# Casting and Forging

## Introduction:

Casting is a process in which a metal is heated to the molten state and is poured into a cavity or a mould which is having the shape of the desired object. The molten metal fills the mould and on solidification gives the metal object of the same shape. The solidified metal object is known as the casting. The mould having the shape of the desired object is prepared using moulding sand and a pattern and the process is more commonly known as sand casting. In sand casting the mould is not permanent and it collapses when the casting is withdrawn. The moulding sand is then reused to prepare the next mould. Casting plays an important role in manufacturing process. The process is very helpful in producing intrinsic parts economically and in large scale. The metals used for casting are iron, steel, aluminum, brass, bronze, zinc etc. of these iron is most commonly used.

## Moulding:

A mould can be described as a cavity created in a compact sand mass which when filled with molten metal will produce the desired casting. It is the impression left behind by a pattern after the withdrawal of the same. It is very natural therefore that the said cavity will exactly resemble the shape and size of the pattern used for producing it. The process of producing this cavity or mould is called molding. Moulding can be done both by hand and by using machines. In hand moulding ramming is done by hand which is a time consuming process as compared to machine moulding. Hand moulding is used for odd shaped castings and when the castings are small in number. Machine moulding is used for mass production work.

## Moulding Sand:

The principal material used in casting is the moulding sand which are generally classified into three different types namely Natural moulding sand or Green sand, Synthetic sand and Special sand.

1. Natural Moulding Sand : This sand is also known as green sand. These are natural sands and are generally taken from river beds. These sands contain sufficient amount of binding clay which act as a bond between the sand grains. It can be used directly for making moulds by just mixing it with water in proper proportion. They are less refractory as compared to synthetic sands. They

are cheap, easily available and have high operational flexibility. These are used for casting cast iron and nonferrous metals.

2. Synthetic Sand: These are basically high silica sands containing little or no clay, to which binders and other ingredients are added to make them suitable for the casting process. They may occur naturally or made in the foundry by crushing and washing quartz sand stones. The desired strength and bonding properties of these sands are achieved by the addition of ingredients such as bentonite, water and other materials. This allows greater flexibility in properties such as green and dry strength, permeability etc. They are more expensive than natural sand. These are used for casting steel, ferrous and nonferrous castings.

3. Special Sand: These are specially made to acquire special characteristics and for some specific use. Different types of sands commonly used are Parting sand, Facing sand, Backing sand, Loam sand and Core sand.

## Moulding Sand Composition:

The principal ingredients of a moulding sand are silica sand grains, binder or clay, water or moisture and special additives.

Silica sand grains: Naturally occurring or crushed granular particles of sand that is silicon dioxide principally comprise nearly 75% of the total material in the moulding sand. Silica sand grains impart refractoriness, chemical resistivity and permeability to the moulding sand.

Clay or Binder: Moulding sand contains about 8 to 15% of clay. With suitable water content clay imparts necessary bonding strength between the silica sand grains so that the mould cavity retains its shape in both wet and dry states. In natural moulding sands clay and silica occur mixed in proper proportions so that it can be used directly for moulding. In other sands clay or any other binder such as bentonite must be added to develop proper bonding strength and plasticity. Binders are less refractory and if the binder content increases the permeability of moulding sand decreases.

Water or Moisture: The amount of water in the moulding sand ranges from 6 to 8%. Water is responsible for the bonding action of clay. It activates the clay in the sand and the clay sand mixture develops necessary plasticity and strength. Water added to the sand mixture also acts as a lubricant and makes the sand more plastic and mouldable so that it properly gets packed around the pattern during the ramming process.

Special Additives: In addition to the above three basic ingredients certain other materials known as additives are added to the moulding sands in order to enhance certain properties. These include limestone, soda potash, magnesia, certain oils etc.

## Properties of Moulding Sand:

The desirable properties possessed by moulding sand are

1. Permeability or Porosity
2. Refractoriness
3. Adhesiveness
4. Cohesiveness
5. Flowability
6. Collapsibility

1. Permeability or Porosity: It is that property of the sand which allows the gases and water vapour to escape through the sand mould. When the molten metal is poured into the mould certain gases and steam is generated due to the heating of moisture, coal dust and other materials present in the mould. The sand therefore should have sufficient porosity to allow for the escape of these gases, otherwise blow holes will be formed in the casting resulting in a defective casting. Permeability depends upon sand grain size, percentage of clay and extent of ramming. In general larger grain size, softer ramming and lesser clay percentage increases permeability.

