At the end, the cupola is shut off by stopping the air blast. Then, the remaining molten metal is removed, the bottom doors are opened, the wastes are dropped down and they are quenched by water.

Application

Cupola is used to melt cast iron.

Advantages

1. Initial cost is comparatively less than other type of furnaces.
2. It is simple in design.
3. It requires less floor area.
4. Operation and maintenance are simple.
5. It can be operated continuously for many hours.

1.20 PRINCIPLE OF SPECIAL CASTING PROCESSES

1.20.1 Shell Mould Casting

The shell mould casting is a semi-precise method for producing small castings in large numbers. The process involves the use of a match plate pattern similar to cope and drag patterns which are used in green sand mould casting.

Initially, the patterns are machined from copper alloys, aluminum or cast iron depending upon the lift of the pattern. They are made with usual allowances and polished surfaces. Then it is attached to the metal match plate.

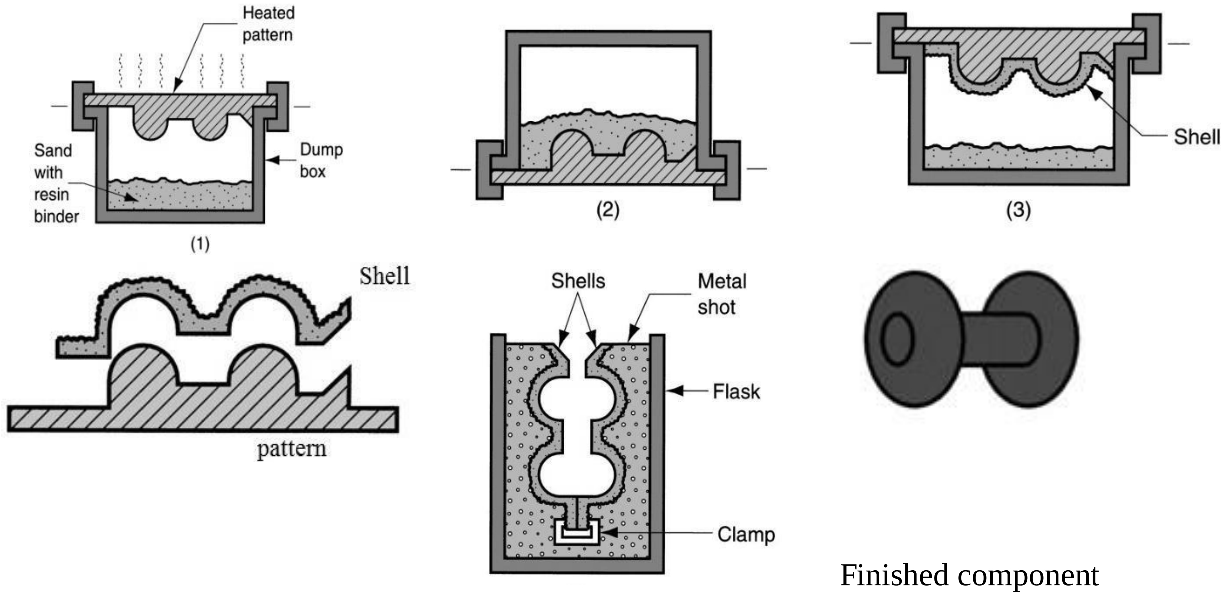


Figure 1.42 Shell Mould Casting

The mould material contains 5 to 10% of phenolic resin mixed with fine dry silica. These are mixed with either dry oil or alcohol. It should be noted that there is no water used.

The pattern is heated to about 230-600°C. Then, the sand-resin mixture is either dumped or blown over its surface. Sometimes, to prevent the sticking of sand with pattern, a release agent silicone is sprayed over the hot pattern. The heated pattern melts and hardens the resin. This results in bonding the sand grains closely together and forms a shell around the pattern. After a specified time of 20-30 sec, the pattern and sand are inverted, as shown in Figure 1.42 (2). The thickness of the shell can be accurately controlled by the time of contact of the mixture with the heated pattern. In about 20-30 sec. A normal shell thickness of 6 mm can be obtained. The extra sand which is not adhered to the shell is removed off. The thickness of the shell is depending on the required strength and rigidity to hold the weight of the liquid metal to be poured into the mould.

Then, the mould is heated in an oven at 300°C for 15-60 sec. This curing makes the shell rigid when it can be stripped off by means of ejector pins mounted on the pattern. Thus, the formed shell constitutes one-half of the mould. Two such halves, placed one over the other make the complete mould, as shown is Figure.

While pouring the molten metal, the two halves are clamped down together by clamps or springs. After cooling and solidification, the shells are broken or shaken away from the castings.

Applications

1. It is used for making brake drums and bushings.
2. Cams, cam shaft, piston and piston rings can be made.
3. It is used for making small pulleys, motor housing, fan blades etc.
4. Air compressor crankcases and cylinders, conveyor, rollers etc., can be made.

