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CHAPTER

MOLD AND CORE MAKING

12.1 INTRODUCTION

A suitable and workable material possessing high refractoriness in nature can be used for mould making. Thus, the mold making material can be metallic or non-metallic. For metallic category, the common materials are cast iron, mild steel and alloy steels. In the non-metallic group molding sands, plaster of paris, graphite, silicon carbide and ceramics are included. But, out of all, the molding sand is the most common utilized non-metallic molding material because of its certain inherent properties namely refractoriness, chemical and thermal stability at higher temperature, high permeability and workability along with good strength. Moreover, it is also highly cheap and easily available. This chapter discusses molding and core sand, the constituents, properties, testing and conditioning of molding and core sands, procedure for making molds and cores, mold and core terminology and different methods of molding.

12.2 MOLDING SAND

The general sources of receiving molding sands are the beds of sea, rivers, lakes, granulular elements of rocks, and deserts. The common sources of molding sands available in India are as follows:

1 Batala sand (Punjab)
2 Ganges sand (Uttar Pradesh)
3 Oyaria sand (Bihar)
4 Damodar and Barakar sands (Bengal- Bihar Border)
5 Londha sand (Bombay)
6 Gigatamannu sand (Andhra Pradesh) and
7 Avadi and Veeriyambakam sand (Madras)

Molding sands may be of two types namely natural or synthetic. Natural molding sands contain sufficient binder. Whereas synthetic molding sands are prepared artificially using basic sand molding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

12.3 CONSTITUENTS OF MOLDING SAND

The main constituents of molding sand involve silica sand, binder, moisture content and additives.

12.3.1 Silica sand

Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities. The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present. The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable. The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded).

12.3.1.1 Effect of grain shape and size of silica sand

The shape and size of sand grains has a significant effect on the different properties of molding and core sands. The shape of the sand grains in the mold or core sand determines the possibility of its application in various types of foundry practice. The shape of foundry sand grains varies from round to angular. Some sands consist almost entirely of grains of one shape, whereas others have a mixture of various shapes. According to shape, foundry sands are classified as rounded, sub-angular, angular and compound. Use of angular grains (obtained during crushing of rocks hard sand stones) is avoided as these grains have a large surface area. Molding sands composed of angular grains will need higher amount of binder and moisture content for the greater specific surface area of sand grain. However, a higher percentage of binder is required to bring in the desired strength in the molding sand and core sand. For good molding purposes, a smooth surfaced sand grains are preferred. The smooth surfaced grain has a higher sinter point, and the smooth surface secures a mixture of greater permeability and plasticity while requiring a higher percentage of blind material. Rounded shape silica sand grain sands are best suited for making permeable molding sand. These grains contribute to higher bond strength in comparison to angular grain. However, rounded silica sand grains sands have higher thermal expandability than angular silica grain sands. Silica sand with rounded silica sand grains gives much better compactability under the same conditions than the sands with angular silica grains. This is connected with the fact that the silica sand with rounded grains having the greatest degree of close packing of particles while sand with angular grains the worst. The green strength increases as the grains become more rounded. On the other hand, the grade of compactability of silica sands with rounded sand grains is higher, and other, the contact surfaces between the individual grains are greater on rounded grains than on angular grains. As already mentioned above, the compactability increases with rounded grains. The permeability or porosity property of molding sand and core sand therefore, should increase with rounded grains and decrease with angular grains. Thus the round silica sand grain size greatly influences the properties of molding sand.

The characteristics of sub-angular sand grains lie in between the characteristics of sand grains of angular and rounded kind. Compound grains are cemented together such that they fail to get separated when screened through a sieve. They may consist of round, sub-angular, or angular sub-angular sand grains. Compound grains require higher amounts of binder and moisture content also. These grains are least desirable in sand mixtures because they have a tendency to disintegrate at high temperatures. Moreover the compound grains are cemented together and they fail to separate when screened.

Grain sizes and their distribution in molding sand influence greatly the properties of the sand. The size and shape of the silica sand grains have a large bearing upon its strength and other general characteristics. The sand with wide range of particle size has higher compactability than sand with narrow distribution. The broadening of the size distribution may be done either to the fine or the coarse side of the distribution or in both directions simultaneously, and a sand of higher density will result. Broadening to the coarse side has a greater effect on density than broadening the distribution to the fine sand. Wide size distributions favor green strength, while narrow grain distributions reduce it. The grain size distribution has a significant effect on permeability. Silica sand containing finer and a wide range of particle sizes will have low permeability as compared to those containing grains of average fineness but of the same size i.e. narrow distribution. The compactability is expressed by the green density obtained by three ram strokes. Finer the sand, the lower is the compactability and vice versa. This results from the fact that the specific surface increases as the grain size decreases. As a result, the number of points of contact per unit of volume increases and this in turn raises the resistance to compacting. The green strength has a certain tendency, admittedly not very pronounced, towards a maximum with a grain size which corresponds approximately to the medium grain size. As the silica sand grains become finer, the film of bentonite becomes thinner, although the percentage of bentonite remains the same. Due to reducing the thickness of binder film, the green strength is reduced. With very coarse grains, however, the number of grains and, therefore, the number of points of contact per unit of volume decreases so sharply that the green strength is again reduced. The sands with grains equal but coarser in size have greater void space and have, therefore greater permeability than the finer silica sands. This is more pronounced if sand grains are equal in size.

12.3.2 Binder

In general, the binders can be either inorganic or organic substance. The inorganic group includes clay sodium silicate and port land cement etc. In foundry shop, the clay acts as binder which may be Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller's earth and Bentonite. Binders included in the organic group are dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc. Organic binders are mostly used for core making. Among all the above binders, the bentonite variety of clay is the most common. However, this clay alone can not develop bonds among sand grins without the presence of moisture in molding sand and core sand.

12.3.3 Moisture

The amount of moisture content in the molding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them. This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand. The effect of clay and water decreases permeability with increasing clay and moisture content. The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.

For increasing the molding sand characteristics some other additional materials besides basic constituents are added which are known as additives.

12.3.4 Additives

Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of molding and core sands are discussed as under.

12.3.4.1 Coal dust

Coal dust is added mainly for producing a reducing atmosphere during casting. This reducing atmosphere results in any oxygen in the poles becoming chemically bound so that it cannot oxidize the metal. It is usually added in the molding sands for making molds for production of grey iron and malleable cast iron castings.

12.3.4.2 Corn flour

It belongs to the starch family of carbohydrates and is used to increase the collapsibility of the molding and core sand. It is completely volatilized by heat in the mould, thereby leaving space between the sand grains. This allows free movement of sand grains, which finally gives rise to mould wall movement and decreases the mold expansion and hence defects in castings. Corn sand if added to molding sand and core sand improves significantly strength of the mold and core.

12.3.4.3 Dextrin

Dextrin belongs to starch family of carbohydrates that behaves also in a manner similar to that of the corn flour. It increases dry strength of the molds.

12.3.4.4 Sea coal

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in molding sand and core sand. When heated, it changes to coke which fills the pores and is unaffected by water: Because to this, the sand grains become restricted and cannot move into a dense packing pattern. Thus, sea coal reduces the mould wall movement and the permeability in mold and core sand and hence makes the mold and core surface clean and smooth.

12.3.4.5 Pitch

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mold and core sand. It enhances hot strengths, surface finish on mold surfaces and behaves exactly in a manner similar to that of sea coal.

12.3.4.6 Wood flour

This is a fibrous material mixed with a granular material like sand; its relatively long thin fibers prevent the sand grains from making contact with one another. It can be added from 0.05 % to 2% in mold and core sand. It volatilizes when heated, thus allowing the sand grains room to expand. It will increase mould wall movement and decrease expansion defects. It also increases collapsibility of both of mold and core.

12.3.4.7 Silica flour

It is called as pulverized silica and it can be easily added up to 3% which increases the hot strength and finish on the surfaces of the molds and cores. It also reduces metal penetration in the walls of the molds and cores.

12.4 KINDS OF MOULDING SAND

Molding sands can also be classified according to their use into number of varieties which are described below.

12.4.1 Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure. Molds prepared by this sand are not requiring backing and hence are known as green sand molds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

12.4.2 Dry sand

Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand. It possesses more strength, rigidity and thermal stability. It is mainly suitable for larger castings. Mold prepared in this sand are known as dry sand molds.

12.4.3 Loam sand

Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. Patterns are not used for loam molding and shape is given to mold by sweeps. This is particularly employed for loam molding used for large grey iron castings.

12.4.4 Facing sand

Facing sand is just prepared and forms the face of the mould. It is directly next to the surface of the pattern and it comes into contact molten metal when the mould is poured. Initial coating around the pattern and hence for mold surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness. It is made of silica sand and clay, without the use of used sand. Different forms of carbon are used to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times as much fine molding sand to make facings. The layer of facing sand in a mold usually ranges from 22-28 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.

12.4.5 Backing sand

Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask. Used molding sand is mainly employed for this purpose. The backing sand is sometimes called black sand because that old, repeatedly used molding sand is black in color due to addition of coal dust and burning on coming in contact with the molten metal.

12.4.6 System sand

In mechanized foundries where machine molding is employed. A so-called system sand is used to fill the whole molding flask. In mechanical sand preparation and handling units, no facing sand is used. The used sand is cleaned and re-activated by the addition of water and special additives. This is known as system sand. Since the whole mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.

