University of Basrah
College of Engineering
Mechanical Engineering Department
Lecture Notes of MANUFACTURING PROCESSES (ME337), 3rd Year (2015-2016)
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Chapter Three: Casting

3.1. General Introduction

Manufacturing processes in which the starting work material is either a liquid or is in a highly plastic condition, and a part is created through solidification of the material. Casting and molding processes dominate this category of shaping operations. With reference to Figure 3.1, the solidification processes can be classified according to the engineering material that is processed:

(1) Metals

(2) Ceramics, specifically glasses

(3) Polymers and polymer matrix composites (PMCs).

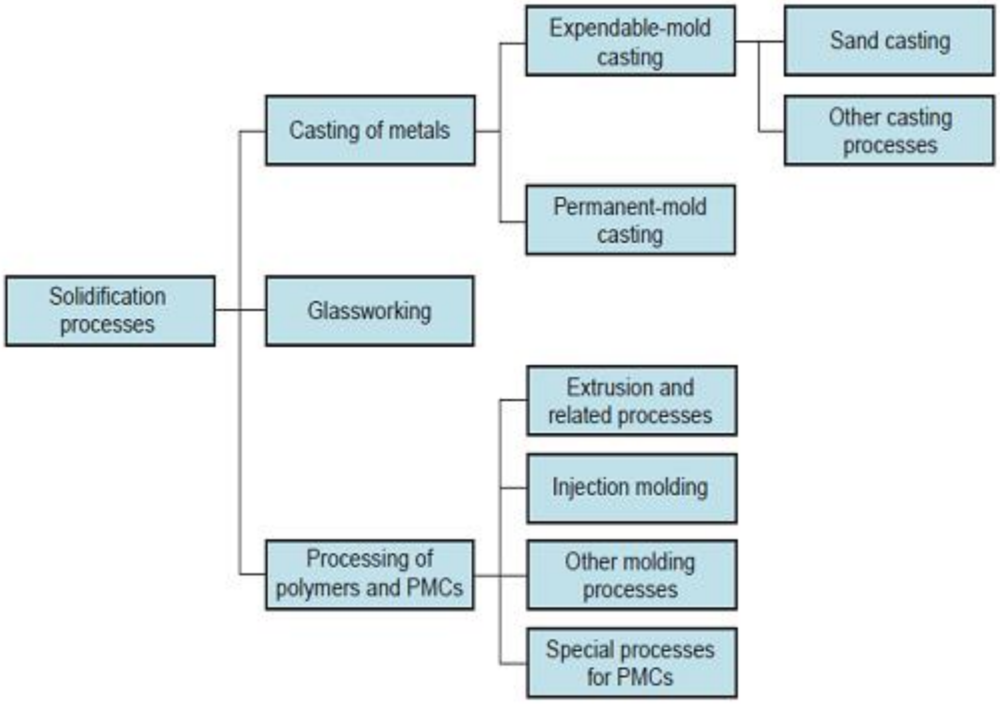


Figure (3.1) (a): Classification of Solidification Processes

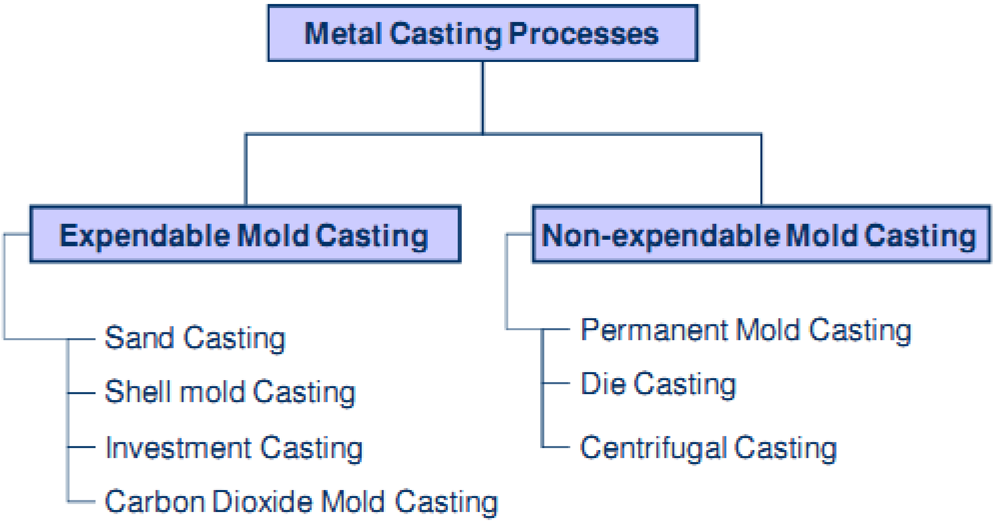


Figure (3.1) (b): Classification of Metal Casting Processes

Casting is a process in which molten metal flows by gravity or other force into a mold where it solidifies in the shape of the mold cavity. The term casting is also applied to the part that is made by this process. It is one of the oldest shaping processes, dating back 6000 years .

The principle of casting seems simple: melt the metal, pour it into a mold, and let it cool and solidify; yet there are many factors and variables that must be considered in order to accomplish a successful casting operation.

Casting includes both the casting of ingots and the casting of shapes. The term **ingot** is usually associated with the primary metals industries; it describes a large casting that is simple in shape and intended for subsequent reshaping by processes such as rolling or forging. involves the production of more complex geometries that are much closer to the final desired shape of the part or product. It is with the casting of shapes rather than ingots that we are concerned.

A variety of shape casting methods are available, thus making it one of the most versatile of all manufacturing processes. Among its capabilities and **advantages** are the following:

1. Casting can be used to create complex part geometries, including both external and internal shapes.
2. Some casting processes are capable of producing parts to net shape. No further manufacturing operations are required to achieve the required geometry and dimensions of the parts.
3. Other casting processes are near net shape, for which some additional shape processing is required (usually machining) in order to achieve accurate dimensions and details.
4. Casting can be used to produce very large parts. Castings weighing more than 100 tons have been made.
5. The casting process can be performed on any metal that can be heated to the liquid state.
6. Some casting methods are quite suited to mass production.

There are **also disadvantages associated** with casting different disadvantages for different casting methods. **These include limitations on mechanical properties, porosity, poor dimensional accuracy** and **surface finish for some casting processes**, **safety hazards to humans when processing hot molten metal's**, and **environmental problems**. **Parts made by casting processes range in size from small components weighing only a few ounces up to very large products weighing**

tons. The list of parts includes dental crowns, jewelry, statues, wood-burning stoves, engine blocks and heads for automotive vehicles, machine frames, railway wheels, frying pans, pipes, and pump housings.

All varieties of metals can be cast, ferrous and nonferrous. Casting can also be used on other materials such as polymers and ceramics.

3.2 Metal Castings & Materials Engineering

Metal castings form integral components of devices that perform useful functions for human beings, an idea shown schematically below: The cast component has a shape, size, chemical composition and metallurgical microstructure which is determined by engineering decisions arrived at by:

1. Design Engineers (Mechanical Engineers).
2. Pattern Makers (Skilled craftsman, CAD).
3. Casting Engineers (Metallurgical Engineers).
4. Manufacturing Engineers (Mechanical, Metallurgical Engineers) .

The engineering professionals that carry out this process work together, sharing information so that the casting will perform as intended in a timely and cost effective manner. It should be noted that the casting may only be a small part of the useful device (usually in more sophisticated devices like an automobile where there may be hundreds of components), or it may be the entire device (simple device like a frying pan).

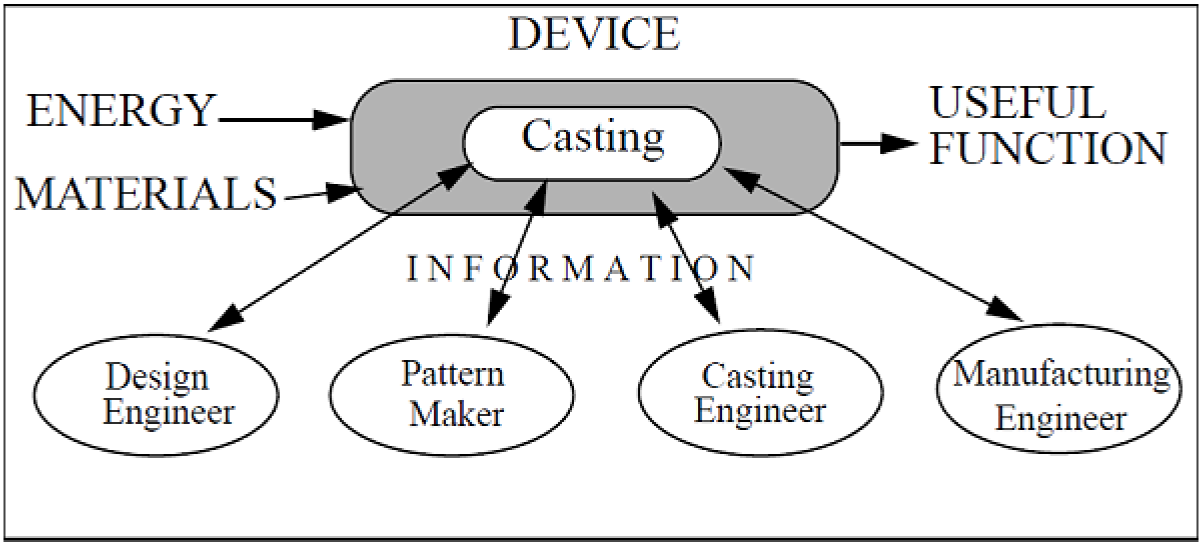


Figure (3.2): Stage of Casting Processes

3.3 Casting Processes & Casting Terms

The casting process involves pouring of liquid metal in to a mold cavity and allowing it to solidify to obtain the final casting. The flow of molten metal into the mold cavity depends on several factors like minimum section thickness of the part, presence of corners, non-uniform cross-section of the cast, and so on. The casting processes can be broadly classified into expendable mold casting and permanent mold casting processes.

1. Flask: A metal or wood frame, without fixed top or bottom, in which the mold is formed. Depending upon the position of the flask in the molding structure, it is referred to by various names such as drag – lower molding flask, cope – upper molding flask, cheek – intermediate molding flask used in three piece molding.

2. Pattern: It is the replica of the final object to be made. The mold cavity is made with the help of pattern.
3. Parting line: This is the dividing line between the two molding flasks that makes up the mold.
4. Molding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.
5. Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mold cavity to give a better surface finish to the castings.
6. Core: A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
7. Pouring basin: A small funnel shaped cavity at the top of the mold into which the molten metal is poured.
8. Sprue: The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.
9. Runner: The channel through which the molten metal is carried from the sprue to the gate.
10. Gate: A channel through which the molten metal enters the mold cavity.
11. Chaplets: Chaplets are used to support the cores inside the mold cavity to take care of its own weight and overcome the metallostatic force.
12. Riser: A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as “feed head”.
13. Vent: Small opening in the mold to facilitate escape of air and gases.

