MECHANICAL ENGINEERING SCIENCE (UE24ME141A)

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MECHANICAL ENGINEERING SCIENCE

Unit3

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Chapter 1 – Casting and Forming

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INTRODUCTION TO MANUFACTURING PROCESSES

- Manufacturing can be broadly defined as **the process of converting raw materials into finished products.**

- A detailed understanding of the manufacturing processes is essential for every engineer. This helps them appreciate the **capabilities, advantages and also the limitations of the various manufacturing processes**.

- This in turn helps in the proper design of any product required by them. Firstly, they would be able to assess the **manufacturing feasibility** of their designs. Secondly, they may also find out that there is **more than one process available for manufacturing** a particular product.

- Keeping this in mind, they can make a **proper choice of the process** which would require the **lowest manufacturing cost** and would deliver the product of **desired quality**.

CLASSIFICATION OF MANUFACTURING PROCESSES

- The various processes used in manufacturing are classified into the following five groups –

1) ***Primary shaping processes*** – Casting, Forming such as rolling, extrusion, forging etc.,

2) ***Machining processes*** – The machining operations are performed on castings, rollings and forgings etc. in order to obtain the desired accuracy and shape. Ex – Turning, Drilling, Milling, Planing etc.

3) ***Surface finishing processes*** – These processes are used effectively to provide a good surface finish to the metal surface of the product. Ex – Buffing, Lapping, Honing, Anodising, Electroplating etc.

4) ***Joining processes*** – These processes are used for joining two or more pieces of metal parts. Ex – Welding, Soldering, Brazing etc.

5) ***Processes affecting change in properties-*** These processes are used to impart certain specific properties to the metal part for specific conditions of use. Ex – Heat treatment, shot peening etc.

METAL CASTING PROCESS

- Casting is one of the earliest metal shaping methods known to human being.

- It generally means pouring molten metal into a refractory **mould** with a cavity of the shape to be made and allowing it to solidify. When solidified, the desired metal object is taken out from the refractory mould either by breaking the mould or taking the mould apart. The solidified object is called **casting**. This process is also called **founding**.

- The principal process among these is **sand casting** where sand is used as the refractory material.

- Some of the other casting processes for specialised needs are as follows:
  - Shell Mould Casting
  - Precision Investment Casting
  - Plaster Mould Casting
  - Permanent Mould Casting
  - Die Casting
  - Centrifugal Casting

CASTING TERMS

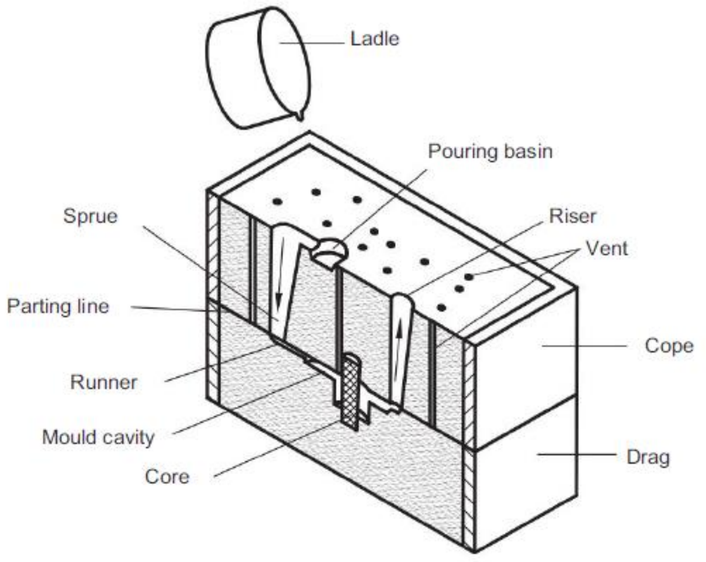
- ***Flask*** - A moulding flask is one which holds the sand mould intact. Depending upon the position of the flask in the mould structure, it is referred to by various names such as drag, cope and cheek.

- ***Drag* -** Lower moulding flask.

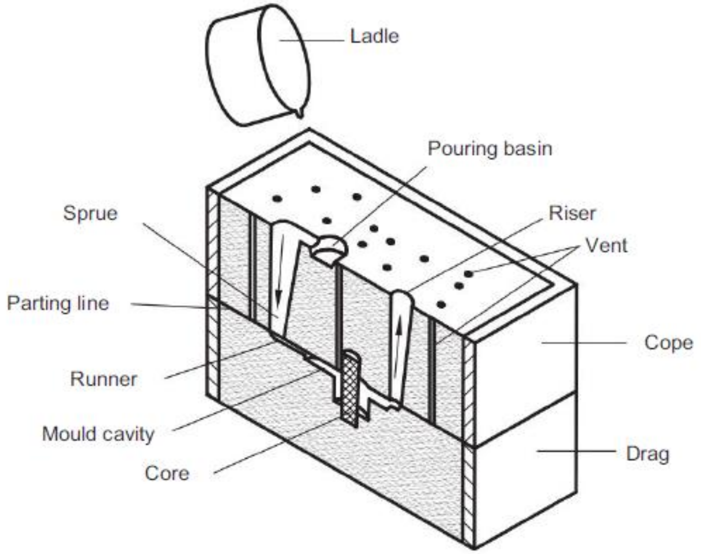
- ***Cope* -** Upper moulding flask.

- ***Pattern*** **-** Pattern is a replica of the final object to be made with some modifications. The mould cavity is made with the help of the pattern.

- ***Parting line*** **-** This is the dividing line between the two moulding flasks that makes up the sand mould. In split pattern it is also the dividing line between the two halves of the pattern.



CASTING TERMS



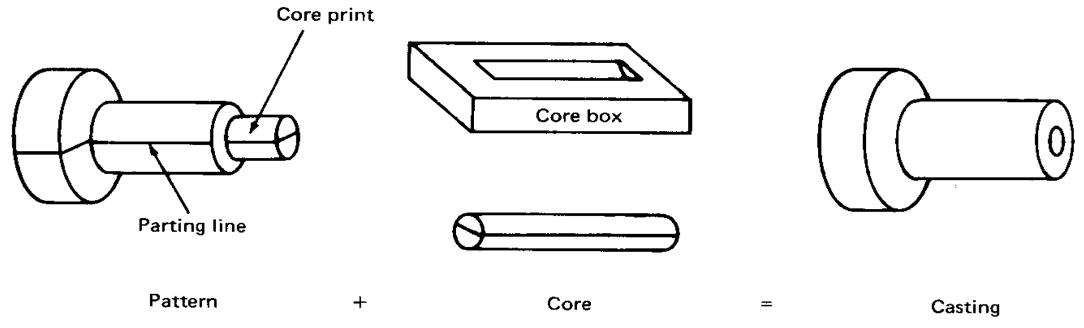
- ***Bottom board*** - This is a board which is normally made of wood and is used at the start of the mould making. The pattern is first kept on the bottom board, sand is sprinkled on it and then the ramming is done in the drag.

- ***Facing sand*** - The small amount of carbonaceous material sprinkled on the inner surface of the moulding cavity to give better surface finish to the castings.

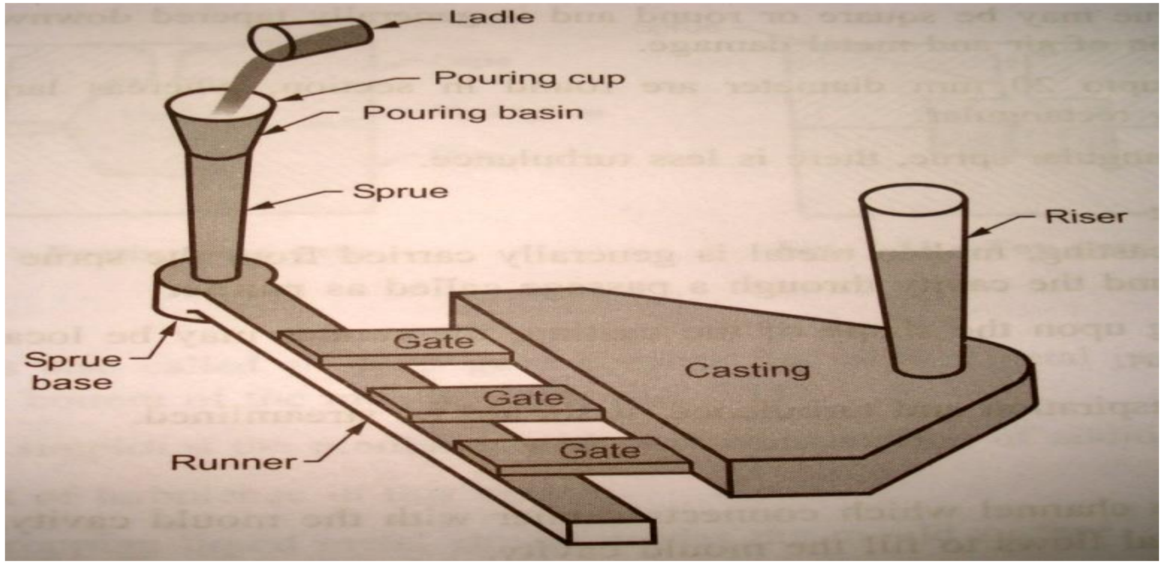
- ***Moulding sand*** - It is the freshly prepared refractory material used for making the mould cavity. It is a mixture of silica, clay and moisture in appropriate proportions to get the desired results and it surrounds the pattern while making the mould.

- ***Backing sand*** - It is what constitutes most of the refractory material found in the mould. This is made up of used and burnt sand.

CASTING TERMS

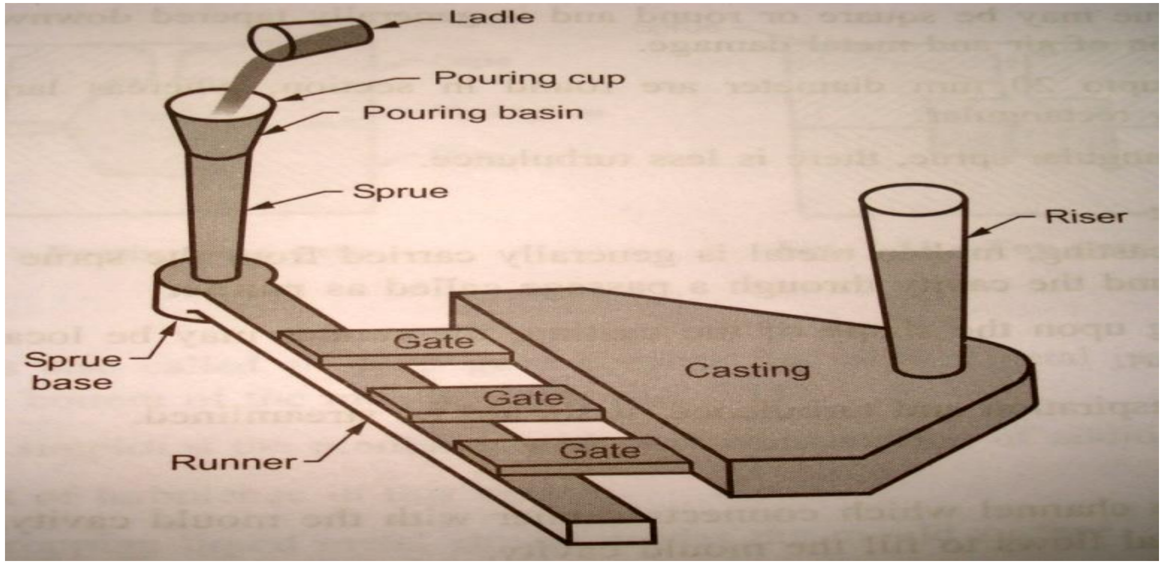


- ***Core*** - It is used for making hollow cavities in castings.
- ***Pouring basin*** - A small funnel shaped cavity at the top of the mould into which the molten metal is poured.
- ***Sprue*** - The passage through which the molten metal from the pouring basin reaches the mould cavity. In many cases it controls the flow of metal into the mould.
- ***Runner*** - The passageways in the parting plane through which molten metal flow is regulated before they reach the mould cavity.
- ***Gate*** - The actual entry point through which molten metal enters mould cavity.



CASTING TERMS

- ***Riser*** - It is a reservoir of molten metal provided in the casting so that hot metal can flow back into the mould cavity when there is a reduction in volume of metal due to solidification.



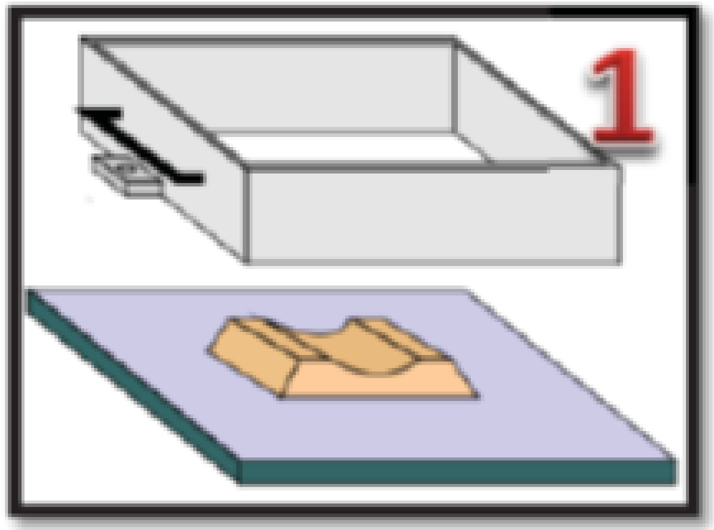
SAND MOULDING PROCEDURE

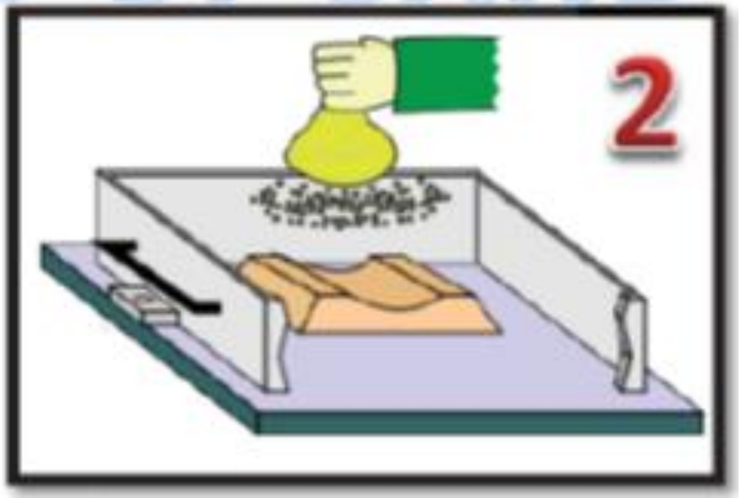
The procedure for making a typical sand mould is described in the following steps -

- First a bottom board is placed either on the moulding platform or on the floor, making the surface even.

- The drag moulding flask is kept upside down on the bottom board along with the drag part of the pattern at the centre of the flask on the board.

- Dry facing sand is sprinkled over the board and pattern to provide a non-sticky layer.



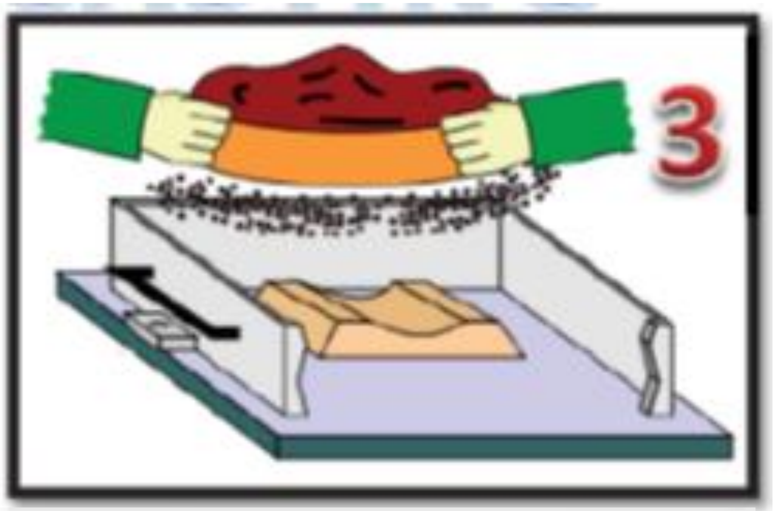


SAND MOULDING PROCEDURE

- Freshly prepared moulding sand of requisite quality is now poured into the drag and on the pattern to a thickness of 30 to 50 mm.

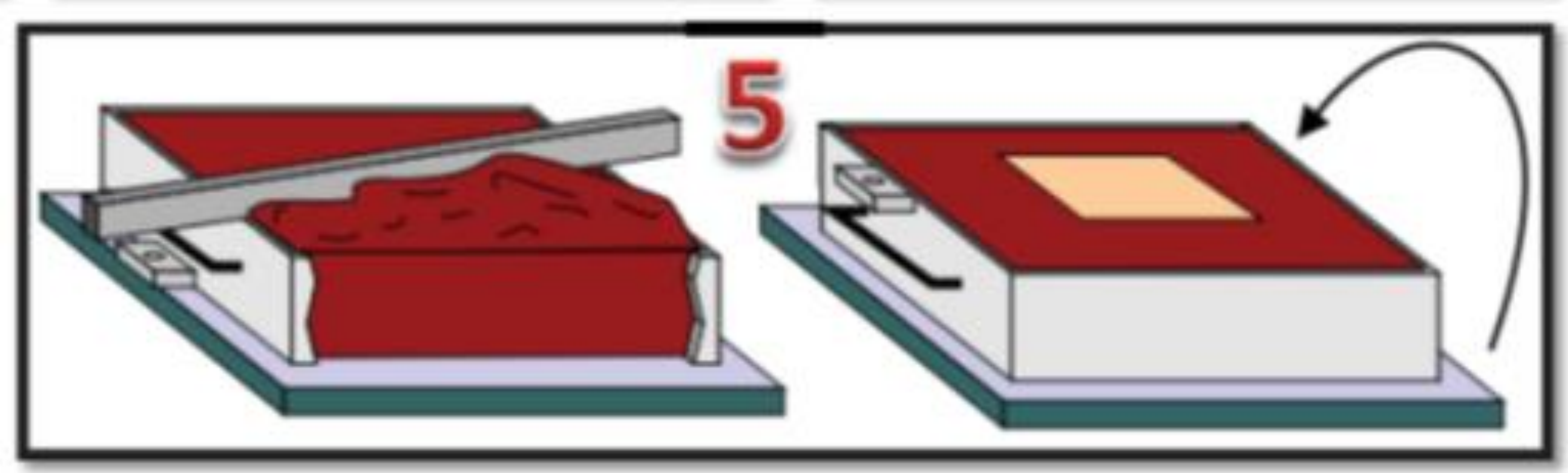
- Rest of the drag flask is completely filled with the backup sand and uniformly rammed to compact the sand.

- The ramming of the sand should be done properly, neither to compact it too hard which makes the escape of gases difficult, nor too loose, so that mould would not have enough strength.



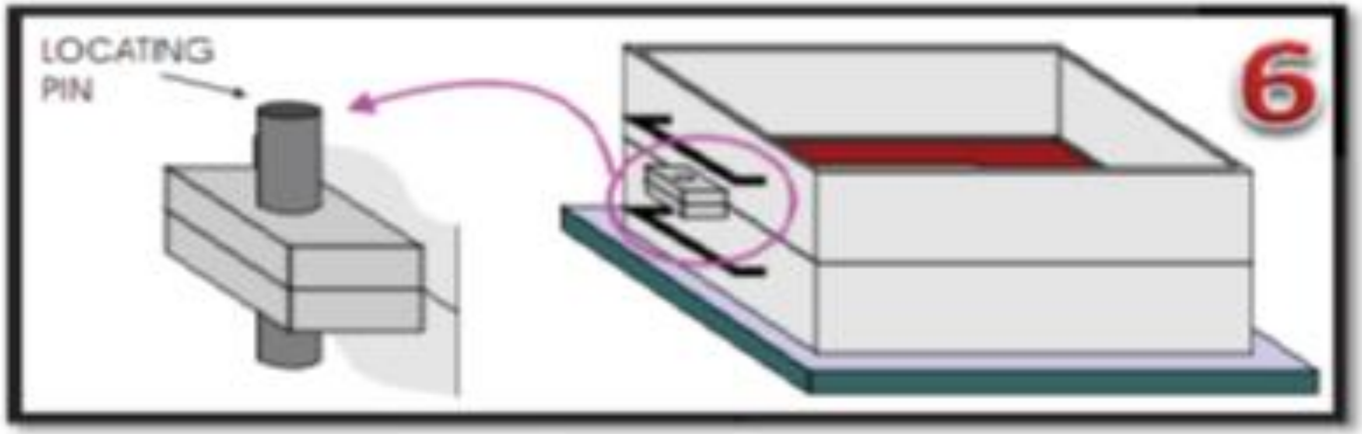
SAND MOULDING PROCEDURE

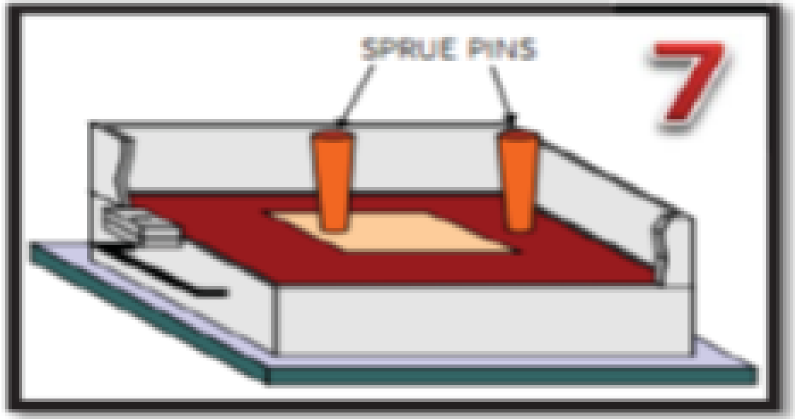
- After the ramming is over, the excess sand in the flask is completely scrapped using a flat bar to the level of the flask edges.
- Now, with a vent wire, which is a wire of 1 to 2 mm diameter with a pointed end, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during casting solidification. This completes the preparation of the drag.
- The finished drag flask is now rolled over to the bottom board exposing the pattern.



SAND MOULDING PROCEDURE

- Using a slick, the edges of sand around the pattern is repaired and cope half of the pattern is placed over the drag pattern, aligning it with the help of dowel pins.
- The cope flask on top of the drag is located aligning again with the help of the pins. The dry parting sand is sprinkled all over the drag and on the pattern.
- A sprue pin for making the sprue passage is located at a small distance of about 50 mm from the pattern. Also a riser pin, if required, is kept at an appropriate place.



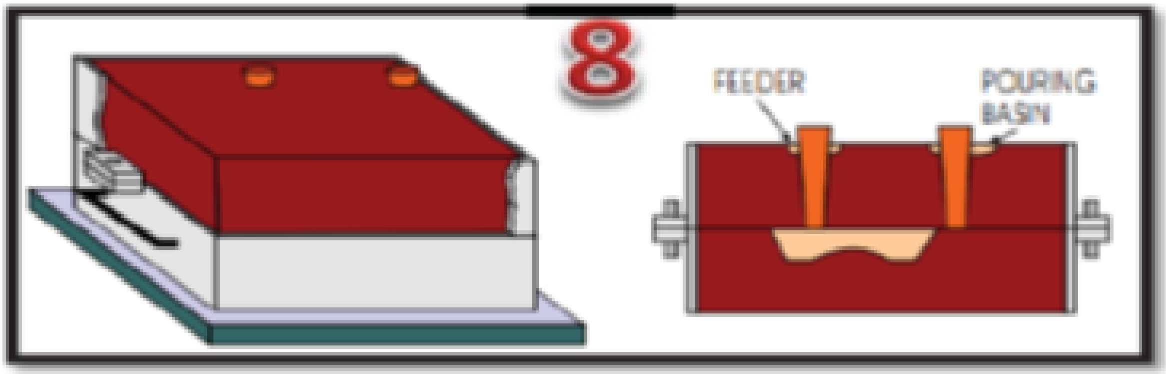


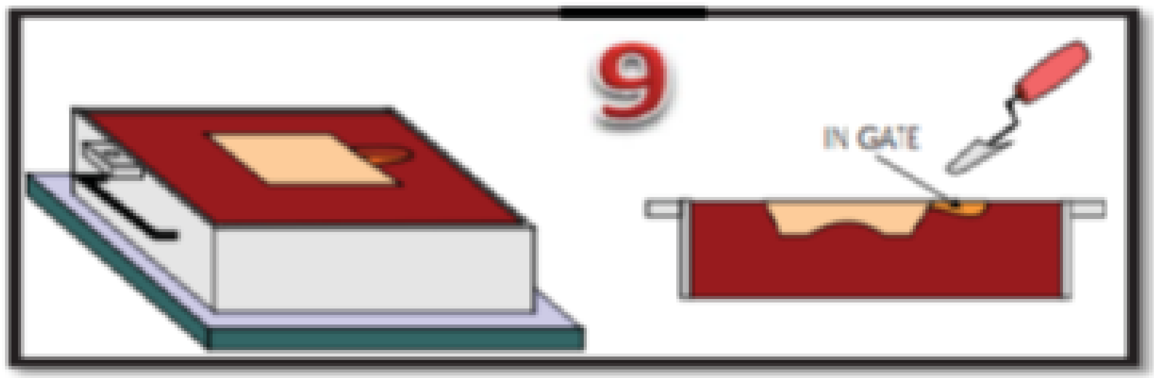
SAND MOULDING PROCEDURE

- Freshly prepared moulding sand similar to that of the drag along with the backing sand is sprinkled. The sand is thoroughly rammed, excess sand scraped and vent holes are made all over in the cope as in the drag.

- The sprue pin and the riser pin are carefully withdrawn from the flask. Later the pouring basin is cut near the top of the sprue.

