Casting

Manufacture of a machine part by heating a metal or alloy above its melting point and pouring the liquid metal/alloy in a cavity approximately of same shape and size as the machine part is called **casting**. After the liquid metal cools and solidifies, it acquires the shape and size of the cavity and resembles the finished product required. The term **casting** also applied to the part that is made by this process. It is one of the oldest shaping processes, dating back 6,000 years .The department of the workshop, where castings are made is called **foundry**.

So the following steps are involved in producing a cast part:

1. Preparing the mould.
2. Preparing the molten metal.
3. Introducing the molten metal into the mould.
4. Solidifying the metal.
5. Removing the piece.

Casting processes are most often selected over other manufacturing methods for the following reasons (**Advantages** of casting):

- Casting can produce complex shapes and can incorporate internal cavities or hollow sections.
- Very large parts can be produced in one piece.
- Casting can utilize materials that are difficult or uneconomical to process by other means.
- The casting process can be economically competitive with other manufacturing processes.

Classification of casting processes

Casting processes can be classified based on the mould material, method of producing the mould ,and the pressure on the molten metal during filling.

1. Expendable mould casting
2. Permanent mould casting
3. Special processes

1. Expendable mould casting

a) Permanent pattern
   I. Water and clay bond
      i. Green sand moulding
      ii. Skin dry sand moulding
      iii. Dry sand moulding
      iv. Core sand moulding
      v. Floor and pit moulding
      vi. Loam moulding
      vii. High pressure moulding
   II. Resin bond
      i. Shell moulding
      ii. Hot box
      iii. Cold box

III. Plaster bond

IV. Silicate bond

  i. CO_2 Process

  ii. Ceramic moulding

  iii. Shaw process

V. No bond

  i. Vacuum "v" process

b) Expendable pattern

I. Investment (wax) casting

II. Full mould (lost foam)casting

2. Permanent mould casting

a) Low pressure

b) Pressure die

I. Hot chamber

II. Cold chamber

c) Gravity die

I. Permanent core

II. Expendable core

III. Slush casting

d) Centrifugal

I. True centrifugal

II. Semi-centrifugal

III. Cnetrifuging

e) Vacuum

3. Special processes

a) Squeeze casting

b) Continuous casting

c) Chilled casting

Pattern

A pattern is a model or the replica of the object (to be casted). It is embedded in molding sand and suitable ramming of molding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mold) in molding sand. Thus it is a mould forming tool. Pattern can be said as a model or the replica of the object to be cast except for the various al1owances a pattern exactly resembles the casting to be made.

Types of pattern

1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern

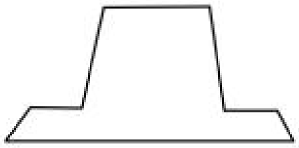
7. Follow board pattern8. Gated pattern

9. Sweep pattern 10. Skeleton pattern

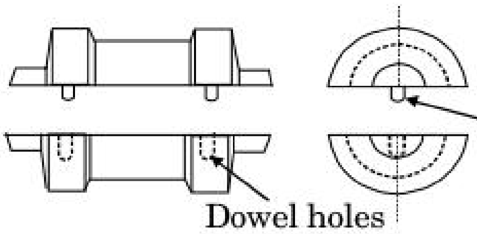
11. Segmental or part pattern

1.**One piece or solid pattern**

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern.



Single piece pattern



Two -piece pattern

2. **Two piece or split pattern**

When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern.

3. **Cope and drag pattern**

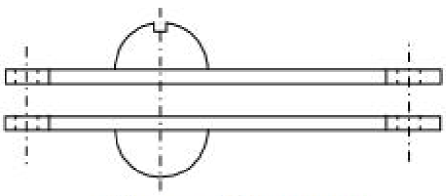
In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates.

4. **Three-piece or multi- piece pattern**

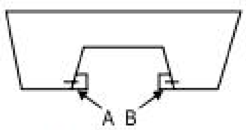
Some patterns are of complicated kind in shape and hence cannot be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore these patterns are made in either three pieces or in multi-pieces. Multi molding flasks are needed to make mold from these patterns.

5. **Loose piece pattern**

Loose piece pattern is used when pattern is difficult for withdrawal from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.



Cope and drag pattern



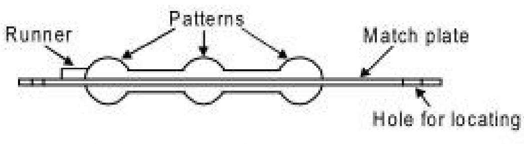
Loose piece pattern

6. **Match plate pattern**

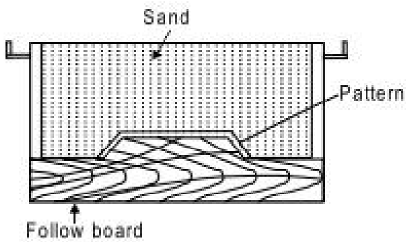
This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine molding.

7. **Follow board pattern**

When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a molding board for the first molding operation as shown in Fig.



Match plate pattern



Follow board pattern

8. **Gated pattern**

In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.

9. **Sweep pattern**

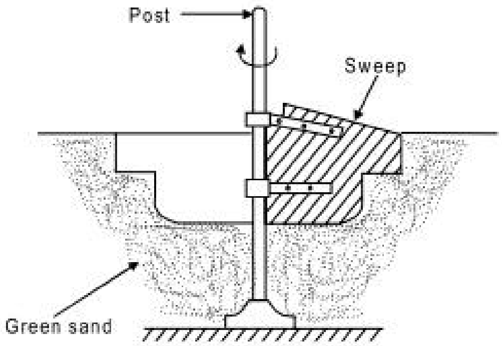
Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the center of the mould.

10. **Skeleton pattern**

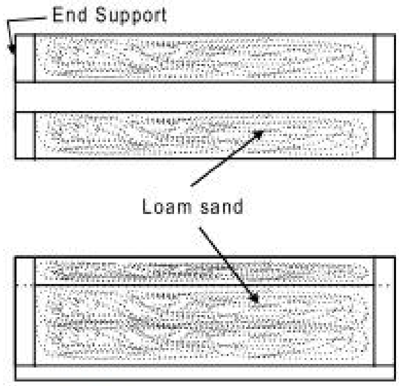
When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made. This frame work is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc. A typical skeleton pattern is shown in Fig

11. **Segmental or part pattern**

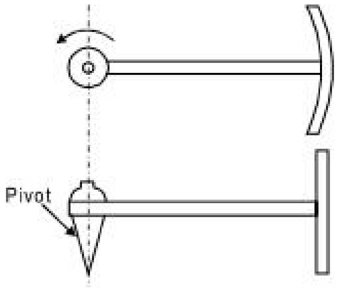
Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown inFig.



Sweep pattern



Skeleton pattern



Segmental pattern

Pattern allowances

In order for a pattern to be successfully employed in producing a casting having the desired dimensions, it must not be an exact replica of the part to be cast. A number of allowances must be made on the dimensions of the pattern:

1. **Shrinkage Allowance**

In practice it is found that all common cast metals shrink a significant amount when they are cooled from the molten state. The total contraction in volume is divided into the following parts:

- ***Liquid contraction***, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquidus temperature.
- Contraction on cooling from the liquidus to the solidus temperature, i.e. ***solidifcation contraction.***
- Contraction that results there after until the temperature reaches the roomtemperature. This is known as ***solid contraction***.

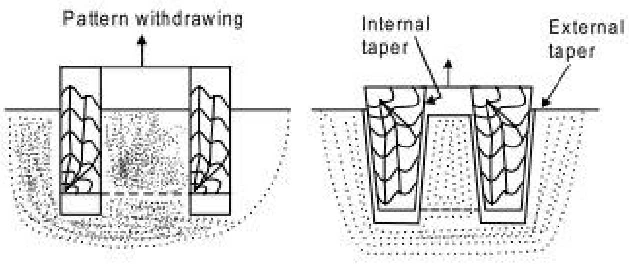
The first two of the above are taken care of by proper ***gating and risering***. Only the last one, i.e. the solid contraction is taken care by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals. The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt.. Brass 16 mm/mt.,Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special rule known as the ***pattern marks contraction rule*** in which the shrinkage of the casting metals is added. It is similar in shape as that of a common rule but is slightly bigger than the latter depending upon the metal for which it is intended.

2. **Machining Allowance**

It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting,methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.

3. **Draft or Taper Allowance**

Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt. These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.



Draft or taper allowance

4. **Rapping or Shake Allowance**

Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases. Actually by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This movement may be insignificant in the case of small and medium size castings, but it is significant in the case of large castings. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5-1.0 mm.

5. **Distortion Allowance**

This allowance is applied to the castings which have the tendency to distort during cooling due to thermal stresses developed. For example a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position. Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.

6. **Mold wall Movement Allowance**

Mold wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mold cavity depends upon the molddensity and mould composition. This effect becomes more pronounced with increase in moisture content and temperature.

Pattern colour coding

Many mistakes may be eliminated by indicating the functions of various parts of the pattern with proper colours:

a) A loose piece may get lost and unless the pattern is marked to indicate the seat of the loose piece ,it is quite possible that the casting will be made from the incomplete pattern.
b) With properly marked core prints, the moulder is constantly reminded that cores must be set in the mould before it is closed.
c) Patterns with stop offs should be marked to remind the moulder to fill the mould cavity made by stop off.
d) If a moulder knows what surfaces are to be machined, he will, if possible mould the pattern in a position to produce a surface more nearly free of impurities.

A common colour scheme is given below :

1. Surface as cast : Black
2. Machined surface : Red
3. Core prints and seats : Yellow
4. Loose pieces : Yellow/Red diagonal stripes
5. Stop off : Yellow/Black diagonal stripes

______________ ______________________ __________________ ___________________ ___________

Constituents of moulding sands

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

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.

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 likephenol 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 cannot develop bonds among sand grins without the presence of moisture in molding sand and core sand.

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.

Additives

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

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.

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.

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.

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.

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.

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.

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.

Kinds of Moulding Sand

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

Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture ofsilica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay andwater 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 underpressure. 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 commonlyemployed for production of ferrous and non-ferrous castings.

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 mainlysuitable for larger castings. Mold prepared in this sand are known as dry sand molds.

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.

Facing sand

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

Backing sand

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

System sand

In mechanized foundries where machine molding is employed. A so called system sand is usedto fill the whole molding flask. In mechanical sand preparation and handling units, no facingsand is used. The used sand is cleaned and re-activated by the addition of water and specialadditives. 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 behigher than those of backing sand.

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.

Core sand

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

Properties Of Moulding Sand

Refractoriness

Refractoriness is defined as the ability of molding sand to withstand high temperatureswithout 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. quartzcontent, and the shape and grain size of the particle. The higher the SiO_2 content and therougher 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.

Permeability

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

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.

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. they 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, thesand grains must have the property known as cohesiveness i.e. ability of the sand grains to stickto 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.

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.

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.

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

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.