12.4.7 Parting sand

Parting sand without binder and moisture is used to keep the green sand not to stick to the pattern and also to allow the sand on the parting surface the cope and drag to separate without clinging. This is clean clay-free silica sand which serves the same purpose as parting dust.

12.4.8 Core sand

Core sand is used for making cores and it is sometimes also known as oil sand. This is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin, light mineral oil and other bind materials. Pitch or flours and water may also be used in large cores for the sake of economy.

12.5 PROPERTIES OF MOULDING SAND

The basic properties required in molding sand and core sand are described as under.

12.5.1 Refractoriness

Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of molding sands. Refractoriness can only be increased to a limited extent. Molding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained. The degree of refractoriness depends on the SiO_2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO_2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its-melting point.

12.5.2 Permeability

It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mold can be further increased by venting using vent rods

12.5.3 Cohesiveness

It is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand. Thus, the binding capability of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core sand.

12.5.4 Green strength

The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. thev must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the molding box. Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

12.5.5 Dry strength

As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal. The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

12.5.6 Flowability or plasticity

It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections. In general, flowability increases with decrease in green strength, an, decrease in grain size. The flowability also varies with moisture and clay content.

12.5.7 Adhesiveness

It is property of molding sand to get stick or adhere with foreign material such sticking of molding sand with inner wall of molding box

12.5.8 Collapsibility

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered by the mold and thus results in tears and cracks in the casting. This property is highly desired in cores

12.5.9 Miscellaneous properties

In addition to above requirements, the molding sand should not stick to the casting and should not chemically react with the metal. Molding sand should be cheap and easily available. It should be reusable for economic reasons. Its coefficients of expansion should be sufficiently low.

12.6 SAND TESTING

Molding sand and core sand depend upon shape, size composition and distribution of sand grains, amount of clay, moisture and additives. The increase in demand for good surface finish and higher accuracy in castings necessitates certainty in the quality of mold and core sands. Sand testing often allows the use of less expensive local sands. It also ensures reliable sand mixing and enables a utilization of the inherent properties of molding sand. Sand testing on delivery will immediately detect any variation from the standard quality, and adjustment of the sand mixture to specific requirements so that the casting defects can be minimized. It allows the choice of sand mixtures to give a desired surface finish. Thus sand testing is one of the dominating factors in foundry and pays for itself by obtaining lower per unit cost and increased production resulting from sound castings. Generally the following tests are performed to judge the molding and casting characteristics of foundry sands:

1. Moisture content Test
2. Clay content Test
3. Chemical composition of sand
4. Grain shape and surface texture of sand.
5. Grain size distribution of sand
6. Specific surface of sand grains
7. Water absorption capacity of sand
8. Refractoriness of sand
9. Strength Test
10. Permeability Test
11. Flowability Test
12. Shatter index Test
13. Mould hardness Test.

Some of the important sand tests are discussed as under.

12.6.1 Moisture Content Test

The moisture content of the molding sand mixture may determined by drying a weighed amount of 20 to 50 grams of molding sand to a constant temperature up to 100°C in a oven for about one hour. It is then cooled to a room temperature and then reweighing the molding sand. The moisture content in molding sand is thus evaporated. The loss in weight of molding sand due to loss of moisture, gives the amount of moisture which can be expressed as a percentage of the original sand sample. The percentage of moisture content in the molding sand can also be determined in fact more speedily by an instrument known as a speedy moisture teller. This instrument is based on the principle that when water and calcium carbide react, they form acetylene gas which can be measured and this will be directly proportional to the moisture content. This instrument is provided with a pressure gauge calibrated to read directly the percentage of moisture present in the molding sand. Some moisture testing instruments are based on principle that the electrical conductivity of sand varies with moisture content in it.

12.6.2 Clay Content Test

The amount of clay is determined by carrying out the clay content test in which clay in molding sand of 50 grams is defined as particles which when suspended in water, fail to settle at the rate of one inch per min. Clay consists of particles less than 20 micron, per 0.0008 inch in dia.

12.6.3 Grain Fineness Test

For carry out grain fineness test a sample of dry silica sand weighing 50 gms free from clay is placed on a top most sieve bearing U.S. series equivalent number 6. A set of eleven sieves having U.S. Bureau of standard meshes 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 are mounted on a mechanical shaker (Fig. 12.1). The series are placed in order of fineness from top to bottom. The free silica sand sample is shaked in a mechanical shaker for about 15 minutes. After this weight of sand retained in each sieve is obtained sand and the retained sand in each sieve is multiplied by 2 which gives % of weight retained by each sieve. The same is further multiplied by a multiplying factor and total product is obtained. It is then divided by total % sand retained by different sieves which will give G.F.N.

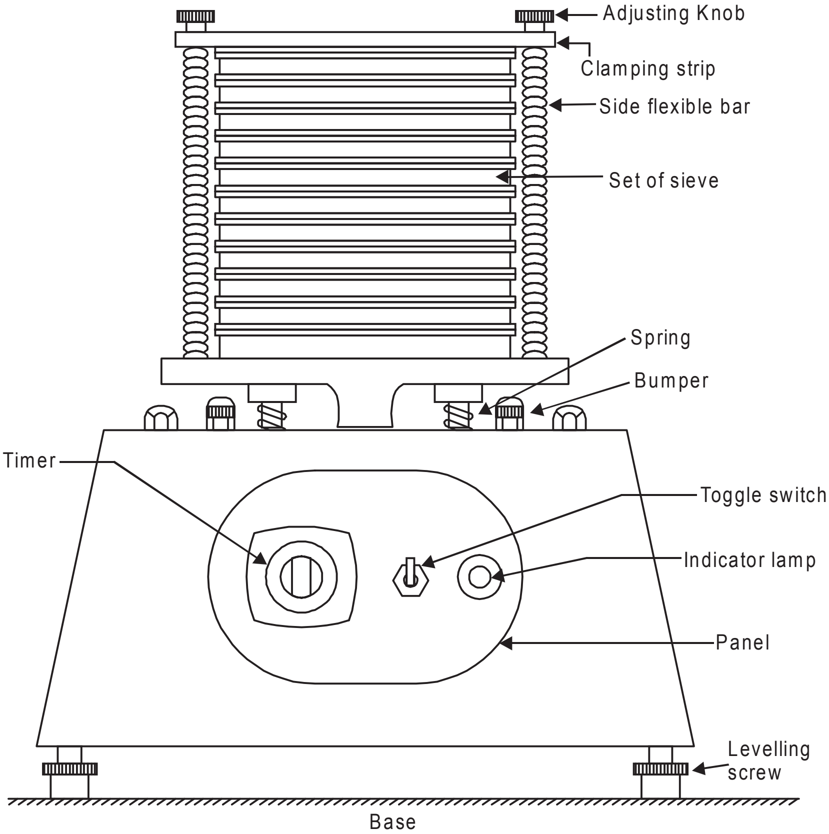

Fig. 12.1 Grain fitness testing mecanical shaker

12.6.4 Refractoriness Test

The refractoriness of the molding sand is judged by heating the American Foundry Society (A.F.S) standard sand specimen to very high temperatures ranges depending upon the type of sand. The heated sand test pieces are cooled to room temperature and examined under a microscope for surface characteristics or by scratching it with a steel needle. If the silica sand grains remain sharply defined and easily give way to the needle. Sintering has not yet set in. In the actual experiment the sand specimen in a porcelain boat is p1aced into an e1ectric furnace. It is usual practice to start the test from l000°C and raise the temperature in steps of 100°C to 1300°C and in steps of 50° above 1300°C till sintering of the silica sand grains takes place. At each temperature level, it is kept for at least three minutes and then taken out from the oven for examination under a microscope for evaluating surface characteristics or by scratching it with a steel needle.

12.6. 5 Strength Test

Green strength and dry strength is the holding power of the various bonding materials. Generally green compression strength test is performed on the specimen of green sand (wet condition). The sample specimen may of green sand or dry sand which is placed in lugs and compressive force is applied slowly by hand wheel until the specimen breaks. The reading of the needle of high pressure and low pressure manometer indicates the compressive strength of the specimen in kgf/cm^2. The most commonly test performed is compression test which is carried out in a compression sand testing machine (Fig. 12.2). Tensile, shear and transverse tests are also sometimes performed. Such tests are performed in strength tester using hydraulic press. The monometers are graduated in different scales. Generally sand mixtures are tested for their compressive strength, shear strength, tensile strength and bending strength. For carrying out these tests on green sand sufficient rammed samples are prepared to use. Although the shape of the test specimen differs a lot according to the nature of the test for all types of the strength tests can be prepared with the of a typical rammer and its accessories. To prepare cylindrical specimen bearing 50.8 mm diameter with for testing green sand, a defined amount of sand is weighed which will be compressed to height of 50.8 mm. by three repeated rammings. The predetermined amount of weighed molding sand is poured into the ram tube mounted on the bottom. Weight is lifted by means of the hand 1ever and the tube filled with sand is placed on the apparatus and the ramming unit is allowed to come down slowly to its original position. Three blows are given on the sample by allowing the rammer weight to fall by turning the lever. After the three blows the mark on the ram rod should lie between the markings on the stand. The rammed specimen is removed from the tube by means a pusher rod. The process of preparing sand specimen for testing dry sand is similar to the process as prepared before, with the difference that a split ram tube is used. The specimen for testing bending strength is of a square cross section. The various tests can be performed on strength tester. The apparatus can be compared with horizontal hydraulic press. Oil pressure is created by the hand-wheel and the pressure developed can be measured by two pressure manometers. The hydraulic pressure pushes the plunger. The adjusting cock serves to connect the two manometers. Deformation can be measured on the dial.

