13
CHAPTER

CASTING

13.1 INTRODUNCTION

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. The solidified object is taken out from the mold either by breaking or taking the mold apart. The solidified object is called casting and the technique followed in method is known as casting process. The casting process was discovered probably around 3500 BC in Mesopotamia. In many parts of world during that period, copper axes (wood cutting tools) and other flat objects were made in open molds using baked clay. These molds were essentially made in single piece. The Bronze Age 2000 BC brought forward more refinement into casting process. For the first time, the core for making hollow sockets in the cast objects was invented. The core was made of baked sand. Also the lost wax process was extensively used for making ornaments using the casting process. Casting technology was greatly improved by Chinese from around 1500 BC. For this there is evidence of the casting activity found in China. For making highly intricate jobs, a lot of time in making the perfect mold to the last detail so hardly any finishing work was required on the casting made from the molds. Indus valley civilization was also known for their extensive use of casting of copper and bronze for ornaments, weapons, tools and utensils. But there was not much of improvement in the casting technology. From various objects that were excavated from the Indus valley sites, they appear to have been familiar with all the known casting methods such as open mold and piece mold. This chapter describes the fluidity of molten metal, different casting techniques and various casting defects occurring in casting processes.

13.2 SIGNIFICANCE OF FLUDITY

Fluidity of molten metal helps in producing sound casting with fewer defects. It fills not only the mold cavity completely and rapidly but does not allow also any casting defect like “misrun” to occur in the cast object. Pouring of molten metal properly at correct temperature plays a significant role in producing sound castings. The gating system performs the function to introduce clean metal into mold cavity in a manner as free of turbulence as possible. To produce sound casting gate must also be designed to completely fill the mold cavity for preventing casting defect such as misruns and to promote feeding for establishing proper temperature gradients. Prevent casting defect such as misruns without use of excessively high pouring temperatures is still largely a matter of experience. To fill the complicated castings sections completely, flow rates must be high but not so high as to cause turbulence. It is noted that metal temperature may affect the ability of molten alloy to fill the mold, this effect is metal fluidity. 1t include alloy analysis and gas content, and heat-extracting power of the molding material. Often, it is desirable to check metal fluidity before pouring using fluidity test. Fig. 13.1 illustrates a standard fluidity spiral test widely used for cast steel. "Fluidity" of an alloy is rated as a distance, in inches, that the metal runs in the spiral channel. Fluidity tests, in which metal from the furnace is poured by controlled vacuum into a flow channel of suitable size, are very useful, since temperature (super-heat) is the most significant single variable influencing the ability of molten metal to fill mold. This test is an accurate indicator of temperature. The use of simple, spiral test, made in green sand on a core poured by ladle from electric furnace steel melting where temperature measurement is costly and inconvenient. The fluidity test is same times less needed except as a research tool, for the lower melting point metals, where pyrometry is a problem. In small casting work, pouring is done by means of ladles and crucibles.

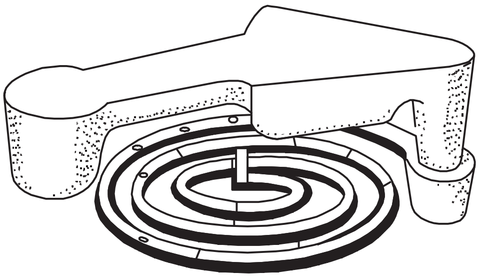

Fig. 13.1 Fluidity spiral test

There are some special casting methods which are discussed as under.

13.3 PERMANENT MOLD OR GRAVITY DIE CASTING

This process is commonly known as permanent mold casting in U.S.A and gravity die casting in England. A permanent mold casting makes use of a mold or metallic die which is permanent. A typical permanent mold is shown in Fig. 13.2. Molten metal is poured into the mold under

