Casting process

Casting process is one of the earliest metal shaping techniques known to human being. It

means pouring molten metal into a refractory mold cavity and allows it to solidify. The

solidified object is taken out from the mold either by breaking or taking the mold apart. The

solidified object is called casting and the technique followed in method is known as casting process.

PATTERN

- A pattern is a model or the replica of the object (to be casted). It is embedded in molding sand and suitable ramming of molding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mold) in molding sand. Thus it is a mould forming tool.

OBJECTIVES OF A PATTERN

- 1 Pattern prepares a mould cavity for the purpose of making a casting.
- 2 Pattern possesses core prints which produces seats in form of extra recess for core placement in the mould.
- 3 It establishes the parting line and parting surfaces in the mould.
- 4 Runner, gates and riser may form a part of the pattern.
- 5 Properly constructed patterns minimize overall cost of the casting.
- 6 Pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.
- 7 Properly made pattern having finished and smooth surface reduce casting defects

COMMON PATTERN MATERIALS

- **Wood** is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface.
- **Advantages of wooden patterns**
- 1 Wood can be easily worked.
- 2 It is light in weight.
- 3 It is easily available.
- 4 It is very cheap.
- 5 It is easy to join.
- 6 It is easy to obtain good surface finish.
- 7 Wooden laminated patterns are strong.
- 8 It can be easily repaired.
- **Disadvantages**
- 1 It is susceptible to moisture.
- 2 It tends to warp.
- 3 It wears out quickly due to sand abrasion.
- 4 It is weaker than metallic patterns.

Metal

- Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence posses longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio.
- **Cast Iron**
- It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, brittle and get rusted easily in presence of moisture.
- **Advantages**
- 1. It is cheap
- 2. It is easy to file and fit
- 3. It is strong
- 4. It has good resistance against sand abrasion
- 5. Good surface finish
- **Disadvantages**
- 1 It is heavy
- 2 It is brittle and hence it can be easily broken
- 3 It may rust

Brasses and Bronzes

- These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern
- **Advantages**
- 1. Better surface finish than cast iron.
- 2. Very thin sections can be easily casted.
- **Disadvantages**
- 1. It is costly
- 2. It is heavier than cast iron.
- **Aluminum Alloys**
- Aluminum alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength.
- They also possesses good resistance to corrosion and abrasion by sand and there by enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

- **Advantages**
- 1. Aluminum alloys pattern does not rust.
- 2. They are easy to cast.
- 3. They are light in weight.
- 4. They can be easily machined.
- **Disadvantages**
- 1. They can be damaged by sharp edges.
- 2. They are softer than brass and cast iron.
- 3. Their storing and transportation needs proper care
- **White Metal (Alloy of Antimony, Copper and Lead)**
- **Advantages**
- 1. It is best material for lining and stripping plates.
- 2. It has low melting point around 260°C
- 3. It can be cast into narrow cavities.
- **Disadvantages**
- 1. It is too soft.
- 2. Its storing and transportation needs proper care
- 3. It wears away by sand or sharp edges.

Plastic

- Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non sticky to molding sand, durable and they are not affected by the moisture of the molding sand. Moreover they impart very smooth surface finish on the pattern surface.
- These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement.
- The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used.
- These are originally in liquid form and get solidified when heated to a specified temperature.

Plaster

- This material belongs to gypsum family which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting.
- The main advantages of plaster are that it has high compressive strength and is of high expansion setting type which compensate for the shrinkage allowance of the casting metal.
- It is also preferred for production of small size intricate castings and making core boxes.

Wax

- Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives which act as polymerizing agents, stabilizers, etc. The commonly used waxes are paraffin wax, shellac wax, bees-wax, cerasin wax, and micro-crystalline wax.
- The properties desired in a good wax pattern include low ash content up to 0.05 per cent, resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength.

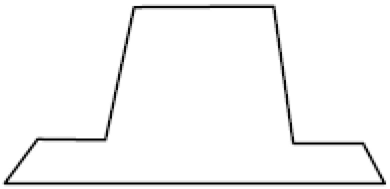
- **FACTORS EFFECTING SELECTION OF PATTERN MATERIAL**
- The following factors must be taken into consideration while selecting pattern materials.
- 1. Number of castings to be produced. Metal pattern are preferred when castings are required large in number.
- 2. Type of mould material used.
- 3. Kind of molding process.
- 4. Method of molding (hand or machine).
- 5. Degree of dimensional accuracy and surface finish required.
- 6. Minimum thickness required.
- 7. Shape, complexity and size of casting.
- 8. Cost of pattern and chances of repeat orders of the pattern

TYPES OF PATTERN

- The types of the pattern and the description of each are given as under.
- 1. One piece or solid pattern
- 2. Two piece or split pattern
- 3. Cope and drag pattern
- 4. Three-piece or multi- piece pattern
- 5. Loose piece pattern
- 6. Match plate pattern
- 7. Follow board pattern
- 8. Gated pattern
- 9. Sweep pattern
- 10. Skeleton pattern
- 11. Segmental or part pattern

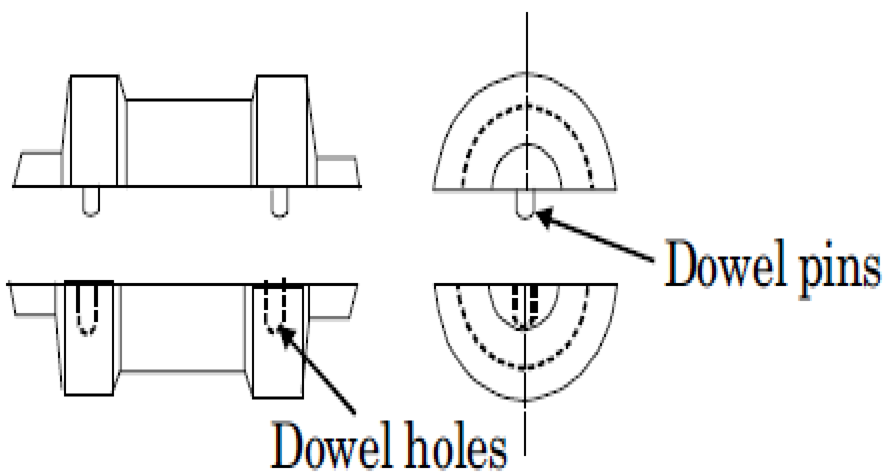
Single-piece or solid pattern

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern



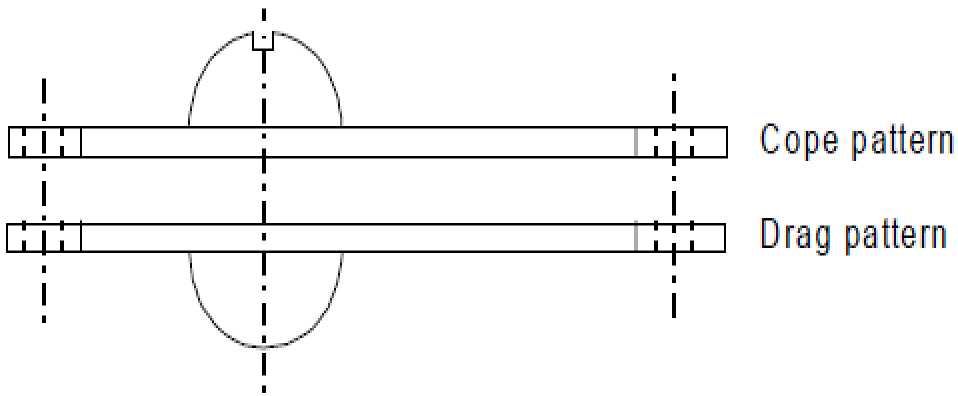
Two-piece or split pattern

- When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern



Cope and drag pattern

- In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates.

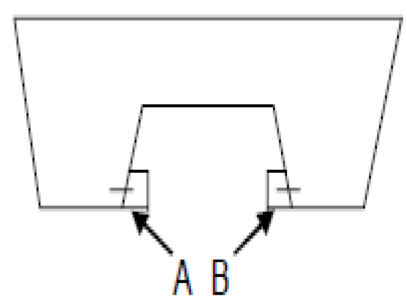


Three-piece or multi-piece pattern

- Some patterns are of complicated kind in shape and hence can not be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore these patterns are made in either three pieces or in multi-pieces. Multi molding flasks are needed to make mold from these patterns

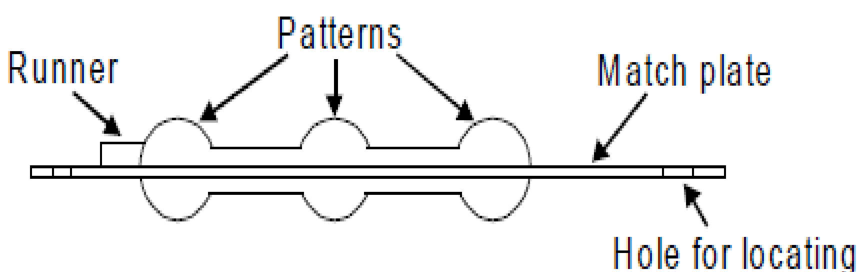
Loose-piece Pattern

- Loose piece pattern is used when pattern is
- difficult for withdrawl from the mould. Loose pieces are provided on the pattern and they are the part of pattern.
- The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.



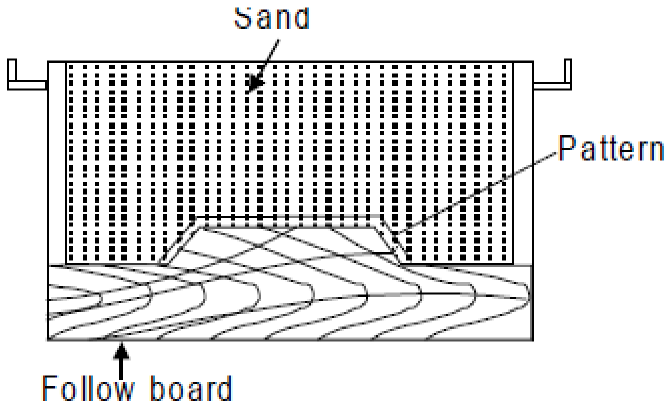
Match plate pattern

- This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate.
- This pattern is used in machine molding.



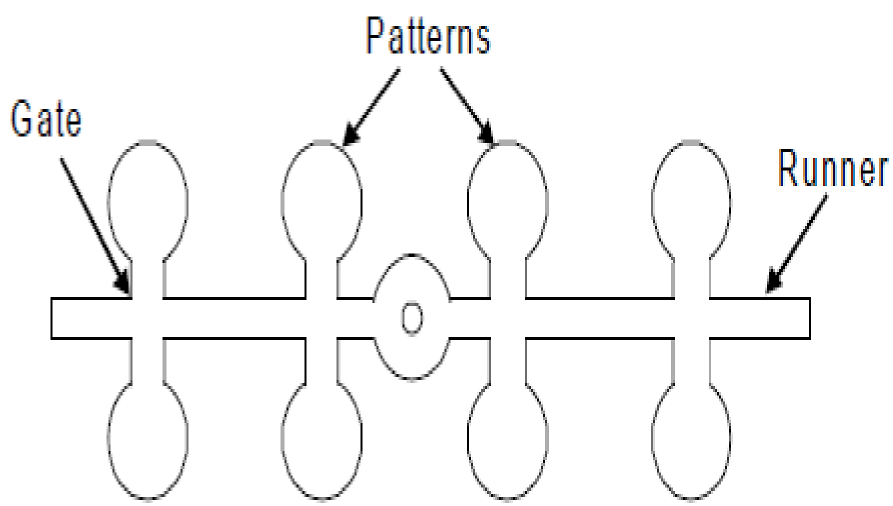
Follow board pattern

- When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a molding board for the first molding operation



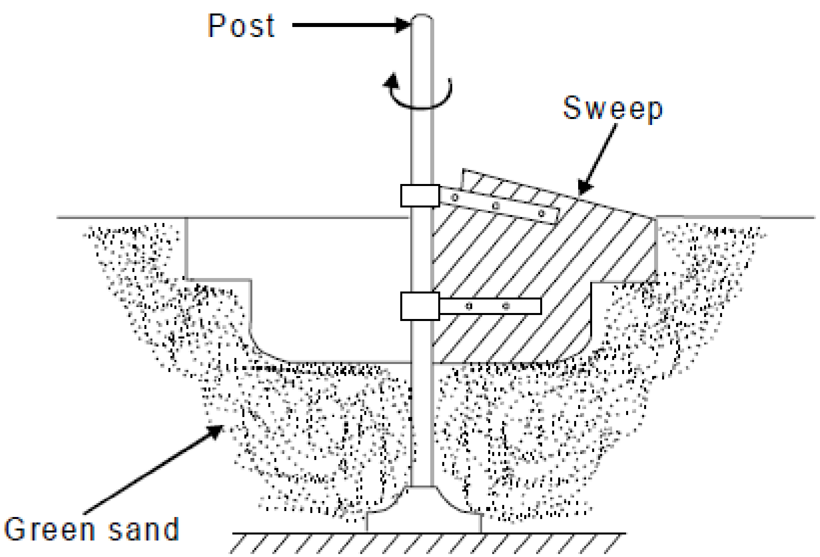
Gated pattern

- In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern



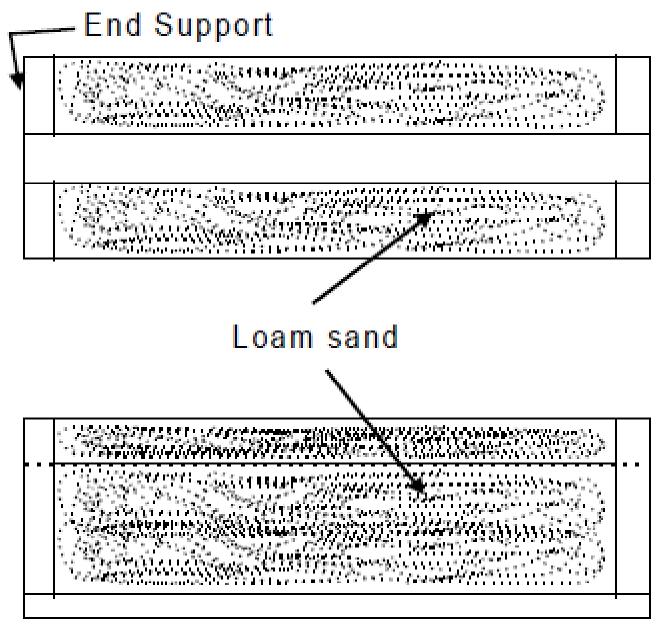
Sweep pattern

- Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the center of the mould.



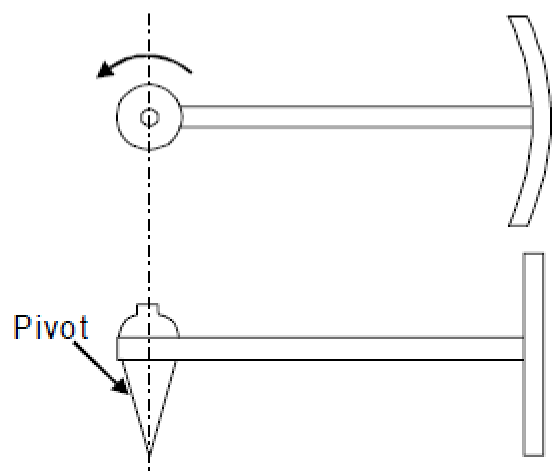
Skeleton pattern

- When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made. This frame work is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc.



Segmental pattern

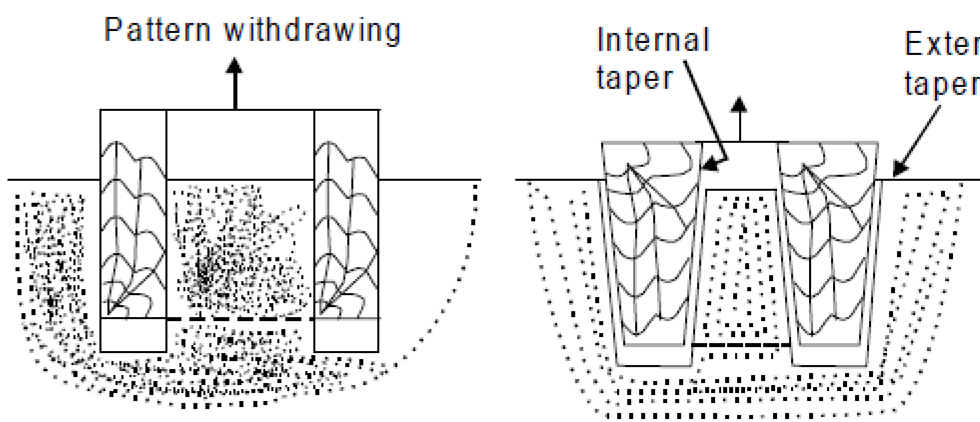
- Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot.



PATTERN ALLOWANCES

- **1. Shrinkage Allowance**
- 1. Liquid contraction, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquidus temperature.
- 2. Contraction on cooling from the liquidus to the solidus temperature, i.e. solidifying contraction.
- 3. Contraction that results there after until the temperature reaches the room temperature. This is known as solid contraction
- The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt.. Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt

- **Machining Allowance**
- It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.
- **Draft or Taper Allowance**
- Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt.

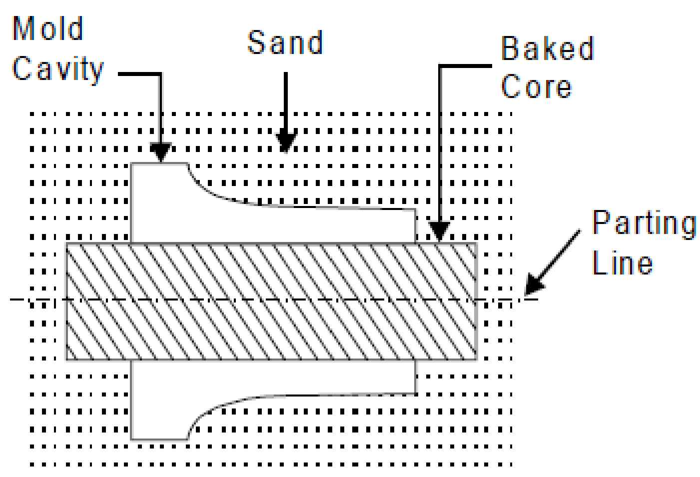


- **Rapping or Shake Allowance**
- Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases. Actually by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This movement may be insignificant in the case of small and medium size castings, but it is significant in the case of large castings. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5-1.0 mm.
- **Distortion Allowance**
- This allowance is applied to the castings which have the tendency to distort during cooling due to thermal stresses developed. For example a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position. Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.

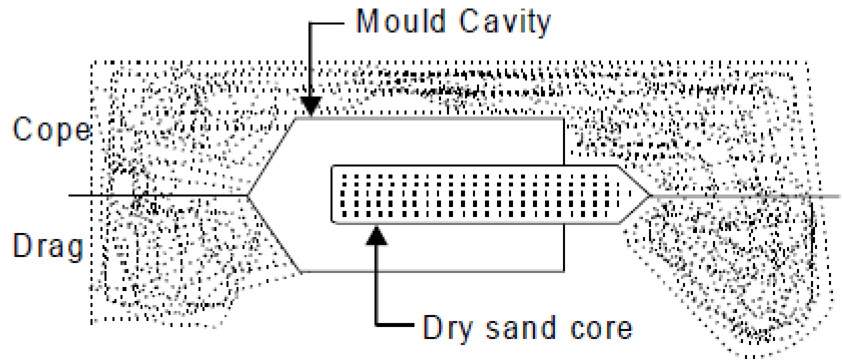
- **Mold wall Movement Allowance**
- Mold wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mold cavity depends upon the mold density and mould composition. This effect becomes more pronounced with increase in moisture content and temperature

CORE AND CORE BOX

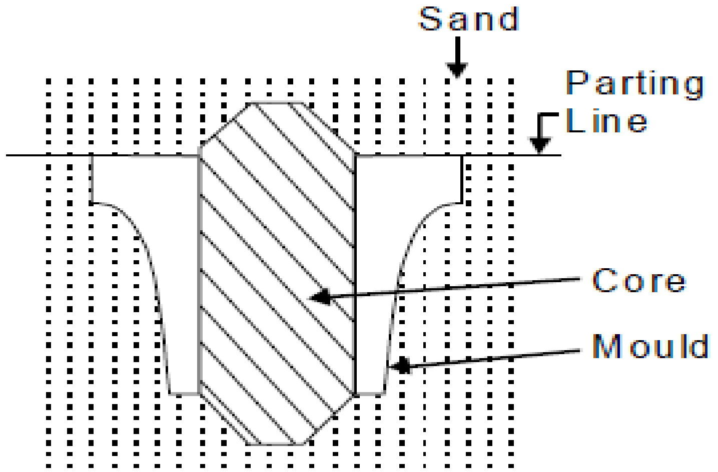
- Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting.
- Cores are classified according to shape and position in the mold.
- **Horizontal core**



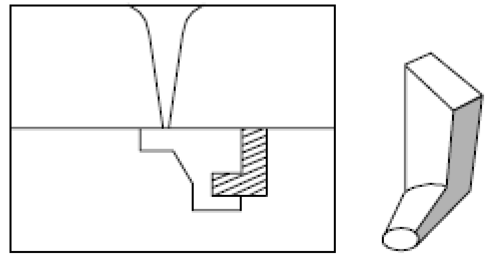
- Vertical core



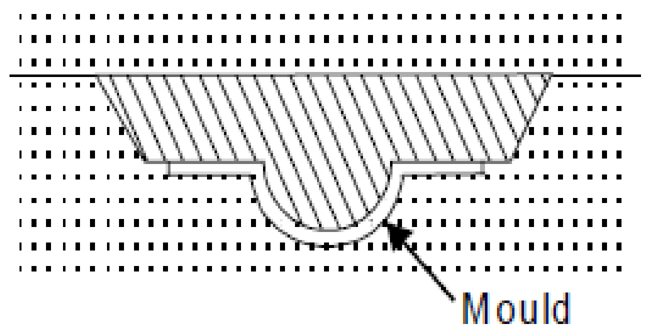
Balanced core



- Drop core



Hanging core



- There are various functions of cores which are given below
- 1. Core is used to produce hollowness in castings in form of internal cavities.
- 2. It may form a part of green sand mold
- 3. It may be deployed to improve mold surface.
- 4. It may provide external under cut features in casting.
- 5. It may be used to strengthen the mold.
- 6. It may be used to form gating system of large size mold
- 7. It may be inserted to achieve deep recesses in the casting

MOLD AND CORE MAKING

- A suitable and workable material possessing high refractoriness in nature can be used for mould making. Thus, the mold making material can be metallic or non-metallic.
- For metallic category, the common materials are cast iron, mild steel and alloy steels.
- In the non-metallic group molding sands, plaster of paris, graphite, silicon carbide and ceramics are included.
- But, out of all, the molding sand is the most common utilized non-metallic molding material because of its certain inherent properties namely refractoriness, chemical and thermal stability at higher temperature, high permeability and workability along with good strength. Moreover, it is also highly cheap and easily available.

MOLDING SAND

- The common sources of molding sands available in India are as follows:
- 1 Batala sand (Punjab)
- 2 Ganges sand (Uttar Pradesh)
- 3 Oyaria sand (Bihar)
- 4 Damodar and Barakar sands (Bengal- Bihar Border)
- 5 Londha sand (Bombay)
- 6 Gigatamannu sand (Andhra Pradesh) and
- 7 Avadi and Veeriyambakam sand (Madras)

- Molding sands may be of two types namely natural or synthetic.
- Natural molding sands contain sufficient binder.
- Whereas synthetic molding sands are prepared artificially using basic sand molding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

CONSTITUENTS OF MOLDING SAND

- **Silica sand**
- Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.
- **Binder**
- In general, the binders can be either inorganic or organic substance. The inorganic group includes clay sodium silicate and port land cement etc. In foundry shop, the clay acts as binder which may be Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller’s earth and Bentonite. Binders included in the organic group are dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc. Organic binders are mostly used for core making.

- **Moisture**
- The amount of moisture content in the molding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them.
- **Additives**
- Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of molding and core sands are **Coal dust, Corn flour, Dextrin, Sea coal etc.**

KINDS OF MOULDING SAND

- **Green sand**
- Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous.
- It is commonly employed for production of ferrous and non-ferrous castings.
- **Dry sand**
- Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand. It possesses more strength, rigidity and thermal stability. It is mainly suitable for larger castings.
- **Loam sand**
- Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. Patterns are not used for loam molding and shape is given to mold by sweeps. This is particularly employed for loam molding used for large grey iron castings.

- **Facing sand**
- Facing sand is just prepared and forms the face of the mould. It is directly next to the surface of the pattern and it comes into contact molten metal when the mould is poured. Initial coating around the pattern and hence for mold surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness. It is made of silica sand and clay, without the use of used sand. Different forms of carbon are used to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times as much fine molding sand to make facings. The layer of facing sand in a mold usually ranges from 22-28 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.
- **Core sand**
- Core sand is used for making cores and it is sometimes also known as oil sand. This is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin, light mineral oil and other bind materials. Pitch or flours and water may also be used in large cores for the sake of economy.