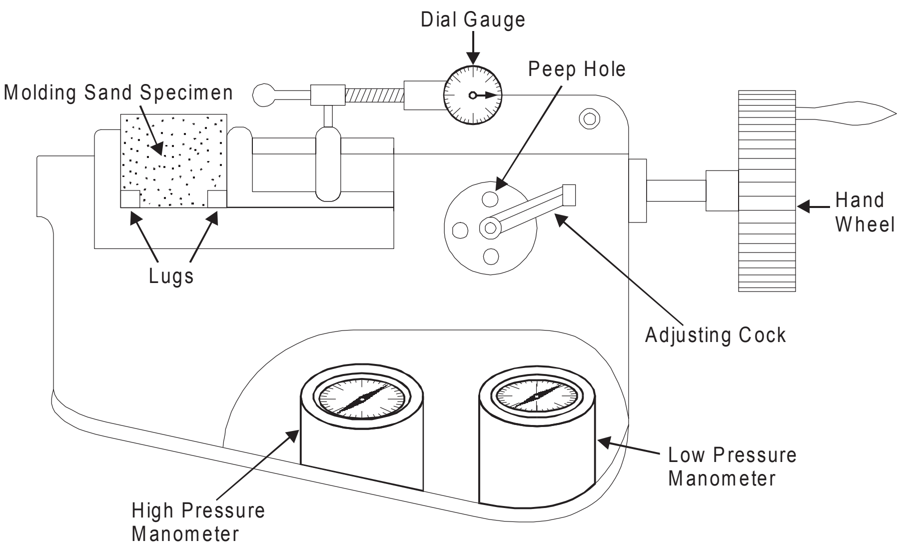

Fig. 12.2 Strength testing machine

The compression strength of the molding sand is determined by placing standard specimen at specified location and the load is applied on the standard sand specimen to compress it by uniform increasing load using rotating the hand wheel of compression strength testing set-up. As soon as the sand specimen fractures for break, the compression strength is measured by the manometer. Also, other strength tests can be conducted by adopting special types of specimen holding accessories.

12.6.6 Permeability Test

Initially a predetermined amount of molding sand is being kept in a standard cylindrical tube, and the molding sand is compressed using slightly tapered standard ram till the cylindrical standard sand specimen having 50.8mm diameter with 50.8 mm height is made and it is then extracted. This specimen is used for testing the permeability or porosity of molding and the core sand. This test is applied for testing porosity of the standard sand specimen. The test is performed in a permeability meter consisting of the balanced tank, water tank, nozzle, adjusting lever, nose piece for fixing sand specimen and a manometer. A typical permeability meter is shown in Fig. 12.3 which permits to read the permeability directly. The permeability test apparatus comprises of a cylinder and another concentric cylinder inside the outer cylinder and the space between the two concentric cylinders is filled with water. A bell having a diameter larger than that of the inner cylinder but smaller than that of outer cylinder, rests on the surface of water. Standard sand specimen of 5.08 mm diameter and 50.8 mm height together with ram tube is placed on the tapered nose piece of the permeability meter. The bell is allowed to sink under its own weight by the help of multi-position cock. In this way the air of the bell streams through the nozzle of nosepiece and the permeability is directly measured.

Permeability is volume of air (in cm^3) passing through a sand specimen of 1 cm^2 cross-sectional area and 1 cm height, at a pressure difference of 1 gm/cm^2 in one minute. In general, permeability is expressed as a number and can be calculated from the relation

$$P = vh/pat$$

Where, P = permeability

v = volume of air passing through the specimen in c.c.

h = height of specimen in cm

p = pressure of air in gm/cm^2

a = cross-sectional area of the specimen in cm^2

t = time in minutes.

For A.F S. standard permeability meter, 2000 cc of air is passed through a sand specimen (5.08 cm in height and 20.268 sq. cm. in cross-sectional area) at a pressure of 10 gms/cm^2 and the total time measured is 10 seconds = 1/6 min. Then the permeability is calculated using the relationship as given as under.

$$P = (2000 \times 5.08) / (10 \times 20.268 \times (1/6)) = 300.66 \text{ App.}$$

12.6.7 Flowability Test

Flowability of the molding and core sand usually determined by the movement of the rammer plunger between the fourth and fifth drops and is indicated in percentages. This reading can directly be taken on the dial of the flow indicator. Then the stem of this indicator rests again top of the plunger of the rammer and it records the actual movement of the plunger between the fourth and fifth drops.

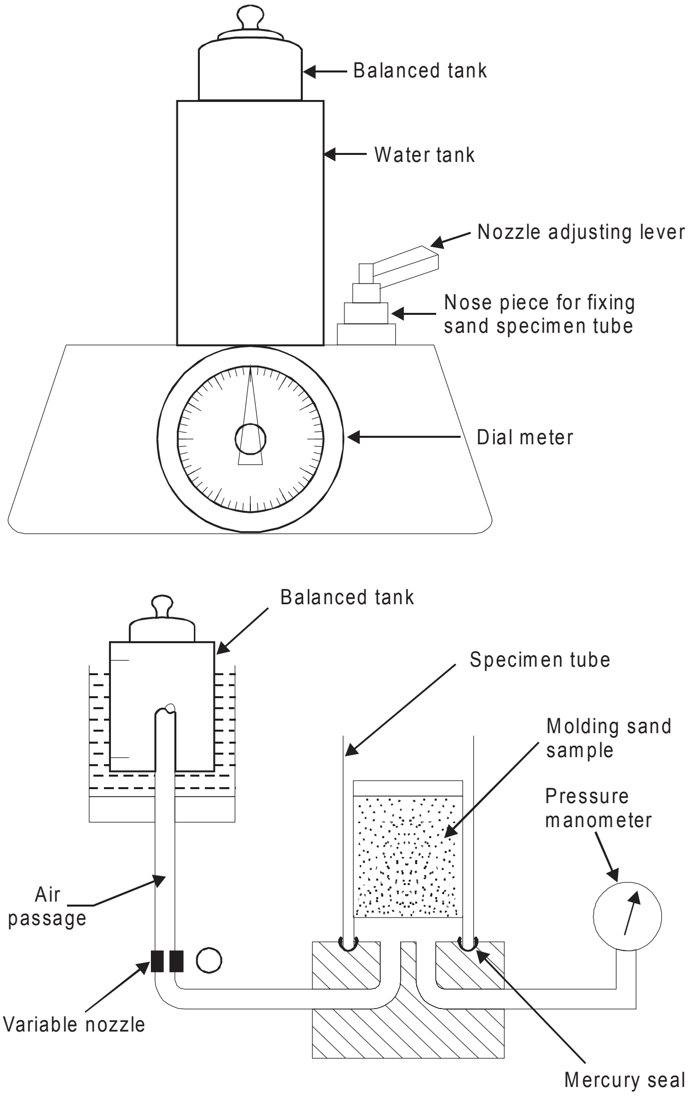

Fig. 12.3 Permeability meter

12.6.8 Shatter Index Test

In this test, the A.F.S. standard sand specimen is rammed usually by 10 blows and then it is allowed to fall on a half inch mesh sieve from a height of 6 ft. The weight of sand retained on the sieve is weighed. It is then expressed as percentage of the total weight of the specimen which is a measure of the shatter index.

12.6.9 Mould Hardness Test

This test is performed by a mold hardness tester shown in Fig. 12.4. The working of the tester is based on the principle of Brinell hardness testing machine. In an A.F.S. standard hardness tester a half inch diameter steel hemi-spherical ball is loaded with a spring load of 980 gm. This ball is made to penetrate into the mold sand or core sand surface. The penetration of the ball point into the mould surface is indicated on a dial in thousands of an inch. The dial is calibrated to read the hardness directly i.e. a mould surface which offers no resistance to the steel ball would have zero hardness value and a mould which is more rigid and is capable of completely preventing the steel ball from penetrating would have a hardness value of 100. The dial gauge of the hardness tester may provide direct readings

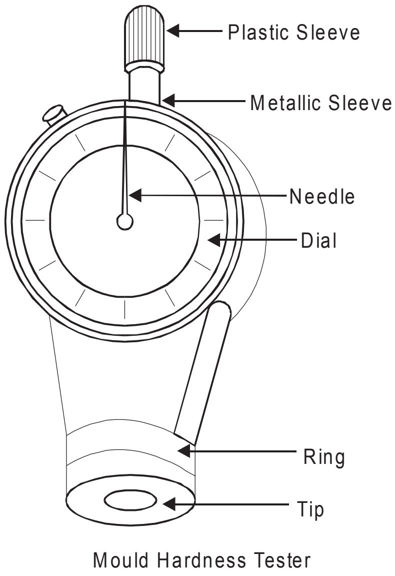

Fig. 12.4 Mould harness tester

12.7 SAND CONDITIONING

Natural sands are generally not well suited for casting purposes. On continuous use of molding sand, the clay coating on the sand particles gets thinned out causing decrease in its strength. Thus proper sand conditioning accomplish uniform distribution of binder around the sand grains, control moisture content, eliminate foreign particles and aerates the sands. Therefore, there is a need for sand conditioning for achieving better results.

