Centrifugal Casting:

A family of casting processes in which the molten metal is pouring into mold which is rotated at high speed (200 - 1000 rpm is reasonable), so centrifugal force distributes molten metal to outer regions of the die cavity.

The group includes:

- **True centrifugal casting.**
- **Semi-centrifugal casting.**
- **Centrifuge casting.**

Centrifugal Casting produces:

- ***Good quality.***
- ***Accurate casting.***
- ***Saves material.***
- ***Dense product & have fine grained structure with uniform & high physical properties.***
- ***Less subjected to directional variation than static casting.***

True Centrifugal Casting:

Molten metal is poured into rotating mold to produce a tubular part (*hollow cylindrical shapes such as pipe are produced*) [see fig. (14) below].

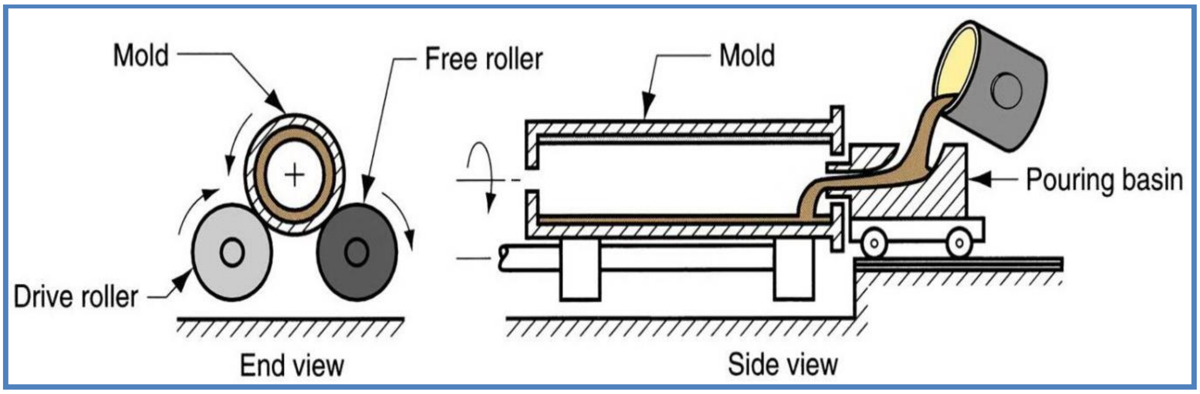

Fig. (14): Setup for true centrifugal casting.

- **In some operations, mold rotation commences after pouring rather than before.**
- **The mold can be rotated about a vertical, horizontal axis [see fig. (15) below].**
- **The length and outside diameter are fixed by the mold cavity dimensions while the inside diameter is determined by the amount of molten metal poured into the mold.**

Parts: pipes, tubes, bushings, and rings.

- **Outside shape of casting can be round, octagonal, hexagonal, etc , but inside shape is (theoretically) perfectly round, due to radially symmetric forces.**

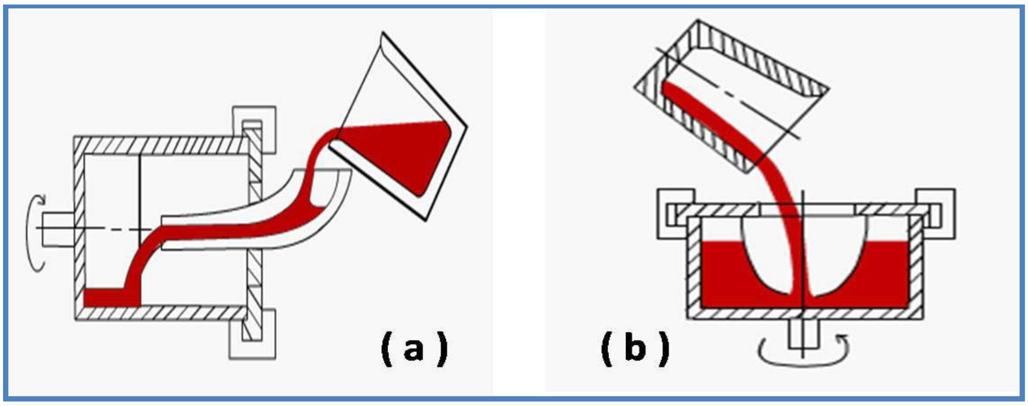

Fig. (15): Centrifugal casting (a) Horizontal axis (b) Vertical axis.

