

Production Technology (25ME304)

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

ON

PRODUCTION TECHNOLOGY

Production Technology (25ME304)

UNIT-I

Metal Casting Process

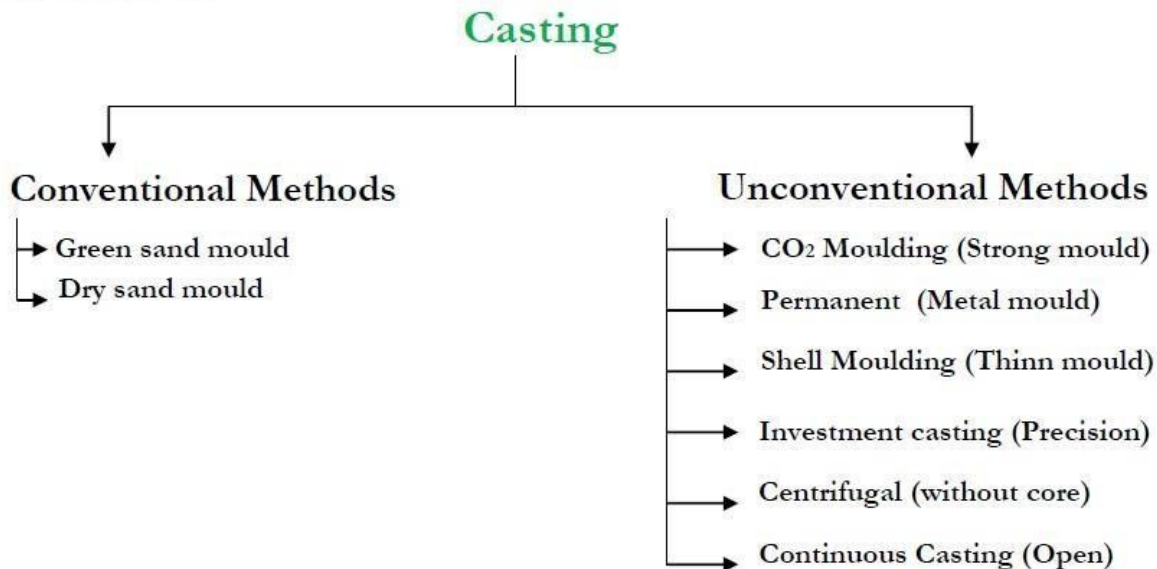
Manufacturing

- 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.

Casting

Casting is the process of producing metal parts by pouring molten metal into the mould cavity of the required shape and allowing the metal to solidify. The solidified metal piece is called as “casting”.

Types of casting



Advantages

- Design flexibility
- Reduced costs
- Dimensional accuracy
- Versatility in production

Disadvantages

- Lot of molten metal is wasted in riser & gating
- Casting may require machining to remove rough surfaces

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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.

- Most widely used casting process.
- Parts ranging in size from small to very large
- Production quantities from one to millions
- Sand mold is used.
- Patterns and Cores
 - Solid, Split, Match-plate and Cope-and-drag Patterns
 - Cores – achieve the internal surface of the part

Molds

- Sand with a mixture of water and bonding clay
- Typical mix: 90% sand, 3% water, and 7% clay
- to enhance strength and/or permeability

Sand – Refractory for high temperature

Size and shape of sand

Small grain size -> better surface finish

Large grain size -> to allow escape of gases during pouring

Irregular grain shapes -> strengthen molds due to interlocking but to reduce permeability

Types of sand

- a) Green-sand molds - mixture of sand, clay, and water; "Green" means mold contains moisture at time of pouring.
- b) Dry-sand mold - organic binders rather than clay and mold is baked to improve strength
- c) Skin-dried mold - drying mold cavity surface of a green-sand
 - mold to a depth of 10 to 25 mm, using torches or heating

Steps in Sand Casting

The cavity in the sand mold is formed by packing sand around a pattern, separating the mold into two halves

