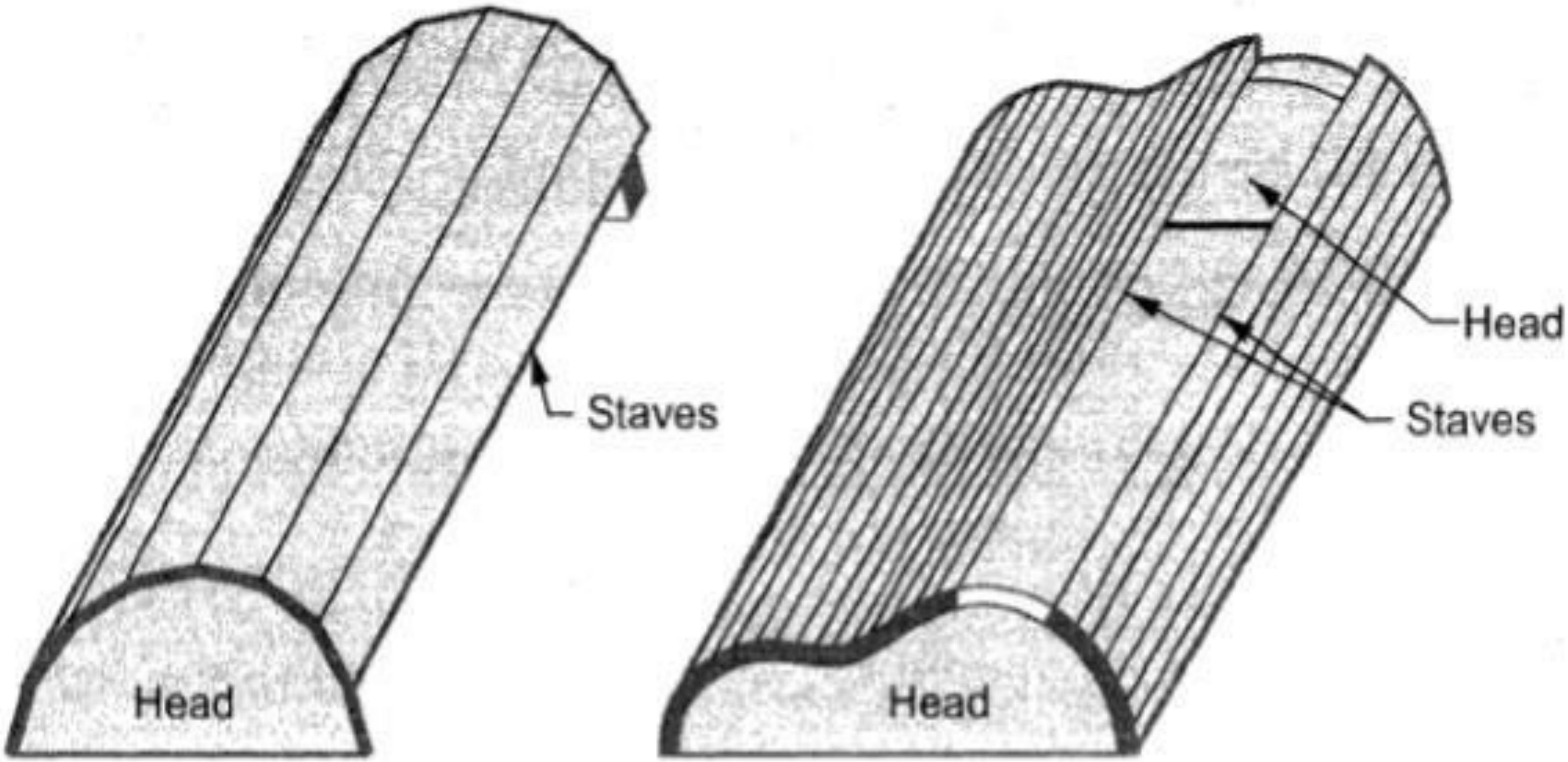


Fig. 2.11: Lagged-up pattern

Selection of materials for pattern

The following factors should be considered while selecting proper material for pattern :

- The number of casting to be made; metal patterns are preferred for large quantity of production.
- Degree of accuracy in dimensions and the quality of surface finish required on the casting.
- Method of moulding to be used i.e. hand or machine.
- Type of casting method to be used i.e. sand casting, investment casting, etc.
- Shape, size and complexity of the casting.
- Casting design parameters.
- Type of moulding material to be used.

Materials for Making Patterns

The common materials of which the patterns are made are as follows :

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

Materials for Making Patterns

1.Wood:

- It is the most common material for making patterns for sand casting because of following advantages : **Advantages:**
- It is cheap and easily available in large quantities.
- It can be easily shaped and machined to different configurations and forms.
- Good surface finish can be easily obtained.
- Due to lightness in weight its manipulation is easy and it can also be repaired easily.

Materials for Making Patterns

1.Wood:

Limitations:

- Wooden patterns are weak as compared to metal patterns.
- They cannot withstand rough handling.

- They possess poor wear resistance and hence they are abraded easily by sand action.
- They absorb moisture, hence get warped and change the shape and size.

Materials for Making Patterns

1.Wood:

Applications:

- Wooden patterns are mostly used where number of casting to be made is small and the size of pattern is large.

The common woods used in pattern making are :

a. White pine
b. Mahogany
c. Maple
d. Cherry
e. Teak
f. Shisham

Materials for Making Patterns

2. Metals: Metal patterns are cast from wooden patterns.

Advantages:

- They do not absorb moisture.
- They are stronger and accurate, hence more life as compared to wooden patterns.
- They have greater resistance to abrasion and wear.
- They can withstand rough handling.

Limitations:

- As compared to wooden patterns they are more expensive.
- They are heavier than wooden patterns.
- Ferrous material patterns get rusted.
- They cannot be repaired easily.

Materials for Making Patterns

2. Metals: Metal patterns are cast from wooden patterns. **Applications:**

− Metal patterns are used where large numbers of castings have to be produced from the same patter.

The various metals and alloys employed for making patterns are :

a. Aluminium and its alloys

b. Steel

c. Brass

d. Cast iron

e. White metal

3. Plastic:

Plastic is now a days considered as a pattern material due to their following advantages :

Advantages:

- Light weight and high strength.
- Resistance to wear and corrosion.
- Provides good surface finish.
- They are easy to make and less costly also. **Limitations:**
- Plastic patterns are fragile; hence light sections may need metal reinforcements.

- They may not work well when subjected to conditions of severe shock.

4. Plaster:

Plaster of Paris or gypsum cement is used as a patterns material because of following advantages : **Advantages:**

- Complicated shapes can be cast without any difficulty.
- It can be easily worked with the help of wood working tools.
- It has high compressive strength.
- Unlike metals it expands while solidifying.

Applications:

- Plaster is used for making small and intricate patterns and core boxes.

5. Wax:

Advantages:

- They provide good surface finish.
- After being moulded, the wax pattern is not taken out; rather the mould is inverted and heated and the molten wax comes out or gets evaporated, hence there is no chance of the mould cavity getting damaged while removing the pattern.
- Also, they provide high accuracy to the castings.

Applications:

Wax patterns are exclusively used in investment casting process.

Pattern Allowances

- A pattern is always made larger than the final casting, because it carries certain allowances due to metallurgical and mechanical reasons.
- The following allowances are provided on the pattern :

a. Shrinkage or contraction allowance
b. Machining allowance
c. Draft or taper allowance
d. Distortion allowance
e. Raping or shake allowance

Pattern Allowances

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a. Shrinkage or contraction allowance
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d. Distortion allowance
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a.Shrinkage or contraction allowance: –

Almost all the metals used in the casting work shrink or contract during cooling from pouring temperature to room temperature.

– This contraction takes place in three forms i.e.

Liquid contraction

Solidifying contraction Solid contraction

Shrinkage or contraction allowance: –

 The shrinkage of metal depends on the following factors :

– The metal to be cast
– Pouring temperature of the molten metal
– Dimensions of the casting
– Method of moulding

Shrinkage allowance for different cast metals is given in the following Table 2.1 :

Table 2.1: Shrinkage allowance for different metals

Metal	Grey cast iron	Steel	Aluminium	Bronze	Brass	Magnesium
Allowance mm/meter	6.95 to 10.4	20.8	16.5	10.5 to 21	15.4	16.5

b. Machining allowance:

The amount of machining allowance depends upon following factors : o Metal of casting o Machining method used o Casting method used o Shape and size of the casting o Amount of finish required on the machined portion

– Ferrous metal needs more allowance than the non-ferrous metals. and similarly, large castings need more allowance than small castings.

– Machining allowance varies from 1.5 mm to 16 mm, but 3 mm allowance is more common for small and medium castings.

b. Machining allowance:

The amount of machining allowance depends upon following factors : o Metal of casting o Machining method used o Casting method used

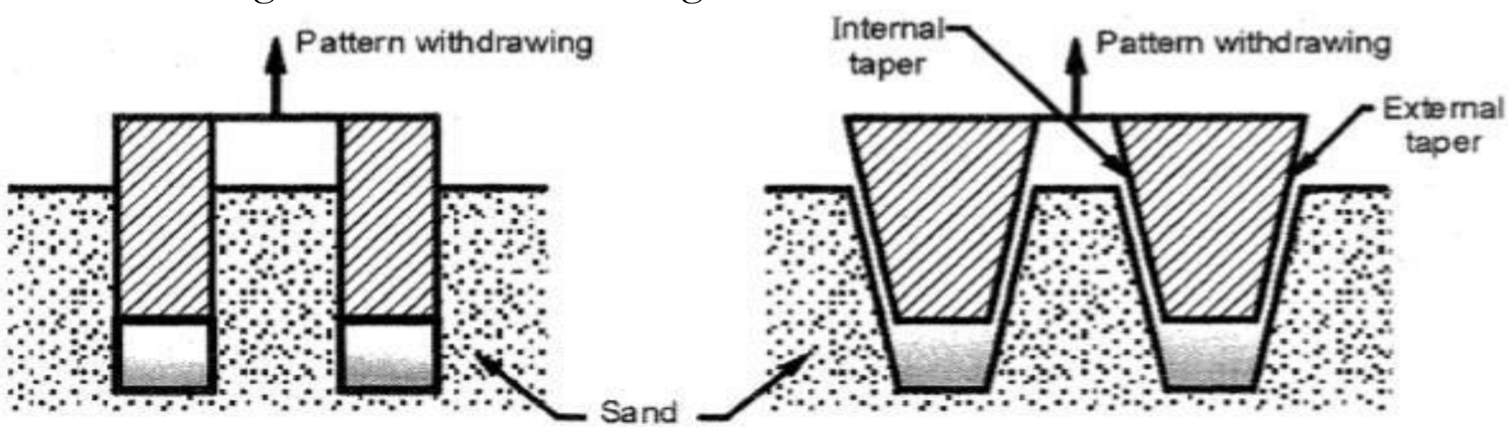
C. Draft allowance:

 Draft allowance or taper allowance is given to all vertical faces of a pattern for their easy removal from sand without damaging the mould.

The amount of draft allowance depends on following factors :

O Shape and size (height) of the pattern

O Method of mouldingo Material of moulding.



(a) Pattern without allowance

(b) Pattern with allowance

Fig.2. 1: Taper or draft allowance

The amount of draft allowance depends on following factors This allowance varies from 10 mm to 25 mm per meter. on external surfaces and 40 mm to 65 mm per meter on internal surfaces.

➢ Fig. 2.1 shows two patterns i.e. one without taper allowance and other with taper allowance

➢ It can be seen that, it is easy to withdraw the pattern having taper allowance out of the mould without damaging the mould cavity.

d. Distortion allowance (Camber allowance):

 The tendency of distortion is not common in all the castings.

 The casting will distort or warp if : o It is of irregular shape.

O It is of or V-shape.

O The arms having unequal thickness.

O One portion of the casting cools at a faster rate than the other To eliminate this defect, an opposite distortion is provided on the pattern, so that the effect is balanced and correct shape of the casting is produced.

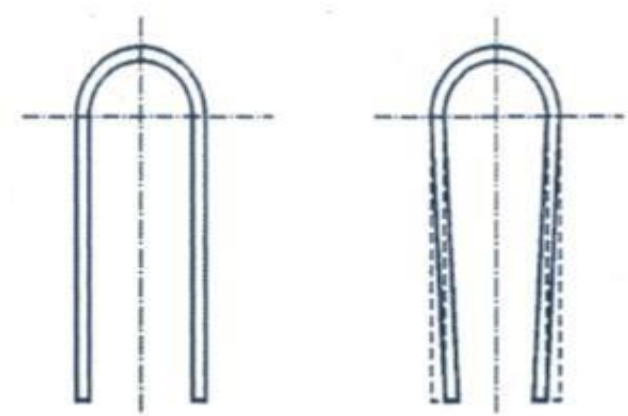


Fig. 2.1 (c): Distortion or camber allowance

− The amount of distortion allowance varies from 2 mm to 20 mm as per the size, shape and casting material.

Refer Fig. 2.1 (c)..

e. Rapping or Shake allowance:

- When a pattern is to be taken out from the mould, it is first rapped or shaken by striking it with a wooden piece from side to side.
- This is done so that the pattern surface becomes free from adjoining sand of the mould.
- Due to this, there is little increase in the size of the mould cavity.
- For this purpose, a negative allowance is provided on the pattern i.e. the dimensions are kept smaller.

 It is normally provided only to the large castings and negligible for small and medium sized castings.

Core

 Core is a sand shape or form which makes the contour of a casting for which no provision has been made in the pattern for moulding.

 Core may be made up of sand, plaster, metal or ceramics.

 Core is an obstruction which when positioned in the mould, does not permit the molten poured metal to fill the space occupied by the core hence produce hollow casting. Cores are used as inserts in moulds to form design features which are difficult to be produced by simple moulding.

Functions of core :

- Core provides a means of forming the main internal cavity for hollow casting.
- Core provides external undercut feature.
- Cores can be inserted to obtain deep recesses in the casting.
- Cores can be used to increase the strength of the mould.
- It can be used as a part of gating assembly.
- It can form a part of green sand mould and can also be used to improve the mould surface

Essential characteristics of core:

A dry sand core must possess following properties :

- It should have sufficient strength to support itself without breaking.
- It should have high permeability and high refractoriness.
- It should have smooth surface to ensure a smooth casting.
- It should have high collapsibility, to assist the free contraction of the solidifying metal.
- It should have those ingredients which does not generate mould gases.