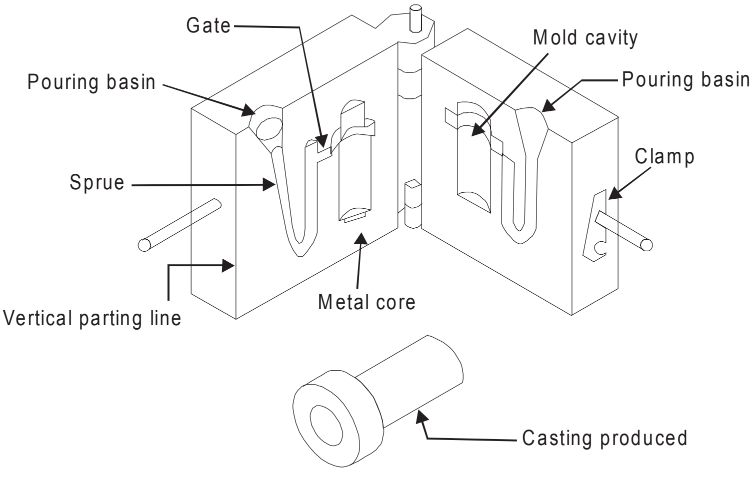

Fig. 13.2 A typical permanent mold

gravity only and no external pressure is applied to force the liquid metal into the mold cavity. However, the liquid metal solidifies under pressure of metal in the risers, etc. The metallic mold can be reused many times before it is discarded or rebuilt. These molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold. It may be designed with a vertical parting line or with a horizontal parting line as in conventional sand molds. The mold walls of a permanent mold have thickness from 15 mm to 50 mm. The thicker mold walls can remove greater amount of heat from the casting. For faster cooling, fins or projections may be provided on the outside of the permanent mold. This provides the desirable chilling effect. There are some advantages, disadvantages and application of this process which are given as under.

Advantages

(*i*) Fine and dense grained structure is achieved in the casting.

(*ii*) No blow holes exist in castings produced by this method.

(*iii*) The process is economical for mass production.

(*iv*) Because of rapid rate of cooling, the castings possess fine grain structure.

(*v*) Close dimensional tolerance or job accuracy is possible to achieve on the cast product.

(*vi*) Good surface finish and surface details are obtained.

(*vii*) Casting defects observed in sand castings are eliminated.

(*viii*) Fast rate of production can be attained.

(*ix*) The process requires less labor.

Disadvantages

(*i*) The cost of metallic mold is higher than the sand mold. The process is impractical for large castings.

(*ii*) The surface of casting becomes hard due to chilling effect.

(*iii*) Refractoriness of the high melting point alloys.

Applications

(*i*) This method is suitable for small and medium sized casting such as carburetor bodies, oil pump bodies, connecting rods, pistons etc.

(*ii*) It is widely suitable for non-ferrous casting.

13.3 SLUSH CASTING

Slush casting is an extension of permanent mold casting or metallic mold casting. It is used widely for production of hollow casting without the use of core. The process is similar to metallic mold casting only with the difference that mold is allowed to open at an early stage (only when a predetermined amount of molten metal has solidified up to some thickness) and some un-solidified molten metal fall down leaving hollowness in the cast object. The process finds wide applications in production of articles namely toys, novelties, statutes, ornaments, lighting fixtures and other articles having hollowness inside the cast product.

13.4 PRESSURE DIE CASTING

Unlike permanent mold or gravity die casting, molten metal is forced into metallic mold or die under pressure in pressure die casting. The pressure is generally created by compressed air or hydraulically means. The pressure varies from 70 to 5000 kg/cm^2 and is maintained while the casting solidifies. The application of high pressure is associated with the high velocity with which the liquid metal is injected into the die to provide a unique capacity for the production of intricate components at a relatively low cost. This process is called simply die casting in USA. The die casting machine should be properly designed to hold and operate a die under pressure smoothly. There are two general types of molten metal ejection mechanisms adopted in die casting set ups which are:

(*i*) Hot chamber type
  (*a*) Gooseneck or air injection management
  (*b*) Submerged plunger management
(*ii*) Cold chamber type

Die casting is widely used for mass production and is most suitable for non-ferrous metals and al1oys of low fusion temperature. The casting process is economic and rapid. The surface achieved in casting is so smooth that it does not require any finishing operation. The material is dense and homogeneous and has no possibility of sand inclusions or other cast impurities. Uniform thickness on castings can also be maintained.

The principal base metals most commonly employed in the casting are zinc, aluminum, and copper, magnesium, lead and tin. Depending upon the melting point temperature of alloys and their suitability for the die casting, they are classified as high melting point (above 540°C) and low melting point (below 500°C) alloys. Under low category involves zinc, tin and lead base alloys. Under high temperature category aluminum and copper base alloys are involved.

There are four main types of die-casting machine which are given as under.

1. Hot chamber die casting machine
2. Cold chamber die casting machine.
3. Air blown or goose neck type machine
4. Vacuum die-casting machine

Some commonly used die casting processes are discussed as under.