Advantages

1. A high accuracy castings with tolerances of ±0.002 to 0.005mm/mm is possible.
2. Good surface finish can be obtained.
3. Complex parts can be made by this method.
4. Less sand is used compared to other methods.
5. Moulds can be stored for long time.
6. Permeability of thin shell moulds is high. Therefore, defects are less. Better quality castings can be made.

Limitations

1. Only small size of the castings can be made.
2. Serious dust and fume problem during sand and resin mixing will occur.
3. The cost is more.
4. Carbon pickup may occur in the case of steels.

1.20.2 Investment Casting (or) Lost Wax Method

A was duplicate of the desired casting is created to be invested into a “Ceramic Slurry”.

The slurry covered investment can be dipped into alternating coatings of sand and slurry until a suitable thickness of shell is achieved that can hold the molten metal after the investment is burnt out.

The “Burn-Out” process requires that the investment and coating are inverted in an oven that is fired to 1800F so that the investment can flow out and be recovered. The refractory coating is also cured in this procedure.

Once the investment is lost, and the Refractory is cured the mould is removed and poured immediately while it is still hot.

Investment casting can make use of most metals, most commonly using aluminum alloys, bronze alloys, magnesium alloys, cast iron, stainless steel, and tool steel.

This process is beneficial for casting metals with high melting temperatures that cannot be moulded in plaster or metal.

Parts that are typically made by investment casting include those with complex geometry such as turbine blades or fire arm components. High temperature applications are also common, which includes parts for the automotive, aircraft, and military industries.

Principle

Method also called as precision investment casting. The method involves the use of expendable Pattern with a shell of refractory material surrounded to form a casting mould. Since the pattern made up of wax is melted out and gets destroyed. That is why the name “Lost wax method”.

Procedure

1. Produced a master pattern

The pattern is a modified replica of the desired product made from metal, wood, plastic, or some other easily worked material.

2. From the master pattern, produce a master die

This can be made from low-melting-point metal, steel, or possibly even wood. If low-meeting-point metal is used.

3. Produce was patterns

Patterns are made by pouring molten wax into the master ide, or injecting it under pressure, and allowing it to harden. Plastic and frozen mercury have also been used as pattern material.