Core Applications

Core and its form increase the versatility of moulding processes and operations.

In addition to recess forming and holes in the casting, cores are used as follows :

- Cores are used for mould making.
- Cores can be used as strainer, gates and pouring cups.
- Cores are used for increasing production from match plate pattern.
- Cores can be used as core mould in centrifugal casting process.
- Also it can be used as slab core for increasing castings output from one mould.

Types of Cores

Various types of cores of different designs and sizes are used in different ways in foundry work.

A general way of classifying them is, according to their shapes and positions in the prepared moulds.

Their main types are as follows:

1. Horizontal core
2. Vertical core
3. Hanging core

4. Balanced core

5. Ram up core

6. Kiss core

7. Drop core

1. Horizontal core

 A horizontal core is positioned horizontally in the mould. Refer Fig. 2.16.

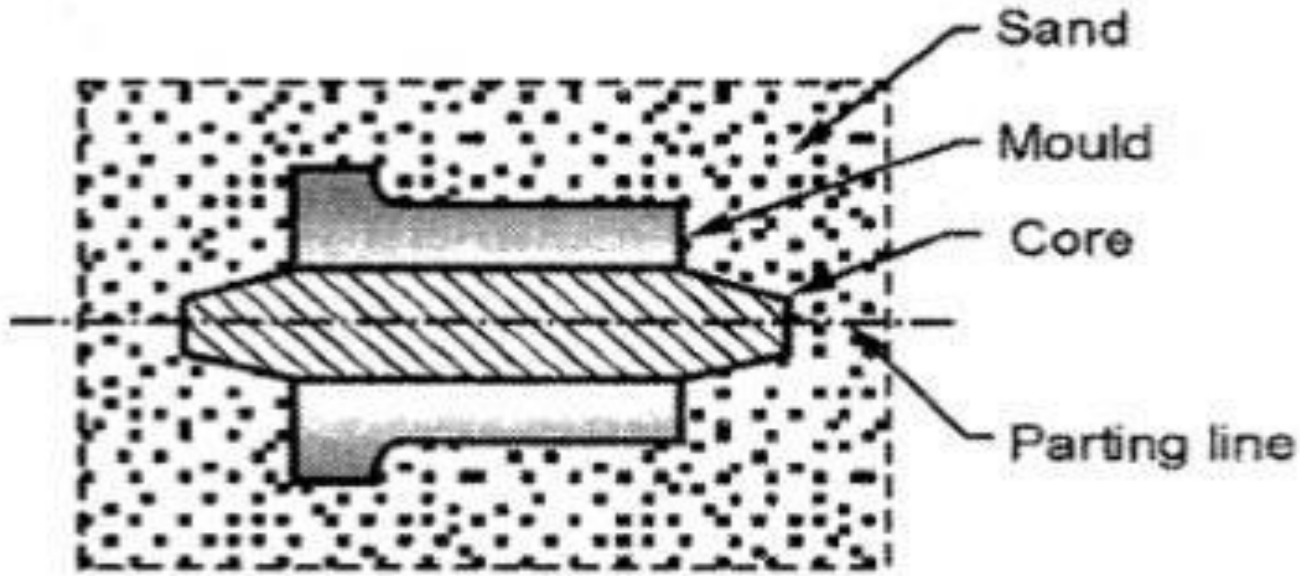


Fig. 2.16: Horizontal core

2. Vertical core

- It is similar to horizontal core, except that it is fitted in the mould with its axis vertical. Refer Fig. 2.17.

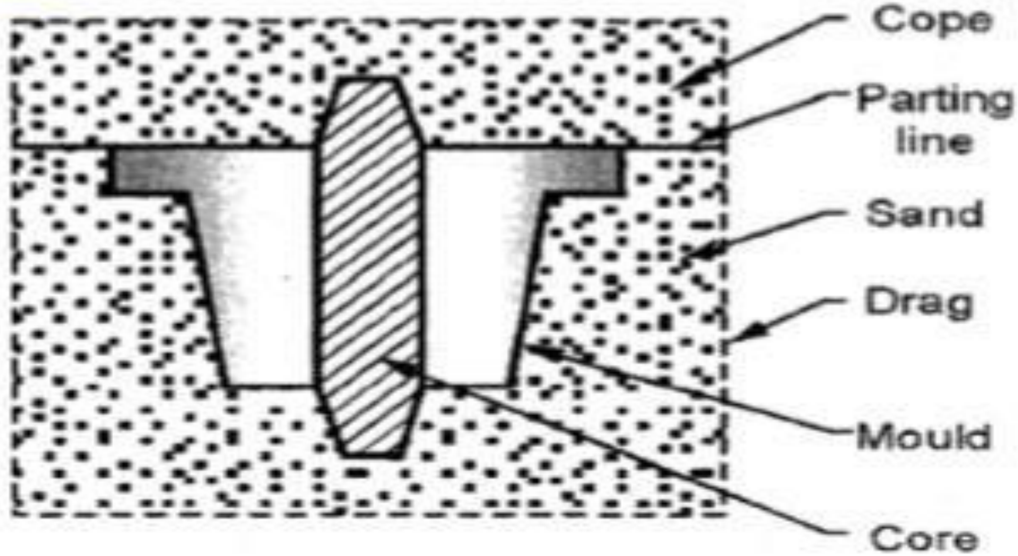


Fig. 2.17: Vertical core

3.Hanging core :

 Hanging core is also called as cover core as shown in Fig.
2.18.

 It is supported from above and it hangs vertically in the mould cavity.

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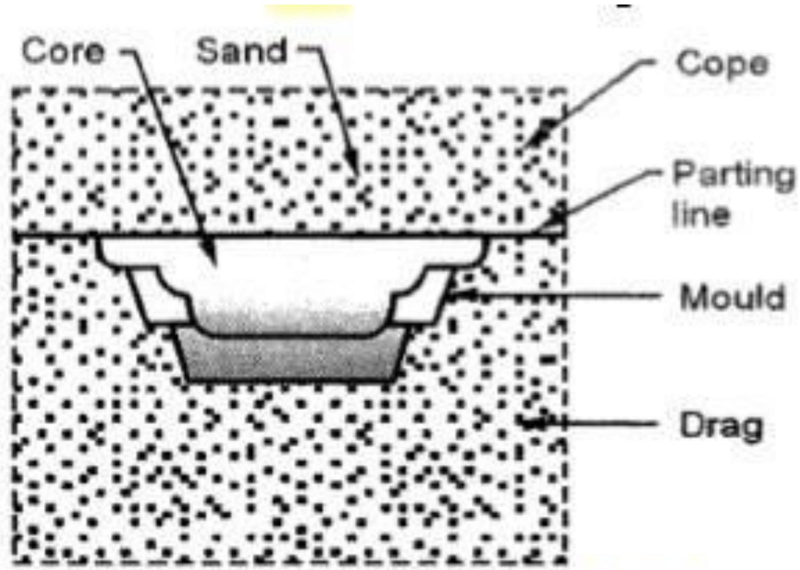


Fig. 2.18: Hanging or cover core

4. Balanced core :

 Balanced core is supported and balanced from its one end only.

  It requires long core seat, so that the core does not fall into the mould cavity. Refer Fig. 2.19.

 It may be supported on chaplets.

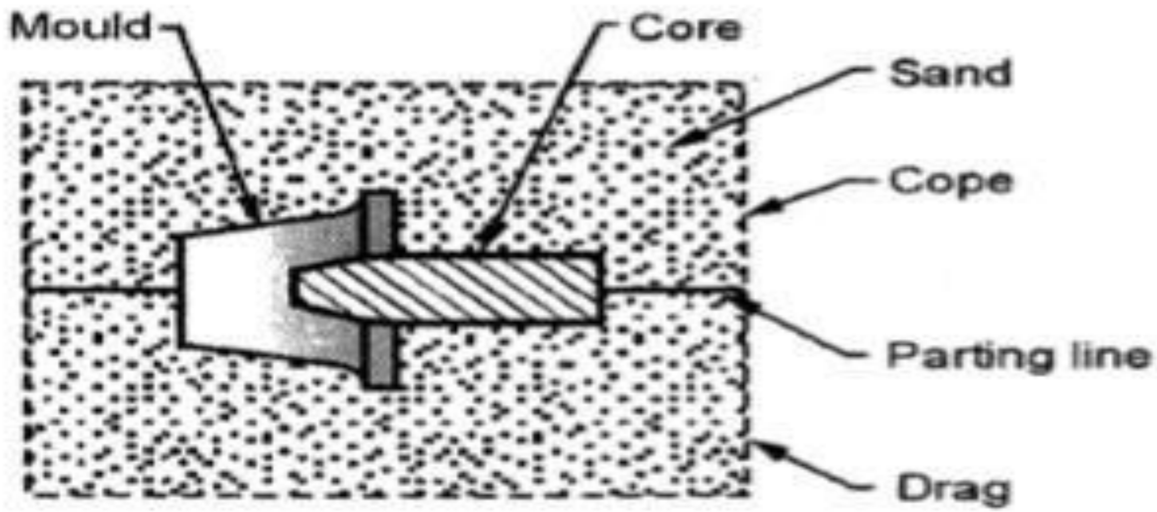


Fig. 2.19: Balanced core

5. Ram up core :

 Ram up core is placed in the sand along with pattern before ramming the mould. Refer Fig. 2.20.

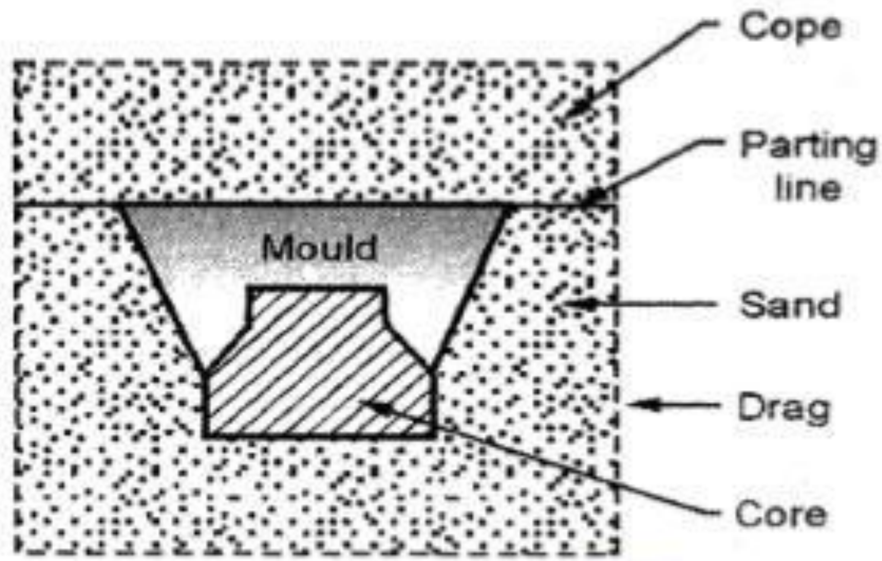


Fig. 2.20: Ram-up core

6.Kiss core:

 It does not require core seats for getting support. It is held in position between drag and cope due to the pressure exerted by core on the drag

 To obtain a number of holes in a casting, a number of kiss cores can be simultaneously positioned. Refer Fig. 2.21.

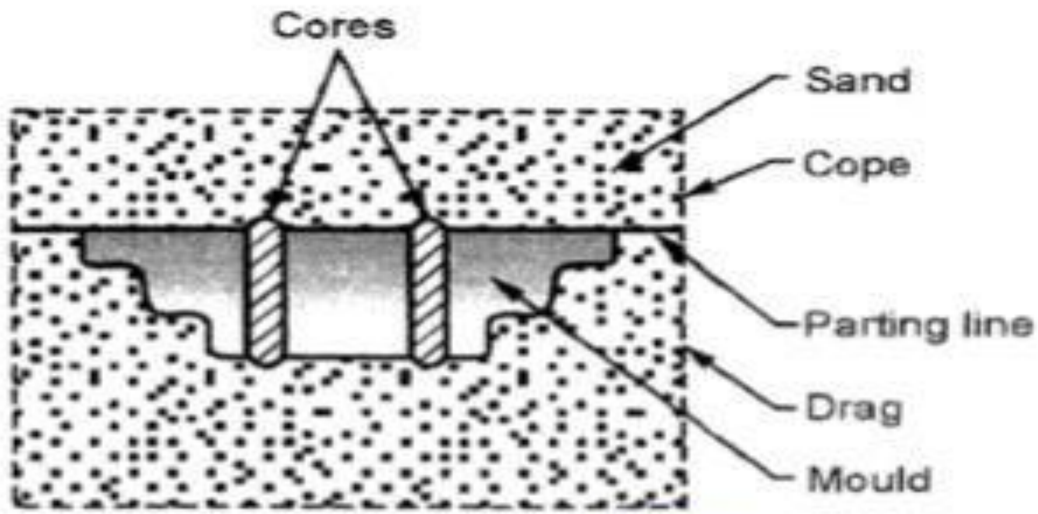


Fig. 2.21: Kiss core

7.Drop core:

 Drop core is also called as stop off core. It is used to make a cavity which cannot be made with other types of cores. Refer Fig. 2.22.

