# UNIT-I

## METAL CASTING PROCESSES

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains hollow cavity of the desired shape and then allow to solidify. The solidified part is called as a casting.

Important factors:

1. Solidification of the metal
2. Molten metal into metal cavity
3. Heat transfer during solidification and cooling of metal in the mould
4. Influence of the type of the mould material

Advantages of casting:

- Can create complex part geometries
- Can create both external and Internal shapes

- can produce very large parts

Disadvantages:

- Limitations on mechanical properties
- Poor dimensional accuracy
- Safety hazards to workers
- Environmental problems.

Mould in casting

- mould contains a cavity whose geometry determines part shape
- Actual size and shape of cavity must be slightly oversized to allow for shrinkage of metal during solidification and cooling
- Expendable moulds, permanent moulds, composite moulds
- Desirable mould properties - strength, Permeability, Thermal stability, Collapsibility, Reusability, size and shape of sand.
- Features - cope, drag, mould cavity, Pattern, sprue, Runners, Risers, vents, cores, chaplets, chills

## Pattern:

A pattern is a model or the replica of the object except for the various allowances.

Functions of the pattern

- A pattern prepares a mould cavity for the purpose of making a casting
- A properly constructed pattern minimizes the overall cost of the castings

## Types of pattern:

- One piece or solid pattern
- Two piece or split pattern
- Loose piece pattern
- Cope and drag pattern
- Match plate pattern
- Three piece or multipiece pattern
- Follow board pattern
- Gated pattern
- Sweep pattern
- Skeleton pattern
- Segmental or part pattern

## Pattern materials:

wood, metals and alloys, plastic plaster of paris, Rubbers, wax and resins

## Pattern allowances:

- Shrinkage allowance
    - It depends upon the metal being casted, pouring temp casting dimensions, moulding conditions

- Machining allowances
    - castings get oxidised inside the mould and during heat treatment
    - for obtaining exact dimensions
    - the value varies from 3mm to 12mm

- Draft or Taper allowance
    - Taper on external surface varies from 10mm to 20mm/mt
    - on interior holes ⇒ 60mm/mt

Rapping or shake allowance

Before with-drawing the pattern it is rapped and thereby the size of the mould cavity increases. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5 - 1.0mm

Distortion and chamber allowance

- the tendency to distort during cooling due to thermal stresses developed

Mould wall movement allowance

- it occurs as a result of heat and static pressure on the surface layer of the sand at the mould metal interface.

<u>Types of moulding sands</u>:-

- Green Sand
- Dry Sand
- Loam Sand
- Facing Sand
- Backing Sand
- System Sand
- Parting Sand
- Core Sand.

Properties of moulding sand

① Refractoriness – to withstand high temp.

② Permeability – porosity of moulding sand

③ Cohesiveness

④ Green strength

⑤ Dry strength

⑥ Flowability or plasticity

⑦ Adhesiveness

⑧ Collapsibility

Moulding Processes:

- Bench moulding, floor moulding
  pit moulding, machine moulding
  Loam moulding

Core:

- Core produces hollowness in castings in the form of internal cavities
- Green sand core / Dry sand core
- Oil bonded cores / Shell core

- Sodium silicate - $CO_2$ core

$$Na_2SiO_3 + CO_2 \rightarrow Na_2CO_3 + SiO_2$$

- Hot box core
- Cold set core

Sand testing

I Moisture content test

Clay content test

Chemical composition of sand

Grain shape and surface texture of sand

Grain size distribution of sand

Specific surface of sand grains

Water absorption capacity of sand

Refractoriness of sand

Strength test

Permeability test

Flowability test

Shatter Index test

Mould hardness test

Moulding Machines

1. Squeezer machine

2. Jolt Machine

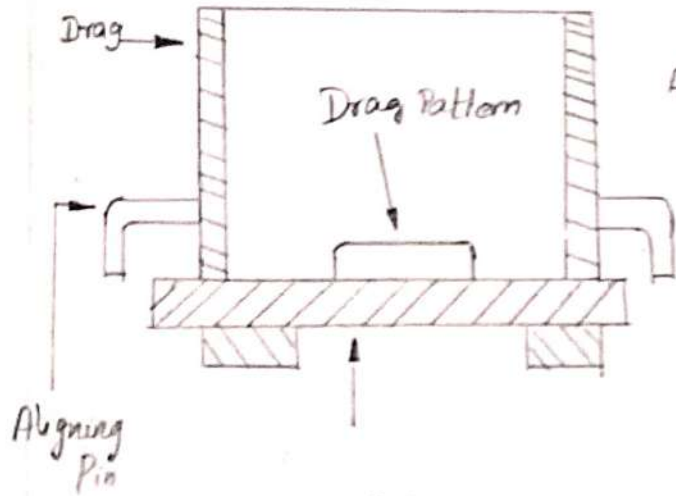
3. Jolt - Squeezer machine

4. Slinging machines

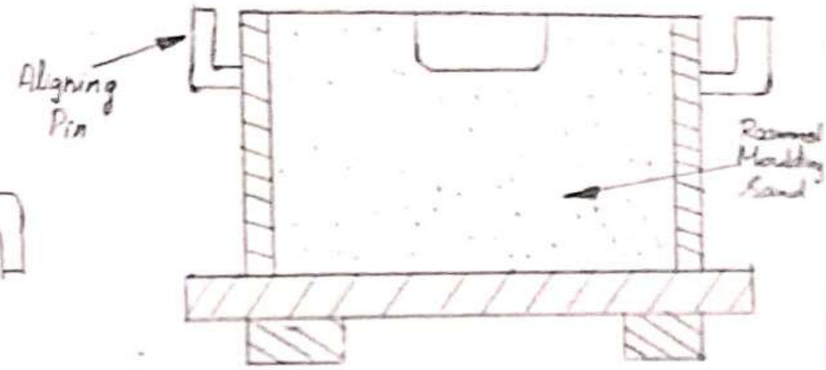
5. Pattern draw machines.

Preparation of moulding sand

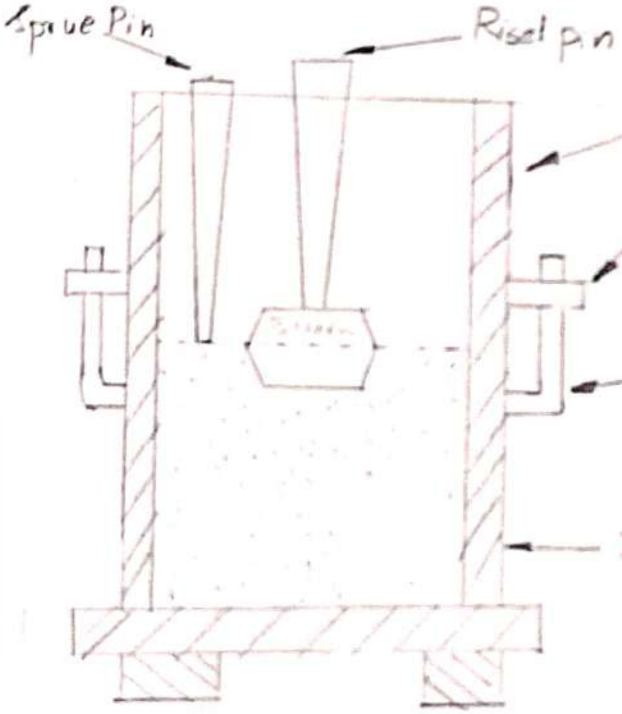
The first step in making mould is to place the pattern on the mould board. The drag is placed on the board. Dry facing sand is sprinkled over the board and pattern to provide a non sticking layer. The moulding sand is then firmly packed in the drag by means of hand ~~rammers~~ rammers with the help of vent rod, vent holes are made in the drag to the full depth of the flask. The finished drag flask is now rolled over the the bottom board exposing the pattern. Cope half of the pattern is then placed over the drag pattern. The cope flask on the drag is located aligning again with the help of pins. The operation of filling, ramming and venting of the cope proceed in the same manner as performed in the drag. The sprue and riser pins are removed first and a pouring basin is scooped out at the top to pour the liquid metal.

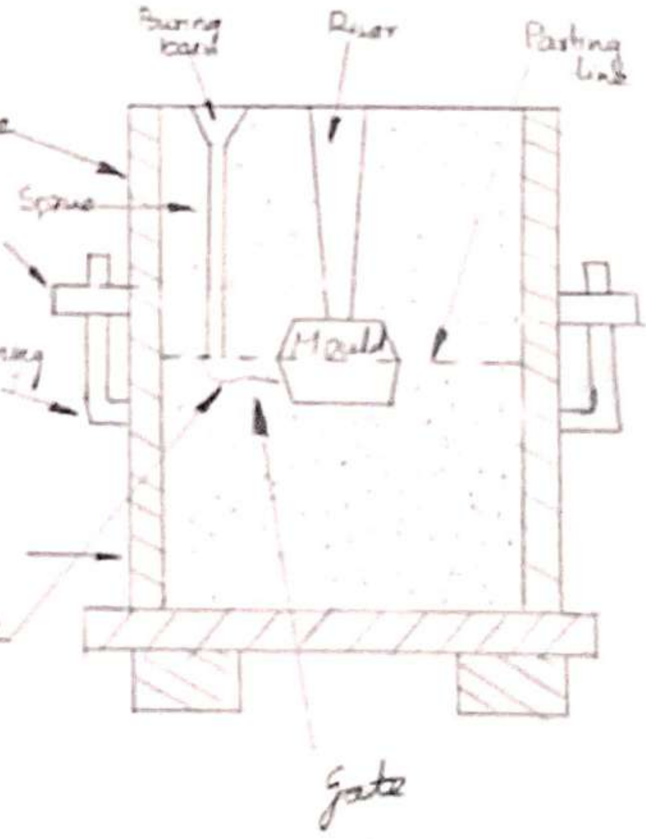



(a)




(b)



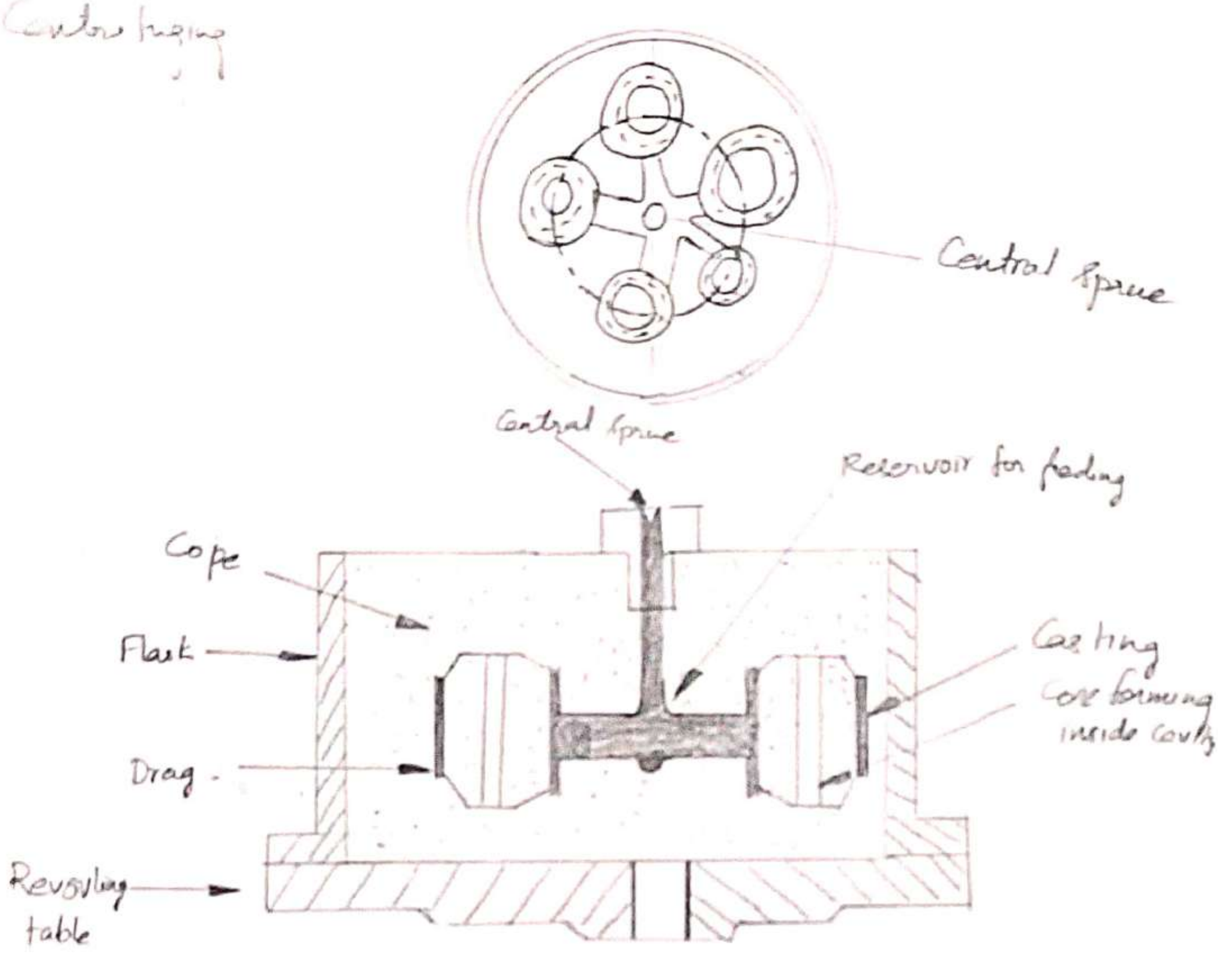




(C)

(d)

Then the pattern from the cope and drag is removed and facing sand in the form of paste is applied all over the mould cavity and runners which would give the finished casting a good surface finish. The mould is now assembled. The mould is now is ready for pouring.

Centrifuging



## Steps involved in Sand Core Manufacturing

### a. Core sand preparation

The preparation of homogeneous mixture of core sand is not possible by manual means. Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type of mechanisms.

### b. Core making process

The process of core making is basically mechanized using core blowing, core ramming and core drawing machines

### c. Core baking

Once the cores are prepared, they will be baked in a baking ovens or furnaces. The main purpose of baking is to drive away the moisture and harden the binder, thereby giving strength to the core. The core drying equipments are usually of two kinds namely core ovens and dielectric bakers.

The core ovens are ~~mainly~~ classified into two types namely continuous type oven and batch type oven.

d. Core finishing:

The cores are finally finished after baking. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing. The dimensional inspection of the cores is very necessary to achieve sound casting. The cores are also coated with refractory or protective materials using brushing, dipping and spraying means to improve their refractoriness and surface finish. The coating on core prevents the molten metal from entering in to the core. Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand.

For handling bulky cores, lifting rings are provided.

## Properties of moulding sand

### 1. Adhesiveness

It is a property of mould sand to get the stick or adhere to foreign material such sticking of mould sand with the inner walls of moulding box.

### 2. Cohesiveness

It is a property of the moulding sand by virtue which the sand grain particles interact and attract each other within the moulding sand. Thus the binding capability of the moulding sand gets enhanced to increase the green, dry and hot strength property of moulding and core sand.

### 3. Collapsibility

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of collapsibility property the contraction of the metal is hindered by the mould and thus results in tears and cracks in the casting. This property is highly required in cores.

4. Porosity or permeability

Permeability is a measure of moulding sand by which the sand allows the steam and gases pass through it. When molten metal is poured into the mould, steam and gases are formed due to moisture, binder and additives present in the sand. If the gases are not removed, casting defects such as blow holes will occur. Even though vent holes and risers are provided, all of these gases will not escape through it. To escape the remaining gases, the moulding sand should have good gas permeability.

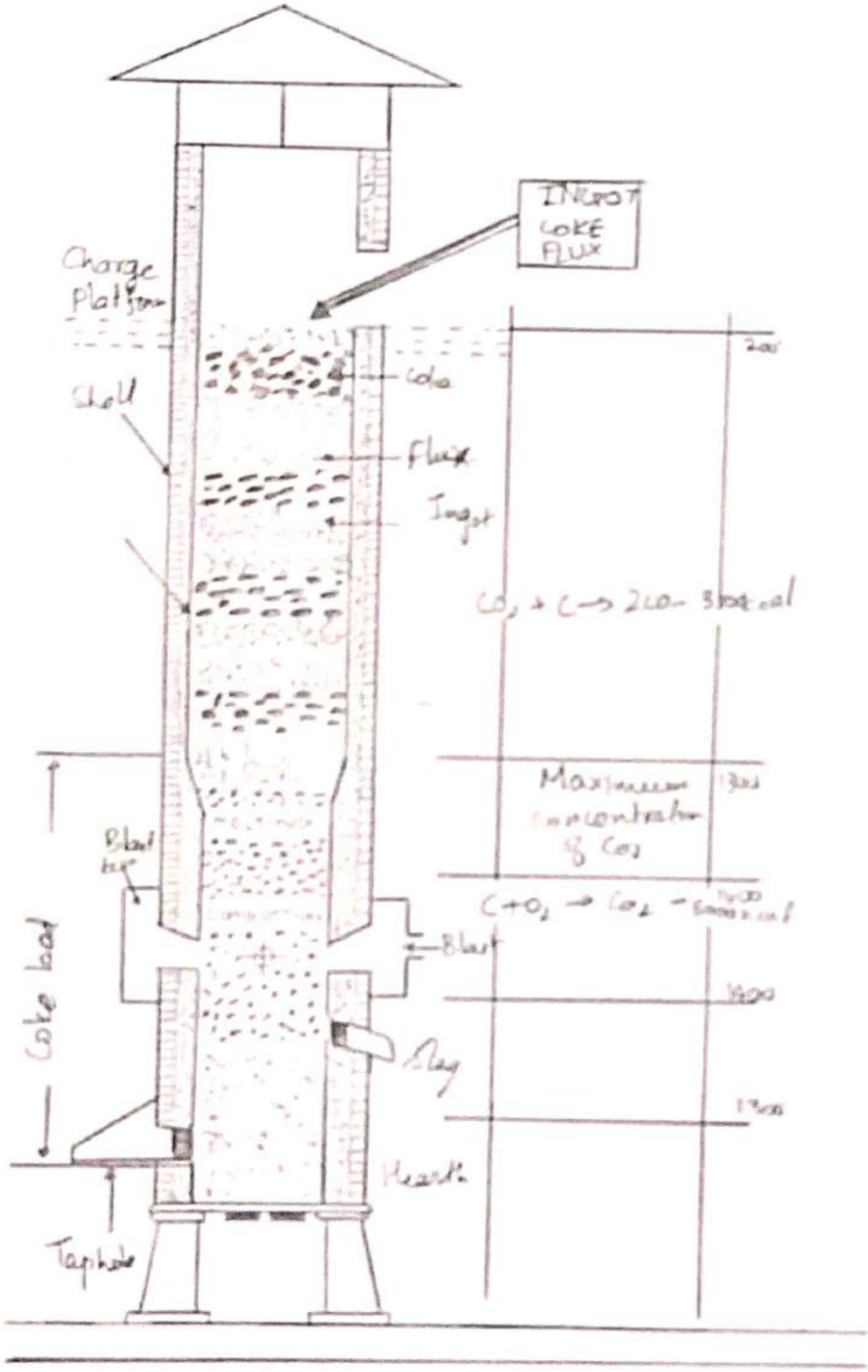
5. Flowability or flowability

It is ability of moulding sand to get compacted to a uniform density. Flowability assists the moulding sand to flow and pack all around the pattern and take up the required shape.

6. Refractoriness

This is the property of the moulding sand to withstand the temperature of the molten metal to be poured so that it does not get crushed and fused with the metal or experience any major physical change. This property mainly depends upon the purity of the sand particles and the size. Rough and large grain and quartz content in moulding sand increase the refractoriness. Poor refractoriness will result the rough surface in casting.

Constructional features of a Cupola furnace




Construction:

* The constructional of a conventional cupola furnace consists of a vertical steel shell which is lined with a refractory brick
* The charge is introduced into furnace body by ~~the~~ means of an opening approximately

halfway up the vertical shaft.

* The charge consists of alternate layers of the metal to be melted, coke fuel and limestone flux.

* The fuel is burnt in air which is introduced through tuyeres positioned above the hearth.

* The hot gases generated in the lower part of the furnace.

* The space between the bottom of the tuyeres and the sand bed inside the cylindrical shell of the cupola is called as well of the cupola.

Combustion zone:

The total ht of the zone is normally from 15 cm to 30 cm. The combustion actually takes place in this zone by consuming the free oxygen completely from the air blast and generating tremendous heat. A temp. of about 1540°C to 1870°C is achieved in this zone.

The exothermic reaction takes place in this zone.

$$C + O_2 \longrightarrow CO_2 + \text{Heat}$$

$$Si + O_2 \longrightarrow SiO_2 + \text{Heat}$$

$$2Mn + O_2 \longrightarrow 2MnO + \text{Heat}$$

Reducing zone:

Reducing zone of cupola is also known as the protective zone which is located between the upper level of the combustion zone and upper level of the coke bed. In this zone, $CO_2$ is changed to CO through an endothermic reaction, as a result of which the temp. fall from the combustion zone temp. to about 1200°c at the top of this zone

$$CO_2 + C\,(coke) \longrightarrow 2CO + Heat$$

Melting zone:

The metal charge starts melting in this zone and trickles down through coke bed and gets collected in the well.

$$3Fe + 2CO \rightarrow Fe_3C + CO_2$$

Preheating zone

Preheating zone starts from the upper end of the melting zone and continues upto the bottom level of the charging door. This zone is to preheat the charges from the room temp to about 1090°c before entering the metal charge to the melting zone

**Stack:**

The empty portion of the cupola above the preheating zone is called as stack. It provides the passage to hot gases to go to atmosphere from the cupola furnace.

**Applications**

Cupola furnace is used to melt cast iron

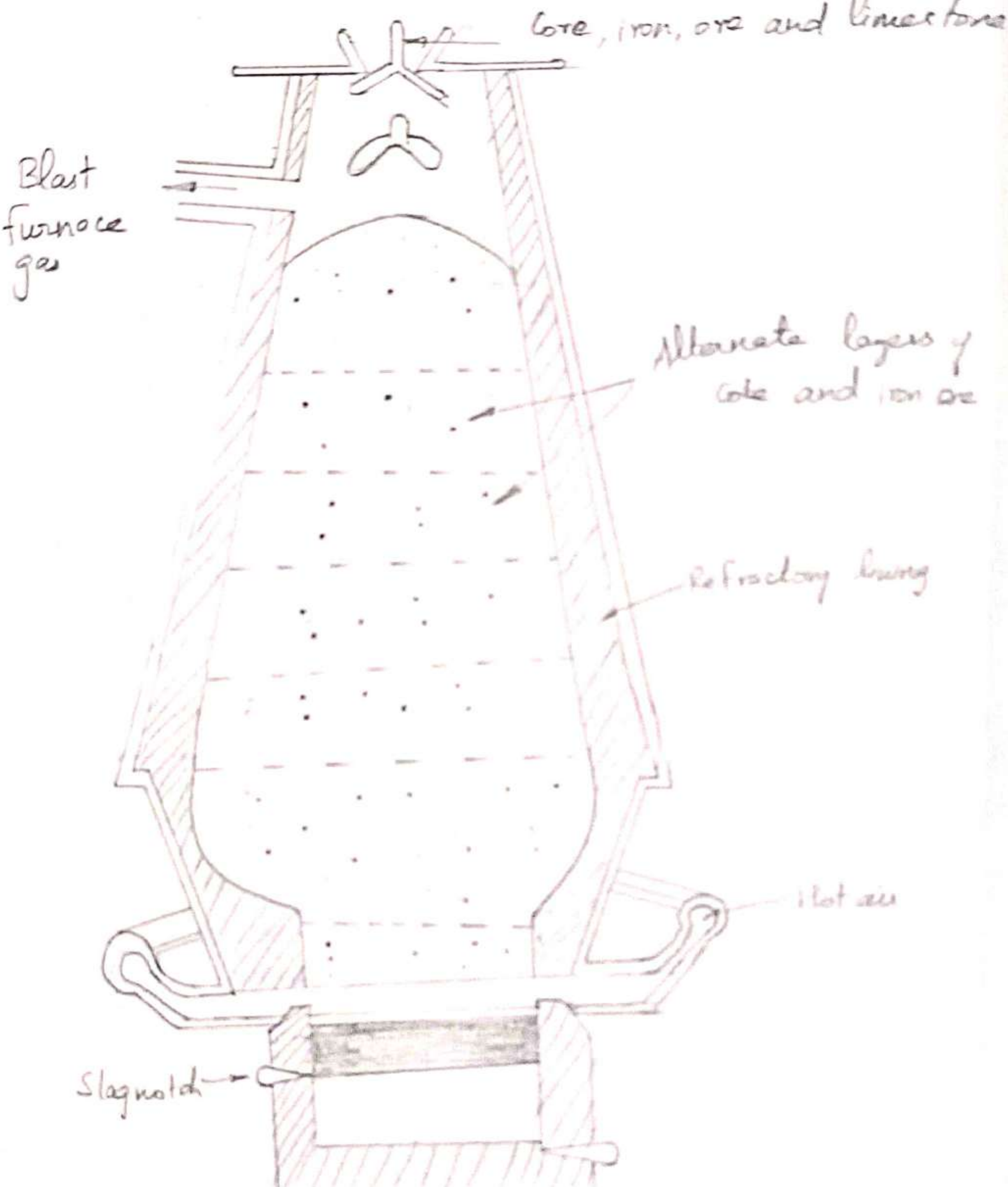
**Advantages:**

1. Initial cost is comparatively less than other type of furnaces
2. It is simple in design
3. It requires less floor area
4. Operation and maintenance are simple
5. It can be operated continuously for many hours.