- The mold must also contain gating and riser system
 - For internal cavity, a core must be included in mold
 - A new sand mold must be made for each part
1. Pour molten metal into sand mold
 2. Allow metal to solidify
 3. Break up the mold to remove casting
 4. Clean and inspect casting
 5. Heat treatment of casting is sometimes required to improve metallurgical properties

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Testing of Mould & Core sand

- 1) Preparation of standard test specimen
- 2) Mould hardness test
- 3) Core hardness test
- 4) Moisture content test on foundry sand
- 5) Sieve analysis
- 6) Clay content test
- 7) Permeability test
- 8) Compression, shear test

Other Expendable Mold Casting

- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment casting
- Plaster and Ceramic Mold casting

Steps in shell-molding

Shell-mold casting yields better surface quality and tolerances. The process is described as follows:

The 2-piece pattern is made of metal (e.g. aluminum or steel), it is heated to between 175°C- 370°C, and coated with a lubricant, e.g. silicone spray.

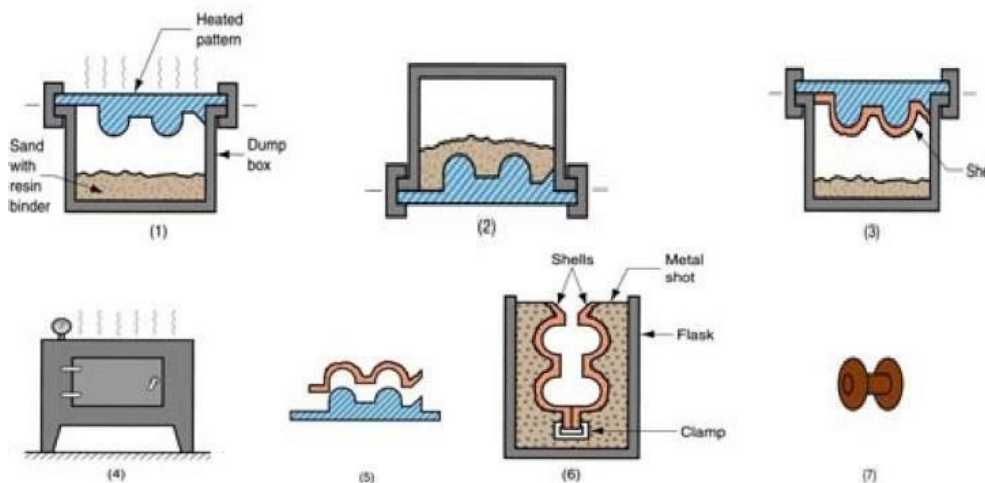
Each heated half-pattern is covered with a mixture of sand and a thermoset resin/epoxy binder.

The binder glues a layer of sand to the pattern, forming a shell. The process may be repeated to get a thicker shell.

The assembly is baked to cure it.

The patterns are removed, and the two half-shells joined together to form the mold; metal is poured into the mold.

When the metal solidifies, the shell is broken to get the part.



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Advantages

- Smoother cavity surface permits easier flow of molten metal and better surface finish on casting
- Good dimensional accuracy
- Machining often not required
- Mold collapsibility usually avoids cracks in casting
- Can be mechanized for mass production