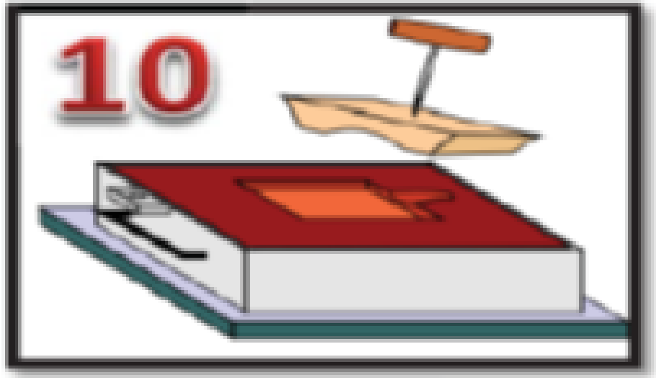
- The cope is separated from the drag and any loose sand on the cope and drag interface of the drag is blown off with the help of bellows.

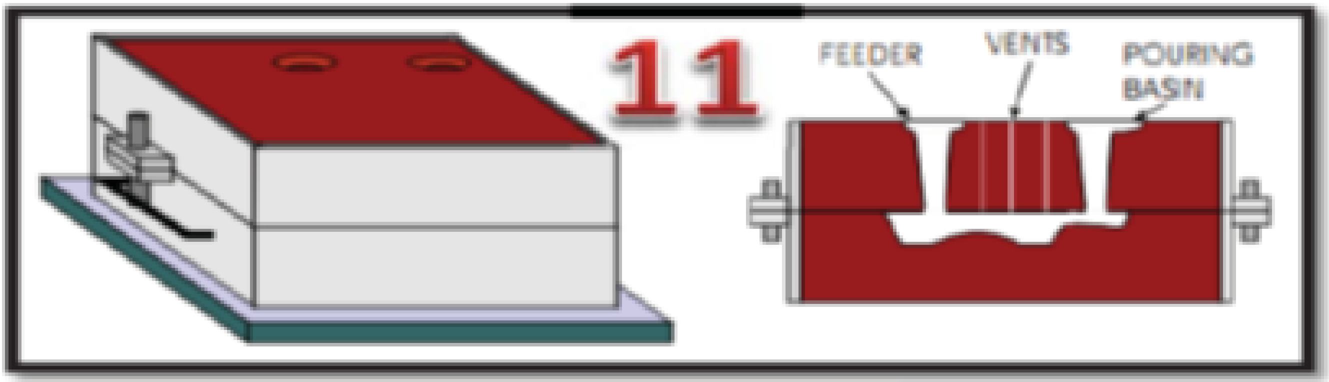




SAND MOULDING PROCEDURE

- Now the cope and the drag pattern halves are withdrawn by using the draw spikes and rapping the pattern all around to slightly enlarge the mould cavity so that the mould walls are not spoiled by the with drawing pattern.
- The runners and the gates are cut in the mould carefully without spoiling the mould.
- The cope is replaced on the drag taking care of the alignment of the two by means of the pins. A suitable weight is kept on the cope to take care of the upward metallostatic force during the pouring of molten metal. The mould now is ready for pouring.





PATTERNS

- A pattern is a replica of the object to be made by the casting process, with some modifications. The main modifications are:

  (a) The addition of pattern allowances,
  (b) The provision of core prints, and
  (c) Elimination of fine details which cannot be obtained by casting and hence are to be obtained by further processing.

Pattern Allowances

- The dimensions of the pattern are different from the final dimensions of the casting required. The following types of allowances are usually provided –

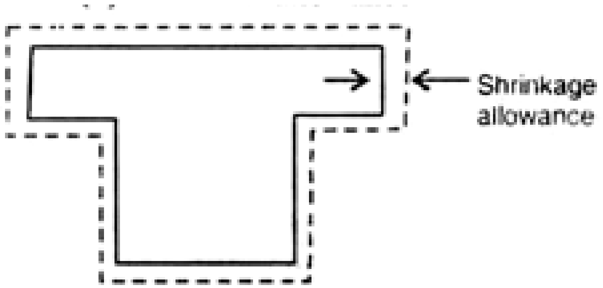
  1) Shrinkage allowance 2) Finish or Machining allowance 3) Draft allowance
  4) Shake allowance 5) Distortion allowance

PATTERNS

Shrinkage Allowance

- All the metals shrink when cooling except perhaps bismuth. This is because of inter– atomic vibrations which are amplified by an increase in temperature. However, there is a distinction to be made between **liquid shrinkage and solid shrinkage**.

- Liquid shrinkage refers to the reduction in volume when the metal changes from liquid to solid state at the solidus temperature. To account for this, risers are provided in the moulds.



- Solid shrinkage is the reduction in volume caused when metal loses temperature in solid state. The shrinkage allowance is provided to take care of this reduction.

- The rate of contraction with temperature is dependent on the material. The pattern maker’s experience and a little bit of trial are to be used in arriving at the final shrinkages provided on the pattern.

PATTERNS

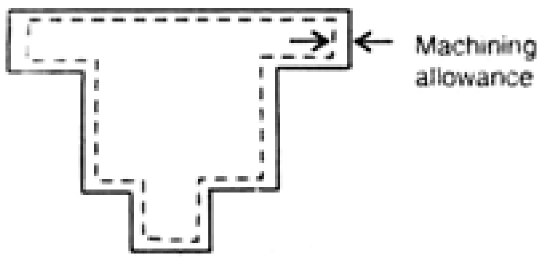
Finish or Machining Allowance

- The finish and accuracy achieved in sand casting are generally poor and therefore when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining.

- Also ferrous materials would have scales on the skin which are to be removed by cleaning.

- Hence, extra material is to be provided which is to be subsequently removed by machining or cleaning process.

- This depends on dimensions, the type of casting material and the finish required.

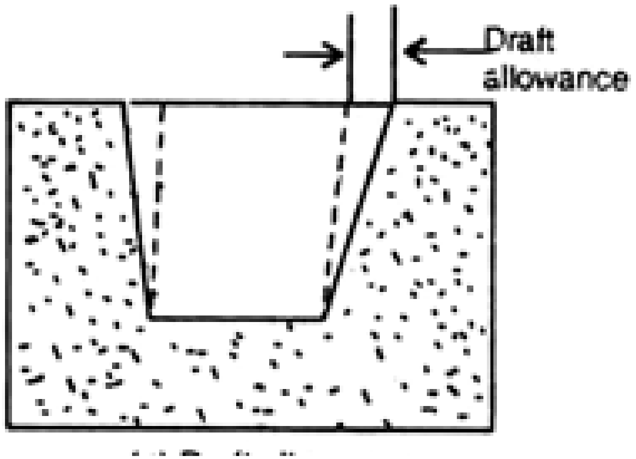


PATTERNS

Draft Allowance

- At the time of withdrawing the pattern from the sand mould, the vertical faces of the pattern are in continual contact with the sand which may damage the mould cavity.

- To reduce its chances, the vertical faces of the pattern are always tapered from the parting line. This provision is called draft allowance.

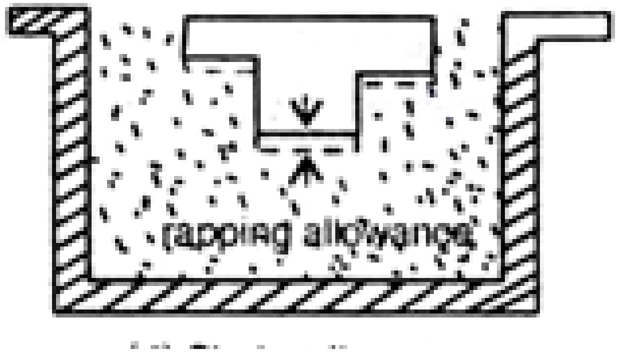


PATTERNS

Shake Allowance

- Before withdrawal from the sand mould, the pattern is rapped all around the vertical faces to enlarge the mould cavity slightly which facilitates its removal.

- Since it enlarges the final casting made, it is desirable that the original pattern dimensions should be reduced to account for this increase. There is no sure way of quantifying this allowance since it is highly dependent on the foundry personnel and practices involved.



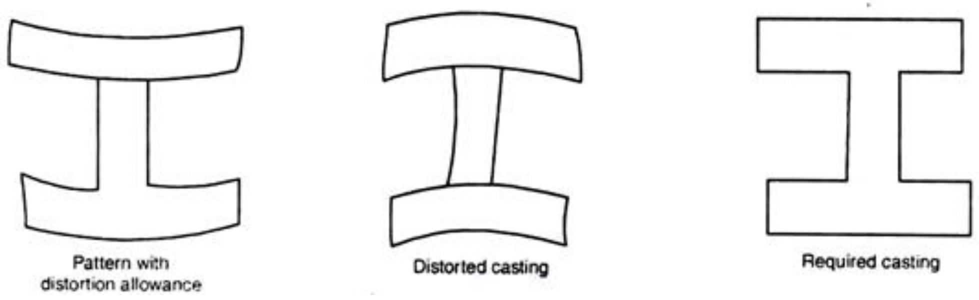
PATTERNS

Distortion Allowance

- A metal when has just solidified is very weak and therefore is likely to be distortion prone. This is particularly so for weaker sections such as long flat portions, V, U sections or in a complicated casting which may have thin and long sections connected to thick sections.

- The foundry practice should be to make extra material provision for reducing the distortion. Alternatively, the shape of pattern itself should be given a distortion of equal amount in the opposite direction of the likely distortion direction.

- This can be done by trial and error basis to get the distortion amount.

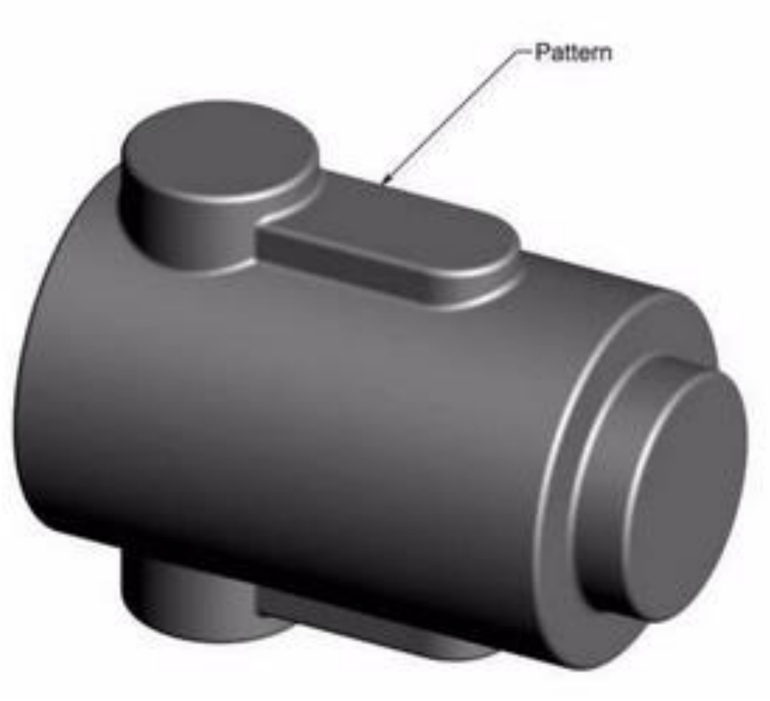


PATTERNS

Types of Patterns

Solid or Single Piece Pattern

- As the name indicates, they are made of a single piece.
- This type of pattern is used only in cases where the job is very simple and does not create any withdrawal problems. It is also used for applications in very small–scale production or in prototype development.
- This pattern is expected to be entirely in the drag.
- One of the surfaces is expected to be flat which is used as the parting plane.



PATTERNS

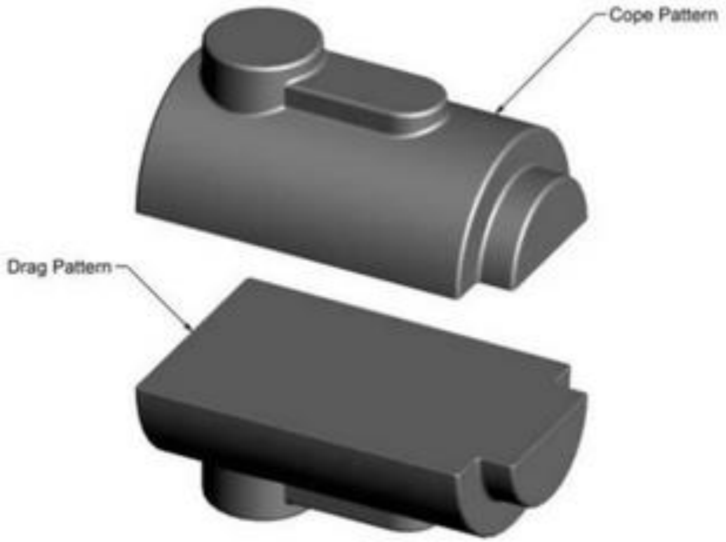
Types of Patterns

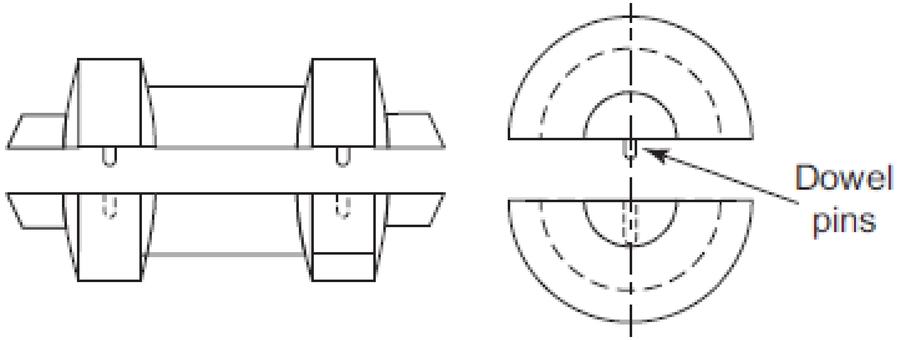
Split Pattern

- When the contour of the casting makes its withdrawal from the mould difficult or when the depth of the casting is too high, then the pattern is split into two parts so that one part is in the drag and the other in the cope.

- The split surface of the pattern is same as the parting plane of the mould.

- The two halves of the pattern should be aligned properly by making use of the dowel pins which are fitted to the cope half. These dowel pins match with the precisely made holes in the drag half of the pattern and thus align the two halves properly.





PATTERNS

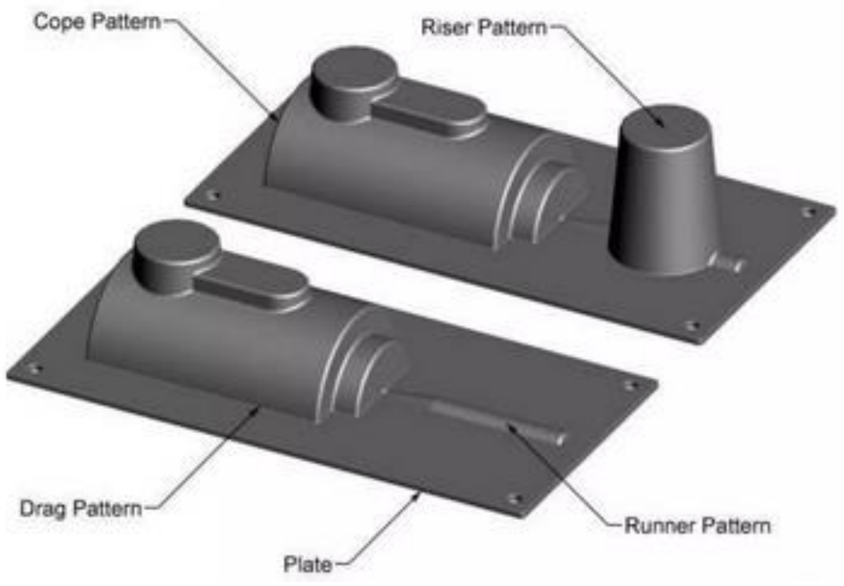
Types of Patterns

Cope and Drag Pattern

- These are similar to split patterns. In addition to splitting the pattern, the cope and drag halves of the pattern along with the gating and risering systems are attached separately to the metal or wooden plates along with the alignment pins. They are called the cope and drag patterns.

- The cope and drag moulds may be produced using these patterns separately by two moulders but they can be assembled to form a complete mould.

- These types of patterns are used for castings which are heavy and inconvenient for handling as also for continuous production.



PATTERNS

Types of Patterns

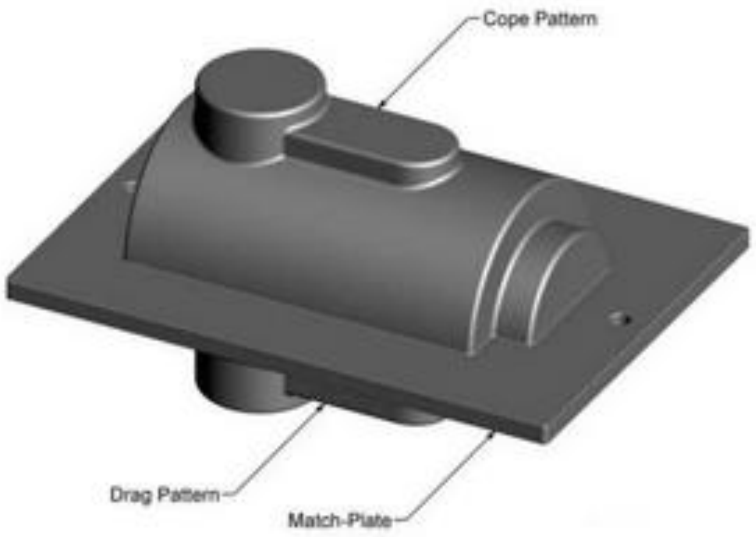
Match Plate Pattern

- Here the cope and drag patterns along with the gating and the risering are mounted on a single matching metal or wooden plate on either side.

- On one side of the match plate the cope flask is prepared and on the other, the drag flask.

- After moulding when the match plate is removed, a complete mould with gating is obtained by joining the cope and the drag together.

- These are generally used for small castings with higher dimensional accuracy and large production.

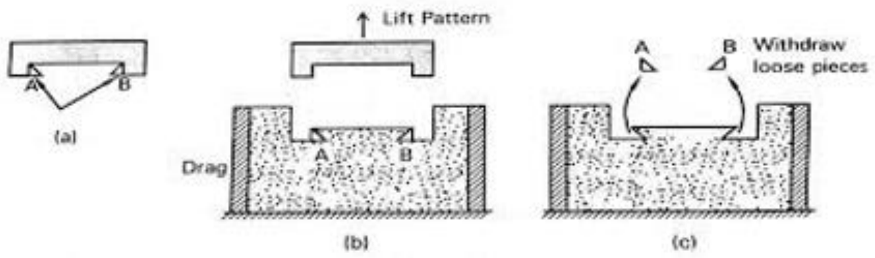


PATTERNS

Types of Patterns

Loose Piece Pattern

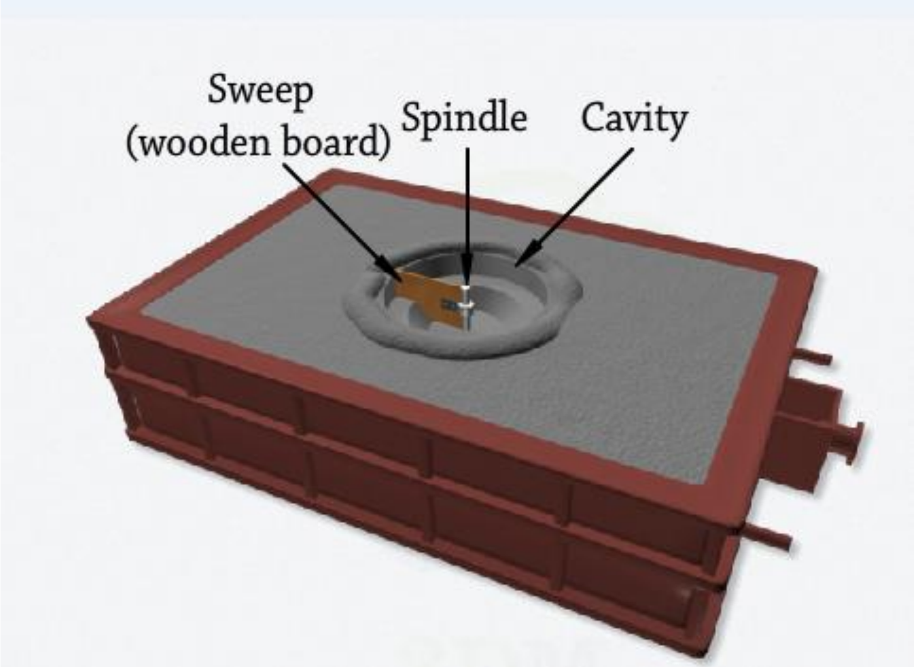
- This type of pattern is used when the contour of the part is such that withdrawing the pattern from the mould is not possible.
- Hence during moulding the obstructing part of the contour is held as a loose piece by a wire.
- After moulding is over, first the main pattern is removed and then the loose pieces are recovered through the gap generated by the main pattern.
- Moulding with loose pieces is a highly skilled job and is generally expensive and therefore, should be avoided where possible.



PATTERNS

Types of Patterns

Sweep Pattern



- It is used to sweep the complete casting by means of a plane sweep. These are used for generating large shapes which are axi–symmetrical or prismatic in nature such as bell shaped or cylindrical.

- This greatly reduces the cost of a three dimensional pattern. This type of pattern is particularly suitable for very large castings such as bells for ornamental purposes used, which are generally cast in pit moulds.

Properties of Moulding materials

1) Refractoriness - It is the ability of the moulding material to withstand the high temperatures of the molten metal so that it does not cause fusion.

2) Green Strength - The moulding sand that contains moisture is termed as green sand. The green sand should have enough strength so that the constructed mould retains its shape.

3) Dry Strength - When the moisture in the moulding sand is completely expelled, it is called dry sand. When molten metal is poured into a mould, the sand around the mould cavity is quickly converted into dry sand as the moisture in the sand immediately evaporates due to the heat in the molten metal. At this stage, it should retain the mould cavity and at the same time withstand the metallostatic forces.

4) Permeability - During the solidification of a casting, large amounts of gases are to be expelled from the mould. The gases are those which have been absorbed by the metal in the furnace, air absorbed from the atmosphere, steam and other gases that are generated by the moulding and core sands. If these gases are not allowed to escape from the mould, they would be trapped inside the casting causing defects. The moulding sand should be sufficiently porous so that the gases are allowed to escape from the mould. **This gas evolution capability of the moulding sand is termed as permeability.**

Properties of Moulding materials

5) Cohesiveness - Cohesiveness is known as the strength of the moulding sand. Cohesiveness is that property of the moulding sand which enables the sand particles to stick together. Following factors may affect the strength or cohesiveness of the moulding sand.

- Shape and size of the grain
- Bonding material and its distribution
- Moisture

For the production of sand casting, the moulding sand must have adequate strength to retain shape when molten material is poured into the mould

6) Adhesiveness - Adhesiveness can be defined as the property of moulding sand, which enables the sand particles to stick with other objects such as moulding box. This property plays an important role in keeping the sand mass together in the moulding box and does not allow it to fall when turned upside down. It should also be ensured that the sand should not stick to the casting and strip off easily, leaving a clean surface.

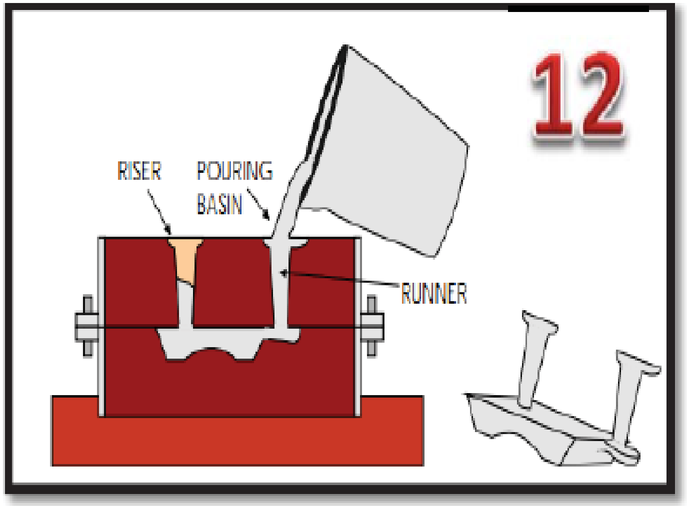
Properties of Moulding materials

7) Flowability - Flowability is the property of moulding sand to properly pack the moulding box all around the pattern. Good flowability ensures the moulding sand to flow all over the pattern when the mould is rammed.

8) Collapsibility **-** The molten material in the mould needs sufficient time to get solidified. Once it is solidified, the mould must be collapsible enough so that free contraction of casting can occur. Collapsibility is that property of the moulding sand, which will permit easy break down of the sand mass and its subsequent use after the casting has been taken out of the mould. Collapsibility can be improved by cereals, or by other organic bonding agents, which “burn out” when it comes in contact with high temperature of the molten material in the mould.

Melting and Pouring

- Molten metal is transferred from the furnace to a ladle and cleaned and held until it reaches the desired pouring temperature. The molten metal is poured into the mould and allowed to solidify.



Cooling and Shakeout

- Once the metal has been poured, the mould is cooled. Castings may be removed manually or using vibratory tables that shake the refractory material away from the casting.

Fettling, Cleaning and Finishing

- Gating system is removed, often using band saws, abrasive cut-off wheels or electrical cut-off devices. A ‘parting line flash’ is removed by grinding or with chipping hammers.

Casting Defects

- Any irregularity in the moulding process causes defects in castings which may sometimes be tolerated, sometimes eliminated with proper moulding practice or repaired using methods such as welding and metallisation.