 It is used when a hole recess or cavity required in a casting is not in line with parting surface

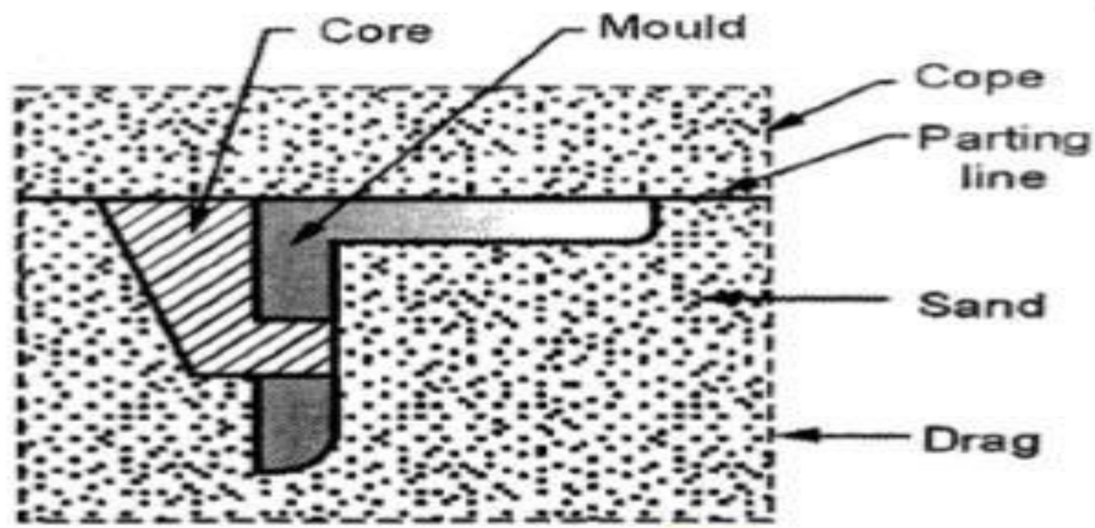


Fig. 2.22: Drop core

Core Boxes

 Basically, core box is a pattern for making cores.

 They are employed for ramming cores in them.

 Core boxes provide the required shape to the core sand.

The commonly used types of core boxes are as follows:

1.Half core box

2.Dump core box

3.Split core box

4.Strickle core box

5. Gang core box:

6. Loose piece core box

7. Left and right hand core boxes

1.Half core box :

- Half core box is shown in Fig. 2.23 which can make cylindrical cores.

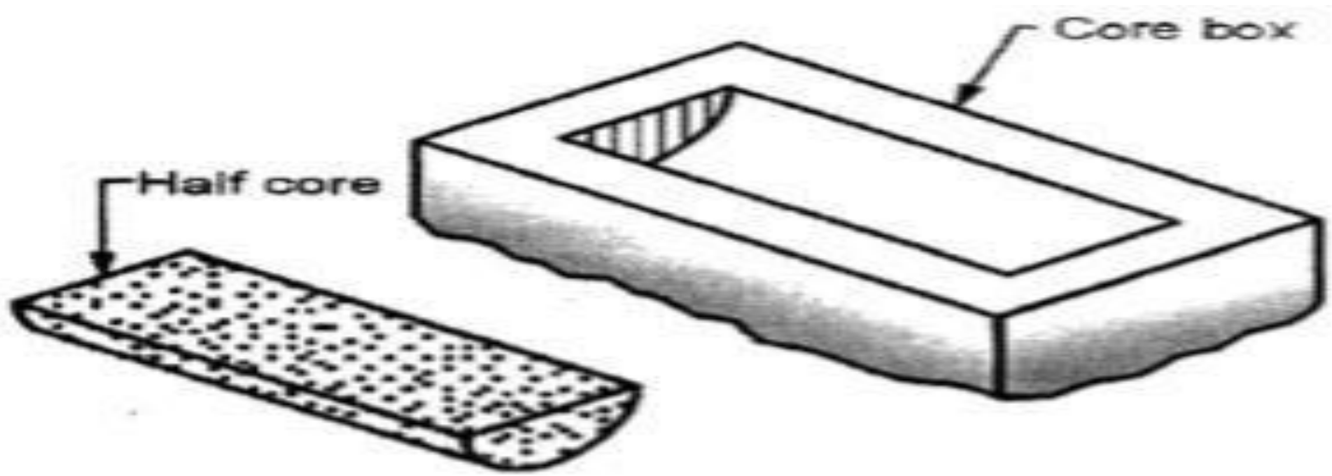


Fig. 2.23: Half core box

2.**Dump core box :**

- It is also called as slab core box
- It is similar to half core box in its construction but, it makes full core at a time, hence used to produce rectangular, square or trapezoidal cores. Refer Fig. 2.24.

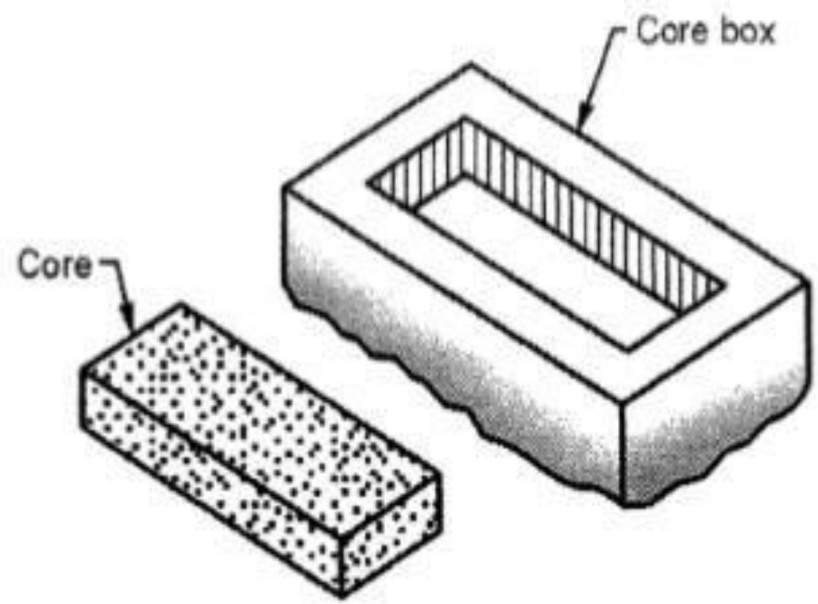


Fig. 2.24: Dump core box

3.Split core box :

➢ This type of core box moulds the entire core, but to remove the core after moulding, the box is separated in two or more parts. Refer Fig. 2.25.

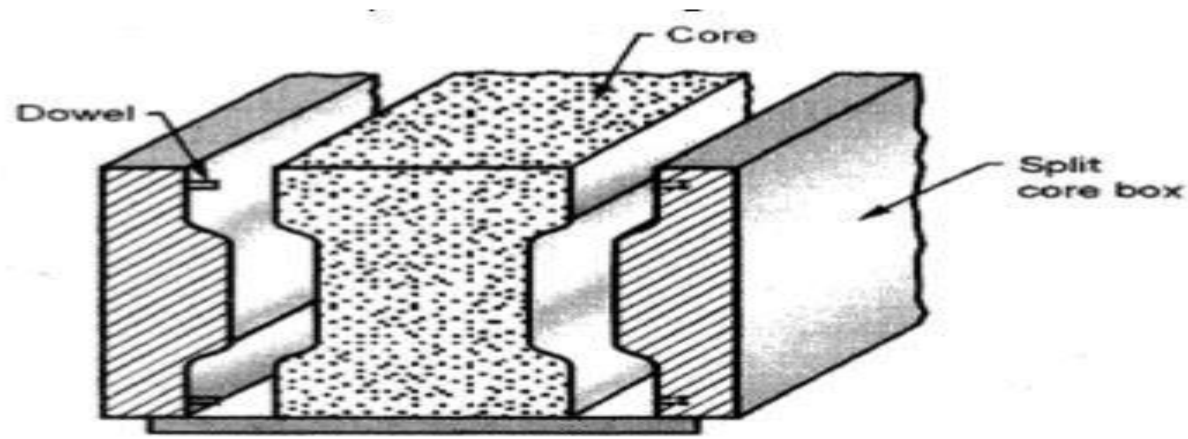


Fig. 2.25: Split core box and rammed core

4.Strickle core box :

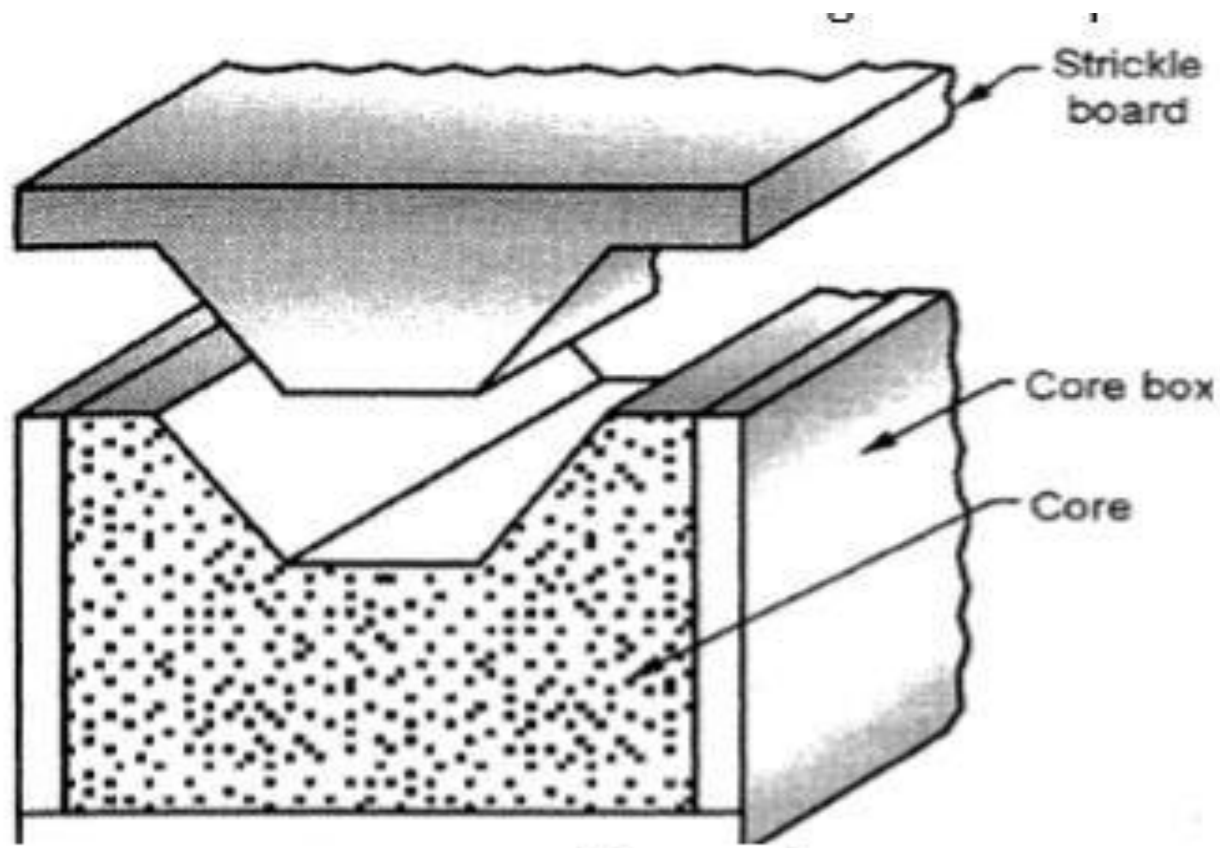


Fig. 2.26: Strickle core boxes

4.Strickle core box :

 Sand is rammed in the dump core box.

- The top surface of the core in the core box is given a required shape by using trickle board cut and finished to the desired shape.
- A strickle board strikes off excess sand not confirming to its shape.
- A strickle board is made up of wood and in any shape, as per the requirement. Refer Fig. 2.26.
- This me7thod of producing cores is less costly as compared to others.

5. **Gang core box**:

- Gang core box contains a number of cavities, so that more than one core can be rammed at a time. Refer Fig. 2.27.

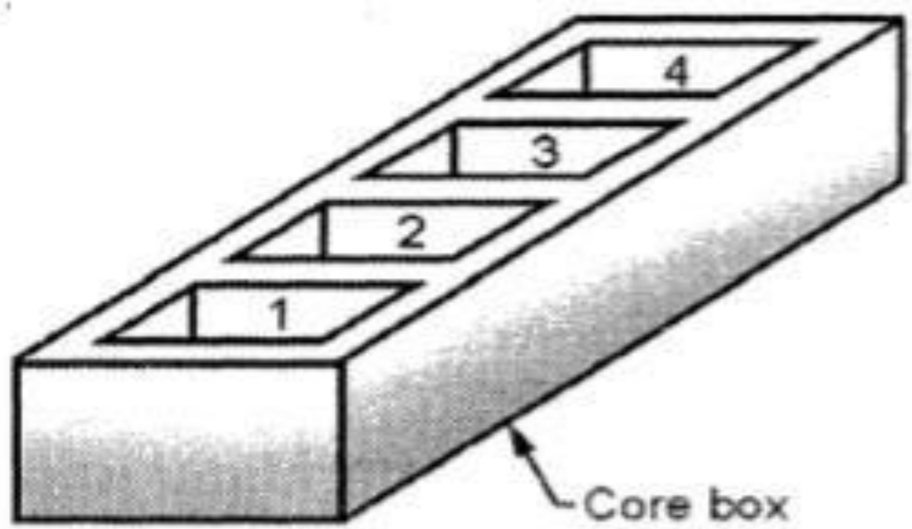


Fig. 2.27: Gang core box

6. Loose piece core box :

- It is similar to half core box.
- But loose piece core box can produce two halves of a core, which may be neither identical in size nor in shape. It is achieved by inserting loose wooden pieces in the core whenever required. Refer Fig. 2.28.

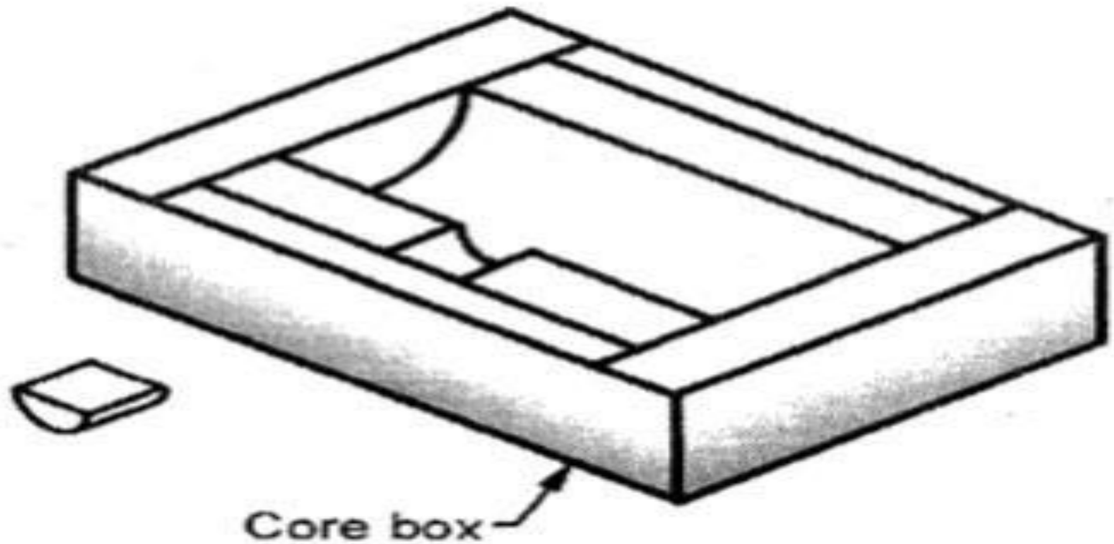


Fig. 2.28: Loose piece core box

7. Left and right hand core boxes :

 These core boxes are used to make cores for producing pipe bends.