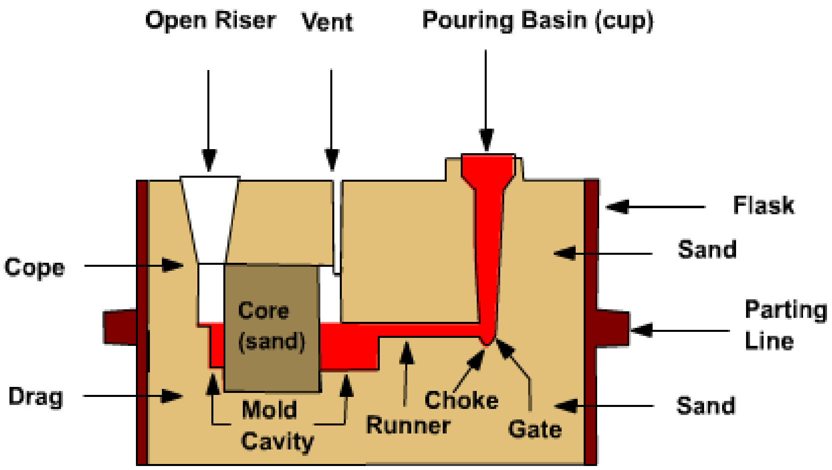


Figure (3.3): Mold Section showing some casting terms

3.3.1 Expendable Mold Casting

Expendable mold casting is a generic classification that includes sand, plastic, shell, plaster, and investment (lost-wax technique) molds. All these methods use temporary, non-reusable molds. After the molten metal in the mold cavity solidifies, the mold is broken to take out the solidified cast. Expendable mold casting processes are suitable for very complex shaped parts and materials with high melting point temperature. However, the rate of production is often limited by the time to make mold rather than the casting itself. Following are a few examples of expendable mold casting processes.

3.3.1.1 Sand Casting

Sand casting uses natural or synthetic sand (lake sand) which is mostly a refractory material called silica ($SiO2$). The sand grains must be small enough so that it can be packed densely; however, the grains must be large enough to allow gasses formed during the metal pouring to escape through the pores. Larger sized molds use green sand (mixture of sand, clay and some water). Sand can be re-used, and excess metal poured is cut-off and re-used also.

Typical sand molds have the following parts (see Figure 3.4):

- The mold is made of two parts, the top half is called the **cope**, and bottom part is the **drag**.
- The liquid flows into the gap between the two parts, called the mold **cavity**. The geometry of the cavity is created by the use of a wooden shape, called the **pattern**. The shape of the patterns is (almost) identical to the shape of the part we need to make.
- A funnel shaped cavity; the top of the funnel is the **pouring cup**; the pipe-shaped neck of the funnel is the sprue – the liquid metal is poured into the pouring cup, and flows down the sprue.
- The **runners** are the horizontal hollow channels that connect the bottom of the sprue to the mould cavity. The region where any runner joins with the cavity is called the **gate**.
- Some extra cavities are made connecting to the top surface of the mold. Excess metal poured into the mould flows into these cavities, called **risers**. They act as reservoirs; as the metal solidifies inside the cavity, it shrinks, and the extra metal from the risers flows back down to avoid holes in the cast part.
- **Vents** are narrow holes connecting the cavity to the atmosphere to allow gasses and the air in the cavity to escape.
- **Cores**: Many cast parts have interior holes (hollow parts), or other cavities in their shape that are not directly accessible from either piece of the mold. Such

interior surfaces are generated by inserts called **cores**. Cores are made by baking sand with some binder so that they can retain their shape when handled. The mold is assembled by placing the core into the cavity of the drag, and then placing the cope on top, and locking the mold. After the casting is done, the sand is shaken off, and the core is pulled away and usually broken off.

Important considerations for casting:

(a) How do we make the pattern?

Usually craftsmen will carve the part shape by hand and machines to the exact size.

(b) Why is the pattern not exactly identical to the part shape?

- you only need to make the outer surfaces with the pattern; the inner surfaces are made by the core
- you need to allow for the shrinkage of the casting after the metal solidifies

(c) If you intersect the plane formed by the mating surfaces of the drag and cope with the cast part, you will get a cross-section of the part. The outer part of the outline of this cross section is called the **parting line**. The design of the mold is done by first determining the parting line (why ?)

(d) In order to avoid damaging the surface of the mould when removing the pattern and the wood-pieces for the vents, pouring cup and sprue, risers etc., it is important to incline the vertical surfaces of the part geometry. This (slight) inclination is called a taper. If you know that your part will be made by casting, you should taper the surfaces in the original part design.

(e) The core is held in position by supporting geometry called core prints (see figure below). If the design is such that there is insufficient support to hold the core in position, then metal supports called chaplets are used. The chaplets will be embedded inside the final part.

(f) After the casting is obtained, it must be cleaned using air-jet or sand blasting

(g) Finally, the extra metal near the gate, risers and vents must be cut off, and critical surfaces are machined to achieve proper surface finish and tolerance.

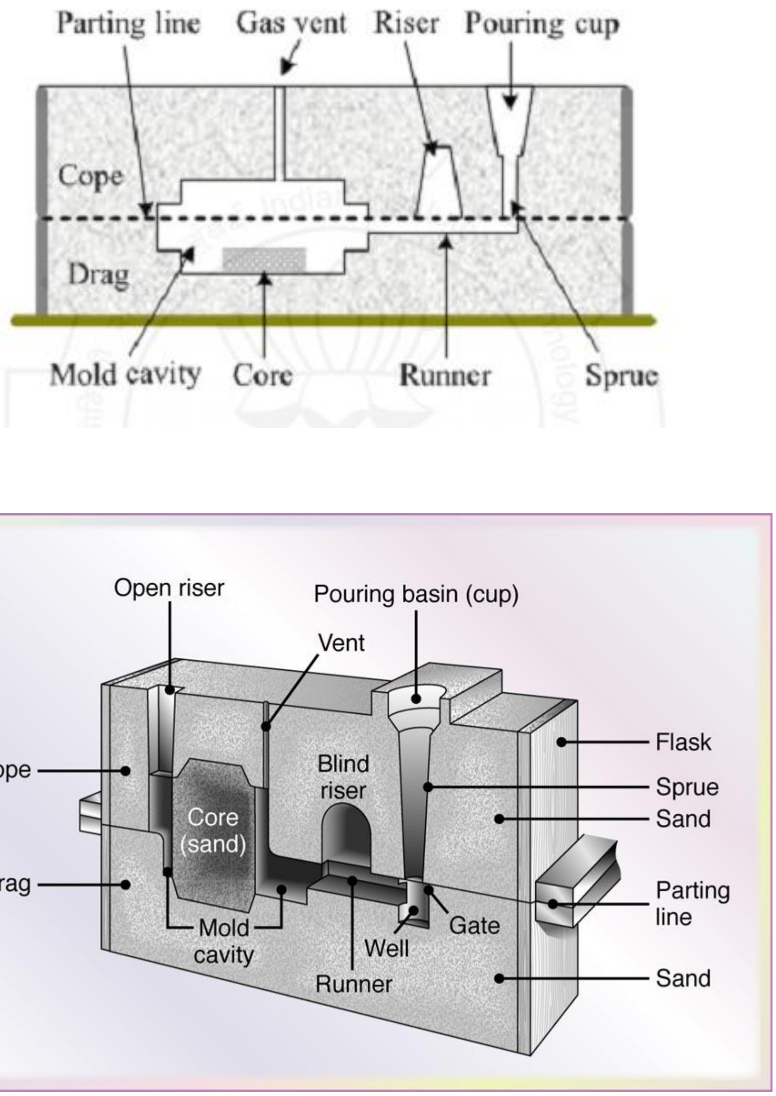


Figure (3.4): Schematic Set-up of Sad Molding/Casting Process

Advantages

1. Castings can be up to several tons.
2. Least expensive casting process.
3. Can be used with most metals.

Disadvantages

1. Rough Surface Finish
2. Large dimensional variation
3. Usually require Secondary Machining
4. Parts have internal porosity
5. Low production volume

3.3.1.2 Shell Casting

Shell mold casting process is recent invention in casting techniques for mass production and smooth surface finish. It was originated in Germany during Second World War. It is also called as Carning or C process. It consists of making a mold that possesses two or more thin shells (shell line parts, which are moderately hard and smooth with a texture consisting of thermosetting resin bonded sands. The shells are 0.3 to 0.6 mm thick and can be handled and stored. Shell molds are made so that machining parts fit together-easily. They are held using clamps or adhesive and metal is poured either in a vertical or horizontal position. They are supported using rocks or mass of bulky permeable material. Thermosetting resin, dry powder and sand are mixed thoroughly in a muller.

Complete shell molding casting processes is carried in four stages as shown in Figure 3.5. In this process a pattern is placed on a metal plate and it is then coated with a mixture of fine sand and Phenol-resin (20:1). The pattern is heated first and silicon grease is then sprayed on the heated metal pattern for easy separation. The pattern is heated to 205 to 230°C and covered with resin bounded sand. After 30 seconds, a hard layer of sand is formed over pattern. Pattern and shell are heated and treated in an oven at 315°C for 60 sec., Phenol resin is allowed to set to a specific thickness. So the layer of about 4 to 10 mm in thickness is stuck on the pattern and the loose material is then removed from the pattern. Then shell is ready to strip from the pattern. A plate pattern is made in two or more pieces and similarly core is made by same technique. The shells are clamped and usually embedded in gravel, coarse sand or metal shot. Then mold is ready for pouring. The shell so formed has the shape of pattern formed of cavity or projection in the shell. In case of unsymmetrical shapes, two patterns are prepared so that two shell are produced which are joined to form proper cavity. Internal cavity can be formed by placing a core. Hot pattern and box is containing a mixture of sand and resin. Pattern and box inverted and kept in this position for some time. Now box and pattern are brought to original position. A shell of resin-bonded sand sticks to the pattern and the rest falls. Shell separates from the pattern with the help of ejector pins. It is a suitable process for casting thin walled articles. The cast shapes are uniform and their dimensions are within close limit of tolerance ± 0.002 mm and it is suitable for precise duplication of exact parts. It has various advantages which are as follows. There are some advantages and disadvantages of this process which are given as under.

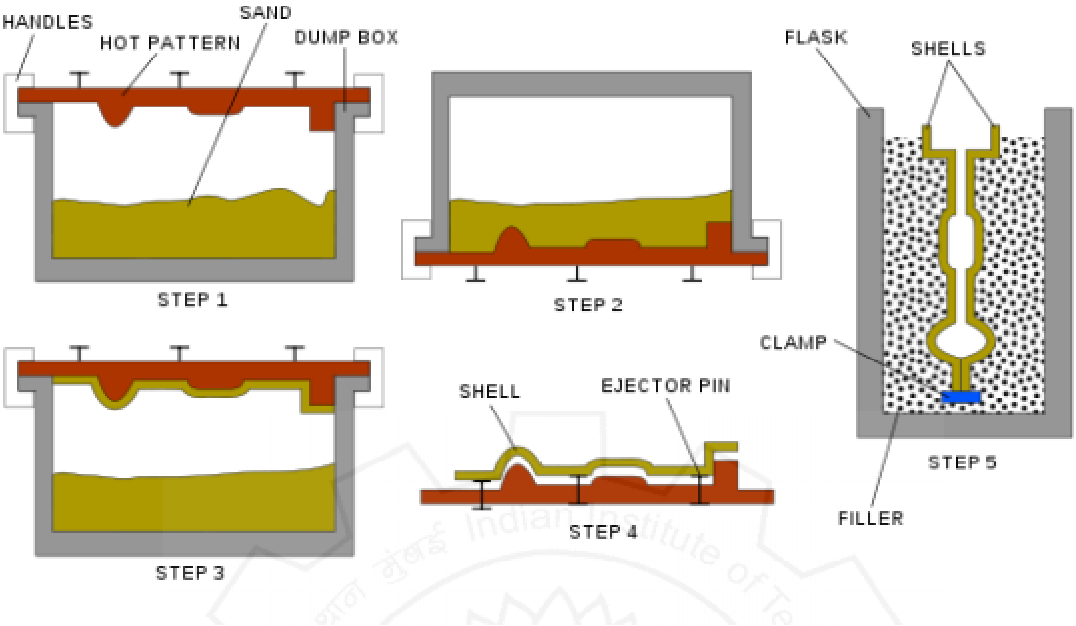


Figure (3.5): Schematic Set-up of Shell Mold Casting Process

Advantages

1. Very suitable for thin sections like petrol engine cylinder.
2. Excellent surface finish.
3. Good dimensional accuracy of order of 0.002 to 0.003 mm.
4. Negligible machining and cleaning cost.
5. Occupies less floor space.
6. Skill-ness required is less.
7. Molds can be stored until required.
8. Better quality of casting assured.
9. Mass production.