PROPERTIES OF MOULDING SAND

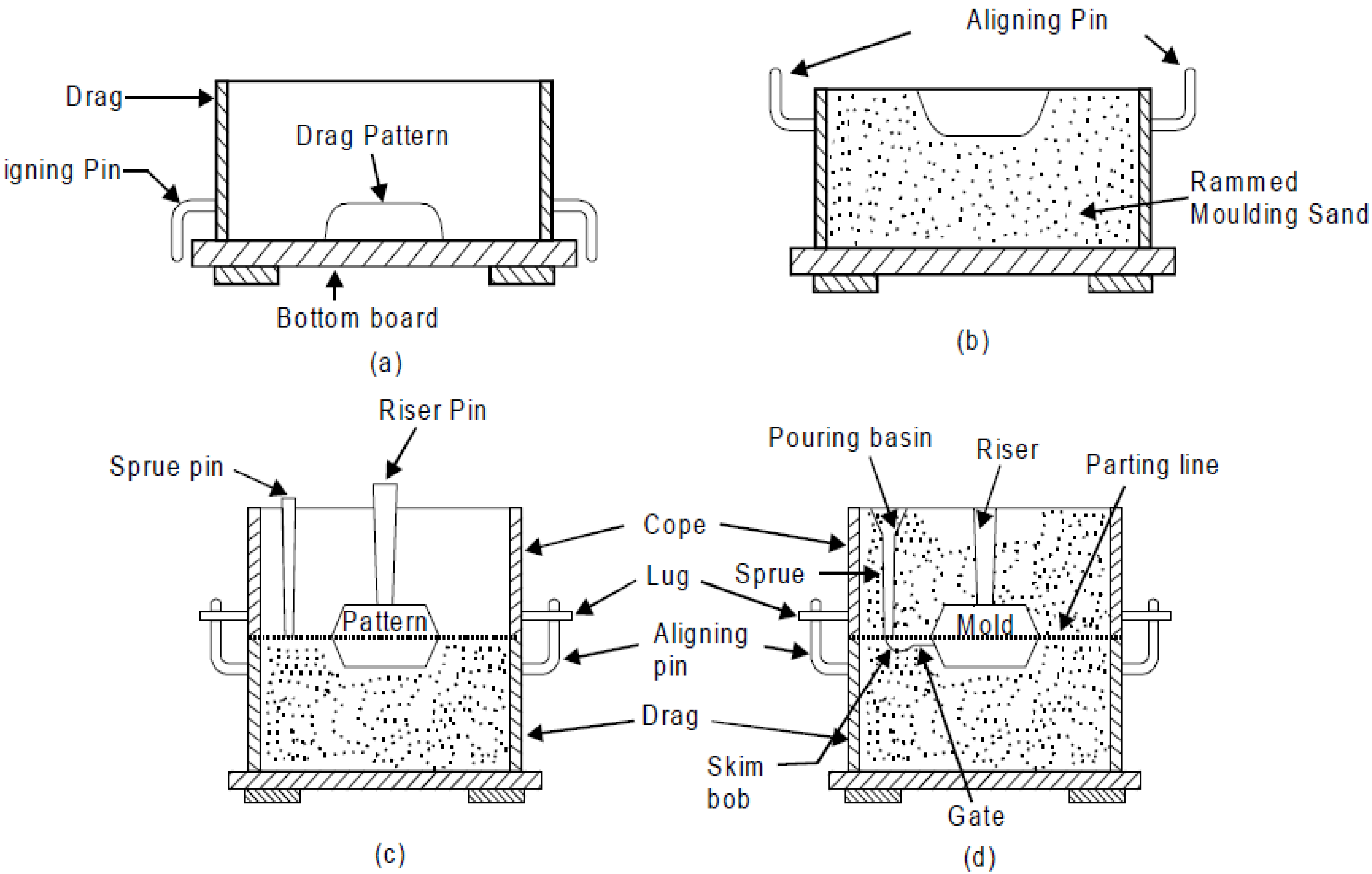
- **Refractoriness**
- Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. The degree of refractoriness depends on the SiO_2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO_2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand.
- **Permeability**
- It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mold can be further increased by venting using vent rods.

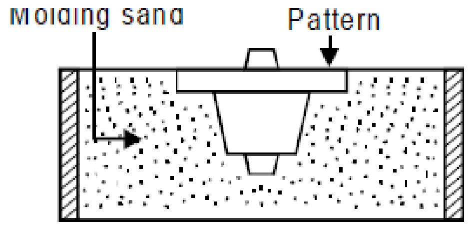
- **Cohesiveness**
- It is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand.
- **Green strength**
- The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. thev must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the molding box.
- **Dry strength**
- As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal. The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

- **Flowability or plasticity**
- It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections.
- In general, flowability increases with decrease in green strength, an, decrease in grain size. The flowability also varies with moisture and clay content.
- **Adhesiveness**
- It is property of molding sand to get stick or adhere with foreign material such sticking of molding sand with inner wall of molding box

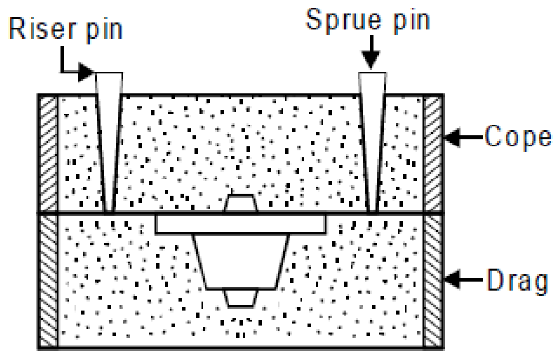
- **Collapsibility**
- After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered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

STEPS INVOLVED IN MAKING A SAND MOLD

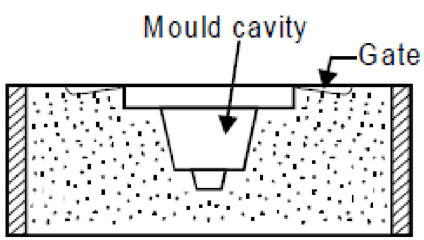


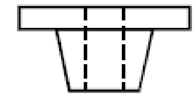


(a)

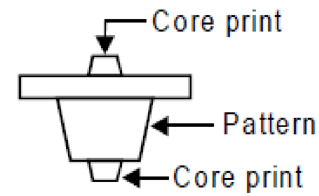


(b)

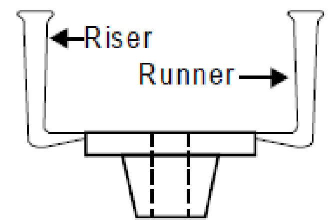




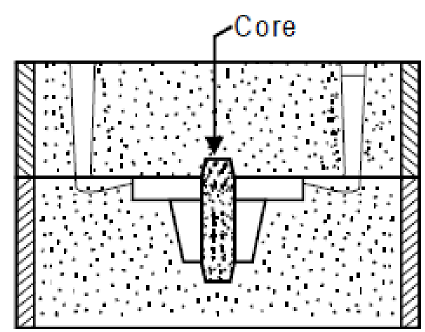
(i) Required casting



(ii) Pattern to be used

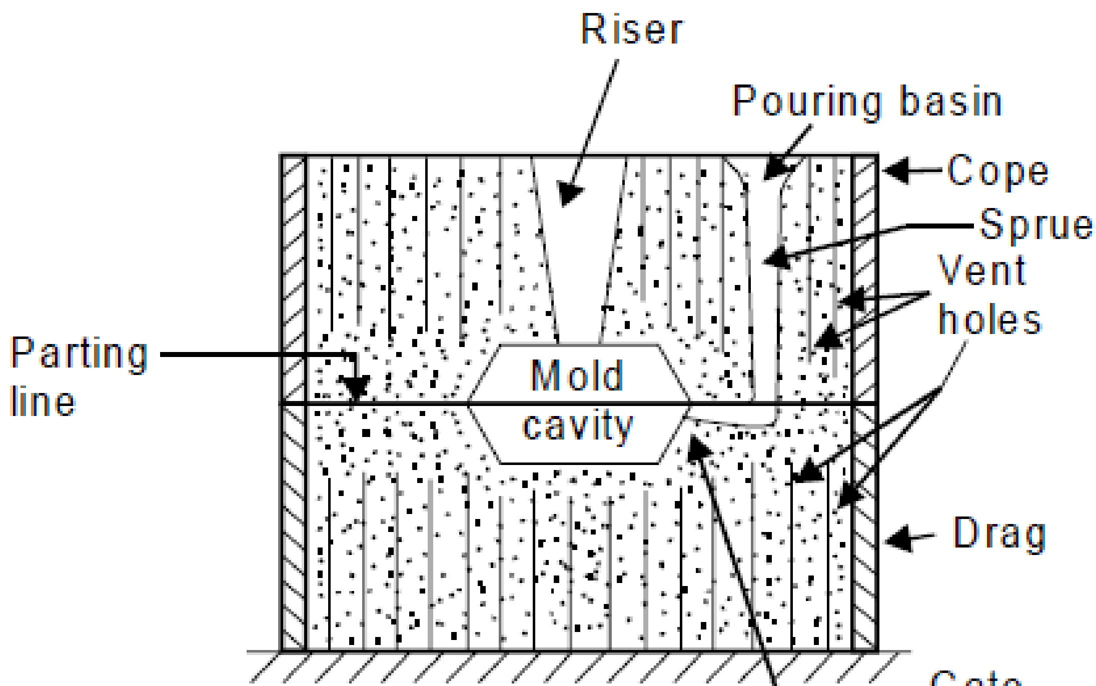


(iii) Casting after being knocked out



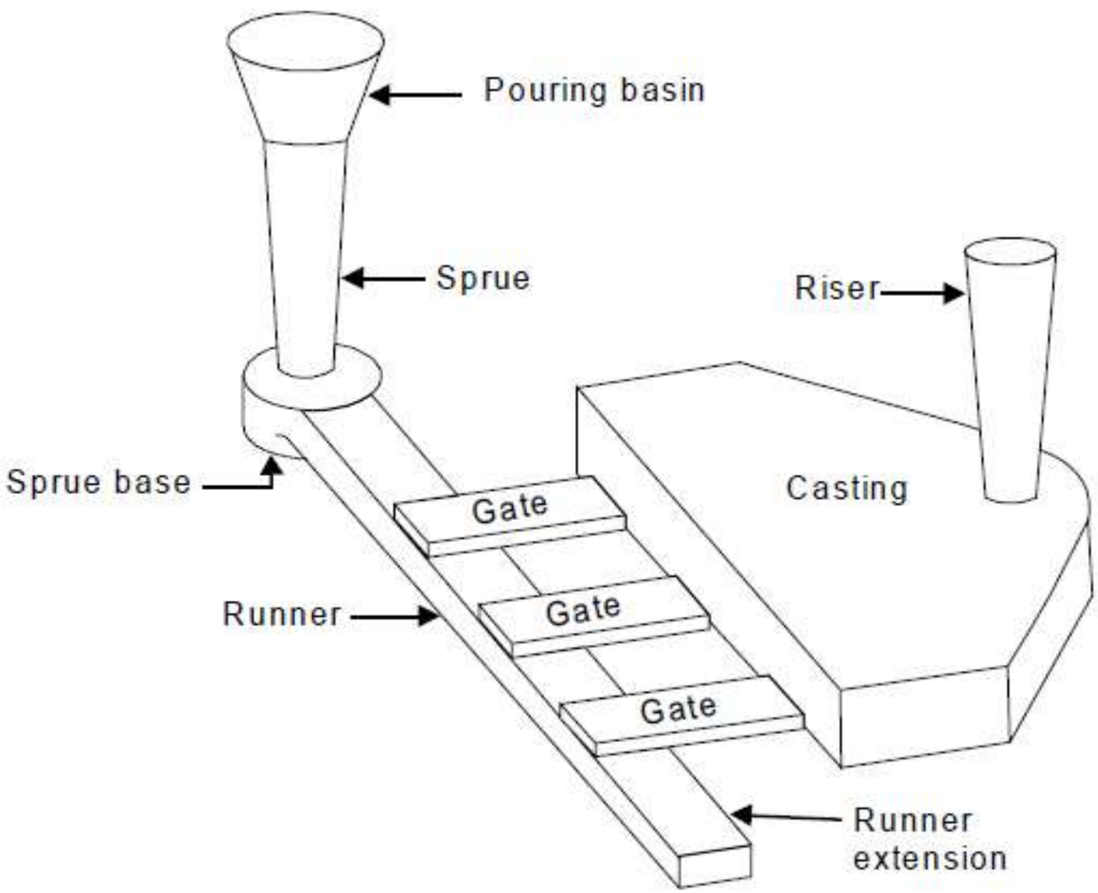
VENTING OF MOLDS

Vents are very small pin types holes made in the cope portion of the mold using pointed edge of the vent wire all around the mold surface.



Vents made in the mold

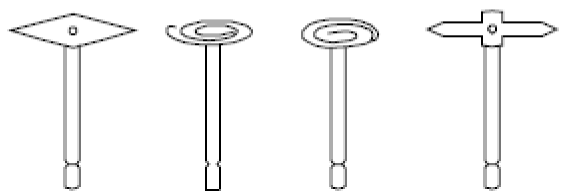
GATING SYSTEM IN MOLD



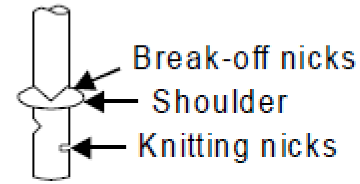
- **Pouring basin**
- It is the conical hollow element or tapered hollow vertical portion of the gating system which helps to feed the molten metal initially through the path of gating system to mold cavity.
- It may be made out of core sand or it may be cut in cope portion of the sand mold.
- It makes easier for the ladle operator to direct the flow of molten metal from crucible to pouring basin and sprue. It helps in maintaining the required rate of liquid metal flow.
- It reduces turbulence and vertexing at the sprue entrance. It also helps in separating dross, slag and foreign element etc. from molten metal before it enters the sprue.
- **Sprue**
- It is a vertical passage made generally in the cope using tapered sprue pin. It is connected at bottom of pouring basin. It is tapered with its bigger end at to receive the molten metal the smaller end is connected to the runner.
- It helps to feed molten metal without turbulence to the runner which in turn reaches the mold cavity through gate. It some times possesses skim bob at its lower end. The main purpose of skim bob is to collect impurities from molten metal and it does not allow them to reach the mold cavity through runner and gate

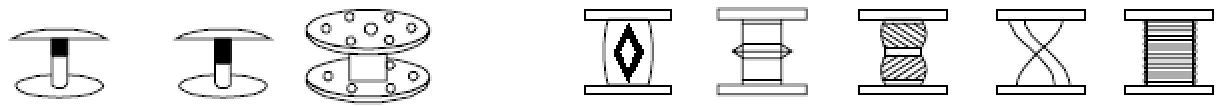
- **Gate**
- It is a small passage or channel being cut by gate cutter which connect runner with the mould cavity and through which molten metal flows to fill the mould cavity. It feeds the liquid metal to the casting at the rate consistent with the rate of solidification.
- **4. Choke**
- It is that part of the gating system which possesses smallest cross-section area. In choked system, gate serves as a choke, but in free gating system sprue serves as a choke.
- **Runner**
- It is a channel which connects the sprue to the gate for avoiding turbulence and gas entrapment.

- **Riser**
- It is a passage in molding sand made in the cope portion of the mold. Molten metal rises in it after filling the mould cavity completely. The molten metal in the riser compensates the shrinkage during solidification of the casting thus avoiding the shrinkage defect in the casting.
- It also permits the escape of air and mould gases. It promotes directional solidification too and helps in bringing the soundness in the casting.
- **Chaplets**
- Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces. The distances pieces in form of chaplets are made of parent metal of which the casting is. These are placed in mould cavity suitably which positions core and to give extra support to core and mould surfaces.
- Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification. When the molten metal is poured in the mould cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material.



Radiator chaplets

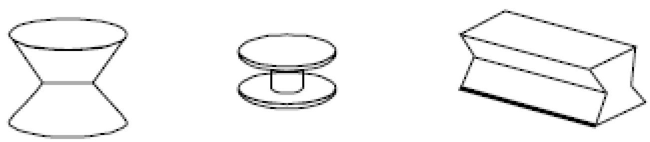




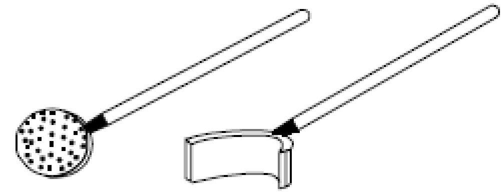
Riveted chaplet

Welded chaplet

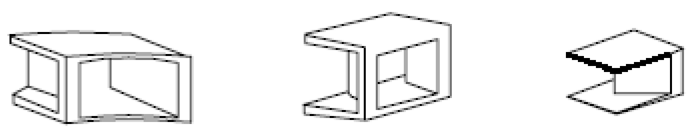
Double-head chaplets



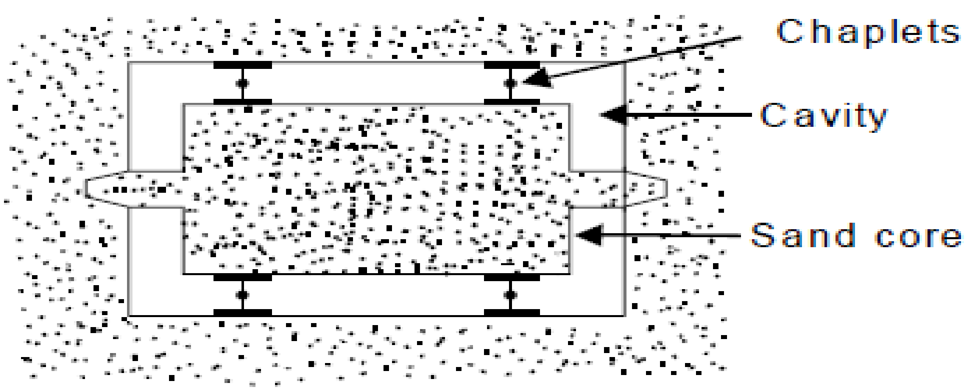
Cast chaplets



Stem chaplets

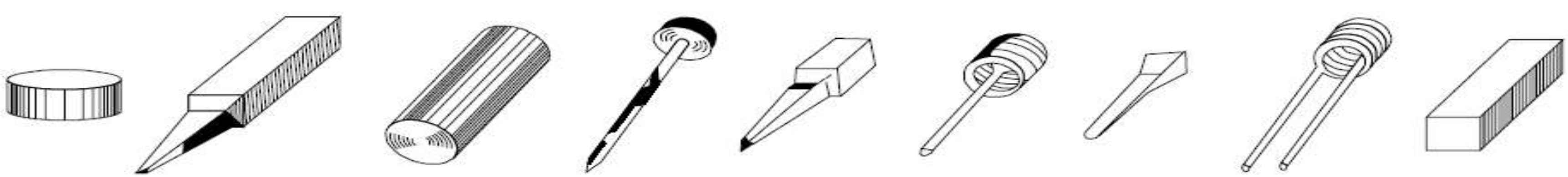


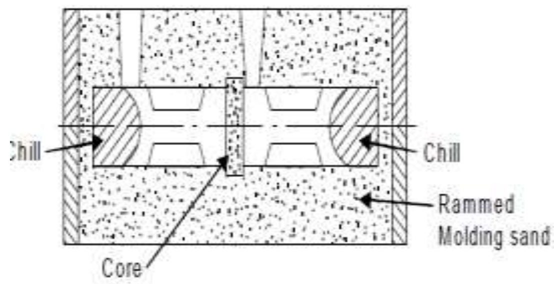
Sheet metal chaplets



Use of chaplets to support a core

- **Chills**
- In some casting, it is required to produce a hard surface at a particular place in the casting. At that particular position, the special mould surface for fast extraction of heat is to be made. The fast heat extracting metallic materials known as chills will be incorporated separately along with sand mould surface during molding.
- After pouring of molten metal and during solidification, the molten metal solidifies quickly on the metallic mould surface in comparison to other mold sand surfaces. This imparts hardness to that particular surface because of this special hardening treatment through fast extracting heat from that particular portion.





FACTORS CONTROLING GATING DESIGN

The following factors must be considered while designing gating system.

(*i) Sharp corners and abrupt changes in at any section or portion in gating system* should be avoided for suppressing turbulence and gas entrapment. Suitable relationship must exist between different cross-sectional areas of gating systems.

(*ii) The most important characteristics of gating system besides sprue are the shape,* location and dimensions of runners and type of flow. It is also important to determine the position at which the molten metal enters the mould cavity.

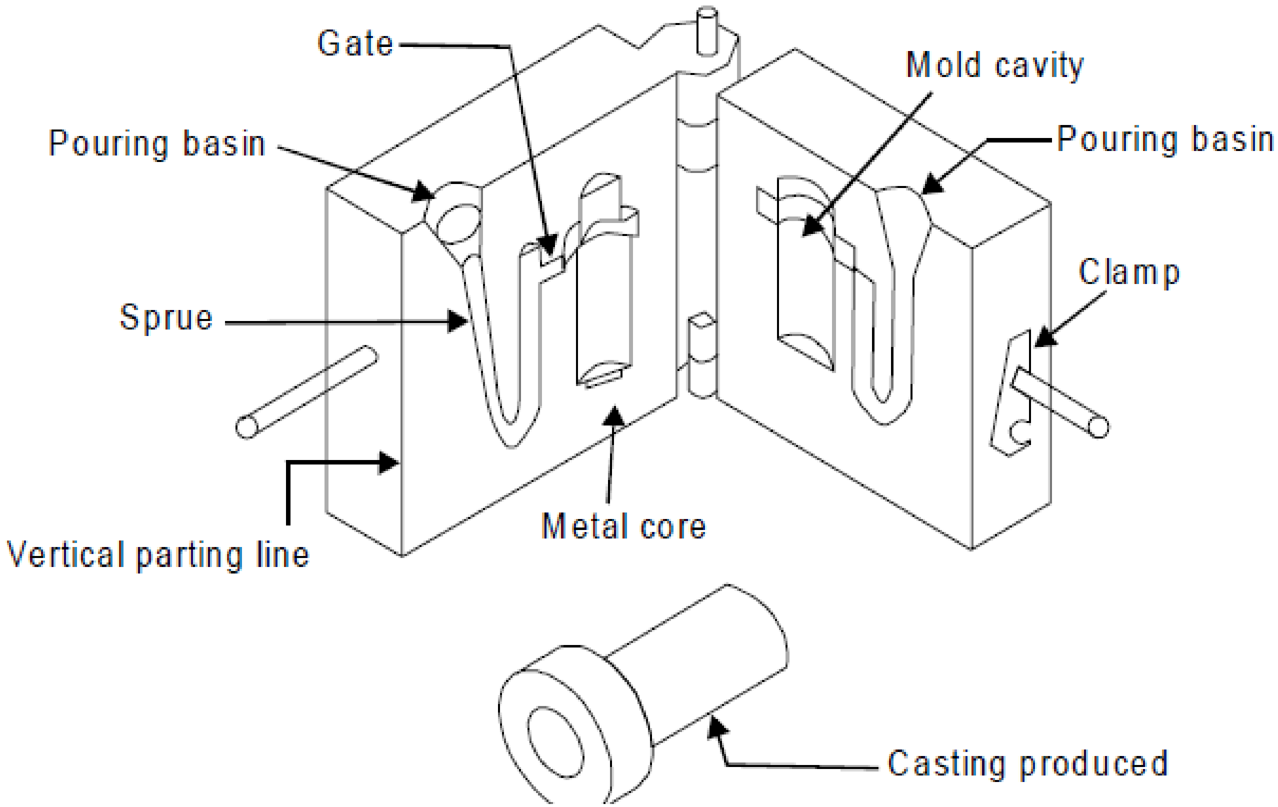
(*iii) Gating ratio should reveal that the total cross-section of sprue, runner and gate* decreases towards the mold cavity which provides a choke effect.

(*iv) Bending of runner if any should be kept away from mold cavity.*

(*v) Developing the various cross sections of gating system to nullify the effect of* turbulence or momentum of molten metal.

(*vi) Streamlining or removing sharp corners at any junctions by providing generous* radius, tapering the sprue, providing radius at sprue entrance and exit and providing a basin instead pouring cup etc.

CASTING-PERMANENT MOLD OR GRAVITY DIE CASTING



- Molten metal is poured into the mold under gravity only and no external pressure is applied to force the liquid metal into the mold cavity.
- However, the liquid metal solidifies under pressure of metal in the risers, etc. The metallic mold can be reused many times before it is discarded or rebuilt.
- These molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold.
- For faster cooling, fins or projections may be provided on the outside of the permanent mold.

- **Advantages**
- (*i) Fine and dense grained structure is achieved in the casting.*
- (*ii) No blow holes exist in castings produced by this method.*
- (*iii) The process is economical for mass production.*
- (*iv) Because of rapid rate of cooling, the castings possess fine grain structure.*
- (*v) Close dimensional tolerance or job accuracy is possible to achieve on the cast* product.
- (*vi) Good surface finish and surface details are obtained.*
- (*vii) Casting defects observed in sand castings are eliminated.*
- (*viii) Fast rate of production can be attained.*
- (*ix) The process requires less labor.*

- **Disadvantages**
- (*i) The cost of metallic mold is higher than the sand mold. The process is impractical* for large castings.
- (*ii) The surface of casting becomes hard due to chilling effect.*
- (*iii) Refractoriness of the high melting point alloys.*
- **Applications**
- (*i) This method is suitable for small and medium sized casting such as carburetor* bodies, oil pump bodies, connecting rods, pistons etc.
- (*ii) It is widely suitable for non-ferrous casting.*

MANUFACTURING PROCESS

PREPARED BY:

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ASSISTANT PROFESSOR

MAE DEPTT.

INTRODUCTION

- Manufacturing is the backbone of any industrialized nation. Manufacturing and technical staff in industry must know the various manufacturing processes, materials being processed, tools and equipments for manufacturing different components or products with optimal process plan using proper precautions and specified safety rules to avoid accidents.

SCOPE OF STUDY

- The scope of the subject of workshop technology and manufacturing practices is a extremely wide as it specifies the need of greatercare for man, machine, material and other equipments involving higher initial investment by using proper safety rule and precautions. The through and deep knowledge in the course of study of this important subject is therefore becoming essential for all kinds of engineers to have sound foundation in their profession.

MANUFACTURING ENGINEERING

- Manufacturing is derived from the Latin word manufactus, means made by hand. In modern context it involves making products from raw material by using various processes, by making use of hand tools, machinery or even computers. It is therefore a study of the processes required to make parts and to assemble them in machines.

Manufacturing

- Manufacturing in its broadest sense is the process of converting raw materials into useful products.
- It includes

i) Design of the product
ii) Selection of raw materials and
iii) The sequence of processes through which the product will be manufactured.

CLASSIFICATION OF MANUFACTURING PROCESSES

- **Primary Shaping Processes:** Primary shaping processes are manufacturing of a product from an amorphous material. Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size.
- Typical examples of the products that are produced by casting process are machine beds, automobile engines, carburetors, flywheels etc.
- Some of the important primary shaping processes is:
- (1) Casting, (2) Powder metallurgy, (3) Plastic technology, (4) Gas cutting, (5) Bending and (6) Forging.

Secondary or Machining Processes

- As large number of components require further processing after the primary processes. These components are subjected to one or more number of machining operations in machine shops, to obtain the desired shape and dimensional accuracy on flat and cylindrical jobs.
- The example of parts produced by machining processes includes hand tools machine tools instruments, automobile parts, nuts, bolts and gears etc.
- Some of the common secondary or machining processes are—
- (1) Turning, (2) Threading, (3) Knurling, (4) Milling, (5) Drilling, (6) Boring, (7) Planning, (8) Shaping, (9) Slotting, (10) Sawing, (11) Broaching, (12) Hobbing, (13) Grinding, (14) Gear cutting, (15) Thread cutting and (16) Unconventional machining processes namely machining with Numerical Control (NC) machines tools or Computer Numerical Control (CNC) machine.

