1) SAND CASTING

Casting as an old technique is the quickest link between engineering drawing 2nd manufacturing .It provides us with the possibility of forming wide range of shapes with wide range of materials.

Sand Casting is simply melting the metal and pouring it into a preformed cavity, called mold, allowing (the metal to solidify and then breaking up the mold to remove casting. In sand casting expandable molds are used. So for each casting operation you have to form a new mold.

Basic Requirements for metal casting

1. A mold cavity
2. Melting process
3. Pouring technique
4. Solidification process
5. Removal of casting
6. Finishing draft allowance

Sand Casting is the most important and mostly used casting technique. To perform sand casting we have to form a pattern (a full sized model of the part), enlarged to account for shrinkage and machining allowances in the final casting.

Materials used to make patterns include wood, plastics, aluminum, fiberglass, cast iron and some other metals. Wood is a common pattern material because it is easily worked into shape. Its disadvantages are that it tends to warp and the sand being compacted around it abrades it, thus limiting the number of times it can be reused (used for a small number castings). Metal patterns are more expensive to make, but they last much longer. For example aluminum is the most common metal to be used if" many castings are to be made by the same pattern. So selection of the appropriate pattern material depends to a large extent on the total quality of castings to be made. The size of the pattern depends upon the shrinkage during cooling and the Finishing allowance.

Some special coating to prevent their destruction should coat patterns.

Patterns have also some identifiers such as colors on them, each of which has different meaning that represent different treatments and requirements far the patterns. The color-coding for patterns in sand casting is as follows

1) *Red* indicates that the surface of the material should be left as it is after casting.
2) ***Black*** indicates that the surface needs core and shows the position of the sand core.
3) ***Yellow*** indicates that the surface needs machining.

The casting will be missing. To ensure that cores retain the correct arrangement core prints are placed into the mold.

Some metal springs called *densiments* are placed into the mold lo provide uniform solidification of the metal throughout the mold. Nails are inserted into thin parts of the mold to reinforce them.

After forming the mold cavity, an alcoholic liquid is sprayed aver the cope (The upper part of the mold) and heated with flames to harden and to dry the surface.

Filling a metal box having two halves, which is called the flask forms *mold*. So mold is also made up of two halves, which is separated by a *parting line*. The reason for this is to remove the tasted part easier from the mold. The upper part of the mold is called the cope and the lower part called the drag. The cope and drag are prepared separately and when they are ready they unites and metal is poured into it through a canal called sprue, which transmits the molten metal via *runner* into the mold cavity. The runner should not be big because it will increase the amount of the waste metal. It should not be small because this enhances rapid solidification in the runner causing a blockage. At the bottom of the sprue there is a gap called *well* far the collection of the unwanted sand, which comes with the flowing metal.

There is also a riser system, which acts as an inventory of molten metal when the mold cavity is fulfilled with the metal and feeds automatically the cavity of the part that we want to get. This system is essential because as the molten metal cools down it shrinks so the amount needed to replace the shrinked metal comes fom the riser itself eliminating shrinkage cavities. A casting may show microporosity. This can be eliminated with directional solidification either by incorporating a metal *chill* into the mold or by tapering the thinnest section of the runner. *Chills* are also used around thicker parts of the casting to provide uniform cooling of these parts with the thinner parts to prevent cracks. Chills, by this way, preserve the mechanical properties of the whole casting.

The steel is melted in electric-arc furnaces. The advantage of electrical furnace, the scrap steel, which was used before (metal left In risers and runners) can be melted in these furnaces and used again. When the furnace reaches the suitable temperature, it is turned off. The molten metal is filed into the portable reservoir called table and then table is moved to just above of the mold and metal is poured into the mold's pouring basin. A powder is added to the mold's surface to prevent metal's rapid cooling during pouring. Another powder is sprayed aver the mold to form a blanket of inert gas to prevent the oxidation of the molten metal. The steel is melted in electric-arc furnaces. The advantage of electrical furnace, the scrap steel, which was used before (metal left In risers and runners) can be melted in these furnaces and used again. When the furnace reaches the suitable temperature, it is turned off. The molten metal is filed into the portable reservoir called *label* and then table is moved to just above of the mold and metal is poured into the mold's pouring basin. A powder is added to the mold's surface to prevent metal's rapid cooling during pouring. Another powder is sprayed aver the mold to form a blanket of Inert gas to prevent the oxidation of the molten metal.