The foreign materials, like nails, gaggers, hard sand lumps and metals from the used sand are removed. For removing the metal pieces, particularly ferrous pieces, the sand from the shake-out station is subjected to magnetic separator, which separates out the iron pieces, nails etc. from the used sand. Next, the sand is screened in riddles which separate out the hard sand lumps etc. These riddles may be manual as well as mechanical. Mechanical riddles may be either compressed air operated or electrically operated. But the electrically operated riddles are faster and can handle large quantities of sand in a short time. The amount of fine material can be controlled to the maximum possible extent by its removal through exhaust systems under conditions of shake out.

The sand constituents are then brought at required proper proportion and mixed thoroughly. Next, the whole mixture is mulled suitably till properties are developed. After all the foreign particles are removed from and the sand is free from the hard lumps etc., proper amount of pure sand, clay and required additives are added to for the loss because of the burned, clay and other corn materials. As the moisture content of the returned sand known, it is to be tested and after knowing the moisture the required amount of water is added. Now these things are mixed thoroughly in a mixing muller (Fig 12.5).

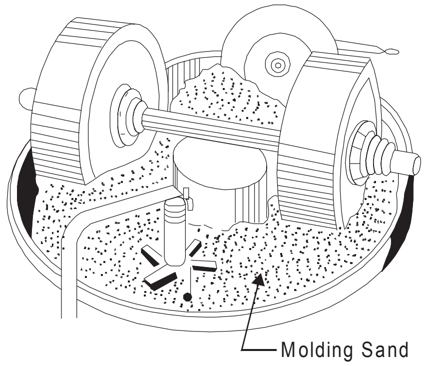

Fig. 12.5 Sand mixing muller

The main objectives of a mixing muller is to distribute the binders, additives and moisture or water content uniformly all around each sand grain and helps to develop the optimum physical properties by kneading on the sand grains. Inadequate mulling makes the sand mixture weak which can only be compensated by adding more binder. Thus the adequate mulling economizes the use of binders. There are two methods of adding clay and water to sand. In the first method, first water is added to sand follow by clay, while in the other method, clay addition is followed water. It has been suggested that the best order of adding ingredients to clay bonded sand is sand with water followed by the binders. In this way, the clay is more quickly and uniformly spread on to all the sand grains. An additional advantage of this mixing order is that less dust is produced during the mulling operation. The muller usually consists of a cylindrical pan in which two heavy rollers; carrying two ploughs, and roll in a circular path. While the rollers roll, the ploughs scrap the sand from the sides and the bottom of the pan and place it in front of For producing a smearing action in the sand, the rollers are set slightly off the true radius and they move out of the rollers can be moved up and down without difficulty mounted on rocker arms. After the mulling is completed sand can be discharged through a door. The mechanical aerators are generally used for aerating or separating the sand grains by increasing the flowability through whirling the sand at a high speed by an impeller towards the inner walls of the casting. Aerating can also be done by riddling the sand mixture oil on a one fourth inch mesh screen or by spraying the sand over the sand heap by flipping the shovels. The aeration separates the sand grains and leaves each grain free to flow in the direction of ramming with less friction. The final step in sand conditioning is the cooling of sand mixture because of the fact that if the molding sand mixture is hot, it will cause molding difficulties.

12.8 STEPS INVOLVED IN MAKING A SAND MOLD

1. Initially a suitable size of molding box for creating suitable wall thickness is selected for a two piece pattern. Sufficient care should also be taken in such that sense that the molding box must adjust mold cavity, riser and the gating system (sprue, runner and gates etc.).
2. Next, place the drag portion of the pattern with the parting surface down on the bottom (ram-up) board as shown in Fig. 12.6 (a).
3. The facing sand is then sprinkled carefully all around the pattern so that the pattern does not stick with molding sand during withdrawn of the pattern.
4. The drag is then filled with loose prepared molding sand and ramming of the molding sand is done uniformly in the molding box around the pattern. Fill the molding sand once again and then perform ramming. Repeat the process three four times,
5. The excess amount of sand is then removed using strike off bar to bring molding sand at the same level of the molding flask height to completes the drag.
6. The drag is then rolled over and the parting sand is sprinkled over on the top of the drag [Fig. 12.6(b)].
7. Now the cope pattern is placed on the drag pattern and alignment is done using dowel pins.
8. Then cope (flask) is placed over the rammed drag and the parting sand is sprinkled all around the cope pattern.

9. Sprue and riser pins are placed in vertically position at suitable locations using support of molding sand. It will help to form suitable sized cavities for pouring molten metal etc. [Fig. 12.6 (c)].
10. The gaggers in the cope are set at suitable locations if necessary. They should not be located too close to the pattern or mold cavity otherwise they may chill the casting and fill the cope with molding sand and ram uniformly.
11. Strike off the excess sand from the top of the cope.
12. Remove sprue and riser pins and create vent holes in the cope with a vent wire. The basic purpose of vent creating vent holes in cope is to permit the escape of gases generated during pouring and solidification of the casting.
13. Sprinkle parting sand over the top of the cope surface and roll over the cope on the bottom board.
14. Rap and remove both the cope and drag patterns and repair the mold suitably if needed and dressing is applied
15. The gate is then cut connecting the lower base of sprue basin with runner and then the mold cavity.
16. Apply mold coating with a swab and bake the mold in case of a dry sand mold.
17. Set the cores in the mold, if needed and close the mold by inverting cope over drag.
18. The cope is then clamped with drag and the mold is ready for pouring, [Fig. 12.6 (d)].