- The following are the major defects which are likely to occur in sand castings:
  (i) Gas defects
  (ii) Shrinkage cavities
  (iii) Moulding material defects
  (iv) Pouring metal defects
  (v) Metallurgical defects

Casting Defects

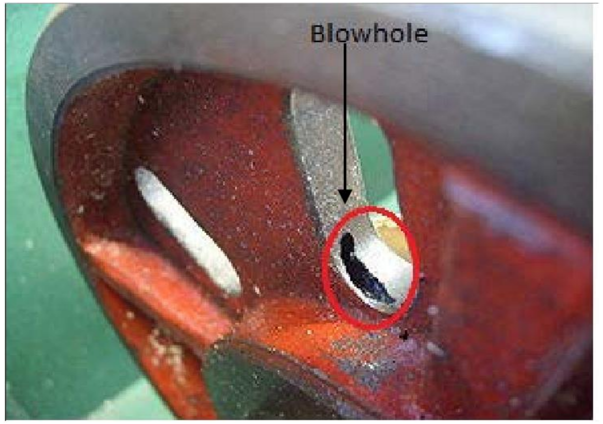
Gas defects

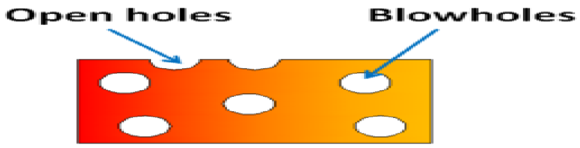
- ***Blow holes and open blows*** - These are the spherical, flattened or elongated cavities present inside the casting or on the surface.

- On the surface they are called ***open blows*** and inside, they are called ***blow holes***. These are caused by the moisture left in the mould and the core.

- Because of the heat in the molten metal, the moisture is converted into steam, part of which when entrapped in the casting ends up as blow hole or ends up as open blow when it reaches the surface.

- The main reason for this is the **low permeability** of the sand mould. Low permeability is caused by the use of too fine sand grains, higher amount of binder or over ramming of the mould. This can also be caused by insufficient venting practice.

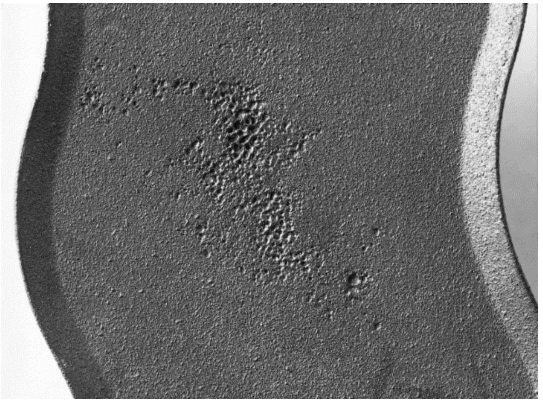




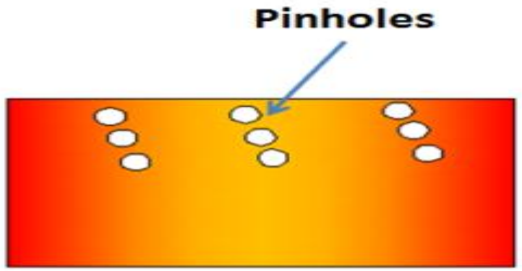
Casting Defects

Gas defects

- ***Pin hole porosity*** - This is caused by hydrogen in the molten metal. This could have been picked up in the furnace or by the dissociation of water inside the mould cavity.



- As the molten metal gets solidified, it loses the temperature which decreases the solubility of gases and there by expelling the dissolved gases. The hydrogen while leaving the solidifying metal would cause **very small diameter** and long pin holes showing the path of escape.

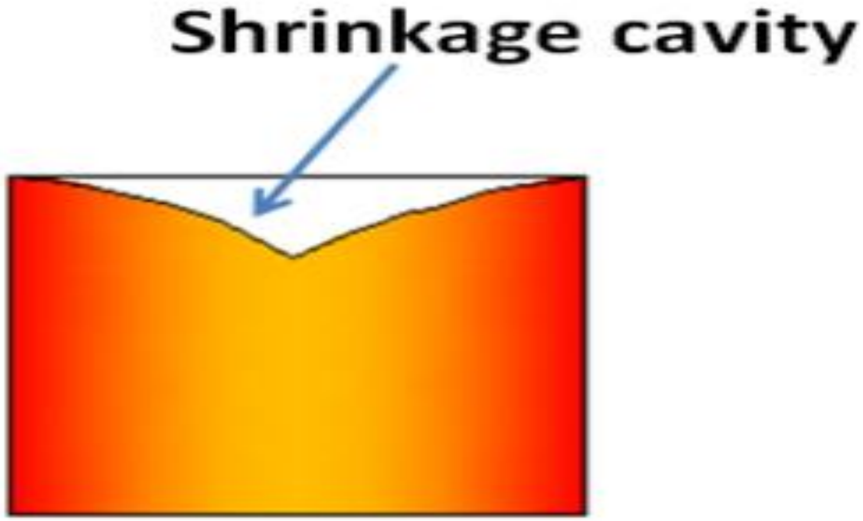


- The main reason for this is the high pouring temperature which increases the gas pick up. This is particularly severe in aluminium alloys or steels and irons having aluminium.

Casting Defects

Shrinkage cavities

- These are caused by the liquid shrinkage occurring during the solidification of the casting. To compensate this, proper feeding of liquid metal is required as also proper casting design.



Casting Defects

Moulding material defects

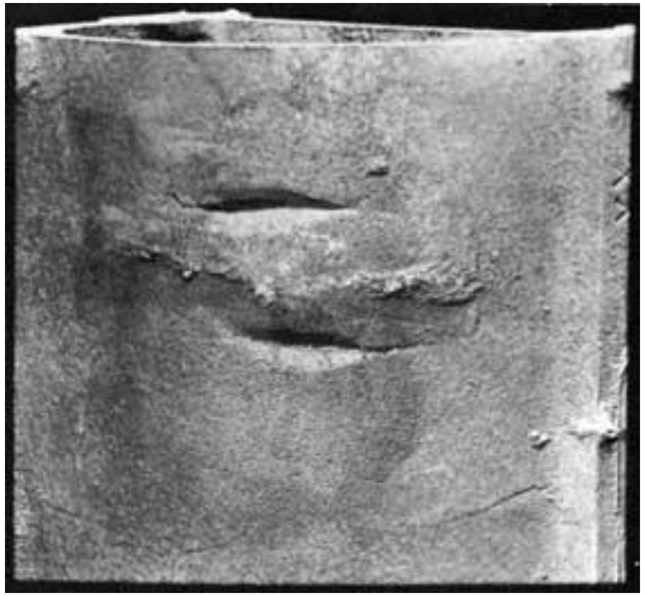
- ***Metal penetration* -** When the molten metal enters the gaps between the sand grains, the result would be a rough casting surface. The main reason for this is that, either the grain size of the sand is too coarse or no mould wash has been applied to the mould cavity.

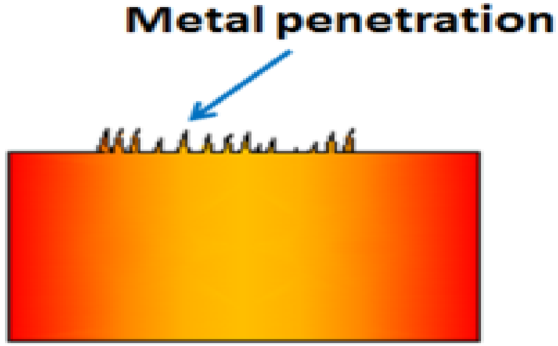
- ***Swell*** - Under the influence of the metallostatic forces, the mould wall may move back causing a swell in the dimensions of the casting. The main cause of this is the faulty mould making procedure adopted.

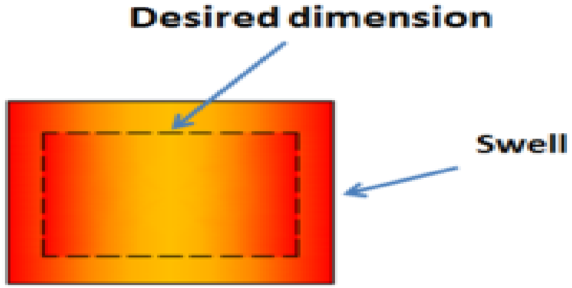
- ***Drop* -** The dropping of loose moulding sand or lumps normally from the cope surface into the mould cavity is responsible for this defect. This is essentially due to improper ramming of the cope flask.

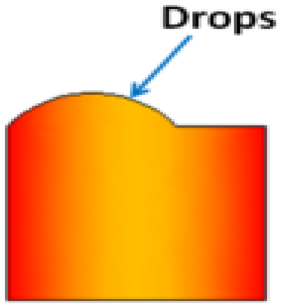
Casting Defects

Moulding material defects









Casting Defects

Pouring metal defects

- ***Mis runs and cold shuts*** - Mis run is caused when the metal is unable to fill the mould cavity completely and thus leaving unfilled cavities.

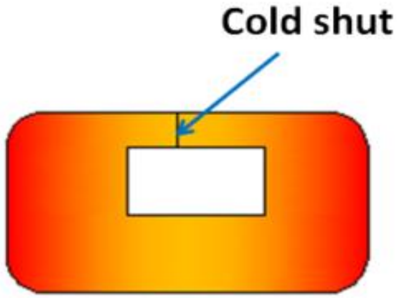
- A cold shut is caused when two metal streams, while meeting in the mould cavity, do not fuse together properly thus causing a discontinuity or weak spot in the casting

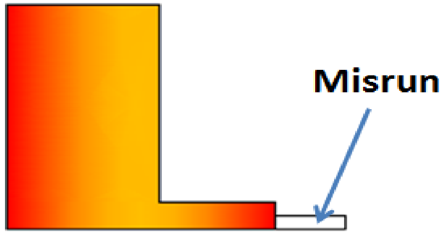
- These defects are caused essentially by the lower fluidity of the molten metal or that the section thickness of the casting is too small. The latter can be rectified by proper casting design.

- The remedy available is to increase the fluidity of the metal by changing the composition or raising the pouring temperature.

Casting Defects

Pouring metal defects

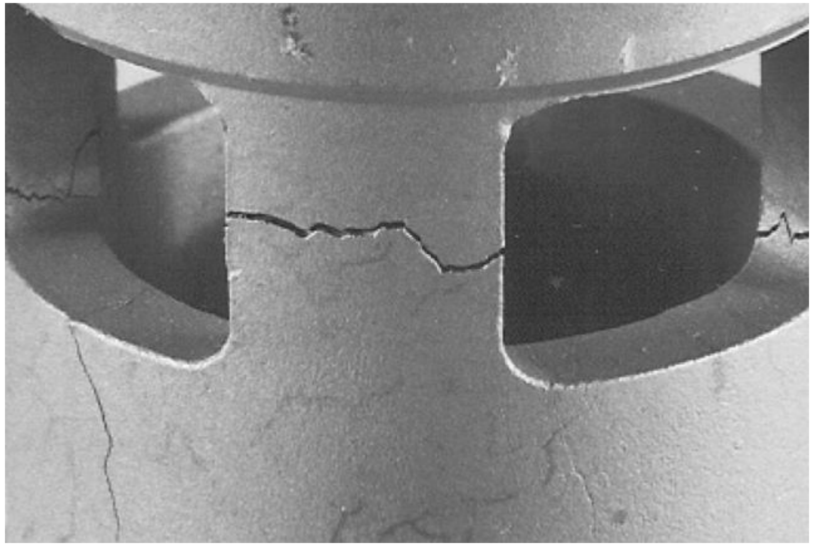


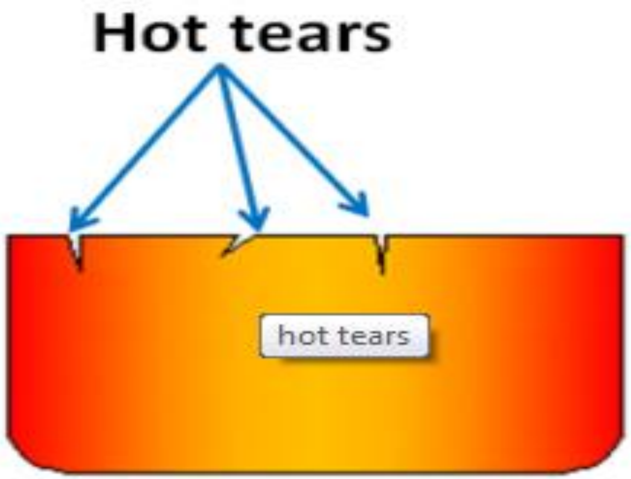


Casting Defects

Metallurgical defects

- ***Hot tears* -** Since metal has low strength at higher temperatures, any unwanted cooling stress may cause the rupture of the casting. The main cause for this is the poor casting design.





Advantages of Sand Casting

- Molten material flows into any small section in the mould cavity and as such any intricate shapes, internal or external, can be made with the casting process.
- It is possible to cast practically any material, be it ferrous or non–ferrous.
- The necessary tools required for casting moulds are very simple and inexpensive. As a result, for trial production or production of a small lot, it is an ideal method.
- It is possible in casting process to place the amount of material where exactly required. As a result, weight reduction in design can be achieved.
- Castings are generally cooled uniformly from all sides and therefore they are expected to have no directional properties.
- Casting of any size and weight, even up to 200 tons, can be made.

Limitations of Sand Casting

- The dimensional accuracy and surface finish achieved by normal sand casting process would not be adequate for final application in many cases.

- The sand casting process is labour intensive to some extent and therefore many improvements are aimed at it like machine moulding and foundry mechanisation.

- With some materials it is often difficult to remove defects arising out of the moisture present in sand castings.

Applications of Sand Casting

Cylinder blocks

Liners

Machine tool beds

Pistons and piston rings

Mill rolls

Wheels

Housings

Bells.

Special Casting Processes

- Sand casting processes described so far are not suitable and economical in many applications. In such situations special casting processes would be more appropriate.

- The following two special casting processes are discussed in the following sections –

1) Precision Investment Casting

2) Centrifugal Casting

Special Casting Processes

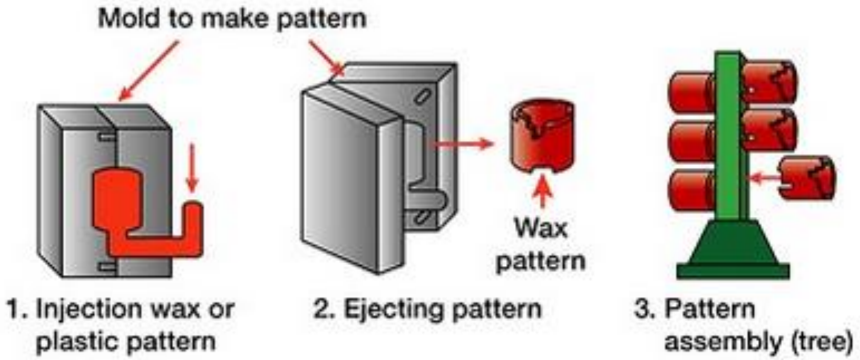
Precision Investment Casting

- This is the process where the mould is prepared around an expendable pattern.

- The first step in this process is the preparation of the pattern for every casting to be made. To do this, molten wax which is used as the pattern material is injected under pressure of about 2.5 MPa into a metallic die and has the cavity of the casting to be made as shown in Step 1.

- The wax when allowed to solidify would produce the pattern. The pattern is ejected from the die as shown in step 2.

- Then the cluster of wax patterns is attached to the gating system by applying heat as shown in step 3.



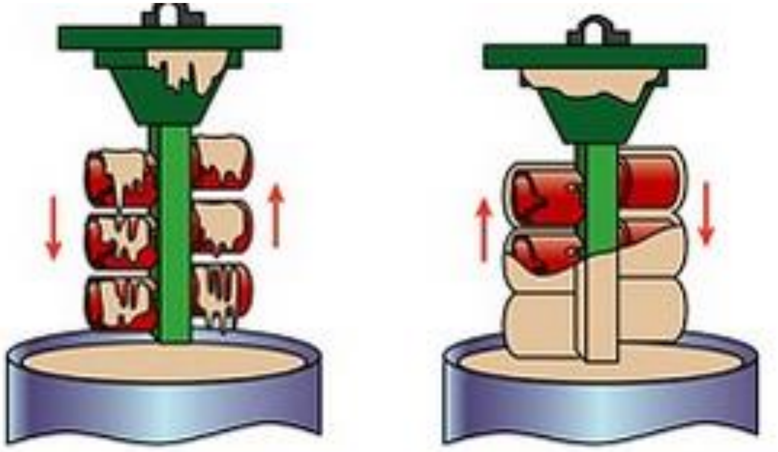
Special Casting Processes

Precision Investment Casting

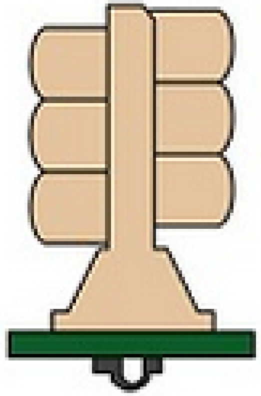
- To make the mould, the prepared pattern is dipped into a slurry made by suspending fine ceramic materials in a liquid such as ethyl silicate or sodium silicate (step 4). The excess liquid is allowed to drain off from the pattern.

- Dry refractory grains such as fused silica or zircon are “stuccoed” on this liquid ceramic coating (step 5). Thus a small shell is formed around the wax pattern.

- The shell is cured and then the process of dipping and stuccoing is continued with ceramic slurries of gradually increasing grain sizes. Finally when a shell thickness of 6 to 15 mm is reached, the mould is ready for further processing.



4. Slurry coating   5. Stucco coating



6. Completed mold

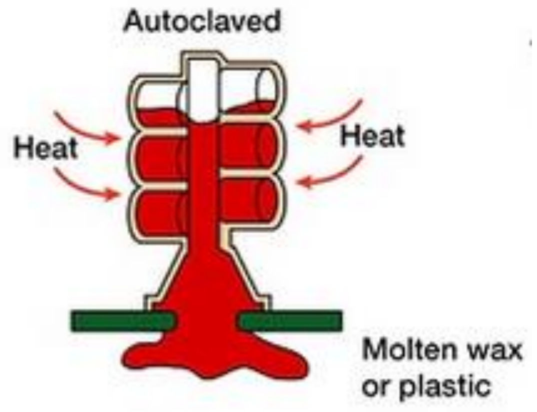
Special Casting Processes

Precision Investment Casting

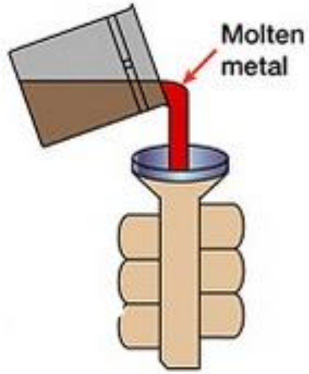
- The next step in the process is to remove the pattern from the mould which is done by heating the mould to melt the pattern (step 6). The melted wax is completely drained through the sprue by inverting the mould.

- The moulds are then pre heated to a temperature of 100 to 1000°C, depending on the size, complexity and the metal of the casting. This is done to reduce any last traces of wax left off and permit proper filling of all mould sections which are too thin to be filled in a cold mould.

- The molten metal is poured into the mould under gravity and under slight pressure, by evacuating the mould first (step 7). The method chosen depends on the type of casting.



7. Pattern meltout



8. Pouring

Special Casting Processes

Precision Investment Casting

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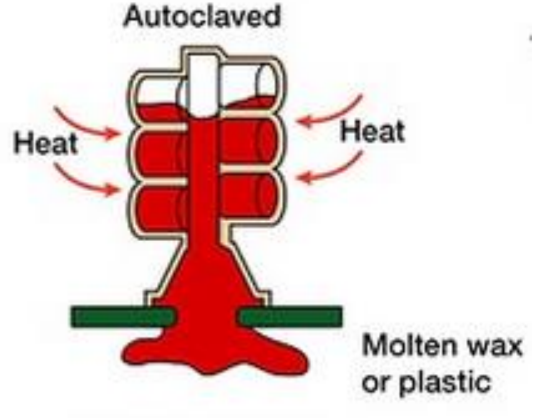
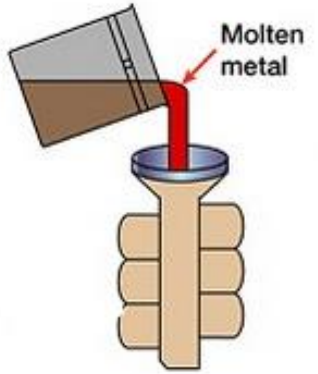


7. Pattern meltout

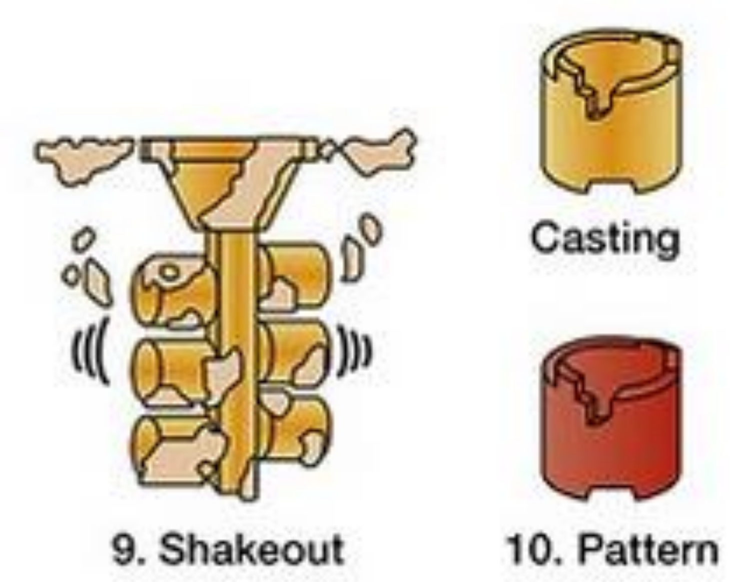


8. Pouring

Special Casting Processes

Precision Investment Casting

- Finally the molten metal is cooled and solidified. Then the moulds are subjected to shakeout using vibratory tables to remove the casting.



Special Casting Processes

Precision Investment Casting

Applications –

- This process was used in the olden days for the preparation of artefacts, jewellery and surgical instruments.

- Presently the products made by this process are vanes and blades for gas turbines, shuttle eyes for weaving, pawls and claws for movie cameras, wave guides for radars, bolts and triggers for fire arms, stain less steel valve bodies and impellers for turbo chargers.

Special Casting Processes

Centrifugal Casting

- This is a process where the mould is rotated rapidly about its central axis as the metal is poured into it.

- Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other inclusions being lighter, gets separated from the metal and segregates toward the centre.

- There are three main types of centrifugal casting processes. They are:
  - **True centrifugal casting**,
  - Semi centrifugal casting, and
  - Centrifuging

Special Casting Processes

True Centrifugal Casting

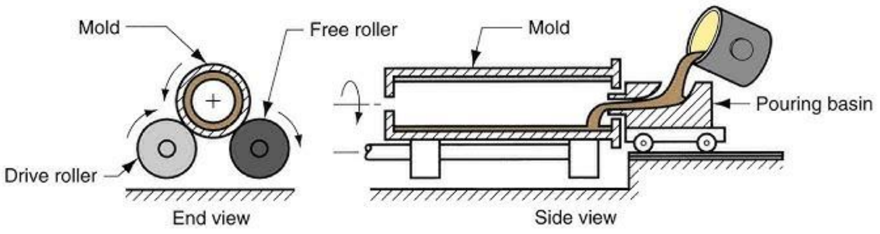
- This is normally used for the making of hollow pipes, tubes, hollow bushes, etc., which are axi-symmetric with a concentric hole.

- Since the metal is always pushed outward because of the centrifugal force, no core needs to be used for making the concentric hole. The axis of rotation can be horizontal, vertical or any angle in between.

- First, the moulding flask is properly rammed with sand to confirm to the outer contour of the pipe to be made.

- Then the flask is dynamically balanced so as to reduce the occurrence of undesirable vibrations during the casting process. The finished flask is mounted in between the rollers and the mould is rotated slowly.

Permanent Mold Casting Processes
Centrifugal Casting



Special Casting Processes

True Centrifugal Casting

- Now the molten metal in requisite quantity is poured into the mould through the movable pouring basin. The amount of metal poured determines the thickness of the pipe to be cast.

- After the pouring is completed, the mould is rotated at its operational speed till it solidifies, to form the requisite tubing. Then the mould is replaced by a new mould machine and the process continues.

FORMING PROCESSES

- These are solid state manufacturing processes involving minimum amount of material wastage and faster production.
- In a forming process, metal may be heated to a temperature which is slightly below the solidus temperature and then a large force is applied such that the material flows and takes the desired shape.
- The desired shape is controlled by means of a set of tools called dies which may be completely or partially closed during manufacturing.
- These processes are normally used for large-scale production rates.
- These are generally economical and in many cases improve the mechanical properties too.

FORMING PROCESSES

Some of the metal forming processes are as follows:

- Rolling
- Drop Forging
- Press Forging
- Upset Forging
- Extrusion
- Wire Drawing
- Sheet Metal Operations

HOT WORKING AND COLD WORKING

- The metal-working processes are traditionally divided into **hot working and cold-working processes**. The division is on the basis of the amount of heating applied to the metal before applying the mechanical force.

- Those processes, working above the **recrystallisation temperature**, are termed as hot-working processes whereas those below are termed as cold-working processes.

- Under the action of heat and the force, when the atoms reach a certain higher energy level, the new crystals start forming which is termed as recrystallisation. Recrystallisation temperature as defined by American Society of Metals is "**the approximate minimum temperature at which complete recrystallisation of a coldworked metal occurs within a specified time**".

- The recrystallisation temperature generally varies between **one third to one half the melting point** of most of the metals. The recrystallization temperature also depends on the amount of cold work a material has already received. Higher the cold work, lower would be the recrystallisation temperature.

HOT WORKING AND COLD WORKING

- **Advantage of Hot Working**: As the material is above the recrystallisation temperature, any amount of working can be imparted since there is no strain-hardening taking place.