Disadvantages

1. Initial cost is high.
2. Specialized equipment is required.
3. Resin binder is an expensive material.
4. Limited for small size.
5. Future of shell molding process is very bright.

Applications

1. Suitable for production of casting made up of alloys of Al, Cu and ferrous metals
2. Bushing
3. Valves bodies
4. Rocker arms
5. Bearing caps
6. Brackets
7. Gears

3.3.1.3 Investment Casting

Investment casting is also referred to as lost-wax casting since the pattern is made of wax. The wax patterns are first dipped into a slurry of refractory material and subsequently, heated so that the wax melts away keeping a refractory mold. The mold is then further cured to achieve proper strength. Very high melting temperature material can be cast in investment casting process because of the refractory mold. Figure 3.6 schematically shows an investment casting process. The molten metal is poured into the mold and is taken out after solidification by breaking the mold. Very high dimensional accuracy and surface finish can be achieved in investment casting process. However, the tooling cast is usually high and hence, investment casting process is primarily used for large size batch production or for specific requirements of complex shape or casting of very high melting temperature material.

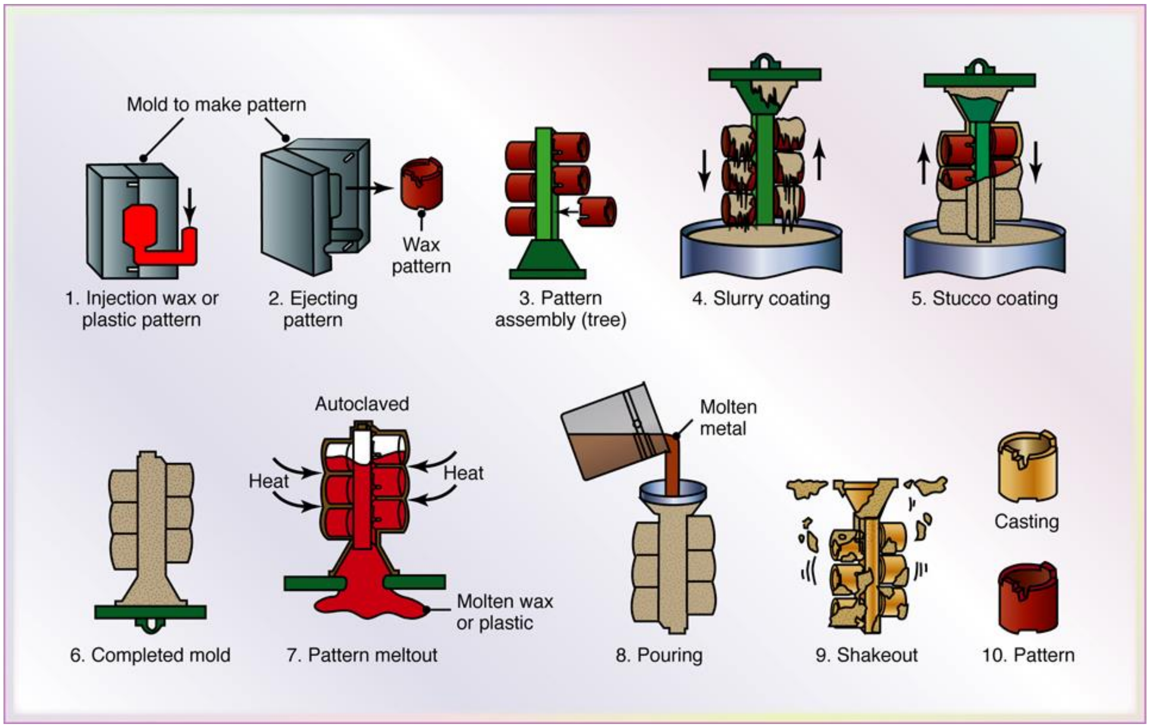


Figure (3.6): Schematic Illustration of Investment Casting (Lost-Wax) Process

Advantages

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

Disadvantages

1. Many processing steps are required
2. Relatively expensive process

3.3.1.4 Vacuum Casting

In this process, a mixture of fine sand and urethane is molded over metal dies and cured with amino vapor. The molted metal is drawn into the mold cavity through a gating system from the bottom of the mold. The pressure inside the mold is usually one-third of the atmospheric pressure. Because the mold cavity is filled under vacuum, the vacuum casting process is very suitable for thin walled, complex shapes with uniform properties. Figure 3.7 schematically shows typical vacuum casting process.

- Large casting tend to have greater porosity problems, due to entrapped air, and the melt solidifying before it gets to the furthest extremities of the die-cast cavity.
- The porosity problem can be somewhat overcome by vacuum die casting

Advantages

1. Easy recovery of the sand, since binders not used
2. Sand does not require mechanical reconditioning normally done when binders are used
3. Since no water is mixed with sand, moisture-related defects are absent

Disadvantages

1. Slow process
2. Not readily adaptable to mechanization

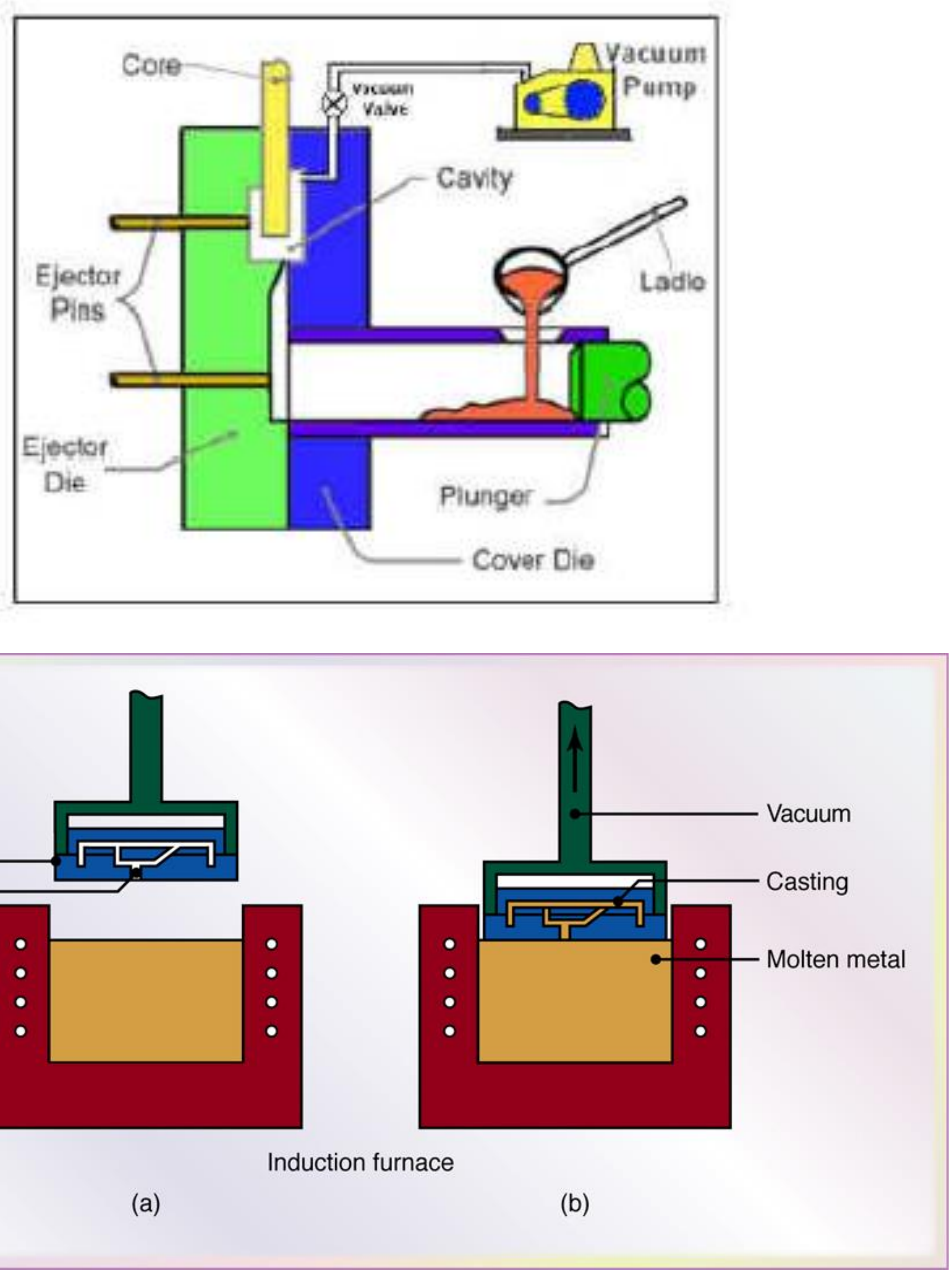


Figure (3.7): Schematic Illustration of the Vacuum Casting Process

3.3.1.5 Plaster Mold Casting

Plaster mold casting, also called rubber plaster molding (RPM), The mold is made by mixing plaster of paris (CaSO4) with talc and silica flour; this is a fine white powder, which, when mixed with water gets a clay-like consistency and can be shaped around the pattern (it is the same material used to make casts for people if they fracture a bone). The plaster cast can be finished to yield very good surface finish and dimensional accuracy. However, it is relatively soft and not strong enough at temperature above 1200°C, so this method is mainly used to make castings from non-ferrous metals, e.g. zinc, copper, aluminum, and magnesium.

Since plaster has lower thermal conductivity, the casting cools slowly, and therefore has more uniform grain structure (i.e. less warpage, less residual stresses).

Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4$-$2H_2O$) .

Advantages

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

Disadvantages

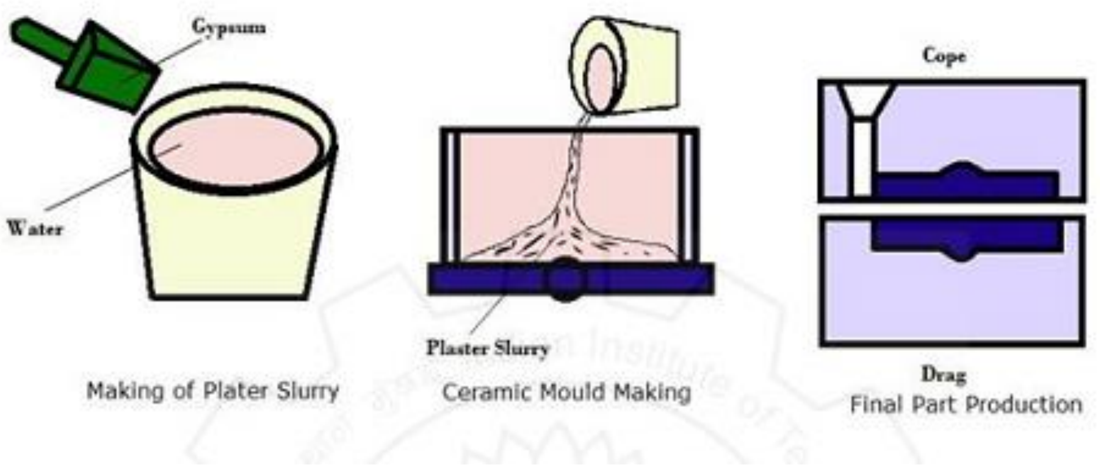
1. Moisture in plaster mold causes problems:
    - Mold must be baked to remove moisture.
    - Mold strength is lost when is over-baked, yet moisture content can cause defects in product.
2. Plaster molds cannot stand high temperatures, so limited to lower melting point alloys.

