Forging

What is forging?

Forging is a manufacturing process involving the shaping of a metal through hammering, pressing, or rolling. These compressive forces are delivered with a hammer or die. Forging is often categorized according to the temperature at which it is performed—cold, warm, or hot forging.

A wide range of metals can be forged. Typical metals used in forging include carbon steel, alloy steel, and stainless steel. Very soft metals such as aluminum, brass, and copper can also be forged. The forging process can produce parts with superb mechanical properties with minimum waste. The basic concept is that the original metal is plastically deformed to the desired geometric shape—giving it higher fatigue resistance and strength. The process is economically sound with the ability to mass produce parts, and achieve specific mechanical properties in the finished product.

Standard Forging Equipment

There are four primary tools that are used in the metal forging process depending on the exact method being used.

Hammers

The hammer, or power hammer, is a tool most commonly associated with forging. Whether a hand-held hammer or a massive power hammer, the tool is used to repeatedly hit the metal in order to deform it. As long as it possesses a 50,000 lbs driving force to deliver high-pressure impact blows, a hammer can pound metal into shape.

Presses

Presses use either mechanical or hydraulic pressure to apply continuous pressure on forging dies. This kind of equipment requires a 50,000 ton driving force to vertically squeeze metal into die cavities with controlled high pressure. Instead of hitting the metal repeatedly to deform it, the metal is slowly pressed into the dies.

Upsetters

Upsetter forging is similar to press forging, however, the main difference is that an upsetter is a forging press that is used horizontally. Instead of forcing the metal downward into a die, the metal is moved into the die impression in a horizontal direction.

Ring Rollers

Ring rollers are used to produce rings with diameters from just a few inches to over 300 inches. Ring rollers squeeze out a one-piece ring, which removes the need for welding. It turns a hollow round piece of metal under extreme pressure against a rotating roll.

Forged process

Drawing It is the operation in which the cross-section area or the thickness of the work piece is reduced with an increase in the length. This is done by striking the metal piece with flat dies.

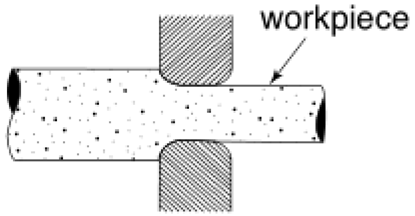
Fullering It is similar to drawing, but this operation is carried out with a set of two fullers. Fullering results in an irregular surface which should be smoothened by means of flatters.

Edging It is a forging operation in which the edge of the raw material is changed to desired shape by pressing it between two dies.

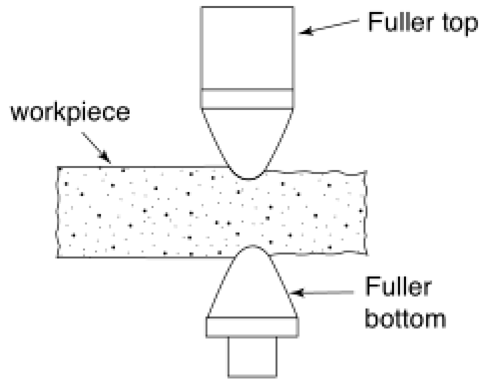
Bending It is an operation to bend the workpiece as desired by using the front portion of the anvil suitably.

Upsetting It is forging operation in which the cross-sectional area or the thickness of the work piece is increased by hammering or pressing. The length of the work piece is decreased.

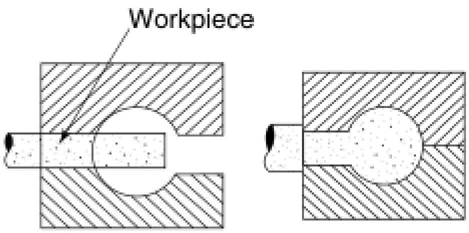
Forge Welding It is a process of joining two metal pieces by pressing or hammering the hot metal pieces.



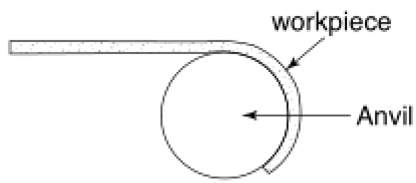
Drawing



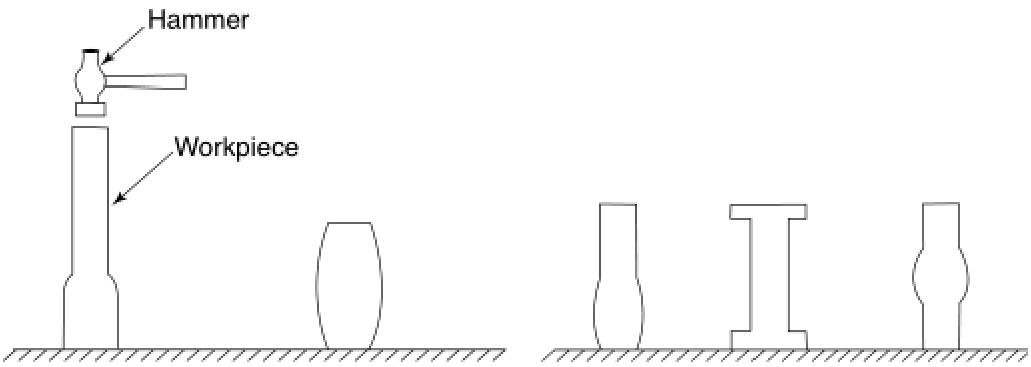
Fullering



Edging



Bending

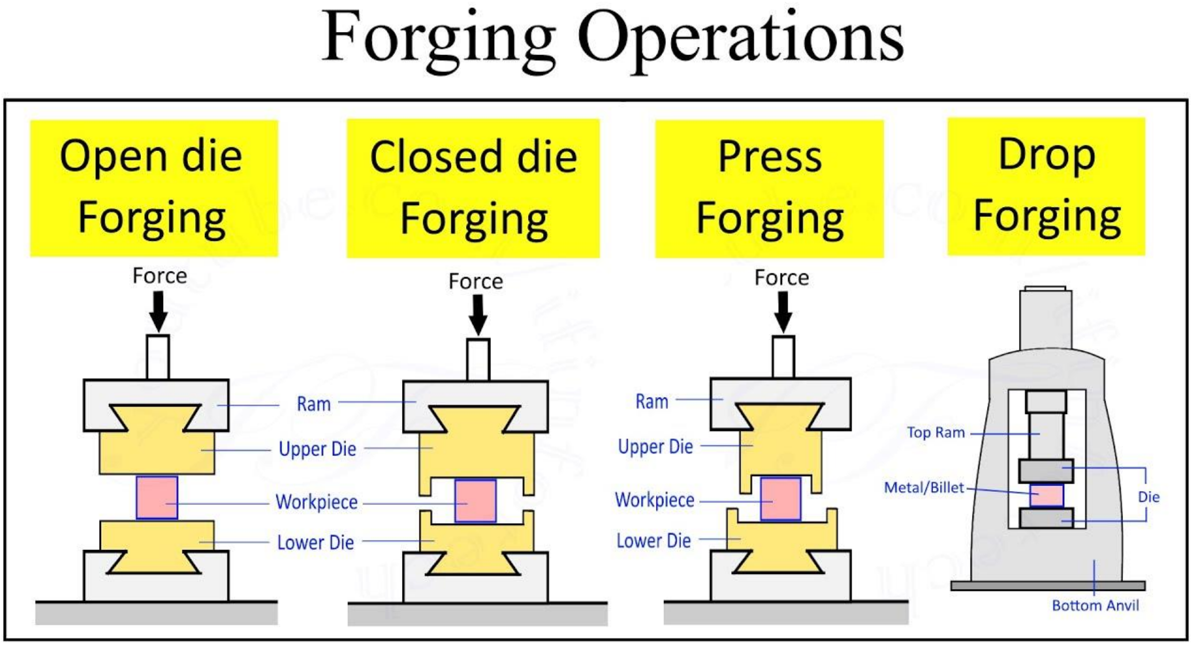


Upsetting

Forging methods

Drop forging

Drop forging derives its name from the process of dropping a hammer onto the metal to mold it into the shape of the die. The die refers to the surfaces that come into contact with the metal. There are two types of drop forging—open-die and closed-die forging. Dies are typically flat in shape with some having distinctively shaped surfaces for specialized operations.



Open-die forging (smith forging)

Open-die forging is also known as smith forging. A hammer strikes and deforms a metal on a stationary anvil. In this type of forging, the metal is never completely confined in the dies—allowing it to flow except for the areas where it is in contact with the dies. It is the operator's responsibility to orient and position the metal to achieve the desired final shape. Flat dies are used, with some having specially shaped surfaces for specialized operations. Open-die forging is suitable for simple and large parts, as well as customized metal components.

Advantages of open-die forging:

- Better fatigue resistance and strength
- Reduces chance of error and/or holes
- Improves microstructure
- Continuous grain flow
- Finer grain size

Closed-die forging (impression-die)

Closed-die forging is also known as impression-die forging. The metal is placed in a die and attached to an anvil. The hammer is dropped onto the metal, causing it to flow and fill the die cavities. The hammer is timed to come into contact with the metal in quick succession on a scale of milliseconds. Excess metal is pushed out from the die cavities, resulting in flash. The flash cools faster than the rest of the material, making it stronger than the metal in the die. After forging, the flash is removed.

Advantages of closed-die forging:

- Produces parts up to 25 tons
- Produces near net shapes that require only a small amount of finishing
- Economic for heavy production

Roll forging

Roll forging consists of two cylindrical or semi-cylindrical horizontal rolls that deform a round or flat bar stock. This works to reduce its thickness and increase its length. This heated bar is inserted and passed between the two rolls—each containing one or more shaped grooves—and is progressively shaped as it is rolled through the machine. This process continues until the desired shape and size is achieved.

Advantages of automatic roll forging:

- Produces little to no material waste
- Creates a favorable grain structure in the metal
- Reduces the cross-sectional area of the metal
- Produces taper ends

Press forging

Press forging uses a slow, continuous pressure or force, instead of the impact used in drop-hammer forging. The slower ram travel means that the deformation reaches deeper, so that the entire volume of the metal is uniformly affected. Contrastingly, in drop-hammer forging, the deformation is often only at the surface level while the metal's interior stays somewhat undeformed. By controlling the compression rate in press forging, the internal strain can also be controlled.

Advantages of press forging:

- Economic for heavy production
- Greater accuracy in tolerances within 0.01–0.02 inch
- Dies have less draft allowing for better dimensional accuracy
- Speed, pressure, and travel of the die are automatically controlled

- Process automation is possible
- Capacity of presses range from 500–9000 tons

Upset forging

Upset forging is a manufacturing process that increases the diameter of the metal by compressing its length. Crank presses, a special high-speed machine, are used in upset forging processes. Crank presses are typically set on a horizontal plane to improve efficiency and the quick exchange of metal from one station to the next. Vertical crank presses or a hydraulic press are also options.

Advantages of upset forging:

- High production rate of up to 4500 parts per hour
- Full automation is possible
- Elimination of the forging draft and flash
- Produces little to no waste

Isothermal forging

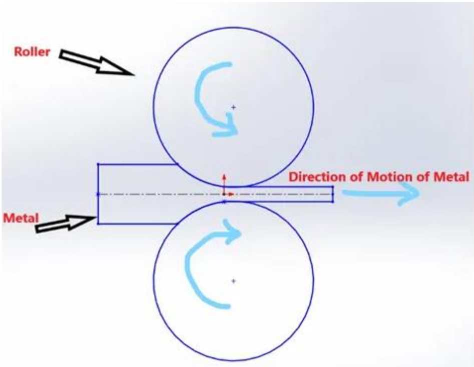
Isothermal forging is a forging process where the metal and die are heated to the same temperature. Adiabatic heating is used—there is no net transfer of mass or thermal exchange between the system and the external environment. The changes are all due to internal changes resulting in highly controlled strain rates. Due to the lower heat loss, smaller machines may be used for this forging process.

Rolling

Rolling is the deformation process of a metal that is widely used in the metal forming process.It is done by passing the strip of the metal between the rollers.

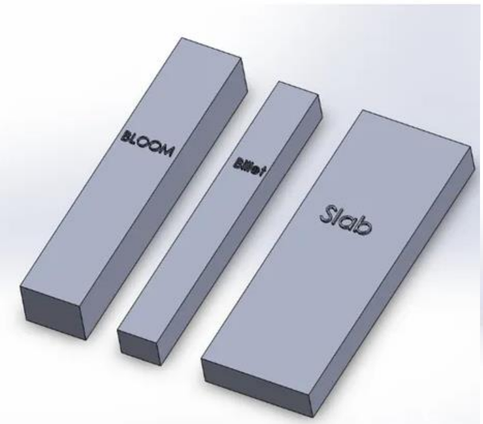
Rolling is defined as a process to form metals where the metal strip is pressed by two or multiple rollers, thus the uniform thickness is formed. To do this, the temperature is essential.

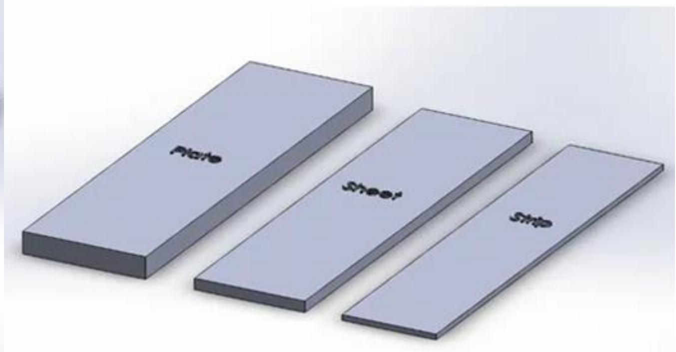
If the strip is rolled after heating the strip **above the recrystallize -tion temperature** then it is termed as **Hot rolled** and if that done in **room temperature** then it is termed as the **Cold rolled**. Rolling is a process that is widely used and has very high production



Terminology used In Rolling Process-

- **Ingot:** It is the Starting Metal that is Provided Input to the Rolling Process. The Ingot is a forging terminology, where metal is taken out from the cast with various defects.
- **Bloom:** It is the first rolled product of Ingot, with a Cross-section area of more than 230 cm^2.
- **Billet:** The product is obtained by further rolling of Bloom, having an area of Cross-section greater than 1600 mm^2.
- **Slab:** It is a hot Rolled Ingot, with a Cross-section area greater than 100 cm^2 and Width>=2*thickness.
- **Plate:** It is the Mill product, with thickness more than 6 mm.
- **Sheet:** It is a Mill product, with thickness less than 6 mm, and width greater than 600 mm.
- **Strip:** It is a Mill product with thickness less than 6 mm, and width less than 600 mm.





Working of Rolling

Primary Rolling:

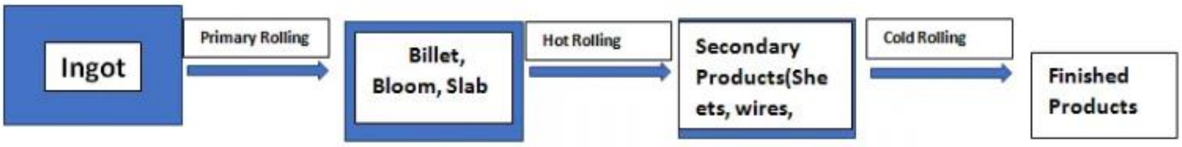
It is the Primary stage of Thickness reduction, in which Ingot is changed into simple stock members like bloom and slab. This process refines the structure, improves the mechanical properties, and removes Internal defects.

Hot Rolling:

Blooms and Slabs Obtained by Primary rolling are converted into plates, sheets, rods, and Other secondary members through Hot Rolling.

Cold Rolling:

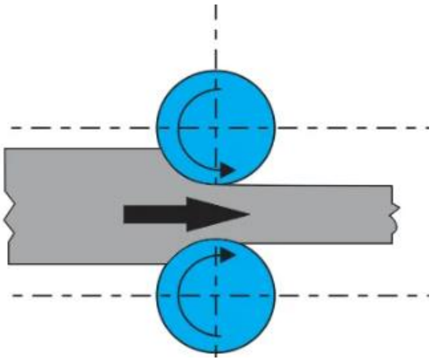
This is a final finishing process, in which the Final products Obtained are given good surface finish, tolerances, and enhancing their mechanical properties.