2. Refractoriness: It is that property of the moulding sand which enables it to withstand the high temperature of the molten metal without fusing. Moulding sand of inferior refractoriness will fuse on coming in contact with the molten metal and forms a slag on the surface of the casting thereby resulting in a defective casting. Moulding sand possesses this property due to the presence of silica in it. Higher the percentage of silica greater will be the refractoriness.

3. Adhesiveness: It is that property of the sand because of which it is capable of adhering to the surfaces of other materials. It is due to this property the rammed sand mass sticks to the surfaces of the moulding boxes and does not fall when the boxes are lifted and placed upside down.

4. Cohesiveness: It is the ability of the sand particles to stick to one another. Because of this property the pattern can be withdrawn from the mould without damaging the mould surfaces and

edges and also the erosion of the mould wall surface does not occur during the flow of molten metal. This property of the sand in its green or moist state is known as green strength. It depends upon the grain size, clay and the moisture content.

When the molten metal is poured into the mould the sand gets dried due to the evaporation of moisture. But the cohesiveness of sand is still required to give sufficient strength to the mould to retain its shape. This property of the sand in its dry state is called dry strength.

5. Flowability: It is the ability of the sand to behave like a fluid so that, when rammed it will flow to all portions of the mould and packs properly around the pattern to acquire the desired shape and distributes the ramming pressure evenly to all parts of the mould. Flowability increases as clay & water content increase.

6. Collapsibility: It is the property due to which the sand mould automatically collapses after solidification of the casting to allow for the free contraction of the metal. This property prevents the tearing and cracking of the contracting metal.

## Pattern:

A pattern may be defined as the replica or the model of the desired casting which is used for producing the cavity or the impression called the mould in the moulding sand. When the mould is filled with molten metal and allowed to solidify it forms the reproduction of the pattern which is known as the casting. The commonly used pattern materials are wood, metals, plastics and plaster of paris.

Wood: Wood is the most commonly used material for pattern making. It is cheap and is readily available. It is easy to work with and can take up any shape easily and is light in weight. The disadvantage of wood is it is readily affected by moisture and can change its shape and wears out quickly as a result of sand abrasion.

Metal: Metal is used as pattern material when large number of castings are desired or when the conditions are too severe for wooden patterns. Metal patterns are very useful in machine moulding since they are capable of withstanding jolts or sudden jerks. They are also used when close dimensional accuracy is required since they do not change their shape under moist conditions. The disadvantage of metal patterns are their high cost, greater weight and tendency to rust. The commonly used metals are cast iron, brass and aluminium. Metal patterns are prepared from wooden master pattern which has to be provided with double shrinkage allowance and suitable machining allowance so that the final casting conforms to the required size.

Plastics: Plastics are often used as pattern material since they do not absorb moisture, are strong and dimensionally stable, resistant to wear, have a very smooth and glossy surface and are light in weight. Because of their glossy surface they can be withdrawn from the mould very easily without injuring the mould.

Plaster of paris: Plaster of paris also known as gypsum cement can also be used for making patterns. It has high compressive strength and intricate shapes can be easily made using wooden tools. The disadvantage of plaster of paris is it gets affected by moisture and hard ramming.

## Types of Patterns:

The type of pattern to be used for a particular casting depends upon many factors like the size of casting, type of moulding process, number of castings required and the anticipated difficulty of moulding on account of the shape or design of casting. The most commonly used patterns are Single Piece or Solid Pattern and Split pattern

1. Single-piece or solid pattern: A pattern which is made without any joints, partings or loose pieces in its construction is called a single-piece or solid pattern as shown in the figure below. This is the simplest of all the patterns and is generally contained only in the drag during the moulding process. These patterns are cheaper. When using such patterns, the molder has to cut runners, feeding gates and risers. Single-piece patterns are usually used for large castings of simple shapes.