 Half of the pipe bend core is made in each core box.

 Two halves of pipe bends are then rammed, baked and joint together to form a full core. Refer Fig. 2.29.

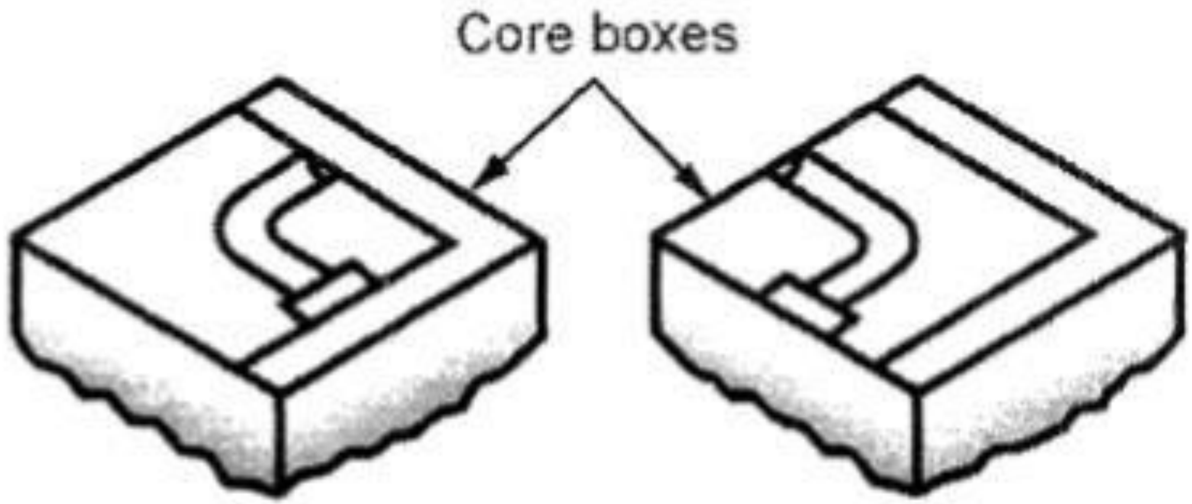


Fig. 2.29: Left and right hand core boxes

Core Prints

➢ Core prints are basically extra projections provided on the pattern.

 They form core seats in the mould when pattern is embedded in the sand for mould making.

➢ Core seats are provided to support all the types of cores. Though the core prints are the part of pattern, they do not appear on the cast part.

 Fig. 2.30 shows a core positioned in the core seat made by the core print provided on the pattern.

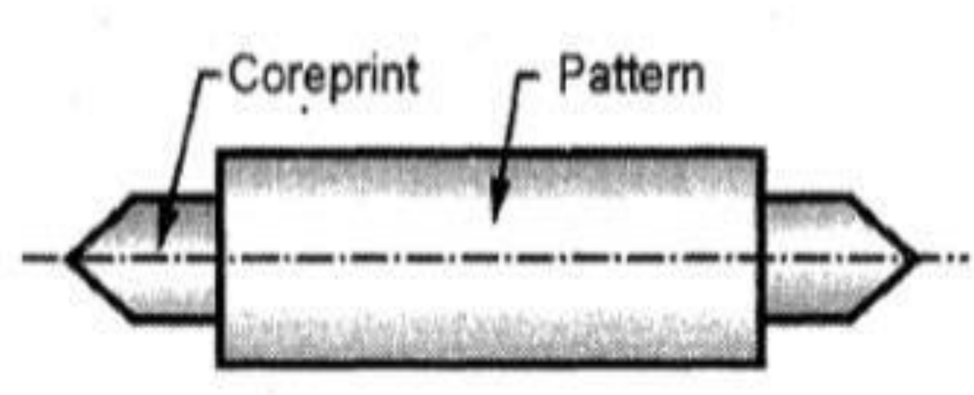


Fig. 2.30: Core print

Core Prints

– Core prints are of the following types:

- Horizontal core print
- Vertical core print
- Cover core print
- Wing core print
- Balance core print

Gating System

- Gating is the term applied to the method of forming channels in the sand through which the molten metal travels from the sprue hole to the mould and out of the mould to the riser.
- Gating system refers to all channels by means of which molten metal is delivered to the mould cavity.

 Since the way in which liquid metal enters the mould has a decided influence on the quality and soundness of a casting.
 The different passages for molten metal are carefully designed and produced.

The various components of gating system which is composed of

a. **Pouring cups and basins**
b. **Sprue**
c. **Runner**
d. **Gates**
e. **Riser**

Gating System

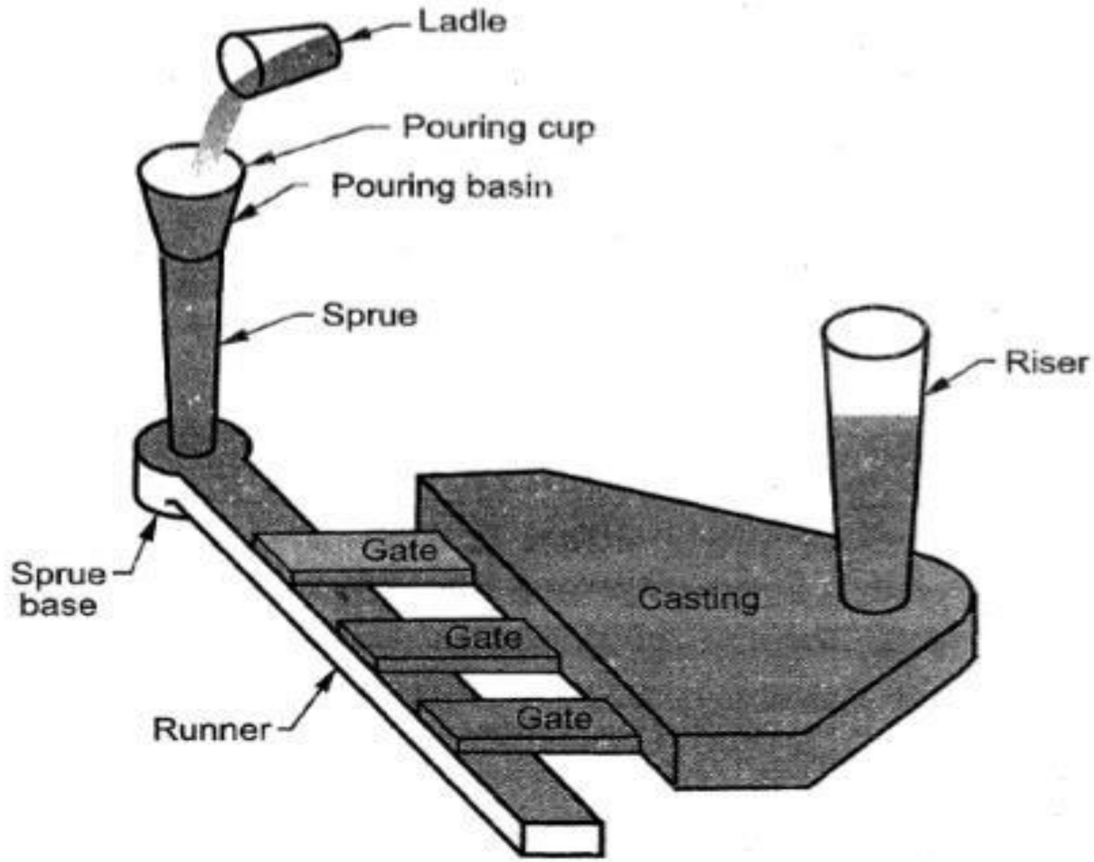


Fig. 2.34: Components of gating system

a. Pouring cups and basins

Pouring cup :

- A pouring cup is a funnel shaped cup which forms the top portion of the sprue.
- It makes easier for the ladle or crucible operator to direct the flow of metal from crucible to sprue.

Pouring basins:

- The molten metal is not directly poured into the mould cavity. It is poured into a pouring basin which acts as a reservoir from which it moves smoothly into the sprue.
- It prevents the slag from entering the mould cavity.
- It holds back the slag and dirt, which floats on the top and allows only the clean metal to enter into the sprue.
- The basin is cut in various shapes into the cope directly.

b.Sprue :

- Sprue is the channel through which the molten metal is brought into the parting plane where it enters the runner and gates.
- The sprue may be square or round and is generally tapered downwards, to avoid aspiration of air and metal damage.
- Sprues up to 20 mm diameter are round in section, whereas larger sprues are generally rectangular.

- In a rectangular sprue, there is less turbulence.

c. Runner

- In large casting, molten metal is generally carried from the sprue base to several gates around the cavity through a passage called as runner.
- Depending upon the shape of the casting, the runner may be located in the cope or drag part.
- To avoid aspiration and turbulence, it should be streamlined.

d.Gates

- A gate is a channel which connects runner with the mould cavity, through which molten metal flows to fill the mould cavity.
- The location and size of the gates are so arranged that, they can feed liquid metal to the casting at a rate consistent with the rate of solidification.
- More than one gate is employed to feed a fast freezing casting.
- The gate should not have sharp edges as they may break during pouring and thus carried with the molten metal into the cavity.

d.Gates

- Choke is that part of the gating system which has the smallest cross-sectional area. Its function is to control the flow rate of metal and to hold back slag, foreign particle, etc.

And float these in the cope side of runner.

The major types of gates are as follows :

a.Parting line gates

b. Bottom gates

c. Top gates

d. Side gates

a. Parting line gates :

- These gates enter the mould cavity along the parting line separating the cope and drag portions of the mould. Refer Fig. 2.35.
- These gates are the simplest in nature and construction.
- Such gates are commonly used and are found to give satisfactory service except when the mould is very deep.

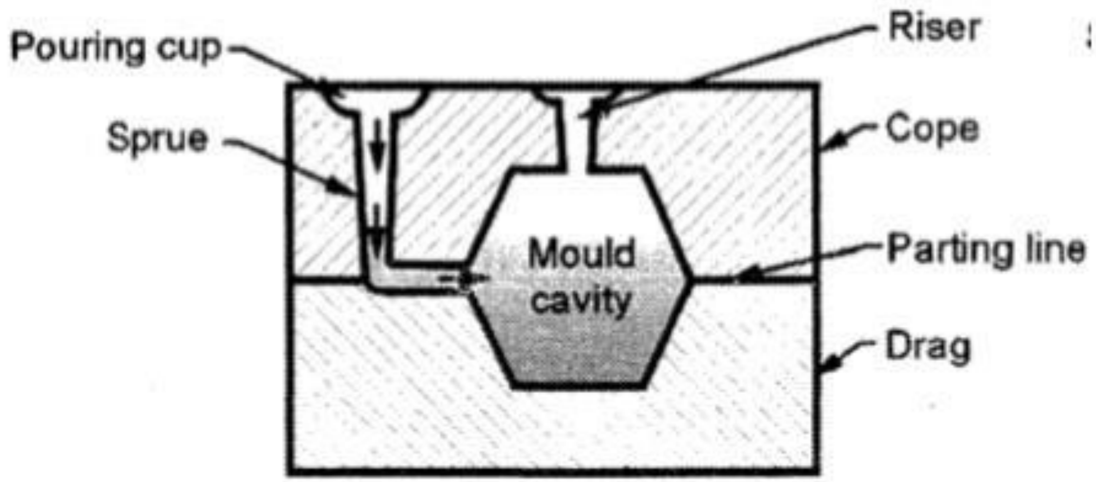


Fig. 2.35: Parting line gate

b. Top gates:

 Top gate is also called as drop gate because the molten metal just drops on the sand in the bottom of the mould:

Refer Fig. 2.36.

 A top gate simplifies the moulding with low consumption of additional metal.

 There is lot of turbulence in this system.

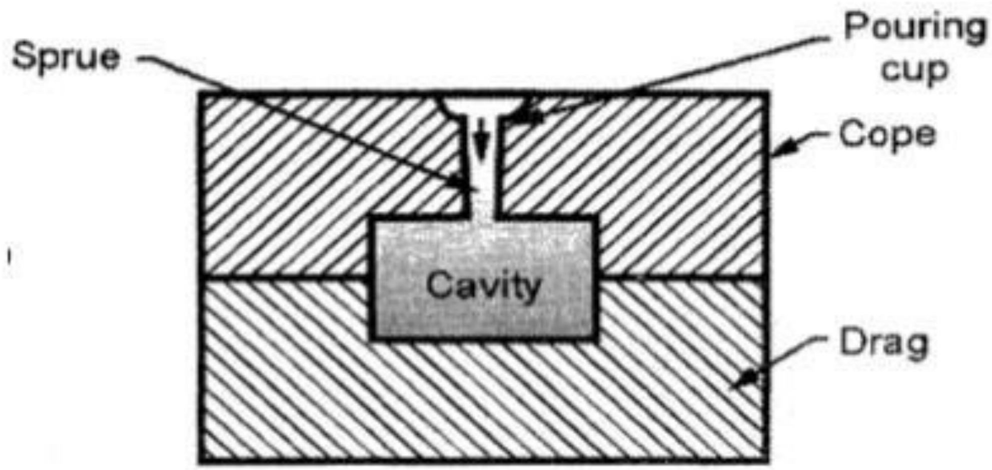


Fig. 2.36: Top gate

b. Top gates:

- Also, the dropping liquid metal stream erodes the mould surface .
- It is not favorable for non-ferrous casting.