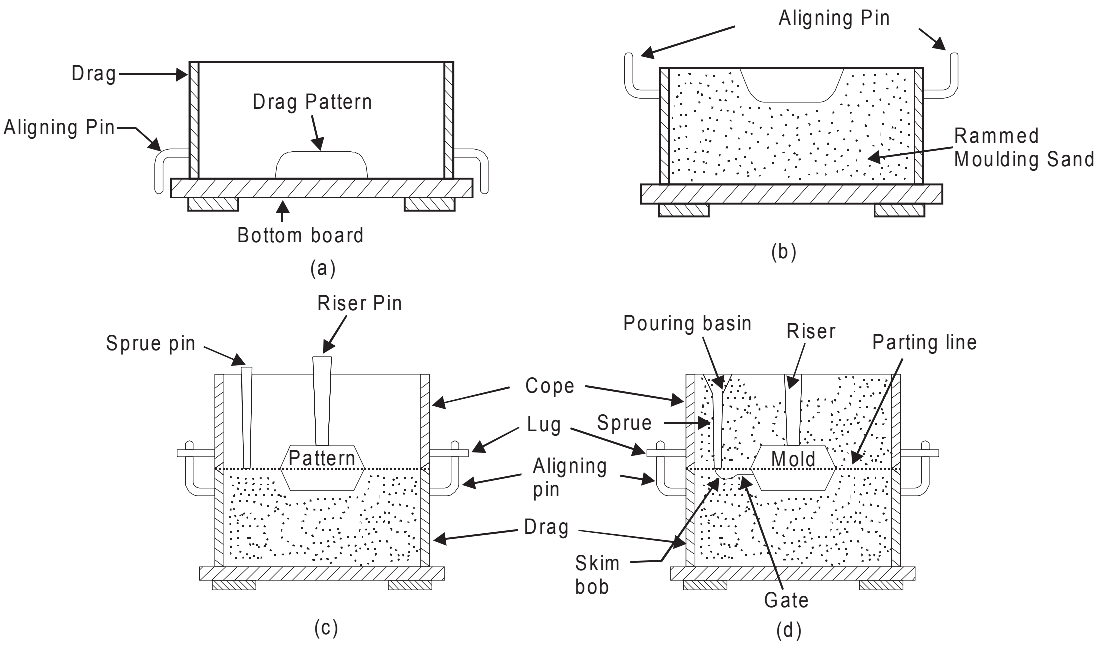

Fig. 12.6 Mold making

Example of making another mold is illustrated through Fig. 12.7

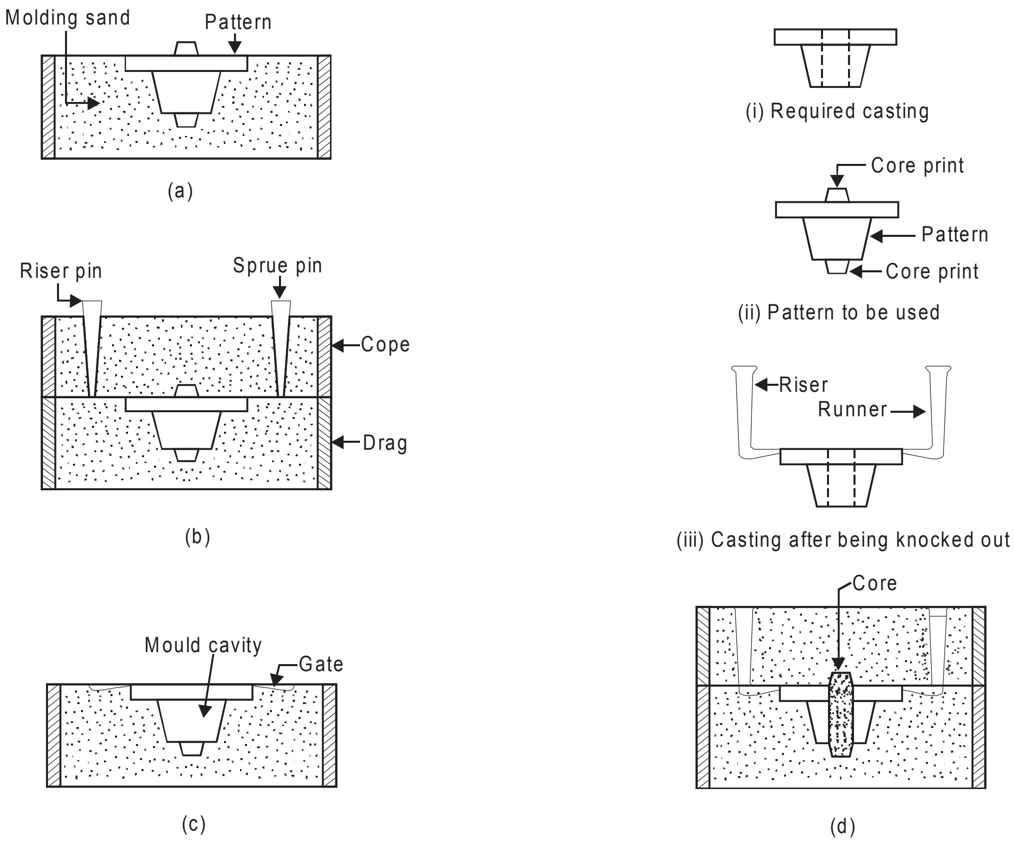

Fig. 12.7 Example of making a mold

12.9 VENTING OF MOLDS

Vents are very small pin types holes made in the cope portion of the mold using pointed edge of the vent wire all around the mold surface as shown in Fig. 12.8. These holes should reach just near the pattern and hence mold cavity on withdrawal of pattern. The basic purpose of vent holes is to permit the escape of gases generated in the mold cavity when the molten metal is poured. Mold gases generate because of evaporation of free water or steam formation, evolution of combined water (steam formation), decomposition of organic materials such as binders and additives (generation of hydrocarbons, CO and CO_2), expansion of air present in the pore spaces of rammed sand. If mold gases are not permitted to escape, they may get trapped in the metal and produce defective castings. They may raise back pressure and resist the inflow of molten metal. They may burst the mold. It is better to make many small vent holes rather than a few large ones to reduce the casting defects.

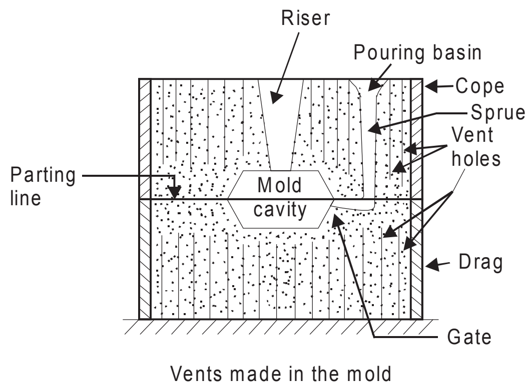

Fig. 12.8 Venting of holes in mold

12.10 GATING SYSTEM IN MOLD

Fig 12.9 shows the different elements of the gating system. Some of which are discussed as under.

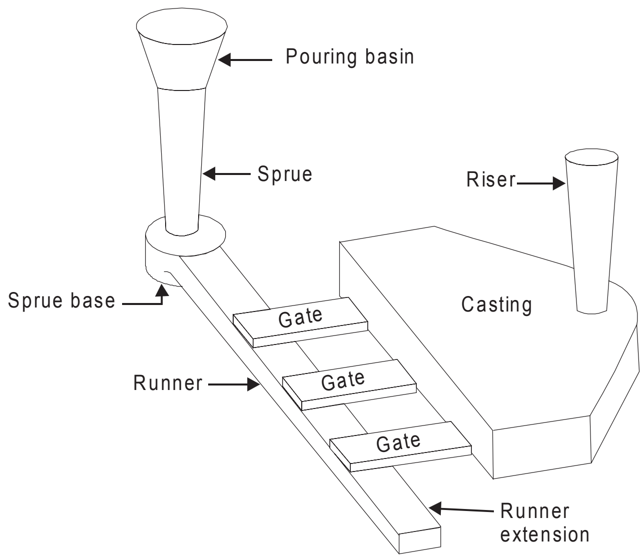

Fig. 12.9 Gating System

1. Pouring basin

It is the conical hollow element or tapered hollow vertical portion of the gating system which helps to feed the molten metal initially through the path of gating system to mold cavity. It may be made out of core sand or it may be cut in cope portion of the sand mold. It makes easier for the ladle operator to direct the flow of molten metal from crucible to pouring basin and sprue. It helps in maintaining the required rate of liquid metal flow. It reduces turbulence and vertexing at the sprue entrance. It also helps in separating dross, slag and foreign element etc. from molten metal before it enters the sprue.

2. Sprue

It is a vertical passage made generally in the cope using tapered sprue pin. It is connected at bottom of pouring basin. It is tapered with its bigger end at to receive the molten metal the smaller end is connected to the runner. It helps to feed molten metal without turbulence to the runner which in turn reaches the mold cavity through gate. It some times possesses skim bob at its lower end. The main purpose of skim bob is to collect impurities from molten metal and it does not allow them to reach the mold cavity through runner and gate.

3. Gate

It is a small passage or channel being cut by gate cutter which connect runner with the mould cavity and through which molten metal flows to fill the mould cavity. It feeds the liquid metal to the casting at the rate consistent with the rate of solidification.

4. Choke

It is that part of the gating system which possesses smallest cross-section area. In choked system, gate serves as a choke, but in free gating system sprue serves as a choke.

5. Runner

It is a channel which connects the sprue to the gate for avoiding turbulence and gas entrapment.

6. Riser

It is a passage in molding sand made in the cope portion of the mold. Molten metal rises in it after filling the mould cavity completely. The molten metal in the riser compensates the shrinkage during solidification of the casting thus avoiding the shrinkage defect in the casting. It also permits the escape of air and mould gases. It promotes directional solidification too and helps in bringing the soundness in the casting.

7. Chaplets

Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces. The distances pieces in form of chaplets are made of parent metal of which the casting is. These are placed in mould cavity suitably which positions core and to give extra support to core and mould surfaces. Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification. When the molten metal is poured in the mould cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material. Various types of chaplets are shown in Fig. 12.10. The use of the chaplets is depicted in Fig. 12.11.

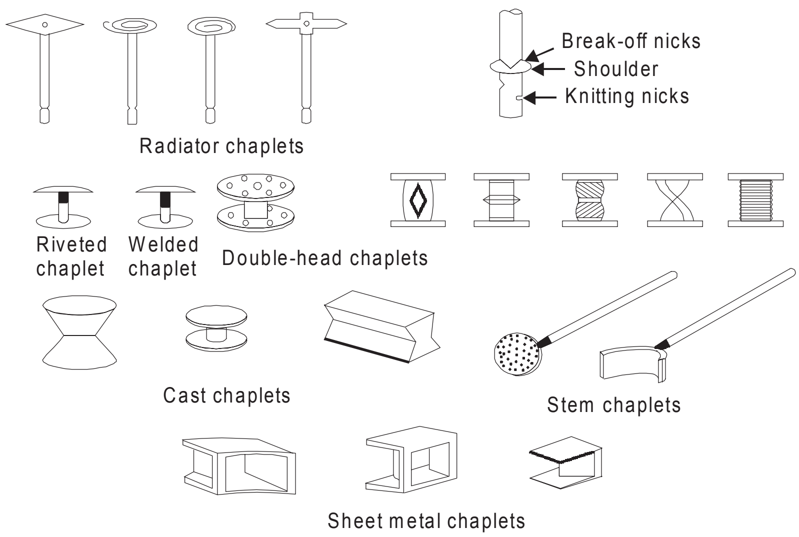

Fig. 12.10 Types of chaplets

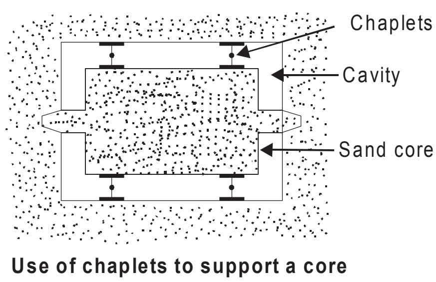

Fig. 12.11 Use of chaplets

8. Chills

In some casting, it is required to produce a hard surface at a particular place in the casting. At that particular position, the special mould surface for fast extraction of heat is to be made. The fast heat extracting metallic materials known as chills will be incorporated separately along with sand mould surface during molding. After pouring of molten metal and during solidification, the molten metal solidifies quickly on the metallic mould surface in comparison to other mold sand surfaces. This imparts hardness to that particular surface because of this special hardening treatment through fast extracting heat from that particular portion. Thus, the main function of chill is to provide a hard surface at a localized place in the casting by way of special and fast solidification. Various types of chills used in some casting processes are shown in Fig. 12.12. The use of a chill in the mold is depicted in Fig. 12.13.