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 andincreased 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 Test3. 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 Test13. Mould hardness Test.

Some of the important sand tests are :

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 apercentage 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.

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.

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 sieveshaving U.S. Bureau of standard meshes 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 are mounted on a mechanical shaker . 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 15minutes. 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.

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 electric 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 byscratching it with a steel needle.

Strength Test

The strength of a foundary moulding sand is determined by a) compression b) tension c) shear and d) transverse test. The most commonly used test is that of compression strength. Specimen for compression, tension, transverse and shear testings can be made on the sand specimen tester using different attachments. The compression test is as follows:

1. The specimen is held between the grips.
2. Hand wheel when rotated actuates a mechanism which builds up hydraulic pressure on the specimen.
3. Dial indicator fitted on the tester measures the deformation occurring in the specimen.
4. There are two indicators (manaometers). One is meant for use when testing low strength sands and other for relatively high strength core sands.
5. Each indicator has three scales- one for reading compressive strengths and the remaining two for recording tensile (or transverse) and shear strength respectively.

Permeability Test

Permeability is that property of molding sand which permits the escape of steam and other gases generated in the mould during hot metal pouring. Since permeability is the property of rammed sand, a standard sized sand specimen is first rammed by a specimen rammer and it is then used in permeability tester. Permeability of the sand specimen prepared is determined by passing a given volume of air through the sand. A permeability tester consists of

1. An inverted bell jar, which floats in a water seal and can permit 2000cc of air to flow
2. Specimen tube, to hold the sample specimen
3. A manometer to read the air pressure

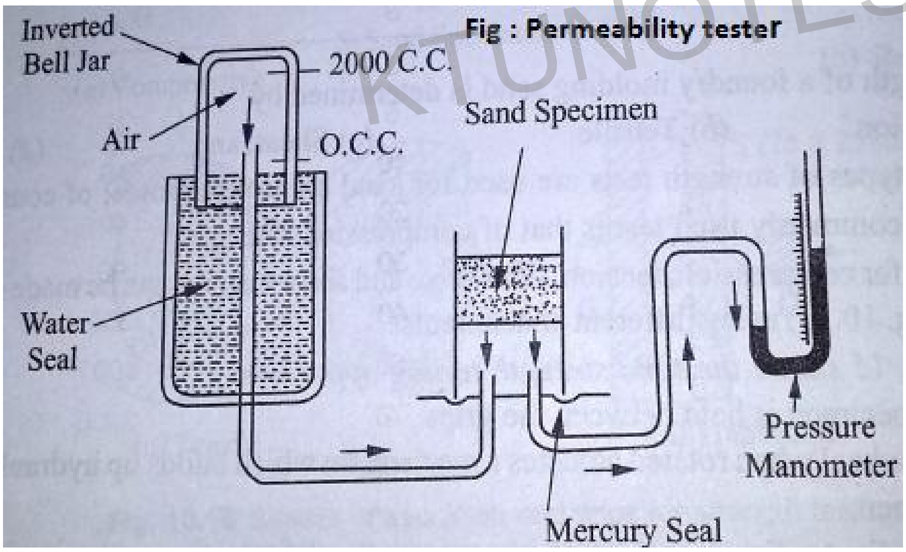


Fig : Permeability tester

Sand permeability can be determined by two methods 1. Standard method 2.Rapid (shop) method

Standard method : 2000cc of air held in the inverted bell jar is forced to pass through the sand specimen. A situation comes when the air entering the specimen equals the air escaped through the specimen to the atmosphere. This gives a stabilized pressure reading (P) on the manometer and the same can be read on the vertical scale. Simultaneously, using a stop watch the time (T) required for 2000cc of air to pass through the sand specimen is also recorded. As the next step, permeability number can be determined by the following relation

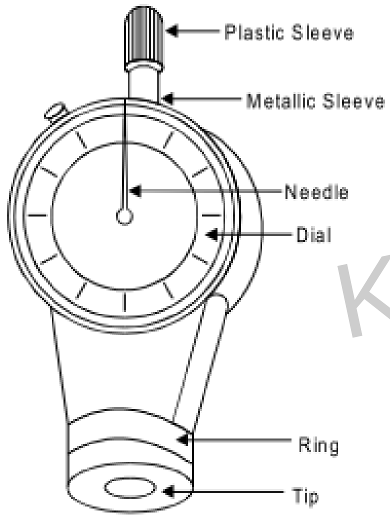
$$\text{Permeability number} = \frac{V.H}{A.P.T}$$

where V = volume of the air passed through the specimen =2000cc, H = height of the specimen = 5.08cm,

A= area of the specimen =20.268cm^2, T =time (in minutes) taken by the 2000cc of air to pass through the sand specimen, P= air pressure (gm/cm^2) recorded by the manometer.

Mould Hardness Test

This test is performed by a mold hardness tester. 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 penetrationof 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.



Mould Hardness Tester

Molding processes

Green sand can be molded by employing a variety of processes,including some that are carried out both by hand and with molding machines.

1. Flask molding.

Flask molding is the most widely used process in both hand- andmachine-molding practices. Fig. illustrates the procedure for simple hand-molding using a single (loose) pattern. First, the lower half of the pattern is placed on a molding board and surrounded by the drag. The drag is then filled with sand (using a shovel) and rammed very firmly. Ventilation holes are made using a steel wire, but these should not reach the pattern. The drag is turned upside down to bring the parting plane up so that it can be dusted. Next, the other half of the pattern is placed in position to match the lower half, and the cope is located around it,with the eyes of the cope fitted to the pins of the drag. Sand is shoveled into the cope and rammed firmly, after using a sprue pin to provide for the feeding passage.Ventilation holes are made in the cope part of the mold in the same way they were made in the other half. The pouring basin is cut around the head of the sprue pin using a trowel, and the sprue pin is pulled out of the cope. The cope is then carefully lifted off the drag and turned so that the parting plane is upward. The two halves of the pattern are removed from both the cope and the drag. The runner and/or gate are cut from the mold cavity to the sprue in the drag part of the mold. Then, any damages are repaired by slightly wetting the location and using a slick. The cope is then carefully placed on the drag to assemble the two halves of themold. Finally, the cope and the drag are fastened together by means of shackles orbolts to prevent the pressure created by the molten metal (after pouring) from separating them.

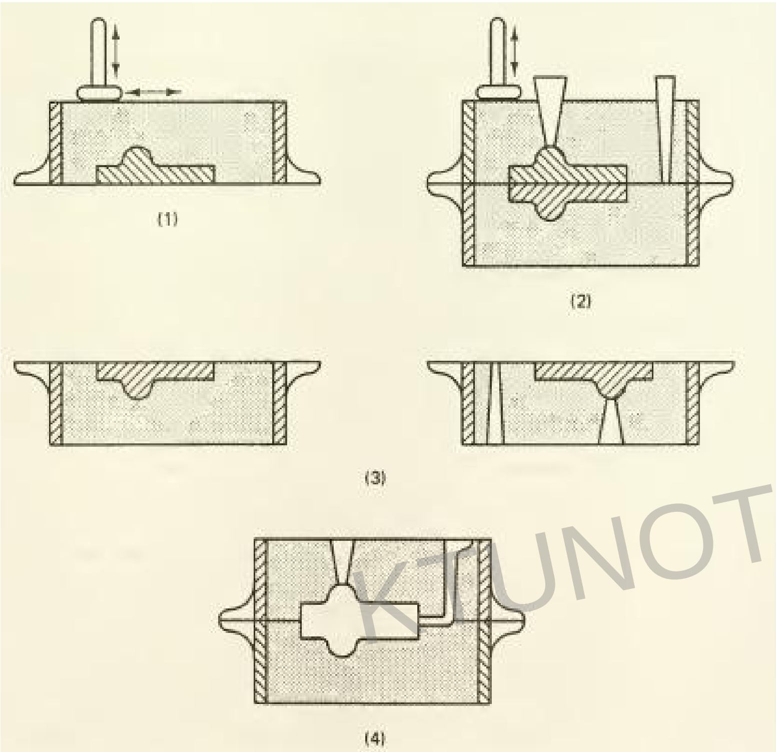


Fig . Flask moulding

2. **Stack molding**

Stack molding is best suited for producing a large number of small,light castings while using a limited amount of floor space in the foundry. As can be seen in Fig, there are two types of stack molding: ***upright***and ***stepped***. In upright stack molding, 10 to 12 flask sections are stacked up. They all have a common sprue that is employed in feeding all cavities. The drag cavity is always molded in the upper surface of the flask section, whereas the cope cavity is molded in the lower surface. In stepped stack molding, each section has its own sprue and is, therefore, offset from the one under it to provide for the pouring basin.In this case, each mold is cast separately.

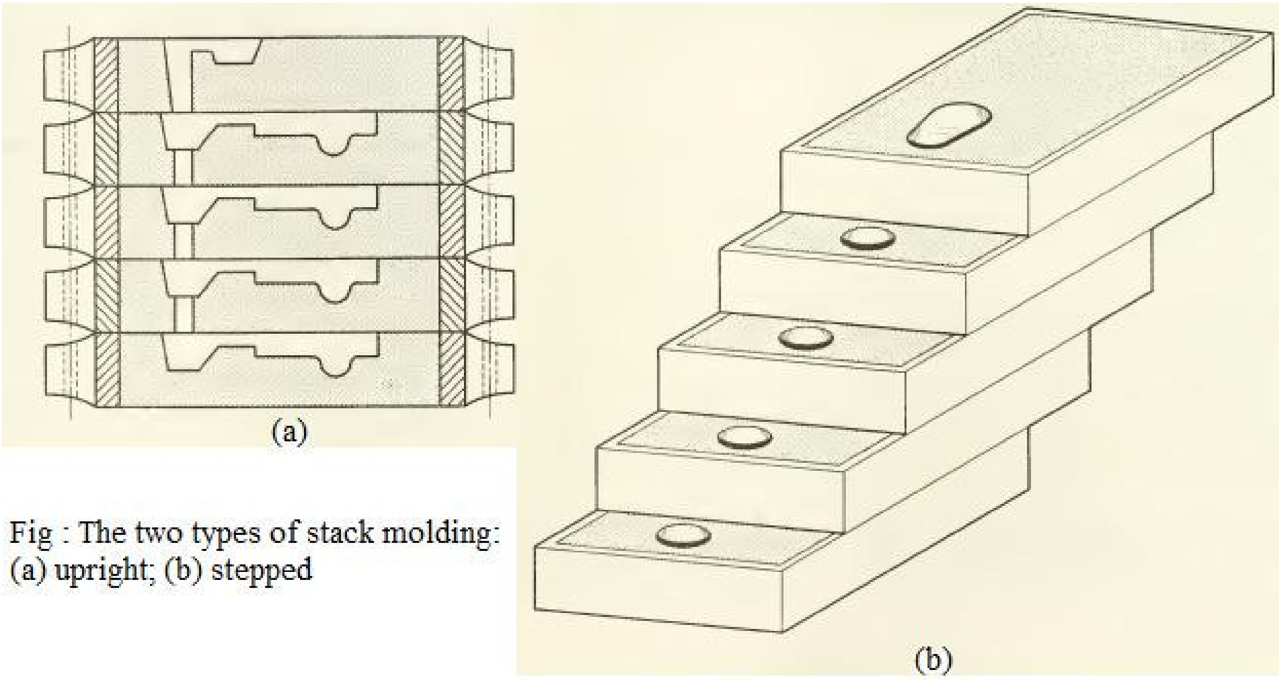


Fig : The two types of stack molding: (a) upright; (b) stepped

3. **Sweep molding.** Sweep molding is used to form the surfaces of the mold cavitywhen a large-size casting must be produced without the time and expenses involved in making a pattern. A sweep that can be rotated around an axis is used for producing a surface of revolution, contrary to a drawing sweep, which is pushed axially while being guided by a frame to produce a surface having a constant section along its length .