Top gates are further classified as : □ Pencil gate

□ Edge gate

□ Gate with Strains core

□ Finger gate

- Ring gate
- Wedge gate

c. **Bottom gates :**

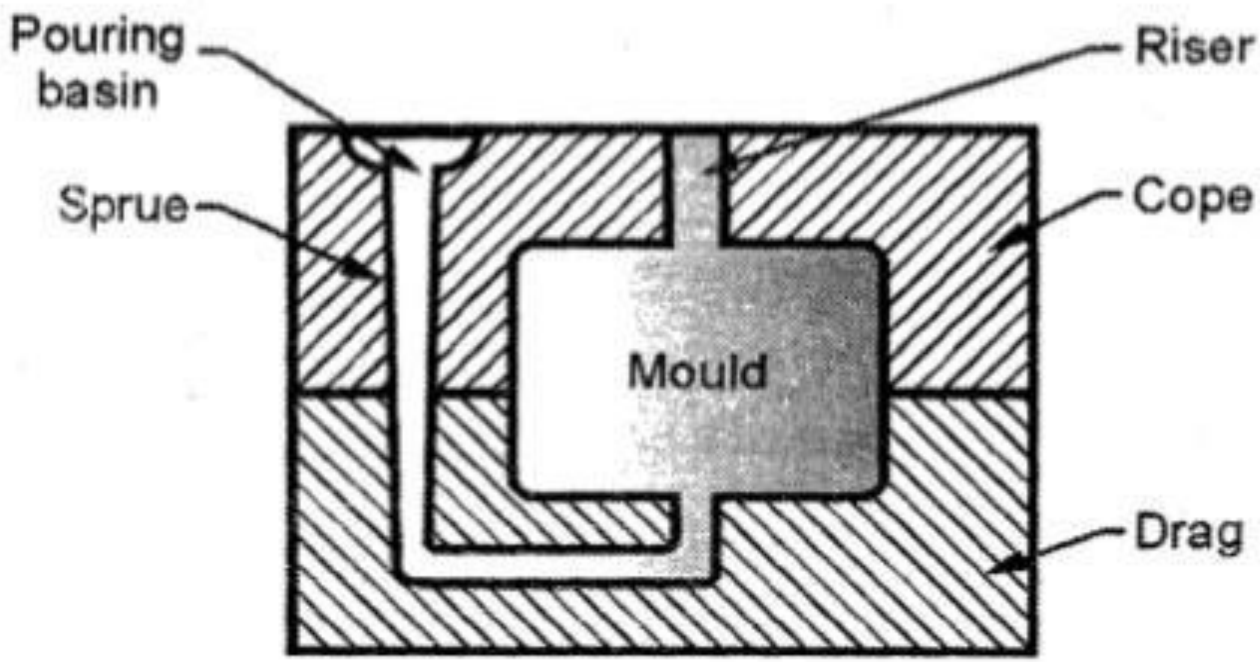


Fig. 2.37: Bottom gate

C. Bottom gates :

- A bottom gate is provided in the drag half of the mould. Refer Fig. 2.37.
- In this, liquid metal fills rapidly the bottom portion of the mould cavity and rises steadily and gently up the mould walls.
- Bottom gates provide less turbulence and erosion in the mould cavity.

 It is not used in large and deep casting because the metal cools gradually as it rises up.

d. Side gates:

- Side gates are provided on either left or right side of the casting.
- Hence, the metal enters into the mould cavity from sides. It enters near the bottom first, and then as the level of the metal rises in the mould the incoming molten metal starts entering near the surface of the rising metal. Refer Fig. 2.39

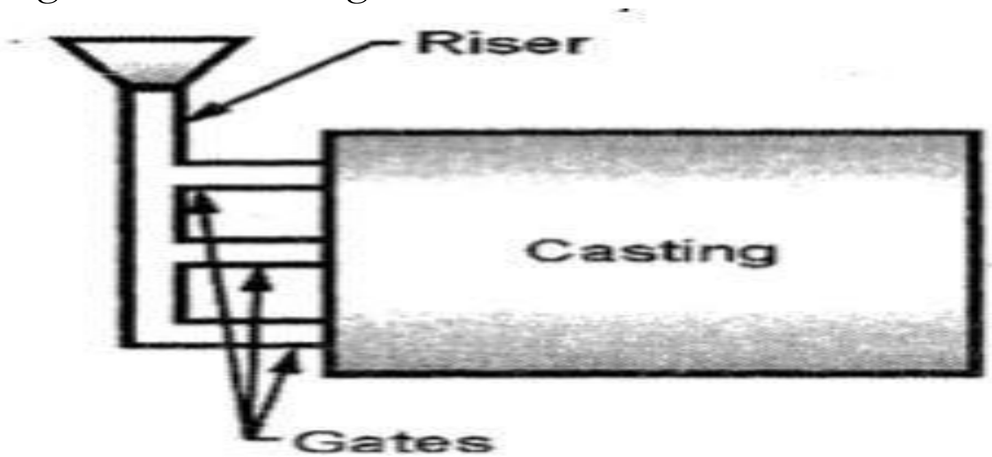


Fig. 2.38: Side gate

e. Riser or Feeder Head:−

A riser is a passage of sand made in the cope to permit the molten metal to rise above the highest point in the casting after the mould cavity is filled up. Refer Fig. 2.35.

− This metal in the riser compensates the shrinkages as the casting solidifies.

The functions of risers are as follows :

O To feed metal to the solidifying casting, so that shrinkage cavities are got rid of.

O It permits the escape of air and mould gases as the mould cavity is being filled with the molten metal.

e. Riser or Feeder Head:−

The functions of risers are as follows

: o It promotes directional solidification.

o Also, it shows that the mould cavity has been completely filled or not.

A casting solidifying under the liquid metal pressure of the riser is comparatively sound.

According to the location of riser, it is classified as

1)Top riser

2)Side riser. The side risers are further classified as

a)open risers and

b)blind risers

1.Top riser:

- It is also called as dead riser or cold riser. It is located at the top of the casting. Refer Fig. 2.39 (a).

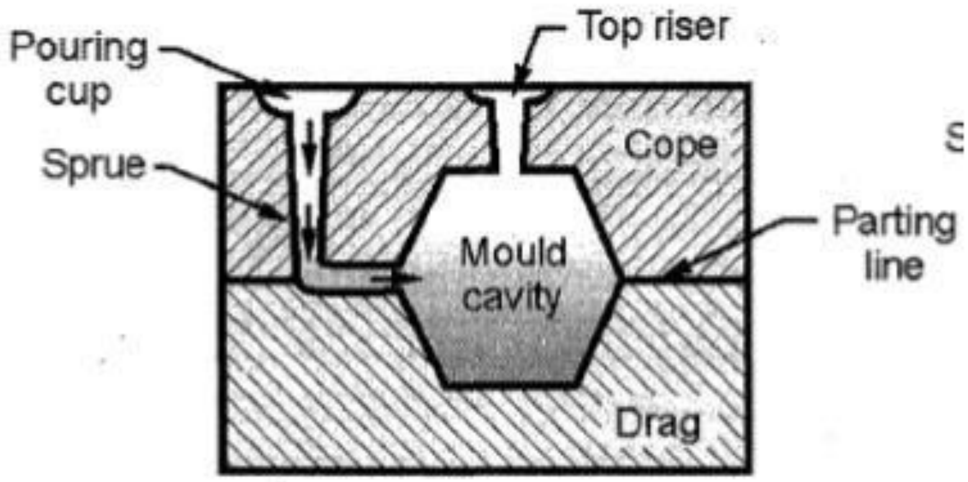


Fig. 2.39 (a): Top riser

2.Side riser:

- It is also called as live riser or hot riser. It is located between runners and casting. Refer Fig. 2.39 (b). □□ It is filled at the last and contains the hottest metal.

The risers are further classified as

□ open risers

➢ blind risers

2(b)Open risers:

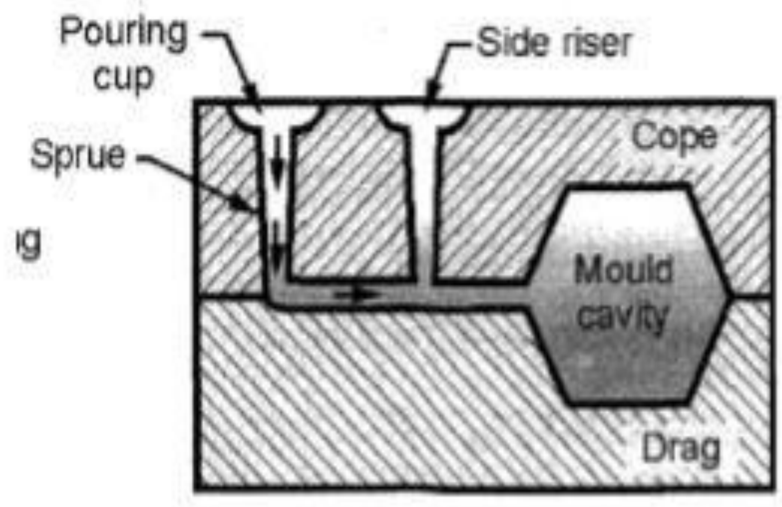


Fig. 2.39 (a): Side riser

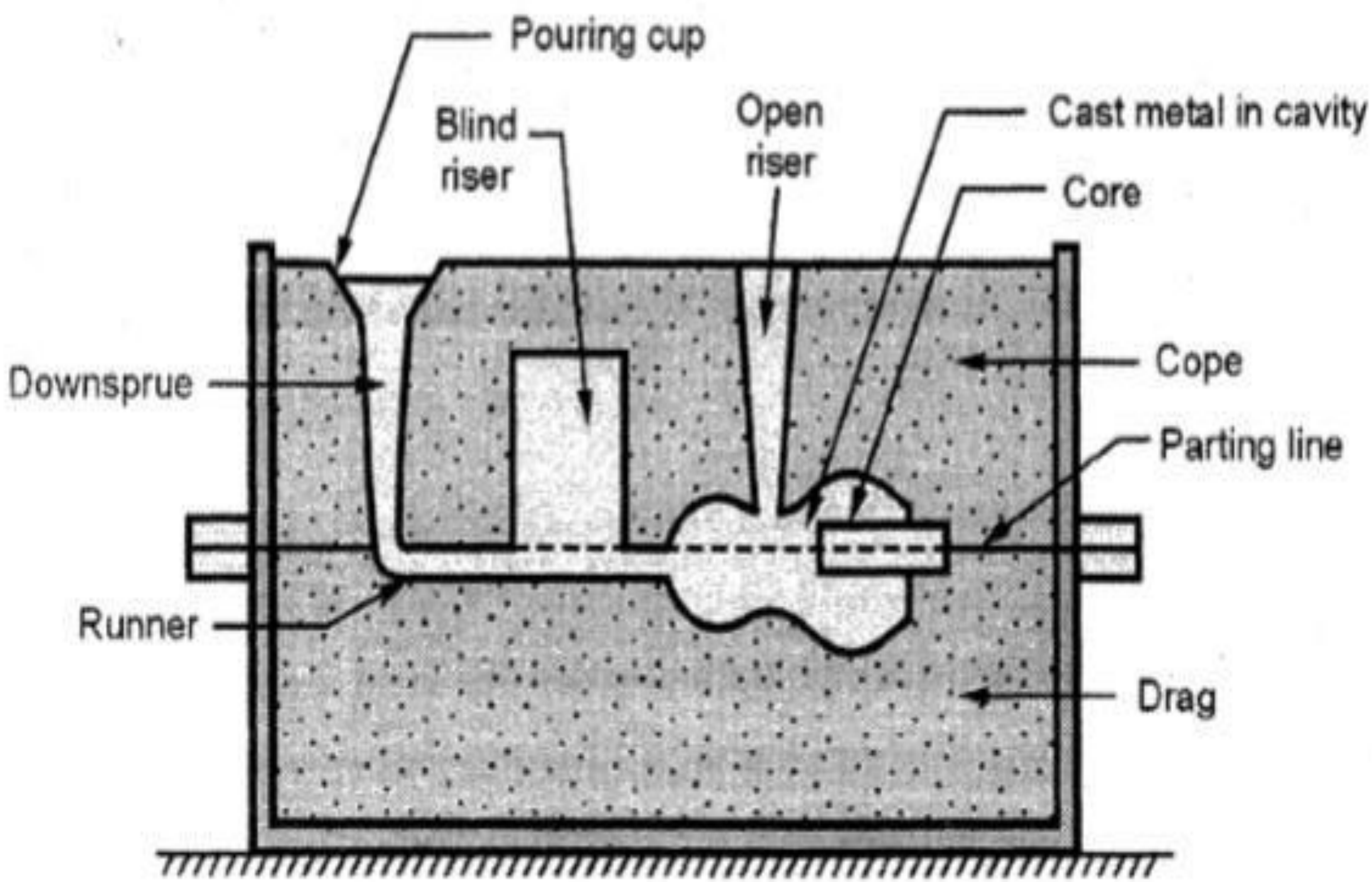


Fig. 2.40: Open and blind riser

2(b)Open risers:

- These risers are open to atmosphere at the top surface of the mould. Refer Fig. 2.40.
- The liquid metal in the riser is fed to the solidifying casting under the force of gravity and atmospheric pressure till the top surface of riser solidifies.

- It is connected to either at the top of cope or on the side of the parting line. Generally, open riser is cylindrical.
  - These type of risers are easy to mould.

Blind risers:

- Blind risers do not break to the top of the cope and are entirely surrounded by the moulding sand. Refer Fig. 2.40.   As it is closed at the top, a vent or permeable core at the top of riser may be provided to have some exposure to the atmosphere.
- It is also connected at the top of the cope or on the side of the casting at the parting line or in the drag.
- Blind riser is a rounded cavity and it associates a slow cooling rate. Also, it is more efficient.
- These risers are difficult to mould.

Design of Riser

- The risers are designed to solidify last so as to feed enough metal to enough sections of the casting. For this purpose, they should loose heat at a slower rate.

➢ The amount of heat content is proportional to the volume of metal and rate of heat dissipation depends upon the surface area of the riser.