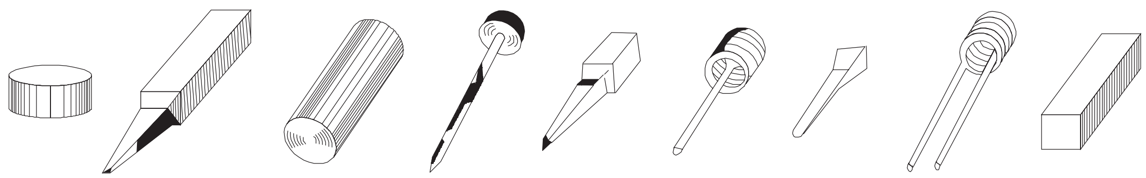

Fig. 12.12 Types of chills

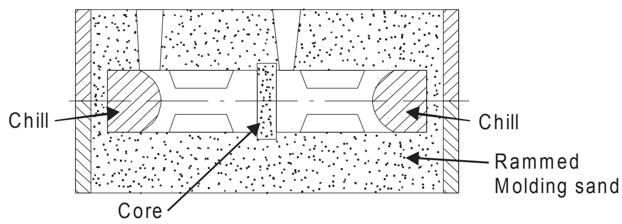

Fig. 12.13 Use of a chill

12.11 FACTORS CONTROLING GATING DESIGN

The following factors must be considered while designing gating system.

(*i*) Sharp corners and abrupt changes in at any section or portion in gating system should be avoided for suppressing turbulence and gas entrapment. Suitable relationship must exist between different cross-sectional areas of gating systems.

(*ii*) The most important characteristics of gating system besides sprue are the shape, location and dimensions of runners and type of flow. It is also important to determine the position at which the molten metal enters the mould cavity.

(*iii*) Gating ratio should reveal that the total cross-section of sprue, runner and gate decreases towards the mold cavity which provides a choke effect.

(*iv*) Bending of runner if any should be kept away from mold cavity.

(*v*) Developing the various cross sections of gating system to nullify the effect of turbulence or momentum of molten metal.

(*vi*) Streamlining or removing sharp corners at any junctions by providing generous radius, tapering the sprue, providing radius at sprue entrance and exit and providing a basin instead pouring cup etc.

12.12 ROLE OF RISER IN SAND CASTING

Metals and their alloys shrink as they cool or solidify and hence may create a partial vacuum within the casting which leads to casting defect known as shrinkage or void. The primary function of riser as attached with the mould is to feed molten metal to accommodate shrinkage occurring during solidification of the casting. As shrinkage is very common casting defect in casting and hence it should be avoided by allowing molten metal to rise in riser after filling the mould cavity completely and supplying the molten metal to further feed the void occurred during solidification of the casting because of shrinkage. Riser also permits the escape of evolved air and mold gases as the mold cavity is being filled with the molten metal. It also indicates to the foundry man whether mold cavity has been filled completely or not. The suitable design of riser also helps to promote the directional solidification and hence helps in production of desired sound casting.

12.12.1 Considerations for Desiging Riser

While designing risers the following considerations must always be taken into account.

(A) Freezing time

1 For producing sound casting, the molten metal must be fed to the mold till it solidifies completely. This can be achieved when molten metal in riser should freeze at slower rate than the casting.

2 Freezing time of molten metal should be more for risers than casting. The quantative risering analysis developed by Caine and others can be followed while designing risers.

(B) Feeding range

1. When large castings are produced in complicated size, then more than one riser are employed to feed molten metal depending upon the effective freezing range of each riser.
2. Casting should be divided into divided into different zones so that each zone can be feed by a separate riser.
3. Risers should be attached to that heavy section which generally solidifies last in the casting.
4. Riser should maintain proper temperature gradients for continuous feeding throughout freezing or solidifying.

(C) Feed Volume Capacity

1 Riser should have sufficient volume to feed the mold cavity till the solidification of the entire casting so as to compensate the volume shrinkage or contraction of the solidifying metal.

2 The metal is always kept in molten state at all the times in risers during freezing of casting. This can be achieved by using exothermic compounds and electric arc feeding arrangement. Thus it results for small riser size and high casting yield.

3 It is very important to note that volume feed capacity riser should be based upon freezing time and freezing demand.

Riser system is designed using full considerations on the shape, size and the position or location of the riser in the mold.

12.12.2 Effect of Riser

Riser size affects on heat loss from top at open risers. Top risers are expressed as a percentage of total heat lost from the rises during solidification. Risers are generally kept cylindrical. Larger the riser, greater is the percentage of heat that flows out of top. Shape of riser may be cylindrical or cubical or of cuboids kind. If shape is cylindrical i.e. 4″ high and 4″ dia, insulated so that heat can pass only into the circumferential sand walls, with a constant K value of 13.7 min./sq.ft. Chvorinov's rule may be used to calculate the freezing time for cylinder as 13.7 min. The freezing time of a 4″ steel cube of same sand is 6.1 minutes and the freezing time of a 2″, 8″ and 8″ rectangular block is also 6.1 min. Since the solidification time as calculated of the cylinder is nearly twice as long as that of either the block of the cube. Hence cylindrical shape is always better. Insulation and shielding of molten metal in riser also plays a good role for getting sound casting

12.13 GREEN SAND MOLDING

Green sand molding is the most widely used molding process. The green sand used for molding consists of silica, water and other additives. One typical green sand mixture contains 10 to 15% clay binder, 4 to 6% water and remaining silica sand. The green sand mixture is prepared and used in the molding procedure described in section 12.8 is used to complete the mold (cope and drag). Cope and drag are then assembled and molten metal is poured while mould cavity is still green. It is neither dried nor baked. Green sand molding is preferred for making small and medium sized castings. It can also be applied for producing non-ferrous castings. It has some advantages which are given as under.

Advantages

1 It is adaptable to machine molding
2 No mould baking and drying is required.
3 Mold distortion is comparatively less than dry sand molding.

12.14 CORE

Cores are compact mass of core sand (special kind of molding sand) prepared separately that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold. In fact the core has to withstand the severe action of hot metal which completely surrounds it. They may be of the type of green sand core and dry sand core. Therefore the core must meet the following functions or objectives which are given as under.

1 Core produces hollowness in castings in form of internal cavities.
2 It must be sufficiently permeable to allow the easy escape of gases during pouring and solidification.
3 It may form a part of green sand mold
4 It may be deployed to improve mold surface.
5 It may provide external under cut features in casting.
6 It may be inserted to achieve deep recesses in the casting.
7 It may be used to strengthen the mold.
8 It may be used to form gating system of large size mold.

12.15 CORE SAND

It is special kind of molding sand. Keeping the above mentioned objectives in view, the special considerations should be given while selecting core sand. Those considerations involves (*i*) The cores are subjected to a very high temperature and hence the core sand should be highly refractory in nature (*ii*) The permeability of the core sand must be sufficiently high as compared to that of the molding sands so as to allow the core gases to escape through the limited area of the core recesses generated by core prints (*iii*) The core sand should not possess such materials which may produce gases while they come in contact with molten metal and (*iv*) The core sand should be collapsible in nature, i.e. it should disintegrate after the metal solidifies, because this property will ease the cleaning of the casting.

The main constituents of the core sand are pure silica sand and a binder. Silica sand is preferred because of its high refractoriness. For higher values of permeability sands with coarse grain size distribution are used. The main purpose of the core binder is to hold the grains together, impart strength and sufficient degree collapsibility. Beside these properties needed in the core sand, the binder should be such that it produces minimum amount of gases when the molt metal is poured in the mould. Although, in general the binder are inorganic as well as organic ones, but for core making, organic binders are generally preferred because they are combustible and can be destroyed by heat at higher temperatures thereby giving sufficient collapsibility to the core sand. The common binders which are used in making core sand as follows:

1. Cereal binder

It develops green strength, baked strength and collapsibility in core. The amount of these binders used varies from 0.2 to 2.2% by weight in the core sand.

2. Protein binder

It is generally used to increase collapsibility property of core.

3. Thermo setting resin

It is gaining popularity nowadays because it imparts high strength, collapsibility to core sand and it also evolve minimum amount of mold and core gases which may produce defects in the casting. The most common binders under this group are phenol formaldehyde and urea formaldehyde.

4. Sulphite binder

Sulphite binder is also sometimes used in core but along with certain amount of clay.

5. Dextrin

It is commonly added in core sand for increasing collapsibility and baked strength of core

6. Pitch

It is widely used to increase the hot strength of the core.

7. Molasses

It is generally used as a secondary binder to increase the hardness on baking. It is used in the form of molasses liquid and is sprayed on the cores before baking.

8. Core oil

It is in liquid state when it is mixed with the core sand but forms a coherent solid film holding the sand grains together when it is baked. Although, the core drying with certain core oils occurs at room temperature but this can be expedited by increasing the temperature. That is why the cores are made with core oils and are usually baked.

12.16 CORE MAKING

Core making basically is carried out in four stages namely core sand preparation, core making, core baking and core finishing. Each stage is explained as under.

12.16.1 Core Sand Preparation

Preparation of satisfactory and homogenous mixture of core sand is not possible by manual means. Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type mechanisms. In the case of roller mills, the rolling action of the mulling machine along with the turning over action caused by the ploughs gives a uniform and homogeneous mixing. Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders. These machines perform the mixing of core sand constituents most thoroughly.

12.16.2 Core Making Process Using Core Making Machines

The process of core making is basically mechanized using core blowing, core ramming and core drawing machines which are broadly discussed as under.