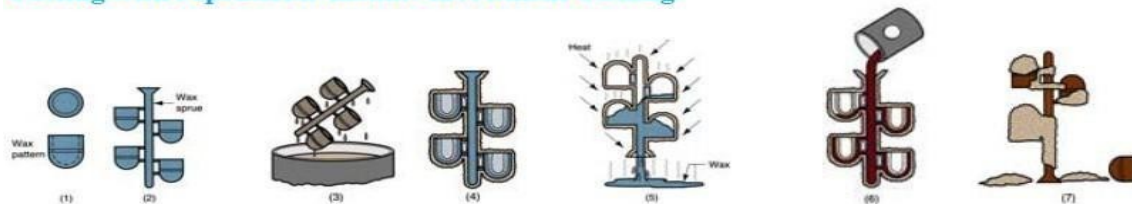
Disadvantages

- More expensive metal pattern
- Difficult to justify for small quantities

Investment Casting

- Investment casting produces very high surface quality and dimensional accuracy.
- Investment casting is commonly used for precision equipment such as surgical equipment, for complex geometries and for precious metals.
- This process is commonly used by artisans to produce highly detailed artwork.
- The first step is to produce a pattern or replica of the finished mould. Wax is most commonly used to form the pattern, although plastic is also used.
- Patterns are typically mass-produced by injecting liquid or semi-liquid wax into a permanent die.
- Prototypes, small production runs and specialty projects can also be undertaken by carving wax models.
- Cores are typically unnecessary but can be used for complex internal structures. Rapid prototyping techniques have been developed to produce expendable patterns.
- Several replicas are often attached to a gating system constructed of the same material to form a tree assembly. In this way multiple castings can be produced in a single pouring.

Casting with expendable mould: Investment Casting



Advantages

- Parts of great complexity and intricacy can be cast
- Close dimensional control and good surface finish
- Wax can usually be recovered for reuse
- Additional machining is not normally required - this is a net shape process

Disadvantages

- Many processing steps are required
- Relatively expensive process

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Plaster Molding

- Similar to sand casting except mold is made of plaster of Paris (gypsum - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
- Plaster and water mixture is poured over plastic or metal pattern to make a mold

Advantages

- Good dimensional accuracy and surface finish
- Capability to make thin cross-sections in casting

Disadvantages

- Moisture in plaster mold causes problems:
- Mold must be baked to remove moisture
- Mold strength is lost when is over-baked, yet moisture content can cause defects in product
- Plaster molds cannot stand high temperatures

Permanent Mold Casting

Basic Permanent Mold Process

- Uses a metal mold constructed of two sections designed for easy, precise opening and closing
- Molds for lower melting point alloys: steel or cast iron and Molds for steel: refractory material, due to the very high pouring temperatures

Permanent Mold Casting Process

- The two halves of the mold are made of metal, usually cast iron, steel, or refractory alloys. The cavity, including the runners and gating system are machined into the mold halves.
- For hollow parts, either permanent cores (made of metal) or sand-bonded ones may be used, depending on whether the core can be extracted from the part without damage after casting.
- The surface of the mold is coated with clay or other hard refractory material – this improves the life of the mold. Before molding, the surface is covered with a spray of graphite or silica, which acts as a lubricant. This has two purposes – it improves the flow of the liquid metal, and it allows the cast part to be withdrawn from the mold more easily.
- The process can be automated, and therefore yields high throughput rates.
- It produces very good tolerance and surface finish.
- It is commonly used for producing pistons used in car engines; gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

Advantage

- Good surface finish and dimensional control and Fine grain due to rapid solidification.

Disadvantage

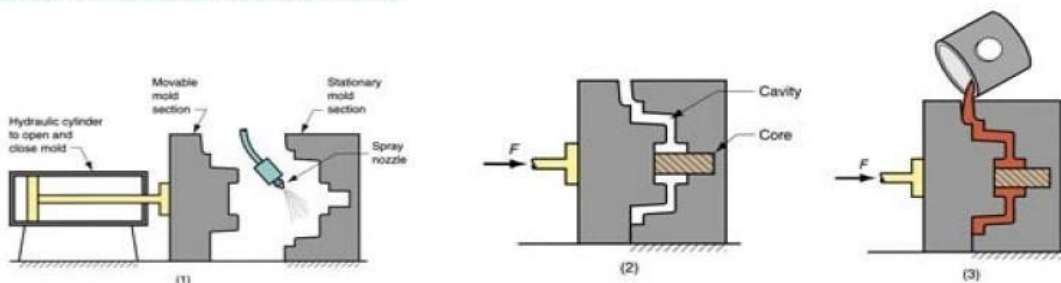
- Simple geometric part, expensive mold.

Example

It is commonly used for producing pistons used in car engines; gear blanks, cylinder heads, and other parts made of low melting point metals, e.g. copper, bronze, aluminum, magnesium, etc.

