CASTING PROCESSES

1.1. Introduction

Casting is defining as the process in which molten metal flows by gravity or other force into a mold or die where it solidifies in the shape of the mold cavity.

The main steps of casting processes are:

1 Creating a **mold**, which is the 'reverse' shape of the part we need. The mold is made from a refractory material, for example, sand.

2 The metal is heated in a furnaces to molten temperature sufficient for casting.

3 The molten metal is poured into the mold cavity manual pouring or by using the pouring machine. For this step to be successful, metal must flow into all regions of the mold cavity, before solidifying. Factors that determine success:

- Pouring temperature
- Pouring rate
- Lack of turbulence

4 The liquid takes the shape of cavity.

5 It is cooled until it solidifies.

6 The solidified metal part is removed from the mold.

Advantages of casting processes

1 Casting can produce very complex geometry parts with internal cavities and hollow sections.

2 It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms)

3 It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used.

4 Cast metal is isotropic – it has the same physical/mechanical properties along any

direction.

Common examples of casting products: door handles, locks, the outer casing or housing for motors, pumps, wheels of cars, toy industry, and so on.

Categories of Casting Process:

There are two main Categories of Casting Process:

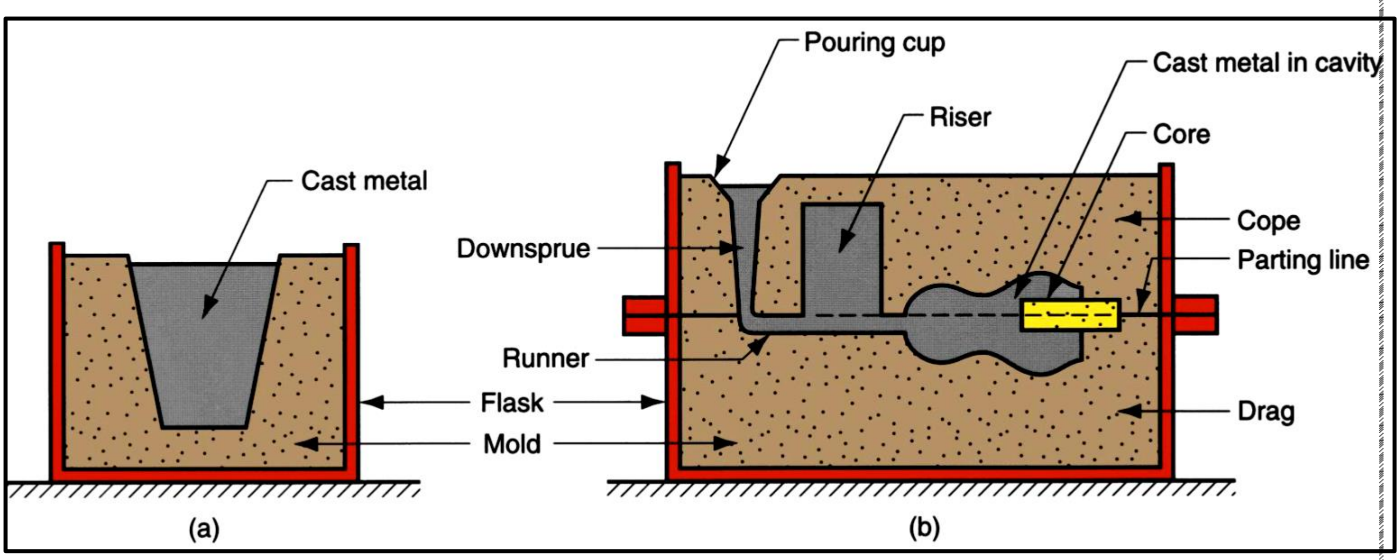
1 **Expendable mold processes** –Mold materials: sand, plaster, and similar materials, plus binders

2 **Permanent mold processes** –Mold materials: made of metal (or, less commonly, a ceramic refractory material)

1.2. Sand casting

Sand casting uses natural or synthetic sand (lake sand) as mold material which is mostly refractory material called silica (SiO2).