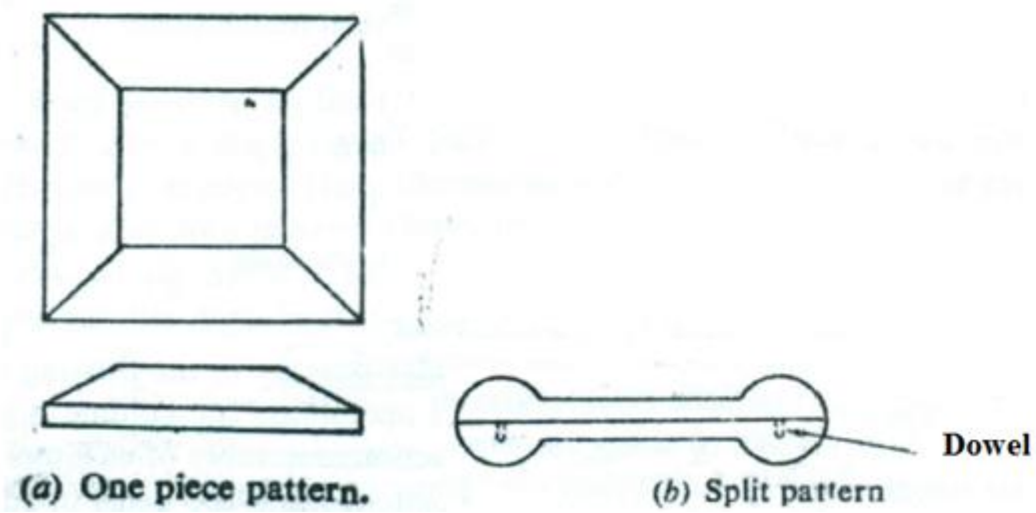



Fig. 8.2: Types of Patterns

2. Split pattern: Many patterns cannot be made in a single piece because of the difficulties encountered in molding them. To eliminate this difficulty whenever the desired casting has a contour or an intricate shape, split patterns are employed to form the mould. These patterns are usually made in two parts, so that one part will produce the lower half of the mould and the other the upper half as shown in the figure above. The lower half is contained in the drag and the upper half in the cope. The two parts which may or may not be of the same size and shape, are held in place by means of dowel-pins fastened in one piece and fitting holes bored in the other. The surface formed at the line of separation of the two parts, usually at the centerline of the pattern is called the parting surface. It will also be the parting surface of the mould.

## Pattern Making Allowances:

A pattern is always made larger than the required size of the castings in order to allow for various factors such shrinkage, machining, distortion, rapping etc. The following allowances are provided in a pattern:

1. Shrinkage allowance
2. Machining Allowance
3. Draft Allowance
4. Rapping or Shake Allowance
5. Distortion Allowance
6. Mouldwall Movement Allowance

1. Shrinkage Allowance: As the molten metal cools and solidifies it shrinks and contracts in size. If the pattern is of the same size as that of the desired casting, then the resulting casting would be smaller in size as compared to the desired size. To compensate for this the pattern is made larger than the desired casting so that the solidified casting conforms to the required size. This increase in size which has to be incorporated in the pattern is called shrinkage allowance. Different metals have different shrinkage rates. The pattern maker uses a pattern makers scale in which the graduations are oversized by a proportionate amount to compensate for the shrinkage of the metal.

2. Machining Allowance: When the solidified casting is withdrawn from the mould it has a rough surface contaminated with sand particles. This will have to be removed by machining in order to improve the surface finish and to bring the casting to the required dimensions. This extra amount of metal which has to provided on the surfaces, that is to be machined off is called machining allowance. The amount of this allowance depends upon the type of metal used in casting process, method of machining to be employed, size and shape of the casting and the degree of finish required on the surface.