**Blast Furnace:**

A blast furnace, is a type of furnace used for smelting metal ore, usually iron ore. The combustion material and ore are supplied from the top while air flow is supplied from the bottom of the chamber so that the chemical reaction takes place not only at the surface throughout the ore. This type of furnace is typically used for smelting iron to produce pig iron which

- is the raw material for wrought and cast iron.




Blast Furnace.

Blast furnace is named so because very high temp is developed inside the furnace by forcing a blast of heated air. Its ht is about 30m the internal dia is of 8 m.

The furnace is built in the form of a tall, chimney like structure lined with refractory bricks. Coke, limestone and iron ore are poured in at the top. Air is blown in through tuyeres near the base. This blast allows the combustion of fuel. It reduces the oxide in the metals which is being heavier sinks into the bottom of furnace. The reaction is

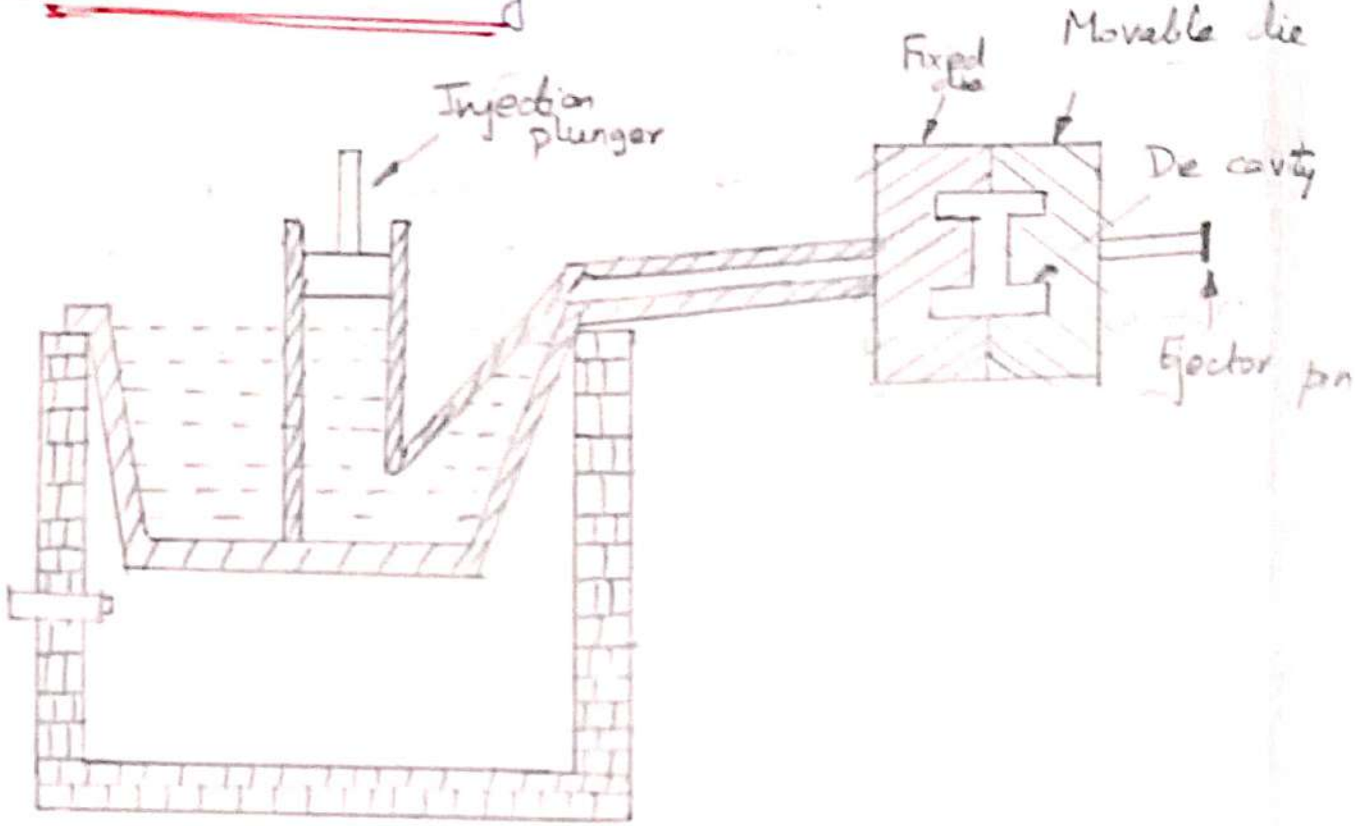
$$Fe_2O_3 + 3CO \Rightarrow 2Fe + 3CO_2$$

More precisely, the compressed air blown into the furnace reacts with the carbon in the fuel to produce carbon monoxide which then mixes with iron oxide, reacting chemically to produce iron and carbon dioxide which leaves out of the furnace at the top. The temp in the furnace is typically about 1500°C which is also enough to decompose limestone into calcium oxide and additional carbon di oxide

$$CaCO_3 \Rightarrow CaO + CO_2$$

The calcium oxide reacts with various acidic impurities in the iron forming a slag containing calcium silicate, $CaSiO_3$ which floats on the iron. The slag floating over the molten metal is removed through the slag notch. The heavier pig iron is taken out using a tap hole at the bottom of furnace. The largest blast furnace produce around 60,000 tonnes of the iron per week.

## Pressure die casting




HOT CHAMBER DIE CASTING

In the die casting process, the mould, called a die, is used for making a casting which is permanent. In this process, the molten metal is forced in to the mould cavity under high pressure. The die casting is carried out as follows.

1. The molten metal is forced under pressure into assembled die
2. The die is water cooled, so the molten metal cools down and immediately becomes solid
3. The die is opened. Then, the finished casting is ejected by pins

The medium carbon and low alloy steel are the most common die materials.

Hot Chamber die casting:

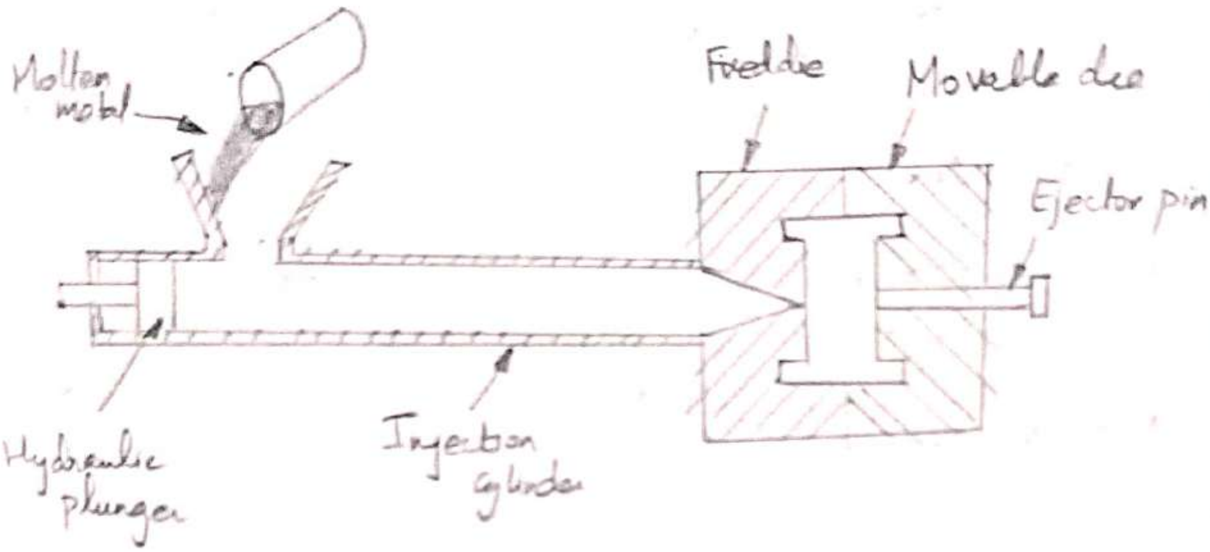
In hot chamber die casting, the melting furnace is an integral part of the mould. There is a gooseneck vessel which is submerged in molten metal. There is a plunger on the top of the gooseneck vessel as shown in figure. When the plunger is in the upward position, the molten metal will flow into the vessel through a port provided on the sidewall.

When the plunger comes down, the molten metal is forced into the dies. Since, the die is immediately cooled by water and sufficient cooling is provided for solidification. ~~Then~~ The movable die are operated by hydraulic systems. The operating pressure of hydraulic plunger is 15 MN/m².

Hot chamber die casting is suitable for casting of metals such as zinc, tin and lead.

2. Cold chamber die casting

In cold chamber die casting, the mould ~~the~~ melting unit is not an integral part of the machine. The metal is melted in a separate furnace and brought to the machine for pouring. This process is shown in figure.




Cold chamber die casting

The machine has a cold chamber of cylindrical shape with a hydraulic plunger. A measured quantity of molten metal is poured into the injection cylinder. Then the plunger moves to the right and forces the molten metal into the die cavity. As the die is water cooled immediate solidification of molten metal will take place. Then, the dies are separated. The finished casting is removed by an ejector pin.

Applications:

Pressure die casting is used for making following equipment / components.

1. House-hold equipment such as washing m/c parts, vacuum cleaner body, fan case, stove parts etc.

2. Automobile parts such as fuel pump, carburettor body, horn, wiper and crank case.

3. Components for telephones, television parts speakers, microphones, record players and so on.

4. Toys such as pistols, electric trains, model aircrafts etc.

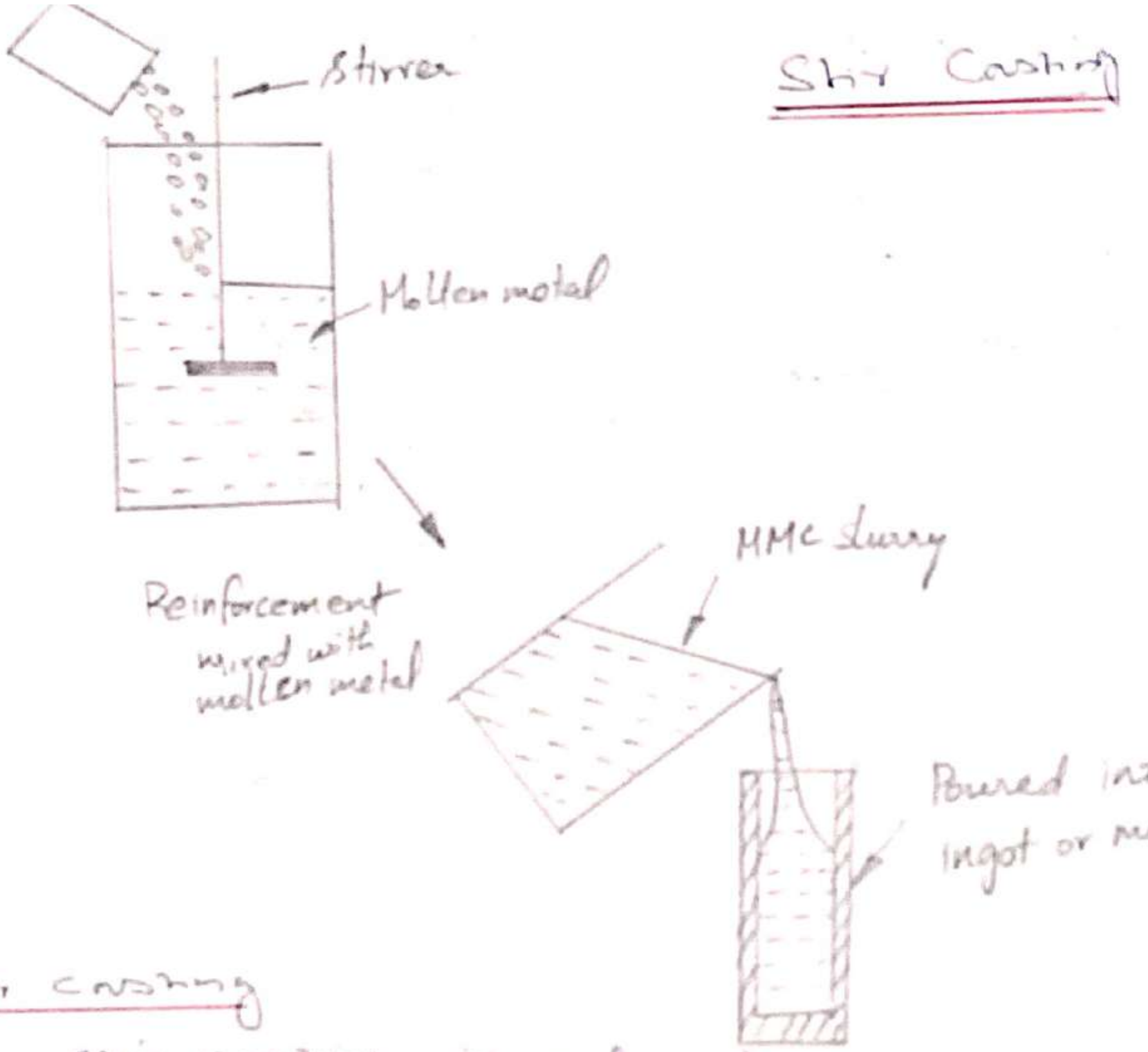
Advantages

1. Very accurate castings can be produced with the dimensional tolerance range of ± 0.03 to 0.25 mm
2. Castings with very good surface finish can be made
3. Rate of production (700 castings/hr) is high
4. Castings with varying thickness wall can be made
5. There is no possibility of sand inclusions
6. Cored holes down to 0.75 mm diameter at accurate locations are possible
7. Casting defects are less
8. It can be stored and used for long time.
9. Die has long life, approximately 75000 castings can be produced using a single die in its life period
10. The sprue, runners and gates can be remelted. Hence the scrap loss is less.

Limitations:

1. Only small parts can be made
2. Only non-ferrous metal can be cast
3. Equipment cost is high
4. It is more suitable for mass production only

# Stir Casting




## Stir casting

Stir casting is a liquid state method of composite materials fabrication in which a dispersed phase (ceramic particles, short fibres) is mixed with a molten matrix metal by means of mechanical stirring. Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted and commonly practiced commercially.

Process of stir casting:

a) In general, stir casting of MMCs (metal matrix composites) involves in producing a melt of the selected matrix material, followed by the introduction of a reinforcing material into the melt and obtaining a suitable dispersion through stirring.

b. The next step is the solidification of the melt containing suspended particles to obtain the desired distribution of the dispersed phase in cast matrix.

c. In composites produced by this method, particle distribution changes significantly. It depends on process parameters during both melting and solidification stages of the process.

d. The addition of particles to melt drastically changes the viscosity of the melt and it has implications for casting processes. It is important that solidification occurs before appreciable settling is allowed to take place.

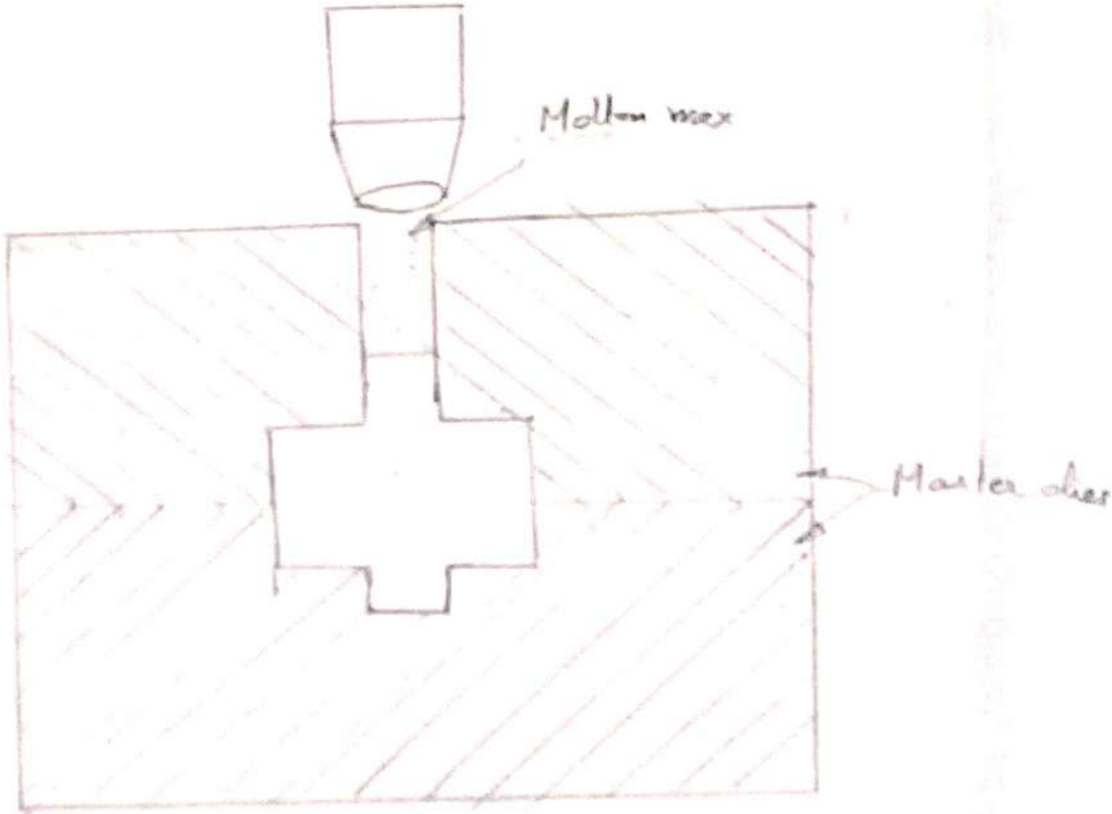
Advantages:

a) Its advantages lie in its simplicity, flexibility and applicability to large scale production because in principle it allows a conventional metal processing route to be used and its cost is low.

b. This liquid metallurgy technique is the most economical of all available routes for metal matrix composite production. This method allows very sized components to be fabricated. It is able to sustain high productivity rates.

c. The cost of preparing composite materials using a casting method is about one-third to one half of a competitive method. For high volume production, there shall be a possibility for further reduction of cost to extent of one-tenth.

# Investment Casting or Lost wax process




The casting obtained by this method have very smooth surfaces and possesses high dimensional accuracy. Hence, it is called precision investment casting. Here, the term "investment" means the layer of refractory material with which the pattern is covered to make the mould. Similar to sand casting method, the mould cannot be used again and again.

The method involves the use of dispensable pattern made of wax surrounded with a shell of refractory material (ie ceramic) to form the casting mould. Once the refractory material is hardened, its internal geometry takes the shape of the casting. The wax is melted out and molten metal is poured into the cavity, where the wax pattern was.

the metal solidifies within the ceramic mould and then metal casting is broken out. This method is also called "Lost wax method" since the pattern made of wax is melted out and gets destroyed.

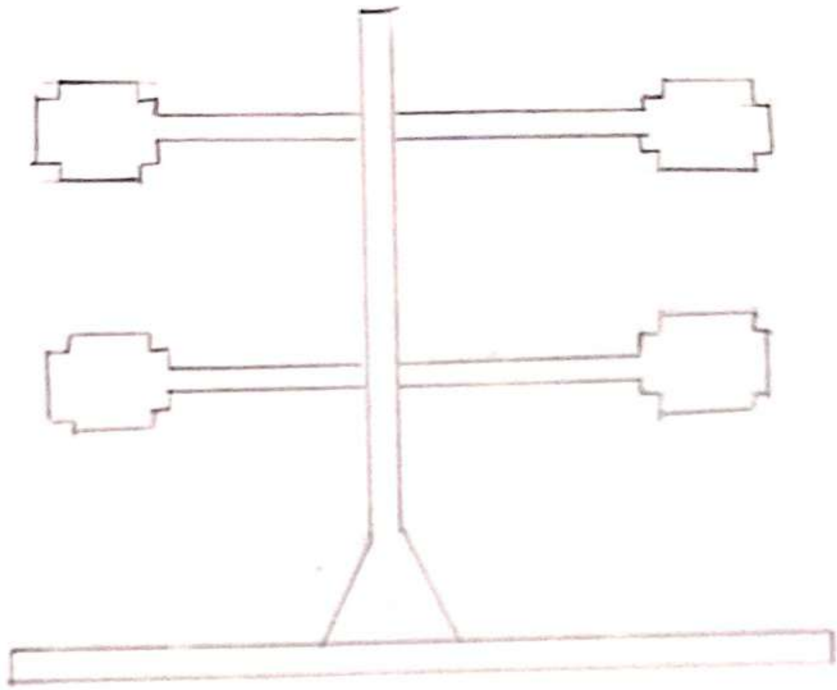
<u>Various steps involved in lost wax process</u>

1. The master pattern is prepared by casting process. It may be made of brass, aluminium alloy or steel. The dimension of the pattern is slightly larger than the actual size of the part to be made to compensate the adjustment in the die, wax in the investment material and casting material.

2. A composite die is used for making master pattern. The die is made of low melting alloy such as bismuth alloys, aluminium, cast iron etc. master pattern die cavity is formed by machining process. Generally, split type cavities are formed.

3. First, halves of the die cavities are clamped together. Molten wax is injected under the pressure of about 4 bars to the die cavity. Die cavities are preheated to avoid immediate solidification of wax.

4. If the size of wax pattern is large, the several small wax patterns are first prepared and assembled together with a



gating system along with central sprue.

5. The assembled wax patterns have to be smoothened / super finished before putting into operation. It is done in the following two stages

Stage (1)

First, slurry is made by mixing fine silica either with water or ethyl silicate. Then wax patterns are dipped in this prepared slurry to give primary coating of 1mm thickness. Then wax patterns are dried.

Stage (2)

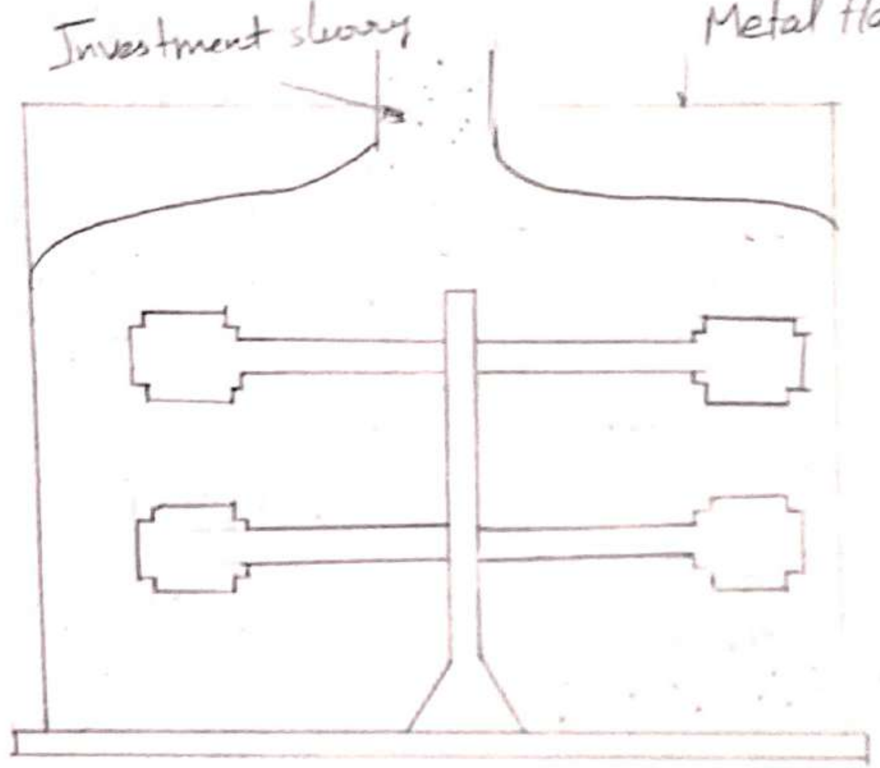
In this stage, ceramic slurry is first prepared by using refractory material such as silica or zirconia and binder such as gypsum. The gypsum is probably water based sodium silicate. Wax is a solid type mould placed over the assembled wax patterns. Then the ceramic slurry

- is poured over these assembled pattern as shown in figure. Then the pattern is taken out of the slurry and rotated to produce a uniform coating to fill inside corners and to drain out the excessive slurry. Finally, fine grain silica sand is sprinkled over the wet slurry surface.

6. After applying coating, the mould is prepared using assembled wax patterns. Next the mould is made along with the wax patterns dried in air for about 2 to 3 hours. Then baking of patterns is done in an oven for 2 hours for melting the wax patterns. When the heating temperature reaches about 100 to 120°C, the wax will start to melt. Finally, the melted wax will flow out through the sprue in molten form.