3.3.1.6 Ceramic Mold Casting

The ceramic mold casting is used to produce split molds from a quick-setting ceramic investment. Blended ceramic particles are mixed rapidly with liquid binder to form free flowing slurry that is poured quickly over a pattern. The casting does not require wax patterns and there are no limits to size or alloy. Foundry applications are large and complex impellers, valve bodies, and military hardware. The green strength of ceramic mold casting is high. Ceramic mold casting method uses a ceramic slurry prepared by mixing fine grained refractory powders of Zircon (ZrSiO4), Alumina (Al2O3), Fused Silica (SiO2) and a liquid chemical binder (Alcohol based Silicon Ester) for making the mold. Figure 3.8 schematically shows a set-up for ceramic mold casting process.

Similar to plaster mold casting except that mold is made of refractory ceramic materials that can withstand higher temperatures than plaster

- Ceramic molding can be used to cast steels, cast irons, and other high-temperature alloys
- Applications similar to those of plaster mold casting except for the metals cast
- Advantages (good accuracy and finish) also similar



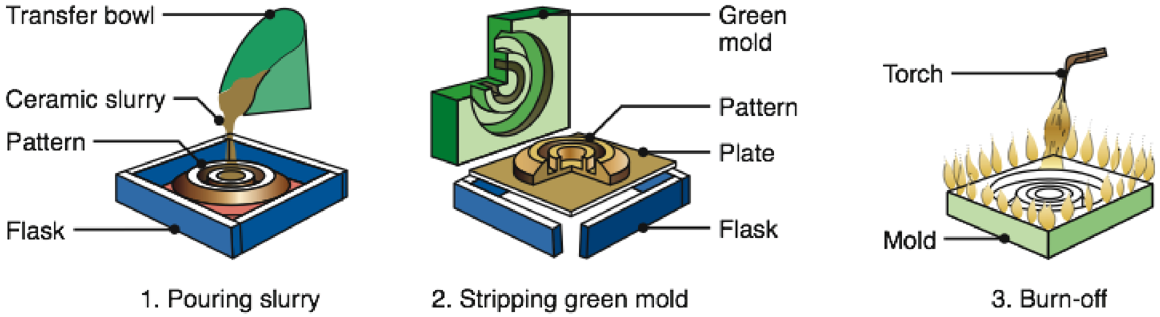


Figure (3.8): Ceramic Mold Casting Process: Sequence of Operations in Making a Ceramic Mold.

3.4 Non Expandable Mold Casting

3.4.1 Permanent Mold Casting processes

Permanent mold casting processes involve the use of metallic dies that are permanent in nature and can be used repeatedly. The metal molds are also called dies and provide superior surface finish and close tolerance than typical sand molds. The permanent mold casting processes broadly include pressure die casting, squeeze casting, centrifugal casting, and continuous casting.

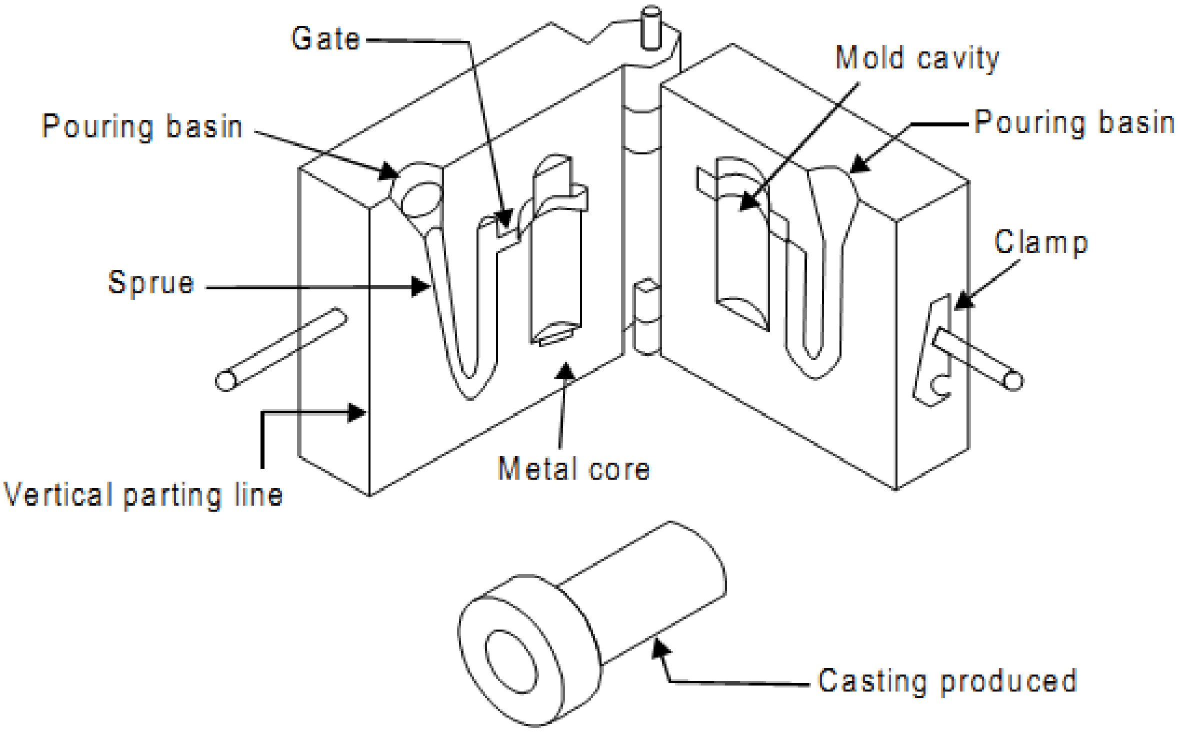


Figure (3.9): A Typical Permanent Mold

Advantages

1. Fine and dense grained structure is achieved in the casting.
2. No blow holes exist in castings produced by this method.
3. The process is economical for mass production.
4. Because of rapid rate of cooling, the castings possess fine grain structure.
5. Close dimensional tolerance or job accuracy is possible to achieve on the cast product.

6. Good surface finish and surface details are obtained.
7. Casting defects observed in sand castings are eliminated.
8. Fast rate of production can be attained.
9. The process requires less labor.

Disadvantages

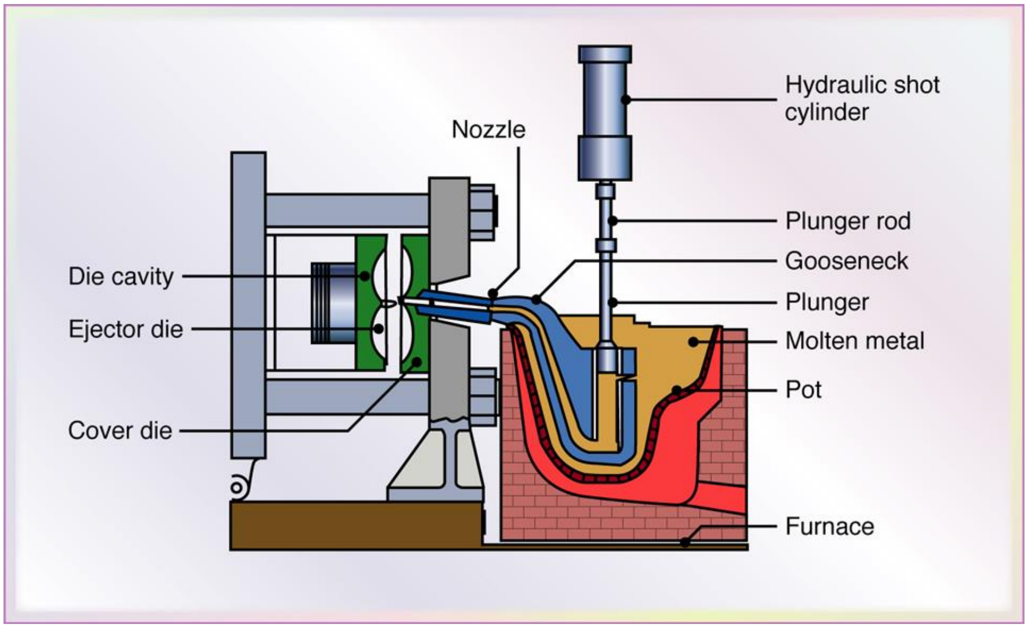
1. The cost of metallic mold is higher than the sand mold. The process is impractical for large castings.
2. The surface of casting becomes hard due to chilling effect.
3. Refractoriness of the high melting point alloys.

Applications

1. This method is suitable for small and medium sized casting such as carburetor bodies, oil pump bodies, connecting rods, pistons etc.
2. It is widely suitable for non-ferrous casting.

3.4.2 Pressures Die Casting

The pressure die casting process is the most common for Al, Zn and Mg castings (low melting point). The liquid metal is injected into the mold under high pressure and allowed to solidify at the high pressure. The solidified cast is then taken out of the mold or the die which is ready for the next cast. Pressure die casting is suitable for large batch size production. Two types of pressure die casting are generally common in the industry – (a) high pressure die casting and (b) low pressure die casting. Very high production rates can be achieved in pressure die casting process with close dimensional control of the casting. However, the process is not suitable for casting of high melting temperature materials as the die material has to withstand the melting (or superheated) temperature of the casting. Pressure die castings also contain porosity due to the entrapped air. Furthermore, the dies in the pressure die casting process are usually very costly. Figure 3.10 schematically presents the hot-chamber and the cold-chamber die casting processes. In the hot-chamber die casting process, the furnace to melt material is part of the die itself and hence, this process is suitable primarily for low-melting point temperature materials such as aluminum, magnesium etc.



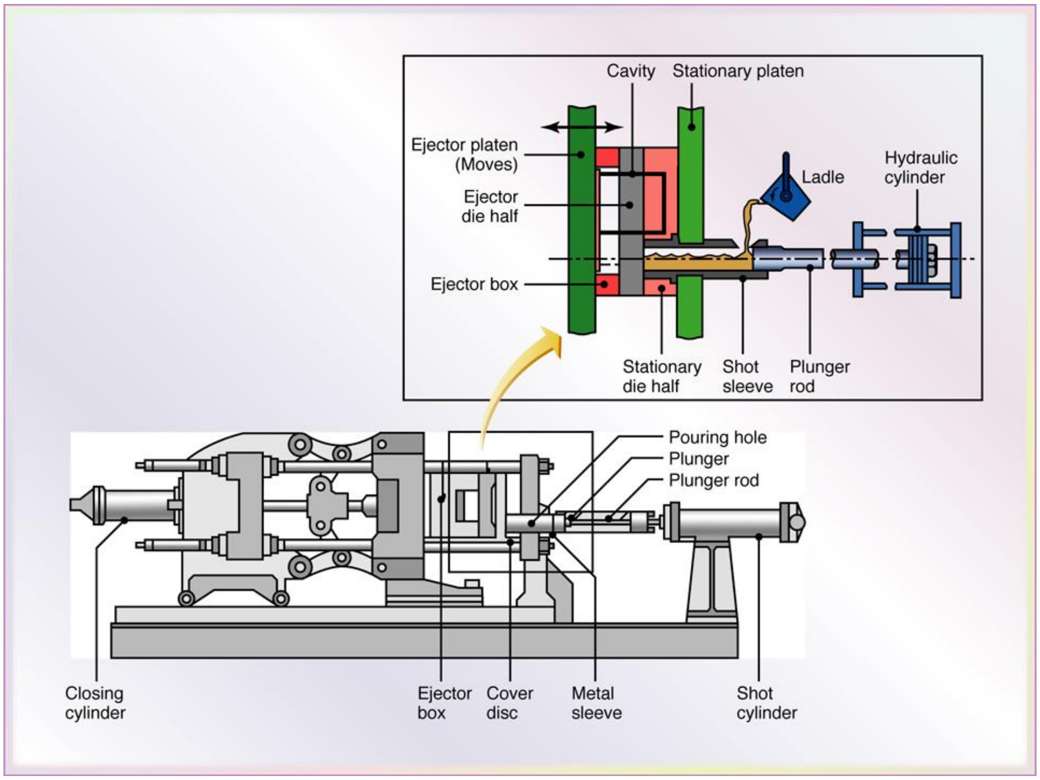


Figure (3.10): Set-up of (a) Hot-Chamber and (b) Cold-Chamber Die Casting Processes

Cold Chamber Die Casting

Cold chamber die casting process differs from hot chamber die casting in following respects.