12.16.2.1 Core blowing machines

The basic principle of core blowing machine comprises of filling the core sand into the core box by using compressed air. The velocity of the compressed air is kept high to obtain a high velocity of core sand particles, thus ensuring their deposit in the remote corners the core box. On entering the core sand with high kinetic energy, the shaping and ramming of core is carried out simultaneously in the core box. The core blowing machines can be further classified into two groups namely small bench blowers and large floor blowers. Small bench blowers are quite economical for core making shops having low production. The bench blowers were first introduced during second war. Because of the high comparative productivity and simplicity of design, bench blowers became highly popular. The cartridge oriented sand magazine is considered to be a part of the core box equipment. However, one cartridge may be used for several boxes of approximately the same size. The cartridge is filled using hands. Then the core box and cartridge are placed in the machine for blowing and the right handle of the machine clamps the box and the left handle blows the core. In a swing type bench blower, the core sand magazine swings from the blowing to the filling position. There is also another type of bench blowing, which has a stationary sand magazine. It eliminates the time and effort of moving the magazine from filling to the blowing position. The floor model blowers have the advantage being more automation oriented. These floor model blowers possess stationary sand magazine and automatic control. One of the major drawbacks in core blowing is the channeling of sand in the magazine which may be prevented by agitating the sand in the sand magazine.

12.16.2.2 Core ramming machines

Cores can also be prepared by ramming core sands in the core boxes by machines based on the principles of squeezing, jolting and slinging. Out of these three machines, jolting and slinging are more common for core making.

12.16.2.3 Core drawing machines

The core drawing is preferred when the core boxes have deep draws. After ramming sand in it, the core box is placed on a core plate supported on the machine bed. A rapping action on the core box is produced by a vibrating vertical plate. This rapping action helps in drawing off the core from the core box. After rapping, the core box, the core is pulled up thus leaving the core on the core plate. The drawn core is then baked further before its use in mold cavity to produce hollowness in the casting.

12.16.3 Core baking

Once the cores are prepared, they will be baked in a baking ovens or furnaces. The main purpose of baking is to drive away the moisture and hard en the binder, thereby giving strength to the core. The core drying equipments are usually of two kinds namely core ovens and dielectric bakers. The core ovens are may be further of two type's namely continuous type oven and batch type oven. The core ovens and dielectric bakers are discussed as under.

12.16.3.1 Continuous type ovens

Continuous type ovens are preferred basically for mass production. In these types, core carrying conveyors or chain move continuously through the oven. The baking time is controlled by the speed of the conveyor. The continuous type ovens are generally used for baking of small cores.

12.16.3.2 Batch type ovens

Batch type ovens are mainly utilized for baking variety of cores in batches. The cores are commonly placed either in drawers or in racks which are finally placed in the ovens. The core ovens and dielectric bakers are usually fired with gas, oil or coal.

12.16.3.3 Dielectric bakers

These bakers are based on dielectric heating. The core supporting plates are not used in this baker because they interfere with the potential distribution in the electrostatic field. To avoid this interference, cement bonded asbestos plates may be used for supporting the cores. The main advantage of these ovens is that they are faster in operation and a good temperature control is possible with them.

After baking of cores, they are smoothened using dextrin and water soluble binders.

12.16.4 CORE FINISHING

The cores are finally finished after baking and before they are finally set in the mould. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing. The dimensional inspection of the cores is very necessary to achieve sound casting. Cores are also coated with refractory or protective materials using brushing dipping and spraying means to improve their refractoriness and surface finish. The coating on core prevents the molten metal from entering in to the core.

Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand. For handling bulky cores, lifting rings are also provided.

12.17 GREEN SAND CORES

Green sand cores are made by green sand containing moist condition about 5% water and 15-30 % clay. It imparts very good permeability to core and thus avoids defects like shrinkage or voids in the casting. Green sand cores are not dried. They are poured in green condition and are generally preferred for simple, small and medium castings. The process of making green sand core consumes less time. Such cores possess less strength in comparison to dry sand cores and hence cannot be stored for longer period.

12.18 DRY SAND CORES

Dry sand cores are produced by drying the green sand cores to about 110°C. These cores possess high strength rigidity and also good thermal stability. These cores can be stored for long period and are more stable than green sand core. They are used for large castings. They also produce good surface finish in comparison to green sand cores. They can be handled more easily. They resist metal erosion. These types of cores require more floor space, more core material, high labor cost and extra operational equipment.

12.19 CLASSIFICATION OF MOLDING PROCESSES

Molding processes can be classified in a number of ways. Broadly they are classified either on the basis of the method used or on the basis of the mold material used.

(*i*) Classification based on the method used

- (*a*) Bench molding.
- (*b*) Floor molding,
- (*c*) Pit molding.
- (*d*) Machine molding.

(*ii*) Classification based on the mold material used:

- (*a*) Sand molding:
  1. Green sand mould
  2. Dry sand mould,
  3. Skin dried mould.
  4. Core sand mould.
  5. loam mould
  6. Cement bonded sand mould
  7. Carbon-dioxide mould.
  8. Shell mould.
- (*b*) Plaster molding,
- (*c*) Metallic molding.
- (*d*) Loam molding

Some of the important molding methods are discussed as under.

12.20 MOLDING METHODS

Commonly used traditional methods of molding are bench molding, floor molding, pit molding and machine molding. These methods are discussed as under.

12.20.1 Bench Molding

This type of molding is preferred for small jobs. The whole molding operation is carried out on a bench of convenient height. In this process, a minimum of two flasks, namely cope and drag molding flasks are necessary. But in certain cases, the number of flasks may increase depending upon the number of parting surfaces required.

12.20.2 Floor Molding

This type of molding is preferred for medium and large size jobs. In this method, only drag portion of molding flask is used to make the mold and the floor itself is utilized as drag and it is usually performed with dry sand.

12.20.3 Pit Molding

Usually large castings are made in pits instead of drag flasks because of their huge size. In pit molding, the sand under the pattern is rammed by bedding-in process. The walls and the bottom of the pit are usually reinforced with concrete and a layer of coke is laid on the bottom of the pit to enable easy escape of gas. The coke bed is connected to atmosphere through vent pipes which provide an outlet to the gases. One box is generally required to complete the mold, runner, sprue, pouring basin and gates are cut in it.

12.20.4 Machine Molding

For mass production of the casting, the general hand molding technique proves un economical and in efficient. The main advantage of machine molding, besides the saving of labor and working time, is the accuracy and uniformity of the castings which can otherwise be only obtained with much time and labor. Or even the cost of machining on the casting can be reduced drastically because it is possible to maintain the tolerances within narrow limits on casting using machine molding method. Molding machines thus prepare the moulds at a faster rate and also eliminate the need of employing skilled molders. The main operations performed by molding machines are ramming of the molding sand, roll over the mold, form gate, rapping the pattern and its withdrawal. Most of the mold making operations are performed using molding machines

12.19.5 Loam Molding

Loam molding uses loam sand to prepare a loam mold. It is such a molding process in which use of pattern is avoided and hence it differs from the other molding processes. Initially the loam sand is prepared with the mixture of molding sand and clay made in form of a paste by suitable addition of clay water. Firstly a rough structure of cast article is made by hand using bricks and loam sand and it is then given a desired shape by means of strickles and sweep patterns. Mould is thus prepared. It is then baked to give strength to resist the flow of molten metal. This method of molding is used where large castings are required in numbers. Thus it enables the reduction in time, labor and material which would have been spent in making a pattern. But this system is not popular for the reason that it takes lots of time in preparing mould and requires special skill. The cope and drag part of mould are constructed separately on two different iron boxes using different sizes of strickles and sweeps etc. and are assembled together after baking. It is important to note that loam moulds are dried slowly and completely and used for large regular shaped castings like chemical pans, drums etc.

12.19.6 Carbon-Dioxide Gas Molding

This process was widely used in Europe for rapid hardening the molds and cores made up of green sand. The mold making process is similar to conventional molding procedure accept the mould material which comprises of pure dry silica sand free from clay, 3-5% sodium silicate as binder and moisture content generally less than 3%. A small amount of starch may be added to improve the green compression strength and a very small quantity of coal dust, sea coal, dextrin, wood floor, pitch, graphite and sugar can also be added to improve the collapsibility of the molding sand. Kaolin clay is added to promote mold stability. The prepared molding sand is rammed around the pattern in the mould box and mould is prepared by any conventional technique. After packing, carbon dioxide gas at about 1.3-1.5 kg/cm^2 pressure is then forced all round the mold surface to about 20 to 30 seconds using CO_2 head or probe or curtain as shown in Fig. 12.14. The special pattern can also be used to force the carbon dioxide gas all round the mold surfaces. Cores can be baked this way. The sodium silicate presented in the mold reacts with CO_2 and produce a very hard constituents or substance commonly called as silica gel.