4. **Pit molding** : Pit molding is usually employed for producing a single piece of a largecasting when it would be difficult to handle patterns of that size in flasks. Molding is done in specially prepared pits in the ground of the foundry. The bottom of the pit is often covered with a layer of coke that is 2 to 3 inches (50 to 75 mm) thick.Then, a layer of sand is rammed onto the coke to act as a "bed" for the mold. Vent pipes connect the coke layer to the ground surface. Molding is carried out as usual, and molds are almost always dried before pouring the molten metal. This drying is achieved by means of a portable mold drier. A cope that is also dried is then placed on the pit, and a suitable weight or a group of weights are located on the cope to prevent it from floating when the molten metal is poured.

Molding machines

The employment of molding machines results in an increase inthe production rate, a marked increase in productivity, and a higher and more consistent quality of molds. The function of these machines is to pack the sand onto the pattern and draw the pattern out from the mold. There are several types of molding machines, each with a different way of packing the sand to form the mold. The main types include ***squeezers, joltmachines,*** and***sandslingers***. There are also some machines, such as ***jolt-squeeze machines***, that employ a combination of the workingprinciples of two of the main types.

1. Squeezers. The pattern plate is clamped on the machine table, and a flask is put into position. A sand frame is placed on the flask, and both are then filled withsand from a hopper. Next, the machine table travels upward to squeeze the sand between the pattern plate and a stationary head. The squeeze head enters into the sand frame and compacts the sand so that it is level with the edge of the flask.

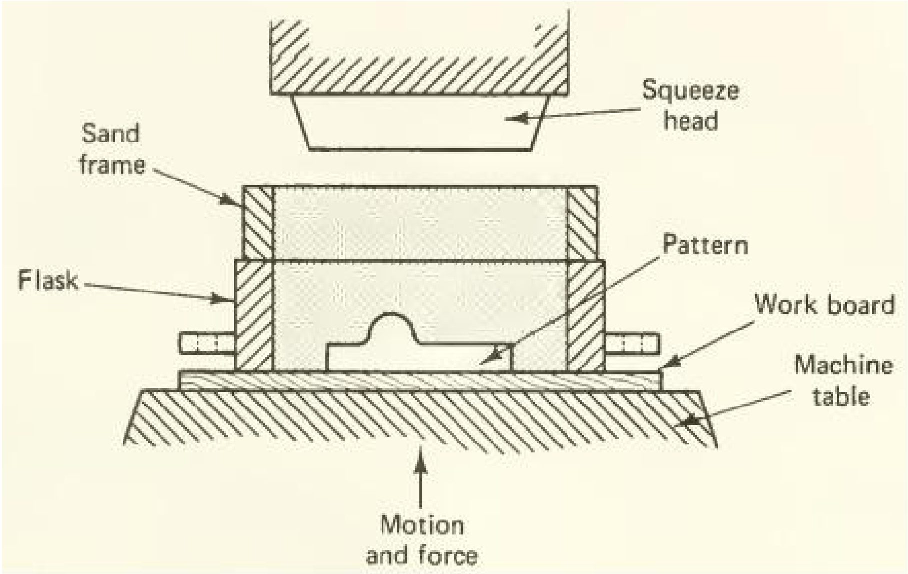


Fig . Squeezer

2. Jolt machines : Compressed air is admitted through the hose to apressure cylinder to lift the plunger (and the flask, which is full of sand) up to a certain height, where the side hole is uncovered to exhaust the compressed air. The plunger then falls down and strikes the stationary guiding cylinder. The shock wave resulting from each of the successive impacts contributes to packing the molding sand in the flask.

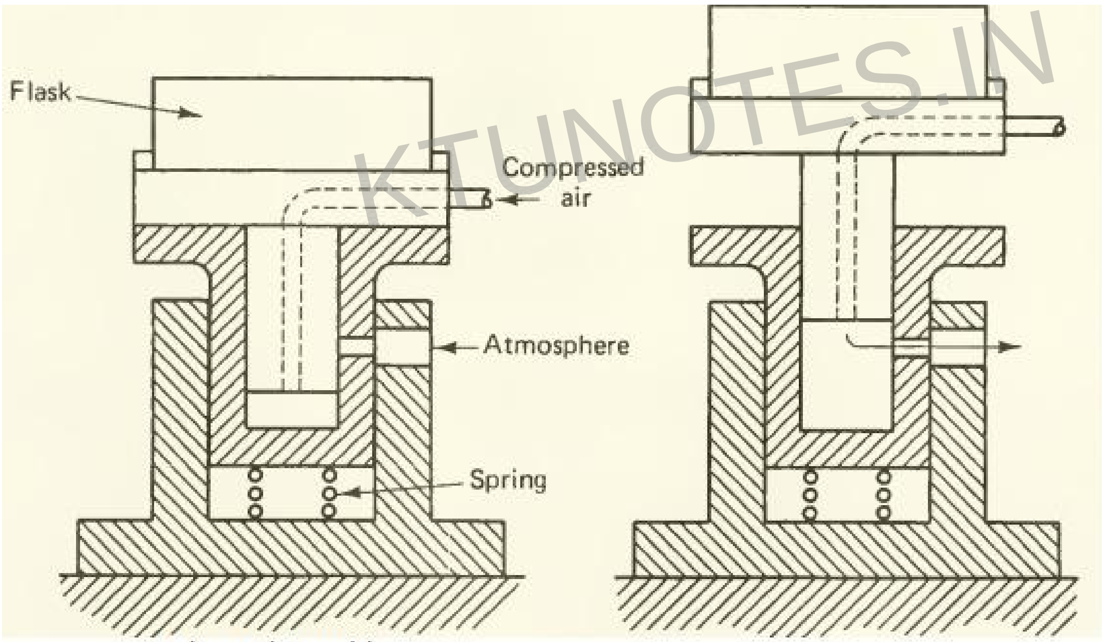


Fig . Jolt machine

3. Sandslingers. This type of machine is employedin molding sand in flasks of any size, whether for individual or mass production of molds. Sandslingers are characterized by their high output, which amounts to 2500 cubic feet (more than 60 cubic meters) per hour. As in fig. , molding sand is fed into a housing containing an impeller that rotates rapidly around a horizontal axis. Sand particles are picked up by the rotating blades and thrown at a high speed through an opening onto the pattern, which is located in the flask.

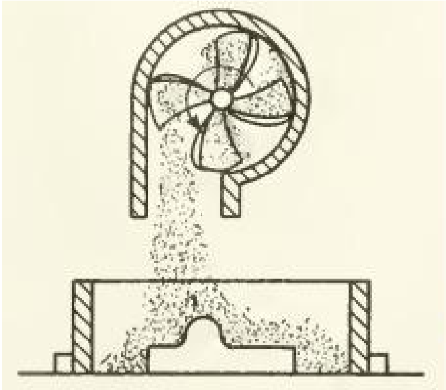


Fig. Sandslinger

Sand conditioning.

The molding sand, whether new or used, must be conditioned before being used. When used sand is to be recycled, lumps should be crushed and then metal granules or small parts removed (a magnetic field is employed in a ferrous foundry). Next, sand (new or recycled) and all other molding constituents must be screened in shakers, rotary screens, or vibrating screens. Molding materials are thenthoroughly mixed in order to obtain a completely homogeneous green sand mixture.The more uniform the distribution, the better the molding properties (like permeability and green strength) of the sand mixture will be.

Mixing is carried out in either continuous-screw mixers or vertical-wheel mullers.The mixers mix the molding materials by means of two large screws or worm gears; the mullers are usually used for batch-type mixing. A sand muller consists primarily of a pan in which two wheels rotate about their ownhorizontal axis as well as about a stationary vertical shaft. Centrifugal mullers are also in use, especially for high production rates.

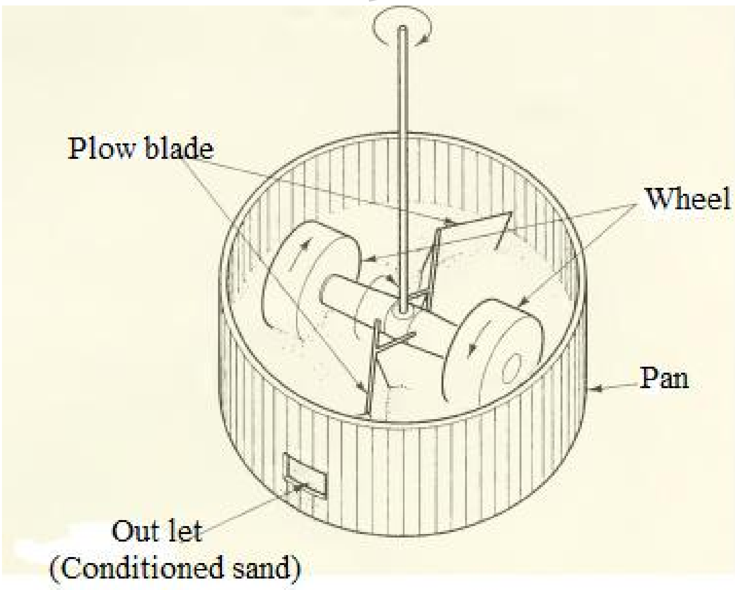


Fig . a muller for sand conditioning

Gating System

When molten metal is poured into a mold, the gating system conveys the material and delivers it to all sections of the mold cavity.The speed or rate of metal movement is important as well as the amount of cooling that occurs while it is flowing. Slow filling and high loss of heat can result in casting defects. Rapid rates of filling, on the other hand, can produce erosion of the gating system and mold cavity, and might result in the entrapment of mold material in the final casting.