7. Again the entire mould is transferred to the heating furnace. First, the mould is held at 150°C for further drying. Next, the heating is continued about 800 to 900°C to vaporize remaining wax inside the mould cavity.

8. The liquid metal is poured into the mould still it is hot. The pre-heated mould ensures that the molten metal completely fills the cavity and also saves the liquid metal from the acquiring the moisture. Then it is allowed to solidify.




9. After the solidification is over, the castings are removed from the mould by shaking out. At that time, the fragile material of the mould will break. Then the gates and sprue called runner are removed usually by machining.

10. Finally, the adhered investment material is removed from the casting surface by sand blasting or tumbling operation. Then the castings are inspected to detect casting defects.

Applications:

1. Production of nozzles, buckets, vanes and blades for gas turbine
2. making parts for aerospace industry such as aircraft engines, frames and fuel systems
3. This process is applied in Costume Jewellery

4. Rock drill thread chaser holder blocks are produced by this method

5. parts for producing machine tools and accessories, Scientific instruments and Sewing machines

6 Small parts such as reciprocating Slides for cloth Cutting machines, movie Camera parts etc, are produced by this method.

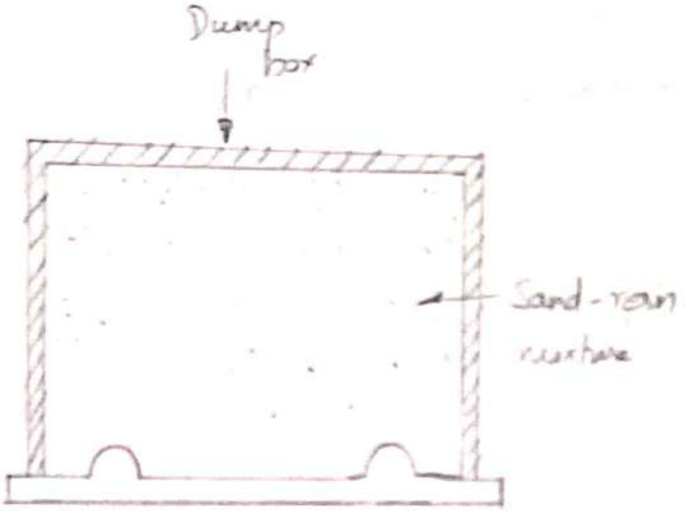
Advantages:

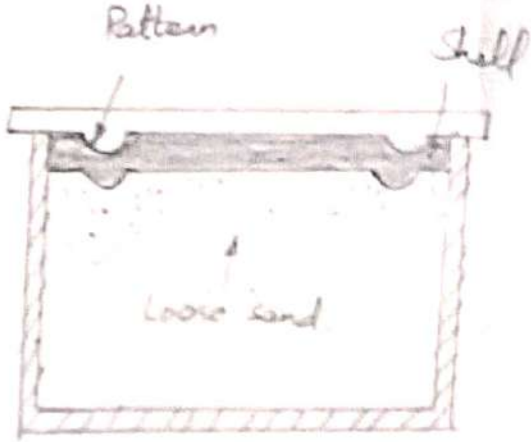
1. Complex shapes can be cast accurately
2. Surface finish is very good
3. High accuracy can be maintained
4. Number of Castings can be made at a time
5. Undercut and other intricate shapes which would not allow the withdrawal of a normal pattern are easily Obtained.
6. Unmachinable alloys can be cast

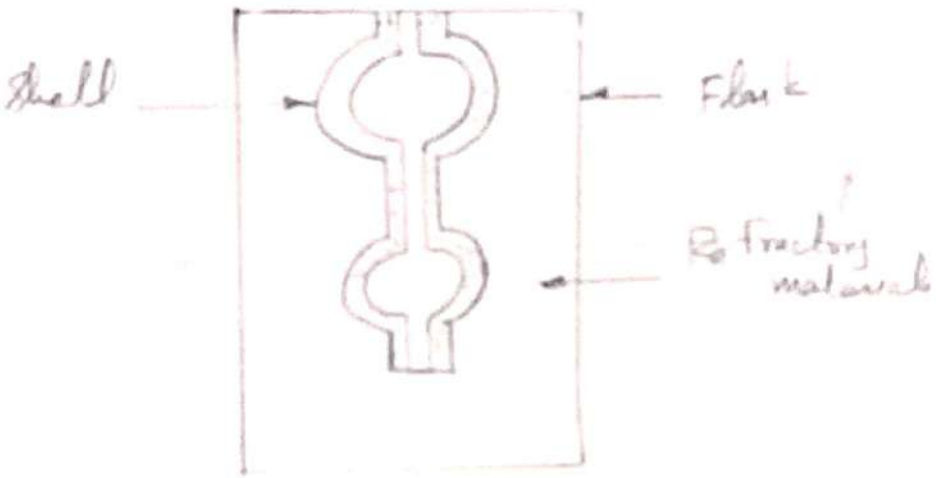
Limitations:

1. Only Small Size of the Casting can be made
2. This process is more expensive
3. Location of holes is impossible.

## Shell mould casting




The shell mould casting is a semi-precise method for producing small castings in large numbers. The process involves the use of a metal plate pattern similar to cope and drag pattern which are used in green sand mould casting. Initially, the patterns are machined from copper alloys, aluminium or cast iron depending upon the life of the pattern. They are made with usual allowances and polished surfaces. Then it is attached to the metal master plate.

The mould material contains 5 to 10% of phenolic resin mixed with fine dry silica. These are mixed with either dry oil or alcohol. It should be noted that there is no water used. The pattern is heated to 230-600°C. Then, the sand resin mixer is either dumped or blown over its surface.

sometimes, to prevent the sticking of sand with pattern, the release agent silicone is sprayed over the hot pattern. The heated pattern melts and hardens the resin. It results in bonding the sand grains closely together and forms shell around the pattern. The thickness of the shell can be accurately controlled by the time of contact of the mixture with the heated pattern. In about 20-30 sec, a normal shell thickness of 6mm can be obtained. The extra sand which is not adhered to the shell is removed off. Then the mould is heated in the oven at 300°c for 15-60 sec. The curing makes the shell rigid when it can be stripped off by means of ejector pins mounted on the pattern. Thus, the formed shell constitutes one half of the mould. Two such halves placed one over the other make the complete mould as shown in Fig.

While pouring the molten metal, the two halves are clamped down together by clamps or springs. After cooling and solidification, the shells are broken or shaken away from the castings.

Applications:

1. It is used for making brake drums and bushings
2. Cams, cam shaft, piston and piston rings can be made
3. It is used for making small pulleys, motor housing, fan blades etc.
4. Air compressor reservoir and cylinders, crank cases, conveyor, rollers etc can be made.

# Defects in Sand Castings

The defects in a casting may arise due to the defects in one or more followings:

1. Design of casting and pattern
2. Moulding and design of mould and core
3. Metal Composition
4. Melting and pouring
5. Gating and riser design

| Defects | Causes | Remedies |
|---|---|---|
| 1. Shrinkage<br>It is a depression on the casting surface | 1. Improper Solidification<br>2. Incorrect pouring temp<br>3. Faulty gating runner and riser systems | Provide proper Solidification<br>Pour at correct temp<br>Modify gating, runner and riser systems |
| 2. blow holes<br>When the molten metal is poured, gases and steam are formed. If these gases could not come out, below holes are formed on the interior of the casting. | 1. Excess moisture in Sand<br>2 Hard ramming<br>3 Improper venting<br>4 Excess binder | Control moisture Content<br>Ram properly<br>provide sufficient vent holes<br>control binder Content |

| | | |
|---|---|---|
| 3. Scab<br>It is the erosion or breaking down a portion of the mould and the recess filled with metal | 1. Uneven ramming<br>2. High velocity of pouring | Provide uniform ramming<br>Pour at correct velocity |
| 4. Swell<br>Swell is the deformation of vertical mould surface | Soft ramming<br>Quick pouring<br>Mould is not properly supported | Ram properly<br>pour at correct velocity<br>provide adequate support the mould |
| 5. Cracks<br>Small cracks appear on the corner of the casting | Due to sharp corners | provide proper or round corners |
| 6. Misrun or cold shut<br>It is the incomplete filling of the mould cavity at one pouring | Low pouring temp<br>Too small gate<br>Insufficient molten metal in the laddle for one pouring | Pouring at correct temp<br>provide correct gating system<br>pour sufficient molten metal in the laddle for one pouring |

# UNIT – II

## JOINING PROCESSES

**Welding**: It is the process of joining two metallic pieces together in permanent manner.

Advantages: Portable, most economical method to join, permanent

**Disadvantages**: Expensive manual labor, Dangerous.

**Classification**:

I. Arc welding

1. Metal arc welding
2. Carbon arc welding
3. Metal inert gas (MIG) welding
4. Tungsten inert gas (TIG) welding
5. Plasma arc welding
6. Submerged arc welding
7. Electro slag welding

II. Gas welding

1. oxy-acetylene welding
2. oxy-hydrogen "
3. Air-acetylene "

III Resistance welding

1. Butt welding
2. Spot welding
3. Seam welding
4. Projection welding
5. Percussion welding

IV Solid State welding

1. Forge welding
2. Friction welding
3. Explosive welding
4. Diffusion welding
5. Ultrasonic welding
6. Friction Stir welding (FSW)

V Thermit welding

VI Modern welding processes

1. LASER beam welding
2. Electron beam welding
3. plasma arc welding

(vii) Related Process

1. oxy-acetylene Cutting
2. Arc-Cutting
3. Hard-facing
4. Brazing
5. Soldering

# Welding Process

## Gas welding

1. oxy-acetylene
2. Air-acetylene
3. oxy hydrogen

## Resistance welding

1. Butt
2. Spot
3. Seam
4. Projection

## Arc welding

1. carbon Arc
2. metal Arc
3. plasma Arc
4. Gas metal Arc (MIG)
5. Gas Tungsten Arc (TIG)

## Newer welding

1. Electron beam
2. LASER

## Solid State welding

1. Friction
2. ultrasonic
3. Diffusion
4. Explosive

Gas welding:

It is a welding process which is done by burning of fuel gases with the help of oxygen which forms a concentrated flame of high temperature this flame directly strikes the weld area and melts the weld surface and filler material. The melted part of welding plates diffused in one another and creates a weld join after cooling.

Types of gas welding

a) Air - acetylene welding

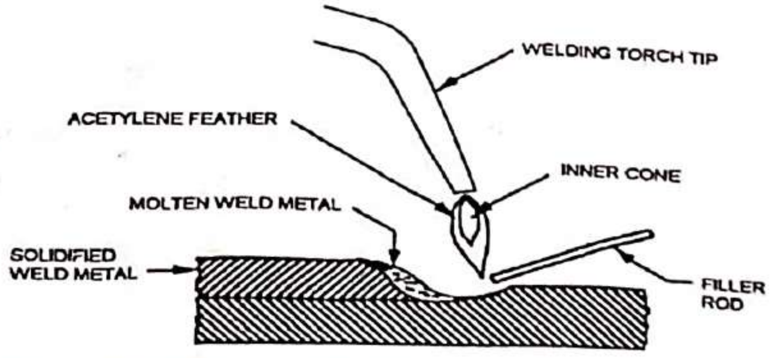
b) oxy - acetylene welding

c) oxy - hydrogen welding

a) Air - acetylene welding:

Principle:

The heat is produced from mixture of - acetylene and air. Weld joint is made without the application of pressure and with or without use of filler metal. The temperature is produced maximum 2700°c.

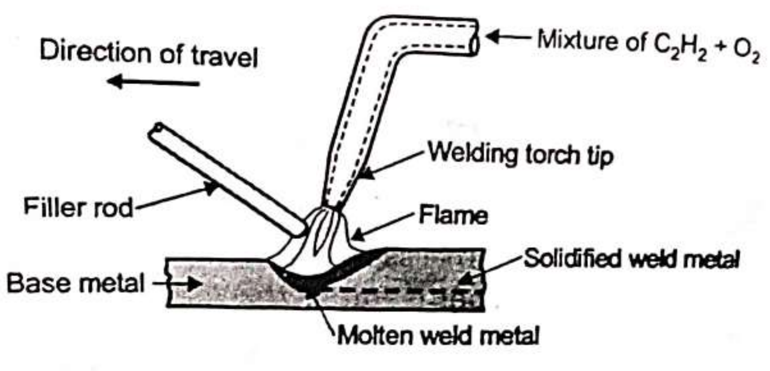


## oxy - acetylene welding

### Principle

Oxyacetylene welding process is accomplished by proper proportion of acetylene and oxygen gases in weld torch, which passed through flame. when the flame is melt the base metal, the filler metal is inserted into the gap between the base metals. Now the base metals are allowed into solidified.

Diagram:




### Working:

In this process the mixture of oxy-acetylene and oxygen presented, which is flow to the burning process and controlled by control valve. The welding torch is opened, both gases are combined together and it is burned due to oxygen mix to acetylene.

The burning process temp is 3200°C for melt the commercial metal welding. The heat is obtained by combustion of acetylene and oxygen gases, during combustion process.

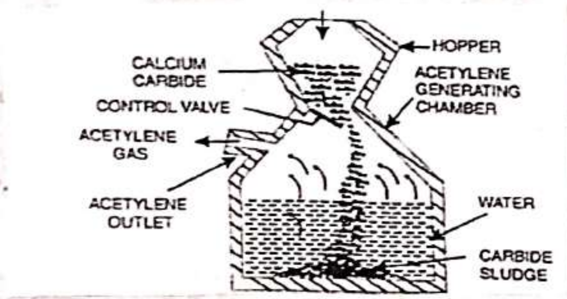
<u>High pressure system</u>:

In this process the oxygen and acetylene are taken for use from high pressure cylinders.

Low pressure system.

In this system, oxygen is taken from high pressure cylinder and the acetylene is produced by the action of calcium carbide and water.

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2$$



Advantages:

1. Equipment is cheap as compared to other welding process.
2. Maintenance of equipment is very less
3. It is a portable process
4. It can be used for cutting of metals of small thickness
5. It is specially used for sheet metal work
6. Metal to be welded from 2mm to 50mm thickness.

Disadvantages:

1. It takes long time for heating the job as compared to the arc welding
2. The heat affected area is more
3. This is prone to corrosion and brittleness
4. Gases are expensive and difficult to store

Applications

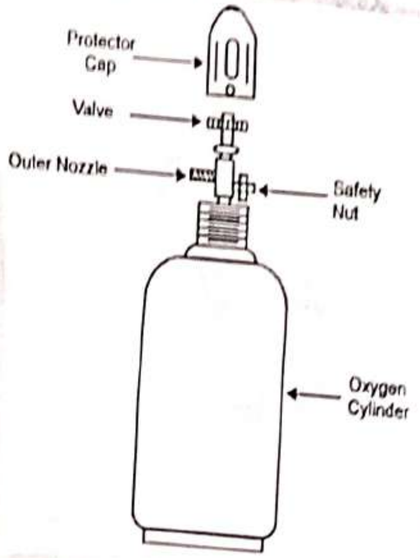
1. It is used to join thin metal plates
2. It can be used to join both ferrous and non-ferrous metals
3. Gas welding mostly used in fabrication of sheet metal
4. It is widely used in automobile and aircraft industries.

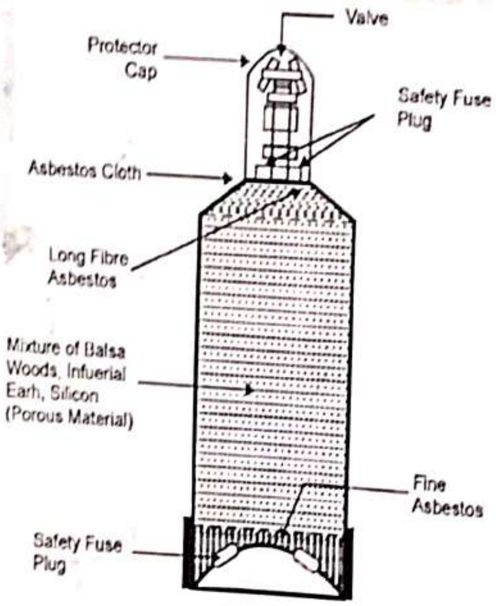
Equipments used for gas welding:

- Gas cylinders, Pressure regulators, Pressure gauges, Hoses, welding torch, check valve or control valve, flash back arrestor, Goggles welding gloves, spark lighter and wire brush.

Gas cylinders

oxygen cylinder / acetylene cylinder.




Oxygen cylinder:

The standard colour of the cylinder is black. The cylinder is made up of steel in capacity range 2.25 to 6.3 $m^3$. The cylinders are filled with oxygen at about 15 $kg/cm^2$ at 21°C. The cylinder can be opened ~~for~~ or closed by a wheel which operates a valve. A protector cap is provided on the top of a cylinder to safe-guard the valve.

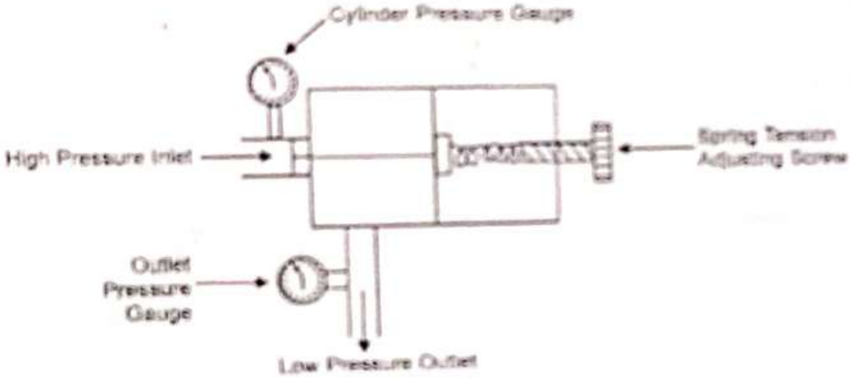
Acetylene cylinder:

The standard colour for acetylene cylinder is maroon. It is also made up of steel. Gas is filled at a pressure of 18 - 20 $kg/cm^2$. The capacity of the cylinder is about 10 $m^3$. Regulator valve and safety valve are mounted on cylinder.

safety plugs are also provided on the bottom of the cylinder / The acetylene is dissolved in acetone.

Pressure regulators

Regulator is used to control the flow of gases from high pressure cylinder. The working pressure of oxygen cylinder is 0.7 bar to 2.8 bar the working pressure of acetylene 0.07 bar to 1.03 bar.




Pressure gauges

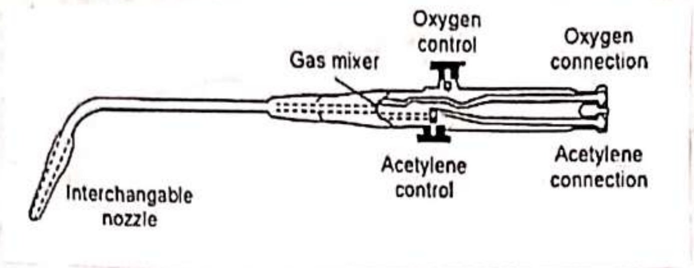
The regulator has two separate gauges: a high pressure gauge for gas cylinder and a low pressure gauge for pressure of gas fed to the torch.

Hoses

Hoses between the torch and the gas regulators should be colour coded.

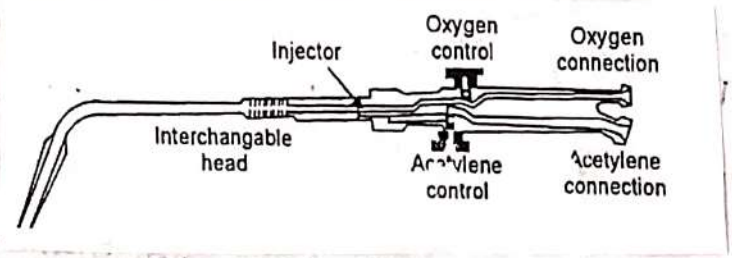
## Welding Torch:

1) Medium Pressure or Equal pressure welding torch




It is a mixing device to supply equal volumes of oxygen and acetylene to the nozzle and is fitted with regulating valves to vary the pressure of the gases as required. The welding torch is made of bronze or brass

2. Low pressure welding torch




It is a device to produce and adjust a suitable oxy-acetylene flame in which the fuel gas is generated at low pressure. The low pressure blow pipe has an injector nozzle inside its body through which the high pressure oxygen streams out. This oxygen draws the low pressure acetylene into the mixing chamber and gives it the necessary velocity to produce a steady flame

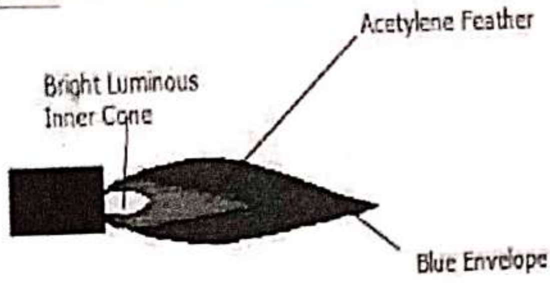
Check valve or control valve - It is a safety device attached between hoses and regulator outlets.

Flash back arrestor

A flash back arrestor is designed to contain a flashback and prevent it from penetrating into upstream equipment. The main parts are non-return valve, sintered flame filter, thermal activated cut off valve.

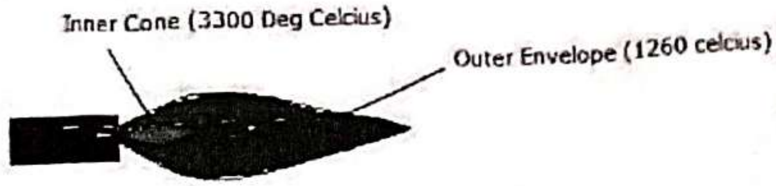
Types of flames:

1) Neutral flame



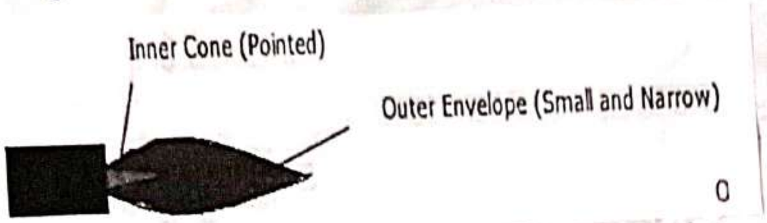

It is produced when the ratio of oxygen to acetylene, in the mixture leaving the torch, is almost exactly one to one. It's termed 'neutral' because it will usually have no chemical effect on the metal being welded. It is commonly used for the welding of mild steel, stainless steel, CI copper and aluminium.

2) Carburizing or Reducing flame.



The carburizing flame is created when the proportion of acetylene in the mixture is higher than that required to produce neutral flame. A carburizing flame has an approximate temperature of 5500°F (3038°C). A reducing flame can be recognised by acetylene feather which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in colour.

Oxidizing flame




The oxidizing flame results from burning a mixture which contains more oxygen than required for a neutral flame. The outer flame envelope is much shorter and tends to out at the end on the other hand the neutral and carburizing envelopes tends to come to a sharp point. An oxidizing flame tends to be hotter than the neutral flame. It is used for welding of copper base metals, zinc base metals, a few types of ferrous metals such as maganese steel.

2022, 15:04

# ARC WELDING

Principle:

It is a welding process, in which heat is generated by an electric arc struck between an electrode and the workpiece. Electric arc is luminous electrical discharge between two electrodes through ionized gas.

Types

1. Carbon Arc welding (CAW)

2. Manual metal Arc welding (MMAW)
   or
   Shielded metal Arc welding (SMAW)

3. Submerged Arc welding (SAW)

4. Gas Tungsten Arc welding (GTAW)
   or
   Tungsten Inert gas welding (TIG)

5. Gas Metal Arc welding (GMAW)
   or
   Metal inert Gas welding (MIG)

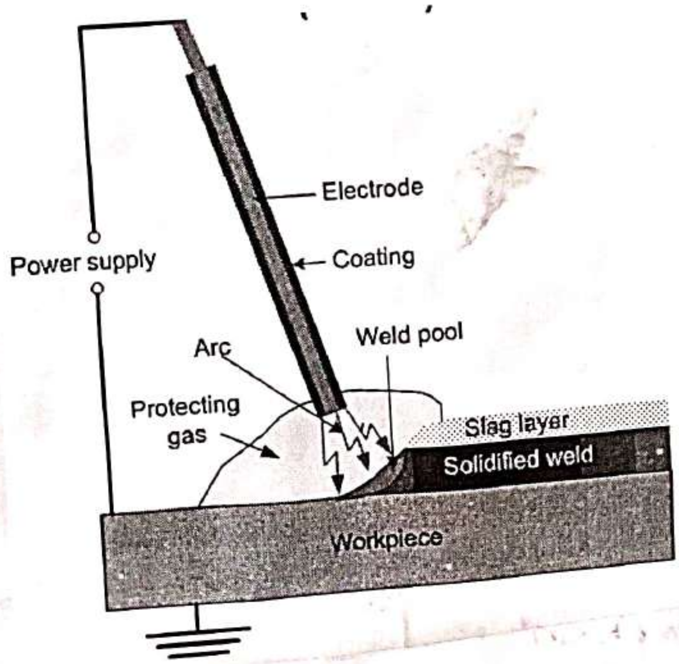
6. Plasma Arc welding (PAW)

7. Electro Slag welding (ESW)

11, 2022, 15:04

## 2 Manual metal Arc welding (Shielded metal Arc Welding)

Principle: Manual metal arc welding process in which an electrical arc burns between a sheathed rod electrode and the material.