The basic process is:

1. **The mold is set up and rotated along a vertical (rpm is reasonable), or horizontal axis.**
2. **The mold is coated with a refractory coating.**
3. **While rotating molten metal is poured in.**
4. **The metal that is poured in will then distribute itself over the rotating wall.**
5. **During cooling lower density impurities will tend to rise towards the center of rotation.**
6. **After the part has solidified, it is removed and finished.**

Mold Speed of Rotation:

Let us consider how fast the mold must rotate in horizontal centrifugal casting for the process to work successfully. Centrifugal force is defined by this physics equation:

$$F = \frac{m.V^2}{R}$$

Where:

F = force, N; m = mass, kg; V = velocity, m/s; and R = inside radius of the mold, m.

The force of gravity is its weight W=mg, where *m* is given in kg, and g = acceleration of gravity, 9.8 m/s^2. The so-called G-factor GF is the ratio of centrifugal force divided by weight:

$$GF = \frac{m.V^2}{R.W} = \frac{m.V^2}{R.m.g} = \frac{V^2}{R.g}$$

Velocity V can be expressed as:

$$V = \frac{2\,\pi.\ R.N}{60} = \frac{\pi.R.N}{30}$$

Where: *N* = rotational speed, rev/min.

Substituting this expression into Eq. in above equation, we obtain:

$$N = \frac{30}{\pi}\,.\sqrt{\frac{2\,g.GF}{D}}$$

Where:

D = inside diameter of the mold, m.

If the G-factor (GF) is too low in centrifugal casting, the liquid metal will not remain forced against the mold wall during the upper half of the circular path but will ''rain'' inside the cavity. Slipping occurs between the molten metal and the mold wall, which means that the rotational speed of the metal is less than that of the mold. On an empirical basis, values of [GF = 60 to 80] are found to be appropriate for horizontal centrifugal casting.

Example:

A true centrifugal casting operation is to be performed horizontally to make copper tube sections with OD ¼ 25 cm and ID ¼ 22.5 cm. What rotational speed is required if a G-factor of 65 is used to cast the tubing?

Solution:

The inside diameter of the mold D = OD of the casting = 25 cm = 0.25 m., it can compute the required rotational speed as follows:

$$N = \frac{30}{\pi}\,.\sqrt{\frac{2\,g.GF}{D}}$$

$$N = \frac{30}{\pi}\sqrt{\frac{2(9.8)(26)}{0.25}} = 61.7 \text{ rev/min.}$$

***<u>In vertical centrifugal casting</u>*:**

The effect of gravity acting on the liquid metal causes the casting wall to be thicker at the base than at the top. The inside profile of the casting wall takes on a parabolic shape. The difference in inside radius between top and bottom is related to speed of rotation as follows:

$$N = \frac{30}{\pi} \cdot \sqrt{\frac{2\, g.L}{R_t^2 - R_b^2}}$$

<u>Where:</u>

L = vertical length of the casting, (m), R_t = inside radius at the top of the casting, (m); and R_b = inside radius at the bottom of the casting, (m). it can be used to determine the required rotational speed for vertical centrifugal casting.
One can see from the formula that for R_t to equal R_b, the speed of rotation N would have to be infinite, which is impossible of course. As a practical matter, part lengths made by vertical centrifugal casting are usually no more than about twice their diameters.

<u>Semi-centrifugal Casting:</u>

It is similar to Centrifugal casting except that in this type the Centrifugal force is used to produce solid castings rather than tubular parts [see fig. (16) below].

- **Molds are designed with <u>risers at center</u> to supply feed metal.**
- **Density of metal in final casting is greater in outer sections than at center of rotation (because of condensation).**
- **Examples: wheels and pulleys.**