Elements of the gating system

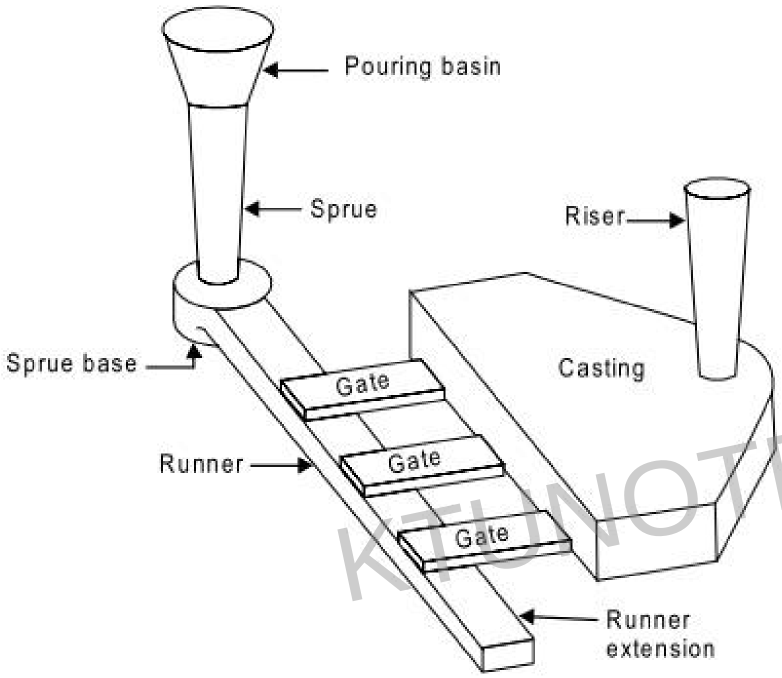


Fig . Gating system

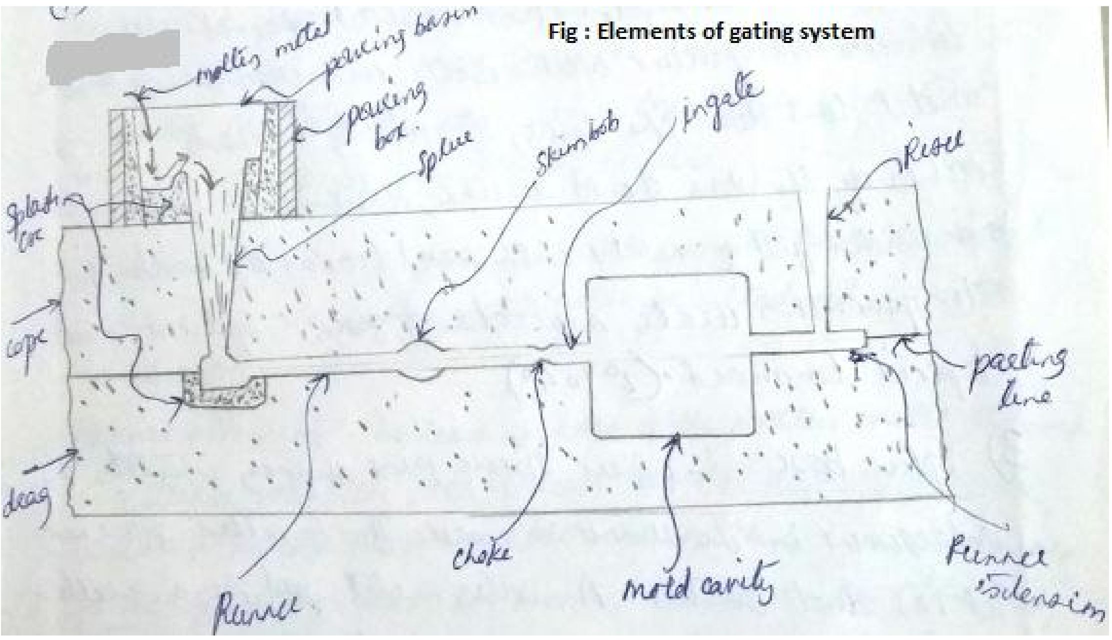


Fig : Elements of gating system

1. **Pouring basin**

It is a reservoir at the top of the sprue that receives the stream of molten metal poured from the ladle. The basin is filled quickly at the start of the pour and it should remain full of moten metal during pouring. Thus , dross consisting of oxides and slags which float , may be kept from entering the sprue. If the depth of metal in the cup is insufficient , a funnel is likely to form above the sprue entrance, through which air and slag may get in to the sprue and then into the mould cavity. The depth of pouring basin is a function of sprue entrance diameter. The pouring basin is designed to reduce turbulence. Experience has shown that the liquid metal depth above the sprue entrance should be 2.5 times the sprue entrance distance diameter to prevent the formation of a vortex.

2. **Sprue or down sprue or downrunner**

From the pouring basin , the molten metal is transported down into the mould cavity by means of sprue. It is a vertical channel that connects the pouring basin with runners and gates .As the metal flows down the sprue ,its velocity increases .Hence the section of the sprue should decrease ,otherwise the sprue will not remain full of metal and with metal leaving the walls of the sprue.This creates aspiration of gases. Therefore sprue is made tapered downward ($2^0 – 4^0$).

Strainer : A ceramic strainer in the sprue removes the dross.

3. **Sprue base**

Where sprue joins runner , usually an enlargement is made in the runner. This is called sprue base , it has dual function. A molten metal pool is an excellent device for preventing excessive sand erosion where the molten metal impinges on the runner at the sprue base. Also there is a sudden slowing of flow which dissipates kinetic energy and helps to drop out inclusions ,scums etc that may have been washed with the molten metal.

Splash core : It is a piece of ceramic or baked sand core insertion in the mould directly beneath the sprue.Its function is to prevent erosion of the mould sand where the molten metal strikes it at the base of the sprue.

4. **Runner**

It is commonly the horizontal channel that carry the molten metal from the sprue into themold cavity or connect the sprue to the gate. The runners and ingates must be designed to withstand the metal impact and reduce the metal velocity sufficiently so that the shape of the mould cavity is not compromised.

Runner extension: The leading edge of the molten metal flowing in a stream follows the path of least resistance and continues to build up kinetic energy until it reaches the end of the runner. If the extension is used ,the kinetic energy may be absorbed ,thus causing a smoother flow of metal in the runners and into the mould cavity.

Choke: The part of the gating system which most restricts or regulates the rate of pouring is the choke.It possesses smallest cross-section area.

Skim – bob :It is an enlargement along the runner ,whose function is to trap heavier and lighter impurities such as dross and eroded sand.

5. **Gates or ingates**

Gates are the channels which connect runner to the mould cavity and through which incoming metal directly enters the mould cavity.

6. **Risers or feeder head**

Risers are reservoirs of molten metal that feed the metal in the casting properly as it solidifies .The riser thus provides the feed metal which flows from the riser to the casting to make up for the shrinkage which takes place in casting metal as it changes from liquid to solid.

Riser design

Requirements of a riser

1. To be effective, a riser must be the last part of the casting to solidify, such that all the shrinkages that are likely to occur should be in the riser.
2. The volume of the riser must be sufficient to compensate for metal shrinkage within the casting.
3. The fluidity of the metal inside the riser must be maintained so that the metal can flow from if and penetrate to the last contraction of the cavity.

Riser location

Before the shape and size of the riser is determined, its location must be specified. Any casting no matter how complex can be subdivided into several geometrical shapes ,consisting of two heavier section joined by a thinner section. A riser should be located close to each heavier section.

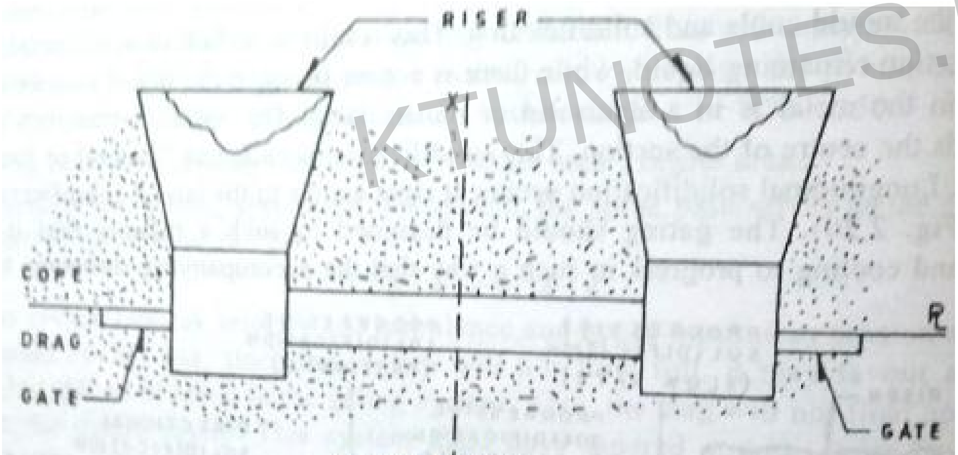
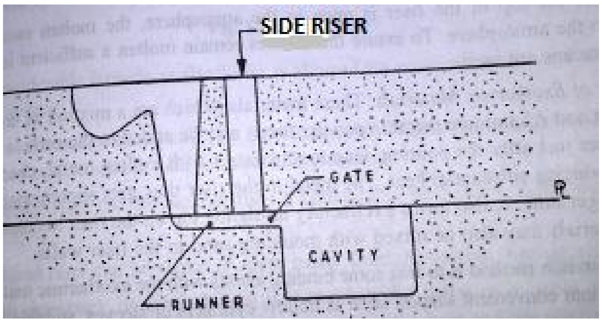
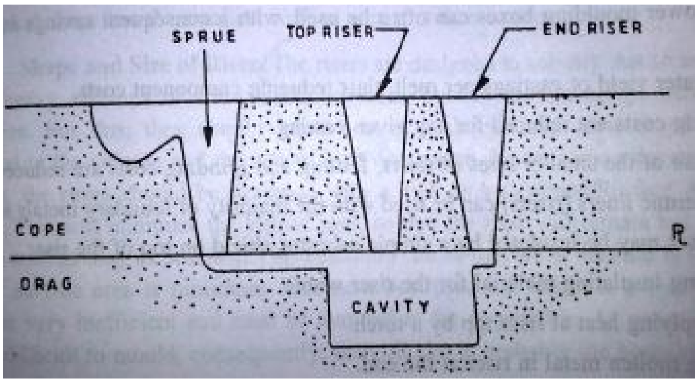


Fig : Riser location

Types of risers

Depending upon its location the riser can be described as "***top-riser or side-riser***". If the riser is located between the runners and casting it is known as ***side riser***. It is also called a "***live or hot riser***" since it is filled last and containing the hottest metal. If the riser must be placed at the top of the casting or at the end of the mould cavity, then it is called as "top riser or dead or cold riser". Also a riser may be ***open or blind***. Open risers are open to atmosphere at the top surface of the mould. Blind riser is a riser that does not break to the top of the cope and is entirely surrounded by moulding sand.





Shape and size of riser

The risers as designed to solidify last so as to feed enough metal to heavy sections of the casting to make up for the shrinkage before and during solidification. For this,they should loose heat at a slower rate. The risers should be assigned with a high volume to surface area ratio (V/A), for a given size. This will minimize the loss of heat. This can be met if the riser is spherical. The next best shape is of cylinder.

The riser size depends primarily on the metal poured. The riser should be tall enough so that any shrinkage cavity in riser (pipe formation) does not penetrate into the castings. In general ,

Height of cylindrical riser = 1.5 x diameter of riser.