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Basic Permanent Mold Process



Advantages

- Good dimensional control and surface finish
- More rapid solidification caused by the cold metal mold results in a finer grain structure, so stronger castings are produced

Limitations

- Generally limited to metals of lower melting point
- Simple part geometries compared to sand casting because of the need to open the mold
- High cost of mold
- Due to high mold cost, process is best suited to automated high volume production

Testing of Mould & Core sand

- 1) Preparation of standard test specimen
- 2) Mould hardness test
- 3) Core hardness test
- 4) Moisture content test on foundry sand
- 5) Sieve analysis
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Die Casting

- Die casting is a very commonly used type of permanent mold casting process.
 - It is used for producing many components of home appliances (e.g rice cookers, stoves, fans, washing and drying machines, fridges), motors, toys and hand-tools
 - The molten metal is injected into mold cavity (die) under high pressure (7-350MPa). Pressure maintained during solidification.
 - Hot Chamber (Pressure of 7 to 35MPa)
 - The injection system is submerged under the molten metals (low melting point metals such as lead, zinc, tin and magnesium)
 - Cold Chamber (Pressure of 14 to 140MPa)
 - External melting container (in addition aluminum, brass and magnesium)
- Molds are made of tool steel, mold steel, maraging steel, tungsten and molybdenum.
- Single or multiple cavity
 - Lubricants and Ejector pins to free the parts

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- Venting holes and passageways in die
- Formation of flash that needs to be trimmed

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)

Advantages

– High production, Economical, close tolerance, good surface finish, thin sections, rapid cooling

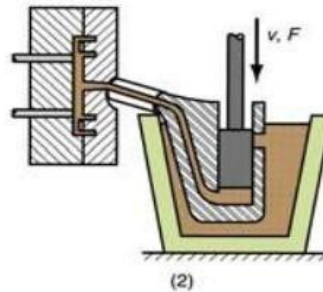
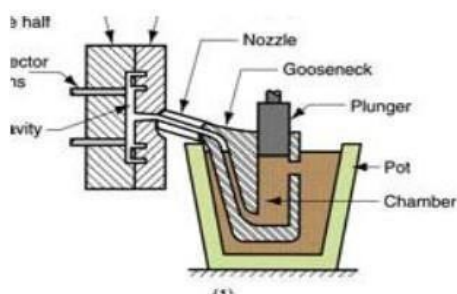
Hot-Chamber Die Casting

In a hot chamber process (used for Zinc alloys, magnesium) the pressure chamber connected to the die cavity is filled permanently in the molten metal.

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 passage and nozzle and into 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, pulling molten metal back through nozzle and gooseneck;
- (iv) ejector pins push casting out of ejector die. As plunger uncovers inlet hole, molten metal refills gooseneck cylinder.

The hot chamber process is used for metals that (a) have low melting points and (b) do not alloy with the die material, steel; common examples are tin, zinc, and lead.



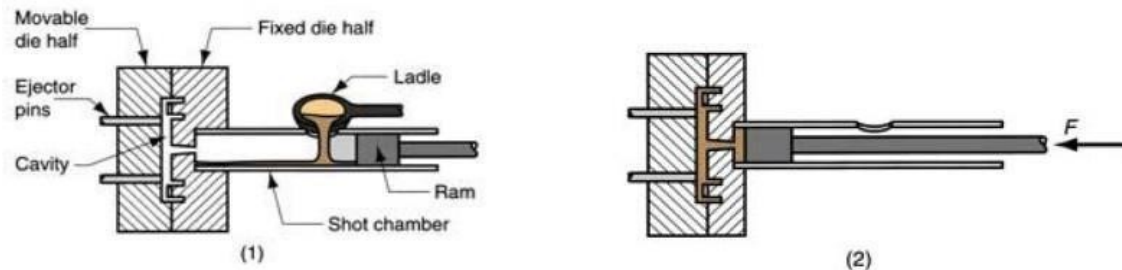
Cold Chamber Die Casting

In a cold chamber process, the molten metal is poured into the cold chamber in each cycle. The operating cycle is

- (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 off ejector die and plunger returns to original position

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This process is particularly useful for high melting point metals such as Aluminum, and Copper (and its alloys).