- Hence, for a given size, the riser should be designed with a high volume to surface area ratio.
- This will reduce the loss of heat, so that the riser will remain hot and the metal in molten state as long as possible.

- To satisfy this condition the riser is spherical or cylindrical in shape. Rectangular shapes are insufficient hence they are not used. Similarly, spherical shapes are difficult to mould hence the common shape of riser is cylindrical.

Casting Processes

Following are the various casting processes which are commonly used:

a. Sand mould casting

b. Plaster mould casting

c. Metallic mould casting

    I. Permanent mould casting

    II. Slush casting

    III. Pressure die casting

d. Centrifugal casting

e. Investment casting

f. Continuous casting

g. C02 - mould casting.

h. Ceramic mould casting

Shell Moulding

- Shell moulding is suitable for thin walled articles. It consists of making a mould that has two or more thin shell like parts consisting of thermosetting resin bonded sand.
- Silica sand is mixed with synthetic resin to form a mixture. The mixture must be dry and free flowing

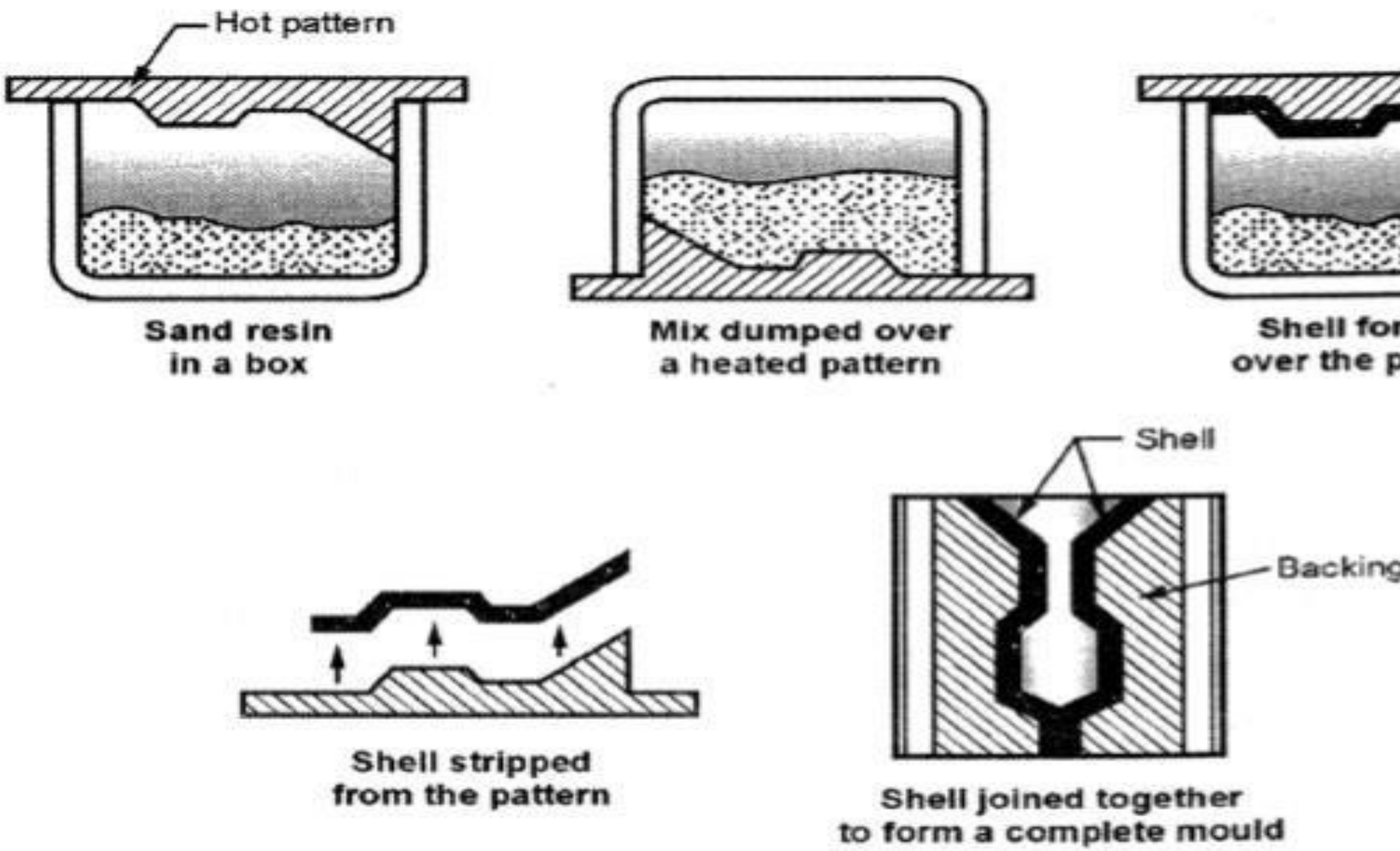


Fig. 2.33: Shell moulding process

Shell moulding process

Procedure of making shell mould:

Fig. 2.33 shows the making of a shell mould and shell core.

- Metal pattern is heated to about 175°C to 350°C and clamped over a box containing sand mixture.
- The box and pattern are inverted for a short time. The mixture when comes in contact with hot pattern, it causes an initial set and binds up a coherent sand shell next to the pattern, which takes 5 to 10 seconds only.
- The thickness of this shell is about 6 to 8 mm and is dependent on pattern temperature, dwell time on the pattern and sand mixture.

Procedure of making shell mould:

- The box and pattern are brought in its original position. The shell of resin bonded sand is retained on pattern surface while unaffected sand falls into the box.
- The shell on the pattern IS cured by heating it m oven from 250°C to 350ocfor 1 to 3 minutes. The assembly is removed from oven and the shell is stripped off from pattern by ejector pins.

- In order to obtain clean stripping, a silicon parting agent may be sprayed on the pattern.The shell halves are assembled with clamps supported in a flask with baking materials.

 The mould is now ready for pouring.

Advantages of shell moulding :

 Very high surface finish is obtained.

 Sand handling is minimum.

 Permeability of the shell is high; hence gases escape readily through them.

 Less floor area is required.

- Casting defects are minimum.

Limitations:

- The pattern equipment cost is more.

 Not economical for fewer casting.

 Complicated jobs cannot be moulded. Weight and size of casting are limited.

Limitations of shell moulding :

- The pattern equipment cost is more.

 Not economical for fewer casting.

 Complicated jobs cannot be moulded. Weight and size of casting are limited.

Applications of shell moulding :

 It is used where greater dimensional accuracy and smoother surface finish are required as in automobile casting.

 Also, used for casting steel, iron or non-ferrous alloys.

Investment Casting

 Investment casting process is also known as lost-wax process. The term investment refers to a clock or special covering apparel.

 In investment casting, the clock is a refractory mould which surrounds the pre coated wax pattern.

 A wax pattern must be made for every casting and gating system also.

 A wax pattern is invested by liquid mould material which is latter allowed to be set and form a hard layer around the pattern.

- A mould cavity is then obtained by melting the wax pattern.
- The steps in an investment casting process are as follows (Refer Fig. 2.56)

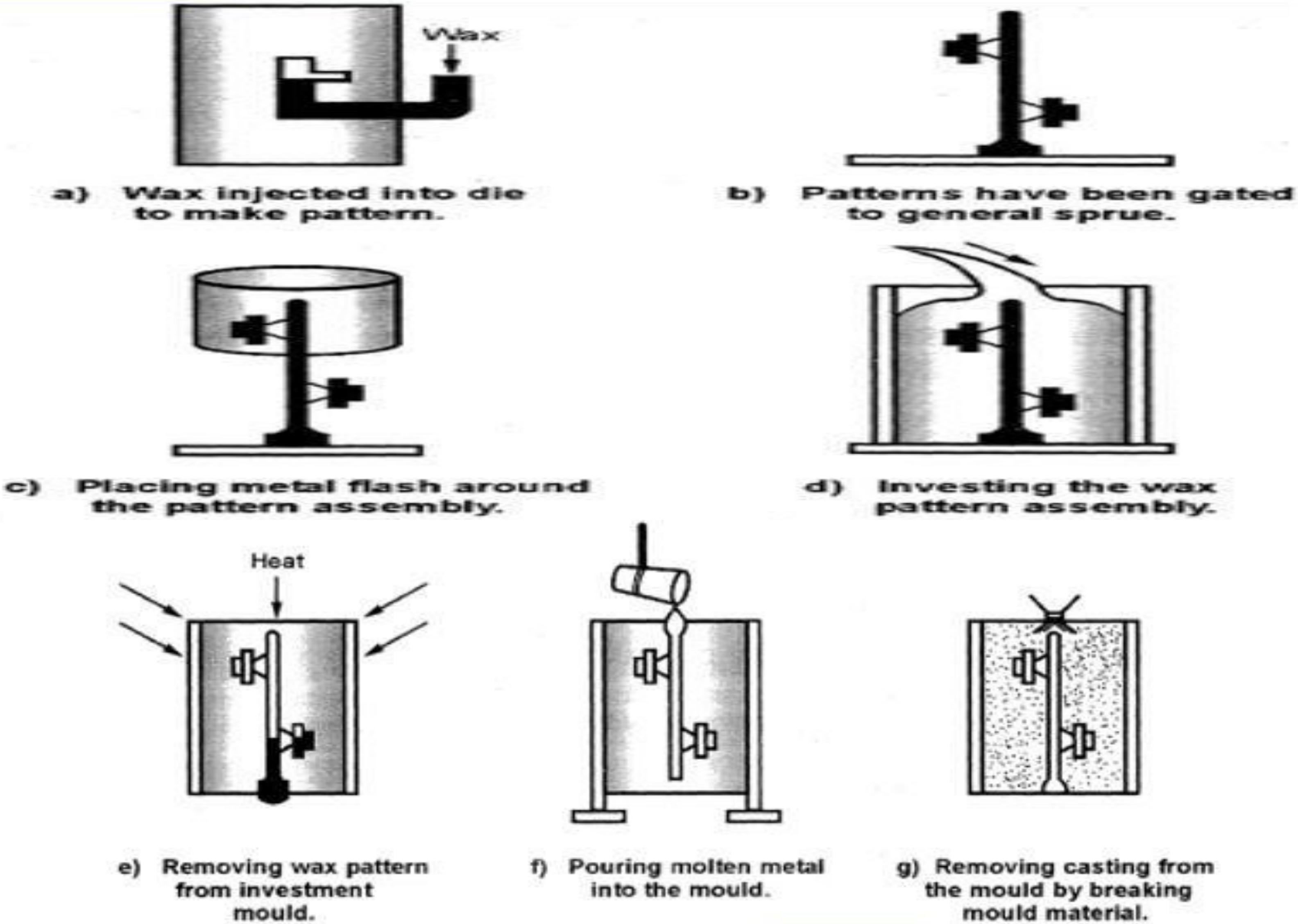


Fig. 2.56: Steps involved in making investment casting

a.Die making :

 A die for casting the wax pattern is made.

- These dies can be made by using a metallic master pattern and casting a low melting point alloy around it.

b. Wax patterns and gating systems :

- Wax patterns and gating systems are produced from the metal dies by injection.
- Wax is injected into the die at a temperature of 70°C to 80°C and at a pressure of 8 to 150 kg/cm2.

c. Assembling the wax patterns:

- The wax patterns so made are then attached to wax gates and Sprues already made with the help of heated tool known as hot wire welder.
- Assembling fixtures are used to minimize the operation time.

d. Pre coating :

  The wax assembly is dipped into slurry of a refractory coating material.

 Typical slurry consists of 325 mesh silica flour suspended in ethyl silica solution of suitable viscosity to produce uniform coating.

e. Investing :

 The coated wax assembly is then invested in the mould. This is done by inverting the wax assembly on a table, surrounding it with a paper lined steel flask and pouring the investment moulding mixture around the pattern.

  The whole system is then vibrated and then the material settles by gravity and the mould is then allowed to air-set.

f. Wax melting :

 The wax is melted out of the hardened mould by heating it in an inverted position at about 200°C. Sometimes, the wax may be reused. **g. Pouring :**

  Prepared moulds are first preheated to a suitable temperature between − 540°C to 1 040°C and the metal is gravity poured into the sprue.

 Air pressure may then be applied to the sprue with force to fill the mould cavity.

h. Cleaning and inspection :

- After solidification, the casting is vibrated to separate itself from the investment material.
- The gates, risers, etc. are then chipped off.
- The castings are then subjected to sand blasting.

- ➢ Then they are inspected through the specified inspection method.

Advantages of investment casting :

- Better dimensional accuracy with close tolerances can be achieved.
- ➢ Complicated shapes and complex contours can be easily cut.
- Extremely thin sections up to 0.75 mm can be cast.
- ➢ Surface finish of the casting is very high.
- Castings are sound and free from defects.

Limitations of investment casting :

- Size of the casting to be made is limited.
- Suitable only for small sized casting.
- Moulds used are single purpose only.
- Cost of investment material is high.
- It is a time consuming process.

Applications of investment casting :

- Parts for aerospace industry, aircraft engines, frames, fuel systems, etc.

- Parts for food and beverage machinery, computers and data processing equipment, machine tools and accessories.
- Nozzles, buckets, blades, etc. for gas turbines.
- Costume jewellery can be made.

Centrifugal Casting

- Centrifugal casting is also known as liquid forging.
- In this process mould is rotated at high speed and molten metal is poured into it. Due to the centrifugal force, the molten metal is directed outwards from the centre i.e. towards the inner surface of the mould with high pressure.
- Hence, a uniform thickness of metal is deposited all along the inner surface of the mould, where it solidifies and the impurities being lighter remains nearer to the rotation axis.
- This process produces casting with greater accuracy and better physical properties.
- This method is mainly suitable for producing casting of symmetrical shapes.

Centrifugal casting processes can be classified as :

a. True centrifugal casting

b. Semi -centrifugal casting

c. Centrifuging

d.

a.True centrifugal casting :

- An important feature of true centrifugal casting is that, the axis of rotation of the mould and that of the casting are the same.
- Also there is no need of central core for producing central hole.
- The axis of rotation· of the mould may be horizontal, vertical or inclined at any suitable angle.
- During the operation, moulding flask is properly rammed with sand to confirm to the outer contour of the casting to be made.
- The flask is then dynamically balanced to reduce undesirable vibrations during the process.