Types of Rolling Mills

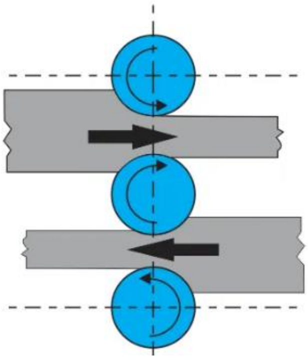
(i) Two-High Rolling Mill:

It Consists of two High stands, and two rolls placed exactly one over the Other. In this type of Rolling Mill, the Rollers rotates in Opposite direction and their direction changes after each Metal pass. The Metal (Ingot) is passed continuously and approximately 25-30 passes are required to convert Ingot to Bloom.



(ii) Three-High Rolling Mill:

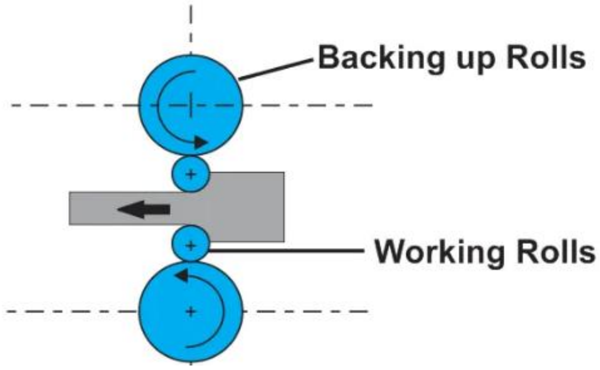
It consists of three high stands and three Rollers present in the same vertical plane. The Top and bottom roller rotate in the same direction, and the middle roller rotates in the Opposite Direction. In this type of Rolling mill, the Direction of the drive is not changed after each pass. It is more Productive and easier with respect to the two-High Rolling Mill.



(iii) Four-High Rolling Mill:

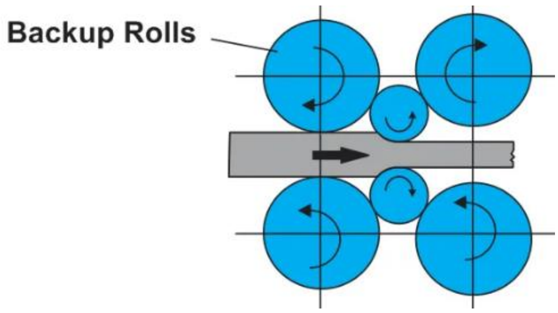
It Consists of two backup rollers and two Working rollers, arranged One over the Other in the same Vertical Plane. The Diameter of Backup rollers is always greater than the Working rollers. This type of rollers is mainly used in Sheet Rolling.

The Two Working Rollers of small diameters are used to reduce the power demands, but it increases the chance of bending of working rollers, and as a result, non-Uniform compression of sheets. This is the reason we use Backup rollers for reducing the bending of Working rollers.



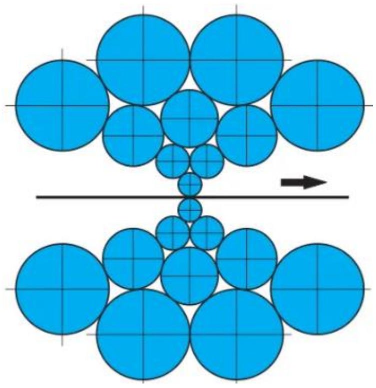
(iv) Cluster Mill:

It consists of Two Working rollers and two or more backup rollers. The number of Backup rollers depend upon the amount of support required for working. It is mostly used in Cold rolling Operations.



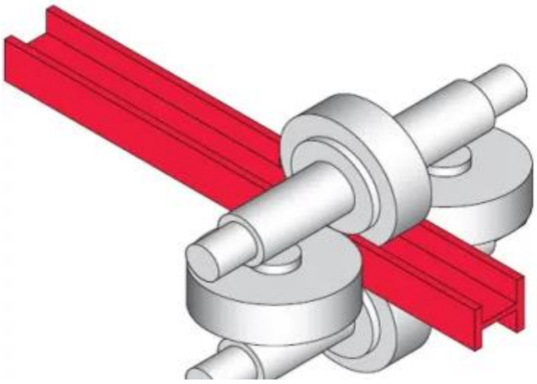
(v) Multi-High Roll Mill:

It consists of two small diameters of working rollers and an intermediate row of driving rolls, and a row of Backup rollers. The arrangement is made in such a way that the whole system achieves exceptional rigidity. Multi-High Rolling mills are used for making a sheet of minimal thickness.



(vi) Universal Rolling Mill:

It consists of two vertical rollers and two Horizontal rollers. The Vertical rollers are arranged between the bearing of horizontal rollers in the vertical plane. It is widely used to produce blooms from Ingot, and for rolling wide flange H-Section beams.



Types of Rolling Process:

(i) Thread and gear Rolling:

(ii) Shape Rolling:

(iii) Ring Rolling:

(iv) Tube Piercing:

(v) Skew Rolling:

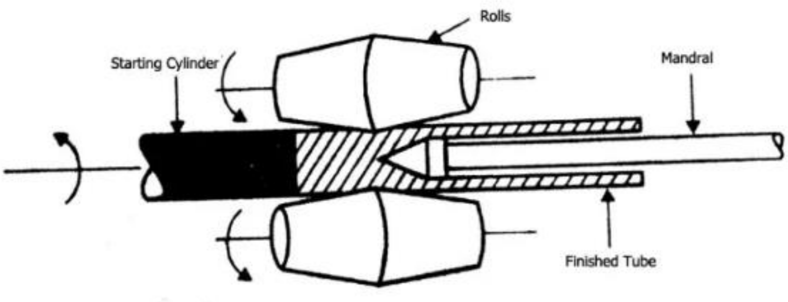
(vi) Transverse Rolling:

(vii) Roll Bending process:

(viii) Flat Rolling:

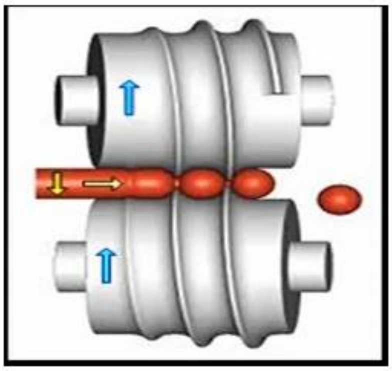
Tube Piercing:

This type of rolling process consists of two Rollers and a stationary mandrel. The rollers rotate on the Metal, and the Metal moves forward towards the mandrel. Metal's movement toward the mandrel creates a hole inside the Metal due to the mandrel's compressive stress. It is used to make a seamless hollow tube of a thick walls.



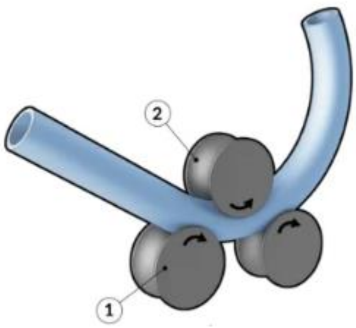
Skew Rolling:

This type of rolling process is used to make ball bearing. In this process, metal is passed through the specially designed roller, and bearing balls come out as a finished product. It is a very convenient method that we can use in the mass manufacturing of ball bearings.



Roll Bending process:

This type of Rolling process is used to bend the metal passed through it. The rollers are arranged that, when the metal is passed through it, gets a curvature along the roller's direction. The roll bending process is mainly used in bending tubes of chassis for the vehicle, which increases its aerodynamic efficiency.



Application of Rolling:

The rolling operation used in various industries such as:

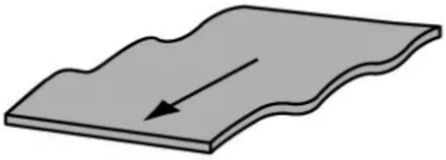
- Rods, seamless hollow tubes are made by rolling.
- Rolling is used to producing cross-section of large sections.
- Rolling is used to cutting the gears on the gear blank.
- The threaded parts, bolts, screws, etc. which have mass production is made by the rolling process.
- In automotive industries, various parts are manufactured by the rolling process.
- The rolling process is used to made plates, steel sheets, etc.
- Bearing, Turbines rings are rolling products.

Defects of Rolling:

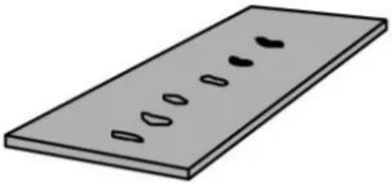
Wavy Edges Crack:

The result is thicker as the middle portion of the rolling part is bent or deflected by the compressive load. There are some different cases. Those are as follows.

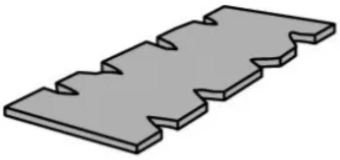
- For the imperfection of the roll gaps, variation occurs on the rolling sheets.
- If the thickness varies and along with that volume and width are constant then the center is shortened than the edges. But the body is continuous.
- Then the edges portions are in the compression and the center portion is the tension.
- The result of the edge is wavy.



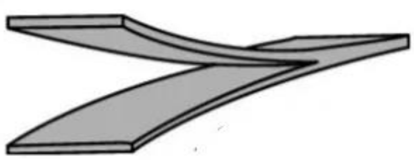
Zipper Cracks in Centre of Strip:
Zipper Crack is a type of Wavy Crack. If there is an uneven stress distribution on the strip, then the crack occurs in the centreline of the strip. It is called Zipper Cracks in the Center of Strip. This crack looks like a zip so that it called Zipper Cracks.



Edge Crack:
Edge cracks occur when the hot rolls are cooled. It happens as excessive quenching effects on the strip.
If excess water is used to cool the edges.
The use of excess water might give the result of unflattens in the strips.
The edges of the metal got rounded off as the friction force prevents the corners and increases the length of the center portion.



Alligator Crack:
Alligator Crack is one type of cracking where the metal has any inclusions or weakness of metallurgy. That causes factor in the strip. As this crack separates the layers and increases the slabs openings, it looks like the mouth of an alligator. So that name of this crack is Alligator Crack.



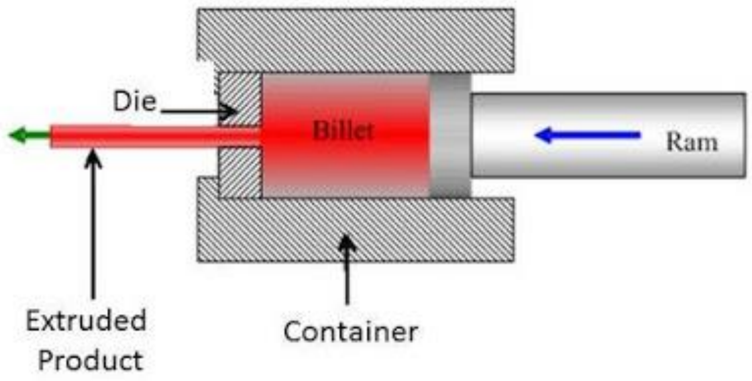
Extrusion

Extrusion is a **metal forming process** in which metal or work piece is forced to flow through a die to reduce its cross section or convert it into desire shape. This process is extensively used in pipes and steel rods manufacturing. The force used to extrude the work piece is compressive in nature. This process is similar to drawing process except drawing process uses tensile stress to extend the metal work piece. The compressive force allows large deformation compare to drawing in single pass.

Working Principle:
Extrusion is a simple compressive metal forming process. In this process, piston or plunger is used to apply compressive force at work piece. These process can be summarized as follow.

- First billet or ingot (metal work piece of standard size) is produced.
- This billet is heated in hot extrusion or remains at room temperature and placed into a extrusion press (Extrusion press is like a piston cylinder device in which metal is placed in cylinder and pushed by a piston. The upper portion of cylinder is fitted with die).
- Now a compressive force is applied to this part by a plunger fitted into the press which pushes the billet towards die.
- The die is small opening of required cross section. This high compressive force allow the work metal to flow through die and convert into desire shape.
- Now the extruded part remove from press and is heat treated for better mechanical properties.

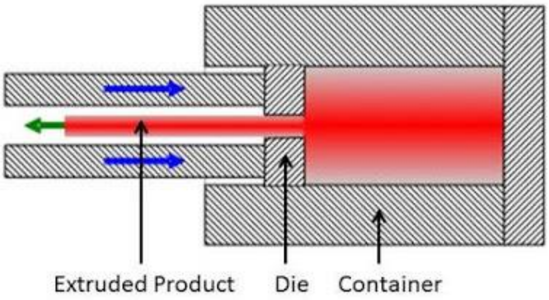
Types of Extrusion
According to the direction of flow of metal
Direct Extrusion:
In this type of extrusion process, metal is forced to flow in the direction of feed of punch. The punch moves toward die during extrusion. This process required higher force due to higher friction between billet and container.



Direct Extrusion

Indirect Extrusion:

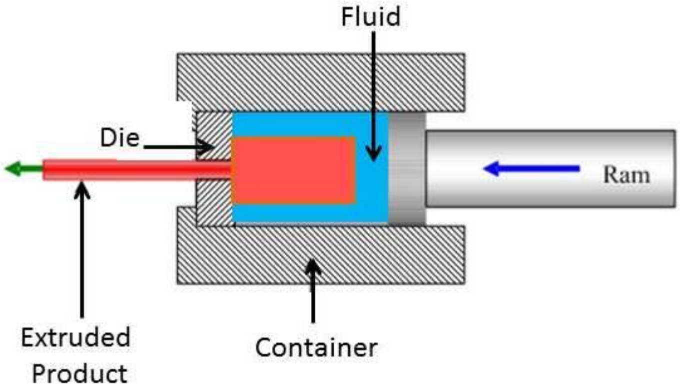
In this process, metal is flow toward opposite direction of plunger movement. The die is fitted at opposite side of punch movement. In this process, the metal is allowed to flow through annular space between punch and container.



Indirect Extrusion

Hydrostatic Extrusion:

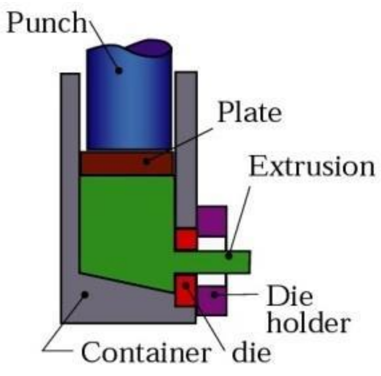
This process uses fluid to apply pressure on billet. In this process, the friction is eliminated because the billet is neither contact with cylinder wall or plunger. There is a fluid between the billet and plunger. The plunger applies force on fluid which further applied on billet. Normally vegetable oils are used as fluid.This process accomplished by leakage problem and uncontrolled speed of extrusion.



Hydrostatic Extrusion

Lateral Extrusion

In **Lateral Extrusion,** the container is in a vertical position as shown in the image and the die is located on the side. This process is suitable for low melting point material.



According to the working temperature

Hot Extrusion:

If the extrusion process takes place above recrystallization temperature which is about 50-60% of its melting temperature, the process is known as hot extrusion.

Advantages:

- Low force required compare to cold working.
- Easy to work in hot form.
- The product is free from stain hardening.

Disadvantages:

- Low surface finish due to scale formation on extruded part.
- Increase die wear.
- High maintenance required.

Cold Extrusion:

If the extrusion process takes place below crystallization temperature or room temperature, the process is known as cold extrusion. Aluminum cans, cylinder, collapsible tubes etc. are example of this process.

Advantages:

- High mechanical properties.
- High surface finish
- No oxidation at metal surface.

Disadvantages:

- High force required.
- Product is accomplished with strain hardening.

Extrusion Defects

Depending on the material condition and process variables, extrudates can develop many types of defects that could affect the quality of the end product. These defects can be grouped under the following three defects.