Two main methods for riser size determination are ;

1. **Chvorinov's rule**

It tells us that solidification time is a function of the volume of a casting and its surface area.

Solidification time, t = C $\left(\frac{V}{A}\right)^n$

Where V = volume of casting , A = surface area of casting ,

C is a constant that reflects (a) the mold material,(b) the metal properties (including latent heat), and (c) thetemperature.The parameter n has a value between 1.5 and 2, but usually is taken as 2. Thus, a large solid sphere will solidify and cool to ambient temperature at a much slower rate than will a smaller solid sphere.

For proper riser design, the time for the riser to solidify, calculated chvorinov's rule , must be more than the solidification time for the casting. i.e,

$\left(\frac{V}{A}\right)_{riser} > \left(\frac{V}{A}\right)_{casting}$

In practice, $\left(\frac{V}{A}\right)_{riser}$= 1.05 to 1.075$\left(\frac{V}{A}\right)_{casting}$

Sincevolume and surface area of casting are known $\left(\frac{V}{A}\right)_{casting}$can be determined. Assuming height to diameter ratio for the cylindrical riser, the riser size can be determined.

2. **Caine's formula**

Caine's method was based on an experimentally determined hyperbolic relationship between relative volumes and relative freezing rates of riser and casting to produce castings free from shrinkage cavities.

Freezing ratio or relative freezing time , X = $\frac{\left(\frac{A}{V}\right)\text{casting}}{\left(\frac{A}{V}\right)\text{riser}}$

volume ratio , Y = $\frac{\text{Volume of riser}}{\text{Volume of casting}}$

The caine's formula is given as ,

$$X = \frac{a}{Y-b} + c$$

Where a = freezing characteristics constant

b = liquid–solid solidification contraction,

c = relative freezing rate of riser and casting

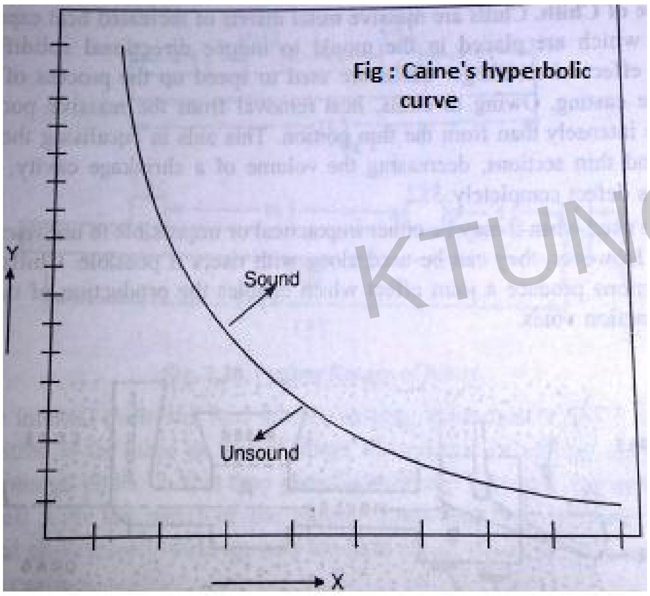


Fig : Caine's hyperbolic curve

Such curves for different cast metals are available in handbooks. To find the riser size for a given casting , the riser diameter and height are assumed . Then knowing the values of a,b and c , the values of X AND Y are calculated. These values of X&Y are plotted on the hyperbolic curve figure. If the value of X&Y met above the curve , the assumed risers size is satisfactory. Otherwise a new assumption is made.

Gating design

Most modern studies of gating systems have been based upon consideration of two laws of fluid dynamics. The first of these, the Equation of Continuity, states that the volume rate of flow is constant throughout a system and is expressed by

$$Q = A_1V_1 = A_2V_2$$

where Q = volume rate of flow, A = cross-sectional area of flow passage, V = linear velocity of flow

The linear velocity of flow in a system is related to other factors in Bernoulli's Theorem, which states that the total energy of unit weight offluid is constant throughout a system:

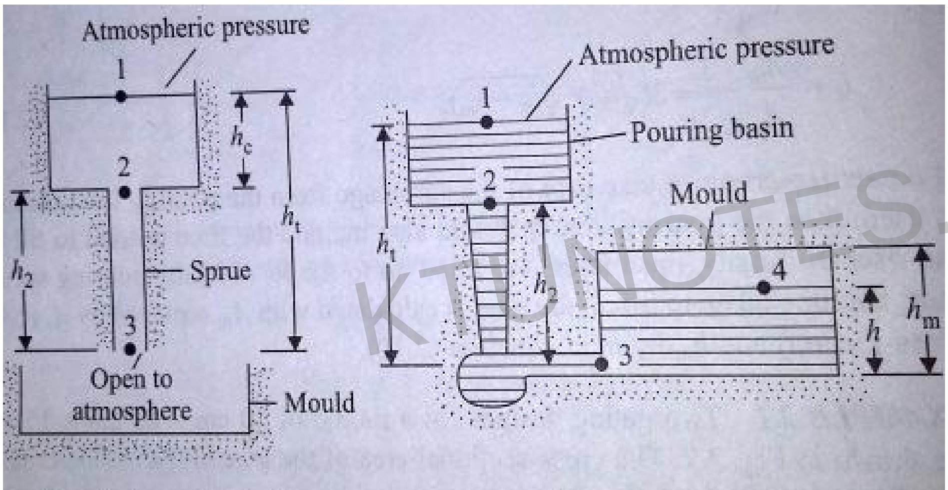
$$\frac{V_1^2}{2g} + h_1 + \frac{P_1}{\rho g} = \frac{V_2^2}{2g} + h_2 + \frac{P_2}{\rho g}$$

where V = linear velocity of flow,h = height above the datum plane,P = pressure,ρ = density.

Gating designs can be classified into three categories ;

(i) Vertical gating (ii)Bottom gating (iii) Horizontal gating

In vertical gating , the liquid metal is poured vertically to fill the mould with atmospheric pressure at the base. In bottom gating , the liquid metal is filled in the mould from bottom to top ,thus avoiding splashing and oxidation associated with vertical gating. In horizontal gating , additional horizontal portions are introduced for better distribution of metal with minimum turbulence.



(a) Simple vertical gating (b) Bottom gating

Simple calculations based on principles of fluid mechanics can lead to an estimate of the time taken to fill the mould. Consider vertical gating system (fig1). Apply Bernoulli's equation between points 1 and 3. It is assumed that the pressure at points 1 and 3 are equal and that level at point 1 is maintained constant. Thus velocity at 1 is zero. Moreover, the frictional losses are neglected. Beroulli's equation between point 1 and 3 ,

$$\frac{V_1^2}{2g} + h_1 + \frac{P_1}{\rho g} = \frac{V_3^2}{2g} + h_3 + \frac{P_3}{\rho g}$$

[$P_1 = P_3$, $V_1 = 0$, $h_3 = 0$, $h_1 = h_t$]

$$gh_1 = \frac{V_3^2}{2} \text{ or } V_3 = \sqrt{2gh_t} = V_g$$

Where V_3 velocity of liquid metal at the gate , subsequently referred to as V_g.

So , time taken to fill up the mould (t_f) is obtained as ,

$t_f = \frac{V}{A_g V_3}$, Where A_g and V are the cross sectional area of the gate and volume of the mould respectively.

In bottom gating (fig 2) apply Bernoulli's equation between points 1 and 3 ,

$$\frac{V_1^2}{2g} + h_1 + \frac{P_1}{\rho g} = \frac{V_3^2}{2g} + h_3 + \frac{P_3}{\rho g}$$

[$V_1 = 0$, $h_3 = 0$, $h_1 = h_t$]

We get ,

$$gh_t = \frac{P_3}{\rho_m} + \frac{v_3^2}{2} \quad \text{-----(1)}$$

ρ_m is the density of the molten metal , and P_3 is the gauge pressure at state 3 and h_t is assumed to be constant.

Furthur applying Bernoulli's equation between points 3 and 4 , with assumption that v_g is very small and all kinetic energy at station 3 is lost after the liquid metal enters the mould , we can write

$$\frac{P_3}{\rho_m} = gh \quad \text{-----(2)}$$

From equation 1 and 2 , the velocity of the liquid metal at the gate we obtain is ,

$$v_g = v_3 = \sqrt{2g(h_t - h)} \quad \text{------(3)}$$

Equation 3 gives the velocity of a jet discharging against a static head h ,making the effective head as

(h_t – h). Now, for instant shown, let the metal level in the mould move up through a height dh in a time interval dt; A_m and A_g be the cross sectional areas of the mould and the gate respectively. Then,

$$A_m dh = A_g V_g dt \quad \text{-----------(4)}$$

Using equations 3 and 4, we get

$$\frac{1}{\sqrt{2g}} \frac{dh}{\sqrt{h_t - h}} = \frac{A_g}{A_m} dt \quad \text{--------(5)}$$

At t = 0 , h = 0

t = t_f (filling time) , h = h_m

Integrating equation (5) between the limits , we have ,

$$\frac{1}{\sqrt{2g}} \int_0^{h_0} \frac{dh}{\sqrt{h_t - h}} = \frac{A_g}{A_m} \int_0^{t_f} dt$$

Or $$t_f = \frac{A_m}{A_g} \frac{1}{\sqrt{2g}} 2\left(\sqrt{h_t} - \sqrt{h_t - h_m}\right) \quad \text{-------(6)}$$

Gating ratio

It is used to describe the relative cross sectional area of components of a gating system.

gating ratio ;

a : b : c

where a = cross-sectional area of sprue (or downrunner) , b = total cross-sectional area of runners,

c = total cross-sectional area of ingates.

Generally the ratio is 1:3:3

Depending upon different gating ratio , gating systems are classified as

- **Pressurised system (High ratio)**
- **Unpressurised system (Low ratio)**

Pressurised gating system

- Total cross sectional area decreases toward the mould cavity
- Back pressure is maintained by the restriction in metal flow
- Flow of liquid (volume) is almost equal from all gates
- Back pressure helps in reducing the aspiration as the sprue always run full
- Because of restriction the metal flows at high velocity leading to more turbulence and chance of erosion (metal enter the mould producing a jet effect)

Unpressurised gating system

- Total cross sectional area increases towards the mould cavity
- Restriction only at the bottom of the sprue
- Flow of liquid (volume) is different from all gates
- Aspiration in gating system as the system never runs full
- Less turbulence

Heat transfer

The resistances to heat flow from the interior ofthe casting are:

1. The liquid.2. The solidified metal.

3. The metal/mould interface.4. The mould.

5. The surroundings of the mould.

In nearly all cases resistance (I) is negligible. The turbulent flow during pouring andmixing quickly transport heat and so smooth outtemperature gradients.In many instances. resistance (5) is also negligiblein practice.