True centrifugal casting :

 The finished flask is mounted between the rollers and the mould is rotated slowly. Refer Fig. 2.53.
 The molten metal is poured into the revolving mould. The centrifugal force throws the metal towards the outer walls.

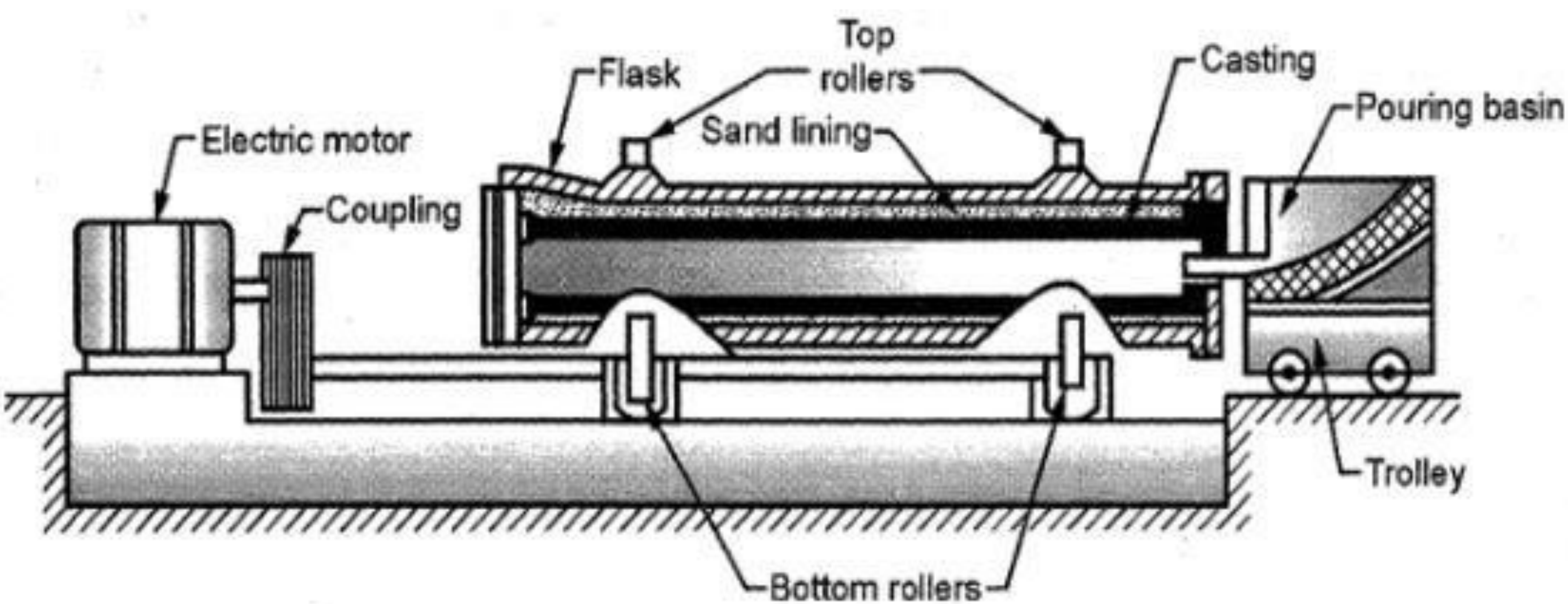


Fig. 2.53 : Horizontal true centrifugal casting machine

b. Semi centrifugal casting:

 In semi-centrifugal casting method the mould is completely full of metal as it is spun about its vertical axis and risers and core may be employed

 Rotational speed for these methods is not as great as for the true centrifugal process.

 The molten metal 1s poured through a central sprue. Refer Fig. 2.54.

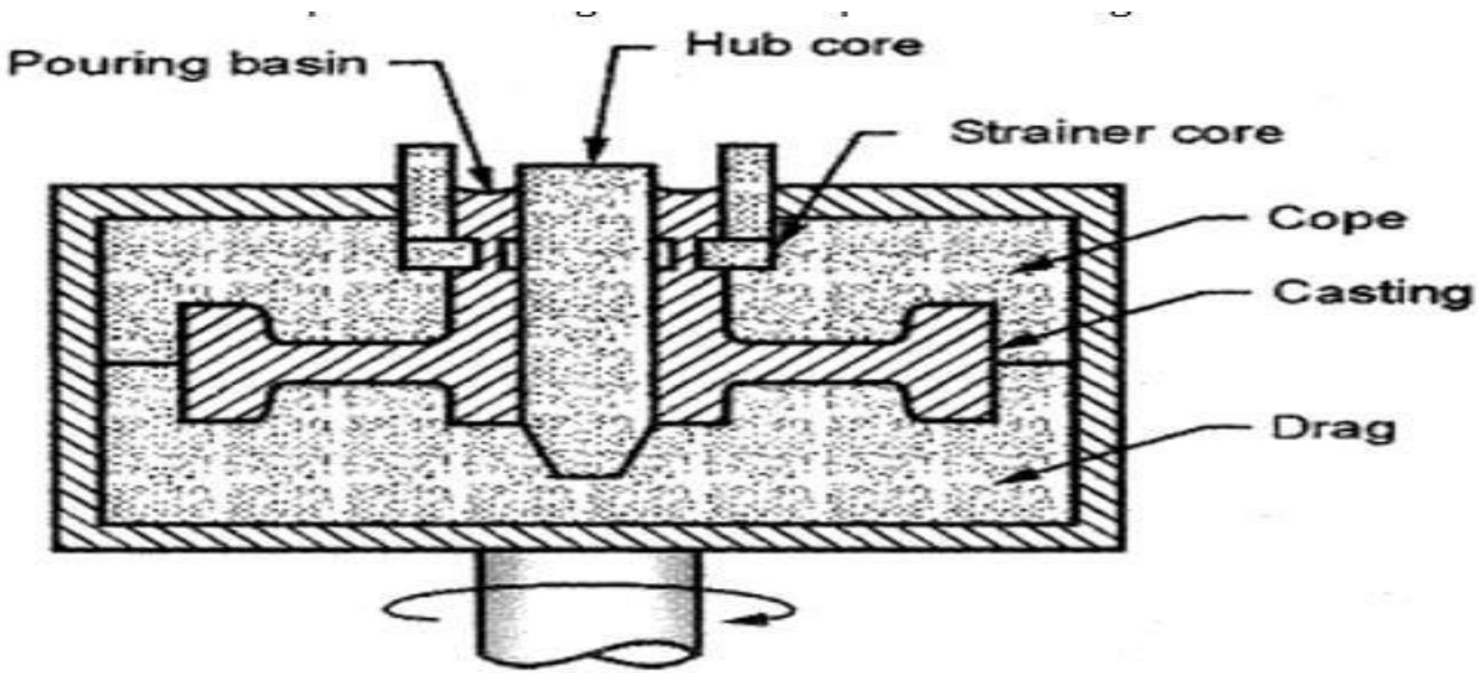


Fig. 2.54: Semi-centrifugal casting

b. Semi centrifugal casting:

- ➢ As the speed of rotation is low, centrifugal force and pouring pressure produced are low.
- The impurities are not collected at the centre.
- The moulds used may be of green sand, dry sand, metal or any other suitable material.
- ➢ A central core is used to form the required inner surface of the casting.
- This method is used to produce larger sized symmetrical casting such as discs, pulleys, gears, sprocket wheels, etc.

c. Centrifuging :

- In this method several casting cavities are located around the outer portion of a mould and the metal is fed to these cavities by radial gates from the centre.
- The centrifugal force produces sufficient pressure, to force the metal into the cavities.
- This method mainly differs from true centrifugal method in that, the axis of rotation and that of the mould do not coincide with each other. Refer Fig. 2.55. This method is also called as pressure casting

c. Centrifuging casting :

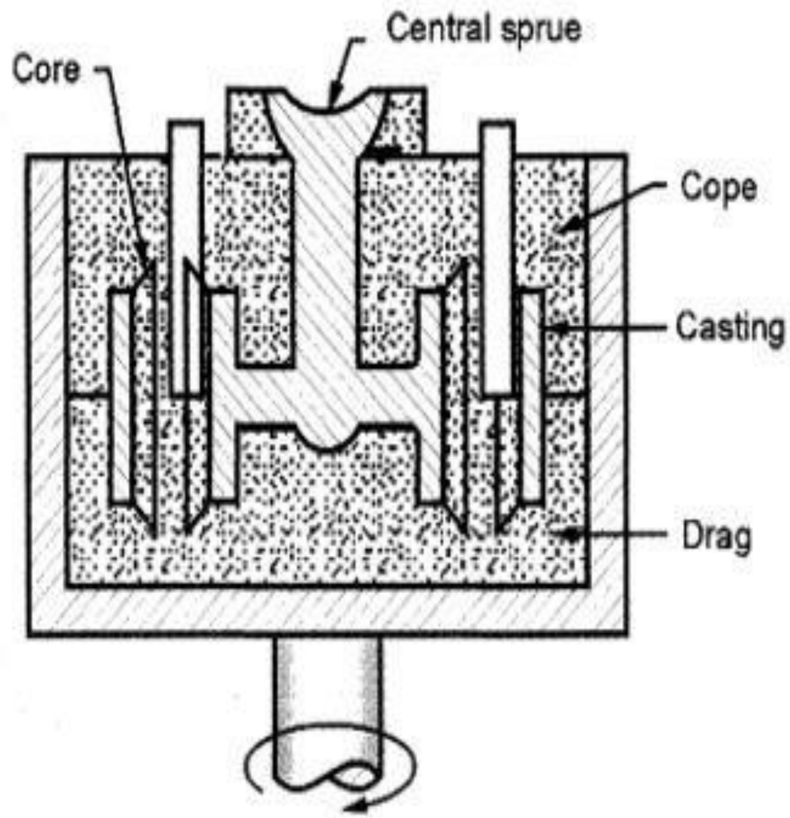
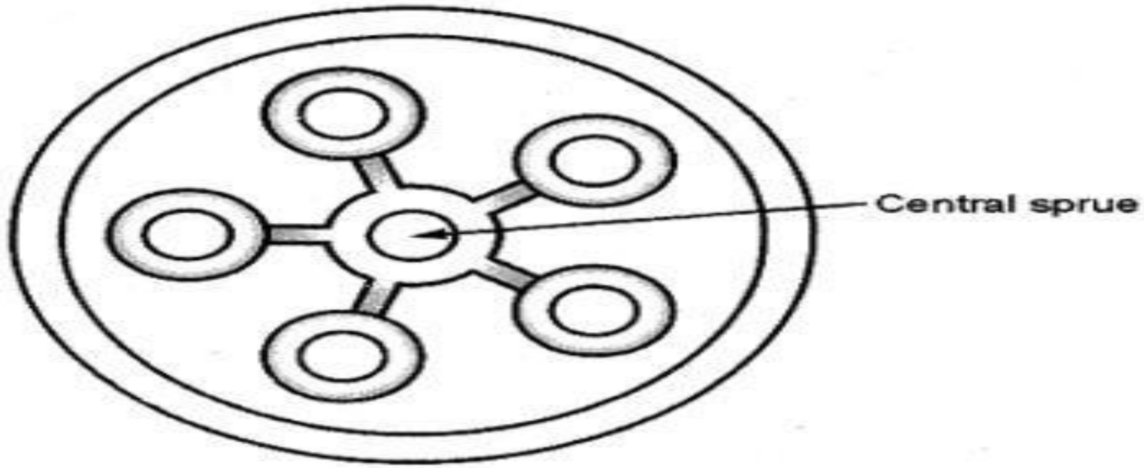


Fig. 2.55: Centrifuged casting

c. Centrifuging casting :



- The internal cavities of these castings are irregular in shape and are formed by dry sand cores.
- This method is also used for unsymmetrical objects. It can produce casting of irregular shapes such as bearing caps or small brackets, etc

Pressure Die-casting

➢ In pressure die-casting molten metal is poured by pressure into a metal mould known as die.

 Because the metal solidifies under pressure, the casting confirms to the die cavity in shape and surface finish. The pressure is generally obtained with the help of compressed air or hydraulically.

➢ The pressure varies from 70 to 5000 kg/cm2 The main types of die-casting machines are : a. Hot chamber die-casting b. Cold chamber die-casting – The principle difference between the two methods is determined by the location of the melting pot.

Pressure Die-casting

 In the hot chamber method, a melting pot is included with the machine and the injection cylinder is immersed in the molten metal at all time.

 The injection cylinder is operated by either hydraulic or air pressure, which forces the metal into the dies to form a casting.

 Whereas, cold chamber machine consists of separate melting furnace and metal is introduced into injection cylinder by hand or mechanical means.

a. Hot chamber Die-casting:

➢ In this method metal is forced into the mould and pressure is maintained during solidification either by a plunger or by compressed air. Fig. 2.51 shows the main parts of hot chamber machine.

➢ The plunger acts inside a cylinder formed at one end of the goose neck type casting submerged in the molten metal.

- Near the top of the cylinder, for entry of molten metal, a port is provided.
- When the bottom of the plunger is above the port, at that time the cylinder is connected to the melting pot through this port.

a. Hot chamber Die-casting:

- This downward stroke of the plunger closes this port, cuts off the supply of metal and applies pressure on the metal present in the goose
- Neck to force it into the die cavity through the injecting nozzle.