Hot chamber die-casting

Hot chamber die-casting machine is the oldest of die-casting machines which is simplest to operate. It can produce about 60 or more castings of up to 20 kg each per hour and several hundred castings per hour for single impression castings weighing a few grams. The melting unit of setup comprises of an integral part of the process. The molten metal possesses nominal amount of superheat and, therefore, less pressure is needed to force the liquid metal into the die. This process may be of gooseneck or air-injection type or submerged plunger type-air blown or goose neck type machine is shown as in Fig. 13.3. It is capable of performing the following functions:

(*i*) Holding two die halves finally together.
(*ii*) Closing the die.
(*iii*) Injecting molten metal into die.

(*iv*) Opening the die.

(*v*) Ejecting the casting out of the die.

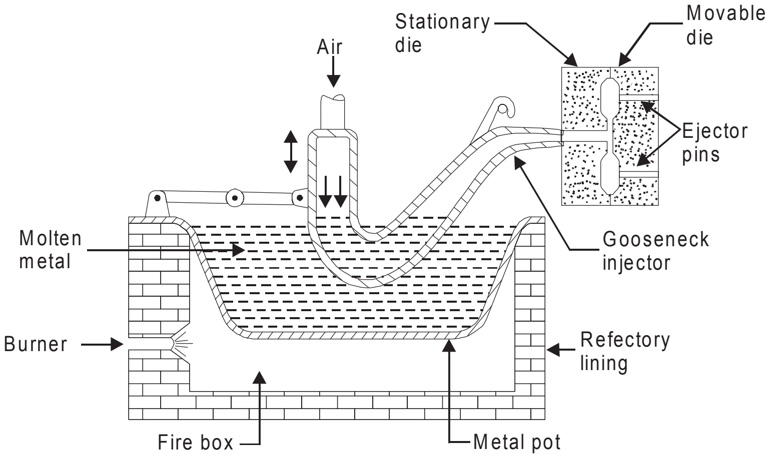

Fig. 13.3 Air blown or goose neck type die casting setup

A die casting machine consists of four basic elements namely frame, source of molten metal and molten metal transfer mechanism, die-casting dies, and metal injection mechanism. It is a simple machine as regards its construction and operation. A cast iron gooseneck is so pivoted in the setup that it can be dipped beneath the surface of the molten metal to receive the same when needed. The molten metal fills the cylindrical portion and the curved passageways of the gooseneck. Gooseneck is then raised and connected to an airline which supplies pressure to force the molten metal into the closed die. Air pressure is required for injecting metal into the die is of the order of 30 to 45 kg./cm^2. The two mold halves are securely clamped together before pouring. Simple mechanical clamps of latches and toggle kinds are adequate for small molds. On solidification of the die cast part, the gooseneck is again dipped beneath the molten metal to receive the molten metal again for the next cycle. The die halves are opened out and the die cast part is ejected and die closes in order to receive a molten metal for producing the next casting. The cycle repeats again and again. Generally large permanent molds need pneumatic or other power clamping devices. A permanent mold casting may range in weight from a few grams to 150 kg. for aluminum. Cores for permanent molds are made up of alloy steel or dry sand. Metal cores are used when they can be easily extracted from the casting. A dry sand core or a shell core is preferred when the cavity to be cored is such that a metal core cannot possibly be withdrawn from the casting. The sprues, risers, runners, gates and vents are machined into the parting surface for one or both mold halves. The runner channels are inclined, to minimize turbulence of the incoming metal. Whenever possible, the runner should be at the thinnest area of the casting, with the risers at the top of the die above the heavy sections. On heating the mold surfaces to the required temperature, a refractory coating in the form of slurry is sprayed or brushed on to the mold cavity, riser, and gate and runner surfaces. French chalk or calcium carbonate suspended in sodium silicate binder is commonly used as a coating for aluminum and magnesium permanent mold castings. Chills are pieces of copper, brass or aluminum and are inserted into the mold's inner surface. Water passages in the mold or cooling fins made on outside the mold surface are blown by air otherwise water mist will create chilling effect. A chill is commonly used to promote directional solidification.

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/cm^2) 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

13.5 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.

13.6 COMPARISON BETWEEN PERMANENT MOLD CASTING AND DIE CASTING

The comparison between permanent mold castings and die casting given as under in Table 13.1.

Table 13.1 Comparison between Permanent Mold Castings and Die Casting

S.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.	It 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.