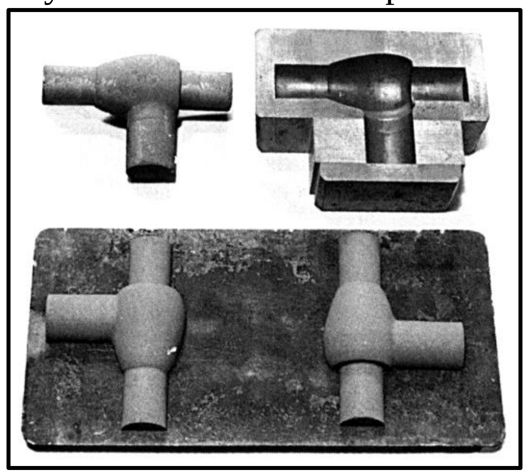
Patterns are used to prepare molds. To remove pattern, mold should be consists of two halves: 1-**Cope**: upper half of mold and 2- **Drag**: bottom half of the mold. Mold halves are contained in a box, called a flask.



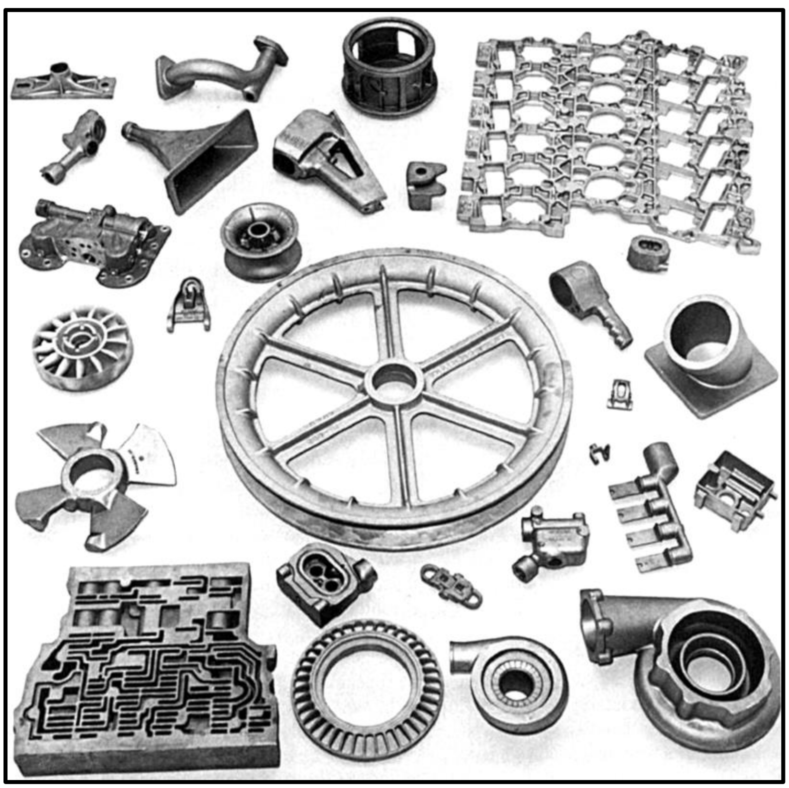
The patterns : Pattern is the duplicate of the part to be cast. It should be modified to take the allowances into consideration. The most commonly used pattern materials are wood, aliminum, magnesium, and certain hard plastics

Pattern allowances: The modifications that must be incorporated to a pattern are called allowances. The main pattern allowances are: Shrinkage allowance, Finish allowance, Draft (taper) allowance.

Cores: are sections of sand, used to obtain hollow sections in castings. Cores are made by baking sand with some binder so that they can retain their shape when handled.