The electric arc develops when electricity jumps across an air gap between the end of metallic electrode and the welding job surface. The electrode is coated with flux which is consumable. The arc created due to the ionization of air between the electrode tip and the base metal generates an intense arc heat having a temperature between 3600°c and 4000°c.

11, 2022, 15:04

The welding current is provided by an AC or DC machine. The intense heat of the arc melts a small portion (molten pool) on the job directly under the arc at the end of the electrode. The melted electrode joins into the molten pool of the welding job and produces a homogeneous weld. The coating (flux coating) on the electrode also melts and provides a gaseous shield around the arc which protects the molten metal from atmospheric contamination. Hence this is called shielded metal arc welding. The welding speed and feed of the electrode is controlled manually by the welder himself. So it is also called manual metal arc welding.

<u>Advantages:</u>

Simple, portable and inexpensive equipment

Wide variety of metals, welding positions and electrodes are applicable

Suitable for outdoor applications

<u>Disadvantages:</u>

The process is discontinuous due to limited length of the electrode.

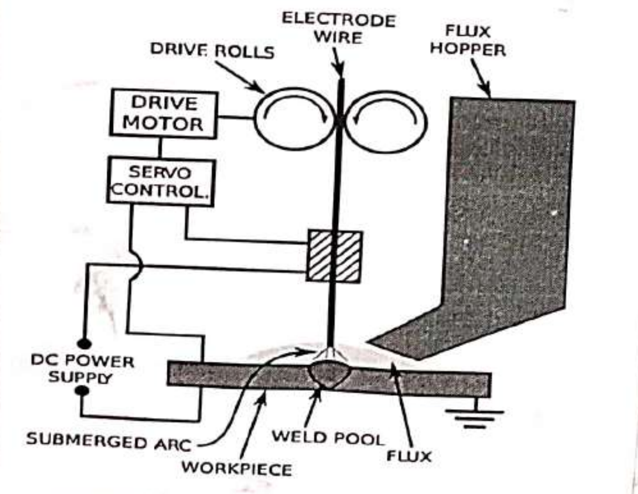
Weld may contain slag inclusions

- Fumes make difficult the process control

## (3) Submerged Arc Welding (SAW)

Principle:

Submerged Arc welding (SAW) is a welding process, which utilizes a bare electrode producing an arc between itself and the workpiece within a granular shielding flux applied around the weld. The arc heats and melts both the workpieces edges and the electrode wire.




Working:

The submerged arc welding, the welding are shielded by thick layer of granular flux fed into welds that cover the weld zone. The granular flux composite of silica, manganese oxide, lime and calcium fluride. The flux is introduced to weld joint slightly ahead of arc.

The flux are slightly melted and mixed with molten metal to remove impurities and solidify at top of the weld joint to form a slag. It provides good protection from atmosphere and then good thermal insulation permit deeper heat penetration. This result slowly cooling and give high quality weld joints. The electrode wire is automatically fed from the coil. It provides high welding productivity and 4-10 times as shielded metal arc welding.

**Advantages:**

- High deposition rate 45 kg/h possible
- No arc flash
- High speed welding, suitable for steel sheet 2.5m/min
- Deep weld penetration

**Limitations:**

- Limited for ferrous metal
- Flux and slag residue can present
- health and safety issue
- Require post weld slag removal and/or pass
- It requires flux handling system.

**Applications:-**

- Stainless steel, Nickel base alloy
- Low alloy steel, carbon steel
- Chromium molybdenum steels.

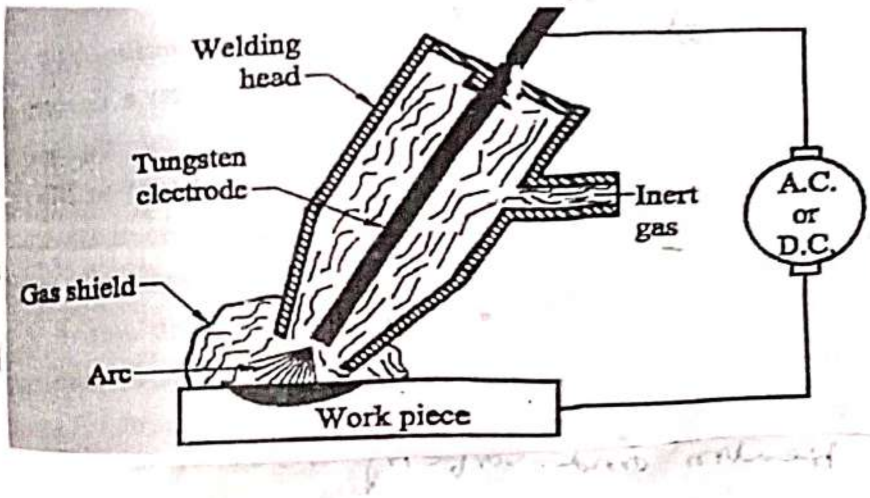
022, 15:04

4 Gas Tungsten Arc Welding (or)

Tungsten inert gas welding

Principle:

In a TIG welding process, a high intense arc is produced between tungsten electrode and workpiece. In this welding workpiece is connected to the positive terminal and electrode is connected to negative terminal. This arc produced heat energy which is further used to join metal plate by fusion welding. A Shielding gas is also used which protect the weld surface from oxidation




Working:

In this method the arc is generated between the base metal and tungsten electrode. There is an electrode holder in which the non-consumable tungsten electrode is fixed, when the arc is produced. By supplying the electric power between electrode and workpiece, the inert gas from the cylinder is passed through nozzle.

2022, 15:04

The inert gas (Argon, helium, nitrogen and $CO_2$) surrounds the arc and it protects the weld from atmospheric effects and hence, defect free joints are made. An electrode has high melting point (3430°C). Therefore, it will not be melted during welding. Nozzle size, gas flow rate, filler rod size, electrode diameter and current are chosen depending on the position of weld and metal thickness.

Advantages:

1. It is applicable to wide range of materials such as aluminium, stainless steel, magnese and copper alloys.
2. It is more suitable for thin section
3. No flux is required
4. It produces high quality weld

Disadvantages:

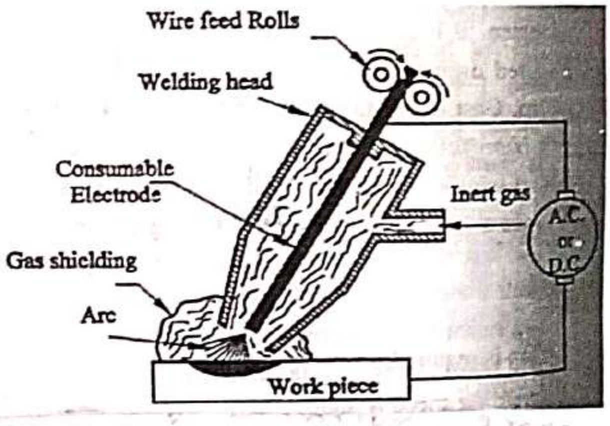
1. It is generally restricted for flat / horizontal welding
2. It is slow in operation than consumable electrode gas metal arc welding
3. Equipment is more sophisticated, so it is also more costly.

Applications:

1. Aluminium, magnesium, copper alloys can be welded easily. Thin parts and sheet metals can be welded easily
2. Aircraft, chemical and instrument industries use this welding process
3. Rocket motor chamber fabrication welding can be done by this process.

## 5 Metal inert gas welding (MIG)

MIG welding is also called Gas metal arc welding (GMAW). In this arc welding, the electric arc is produced between a consumable metal wire electrode and the workpiece. Argon, helium, $CO_2$, argon-oxygen or other gas mixture are used as inert gas. The surrounded inert gas protects the weld from atmosphere.




The welding can be done manually or automatically. Either DC generator or AC transformer is used for MIG welding. The current ranges from 100A to 400A depending upon the diameter of the wire. The Gas metal arc welding equipment consist of a welding torch or gun, power supply, shielding gas supply and wire drive system.

Advantages:

1. It is suitable for welding a variety of ferrous and non ferrous metals
2. No flux is required
3. High welding speed is obtained
4. It produces high quality weld

Limitations:

1. It cannot be used in the vertical or overhead welding positions
2. It needs more maintenance
3. The process is more expensive

Applications:

1. It is suitable for thin sheets
2. Industries: motor car manufacture, ship-building, aircraft engineering and manufacture of tanks, pressure vessels and pipes.

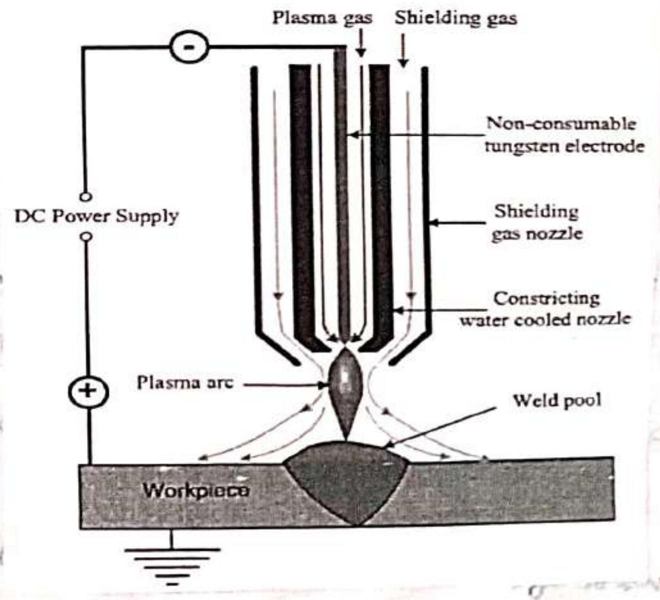
Difference between MIG and TIG welding

| | MIG | TIG |
|---|---|---|
| 1. | It uses consumable electrode | - Non consumable electrode |
| 2. | It is used for thicker material | - Thinner material |
| 3 | Feeding of electrode is continuous | - Feeding of electrode is discontinuous |
| 4. | - Low Quality weld | - High quality weld |
| 5. | needs less skilled welder | - Highly skilled welder |
| 6 | Process is fast | process is slow |
| 7 | Automation is easy | Automation is difficult |
| 8 | It produces more smoke | It produces less smoke |

022, 15:04

## 6. Plasma arc welding (PAW)

**Principle:** plasma is high temperature ionized gas. A plasma is the gas region in which there is practically no resultant charge (ie) where positive ions and electrons are equal in number. When high temp. plasma is passed through the orifice, the proportion of the ionised gas increases and plasma arc welding is formed.




**Plasma arc welding equipment**

① power source: A constant current drooping characteristics power source which the supplied DC welding current.

② plasma torch:

All plasma torches are water cooled even the lowest current range torch because the arc is contained inside a chamber in the torch where it generates considerable heat. If water flow is interrupted briefly, the nozzle may melt.

③ Shielding gases

Very pure argon is used for plasma and shield when welding reactive metals such as titanium and zirconium which have a strong affinity for hydrogen.

④ Control console

The plasma arc torches are designed to connect to the control console rather than power source.

Advantages:

1. Penetration is uniform, Arc stability is good
2. High speed weld can be obtained
3. The production rate is high

Limitations

1. Huge noise occurs during welding
2. It is limited to high thickness applications
3. Cost of equipment is high
4. Ultra violet ray radiation can affect human body
5. Gas consumption is high

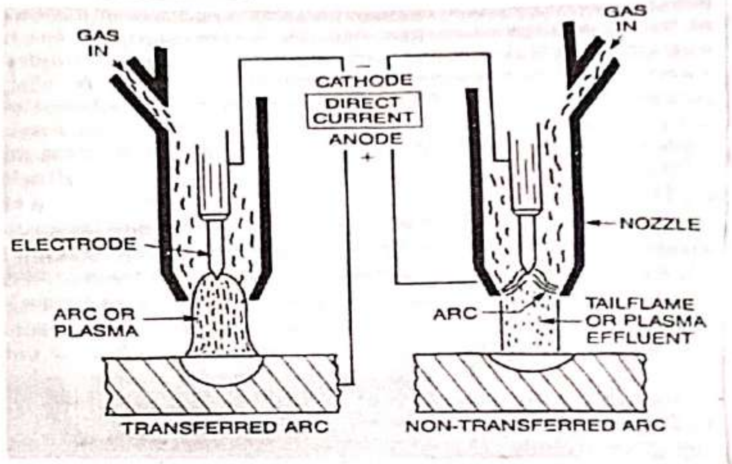
Applications:

It is used in aerospace applications, welding titanium plates, welding nickel alloys, tube mill applications

It is used for high melting point metals.

22,15:04

**Types of Plasma Arc Welding**




Transferred type:

In the transferred type, the restricting orifice is in an inner water cooled nozzle within which the tungsten electrode is centrally placed. Both work and nozzle are connected to the anode and the tungsten electrode to the cathode of a DC supply. The temperature of a constricted plasma arc may be in the order of 8000°C to 25000°C

Non-transferred type

In this type, power is directly connected with the electrode and the torch of nozzle. The tungsten is connected to the negative pole (cathode) of a DC supply and the nozzle to the positive pole.

The non transferred plasma arc possesses comparatively less energy density as compared to transferred arc plasma and it is employed for welding and applications involving ceramics or metal plating.

# Electro Slag welding (ESW)

Principle: It is a welding process in which the heat is generated by an electric current passing between consumable electrode (filler metal) and the workpiece through a molten slag covering the weld surface.

Working:

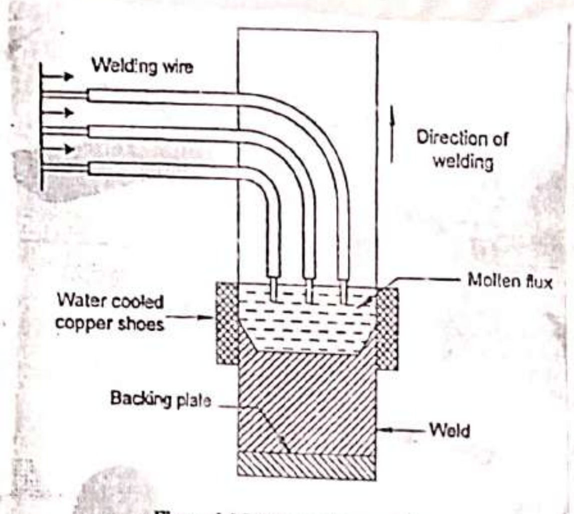



Figure 1.25 Electroslag welding

In this process, prior to welding gap between two workpieces is filled with a welding flux powder. Electro slag welding is initiated by an arc between electrode and workpiece. Heat generated by the arc melts the fluxing powder and it forms molten slag. Heat is continuously produced by the electrical resistance of the molten slag.

Quality of the weld depends on

1. The ratio of width of the weld pool and its maximum depth known as form factor.
2. Weld current and voltage
3. Slag depth
4. Number of electrodes and their spacing

Advantages:

1. Heavy thickness metals can economically be welded

2. Stress formation is low

3. Preparation of joints is easier

4. Slag consumption is low

5. High deposition rate of upto 20 kg/h is obtained during the weld

Limitations

1. It is difficult to weld cylindrical objects

2. Hot cracking may occur

3. Grain size becomes larger

4. Toughness of the weld is low

5. Only vertical position is possible

6. The cost is high as the equipment is fully automatic and it is of special design

Applications

1. To join low carbon steel plates and sections are very thick

2. Carbon steel alloys steels and nickel alloys

3. Used for large structural steel sections such as heavy machinery, bridges ships and nuclear reactor vessels.

## Resistance welding

**Principle:**

Resistance welding is a liquid state welding process in which the metal to metal joint created in liquid or molten state.

It is a thermo electric process in which heat is generated at the interface surfaces of welding plates due to electric resistance and a controlled low pressure is applied to the plates to create a weld joint.

**Types of resistance welding**

1. Spot welding
2. Seam welding
3. Projection welding
4. Resistance butt welding
5. Percussion welding
6. High frequency resistance welding

$$Q = KI^2RT$$

$Q$ → heat generated

$K$ → Thermal constant

$I$ → current in amperes

$R$ → Resistance of area being welded

$T$ → Time for flow of current

## (1) Resistance Spot welding (RSW)

It is one type of electrical resistance welding processes. Spot welding is used for making lap joints. By using this method, the metal sheets ranging from 0.025 mm to 1.25 mm thickness can be easily welded. The parts are heated at the area of contact by electrical resistance. Then the electrodes are pressed against the metal pieces by mechanical or hydraulic pressure.

The electrodes must possess high electrical and thermal conductivity and they retain the strength on high temperature. So they are made of pure copper for a limited amount of service and alloys of copper or tungsten alloys for extended service life. Electrodes are cooled by water during the operation to prevent overheating.

Spot welding can be done on metal sheets upto 12 mm thick. All combination of ductile metals and alloys can be spot welded. The electrode pressure can be in the range of upto 2 kN.

2022, 15:04

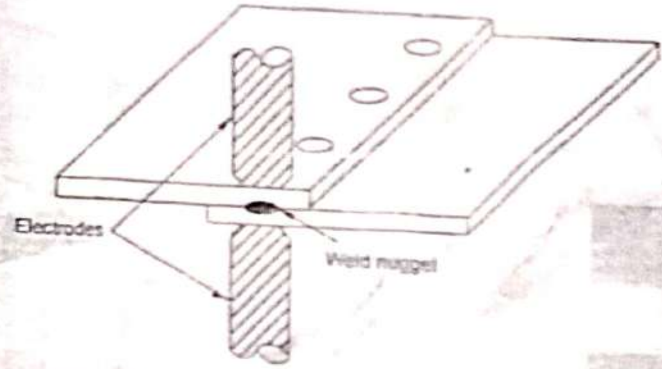



*Figure 2.2 Spot welding*

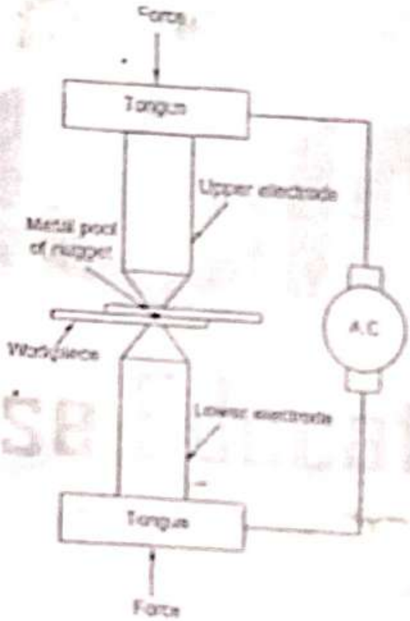



*Figure 2.3 Principle of resistance spot welding*

Sequence of a resistance spot welding

1. Squeezing
2. welding
3. Holding
4. off or releasing

22, 15:04

## Electrode force:

$$F = \frac{\pi D^2 P}{4}$$

where $D$ - piston diameter

$P$ - line pressure

Electrode force is most commonly provided by pneumatic or hydraulic systems

Electrode used in resistance welding should be cooled properly in order to avoid losing hardness and deterioration.

## Advantages:

1. It is quick and easy
2. There is no need to use any fluxes and or filler metal to create a joint by spot welding
3. It can be performed without any special skill
4. The rate of production is high
5. Less amount of maintenance cost
6. Process - free from fumes and spatter
7. It is more economical
8. No edge preparation is required
9. Smaller heat affected zone is produced

10. It eliminates warping and distortion of parts.

## Limitations:

1. It can create only localized joints which may not be particularly strong
2. The electrodes have to be able to reach both sides of the pieces of metal that are being joined together.
3. Warping and a loss of fatigue strength can occur around the points
4. It is suitable for thin sheets only
5. Equipment used in spot welding is costly

## Applications

1. It is used in joining killed carbon steel low alloy steel, high alloy steel, titanium
2. It is frequently used in the creation of autobody components with a robot arm moving the spot welding device. Typical car body has about 10,000 spot welds.
3. It is widely used in mass production of automobiles, appliances, metal furniture and other products made of sheet metal.
4. It is used in manufacture of sheet metal goods.

## (2) Seam welding or Resistance Seam welding

In spot welding, if both bottom and top electrodes are replaced by rotating wheels it is called Seam welding. In resistance seam welding, the welding electrodes are motor driven wheels as opposed to stationary rods. In this welding, overlapping sheets are gripped between two wheels or roller disc. The workpiece are placed between two rotating wheel electrodes as shown in figure.

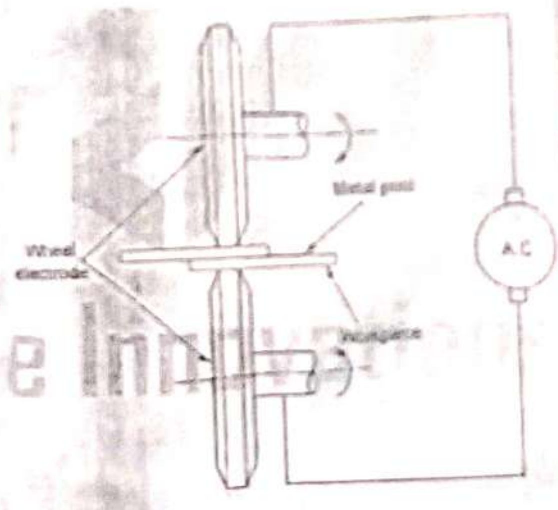



*Figure 2.11 Seam welding*

022 15:04

Advantages:

1. Gas tight as well as liquid tight joints can be made.

2. Overlap is less than spot or projection welding

3. This method is efficient energy use

4. Filler materials are not required and hence, there are no associated gases and fumes.

5. It produces clean welds.

Limitations:

1. The welding process is restricted to a straight line or uniformly curved line.

2. The metal sheets having thickness more than 3 mm can cause problems while welding.

3. The design of the electrodes may be needed to change to weld metal sheets having obstructions

4. The workpiece to be welded should overlap sufficiently to prevent metal flowing out from the edges of the pieces during welding under pressure.

## Applications

1. It is used to make tin cans, leak proof tanks, automobile mufflers, gasoline tanks, drums, radiators, house hold utensils, transformers, refrigerators, evaporators and condensers, automobile bodies
most of the metals can be welded.

## 3 Projection Welding

Projection welding is an electric resistance welding process that uses small projections, embossments or intersections on one or both components of the weld to localize the heat and pressure.

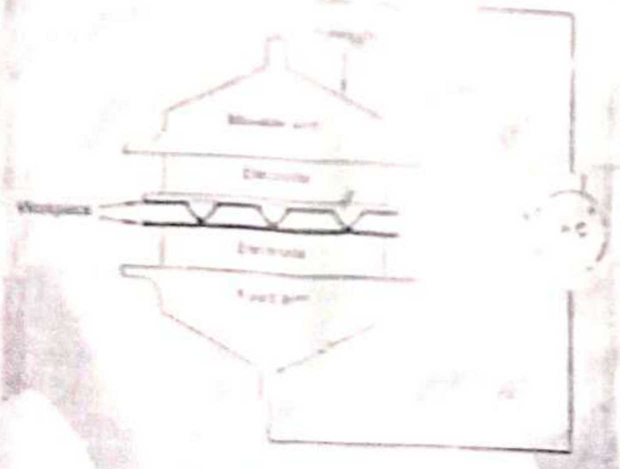



Figure 2.14 Projection welding

Advantages:

1. More than one weld can be made simultaneously

2. Projection welding electrodes have a longer life when compared to spot welding electrodes

3. Heat treated parts can be easily welded without affecting the heat treatment

4. Welding current and pressure required is less.

5. It is more suitable for automation

6. Filler metals are not used, Therefore clean weld joints are produced

Limitations:

1. All types of metals can't be welded using projection method

2. Projections can't be made in thin workpieces.

Jul 11, 2022, 15:04

3. There are is an extra operation required called forming of operation projection

4. Thin workpieces can't withstand the electrode pressure.

5. The area which is less than 65 $mm^2$ can't be welded by this method

Applications

1. It is used to make press parts
2. It is mainly used in automobile sector
3. Fasteners can be welded to surfaces when the fasteners has machined or formed projections on its head
4. It is used in refrigeration systems such as condensers, grilles, racks etc.

④ Resistance butt welding

Upset butt welding

For making upset welding, edges of the workpiece should be cleaned perfectly and flatten. The Jaws act as electrodes. Then the jaws are brought together in a solid contact when the current flows through the point of contact of Jaws to form a locality of high electric resistance. At this point, the applied pressure upsets or forges the parts together.