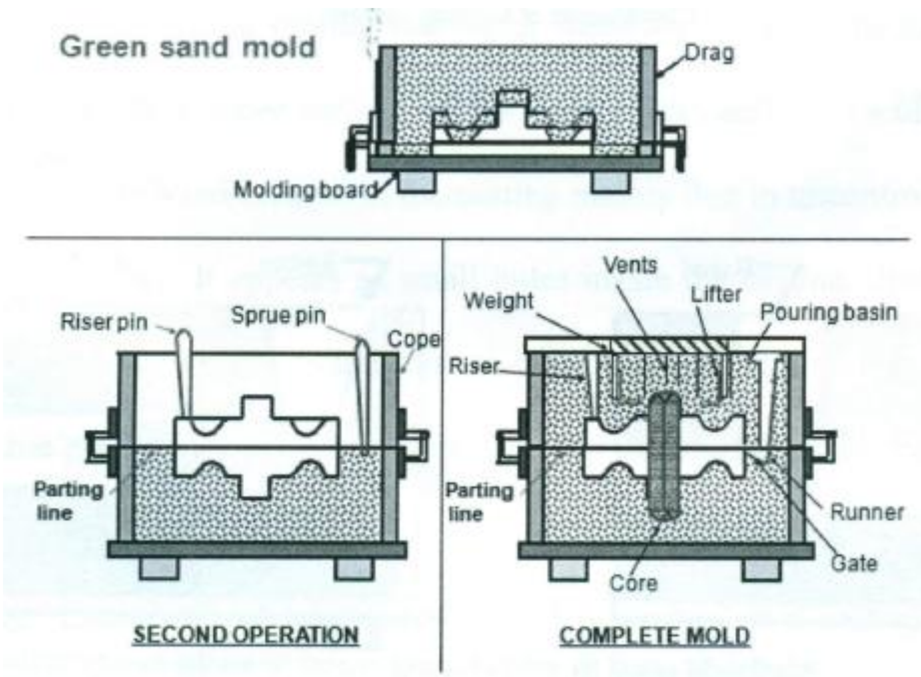
3. Draft Allowance: When the pattern is withdrawn from the mould there is always a possibility of damaging the vertical surfaces and edges of the mould. This difficulty can be overcome if the vertical surfaces of a pattern are tapered slightly. This taper on the vertical surface of a pattern is known as draft allowance which facilitates easy withdrawal of pattern from the mould. It may be expressed either in degrees or in terms of linear measures. Draft allowance may be provided both on internal and external surfaces.

4.Rapping or Shake Allowance: When a pattern is to be withdrawn from the mould, it has to be first rapped or struck lightly in ordered to free it from the sand. As a result of this the size of the mould cavity increases slightly. To compensate for this a negative allowance is provided in the pattern by making it smaller than the actual size. However, it may be considered negligible for all practical purposes in small and medium sized castings.

5. Distortion Allowance: Some castings because of their size and shape tend to get distorted during solidification period due to the thermal stresses developed in them. The shape of the pattern is thus bent in the opposite direction to overcome this distortion. This is called distortion allowance. For example, a casting in the form of U shape will get distorted with the legs diverging instead of being parallel. To compensate for this the pattern is made with its legs converging slightly, so that as the casting cools and after its removal from the mould the legs straighten and remain parallel.

6. Mouldwall Movement Allowance: Movement of mould walls in sand moulds takes place on account of the excessive heat and the static pressure exerted on the surface layer of sand which comes in contact with the molten metal. This movement of mould walls affects the ultimate size of the castings and needs to be compensated by providing corresponding allowance in the pattern and by controlling the density and temperature of the molten metal and composition of the moulding sand.

## Two Box Moulding Procedure:




Two Box Moulding Procedure

The step by step procedure involved in two box moulding is as follows.

1. First the drag is placed in the upside down position on the moulding board, and the bottom half of the pattern is placed centrally inside the drag.
2. The drag is completely filled with molding sand. The sand is rammed around the pattern. After ramming the excess sand is leveled off with a strike rod. Venting holes are made through sand.
3. The drag is then turned over and the cope is placed on the drag. The upper half of the pattern is placed over the bottom half of the pattern. Two sprue pins are placed on either side of the pattern. These pins which are withdrawn later from the cope leave two passages known as the runner and riser. Runner is used for pouring the molten metal into the mould and riser will ensure that the mould cavity has been filled up. After that cope is filled with moulding sand and is properly rammed. Excess sand from the top surface is removed and vent holes are made to provide for the escape of hot gases
4. The sprue pins are withdrawn, a funnel shaped opening is scooped out at the top surface near the runner to form the pouring basin. The cope is lifted from the drag and is placed separately with its parting surface in the upward position. Next both the halves of the pattern are withdrawn and a gate is cut in the drag to connect the runner to the mould cavity.
5. If a core is used , using the core box and core sand the core is separately made and placed in position in the drag. The cope is then placed in position over the drag so that the mould is closed. The two boxes are then clamped with each other. Before pouring the molten metal a weight is placed over the cope to prevent the metal from flowing at the parting surface.
6. After the molten metal solidifies the casting is withdrawn by collapsing the sand, the runner and riser extensions are sheared using a saw and cleaning and machining operations are carried out to finish the casting.