- Surface cracking
- Piping
- Internal cracking

Application:

- Extrusion is widely used in production of tubes and hollow pipes.
- Aluminum extrusion is used in structure work in many industries.
- This process is used to produce frames, doors, window etc. in automotive industries.
- Extrusion is widely used to produce plastic objects.

Advantages and Disadvantages:

Advantages:

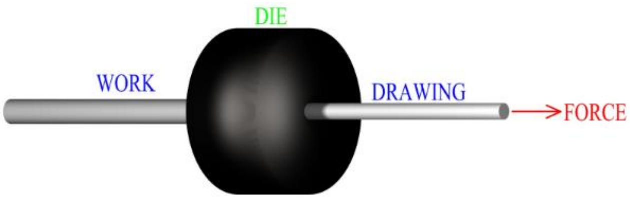
- High extrusion ratio (It is the ratio of billet cross section area to extruded part cross section area).
- It can easily create complex cross section.
- This working can be done with both brittle and ductile materials.
- High mechanical properties can achieved by cold extrusion.

Disadvantages:

- High initial or setup cost.
- High compressive force required.

Drawing

Drawing is a **metal forming process** used to reduce cross section and increase length of work piece. This process associated with tensile force which distinguishes it from other metal forming processes like **extrusion**, **forging** etc. In this process a large cross section work piece is forced to pass through a die which has smaller opening comparing cross section area of work piece. This will plastically deform the work piece by decreasing its cross section area and increases its length. This process is used for making wires, rods, tubes etc.



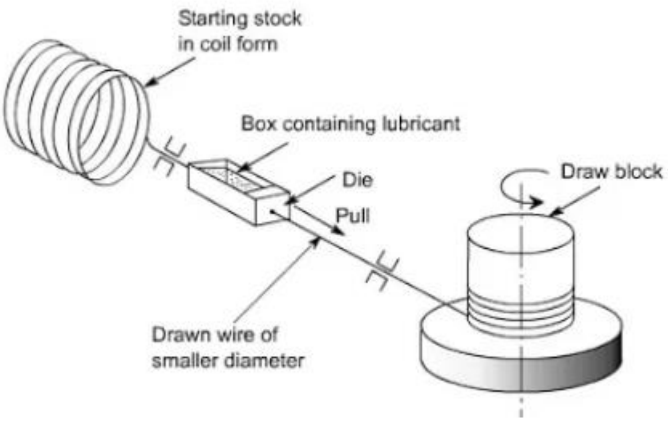
Requirement of Drawing Process:

- The material should have sufficient ductility so it can sustain tensile force.
- The material should possess high tensile stress.
- The rod or wire should be properly cleaned and dust or scale free before drawing.
- It should be properly lubricated to reduce friction associated with operation.

Drawing Process:

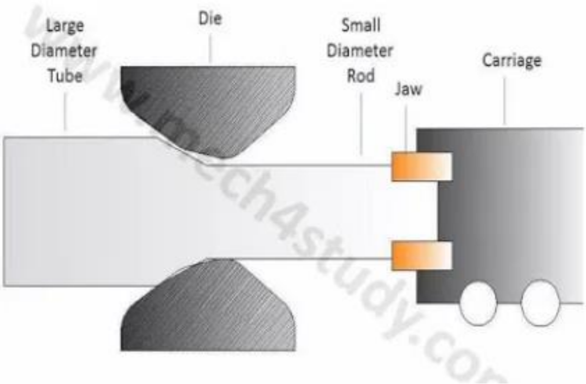
Wire Drawing:

A wire is a circular, small diameter flexible rod. Wire drawing is an **cold working** process. It is an operation to produce wire of various sizes within certain specific tolerances. This process involves reducing diameter of thick wire by passing it through a series of wire drawing dies with successive die having smaller diameter than the preceding one. Mostly die are made by chilled cast iron, tungsten carbide, diamond or other tool material. The maximum reduction in area of wire is less than 45% in one pass.



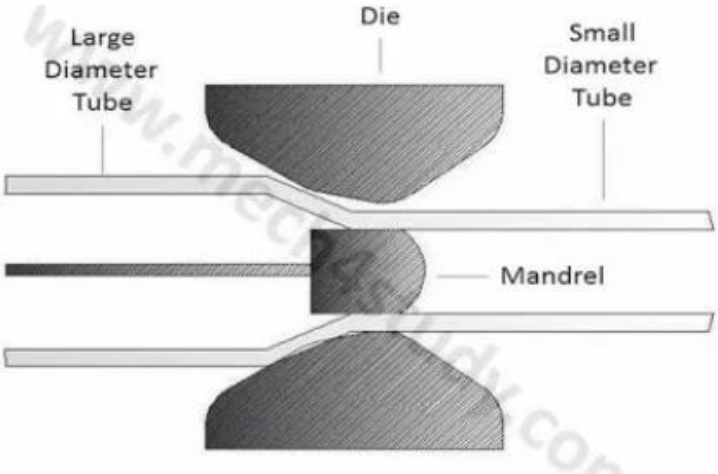
Rod Drawing:

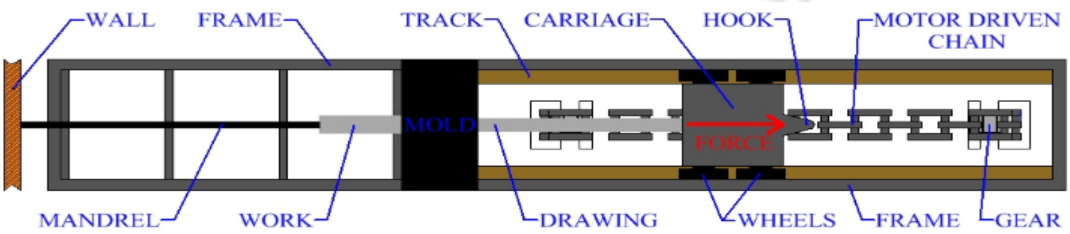
Rod drawing is similar process like wire drawing except it is rigid and has larger diameter compare to wire. This process need heavier equipment compare to wire drawing because the wire can be coiled but a rod should be kept straight. The work piece is first fed into die and pulled by a carriage which increase its length and decrease its cross section. Now the rod is to be cut into sections.



Tube Drawing:

Tube drawing is also similar to other two processes except it uses a mandrel to reduce wall thickness and cross section diameter of a tube. This mandrel placed with die and the work piece is pulled by a carriage system as describe in rod drawing. The tube is either circular or rectangular. It also required more than one pass to complete drawing operation.

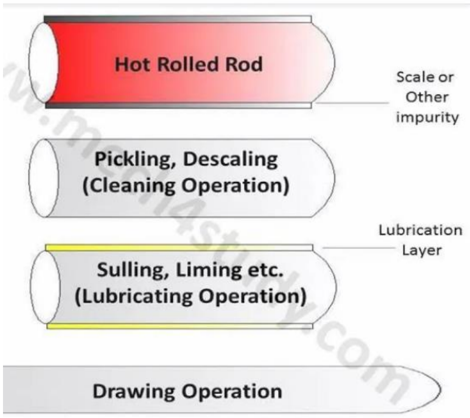




Working Process:

All drawing process works on same principle. Its working can be summarized as follow.

- First a hot rolled rod is created by other metal forming processes like forging, extruding, centrifugal casting etc.
- Now the rod is made pointed to facilitate the entry into the die.
- The dust or other scale particle should clean from the rod. This process is done by acid pickling.
- Now the prepared skin is coated with lubricant. This process uses either sulling, coppering, phosphating or liming process. Sulling is a process of coating with ferrous hydroxide. In phosphating magnesium or iron phosphate is coated. Cu and Sn are used for lubricant high strength material. Oil and grease use for wire drawing and soap is used for dry drawing.
- Now the rod is pulled through various dies to convert it into desire shape. The die is affected by several stresses so it is made by high strength alloy steel like tungsten carbide etc.



Application:

- This process is used for making wire of copper, aluminum etc. which are used in electrical industries.
- Paper clip, helical spring etc. are wire drawing product.
- Small diameter rods and tubes are drawing product.
- It is used to produce large length of small cross section.

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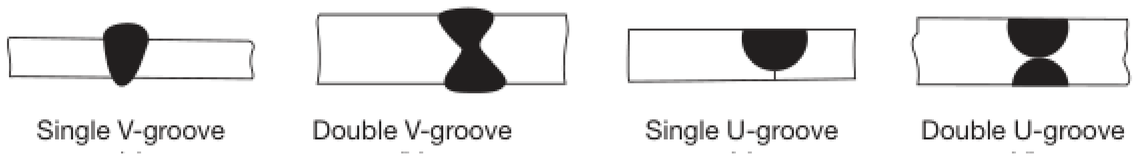
Welding

Welding is a joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure alone, and with or without the use of filler material. This is a permanent joint. It cannot be disassembled easily. The ability of a metal to be welded easily is known as Weldability.Weldability is ability or property of a metal due to which it can be easily welded. It depends on the following factors:-

1. Heat applied during the welding process.
2. Welding process, i.e., types of welding used to make the joint.
3. Thermal conductivity of the work materials.
4. Constituents of the materials.
5. Melting point of the parent metal.

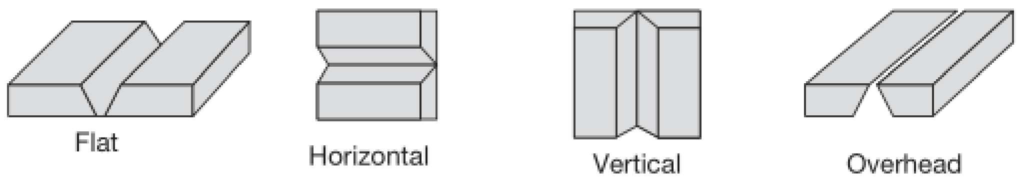
Types of grooves

For complete penetration, sound welded joints, and good strength, beveling preparation of edges and cleaning are required.



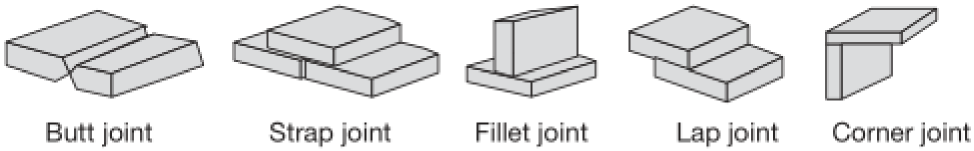
W**elding positions**:

According to welding position the welding can be classified as flat, horizontal, vertical, and overhead welding.

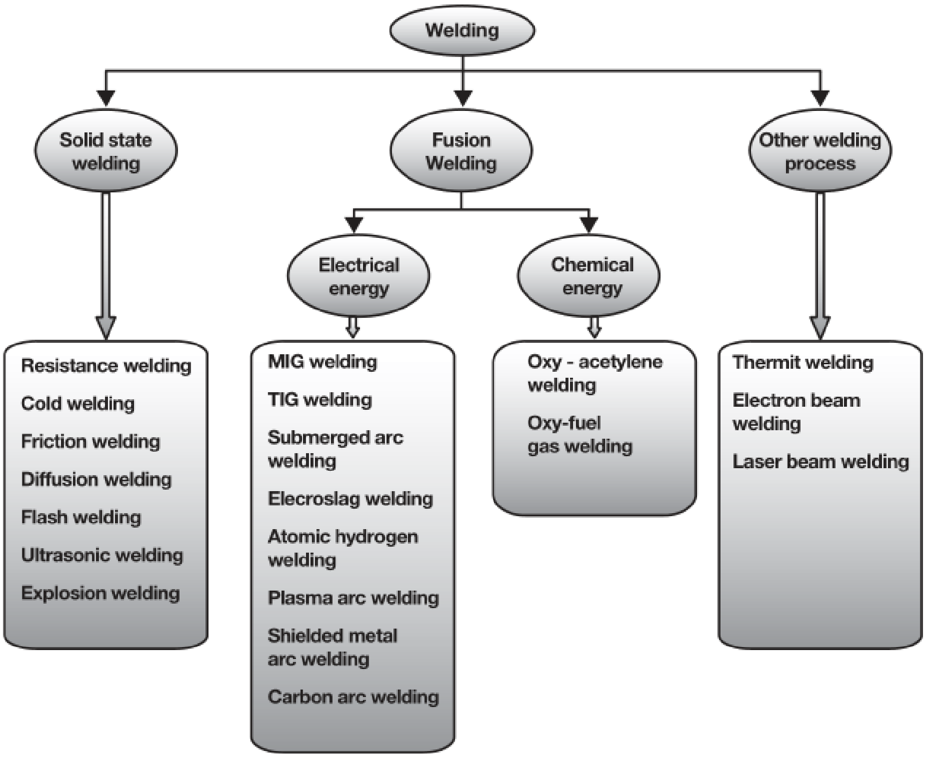


Welded joints:

According to the relative position of two pieces of metal, which are to be joined,



WeldIng process



Gas welding

The various types of gases are burnt in combination with oxygen and the flame is applied at the edge of metal plates to be joined. The heat of combustion of the gas melts the metal; filler material may or may not be applied to fill the groove. The molten metal fills the groove which after complete fusion and solidification forms a strong joint. External pressure may or may not be applied at the joint.The different types of gases used in gas welding are:

1. Acetylene; 2. Hydrogen; 3. Methane;4. City gas; 5. Natural gas; etc.

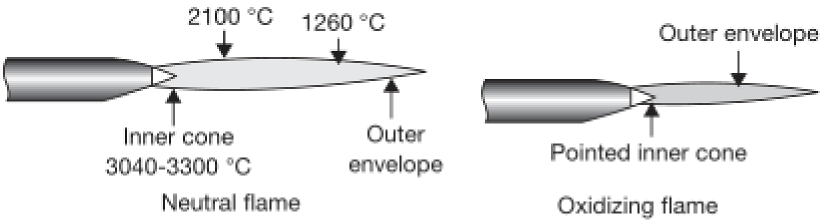
Oxyacetylene Welding

The highest temperature obtained in oxy-acetylene welding is 3200°C. Acetylene can be used as a gas from a separate cylinder or through reaction of water on calcium carbide. Three different types of flames such as neutral, oxidizing, and carburizing, are generated at the tip of welding torch by regulating the amount of acetylene and oxygen with the help of pressure regulators and control valve. These flames are-

Neutral Flame:

Neutral flame is generated at the tip of the welding torch with an equal volume of oxygen and acetylene mixing in the torch. The two sharply defined zones are inner white cone and outer blue envelope. The maximum temperature occurs at a distance of 3 to 5 mm from the inner cone.The reaction at the inner cone is:

$$C_2H_2 + O_2 = 2CO + H_2$$



The outer envelope works as a protector and pre-heater of the workpiece. The metals using a neutral flame for welding are cast iron, mild steel, stainless steel, copper, aluminum, etc.

Oxidizing Flame:

Oxidizing flame is generated with a higher proportion of oxygen. The proportion of oxygen and acetylene used is 1.15–1.5. The flame is similar to neutral flame but the inner cone is shorter than that of neutral flame; the outer envelope is light blue. In this flame, there is complete combustion of acetylene and forms carbondioxide and water vapor. This is oxidizing in nature and used in welding of brass, zinc, bronze, and gold, etc.

Reducing Flame or Carburizing Flame:

In this flame, acetylene is used in excess amount than the theoretically required. The ratio of oxygen and acetylene used is 0.85 to 0.95. The three zones in this flame are the inner cone, which is not sharply defined; the outer envelope is similar to neutral flame; the third zone surrounding the inner cone extends up to the outer envelope. It is whitish color and shows the excess of acetylene used. This flame is used for welding of low carbon steel, aluminum, non-ferrous metals like Monel metal, nickel, etc.

Oxyacetylene Welding Equipments:

Following equipments are used in oxy-acetylene welding

Gas Cylinders:

Two gas cylinders made of steel are used. One is of black color used for oxygen and other is of maroon or red color used for acetylene.