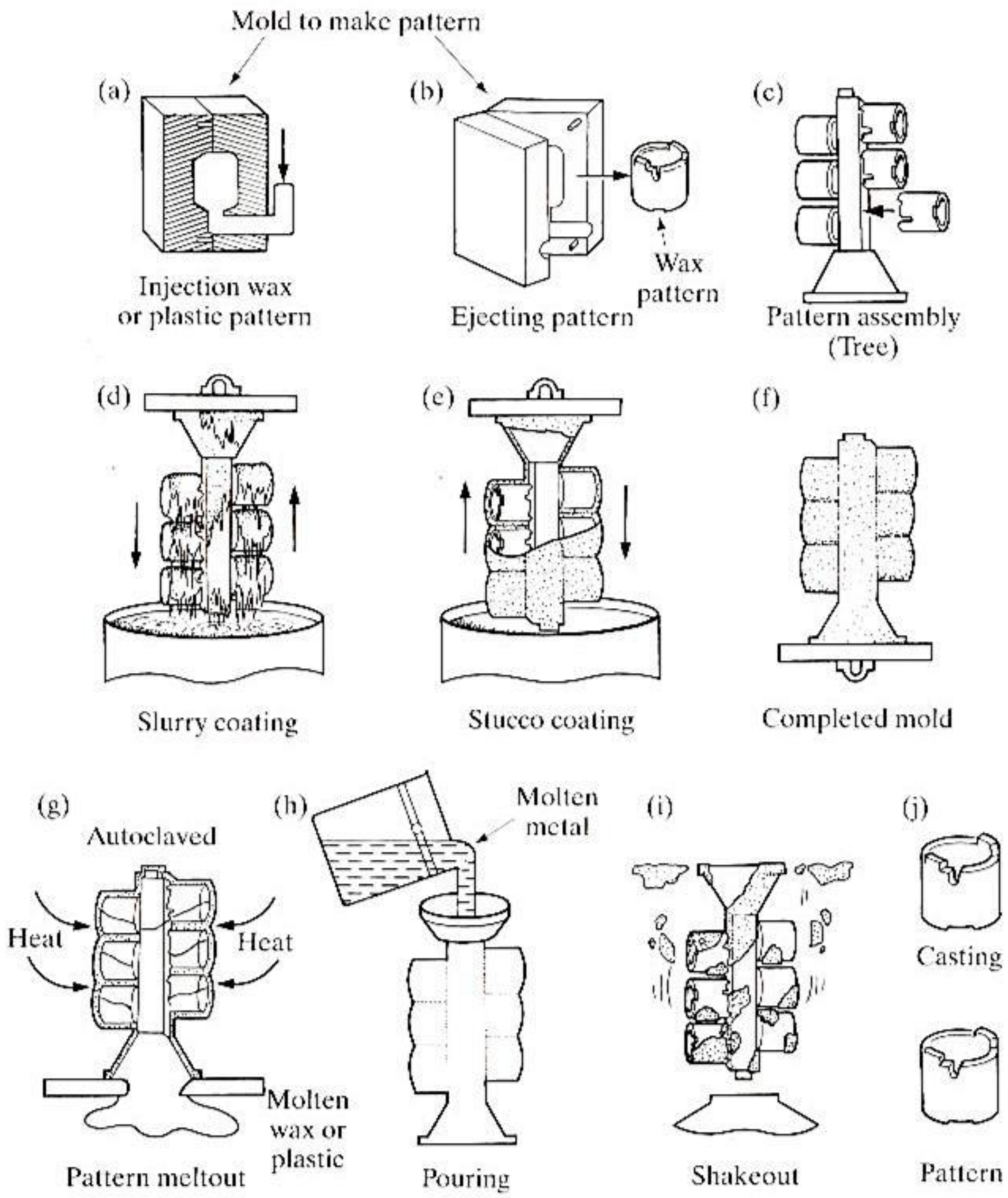


Figure 1.43 Investment Casting Process

4. Assemble the wax patterns onto a common wax sprue

The individual wax patterns are attached to a central sprue and runner system by means of heated tools and melted wax. In some cases, several pattern pieces may first be united to form a complex.

5. Coat the cluster with a thin layer of investment material

This step is usually accomplished by dipping the cluster into a watery slurry of finely ground refractory material.

6. Produce the final investment around the coated cluster

After the initial layer is formed, the cluster can be redipped, but this time the wet ceramic is coated with a layer of sand and allowed to dry. This process can be repeated until the investment coating is the desired thickness (typically 5 to 15 mm).

7. Allow the investment to fully harden

8. Melt or dissolve the wax pattern to remove it from the mould

This is generally accomplished by placing the moulds upside down in an oven, where the wax melts and runs out, and any residue subsequently vaporizes.

9. Preheat the mould in preparation for pouring

Heating to 550 to 1100°C (1000 to 2000°F) ensures complete removal of the mould wax, curves the mould to give added strength, and allows the molten metal to retain its heat and flow more readily into all of the thin sections.

10. Pour the molten metal

Various methods, beyond simple pouring, can be used to ensure complete filling of the mould, especially when complex, thin sections are involved.

11. Remove the casting from the mould

This is accomplished by breaking the mould away from the casting. Techniques include mechanical vibration and high-pressure water.

Advantages

1. Smoother surfaces (1500 to 2250 micro-mm root mean-square). Close tolerance (of +0.003 mm/mm)
2. High dimensional accuracy
3. Intricate shape can be cast
4. Castings do not contain any disfiguring parting line
5. Machining operation can by eliminated

Disadvantages:

1. Process is relatively slow.
2. Use of cores makes the process more difficult.
3. The process is relatively expensive than other process.
4. Pattern is expandable.
5. Size limitation of the component part to be cast. Majority of the castings produced weight less than 0.5 kg.

Applications

The products made by this process are vanes and blades for gas turbines, shuttle eyes for weaving, pawls and claws of movie cameras, wave guides for radars, bolts and triggers for fire arms, stainless steel valve bodies and impellers for turbo chargers.

While investment casting is actually a very old process and has been performed by dentists and jewelers for a number of years, it was not until the end of Word War II that it attained any degree of industrial importance.

Developments and demands in the aerospace industry. Such as rocket components and jet engine turbine blades, required high-precision complex shapes from high-melting-point metals that are not readily machinable.

Investment casting offers almost unlimited freedom in both the complexity of shapes and types of materials that can be cast.

Process parameters of Investment casting

Process principle

A refractory sluury is formed around a wax or plastic pattern and allowed to hardened. The pattern is then melted but under mould is baked. The molten metal into the mould and solidifies.

Size limits

As small as (1/10) inch but usually less than 10 lb.

Thickness limits

As thickness as 0.025 inch but less than 3 inch/

Typical tolerance

Approximately 0.005 inch.

For the first inch and 0.002 inch for each additional inch.

Draft allowance

Not required

Surface finish

50 to 125 micron

1.20.3. Ceramic Mould Casting (or) Cope and Drag Investment Casting (or) Plaster Moulding

The ceramic mould casting used permanent patterns made of plaster, plastic, wood, metal or rubber and utilizes fine grain zircon and calcined, high-alumna mullite slurries for moulding. These slurries are comparable in composition to those used in investment castings. Like investment moulds, ceramic moulds are expendable. However, unlike the monolithic moulds obtained in investment castings, ceramic moulds consist of a cope and a drag setup.