Metal Forming Processes

- Forming processes encompasses a wide variety of techniques, which make use of suitable force, pressure or stresses, like compression, tension and shear or their combination to cause a permanent deformation of the raw material to impart required shape.
- kitchen utensils, rods, wires, rails, cold drink bottle caps, collapsible tubes etc
- **Hot working Processes**
- (1) Forging, (2) Rolling, (3) Hot spinning, (4) Extrusion, (5) Hot drawing and (6) Hot spinning.
- **Cold working processes**
- (1) Cold forging, (2) Cold rolling, (3) Cold heading, (4) Cold drawing, (5) Wire drawing, (6) Stretch forming, (7) Sheet metal working processes such as piercing, punching, lancing, notching, coining, squeezing, deep drawing, bending etc

Joining Processes

- The process of putting the parts together to form the product, which performs the desired function, is called assembly. An assemblage of parts may require some parts to be joined together using various joining processes.
- In these process two or more pieces of metal parts are joined together to produce desired shape and size of the product.
- The joining processes are carried out by fusing, pressing, rubbing, riveting, screwing or any other means of assembling.
- Temporary, semi-permanent or permanent type of fastening to make a good joint is generally created by these processes. Temporary joining of components can be achieved by use of nuts, screws and bolts. Adhesives are also used to make temporary joints. Some of the important and common joining processes are:
- (1) Welding (plastic or fusion), (2) Brazing, (3) Soldering, (4) Riveting, (5) Screwing, (6) Press fitting, (7) Sintering, (8) Adhesive bonding, (9) Shrink fitting, (10) Explosive welding, (11) Diffusion welding, (12) Keys and cotters joints, (13) Coupling and (14) Nut and bolt joints.

Surface Finishing Processes

- Surface finishing processes are utilized for imparting intended surface finish on the surface of a job.
- Some of the commonly used surface finishing processes are:
- (1) Honing, (2) Lapping, (3) Super finishing, (4) Belt grinding, (5) Polishing, (6) Tumbling, (7) Organic finishes, (8) Sanding, (9) deburring, (10) Electroplating, (11) Buffing, (12) Metal spraying, (13) Painting, (14) Inorganic coating, (15) Anodizing, (16) Sheradising, (17) Parkerizing, (18) Galvanizing, (19) Plastic coating, (20) Metallic coating, (21) Anodizing and (22) Sand blasting.

PROPERTIES AND TESTING OF METALS

Mechanical Properties

- **Elasticity:** It is defined as the property of a material to regain its original shape after deformation when the external forces are removed.
- **Proportional limit:** It is defined as the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress.
- **Elastic limit:** The greatest stress that a material can endure without taking up some permanent set is called elastic limit.
- **Yield point:** At a specific stress, ductile metals particularly ceases, offering resistance to tensile forces. This means, the metals flow and a relatively large permanent set takes place without a noticeable increase in load. This point is called yield point.

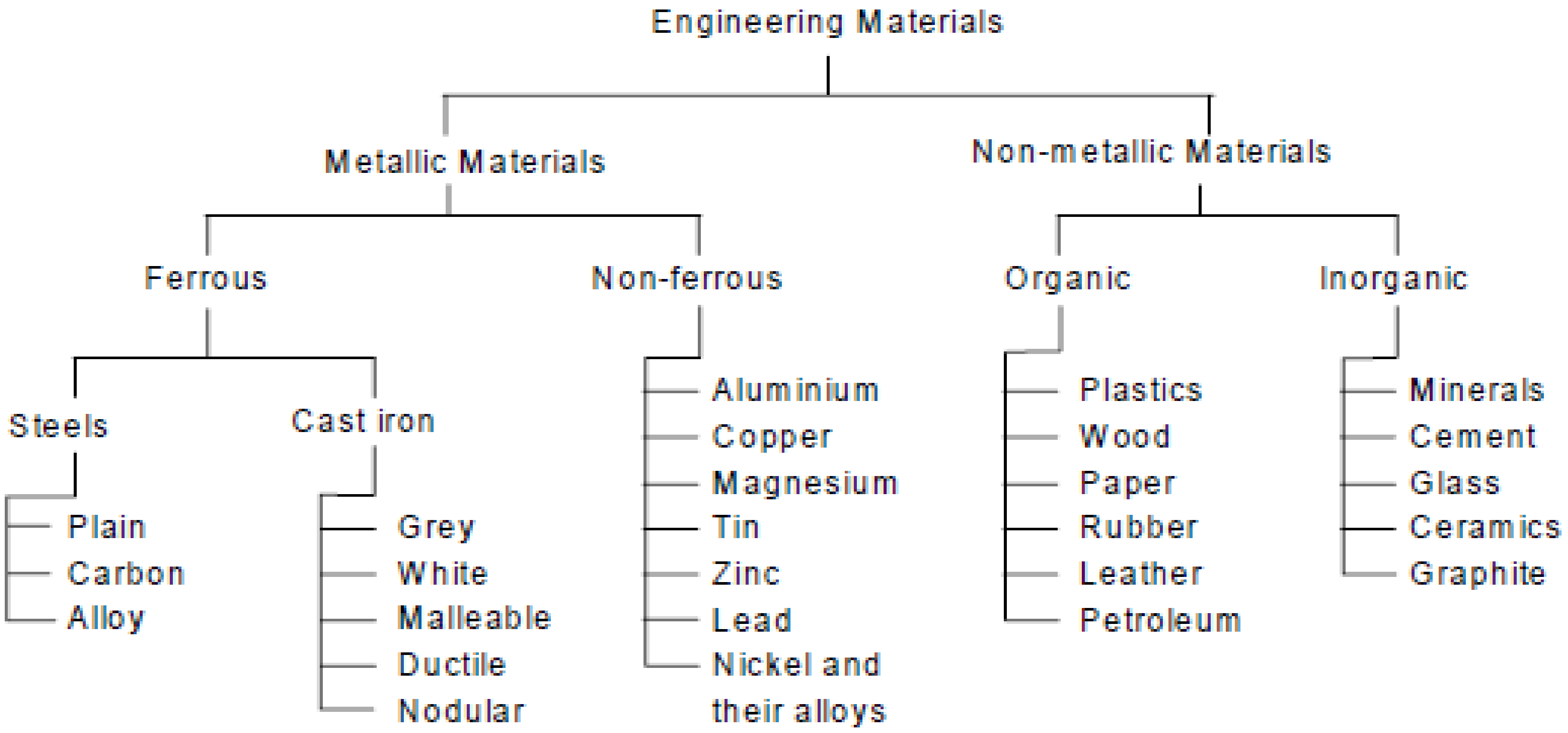
- **Strength:** Strength is defined as the ability of a material to resist the externally applied forces with breakdown or yielding.
- **Stiffness:** It is defined as the ability of a material to resist deformation under stress. The resistance of a material to elastic deformation or deflection is called stiffness or rigidity.
- **Plasticity:** Plasticity is defined the mechanical property of a material which retains the deformation produced under load permanently. This property generally increases with increase in temperature of materials.
- **Ductility:** Ductility is termed as the property of a material enabling it to be drawn into wire with the application of tensile load. A ductile material must be strong and plastic. The ductile material commonly used in engineering practice in order of diminishing ductility are mild steel, copper, aluminium, nickel, zinc, tin and lead.
- **Malleability:** Malleability is the ability of the material to be flattened into thin sheets under applications of heavy compressive forces without cracking by hot or cold working means. It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. Aluminium, copper, tin, lead, steel, etc. are recognized as highly malleable metals.

- **Hardness:** Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by virtue of its hardness.
- **Brittleness:** Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. Glass, cast iron, brass and ceramics are considered as brittle material.
- **Creep :** When a metal part when is subjected to a high constant stress at high temperature for a longer period of time, it will undergo a slow and permanent deformation (in form of a crack which may further propagate further towards creep failure) called creep.
- **Formability :** It is the property of metals which denotes the ease in its forming in to various shapes and sizes. The different factors that affect the formability are crystal structure of metal, grain size of metal hot and cold working, alloying element present in the parent metal. Low carbon steel possesses good formability.

- **Castability :** Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. Cast iron, aluminium and brass are possessing good castability.
- **Weldability :** Weldability is defined as the property of a metal which indicates the two similar or dissimilar metals are joined by fusion with or without the application of pressure and with or without the use of filler metal (welding) efficiently.
- **Fatigue:** Fatigue is the weakening of material caused by the repeated loading of material. When a material is subjected to cyclic loading, and loading greater than certain threshold value but much below the strength of material (ultimate tensile strength limit or yield stress limit, microscopic cracks begin to form at grain boundaries and interfaces

Engineering materials

- Engineering materials used to manufacture of articles or products, dictates which manufacturing process or processes are to be used to provide it the desired shape.



- Ferrous metals are those which have the iron as their main constituent, such as pig iron, cast iron, wrought iron and steels.
- Non-ferrous metals are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver zinc, invar etc.

Ferrous Metals

- The basic principal raw material for all ferrous metals is pig iron which is obtained by smelting iron ore, coke and limestone, in the blast furnace. The principal iron ores with their metallic contents are shown in Table

Table 4.1 Types of Iron Ore

S.No.	Iron ore	Color	Iron %
1.	Haematite (Fe_3O_4)	Red	70%
2.	Magnetite (Fe_2O_3)	Black	72%
3.	Limonite	Brown	62.5%
4.	Siderite	Brown	48%

Main Types of Iron

- 1. Pig iron
- 2. Cast iron : (A) White cast iron (B) Gray cast iron (C) Malleable cast iron (D) Ductile cast iron (E) Meehanite cast iron (F) Alloy cast iron
- 3. Wrought iron
- 4. Steel : (A) Plain carbon steels
- 1. Dead Carbon steels
- 2. Low Carbon steels
- 3. Medium Carbon steels
- 4. High Carbon steels
- (B) Alloy steels
- 1. High speed steel
- 2. Stainless steel

Pig Iron

- It is produced in a blast furnace and is the first product in the process of converting iron ore into useful ferrous metal. The iron ore on initial refining and heating in blast furnace becomes pig iron when the impurities are burnt out in a blast furnace.
- Pig iron acts as the raw material for production of all kinds of cast iron and steel products. It is obtained by smelting (chemical reduction of iron ore in the blast furnace. It is of great importance in the foundry and in steel making processes.
- It is partly refined in a **cupola furnace** that produces various grades of cast iron. By puddling processes, wrought iron is produced from pig iron. Steel is produced from pig iron by various steel making processes such as bessemer, open-hearth, oxygen, electric and spray steel making. The charge in the blast furnace for manufacturing pig iron is
- (*a*) Ore Consisting of iron oxide or carbonate associated with earth impurities.
- (*b*) Coke A fuel
- (*c*) Limestone A flux
- In addition to iron, pig iron contains various other constituents in varying form of
- impurity such carbon, silicon, sulphur, manganese and phosphorus etc. It has the following
- approximate composition which is as given as under.
- Carbon — 4 to 4.5% Phosphorus — 0.1 to 2.0%
- Silicon — 0.4 to 2.0% Sulphur — 0.4 to 1.0%
- Manganese — 0.2 to 1.5 % Iron — Remainder

PIG IRON CLASSIFICATION

- **1. Grey pig iron (Grades 1, 2 and 3)**
- Grey pig iron contains about 3% carbon in free form (i.e., graphite form) and about 1% carbon in combined form. This is a soft type of pig iron.
- **2. White pig iron (Grades 4)**
- White pig iron is hard and strong. It contains almost all of the carbon in the combined form.
- **3. Mottled pig iron (Grade 5)**
- This type of pig iron is in between the grey and white variety. It has an average hardness and molted appearance. The free and combined forms of carbon are in almost equal proportion in mottled pig iron.

Cast Iron

- Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements.
- **General properties of cast iron**
- Cast iron is very brittle and weak in tension.
- It has low cost, good casting characteristics, high compressive strength, high wear resistance and excellent machinability. These properties make it a valuable material for engineering purposes. Its tensile strength varies from 100 to 200 MPa, compressive strength from 400 to 1000 MPa and shear strength is 120 MPa. The compressive strength of cast iron is much greater than the tensile strength.
- The carbon in cast iron is present either of the following two forms:
- 1. Free carbon or graphite.
- 2. Combined carbon or cementite.
- The cast iron is classified into seven major kinds as follows:
- (*a*) Grey cast iron, (*b*) White cast iron, (*c*) Mottled cast iron (*d*) Malleable cast iron, (*e*) Nodular cast iron, (*f*) Meehanite cast iron. (*g*) Alloy cast iron and The chemical composition, extraction, properties and general applications of these types of cast iron are discussed as under

Grey cast iron

- Grey cast iron is grey in color which is due to the carbon being principally in the form of graphite (C in free form in iron). It contains:
- C = 2.5 to 3.8%.
- Si = 1.1 to 2.8 %
- Mn = 0.4 to 1.0%
- P = less than 0.15%
- S = less than 0.1%
- Fe = Remaining
- It is produced in cupola furnace by refining or pig iron.

Properties

- (*i*) When fractured it gives grey color.
- (*ii*) It can be easily cast.
- (*iii*) It is marked by presence of flakes of graphite in a matrix of ferrite and pearlite or austenite; graphite flakes occupy 10% of metal volume.
- (*iv*) It can be easily machined and possesses machinability better than steel.
- (*v*) It possesses lowest melting of ferrous alloys.
- (*vi*) It possesses high vibration damping capacity.
- (*vii*) It has high resistance to wear.
- (*viii*) It possesses high fluidity and hence can be cast into complex shapes and thin sections.
- (*ix*) It possesses high compressive strength.
- (*x*) It has a low tensile strength.
- (*xi*) It has very low ductility and low impact strength as compared with steel.

Applications

- The grey iron castings are mainly used for machine tool bodies, automotive cylinder blocks, pipes and pipe fittings and agricultural implements. The other applications involved are
- (*i*) Machine tool structures such as bed, frames, column etc.
- (*ii*) Household appliances etc.
- (*iii*) Gas or water pipes for under ground purposes.
- (*iv*) Man holes covers.
- (*v*) Piston rings.
- (*vi*) Rolling mill and general machinery parts.
- (*vii*) Cylinder blocks and heads for I.C. engines.
- (*viii*) Frames of electric motor.
- (*ix*) Ingot mould. And
- (*x*) General machinery parts.
- (*xi*) Sanitary wares.
- (*xii*) Tunnel segment.

White cast iron

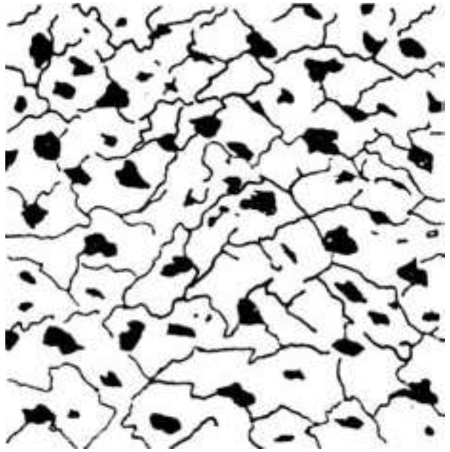
- The white color is due to the fact that the carbon is this iron is in combined form as iron carbide which is commonly specified as cementite. It is the hardest constituent of iron.
- It is produced in cupola furnace by refining or pig iron. The white cast iron may be produced by casting against metal chills or by regulating analysis. The chills are used when a hard and wear resistance surface is desired for products such as for wheels, rolls crushing jaw, crusher plates. The chemical composition of white cast iron is given as under.
- C = 3.2 to 3.6%
- Si = 0.4 to 1.1 %
- Mg = 0.1 to 0.4%
- P = less than 0.3%
- S = less than 0.2%
- Fe = Remaining

Properties

- (*i*) Its name is due to the fact that its freshly broken surface shows a bright white fracture.
- (*ii*) It is very hard due to carbon chemically bonded with iron as iron carbide (Fe_3C), which is brittle also.
- (*iii*) It possesses excellent abrasive wear resistance.
- (*iv*) Since it is extremely hard, therefore it is very difficult to machine.
- (*v*) Its solidification range is 2650-2065°F.
- (*vi*) Shrinkage is 1/8 inch per foot.
- (*vii*) The white cast iron has a high tensile strength and a low compressive strength.
- **Applications**
- (*i*) For producing malleable iron castings.
- (*ii*) For manufacturing those component or parts which require a hard, and abrasion resistant surface such as rim of car.
- (*iii*) Railway brake blocks.

Ductile cast iron

- When small quantities of magnesium or cerium is added to cast iron, then graphite content is converted into nodular or spheroidal form and it is well dispersed throughout the material.
- Graphite is in spheroidal form instead of in flaky form. Its structure may be modified by alloys or heat treatment, as in steel to produce austenite, acicular, martensite, pearlite, and ferrite structure.
- Compositions of ductile cast iron are as follows:
- Carbon = 3.2 to 4.2%
- Silicon = 1.0 to 4.0 %
- Magnesium = 0.1 to 0.8%
- Nickel = 0.0 to 3.5%
- Manganese = 0.5 to 0.1%
- Iron = Remaining



Silicon is also used as an alloying element since it has no effect on size and distribution of carbon content.

The magnesium controls the formation of graphite. But it has little influence on the matrix structure. Nickel and manganese impart strength and ductility.

Ductile cast iron has high fluidity, excellent castability, strength, high toughness, excellent wear resistance, pressure tightness, weldability and higher machinability in comparison to grey cast iron.

Malleable cast iron

- It is an alloy in which all combined carbon changed to free form by suitable heat treatment. Graphite originally present in iron in the form of flakes which is the source of weakness and brittleness.
- The tensile strength of this cast iron is usually higher than that of grey cast iron. It has excellent machining quality and is used for making machine parts for which the steel forging and in which the metal should have a fair degree of machining accuracy e.g., hubs of wagon, heels small fittings for railway rolling brake supports, parts of agricultural machinery, pipe fittings, hinges, locks etc.
- It can be obtained by annealing the castings. The cast iron castings are packed in an oxidizing material such as iron ore or in an inert material such as ground fire clay depends upon the process used either white heart or black heart. The packed casting is put into an oven and is heated around 900°C temperature and is kept at that temperature for about two days and it is then allowed to cool slowly in the furnace itself.
- Iron ore acting as an oxidizing agent reacts with C and CO_2 escape. Thus annealed cast product is free from carbon.

White heart malleable iron casting

- The castings taken out of the mould are put into a drum having sand and powdered slag.
- The drum is then closed and kept in the air furnace and it is raised to highly temperature slowly. The temperature is raised to 920°C in two days time, kept at this temperature for nearly up to 50 to 80 hours then the drum is allowed to cool in the furnace (generally air furnaces) at the rate 5 to 10°C per hour till it reaches to room temperature. The whole cycle takes about one weak. During this treatment combined carbon separates out and all the carbon does not change into graphite state but change in other form of free carbon called tempered carbon.
- $Fe3C \longrightarrow 3Fe + C$
- This makes the casting less brittle and malleable. The fracture portion of such a casting is dark grey or black in appearance. These castings are specially used in automobile industries.

Black heart malleable iron casting

- The castings packed in a drum of oxidizing media which is generally powdered iron ore or powered scale (film of Fe_3O_4 on surface). This close drum is kept in the furnace and heated to 900°C. It is then maintained at this temperature to nearly 40 to 70 hours and allowed to cool slowly in a furnace itself. The castings become malleable like white heart cast iron. The percentage of carbon and silicon should be so selected that it can promote the development of free carbon when these castings are annealed.
- **Properties**
- 1. Malleable cast iron is like steel than cast iron.
- 2. It is costly than grey cast iron and cheaper than softer steel.
- **Applications**
- Malleable cast iron are generally used to form automobile parts, agriculture
- implementation, hinges, door keys, spanners mountings of all sorts, seat wheels, cranks,
- levers thin, waned components of sewing machines and textiles machine parts.

- **Meehanite cast iron** is an inoculated iron of a specially made white cast iron. The composition of this cast iron is graphitized in the ladle with calcium silicide. There are various types of meehanite cast iron namely heat resisting, wear resisting and corrosion resisting kind. These materials have high strength, toughness, ductility and good machinability. It is highly useful for making castings requiring high temperature applications.
- **Alloy cast iron**
- The alloy cast iron is produced by adding alloying elements like nickel, chromium, molybdenum, copper and manganese in sufficient quantities in the molten metal collected in ladles from cupola furnace. These alloying elements give more strength and result in improvement of properties. The alloy cast iron has special properties like increased strength, high wear resistance, corrosion resistance or heat resistance. The alloy cast irons are extensively used for automobile parts like cylinders, pistons, piston rings, crank cases, brake drums, parts of .crushing and grinding machinery etc.

- **Effect of impurities on cast iron**
- The cast iron contains small percentages of carbon, silicon, sulphur, manganese and phosphorus. The affect of these impurities on the cast iron are as follows:
- (1) **Carbon.** Carbon is one of the important elements in cast iron. It reduces melting point of iron. Pure iron has a melting point of about 1500°C but iron with 3.50% C has melting point of about 1350°C. When carbon is in free form i.e. as graphite form, the resulting cast iron is known grey cast iron. On the other hand, when the iron and carbon are chemically combined form of cementite, the cast iron will be hard and known as white cast iron.
- (2) **Silicon.** Presence of silicon in cast iron promotes the decomposition of cementite into graphite. It also helps to reduce the shrinkage in cast iron when carbon is changed to graphite forms.
- (3) **Sulphur.** It makes the cast iron hard and brittle. Since too much sulphur gives unsound casting, therefore, it should be kept below 0.1% for most casting purposes. It is often responsible for creating troubles to foundry men. It will make cast iron hard thereby counteracting the softening influences of silicon. It decreases strength and increases brittleness. It also promotes oxidation of cast iron. Hence, it is kept as low as possible in cast iron.
- (4) **Manganese.** It makes cast iron white and hard. It is often kept below 0.75%. It helps to exert a controlling influence over the harmful effect of sulphur. It reduces the harmful effects of the sulphur by forming the manganese sulphide which is not soluble in cast iron.
- **Phosphorus.** It increases fusibility and fluidity in cast iron but induces brittleness. It is rarely allowed to exceed 1 %. Phosphorus in irons is useful for casting of intricate shapes and for producing very cheap and light engineering castings. Phosphorus has no effect on the carbon as well as on shrinkage in the cast iron.

Comparison

S.No	Grey Cast Iron	White Cast Iron	Spherodidal Cast Iron
1.	It is an alloy of carbon and silicon with iron having grey color when fractured. It is marked by the presence of flakes of matrix of ferrite, pearlite or austenite. Carbon in iron exists in free form as graphite	White cast iron has almost all its carbon as iron carbide. Its broken surface shows a bright white fracture.	Graphite appears as around Particles or spheroids.
2	It has good machinability, high resistance to wear, high vibration damping capacity and high compressive strength.	It has poor machinability, excellent abrasive wear resistance.	It has good machinability, good damping, excellent castability and sufficient wear resistance
3	It is used in machine tool structure, Main-hole covers, cylinder blocks, heads for I.C. engines, gas or water pipes for underground purposes, frames for electric motors, piston rings and sanitary wares.	It is used for producing malleable iron castings and manufacturing those structural component parts which require a hard and abrasion resistant material.	It is used in I.C. engines, paper Industry machinery, machinery for farming and tractor, application, earth moving machinery, valve and fittings, pipes, pumps, compressors and construction machinery.

Wrought Iron

- Wrought iron is the assumed approximately as purest iron which possesses at least 99.5% iron.
- **Chemical Composition**
- A chemical composition range of typical wrought iron includes:
- C = 0.02 – 0.03% P = 0.05 – 0.25% Si = 0.02 – 0.10%
- S = 0.008 – 0.02% Mn = 0.0 – 0.02% Slag = 0.05 – 1.5%
- Fe = remainder
- **Properties**
- The wrought iron can be easily shaped by hammering, pressing, forging, etc.
- It is never cast and it can be easily bent when cold.
- It is tough and it has high ductility and plasticity with which it can be forged and welded easily.
- It possesses a high resistance towards corrosion.
- It can accommodate sudden and excessive shocks loads without permanent injury.
- It has a high resistance towards fatigue. Its ultimate tensile strength is 2,500 kg/cm2 to 5,000 kg/cm2 and the ultimate compressive strength is 3,000 kg/cm2. It can be elongated considerably by cold working.
- It has high electrical conductivity.
- The melting point of wrought iron is about 1530°C. It has elongation 20% in 200 mm in longitudinal direction and 2–5 % in transverse direction. Its poison’s ratio is 0.30.
- It can be easily formed when cold, without the outer side cracking at the formed portion.

Applications

- It is used for making chains, crane hooks, railway couplings, and water and steam pipes.
- It has application in the form of plates, sheets, bars, structural works, forging blooms and billets, rivets, and a wide range of tubular products including pipe, tubing and casing, electrical conduit, cold drawn tubing, nipples and welding fittings, bridge railings, blast plates, drainage lines and troughs, sewer outfall lines, weir plates, sludge tanks and lines, condenser tubes, unfired heat exchangers, acid and alkali process lines, skimmer bars, diesel exhaust and air brake piping.

Steels : It is an alloy of iron and carbon with carbon content maximum up to 1.7%.

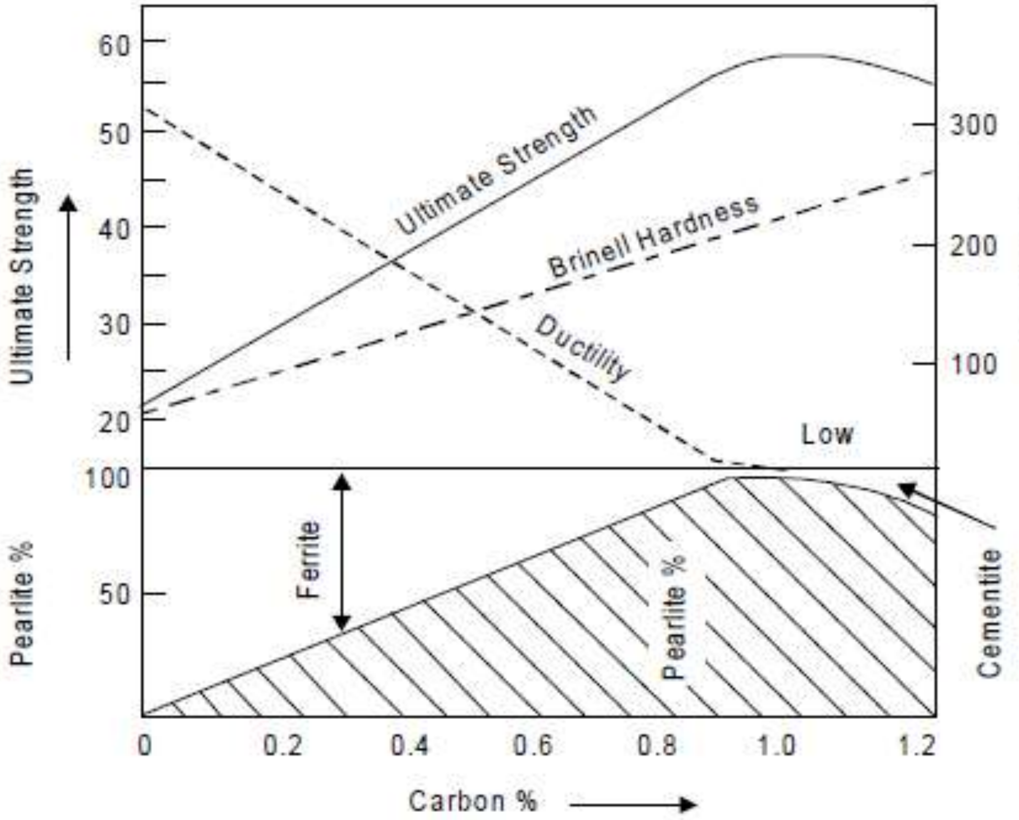


Fig. 4.3 Effect of carbon on properties of steel

Effect of impurities on steel

- **Silicon. Silicon content in the finished steel usually ranges from 0.05 to 0.30%. It** is added in low carbon steels for preventing them from becoming porous.
- **Sulphur. It renders free cutting properties in steel. It is found in steel either as** iron sulphide or manganese sulphide.
- **Manganese. It serves as a valuable deoxidizing and purifying agent, in steel.** Manganese also combines with sulphur and thereby decreases the harmful effect of this element remaining in the steel. It increases wear resistance, hardness and strength and decreases machineability.
- **Phosphorus. It induces brittleness in steel. It also produces cold shortness in steel.** In low carbon steels, it raises the yield point and improves the resistance to atmospheric corrosion.