The completed casting is left for cooling and when it completely cools down the whole flask is taken to a vibrating platform to remove the casting from the mold. Excess parts are cut either by oxygen if the casting is of steel (hard), or by hammering if the casting is of cast iron (brittle).

Automated Sand Casting in Foundries

Today 70 % of the casting processes are achieved with automation. Because upto 200 components sand casting is ideal but in the case of long production lines arid for higher number of components arid far small components sand casting is not economic. For this purpose automated foundry is the right choice. High melting temp metals are used for castings. There are three kinds of production

1) **Jobbing factory** upto 100 parts but lots of varieties

2) **Batch factory** 500-1000 parts
3) **Mass production:** lots of parts ,can be more than 1000.

In automated foundries there is continuous pouring on a conveyor into the pre-formed molds.
This continuous process has two levels

1) **Pooring** the metal continuously into the molds.
2) **Charging** metal into the tables from the furnace (mostly gray iron) (each of tables holding 6 tones)

In automated sand casting sand is carried automatically arid pattern is made of metal. More water is added to the sand. But sand must riot be too damp otherwise it easily disintegrates. The pattern is pressed into prepared sand by automatic hydraulic press and the mold is formed. By the same procedure many molds are formed then non-stop casting operation starts on a conveyor

After the castings have cooled down completely, molds are destroyed arid they are passed through a rotating recycling drum in which sand is removed arid added again to the sand carrying system and the casting is moved in the drum for further operations such as the removal of the excess parts (risers arid runners) from their bodies, and blasting arid finishing operations.
For small numbers of large components to be casted with high melting temp, metals, sand casting is suitable But the as a disadvantage every time you need a new mold so this technique would riot be economic for low melting temp metals.

Advantages of Sand Casting:

1) Casting can be used to create complex pad geometries, including Goth external arid internal shapes.
2) Some casting operations are capable of producing parts to net shape. No further manufacturing parts are needed.
3) Casting can be used to produce
4) Casting process can be performed on any metal that can be heated to the liquid state.
5) Some casting methods are highly suited far mass production.
6) Casting is the easiest and quickest way (technique) from drawing (design) to the production.

Disadvantages of Sand Casting

1) Limitation on mechanical properties
2) Porosity (empty spaces within the metal - reduces the strength of metal)
3) Poor dimensional accuracy and surface finish
4) Safety hazards to humans and environmental problems
5) Removal of pattern of the thin and small parts is very difficult

Casting Quality:

There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the cast product.

Casting Defects:

1) *Misruns* (due to rapid solidification in the runner)
2) *Cold shuts* (due to rapid solidification before complete filling of the mold)

3) *Cold shots* (due to splattered globules of metal during pouring)
4) Shrinkage cavity (due to lack of riser system)
5) *Microporosity* (due to localized solidification shrinkage)
6) *Hot tearing* (due to the die's prevention of contraction)

Defects related with sand molds :

1) Sand blow
2) Pinholes
3) Sand wash
4) Scabs
5) Penetration
6) Mold shift
7) Core shift
8) Mold crack

Inspection Methods:

1) Visual Inspection to detect obvious defects such as Misruns, surface flaws.
2) Dimensional measurements to ensure that tolerances have been met.
3) Metallurgical, chemical, physical, and other tests related with the quality
    a) Pressure testing to locate teaks in the casting
    b) Radiographic methods magnetic particle tests, use of fluorescent penetrants, and supersonic testing to detect either surface or internal defects in casting.
    c) Mechanical testing to determine properties such as tensile strength and hardness.

If defects are discovered but are not too serious, it is often possible to save the casting by welding, grinding or other salvage methods to which the customer has agreed.