Principle

The mould is made of plaster of paris (Gypsum or $CaSo_4½H_2O$) with the addition of talc and Silica flour to improve strength and to control the time required for the plaster to set. These components are mixed with water and the resulting slurry is poured over the Pattern. After removing the pattern, mould is cured in an oven and it is ready to receive the molten metal.

Procedure

One of the most popular of the ceramic moulding techniques is the Shaw process. A reusable pattern is placed inside a slightly tapered flask, and a slurry like mixture of refractory aggregate, hydrolyzed ethyl silicate, alcohol, and a getting agent is poured on top.

This mixture sets to a rubbery state that permits removal of the pattern and the flask, and the mould surface is then ignited with a torch.

During "burn-off", most of the volatiles are consumed, and a three-dimensional network of microscopic cracks (microcrazing) forms in the ceramic.

The gaps are small enough to prevent metal penetration but large enough to provide venting of air and gas (permeability) and to accommodate both the thermai expansion of the ceramic particles during the pour and the subsequent shrinkage of the solidified metal (i.e provide collapsibility.

A subsequent baking operation removes all of the remaining volatiles, making the mould hard and rigid. Before pouring, the ceramic moulds are often preheated to ensure proper filling and to control the solidification characteristics of the metal.

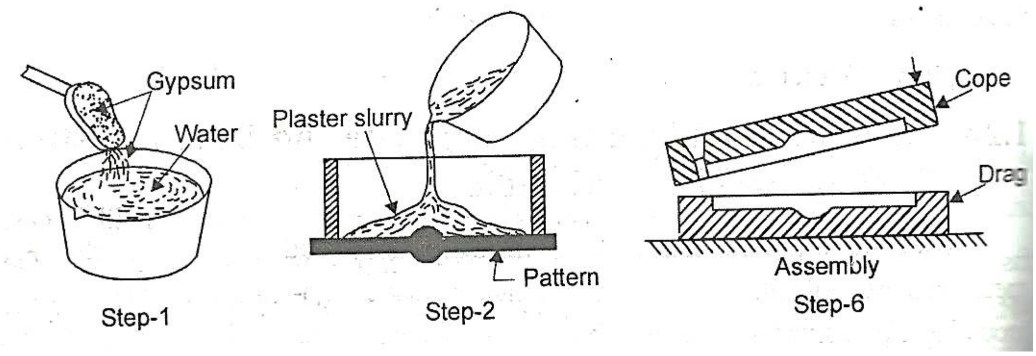


Figure 1.44 Ceramic Moulding

Advantages

1. High production rates are possible
2. High dimensional accuracy is achieved.
3. No cores are needed.

4. Complex shapes can be cast.
5. Machining can be eliminated.
6. Expensive tooling restricts the process to long run castings.
7. Long lead times are needed to develop new castings.

1.20.4. Pressure Die Casting

In the previous casting processes, expendable moulds are used where it must be broken in order to obtain the castings. In the die casting process, the mould used for making a casting is permanent, called a die. In this process, the molten metal is forced into the mould cavity under high pressure. The process is used for casting a low melting temperature material, e.g. Aluminum and Zinc alloys, brass etc. the die-casting is carried out as follows:

1. The molten metal is forced under pressure into the assembled die.
2. The die is water-cooled. So, the molten metal cools down and immediately becomes solid.
3. The die is opened. Then, the finished casting is ejected by pins.

The mould normally called die is made in two halves in which one is fixed and the other one is movable. Medium carbon and low allowy tool steel are the most common die materials. There are two types of die casting processes. They are,

1. Hot Chamber Die Casting
2. Cold Chamber Die Casting
3. Gravity Die Casting

1. Hot Chamber Die-Casting

In hot chamber die-casting, the melting furnace is an integral part of the mould. There is a gooseneck vessel which is submerged in molten metal. There is a plunger at the top of the gooseneck vessel, when the plunger is in the upward position, the molten metal flows into the vessel through a port provided on the sidewall.

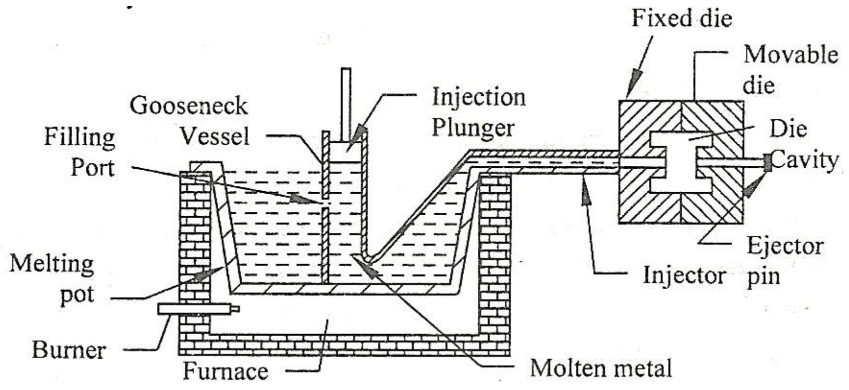


Figure 1.45 Hot Chamber Die-Casting

When the plunger comes down, the molten metal is forced into the dies. Since, the die is immediately cooled by water and sufficient cooling is provided for solidification. Then, the movable die is moved some distance and finished casting is removed by ejectors. The plunger and movable die are operated by hydraulic systems. The operating pressure of hydraulic plunger is $15MN/M^2$.