Sand Core - Core Box



Some of sand casting products

1.3 Shell mold casting

The process was invented in Germany by Dr. Croning. In this process the silica sand is mixed with phenolic resin along with a curing agent.

The main steps to prepare the shell mould are: Figure: (1)

1- The moulds and cores are fitted over the dump box which prepared by mixing the fine sand with thermosetting resins /epoxy binder.

2- The box is inverted, the mixture falls on the hot pattern made of metal (e.g. aluminum or steel), which is heated to between 175°C-370°C, and coated with a lubricant, e.g. silicone spray. The process may be repeated to get a thicker hard shell.

3- The box is rotated back to its original upside position. The excess sand then falls back into the box, thus forming a shell over the pattern with thickness range from 2-8 mms.

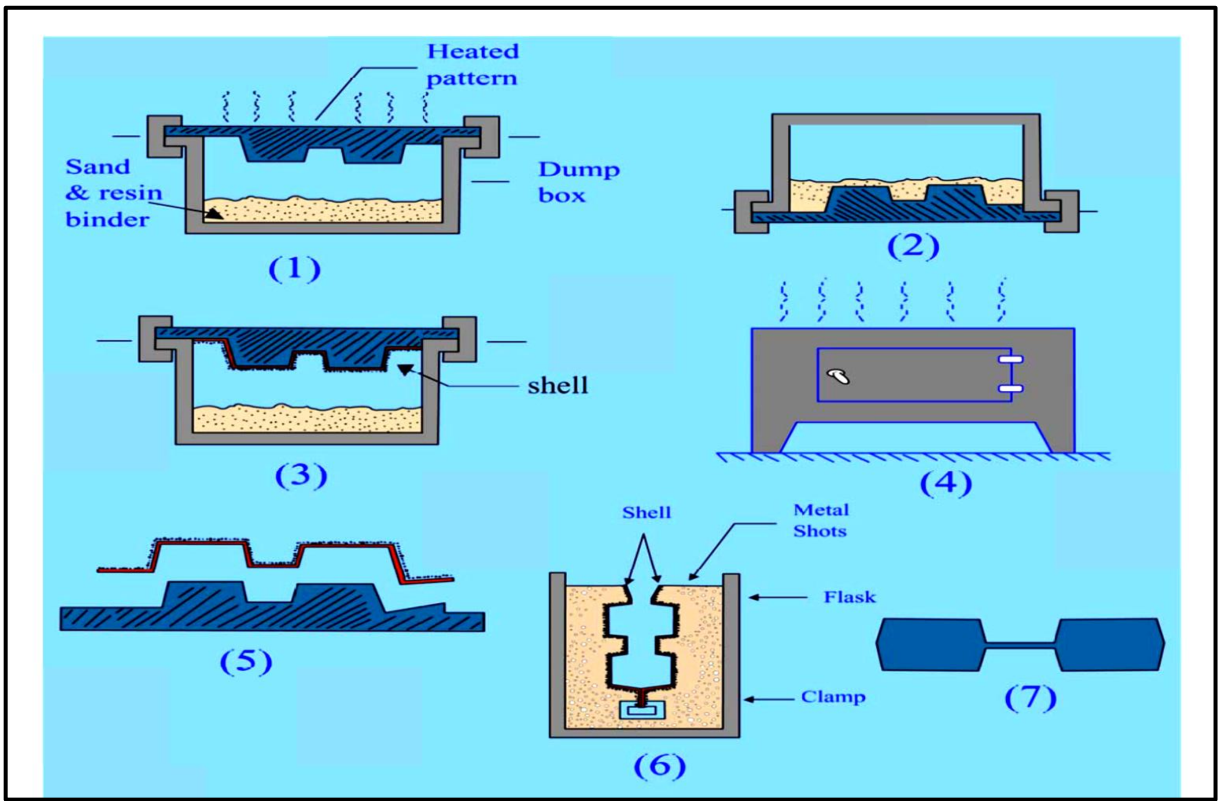


Figure (1): The shell mould casting process sequence

4- The sand shell along with the metal plate is heated and baked to cure it in an oven for some calculated time.
5- The obtained shell is removed from the pattern.
6- If the pattern is of two pieces then the other half of the shell is also prepared the same way. Two halves of the shells prepared are placed together after inserting the core, if any, to make the assembly of the mould.
7- The assembly the two portions is joined together to form the mold then placed in a molding flask and some sand particles or metal backing shots is placed all around the shell mould assembly in a box.
8- Pouring the liquid metal.
9- When the metal solidifies, the shell is broken to get the part.

Advantages:

- Excellent Surface Finish (near to net shape castings)
- Better Dimensional Accuracy
- Low labor cost,
- Low machining cost,
- High productivity,
- Simple to operate.
- Used for all types of metals both ferrous & nonferrous e.g. cast iron, carbon steel, high alloys, stainless steel, manganese steel, aluminum & copper alloys.

Disadvantages

- Long cycle time required for cold box.
- Limited lasting weight.

Application

- Used in the mass and particularly in the small & medium range productions.
- Widely accepted for producing the casting for automobile and hydraulic

applications.

1.4 Investment casting (lost wax process)

The investment casting process, which is commonly referred to as the "lost wax method", originated in and around the fourth millennium B.C. It is evidenced through the architectural works found in the form of idols, pectorals and jewelry in remains of the ancient Egypt and Mesopotamia.

The basic steps of the shell investment casting process are:

1. Preparing the heat-disposable wax, plastic or polystyrene patterns in a metallic die of the required shape of castings. Each and every casting requires a pattern to be produced. Wax or polystyrene is made used as the injecting machine.
2. Assembly of large number of the prepared patterns onto a gating system (attached to a wax sprue centrally).