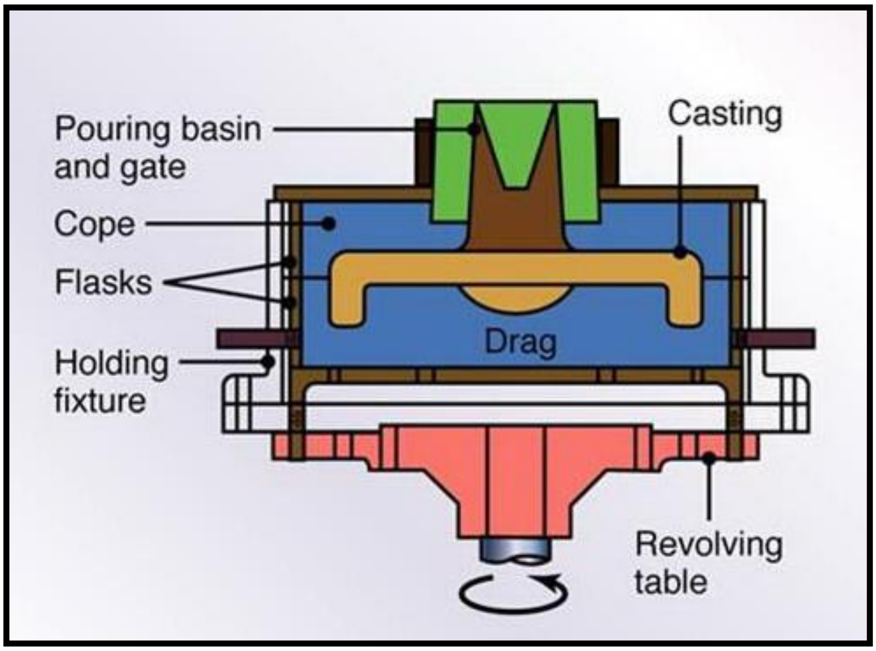

Fig. (16): Semi-centrifugal casting.

<u>Centrifuge Casting:</u>

Mold is designed with part cavities located away from axis of rotation (*placed at a certain radius from the axis of rotation*), so that molten metal poured from the center into mold is distributed to these cavities by centrifugal force [see fig. (17) below].

- **Used for <u>smaller parts</u>.**
- **Radial symmetry of part is not required as in other centrifugal casting methods.**

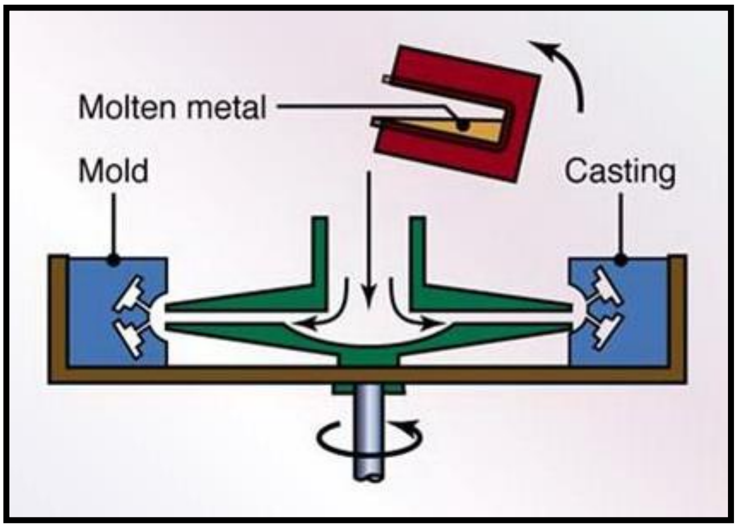

Fig. (17): Centrifuge casting.

Furnaces for Casting Processes:

Furnaces most commonly used in foundries are:

- **Direct fuel-fired furnaces**
- **Crucible furnaces**
- **Electric-arc furnaces**
- **Induction furnaces**

1. ***Direct Fuel-Fired Furnaces:***

Small open-hearth in which charge is heated by natural gas fuel burners located on side of furnace [see fig. (18) below].

- **Furnace roof assists heating action by reflecting flame down against charge.**
- **At bottom of hearth is a tap hole to release molten metal.**
- **Generally used for nonferrous metals such as copper-base alloys and aluminum.**