Advantages

- Economical for large production quantities
- Good dimensional accuracy and surface finish
- Thin sections are possible
- Rapid cooling provides small grain size and good strength to casting

Disadvantages

- Generally limited to metals with low metal points
- Part geometry must allow removal from die cavity

Centrifugal casting

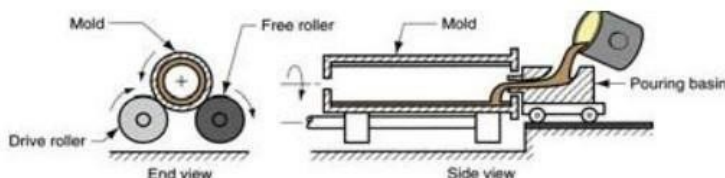
Centrifugal casting uses a permanent mold that is rotated about its axis at a speed between 300 to 3000 rpm as the molten metal is poured.

Centrifugal forces cause the metal to be pushed out towards the mold walls, where it solidifies after cooling.

Centrifugal casting has greater reliability than static castings. They are relatively free from gas and shrinkage porosity.

Surface treatments such as case carburizing, flame hardening and have to be used when wear resistant surface must be combined with a hard tough exterior surface.

One such application is bimetallic pipe consisting of two separate concentric layers of different alloys/metals bonded together.



Carbon Dioxide Moulding

- This sand is mixed with 3 to 5 % sodium silicate liquid base binder in a muller for 3 to 4 minutes. Additives such as coal powder, wood flour, sea coal, dextrine may be added to improve its properties.
- Aluminium oxide Kaolin clay may also be added to the sand.

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- Patterns used in this method may be coated with Zinc of 0.05 mm to 0.13 mm and then spraying a layer of aluminium or brass of about 0.25 mm thickness for good surface finish and good results.

Advantages

- Operation is speedy since we can use the mould and cores immediately after processing.
- Heavy and rush orders
- Floor space requirement is less
- Semi skilled labour may be used.

Disadvantages

Difficult in reusing the moulding sand.

Process	Advantages	Disadvantages	Examples
Sand	Wide range of metals, sizes, shapes, low cost	poor finish, wide tolerance	engine blocks, cylinder heads
Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
Expendable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
Investment	complex shapes, excellent finish	small parts, expensive	jewellery
Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	precision gears, camera bodies, car wheels
Centrifugal	Large cylindrical parts, good quality	Expensive, limited shapes	pipes, boilers, flywheels

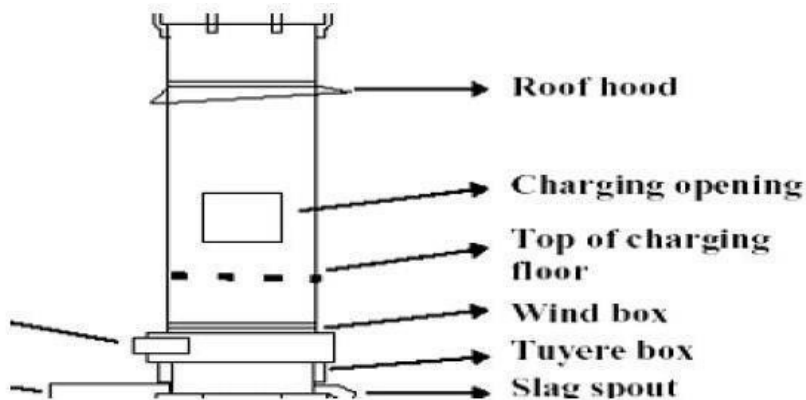
Furnaces

Cupola Furnace

- A continuous flow of iron emerges from the bottom of the furnace.
- Depending on the size of the furnace, the flow rate can be as high as 100 tonnes per hour.