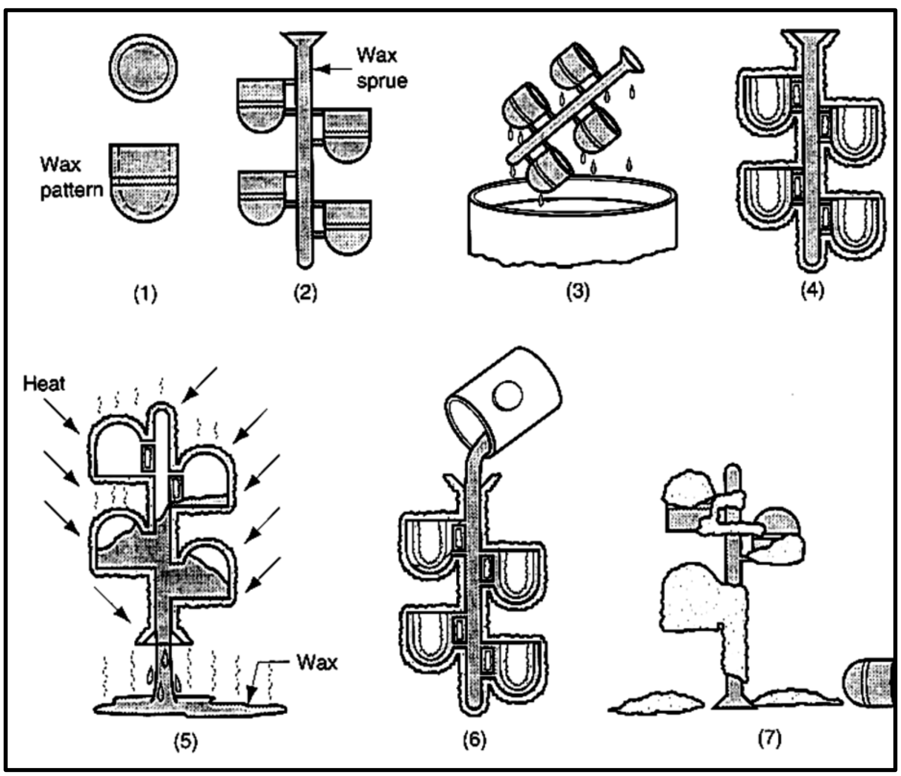


Figure 1. Steps in the investment casting process

3. "Investing," (covering) the pattern assembly by immersed in refractory slurry which completely surrounds it builds the shells at room temperature forming the mold.
4. The mold is further heated, so that the pattern assembly melt and the wax flows out, leaving the required cavity behind.
5. The metal in molten state is poured into the formed mold.
6. Once the metal solidifies, the shell is removed.
7. Fettling (cutting off) of the pouring basin and gates followed by finishing operations to get the desired dimensional tolerances and finish.

Advantages

- Complex shapes can be produced easily.
- No or little additional machining (net or near-net process), making it economical in cost.
- No metallurgical limitations.
- Excellent surface finish.
- Good dimensional tolerances (accuracy)
- Wax can be reused

Disadvantages

- Expensive process due to the cost of pattern (wax cost).
- The process is limited by the size and mass obtained.
- Making high quality pattern increases the process costs.
- Used for small products (few grams, up to a few kilograms).
- Requires skilled labour

Applications