Pressure Gages:

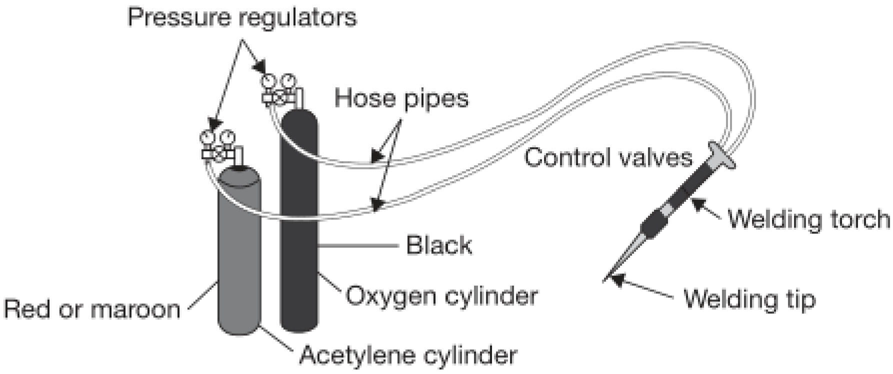
Each cylinder consists of two pressure gages. One pressure gauge shows the pressure of the gas inside the cylinder and other shows pressure of the gas supplied to blowpipe.

Pressure Regulator:

Each cylinder is provided with a pressure regulator. The function of the pressure regulator is to control the pressure of gas supply to blowpipe or to maintain the constant pressure of the gas.

Blowpipe or Welding Torch:

The cross-sectional view of welding torches has high-pressure welding torch and low-pressure welding torch,respectively.The high-pressure blow pipe consists of two passages one is for oxygen and other is for acetylene. Both the gases are mixed in a chamber and then driven out through the orifice of the blowpipe nozzle with the desired velocity. These nozzles are usually known as tips and are made interchangeable so that the same blowpipe can be used for different sizes of the tips.



Advantages

- The equipment used in oxy-fuel welding is less costly and easily maintainable.
- It is portable and can be used anywhere.
- It can be used to join most of the common metals.
- The flame temperature can be easily controlled.
- This can be used for cutting purposes.

Limitations

- Due to lack of concentration of heat, a large area of the metal is heated and distortion is likely to occur.
- Oxygen and acetylene gases are expensive.
- Storing and handling of gas cylinders involve greater safety measures.

Welding Rod and Fluxes:

Welding rod used in a gas welding has a similar composition to work material. The diameter of welding rod depends on the thickness of the metal plate.The diameter of welding rod used is half of the thickness of the plate. To increase the fluidity of molten metal and to protect the weld pool from the atmospheric gases, fluxes are used. Various types of fluxes are used to weld the different types of metals but for mild steel, no flux is required.

1. Copper and Copper Alloys: Mixture of sodium and potassium borates, carbonates, chlorides, sulphates, borax ($Na_2B_4O_7.10H_2O$), Boric acid (H_3BO_3) and Di-sodium hydrogen phosphate (Na_2HPO_4) are used for dissolving oxides of copper.

2. Ferrous Metals

- Carbon steel: Dehydrated Borax, calcium oxide, dissolved in liquid.
- Alloy steel: Boric acid, dehydrated borax, calcium fluoride.

3. Aluminum and Aluminum Alloys: Mixture of alkaline fluorides, chlorides and bisulphate of calcium, sodium, potassium, lithium and barium.

Gas Welding Methods

1. Leftward welding (Forehand welding).

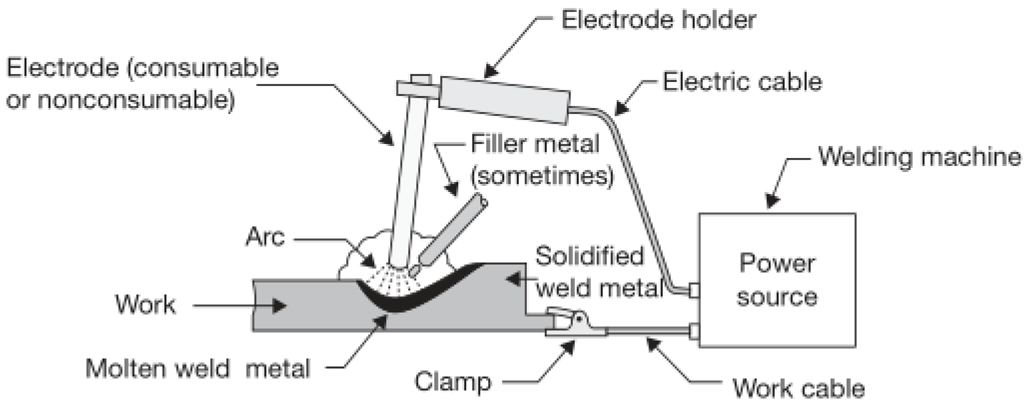
The welding rod is held in left hand and blowpipe is held in in right hand. Leftward welding is used for the metal plate thickness up to 3 mm. Welding proceeds from right to left. It is also known as forward or forehand welding. The inclination of welding rod with the plate is 30-40 and inclination of blowpipe with the plate is 60°–70°.

2. Rightward welding (Backhand welding).

Rightward welding is used for thicker plates and proceeds from left to right. The inclination of welding rod is same as in the leftward welding but the inclination of blowpipe is 10-20 less than that in the leftward welding, i.e., at 40°–50°. It is also known as backward or backhand welding.

Electric arc welding

In electric arc welding, the heat required for melting the metal is generated by short-circuiting the electrodes. An intense heat is produced in the electric arc. Various types of mechanism are used to produce arc and to stabilize it. The selection of the mechanism, i.e., type of electric arc welding depends on the heat required to melt the metal



Mechanism of Arc Generation:

When two electrodes are brought into contact with each other, electric spark is produced due to short-circuiting. Just after sparking, the electrodes are separated by 2 to 4 mm distance. The air-gap between the electrodes is ionized due to the flow of electron from the cathode to anode and heavier positive ion from the anodeto the cathode. Thus, the arc is continued. The arc length is 0.6 to 0.8 of the electrode diameter.

Modes of Metal Transfer in Arc Welding:

There are numbers of forces dominant in arc welding, which are responsible for the metal transfer. These forces are gravity force, surface tension, electromagnetic interaction, and hydrodynamic action.

Methods of Arc Generation:

1. Between consumable electrode and workpiece.
2. Between two non-consumable electrode and workpiece.
3. Between a non-consumable electrode and workpiece.

Polarity:

Polarity is a connection of the electrodes and work metal with particular electric terminals. Polarity is significant in only D.C. supply. Two types of polarity are used:

1. Straight Polarity.
2. Reverse Polarity

Differences between A.C. and D.C. Welding

A.C. Welding	D.C. Welding
Advantages:	**Advantages:**
1. Equipment of A.C. welding is less expensive, light in weight, easy maintainable and having low operating cost.	1. It has higher arc stability than that of A.C. welding.
2. It has higher efficiency in comparison to D.C. welding (85%).	2. The Bare electrode can be used easily.
3. It consumes low electrical energy per Kg of metal deposited (3 to 4 kwh / Kg).	3. It has high power factor (0.6 to 0.7).
4. Minor magnetic arc blow problem occurs in comparison to D.C. welding.	4. Facility of change of polarity is done easily.
Disadvantages:	**Disadvantages:**
1. It has low power factor. (0.3 to 0.4).	1. It has low efficiency (30 to 60%).
2. For stability of the arc, voltage/ frequency requirement of A.C. current is high.	2. It involves high cost of equipment and operation.
3. Only coated electrodes can be used with A.C. If bared electrode is used, shielding gas must be there to keep the continuous ionized path of the arc.	3. It consumes high power (6 to 10 KWH / Kg of metal deposited).
	4. Chances of the magnetic arc blow problem are more.

Types of Electrodes:

1. Coated electrode.
2. Bared electrode.

Coated electrode consists of a coating of the flux of various ingredients on its surface. The coating is generally used for arc stability. Normally, sticks of electrodes are available in the sizes of 3.2, 4, 5, 6, 8, 9, and 12 mm of diameter and 350 mm or 450 mm in length.In the case of coated electrodes, the diameter is measured in the bare portion, i.e., without coating.

Functions of Electrode Coatings

1. To stabilize the arc:
2. To provide a gaseous atmosphere for protection from atmospheric gases like O, H, N,
3. To remove impurity in the form of slag. Slag also protects the molten pool of metal and reduces cooling rate.
4. To reduce spatter of weld metal.
5. Acts as deoxidizer, i.e., reduces the melting point of metal oxide.
6. To include or add the alloying elements.
7. To insulate the electrode.
8. Slow down the fast cooling rate of the weld.
9. Increase the deposition efficiency.

Ingredients of Electrode Coating

1. Ingredients for slag formation—Asbestos, fluorspar, mica, silica, titanium dioxide, iron oxide, calcium carbonate, aluminum oxide, magnesium carbonate, etc.
2. Ingredients for arc stabilization Feldspar, sodium oxide, magnesium oxide, calcium oxide, mica, potassium silicate.
3. Ingredients for deoxidizing metal oxide Cellulose, calcium carbonate, dolomite, starch, dextrin, wood flour, graphite, aluminum, ferromanganese.

4. Ingredients for binding Sodium silicate, potassium silicate, asbestos.
5. Ingredients for improvement in strength of weld TiO, Iron power.
6. Ingredients for gas formation Cellulose, carbohydrate, etc.

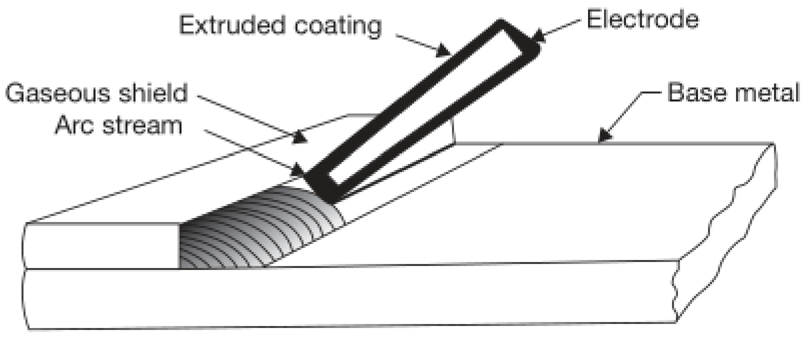
Selection of Electrodes

Selection of electrodes is based on the following factors:
1. Composition of the base metal.
2. Thickness of base metal.
3. Depth of penetration required.
4. Welding position.
5. Use of A.C. or D.C.
6. Mechanical strength required for the joint.

Types of electric Arc welding
1. Carbon arc welding.
2. Metal arc welding.
3. Metal inert gas arc welding (MIG).
4. Tungsten inert gas arc welding (TIG).
5. Submerged arc welding.
6. Electroslag welding.
7. Atomic hydrogen welding.
8. Plasma arc welding.

Shielded Metal Arc Welding (SMAW)

In this welding process, a special electrode that consists of metal wire which has bonded coating containing flux of desired gradients. The heat required for welding is generated by an arc between the flux covered consumable electrode and the workpiece. . As the coating on the electrode melts and vaporizes, it forms a protective layer of gases that stabilizes the arc and protect. Flux also reacts with impurities of the metal and forms slug which floats on the surface of the molten metal and protects from contamination of atmospheric gases. After solidification, the slug is chipped out from the weld.



Advantages

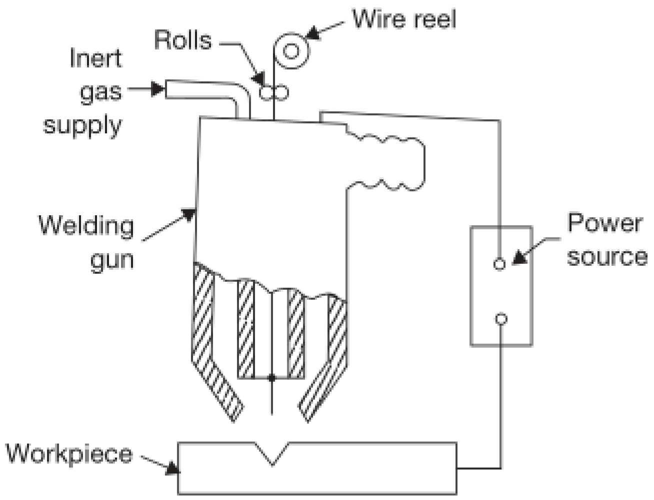
- The equipment required is simple, portable, and less expensive.
- Welds can be used in all positions.

Disadvantages

- The process has to change the electrode frequently due to consumable in
- Low melting metals such as zinc, lead, and tin are not welded by SMAW.

Metal Inert Gas Arc Welding (MIG)/Gas Metal Arc Welding(GMAW)

In MIG welding, a high current density is supplied to the electrode and workpiece. Carbon dioxide gas or any inert gas like helium or argon is supplied to protect the weld pool. The electrode used is consumable and is in the form of a wire. The welding current is used in the range of 100-300 amp. In this welding process, the metal transfer rate is very high. Therefore, it is generally used for welding of thick plate. The metals, welded by MIG welding are alloy steel, stainless steel, copper,brass, aluminum, magnesium, nickel, lead, silver, tungsten, etc. The current used is direct current and voltage is constant-arc voltage (CAV). Electrode used as a positive pole and work as the negative pole.



Advantages

- The rate of weld deposition is very high.
- The quality of the weld is good due to the transfer of molten metal under the protection of inert gases.
- No frequent change of electrode is required.
- No flux is required; therefore no slug forms over the weld. This makes the process cleaner.
- It is a versatile process and can be used on both light and heavy gauge structural plates.

Limitations

- The cost of equipment and the consumable wire is much higher as compared to shielded arc welding.

Resistance weldIng

In a resistance welding, heat is generated by passing an electric current through the high resistance. The amount of heat generated depends on the value of current and resistance as

$$H = I^2 . R. t \text{ Joule.}$$

where I = Current in ampere, R = Resistance in ohm, t = Time in second.

When the electric current is passed through the welding members, they offer maximum resistance at the interface in comparison to other parts of the member. Hence largest heat is generated at the interface. When the proper temperature is reached, the pressure is applied to complete the weld. Because of application of pressure, the process requires lower tem perature as compared to oxy-fuel gas or arc welding as the metal has to reach the softened state, not in the molten state.

There are six types of resistance welding:

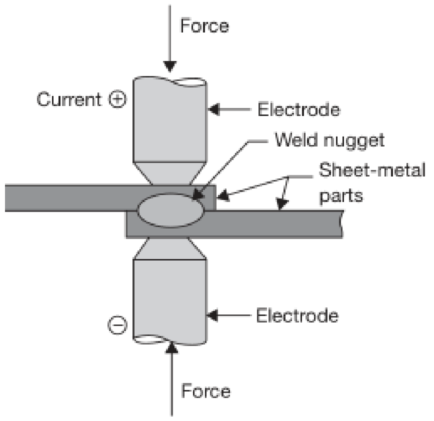
1. Spot welding.
2. Seam welding.
3. Projection welding.
4. Flash welding.
5. Percussion welding.
6. Butt-welding.

Advantages

- This is a fast process and suitable for mass production.
- No fluxes or filler materials are required.
- Less skilled operators may be employed.
- Practically all conductive materials can be welded by this method.

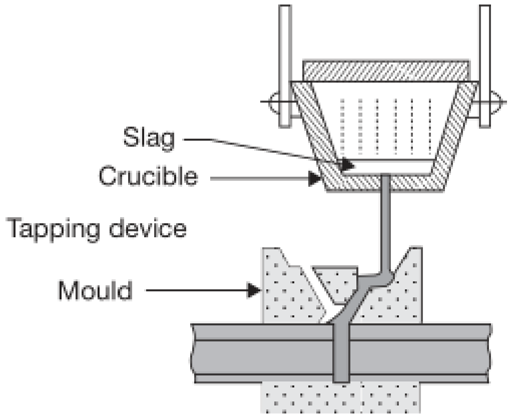
Limitations

- Few metals like tin, zinc, and lead are difficult to weld by this method.
- Control of pressure and current during the process is critical.
- Equipment cost is high.