1. Melting unit is generally not an integral part of the cold chamber die casting machine. Molten metal is brought and poured into die casting machine with help of ladles.
2. Molten metal poured into the cold chamber casting machine is generally at lower temperature as compared to that poured in hot chamber die casting machine.
3. For this reasoning, a cold chamber die casting process has to be made use of

pressure much higher (of the order of 200 to 2000 kgf/cm2) than those applied in hot chamber process.

4. High pressure tends to increase the fluidity of molten metal possessing relatively lower temperature.
5. Lower temperature of molten metal accompanied with higher injection pressure with produce castings of dense structure sustained dimensional accuracy and free from blow-holes.
6. Die components experience less thermal stresses due to lower temperature of molten metal. However, the dies are often required to be made stronger in order to bear higher pressures.

There are some advantages, disadvantages and application of this process which are given as under.

Advantages

1. It is very quick process
2. It is used for mass production
3. castings produced by this process are greatly improved surface finish
4. Thin section (0.5 mm Zn, 0.8 mm Al and 0.7 mm Mg) can be easily casted
5. Good tolerances
6. Well defined and distinct surface
7. Less nos. of rejections
8. Cost of production is less
9. Process require less space

10. Very economic process
11. Life of die is long
12. All casting has same size and shape.

Disadvantages

1. Cost of die is high.
2. Only thin casting can be produced.
3. Special skill is required.
4. Unless special precautions are adopted for evaluation of air from die-cavity some air is always entrapped in castings causing porosity.
5. It is not suitable for low production.

Applications

1. Carburetor bodies
2. Hydraulic brake cylinders
3. Refrigeration castings
4. Washing machine
5. Connecting rods and automotive pistons
6. Oil pump bodies
7. Gears and gear covers
8. Aircraft and missile castings, and
9. Typewriter segments

Advantages of Die Casting Over Sand Casting

1. Die casting requires less floor space in comparison to sand casting.

2. It helps in providing precision dimensional control with a subsequent reduction in machining cost.
3. It provides greater improved surface finish.
4. Thin section of complex shape can be produced in die casting.
5. More true shape can be produced with close tolerance in die casting.
6. Castings produced by die casting are usually less defective.
7. It produces more sound casting than sand casting.
8. It is very quick process.
9. Its rate of production is high as much as 800 casting / hour.

Table 3.1: Comparison Between Permanent Mold casting and Die Casting

No.	Permanent Mold Castings	Die Casting
1	Permanent mold casting are less costly	Die casting dies are costly
2	It requires some more floor area in comparison to die casting	It requires less floor area
3	t gives good surface finishing	It gives very fine surface finishing
4	It requires less skill	It requires skill in maintenance of die or mold
5	Production rate is good	Production rate is very high
6	It has high dimensional accuracies	It also have very high dimensional accuracies
7	This is suitable for small medium sized non-ferrous	There is a limited scope of non- ferrous alloys and it is used for small sizes of castings
8	Initial cost is high hence it is used for large production	Initial cost is also high hence used for large production
9	Several defects like stress, surface hardness may be produced due to surface chilling effect	This phenomenon may also occur in this case

3.4.3 Squeeze casting

Molten metal is poured into a metallic mold or die cavity with one-half of the die squeezing the molten metal to fill in the intended cavity under pressure as shown in Figure 3.11. Fiber reinforced casting with SiC or Al2O3 fibers mixed in metal matrix have been successfully squeeze cast and commercially used to produce automobile pistons. However, squeeze casting is limited only to shallow part or part with smaller dimensions.

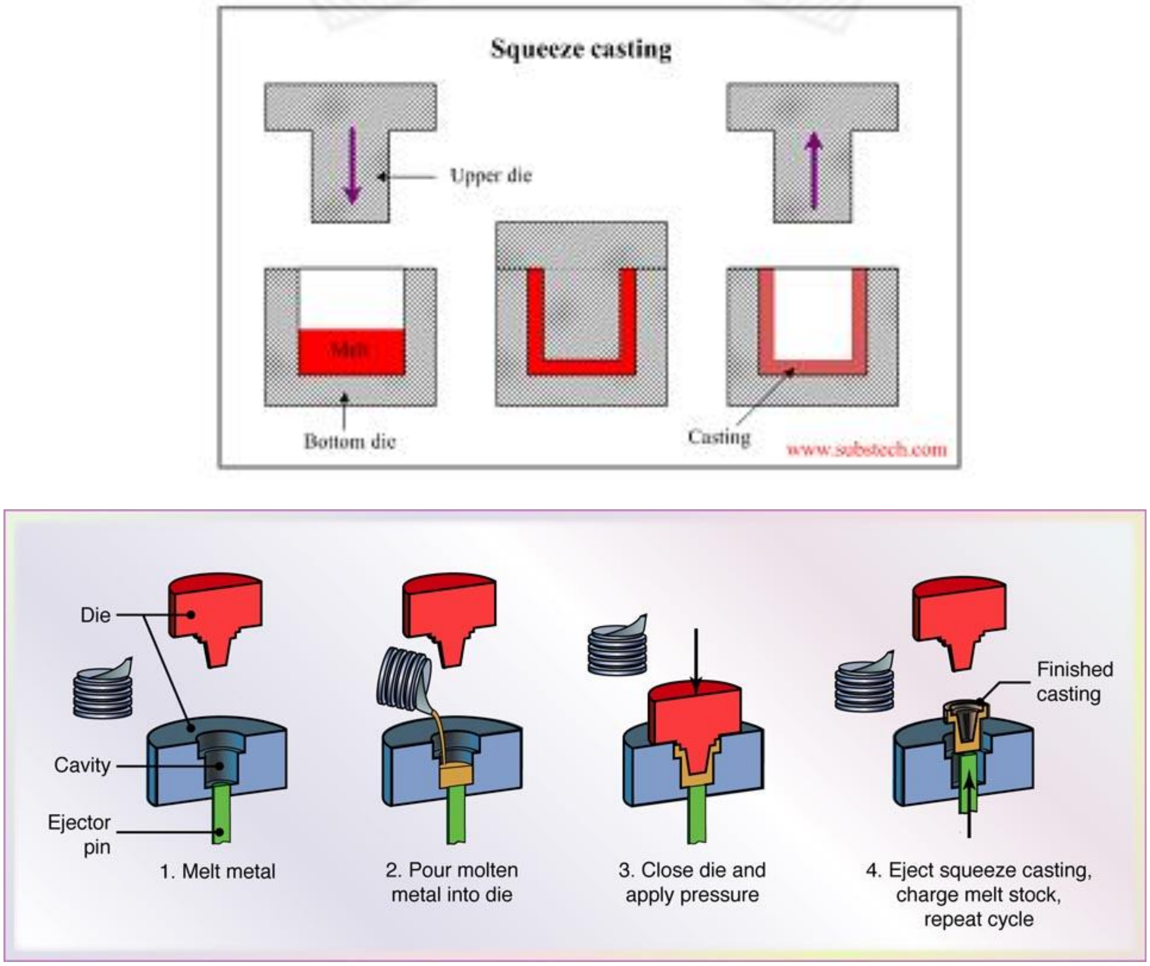


Figure (3.11): Schematic Set-up of Squeeze Casting Process

3.4.4 Centrifugal Casting

In centrifugal casting process, molten metal is poured into a revolving mold and allowed to solidify molten metal by pressure of centrifugal force. It is employed for mass production of circular casting as the castings produced by this process are free from impurities. Due to centrifugal force, the castings produced will be of high density type and of good strength. The castings produced promote directional solidification as the colder metal (less temperature molten metal) is thrown to outside of casting and molten metal near the axis or rotation. The cylindrical parts and pipes for handling gases are most adoptable to this process. Centrifugal casting processes are mainly of three types which are discussed as under.

(1) True centrifugal casting
(2) Semi-centrifugal casting and
(3) Centrifuged casting

3.4.4.1 True Centrifugal Casting

In true centrifugal casting process, the axis of rotation of mold can be horizontal, vertical or inclined. Usually it is horizontal. The most commonly articles which are produced by this process are cast iron pipes, liners, bushes and cylinder barrels. This process does not require any core. Also no gates and risers are used. Generally pipes are made by the method of the centrifugal casting. The two processes namely De Lavaud casting process and Moore casting process are commonly used in true centrifugal casting.

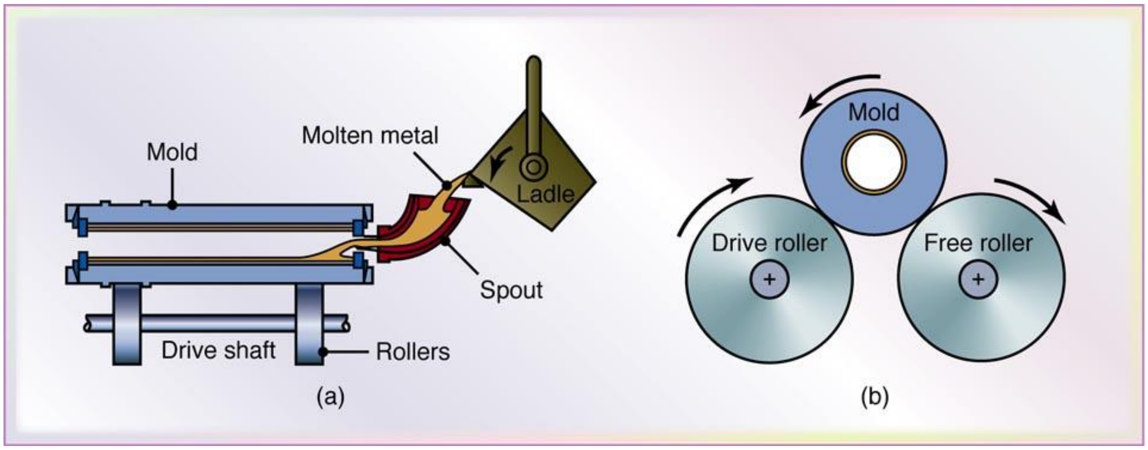


Figure (3.12): Schematic Set-up of Horizontal Centrifugal Casting Process

Figure (3.13): Metallic Pipes Made Using Centrifugal Casting Process

3.4.4.2 Semi-Centrifugal Casting

It is similar to true centrifugal casting but only with a difference that a central core is used to form the inner surface. Semi- centrifugal casting setup is shown in Figure 13.4. This casting process is generally used for articles which are more complicated than those possible in true centrifugal casting, but are axi-symmetric in nature. A particular shape of the casting is produced by mold and core and not by centrifugal force. The centrifugal force aids proper feeding and helps in producing the castings free from porosity. The article produced by this process is shown in Figure

13.15. Symmetrical objects namely wheel having arms like flywheel, gears and back wheels are produced by this process.

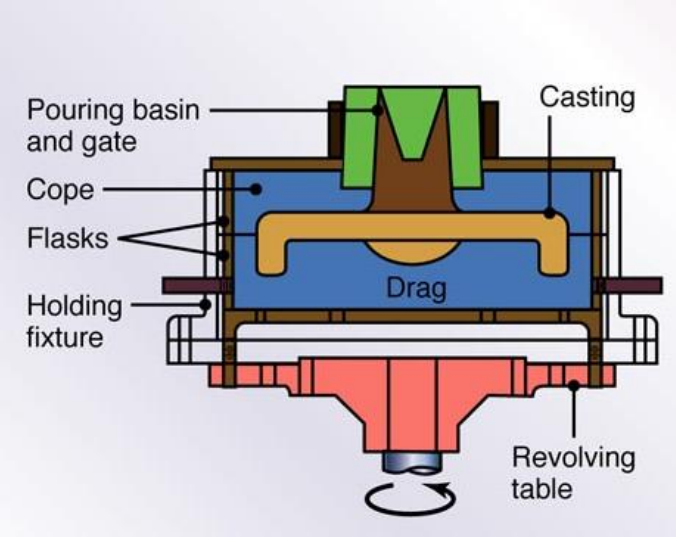


Figure (3.14): Semi-Centrifugal Casting Setup

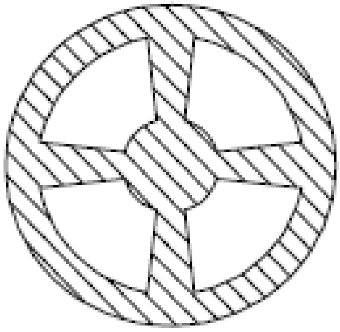


Figure (3.15): Article Produced by Semi-Centrifugal Casting Process

3.4.4.3 Centrifuging Casting

Centrifuging casting setup is shown in Figure 13.16. This casting process is generally used for producing non-symmetrical small castings having intricate details. A number of such small jobs are joined together by means of a common radial runner with a central sprue on a table which is possible in a vertical direction of mold rotation. The sample article produced by this process is depicted in Figure 13.17.