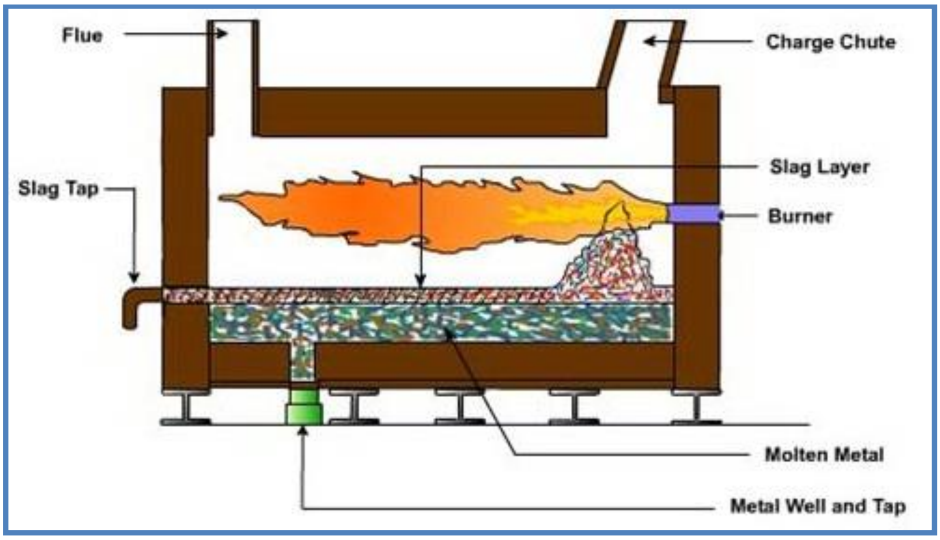

Fig. (18): Direct Fuel – Fired Furnace.

2. ***Crucible Furnaces:***

Metal is melted without direct contact with burning fuel mixture. Sometimes called *indirect fuel-fired furnaces* [see fig. (19) below].

- **Container (crucible) is made of refractory material or high-temperature steel alloy.**

- **Used for nonferrous metals such as bronze, brass, and alloys of zinc and aluminum**

Three types used in foundries: (a) lift-out type, (b) stationary, (c) tilting.

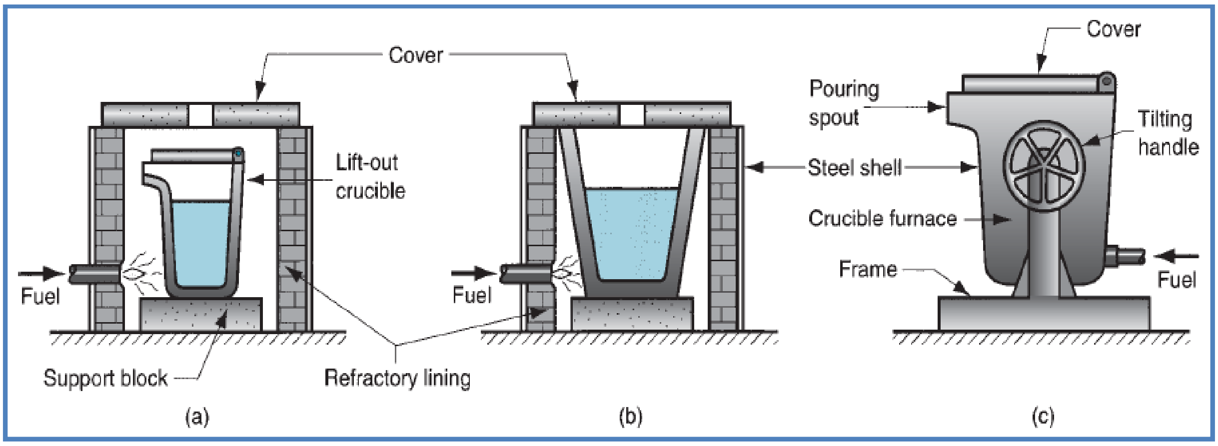

Fig. (19): Crucible Furnace.

3. ***Electric - Arc Furnaces:***

Charge is melted by heat generated from an electric arc [see fig. (20) below].

- **High power consumption, but electric-arc furnaces can be designed for high melting capacity.**
- **Used primarily for melting steel.**