Plain carbon steel

- Plain carbon steel is an alloy of iron and carbon. It has good machineability and malleability.
- It is different from cast iron as regards the percentage of carbon. It contains carbon from 0.06 to 1.5% whereas cast iron possesses carbon from 1.8 to 4.2%. Depending upon the carbon content, a plain carbon steels can divided to the following types:
- 1. Dead carbon steel — up to 0.15% carbon
- 2. Low carbon or mild steel — 0.15% to 0.45% carbon
- 3. Medium carbon steel — 0.45% to 0.8% carbon
- 4. High carbon steel — 0.8% to 1.5% carbon

DEAD CARBON STEEL

- It possesses very low percentage of carbon varying from 0.05 to 0.15%. It has a tensile strength of 390 N/mm2 and a hardness of about 115 BHN.
- Steel wire, sheets, rivets, screws, pipe, nail and chain are made from this steel. This steel is used for making camshafts, sheets and strips for fan blades, welded tubing, forgings, chains, stamping, rivets, nails, pipes, automobile body etc.

LOW CARBON OR MILD STEEL

- Low carbon steel is sometimes known as mild steel also. It contains 0.20 to 0.30% C which has tensile strength of 555 N/mm2 and hardness of 140 BHN.
- It possesses bright fibrous structure. It is tough, malleable, ductile and more elastic than wrought iron.
- It can be easily forged and welded. It can absorb shocks. It rusts easily.
- Its melting point is about 1410°C.
- It is used for making angle, channels, case hardening steel, rods, tubes, valves, gears, crankshafts, connecting rods, railway axles, fish plates, small forgings, free cutting steel shaft and forged components etc.

MEDIUM CARBON STEELS

- Medium carbon steel contains carbon from 0.30 to 0.8%.
- It possesses having bright fibrous structure when fractured. It is tough and more elastic in comparison to wrought iron.
- It can be easily forged, welded, elongated due to ductility and beaten into sheets due to its good malleability. It can easily absorb sudden shocks.
- It is usually produced as killed or semi killed steels and is harden able by treatment. Hardenability is limited to thin sections or to the thin outer layer on thick parts.
- Its tensile strength is better than cast iron and wrought iron but compressive strength is better than wrought iron but lesser than cast iron.
- It rusts readily. Its melting point is 1400°C. It can be easily hardened and it possesses good balance of strength and ductility.
- It is generally used for making railway coach axles, bolts, connecting rods, key stock, wires and rods, shift and break levers, spring clips, gear shafts, small and medium forgings, railway coach axles, crank pins on heavy machines, spline shafts, crankshafts, forging dies, set screws, die blocks, self tapping screws, clutch discs, valve springs, plate punches, thrust washers etc.

Applications of different kinds of medium carbon steel

- **Applications**
- 1. **Plain carbon steels having carbon % 0.30 to 0.45.** Axles, special duty shafts, connecting rods, forgings, machinery steel, spring clips, turbine, rotors, gear shafts, key stock, forks and bolts.
- 2. **Plain carbon steels having carbon % 0.45 to 0.60.** Railway coach axles, crank pins, crankshafts, axles, spline shafts, loco tyres.
- 3. **Plain carbon steels having carbon % 0.60 to 0.80**. Drop forging dies, die blocks, bolt heading dies, self-tapping screws, valve spring, lock washers, hammers, cold chisels, hacksaws, jaws for vices etc.

HIGH CARBON STEELS

- High carbon steels **(HCS)** contain carbon from 0.8 to 1.5%. Because of their high hardness, these are suitable for wear resistant parts.
- Spring steel is also high carbon steel. It is available in annealed and pre-tempered strips and wires.
- High carbon steel loses their hardness at temperature from 200°C to 250°C.
- They may only be used in the manufacture of cutting tools operating at low cutting speeds.
- These steels are easy to forge and simple to harden.

HIGH CARBON STEELS TYPES

- **HCS containing 0.7 to 0.8% carbon** possesses hardness of 450-500 BHN. It has application for making cold chisels, drill bits, wrenches, wheels for railway service, jaws for vises, structural wires, shear blades, automatic clutch discs, hacksaws etc.
- **Steel containing 0.8 to 0.9% C** possesses hardness of 500 to 600 BHN. This steel is used for making rock drills, punches, dies, railway rails clutch discs, circular saws, leaf springs, machine chisels, music wires,
- **Steel containing 0.90 to 1.00% carbon** is also known as high carbon tool steel and it possesses hardness of 550-600 BHN. Such steel is used for making punches, dies, springs keys and shear blades.
- **Steel containing 1.0 to 1.1 % C** is used for making railway springs, mandrels, taps, balls, pins, tools, thread metal dies.
- **Steel containing 1.1 to 1.2% C** is used for making taps, twist drills, thread dies, knives.
- **Steel containing 1.2 to 1.3%** carbon is used for making files, reamers Files, dies for wire drawing, broaches, saws for cutting steel, tools for turning chilled iron

Alloy steel

- For improving the properties of ordinary steel, certain alloying elements are added in it in sufficient amounts.
- The compositional and structural changes produced by alloying elements change and improve the physical, mechanical and processing properties of steel.

Effect of alloying elements in steel

- **Nickel.** Steels contain 2 to 5% nickel and from 0.1 to 0.5% carbon increase its strength and toughness. In this range, nickel contributes great tensile strength, yield strength, toughness and forming properties and hardness with high elastic limit, good ductility and good resistance to corrosion. An alloy containing 25% nickel possesses maximum toughness and offers the greatest resistance to rusting, corrosion and burning at high temperature. It has proved beneficial in the manufacture of boiler tubes, valves for use with superheated steam, valves for I.C. engines and sparking plugs for petrol engines. A nickel steel alloy containing 36% of nickel is known as invar. It has nearly zero coefficient of expansion. Therefore, it is in great demand for making measuring instruments for everyday use.

- **Chromium.** It improves corrosion resistance (about 12 to 18% addition). It increases tensile strength, hardness, wear resistance and heat resistance. It provides stainless property in steel. It decreases malleability of steel. It is used in steels as an alloying element to combine hardness with high strength and high elastic limit. It also imparts corrosion resisting properties to steel.
- The most common chrome steels contain from 0.5 to 2% chromium and 0.1 to 1.5% carbon.
- The chrome steel is used for balls, rollers and races for bearings. A Nickel-Chrome steel containing 3.25% nickel, 1.5% chromium and 0.25% carbon is much used for armour plates.
- Chrome nickel steel is extensively used for motor car crank shafts, axles and gears requiring great strength and hardness.

- **Tungsten.** It increases hardness, wear resistance, shocks resistance and magnetic reluctance. It increases ability to retain hardness and toughness at high temperature. It prohibits grain growth and increases wear resistance, shock resistance, toughness, and the depth of hardening of quenched steel. The principal uses of tungsten steels are for cutting tools, dies, valves, taps and permanent magnets.
- 4. **Vanadium.** It improves tensile strength, elastic limit, ductility, fatigue resistance, shock resistance and response to heat treatment. It also acts as a degasser when added to molten metal. It aids in obtaining a fine grain structure in tool steel. The addition of a very small amount of vanadium (less than 0.2%) produces a marked increase in tensile strength and elastic limit in low and medium carbon steels without a loss of ductility. The chrome- vanadium steel containing about 0.5 to 1.5% chromium, 0.15 to 0.3% vanadium and 0.13 to 1.1% carbon have extremely good tensile strength, elastic limit, endurance limit and ductility. These steels are frequently used for parts such as springs, shafts, gears, pins and many drop forged parts.

- **Molybdenum.** A very small quantity (0.15 to 0.30%) of molybdenum is generally used with chromium and manganese (0.5 to 0.8%) to make molybdenum steel. It increases hardness, wear resistance, thermal resistance. When added with nickel, it improves corrosion resistance. It counteracts tendency towards temper brittleness.
- It makes steel tough at various hardness levels. It acts as a grain growth inhibitor when steels are heated to high temperatures. Molybdenum steels possesses hardness, wear resistance, thermal resistance and extra tensile strength.
- It is used for airplane fuselage and automobile parts. It can replace tungsten in high speed steels.
- **Cobalt. W**hen added to steel, it refines the graphite and pearlite and acts as a grain refiner. It improves hardness, toughness, tensile strength and thermal resistance.
- **Titanium.** It acts as a good deoxidizer and promotes grain growth. It prevents formation of austenite in high chromium steels. It is the strongest carbide former.
- It is used to fix carbon in stainless steels and thus prevents the precipitation of chromium carbide.
- 8. **Aluminium.** It is used as a deoxidizer. If present in an amount of about 1 %, it helps promoting nitriding.
- 9. **Copper.** It improves resistance to corrosion. It increases strength. More than 0.6 per cent copper for precipitation.

- **Silicon.** It improves magnetic permeability and decreases hysteresis losses. It decreases weldability and forgeability. It is also added as a deoxidizer during casting of ingots. It takes care of oxygen present in steel by forming SiO_2. Silicon steels behave like nickel steels. These steels have a high elastic limit as compared to ordinary carbon steel. Silicon steels containing from 1 to 2% silicon and 0.1 to 0.4% carbon and other alloying elements are used for electrical machinery, valves in I.C. engines, springs and corrosion resisting materials.
- 11. **Manganese.** It improves the strength of the steel in both the hot rolled and heat treated condition. The manganese alloy steels containing over 1.5% manganese with a carbon range of 0.40 to 0.55% are used extensively in gears, axles, shafts and other parts where high strength combined with fair ductility is required. The principal use of manganese steel is in machinery parts subjected to severe wear. These steels are all cast and ground to finish.
- 12. **Carbon.** It increases tensile strength and hardness. It decreases ductility and weldability. It affects the melting point.

- **Nickel steel**
- The percentage of Nickel varies from 2 to 45 in steel. Steel having 2% Ni makes steel more suitable for rivets, boiler plates, bolts and gears etc. Steel having Ni from 0.3 to 5% raises elastic limit and improves toughness. Steel containing Nickel has very high tensile strength. Steel having 25% Ni makes it stainless and might be used for I.C. engine turbine blade etc. If Ni is present up to 27%, it makes the steel non-magnetic and non-corrodible. Invar (Ni 36%) and super-invar (Ni 31%) are the popular materials for least coefficient of expansion and are used for measuring instruments, surveyor tapes and clock pendulums.
- Steel having 45% Ni steel possesses extension equal to that of glass, a property very import making links between the two materials i.e. in electronic valves and bulbs.
- **Vanadium steel**
- Vanadium when added even in small proportion to an ordinary low carbon increases significantly its elastic limit and fatigue resistance property. Vanadium makes steel strong and tough. When vanadium is added up to 0.25%, the elastic limit of the steel is raised by 50% can resist high alternating stresses and severe shocks.
- **Applications**
- 1. It is widely used for making tools.
- 2. It can also be used for shafts, springs, gears, steering knuckles and drop forged parts
- **Manganese steel**
- Manganese when added in steel between 1.0 to 1.5% makes it stronger and tougher. Manganese between 1.5 to 5% in steel makes it harder and more brittle. 11 to 14% manganese in steel with carbon 0.8 to 1.5% makes it very hard, tough, non-magnetic and possesses considerably high tensile strength. Manganese steel may be forged easily but it is difficult to machine and hence it is usually ground. It is weldable and for welding it, a nickel manganese welding rod is used.
- **Applications**
- 1. Because of work hardening, it is suitable for jaws of stone and ore crushers, grinding plants, tramway and railway points and crossing etc.
- 2. Manganese steel in the form of bars is now widely used for screening coke.
- 3. It is also used for helmets and shields.
- 4. It is used for agricultural implements such as shovels etc.

- **Tungsten Steel**
- Tungsten when added to steel improves its magnetic properties and hardenability. When tungsten is added to an extent of 6% to high carbon steel, it retains the magnetic properties to high degree and produce field more intense than ordinary steel. Steel having 8% tungsten gives sufficient hardness to it to scratch even glass.
- **Applications**
- It is used for making permanent magnets and high speed cutting tools.
- **Silicon steel**
- Silicon addition improves the electrical properties of steel. It also increases fatigue strength and ductility.
- **Applications**
- 1. Steel with Mn = 1 %, Si = 2% and C = 0.4 to 0.6% has very high elastic limit and is used for springs.
- 2. Steel containing 5 to 7% silicon retains its hardness and resistance to oxidation at high temperature. It is used for making internal combustion engines.
- 3. Steel possessing 13% Si has a very high corrosion resistance and it can be used in chemical industrial applications.
- 4. Steel possessing 1% Si and up to 0.95% Mn is suitable for structural purposes.

- **Magnetic steels**
- Steels having 15 to 40% Co, 0.4 to 1 % C, 1.5 to 9% Cr, 0-10% W and remaining Fe possesses very good magnetic properties. High Cobalt steels, when correctly heat treated, are frequently used in the making of permanent magnets for magnetos, loud speakers and other electrical machines.
- An important permanent magnet alloy called Alnico contains approximately 60% Iron, 20% Nickel, 8% Cobalt and 12% Aluminium. This alloy cannot be forged and is used as a casting hardened by precipitation heat treatment.

Spring steels

- Spring steels are used for the making springs. Various types of these steel along with their composition and uses are discussed as under.
- (*i*) **Carbon-manganese spring steels.** This type of steel contains
- C = 0.45 to 0.6, Si = 0.1 to 0.35% and Mn = 0.5 to 1.0%.
- These steels are quenched and tempered up to 350 BHN. They are widely used for laminated springs for railway and general purposes.
- (*ii*) **Hyper-eutectoid spring steels.** This type of steel contains
- C = 0.9 to 1.2%, 0.3% (max) and Mn = 0.45 to 0.70%.
- These steels are oil quenched and tempered at low temperature. This type of steel is used for volute and helical springs.
- (*iii*) **Silicon-manganese spring steels.** This type of steel contains
- C = 0.3 to 0.62%, Si = 1.5 to 2% and Mn = 0.6 to 1 %.
- These steels are hardened and tempered. This type of steel is used for the manufacturing of railway and road springs generally.

Structural steels

- Structural steels possess high strength and toughness, resistance to softening at elevated temperatures and enough resistance to corrosion. In addition, they should possess weldability, workability and high hardenability. The principal alloying elements in structural steels are chromium, nickel and manganese. These steels has various applications which are given as under:
- **Applications**
- They are used for structural members of bridges, buildings, rail road, cars etc.
- They are also used for manufacturing components subjected to static and dynamic loads. These components include valves, pins, studs, gears, clutches, bushes, shafts etc.

Stainless steel

- Stainless steel contains chromium together with nickel as alloy and rest is iron. It has been defined as that steel which when correctly heat treated and finished, resists oxidation and corrosive attack from most corrosive media. Stainless steel surface is responsible for corrosion resistance. Minimum chromium content of 12% is required for the film's formation, and 18% is sufficient to resist the most severe atmospheric corrosive conditions. Their principal alloying element is chromium while some other elements like nickel, manganese etc. can also be present in small amounts.
- Addition of nickel improves ductility and imparts strength.
- Corrosion resistance to stainless steels increases with increase in nickel content against neutral chloride solution and weakly oxidizing acids.
- Addition of molybdenum improves its resistance to sulphuric, sulphurous and organic acids.
- Addition of manganese increases hot workability of these steels.
- Steels having 15 to 20% Ni and about 0.1 % carbon possesses great strength and toughness and extremely good resistance to corrosion. Such steels are called stainless steels.
- Another type of stainless steel containing 11 to 14% chromium and about 0.35% carbon is used for cutlery, surgical and dental instruments and other purposes where hard edges are required.
- Maximum resistance to corrosion is obtained when this steel is ground and polished after heat-treating.

- **General Properties of Stainless Steels**
- It possesses wide range of strength and hardness, high ductility, formability, high corrosion resistance, good creep resistance, good thermal conductivity, good machinability, good weldability, high hot, cold workability, high resistance to scaling and oxidation at elevated temperatures, excellent surface appearance and finish.
- **Classification of Stainless Steel**
- On basis of their structure, stainless steels are classified as follow:
- 1. Martensitic stainless steels
- 2. Ferritic stainless steels
- 3. Austenitic stainless steels.

- **Martensitic Stainless Steels**
- These steels contain 12 to 16% chromium and 0.1 to 1.2 per cent carbon. The structure consists of hard martensite phase after hardening. The general utility chromium stainless steel with 12% chromium and 0.15% carbon are ferromagnetic and air hardening. It is very hard and possesses high strain and high corrosion resistance properties.
- **Applications**
- Stainless steels containing 12 to 14% chromium and 0.3% carbon are extensively used for table cutlery, tools and equipments etc. Stainless steels containing 16-18% chromium and 0.2% carbon are used as springs, ball bearing, valves, knife blades and instruments under high temperature and corrosive conditions. These steels are generally used for making utensils, surgical and dental instruments, and springs of high temperature operations, ball valves and toilet seats.
- **Ferritic Stainless Steels**
- Ferritic stainless steels are non hardenable and contain 16 to 30% chromium and 0.08 to 0.2 per cent carbon. Structure of these steel consists of ferrite phase which cannot be hardened by heat treatment. They have very low carbon and possess considerable ductility, ability to be worked hot or cold, excellent corrosion resistance and are relatively in expensive.
- They are always magnetic and retain their basic microstructure up to the melting point

- **Applications**
- These are extensively used for kitchen equipment, diary machinery interior decorative work, automobile trimmings, chemical engineering industry, stainless steel sinks, food containers, refrigerator parts, beer barrels, automobile trimming etc. These are also used as high temperature furnace parts when chromium content is high.
- **Austenitic Stainless Steel**
- Addition of substantial quantities of Ni to high Cr alloys gives rise to, austenitic steel.
- It has good resistance to many acids (even hot or cold nitric acid). Slight amount of W and Mo are added in such steels to increase its strength at elevated temperatures. This steel contains 16 to 24% Cr, 8 to 22% Ni and less than 0.2% C. Addition of nickel stabilizes austenite, and hence the structure of these steels consists of austenite at room temperature. A steel containing 18% Cr and 8% Ni is very widely used and is commonly referred to as 18/8 stainless steel. These steels do not harden by heat treatment but can be rolled hard. These steels possess a brilliant luster when polished. These are highly resistant to many acids even nitric acids. The heat conductivity of steel is low, about 5% that of copper. Tungsten and molybdenum are added to increase the strength at elevated temperatures, silicon and aluminium to improve the resistance to scaling and selenium and sulphur are added to improve machinability. This steel is easily weldable. After welding, it is susceptible to corrosive attack in the area adjacent to the weld.
- **Applications**
- It is used for making heat exchangers, conveyors chains, furnaces, spokes, brewery, dairy and chemical industrial components, cutlery parts, surgical and dental instruments, household appliances such as kitchen utensils, sinks and saucepans. These are also used in making components in power stations, especially in nuclear power stations, steam pipes, boiler tubes, radiator and super heater tubes.

High speed steels

- High speed steels cutting tools operate at cutting speed 2 to 3 times higher than for High carbon steels.
- **High speed steel (18:4:1)**
- High speed steels (HSS) are most commonly operated as cutting tools at much higher speed i.e. twice or thrice where as tool steel. It is the most common kind of cutting tool. It contains 18% tungsten, 4% chromium and 1 % vanadium, 0.8 carbon and remaining iron. It is considered to be one of the best of all purpose tool steels.
- This brand of high speed steel is used for machining operations on steel and non-ferrous materials.
- This is generally used for lathe, planer and shaper tools, drills, millings cutters, punches etc.
- **2. Molybdenum based high speed steel**
- It contains 6% Mo, 6% W, 4% Cr, 2% V, 0.8% C and remaining Fe. It has excellent toughness and cutting ability. Molybdenum high speed steels are cheaper than other types of steels and are particularly used for drilling and tapping tools. These steels are also used for making rough cutting tools, lathe tools and various kinds of milling cutters.

- **3. Cobalt based high speed steel**
- It contains 1 to 12% Co, 20% W, 4% Cr, 2% V, 0.8 carbon and remaining iron. This is also known as super high speed steel, because cutting tool made of this steel can be operated at much higher speeds in comparison to high speed steel of 18:4:1 kind. In this steel, cobaltis added from 2 to 15 per cent in order to increase the cutting efficiency especially at high temperature. Cobalt high speed steel generally contains 20% W, 4% Cr, 2% V and 12% Co and remaining Fe.
- Since the cost of this steel is more, therefore, it is principally used for making cutting tools for heavy operations which impose high pressure and temperature on the tool.
- It is extensively used for making high production tools of heavy work for high production lathe, planer, shaper, milling and boring machine
- **Vanadium High Speed Steel**
- Generally, this steel contains more than 1% V and 0.70% C. This steel possesses better abrasive resistance in comparison to normal HSS type steel.
- It is preferred for machining materials which are highly difficult to machine by conventional means.
- These steels cutting tools are close competitors of carbides cutting tools such as drills, reamers, milling cutters etc.
- In addition to having heat resistance properties of high speed steels possesses desirable properties of high hardness, high compressive strength and outstanding wear resistance.

NON-FERROUS MATERIALS

- ALUMINIUM: It is a white metal produced by electrical processes from the oxide (alumina) which is prepared from clay mineral called bauxite. Bauxite is hydrated aluminium oxide.
- It is found in India in the states of Bihar and Madhya Pradesh.
- **Manufacture**
- The bauxite is purified and then dissolved in fused cryolite (double fluoride of aluminium and sodium). The aluminium is then separated from this solution by electrolysis at about 910°C.
- **Properties**
- Pure aluminium has silvery color and lusture. It is ductile, malleable and very good conductor of heat and electricity. It has a very high resistance to corrosion than the ordinary steel. Its specific gravity is 2.7 and melting point is 658°C. Its tensile strength varies from 95 to 157 MN/m2. In proportion to its weight it is quite strong. In its pure state the metal would be weak and soft for most purposes, but when mixed with small amounts of other alloys, it becomes hard and rigid. It may be blanked, formed, drawn, turned, cast, forged and die cast.
- Its good electrical conductivity is an important property and is broadly used for overhead cables. It forms useful alloys with iron, copper, zinc and other metals.

Applications

- It is mainly used in aircraft and automobile parts where saving of weight is an advantage.
- The high resistance to corrosion and its non-toxicity make it a useful metal for cooking utensils under ordinary conditions.
- Aluminium metal of high purity has got high reflecting power in the form of sheets and is, therefore, widely used for reflectors, mirrors and telescopes.
- It is used in making furniture, doors and window components, rail road, trolley cars, automobile bodies and pistons, electrical cables, rivets, kitchen utensils and collapsible tubes for pastes.
- Aluminium foil is used as silver paper for food packing etc. In a finely divided flake form, aluminium is employed as a pigment in paint.
- It is a cheap and very important non ferrous metal used for making cooking utensils.

Aluminium alloys- Duralumin

- It is an important wrought alloy. Its composition contains following chemical contents.
- Copper = 3.5-4.5%
- Manganese = 0.4-0.7%
- Magnesium = 0.4-0.7%
- Aluminium = 94%

- **Properties**
- Duralumin can be very easily forged, casted and worked because it possesses low melting point. It has high tensile strength, comparable with mild steel combined with the characteristics lightness of Al.
- It however possesses low corrosion resistance and high electrical conductivity.
- This alloy possesses higher strength after heat treatment and age hardening. After working, if this alloy is age hardened for 3 or 4 days. This phenomenon is known as age hardening. It hardens spontaneously when exposed to room temperature. This alloy is soft enough for a workable period after it has been quenched.
- It is light in weight as compared to its strength in comparison to other metals. It can be easily hot worked at a temperature of 500°C.
- However after forging and annealing, it can also be cold worked.
- **Applications**
- Duralumin is used in the wrought conditions for forging, stamping, bars, sheets, tubes, bolts, and rivets.
- Due to its higher strength and lighter weight, this alloy is widely used in automobile and aircraft components.
- To improve the strength of duralumin sheet, a thin film of Al is rolled along with this sheet. Such combined sheets are widely used in air-craft industries. It is also employed in surgical and orthopedic work, non-magnetic work and measuring instrument parts constructing work.

COPPER

- Copper is one of the most widely used non-ferrous metals in industry. It is extracted from ores of copper such as copper glance, copper pyrites, melachite and azurite. Copper ores are found in the state of Sikkim and Bihar of India and Bharma.
- **Manufacture**
- Copper ore is first ground and then smelted in a reverberatory or small blast furnace for producing an impure alloy. Then the air is blown through the molten metal to remove sulphur and iron contamination to obtain blister copper in the converter. Copper is then refined further using electrolysis processes.

- **Properties**
- Pure copper is soft, malleable and ductile metal with a reddish-brown appearance.
- It is a good conductor of electricity.
- It is non-corrosive under ordinary conditions and resists weather very effectively.
- Its tensile strength varies from 300 to 470 MN/m2 and melting point is 1084°C. It is one of the best conductors of heat and it is highly resistant to corrosion.
- This non ferrous metal can withstand severe bending and forging without failure.
- It does not cast well. If copper is heated to red heat and cooled slowly it becomes brittle, but if cooled rapidly it becomes soft, malleable and ductile. It can be welded at red heat.
- **Applications**
- Copper is mainly used in making electric cables and wires for electric machinery, motor winding, electric conducting appliances, and electroplating etc. It can be easily forged, casted, rolled and drawn into wires. Copper in the form of tubes is used widely in heat transfer work. mechanical engineering field.
- It is used for household utensils.
- It is also used in production of boilers, condensers, roofing etc.
- It is used for making useful alloys with tin, zinc, nickel and aluminium. It is used to form alloys like brass, bronze and gun metal.
- Alloys of copper are made by alloying it with zinc, tin, and lead and these find wide range of applications.
- Brass, which is an alloy of copper and zinc, finds applications in utensils, household fittings, decorative objects, etc. Bronze is an alloy of copper and tin and possesses very good corrosion resistance. It is used in making valves and bearings.