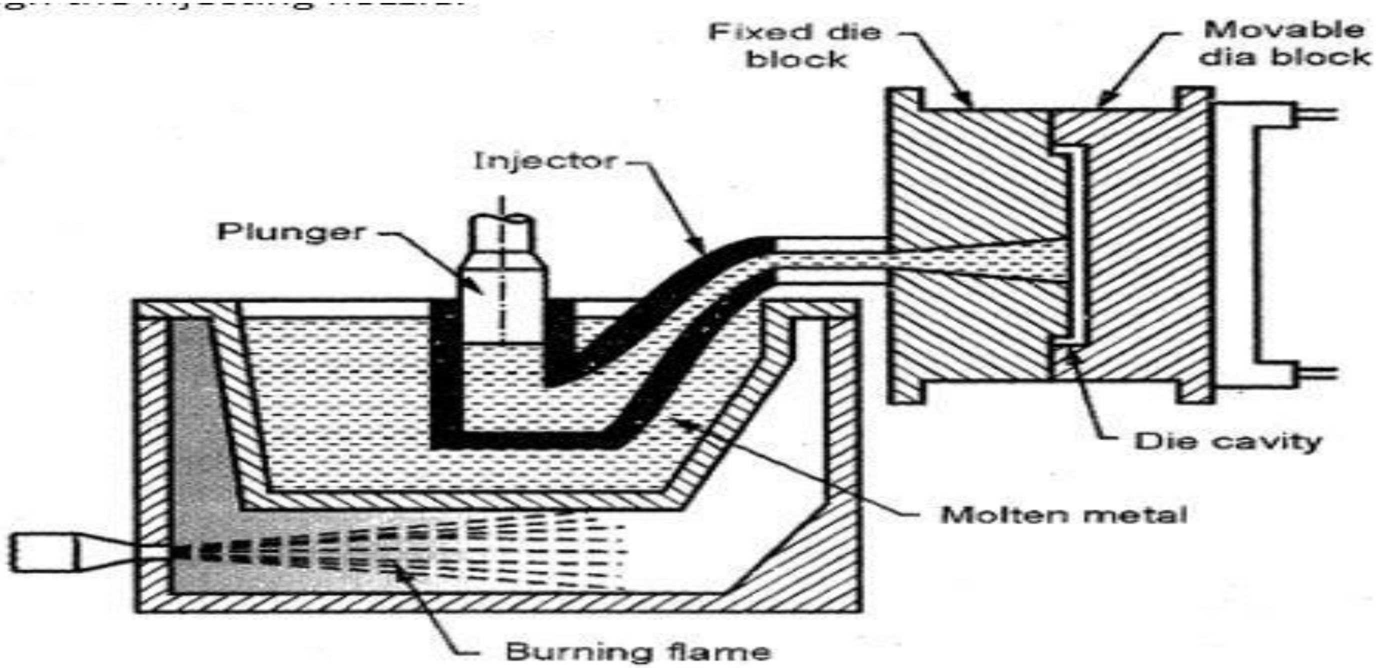


Fig. 2.51 : Hot chamber die-casting machine

Hot chamber Die-casting:

- After sometime, the plunger is raised up, causing the remaining molten metal in the nozzle and channel to fall back into the casting.

- Before the end of upward stroke, the plunger uncovers the port, through which more amount of molten metal enters into the cylinder.

- Then the dies are opened and casting is ejected.

- These machines are generally used for producing castings of low melting point metals like zinc, tin and lead.

b. Cold chamber Die-casting:

Fig. 2.52 shows the working principle of cold chamber machine.

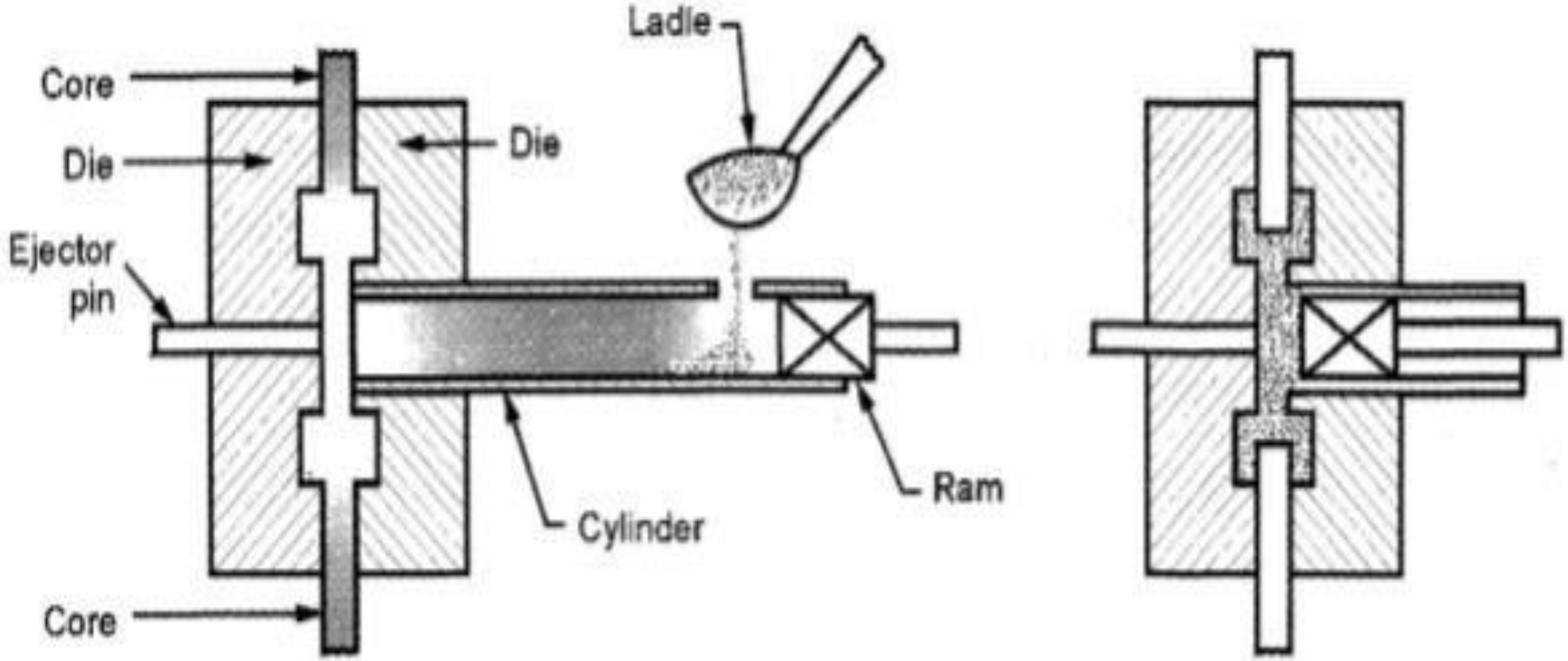


Fig. 2.52: Cold chamber die casting machine

b. Cold chamber Die-casting:

 The machine consists of separate furnace for melting the metal.

 The metal is melted separately in the furnace and transferred to cold chamber by using small hand ladle. Refer Fig. 2.52 (a).

 After closing the die, the molten metal is poured into the horizontal chamber through the metal inlet.

 To force the metal into the die, the plunger is pushed forwards hydraulically. Refer Fig. 2.52 (b).

b. Cold chamber Die-casting:

 After solidification, the die is opened and the casting is ejected.

 Cold chamber machines are mainly used for making castings in aluminum, brass and magnesium. The life of these machines is more, because the melting unit is separated from the working parts. − But, the life of die is less because the machine involves very high pressure i.e. about200 to 2000 kg/cm

Advantages of pressure die casting:

 High production rates are possible.

  Economical for large production quantities.

 Close tolerances up to ± 0.076 mm on small parts is possible.

 Good surface finish can be obtained. Thin sections up to 0.5 mm can be cast.· **Limitations of pressure die casting** :

 Only small parts can be made.

 Only non-ferrous alloys and metals can be commercially cast. Due to high cost of equipment and dies, the process is economical only for mass production.

 Due to entrapped air, the die castings are porous which reduces mechanical properties of the component.

Applications of pressure die casting:

 Household equipments like decorative parts, mechanical parts of mixers, fans, vacuum cleaners, washing machines, can openers; refrigerators, etc. can be made.

 Industrial equipments like motor housing, crane parts, motor, rotor fan, impeller wheel, etc. can be made.

➢ Automotive parts like windshield frames, window channels, bodies of fuel pump and carburetor, handles, rear view mirror parts, brake shoe (Al), etc. can be made.

 Toys like pistols, electric trains, model aircraft, automobiles, etc. can be made.

- Other parts like taps, valves, burners, fire alarm system, telephone sets, speakers, staplers, typewriters, etc. can be made

Casting Defects and Remedies

- A large number of defects occur in sand casting produced through different methods.

 These defects offer a great problem to the foundry industry.

 Casting defects are usually not accidents, they occur because some manufacturing steps are not properly controlled.

 A defect may be the result of single cause or a combination of factors.

Casting Defects and Remedies

The factors which are generally responsible for these defects are :

 Design of casting and pattern equipment

 Moulding and core making equipment

 Mould and core materials

 Metal composition Gating and risering

 Melting and pouring, etc.

1. **Blow holes:**

- Blow holes appear as cavities in a casting.
- These blows are normally rounded and have smooth walls.
- They are not visible from the outside.

2. Porosity :

- This defect occurs in the casting in the form of pinhole porosity or gas porosity.
- Gas porosity is more pronounced with higher melting temperature and slower solidification of metal.

3. Shrinkage :

- During solidification of metal, there is a volumetric shrinkage.
- They may exist on the surface as depression, called as surface shrinkage or with in the casting called as internal shrinkage.

4. Inclusions :

- Any separate non-metallic foreign material present in the cast metal is known as inclusions.
- These inclusions may be in the form of oxides, slags, dirt, sand or gas.

5. Hot tears :

- Hot tears are also called as pulls or hot cracks.
- They are supposed to be more harmful when present internally.
- Their presence is identified by an oxidized surface showing an irregular and ragged appearance on the fracture..

6. Misrun and cold shuts :

- When the molten metal fails to reach all the sections of the mould, certain part of it remains unfilled.
- This result in an incomplete casting, the defect is known as misrun.
- When two streams of molten metal approach each other in the mould from opposite directions, a physical contact between them is established.
- But, if they fail to fuse together, then it results in discontinuity between them, which is known as cold shuts.

7. Cuts and washes (scabs) :

- The cavities formed on the mould and core surfaces due to erosion are filled by the molten metal and it appears on the casting surface as an excess metal in the form of ragged parts.
- These spots are called as scabs.

8. Mismatch (Shift) :

- Shift is a misalignment between two mating surfaces, leaving a small clearance between them and changing their location.
- It occurs at· the parting surface between two parts of the mould, called as mould shift or at core prints i.e. the gap between core and core seats are called as core shift.

9. Hard spots :

- Hard spots on surfaces are generally developed on iron casting, rich in silicon content, due to local chilling of those spots by moulding sand.
- Due to this, white cast iron is formed at those places and makes them hard.

10. Warpage :

- Warpage is an undesirable deformation in the casting which may occur during or after solidification.

- The deformation takes place because of internal stresses developed in the casting due to differential solidification in various sections.

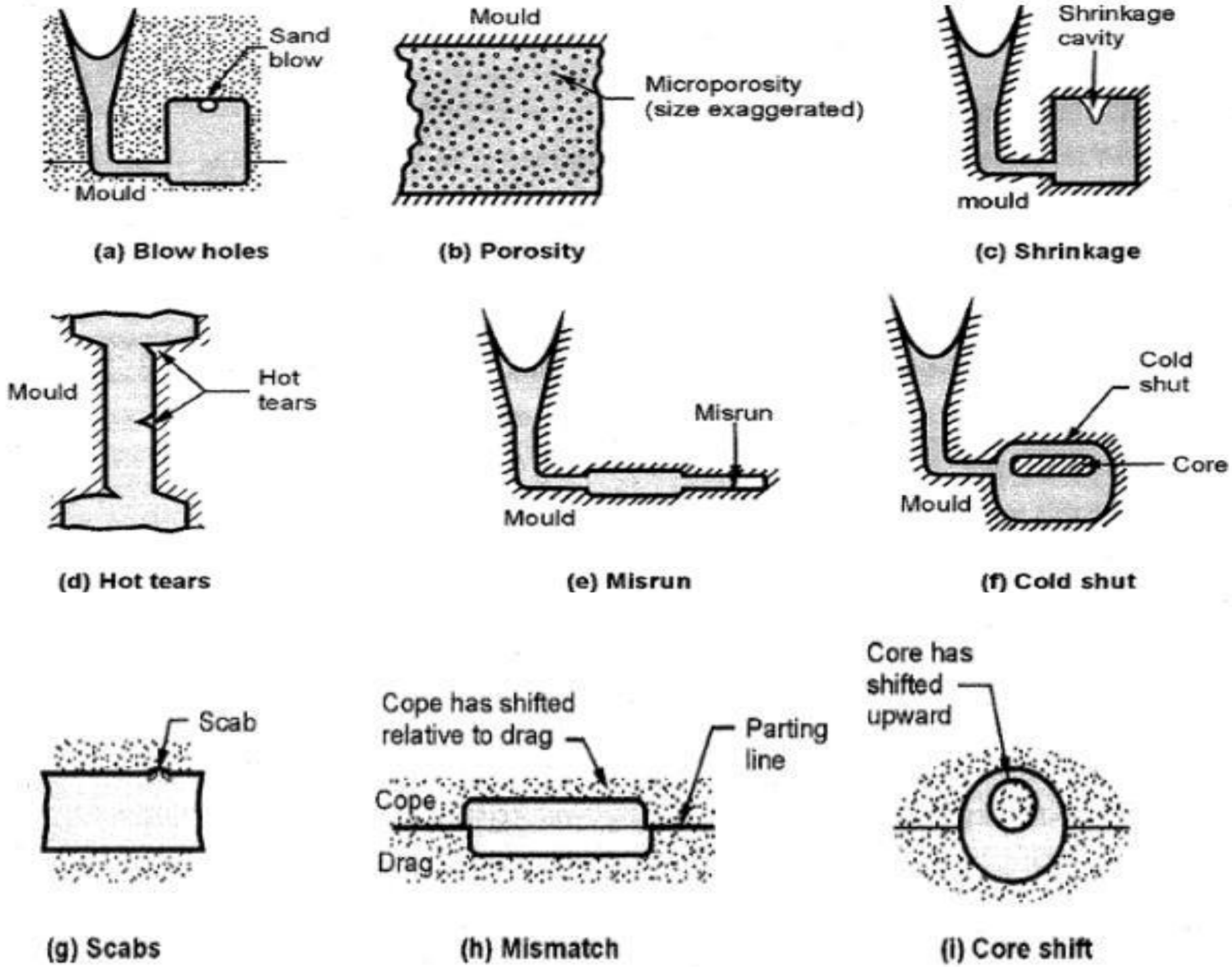


Fig. 2.58: Casting defects