13.7 SHELL MOLD 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 Fig. 13.4. 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 secs., 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

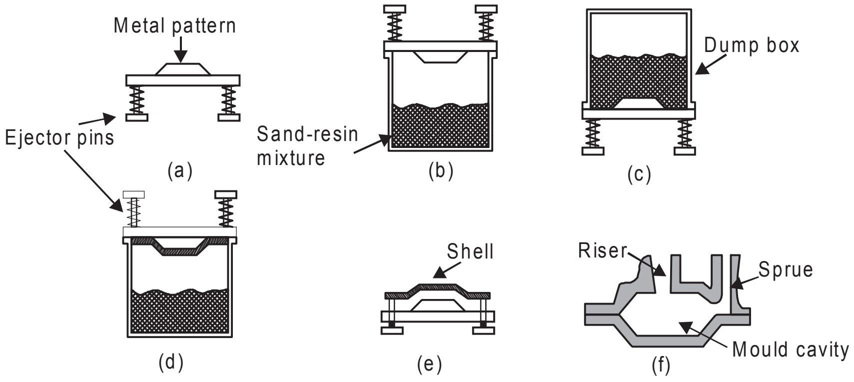

Fig. 13.4 Shell mold casting process

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.

Advantages

The main advantages of shell molding are:

(*i*) Very suitable for thin sections like petrol engine cylinder.
(*ii*) Excellent surface finish.
(*iii*) Good dimensional accuracy of order of 0.002 to 0.003 mm.
(*iv*) Negligible machining and cleaning cost.
(*v*) Occupies less floor space.
(*vi*) Skill-ness required is less.
(*vii*) Molds can be stored until required.
(*viii*) Better quality of casting assured.
(*ix*) Mass production.

Disadvantages

(*i*) Initial cost is high.
(*ii*) Specialized equipment is required.
(*iii*) Resin binder is an expensive material.
(*iv*) Limited for small size.
(*v*) Future of shell molding process is very bright.

Applications

(*i*) Suitable for production of casting made up of alloys of Al, Cu and ferrous metals
(*ii*) Bushing
(*iii*) Valves bodies
(*iv*) Rocker arms
(*v*) Bearing caps
(*vi*) Brackets
(*vii*) Gears

13.8 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

True Centriugal 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. The same are discussed as under:

De Levaud Casting Process

Fig 13.5 shows the essential components of De Levaud type true centrifugal casting process. The article produced by this process is shown in Fig 13.6. In this process, metal molds prove to be economical when large numbers of castings are produced. This process makes use of metal mold. The process setup contains an accurately machined metal mold or die surrounded by cooling water. The machine is mounted on wheels and it can be move lengthwise on a straight on a slightly inclined track. At one end of the track there is a ladle containing proper quantities of molten metal which flows a long pouring spout initially inserted to the extremity of the mold. As pouring proceeds the rotating mold, in the casting machine is moved slowly down the track so that the metal is laid progressively along the length of the mold wall flowing a helical path. The control is being achieved by synchronizing the rate of pouring, mold travel and speed of mold rotation. After completion of pouring the machine will be at the lower end of its track with the mold that rotating continuously till the molten metal has solidified in form of a pipe. The solidified casting in form of pipe is extracted from the metal mold by inserting a pipe puller which expands as it is pulled.

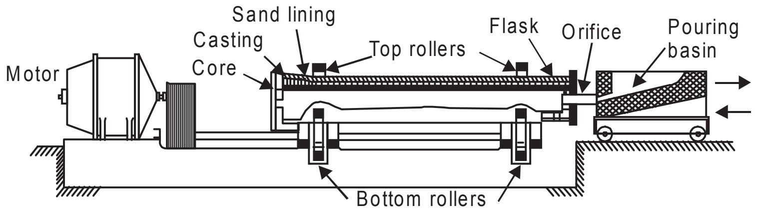

Fig. 13.5 De Levaud type true entrifugal casting process.

Moore Casting System

Moore casting system for small production of large cast iron pipes employs a ram and dried sand lining in conjunction with end pouring. As the mold rotates, it does not move lengthwise rather its one end can be raised up or lowered to facilitate progressive liquid metal. Initially one end of the mold is raised as that mold axis gets inclined. As the pouring starts and continues, the end is gradually lowered till the mold is horizontal and when the pouring stops. At this stage, the speed of mold rotation is increased and maintained till the casting is solidified. Finally, the mold rotation is stopped and the casting is extracted from the mold.