- Aircraft: Turbine blades; carburetor and fuel-pump parts; cams; pinion gears, jet nozzles; special alloy valves.

- Chemical Industries: Impellors; pipe fittings; evaporators; mixers
- Tool and Die: Milling cutters; lathe bits; forming dies; stamping dies; permanent molds etc.
- General and Industrial applications: cloth cutters, sewing machine parts; welding torches; cutter, spray nozzles; metal pumps; etc.
- Jewellery makes.
- Dental fixtures from all types of metals.

1.5 Die casting Processes

Die casting is a very commonly used type of permanent mold casting process. Molten metal is forced into the die by pressure and held under pressure during solidification.

There are two common types of die casting:

1- **Hot chamber die casting**

Some specifications of the process:

- Metal is melted within the machine.
- Fast operation.
- Cannot be used for higher melting-point metals above 450C (e.g. brass, bronze, magnesium (Mg)).
- Mainly used for mass production of non-ferrous alloys with very low melting point e.g. zinc (Zn), tin (Sn) and lead (Pb) base alloys.
- Higher maintenance costs.

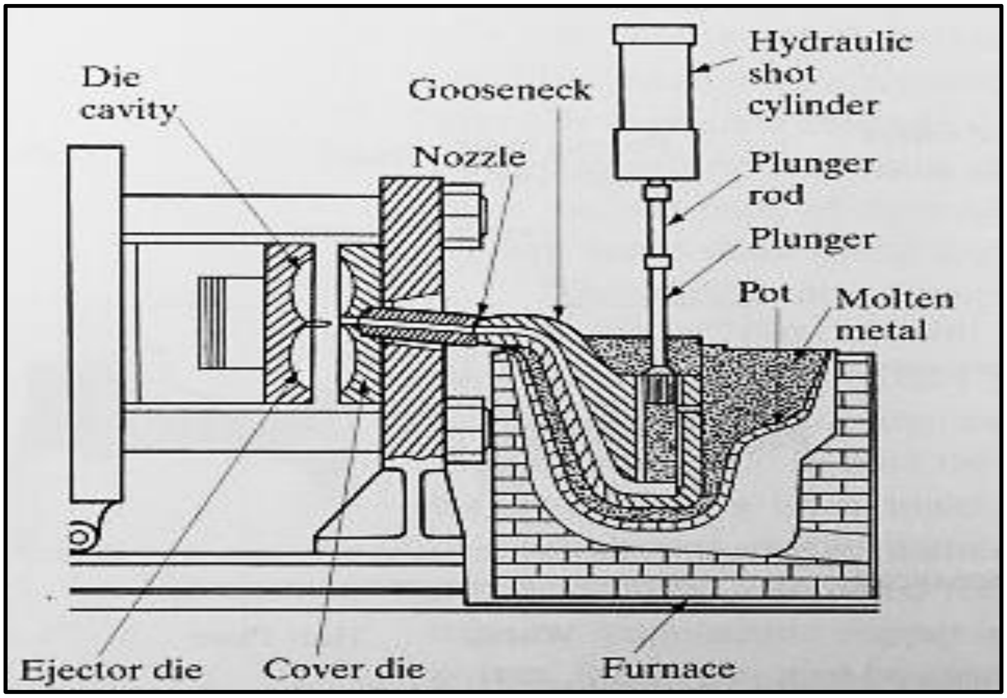
The basic cycle of operation is as follows:

(i) Die is closed and gooseneck cylinder is filled with molten metal.

(ii) Plunger pushes molten metal through gooseneck to the die cavity; metal is held under pressure until it solidifies.

(iii) Die opens and cores, if any, are retracted; casting stays in ejector die, plunger returns.

(iv) Ejector pins push casting out of ejector die.



Hot chamber die casting machine

Advantages:

High production rate (up to 500 parts per hour)

- Good surface finish
- It is also possible to cast ferrous metals
- Excellent accuracy and excellent details
- Low labor cost

Disadvantages:

- The injection system is submerged in the molten metal
- Only simple shapes

2- Cold chamber die casting

In cold-chamber die-casting, molten metal is poured into the chamber from an external melting container, and a piston is used to inject the metal under high pressure into the die cavity.

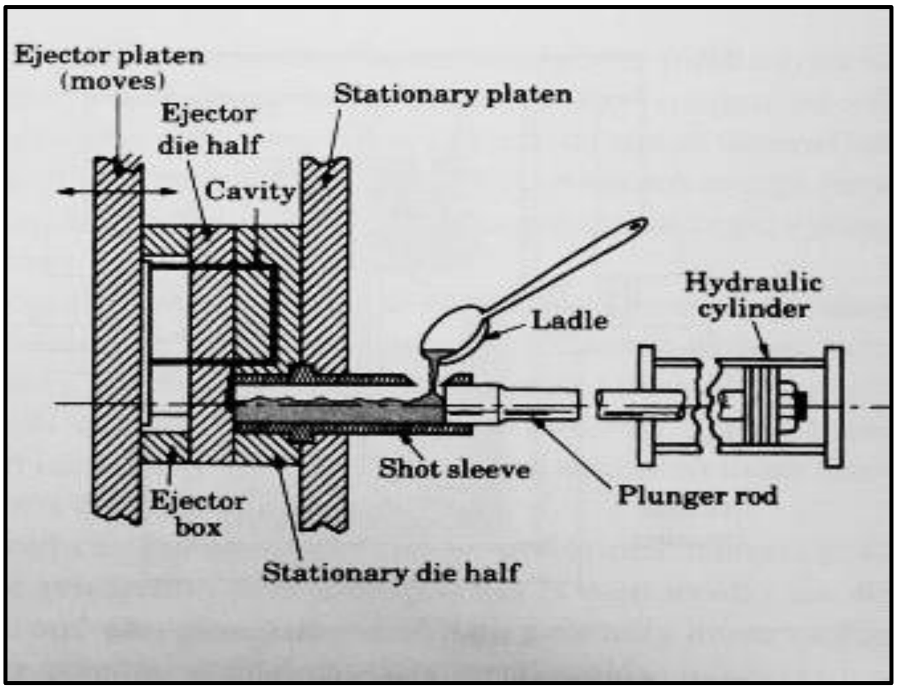
The operating cycle steps are:

(i) Die is closed and molten metal is ladled into the cold chamber cylinder;

(ii) Plunger pushes molten metal into die cavity; the metal is held under high pressure until it solidifies;

(iii) Die opens and plunger follows to push the solidified slug from the cylinder, if there are cores, they are retracted away;

(iv) Ejector pins push casting and plunger returns to original position.