Copper alloys

- 1. Copper-zinc alloys (Brasses)
  2. Copper-tin alloys (Bronzes)
- **Brasses**
- Brasses are widely used alloy of copper (main constituent) and zinc. They also contain small amounts of lead or tin or aluminium. The most commonly used copper-zinc alloy is brass. There are various types of brasses, depending upon the proportion of copper and zinc.
- **Alpha Phase**
- If the copper crystal structure is face centered cubic (FCC), there will be up to 36% of zinc. This solid solution is known as alpha brass. It has good mechanical properties, good corrosion resistance but it possesses lower electrical conductivity than copper.
- **Beta Phase**
- If the amount of zinc increases beyond 36%, beta brass will appear in the microstructure of the slowly cooled brass. This has body centered cubic structure (BCC). This phase is hard but quite tough at room temperature.
- **Gamma Phase**
- When zinc content is increased in brass beyond 45%, then gamma phase is appeared in its structure. This structure is extremely brittle, rendering an alloy which makes it unsuitable for general engineering purposes.

- **Red Brass :** Red brass is an important material used for heat conducting purposes. It contains
- Cu = 85%
- Zn = 15%.
- **Properties**
- Red brass is having excellent corrosion resistance and workability. It possesses tensile strength ranging from 27-31 kg/mm 2. Percentage elongation of this brass is 42-48.
- **Applications**
- Red brass is mainly utilized for making, heat exchanger tubes, condenser, radiator cores, plumbing pipes, sockets, hardware, etc.
- **Yellow Brass or Muntz Metal**
- Yellow brass is also known as muntz metal. It contains
- Cu = 60%
- Zn = 40%
- Muntz metal is having high strength and high hot workability. It is having tensile strength 38 Kg/mm2 (approximately). The percentage elongation of this brass is 45%.
- **Applications**
- Yellow brass or muntz metal is suitable for hot working by rolling, extrusion and stamping.
- It is utilized for making small various components of machine and electrical equipment such as bolts, rods, tubes, valves and fuses. This metal is utilized for making for pump parts, valves, taps, condenser tubes, sheet form for ship sheathing (because of excellent corrosion resistance).

- **Cartridge Brass**
- It contains 70% Cu and 30% Zn. It is having good combination of strength and ductility.
- It is having tensile strength between 31-37 kg/mm2. Percentage elongation of this brass is 55-66%. It is generally processed into rolled sheets.
- The metal alloy can be easily cold worked using cold working processes such as wire drawing, deep drawing and pressing.
- **Applications**
- It is utilized for making for making tubes, automotive radiator cores, hardware fasteners, rivets, springs, plumber accessories and in tube manufacture.
- **Admiralty Brass**
- It contains Cu = 71%
- Zn = 29%
- Sn = 1%
- **Properties**
- 1. Admiralty brass is highly resistant to corrosion.
- 2. It is highly resistant to impingement attack of sea water.
- 3. It is having tensile strength 30 kg/mm2 (approx.).
- 4. It can be cold worked
- 5. It possesses good corrosion resistance to sea water corrosion.
- 6. The percentage elongation of admiralty brass is 65%.
- **Applications**
- Admiralty brass is utilized for making condenser tubes in marine and other installations.
- It is used for making plates used for ship building. It is utilized also for making bolts, nuts, washers, condenser plant and ship fittings parts, etc.

- **Naval Brass**
- Navel brass is commonly used for making marine components. It contains
- Cu = 59% Zn = 40% Sn = 1%
- **Properties**
- Properties of naval brass are similar to muntz metal. As 1% zinc is replaced by 1% tin in Muntz metal to make navel brass, corrosion resistance of this material to sea water is significantly improved. The percentage elongation of navel brass is 47% and its tensile strength is 38 kg/mm2 (approx.).
- **Applications**
- Navel brass is commonly utilized for making marine hardware casting, piston rods, propeller shafts, welding rods etc.
- **5.3.1.6 Manganese Brass**
- Manganese brass is sometimes also called manganese bronze. It contains
- Cu = 60%
- Zn = 38%
- Mn = 0.5%
- Fe = 1.0%
- Sn = 0.5%
- **Properties**
- Manganese brass possesses sufficient toughness and good corrosion resistance. It is very active in reducing the oxides of other metals.
- **Applications**
- Manganese brass is utilized for making hydraulic rams, valves and cylinders, tubes, pump rods, propellers, bolts, nuts etc.

- **Iron Brass or Delta Metal**
- Iron brass or delta brass contains
- Cu = 60%
- Zn = 37%
- Fe = 3%
- Iron brass or delta metal is hard, strong, tough, and having good corrosion resistance.
- It can be casted easily.
- **Applications**
- If corrosion is to be resisted in mild steel, then some amount of iron brass or delta metal is added in mild steel.

- **Gilding Brass**
- Gilding brass is a very cheap metal for making jewellery, decorative and ornamental products. It generally contains
- Cu = 85% Zn = 15%
- **Applications**
- Because of better appearance this metal is commonly used for jewellery, decorative and ornamental work.
- **Free Cutting Brass**
- Free cutting brass contains
- Cu = 57.5% Zn = 40% Pb = 2.5%
- Free cutting brass is highly machinable and it does not allow bending.
- **Applications**
- Free cutting brass is used for making cast, forged or stamped blanks to be used for further machining such as high speed turning and screwing.
- **Lead Brass**
- Lead brass is also known as cloak brass which contains
- Cu = 65% Zn = 34% Pb = 1%
- **Applications**
- Lead brass or cloak brass is used in making small gears and pinions for clock work.

- **Bronzes**
- Bronze is a common alloy of copper and tin. The alloys of copper and tin are generally termed
- as bronzes. The wide range of composition of these alloys comprise of 75 to 95% copper and
- 5 to 25% tin.
- **Properties of bronzes**
- Bronze has higher strength, better corrosion resistance than brasses. It is comparatively hard and resists surface wear and can be shaped or rolled into wire, rods and sheets very easily. It has antifriction or bearing properties. Bronze is costlier than brass.
- The tensile strength of bronze increases gradually with the amount of tin, reaching a maximum when tin is about 20%. However the percentage of tin content if increases beyond this amount, the tensile strength decreases very rapidly.
- Bronze is most ductile when it contains about 5% of tin. As the amount of tin increases about 5%, the ductility gradually decreases and practically disappears with about 20% of tin. Whereas presence of zinc in the bronze increases fluidity of molten metal, strength and ductility.

Types of Bronzes

- **Phosphor Bronze**
- When bronze contains phosphorus in very small amount, then phosphor bronze is produced.
- A common type of phosphor bronze has the following composition.
- Cu = 89 to 94%
- Sn = 6 to 10%
- P = 0.1 to 0.3%
- **Properties**
- Tensile strength, ductility, elasticity, soundness of castings, good wearing quality and resistance to fatigue of phosphor bronze increases with increase of phosphorus in bronze.
- This material possesses good corrosion resistance especially for sea water, so that it is much used for propeller blades.
- Phosphor bronze of proper composition can be easily casted, forged, drawn, and cold rolled.
- **Applications**
- Phosphorus bronze is used making for bolts, electric contact springs, bearings, bushes, gears, ship sheathing, valve parts, propeller blades, worm wheels, gears, nuts for machine lead screws, pump parts, linings and for many other purposes.
- It is also suitable for making springs and corrosion resistance mine cables

- **Silicon bronze**
- Silicon bronze contains
- Cu = 96%
- Si = 3%
- Mn or Zn = 1%
- Silicon bronze has good general corrosion resistance of copper combined with higher strength. It can be cast, rolled, stamped, forged and pressed either hot or cold and it can be welded by all the usual methods.
- **Applications**
- Silicon bronze is widely used for making boilers, tanks, stoves or where high strength and good corrosion resistance is required. It is used also for making screws, tubing’s, pumps etc.
- **Beryllium bronze**
- Beryllium bronze is a copper base alloy contains
- Cu = 97.5%
- Br = 2.5%
- Beryllium bronze possesses higher tensile strength than other bronzes. It possesses excellent corrosion resistance. It is having high yield point and high fatigue limit. It is having good hot and cold resistance. This can be heat treated by precipitation hardening. It possesses excellent formability in soft condition, and high fatigue and creep resistance in hardened condition. However it involves high cost.
- **Applications**
- Beryllium bronze is particularly suitable material for making springs, tubes, diaphragms and electrical contacts, heavy duty electrical switches, cams and bushings. This is used for springs, heavy duty electrical switches, cams and bushings.
- Having non-sparking characteristics, it is used for making chisels and hammers using for such conditions where spark might cause explosion. It has a film forming and a soft lubricating property, which makes it more suitable as a bearing metal. Since the wear resistance of beryllium copper is five times that of phosphorous bronze, therefore it is used as a bearing metal in place of phosphor bronze.

- **Manganese bronze**
- Manganese bronze is an alloy of copper, zinc and little percentage of manganese. The usual composition of this bronze is
- Copper = 60%
- Zinc = 35%
- Manganese = 5%
- Manganese bronze is highly resistant to corrosion. It is stronger and harder than phosphor bronze.
- **Applications**
- Manganese bronze is mainly used for bushes, plungers, feed pumps, rods etc. Worm gears are frequently made from this bronze.
- **Aluminium Bronze**
- Aluminium bronze possesses
- Cu = 85 to 88%
- Al = 8 to 11%
- Fe = 3%
- Sn = 0.5%
- **Properties**
- The aluminium bronze with 8% aluminium possesses very good cold working properties.
- When iron is added to this metal, its mechanical properties are greatly improved by refining the grain size and improving the ductility. The maximum tensile strength of this alloy is 450 MPa with 11 % aluminium. This material possesses good resistance to corrosion and it is somewhat difficult to cast due to oxidation problem.
- **Applications**
- Aluminium bronze is generally used for making fluid connection fittings, gears, propellers, air pumps, bushings, tubes, slide and valves etc. Cams and rollers are commonly produced using this alloy.

- **Bell Metal**
- Bell metal generally contains
- Cu = 66.7%
- Sn = 33.3%
- Bell metal is very strong. It possesses resistance to corrosion water and atmosphere. It is used to make bells.
- **Constantan**
- The composition of constantan is
- Cu = 55%
- Ni = 45%
- **Properties**
- (*i*) Constantan is high specific resistance
- (*ii*) Specific resistance is unaffected by temperature variation.
- **Applications**
- Constantan is used for accurate resistors like thermo-couples,
- (*i*) Wheet-stone bridge,
- (*ii*) Low temperature heaters and
- (*iii*) Resistances

SPECIAL PURPOSE CASTING

Centrifugal casting

Centrifugal casting or **rotocasting** is a casting technique that is typically used to cast thin-walled cylinders. It is typically used to cast materials such as metals, glass, and concrete. A high quality is attainable by control of metallurgy and crystal structure. Unlike most other casting techniques, centrifugal casting is chiefly used to manufacture rotationally symmetric stock materials in standard sizes for further machining, rather than shaped parts tailored to a particular end-use.

Materials

Typical materials that can be centrifugal cast are metals, cements, concretes, glass, and pottery materials. Typical metals cast are iron, steel, stainless steels, and alloys of nickel, aluminum, and copper.
Two materials can be combined by introducing a second material during the process. A common example is cast iron pipe coated on the interior with cement.

Process for casting metal

In centrifugal casting, a permanent mold is rotated continuously at high speeds (300 to 3000 rpm) as the molten metal is poured. The molten metal spreads along the inside mold wall, where it solidifies after cooling. The casting is usually a fine-grained casting with an especially fine-grained outer diameter, due to the rapid cooling at the surface of the mold. Lighter impurities and inclusions move towards the inside diameter and can be machined away following the casting.
Casting machines may be either horizontal or vertical-axis.[1] Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings and bearings.[2]
Castings usually solidify from the outside in. This directional solidification improves some metallurgical properties. Often the inner and outermost layers are removed and only the intermediary *columnar zone* is used.[3]
Centrifugal casting was the invention of Alfred Krupp, who used it to manufacture railway tyres (cast steel tyres for railway wheels) starting in 1852.[4]

Applications

Typical parts made by this process are pipes, flywheels, cylinder liners, and other parts that are axi-symmetric. It is notably used to cast cylinder liners and sleeve valves for piston engines, parts which could not be reliably manufactured otherwise.

Features of centrifugal casting

Castings can be made in almost any length, thickness and diameter.
Different wall thicknesses can be produced from the same mold.
Eliminates the need for cores.
Good mechanical properties due to the grain structure formed by centrifugal action.
Typically cylindrical shapes are produced:
In sizes of up to 6 m (20 ft) diameter and 15 m (49 ft) length.
With a wall thickness range from 2.5 to 125 mm (0.098 to 4.921 in).
In tolerance limits of the outer diameter of 2.5 mm (0.098 in) an die inner diameter of 3.8 mm (0.15 in).
In a surface finish from 2.5 to 12.5 mm (0.098 to 0.492 in) rms.

Glass

The technique is known in the glass industry as "spinning". The centrifugal force pushes the molten glass against the mold wall, where it solidifies. The cooling process often takes between 16 and 72 hours depending on the impurities or volume of material. Typical products made using this process are television tubes and missile nose cones.[
Spin casting is also used to manufacture large telescope mirrors, where the natural curve followed by the molten glass greatly reduces the amount of grinding required. Rather than pouring glass into a mold an entire turntable containing the peripheral mold and the back pattern (a honeycomb pattern to reduce

the mass of the finished product) is contained within a furnace and charged with the glass material used. The assembly is then heated and spun at slow speed until the glass is liquid, then gradually cooled over a period of months.

Centrifugal casting is also commonly used to shape glass into spherical objects such as marbles.[

Benefits

Cylinders and shapes with rotational symmetry are most commonly cast by this technique. Long castings are often produced with the long axis parallel to the ground rather than standing up in order to distribute the effect of gravity evenly.

Thin-walled cylinders are difficult to cast by other means. Centrifugal casting is particularly suited as they behave in the manner of shallow flat castings relative to the direction of the centrifugal force.

Centrifugal casting is also used to manufacture disk and cylinder shaped objects such as railway carriage wheels or machine fittings where grain, flow, and balance are important to the durability and utility of the finished product.

Noncircular shapes may also be cast providing the shape is relatively constant in radius.

Shell Mold Casting

Shell mold casting is a metal casting process similar to sand casting, in that molten metal is poured into an expendable mold. However, in shell mold casting, the mold is a thin-walled shell created from applying a sand-resin mixture around a pattern. The pattern, a metal piece in the shape of the desired part, is reused to form multiple shell molds. A reusable pattern allows for higher production rates, while the disposable molds enable complex geometries to be cast. Shell mold casting requires the use of a metal pattern,oven,sand-resinmixture, dump box, and molten metal.

Shell mold casting allows the use of both ferrous and non-ferrous metals, most commonly using cast iron, carbon steel, alloy steel, stainless steel, aluminum alloys, and copper alloys. Typical parts are small-to-medium in size and require high accuracy, such as gear housings, cylinder heads, connecting rods, and lever arms.

The shell mold casting process consists of the following steps:

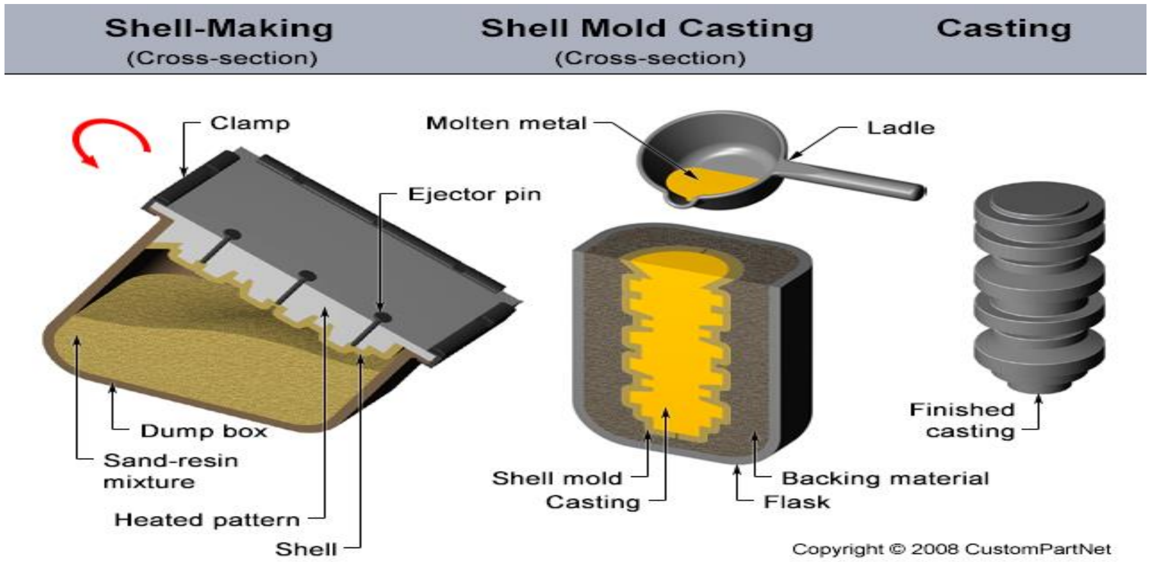
Pattern creation - A two-piece metal pattern is created in the shape of the desired part, typically from iron or steel. Other materials are sometimes used, such as aluminum for low volume production or graphite for casting reactive materials.

Mold creation - First, each pattern half is heated to 175-370°C (350-700°F) and coated with a lubricant to facilitate removal. Next, the heated pattern is clamped to a dump box, which contains a mixture of sand and a resin binder. The dump box is inverted, allowing this sand-resin mixture to coat the pattern. The heated pattern partially cures the mixture, which now forms a shell around the pattern. Each pattern half and surrounding shell is cured to completion in an oven and then the shell is ejected from the pattern.

Mold assembly - The two shell halves are joined together and securely clamped to form the complete shell mold. If any cores are required, they are inserted prior to closing the mold. The shell mold is then placed into a flask and supported by a backing material.

Pouring - The mold is securely clamped together while the molten metal is poured from a ladle into the gating system and fills the mold cavity.

Cooling - After the mold has been filled, the molten metal is allowed to cool and solidify into the shape of the final casting.
Casting removal - After the molten metal has cooled, the mold can be broken and the casting removed. Trimming and cleaning processes are required to remove any excess metal from the feed system and any sand from the mold.



Pressure Die Casting

Pressure die casting is a quick, reliable and cost-effective manufacturing process for production of high volume, metal components that are net-shaped have tight tolerances. Basically, the pressure die casting process consists of injecting under high pressure a molten metal alloy into a steel mold (or tool). This gets solidified rapidly (from milliseconds to a few seconds) to form a net shaped component. It is then automatically extracted.

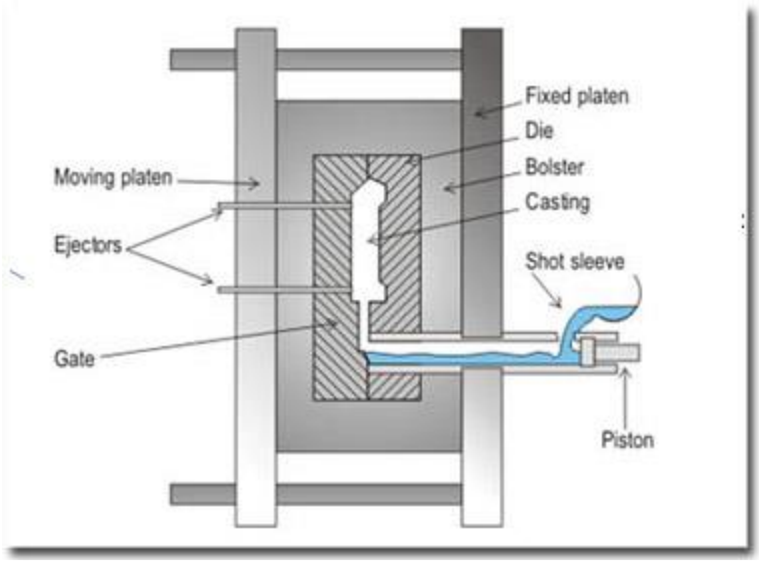
Advantages of Pressure Die Casting :

- Lower costs compared to other processes.
- Economical - typically production of any number of components from thousands to millions before requiring replacement is possible.
- Castings with close dimensional control and good surface finish
- Castings with thin walls, and therefore are lighter in weight

Types of Pressure Die Casting

High Pressure Die Casting
Here, the liquid metal is injected with high speed and high pressure into the metal mold. The basic equipment consists of two vertical platens. The bolsters are placed on these platens and this holds the die halves. Out of the two platens, one is fixed and the other movable.

High Pressure Die Casting Process



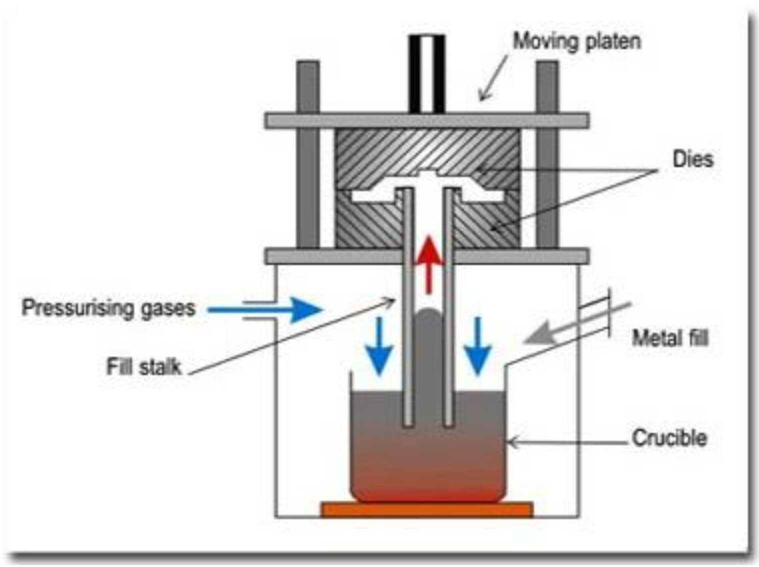
This helps the die to open and close. A specific amount of metal is poured into the shot sleeve and afterwards introduced into the mold cavity. This is done using a hydraulically-driven piston. After the metal has solidified, the die is opened and the casting eventually removed.

Low Pressure Die Casting
High quality castings, of aluminium alloys, along with magnesium and other low melting point alloys are usually produced through this process. Castings of aluminium in the weight range of 2-150 kg are a common feature.

The process works like this, first a metal die is positioned above a sealed furnace containing molten metal. A refractory-lined riser extends from the bottom of the die into the molten metal. Low pressure air (15 - 100 kPa, 2- 15 psi) is then introduced into the furnace. This makes the molten metal rise up the tube and enter the die cavity with low turbulence. After the metal has solidified, the air pressure is released . This makes the metal still in the molten state in the riser tube to fall back into the furnace. After subsequent cooling, the die is opened and the casting extracted.

With correct die design it is possible to eliminate the need of the riser also. This is because of the directional freezing of the casting. After the sequence has been established, the process can be controlled automatically using temperature and pressure controllers to oversee the operation of more than one diecasting machine.

Casting yield is exceptionally high as there is usually only one ingate and no feeders.



Application of Pressure Die Casting

Automotive parts like wheels, blocks, cylinder heads, manifolds etc.
Aerospace castings.
Electric motor housings.
Kitchen ware such as pressure cooker.
Cabinets for the electronics industry.
General hardware appliances, pump parts, plumbing parts.

CASTING DEFECTS

Casting defects are caused by an incorrect filling or solidification phase and they can be divided into two category:

Internal:

Gas porosity
Shrinkage porosity
Inclusions

Superficial:

Cold laps
Laminations
Blister
Cracks
Lakes

Internal defects

These kind of **die casting defects** are more difficult to find and are responsible for weakening component structural resistance.

GAS POROSITY

Due to fluid high speed during filling phase turbulences are generated, these turbulences can include air or other gases. During solidification phase, if gas concentration is not homogeneous inside casting, air bubbles generate cavities which weaken resistant sections of component.
These cavities are rounded and can be shiny or opaque, depending on gas type entrapped during filling phase: for example air, water or lubricant.

SHRINKAGE POROSITY

Shrinkage porosity defects are created during solidification and cooling phase of casting. They are created due to material shrinking and for this reason are widely spread in massive parts.
During solidification phase, the material tend to move near colder zones, for this reason, due to different temperature between casting surface and core, cavities are concentrated inside the part. The morphology of these cavities has an angular shape.
In some cases there is the risk of creating cavities on component surface if part and runner geometry is suitable for hot spot setting up.

INCLUSIONS

In zinc alloys intermetallic compound can be created: in particular the most common is $FeAl_3$, which is a compound of iron and aluminum.
Is important to say that these compound are tougher and have a different colour than zamak alloy: for this reason can cause problems during following phases of mechanical and finishing process.
Moreover with components under mechanical fatigue stress concentration and cracks can be created.

Superficial defects

These kind of **casting defects** are visible and worsens component surface and its aesthetical quality.

COLD LAPS

Cold laps are the most common **die casting defects**: they are caused by irregular flows and low temperatures. Cold laps include a wide selection of defects such as flow marks or lack of material. Depending on defect rate components can have a poor surface quality or in the worst case it can be incomplete.
This phenomenon is generated from matching two or more flows of material which, due to low temperature, oxide formation and dirt inclusion, flows welding is incomplete or absent.

LAMINATIONS

Laminations can be classified as part of cold laps category. They are generated from overlapping of two layers which are always separated during filling phase.
These defects are difficult to detect after die casting, while they appear after finishing or pre-finishing operations like tumbling and sand blasting. During these phases, the impact between inserts and casting causes lifting of subtle zinc layers.
In the middle of these layers other fluids and dirt of die casting process like lubricant or oil can be hidden. These substances can come out during surface treatment like painting or galvanization and worsen the outcome.

BLISTERS

During mould filling phase, air inside the mould and machine is compressed, and one part is ejected from the casting using vacuum valve, chill vent or overflows. Air remained inside the component can be dissolved inside the melted metal with an homogeneous distribution.
Due to many turbulences, air is concentrated creating high pressure cavities.
Very often, if the component does not have high temperature extra operations, this **die casting defect** is hidden and causes diminishing of component strength; otherwise in processes like powder painting where the temperature is higher, gases inside the casting expand and generate bubbles on the surface.

CRACKS

Cracks are material breakage caused by stress inside and outside the material.
The first ones are created during solidification and cooling phase: due to cavity geometry material is not allowed to shrink in its natural directions, what results is residual stress that can generate cracks inside the mould or deformations after ejection.
The second ones are caused by external forces on components: these forces can be found during parts ejection from the mould or cutting phase.