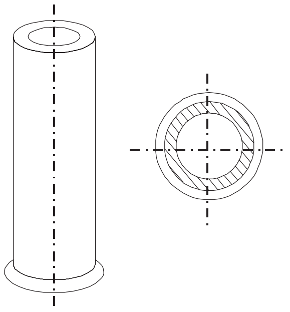

Fig. 13.6 Article produced by true centrifugal casting process

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 Fig. 13.7. 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 Fig. 13.8. Symmetrical objects namely wheel having arms like flywheel, gears and back wheels are produced by this process.

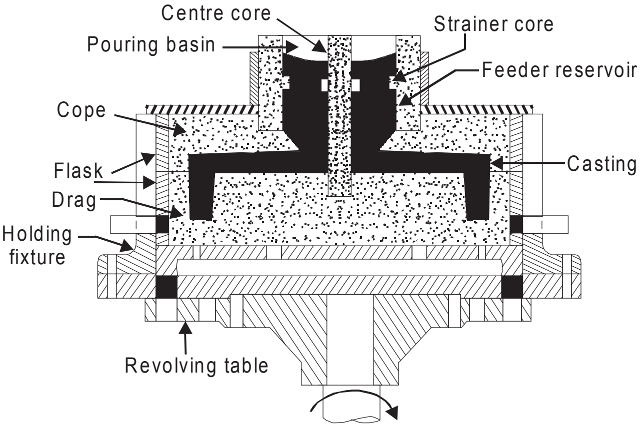

Fig. 13.7 Semi-centrifugal casting setup

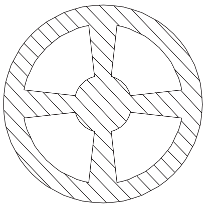

Fig. 13.8 Article produced by semi-centrifugal casting process

Centrifuging Casting

Centrifuging casting setup is shown in Fig. 13.9. 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 Fig. 13.10.

13.9 CONTINNOUS 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.

Advantages of Continuous Casting

(*i*) The process is cheaper than rolling

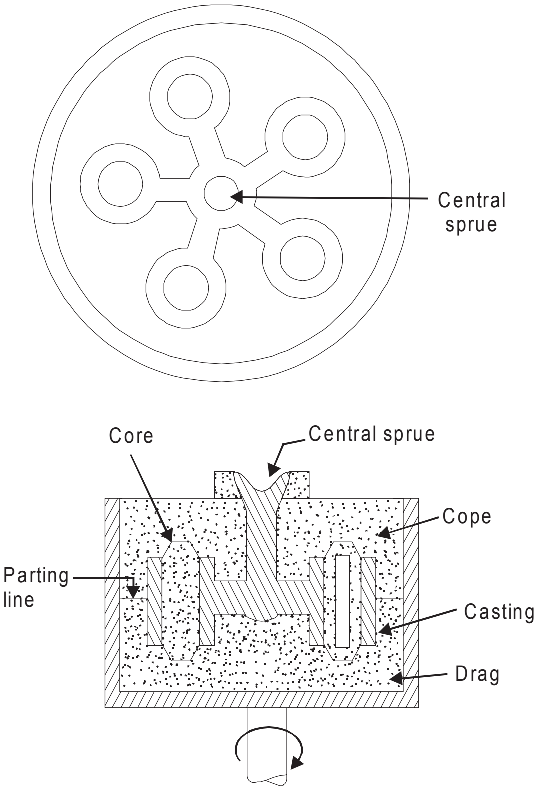

Fig. 13.9 Centrifuging casting setup

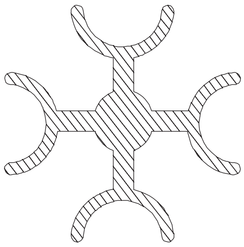

Fig. 13.10 Article produced by centrifuging casting process

(*ii*) 100% casting yield.

(*iii*) The process can be easily mechanized and thus unit labor cost is less.

(*iv*) Casting surfaces are better.

(*v*) Grain size and structure of the casting can be easily controlled.

Applications of Continuous Casting

(*i*) It is used for casting materials such as brass, bronzes, zinc, copper, aluminium and its alloys, magnesium, carbon and alloys etc.

(*ii*) Production of blooms, billets, slabs, sheets, copper bar etc.

(*iii*) It can produce any shape of uniform cross-section such as round, rectangular, square, hexagonal, fluted or gear toothed etc.

13.10 PROBABLE CAUSES AND SUGGESTED REMEDIES OF VARIOUS CASTING DEFECTS

The probable causes and suggested remedies of various casting defects is given in Table 13.1.