Cold chamber die casting machine

Advantages

- Mass production of mostly all non-ferrous metals and alloys are cast such as Aluminum, Copper alloys (brass) and magnesium alloys.
- Same as in hot chamber die-casting, but less productivity.

Disadvantages:

- Only simple shapes

Applications

- components for rice cookers, stoves, fans, washing, drying machines, fridges, motors, toys, hand-tools, car wheels.

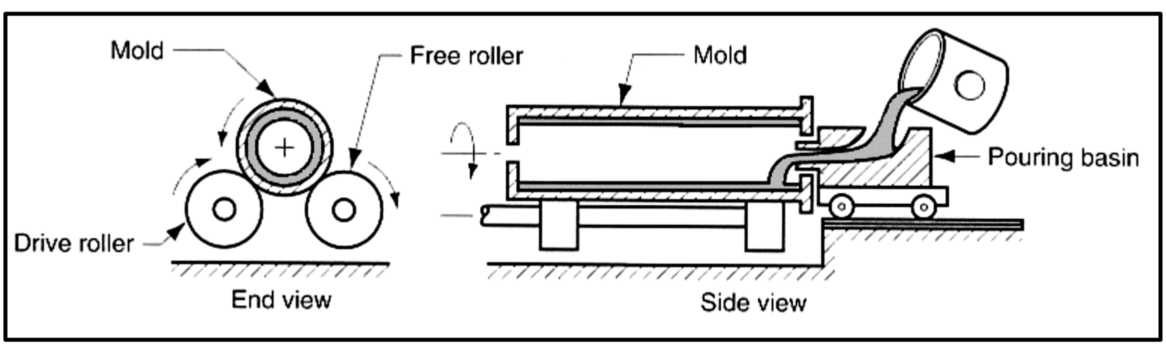
1.6 Centrifugal casting

1.6.1 True centrifugal casting

Centrifugal casting uses a permanent mold that is rotated about its axis at a speed between 300 to 3000 rpm as the molten metal is poured. Centrifugal forces cause the metal to be pushed out towards the mold walls, where it solidifies after cooling.

Parts cast in this method have a fine grain microstructure, which is resistant to atmospheric corrosion.

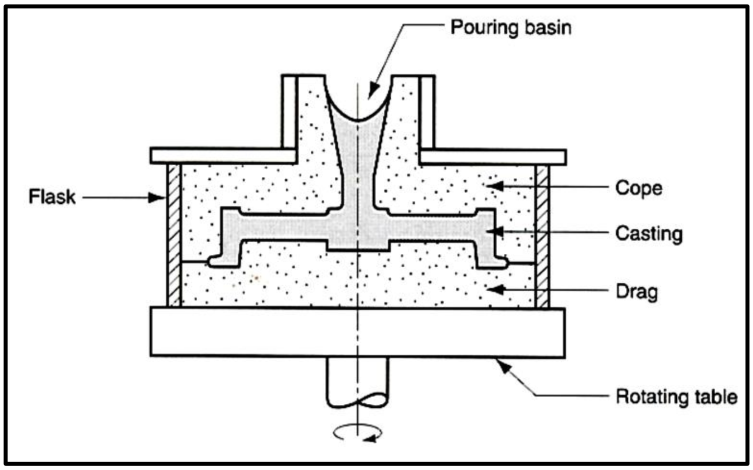
This method has been used to manufacture tubular parts such as pipes, tubes, and rings. Since metal is heavier than impurities, most of the impurities and inclusions are closer to the inner diameter and can be machined away.



True horizontal centrifugal casting

1.6.2 Semi-centrifugal casting

In this method, centrifugal force is used to produce solid castings rather than tubular parts. Density of the metal in the final casting is greater in the outer sections than at the centre of rotation. The process is used on parts in which the centre of the casting is machined away, such as wheels and pulleys.