Hot chamber die-casting is suitable for casting of metals such as Zinc, tin and lead.

2. Cold Chamber Die-Casting

In cold chamber die-casting, the metal melting unit is not an integral part of the machine. The metal is melted in a separate furnace and brought to the machine for pouring. The process is shows in Figure 1.46.

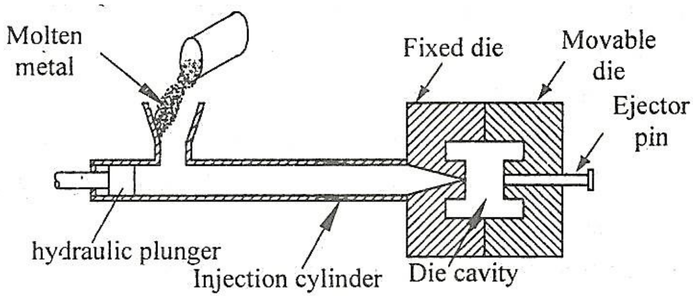


Figure 1.46 Cold Chamber Die-Casting

The machine has a cold chamber of cylindrical shape with a hydraulic plunger. A measured quantity of molten metal is poured into the injection cylinder. Then the plunger moves to the right and forces the molten metal into the die cavity. As the die is water – cooled, immediate solidification of molten metal takes place. Then the dies are separated. The finished casting is removed by an ejector pin.

Applications

1. Household equipments such as washing machine parts, vacuum cleaner body, fan case, store parts etc.
2. Automobile parts such as fuel pump, carburetor body, horn, wiper and crank case.
3. Components for telephones, television sets, speakers, microphones, record players and soon.
4. Toys, such as pistols, electric trains, model aircraft's etc.

Advantages

1. Very accurate castings can be produced with the dimensional tolerance rang of ±0.03 to 0.25 mm.
2. Castings with very good surface finish can be made.

3. Rate of production (700 castings per hour) is high.
4. Castings with varying thickness wall can be made.
5. There is no possibility of sand inclusions.
6. Cored holes down to 0.75 mm diameter at accurate locations are possible.
7. Casting defects are less.
8. It can be stored and used for long time.
9. Die has long life. Approximately 75000 castings can be produced in a single throughout its life period.
10. The process depends on the metal to be cast.
11. The spire, runners and gates can be remelted, hence, scrap loss is less.

Limitations

1. Only small parts can be made.
2. Only non-ferrous metals can be cast.
3. Equipment cost is high.
4. It is more suitable for mass production only.

3. Gravity Die Casting

Gravity die casting is also called Permanent Mould Casting. The mould is generally made of two halves. They are hinged, at one end. These are provision for clamping them together at the other end. A permanent mould is necessary for producing large number of casting of similar shape. A permanent mould is made of heat resisting cast iron, alloy steel, graphite or other suitable material.

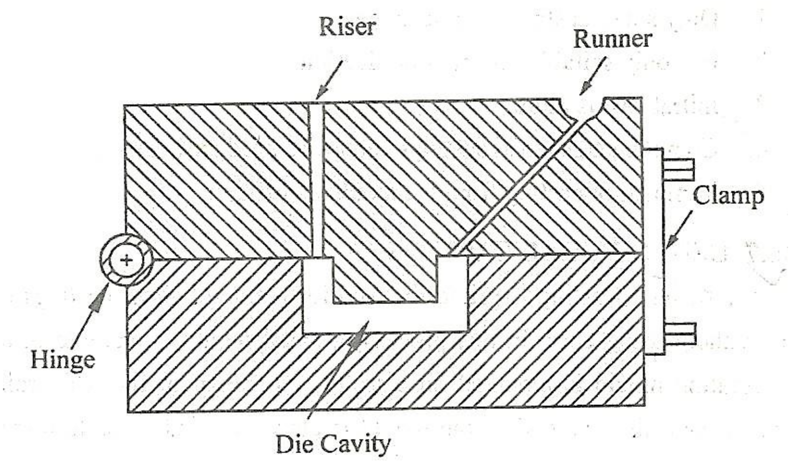


Figure 1.47 Gravity Die Casting

Pouring cup, sprue, gates and riser are made in this mould itself. First, the mould is preheated. Then refractory coating is done by spraying or brushing. This coating protects mould surfaces from erosion and sticking. Lubricated casting may also be given for easy removal or castings. The molten metal is fed into the mould with the help of gravitational force. Hence, this process is called gravity die-casting. After the solidification, the casting is removed by opening the top die. Almost all metals can be cast in this mould. Non-ferrous materials, such as zinc, copper, aluminum, lead magnesium and tin alloys are most often cast in this method.