2) DIE CASTING

Sand casting is suitable for small numbers of large components and for metals that melt at high temperatures. But it has a disadvantage that every time you need a new mold. As a result this technique is quite uneconomic for low melting temperature metals. For low melting temperature metals there is another suitable casting technique. Die casting. The usage of die-casting depends on the melting temperature of metal being tasted. (Bronze & brass door handles are made from this technique- Also certain types of car wheels complex transmission cases, and carburetor parts can be produced by die casting.)

Properties of die-casting:

1) Huge numbers of small, light castings can be produced with great accuracy.
2) Little surface finishing is required.
3) Permanent mold (dies can be used over and over)

Simplest method of die-casting is gravity die-casting. It is just pouring from a label; no pressure or external forces are involved. Mainly Magnesium (Mg) is suitable for this technique. Before pouring the metal a powder called french ***chalk*** is put into the die made of cast iron to prevent sticking of the metal. Magnesium is heated continuously during the process to keep right thermal ingredients and to maintain the fluidity of magnesium while is kept under flask to prevent contact with air (0_2) to inhibit its explosive property and for this reason while pouring Mg, again the surface is being powdered. This powdering result in inert gases ($S0_2$) heavier than air, which prevents explosive reactions and also keeps the metal surface clean and shiny. Mg is ideal for making rising wheels by using gravity die-casting, because it is tight and strong.

Low-pressure die-casting:

In this technique die is surrounded by gas burner to keep right thermal ingredients. One of the great advantages of this process; there is no need to remove riser and runner, so wastes are minimized. Little final machining is needed. Aluminum is suitable for this process because it doesn't readily react with oxygen gas, so it is easier than Mg to work with (It can be shaped, and carried easily). Solidification starts at the edges of the rim and moves inwards to the center.

To check if there are any cracks, the casting is painted with engineering blue color. In aeroplane industry X-ray technique is used instead.

High Pressure die-casting:

In high pressure die casting to shorten the time For the metal to be solidified and to increase the output metal is infected into a water cooled die under high pressure and squeezed two times. Between each injection of metal, metal is sprayed with graphite-based oil, to prevent sticking of metal to the die. Because of high pressures involved safety regulations should be obeyed with great accuracy.

The metal injection:

1) Metal in the plunger, closing of pouring hole
2) Moving the metal into the die
3) Filling the cavity by the metal
4) Intensification to compact the metal and reduce the cavitations (applying high pressure)

Speed of operation depends on the cooling rate. In this technique careful die design is important and usually a die made of steel is used High output justifies the quality of the output. A plunger makes metal injection into the die. The metal is injected into 2 identical dies at the same time producing two identical castings, which increases output. Higher the melting point of metal being tasted, lower the life of the die.

High-pressure die-casting provides a good surface and good die dimensions. It is suitable for all nonferrous alloys. This technique is also successful in thin walled structures. Ideal for a mass production.

3) INVESTMENT CASTING

To check if the casting complete and flawless, infrared sensors are used.

For high melting temperature metals, if small numbers of specialized castings with high tolerances are required investment casting is ideal. Investment casting produces bioengineering components, and some used in aerospace industry. This technique provides us with good dimensional accuracy and at the end little surface finishing operations are needed. Light allay materials are used. Because of these properties products should be produced on time and be at right value. Die will be used over and over.

Lost wax method of *investment* casting: First is prepared for wax injection. After injection of wax (30 sec) die is opened, then the wax pattern is put into very dilute HCl acid. This process is for dissolving out the soluble core. (Core dissolved in 12 hours) Then the tree holding the small patterns is hold into isopropanol and tridoroethene, then into pure isopropanol and dried by compressed air. We then give the pattern a ceramic coating; this will eventually form the foal mold. (By dipping it in zircon, coated with foe refractory powder; now it is called mold). We dry the mold by passing it through ammonia vapor. Then dewaxing process comes, any wax left could ruin a costly casting. For the process a 900˚C gas fire oven is used. We then left the work to be cooled down on shelves. Now, it is extremely heavy and brittle. Molds are heated again for four hours, now the mold is ready for casting. This is very economic because you gel many castings from one melt of the furnace.