## Cores:

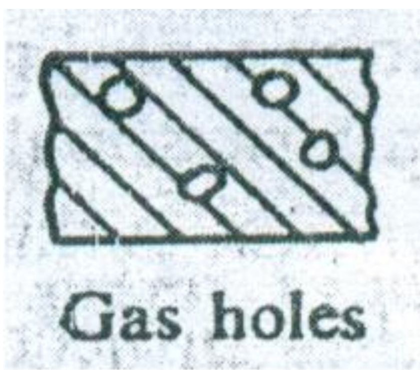
Whenever hollow portions are desired in the casting the molten metal must be prevented from occupying those portions, which can be done by placing cores at those particular locations in the mould. A core is a body of sand prepared separately in a core box which is used to form cavity of desired shape and size in the casting.

Cores are subjected to severe conditions because after pouring the molten metal the cores are surrounded on all sides by molten metal. Therefore they must be strong enough to resist erosion by the molten metal, must have adequate permeability to permit the escape of hot gases, should be highly refractory in nature to withstand the high temperature of molten metal and must have good collapsibility to minimize strains on the casting and to facilitate their removal from the casting.

The sand used for making cores is clay free silica sand which should be smaller in grain size and should have a high degree of refractoriness. Linseed oil is generally used as the binder.

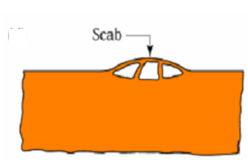
## Defects in Casting:

Blowholes:



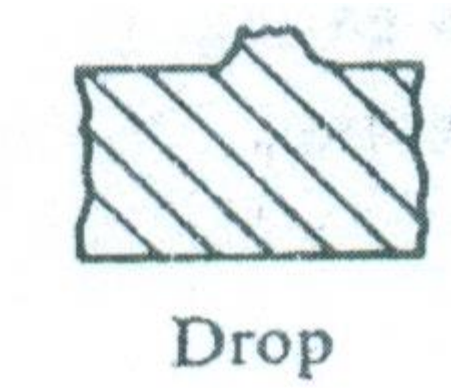

Blow holes are the cavities in the casting. These are entrapped bubbles of gases with smooth walls. They are caused due to excessive moisture in the sand or when the porosity of the sand is low or when the sand is rammed too hard or when the venting is insufficient.

Scabs:



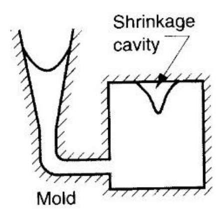

Projection on the casting that occur when a portion of the mould lifts and metal flows.

Drop:



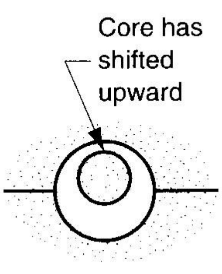

Drop occurs when upper surface of the mold cracks and pieces of sand falls in to the molten metal. This is caused by low strength and soft ramming of the sand.

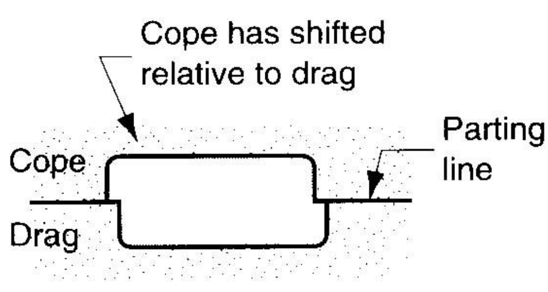
Shrinkage cavity:




Void created in the casting mainly due to uncontrolled solidification of the metal.

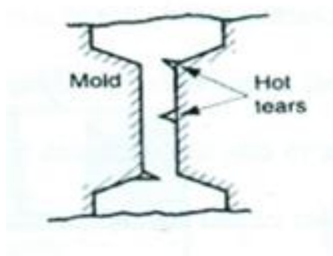
Shifts:




An external defect caused due to core misplacement or mismatching of top and bottom parts of the casting. This may occur due to improper clamping of the moulding boxes.

Hot tears (Pulls):




They are internal or external cracks having ragged edges occurring immediately after the metal has been solidified. Hot tears may be produced if the casting is poorly designed and abrupt sectional changes take place, no proper fillets and corer radii are provided, incorrect pouring temperatures and improper placement of gates and risers and hard ramming can also create hot tears.