Semi-centrifugal casting

1.7 Casting Quality

There are numerous opportunities in the casting operation for different defects to appear in the cast product. Some of them are common to all casting processes:

Misruns**:** Casting solidifies before completely fill the mould. Reasons are low pouring temperature, slow pouring or thin cross section of casting.

Cold shut: Two portions flow together but without fusion between them. Causes are similar to those of a misrun.

Cold shots: When splattering occurs during pouring, solid globules of metal are entrapped in the casting. Proper gating system designs could avoid this defect.

Shrinkage cavity: Voids resulting from shrinkage. Proper riser design can often solve the problem but may require some changes in the part design as well.

Microporosity: Network of small voids distributed throughout the casting. The defect occurs more often in alloys, because of the manner they solidify.

Hot tearing: These are cracks caused by low mould collapsibility. They occur when the material is restrained from contraction during solidification. A proper mould design can solve the problem.

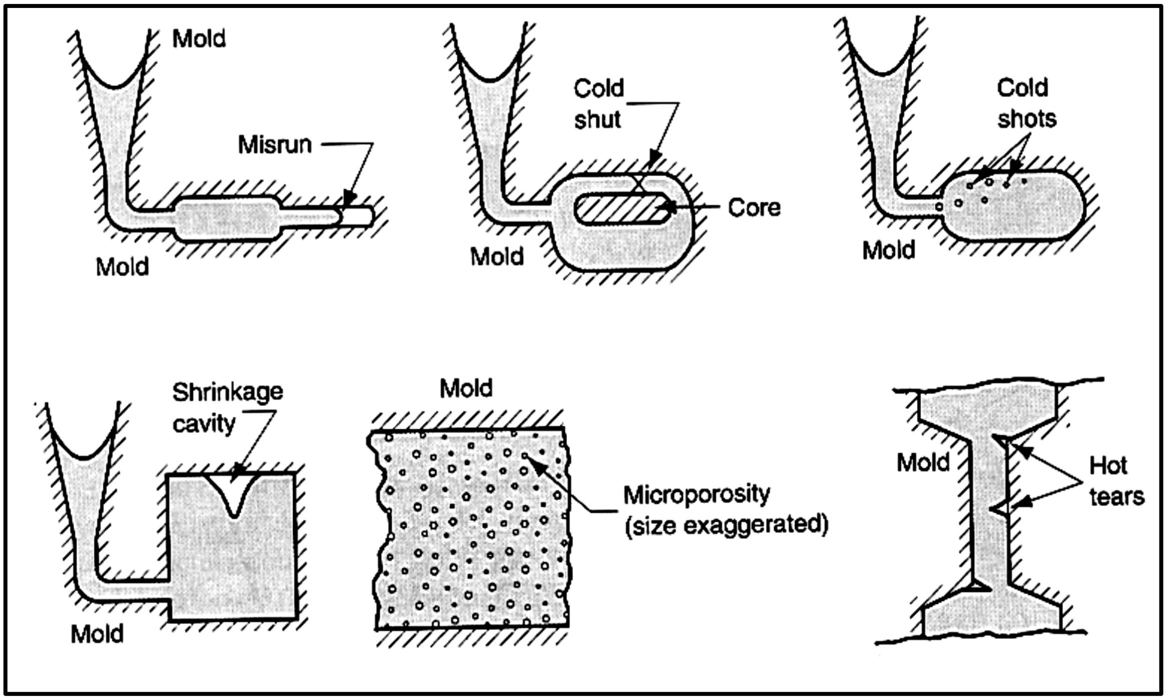


Figure: Some defects of casting

Some defects are typical only for some particular casting processes, for instance, many defects occur in sand casting because of interaction between the sand mould and the molten metal. Defect found primarily in sand casting are gas cavities, rough surface areas, shift of the two halves of the mould, or shift of the core, etc.