Adv

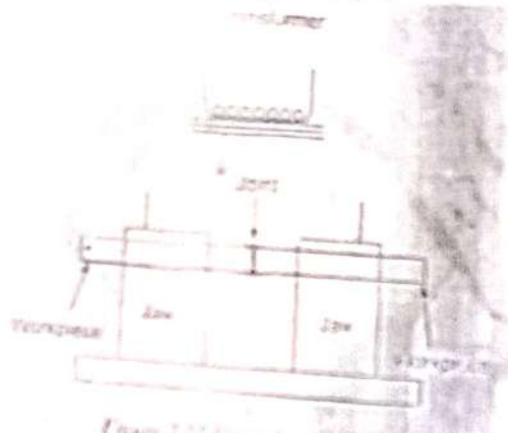


Figure 2.11 Upset butt welding

## Advantages:

1. It is more suitable for welding many alloys.
2. The metal retains base metal characteristics because the base metal does not melt during welding.
3. Upset welding is mainly adopted to fabricate very large structures compared to conventional resistance welding.

## Applications:

- Welding non ferrous materials for smaller cross-section such as bars, rods, wires, tubes etc.
- It is applied in welding steel rails.

Flash butt welding

The welding process in which the ends of rods are heated and fused by an arc struck between them and forged to produce a weld is called flash butt welding

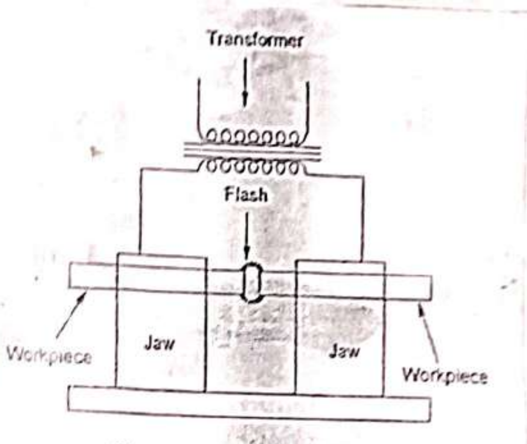


*Figure 2.16 Flash butt welding*

In this process the parts to be welded are clamped in copper jaws of the welding machine one of the jaws is stationary and other one is made as movable the ends are forced together by applying mechanical force to complete the weld.

Advantages:

1. Many dissimilar metals with different melting temperature can be flash welded.
2. It allows fast joining of large and complex parts
3. Power consumption is less
4. Clean welds can be made.

Applications

Butt welding is used in automobile construction of the body, axles, wheels, frames etc.

Non ferrous alloys such as lead, tin, zinc, antimony, bismuth and their alloys can not be welded by this method.

2022, 15:04

2. It is also used in welding motor frames, transformers boxes, and many types of sheet steel containers such as barrels and floors.

(5) Percussion Welding →

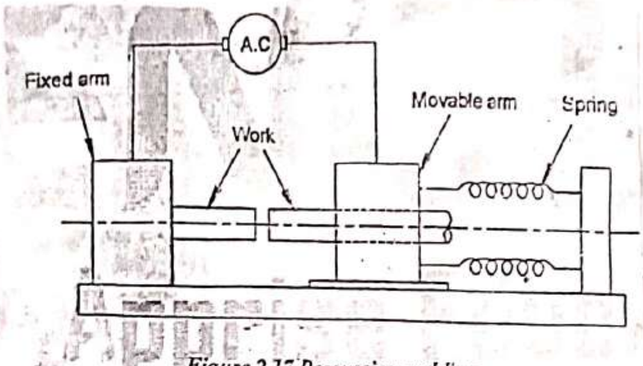


Figure 2.17 Percussion welding

The parts to be welded are clamped in copper jaws of the welding machine in which one clamp is fixed and other one is movable. Heavy electric current is connected to the workpieces.

Now, the movable clamp is released rapidly and it moves forward at high velocity. When the two parts are approximately 1.6 mm apart, a sudden discharge of electrical energy is released thereby causing an intense arc between two surfaces. The arc is extinguished by the percussion blow of two parts coming together with sufficient force to complete in 0.1 second.

$$\text{Welding energy } E = \frac{1}{2} C V^2$$

E → energy in watt seconds

C → capacitance in farads

V → voltage

Amount of energy required to make joints

(1) cross sectional area of joint

(2) properties of work metal or metals

(3) Depth to which metal is melted on w/p

Advantages:

1. The time cycle involved is very short
2. Shortness of arc limits melting and heating
3. Heat treated and cold worked materials can be welded without annealing.
4. No filler metal is required
5. No cast structure is produced at interface
6. Charging rate is low and controlled
7 welding of dissimilar metal and copper to steel is possible
8. welding of metals with high melting point such as tungsten, molybdenum etc, are possible by this method.

Limitations.

1. The welding process is limited to butt joints
2. Total area is limited
3. Similar metals can usually be joined more economical
4. welding is typically dirtier and less smooth than resistance welding
5. The workpieces must be free of oil or dirt.

Applications:

1. It is used for fine wire leads to filaments such as in lamps and electrical components
2. The method is also used to weld pins studs, bolts and so on.

## 6 Stud welding

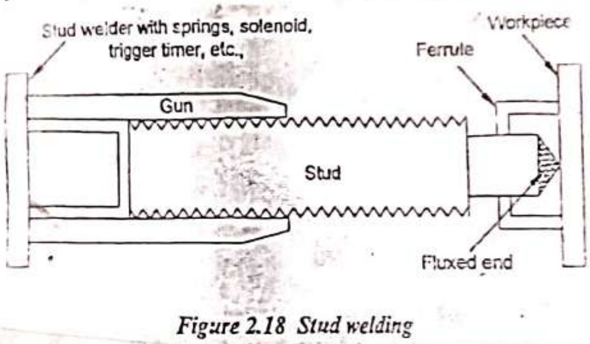



*Figure 2.18 Stud welding*

An electric arc is produced between stud and flat surface of the w/p. The arc melts the end of the stud and the pressure is applied on the stud to fix it on the work metal surface.

A special welding gun is used for stud welding ~~which~~ which consists of spring, solenoid, trigger timer etc. The stud is placed in the welding gun. The front end of the gun is held against the work surface. When the trigger of the gun is pressed, welding current flows between end of the stud and work surface. An arc is produced between the gap of the stud and work. A molten pool is formed on the work surface. Next, the melted end of the stud is pressed on the molten pool of work and it gets welded to the work. The front end of the stud has a flux coated conical surface. The flux protects the welding from atmospheric effects. The time required for welding is approximately one second. This process is used in mass production.

Advantages:

1. The welded joint is stronger than the parent material or the stud.
2. Deep weld penetration is possible
3. High speed welding of studs on thin steel sheets is possible.
4. It brings down time and it cuts labour and material cost
5. It is user friendly and easy to operate
6. Machine is equipped with effective safety operations for user
7. It has very low distortion by extremely short welding time.
8. The process is normally free from smoke and spatter
9. The process involves less maintenance cost.

Applications:

1. Stud welding is used in fixing floor, air lines, wiring looms, machine guards, handles, insulations and fireproofing materials.

2. In the automotive industry, the process is used to assemble heat shields, power steering and dash board components, instrument panels installation, exhaust system, lighting systems brake lines and electrical wire routing. dish washers, bottle washers

3. In the farm equipment industry, it is used to assemble tractors, cabs, spreaders etc

4. Cookware such as utensils, pots, pans and handles are made.

22, 15:04

## (5) Friction Welding

Principle:

Friction welding is a solid state welding process in which coalescence is achieved by frictional heat combined with pressure. The heat is obtained through mechanical friction between rubbing surfaces of workpiece in relative motion to one another.

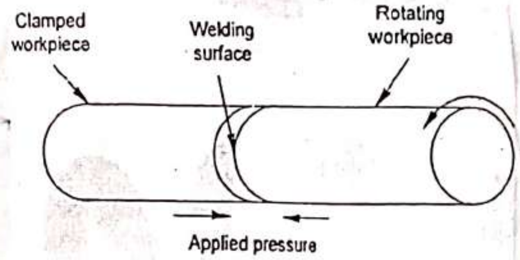



*Figure 3.14 Principle of friction welding*

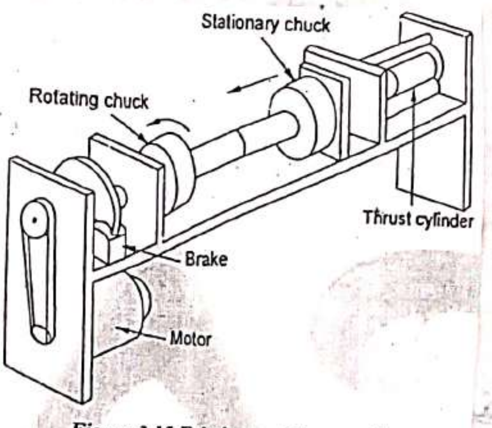



*Figure 3.15 Friction welding machine*

Working:

Initially the components to be welded are held in chucks or clamps. One part is rotated at high speed (1500 to 3000 rpm) using rotating chuck and other part is held stationary using stationary chuck as shown in fig. During welding, the stationary chuck is moved and contacted with the rotating component under pressure. The heat is produced between contact surfaces. This heat is used to weld the components under pressure. The heat is produced between contact surfaces. This heat is used to weld the components under pressure. Pressure is used to generate sufficient heat to reach a bonding temperature within a few seconds. The pressure during welding varies between 40 MPa to 450 MPa. The heat is concentrated and localised at the interface. Grain structure is refined by hot work and there is little diffusion across the interface. During this period, the rotation is stopped and pressure is retained or increased to complete the weld. Then the metal is slowly extruded from the weld region to form an upset. For stopping the relative motion the brake system is used.

The materials that can be welded using friction welding are listed as follows.

1. brass and bronze

2. copper and nickel

3. lead

4. ceramics

5. Titanium alloys

6. Stainless steel

7. Tungsten

8. Vanadium

9. Aluminium and aluminium alloys

10. Magnesium alloys

Sequence of operation in friction welding

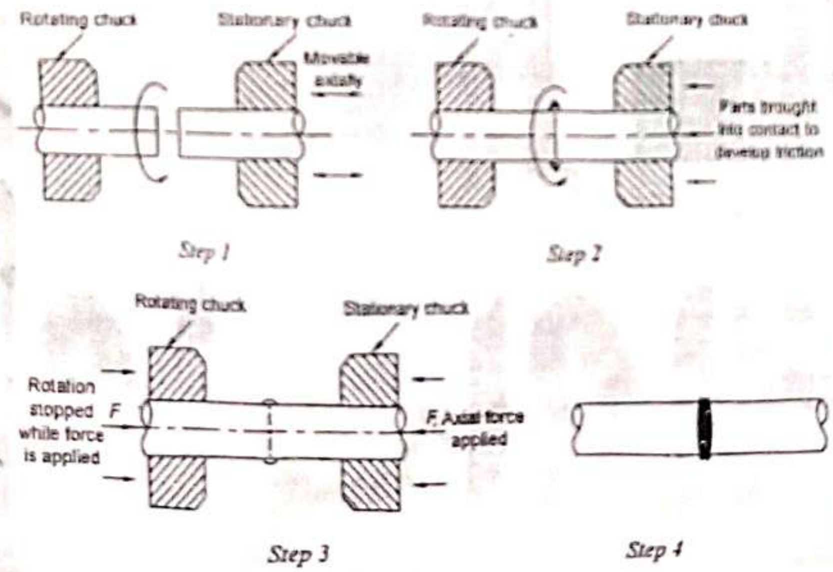



Figure 3.16 Sequence of operation in friction welding

Step-1 - Component fitted to rotating chuck is rotated at high speed

Step-2 - Component fitted to stationary chuck is brought into contact under an axial force.

Step-3 : As axial force is increased, the flash begins to form

Step-4 Component fitted to rotating chuck comes to stop as the weld is completed.

Types:

1) Continuous drive or Spin friction welding

2) Inertia friction welding

3) Linear friction welding

Process parameters

1. power required (25 KVA to 175 KVA)

2. peripheral speed of the rotating component (1500 to 3000 rpm)

3. Axial pressure applied (40 MPa to 450 MPa)

4. Time of duration of the operation

# ① Thermit Welding

Principle:

Thermit welding is a welding process in which heat produced during an exothermic reaction is used to weld two metal pieces together. No external heat source is required during this welding process except initiate the process. Thermite material (mixture of a metal oxide, aluminium powder and fuel) is used for the welding process.

Thermite welding is the process of placing the thermite mixture in a crucible, igniting it then pouring the resulting molten iron into a mold around the piece to be welded.

The mixture reacts according to the chemical reactions

Metal oxide + Al(powder) → metal + Al oxide + heat

with Iron,

① $8Al + 3Fe_2O_4 \rightarrow 9Fe + 4Al_2O_3 + heat$ (3000°C, 35KJ/kg of mixture)

with copper

② $3CuO + 2Al \rightarrow 3Cu + Al_2O_3 + heat$ (4860°C, 275Kcal)

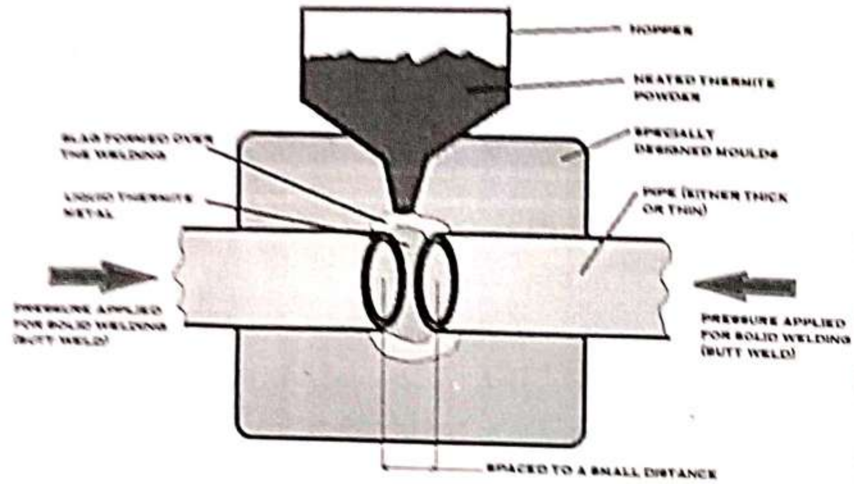
with chromium

③ $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3 + heat$ (3000°C 540 Kcal)

## Classification of Thermit welding

I Pressure thermit welding

II Non-pressure Thermit welding

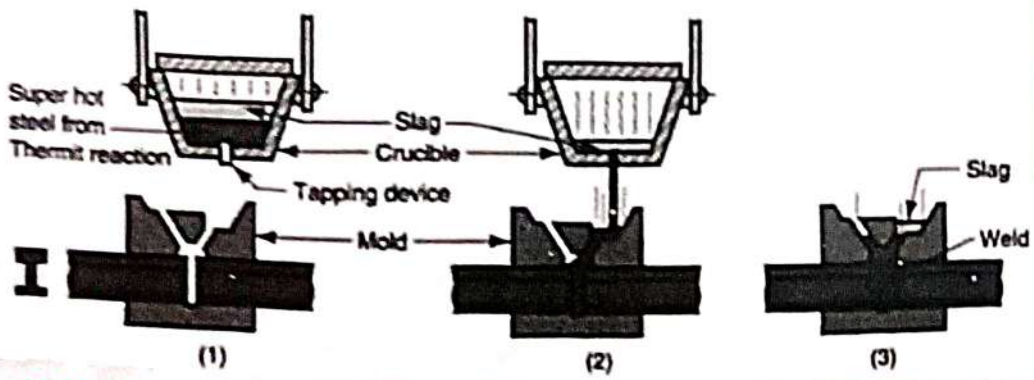



with nickel

$3NiO + 2Al \rightarrow 3Ni + Al_2O_3 + 864\ KJ/mol$

temp: 3170

Non Pressure Thermit welding




with manganese

$3MnO + 2Al \rightarrow 3Mn + Al_2O_3 + 1686\ KJ/mol$

temp: 2425°C

$3MnO_2 + 4Al \rightarrow 3Mn + 2Al_2O_3 + 4356\ KJ/mol$

temp: 4990°C

## Equipments

1. Refractory crucible:

The thermit mixture of iron oxide and aluminium reacts in a refractory crucible. This crucible is made by graphite or other

Suitable refractory materials, which can handle temperature around 3000°C. There is a zone at bottom of the crucible for exit of molten metal, The slag form by aluminium oxide floats over molten metal due to density difference which is removed from there.

Thermite mixture:

A mixture of aluminium and iron oxide in proper ratio known as thermite mixture. The ratio of aluminium to iron oxide is about 1:3 by weight, In the copper thermite welding copper oxide with aluminium mixture is used.

(Quantity) $Q = \frac{M}{0.5 + 0.07S}$  M – molten metal required, S – percentage of steel punchings

Mold:

In the thermit welding mold is created by either graphite or sand. Graphite molds are permanent mold which is used to make various similar joints. Sand mold are used where the join design is different everytime. For making sand mold, wax pattern is used. This mold made around the part that needs to be welded. The mold contains runner, riser gating system, etc same as used in casting.

Wax pattern:

Wax pattern is used to make sand mold. The sand is rammed around the welding workpieces. The sand is rammed around the wax pattern to make sand mold. After proper ramming action, the mold is heated which removes the wax pattern by melting of it.

Moulding flask:

The sand mold creates into the moulding flask. The wax pattern which is created around the weld cavity is placed at the middle of the flask. The molding sand rammed into the flask to make sand mould. Mold handle clamp which is used to fix moulding flask around the welding plates.

To ignite the thermit mixture, preheating of the mixture is essential which is done by ignite powder. It is highly inflammable powder which can achieve the maximum temperature of 1200°, which is essential to start thermite reaction.

Working:

For both the workpieces which are now to be weld are cleaned. Now the wax pattern is created around the weld cavity. A molding flask is fixed around the joint with the help of mold handle clamp. This wax pattern is situated at the middle of the flask. Then the molding sand is rammed around the wax pattern to create mold in which the molten metal will pour. This mold involves all necessary parts like runner, riser, pouring basin, gating system, opening for wax pattern etc. same as involved in casting. Then the mold is heated to remove wax pattern. The wax is melted and run offs the wax pattern earlier prepared at bottom of the sand mold. The thermit mixture is taken into the refractory crucible. The ignite powder is placed over the mixture. This mixture is ignited by a magnesium ribbon. This will start the thermite reaction which liberates a huge amount of heat. This reaction form molten state of iron which flows from crucible to sand mold. This molten metal fills the weld cavity and fuses the parent metal to make a permanent joint. This will allow to cool down. After proper cooling, flask is removed from the joint

After removing the flash, machining is done to remove the welding burr or some extra metal.

Advantages:

1. It is simple and easy process
2. Low setup cost
3. Metal joining rate is high
4. Thermite welding can be done at site where casting is impossible
5. This can be used where power supply is not available.

Disadvantages:

1. It is used for limited metals like iron and copper.
2. It is uneconomical for welding light parts.
3. Highly depends on environmental condition like moisture content, workpiece alignment

Applications

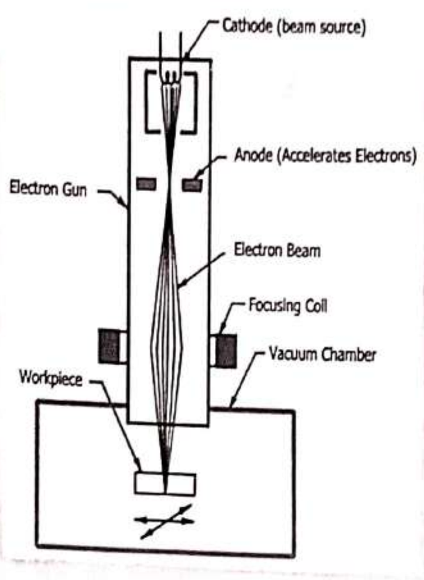
1. It is mostly used to weld railroad at the site
2. It is used to weld thick plate before introduce electroslag welding.
3. They are used to repair heavy castings.
4. It is used to weld cable connectors of copper.
5. It is used to make structure joints in large ships (hulls) etc.
6. It is used to joint pipe, thick plate etc where power supply is not available.

22, 15:04

## 3. Electron beam welding (EBW)

**Principle:**

It is a welding process utilizing a heat generated by a beam of high energy electrons. The electron strikes the workpiece and their kinetic energy converts into thermal energy, heating the metal so that the edges of workpiece are fused and joined together forming a weld after solidification.




Working:

In Electron beam welding, the electron is produced by the cathode of the electron gun. After cathode a cup grid is provided. It prevents the divergence of electron and controls it. Because of the high voltage applied across the cathode and anode, the anode which is positively charged attracts the electron from the cup grid. The anode accelerates the electron and its velocity increase and reaches to the range of 50000 - 200000 km/sec. From the anode, the high velocity electron beam is passed through the magnetic lens and deflector coils. The magnetic lens focuses the electron beam to the desired location on the workpiece. As the high velocity of electron beam strikes the workpiece, an intense heat is produced and it melts the metal of the two workpiece and fills the weld area. The molten weld solidifies and forms a strong weld joint.

Types of Vacuum Levels in electron beam welding

I. High Vacuum (HV-EBW)

- highest purity welds
- Deepest penetration
- Lowest shrinkage and distortion
- Highest capital and maintenance costs
- Slowest production rate

II. Medium Vacuum (MV-EBW)

- Lowest purity
- Less penetrating welds
- more shrinkage and distortion than HV-EBW
- Higher production rate and lower costs

III. Non-vacuum (NV-EBW)

- Workpiece at atmospheric pressure in air or an inert gas.
- Lowest quality welds but lowest cost highest production rate and largest components
- The power density input to the workpiece depends on the ambient gas used.

Advantages:

- high welding speed
- Welding of dissimilar metal can be done
- High weld quality and precission
- Less operating cost
- Materials with high welding temperatures can be welded easily
- Less distortion due to less HAZ
- It welds thicker sheets, ranges from 0.025 mm to 100 mm.
- It is capable of welding inaccessible joints

Disadvantages:

- Cost of equipment is very high
- High skilled operator is required
- High vacuum is required
- Large workpiece can't weld
- High safety measures are needed to work

Applications:

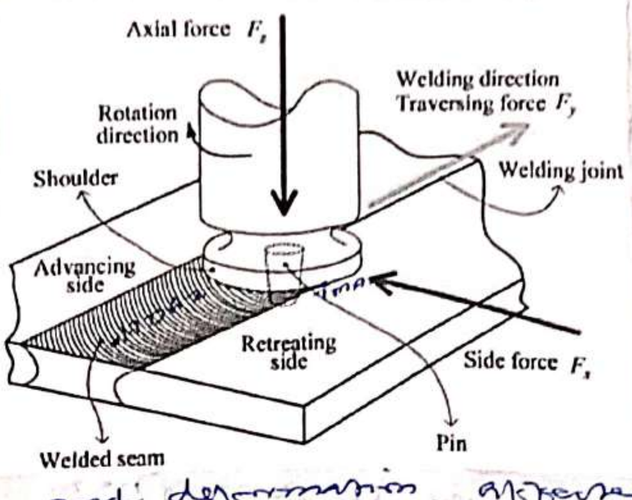
1. It is used in aerospace industries for manufacturing jet components, parts of structures, transmission parts and sensors.
2. It is used in power generation industries
3. It is used in space industries to build titanium rockets and sensors.
4. It is used in automobile industries to manufactures transmission system, gears and turbochargers.
5. It is used in electrical industries to manufactures parts of copper structures.
6. The other areas where it is used are nuclear industries, medical, research centres etc.

22, 15:04

# 5. Friction Stir Welding (FSW)

Principle:

In friction stir welding, a rotating tool is used to applied friction and pressure force on the plates. This tool rotates on its own axis and move longitudinally on the plates interface which generates heat by friction between rotating tool and workpiece. This heat deformed the interface surface and diffuses the two piece of workpiece into one another by applying a high pressure force. This joint is created due to thermo mechanical treatment on the interface surface.
The process is solid state in nature and relies on localized forging of the weld region to produce the joint.




HDAZ → heat and deformation affected zone
TMAZ → Thermo mechanically affected zone
HAZ → heat affected zone

Working:

In FSW, a cylindrical, shouldered tool with a profiled probe is rotated and slowly plunged into the weld joint between two pieces of sheets or plate material that are to be welded together. Frictional heat is generated between the wear resistant welding tool and the material of workpieces. This heat causes the workpieces to soften without reaching the melting point and allow the tool to traverse along the weld line. This will deform the material plastically due to heating by friction force. The resultant plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged together by the intimate contact of the tool shoulder and the pin profile. This leaves a solid phase bond between the two pieces. The tool continues to move until the whole weld is formed.

Advantages:

1. For joining non-ferrous materials, no filler material or shielding gases are required in this process
2. FSW can be used to weld both similar and dissimilar metals.
3. Fine grain size and quality weld can be obtained by this process
4. Lower power consumption due to absence of external heating
5. Highly automated
6. Low maintenance is required
7. Large welding joint design available and it can weld in all direction.
8. Easy to operate and does not involve any environmental pollution.

Disadvantages:

1. Complicated or special fixture arrangement is required
2. Exit hole left when tool is withdrawn
3. High initial or setup cost
4. It is less flexible compare to arc welding process
5. Non-forgeable material cannot be weld.