Heat flow at different locations in the system is a complex phenomenon and dependson several factors relating to the material cast and the mold and process parameters.For instance, in casting thin sections, the metal flow rates must be high enough toavoid premature chilling and solidification. On the other hand, the flow rate mustnot be so high as to cause excessive turbulence-with its detrimental effects on thecasting process.

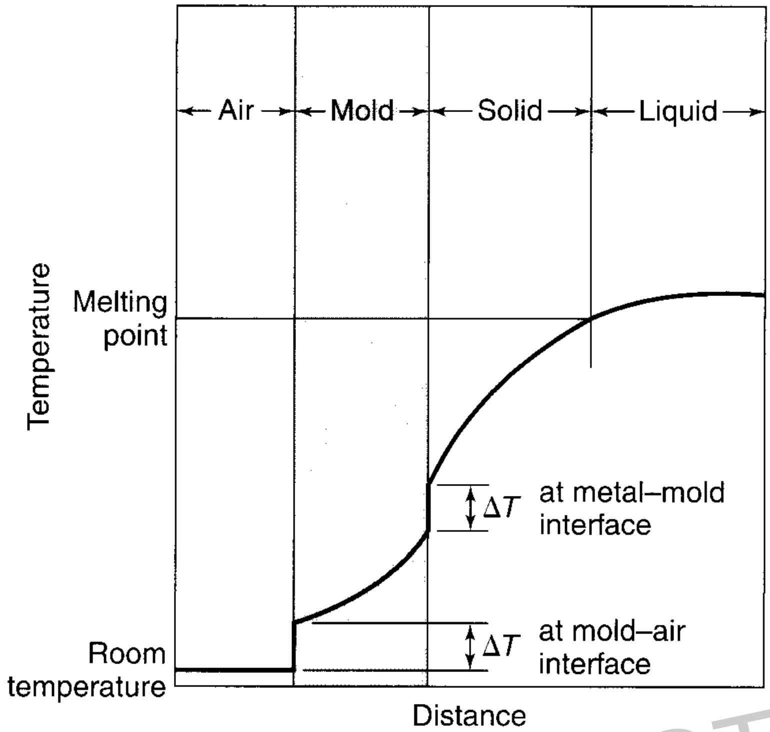


Fig . Temperature distribution at the interface of the mold wall and the liquid metal during the solidification of metals in casting

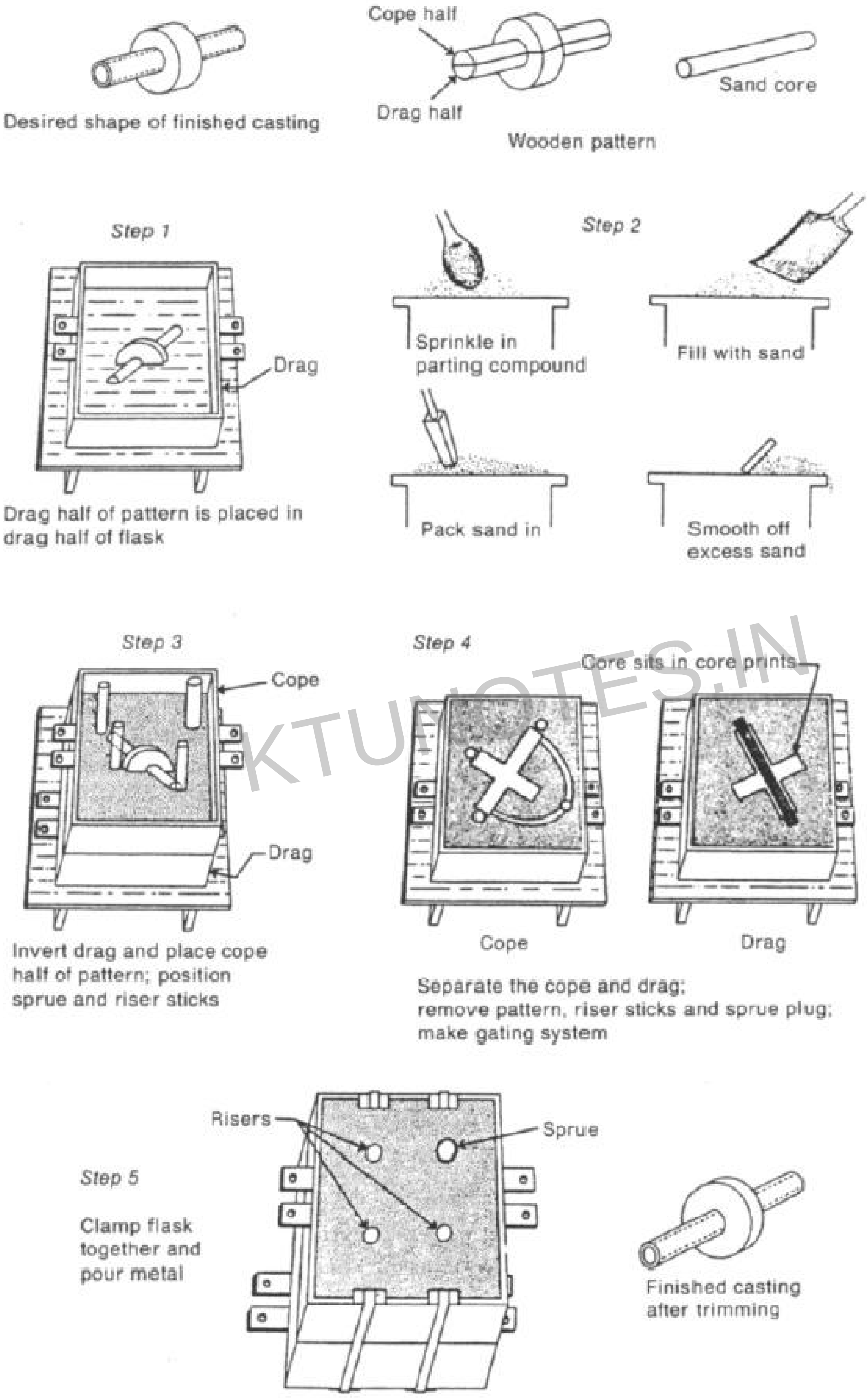
The temperature drop at the air-mold and mold-metalinterfaces is caused by the presence of boundary layers and imperfect contact atthese interfaces. The shape of the curve depends on thethermal properties of the molten metal and the mold.

Expendable-mold, Permanent-pattern Casting Processes

Sand, shell mold, plaster mold, ceramic mold

Sand casting

As the name implies sand is used as the mouldmaterial. The process has the advantages of low capital investment, design flexibilityand large alloy selection. The major steps involved when sand casting a pipe with anintegral flange are illustrated in Fig. A split wooden or metal master *pattern* ismade of the shape to be cast. One half of the pattern is positioned on a bottomboard and surrounded by the *drag* (bottom) half of the moulding *flask* (step 1). Aparting compound (step 2), such as talc, is sprinkled over the pattern to facilitateseparation of the pattern from the mould prior to pouring the liquid metal. Often afine sand is placed against the pattern and then a coarser sand mixture is used tofill the rest of the drag. A fine sand provides a relatively good surface finish on thecast part. The sand is packed tightly to ensure that the shape of the pattern is retainedand excess sand removed. The drag is inverted and the top half, or *cope,* of the mouldprepared in the same manner as the drag (step 3).


Desired shape of finished casting
Cope half
Drag half
Wooden pattern
Sand core
Step 1
Drag
Drag half of pattern is placed in drag half of flask
Step 2
Sprinkle in parting compound
Fill with sand
Pack sand in
Smooth off excess sand
Step 3
Cope
Drag
Invert drag and place cope half of pattern; position sprue and riser sticks
Step 4
Core sits in core prints
Cope
Drag
Separate the cope and drag; remove pattern, riser sticks and sprue plug; make gating system
Risers
Sprue
Step 5
Clamp flask together and pour metal
Finished casting after trimming

A feeding system for delivery of the molten metal is formed in the cope. Thistypically consists of a *pouring basin, a sprue* (vertical metal transfer channel), *runners*(horizontal transfer channels) and *ingates* connecting the runners to the mould cavity.The feeding

system can be made part of the pattern or can be carved into the splitmould after the pattern has been removed. In addition to the feeding system, *riser*cavities are designed into strategic positions, as shown in Fig. These serve asreservoirs of molten metal which are fed into the casting as it cools to compensatefor solidification shrinkage.

The cope and drag are separated and the pattern removed (step 4). A *core* of sandmixed with resin or ceramic is placed in the mould to form the hollow of the pipe. Thestrength of the core must be higher than the rest of the mould to prevent damage fromthe inrush of molten metal. The cope and drag are reassembled (step 5) and clampedtogether, ready for receipt of the metal. The metal is poured from a small ladle intothe sprue, flows into the mould cavity and solidifies. Once solidification is completethe mould is broken and the cast part removed, all sand cleaned off and the riserand feeding system are cut away.

Shell Molding

the basic steps shell moulding aredescribed below and illustrated in Fig.

1. The individual grains of fine silica sand are first precoated with a thin layer of thermosettingphenolic resin and heat-sensitive liquid catalyst. This material is thendumped, blown, or shot onto a metal pattern (usually some form of cast iron) that hasbeen preheated to a temperature between 230° and 315°C (450° and 600°F). Duringa period of sustained contact, heat from the pattern partially cures (polymerizes andcrosslinks) a layer of material. This forms a strong, solid-bonded region adjacent tothe pattern.The actual thickness of cured material depends on the pattern temperatureand the time of contact but typically ranges between 10 and 20mm(0.4 to 0.8 in.).

2. The pattern and sand mixture are then inverted, allowing the excess (uncured) sandto drop free. Only the layer of partially cured material remains adhered to the pattern.

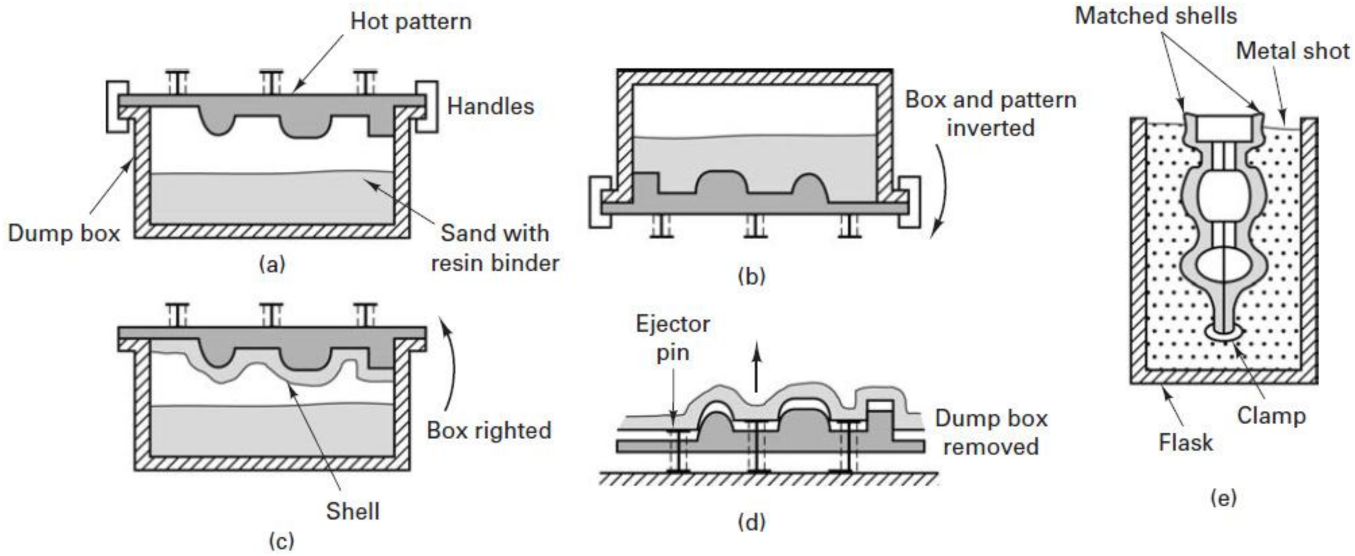
3. The pattern with adhering shell is then placed in an oven, where additional heatingcompletes the curing process.