- **Limitations of Hot Working**:
  1) Higher temperatures of metal give rise to scaling of the surface and as a result, the surface finish obtained is poor.
  2) Because of the thermal expansion of metals, the dimensional accuracy in hot working is difficult to achieve since it is difficult to control the temperature of work pieces.
  3) Handling and maintaining of hot metal is difficult and troublesome.

- **Advantage of Cold Working**: Cold working increases the strength and hardness of the material due to strain hardening which would be beneficial in some situations.

- **Limitation of Cold Working**: Since the material has higher yield strength at lower temperatures, the amount of deformation that can be given to is limited by the capability of the presses or hammers used.

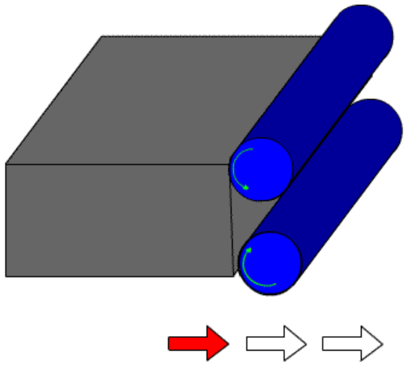
ROLLING

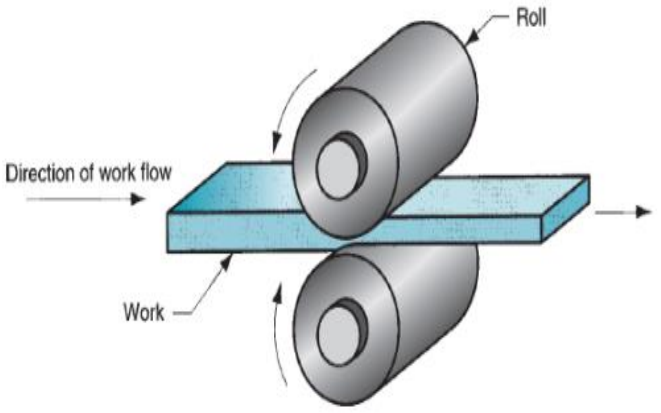
- Rolling is a process where the metal is compressed between two rotating rolls for reducing its cross-sectional area.

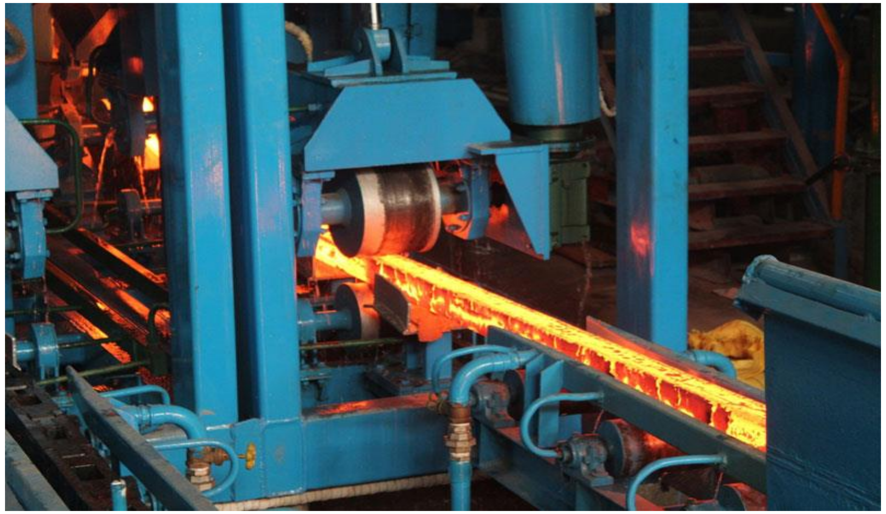
- It is one of the most widely used of all the metal-working processes, because of its higher productivity and low cost.

- Rolling would be able to produce components having constant cross section throughout its length. Many shapes such as I, T, L, and channel sections are possible, but not very complex shapes.

- Rolling is normally a hot working process unless specifically mentioned as cold rolling.



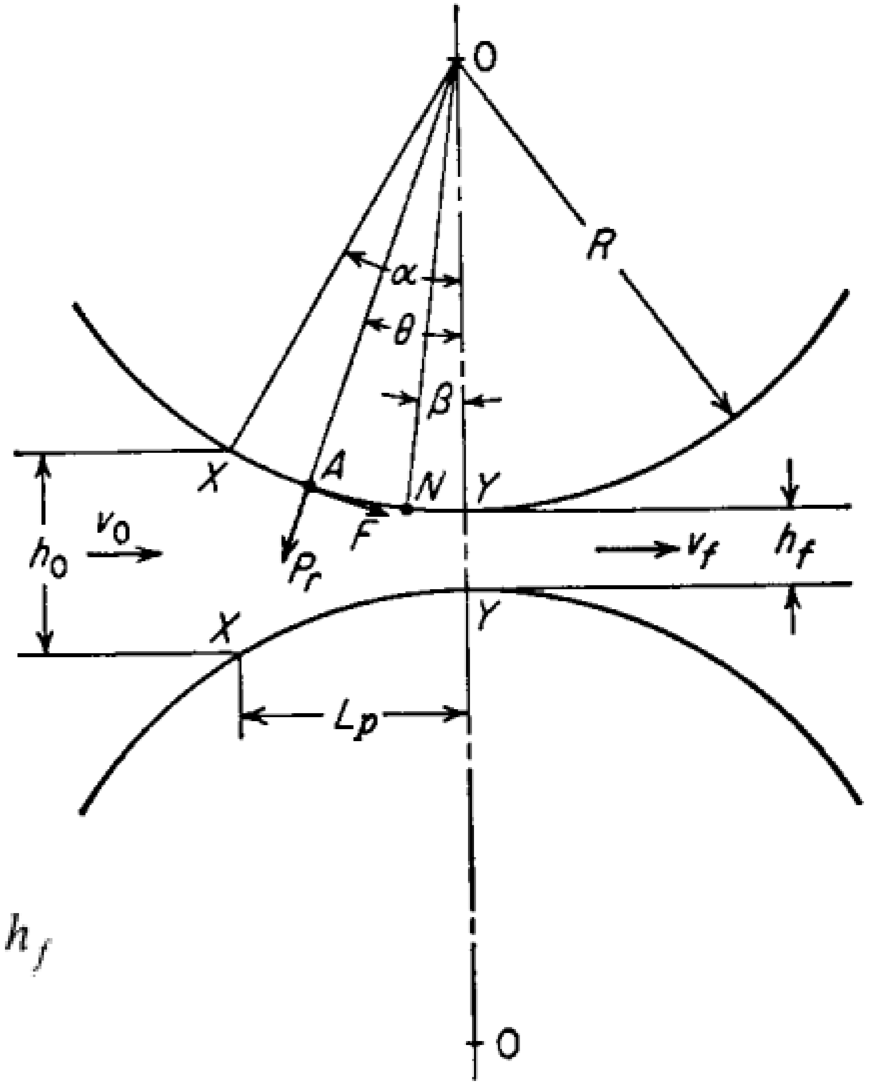




FORCES ACTING DURING ROLLING

- A metal sheet with thickness h0 enters the rolls at the entrance plane XX with a velocity v0. It passes through the roll gap and leaves the exit plane YY with a reduced thickness hf.

- Vertical compression of the metal is translated into an elongation in the rolling direction. Since equal volumes of metal must pass a given point per unit time, we can write



$$bh_0v_0 = bhv = bh_fv_f$$

where $b =$ width of sheet

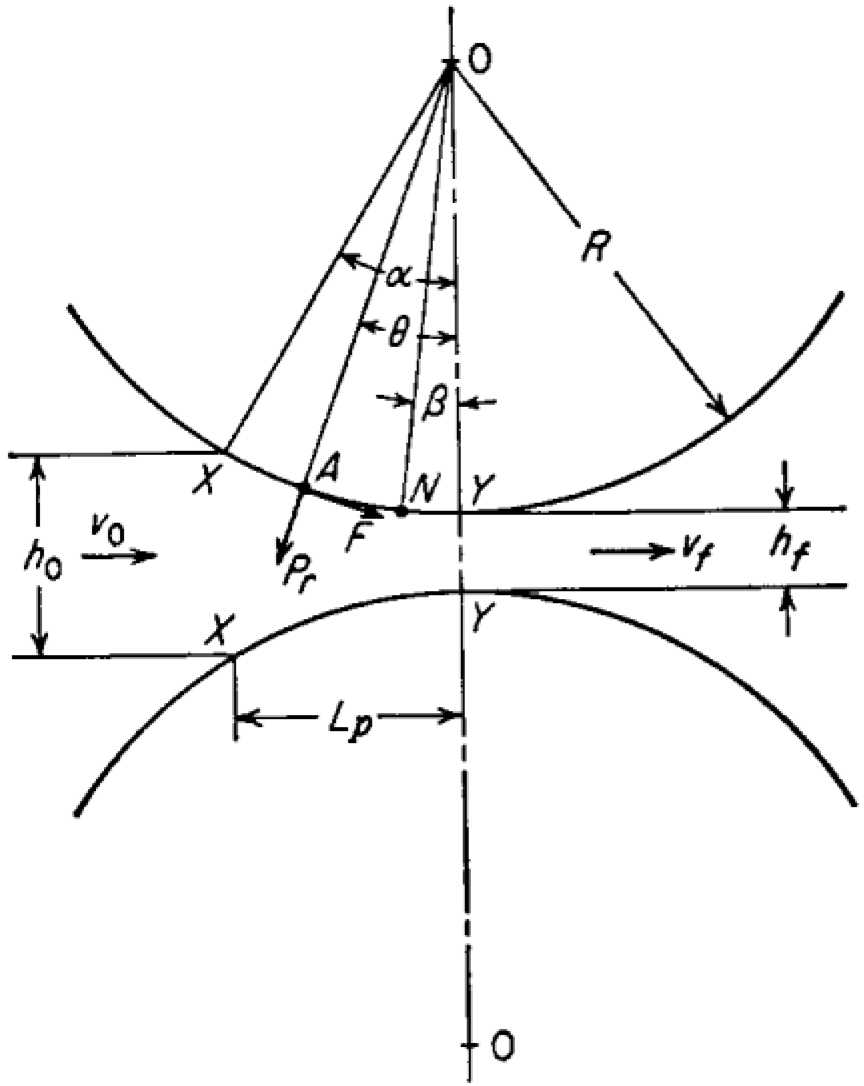
$v =$ its velocity at any thickness h intermediate between h_0 and h_f

FORCES ACTING DURING ROLLING

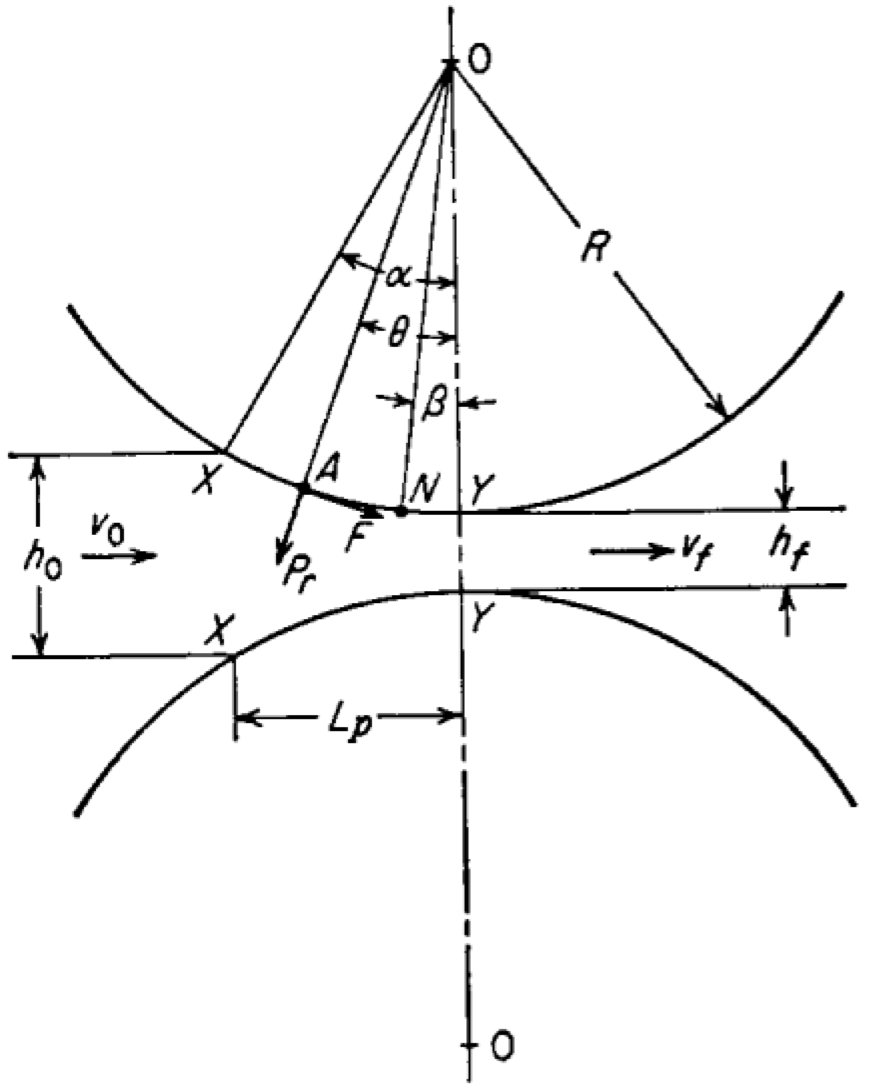
- Equation above requires that the exit velocity must be greater than the entrance velocity. Therefore the velocity must steadily increase from entrance to exit.

- At only one point along the surface of contact between the roll and the sheet is the surface velocity of the roll equal to the velocity of the sheet. This point is called the ***neutral point or no slip point. (N)***

- At any point along the surface of contact, such as point A, two forces act on the metal. These are a radial force Pr and a tangential frictional force F.



FORCES ACTING DURING ROLLING



- Between the entrance plane and the neutral point, the sheet is moving slower than the roll surface an the frictional force acts in the direction shown in figure so as to draw the metal into rolls.

- On the exit side of the neutral point, the sheet moves faster than the roll surface. The direction of the frictional force is reversed so that it acts to oppose the delivery of the sheet from the rolls.

- The vertical component of Pr is called the rolling load P. It is the force with which the rolls press against the metal.

- The specific roll pressure p is the rolling load divided by the contact area.

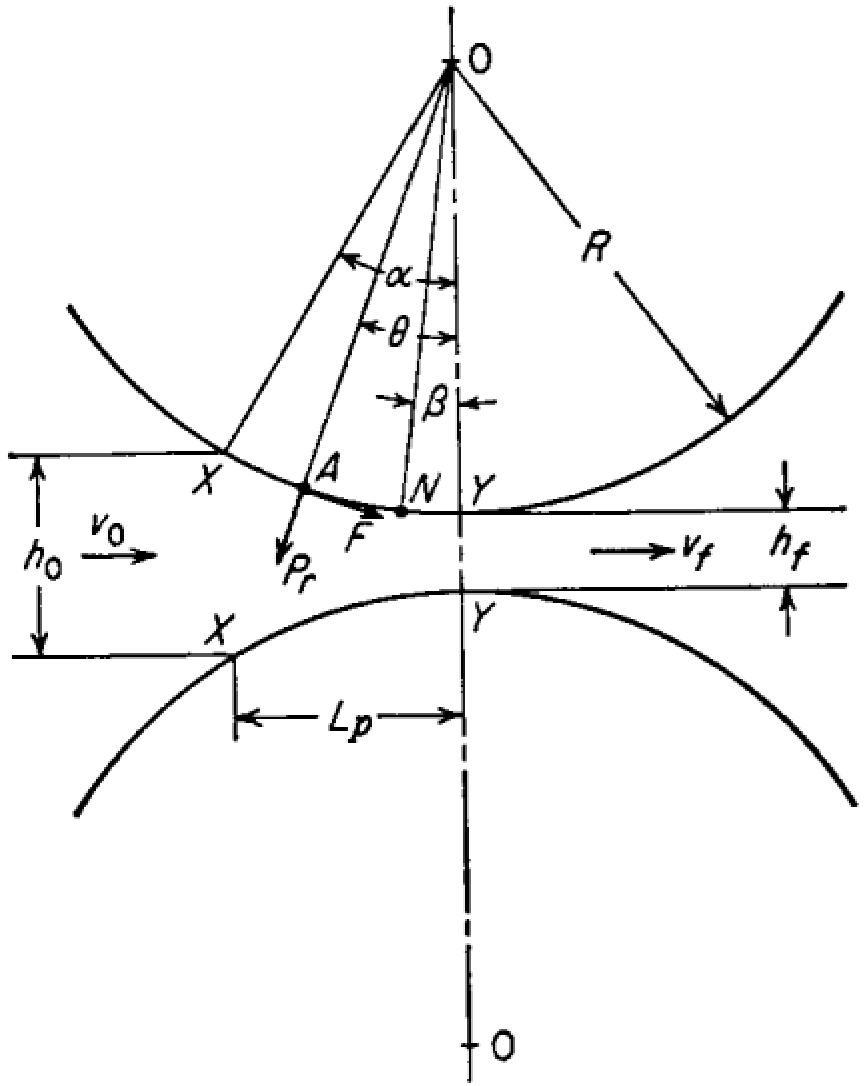
FORCES ACTING DURING ROLLING

- The contact area between the metal and the rolls is equal to the product of the width of the sheet b and the projected length of the arc of contact Lp.

- The angle α between the entrance plane and the centerline of the rolls is called the angle of contact or angle of bite. It can be shown that,

$$\mu = \tan \alpha$$

- The workpiece can be drawn into rolls if the tangent of the contact angle exceed the coefficient of friction.



FORCES ACTING DURING ROLLING

- The contact area between the metal and the rolls is equal to the product of the width of the sheet b and the projected length of the arc of contact Lp.

- Referring to the figure, we can write,

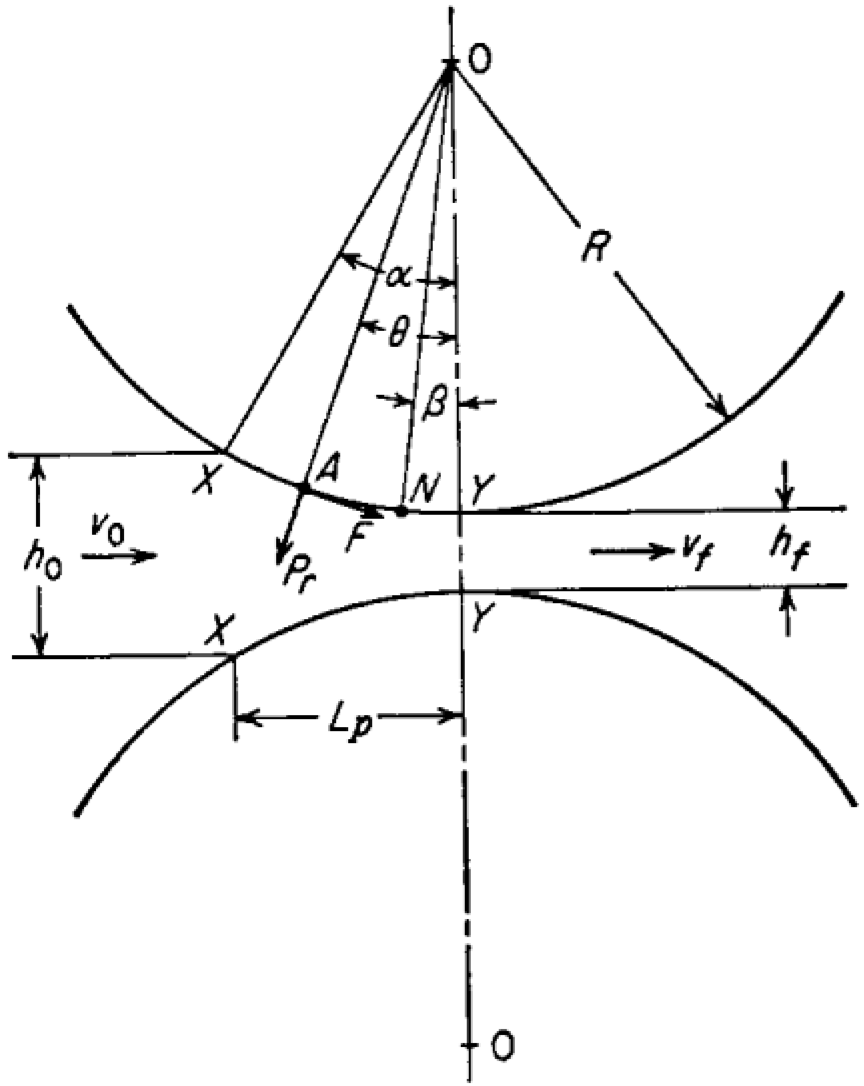
$$L_p \approx \sqrt{R\Delta h}$$

where Δh = the "draft" taken in rolling

$$\tan\alpha = \frac{L_p}{R - \Delta h/2} \approx \frac{\sqrt{R\Delta h}}{R - \Delta h/2} \approx \sqrt{\frac{\Delta h}{R}}$$

From Eq. (17-4), $\mu \geq \tan\alpha = \sqrt{\Delta h/R}$

or $$(\Delta h)_{max} = \mu^2 R$$



FORCES ACTING DURING ROLLING

Example Determine the maximum possible reduction for cold-rolling a 300 mm-thick slab when $\mu = 0.08$ and the roll diameter is 600 mm. What is the maximum reduction on the same mill for hot rolling when $\mu = 0.5$?

FORCES ACTING DURING ROLLING

$$\tan \theta_{max} = \mu \qquad \alpha = \theta_{max} = \tan^{-1}(0.08) = 4.6^\circ$$

From Fig. 17-5 $\sin \alpha = L_p/R = \sqrt{R\Delta h}/R$, $\Delta h = 1.91$ mm. Note that the same result would be obtained from Eq. (17-5).

$$(\Delta h)_{max} = \mu^2 R = (0.08)^2(300) = 1.92 \text{ mm}$$

For hot rolling

$$(\Delta h)_{max} = (0.5)^2(300) = 75 \text{ mm}$$

FORGING

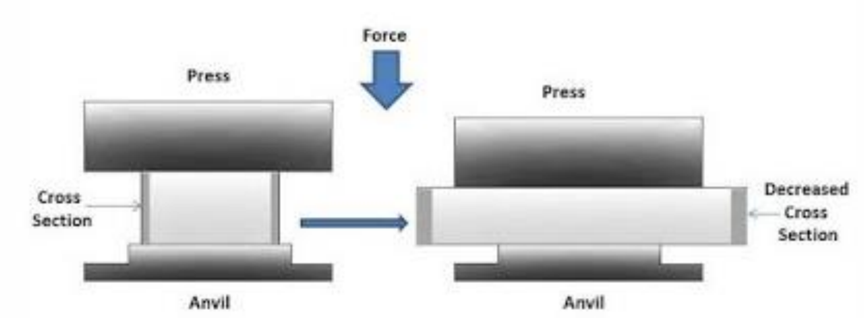
- Forging is the operation where the metal is heated and then a force is applied to manipulate the metal in such a way that the required final shape is obtained.

- Forging is generally a hot-working operation though cold forging is used sometimes.

- Two types of operations are used in forging in order to arrive at the final object configuration. They are

Drawing Out

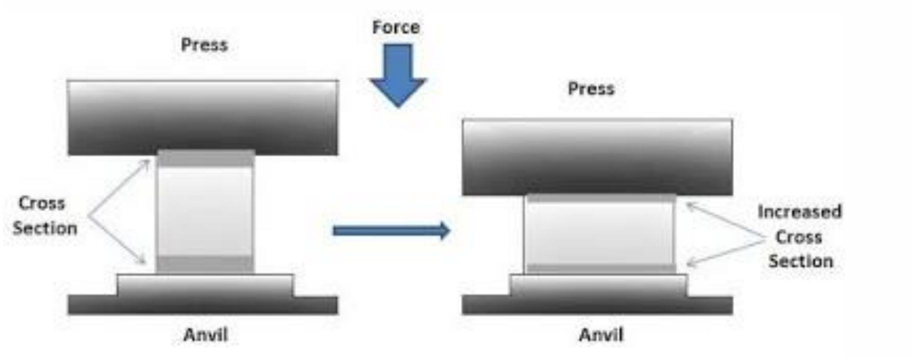
- This is the operation in which the metal gets elongated with a reduction in the cross-sectional area. For this purpose, the force is to be applied in a direction, perpendicular to the length axis.



FORGING

Upsetting

- This is applied to increase the cross-sectional area of the stock at the expense of its length. To achieve the upsetting, force is applied in a direction parallel to the length axis.

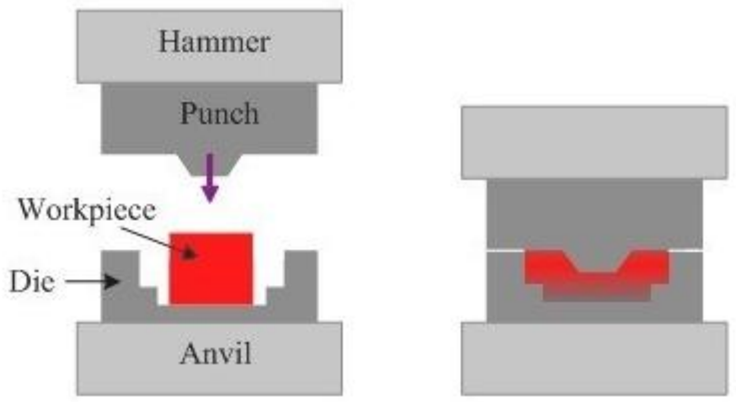


Forging Types

- There are four types of forging methods, which are generally used.

Smith Forging - This is the traditional forging operation done openly or in open dies by the village blacksmith or modern shop floor by manual hammering or by power hammers.