Applications:

1. Used in ship building companies to weld big parts of the ship (structure work)
2. Mostly used in aerospace industries to join or weld the bigger parts like wings, fuel tanks aircraft structure work.
3. Used in automotive industries to weld wheel rims, chassis, fuel tanks and other structure work.
4. It is used in chemical industries for joining pipelines, heat exchanger, air conditioner etc
5. FSW is also used in electronic industries for joining bus bar, aluminium to copper connections
6. It is widely used in fabrication Industries
7. In railway industries, it has applications like building of railway tankers and building of container bodies.

# UNIT-III

# METAL FORMING PROCESSES

## Purpose of Mechanical working

a. To reduce the original block or ingot to the finished dimensions of the part, thereby, saving material, machining cost and time.

b. To improve mechanical properties of the metals by refinement of the grain structure, directional control of flow lines and removal of cavities and other impurities

## Hot working:

It is metal forming process in which metals are given desired shape by subjecting them to forces which causes them to undergo plastic deformation above the recrystallisation temperature.

Methods: Rolling, forging, extrusion piercing
Drawing Spinning

Advantages:
- refinement of grain occurs
- to eliminate porosity
- mechanical properties are improved

Cold working

- Working below recrystallization temperature
- No crystal formation
- Good surface finish
- Internal stress formation
- Limited size.

Forging

Forging is a manufacturing process involving the shaping of metal using localized compressive forces.

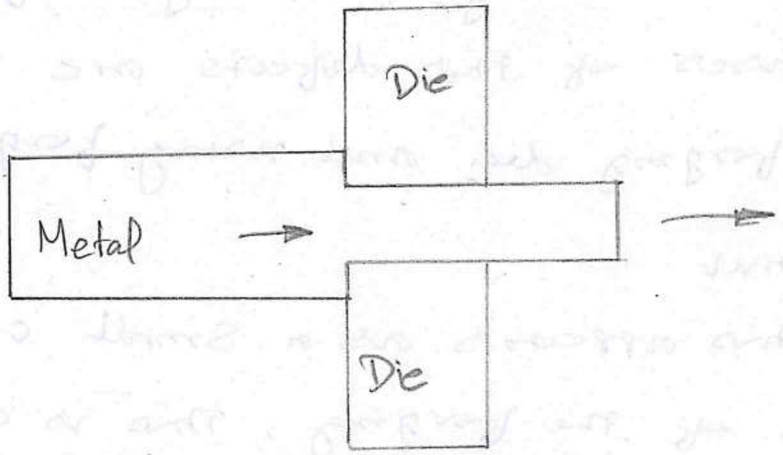
Classification forging

Forging Process

- Open die forging
  - Hand forging
  - Power forging
    - Power Hammer
    - Press forging
- Closed die forging
  - Drop forging
  - Press forging
  - Machine forging

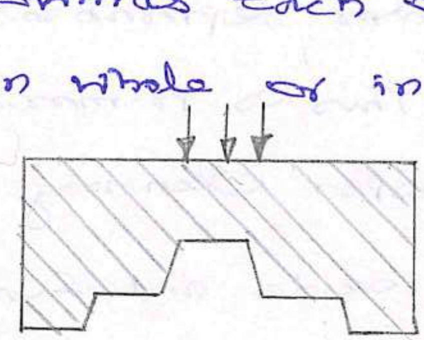
## Open die forging

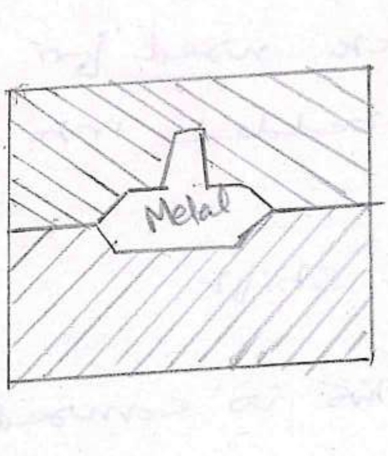
It is the process of deforming a piece of metal between multiple dies that do not completely enclose the material.

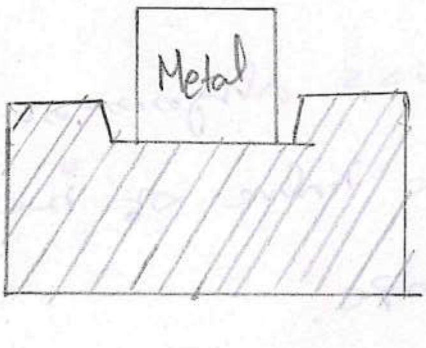



## Closed die forging

It is a forging process in which dies moves towards each other and covers the workpiece in whole or in part.





Forging defects:

Unfilled Section

In this some section of the die cavity are not completely filled by the flowing metal. The causes of this defects are improper design of the forging die and using forging techniques.

Cold Shut

This appears as a Small cracks at the corners of the forging. This is caused mainly by the improper design of die

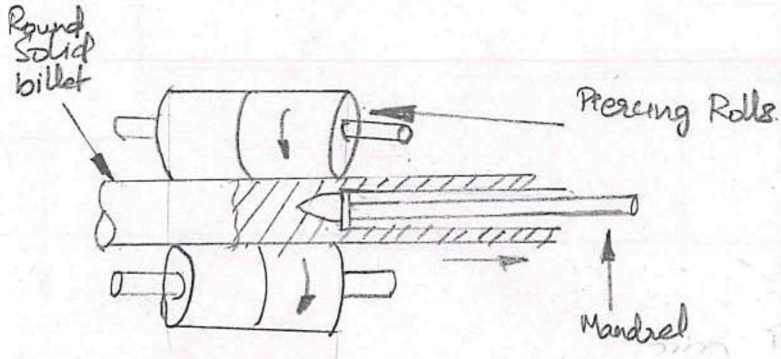
Scale pits

This is seen as irregular depressions on the surface of the forging. This is primarily caused by because of improper cleaning of stock used for forging. The oxide and Scale get embedded into the finish forging surface.

Die Shift

This is caused by the miss alignment of the die halve, making the two halve of the forging to be improper shape.

3) Piercing

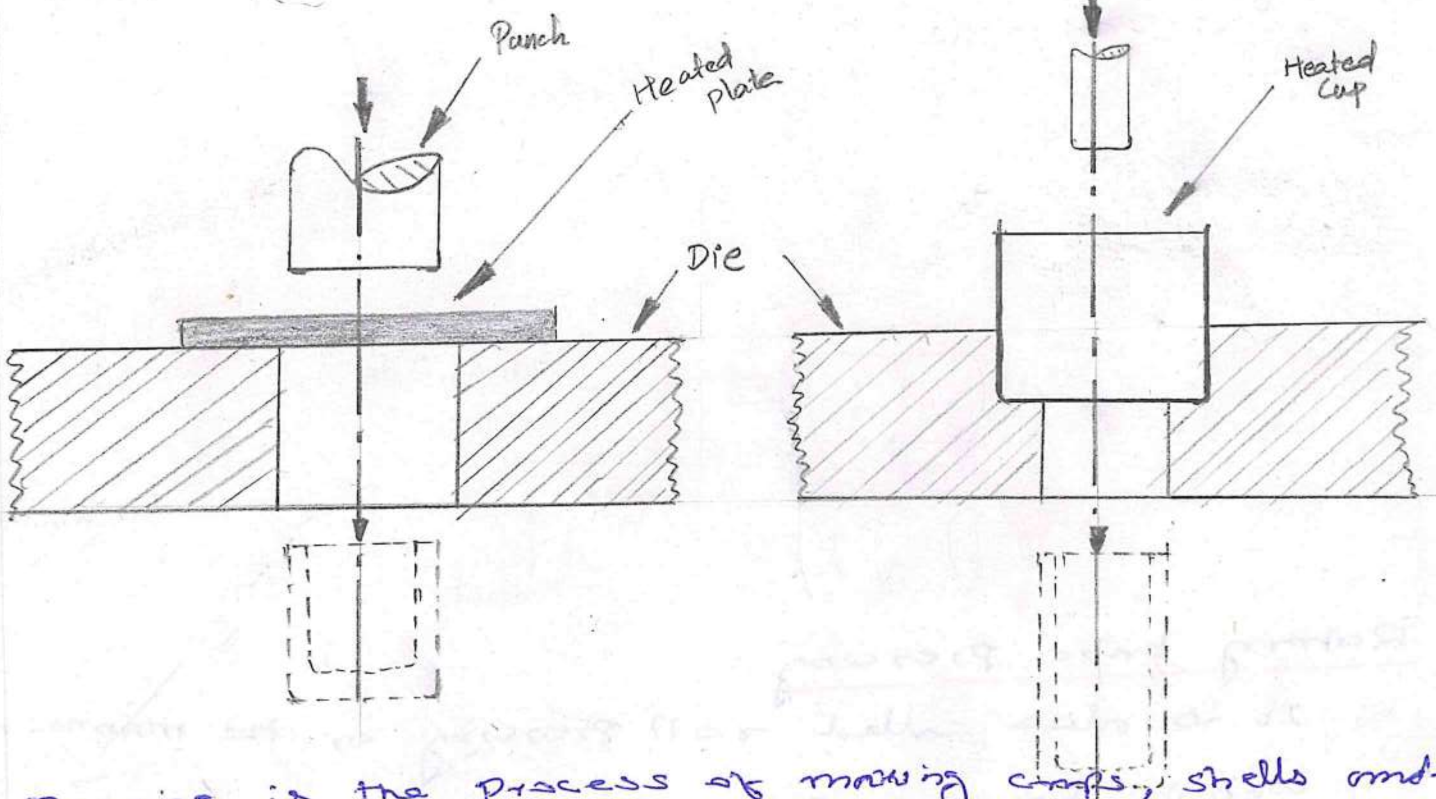



Rotary tube piercing

It is also called roll piercing or the mannes mann. It is a hot forming process that can manufacture long lengths of seamless tube and pipe. The compressive forces applied to a cylinder will create internal stresses at the center. These stresses result in crack propagation. A round stock is center drilled at its end and compressive forces are applied by the use of two rolls. A mandrel is used to shape and size the internal cavity formed at the centre of the round stock.

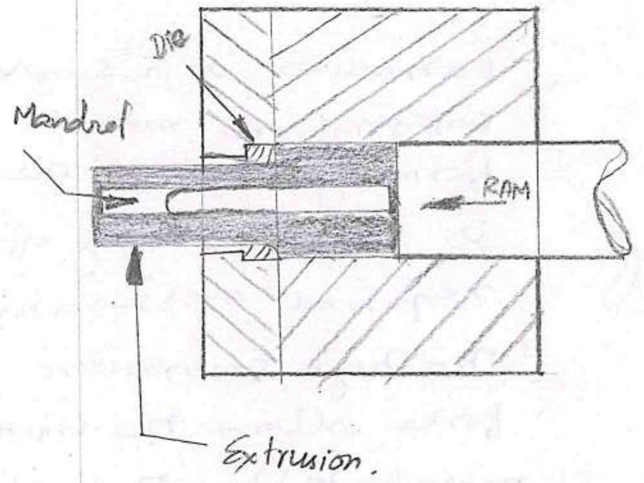
The rolls rotate in the same direction and are oriented at an axis that is at a slight skewed angle to the axis of the part. This causes the stock to be pulled through the rolls and forces it against the mandrel.

4) Drawing:




Drawing is the process of making cups, shells and similar articles from metal blanks. The set up is similar to that used in blanking except that the punch and die are provided with necessary rounding on the corner to allow for the smooth flow of the metal during drawing. The blank is first kept on the die plate, The punch slowly descend on the blank and forces it to take the cup shape formed by the end of the punch, by the time it reaches the bottom of the die. when the punch moves in the return stroke, the cup would be stripped by this counter bored portion.

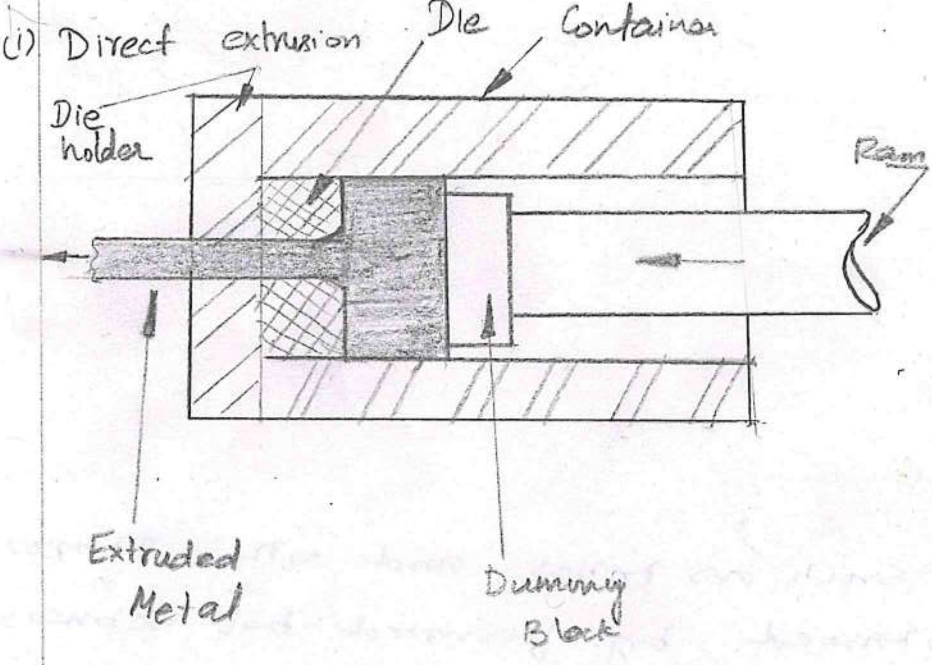
(iii) Tube extrusion.




Hollow objects such as tubes and other shapes can also be obtained by forward hot extrusion. One way of obtaining a tube is by means of a solid ram in a double action press as shown in above figure. First, the solid ram moves through the heated metal billet creating a hole at the centre. Later, the hollow plunger moves the metal billet through the die. Because of the presence of the solid ram very close to the die, the necessary hole is made in the extruded metal.

5) Extrusion

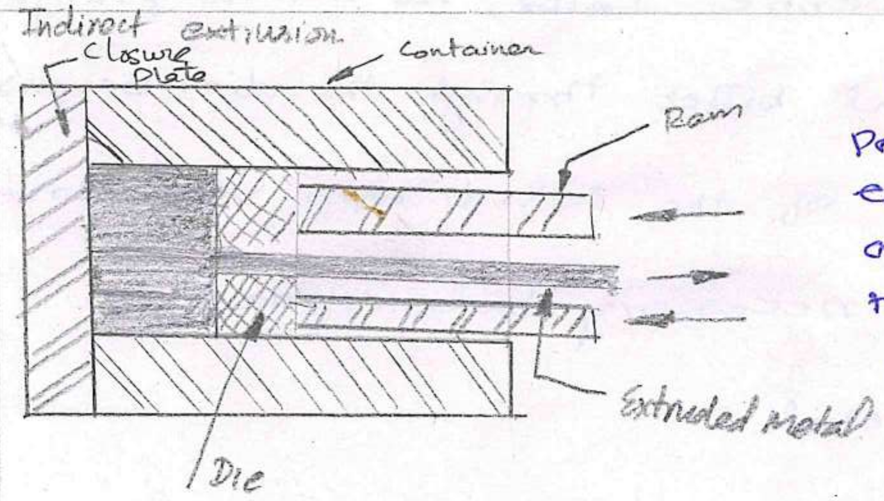
(i) Direct extrusion




Extrusion is a simple compressive metal forming process. Die is small opening of required cross-section. The high compressive force allow the work metal to flow through d and convert into desire sh shape.

In this type of extrusion process, metal is forced to flow in the direction of feed of Punch. The Punch moves towards die during extrusion. This process required higher force due to higher friction between billet and container.

(ii) Indirect extrusion

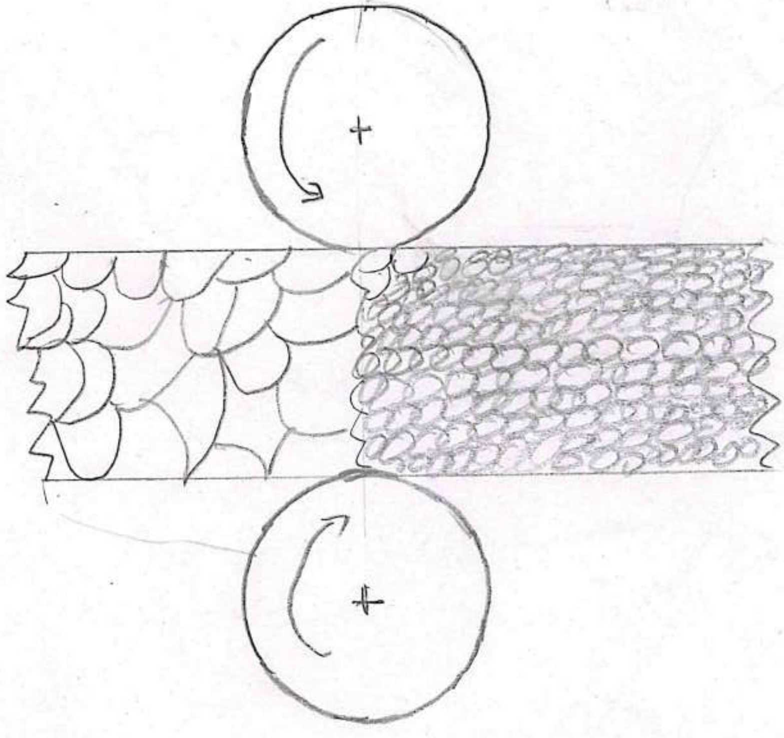



Hollow or semi hollow Parts can be directly extruded with the use a mandrel attached to the dummy block. The mandrel is fitted within the hole.

Once the operation begins, the ram is forced forward. The extruded metal flows between the mandrel and die surfaces, forming the part. The interior profile of the metal extrusion is formed by the mandrel, while the exterior profile is formed by the extruding die.

Hot-Working :-

1) Rolling



2) Rolling : It is a deformation process in which the thickness is reduced by compressive forces exerted by two opposing rolls.

Types of rolling mill

1) Two high mill 2) Three high mill

3) Four high mill 4) cluster mill

Flat rolling process

Metal strips enters the roll gap.

The strip is reduced by the metal rolls

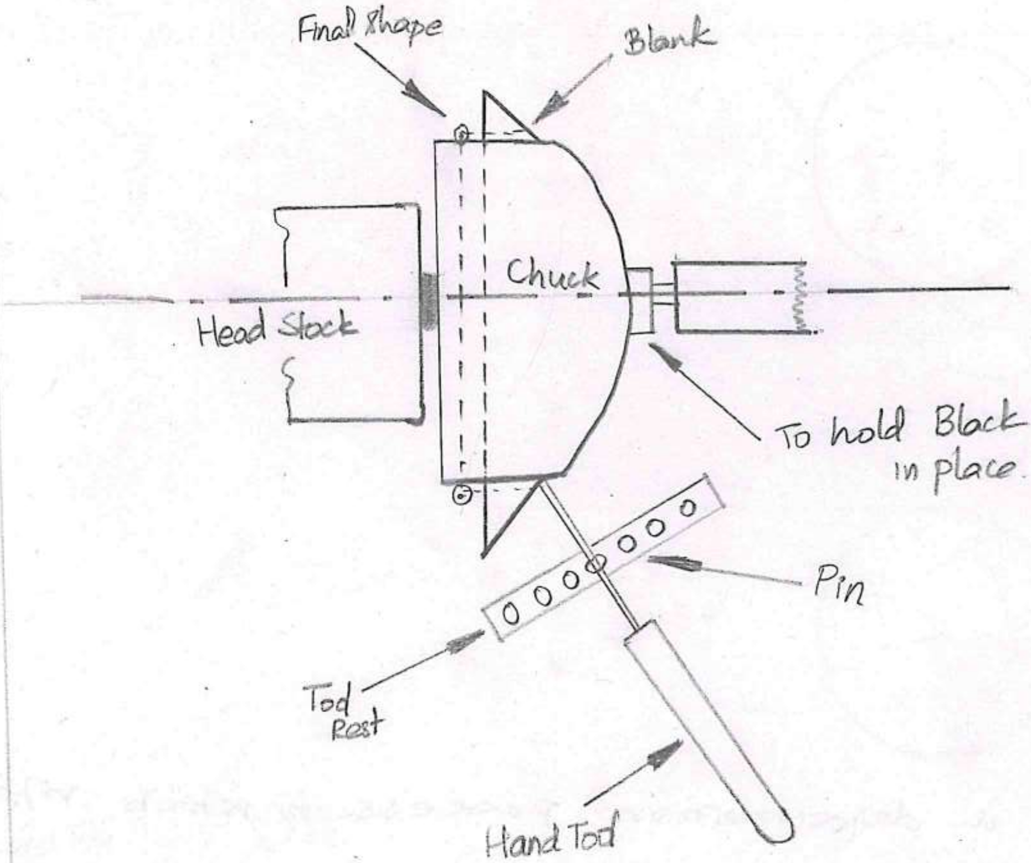
The velocity of the strip is increased the metal strip is reduced in size

Factors affecting rolling process

Frictional force

Roll force and power requirement.

2) Spinning (Hot and cold




Spinning: It is the process used for making the cup shaped articles which are symmetrical. The process of spinning consists of rotating the blank, fixed against the form block and then applying a gradually moving force on the blank so that, the blank takes the shape of the form block.

Spinning is comparable to drawing for making cylindrical shaped parts. Because of the simple tools used in spinning, It is economical for smaller lots.

# UNIT - IV

## SHEET METAL PROCESSES

Many of the consumer goods engaged today by the modern man owe their low cost to the press tools. But for the cheap way of making these sheet metal components, we possibly could not have even thought of having automobiles, type writers, mechanical toys etc. at such a low cost. The press tool operation is by far one of the cheapest and fastest way of the complete manufacture of a component.

Classification of press tool operations:

| Stresses Induced | Operations |
| --- | --- |
| 1. Shearing | shearing, blanking, piercing trimming, shaving, notching nibbling |
| 2. Tension | stretch forming |
| 3 Compression | coining, sizing, ironing hobbing |
| 4. Tension and compression | Drawing, spinning, bending forming, embossing |

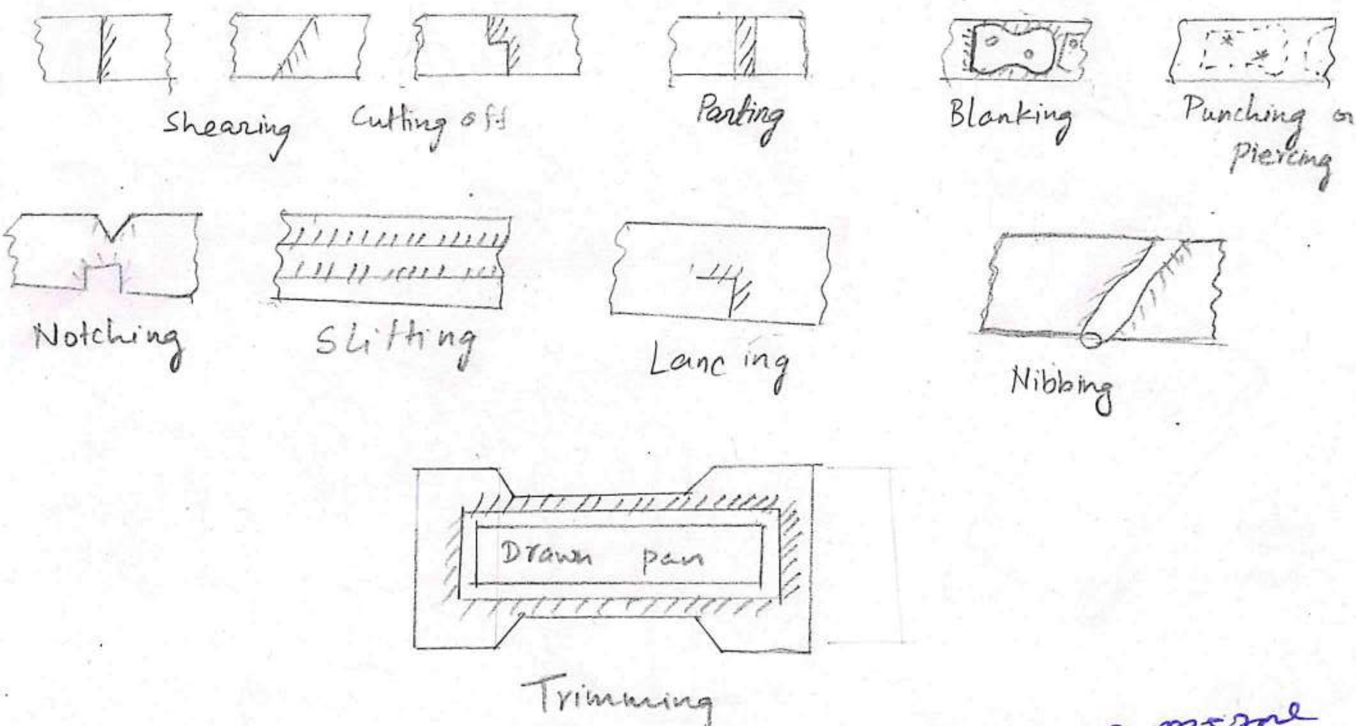
Shearing action has three basic stages

1. Plastic deformation
2. Fracture
3. Shear

When metal is placed between the upper and Lower blades of the shear and pressure is applied plastic deformation first takes place. This extends into the interior of the metal from 5 to 40 % of its thickness. As continued pressure is applied to the cutting blade, the fracture or crack start at the cutting edge of each blade, the points of the greatest stress concentration. As the blade decends further, the small fractures meet and the metal is then sheared.