Thermit weldIng

Thermit welding is similar to casting. A mixture of powdered aluminum and iron oxide is placed inside a vessel.The mixture is ignited by heating to about 1550°C with the help of barium oxide powder. A chemical reaction takes place in a vessel as Due to the chemical action, a bright white heat is produced and reaction leads to molten iron. The molten iron is tapped from the vessel and made to run in the cavity of the joint. The temperature attained is about 3000°C.



Advantages

▸ It produces high-quality welds because the metal solidifies from the inside towards the outside, and all air is executed from around the molds.

▸ There is no limit to the size of welds that can be made by thermit welding.

Disadvantages

▸ It is an extremely old process and has been replaced to a large degree by an alternative method such as electroslag welding.

Oxy-fuel welding (oxyacetylene welding, oxy welding, or gas welding) and oxy-fuel cutting

These are processes that use fuel gases (or liquid fuels such as gasoline or petrol, diesel, bio deisel, kerosene etc) and oxygen to weld or cut metals.

Oxy-fuel welding, a welding torch is used to weld metals. Welding metal results when two pieces are heated to a temperature that produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material selection depends upon the metals to be welded.

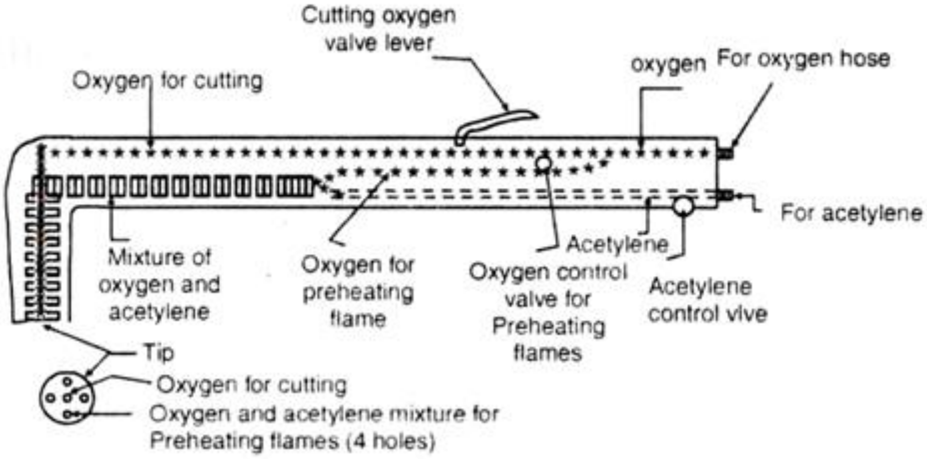
Oxy-fuel cutting, a torch is used to heat metal to its temperature. A stream of oxygen is then trained on the metal, burning it into a metal oxide that flows out of the kerf as dross.Torches that do not mix fuel with oxygen (combining, instead, atmospheric air) are not considered oxy-fuel torches and can typically be identified by a single tank (oxy-fuel cutting requires two isolated supplies, fuel and oxygen). Most metals cannot be melted with a single-tank torch.

Equipment’s for Gas Cutting:

The equipments used for Gas-cutting is similar to that of gas-welding except that the welding torch is replaced by a special designed cutting torch.

1. Gas cutting torch.
2. Pressure regulators.
3. Gas cylinders.
4. Hose and hose fittings.
5. Goggles and glasses.
6. Gloves and apron.

7. Spark lighter and spanners.
8. Cylinder valves.
9. Chipping hammer and wire brush.



Gas Cutting Torch:

A specially designed gas cutting torch has a tip of the cutting torch has a larger centre opening from which a jet of oxygen comes to cut the metal. This central opening surrounded by a set of orifices (generally four) which supply the oxygen-acetylene mixture for pre-heating. The cutting torch is provided with a high pressure valve in from oxygen and acetylene control valves. On pressing the lever, the high pressure valve releases a jet of oxygen from central orifice, after preheating.

Limitations of Gas-Cutting:

(i) Gas cutting only successfully used when the oxidation (ignition) temperature of the metal being cut is lower than it melting point.

(ii) Therefore, oxy-fuel cutting is not recommended for the cast iron because its ignition temperature is higher than its melting temperature.

(iii) Another condition for the successful application of this process involves ensuring that the melting points of the oxides formed are lower than that of the base metal to be cut.

(iv) Therefore, The process is not appropriate for cutting stainless-steel, high-alloy chromium, chrome- nickel alloys, and non-ferrous alloys because oxides has higher melting point than base metal itself.

Soldering

Soldering is a process of joining two metals by applying low melting point metal or alloy in the gap between the joining parts. The metal or alloy used for filling or joining is known as solder. The melting point of solder is less than 450°C. In soldering joining process, the heat is supplied to the joint by soldering iron. The soldering iron may be heated electrically or by other means. The function of soldering iron is to heat the joint. The flat face of the soldering iron is held directly against the joint assembly so that the heat is transferred effectively to the parts being soldered. In soldering joining process, the heat is supplied to the joint by soldering iron. The soldering iron may be heated electrically or by other means. The function of soldering iron is to heat the joint. The flat face of the soldering iron is held directly against the joint assembly so that the heat is transferred effectively to the parts being soldered. Most of the solders used in soldering joining process are made of lead and tin alloys. Some solders also contain small amounts of cadmium and antimony. The amount of percentage composition of tin and lead determines the physical and chemical properties of joints made with solder. Solders are divided into two categories.

- Soft solder is an alloy of tin and lead.
- Hard solder is alloy of copper and zinc.
- Flux Used: Chlorides fluxes (Zinc Chloride, Ammonium Chloride, and Zinc ammonium chloride).
- This joining process forms a weak joint.

Brazing

Brazing is a hard soldering process, but in this process, metal pieces are heated which are to be joined in this place of the bit as in soldering. In a brazing. spelter is used it is a mixture of copper, zinc and tin. It is stronger in comparison to soldering joint. Brazing may be defined as a joining process that takes place above 450°C but below the melting point of the base metals. Most of the brazing operations are done at temperatures ranging from 600 to 800°C. Since, brazing is done at high-temperature, brazing is useful for joining thick metal parts for making relatively stronger joints. Both similar and dissimilar parts can be joined. The success of brazing operation depends upon that a fact that a molten metal of low surface tension will flow easily and evenly over the surface of a properly heated and chemically clean base metal, just as water flows over a clean glass plate. During brazing, the base metal of two pieces to be joined is not melted. An importantrequirement is that, similar to soldering, the filler metal must be wet the base metal surfaces to which it is applied. Some diffusion or alloying of the filler material with the base metal takes place even through the base metal does not reach its solidus temperature. The surfaces to be joined must be made chemically clean before brazing operation is started. However, the fluxes are applied to remove oxides from the surfaces. Borax is the most commonly used flux during the brazing process. It will dissolve the oxides of most of the common metals.

Advantages of Soldering and Brazing:

- Low operation temperature.
- Joints can be made be permanently or temporarily.
- Metals of dissimilar can be joined.
- High speed of joining.
- Less chance of damaging parts.
- Parts of varying thickness can be joined.
- Easy re-alignment.

Braze Welding

In braze welding, the molten filler metal is not distributed at the joint by capillary action as it happens in brazing or soldering but it is deposited at the point where the weld is required to be made as in the case of gas welding. The braze welding process is a variant of the MIG/MAG welding process, where the majority of the process essential variables are identical to conventional MIG/MAG welding processes. However, in the braze welding process, the melting point of the filler wires is significantly lower than the melting point of the parent material. During the arc welding process, the filler wire melts at temperatures typically over 1600°C, whereas for brazing the wire melts at less than 1000°C.As in the standard MIG/MAG welding process, a continuously fed wire electrode is melted by an arc formed between the electrode and the workpiece, but no significant melting or fusion of the parent metal occurs because of the lower temperature. The molten metal flows into the gap between the parts to be joined and solidifies after wetting either across or between the surfaces via capillary action to form the solid joint.

Advantages

- The requirement of less preheating and permitting greater welding speed, a shorter cooling off period, and is less likely to crack metals.
- No splash or weld spatter.
- A little or no finishing requirement of the completed joints.
- No requirement of as much skill as the technique required for fusion welding.

Disadvantages

- If the joint is to be exposed to corrosive media, the filler metal must have the required corrosion-resistant characteristics.
- All brazing alloys lose strength at elevated temperatures.
- If the joint is to be painted, all traces of the flux must be removed.

WeldIng defects

Cracks:

Cracks occur in the welded joint due to improper welding and solidification of different metals. Cracks may be of following types.

Micro Cracks:

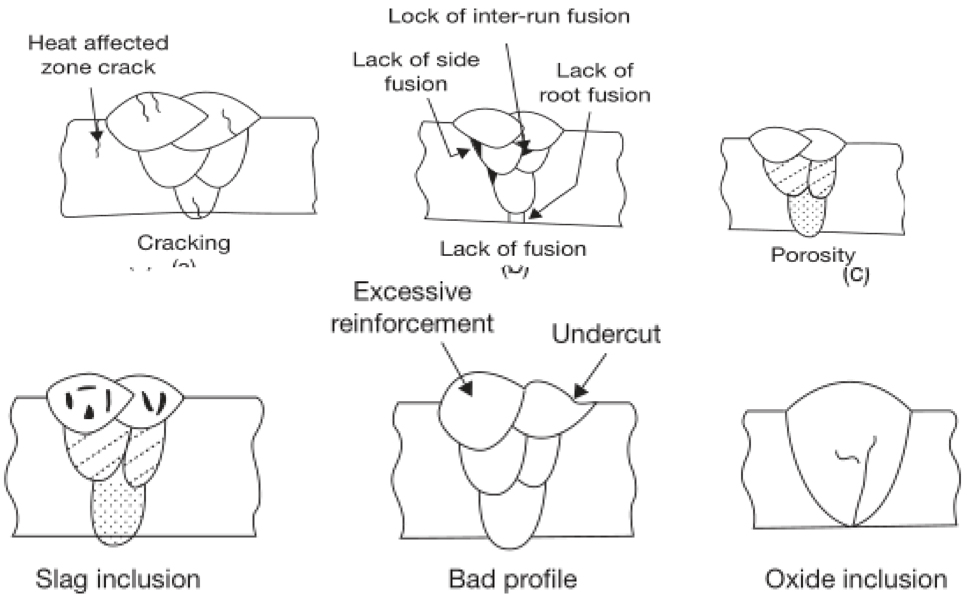
Very small Cracks, which can be seen with the help of microscope only. Macrocracks: These cracks can be seen by naked eye.

Fissures:

These cracks are wider, which occur at the surface of the metal.

Lack of Fusion:

Wrong weld parameters, such as poor weld design, feed rate, welding speed, current, and voltage, lead the problem of fusion and penetration. A proper arc length, good weld design may prevent the problem of poor fusion and improper penetration.



Porosity:

Porosities are voids, holes or cavities of usually spherical shapes. It is caused by gas entrapped in weld metal during solidification, and chemical reactions during welding contaminates such as dirt, oil, grease, rust, paint, etc. Blowholes are voids of large size. Porosity and blowholes are scattered throughout the cross-section of a weld randomly. Small porosities appeared on the surface are known as pinholes. Pinholes are smaller in size.

Slag Inclusion:

Slag inclusion in the form of oxides, sulphur, and flux in the weld causes poor strength and leads to corrosion in the metal. It occurs due to inadequate cleaning of the welding areas.

Shrinkage Cavity:

It occurs in the welding of thicker parts where a large amount of filler metal is required. The molten metal shrinks during solidification and forms a cavity on the surface, which is known as shrinkage cavity.

Undercutting:

Undercutting is a form of a groove on the welding surface. It occurs due to high current and high arc voltage. Proper controlling of current and voltage can prevent it.

Spatter:

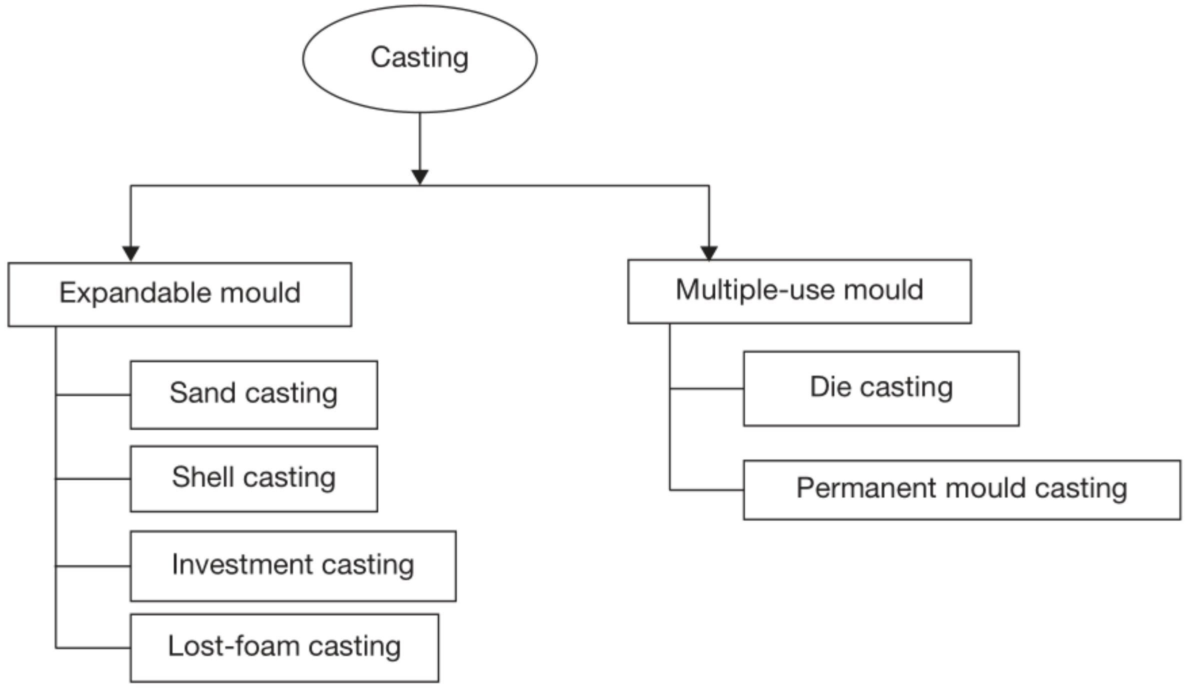
Spatters are small bead thrown in all directions during welding. It occurs due to very large current and wrong electrode selection.

Distortion:

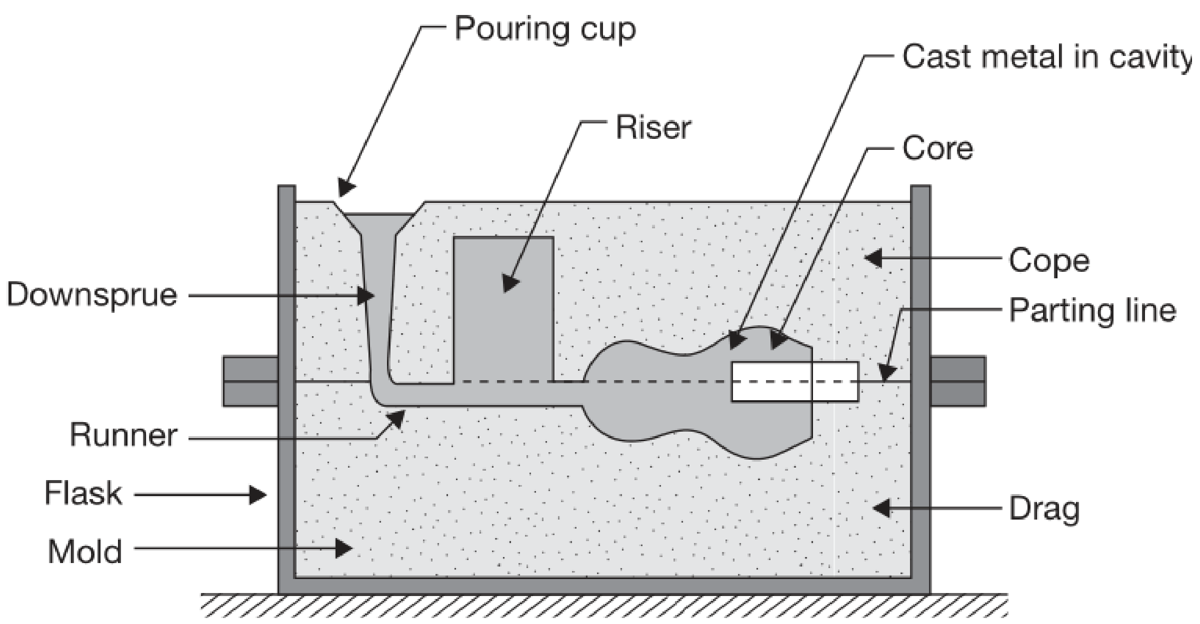
Distortion is a result of the improper rate of heating and cooling in the weld zone or adjacent metal leading to the generation of stresses. Proper clamping and smaller diameter electrode may reduce the problem.