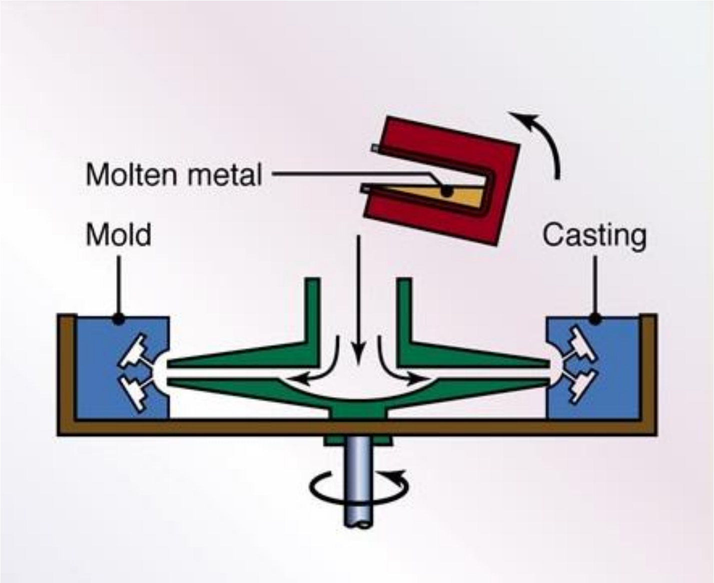


Figure (3.16): Semi-Centrifuging Casting Setup

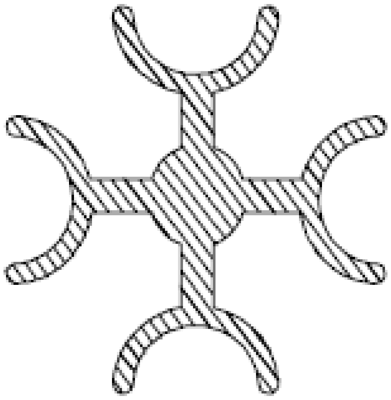


Figure (3.17): Article Produced by Centrifuging Casting Process

3.4.5 Continuous Casting

In this process the molten metal is continuously poured in to a mold cavity around which a facility for quick cooling the molten metal to the point of solidification. The solidified metal is then continuously extracted from the mold at predetermined rate. This process is classified into two categories namely Asarco and Reciprocating. In reciprocating process, molten metal is poured into a holding furnace. At the bottom of this furnace, there is a valve by which the quantity of flow can be changed. The molten metal is poured into the mold at a uniform speed. The water cooled mold is reciprocated up and down. The solidified portion of the casting is withdrawn by the rolls at a constant speed. The movement of the rolls and the reciprocating motion of the rolls are fully mechanized and properly controlled by means of cams and follower arrangements.

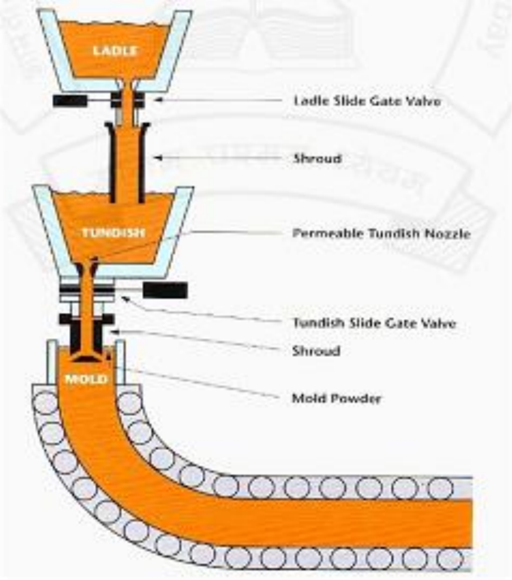


Figure (3.18): Schematic Set-up of Continuous Casting Process

Advantages of Continuous Casting

1. The process is cheaper than rolling
2. 100% casting yield.
3. The process can be easily mechanized and thus unit labor cost is less.
4. Casting surfaces are better.
5. Grain size and structure of the casting can be easily controlled.

Applications of Continuous Casting

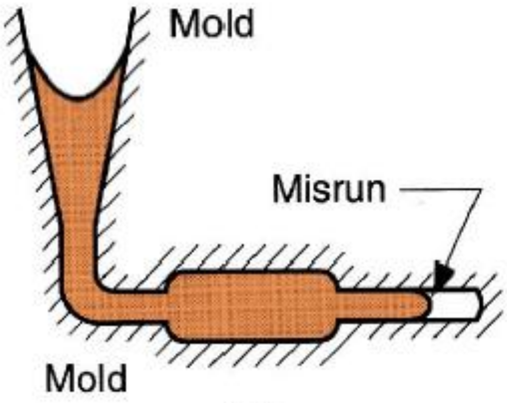
1. It is used for casting materials such as brass, bronzes, zinc, copper, aluminium and its alloys, magnesium, carbon and alloys etc.
2. Production of blooms, billets, slabs, sheets, copper bar etc.
3. It can produce any shape of uniform cross-section such as round, rectangular, square, hexagonal, fluted or gear toothed etc.

3.5 Defects in Casting Processes

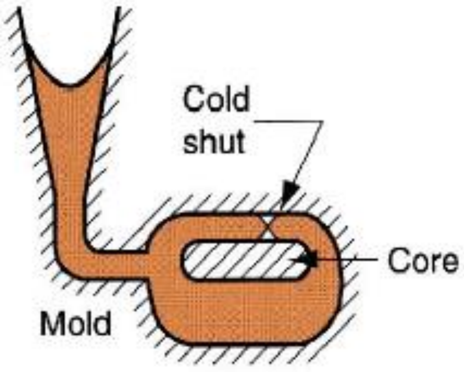
The defects can be classified as follows:

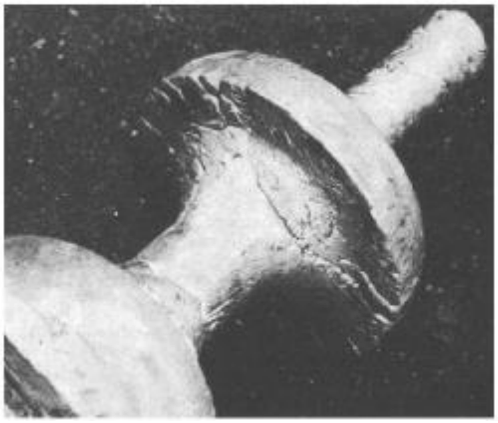
- Defects common to all casting processes
- Defects related to sand casting process

3.5.1 Misrun: A casting that has solidified before completely filling mold cavity

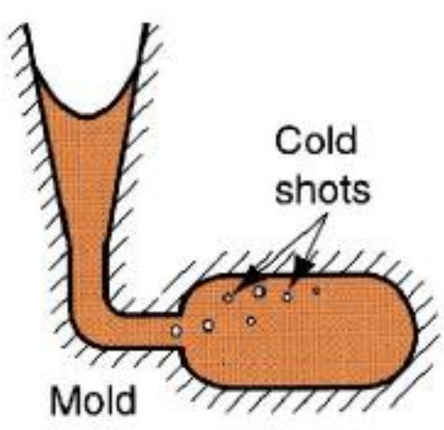


3.5.2 Cold Shut: Two portions of metal flow together but there is a lack of fusion due to premature freezing

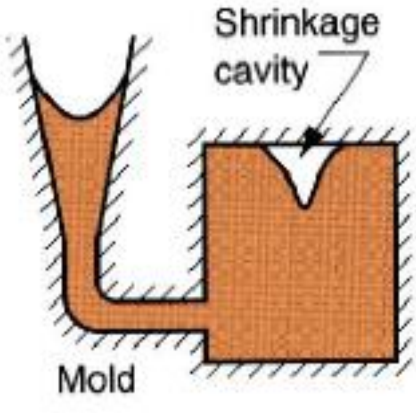




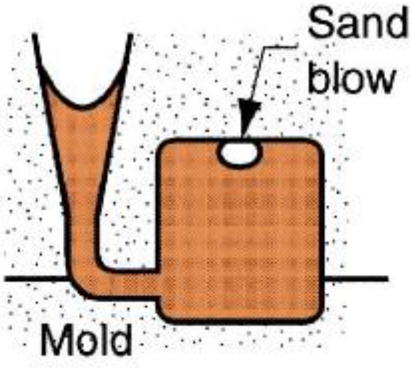
3.5.3 Cold Shot: Metal splatters during pouring and solid globules form and become entrapped in casting



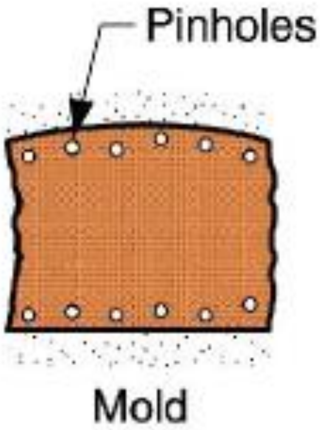
3.5.4 Shrinkage Cavity: Depression in surface or internal void caused by solidification shrinkage that restricts amount of molten metal available in last region to freeze



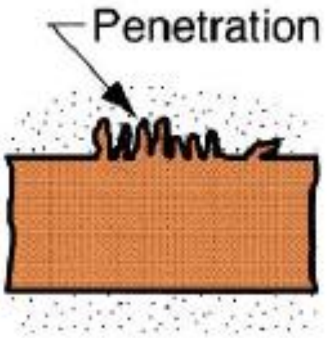
3.5.5 Sand Blow: Balloon-shaped gas cavity caused by release of mold gases during pouring



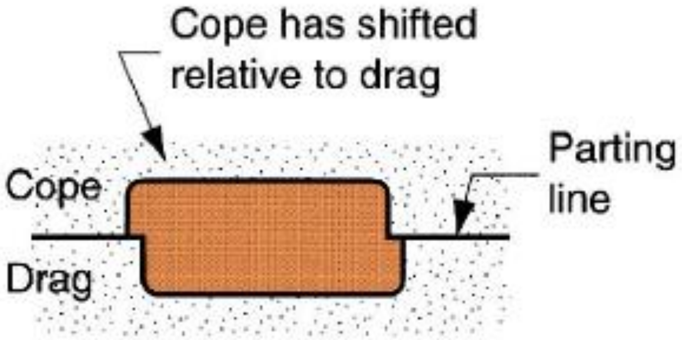
3.5.6 Pin Holes: Formation of many small gas cavities at or slightly below surface of casting