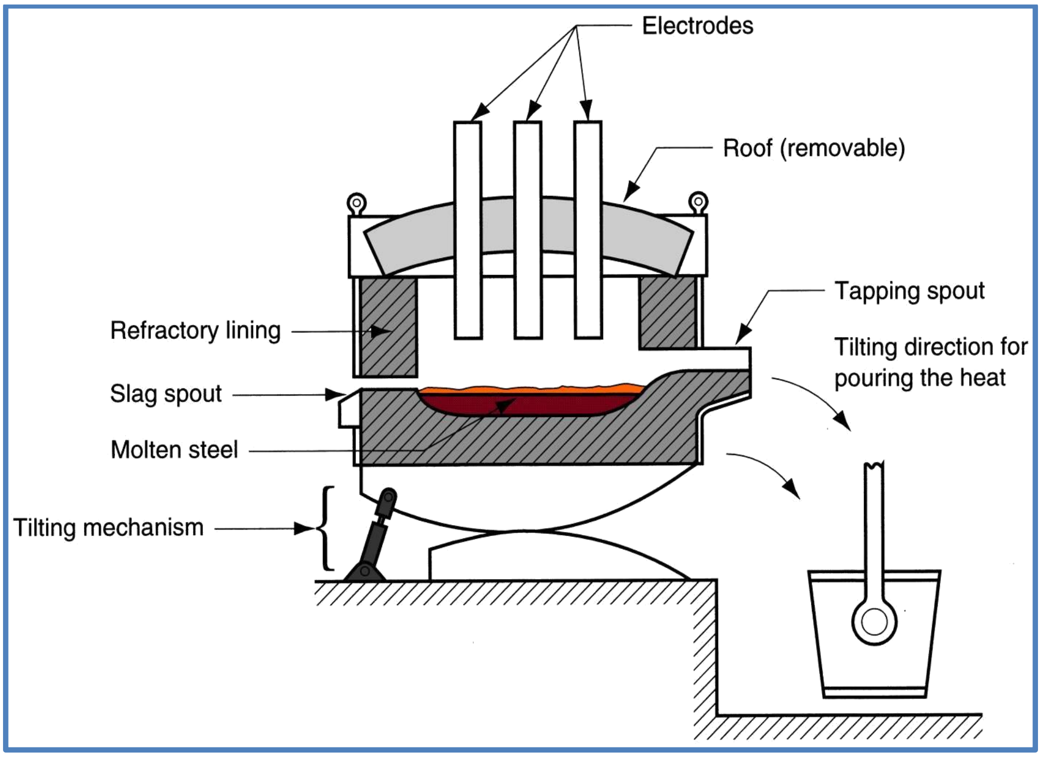

Fig. (20): Electric - Arc Furnace.

4. ***Induction Furnaces:***

Uses alternating current passing through a coil to develop magnetic field in metal, in which the induced current causes rapid heating and melting [see fig. (21) below].

- **Electromagnetic force field also causes mixing action in liquid metal.**
- **Since metal does not contact heating elements, environment can be closely controlled to produce molten metals of high quality and purity.**
- **Melting steel, cast iron, and aluminum alloys are common applications in foundry work.**

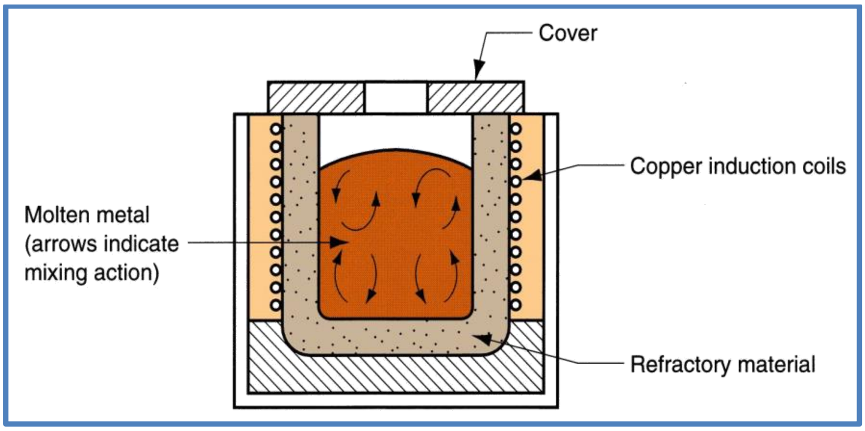

Fig. (21): Induction Furnace.

Ladles:

- **Moving molten metal from melting furnace to mold is sometimes done using crucibles**
- **More often, transfer is accomplished by *ladles*.**

Fig. (22) shows the crucible and two types of ladles (a) Crane ladle (b) Two man ladle.