CASTING

The casting process can be defined as a primary shaping process in which a molten metal is poured into a mold cavity and allowed to solidify for a predetermined time so as to take the shape of the mold, after complete solidification, it is taken out from the mold. The prod uct of casting is also known as casting and the place where casting work is done is known as “foundry shop.

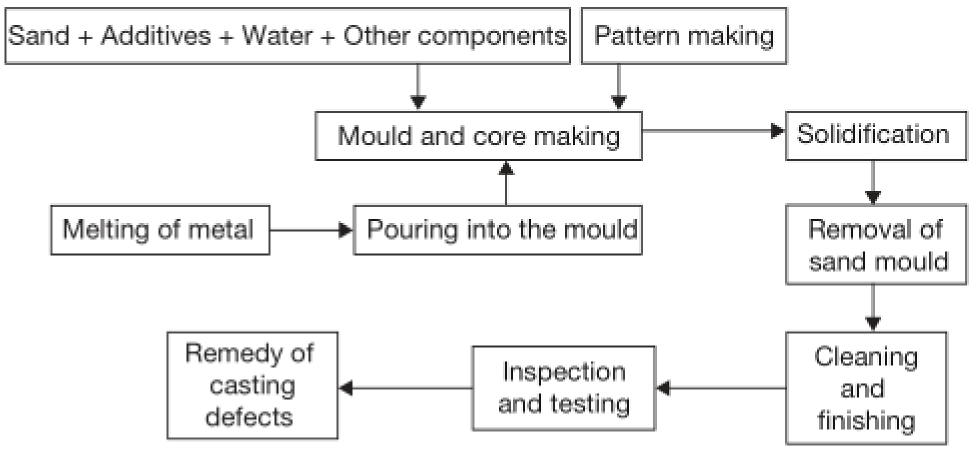


Sand casting



Flask: It is a rigid box opens at top and bottom that holds the complete mold. Flask may be divided into three parts—the upper, middle, and lower; these three parts are known as cope, cheek, and drag, respectively.
Core: A sand or metal shape that is inserted into the mold to create internal hole or recess.
Mold Cavity: It is a cavity of casting shape in the mold connected to runner and riser. It is used to pour the molten metal in which metal solidifies and gets the shape of the cavity.
Riser: An additional opening in the mold that provides additional metal to compensate for shrinkage and also helps to remove gas or vapor formed during pouring the molten metal into the cavity.
Gating System: It is a network of channels that delivers the molten metal to the mold cavity.
Pouring Cup/Basin: It is located at the top surface of the mold and connected to an upper part of down sprue. It prevents the splitting of molten metal.
Downsprue: It is a vertical portion of the gating system. It facilitates the streamline flow of molten metal.
Runners: It is a horizontal channel which connects the down sprue and gates.
Gate: It controls the amount of flow of molten metal at the entrance of cavity.
Parting Line: It is dividing a line of Cope and drag.

Steps in Sand Casting



Pattern Making
The pattern is a replica of the product, which is to be manufactured through casting. It is used to make a mold cavity of required shape and size. Various types of pattern materials such as wood, aluminum, steel, plastic, cast iron are used in sand casting. The selections of pattern materials are based on their properties,
Pattern allowances
The surface finish of the casting product may not be as good as required, therefore, extra dimensions in the pattern are provided. The extra dimensions or extra materials provided for the pattern are known as allowances. The following allowances are provided for pattern making**:**
(a) Draft Allowance/Taper allowance.
(b) Machining allowance.
(c) Shrinkage allowance.

(d) Distortion allowance.
(e) Shaking allowance/Rapping allowance.

Draft Allowance: To exit out the pattern from the mold easily, the surfaces of the pattern are made taper. The larger dimension side of the pattern is at the parting line. The taper provided may be 1^0 to 3^0

Shaking/Rapping Allowance: To remove the pattern from the mold, the pattern is rapped with the help of draw spike so that they can be detached from the mold. But to the rapping, the cavity in the mold gets enlarged. Therefore, the pattern is made smaller than the casting, which is known as shaking allowance. This is a negative allowance.

Machining Allowance: The dimensional accuracy and surface finish of the casting (especially sand casting) is poor. Therefore, machining is required for good surface finish and dimensional accuracy; to compensate the removal of unwanted materials, extra materials are provided to the pattern, which is known as machining allowance.

Shrinkage/Contraction Allowance: Most of the metals occupy more volume in a molten state in comparison to solid state. When molten metal is poured into a mold cavity there is shrinkage in metal during solidification. When metal is transferred from molten state to solid state there is shrinkage and from hot solid state to room temperature solid state, there is additional shrinkage. So the volume of the pattern is larger than the casting. The extra dimension provided to the pattern to compensate the shrinkage is known as shrinkage allowance.

Distortion Allowance: Distortion in casting occurs in the process of cooling. It occurs due to thermal stresses developed due to differential solidification. It applies to the casting of irregular shape. To eliminate this defect, an opposite allowance of equal amount is provided in the pattern, which is known as Distortion Allowance.

Types of Pattern

(a) Solid pattern or Single piece pattern.
(b) Split pattern.
(c) Loose piece pattern.
(d) Gated pattern.
(e) Match plate pattern.
(f) Sweep pattern.
(g) Skeleton pattern.
(h) Cope and Drag pattern.
(i) Segmental pattern.
(j) Follow board pattern.

Solid Pattern/Single Piece Pattern: A single piece pattern is used for a simple casting. In this pattern, no joint or partition is used. It can be molded in a single molding box .

Split Pattern: If the design of the pattern is not simple, it difficult to withdraw as a single piece from the mold. The pattern is made into two pieces or into a split form and joined together by dowels.

Loose Pieces Pattern: Some single piece patterns are made to have loose pieces in order to enable their easy withdrawal from the mold. These pieces form an integral part of the pattern

during molding . After the mold it completes, the pattern is withdrawn leaving the pieces in the sand, which are later withdrawn separately through the cavity formed by the pattern.
Gated Pattern: In a mass production, where many castings are required, gated pattern may be used. Such patterns are made of metal to give them strength and to eliminate any warping tendency. The connecting parts between the patterns from the gates or runners for the passage of molten metal into the mold cavity, are the integrated parts of these patterns

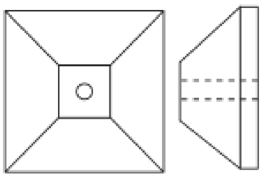


FIGURE 20.4

Single Piece Pattern

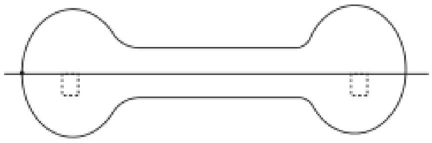


FIGURE 20.5

Split Pattern

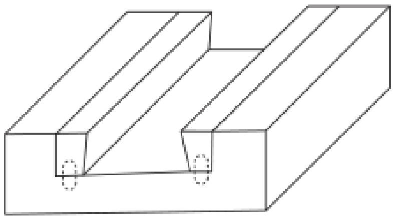


FIGURE 20.6

Loose Piece Pattern

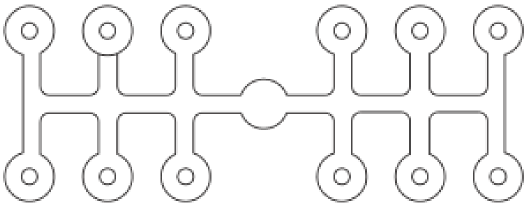


FIGURE 20.7

Gated Pattern

Match Plate Pattern: Match plates provide a substantial mounting for patterns and are widely used with machine molding. a match plate is shown upon which are mounted the patterns for two small dumb bells. It consists of a flat metal or wooden plate, to which the patterns and gates are permanently fastened. On either end of the plate are holes to fit into a standard flask.
Sweep Pattern: Sweeps can be used for preparing molds of large symmetrical castings of circular cross-section. The sweeping equipment consists of a base, suitably placed in the sand mass, a vertical spindle and a wooden template, called a sweep.
Skeleton Pattern: Skeleton pattern requires a large amount of wooden work. It is used for large size casting. A pattern consists of a wooden frame and strips, called skeleton pattern

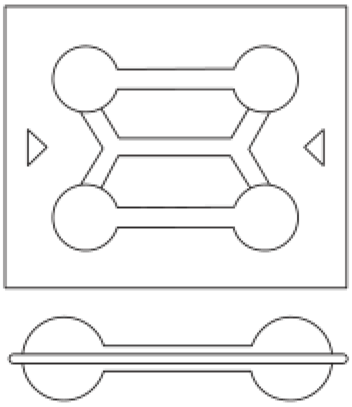


FIGURE 20.8

Match Plate Pattern

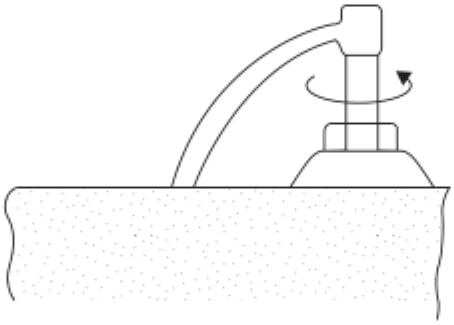


FIGURE 20.9

Sweep Pattern

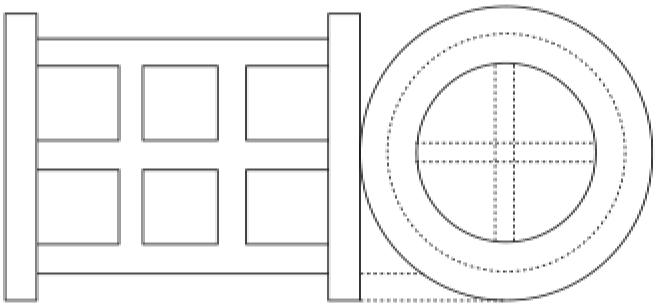


FIGURE. 20.10

Skeleton Pattern

Cope and Drag Pattern

Cope and drag pattern is used for heavy casting which is difficult to handle in a single piece. This pattern is made in two parts in cope and drag and finally assembled together to form a complete mold cavity

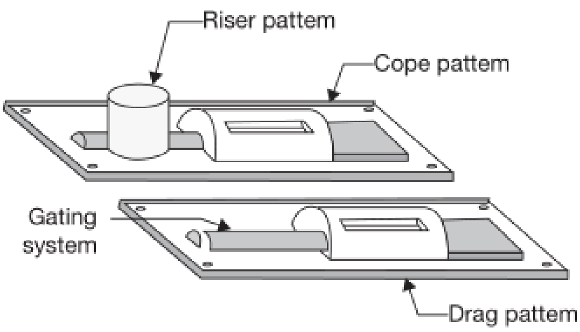


FIGURE 20.11

Cope and Drag Pattern

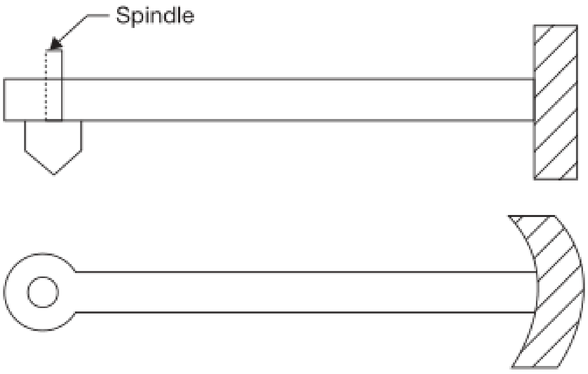


FIGURE 20.12

Segmental Pattern

Segmental Pattern

The segmental pattern is used for large ring-shaped casting . A vertical central spindle is firmly fixed near the center of a drag flask. The bottom of the mold is then rammed and swept level with a sweep. Now, with the segmental pattern is properly fastened to the spindle and in a starting position, molding sand is rammed up on the inside and outside of the pattern but not at the ends. After the surplus sand has been leveled off from its top, the segmental pattern is unfastened from the spindle, rapped and drawn.

Follow Board Pattern: Follow board is a wooden board, which is used to support a thin section pattern. The pattern may have a cavity shape or projection shape. Due to thin section during ramming, there is a chance of breaking of pattern, therefore, a support of the same shape follow board is required

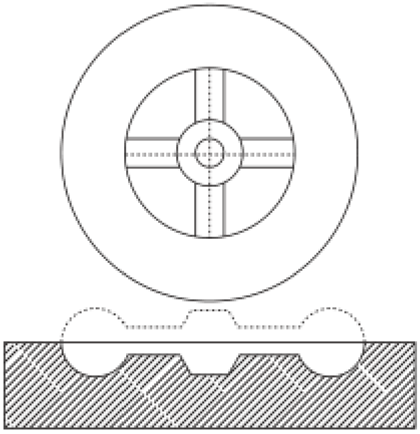


FIGURE 20.13

Follow Board Pattern

Color Codes Used in Pattern

Following color codes are used on the pattern for various purposes as given below:

- Red: Surface is to be machined.
- Black: Surface is to be left unmachined.
- Yellow: core print is to be used.
- Black Stripes or Yellow Base: Stop offs.
- Clear or No Color: Parting surface.

Mould Making

Green Sand: Green sand is a mixture of silica sand, clay and water. Normally percentages of water and silica in the green sand are 6% and 18% respectively.

Dry Sand: Dry sand initially has high moisture content but the moisture has been evaporated from it by drying its mold in an oven.

Parting Sand: Paring sand is used on the parting plane to prevent the sticking of cope and drag part.

Baking Sand: This is already used sand in casting. Before reuse, it is riddled to remove all foreign materials and used to fill the molding flask after facing sand has been rammed around the pattern.

Facing Sand: This is freshly prepared and tempered foundry sand and it is used all around the pattern and remainder may be green sand.

Types of Molds

Mold is a cavity of heat resistant materials into which a molten metal is poured. Sand is most suitable for mold material due to heat receptivity, permeability, and low cost but metal molds are also used for small nonferrous and precision casting. The various types of molds used in casting can be classified as

Green Sand Mold: Green sand is a mixture of silica sand, clay and water.

Skin-dried Molds: In this mold, the cavity surface up to a depth of ½ inch is dried and hard.

Dry Sand Molds: Dry sand mold is made from coarse molding sand with a binding material. It is a mixture of green sand and cereal four and pitch. The prepared mold is baked in an oven at 110 to 260°C for several hours for hardening. This type of mold is generally used for large steel castings.

Loam Sand Moulds: Loam sand molds are used for large work like Pit molding. The mold is first built with bricks or iron parts. These parts are then plastered over with a thick loam mortar, the shape of the mold is obtained with sweeps or skeleton pattern.

Core Sand Molds: Core sand molds are made from core sand in subparts and assembled together. They are made in subparts due to difficulty in handling during baking.

Metal Molds: Metal molds are used in die-casting of low melting temperature alloys. It may be used for ferrous and non-ferrous casting but it is more suitable for non-ferrous casting.

Properties of Mouldings Sands

Refractoriness: Refractoriness is a property of molding sand due to which it can withstand the high-temperature of molten metal without fusing and burning.

Permeability: Permeability is the ability of molding sand to escape vapor and gases formed during pouring the molten metal into the mold cavity. Due to lack of permeability, there may be casting defects like blowhole, porosity, and pinholes.