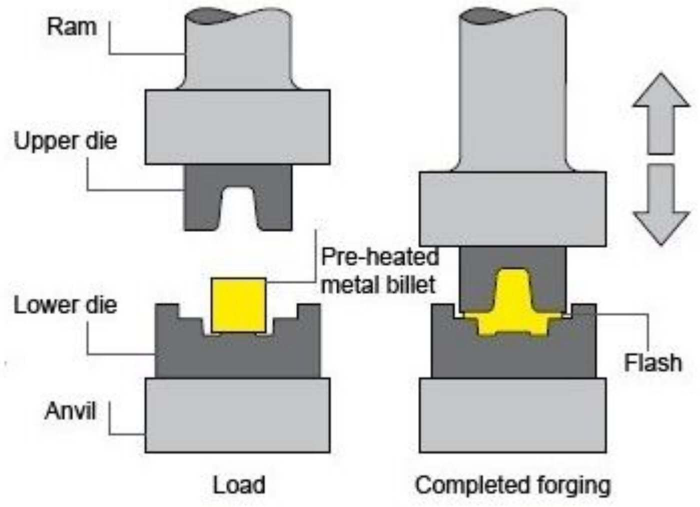
Drop Forging - This is the operation done in closed impression dies by means of the drop hammers. Here the force for shaping the component is applied in a series of blows.



FORGING

Press Forging - Similar to drop forging, the press forging is also done in closed-impression dies with the exception that the force is a continuous squeezing type applied by the hydraulic presses.

Machine Forging - Unlike the drop or press forging where the material is drawn out, in machine forging, the material is only upset to get the desired shape.



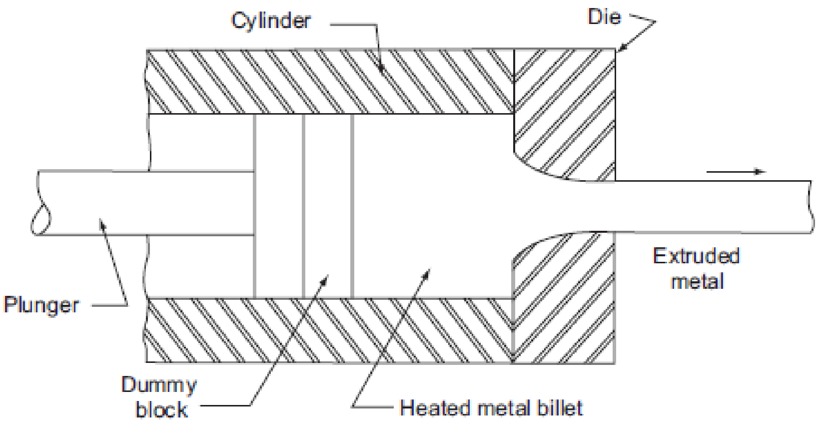
EXTRUSION

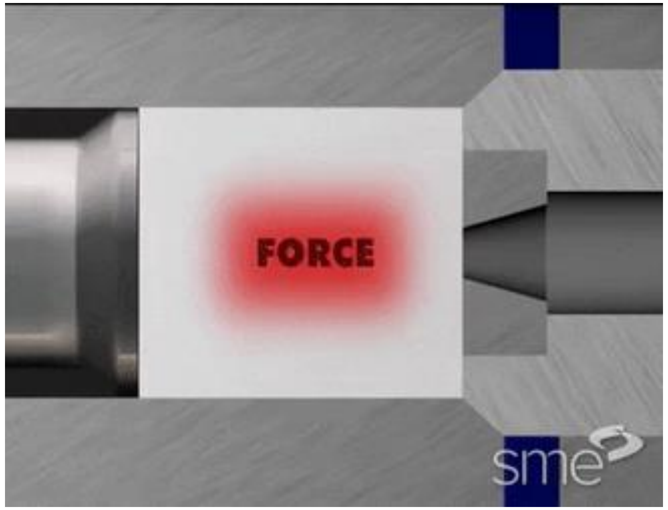
- Extrusion is the process of confining the metal in a closed cavity and then allowing it to flow from only one opening so that the metal will take the shape of the opening.

- The equipment consists of a cylinder or container into which the heated metal billet is loaded.

- On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening.

- The extruded metal is then carried by the metal handling system as it comes out of the die.





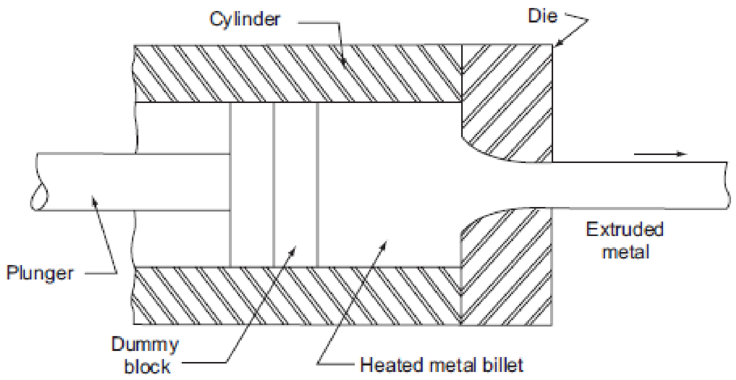
FORWARD EXTRUSION

- The process represented in Fig. is called the forward extrusion, signifying the flow of metal in the forward direction, i.e. the same as that of the ram.

- In forward extrusion, the problem of friction is prevalent because of the relative motion between the heated metal billet and the cylinder walls. This is particularly severe in the case of steels because of their higher extrusion temperatures.

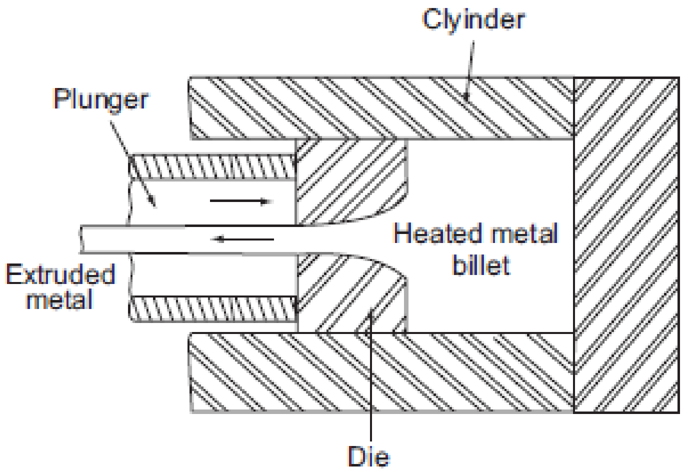
- To reduce this friction, lubricants are to be used. The problem of lubrication gets compounded at the higher operating temperatures. Molten glass is generally used for extruding steels. This stays in liquid form at the operating temperature and provides necessary heat insulation to the hot metal billet in addition to lubrication.

- To reduce the damage to equipment, extrusion is finished quickly and the cylinder is cooled before further extrusion.



BACKWARD EXTRUSION

- In order to completely overcome the friction, the backward extrusion, as shown in Fig. is used.
- In this, the metal is confined fully by the cylinder. The ram which houses the die, also compresses the metal against the container, forcing it to flow backwards through the die in the hollow plunger or ram.
- It is termed backward because of the opposite direction of the flow of metal to that of ram movement.
- Thus, the billet in the container remains stationary and hence no friction.
- Though advantageous, this process is not extensively used because of the problem of handling extruding metal coming out through the moving ram.



WIRE DRAWING

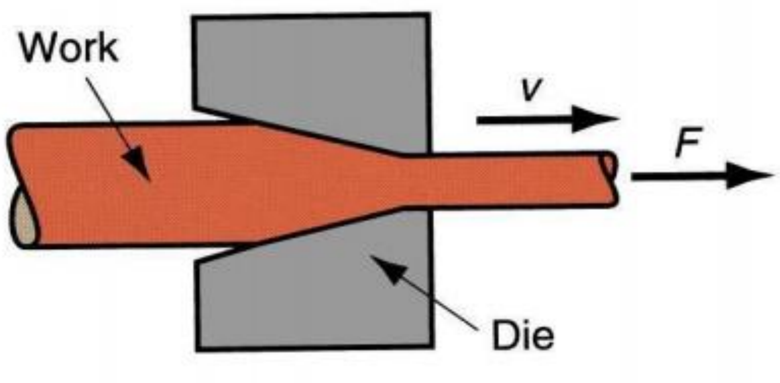
- A wire by definition, is circular with small diameters so that it is flexible. The process of wire drawing is to obtain wires from rods of bigger diameter through a die.

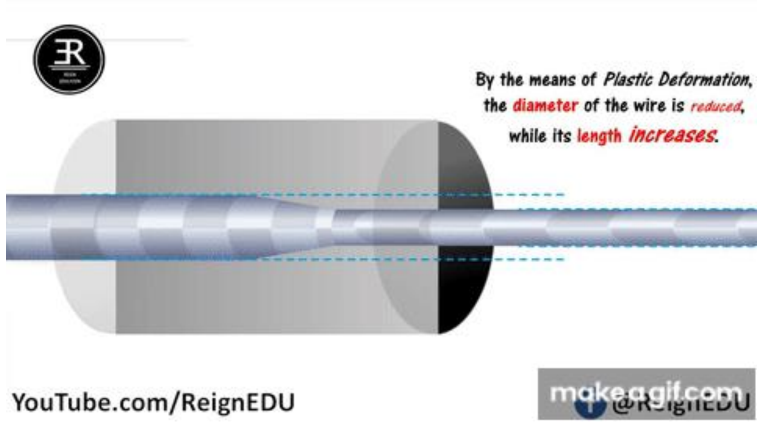
- The wiredrawing die is of conical shape.

- The end of the rod or wire, which is to be further reduced is made into a point shape and inserted through the die opening.

- This end is then gripped on the other side with a gripper, which would then pull the wire through the die. The wire thus drawn is then coiled round a power reel.

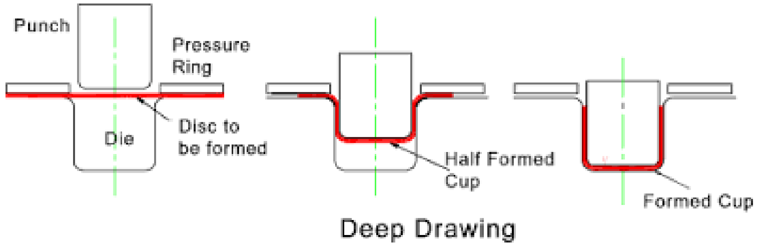
- Wire drawing is always a cold-working process.

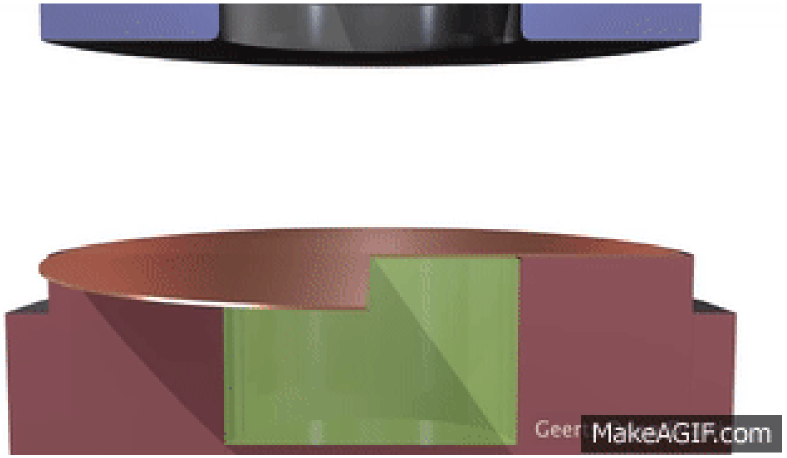




SHEET METAL DRAWING

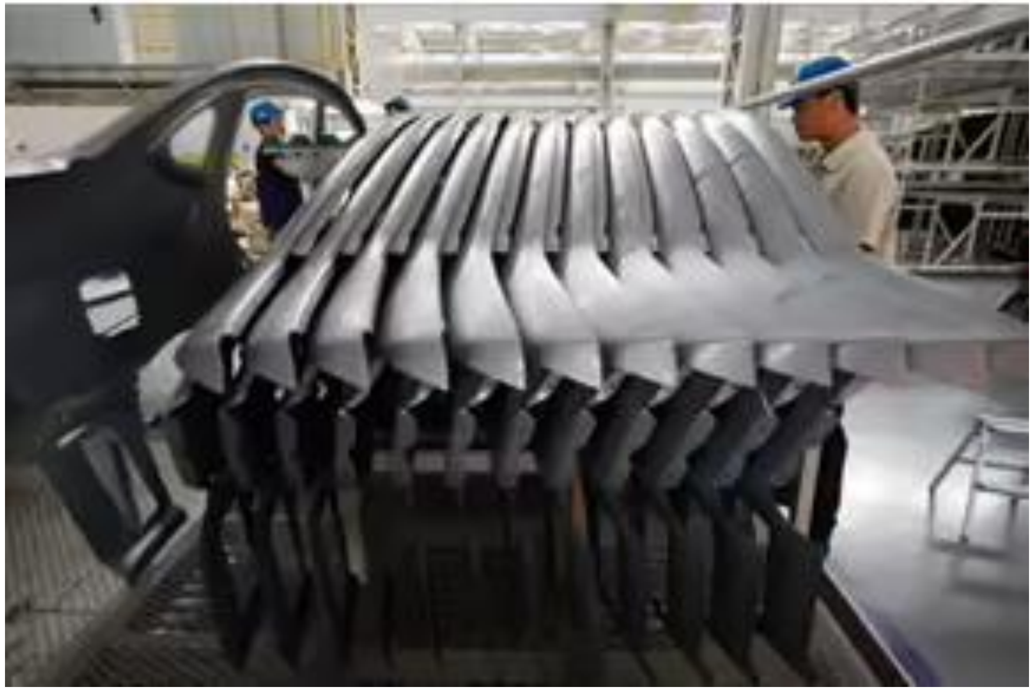
- Sheet metal is generally considered to be a plate with thickness less than about 5 mm.
- Sheet metal operations are mostly cold working operations that manufacture low cost parts with very high volumes and at a fast rate.
- Sheet metal drawing is the process of making cups, shells and similar articles from metal sheet blanks.
- The blank is first kept on the die plate. The punch slowly descends 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.
- Shallow drawing is defined as where the cup height is less than half the diameter. Otherwise it is referred to as deep drawing.





APPLICATIONS OF METAL FORMING

- **Automotive Manufacturing: Automobile body panels**
- **Aerospace Engineering: Airplane fuselage, wings and engine components**
- **Construction: Pipelines**



JOINING PROCESSES

- Joining two or more elements to make a single part.

- A fairly large number of industrial components are made by joining processes. Common examples are aircraft and ship bodies, bridges, building trusses, welded machine frames, sheet metal parts, etc.

- The joining process is often, the most economical method and relies on raw material obtained from one of the primary manufacturing processes.

- The various joining processes can be classified as follows:
  - **Mechanical joining by means of bolts, screws and rivets.**
  - **Adhesive bonding by employing synthetic glues such as epoxy resins.**
  - **Welding, brazing and soldering.**

JOINING PROCESSES

Temporary, Semi – Permanent and Permanent joining processes

- Joining obtained by bolts and screws is **temporary** in nature and can be disassembled whenever necessary.

- Rivets are **semi permanent** fastening devices and the joint can be separated only by destroying the rivet without harming the parent elements.

- Welding produces a **permanent** joint as a welded part needs to be broken to dismantle it.

WELDING

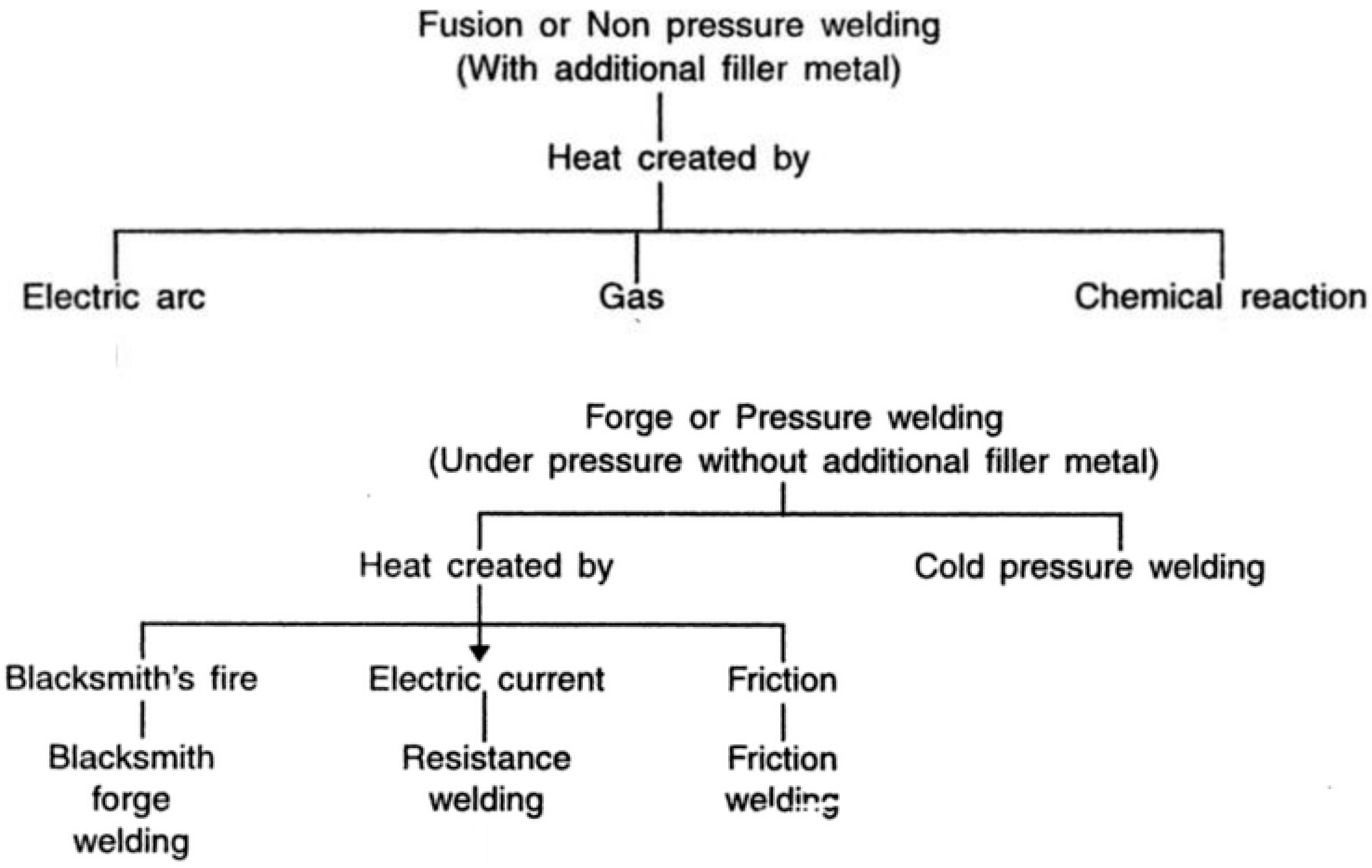
- Welding is defined as **a localised coalescence of metals, wherein coalescence is obtained by heating to a suitable temperature, with or without the application of pressure and with or without the use of filler metal.**

- Based on the use of pressure, welding can be mainly classified as

- **Plastic Welding** – Here parts being joined are heated to their plastic states and then joined together by applying external pressure.

- **Fusion Welding** - Here, the interface of the two parts to be joined is brought to a temperature above the melting point and then allowed to solidify so that joining takes place.

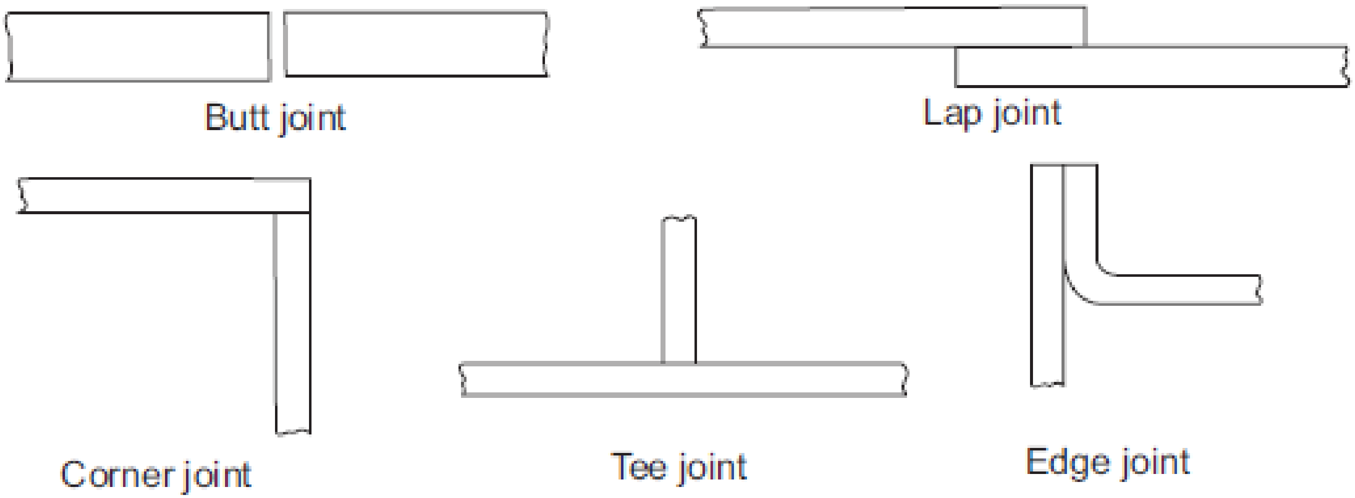
WELDING


Fusion or Non pressure welding
(With additional filler metal)
Heat created by
Electric arc
Gas
Chemical reaction
Forge or Pressure welding
(Under pressure without additional filler metal)
Heat created by
Cold pressure welding
Blacksmith's fire
Electric current
Friction
Blacksmith forge welding
Resistance welding
Friction welding

GENERAL CONSIDERATIONS

Types of Joints

- Different types of welding joints are classified as **butt, lap, corner, tee and edge** joints. The choice of the type of joint depends on the weldment being made and the sheet thickness.



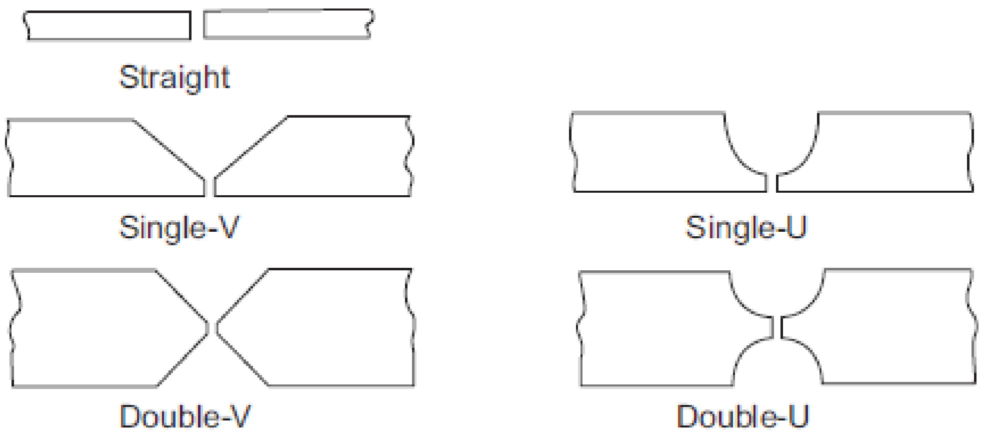
GENERAL CONSIDERATIONS

Edge Preparation

- The straight edges of the joint is used when the thickness of the two pieces to be joined is small, so that heat of welding penetrates the full depth of the joint.

- However, when the thickness increases it becomes necessary to prepare the edge in such a way that heat would be able to penetrate the entire depth.

- To facilitate this, the joint is widened. For very thick plates, the welding needs to be done from both sides. To provide the necessary access into the joint, it could be made as a V or U.



GENERAL CONSIDERATIONS

Cleaning

- By virtue of the metal being melted at the interface in a welded joint it is necessary that the interfaces are very clean.

- If the interfaces are not clean, with any oil, dirt, paint or grease residue left would interfere with the proper fusing of the metal and thus weaken the joint. Hence it is essential that the joint surfaces are thoroughly cleaned before the welding is attempted.

- To remove the oily substances from the surface, the organic solvents such as **acetone and carbon tetrachloride** may be used. The foreign substances may be removed by means of cleaning with a rag soaked in the solvent.

- The heavier oxide films may be removed by **acid pickling, wire brushing or emery**.

ELECTRIC ARC WELDING

- The electric arc welding process makes use of the **heat produced by the electric arc** to fusion weld metallic pieces.

- This is one of the most widely used welding process, mainly because of the ease of use and high production rates that can be achieved economically.

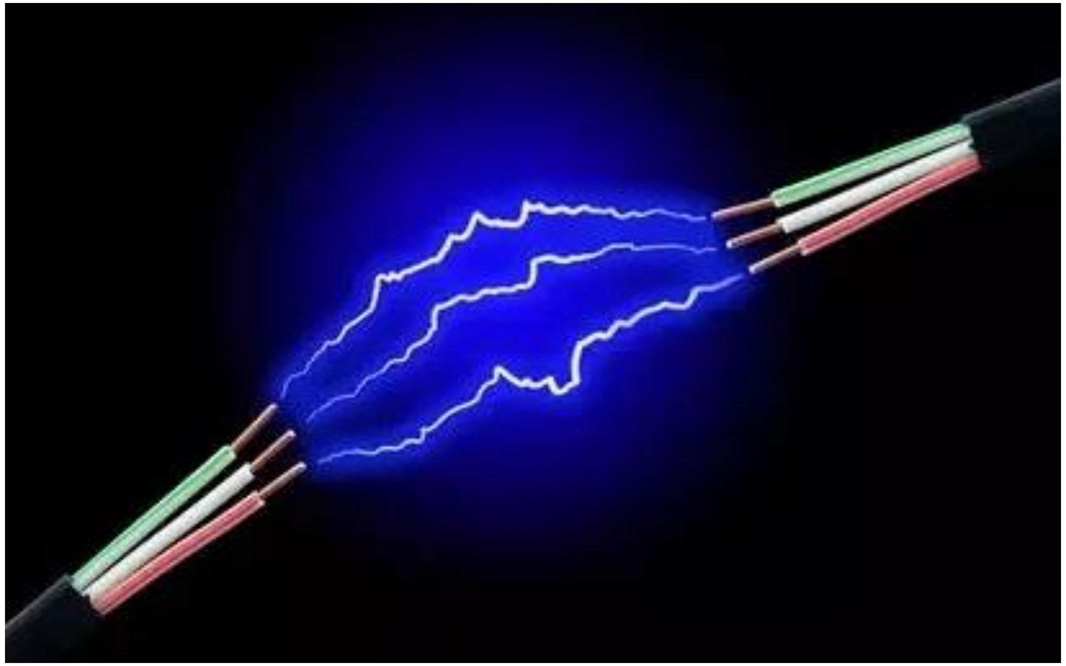
Principle of Arc

- An arc is generated between two conductors of electricity, cathode and anode, when they are touched to establish the flow of current and then separated by a small distance.