This method is suitable only for making components of simple shapes and design, and uniform wall thickness.

Applications

1. Accurate casting can be made.
2. It gives good surface finish to castings.
3. It is more suitable for mass production.
4. Wastage and rejection of metal is less.
5. Less floor space is enough.
6. Production rate is high.
7. Production cost is less.
8. Castings are free from defects.

Limitations

1. Only small castings can be made.
2. It is only suitable for mass production.
3. Initial cast is more.
4. Complicated shaped castings cannot be produced easily.
5. The removal of casting from the mould is difficult.

1.20.5 Centrifugal casting

Centrifugal Casting is primarily used for making hollow castings, such as pipe without using core. In this process, a metal mould is made to rotate. The rotating mould is mounted on a trolley, as shown in Figure1.48.

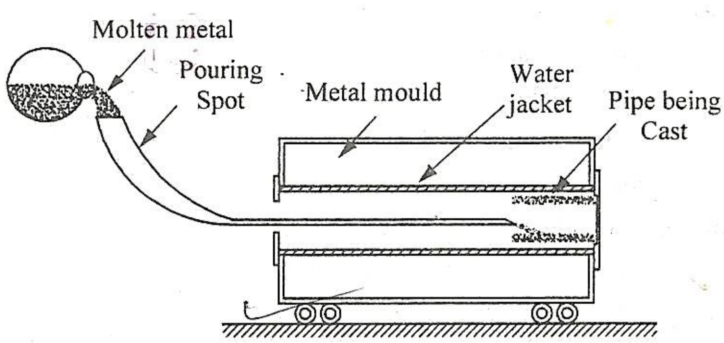


Figure 1.48 Centrifugal casting

The trolley moves over rails. The end of the mould is closed by end cores to prevent the flow of metal. The metal is poured into the mould through a long spout. The mould is rotated by electric motor or mechanical means as well as moves axially on the rails. Due to centrifugal force, the molten metal is thrown to the walls of the mould. The outside of the mould is water-cooled. So, the molten metal immediately solidifies. The centrifugal casting method is used for producing cylindrical and symmetrical objects.

Applications

Components, such as water pipes, gears, bush bearings, fly wheels, piston rings, brake drums, Gun barrels etc.

Advantages

1. Core is not required to produce hollow components.
2. Rate of production is high.
3. Patten, runner, and riser are not required.
4. Impurities in the metal are driven out. Therefore, defects in castings are very less.
5. Thin castings can be made.
6. Castings have uniform physical properties.

Limitations

1. It is suitable only for cylindrical and symmetrical shaped castings.
2. The cost of equipment is high.

1.20.6 Carbon-dioxide Moulding

CO_2 cores are used to make good quality castings in large numbers.

These cores use a core material consisting of clean, dry sand mixed with a solution of sodium silicate. Generally, the mixing is done in Muller.

The sand mixture is rammed into the core box.

The rammed core while it is in the core box is gassed for 30 seconds at a pressure of 130 to 140 KPa with CO_2 gas. Refer Figure 1.49.

This results in a formation of silica gel which binds sand grains into a strong, solid form.

$Na_2 SiO_3 + CO_2 \; Na_2CO_3 + SiO_2$ (Silica gel)

The main limitation of CO_2 cores is that, the used sand mixture cannot be recovered and reused.

These cores are used in production of cast iron, steel, aluminum and copper-base alloy castings.

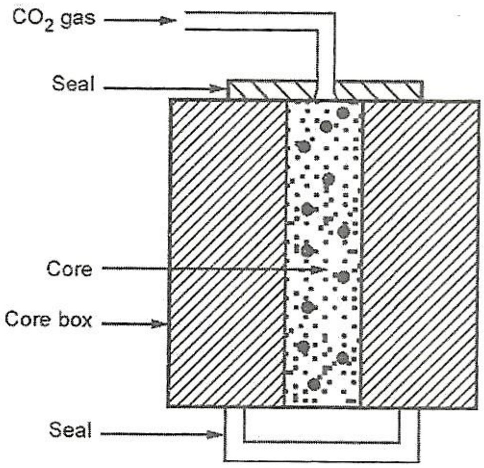


Figure 1.49 CO_2 cores

Advantages

- Baking is not required for these cores.
- These cores possess more strength and harness.
- For this type of cores, core-dryer is not required.
- This method saves time and cost of heating.
- Semi skilled operator is required.
- For the production of cores and moulds same sand is used.
- Hollow cores can be easily made.

Disadvantages

- CO_2 cores are susceptible to moisture.
- CO_2 moulding is less suitable for non-ferrous castings and for small or thin walled castings.
- Due to inorganic nature of the bond, the sand has poor collapsibility.
- It is difficult to reclaim the used sand.