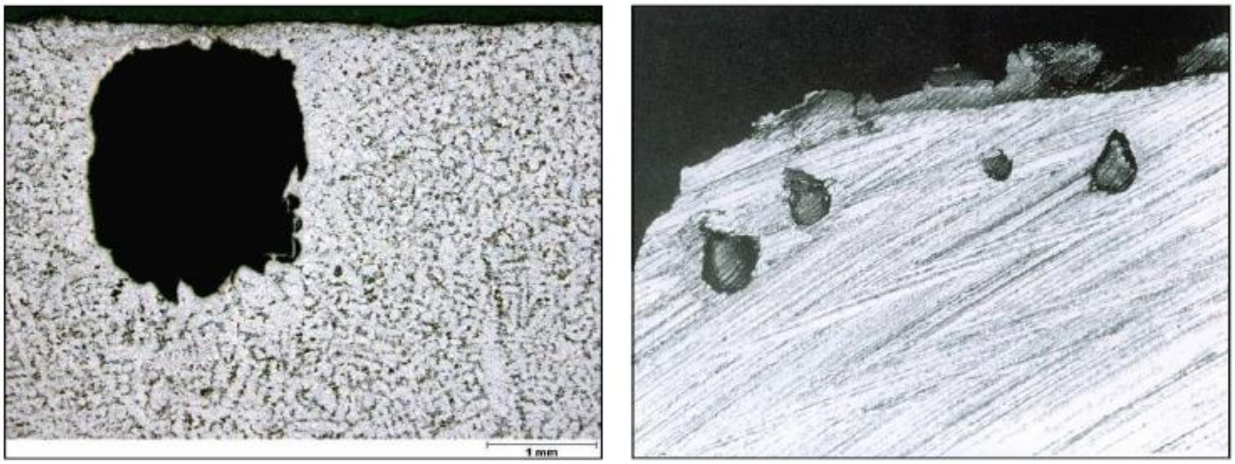
3.5.7 Penetration: When fluidity of liquid metal is high, it may penetrate into sand mold or sand core, causing casting surface to consist of a mixture of sand grains and metal



3.5.8 Mold Shift: A step in cast product at parting line caused by sidewise relative displacement of cope and drag



3.5.9 Gas Cavities:



Prevention:

- use of dry materials and ladles
- use of clean charge
- degasification of the melt
- look at the mould sands (permeability of gas, vent…)

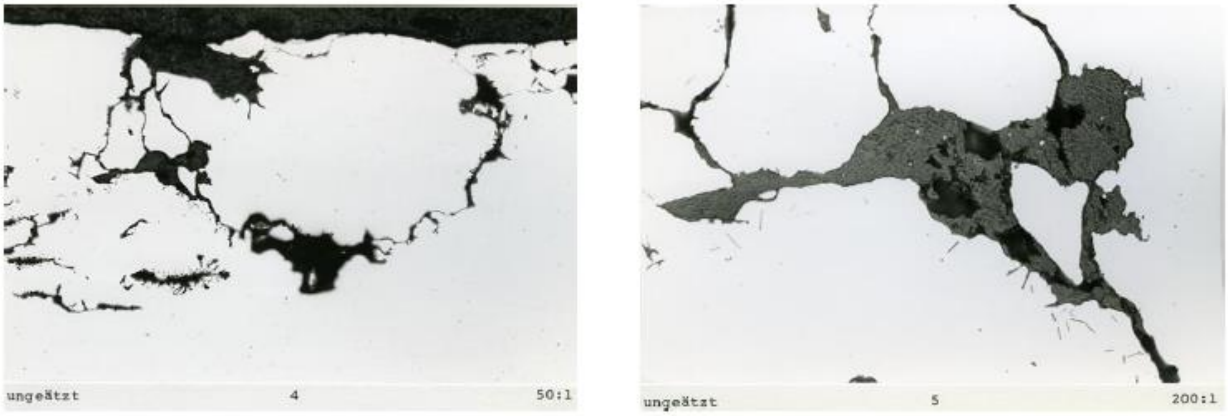
3.5.9 Oxide and Slag Inclusions, Nonmetallic Inclusions:

Description and Reasons:

- Classification: endogenous and exogenous inclusions
- endogenous inclusions are caused by the reaction products during the melting process (especially during deoxidation)
- exogenous inclusion are caused by other materials in the melt (e.g. refractory lining)
- thin fluid slag can precipitate at the grain boundaries → danger of formation of hot tears is higher
- Classification of size:

  Macro inclusions > 20 μm

  Micro inclusions < 20 μm



Slag inclusions

GX3CrNiMoN17-13-5 GX2CrNiMo18-14-3

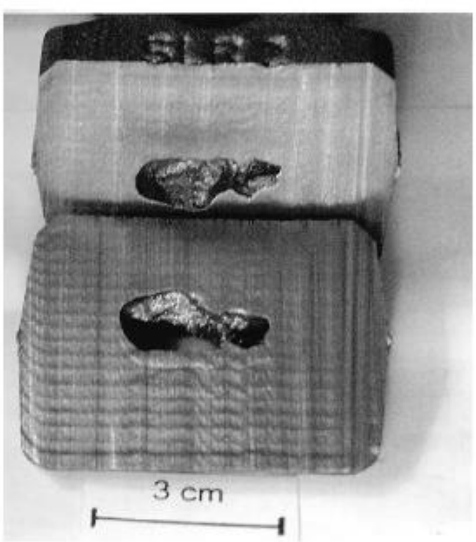
Prevention:

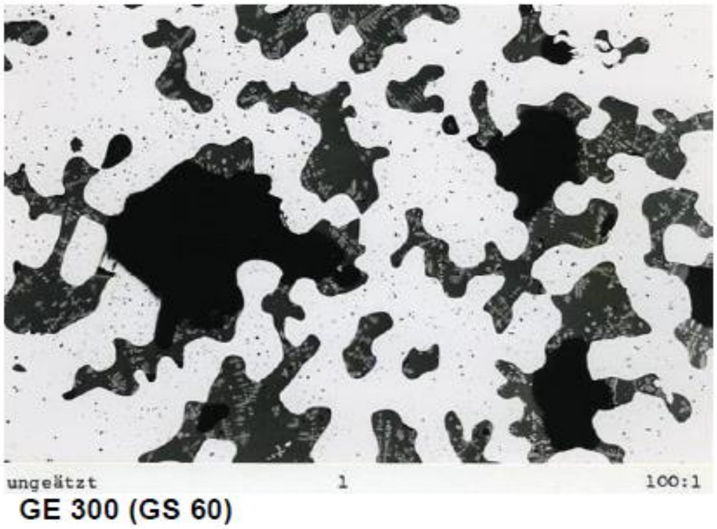
- use of clean charge
- optimization of gating and feeding system (lamellar flow)
- decrease of the dissolved oxygen
- decrease of the overheating temperature

3.5.10 Shrinkage Cavities:

Description and Reasons:

- specific volume of melt is higher than the specific volume of solid
- contraction during solidification and cooling
- feeding is necessary – if the feeding is not optimal formation of shrinkage cavities
- the shrinkage volume of cast steel is about 4-7 %
- the inner surface is rough





Prevention:

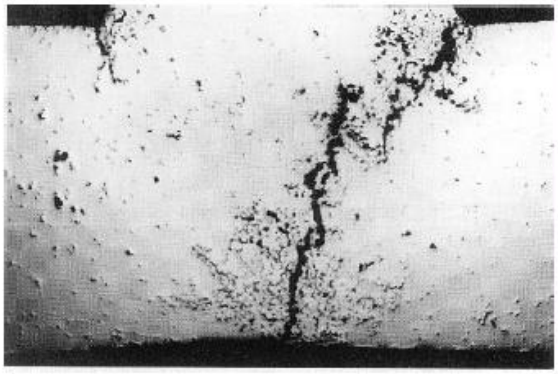
- use of optimal feeding system (calculation and simulation)
- warranty of directional solidification
- use of exothermic feeder sleeve
- decrease of the pouring temperature

3.5.11 Hot Tear:

Description and Reasons:

- hot tears are intercrystalline discontinuity
- cracks run along the grain boundaries
- the risk of cracks at alloys with a high freezing range is higher than with a small freezing range
- the reason are stresses during solidification because of hindered contraction (residual stress)
- the main reason for formation of hot tears are the geometry of casting

- if melt can flow into the crack - partial or completely annealed hot tears are possible



Prevention:

- design appropriate to casting, prevention of residual stresses, wide difference in the wall thickness and hot spots)
- prevention of hot sand effects

3.6 Inspections of Casting

3.6.1 Visual Inspection

Visible defects that can be detected provide a means for discovering errors in the pattern equipment or in the molding and casting process. Visual inspection may prove inadequate only in the detection of sub surface or internal defects.

3.6.2 Dimensional Inspection

Dimensional inspection is one of the important inspection for casting. When precision casting is required, we make some samples for inspection the tolerance, shape size and also measure the profile of the cast. This dimensional inspection of casting may be conducted by various methods:

- Standard measuring instruments to check the size of the cast.
- Contour gauges for the checking of profile, curves and shapes
- Coordinate measuring and Marking Machine
- Special fixtures

3.6.3 X-Ray Radiography

In all the foundries the flaw detection test are performed in the casting where the defects are not visible. This flaw detection test is usually performed for internal defects, surface defects etc. These tests are valuable not only in detecting but even in locating the casting defects present in the interior of the casting. Radiography is one of the important flaw detection test for casting. The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.

3.6.4 Magnetic Particle Inspection

This test is used to reveal the location of cracks that extend to the surface of iron or steel castings, which are magnetic nature. The casting is first magnetized and then iron particles are sprinkled all over the path of the magnetic field. The particles align themselves in the direction of the lines of force. A discontinuity in the casting causes the lines of the force to bypass the discontinuity and to concentrate around the extremities of the defect.

3.6.5 Fluorescent Dye-Penetration Test

This method is very simple and applied for all cast metals. It entails applying a thin penetration oil-base dye to the surface of the casting and allowing it to stand for some time so that the oil passes into the cracks by means of capillary action. The oil is then thoroughly wiped and cleaned from the surface. To detect the defects, the casting is pained with a coat of whitewash or powdered with tale and then viewed under ultraviolet light. The oil being fluorescent in nature, can be easily detect under this light, and thus the defects are easily revealed.

3.5.6 Ultrasonic Testing

Ultrasonic testing used for detecting internal voids in casting is based on the principle of reflection of high frequency sound waves. If the surface under test contains some defect, the high frequency sound waves when emitted through the section of the casting, will be reflected from the surface of defect and return in a shorter period of time. The advantage this method of testing over other methods is that the defect, even if in the interior, is not only detected and located accurately, but its dimension can also be quickly measured without in any damaging or destroying the casting.

3.6.7 Fracture Test

Fracture test is done by examining a fracture surface of the casting. it is possible to observe coarse graphite or chilled portion and also shrinkage cavity, pin hole etc. The apparent soundness of the casting can thus be judged by seeing the fracture.

3.6.8 Macro-Etching Test (Macroscopic Examination)

The macroscopic inspection is widely used as a routine control test in steel production because it affords a convenient and effective means of determining internal defects in the metal. Macro-etching may reveal one of the following conditions:

- Crystalline heterogeneity, depending on solidification
- Chemical heterogeneity, depending on the impurities present or localized segregation and
- Mechanical heterogeneity, depending on strain introduced on the metal, if any.

3.6.9 Sulphur Print Test

Sulphur may exist in iron or steel in one of two forms; either as iron sulphide or manganese sulphide. The distribution of sulphur inclusions can easily examined by this test.

3.6.10 Microscopic Examination

Microscopic examination can enable the study of the microstructure of the metal alloy, elucidating its composition, the type and nature of any treatment given to it, and its mechanical properties. In the case of cast metals, particularly steels, cast iron, malleable iron, and SG iron, microstructure examination is essential for assessing metallurgical structure and composition. Composition analysis can also be done using microscopic inspection. Distribution of phase can be observed by metallographic sample preparation of cast product. Grain size and distribution, grain boundary area can be observed by this procedure. Distribution of nonmetallic inclusion can also be found from this process of inspection.