The same shearing action takes when a punch and die are used. The quality of cut surface is greatly influenced by the clearance between the two shearing edges.

Sheat Metal Operations:




Shearing is a general name for most sheet metal cutting but in a specific sense designates a cut in a straight line across the strip, sheet or bars.

Cutting off: This means severing a piece from a strip with a cut along a single line.

Parting - It signifies that scrap is removed between the two pieces to part them.

Blanking: This means cutting a whole piece from sheet metal just enough scrap is left all around the opening to assure that the punch has metal to cut along its entire edge.

Punching: Punching operation of producing circular holes on a sheet metal by a punch and die.

Notching - This is a process of removing metal to the desired shape from the side or edge of a sheet.

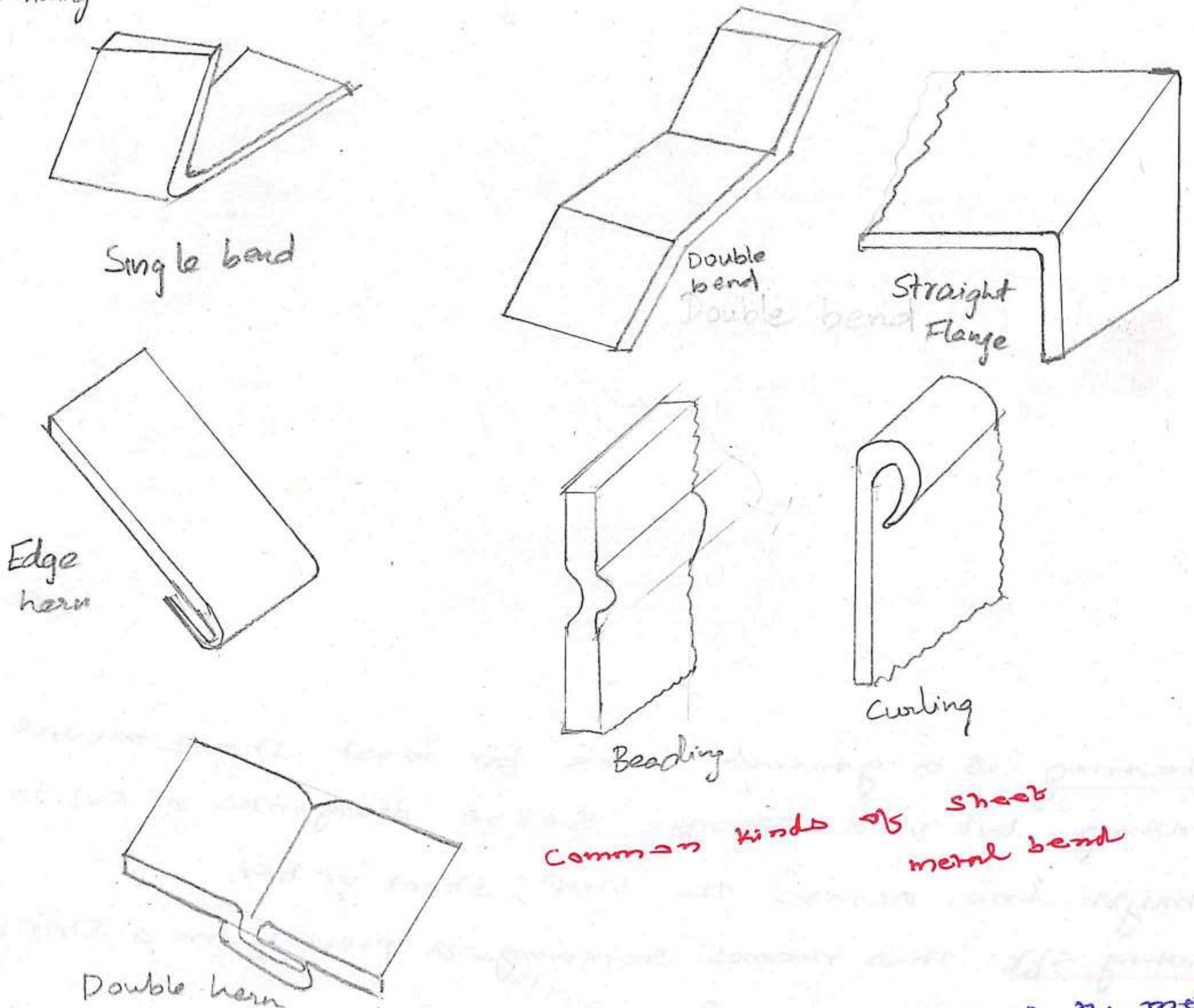
Slitting: when shearing is conducted between rotary blades, the process is referred to as slitting

Lancing - This makes a cut part way across a strip

Nibbling: It is an operation of cutting any shape from sheet metal without special tools.

Trimming: - cutting away excess metal in a flange from a piece

Bending :-




Common kinds of sheet metal bend

Sheet bending is defined as the straining of the metal sheet around a straight axis as shown in above figures. During bending operation, the metal on the inner side of the neutral plane is compressed and the metal on the other side of the neutral plane is stretched. Bending causes no change in the thickness of the sheet metal.

Bend allowance (B) = $\alpha (R + Kt)$

$\alpha \rightarrow$ bend angle (radians)

$R \rightarrow$ Inside radius of the bend

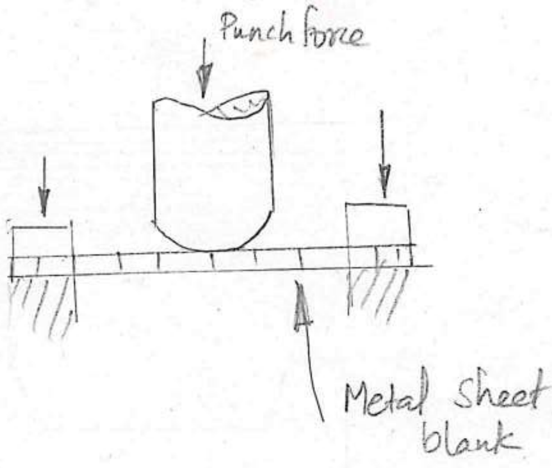
$K \rightarrow$ location of neutral axis from bottom surface

$= 0.33$ when $R < 2t$

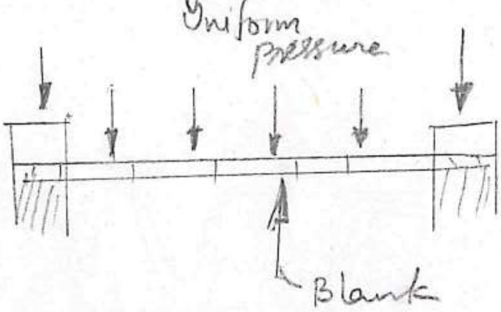
$= 0.50$ when $R > 2t$

$t \rightarrow$ sheet thickness (mm)

(i) Hydraulic press forming



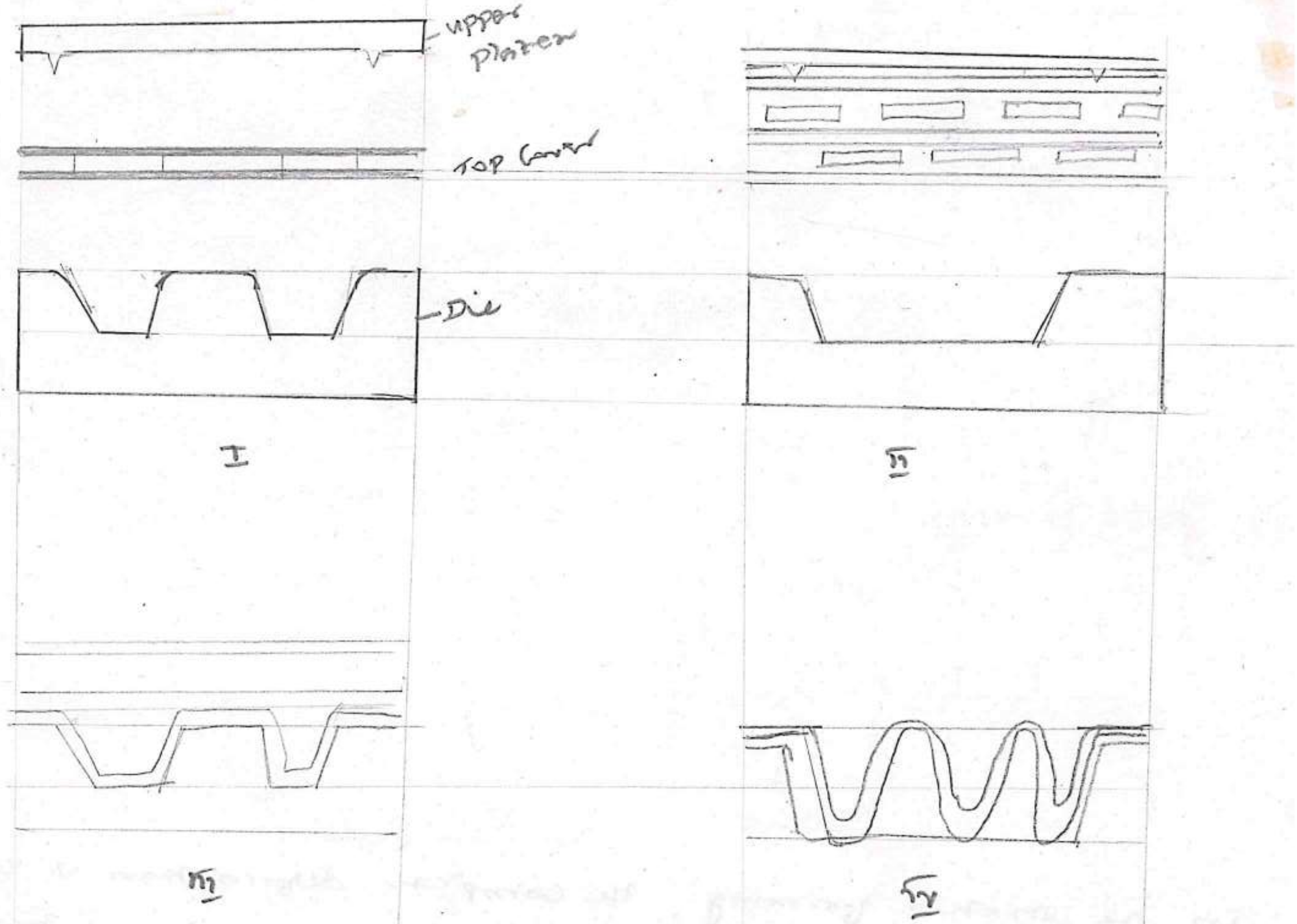

ii) Stretch forming




In the stretch forming, the complex deformation is carried out in plastic state only. The material is first brought into plastic state by stretching. In the process, the sheet is held in the jaws of hydraulic cylinders and is stretched beyond elastic limit. Stretch forming is comparatively simple and inexpensive, because it uses a single die.

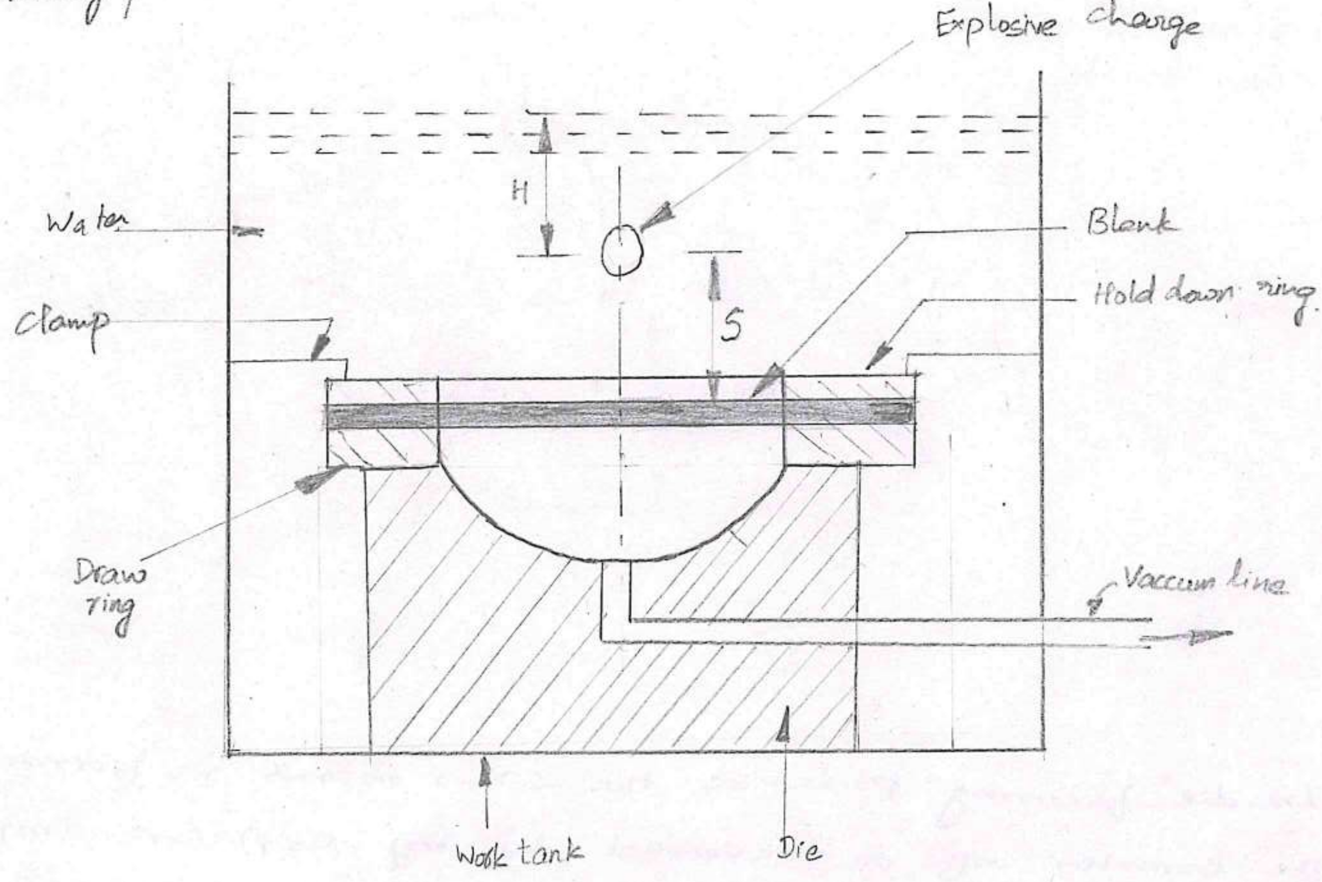
The sheet used in stretch forming should have uniform thickness, otherwise, the thinner portions are likely to be over stretched.

# Super plastic forming.




Super plastic forming is a technique allowing to manufacture complex shaped hollow metallic parts. It combines super plastic forming with a second element Diffusion bonding to create the complexed structures.

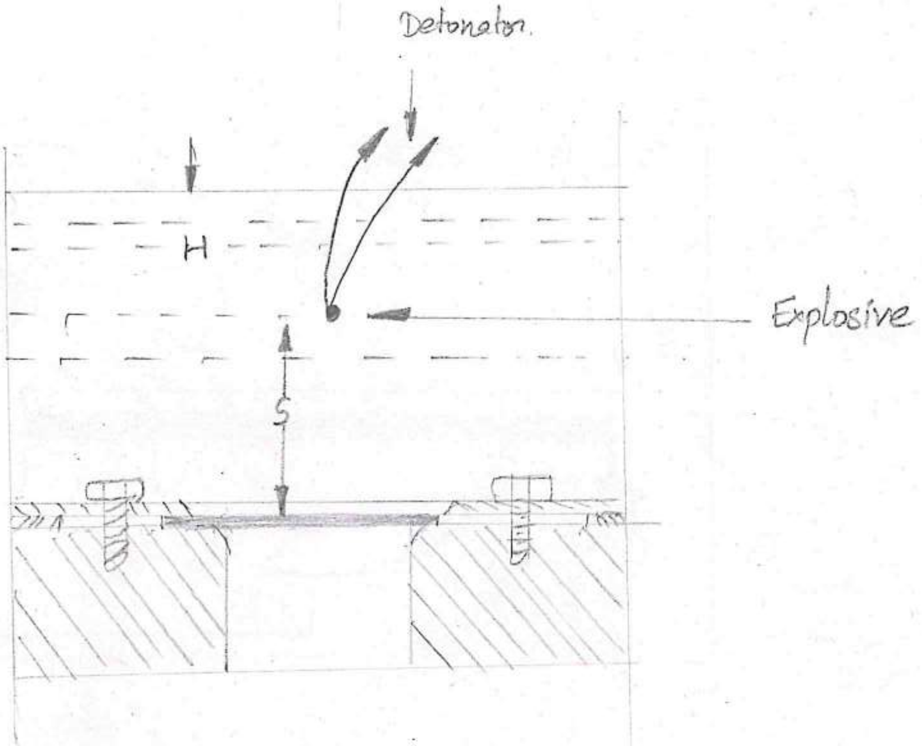
③ Die-forming /




The above figure shows die forming process. The charge is placed at a same distance from the sheet metal blank and is immersed in a transmitting medium usually water. When explosive is ignited the energy released forces the metal into the die to take the required shape. In free forming stretching of the blank takes place and deformation of the workpiece depends on its ability to get stretched. This method is generally used to produce smaller components. The free forming technique looks promising for axially symmetrical shapes like domes. Its ultimate accuracy limitations depends upon the reproducibility of the materials used, their deformation the reproducibility of the hardening characterstics and the reproducibility of the explosive charge.

Explosive forming :-

1) Stand- off operation.
2) Free forming.




In die forming process the sheet metal is formed to the contour of a prepared die by explosive Impact. This process makes use of an explosive which is detonated and its energy transmitted to the workpiece through a fluid

This process has been used successfully for forming complex sheet metal parts for jet aircraft engines guided missiles, nuclear and rocket requirements. Materials like aluminium alloys, copper, low and medium carbon steels stainless steels, titanium etc. can be easily explosive form

Advantages;

1) By this process sheet metal is formed into shapes which cannot be produced economically by other conventional processes.

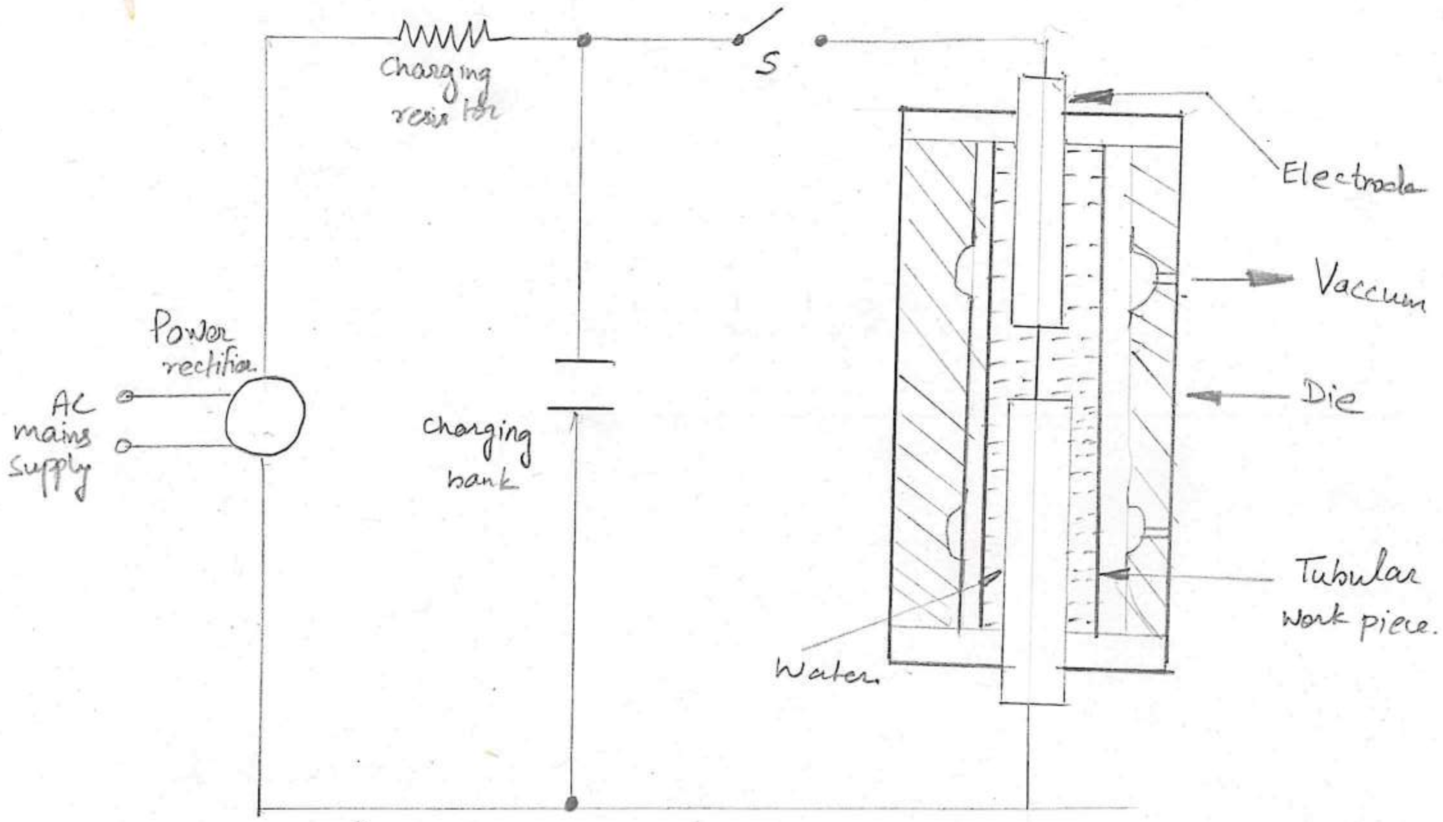
2. Investment cost in dies is low

3. Components can be made to close tolerances.

Disadvantages;

The process should be conducted at safe and remote places because a lot of sound and noise is produced.

Electro-Hydraulic forming.




The principle used in electro-hydraulic forming can be stated as the ability to generate high intensity shock waves by discharging stored electrical energy across electrodes submerged in a liquid medium. It uses two electrodes which are connected by a thin initiating wire which is vaporised during the discharge. The workpiece is immersed in water together with electrodes which are connected via a switch to a bank of capacitors. The capacitors are charged from a power unit through a charging resistor to a predetermined voltage and energy level. When the switch connecting the capacitors to the electrode is closed, the stored energy is discharged across the gap at the ends of the electrodes. The electric energy is converted into a shock wave in the water which forms the workpiece into a die.

# UNIT-V Manufacture of plastic Components

## Introduction:

In general the term 'plastic' is applied to all materials capable of being molded or modeled. plastics have been increasingly accepted for modern Engineering application due to the fact that plastics are attractive materials and offer advantages in weight, cost, moisture strength and chemical resistance, toughness, abrasive resistance, strength, appearance, insulation (both thermal and electrical), formability and machinability.

## Types of plastics:

plastics can be divided into two major categories:

(a) Thermo set or thermo setting plastics:

once cooled and hardened, these plastics retain their shapes and can't return to their orginal form. They are hard and durable. Thermosets can be used for autoparts, aircraft parts and tire

(e.g) polyurethanes, polyesters, epoxy resin and phenolic resin.

(b) Thermoplastics.