All steel in the furnace must be at the same temperature (1650 C). When the furnace is reached the suitable temperature, small amount of silicon is added to help metal run more easily in the mold. Temperature is checked again. Mold is placed upside down on the furnace. Then the whole lot is tipped over. When the metal is flowed into mold, it is allowed to cool, a powder is added to ensure the cooling is uniform throughout the mold. 20 minutes later mold is taken to further cooling.

The best way (efficient and safest) of removing the ceramic coating is by hammering, although it is dusty and noisy.

Finally the castings are passed through some vigorous tests such as X-Rays, Ultraviolet light testing. Then dimensional accuracy is also tested.

Investment casting is an ideal method for the metals that cannot be successfully machined such as Tungsten and Cobalt. It is a profitable production method; and you have the possibility to make both small and large castings.

4) FORGING

Machining of the materials is expensive and not all materials can be machined easily and the finished article may not have mechanical properties and machining weakens the fibrous structure. For example

metal blank drawing : it is a technique to cut and tear the metals into desired shapes. It is the mast expensive and wasting method of manufacturing.

On the other hand casting has not uniform cooling and good fluidity and does not give enough tensile strength and toughness.

Forging is simply forming the metal in specified shapes by applying large external force on hot ingot. It is a speedy operation but the running expense of the pressing machine is relatively high. Forging gives perfect tensile strength and toughness to the material at high speed with great pressure. It is one of the most popular manufacturing techniques. Forging makes switching tools.

Forging is done after heating up the material because it is easier to work with hot metal. High temperatures cause the material to crumble and lose its malleability. However forging

1) Refrain the grain structure
2) Draws out the undesirable (nonmetallic) substances
3) Removes internal Cavities
4) Enhances mechanical properties but does not increase hardness
5) Fibrous structure is enhanced
6) Removes oxide layer on the hot material

Grain structure of the metal is same as wood's and it is easier to split It along axis. This fibrous structure affects the strength.

Types of forging:

1) *Open die forging:* There is no die, only the material is pressed to be made thinner and stronger. E.g. ships propeller shall. Open die forging can also be used for preparing raw material. Forging process in order to reach the needed grain flow usually makes die blocks.
2) *Hot ores forging:*Correct-forging temperature is reached gradually. By this heat treatment internal stresses are reduced and metal relax. After removing the ingot from the furnace it is forged immediately giving it max strength. Fibrous structure is enhanced in all 3 dimensions. Excess metal called flash is removed from the finished article after forging.
3) *Upset Forging:* Some part of the metal (billet) goes under forging. By This technique diameter is increased without decreasing its strength. The forging should be done at right temp to prevent cracks. A head on a bolt, round *head formed* by punch or similar hardware item can be formed by this operation. After forging machining is applied to the metal.
4) *Roll Forging:* Material is passed through a rolling die, which has non-uniform surface with different depths, and the pad facing the metal gives its shape to the surface of the metal.
5) *Drop Hammer Forging:* Huge cyclic force is dropped on uniform material and removed by this technique *diesel* crankshaft is produced. In this technique 20% of the material is waste called *flash.* Between each operation the two halves of the die is sprayed with fine graphite oil to prevent the metal from sticking to the die and to prevent wearing of the die and to cool the die. After forging operation the part is oil quenched and tempered to increase its hardness.

Some principles and limitations in die design to be considered

1) *Parting line:* It divides the upper die from the lower die. Its design affects grain flow in the part, flash formation.
2) *Draft*: Amount of taper on the sides of the part required to remove from the die. Draft angles on precision forgings are near zero.
3) *Webs and ribs*: A web is a thin portion of the forging that is parallel to the line while a rib is a thin portion that is perpendicular to the parting line. These features cause difficulty in metal flow as they become thinner

4) *Fillet and comer radii:* Small radii tend to limit metal flow and increase stresses on die surfaces of forging.

5) *Flash:* Flash formation plays a critical role in impression-die forging by the pressure buildup inside the die to promote filling of the cavity. This pressure is controlled by designing a flash land gutter into the die