Applications

- It is used for heavy or thick walled steel castings.
- It is widely used for making larger cores for heavy ferrous castings.
- It is also used for producing cores for iron, aluminum and copper based alloy castings.

1.20.7 Stir Casting

Conventional casting processes produces metallurgical flaws like porosity and microstructural defects.

Hence to provide uniform microstructure and eliminate many defects, stir casting process is used.

Figure 1.50 shows the setup for the stir casting process.

In this process, liquid cast metal in homogenize by vigorously stirring it with the help of stirrer.

Stirring helps in reducing grain size hence the ductility and strength of cast metal part is increased.

Stir casting also used in fabrication on composite materials.

In this, the dispersed phase such as ceramic particles or short fibres are mixed with molten matrix metal with the help of mechanical stirring.

The liquid composite material is then cast by various casting methods.

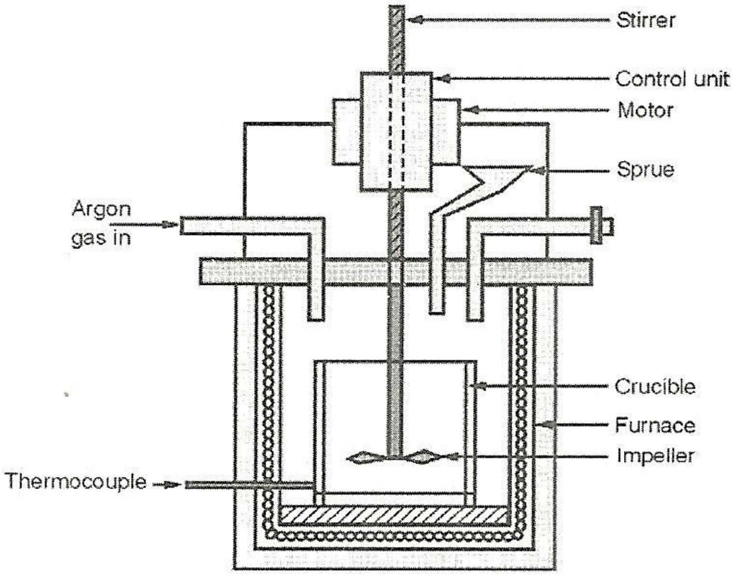


Figure 1.50 Stir Casting

Advantages

1. Casting parts free from porosity.
2. Complex shaped parts are produced neatly.
3. Excellent mechanical properties of cast component.
4. Stir casted parts have good geometrical tolerances.
5. Design of components is relatively simple and of low cost.

1.21 Cleaning of casting (Fettling)

After solidification of casting, the moulds are broken to obtain the final casting.

This operation is known as shake out operation, which may be performed manually or mechanically.

The casting so obtained is not fully finished component, as it carries risers, gates, runners, etc. attached to it.

Also, lot of sand remains adhered to its surface in the form of core.

Hence, cleaning of casting is necessary.

The various operations which are performed after shake out are as follows:

a) Removal of dry sand cores
b) Removal of gates, risers, runners, etc.
c) Removal of unwanted metal projections, fins, etc.

a) Removal of dry sand cores

Cores can be removed by rapping action on the casting.

For quicker removal, pneumatic rapping and hydro-blasting are also preferred.

b) Removal of gates and risers

Gates and risers attached to the casting can be removed by following methods:

They can be broken away by hammering.

They can be sawn by using suitable metal cutting saw.

They can be chipped-off either by hand or by using pneumatic chipping hammers.

They can be sheared off with the help of suitable punches mounted on punch press, called as sprue cutter.

They can be cut off by using an oxy-acetylene flame or plasma torch.

Sometimes, they can be removed by means of abrasive cut-off wheels.

c) Removal of unwanted metal projections and fins

The operation of removal of unwanted metal projections and fins is called as snagging. The commonly used methods for this purpose are as follows:

Chipping with hand or by pneumatic chisels.

Cutting with the help of an oxy-acetylene flame.

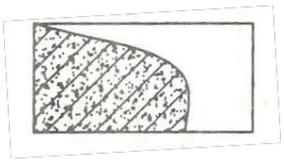
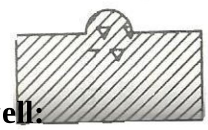
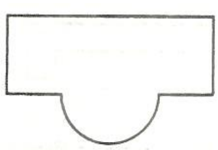
Sometimes, unwanted metal parts are also cut by grinding, machining or filing.