- An arc is a sustained electric discharge through the ionised gas column called plasma between the two electrodes.

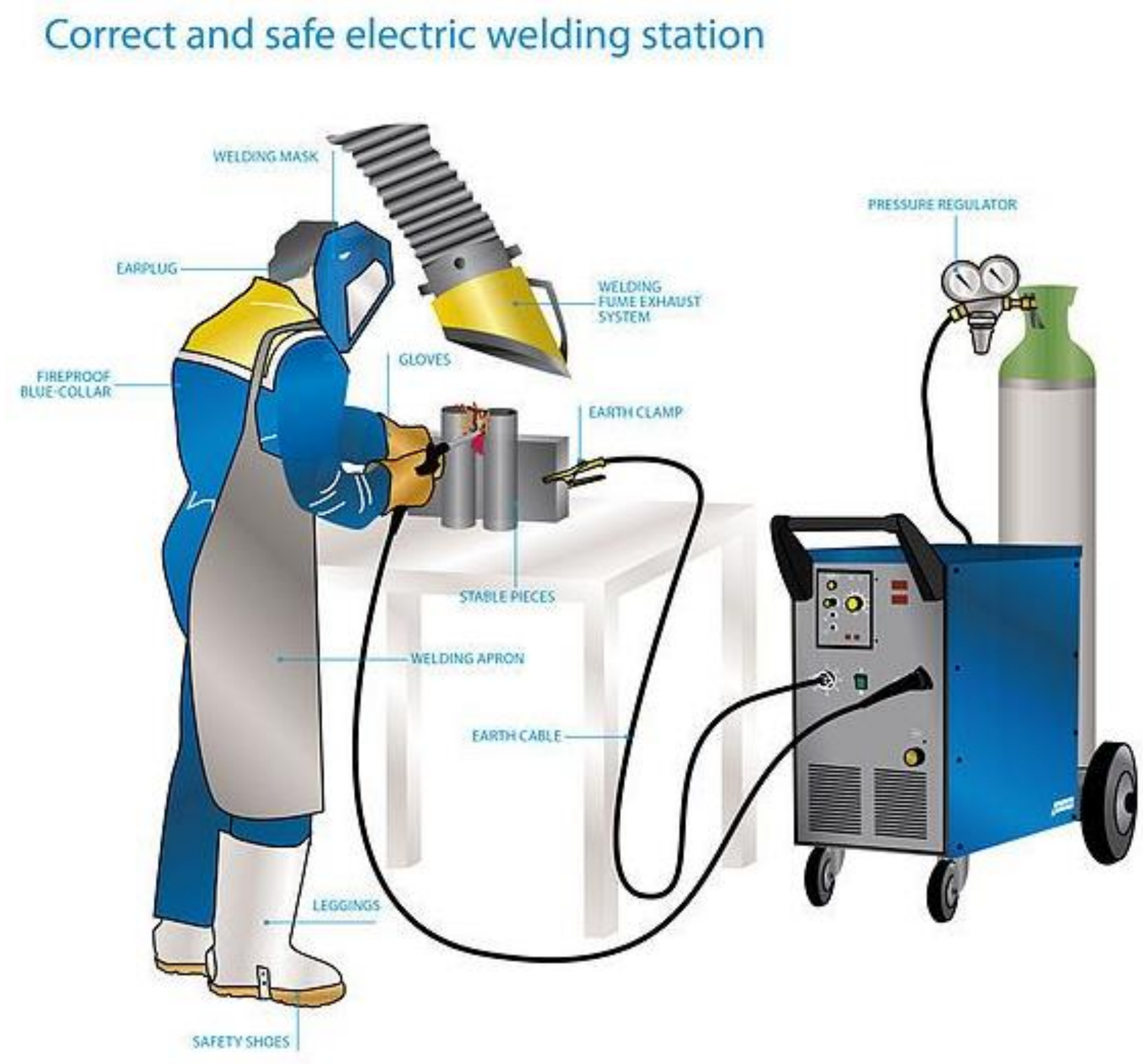
- It is generally believed that electrons liberated from the cathode move towards the anode and are accelerated in their movement. When they strike the anode at high velocity, large amount of heat is generated.

- A temperature of the order of 6000°C is generated at the anode.



ARC WELDING EQUIPMENT

- AC or DC machine
- Electrode and electrode holder
- Chipping hammer
- Earthing clamps
- Wire brush
- Helmet
- Safety goggles, Hand gloves, etc.



ARC WELDING PROCEDURE

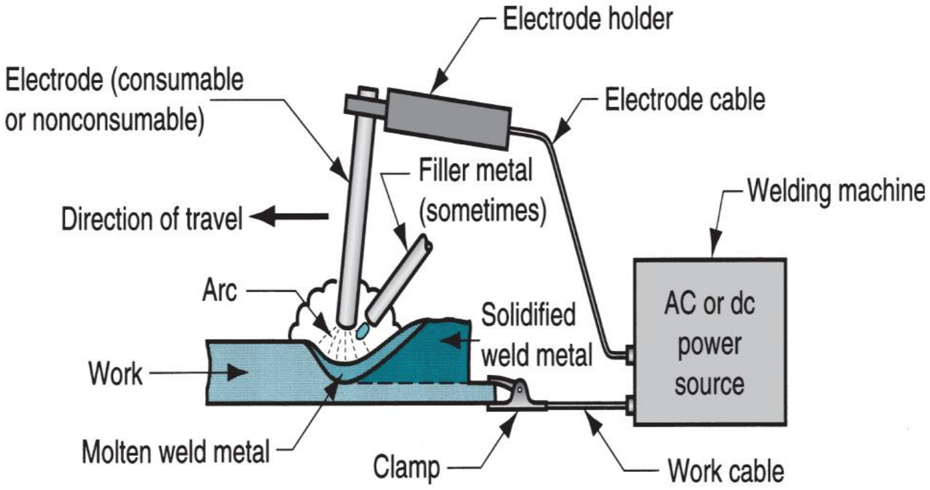
- In operation, an arc is struck by touching the tip of the electrode on the workpiece and instantaneously the electrode is separated by a small distance of 2 – 4 mm such that the arc still remains between the electrode and the workpiece.

- The high heat at the tip of the arc melts the workpiece metal forming a small molten metal pool. At the same time, the tip of the electrode also melts.

- The molten metal of the electrode is transferred into the molten metal of the workpiece in the form of globules of molten metal.

- The deposited metal fills the joint and bonds the joint to form a single piece of metal.

- The electrode is moved along the surface to be welded to complete the joint.



ELECTRODES

- The electrodes used for providing heat input in arc welding are of two types, **the consumable and the nonconsumable electrodes**.

- When the arc is obtained with a **consumable electrode**, the **weld metal under the arc melts as also the tip of the electrode**. The molten metal from the electrode and that obtained from the base metal gets intimately mixed under the arc and provides the necessary joint after solidification.

- Consumable electrodes are made of various materials depending on the purpose and chemical composition of the metals to be welded. Thus, they may be made of steel, cast iron, copper, brass, bronze or aluminium.

- It is also possible to use **non-consumable electrodes** made of carbon, graphite or tungsten. The carbon and graphite electrodes are used only in DC welding, whereas tungsten electrodes are used for both AC and DC welding. The filler metal required has to be deposited through a **separate filler rod**.

ELECTRODES

- A consumable electrode, used in welding, can be either **bare or coated**. The coated electrode also called stick electrode, is used for the manual arc welding process.

- The coating on the electrodes serves a number of purposes –

1) The coatings give off inert gases such as carbon dioxide under the arc heat, which **shields** the molten metal pool and protects it from the atmospheric oxygen, hydrogen and nitrogen pick up thus, reducing contamination of the weld metal.

2) The coatings provide flux to the molten metal pool, which mixed with the oxides and other impurities present in the puddle, forms a **slag**. The slag being lighter, floats on the top of the puddle and protects it against the surrounding air during the weld bead solidification. The slag covering also helps the metal to cool slowly preventing the formation of a brittle weld. When the weld is sufficiently cooled, the slag can be removed exposing the shiny weld underneath.

ELECTRODES

3) Some elements that are required for stabilisation of the arc are also added in these coatings. The coatings are different for AC welding and DC welding.

4) Special alloying elements can be introduced through these coatings to improve the strength and physical properties of the weld metal.

5) The coatings also contain materials which can control the slag to be viscous or fluid. Viscous slag would be useful for making welds in vertical position to cover the metal puddle for a longer time.

GAS WELDING

- As the name implies, gas welding also called as oxy-fuel gas welding (OFW), derives the heat from the **combustion of a fuel gas** such as acetylene in combination with oxygen.

- The process is a fusion welding process wherein the joint is completely melted to obtain the fusion. The heat produced by the combustion of gas is sufficient to melt any metal and as such is universally applicable.

- The fuel gas generally used is acetylene because of the high temperature generated in the flame. This process is called **oxy-acetylene welding** (OAW).

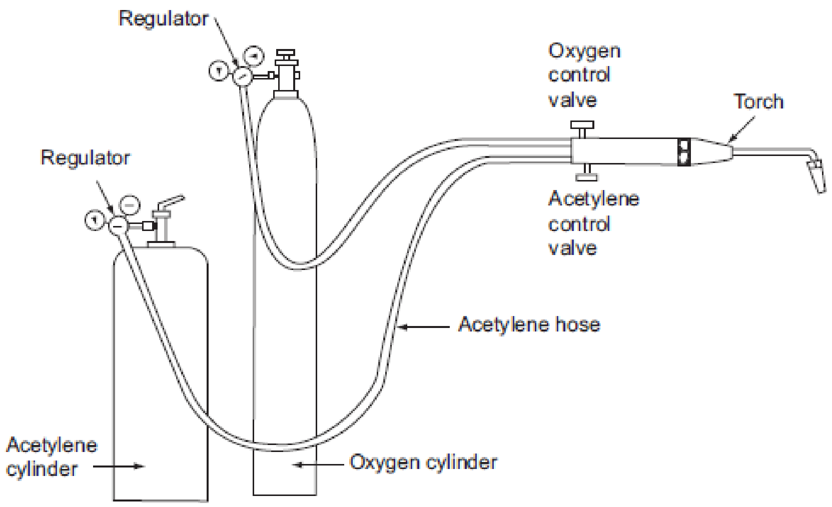
GAS WELDING

- A typical oxy-acetylene welding outfit contains the supply units for oxygen and acetylene with associated regulators and the torch which mixes the two gases before they are ignited.

- Free acetylene is highly explosive, if stored at a pressure more than 200 kPa, where it becomes very unstable and likely to explode. Hence, acetylene needs to be carefully stored in a strong cylinder, filled with 80 to 85% porous material such as calcium silicate and then filled with acetone.

- Acetylene would be released from acetone at a slow rate and thus would not form any pockets of high pressure acetylene.

- It is also possible to have an acetylene generator in the place of an acetylene cylinder. Acetylene is normally produced by a reaction between calcium carbide and water which is instantaneous.



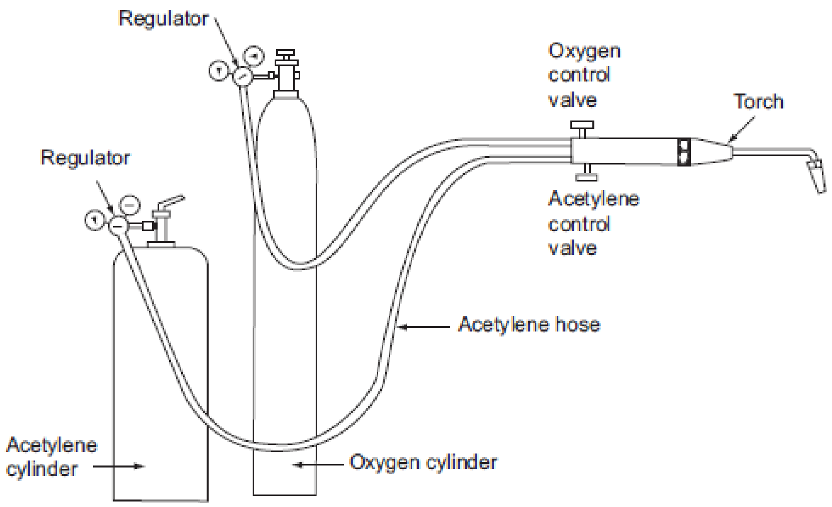
GAS WELDING

- The oxygen and acetylene from the two cylinders are brought through separate hose pipes to the welding torch.

- In the torch the two gases are mixed and then flowed out through the nozzle at the torch tip.

- To light the flame, the acetylene valve on the torch is opened slightly and lighted with the help of a friction spark lighter.

- Then the acetylene valve is opened to get the required flow of acetylene. The oxygen valve is then slowly opened. The actual adjustment of the flame depends on the type of material to be joined.



GAS WELDING

- In all the oxy-fuel gas welding processes, the combustion takes place in two stages.

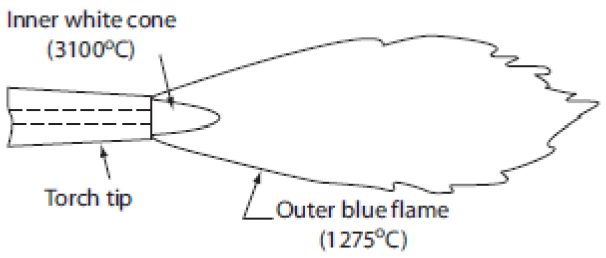
- The first reaction takes place when the fuel gas such as acetylene and oxygen mixture burn releasing intense heat. This is present as a small white cone.

- For the oxy-acetylene welding, the following reaction takes place in this zone.

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + 448 \text{ kJ/mol } (18.75 \text{ MJ/m}^3 \text{ of acetylene})$$

- The carbon monoxide (CO) and hydrogen produced in the first stage further combine with the atmospheric oxygen and give rise to the outer bluish flame, with the following reaction.

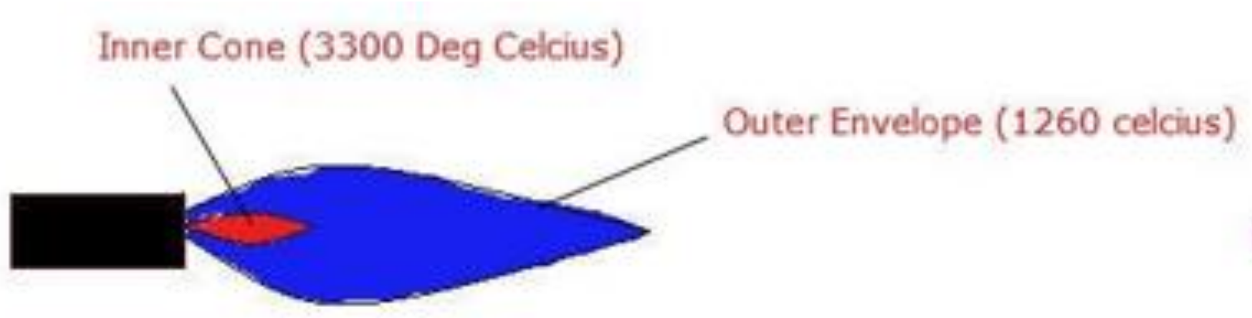
$$4CO + 2H_2 + 3O_2 \rightarrow 4CO_2 + 2H_2O + 812 \text{ kJ/mol } (35.77 \text{ MJ/m}^3)$$



GAS WELDING – TYPES OF FLAMES

- A certain amount of oxygen is required for complete combustion of fuel gases. When the oxygen supply varies, the flame appearance obtained would also vary.

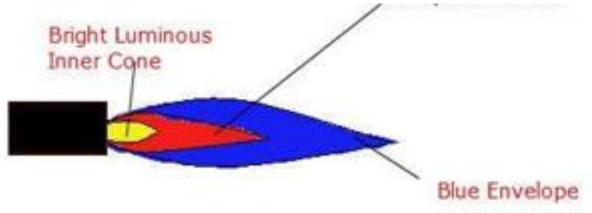
- **Neutral Flame**: In neutral flame all the acetylene present is completely burned and thus all the available heat in the acetylene is released. Thus, this is the most desirable flame to be used in oxy-acetylene welding.



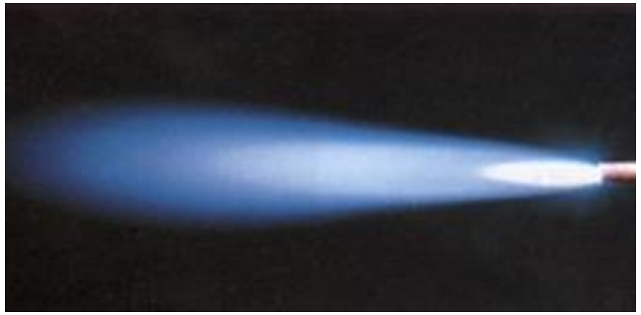
Neutral Flame

GAS WELDING – TYPES OF FLAMES

Reducing (Carburising) Flame: When less oxygen is provided, part of the combustible matter is left as it is and it results in a **reducing or carburising** flame.



This flame is similar to the neutral flame, only with the addition of a third phase in between the outer blue flame and the inner white cone. It is called '**intermediate flame feather**' which is reddish in colour. The length of the flame feather is an indication of the excess acetylene present.



The carburising flame is not suggested for general use. However, since this flame provides a strong reducing atmosphere in the welding zone, it is useful for those materials which are readily oxidised, for example, oxygen free copper alloys. It is also used for high carbon steels, cast irons and hard surfacing with high speed steel and cemented carbides.

GAS WELDING – TYPES OF FLAMES

Oxidising Flame: When oxygen is in excess, it is called the **oxidising flame**.

The flame is similar to the neutral flame with the exception that the inner white cone is somewhat small, giving rise to higher tip temperatures (3300°C).

There is an excess amount of oxygen present in the flame which badly oxidises the weld metal.

This flame would be useful for welding some non-ferrous alloys such as copper base alloys and zinc base alloys.

GAS WELDING – TYPES OF FLAMES

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RESISTANCE WELDING

- Resistance welding process is a welding process where both heat and pressure are applied on the joint but no filler metal or flux is added.

- The heat necessary is obtained by the **heating effect of the electrical resistance** of the joint and hence, the name resistance welding.

Principle:

- In resistance welding (RW), a low voltage (typically 1 V) and very high current (typically 15000 A) is passed through the joint for a very short time (typically 0.25 s).

- This high amperage heats the joint, due to the contact resistance at the joint and melts it. The pressure on the joint is continuously maintained and the metal fuses together under this pressure.

RESISTANCE WELDING

- The heat generated in resistance welding can be expressed as

$$H = kI^2Rt$$

- where, H = the total heat generated in the work, J
  I = electric current, A
  t = time for which the electric current is passing through the joint, s
  R = the resistance of the joint, ohms
  and k = a constant to account for the heat losses from the welded joint.

- The amount of heat released is directly proportional to the resistance.

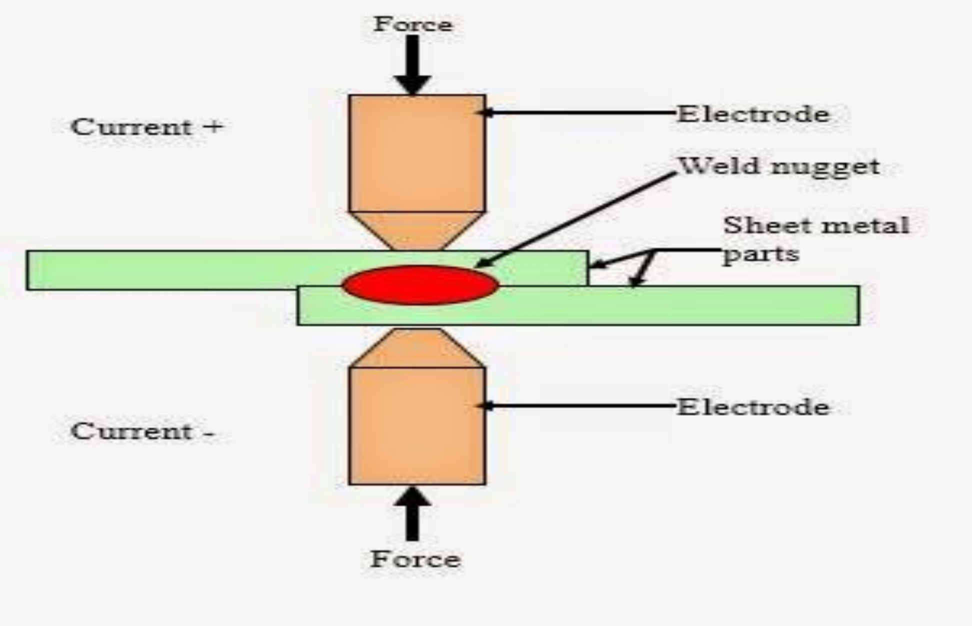
- The only place where large amount of heat is to be generated to have an effective fusion is at the interface between the two work piece plates.

RESISTANCE SPOT WELDING

- This is the most common resistance welding process. This is essentially done to join two sheet metal jobs in lap joint forming a small nugget at the interface of the two plates, as shown in Fig.

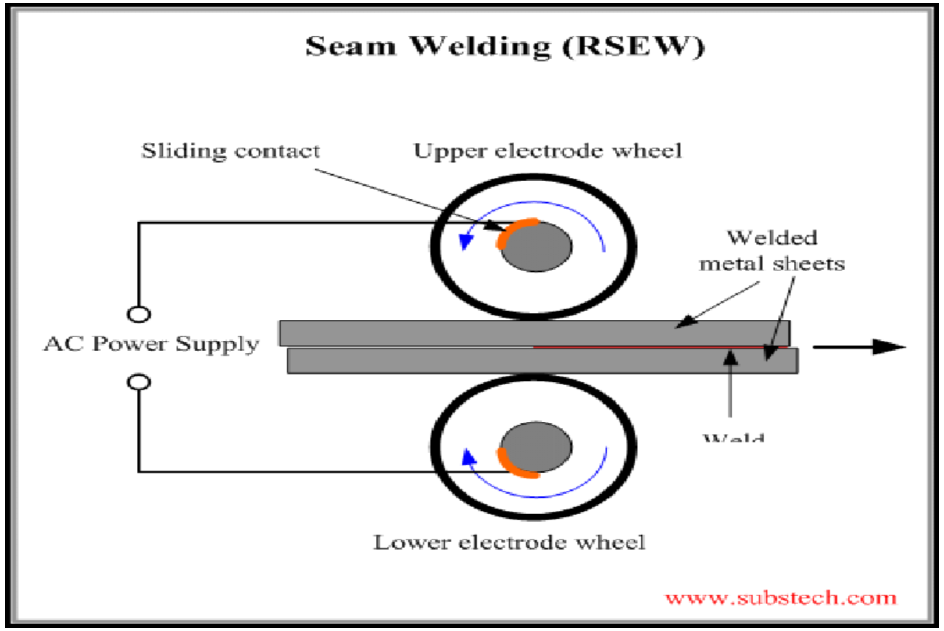
- It essentially consists of two electrodes, out of which one is fixed. The other electrode is fixed to a rocker arm (to provide mechanical advantage) for transmitting the mechanical force from a pneumatic cylinder. This is the simplest type of arrangement.

- The other possibility is that of a pneumatic or hydraulic cylinder being directly connected to the electrode without any rocker arm.



RESISTANCE SEAM WELDING

- The resistance seam welding (RSEW) is a specialised process of spot welding. Here the cylindrical electrodes are replaced by disc electrodes.
- The disc electrodes are continuously rotated so that the work pieces get advanced underneath them while at the same time the pressure on the joint is maintained.
- The electrodes need not be separated at any time



Numerical on Resistance Welding

Two steel sheets of 1.0 mm thick are resistance welded in a lap joint with a current of 10,000 A for 0.1 second. The effective resistance of the joint can be taken as 100 micro ohms. The joint can be considered as a cylinder of 5 mm diameter and 1.5 mm height. Density of steel is 0.00786 g/mm3 and heat required for melting steel be taken as 10 J/mm3. Calculate the melting efficiency.