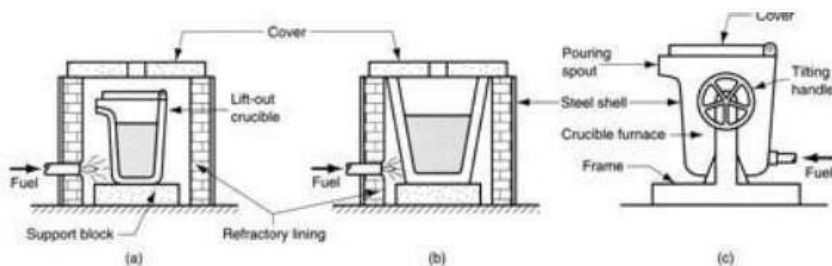
At the metal melts it is refined to some extent, which removes contaminants. This makes this process more suitable than electric furnaces for dirty charges.

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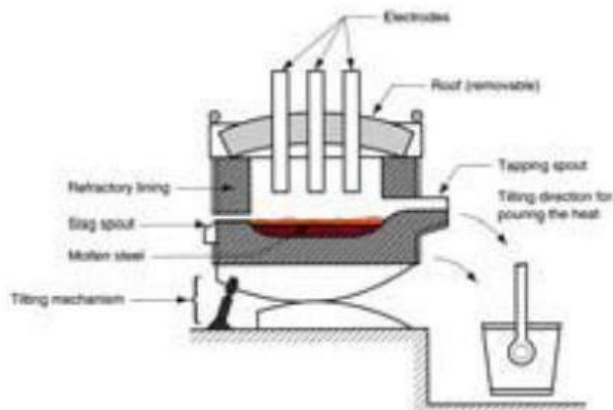


Direct Fuel-fired furnace

- Crucible Furnace
- Electric-arc Furnace
- Induction Furnace
- Pouring with ladle
- Solidification – watch for oxidation
- Trimming, surface cleaning, repair and heat treat, inspection

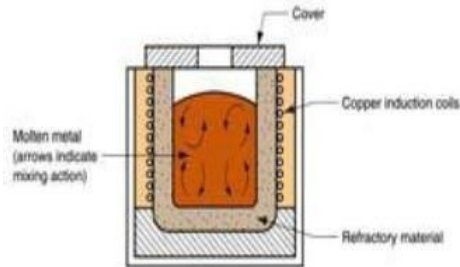


Three types: (a) lift-out crucible, (b) stationary pot, from which molten metal must be ladle (c) tilting-pot furnace



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Induction Furnace:



Casting defects

Defects may occur due to one or more of the following reasons:

- Fault in design of casting pattern
- Fault in design on mold and core
- Fault in design of gating system and riser
- Improper choice of moulding sand
- Improper metal composition
- Inadequate melting temperature and rate of pouring

Some common defects in castings:

a) Misruns b) Cold Shut c) Cold Shot d) Shrinkage Cavity e) Microporosity f) Hot Tearing

Misruns:

a) Misruns

It is a casting that has solidified before completely filling the mold cavity.

Typical causes include

- 1) Fluidity of the molten metal is insufficient,
- 2) Pouring Temperature is too low,
- 3) Pouring is done too slowly and/or
- 4) Cross section of the mold cavity is too thin.

b) Cold Shut

A cold shut occurs when two portion of the metal flow together, but there is lack of fusion between them due to premature freezing. Its causes are similar to those of a Misruns.

c) Cold Shots

When splattering occurs during pouring, solid globules of the metal are formed that become entrapped in the casting. Poring procedures and gating system designs that avoid splattering can prevent these defects.

d) Shrinkage Cavity

This defects is a depression in the surface or an internal void in the casting caused by solidification shrinkage that restricts the amount of the molten metal available in the last region to freeze.

e) Microporosity

This refers to a network of a small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal in the dendritic structure.

f) Hot Tearing

This defect, also called hot cracking, occurs when the casting is restrained or early stages of cooling after solidification.

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