4. The hardened shell, with tensile strength between 2.4–3.1 MPa, isthen stripped from the pattern.

5. Two or more shells are then clamped or glued together with a thermoset adhesive toproduce a mold, which may be poured immediately or stored almost indefinitely.

6. To provide extra support during the pour, shell molds are often placed in a pouring jacket and surrounded with metal shot, sand, or gravel.

Advantages : excellent dimensional accuracy ,smooth casting surface ,Cleaning,machining, and other finishing costs can be significantly reduced



Plaster-mold Casting

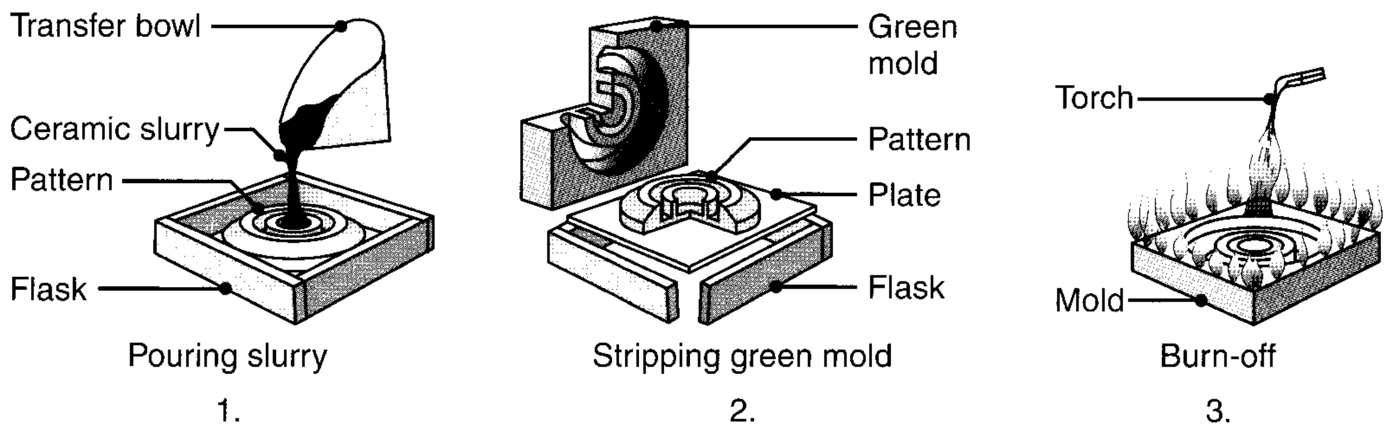
In the plaster-molding process, the mold is made of plaster of paris (gypsum or calcium sulfate) with the addition of tale and silica flour to improve strength and to control the time required for the plaster to set. These components are mixed with water, and the resulting slurry is poured over the pattern. After the plaster sets (usually within 15 minutes), it is removed, and the mold is dried at a temperature range of 120° to 260°C. Higher drying temperatures may be used, depending on the type of plaster. The mold halves are assembled to form the mold cavity and are preheated to about 120°C. The molten metal is then poured into the mold.

Because plaster molds have very low permeability, gases evolved during solidificationof the metal cannot escape. Consequently, the molten metal is poured eitherin a vacuum or under pressure. Mold permeability can be increased substantially bythe Antioch process, in which the molds are dehydrated in an autoclat/e (pressurizedoven) for 6 to 12 hours and then rehydrated in air for 14 hours. Another method ofincreasing the permeability of the mold is to use foamed plaster containing trappedair bubbles.

Ceramic-mold Casting

The ceramic-mold casting process (also called cope-and-drag investment casting) issimilar to the plaster-mold process, except that it uses refractory mold materialssuitable for high-temperature applications.The slurry is a mixture of fine-grained zircon ($ZrSiO_4$), aluminum oxide, andfused silica, which are mixed with bonding agents and poured over the pattern(Fig. 11.10), which has been placed in a flask.

The pattern may be made of wood or metal. After setting, the molds (ceramicfacings) are removed, dried, ignited to burn off volatile matter, and baked. The moldsare clamped firmly and used as all-ceramic molds. In the Shaw process, the ceramic facingsare backed by fireclay (which resists high temperatures) to give strength to themold. The facings then are assembled into a complete mold, ready to be poured



Expendable-mold, Expendable-pattern Casting Processes

Evaporative-pattern Casting (Lost-foam Process)

The evaporative-pattern casting process uses a polystyrene pattern, which evaporatesupon contact with molten metal to form a cavity for the casting; this process isalso known as ***lost-foam casting*** and falls under the trade name ***full-mold process***. Ithas become one of the more important casting processes for ferrous and nonferrousmetals, particularly for the automotive industry.

In this process, polystyrene beads containing 5 to 8% pentane (a volatile hydrocarbon)are placed in a preheated die that is usually made of aluminum. Thepolystyrene expands and takes the shape of the die cavity. Additional heat is appliedto fuse and bond the beads together. The die is then cooled and opened, and thepolystyrene pattern is removed.

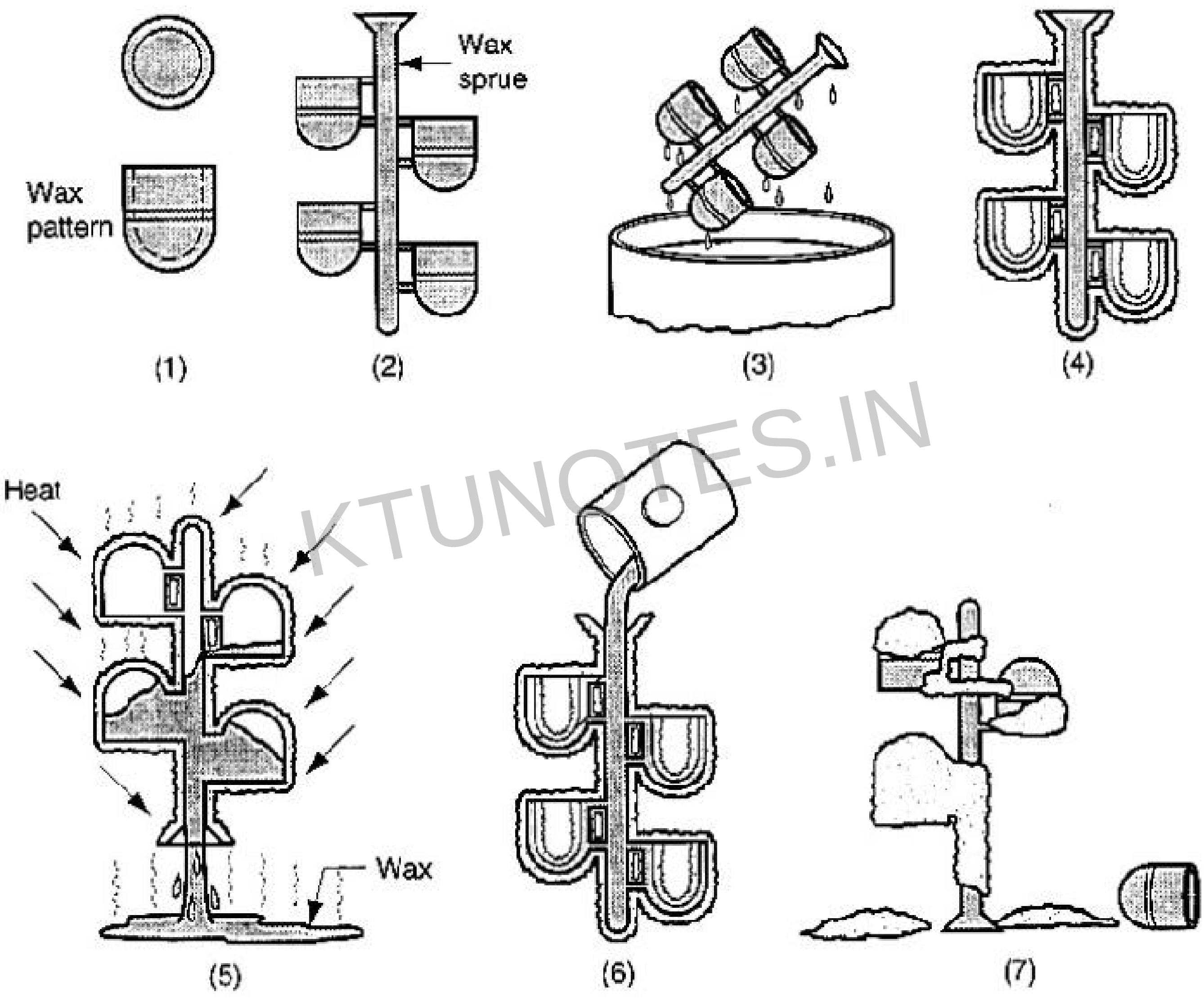
The pattern is coated with a water-based refractory slurry, dried, and placed ina flask. The flask is then filled with loose, fine sand, which surrounds and supportsthe pattern and may be dried or mixed with bonding agents to give it additionalstrength. The sand is compacted periodically, without removing the polystyrenepattern; then the molten metal is poured into the mold. The molten metalvaporizes the pattern and fills the mold cavity, completely replacing the space previouslyoccupied by the polystyrene. Any degradation products from the polystyreneare vented into the surrounding sand.

Advantages over other castingmethods:

- The process is relatively simple because there are no parting lines, cores, or riser systems. Hence, it has design flexibility.
- Inexpensive flasks are satisfactory for the process.
- Polystyrene is inexpensive and can be processed easily into patterns having complex shapes, various sizes, and fine surface detail.
- The casting requires minimal finishing and cleaning operations.
- The process can be automated and is economical for long production runs. However, major factors are the cost to produce the die used for expanding the polystyrene beads to make the pattern and the need for two sets of tooling.