Numerical on Resistance Welding

$$\text{Heat supplied} = 10\,000^2 \times 100 \times 10^{-6} \times 0.1\ 1 = 1000\ \text{J}$$

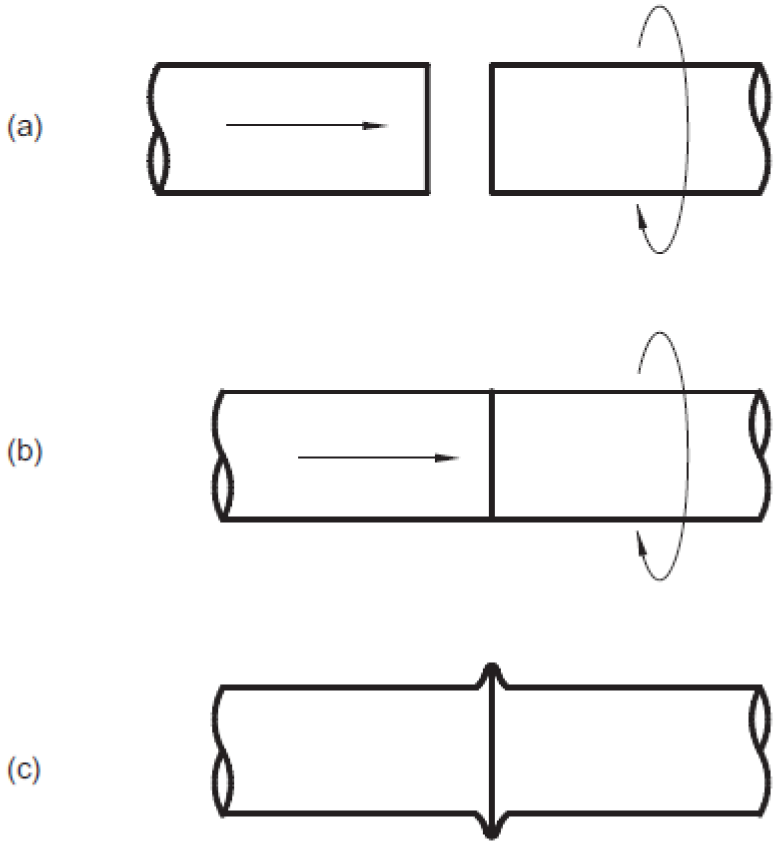
$$\text{Volume of the joint} = \frac{\pi \times 5^2 \times 1.5}{4} = 29.452\ \text{mm}^3$$

$$\text{Heat required for melting} = 29.452 \times 10 = 294.52\ \text{J} \approx 295\ \text{J}$$

$$\text{Heat lost to surroundings} = 1000 - 295 = 705\ \text{J} = 70.5\%$$

FRICTION WELDING

- The heat required for welding in this process is obtained by the **friction between the ends of the two parts** to be joined.
- One of the parts to be joined is rotated at a high speed around 3000 revolutions per minute, and the other part is axially aligned with the second one and pressed tightly against it, as shown.
- The friction between the two parts raises the temperature of both the ends.
- Then the rotation of the part is stopped abruptly and the pressure on the fixed part is increased so that the joining takes place. This process is termed **Friction Welding (FRW).**



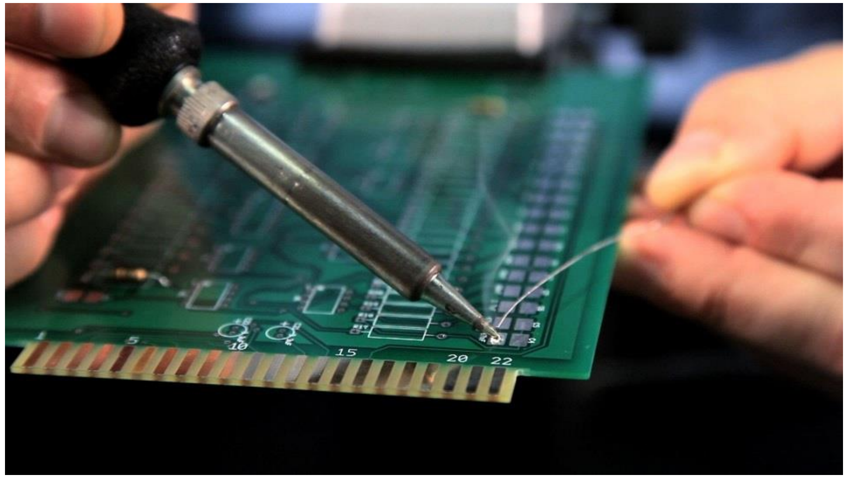
SOLDERING

- Soldering is a method of joining similar or dissimilar metals by means of a filler metal whose **melting point is below 450°C**.

- The filler metal is drawn into the joint by means of **capillary action** (entering of fluid into tightly fitted surfaces).

- Though soldering obtains a good joint between the two plates, the strength of the joint is limited by the strength of the filler metal used.

- Soldering is normally used for obtaining a neat leak proof joint or a low resistance electrical joint. The soldered joints are not suitable for high temperature service because of the low melting temperatures of the filler metals used.



SOLDERING

Procedure

- **Cleaning -** The soldering joints also need to be cleaned meticulously to provide chemically clean surfaces to obtain a proper bond. Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering.

- **Flux application** - To remove the oxides from joint surfaces and to prevent the filler metal from oxidizing, fluxes are generally used in soldering.

- Rosin and rosin plus alcohol based fluxes are least active type and are generally used for electrical soldering work. The organic fluxes such as zinc chloride and ammonium chloride are quick acting and produce efficient joints. These are to be used for only non-electrical soldering work.

SOLDERING

Procedure

Types of Solders – There are two types – ***soft solder and hard solder***

- Soft solders are usually alloys of tin and lead which have low melting points (150 – 190 degree Celsius).
- Soft solders are used in those applications, where the joint is not subjected to heavy loads and high temperatures.
- Hard solders are alloys of silver and lead or alloys of silver and copper and zinc.
- The melting point of hard solder ranges from 300 – 600 degree Celsius.
- Hard solder is used to make strong joints that can resist high temperatures.

SOLDERING

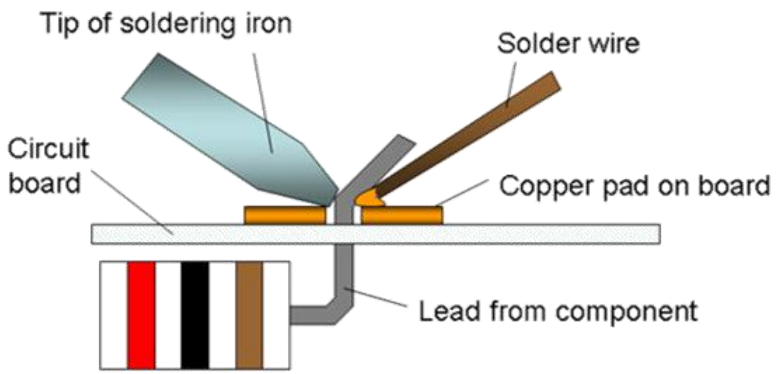
Procedure

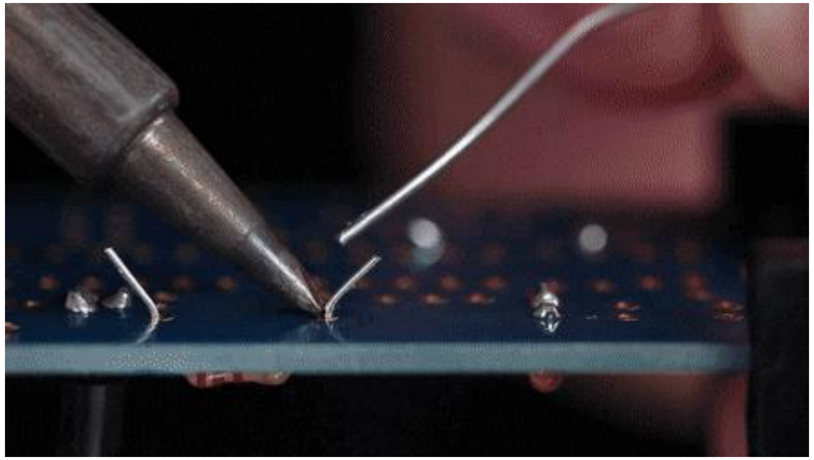
- The most commonly used soldering methods are,
  - **With soldering iron (flame or electrically heated)**
  - Dip soldering
  - Wave soldering

- A soldering iron is a copper rod with a thin tip which can be used for flattening the soldering material.

- The soldering iron can be heated by keeping in a furnace or by means of an internal electrical resistance whose power rating may range from 15 W for the electronic applications to 200 W for sheet metal joining.

- This is the most convenient method of soldering but somewhat slower compared to the other methods.





SOLDERING

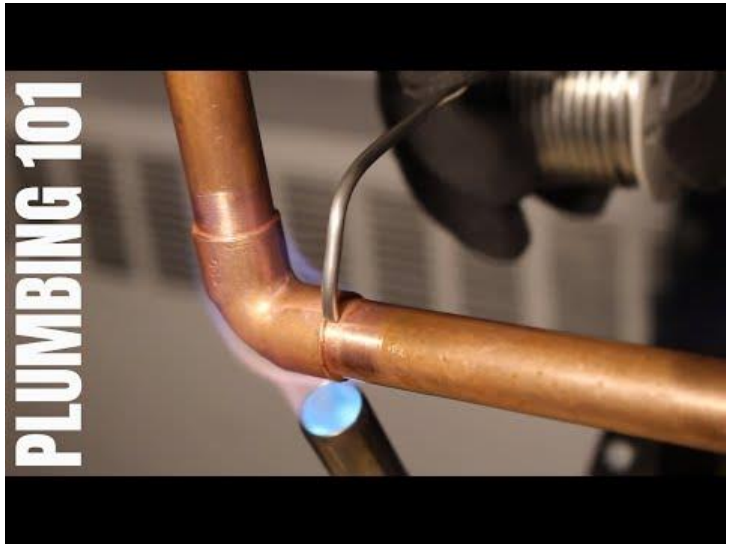
Applications

Assembling electronic components to printed circuit boards

Making connections between copper pipes in plumbing systems

Joints in sheet metal objects such as food cans, metal containers

Semi – permanent patch for a leak in a container, or cooking vessel



BRAZING

- **Brazing is the coalescence of a joint with the help of a filler metal whose melting point is above 450°C and is below the melting point of the base metal.**

- The filler metal is drawn into the joint by means of capillary action (entering of fluid into tightly fitted surfaces).

- Brazing is a much widely used joining process in various industries because of its many advantages.

- Dissimilar metals such as stainless steel to cast iron can be joined by brazing. Except aluminium and magnesium, brazing can join almost all metals.

- The brazed joints are reasonably stronger, depending on the strength of the filler metal used. But the brazed joint is generally not useful for high temperature service because of the low melting temperature of the filler metal.

BRAZING

Procedure

- In brazing, joints need to be extremely clean. Any grease or oil present in the joint prevents the flow of filler metal. Hence, the joint should be thoroughly cleaned using proper solvents. Oxides and scales present are removed by acid pickling.

- Fluxes are added into the brazed joint to remove any of the oxides present or prevent the formation of the oxides so that the base metal and the filler metal remain pure during the joining.

- The fluxes generally used are combinations of borax, boric acid, chlorides, fluorides and tetraborates, and other wetting agents.

BRAZING

Procedure

- Depending on the type of base metals brazed, a number of filler metals (**spelter**) are available.

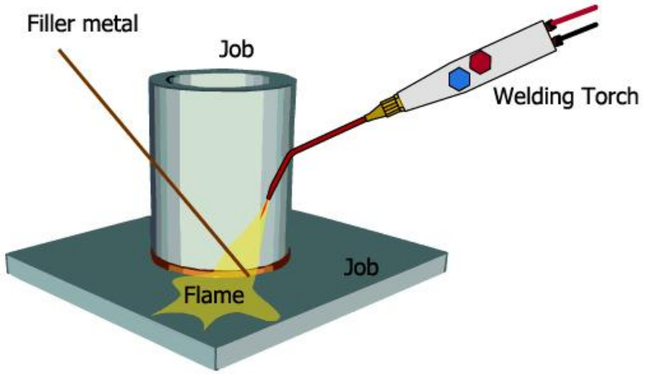
- The joint obtained in brazing is by means of the diffusion of the filler metal into the base material, associated with the surface alloying. Copper based materials are generally used for brazing ferrous materials.

- Silver brazing makes use of a silver based filler metal. Silver brazing is used to give high strength (tensile strength up to 900 MPa) joints. Though originally used for jewellery applications, silver brazing is now extensively used in industrial applications

BRAZING

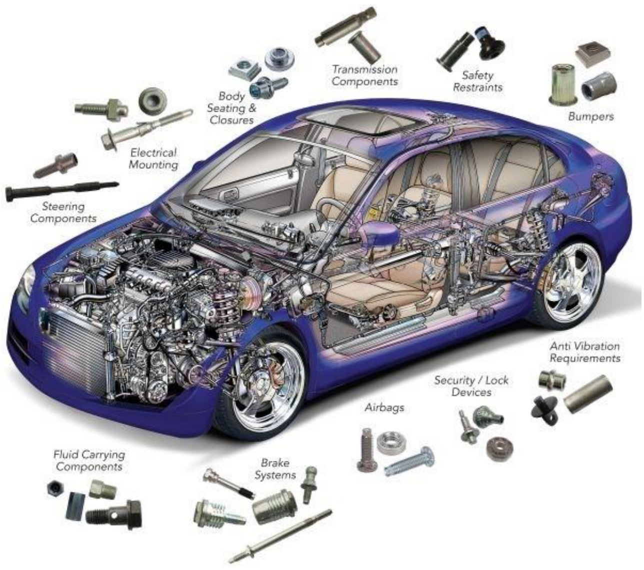
Procedure

- Heat sources that are used for brazing are a molten bath of brazing filler metal, **oxy-acetylene torch, controlled atmosphere furnace, electrical resistance heating and induction heating.**
- In torch brazing, a reducing flame (oxy-acetylene or propane) is generally used to inhibit oxidation.
- Torch brazing is generally a manual operation with the operator having considerable skill in judging the operating conditions of the brazing.
- It is also possible to mechanize torch brazing by employing multiple torches with a conveyor line that can bring the brazing joints to the torches.



FASTENERS

- Fasteners are small to large pieces of hardware that is used to affix or join objects together.
- From rivets, nuts, bolts, screws to paper clip, split clip and nails are all considered to be fasteners.



FASTENERS

FASTENING TYPE

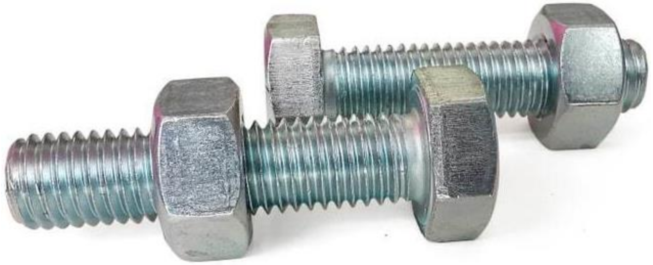
2. Temporary

2.1 *Threaded fastener*

- bolts
- studs
- screws

2.2 *Non-threaded fastener*

- keys
- pin



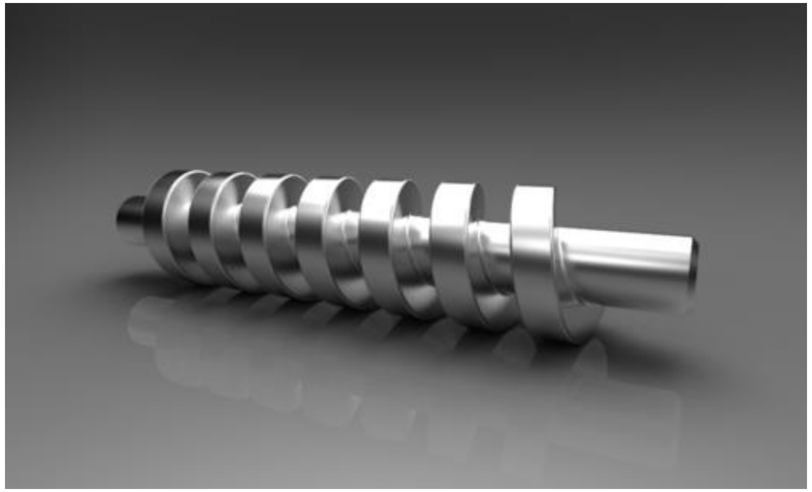
FASTENERS

THREAD APPLICATION

1. To hold parts together.
2. To move part(s) relative to others.

FASTENERS


THREAD APPLICATION
1. To hold parts together.
2. To move part(s) relative to others.
Wood working vise
Palm fruit pressing machine



FASTENERS

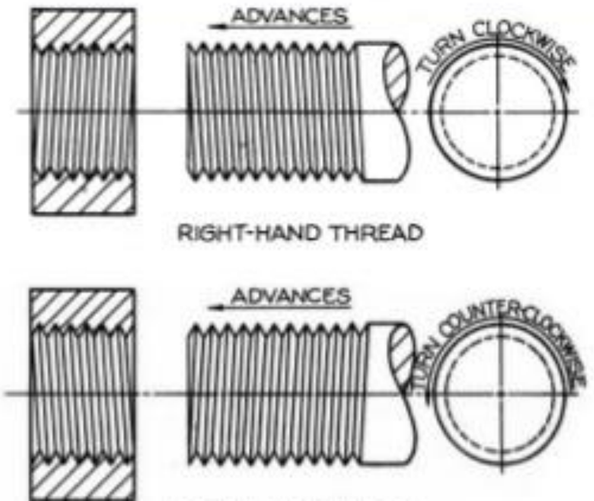
THREAD TERMINOLOGY

External (male) thread	A thread cut on the ***outside*** of a cylindrical body.
Internal (female) thread	A thread cut on the ***inside*** of a cylindrical body.

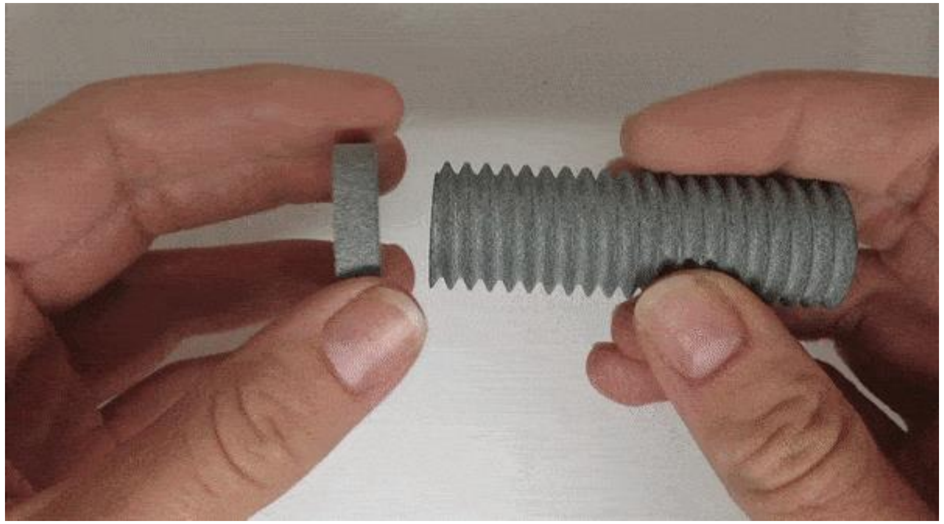
FASTENERS

THREAD TERMINOLOGY

Right-hand thread	Thread that will ***assemble*** when turned ***clockwise***.
Left-hand thread	Thread that will ***assemble*** when turned ***counter-clockwise***.



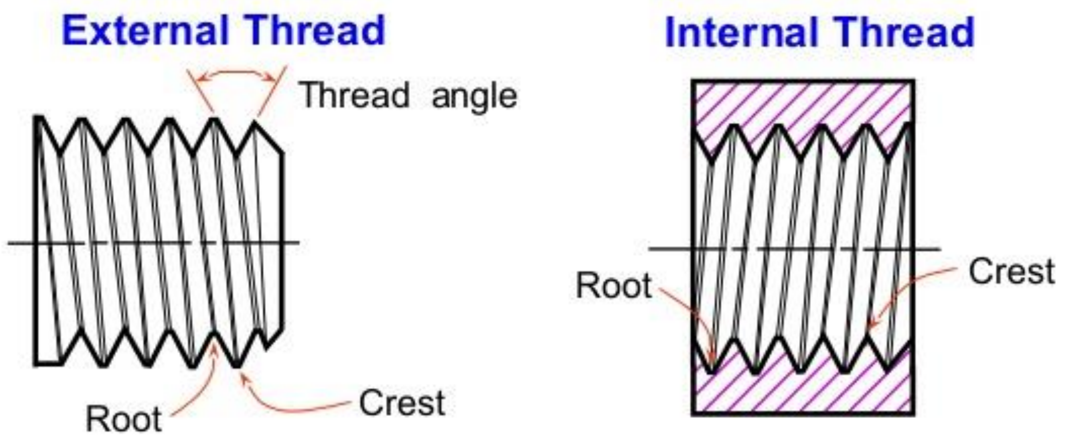
Turnbuckle use RH and LH thread at each end to double displacement.



FASTENERS

THREAD TERMINOLOGY

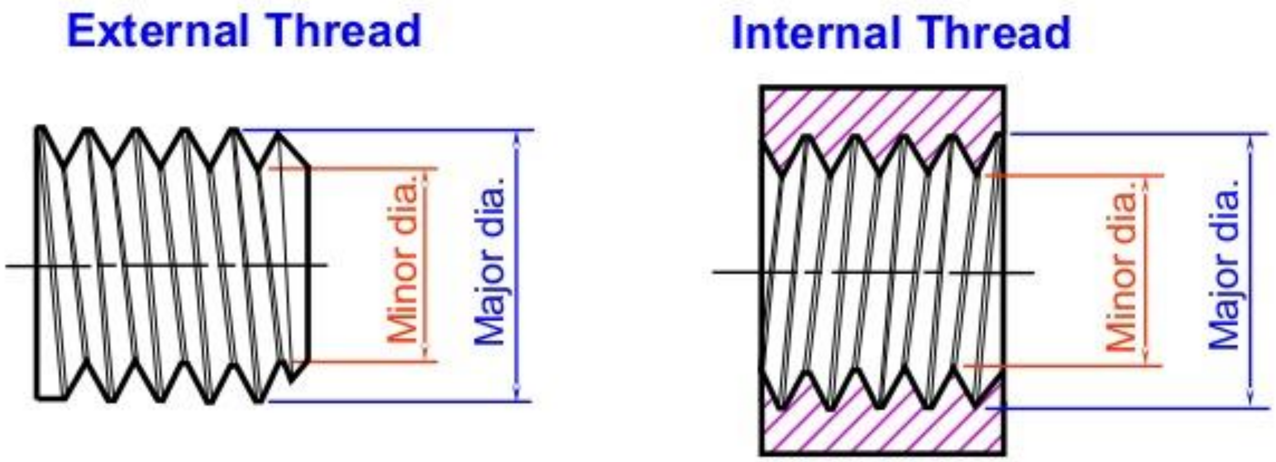
Crest	The ***peak edge*** of a thread.
Root	The ***bottom*** of the thread cut into a cylindrical body.
Thread angle	The angle between threads faces.



FASTENERS

THREAD TERMINOLOGY

Major diameter	The ***largest diameter*** on an internal or external thread.
Minor diameter	The ***smallest diameter*** on an internal or external thread.

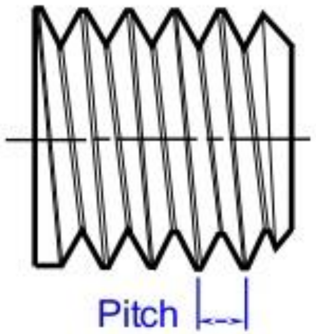


FASTENERS

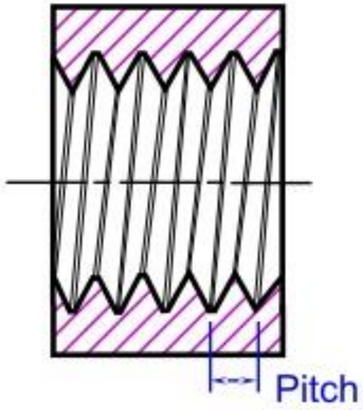
THREAD TERMINOLOGY

Pitch	The distance between crests of threads.
Lead	The distance a screw will advance when turned 360º.

External Thread



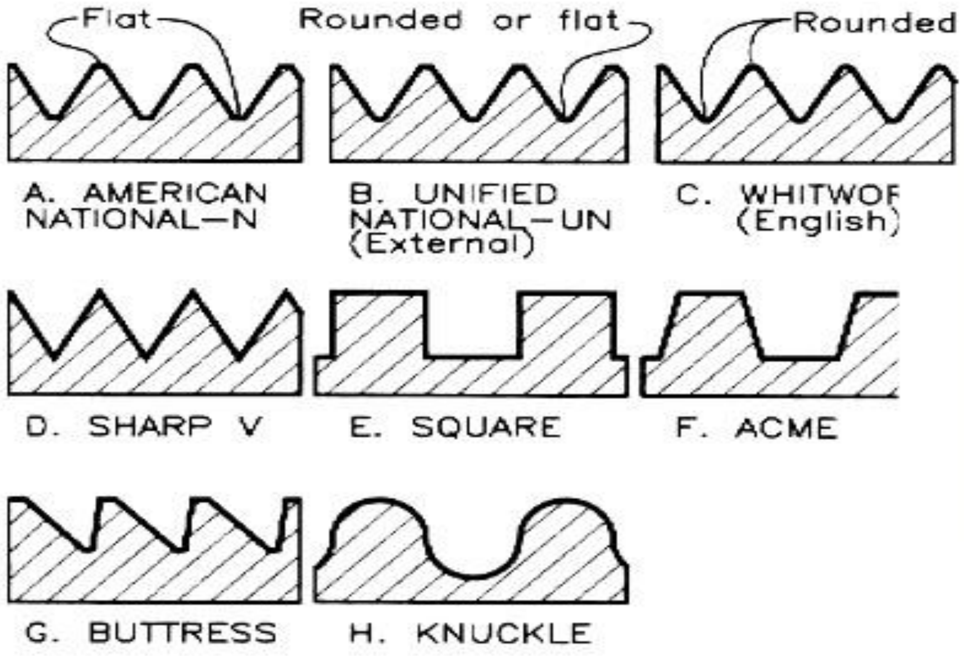
Internal Thread



FASTENERS

THREAD TERMINOLOGY

Thread Form	Form is the profile shape of the thread.