$$Na_2SiO_3 + CO_2 \longrightarrow Na_2CO_3 + SiO_2.xH_2O \text{ (Silica Gel)}$$

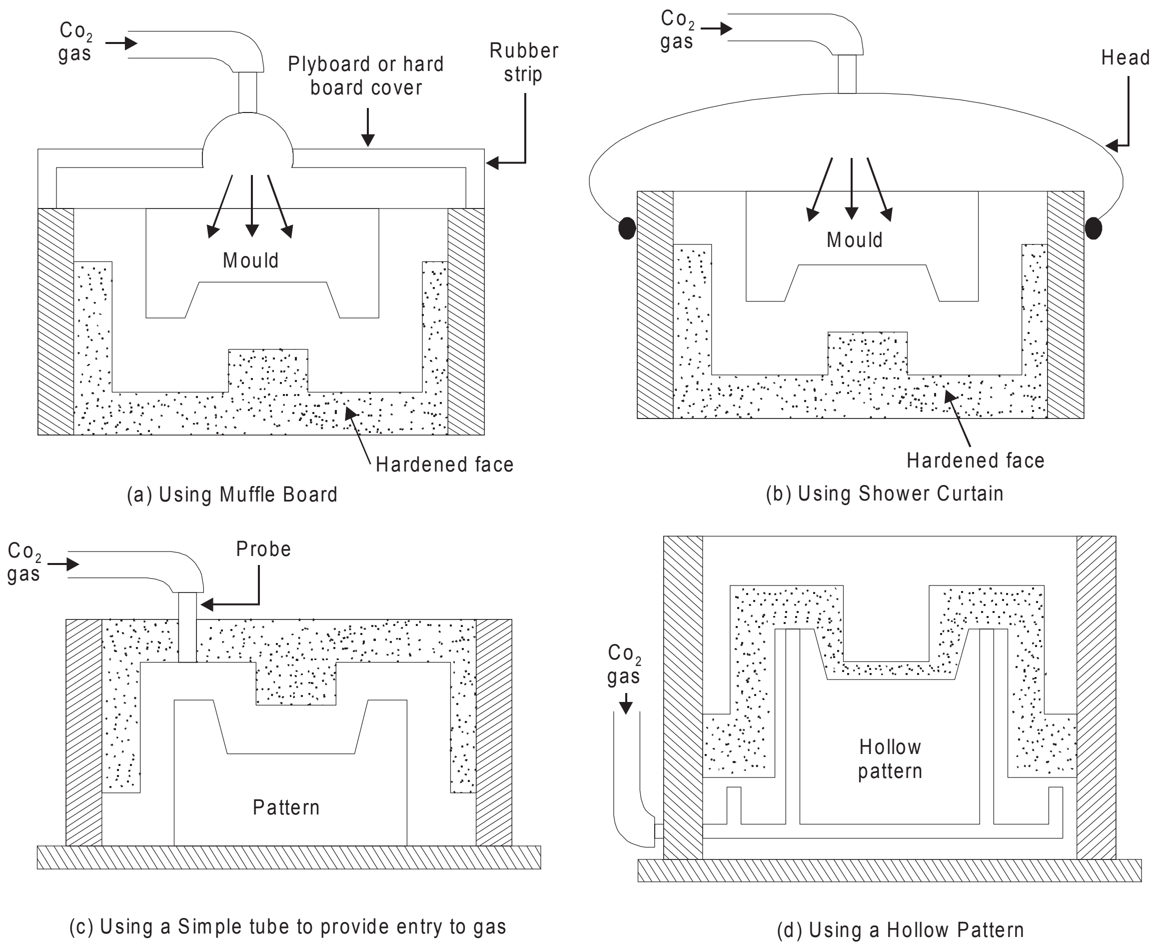

Fig. 12.14 Carbon dioxide molding

This hard substance is like cement and helps in binding the sand grains. Molds and cores thus prepared can be used for pouring molten metal for production of both ferrous and non-ferrous casting. The operation is quick, simple require semi-skilled worker. The evolution of gases is drastically reduced after pouring the thus prepared mould. This process eliminates mold and core baking oven. Reclamation of used sand is difficult for this process

Few other special molding methods are also discussed as under

12.20.6 Shell Molding

Shell mold casting is recent invention in molding techniques for mass production and smooth finish. Shell molding method was invented in Germany during the Second World War. It is also known as Carning or C process which is generally used for mass production of accurate thin castings with close tolerance of +_ 0.02 mm and with smooth surface finish. It consists of making a mould that has two or more thin lines shells (shell line parts, which are moderately hard and smooth. Molding sand is prepared using thermosetting plastic dry powder and find sand are uniformly mixed in a muller in the ratio 1: 20. In this process the pattern is placed on a metal plate and silicon grease is then sprayed on it. The pattern is then heated to 205°C to 230°C and covered with resin bonded sand. After 30 second a hard layer of sand is formed over the pattern. Pattern and shell are then heated and treated in an oven at 315°C for 60 sec. Then, the shell so formed as the shape of the pattern is ready to strip from the pattern. The shell can be made in two or more pieces as per the shape of pattern. Similarly core can be made by this process. Finally shells are joined together to form the mold cavity. Then the mold is ready for pouring the molten metal to get a casting. 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.

The shells formed by this process are 0.3 to 0.6 mm thick and can be handled and stored. Shell moulds are made so that machining parts fit together-easily, held clamps or adhesive and metal is poured either in a vertical or horizontal position. They are supported in rocks or mass of bulky permeable material such as sand steel shot or gravel. Thermosetting plastics, dry powder and sand are mixed ultimately in a muller. The process of shell molding possesses various advantages and disadvantages. Some of the main advantages and disadvantages of this process are given as under.

Advantages

The main advantages of shell molding are:

(*i*) High 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*) Moulds formed by this process can be stored until required.

(*viii*) Better quality of casting assured.

(*ix*) Mass production.

(*x*) It allows for greater detail and less draft.

(*xi*) Unskilled labor can be employed.

(*xii*) Future of shell molding process is very bright.

Disadvantages

The main disadvantages of shell molding are:

1. Higher pattern cost.
2. Higher resin cost.
3. Not economical for small runs.
4. Dust-extraction problem.
5. Complicated jobs and jobs of various sizes cannot be easily shell molded.
6. Specialized equipment is required.
7. Resin binder is an expensive material.
8. Limited for small size.

12.20.7 Plaster Molding

Plaster molding process is depicted through Fig. 12.15. The mould material in plaster molding is gypsum or plaster of paris. To this plaster of paris, additives like talc, fibers, asbestos, silica flour etc. are added in order to control the contraction characteristics of the mould as well as the settling time. The plaster of paris is used in the form of a slurry which is made to a consistency of 130 to 180. The consistency of the slurry is defined as the pounds of water per 100 pounds of plaster mixture. This plaster slurry is poured over a metallic pattern confined in a flask. The pattern is usually made of brass and it is generally in the form of half portion of job to be cast and is attached firmly on a match plate which forms the bottom of the molding flask. Wood pattern are not used because the water in the plaster raises the grains on them and makes them difficult to be withdrawn. Some parting or release agent is needed for easy withdrawal of the pattern from the mold. As the flask is filled with the slurry, it is vibrated so as to bubble out any air entrapped in the slurry and to ensure that the mould is completely filled up. The plaster material is allowed to set. Finally when the plaster is set properly the pattern is then withdrawn by separating the same, from the plaster by blowing compressed air through the holes in the patterns leading to the parting surface between the pattern and the plaster mold. The plaster mold thus produced is dried in an oven to a temperature range between 200-700 degree centigrade and cooled in the oven itself. In the above manner two halves of a mould are prepared and are joined together to form the proper cavity. The necessary sprue, runner etc. are cut before joining the two parts.

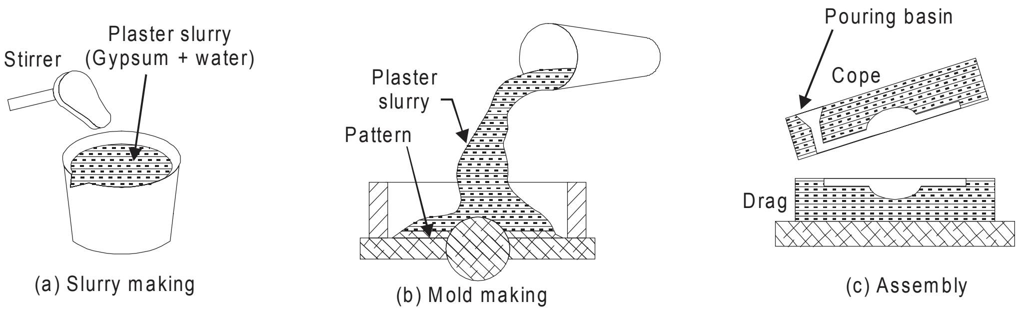

Fig. 12.15 Plaster molding

Advantages

(*a*) In plaster molding, very good surface finish is obtained and machining cost is also reduced.

(*b*) Slow and uniform rate of cooling of the casting is achieved because of low thermal conductivity of plaster and possibility of stress concentration is reduced.

(*c*) Metal shrinkage with accurate control is feasible and thereby warping and distortion of thin sections can be avoided in the plaster molding.

Limitations

(*a*) There is evolution of steam during metal pouring if the plaster mold is not dried at higher temperatures avoid this, the plaster mold may be dehydrated at high temperatures, but the strength of the mould decreases with dehydration.

(*b*) The permeability of the plaster mold is low. This may be to a certain extent but it can be increased by removing the bubbles as the plaster slurry is mixed in a mechanical mixer.

12.20.8 Antioch Process

This is a special case of plaster molding which was developed by Morris Bean. It is very well suited to high grade aluminum castings. The process differs from the normal plaster molding in the fact that in this case once the plaster sets the whole thing is auto-laved in saturated steam at about 20 psi. Then the mold is dried in air for about 10 to 12 hours and finally in an oven for 10 to 20 hours at about 250°C. The autoclaving and drying processes create a granular structure in the mold structure which increases its permeability.

12.20.9 Metallic Molding

Metallic mold is also known as permanent mold because of their long life. The metallic mold can be reused many times before it is discarded or rebuilt. Permanent 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. Usually the metallic mould is called as dies and the metal is introduced in it under gravity.

Some times this operation is also known as gravity die casting. When the molten metal is introduced in the die under pressure, then this process is called as pressure die casting. It may be designed with a vertical parting line or with a horizontal parting line as in