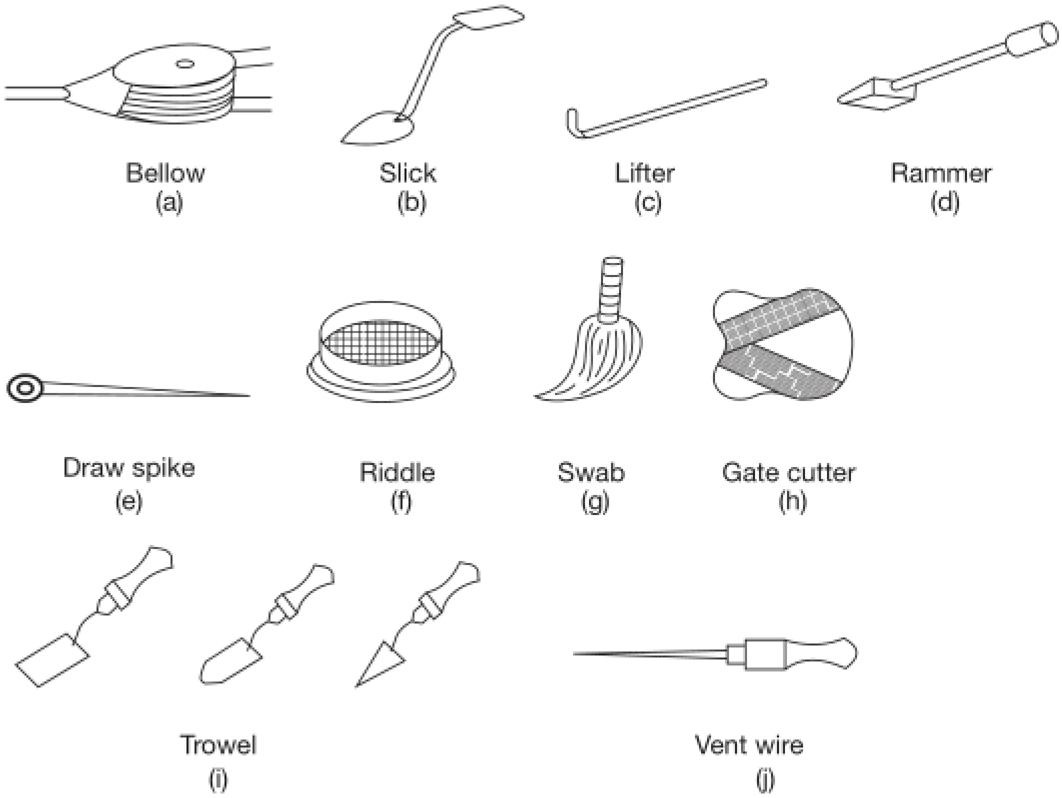
Flowability or Plasticity: Flowability is that property of molding sand due to which it flows uniformly into the molding box during ramming.

Adhesiveness: Adhesiveness is the adhering ability of the sand particles to other materials due to which the heavy sand mass is successfully held in a molding flask without any danger of its falling down.

Cohesiveness: This is a property of sand particles due to which it bind together firmly so that it can be easily withdrawn from molding box without damage the mold surfaces and edges.

Collapsibility: It is a property of the molding sand due to which mold collapses automatically after solidification of the casting to allow free contraction of the metal.

<u>**Hand Tools Used in Moulding**</u>



Bellows: This is used to blow out loose sand from the cavities and surface of the mold.

Slick: Slick is used for repairing molds is called a slick. It is a small double-ended tool having a flat on one end and a spoon on the other. It is also available in various shapes.

Lifter: Lifters are used for smoothing and cleaning out depressions in the mold. They are made of thin sections of steel of various widths and lengths with one end bent at right angle.

Rammer: A hand rammer is used to pack the sand in the mold. One edge of the rammer,called the peen end, is wedge-shaped, and the other end called butt end, is flat..

Draw Spike: A draw spike is a pointed tool at one end and loop at another end. It is driven into a wooden pattern and withdraws the pattern from the mold.

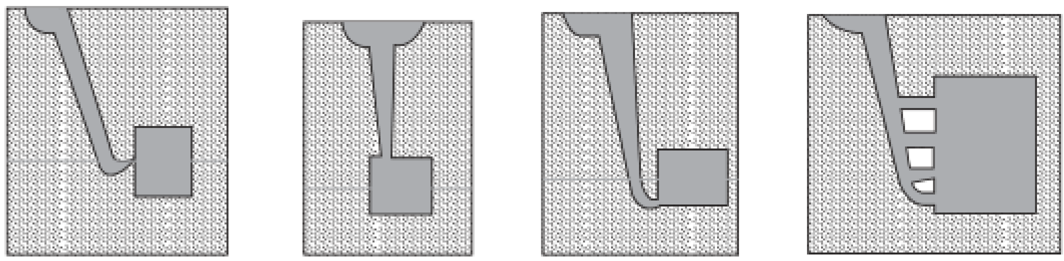
Riddle: A riddle is a standard mesh screen is used to remove foreign particles from the sand.

Swab: A swab is a small brush having long hemp fibres, and is used for moistening the sand around the edge before the pattern is removed.

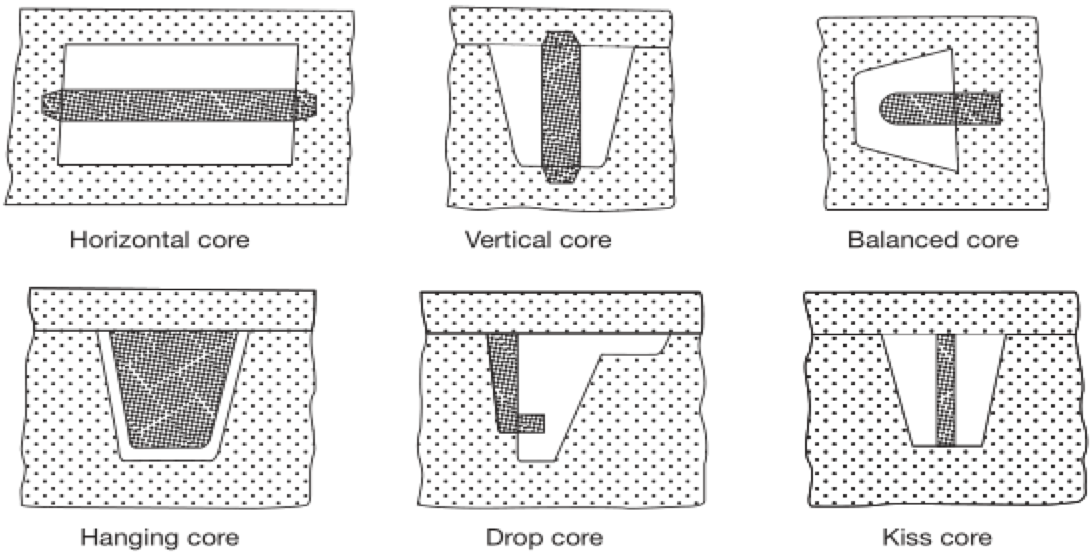
Gate Cutter: This is u-shaped thin metal strip, which is used to cut a gate for metal feeding into the cavity.

Trowel: It is available in various shapes and is used for finishing and repairing mold cavitiesas well as for smoothing over the casting surface of the mold.
Vent Wire: This is a sharp pointed wire and used to punch holes through the sand after ramming for the escape of the vapor and gases produced by pouring the molten metal.
Cope and Drag: Cope is the upper part of molding box. Drag is the lower part of molding box. The middle part of the molding box is known as a chick if three parts of molding box are used.

Types of Gates


(a) Parting line gate (b) Top gate (c) Bottom gate (d) Side gate

Cores
The core is a sand body specially prepared in a core box and it is used to form a cavity/hole/recess or projection in a casting for different purposes. As core is surrounded by liquid metalfrom all the sides, it has to have better characteristics than the molds. Better raw sand andbinder are used for the purpose. The main characteristics of the core are highly permeable,highly refractory, hard, and high collapsible

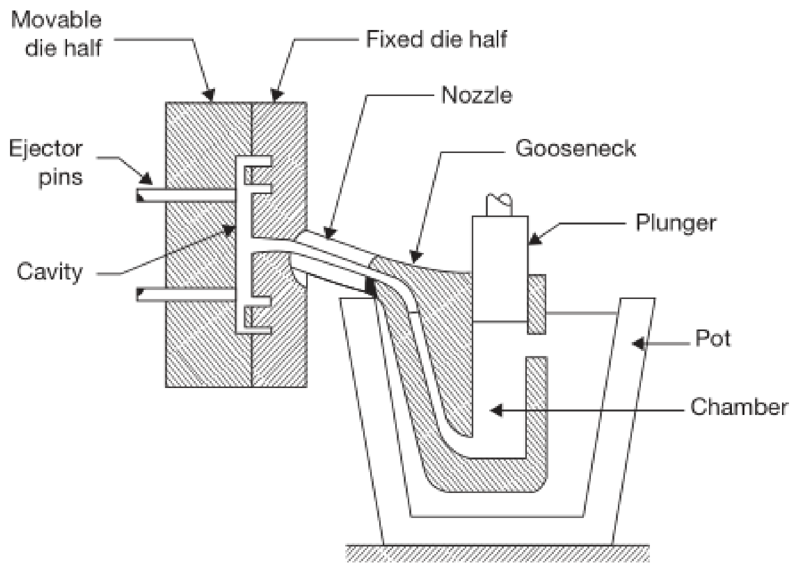


Special casting methods

Gravity/Permanent Mould Casting

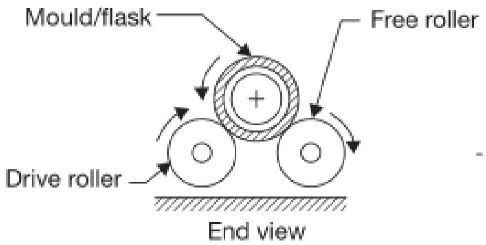
In this casting method, metallic molds are used which can withstand the high-temperature of molten metal. The permanent mold is made into two parts; both parts are hinged at one end and clamped at another end. Mold is preheated before filling the molten metal. After solidification mold is opened and casting is removed

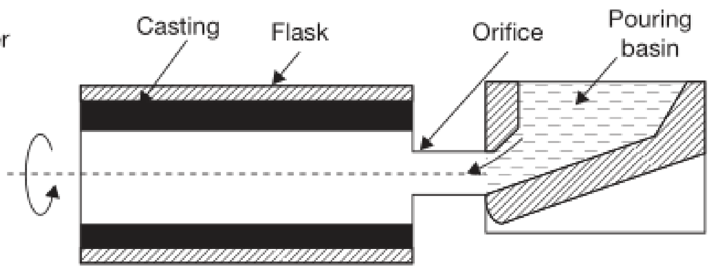
Die Casting



Centrifugal Casting

In this casting process, centrifugal force is used to feed the molten metal into the mold cavity, i.e., mold is rotated at high speed (300-3000 rpm). This process is more suitable for symmetrical shaped casting but other types of casting can also be produced





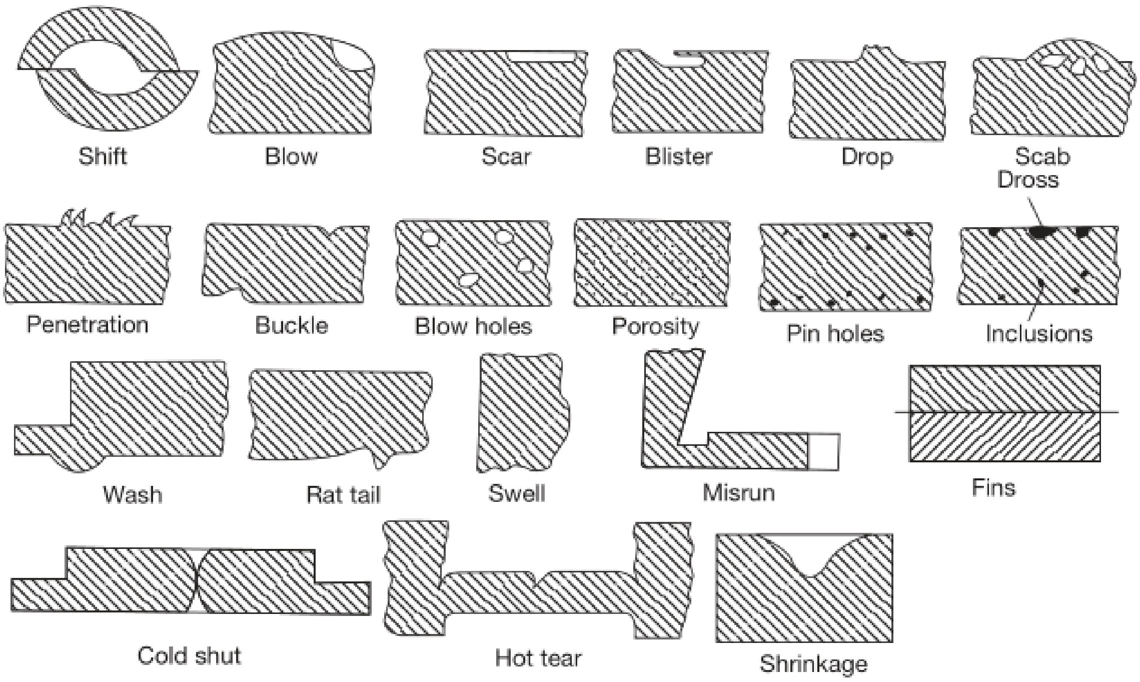
<u>**Casting Defects**</u>

Shifts: Misalignment of flask, i.e., cope and drag and mismatching of core cause shifts. Thesecan be prevented by proper alignments

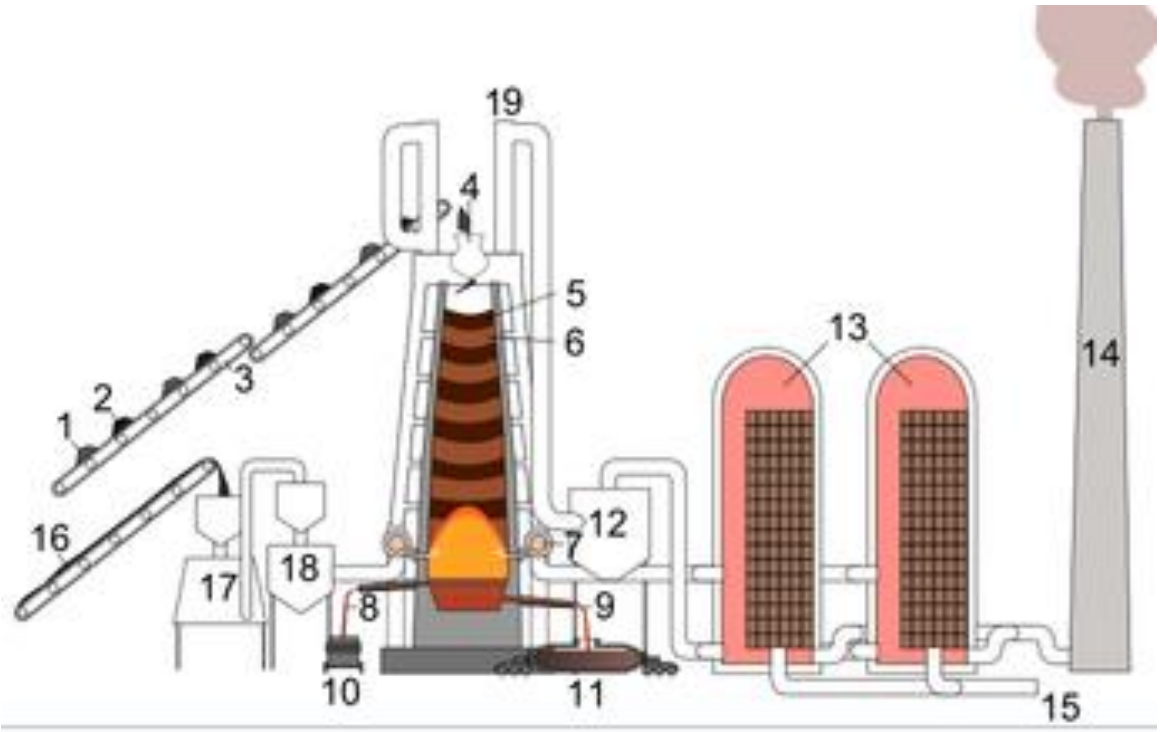
Blow: Blow is a small, round holes appearing at the surface of the casing covered with a thin layer of metal.