LAKES

These kind of defects are seen in aesthetical components: are caused by different solidification time of the filled metal which in some part of the casting generates a different skin from the surface. This area is fine grained and appears different from the rest.

If you want to be updated on trends and innovations in die casting industries, please subscribe to our blog; and if you have any comments or questions, please feel free to fill in the form here below.

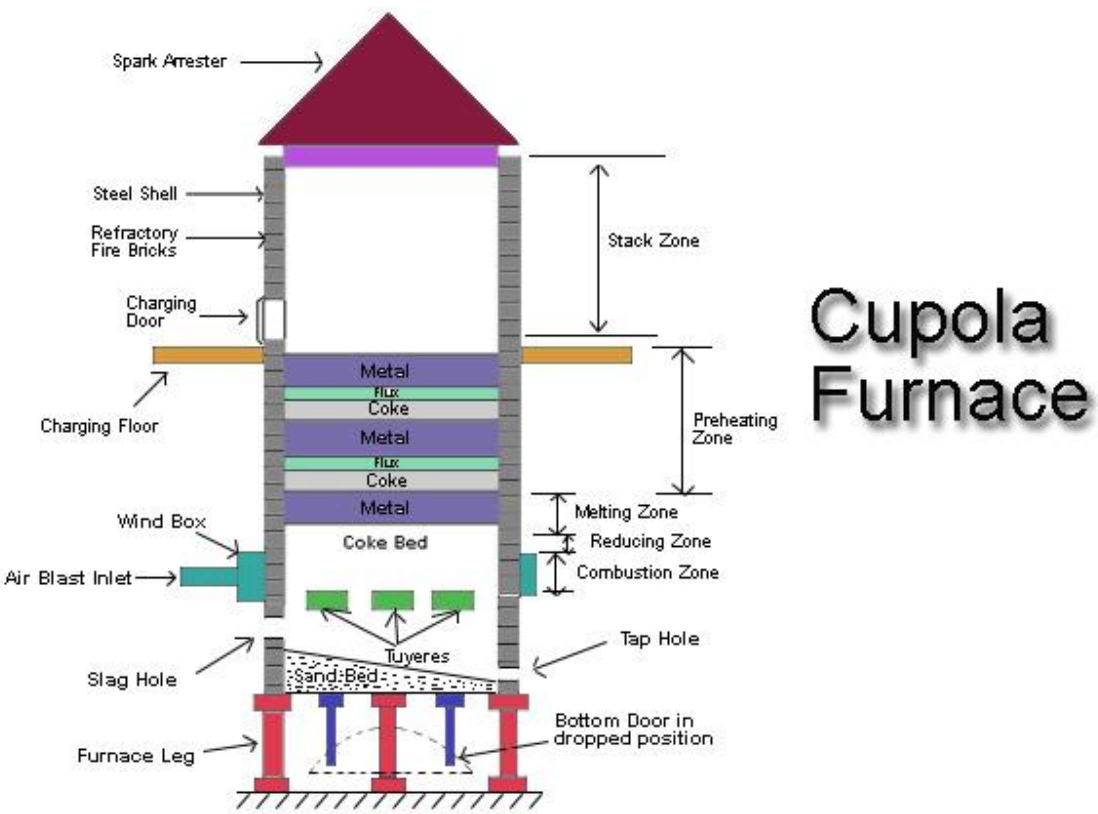
Cupola Furnace -Construction, Working and Applications

Cupola Furnace is a melting device which used to melt cast iron, Bronze and other alloying elements are melted. It is mainly used to convert pig iron to cast iron.
Cupola Furnace was first built in China in the Warring States Period (403 -221 BC).
Cupola furnace is cylindrical in shape and the equipment of this furnace is vertically fitted inside this cylindrical shell with doors.

For many years Cupola Furnace was used to melt iron in iron foundries because it produces good Cast iron from Pig Iron.

The top of the cupola furnace is sometimes fitted with a cap to prevent the escape of harmful gases to the environment and this cap also protect it from rainwater.

The cupola shell is made of steel and has a lining of refractory brick and plastic refractory patching material. The bottom of this shell is lined with clay and sand mixture and it is a temporary lining. Sometimes coal is mixed with clay lining so that when coal heats up it decomposes and the bond becomes friable.
In some cupola lining cooling jackets are also fitted to keep the sides cool. Sometimes oxygen injection are also provided to make the coke fire burn hotter.



Parts of Cupola Furnace :-

1 Cylindrical Shell:
It is the outermost part of the Cupola Furnace. It is made up of steel sheet and other parts of this furnace are present inside this shell.

1 Legs:
At the bottom of the Cupon Frunace legs are provided to support this furnace.

2 Cast Iron Door:
This cast iron is present at the bottom of the furnace above the legs which is closed by the support of the legs.

3. Sand Bed:
Above the cast iron door sand bed is present. It is in taperred form so that the melted iron can flow out easily from its top.

4. Slag Hole:
It is present at the opposite side of the hole from which melted iron comes out.It is present near the elevated part of sand bed. This slag hole is used to remove slag formed on melted iron due to impurities.

5. Air Pipes and Tuyers:
The air pipe is provided to allow the air to reach inside the furnace. Inside the furnace wind belt is present. The air entering from the air pipes reaches each part of the wind belt and in the wind belt there are holes which are called tuyers. Air reaches the furnace through this tuyers and will help in combustion.

6. Spark Arrester Or Cap Of Furnace :
It is present at the top of the furnace. When gases are released out of the furnace, some burning particles are present in it which can harm the environment. So this cap or spark arrester is used to capture the burning particles and only allow the gas to pass to the environment.

7. Charging Door :
It is present near the top of the furnace. It is used to supply charge to the furnace. The charges in this furnace are Pig Iron, Coke and Lime Stone. Coke is used for combustion, pig iron is the material that is to be melt and lime stone is used as a flux. This flux mix with impurities to form slag and this slag comes out of the slag hole.

8. Well:
The part of the furnace from the send bed to lower part of tuyers is known as Well. It is named as well as in this part molten iron is stored and then the molten iron comes out of the tapping hole.

9. Tuyers Zone:
The part of the furnace in which the wind belt and tuyers are present is known as Tuyers Zone.

10. Combustion Zone:
In this zone combustion takes place. The air coming from the tuyers contains oxygen and this oxygen reacts with carbon to form carbon dioxide. It is also known as oxidixing zone as carbon oxidizes in this zone to form carbon dioxide and liberate heat. Apart from carbon other impurities like manganese,silicon also oxidizes in this zone to form their oxides and liberate heat.

11. Reducing Zone:
It is present above the combustion or oixdizing zone. It this zone carbon reacts with carbon dioxide to form carbon monoxide. In this zone temperature is reduced by a small amount, so this zone is known as reducing zone.

12. Melting Zone:
In this zone iron melts and this molten iron comes out of the tap hole. The temperature of this zone is very high nearly 1600 degree Celcius.

13 Peheating Zone:
In this zone the metal to be melted is preheated, in this zone metal is heated to about 1090 degree celcius.

14 Stack Zone:
Gases formed in the furnace after burning passes to the environment through this zone. In this zone, spark arrester is present which prevent burning particles to reach the environment.
Construction Of Cupola Furnace :

The outermost part of cupola furnace is cylindrical steel shell. The diameter of this shell ranges from 1.5 to 13 feet depending upon the size of the furnace. The inner side of the furnace is lined with
refractory brick and plastic refractory patching material.

This furnace is supported on Cast iron legs mounted on concrete base. At the bottom of the furnace, two cast iron doors are hinged with the bed plate of the furnace. Near the bottom, it has send bed above which the melted iron flow. This sand bed is tapered. Near the elevated side of the tapered sand bed, slag hole is present through which slag formed from impurities comes out. Near the downside of the down bed, the tap hole is present through which molten iron comes out.
Above the send bed, tuyers are present through which air reaches the furnace and helps in combustion.
At the top of the furnace spark arrester or cap is present that traps the burning particles and only allow the gases to release to the environment.
Near the top of the furnace, charging door is present through which metal, coke and lime stone are fed into the furnace.

Working of Cupola Furnace :

At first wood is ignited above the sand bed. When the wood starts burning properly, coke is dumped on the well from the top to a predetermined height of nearly 40 inches. This forms a 40 inch coke bed.
Then the combustion starts in the coke bed using the fire from the burning wood and using the

air from the tuyers. At this time, the air blast is turned out at a lower blowing rate than normal to provoke the coke.
After nearly 3 hours of burning when the coke starts burning properly, alternate layers of limestone, pig iron and coke is charged until it reaches the level of charging door is reached. At this time the air blast is tuned on to normal blowing rate and the combustion occurs more rapidly in the coke bed.
All oxygen from the air blast is consumed by the combustion in the combustion zone.The chemical reaction which takes place is,
$C + O_2 \rightarrow CO_2 + \text{Heat}$
This is an exothermic reaction and in the combustion zone the temperature varies from 1150 to 1850 degree Celcius.
The portion of the coke bed above the combustion zone is reducing zone. This zone prevent the oxidation of metal charge above and while dropping through it.As the ho carbon dioxide moves up through this zone, some of it is reduced by the following reaction,
$CO_2 + C \rightarrow 2CO$
The layer of iron above reducing zone is melting zone where the solid iron is converted into molten iron.This melted iron trickles down through the coke bed and is collected in the well. Sufficient carbon comtent is picked up by the molten metal in this zone and is represented by the chemical reaction given as :-
$3\,Fe + 2\,CO \longrightarrow Fe_3C + CO_2$
Above the melting zone, there is preheating zone where the charge is preheated by the outgoing gases and the temperature of this zone is about 1900 degree Celcius.

Apart from limestone, fluorspar and soda ash are also used as flux material. Main function of flux is to remove impurities from iron and protect iron from oxidation.
Within 5 to 10 minutes of starting of air blast to normal blowing rate , the first molten iron appears at the tap hole.
The charging door is closed till the metal melts. The contents of the charge move down as the melting proceeds. The rate of charging i.e the rate of adding layers of charge is equal to the rate of melting. The furnace is kept full throughout the process.
When the melting process is finished and no more molten irons is required then the feed of charge is stopped and the air blast is also stopped. The bottom plate swings to open when the prop is removed and the slag is removed.
Normally copula furnace is not used more than 4 hours but can be used for 10 hrs of continuous operation.
Advantages of Cupola Furnace :-

- Simple in Construction.
- Wide range of material can be melted.
- Less floor space is reuired.
- Very skilled operators are not required. Can be easily operated by low skill person.

WELDING

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. The completed welded joint may be referred to as a weldment.

Some materials require the use of specific processes and techniques. A number are considered '**unweldable**,' a term not usually found in dictionaries but useful and descriptive in engineering.

The parts that are joined are known as a **parent material**. The material added to help form the join is called **filler** or **consumable**. The form of these materials may see them referred to as parent plate or pipe, filler wire, consumable electrode (for arc welding), etc.

Consumables are usually chosen to be similar in composition to the parent material, thus forming a homogenous weld, but there are occasions, such as when welding brittle cast irons, when a filler with a very different composition and, therefore, properties is used. These welds are called heterogeneous.

The completed welded joint may be referred to as a **weldment**.

How Does Welding Work?

Joining Metals

As opposed to brazing and soldering, which do not melt the base metal, welding is a high heat process which melts the base material. Typically with the addition of a filler material.

Heat at a high temperature causes a weld pool of molten material which cools to form the join, which can be stronger than the parent metal. Pressure can also be used to produce a weld, either alongside the heat or by itself.

It can also use a shielding gas to protect the melted and filler metals from becoming contaminated or oxidised.

Joining Plastics

Plastics welding also uses heat to join the materials (although not in the case of solvent welding) and is achieved in three stages.

Firstly, the surfaces are prepared before heat and pressure is applied and, finally, the materials are allowed to cool to create fusion. Joining methods for plastics can be separated into external or internal heating methods, depending on the exact process used.

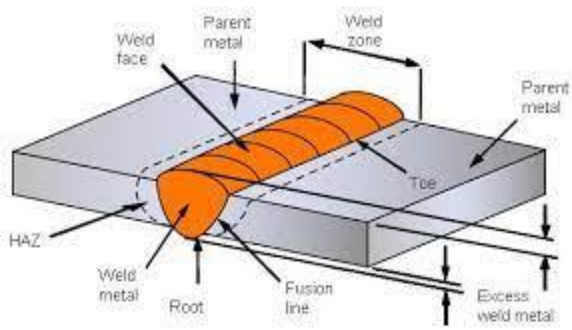
Joining Wood

Wood welding uses heat generated from friction to join the materials. The materials to be joined are subjected to a great deal of pressure before a linear friction movement creates heat to bond the workpieces together.

This is a fast process which allows wood to be joined without adhesives or nails in a matter of seconds.

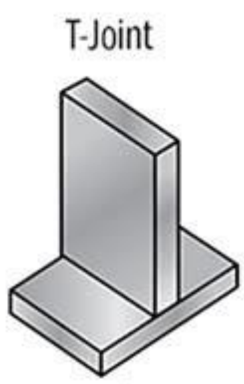
Common Joint Configurations

Butt Joint



A connection between the ends or edges of two parts making an angle to one another of 135-180° inclusive in the region of the joint.

T Joint

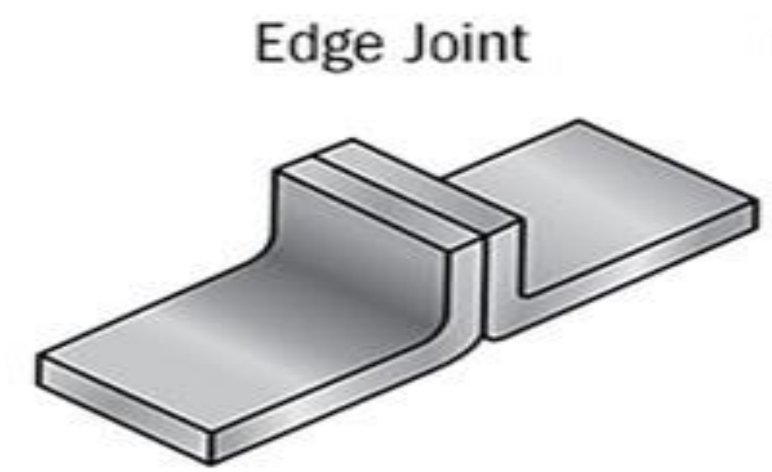


A connection between the end or edge of one part and the face of the other part, the parts making an angle to one another of more than 5 up to and including 90° in the region of the joint.

Corner Joint

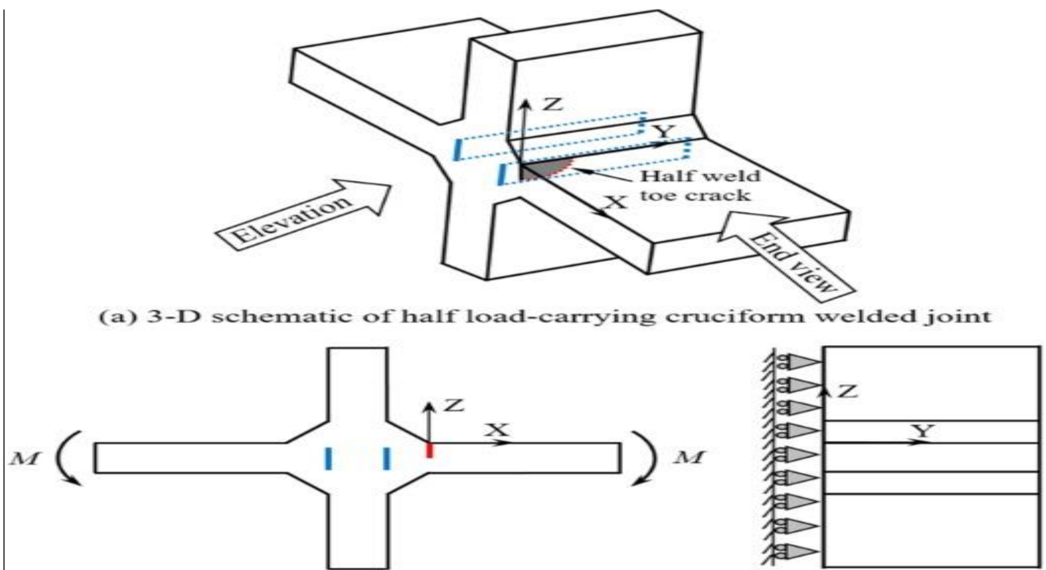
A connection between the ends or edges of two parts making an angle to one another of more than 30 but less than 135° in the region of the joint.

Edge Joint



A connection between the edges of two parts making an angle to one another of 0 to 30° inclusive in the region of the joint.

Cruciform Joint



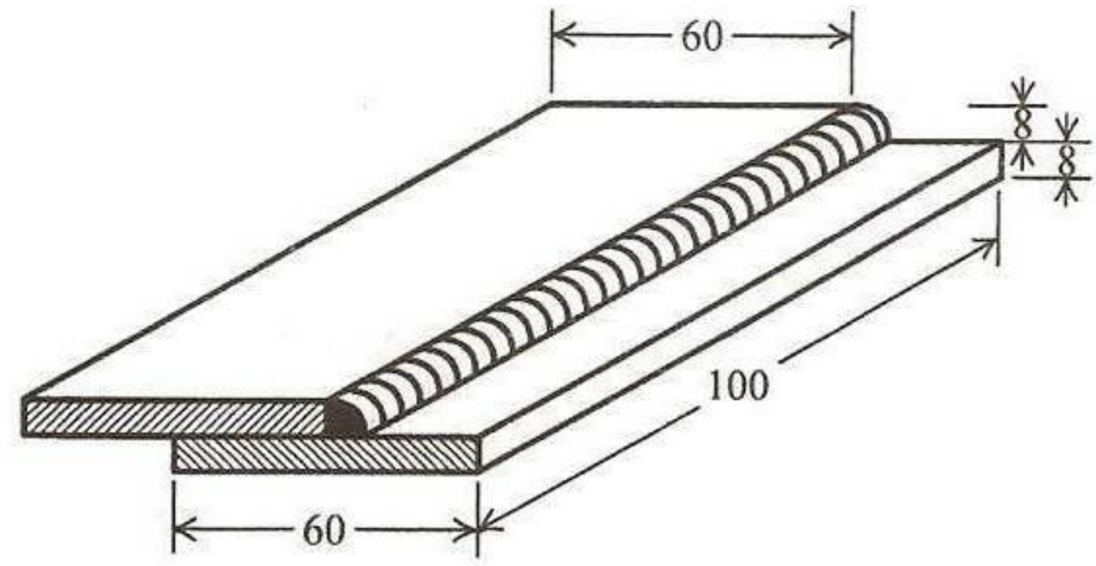
(a) 3-D schematic of half load-carrying cruciform welded joint

(b) Elevation

(c) End view

A connection in which two flat plates or two bars are welded to another flat plate at right angles and on the same axis.

Lap Joint

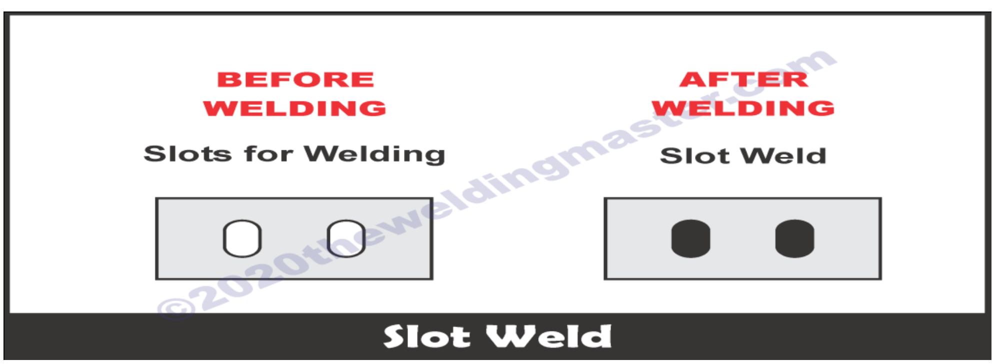


A connection between two overlapping parts making an angle to one another of 0-5° inclusive in the region of the weld or welds.

Types of Welding Joints

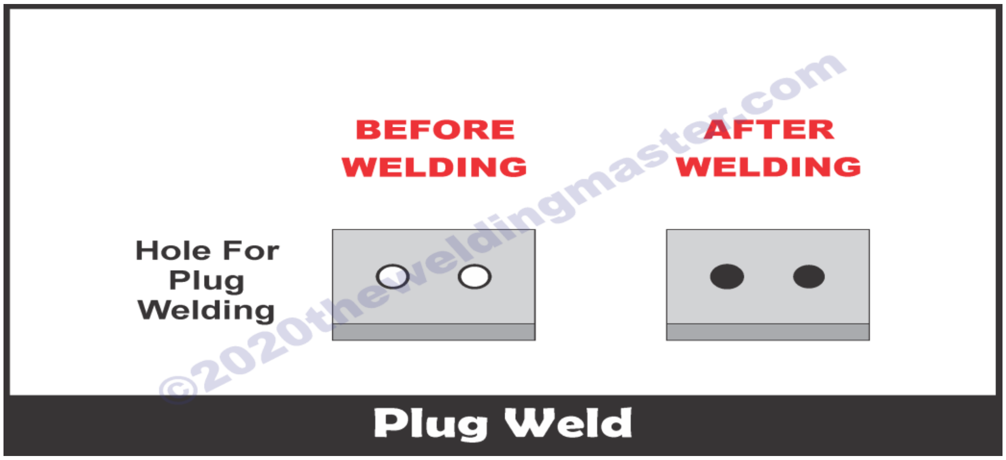
Welds Based on Configuration

Slot weld



Joint between two overlapping components made by depositing a fillet weld around the periphery of a hole in one component so as to join it to the surface of the other component exposed through the hole.

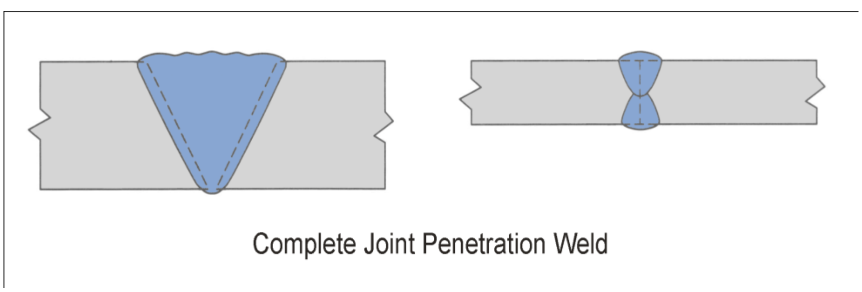
Plug weld



Weld made by filling a hole in one component of a workpiece with filler metal so as to join it to the surface of an overlapping component exposed through the hole (the hole can be circular or oval).

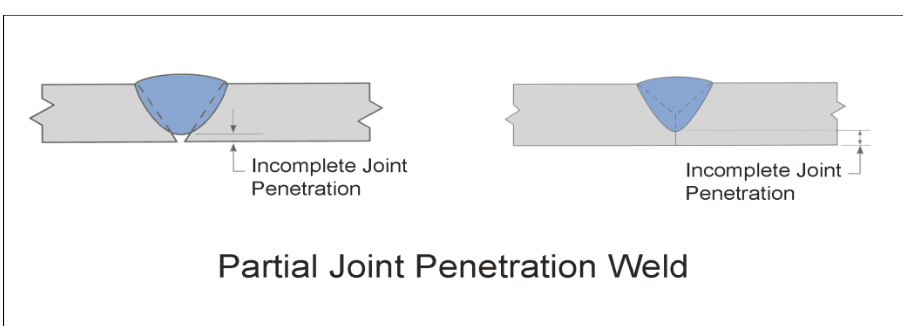
Based on Penetration

A:- Full penetration weld



Welded joint where the weld metal fully penetrates the joint with complete root fusion. In US the preferred term is complete joint penetration weld (CJP, see AWS D1.1).

B:- Partial penetration weld



Weld in which the fusion penetration is intentionally less than full penetration. In the US the preferred term is partial joint penetration weld (PJP).

WELDING TERMINOLOGY

Parent Metal

Metal to be joined or surfaced by welding, braze welding or brazing.

Filler Metal

Metal added during welding, braze welding, brazing or surfacing.

Weld Metal

All metal melted during the making of a weld and retained in the weld.

Heat Affected Zone (HAZ)

The part of the parent metal metallurgically affected by the weld or thermal cutting heat, but not melted.

Fusion Line

Boundary between the weld metal and the HAZ in a fusion weld. This is a non-standard term for weld junction.

Weld Zone

Zone containing the weld metal and the HAZ.

Weld Face

The surface of a fusion weld exposed on the side from which the weld has been made.

Weld Root

Zone on the side of the first run furthest from the welder.

Weld Toe

Boundary between a weld face and the parent metal or between runs. This is a very important feature of a weld since toes are points of high stress concentration and often they are initiation points for different types of cracks (eg fatigue cracks, cold cracks).

In order to reduce the stress concentration, toes must blend smoothly into the parent metal surface.

Excess Weld Metal

Weld metal lying outside the plane joining the toes. Other non-standard terms for this feature: reinforcement, overfill.

Note: the term reinforcement, although commonly used, is inappropriate because any excess weld metal over and above the surface of the parent metal does not make the joint stronger.

In fact, the thickness considered when designing a welded component is the design throat thickness, which does not include the excess weld metal.

Run (pass)

The metal melted or deposited during one passage of an electrode, torch or blowpipe.

Layer

Stratum of weld metal consisting of one or more runs.

Energy Sources

Different processes are determined by the energy source used, with a variety of different techniques available.

Until the end of the 19th century, forge welding was the only method used, but later processes, such as arc welding, have since been developed. Modern methods use gas flame, electric arc, lasers, electron beam, friction and even ultrasound to join materials.

Care needs to be taken with these processes as they can lead to burns, electric shock, damaged vision, exposure to radiation or inhaling of poisonous welding fumes and gases.

What are the Different Welding Types and What are They Used for?

There are a variety of different processes with their own techniques and applications for industry, these include:

Arc

This category includes a number of common manual, semi-automatic and automatic processes. These include metal inert gas (MIG) welding, stick welding, tungsten inert gas (TIG) welding also know as gas tungsten arc welding (GTAW), gas welding, metal active gas (MAG) welding, flux cored arc welding (FCAW), gas metal arc welding (GMAW), submerged arc welding (SAW), shielded metal arc welding (SMAW) and plasma arc welding.

These techniques usually use a filler material and are primarily used for joining metals including stainless steel, aluminium, nickel and copper alloys, cobalt and titanium. Arc welding processes are widely used across industries such as oil and gas, power, aerospace, automotive, and more.