3.6.11 Chill Test

Chill test offers a convenient means for an approximate evaluation of the graphitizing tendency of the iron produced and forms an important and quick shop floor test for ascertaining whether this iron will be of the class desired. In chill test, accelerated cooling rate is introduced to induce the formation of a chilled specimen of appropriate dimension. It is then broken by striking with a hammer in such a manner that the fracture is straight and midway of its length. The depth of chill obtained on the test piece is affected by the carbon and silicon present and it can therefore be related to the carbon equivalent, whose value in turn determines the grade of iron.

3.7 Furnaces for Casting Processes

Melting is an equally important parameter for obtaining a quality castings. A number of furnaces can be used for melting the metal, to be used, to make a metal casting. The choice of furnace depends on the type of metal to be melted. Some of the furnaces used in metal casting are as following:

- Crucible Furnaces
- Cupola
- Induction Furnace
- Reverberatory Furnace

3.7.1 Crucible Furnace.

Crucible furnaces are small capacity typically used for small melting applications. Crucible furnace is suitable for the batch type foundries where the metal requirement is intermittent. The metal is placed in a crucible which is made of clay and graphite. The energy is applied indirectly to the metal by heating the crucible by coke, oil or gas. The heating of crucible is done by coke, oil or gas. .

Coke-Fired Furnace (Figure 19**).**

- Primarily used for non-ferrous metals
- Furnace is of a cylindrical shape
- Also known as pit furnace
- Preparation involves: first to make a deep bed of coke in the furnace
- Burn the coke till it attains the state of maximum combustion
- Insert the crucible in the coke bed
- Remove the crucible when the melt reaches to desired temperature

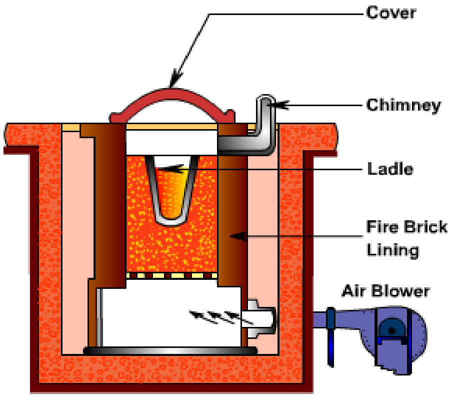


Figure (3.19): Coke Fired Crucible Furnace

Oil-Fired Furnace.

- Primarily used for non-ferrous metals
- Furnace is of a cylindrical shape
- Advantages include: no wastage of fuel
- Less contamination of the metal
- Absorption of water vapor is least as the metal melts inside the closed metallic furnace

Cupola

Cupola furnaces are tall, cylindrical furnaces used to melt iron and ferrous alloys in foundry operations. Alternating layers of metal and ferrous alloys, coke, and limestone are fed into the furnace from the top. A schematic diagram of a cupola is shown in Figure 20 . This diagram of a cupola illustrates the furnace's cylindrical shaft lined with refractory and the alternating layers of coke and metal scrap. The molten metal flows out of a spout at the bottom of the cupola.

Description of Cupola

- The cupola consists of a vertical cylindrical steel sheet and lined inside with acid refractory bricks. The lining is generally thicker in the lower portion of the cupola as the temperature are higher than in upper portion
- There is a charging door through which coke, pig iron, steel scrap and flux is charged
- The blast is blown through the tuyeres
- These tuyeres are arranged in one or more row around the periphery of cupola
- Hot gases which ascends from the bottom (combustion zone) preheats the iron in the preheating zone
- Cupolas are provided with a drop bottom door through which debris, consisting of coke, slag etc. can be discharged at the end of the melt
- A slag hole is provided to remove the slag from the melt
- Through the tap hole molten metal is poured into the ladle
- At the top conical cap called the spark arrest is provided to prevent the spark emerging to outside

Operation of Cupola

The cupola is charged with wood at the bottom. On the top of the wood a bed of coke is built. Alternating layers of metal and ferrous alloys, coke, and limestone are fed into the furnace from the top. The purpose of adding flux is to eliminate the impurities and to protect the metal from oxidation. Air blast is opened for the complete combustion of coke. When sufficient metal has been melted that slag hole is first opened to remove the slag. Tap hole is then opened to collect the metal in the ladle.

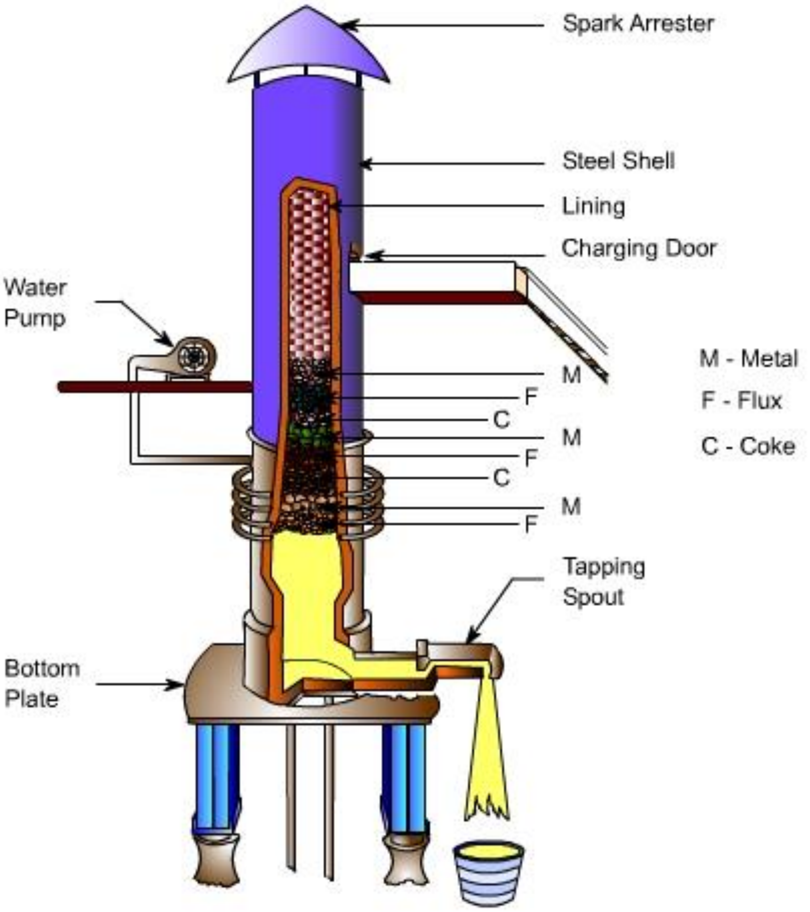


Figure (3.20): Schematic of a Cupola

Reverberatory Furnace

A furnace or kiln in which the material under treatment is heated indirectly by means of a flame deflected downward from the roof. Reverberatory furnaces are used in opper, tin, and nickel production, in the production of certain concretes and cements, and in aluminum. Reverberatory furnaces heat the metal to melting temperatures with direct fired wall-mounted burners. The primary mode of heat transfer is through radiation from the refractory brick walls to the metal, but convective heat transfer also provides additional heating from the burner to the metal. The advantages provided by reverberatory melters is the high volume processing rate, and low operating and maintenance costs. The disadvantages of the reverberatory melters are the high metal oxidation rates, low efficiencies, and large floor space requirements. A schematic of Reverberatory furnace is shown in Figure 21

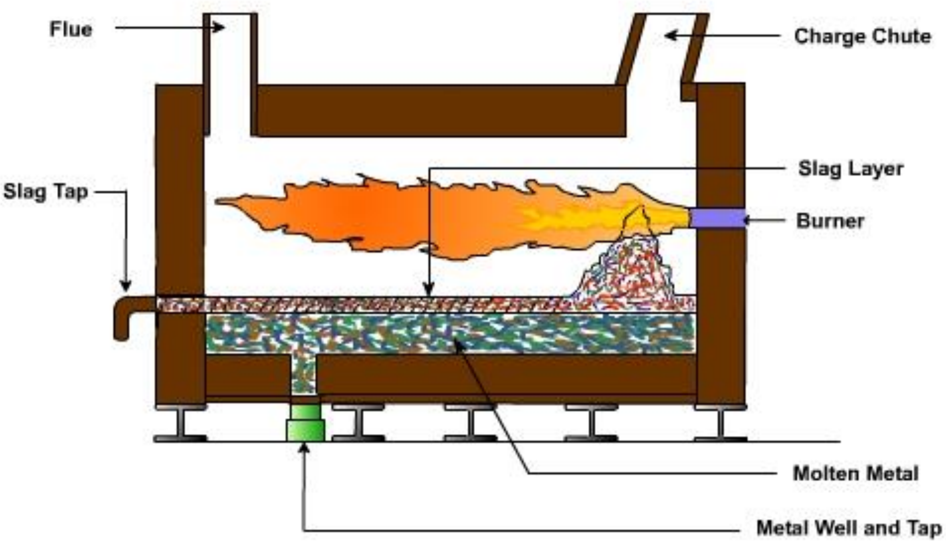


Figure (3.21): Schematic of a Reverberatory Furnace

Induction Furnace

Induction heating is a heating method. The heating by the induction method occurs when an electrically conductive material is placed in a varying magnetic field. Induction heating is a rapid form of heating in which a current is induced directly into the part being heated. Induction heating is a non-contact form of heating.

The heating system in an induction furnace includes:

1. Induction heating power supply,
2. Induction heating coil,
3. Water-cooling source, which cools the coil and several internal components inside the power supply.

The induction heating power supply sends alternating current through the induction coil, which generates a magnetic field. Induction furnaces work on the principle of a transformer. An alternative electromagnetic field induces eddy currents in the metal which converts the electric energy to heat without any physical contact between the induction coil and the work piece. A schematic diagram of induction furnace is shown in Figure 22. The furnace contains a crucible surrounded by a water cooled copper coil. The coil is called primary coil to which a high frequency current is supplied. By induction secondary currents, called eddy currents are produced in the crucible. High temperature can be obtained by this method. Induction furnaces are of two types: cored furnace and coreless furnace. Cored furnaces are used almost exclusively as holding furnaces. In cored furnace the electromagnetic field heats the metal between two coils. Coreless furnaces heat the metal via an external primary coil.

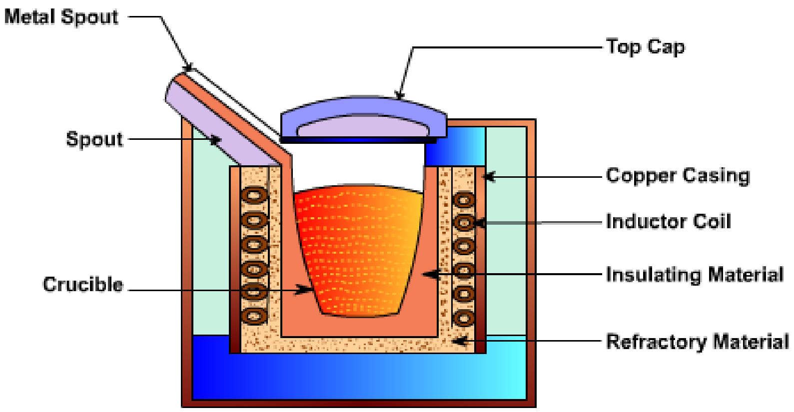


Figure (3.22): Schematic of a Induction Furnace

Advantages of Induction Furnace

- Induction heating is a clean form of heating
- High rate of melting or high melting efficiency
- Alloyed steels can be melted without any loss of alloying elements
- Controllable and localized heating

Disadvantages of Induction Furnace

- High capital cost of the equipment
- High operating cost