Fin: A thin projection of the metal at the parting surface. It is caused due to incorrect assembling of molds or cores.

Swell: Enlargement of mould cavity by molten metal pressure. This is caused by improper ramming.

Warpage: Unintentional and undesirable deformation in a casting that occurs during or after solidification due to internal stresses developed or different rates of solidification in different sections of the casting.

Misrun and Cold Shut: A misrun casting is the one which lacks completeness due to failure of the metal to fill the mould cavity.

When two streams of molten metal approach each other in the mould from opposite directions, establish a physical contact between them, but fail to fuse together resulting in discontinuity between them, it is known as cold shut. The defect may appear like a crack or seam with round edges. Both these defects occur due to lack of fluidity of the molten metal.

Introduction to Forging

Forging involves heating a metal stock to a desired temperature, enabling it to acquire sufficient plasticity, followed by operations such as hammering, bending, pressing etc. to give it the required shape. These operations can be carried out either by hand hammers or by power hammers.

Smithing is a hand forging operation wherein small parts are produced by heating the metal stock in an open fire or hearth and then working on it with hand hammers to give the desired shape.

Forging involves heating the metal stock in a closed furnace and working on it with the help of power driven hammers to give the desired shape. It is generally used in the production of heavy parts

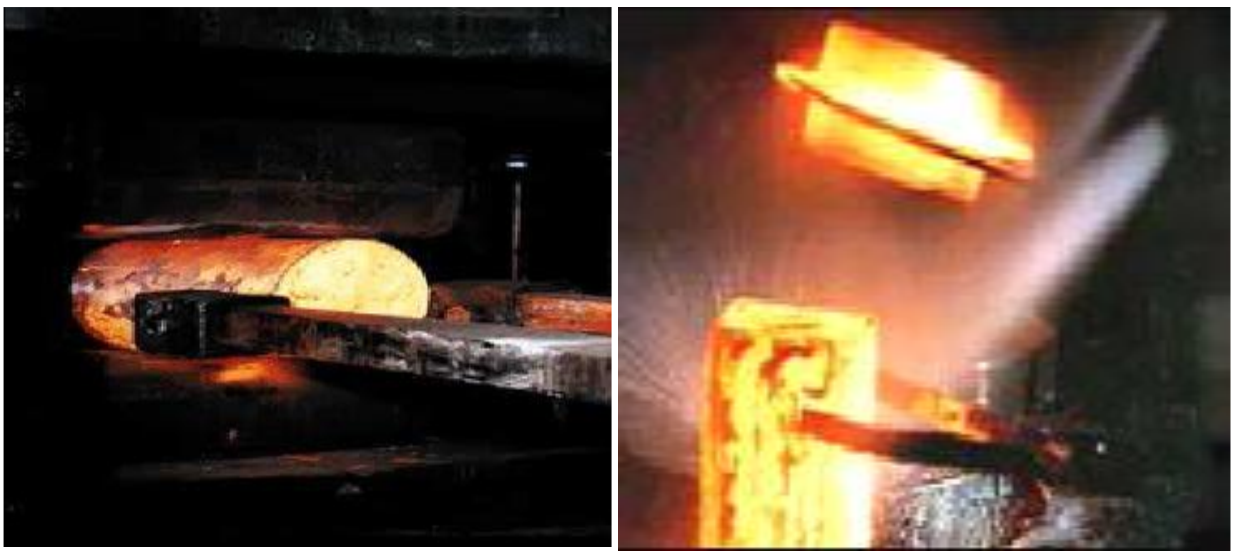


Fig. 8.5. Forging

## Characteristics of Forging:

- Forging refines the structure of the metal by smashing up large grain formations and closing up any cavities that may be present in the metal.
- In forging the grains rearrange themselves according to the shape of the object hence, forged components exhibit directional properties indicated by the flow lines which increases the strength of the component.

- In forging certain mechanical properties, resistance to shock and vibration are improved and cracks and blow holes are welded up,  hence the component will be free from internal defects
- Forging produces poor surface finish due to scale or oxide formation at high temperatures with the result the dimensional accuracy of the components is difficult to maintain.
- Forging is a costlier process requiring expensive tools and dies, hence it is suitable only for mass production work