Friction

Friction welding techniques join materials using mechanical friction. This can be performed in a variety of ways on different welding materials including steel, aluminium or even wood.

The mechanical friction generates heat which softens the materials which mix to create a bond as they cool. The manner in which the joining occurs is dependant on the exact process used, for example, friction stir welding (FSW), friction stir spot welding (FSSW), linear friction welding (LFW) and rotary friction welding (RFW).

Friction welding doesn't require the use of filler metals, flux or shielding gas.

Friction is frequently used in aerospace applications as it is ideal for joining otherwise 'non-weldable' light-weight aluminium alloys.

Friction processes are used across industry and are also being explored as a method to bond wood without the use of adhesives or nails.

Electron Beam

This fusion joining process uses a beam of high velocity electrons to join materials. The kinetic energy of the electrons transforms into heat upon impact with the workpieces causing the materials to melt together.

Electron beam welding (EBW) is performed in a vacuum (with the use of a vacuum chamber) to prevent the beam from dissipating.

There are many common applications for EBW, as can be used to join thick sections. This means it can be applied across a number of industries from aerospace to nuclear power and automotive to rail.

Laser

Used to join thermoplastics or pieces of metal, this process uses a laser to provide a concentrated heat ideal for barrow, deep welds and high joining rates. Being easily automated, the high welding speed at which this process can be performed makes it perfect for high volume applications, such as within the automotive industry.

Laser beam welding can be performed in air rather than in a vacuum such as with electron beam joining.

Resistance

This is a fast process which is commonly used in the automotive industry. This process can be split into two types, resistance spot welding and resistance seam welding.

Spot welding uses heat delivered between two electrodes which is applied to a small area as the workpieces are clamped together.

Seam welding is similar to spot welding except it replaces the electrodes with rotating wheels to deliver a continuous leak-free weld.

26 ESSENTIAL WELDING TOOLS AND EQUIPMENTS

Welding Tools

The common welding tools used for gas welding purposes are as follows:

1. Spanner

Spanners are generally used for tightening or loosening various fasteners. These are designed with drop-forge steel or carbon steel. But in welding, a double-ended spanner is used for tightening and opening the nuts of the welding apparatus and job.

2. Hammer

Welding hammers are essential tools used for chipping to remove slab-coating from the weld area. It is used for shaping the job. Normally a 500 grams hammer is used for the purpose. There are three types of hammers – ball pane, cross pane, and straight one. For large-sized jobs, a Sledgehammer may be used.

3. Pliers

Welding pliers are specially designed to effectively remove welding spatter. The multiple jaws of the piler are used to pull the wire and install the tips and nozzles.

4. Chisel

Normally, chisels are used to cut flat, round, or angled iron and cut sheets of thick metal. They are also used to remove unnecessary metal from a work surface by cutting it into small pieces. But in welding, It is used for cutting the jobs and for cleaning the slag, spatter, and surplus metal from the job after welding

5. Tongs

Tongs are hand tools used by blacksmiths to lift and hold hot weld pieces of metal. They are usually made of wrought iron or steel and are better than pliers or vice grips. These are available in different sizes and shapes which are intended to hold the job while welding.

6. Cylinder key

It is used for opening and tightening the spindle valve of the gas cylinder.

7. Wire brush

It is used for cleaning the welding surface before and after welding. It consists of steel wires and is made of stainless steel. Keep in mind that in welding, always use a brush with stainless steel bristles and a chipping hammer made of stainless steel.

8. Clamps

Welding clamps are sheets of metal that temporarily hold two parts of material tightly together. Welding clamps permit you to securely hold your workpiece, so the operator will produce a tighter joint.

This makes it easy to run the arc and join the pieces together without worrying about moving sheets. These types of clamps are generally available in varieties of sizes and shapes.

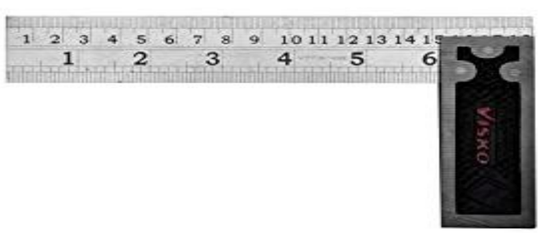
9. Angular grinder

Angular grinders are commonly seen in metal fabrication and some metal shops. They are types of handheld power tools attached to consumable stone discs or blades. These discs spin at high speed to grind, cut or give a smooth finishing touch to weld metal.

10. Spark lighter

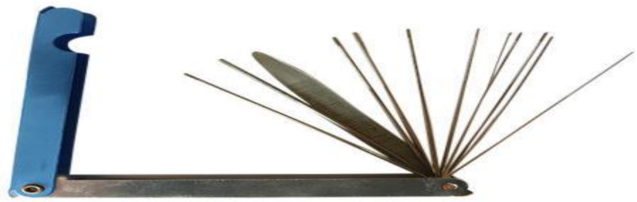
It consists of a shape edges stone piece that produces a spark when it is rubbed with a hatched cast-iron wheel. It is used for lighting the gas released from the welding torch.

11. Try square



It is an L-shaped measuring instrument. Its blade is usually graduated in centimeters and the same is used for job measurement purposes. It is also used for checking the right angles of a rectangular job.

12. Tip cleaner



There is a fine hole in the nozzle. The hole may get dirty and even closed during use. A nozzle edges tip cleaner is used for cleaning the hole, see in the figure. A tip cleaner may also be used for removing slag from the job after welding is done.

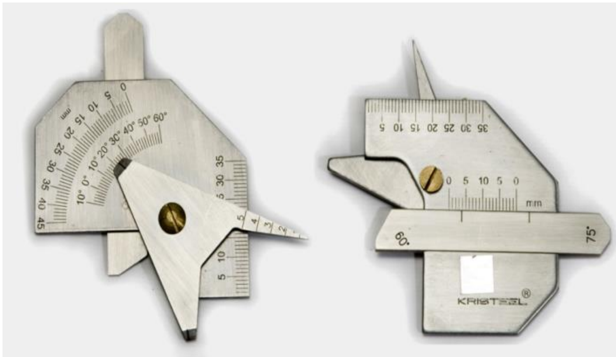
13. Files

These are similar to angular grinders, used to remove rough edges and burrs from the metal you cut.

14. Centre punch

The punch tools are often used to mark holes that must be drilled in secondary operations, or as gauging marks for bend lines, shearing, spot weld locations. It is used for marking on a job piece before cutting the same into a desired shape.

15. Scale and weld-gauge



Scale is used for measuring the size of a job and the weld-gauge is used for measuring the depth of the weld, see in the figure.

16. Steel tape

Long jobs are measured by steel tape. It is marked in inches and centimeters and it is housed in a steel or plastic case. The spring for the assembly helps in the quick and automatic collection of the tape, see in the figure.

Welding Equipments

The equipments used in welding are as follows:

1. Gas cylinder

Welding gas cylinders are made with thick steel sheets as they have to bear high gas pressure. Manufacturers supply gas-filled cylinders to the users. Generally, oxygen and acetylene gas cylinders are used for gas welding purposes. The two gases are supplied in separate cylinders.

1. Oxygen Cylinder

Oxygen gas can be stored in a cylinder for a long time. The temperature of the cylinder remains 70° Fahrenheit and the gas pressure is kept at about 2200 pounds per square inch.

The Oxygen cylinder is colored to black and its valve has right-handed threads. These two points are useful in the identification of oxygen cylinders.

2. Acetylene Cylinder

The acetylene cylinder contains acetylene gas in liquid form. The temperature of the cylinder remains 70° Fahrenheit and the gas pressure is kept at about 250 pounds per square inch.

Before filling the gas, some quality of dry porous material (charcoal) and then acetone is filled in the cylinder. Now, acetylene gas is filled in the cylinder at about 250 pounds per square inch pressure and finally, the cylinder is rotated for some time.

The acetylene cylinder is colored to dark red and its valve has left-handed threads; These two points are useful in the identification of acetylene cylinders. There are also two safety valves that are mounted at the bottom of the cylinder.

Both cylinders are provided with safety caps. Acetylene cylinders should not be used in a lying position.

2. Gas regulator

For the welding process, the oxygen and acetylene gases reach the welding torch through gas regulators. There are two main functions of a gas regulator:

1. To maintain necessary gas pressure during the course of welding.
2. To supply the gas to the welding torch at a low pressure. The regulator's body is generally made of brass metal.

1. Single Stage Regulator

It mainly consists of diaphragm, spring, control-valve, body, pressure gauge, pressure adjusting screw.This type of regulator has two ports; (i) Inlet – through which the gas at high pressure enters the regulator from the cylinder, (ii) outlet – through which the gas at low pressure is pulled to the welding torch through the hose pipe.

The gas enters the regulator under high pressure through the inlet and exerts pressure on the diaphragm. The diaphragm is supported by a spring which is also used as a pressure adjusting device with the help of a screw.The regulator valve and diaphragm reduce the gas pressure and supply the same to the welding torch through the hose pipe from the outlet.

2. Double Stage Regulator

In this type of regulator, the pressure of the gas is reduced from high to low in two steps. The device consists of two gas chambers i.e., the main chamber and the auxiliary chamber. The device has two springs and two diaphragms.

The gas enters the main chamber and its pressure is reduced to some extent. The gas then enters the auxiliary chamber from the main chamber at reduced pressure. Here, the gas pressure is further reduced and the same working pressure is carried through the hose pipe to the welding torch.

3. Hose-pipe

The hosepipe is the medium through which gas is supplied from the regulator to the welding torch. Separate hose pipes are used for oxygen and acetylene gases.These are made of good quality rubber and are fitted with the help of clamps in their respective regulators and welding torches. Typically, a black or blue pipe is used for oxygen gas while a red pipe is used for acetylene gas.

4. Welding goggles

Goggles are used for the protection of eyes against any possible bad effect of the gas flame. Green or blue glasses are used in the goggles which are capable to protect the eyes from ultraviolet and infra-red radiation of the high-temperature gas flame.

5. Welding Helmet

It is an essential type of welding equipment that is considered the most important piece of personal protective equipment that a welder should have. This helmet not only protects the eyes and skin from serious sparks, but also from potentially vision-damaging ultraviolet and infrared rays released by arcs.

6. Handy gloves

Welding gloves are tools that protect a welder's hands from the dangers of welding. Leather or asbestos gloves are used for the protection of hands against any possible burn during welding.
These gloves allow the operator to be protected from electric shock, extreme heat, and ultraviolet and infrared radiation, and also provide abrasion resistance and increased grip.

7. Anvil

An anvil is consisting of a strong metal (usually forged or cast steel) with a flattened top surface upon which another object strikes. An anvil is used for hammering a hot job as required. It is made of steel so as to have sufficient toughness, see in the figure. The anvil is used as a forging tool in most cases.

8. Cylinder trolly

A cylinder trolly is very helpful for conveying the two gas cylinders from one place to another for gas welding purposes.

9. Apron

A leather apron is very useful equipment for protecting a welder's clothing against sparks and red-hot particles. It is usually tied to the chest portion of the body.

10. Welding torch

It is also known as a blow-pipe. The instrument is meant for producing the oxygen-acetylene flame. It is provided with two gas adjusting knobs (one for each gas). The desired type of flame can be produced by adjusting the two knobs. Two hose pipes are clamped on the two inlets of the instrument.

Gases are mixed in the mixing chambers and then the mixture comes out of the welding torch through its nozzle or tip where it is converted into flame with the help of a spark lighter. The nozzle or tip is made to bear the high temperatures.

Nozzle's size depends on the size of its hole and they are replaceable. The size is marked on the nozzle which indicates the thickness of the metallic sheets to be welded with that nozzle. There are two main types of welding torches.

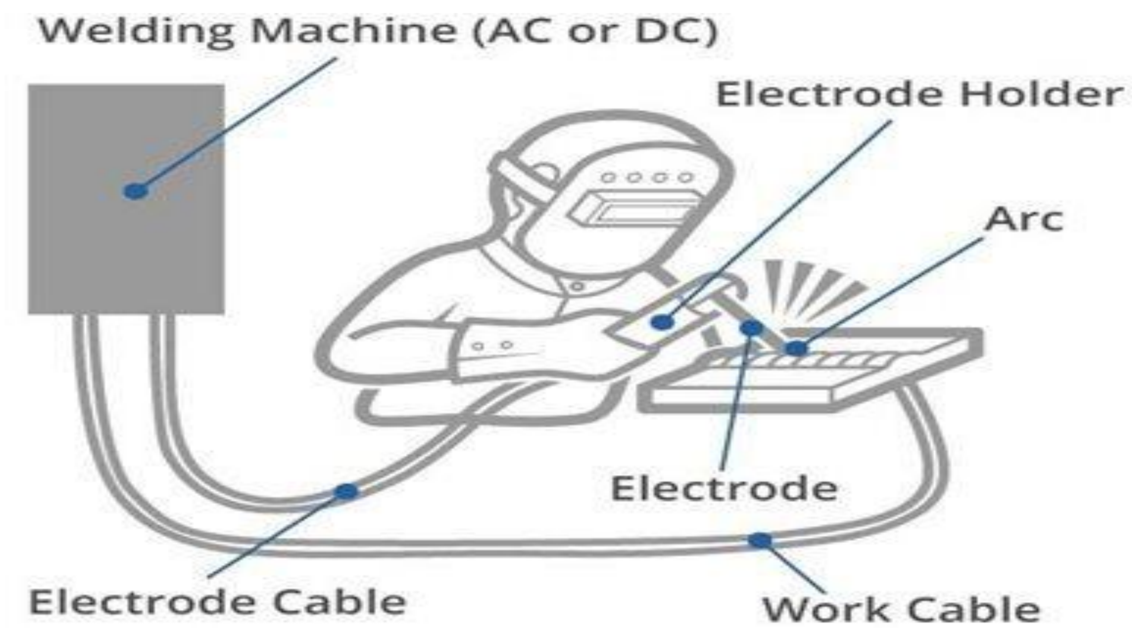
1. Low Pressure Welding Torch

In this type of torch, the pressure of oxygen gas is kept at about 10 to 40 pounds per square inch, while the pressure of acetylene gas is kept at about 1 to 2 pounds per square inch. The tip of this type of torch can only be replaced together with its neck.

2. Medium Pressure Welding Torch

In this type of torch, the pressure of the oxygen is kept at about 1 to 24 pounds per square inch, while the pressure of the acetylene is kept at about 1 to 15 pounds per square inch. The tip of this type of welding torch can be replaced without the replacement of its neck.

Electric ARC Welding : Working Principle & Types



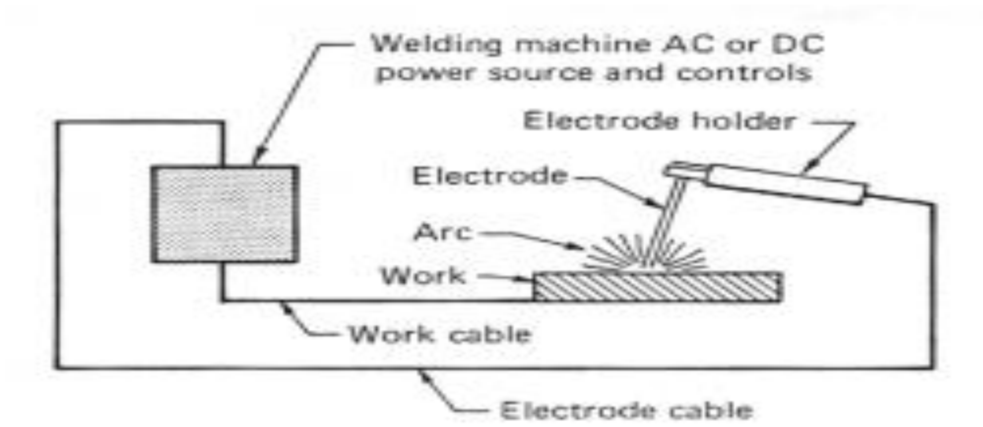
The first arc welding method was developed in the 19th century, and it has become commercially significant within shipbuilding throughout II-World War. Nowadays it remains a significant process for vehicles as well as steel structure fabrication. This is one of the famous welding methods which are used for joining metals in industries. In this type of welding, the joint can be formed by melting the metal with the help of electricity. So due to this reason, it is named an electric arc. The main benefit of this welding is, a high-temperature can be easily developed for welding. The arc welding temperature range will be 6k degrees centigrade to 7k degrees centigrade. This article discusses an overview of electric arc welding.

What is Electric Arc Welding?

The definition of arc welding is a welding process that is used for welding the metals with the help of electricity to generate sufficient heat for softening the metal, as well as when the softened metal is cooled then the metals will be welded. This kind of welding uses a power supply to make an arc among a metal stick & the base material to soften the metals at the end of the contact.
These welders can utilize either DC otherwise AC, & electrodes like consumable otherwise non-consumable. Generally, the welding location can be defended with some kind of shielding gas, slag, otherwise, vapor. This welding process could be manual, fully, or semi-automated.

Circuit Diagram

In Arc welding process, heat can be generated through an electric arc struck among an electrode as well as the workpiece. The electric arc is glowing electrical discharge among two electrodes using ionized gas.
Any type of arc welding technique depends on an electric circuit that mainly includes different parts like power supply, workpiece, welding electrode & electric cables to connect the electrode as well as workpiece toward the power supply.



The **electric arc winding circuit** can be formed by an electric arc among the electrode as well as the workpiece. The temperature of the arc may arrive at 5500°C (10000°F), which is enough to combine the edges of the workpiece.
Once a long join is necessary then the arc can be moved through the joint line. The weld pool of the front edge dissolves the welded surface once the back edge of the pool hardens to form the joint.
Once a filler metal is necessary for enhanced bonding, the wire can be used outside of the material which is fed to the arc region, which dissolves & loads the weld pool. A filler metal's chemical composition is related to that of the workpiece.

Molten metal within the weld pool can be active chemically & responds through the nearby atmosphere. Consequently, the weld may be infected through oxide as well as nitride inclusion to weaken its mechanical properties. So, the weld pool can be protected through Neutral shielding gases like helium, argon & shielding fluxes from contamination. Shields are supplied for the weld zone in the form of a flux coating for the electrode otherwise in other forms.

Working Principle

The **working principle of arc winding** is, in a welding process the heat can be generated with an electric arc strike among the workpiece as well as an electrode. This is glowing electrical discharge among two electrodes throughout ionized gas.

The **arc welding equipment** mainly includes an AC machine otherwise DC machine, Electrode, Holder for the electrode, Cables, Connectors for cable, Earthing clamps, Chipping hammer, Helmet, Wire brush, Hand gloves, Safety goggles, sleeves, Aprons, etc.

Types of Arc Welding

Arc welding is classified into different types which include the following

- Plasma Arc Welding
- Metal Arc Welding
- Carbon Arc Welding
- Gas Tungsten Arc Welding
- Gas Metal Arc Welding
- Submerged Arc Welding
- SMAW – Shielded Metal Arc Welding
- FCAW (Flux Cored Arc Welding)
- ESW (Electro-Slag Welding)
- Arc Stud Welding

Plasma Arc Welding

Plasma arc welding (PAW) is similar to GTAW or gas tungsten welding. In this kind of welding process, the arc will generate among the work part as well as the tungsten electrode. The major dissimilarity between plasma arc welding and gas tungsten welding is that the electrode is located within the torch of Plasma arc welding. It can be heated the gas at **the temperature** of 30000oF & change it into the plasma to attack the welding region.

Metal Arc Welding

The metal arc welding (MAW) process mainly uses a metal electrode for the welding process. This metal electrode can be either consumable otherwise non-consumable based on the requirement. Most of the used consumable electrode can be covered with flux, and the main benefit of this type of welding process is that it requires low temperature compared with others.

Carbon Arc Welding

The Carbon arc welding (CAW) process mainly uses a carbon rod like an electrode for welding the metal joint. This kind of arc welding is the oldest arc welding process and requires high current, low voltage for generating the arc. In some cases, an arc can be generated among two carbon electrodes which are named twin carbon arc welding.

Gas Tungsten Arc Welding

The gas tungsten arc welding (GTAW) is also called Tungsten inert gas welding (TIGW). In this type of welding process, a tungsten electrode that is non-consumable can be employed for welding the material. The electrode which is used in this welding can be enclosed with gases such as argon, helium, etc. These gases will guard the weld region against oxidization. This kind of welding can be used for welding thin sheets.

Gas Metal Arc Welding

Gas metal arc welding (GMAW) is also called Metal inert gas welding (MIGW). It uses a fresh metal electrode that is protected by gas like helium, argon, etc. These gases will protect the join area from oxidation and generates multiple welding material layers. In this type of arc welding process, a filler wire can be fed constantly using a non-consumable metal electrode for welding the metal.

Submerged Arc Welding

The Submerged arc welding (SAW) can be extensively utilized within an automatic welding method. In this kind of welding process, an electrode is completely submerged by the granular coating of flux, and this flux can be an electric conductor that will not oppose the electric supply. The solid coating of flux stops the melted metal from ultra-violate radiation and atmosphere.

SMAW – Shielded Metal Arc Welding

The term SMAW stands for "Shielded Metal Arc Welding" which is also called stick welding; flux shielded arc welding or manual metal arc welding (MMA/MMAW). This kind of welding is used where the arc is struck among the workpiece as well as the metal rod. So the surface of both of these can dissolve to form a weld pool.

When the flux coating melts immediately on the rod then it will form slag & gas to protect the weld pool from the surroundings. This is a flexible method and suitable for connecting the materials like ferrous & non-ferrous through a thickness material in all locations.

FCAW (Flux Cored Arc Welding)

This kind of welding is an alternative to shield metal arc welding. This flux-cored arc welding works with an electrode as well as a stable voltage power supply so that it provides a stable arc length. This method works by using a shielding gas or the gas which is formed through the flux to give safety from contagion.

ESW (Electro-Slag Welding)

In this kind of welding, the heat is produced through current and passes among the filler metal as well as the workpiece using a molten slag to the surface of the weld. Here, welding flux is used to fill the gap between the two workpieces. This kind of welding can be started through an arc among the electrode as well as the workpiece.

The arc generates the heat to melt the fluxing powder & makes molten slag. Here the slag includes less electric conductivity that can be maintained within liquid condition because of the heat generated through the electric current. The slag gets a 3500°F of temperature and it is adequate for melting the edges of the workpiece and consumable electrode. Metal droplets will drop toward the weld pool & connects the workpieces. This kind of welding is mainly applicable to steel.

Arc Stud Welding

This type of welding is extremely reliable and used in a wide range of applications. This method is used to weld any size of metal with a workpiece through the highest weld penetration.

This type of welding can create tough, welds on a single side over base metals with 0.048-inch thickness. This arc can be formed by using a DC power supply; metal fasteners; ferrules & a stud welding gun. In this welding, there are three common methods used like drawn arc, short arc stud & gas arc stud welding.

The drawn arc method works with flux by fixed within the stud to clean the surface of metal throughout the welding. Throughout arcing, the flux can be vaporized & responds through the polluting elements within the environment to maintain the weld region clean.

The short arc method is similar to drawn arc, apart from that it utilizes no flux load otherwise ferrule. So, this method gives the shortest welding times of the arc stud welding techniques. The gas arc stud method works through static shielding gas with no ferrule or flux which makes it easier to automate.

Oxy-Fuel Welding

This kind of welding is a method that uses oxygen & liquid fuel to fuse metal into form. French engineers Charles Picard & Edmond Fouché was invented in the 20th century. In this process, the oxygen-generated temperature is used in metal surface areas. This welding takes place in an indoor atmosphere.

Resistance Spot Welding

Resistance spot welding is used where heat connects the surfaces of metal. The heat can be generated from the resistance of electrical currents. This kind of welding belongs to a collection of welding techniques called electric resistance welding.

Resistance Seam Welding

Resistance seam welding is a technique that produces heat among the metal faying surfaces through related properties. This kind of welding begins on one face of a joint & works its mode to the other end. So, this method mainly depends on twin electrodes which are normally made of copper material.

Advantages of Arc Welding

The advantages of Arc welding mainly include the following.

- Arc welding has high speed as well as welding efficiency
- It includes a simple welding apparatus.
- It is simply moveable.
- Arc welding forms the physically powerful bond between the welded metals.
- It provides reliable welding quality
- Arc welding offers a superior welding atmosphere.
- The power source of this welding is not costly.
- This welding is a quick and consistent process.
- The welder can utilize ordinary domestic current.

Disadvantages of Arc Welding

The disadvantages of Arc welding include the following.

- A high expert operator is necessary to perform arc welding.
- The rate of deposition can be incomplete as the electrode covering tends to burn and decrease
- The length of the electrode is 35mm and needs electrode changing for the entire production rate.
- These are not clean for reactive metals such as titanium & aluminum

Applications

The applications of Arc Welding include the following.

- Used in the weldings of sheet metals
- For welding thin, ferrous & non-ferrous metals
- Used to design pressure & pressure vessels
- The developments of piping in industries
- Used in the domains of automotive and home furnishing
- Industries of Shipbuilding
- Used in the manufacturer of aircraft & aerospace
- Auto body restorations
- Railroads
- Industries like construction, automotive, mechanical, etc
- Gas Tungsten Arc Welding is used in aerospace industries to connect many areas like sheet metals
- These weldings are used for repairing dies, tools, and mostly on metals that are made with magnesium & aluminum.
- Most of the fabrication industries use GTAW to weld thin workpieces, particularly nonferrous metals.
- GTAW weldings are used where extreme resistance to corrosion as well as cracking over a long period of qualities are required.
- It is used in space vehicles manufacturing
- Used to weld small-diameter parts, thin wall tubing, making it applicable in bicycle industries

Thus this is all about electric arc welding, and it is the flexible welding method. The electric arc welding applications involve in manufacturing industries for generating powerful joints worldwide because of their features like ease & superior welding efficiency. It is most broadly used in different industries for the protection otherwise renovate works such as automotive, construction, shipbuilding, and aerospace. Here is a question for you, what is the range of arc welding temperature?

TIG Welding (GTAW) Process & How it Works

TIG welding (GTAW or gas tungsten) is an arc welding process that operates at high temperatures (over 6,000 degrees Fahrenheit) to melt and heat metals.

While it is more expensive than stick welding, it is cleaner and more versatile (works on steel, aluminum, brass and many other metals).

It also results in high-quality welds.

On the downside, the equipment is more expensive and the process is slower than other welding processes.

Unlike GMAW or MIG welding, a non-consumable (doesn't get melted) tungsten electrode is used.

The electrode creates an electrical arc that produces the required heat.

The TIG torch is cooled by air or water and the process uses a filler metal in rod form.
GTAW also requires a shielding gas such as argon or helium to protect the weld from the atmosphere.

The gas tungsten arc welding process is generally not commercially competitive with other processes for welding heavier gauges of metal if they can be readily welded by the shielded metal arc, submerged arc, or gas metal arc welding processes with adequate quality.