Scar: It is a shallow blow, which is usually found on a flat casting surface.

Swell: Swell is an enlargement of the mold cavity due to metal pressure. It caused due to defective ramming of the mold.
Blister: This is scar covered by a thin layer of a metal.
Drop: When the upper surface of the mold cracks and pieces of sand fall into the molten metal,



Scab: Liquid metal penetrates the surface layer of sand.
Blowholes: Blowholes are smooth, round holes appearing in the form of a cluster of a large no. of small holes below the surface of a casting.
Porosity: Porosity is entrapped gases in the form of fine small bubbles throughout the casting.
Pinholes: Pinholes are numerous small holes, usually less than 2 mm, visible on the surface of the casting cleaned by shot blasting.
Inclusions: Inclusions is mixing of foreign particles such as sand and slag in the casting.
Mis-run: A mis-run is the incomplete filling of the mold that results when the metal lacks fluidity or temperature.
Cold Shut: It is the type of mis-run occurs in the center of a casting having gates at its two sides.
Hot Tears: They are internal and external cracks having a ragged edge occurring immediately after the metal has solidified. Hot tears may be produced if the casting is poorly designed and abrupt change in sections take place,
Shrinkage Cavity: Shrinkage cavity is a void or depression in the casting caused mainly by uncontrolled solidification of the metal.

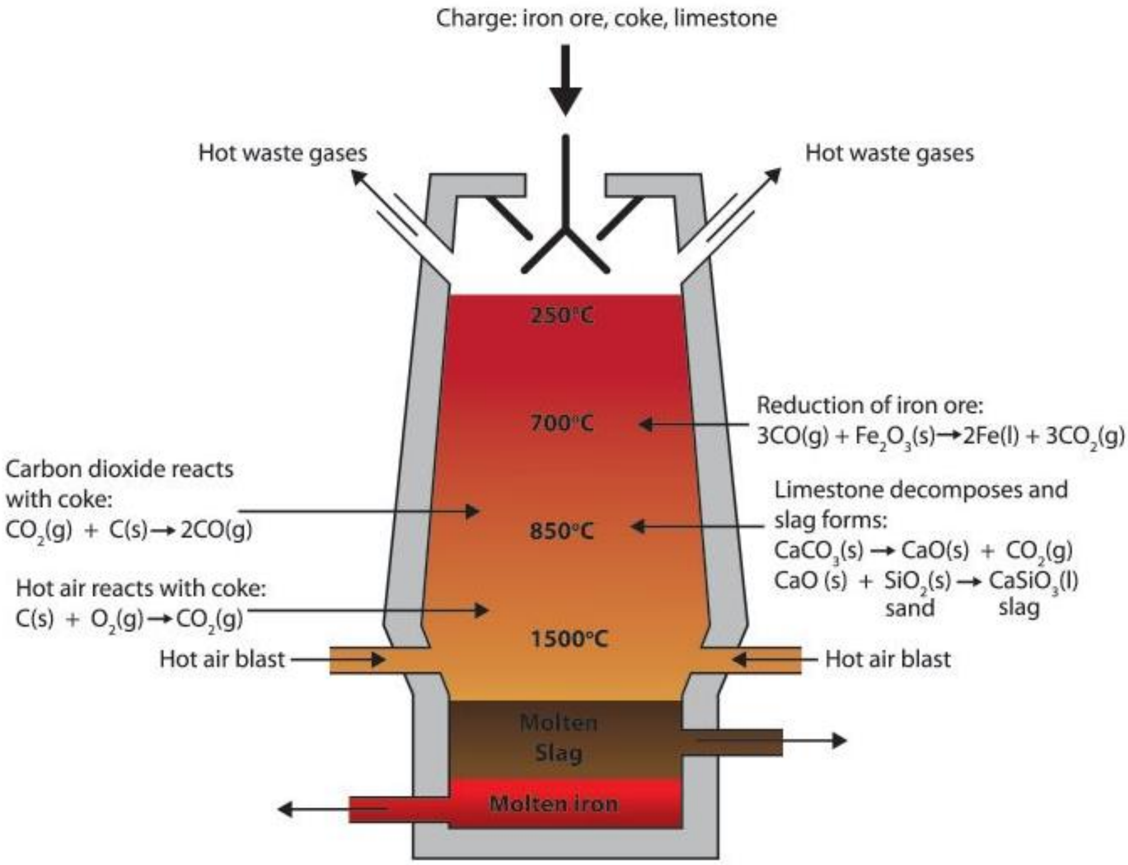


Blast furnace

1. Iron ore + limestone sinter
2. Coke
3. Elevator
4. Feedstock inlet
5. Layer of coke
6. Layer of sinter pellets of ore and limestone
7. Hot blast (around 1200 °C)
8. Removal of slag
9. Tapping of molten pig iron
10. Slag pot
11. Torpedo car for pig iron
12. Dust cyclone for separation of solid particles
13. Cowper stoves for hot blast
14. Smoke stack
15. Feed air for Cowper stoves (air pre-heaters)
16. Powdered coal
17. Coke oven
18. Coke
19. Blast furnace gas down comer

Blast Furnace Process

The blast furnace is a counter-current gas/solids reactor in which the descending column of burden materials [coke, iron ore and fluxes/additives] reacts with the ascending hot gases. The process is continuous with raw materials being regularly charged to the top of the furnace and molten iron and slag being tapped from the bottom of the furnace at regular intervals.



- **upper part** of the furnace - free moisture is driven off from the burden materials and hydrates and carbonates are disassociated.
- **lower part** of the blast furnace shaft - indirect reduction of the iron oxides by carbon monoxide and hydrogen occurs at 700-1,000°C.
- **Bosh area** of the furnace where the burden starts to soften and melt - direct reduction of the iron [and other] oxides and carbonization by the coke occurs at 1,000-1,600°C. Molten iron and slag start to drip through to the bottom of the furnace [the hearth].

Between the bosh and the hearth are the tuyeres [water cooled copper nozzles] through which the blast - combustion air, preheated to 900-1,300°C, often enriched with oxygen - is blown into the furnace. Immediately in front of the tuyeres is the combustion zone, the hottest part of the furnace, 1,850-2,200°C, where coke reacts with the oxygen and steam in the blast to form carbon monoxide and hydrogen [as well as heat] and the iron and slag melt completely.

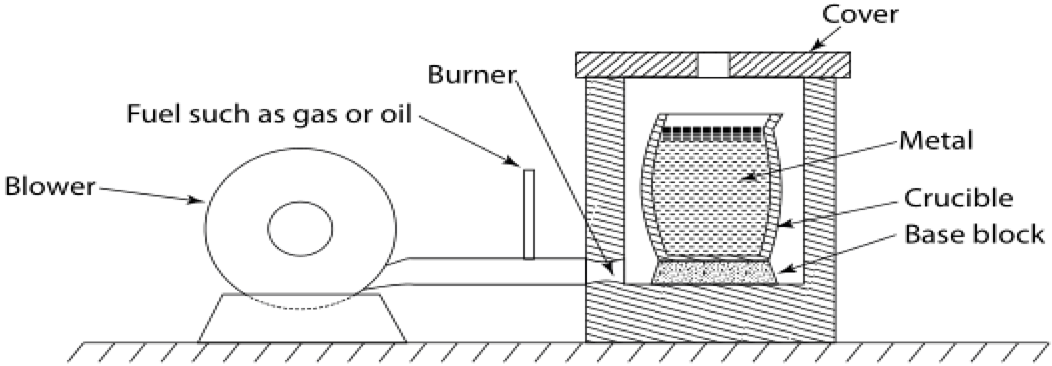
Molten iron and slag collect in the furnace hearth. Being less dense, the slag floats on top of the iron. Slag and iron are tapped at regular intervals through separate tap holes. For merchant pig iron production, the iron is cast into ingots; in integrated steel mills, the molten iron or hot metal is transferred in torpedo ladle cars to the steel converters. Slag is transferred to slag pits for further processing into usable materials, for example raw material for cement production, road construction, etc.

When charging the blast furnace, burden materials are added in layers. Charging is done either with an elevator in which a bucket is lifted up and set down on the top of the furnace o be emptied directly into the furnace [bell system] or by conveyor belts to the top of the furnace where materials are charged into a bin fixed to the top of the furnace [bell-less system] and from there into the furnace. By means of a rotating chute it is possible to achieve very uniform distribution of the charge materials across the furnace. The bell-less system has the additional advantage that less energy rich blast furnace gas is lost during charging.

The additives and fluxes serve to convert the waste or gangue materials in the charge [mainly silica and alumina] into a low melting point slag which also dissolves the coke ash and removes sulphur The blast furnace itself is a steel shaft lined with fire resistant, refractory materials. The hottest part of furnace - where the walls reach a temperature >300°C - are water cooled. The whole structure is supported from the outside by a steel frame.

Crucible Furnace

The Crucible Furnace is used to melt non-ferrous metals like Brass, Bronze, Aluminium, etc. The crucible process is the oldest process for melting metals. Crucibles are usually made of a mixture of graphite and clay. They possess greater strength when they are heated. The material to be melted is placed inside the crucible and they are heated with coke or oil as fuel. The molten metal can be transferred to a ladle. The two types of crucible furnace are explained below.

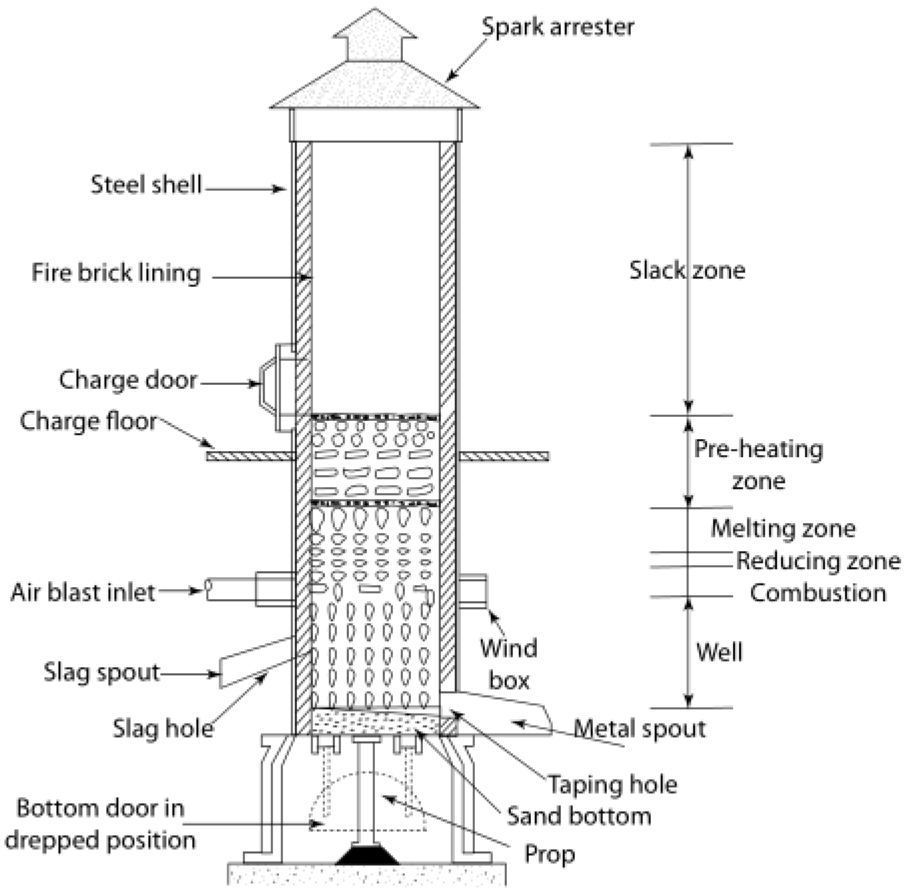


CUPOLA FURNACE

A cupola furnace basically consists of a cylindrical steel shell with both its top and bottom open. The inner walls of the shell are lined with heat resisting materials such as the fire brick. The bottom opening is closed by a cast iron drop bottom door supported by a metal prop. This door swings out after the melting when the metal prop support is removed. This arrangement is shown in Fig. After closing the bottom door, a sloping sand bed is prepared for giving the necessary heat resistant bottom for the molten metal and the fuel. Just above the sand bed is the metal tapping hole through which the molten metal is taken out to pour into the mould or the ladle. A spout called the tapping spout is provided for guiding the molten metal out. Above the tapping hole and opposite to it is a hole with a spout for removing the slag generated during the melting. It is called the slag hole.

Above the slag hole is the wind box which surrounds the cupola shell and supplies air at a given pressure and quantity. Air comes to the wind box through an air blast pipe from an air blower (not shown in the figure). Air enters into the cupola furnace through tuyers which extend through the steel shell and the refractory lining. The number of tuyers and their spacing along circumference of the shell varies with the size of the cupola furnace.

A cupola furnace is also provided with a charging platform or floor and a charging door for feeding the charges. The charge consists of pig iron, scrap iron, coke and fluxes. At its top, the cupola furnace has a metal shield or a spark arrester. It arrests the spark or burning particles from going outside while allowing the hot gases to escape out. The schematic diagram is shown in



Preparation of Cupola The preparation of a cupola furnace begins after dropping the bottom at the completion of the previous melting. In this step, the remaining materials (coke, slag, and metal) in the cupola in the previous melting are removed. Slag, coke and the metal pieces adhering to the side linings are chipped off. Heat resistant linings are repaired with new fire bricks and clay. Then the bottom door is closed and duly supported with the metal prop. A sloping sand bed is prepared with tempered sand over the bottom door. The slope gives a better metal flow. The sand bed is prepared by uniform ramming to avoid any leakage of molten metal.

Starting of Ignition For starting the cupola, soft and dry pieces of woods are spread over the sand bed. A coke bed is prepared over the wooden pieces. The wooden pieces are ignited either through the tap hole or through some other opening. The height of coke bed is maintained in the order of about 75 cm above the tuyers by adding an additional amount of coke as the initial coke bed burns well. The ignition is started about three hours before the molten metal is needed for pouring into the moulds.

Charging After the coke bed is properly ignited, the charging is done. The charging of cupola is adding alternate layers of lime stone (flux), iron and coke upto the level of the charging floor. The flux is a substance added for slag formation and for easy removal of impurities. It also reduces the oxidation of iron and lowers the melting point of slag. It increases the fluidity of slag. lime stone ($CaCO_3$) is mostly used as flux. Coke is the fuel commonly used in cupola. The metal charge consists of pig iron (30%), new scrap iron (30%) and returns (sprue, gates, risers, and defective castings).

Melting After the cupola furnace has been fully charged, the charge is allowed to get heated slowly for about 45 minutes without allowing the air blast. This is called the soaking of iron.

At the end of soaking period, the air blast is opened. The tapping hole is closed by means of a bolt or a plug till sufficient amount of molten metal gets accumulated inside the furnace. As the melting continues, additional charges are added and the charge level is kept upto the charging door during the entire operation of the cupola.

Slagging and Tapping After sufficient amount of molten metal gets accumulated inside the cupola, the slag hole is opened and the slag is removed through the spout. This process is called slagging.

The plug closing the tap hole is then removed and the molten metal is taken out through tapping spout for pouring into the mould. This process is called tapping.

Dropping Down the Bottom Once sufficient amount of molten metal is taken out from the cupola, the charging is stopped. Then all the contents of the cupola are allowed to melt by keeping the air blast closed. The metal prop is knocked down making the drop bottom door to swing out. Hence the remaining material in the cupola drops down on to the floor or into some vessels.