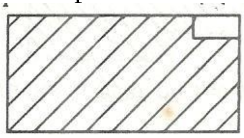
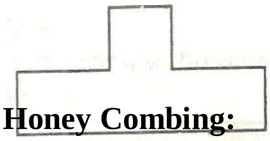
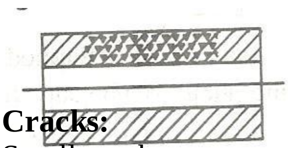
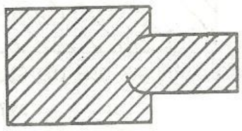
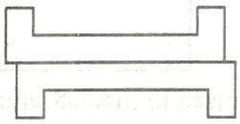
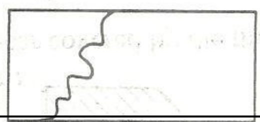
1.22 Defects in Casting:

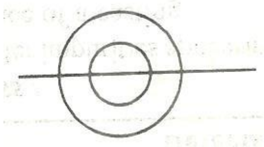
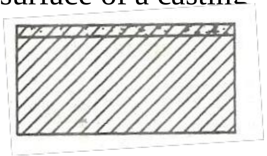
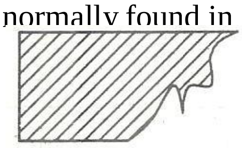
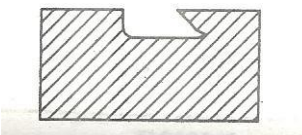
Because of some reasons, castings may have some defects. The defects in a casting may arise due to the defects in one or more of the followings:

1. Design of casting and pattern
2. Moulding and design of mould and core
3. Metal composition
4. Melting and pouring
5. Gating and risering

These defects may be reduced by proper control of manufacturing cycle and proper foundry techniques. The following defects are most commonly encountered in the sand mould castings.

S.No	Defects	Causes	Remedies
1	**Shrinkage:** It is a depression on the casting surface 	1. Improper solidification 2. Incorrect pouring temperature 3. Faulty gating, runner and riser system	1. Proper solidification 2. Correct pouring temperature 3. Modify gating, runner and riser system
2	**Blow Holes:** When the molten metal is poured, gases and steam are formed. If these gases could not come out, blow holes are formed on the interrier of the casting. 	1. Hard ramming 2. Improper venting. 3. Excess binder	1. Ram properly 2. Provides sufficient vent holes 3. Control binder content
3	**Scab:** It is the erosion or breaking down a portion of the mould and the recess filled with metal. 	1. Uneven ramming 2. High velocity of pouring	1. Provide uniform ramming 2. Pour with correct velocity
4	**Swell:** It is the enlargement of casting. 	1. Soft ramming 2. Quick pouring 3. Mould not properly supported	1. Ram properly 2. Pour with correct velocity 3. Provide adequate support to the mould

5	**Hard Spots:** Some spots on the surface become hard 	1. Rapid cooling 2. Pouring at low temperature	1. Provide uniform cooling. 2. Pour at correct temperature.
6	**Runout:** It is the leakage of metal out of the mould while pouring. 	1. Faulty moulding 2. Improper parting line 3. Improper gating system	1. Modify moulding system 2. Provide proper parting line 3. Provide proper gating system
7	**Honey Combing:** Number of small cavities present on the casting surface. 	1. Soft ramming 2. Faulty gating 3. Faulty pouring	1. Provide correct ramming 2. Provide correct gating system 3. Pour at correct temperature
8	**Cracks:** Small cracks appear on the corner of the casting. 	Due to sharp corners	Provide taper or round corners
9	**Shift:** Mismatching of casting sections 	1. Worn-out or bent clamping pins in the moulding box 2. Loose dowels in patterns 3. Misalignment of moulding boxes 4. Improper box locating of core	1. Repair or replace the pins and dowel pins in the pattern 2. Assemble the moulding boxes properly 3. Provide proper box locating of core
10	**Cold Shut:** It is the incomplete filling of the mould cavity at one pouring 	1. Low pouring temperature 2. Too small gate 3. Insufficient molten metal in the ladle for one pouring	1. Pour at correct temperature 2. Provide correct gating system 3. Pour sufficient molten metal in ladle for one pouring
11	**Inclusions:** Foreign material present in casting 	1. Low grade moulding sand 2. Improper skimming	1. Use correct grade of moulding sand 2. Use proper skimming for removing impurities

12	**Fins:** This projection on parting line. 	1. Incorrect assembly of core or moulds 2. Inadequate weights 3. Improper pouring temperature 4. Improper gating system	1. Assemble the moulds and cores correctly 2. Provide enough weight in a correct place 3. Pour at correct temperature 4. Modify gating system
13	**Dress:** Lighter impurities appearing on the top surface of a casting 	Improper using of strainer and skim bob	Use strainer and skim bob properly
14	**Rat tail:** It is a long, shallow, angular depression normally found in a thin casting. 	Improper compressed layer fails by one layer instead of expanding	Provides proper expansion instead of forming compressed layer
15	**Blister:** The scar covered by the thin layer of a metal 	1. Improper pouring temperature 2. Insufficient molten metal	1. Pour at correct temperature 2. Use sufficient molten metal