Overview


TIG Weld Example

Gas tungsten arc welding (GTAW) is a process in which the joining of metals is produced by heating therewith an arc between a tungsten (non-consumable) electrode and the work with a TIG welding machine.
A shielding gas is used, normally argon.

Normally done with a pure tungsten or tungsten alloy rod, but multiple electrodes are sometimes used.
The heated weld zone, molten metal, and tungsten electrode are shielded from the atmosphere by a covering of inert gas fed through the electrode holder.

Filler metal may or may not be added. A weld is made by applying the arc so that the touching workpiece and filler metal are melted and joined as the weld metal solidifies.

This process is similar to other arc welding processes in that the heat is generated by an arc between a non-consumable electrode and the workpiece, but the equipment and electrode type distinguish it from other arc welding processes.

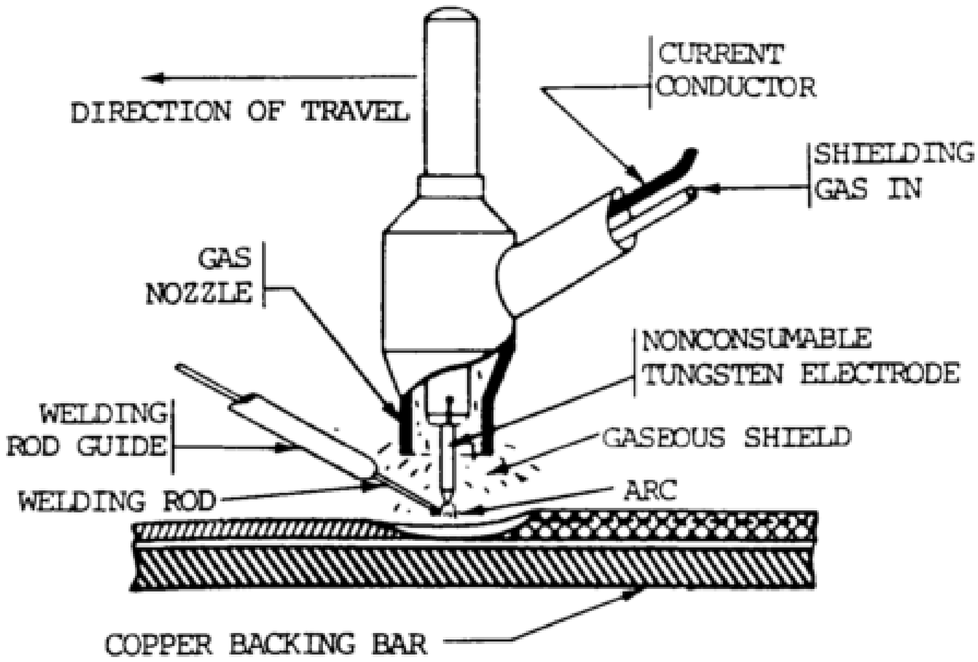


Figure 10-32. Gas tungsten arc (TIG) welding (GTAW). Figure 10-32: TIG Gas tungsten arc welding (also called GTAW)

Advantages And Disadvantages

Advantages

- Works on almost all types of metals with higher melting points. Gas tungsten arc welding is the most popular method for welding aluminum stainless steels, and nickel-base alloys. It is generally not used for the very low melting metals such as solders, or lead, tin, or zinc alloys. It is especially useful for joining aluminum and magnesium which form refractory oxides, and also for the reactive metals like titanium and zirconium, which dissolve oxygen and nitrogen and become embrittled if exposed to air while melting.
- Pinpoint accuracy and control. The process provides more precise control of the weld than any other arc welding process because the arc heat and filler metal are independently controlled.
- Good looking weld beads
- For metals of varying thickness including very thin metals (amperage range of 5 to 800, which is the amount of electricity created by the welding machine). The gas tungsten arc welding process is very good for joining thin base metals because of the excellent control of heat input.
- Creates strong joints. It produces top quality welds in almost all metals and alloys used by industry.
- A clean process with a minimal amount of fumes, sparks, spatter and smoke
- High level of visibility when working due to low levels of smoke. Visibility is excellent because no smoke or fumes are produced during welding, and there is no slag or spatter that must be cleaned between passes or on a completed weld.

- Minimal finishing required. In very critical service applications or for very expensive metals or parts, the materials should be carefully cleaned of surface dirt, grease, and oxides before welding.
- Works in any welding position
- TIG welding also has reduced distortion in the weld joint because of the concentrated heat source.
- As in oxyacetylene welding, the heat source and the addition of filler metal can be separately controlled.
- Because the electrode is non-consumable, the process can be used to weld by fusion alone without the addition of filler metal.

Disadvantages

- Brighter UV rays when compared to other welding processes
- Slower process than consumable electrode arc welding processes.
- Takes practice
- More expensive process overall. Expensive welding supplies (vs. other processes) because the arc travel speed and weld metal deposition rates are lower than with some other methods. Inert gases for shielding and tungsten electrode costs add to the total cost of welding compared to other processes. Argon and helium used for shielding the arc are relatively expensive. Equipment costs are greater than that for other processes, such as shielded metal arc welding, which requires less precise controls.
- Not easily portable, best for a welding shop
- Transfer of molten tungsten from the electrode to the weld causes contamination. The resulting tungsten inclusion is hard and brittle.
- Exposure of the hot filler rod to air using improper welding techniques causes weld metal contamination.

Tips

As mentioned, since tungsten welding operates at high temperatures, ideal metals are those that have a low melting point. This includes:

- Aluminum: use on AC output and high-frequency setting. Keep the tungsten from touching the piece being welded to avoid contamination. Conducts heat. Clean aluminum with a wire brush (even if it looks clean) to remove aluminum oxide. Use high heat settings to increase welding speed.
- Magnesium: similar properties to aluminum
- Copper alloys (brass, bronze, copper nickel, copper aluminum, silicon): use DC current with electrode negative
- Stainless steel: requires the use of a filler rod with high chrome component. Use gas lenses for better gas coverage of weld. Keep gas flow at 15 to 20 cfh.
- Mild steel: use rods with deoxidizers. The tungsten electrode should be 2% thoriated. Clean the steel before welding.

If TIG weld cracking occurs preheat the metal to 400 degrees Fahrenheit. This helps with the contraction and expansion of the metals when welding.

- Operate with safety in mind – Use dedicated TIG gloves
- Ensure that the argon or helium gas supply has low moisture
- Use filler rods that are clean and keep the welding area dry
- Tungsten electrode selection and parameters for welds are guidelines not absolute
- Follow the welding safety precautions provided by all material providers. Since tungsten has some radioactivity, if grinding wear a respirator
- Bigger rods are easier to handle

- The tungsten electrode should be the smallest needed to do the job
- Keep the rod and torch at different angles
- Wind drafts will reduce the effectiveness of shielding argon or helium gas resulting in pinholes in weld
- Higher amps require larger orifice
- If the tungsten moves or wiggles during the welding process it indicates that the tungsten is near its capacity. Use the balance dig dial moved to the penetration side.

Also Read: 4 Main Types of Welding Processes

GTAW Gasses

- 100% Argon (most common, coolest)
- 75% Argon/25% Helium
- 75% Helium/25% Argon (hottest gas, higher % of helium can result in arc starting issues)
- 100% Helium (hard to start arc, very hot.)

What is Metal Inert Gas (MIG) Welding?

Metal Inert Gas (MIG) welding is an arc welding process that uses a continuous solid wire electrode heated and fed into the weld pool from a welding gun. The two base materials are melted together forming a join. The gun feeds a shielding gas alongside the electrode helping protect the weld pool from airborne contaminants.

Metal Inert Gas (MIG) welding was first patented in the USA in 1949 for welding aluminium. The arc and weld pool formed using a bare wire electrode was protected by helium gas, readily available at that time. From about 1952, the process became popular in the UK for welding aluminium using argon as the shielding gas, and for carbon steels using CO_2. CO_2 and argon-CO_2 mixtures are known as metal active gas (MAG) processes. MIG is an attractive alternative to MMA, offering high deposition rates and high productivity.

Process Characteristics

MIG/MAG welding is a versatile technique suitable for both thin sheet and thick section components. An arc is struck between the end of a wire electrode and the workpiece, melting both of them to form a weld pool. The wire serves as both heat source (via the arc at the wire tip) and filler metal for the welding joint. The wire is fed through a copper contact tube (contact tip) which conducts welding current into the wire. The weld pool is protected from the surrounding atmosphere by a shielding gas fed through a nozzle surrounding the wire. Shielding gas selection depends on the material being welded and the application. The wire is fed from a reel by a motor drive, and the welder moves the welding torch along the joint line. Wires may be solid (simple drawn wires), or cored (composites formed from a metal sheath with a powdered flux or metal filling). Consumables are generally competitively priced compared with those for other processes. The process offers high productivity, as the wire is continuously fed.

Manual MIG/MAG welding is often referred as a semi-automatic process, as the wire feed rate and arc length are controlled by the power source, but the travel speed and wire position are under manual control. The process can also be mechanised when all the process parameters are not directly controlled by a welder, but might still require manual adjustment during welding. When no manual intervention is needed during welding, the process can be referred to as automatic.

The process usually operates with the wire positively charged and connected to a power source delivering a constant voltage. Selection of wire diameter (usually between 0.6 and 1.6mm) and wire feed speed determine the welding current, as the burn-off rate of the wire will form an equilibrium with the feed speed.

Metal Transfer Mode

The manner, or mode, in which the metal transfers from the electrode to the weld pool largely determines the operating features of the process. There are three principal metal transfer modes:

- Short circuiting/ Dip
- Droplet / spray
- Pulsed

Short-circuiting and pulsed metal transfer are used for low current operation while spray metal transfer is only used with high welding currents. In short-circuiting or 'dip' transfer, the molten metal forming on the tip of the wire is transferred by the wire dipping into the weld pool. This is achieved by setting a low voltage; for a 1.2mm diameter wire, arc voltage varies from about 17V (100A) to 22V (200A). Care in setting the voltage and the inductance in relation to the wire feed speed is essential to minimise spatter. Inductance is used to control the surge in current which occurs when the wire dips into the weld pool.

For droplet or spray transfer, a much higher voltage is necessary to ensure that the wire does not make contact i.e. short-circuit, with the weld pool; for a 1.2mm diameter wire, the arc voltage varies from approximately 27V (250A) to 35V (400A). The molten metal at the tip of the wire transfers to the weld pool in the form of a spray of small droplets (about the diameter of the wire and smaller). However, there is a minimum current level, threshold, below which droplets are not forcibly projected across the arc. If an open arc technique is attempted much below the threshold current level, the low arc forces would be insufficient to prevent large droplets forming at the tip of the wire. These droplets would transfer erratically across the arc under normal gravitational forces. The pulsed mode was developed as a means of stabilising the open arc at low current levels i.e. below the threshold level, to avoid short-circuiting and spatter. Metal transfer is achieved by applying pulses of current, each pulse having sufficient force to detach a droplet. Synergic pulsed MIG refers to a special type of controller which enables the power source to be tuned (pulse parameters) for the wire composition and diameter, and the pulse frequency to be set according to the wire feed speed.

Shielding Gas

In addition to general shielding of the arc and the weld pool, the shielding gas performs a number of important functions:

- forms the arc plasma
- stabilises the arc roots on the material surface
- ensures smooth transfer of molten droplets from the wire to the weld pool

Thus, the shielding gas will have a substantial effect on the stability of the arc and metal transfer and the behaviour of the weld pool, in particular, its penetration. General purpose shielding gases for MIG welding are mixtures of argon, oxygen and CO_2, and special gas mixtures may contain helium. The gases which are normally used for the various materials are:

Steels:

- CO_2
- argon +2 to 5% oxygen
- argon +5 to 25% CO_2

Non-ferrous (e.g. Aluminium, copper or nickel alloys):

- argon
- argon / helium

Argon based gases, compared with CO_2, are generally more tolerant to parameter settings and generate lower spatter levels with the dip transfer mode. However, there is a greater risk of lack of fusion defects because these gases are colder. As CO_2 cannot be used in the open arc (pulsed or spray transfer) modes due to high back-plasma forces, argon based gases containing oxygen or CO_2 are normally employed.

Applications

MIG/MAG is widely used in most industry sectors and accounts for more than 50% of all weld metal deposited. Compared to MMA, MIG/MAG has the advantage in terms of flexibility, deposition rates and suitability for mechanisation. However, it should be noted that while MIG/MAG is ideal for 'squirting' metal, a high degree of manipulative skill is demanded of the MIG welder.

WELDING DEFECTS: THEIR CAUSES AND REMEDIES

Welding defects are formed in a welding work due to the weak or poor technique used by the inexperienced or untrained welders or due to structural problems in the welding operation.

Or you can say, in a welding process, the size and shape of the metal structure are varied. It is maybe due to the incorrect welding process or the application of the incorrect welding procedure.

An ideal weld or good weld must be one that exists with good penetration with sufficient fusion between the filler metal and the edge preparation.

You can read also about different welding processes like plasma arc welding, laser beam welding, resistance welding, gas welding, and arc welding you can check it out by clicking on them.

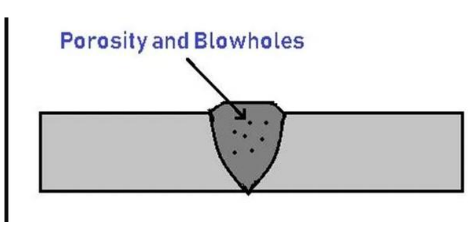
For this article, let's discuss the types of welding defects that appear while welding.

Types of Welding Defects

Following are the **types of welding defects:**

1. Porosity and Blowholes
2. Undercut
3. Weld crack
4. Incomplete fusion
5. Slag inclusion
6. Incomplete penetration
7. Spatter
8. Distortion
9. Hot Tear

#1 Porosity and Blowhole

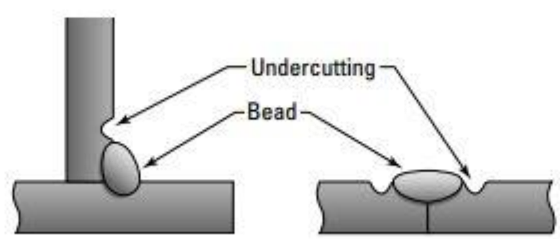


Porosity is a group of small bubbles and blowholes are relatively large hidden holes or pores. They are mainly caused by trapped gases. Porosity is a result of weld metal contamination.

Causes and Remedies of Porosity

Causes of Porosity	Remedies of Porosity
Using insufficient electrode deoxidant.	Choosing suitable electrode and filler materials.
Applying too large a gas flow.	Checking the gas flow meter and ensure that it is adapted as needed with appropriate pressure and flow settings.
Using a larger arc.	Make sure that arc distance is correct.
Existence of moisture in the process.	Cleaning the metal before starting the welding process.
Unsuitable gas shield.	Decreasing welding speed, it will allow the gas to escape.
Dirty job surface i.e. the occupation of scales, rust, oil, and grease, etc. on the surface of the job.	Individual cleaning and prevention of pollution from entering the weld zone.

#2 Undercut

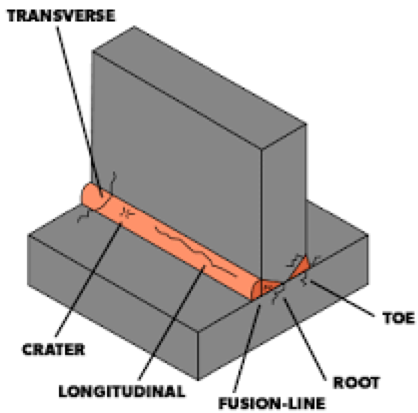


Undercut in welding makes imperfection, it is the formation of grooves in the weld toe, which decreases the cross-sectional thickness of the base metal. As a result of this weld and workpiece get weakened.

Causes and Remedies of Undercut

Causes of Undercut	**Remedies of Undercut**
Incorrect use of angle, which will deliver more heat to the free edges.	Using of suitable electrode angle, with more heat delivered towards thicker components.
Because of too fast weld speed.	Decreasing the travel speed of the electrode, but it should not be too slow.
Using poor welding methods.	Applying the multipass technique.
Use of incorrect gas shielding and filler metal.	Selecting the shielding gas with the right structure for the material you are welding.
Doing too high weld current.	When approaching thin areas and free edges, use an appropriate stream to reduce them.
Using larger diameter electrodes.	Decreasing the arc length.

#3 Weld Crack



There are different types of cracks that occur during welding, it depends on the temperature.

1. Hot Cracks

Hot cracks happen while the welding process or during the crystallization process of the weld joint. Temperatures at this point can exceed 10,000C.

2. Cold Cracks

These cracks occur after the weld is created and the metal temperature has passed down. They can also be made hours or days after welding steel. This mostly occurs when the deformation is made in the steel structure.

3. Crater Cracks

These cracks occur at the end of the welding process before the operator completes the weld joint. They are usually made near the end of the process.

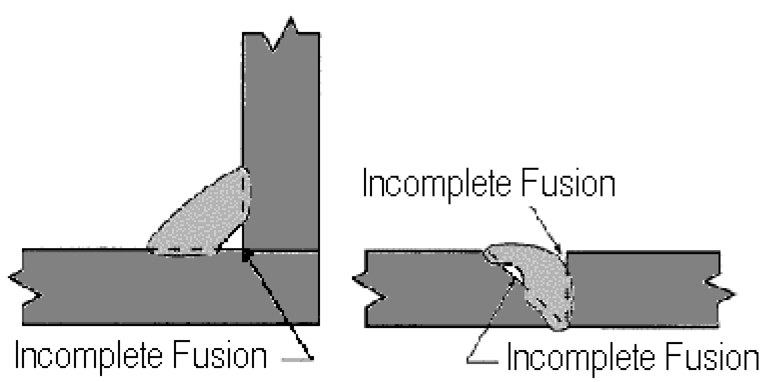
When the weld pool cools and freezes, the weld must be sufficient in volume to overcome the metal shrinkage. Otherwise, it will make a crater crack.

Causes and Remedies of Weld Crack

Causes of Weld Crack	**Remedies of Weld Crack**
Using hydrogen while welding ferrous metals.	Using suitable metals.

Applying low current with high welding speed.	Utilizing the appropriate welding speed and current.
The design concept is poor.	Using proper design concept.
Not doing preheating before starting welding.	Preheating the metal before starting welding.
Contamination of base metal.	Cleaning the metal surface before welding.
Residual stress solidification due to shrinkage.	Giving decent cooling of the weld area.
The high mixture of sulfur and carbon in the metal.	Using a correct mixture of sulfur and carbon in the metal.
Improper filling of the crater in welding.	Ensure that the crater is properly filled to prevent crater cracks.

#4 Incomplete Fusion



These types of welding defects occur when there is a shortage of suitable fusion between the metal and weld. It may also be visible between adjacent weld beads. This produces a gap inside the joint that is not filled with molten metal.

Causes and Remedies of Incorrect Fusion

Causes of Incorrect Fusion	Remedies of Incorrect Fusion
Contamination of metal surface.	Cleaning the welding area of the metal surface before welding.
Using low heat input.	Utilizing the proper heat input for welding.
The diameter of the electrode is wrong for the thickness of the material you are welding.	Using the correct diameter of the electrode to fit the thickness of the material that you are welding.
Incorrect electrode angle.	Ensure the angle of the electrode is suitable for welding.
Employing too fast travel speed.	Decreasing the speed of arc travel.
The weld pool is very large and it moves ahead of the arc.	Make sure the weld pool that you are using is proper according to the movement of the arc.

#5 Slag Inclusion

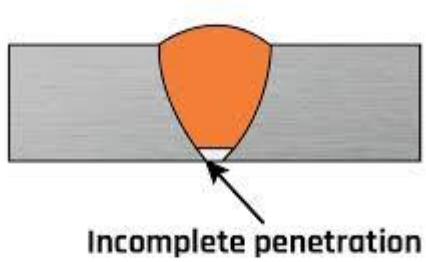
Slag inclusion is welding defects that are usually visible in welds. The slag is a dangerous substance that appears as a product of stick welding, flux-core arc welding, and submerged arc welding.

It is can occur when the flux, which is a solid shielding material applied when welding, melts in the weld or on the surface of the weld region. Slag inclusion decreases the strength of the joint and hence makes it weaker.

Causes and Remedies of Slag Inclusion

Causes of Slag Inclusion	**Remedies of Slag Inclusion**
Poor chipping and cleaning of previous passes in multipass welding.	Through the wire brush, cleaning the weld bed surface before the next layer is deposited.
Due to the incorrect angle of the electrode.	Adjusting the angle of the electrode.
Using too low welding current.	Increasing the current density.
Insufficient space for the puddle of molten weld metals.	Redesigning the joint to allow sufficient space for proper use of the puddle of molten weld metals.
Maybe cooling is very fast.	Decreasing the rapid cooling.
Cleaning of the metal may be improper.	Proper cleaning of the metal before welding.
The speed of welding is fast.	Reducing the speed of the welding.

#6 Incomplete Penetration



In these types of welding defects, penetration is defined as the distance from the uppermost surface of the base plate to the maximum extent of the weld nugget.

Incomplete penetration happens when the metal groove is not entirely filled, which means that the weld metal does not fully spread through the joint thickness.

Causes and Remedies of Incomplete Penetration

Causes of Incomplete Penetration	**Remedies of Incomplete Penetration**
There was too much space between the metal that you are welding with.	Assuring that the surface is jointly fine.
You are moving the bead too fast, which does not allow sufficient metal to accumulate in the joint.	Decreasing the arc travel speed.
You are using a very low amper setting, which results in the current not being strong enough to melt the metal properly.	Selecting a decent welding current.
Using improper joints.	Improving the design of the joint.
Wrong position of the electrode.	Make sure the position of the electrode is very accurate.
Using of larger diameter electrode.	You must need to use proper diameter electrodes as suitable for your welding.

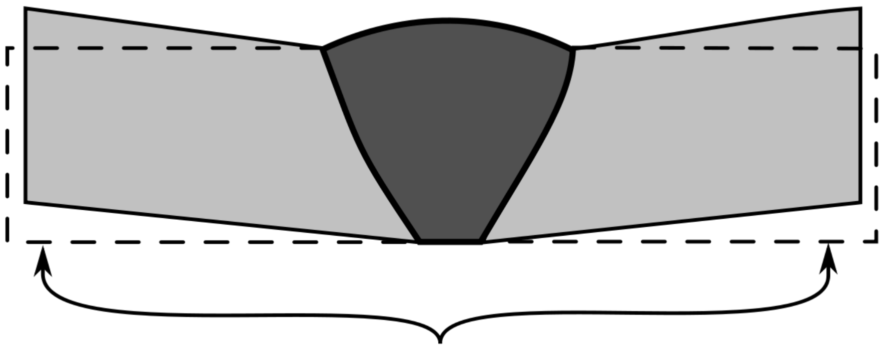
#7 Spatter

Spatters are tiny metal particles that are ejected from the arc during welding and accumulate on the base metal throughout the weld bead along its length. This is particularly common happens in gas-metal arc welding.

Causes and Remedies of Spatter

Causes of Spatter	**Remedies of Spatter**
Contamination of metal surface.	Cleaning metal surfaces before welding.
The working angle of the electrode is much more rigid.	Decreasing the arc length and increasing the electrode angle.
Utilizing too high amper current and too low voltage settings.	Using proper polarity with adjusting the weld current.
Using the larger arc and wet electrode.	Make sure to use proper arc and electrode according to the welding.

#8 Distortion



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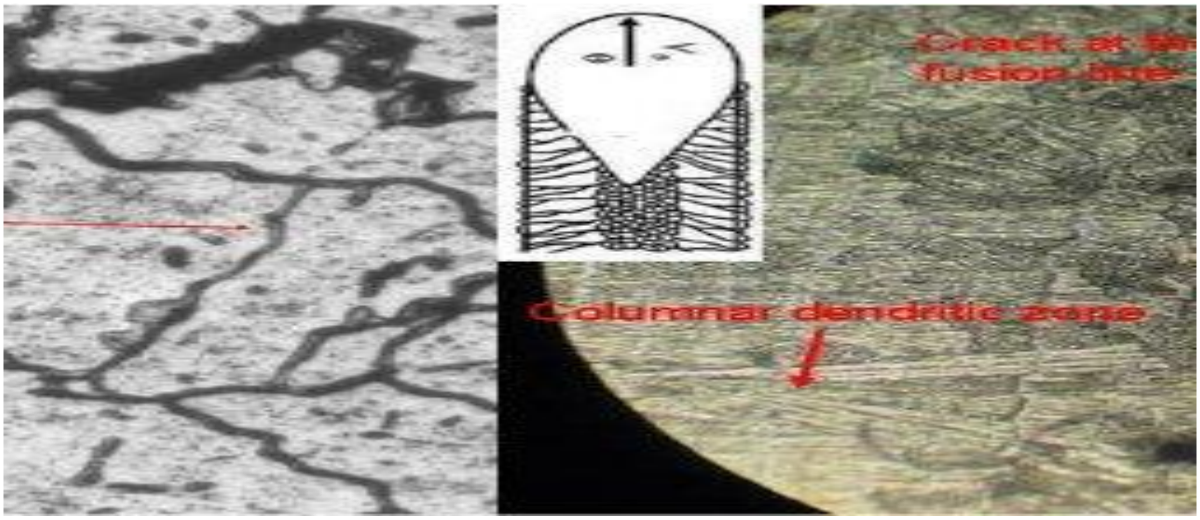
Or in other words, you can say that the distortion is due to uneven extension and reduction of the weld metal and that all kinds of distortion rise with the number of metal depositions.

Causes and Remedies of Distortion

Causes of Distortion	**Remedies of Distortion**
Employing incorrect welding orders.	Ensure to use the correct welding order.
Using a large number of passes with small diameter electrodes.	Using the appropriate number of weld passes.
Because of high residual stresses in the plate to be welded.	Make sure you use the appropriate amount of weld metal as required by the joint. This will decrease contraction forces.
Due to the slow speed of arc travel.	Maintaining the speed of arc travel.
Not using any measuring instrument for dimension purpose.	If required you can use a measuring instrument, so that dimensional accuracy is accurate.

Using too much time for the welding process.	Decreasing the time of the welding process so that the volume around the metal is not even expanded.

#9 Hot Tear



In these types of welding defects, the deposited metal starts to develop cracks from the nearby edge so that it will solidify the crack increase.

Due to the tearing of grain boundaries of the weld metal before it freezes and the metal is still in plastic condition. Therefore, it is also known as solidification cracking.

Causes and Remedies of Hot Tear

Causes of Hot Tear	**Remedies of Hot Tear**
The thickness of the electrode is may be wrong.	Using the right thickness of the electrode according to the base metal to be welded.
Not using a suitable welding current.	Ensure the use of suitable welding current as needed.
It is due to the incorrect choice of proper materials.	Using a suitable type of material for the electrode.