Less rigid than thermosets, thermoplastics can soften upon heating and return to their orginal form they are easily molded and extruded into films, fibres and packaging

(e.g) polyethylene (PE), polypropylene polyvinyl chloride (PVC)

Difference between thermoplastics and thermosetting plastics.

| Thermoplastics | Thermosetting plastics |
| --- | --- |
| Softened by heating | can't be softened |
| Structure is made of linear chain molecules | Structure is made of cross linked molecules |
| Produced by addition of polymerization process | Produced by condensation polymerization process |
| can be produced by heating | can't be reproduced |
| Temp increases with increase in plasticity | plasticity is simple at high temp |
| Softer and less strong | Harder and strong |
| Scrap can be reused | Scrap can't be reused. |

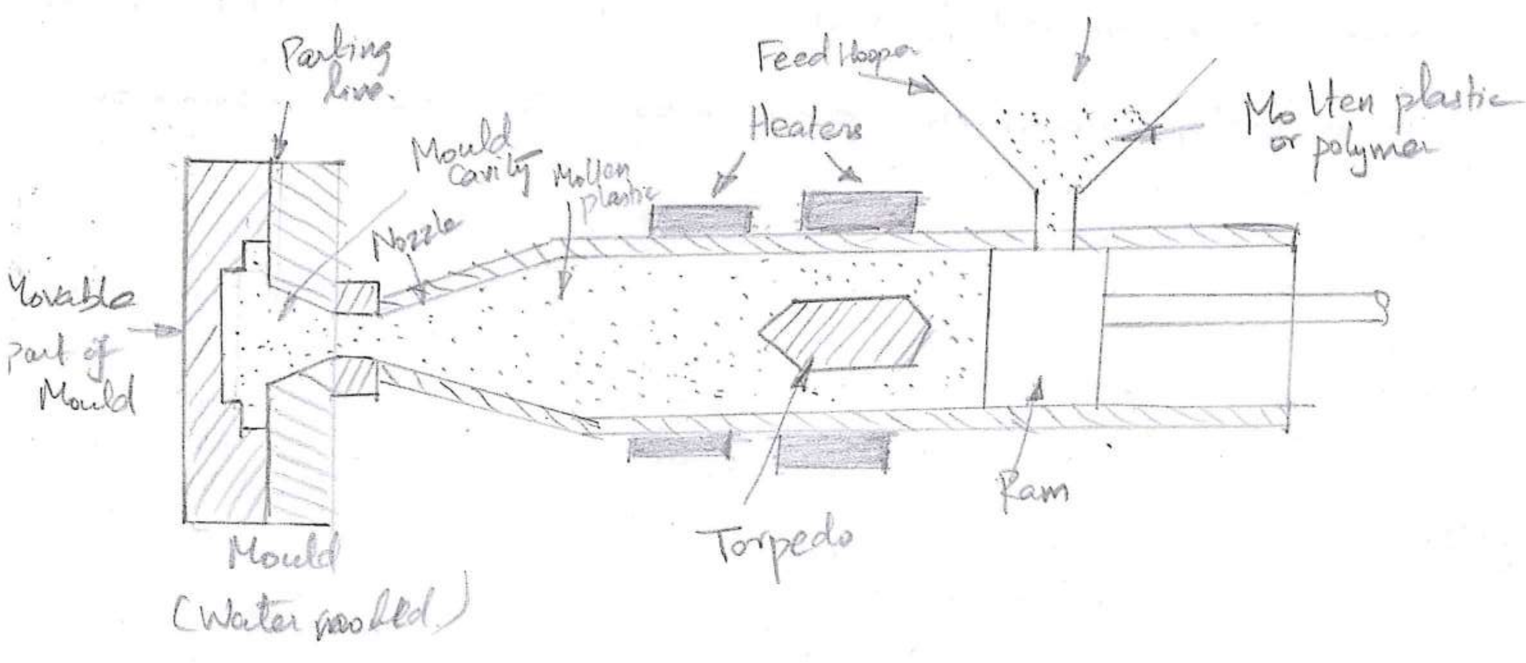
Characteristics of plastics:

1. Elongation
2. Heat resistance
3. High rigidity
4. Surface hardness
5. High viscosity
6. maximum range temp.
7. Density
8. Ignition temp
9. Humidity absorption
10. chemical resistance

# Moulding of thermoplastics:

## INJECTION MOULDING:

Injection moulding is the most widely used method of producing parts of thermoplastic and more recently, thermosetting resins as well. The process resembles the hot chamber die casting of metals; the die, split to allow removal of the solidification of product, is kept shut with an appropriate press force and ejectors are provided for removing the moulded component. The difference between metals and plastics lies in the supply of the polymer which is usually fed in solid form, pellets or powder through a hopper to a injector screw, the die end of which is surrounded with heaters that gradually bring the polymer to the required temperature. There the material is softened.

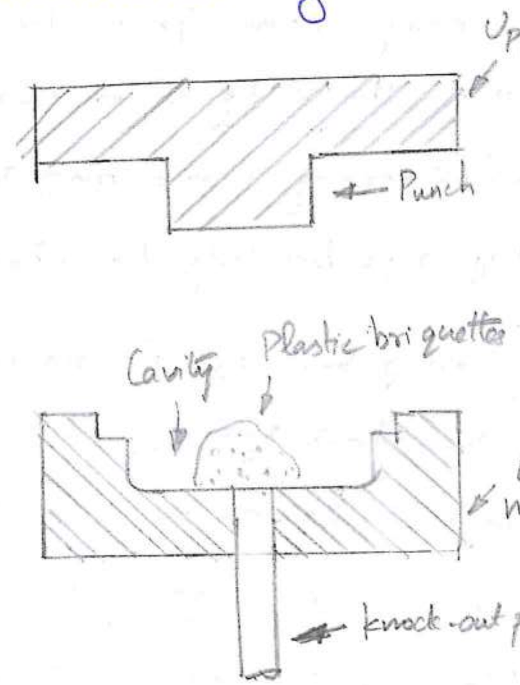


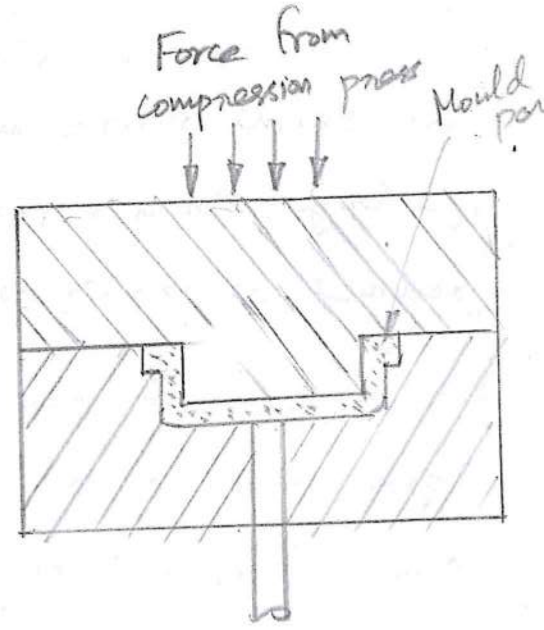
The process starts with feeding plastic pellets into the hopper above the heating cylinder of the machine. The resin falls into and is pushed along the heated tube by reciprocating screw (feeder) until a sufficient volume of melted plastic is available at the injection nozzle end. This may range from 10 sec to 5 or 6 min per shot. The entire screw is then plunged forwarded 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 the pressure for a few seconds so that the moulded part can solidify (cool). It then retracts slightly and the mould opens. Knock out pins eject the moulded piece. The sprue and runners are trimmed off, usually in a separate trimming press.

Injection moulding provides the highest production rate of producing plastic parts at a low cost. The time required per shot will vary with the material and size of the mould. But 300 to 400 shots per hour in a fully automatic equipment are not uncommon

## (iv) Compression moulding

Compression moulding is essentially a forging process, performed in a heated die that forms a premeasured quantity of the polymer. The process is most widely used for the forming of the thermosetting plastics




The basic procedure for compression moulding illustrated in the figure, consists of placing a measured amount of powder or a compressed preform, into the open mould cavity, closing the mould and then applying heat and pressure through a downward moving die to the material until it softens and is forced fill the mould cavity. In the closed mould, a chemical reaction or polymerization, that cross links the polymer chains takes place and the material hardens into the required shape. Heat for polymerization or curing is supplied through the walls by steam or electric moulding pressures (hydraulic) may be as low as 0.35 Kgf/mm$^2$ (3.5 MPa) for polyester and epoxy but most thermosets require 1.4 to 4.2 Kgf/mm$^2$ depending largely on the filler or plasticizer used.

moulding temp are from 1100 to 2200°C depending on the plastic, filler etc.

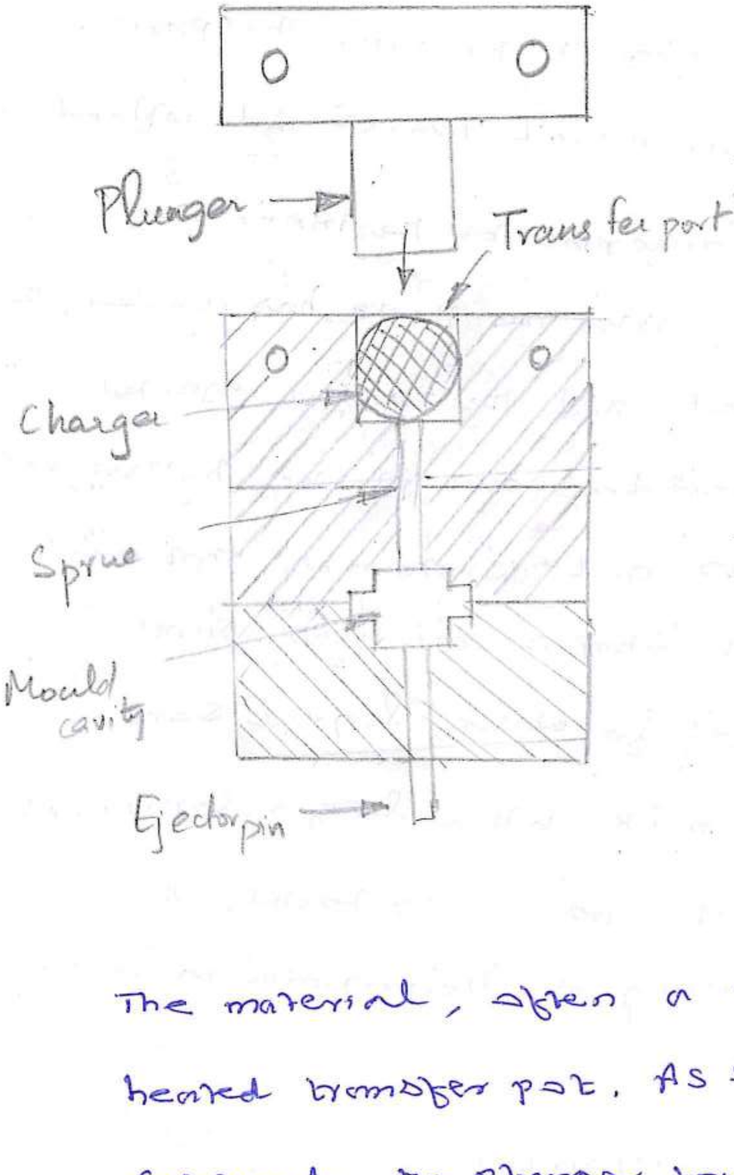
The complete cycle may take from 10 sec, for small parts under 2.5 mm thick to 5 or 10 min for large, thicker parts. This curing time may be reduced as much as 50% by preheating the charge.

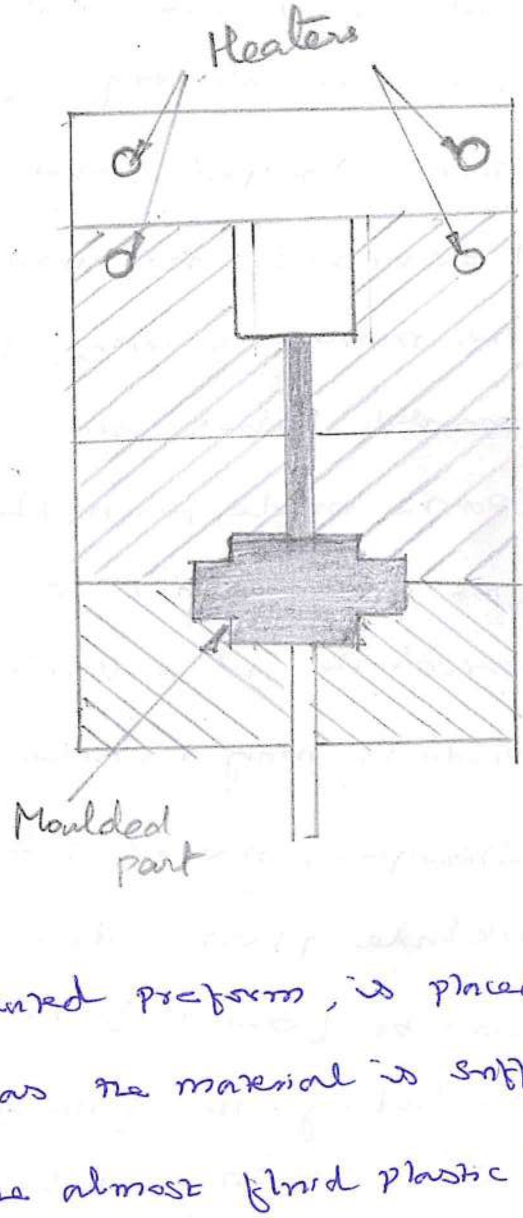
Compression moulding may be of the positive type, semi positive type or the flash type. In the latter, some of the material is allowed to escape, usually along the mating die perimeter, over a land or cut-off area, in the form of a thin flash or fin which is finally trimmed off. A mould of this type gives closer tolerances and is usually cheapest to make.

cold moulding: Although compression moulding is mostly done hot, some cold moulding is done. A powder or fibres (often of refractory materials) are mixed with a binder and compacted in a cold die. These procedures are followed by curing in a separate oven. This method is not suitable where close tolerance and good surface finish is required

## Transfer moulding

Transfer moulding, also called extrusion or gate moulding is the process of forming articles in a closed mould, where the fluid plastic material is conveyed into the mould cavity under pressure from outside of the mould.




The material, often a preheated preform, is placed in a heated transfer pot. As soon as the material is sufficiently softened, the plunger forces the almost fluid plastic through the orifice (sprue) into the closed mould where final cure takes place. pressure used are 50 to 100 % higher than those used for compression moulding; thus better details and higher strengths are possible.

Blow moulding:

Blow moulding is a manufacturing process that is used to create hollow plastic parts by inflating a heated plastic tube until it fills a mold and forms the desired shape. The raw material in this process is a thermoplastic in the form of small pellets or granules, which is first melted and formed into hollow tube, called the parison. There are various ways of forming the parison. The parison is then clamped between two mould halves and inflated by pressurized air until it conforms to the inner shape of the mould cavity. Lastly, after the parts has cooled, the mould halves are separated and the part is ejected.

Parts made from blow moulding are plastic, hollow and thin walled such as bottles and containers that are available in a variety of shapes and sizes. Small products may include bottles for water, liquid soap, shampoo, motor oil and milk, while larger containers include plastic drums, tubs and storage tanks. The parts can be formed from a variety of thermoplastic materials, including the following:

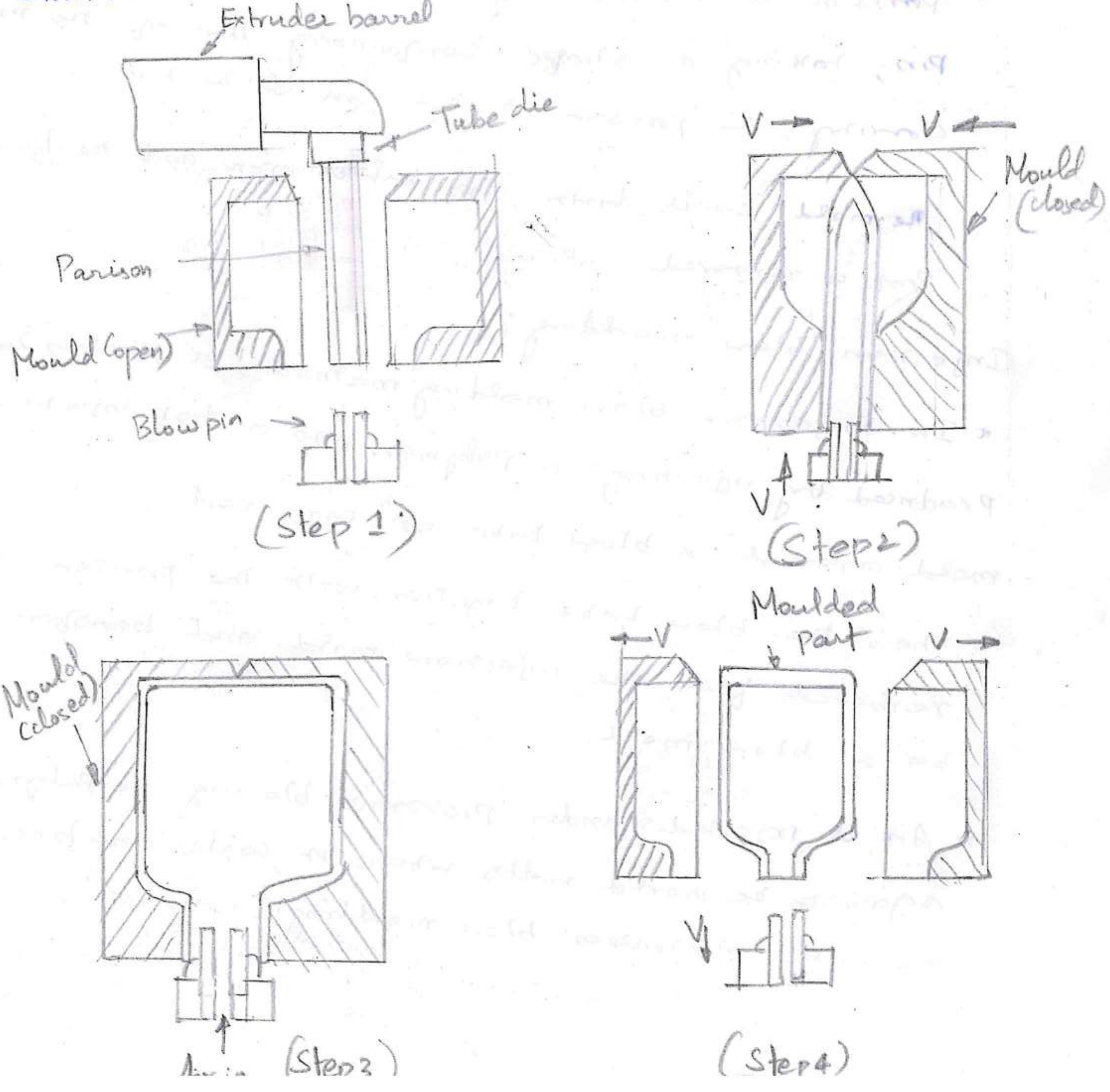
Low density polyethylene (LDPE)
High density polyethylene (HDPE)
Polyethylene Terephthalate (PET)
Poly Propylene (PP)
Polyvinyle chloride (PVC)

There are three principal techniques of blow moulding differing in the method by which parisons are prepared.

* Extrusion blow moulding
* Injection blow moulding
* Stretch blow moulding

## Extrusion blow moulding

Extrusion blow moulding involves manufacture of parison by conventional extrusion method using a die similar to that used for extrusion pipes.



Extrusion blow molding is commonly used for mass production of plastic bottles.

The production cycle consists of the following steps

* The parison is extruded vertically in downward direction between two mold halves.

* When the parison reaches the required length the two mold halves close resulting in pinching the top of parison end and sealing the below pin in the bottom of the parison end

* parison is inflated by air blown through the blow pin, taking a shape conforming that of the mold cavity. The parison is then cut on the top.

* The mold cools down, its halves open and the final part is removed

Injection blow molding:

* In Injection blow molding method, a parison tag is produced by injecting a polymer into a hot injection mold around a blow tube or core rod

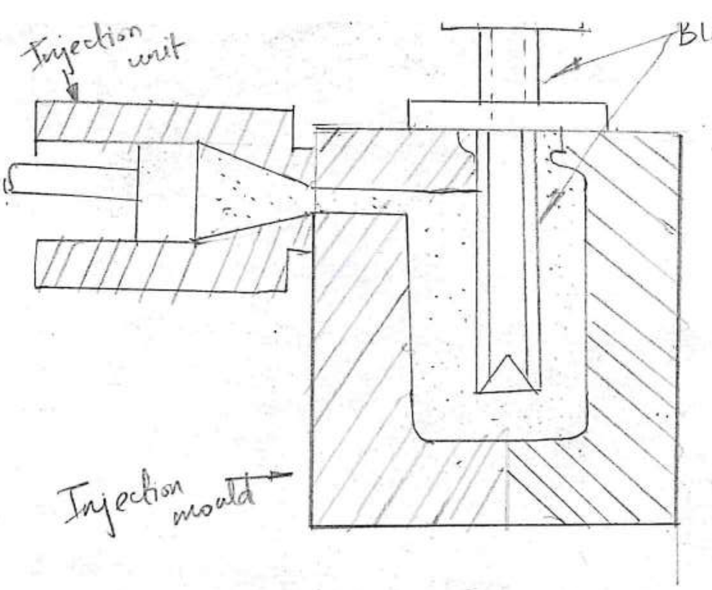
* Then the blow tube together with the parison is removed from the injection mold and transferred to a blow mold.

* Air is injected under pressure blowing the polymer against the mold walls where it cools and freezes as with extrusion blow molding.

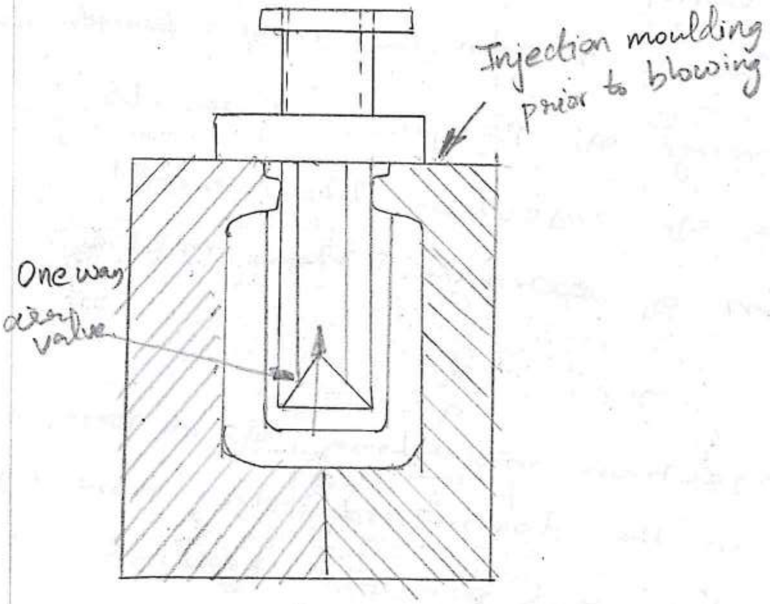
Injection blow moulding is a more accurate and controllable process as compared to the extrusion blow moulding. It allows producing more complicated products from a wider range of polymer materials. However production rate of injection blow moulding method is lower than that of extrusion blow molding.

Stretch blow moulding

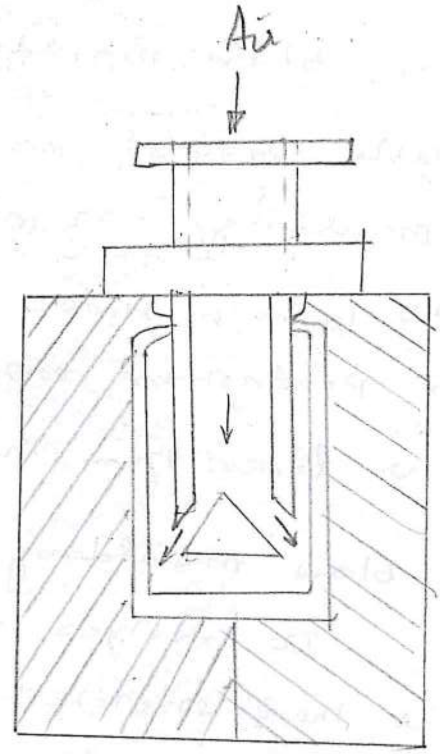
It involves injection moulding of a parison, which is then stretched in the downward direction by means of the blow tube. In this method biaxial molecular orientation is produced. The specific molecular orientation provides higher mechanical strength, rigidity and transparency of the material. That is why this method is used for manufacturing containers for carbonated beverages. material, Common used in this method is poly-ethylene Teraphthalate. (PET)



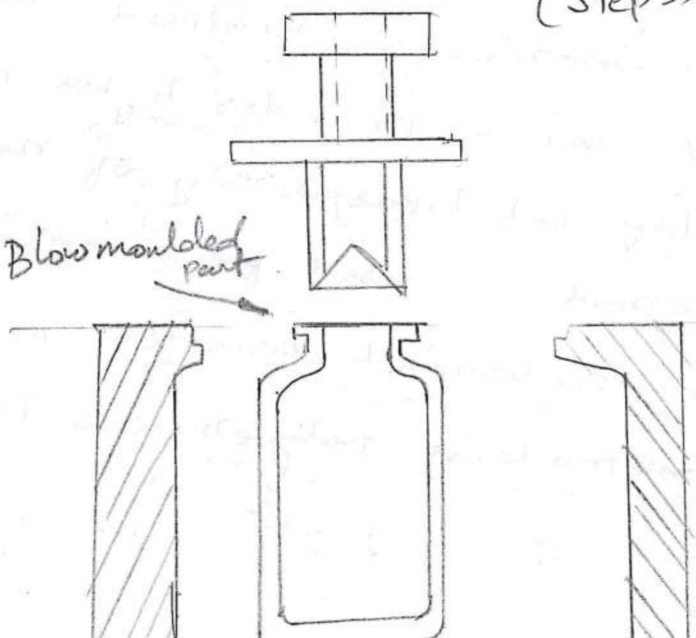

(Step 1)




(Step2)




(Step3)




(Step 4)