Example :

“knuckle thread form”

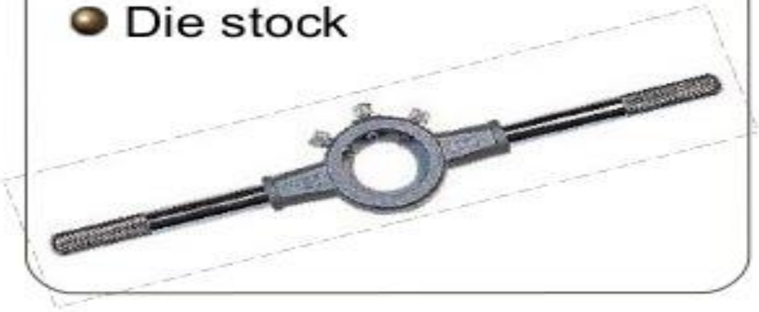
FASTENERS

EXTERNAL THREAD CUTTING

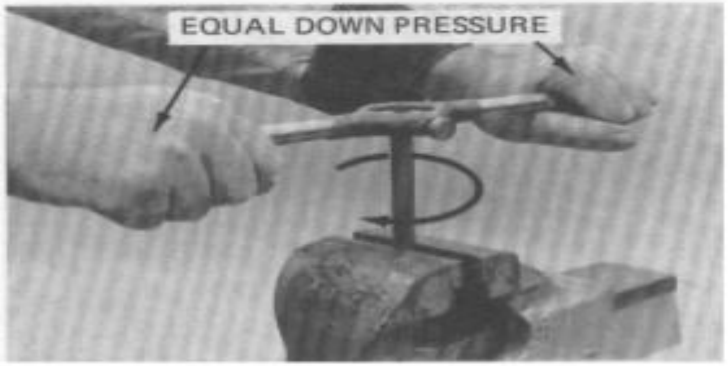
Tools

- Threading Die

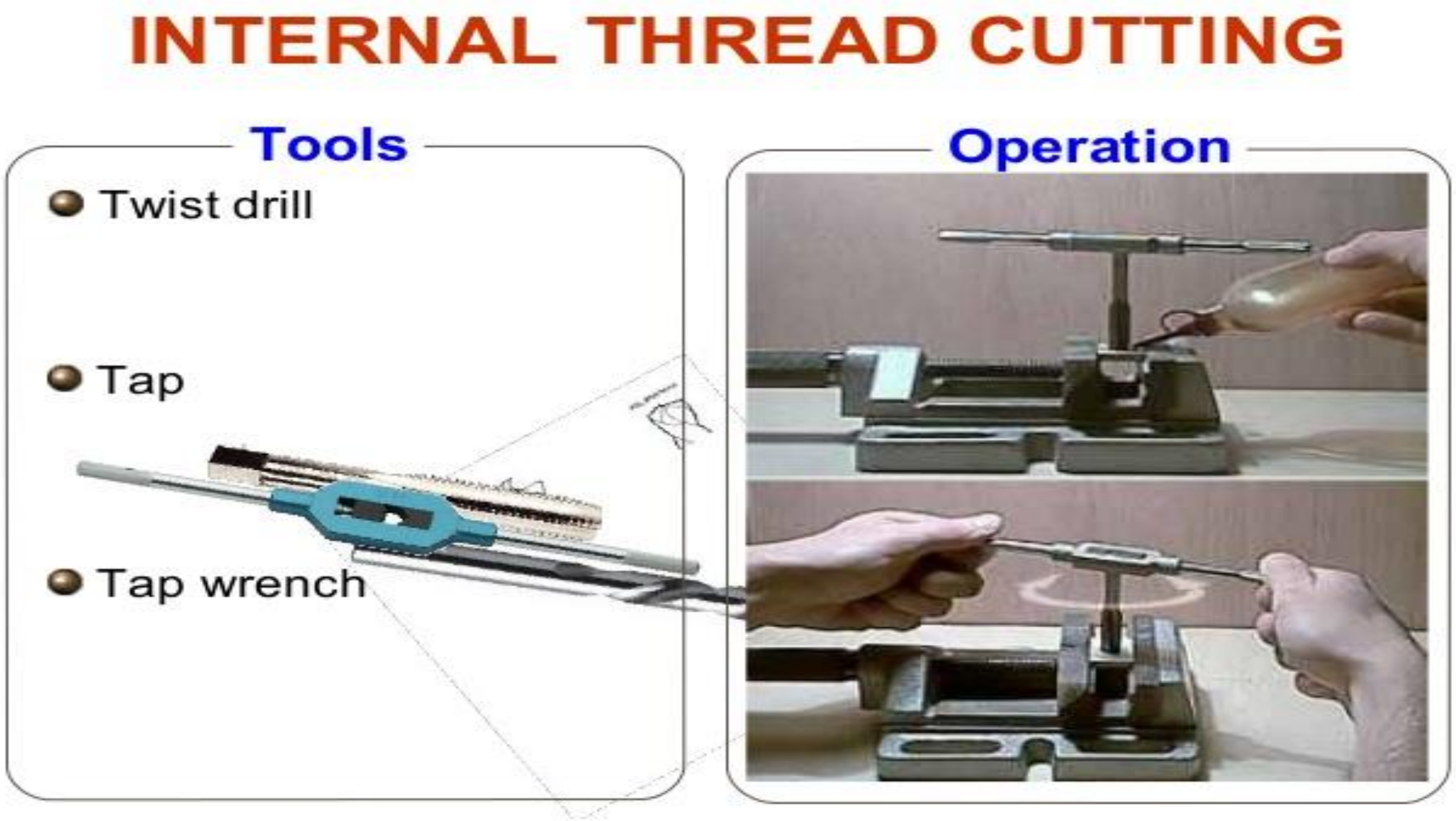
- Die stock



Operation

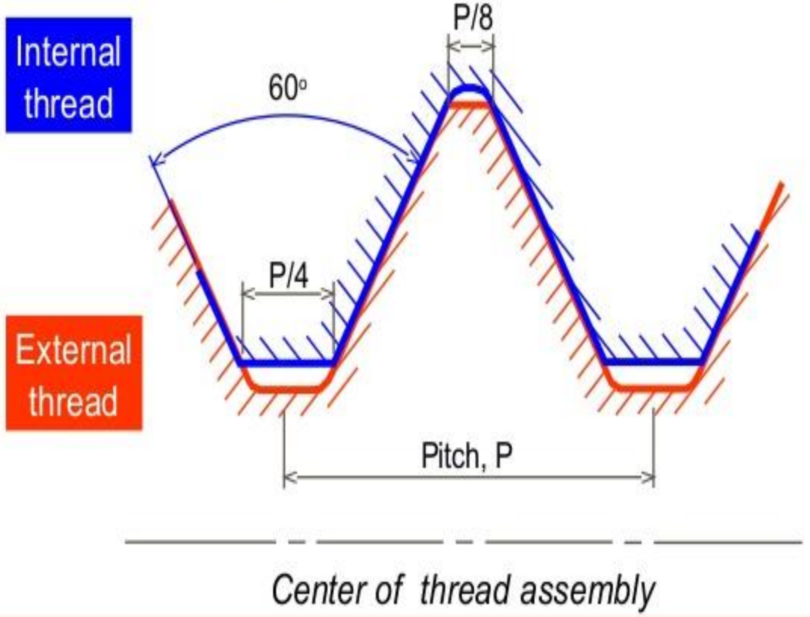


FASTENERS


INTERNAL THREAD CUTTING
Tools
Twist drill
Tap
Tap wrench
Operation

FASTENERS

ISO (METRIC) THREAD



Thread assemble occurs if and only if both (internal & external) thread have an equal ***nominal size*** *(or diameter)* and ***pitch***.

METRIC FINE THREAD

[Table 9.2]

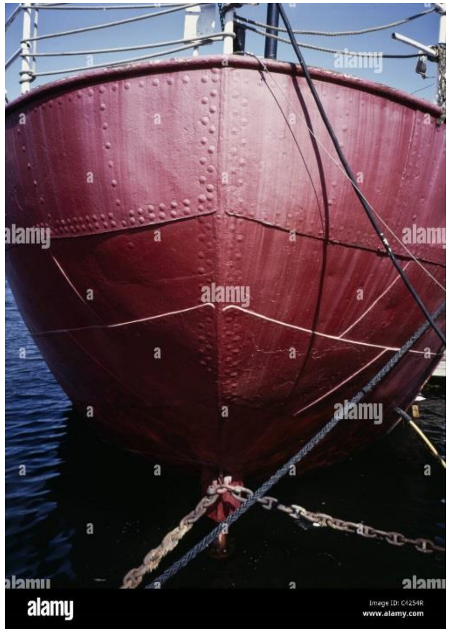
Nominal size	**Major diameter**	**Pitch**	Minor diameter	Tap drill size
M8	8.00	0.75	7.188	7.25
		1.00	6.917	7.00
M10	10.00	0.75	9.188	9.25
		1.00	8.917	9.00
		1.25	8.647	8.75

Minor diameter ≈ Tap drill size

In thread ***drawing***, the following relationship is used.

Minor diameter = ***Major*** diameter – Pitch

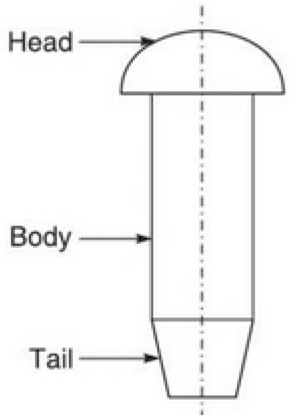
RIVETS

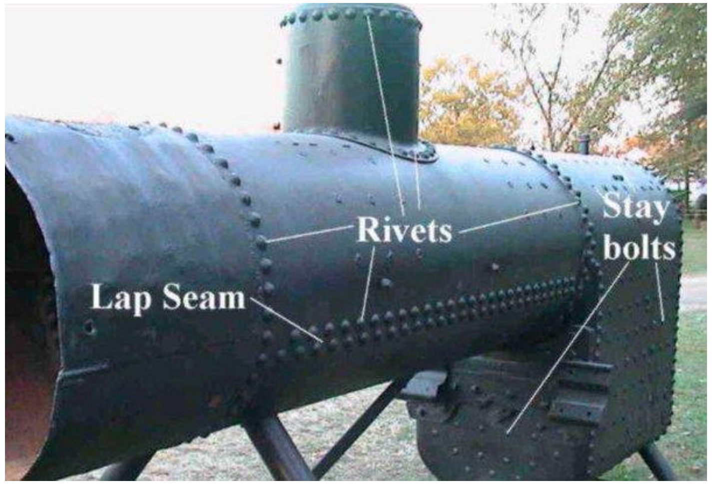


- Rivets are used as fasteners for making semi permanent joints of two or more pieces of metals.

- They are commonly used in ship building, construction of steel structures, bridges, boiler drum, tank etc.

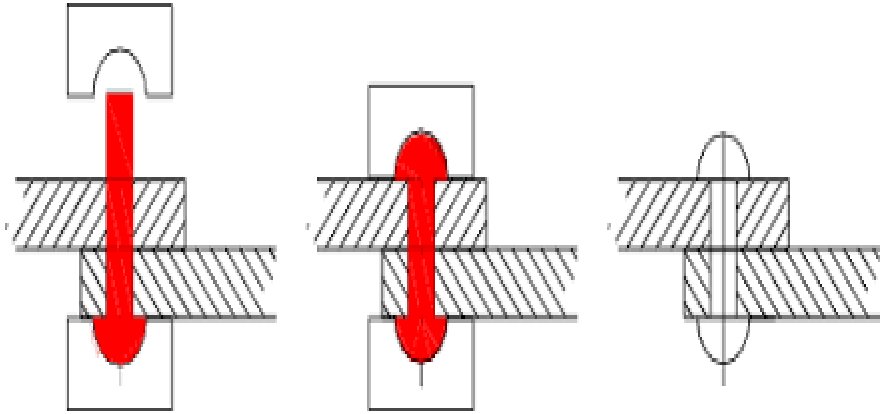
- A rivet comprises of head, tail and shank.



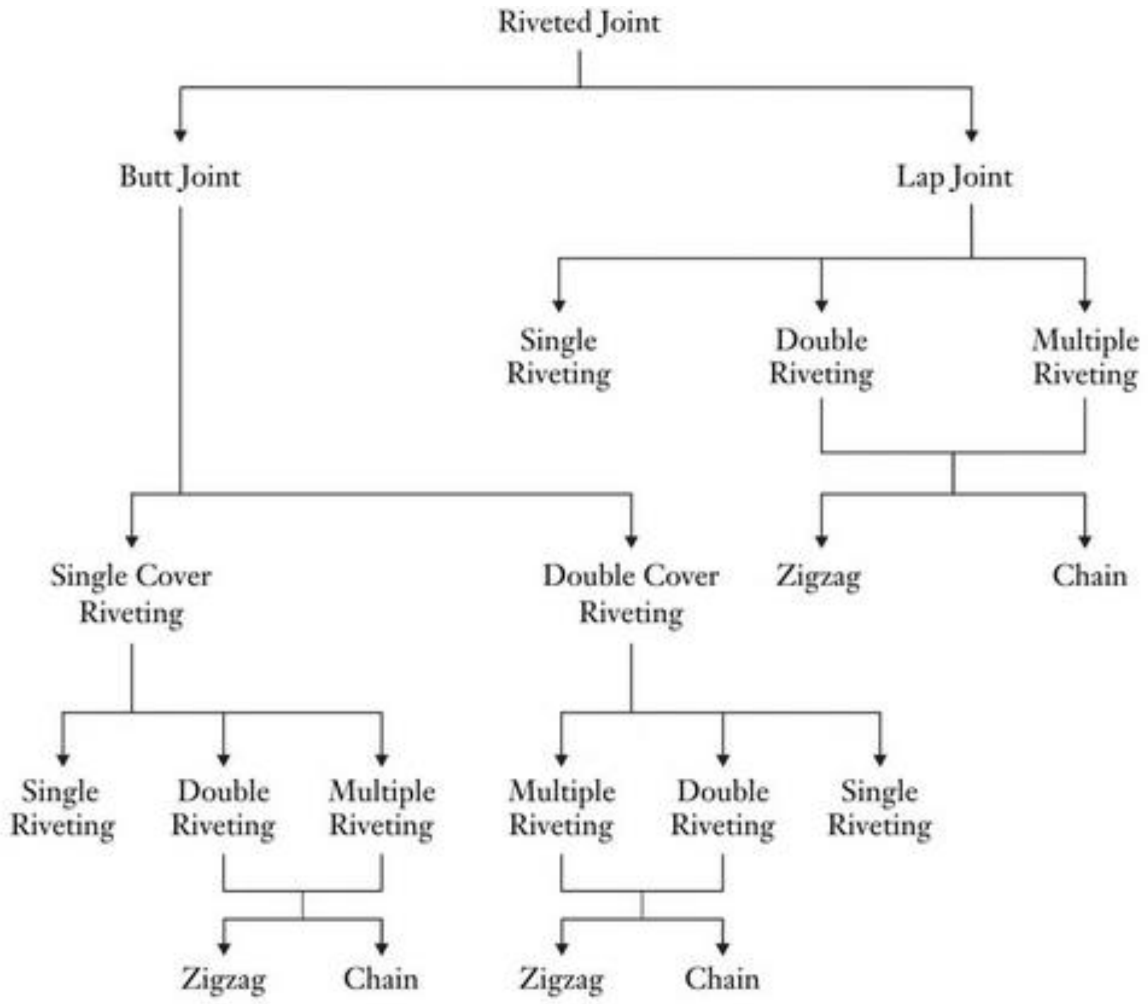


RIVETS

- First, the two metal sheets to be joined are held in proper relationship and then the holes are drilled through them.
- The diameter of the hole is kept slightly more than the shank diameter of the rivet.
- The rivet is then passed through the hole in such a way that the pre – formed head rests against an anvil.
- Next, the tail is forged to form another head. This is achieved by exerting the pressure on the die bar that covers the buck – tail. The clearance between the shank and hole is filled in when the rivet is fully set.

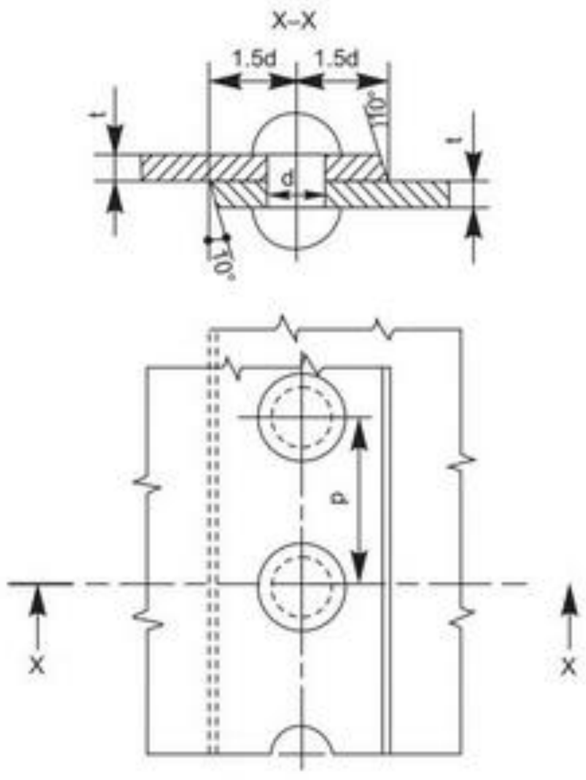


RIVETS

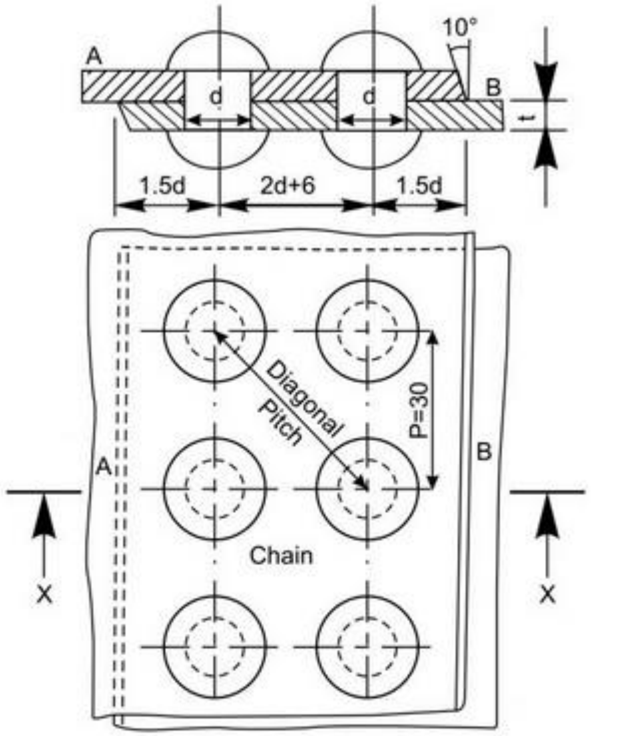

Riveted Joint
Butt Joint
Lap Joint
Single Riveting
Double Riveting
Multiple Riveting
Single Cover Riveting
Double Cover Riveting
Zigzag
Chain
Single Riveting
Double Riveting
Multiple Riveting
Multiple Riveting
Double Riveting
Single Riveting
Zigzag
Chain
Zigzag
Chain

RIVETS

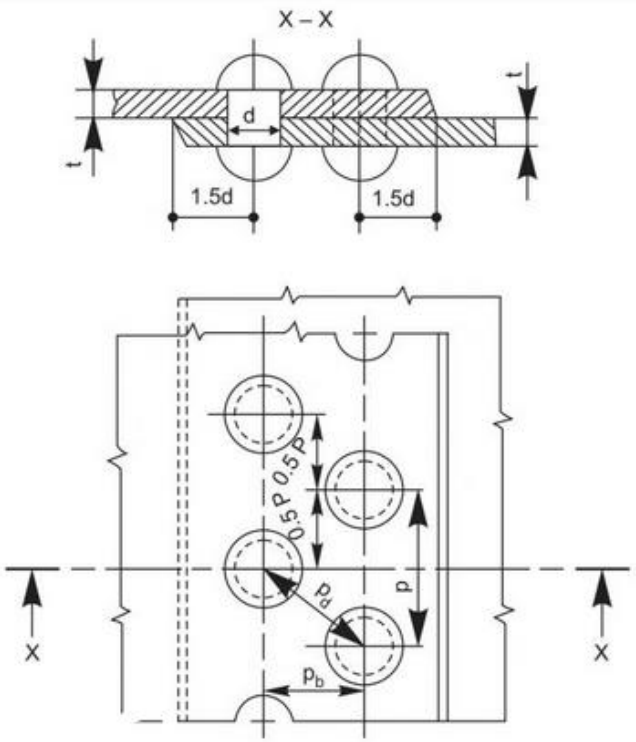
Lap joint – Here, one plate overlaps the other. All the rivets pass through the plates.



Single Riveted Lap Joint



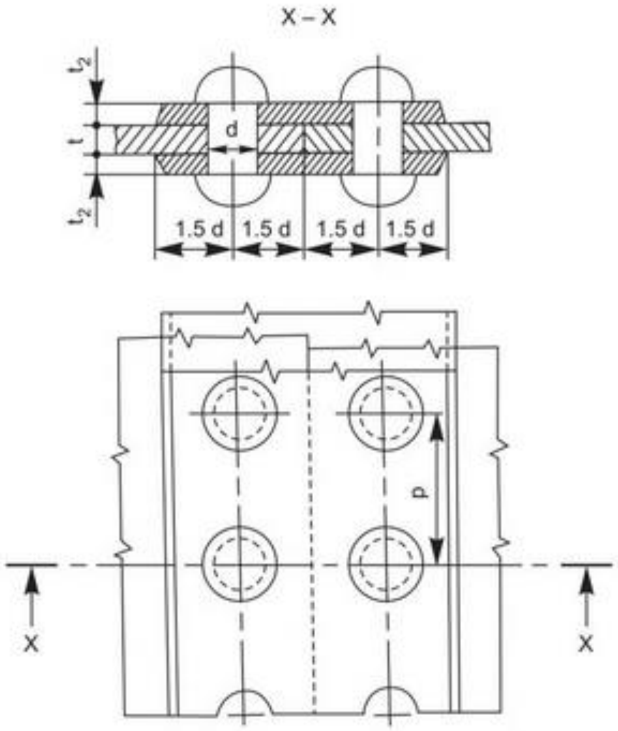
Double Riveted Lap Joint with Chain Riveting



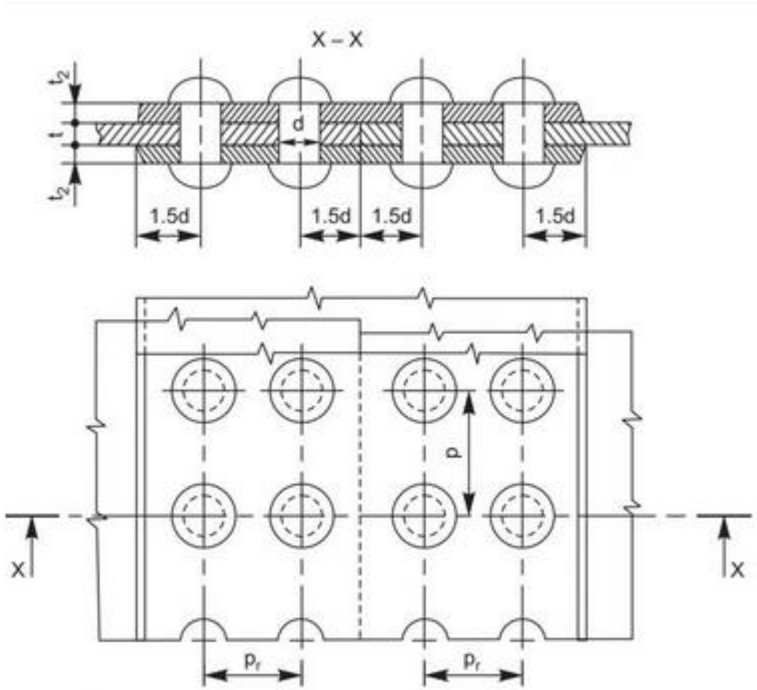
Double Riveted Lap Joint with Zigzag Riveting

RIVETS

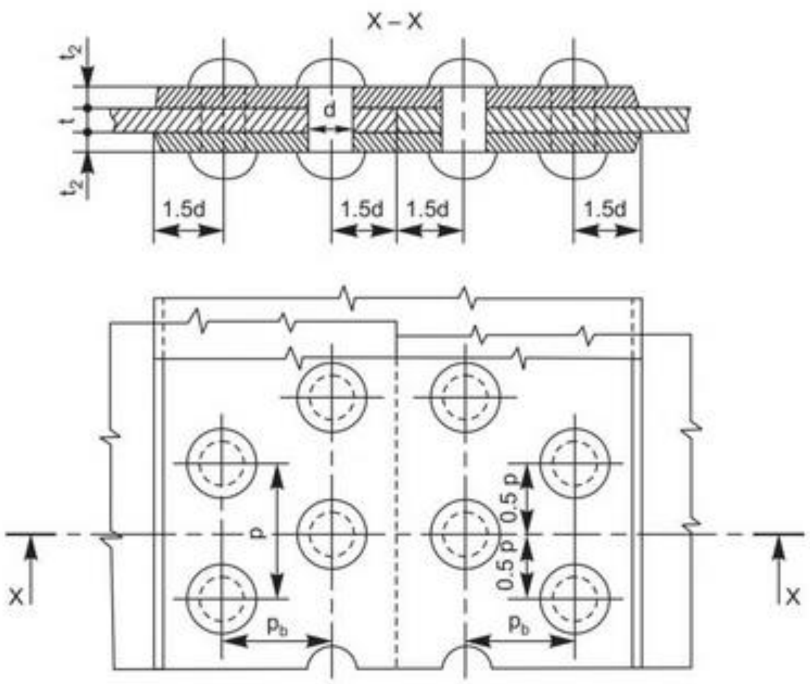
Butt joint – Here, the ends of the main plates butt up against other and may be considered as lying in the same plane. One or two strap or cover plates are placed over the joint and riveted to each plate.



Single Riveted Double Strap Butt Joint



Double Riveted Butt Joint Double Cover Plate Chain Riveting



Double Riveted Butt Joint Double Cover Plate Zigzag Riveting