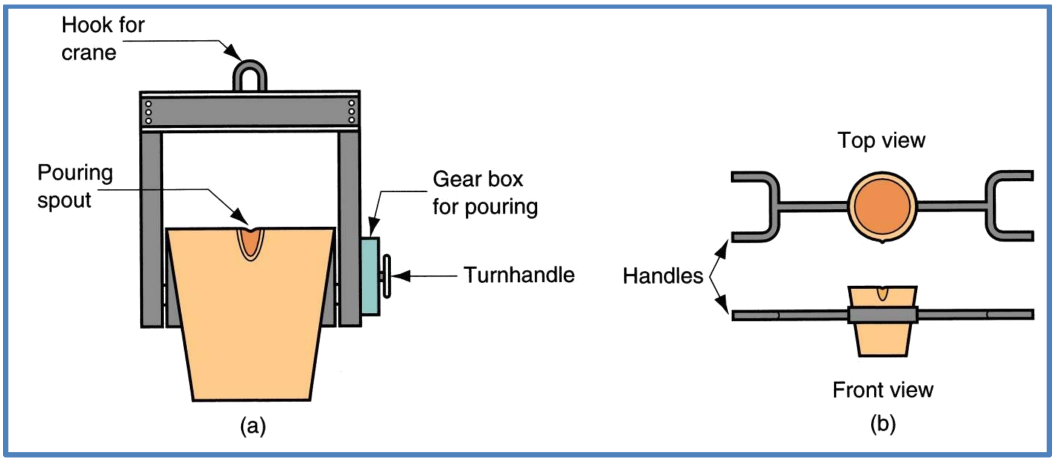

Fig. (22): Two common types of ladles.

Additional Steps After Solidification:

1. Trimming:

- **Removal of sprues, runners, risers, parting-line flash, fins, chaplets, and any other excess metal from the cast part [see fig. (23) below].**
- **Otherwise, hammering, shearing, hack-sawing, band-sawing, abrasive wheel cutting, or various torch cutting methods are used.**

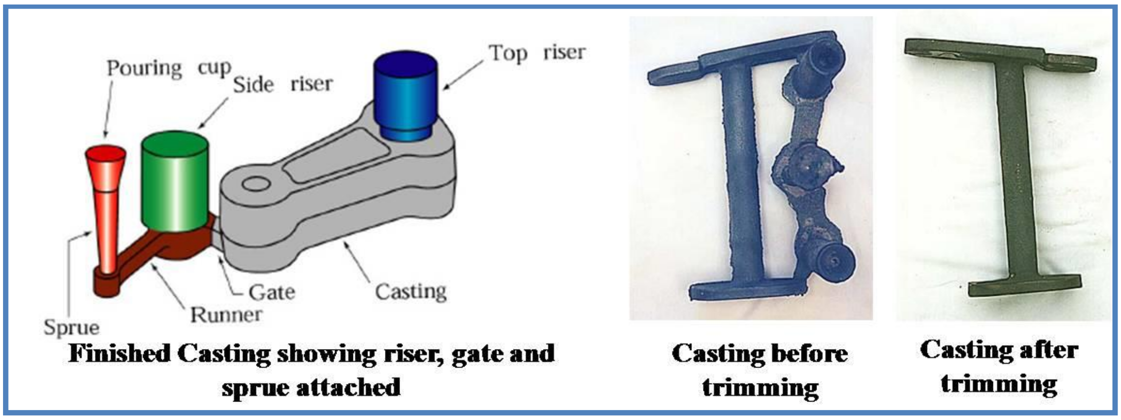

Fig. (23): Casting before and after Trimming.

2. *Removing the Core:*

If cores have been used, they must be removed.

- **Most cores are chemically bonded or oil bonded, and they often fall out of casting as the binder deteriorates.**
- **In some cases, they are removed by shaking casting, manually or mechanically.**
- **In rare cases, cores are removed by chemically dissolving bonding agent.**
- **Solid cores must be hammered or pressed out.**

3. *Surface Cleaning:*

It is the process of removal of sand from casting surface and otherwise enhancing appearance of surface.

- **Cleaning methods: tumbling, air-blasting with coarse sand grit or metal shot, wire brushing, polishing and buffing, and chemical pickling (to give a light finish to by bleaching or painting and wiping)**
- **Surface cleaning is most important for sand casting:**
  - **In many *permanent mold processes*, this step can be avoided.**

4. *Heat Treatment:*

Castings are often heat treated to enhance good mechanical properties.

Reasons for heat treating a casting:

- **For subsequent processing operations such as machining.**
- **To bring out the desired prope66[rties for the *application of the part in service*.**