Table 13.1: Probable Causes and Suggested Remedies of Various Casting Defects

S.No.	Name of Casting Defect	Probable Causes	Suggested Remedies
1.	Blow holes	1. Excess moisture content in molding sand. 2. Rust and moisture on Chills, chaplets and inserts 3. Cores not sufficiently baked. 4. Excessive use of organic binders. 5. Molds not adequately vented. 6. Molds not adequately vented. 7. Molds rammed very hard.	1. Control of moisture content. 2. Use of rust free chills, chaplet and clean inserts. 3. Bake cores properly. 4. Ram the mold s less hard. 5. Provide adequate venting in mold and cores
2.	Shrinkage	1. Faulty gating and risering system. 2. Improper chilling.	1. Ensure proper directional solidification by modifying gating, risering and chilling
3.	Porosity	1. High pouring temperature. 2. Gas dissolved in metal charge. 3. Less flux used. 4. Molten metal not properly degassed. 5. Slow solidification of casting. 6. High moisture and low permeability in mold.	1. Regulate pouring temperature 2. Control metal composition. 3. Increase flux proportions. 4. Ensure effective degassing. 5. Modify gating and risering. 6. Reduce moisture and increase permeability of mold.
4.	Misruns	1. Lack of fluidity ill molten metal. 2. Faulty design. 3. Faulty gating.	1. Adjust proper pouring temperature. 2. Modify design. 3. Modify gating system.
5.	Hot Tears	1. Lack of collapsibility of core. 2. Lack of collapsibility of mold 3. Faulty design. 4. Hard Ramming of mold.	1. Improve core collapsibility. 2. Improve mold collapsibility. 3. Modify casting design. 4. Provide softer ramming.
6.	Metal penetration	1. Large grain size and used. 2. Soft ramming of mold. 3. Molding sand or core has low strength. 4. Molding sand or core has high permeability. 5. Pouring temperature of metal too high.	1. Use sand having finer grain size. 2. Provide hard ramming. 3. Suitably adjust pouring temperature.
7.	Cold shuts	1. Lack of fluidity in molten metal. 2. Faulty design. 3. Faulty gating.	1. Adjust proper pouring temperature. 2. Modify design. 3. Modify gating system
8.	Cuts and washes	1. Low strength of mold and core. 2. Lack of binders in facing and core stand. 3. Faulty gating.	1. Improve mold and core strength. 2. Add more binders to facing and core sand. 3. Improve gating

9.	Inclusions	1. Faulty gating.	1. Modify gating system
		2. Faulty pouring.	2. Improve pouring to minimize turbulence.
		3. Inferior molding or core sand.	3. Use of superior sand of good strength.
		4. Soft ramming of mold.	4. Provide hard, ramming.
		5. Rough handling of mold and core.	
10.	Fusion	1. Low refractoriness in molding sand	1. Improve refractoriness of sand.
		2. Faulty gating.	2. Modify gating system.
		3. Too high pouring temperature of metal.	3. Use lower pouring temperature.
		4. Poor facing sand.	4. Improve quality of facing sand.
11.	Drops	1. Low green strength in molding sand and core.	1. Increase green strength of sand mold.
		2. Too soft ramming.	2. Provide harder ramming.
		3. Inadequate reinforcement of sand and core projections	3. Provide adequate reinforcement to sand projections and cope by using nails and gaggers.
12.	Shot Metal	1. Too low pouring temperature.	1. Use proper pouring temperature.
		2. Excess sulphur content in metal.	2. Reduce sulphur content.
		3. Faulty gating.	3. Modify gating of system.
		4. High moisture content in molding sand.	
13.	Shift	1. Worn-out or bent clamping pins.	1. Repair or replace the pins, for removing defect.
		2. Misalignment of two halves of pattern.	2. Repair or replace dowels which cause misalignment.
		3. Improper support of core.	3. Provide adequate support to core.
		4. Improper location of core.	4. Increase strength of both mold
		5. Faulty core boxes.	and core
		6. Insufficient strength of molding sand and core.	
14.	Crushes	1. Defective core boxes producing over-sized cores.	1. Repair or replace the pins, for removing defect.
		2. Worn out core prints on patterns producing under sized seats for cores in the mold.	2. Repair or replace dowels which cause misalignment.
		3. Careless assembly of cores in the mold	3. Provide adequate support to core.
			4. Increase strength of both mold and core.
15.	Rat-tails or Buckles	1. Continuous large flat surfaces on casting.	1. Break continuity of large flat groves and depressions
		2. Excessive mold hardness.	2. Reduce mold hardness.
		3. Lack of combustible additives in molding sand.	3. Add combustible additives to sand.