Investment Casting

Steps : 1) Wax patterns are produced (2) Several patterns are attached to a sprue to form a pattern tree (3) The pattern tree is coated with a thin layer of refractory material.(4)The full mould is formed by covering the coated tree with sufficient refractory material to make it rigid. (5) The mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity.(6) The mold is preheated to a high temperature , which ensures that all contaminants are eliminated from the mold; it also permit the liquid metal to flow more easily into the detailed cavity; the molten metal is poured; it solidifies ,and (7) The mold is broken away from the finished casting. Parts are separated from the sprue.



Permanent-mold Casting Processes

In permanent-mold casting (also called hard-mold casting), two halves of a mold aremade from materials with high resistance to erosion and thermal fatigue, such as castiron, steel, bronze, graphite, or refractory metal alloys. Typical parts made are automobilepistons, cylinder heads, connecting rods, gear blanks for appliances, andkitchenware.

In order to increase the life of permanent molds, the surfaces of the mold cavityusually are coated with a refractory slurry (such as sodium silicate and clay) orsprayed with graphite every few castings. These coatings also serve as parting agentsand as thermal barriers, thus controlling the rate of cooling of the casting. Mechanicalejectors (such as pins located in various parts of the mold) may be required for the removalof complex castings; ejectors usually leave small round impressions.

The molds are clamped together by mechanical means and heated to about150° to 200°C to facilitate metal flow and reduce thermal damage to the dies due tohigh-temperature gradients. Molten metal is then poured through the gating system.After solidification, the molds are opened and the casting is removed. The mold oftenincorporates special cooling features, such as a means of pumping cooling waterthrough the channels located in the mold and the use of cooling fins. Although thepermanent-mold casting operation can be performed manually, it is often automatedfor large production runs. The process is used mostly for aluminum, magnesium, andcopper alloys, as well as for gray iron, because of their generally lower melting points,although steels also can be cast using graphite or heat-resistant metal molds.Permanent-mold casting produces castings with a good surface finish, close dimensionaltolerances, uniform and good mechanical properties, and at high production rates.

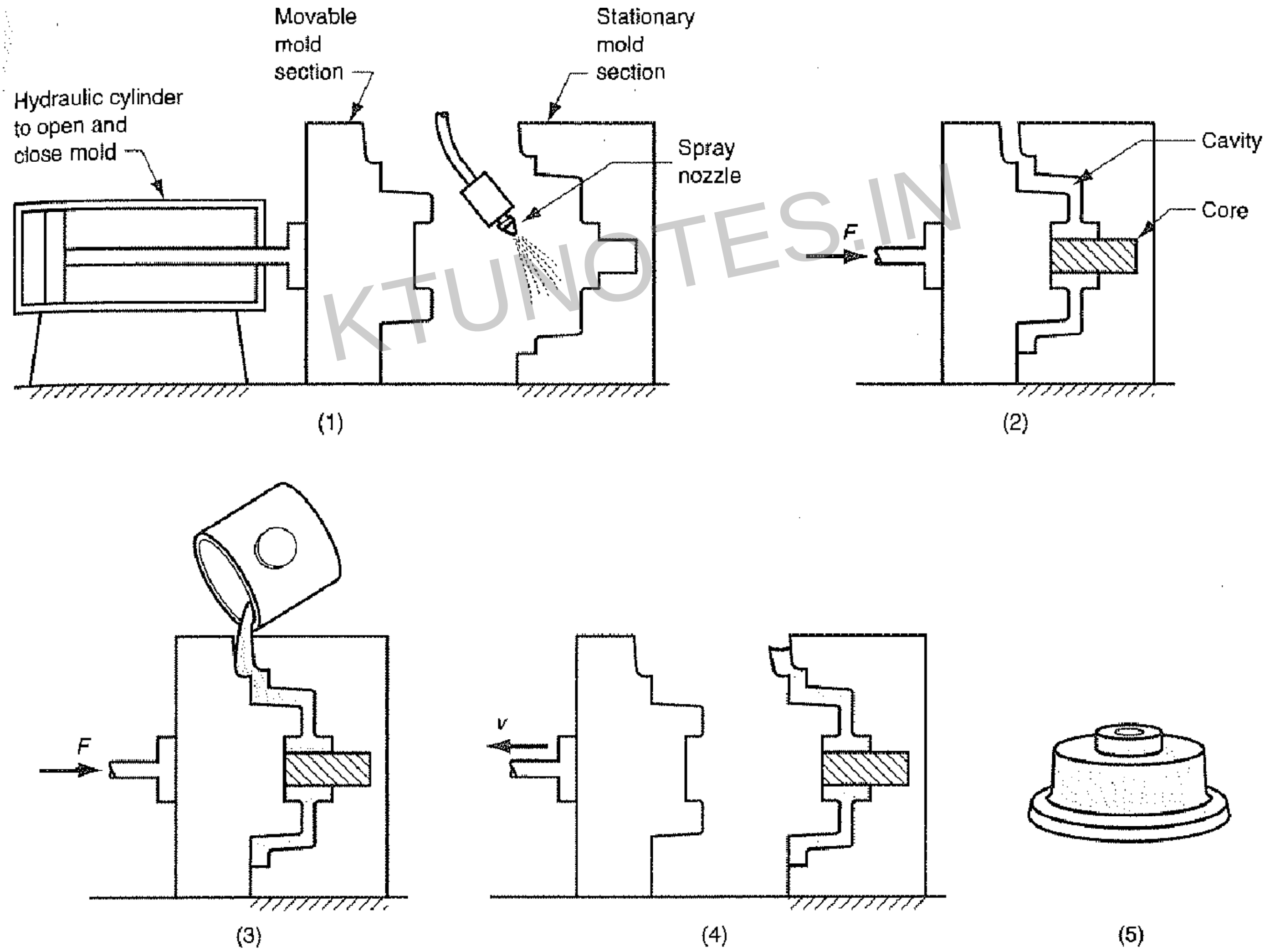


Fig : Steps in permanent mould casting (1) mold is prehestedand coated (2) cores (if used) are inserted , mold is closed (3) molten metal is poured into the mold (4) mold is opened (5) finished part.

Vacuum Casting(or countergrazvity lowpressure(CL) process)

In the vacuum-casting process, a mixture of fine sand and urethane is moldedover metal dies and cured with amine vapor. The mold is then held with a robot armand immersed partially into molten metal held in an induction furnace. The metalmay be melted in air (CLA process) or in a vacuum (CLV process). The vacuum reducesthe air pressure inside the mold to about two-thirds of atmospheric pressure,thus drawing the molten metal into the mold cavities through a gate in the bottom ofthe mold. The metal in the furnace is usually at a temperature of 55°C above the liquidustemperature of the alloy. Consequently, it begins to solidify within a very shorttime. After the mold is filled, it is withdrawn from the molten metal.

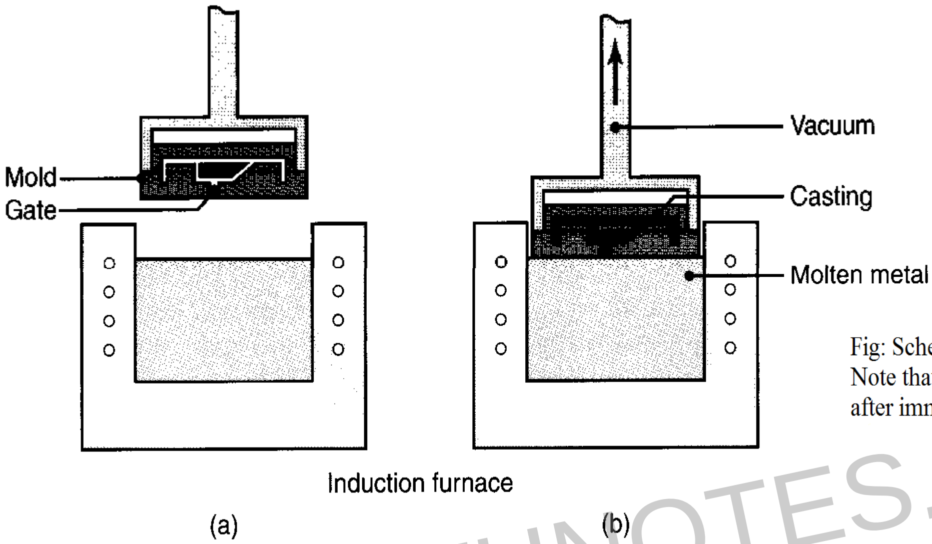


Fig: Schematic illustration of the vacuum-casting process. Note that the mold has a bottom gate. (a) Before and (b) after immersion of the mold into the molten metal.

Slush Casting

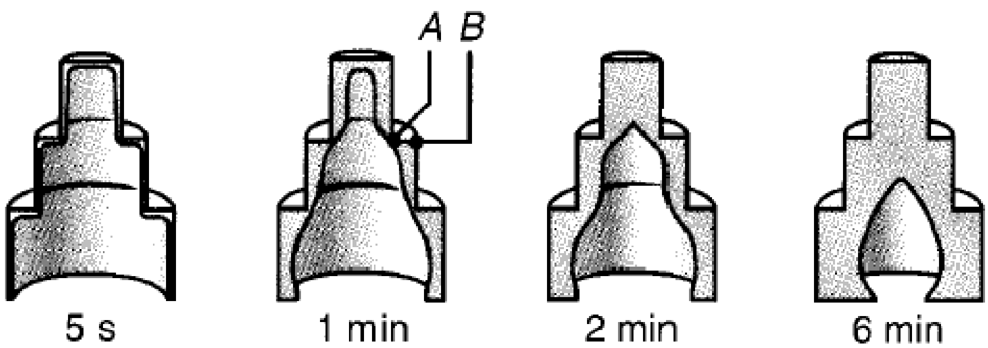


Fig: Solidified skin on a steel casting. The remaining molten metal is poured out at the times indicated in the figure. Hollow ornamental and decorative objects are made by a process called slush casting, which is based on this principle.

Hollow castings with thin walls can be made by permanent-mold casting using the principle illustrated in the above figure: a process called slush casting. This process is suitable for small production runs and generally is used for making ornamental and decorative objects (such as lamp bases and stems) and toys from low-melting-point metals such as zinc, tin, and lead alloys.

The molten metal is poured into the metal mold. After the desired thickness of solidified skin is obtained, the mold is inverted (or slung) and the remaining liquid metal is poured out. The mold halves then are opened and the casting is removed. This operation is similar to making hollow chocolate shapes, eggs, and other confectionaries.

Pressure Casting

In the two permanent-mold processes described previously, the molten metal flowsinto the mold cavity by gravity. In pressure casting (also called pressure pouring orlow-pressure casting), the molten metal is forced upward by gas pressure into a graphite or metal mold. The pressure is maintained until the metal has solidifiedcompletely in the mold. The molten metal also may be forced upward by a vacuum,which also removes dissolved gases and produces a casting with lower porosity.Pressure casting generally is used for high-quality castings, such as steel railroad-carwheels, although these wheels also may be cast in sand molds or semipermanentmolds made of graphite and sand.

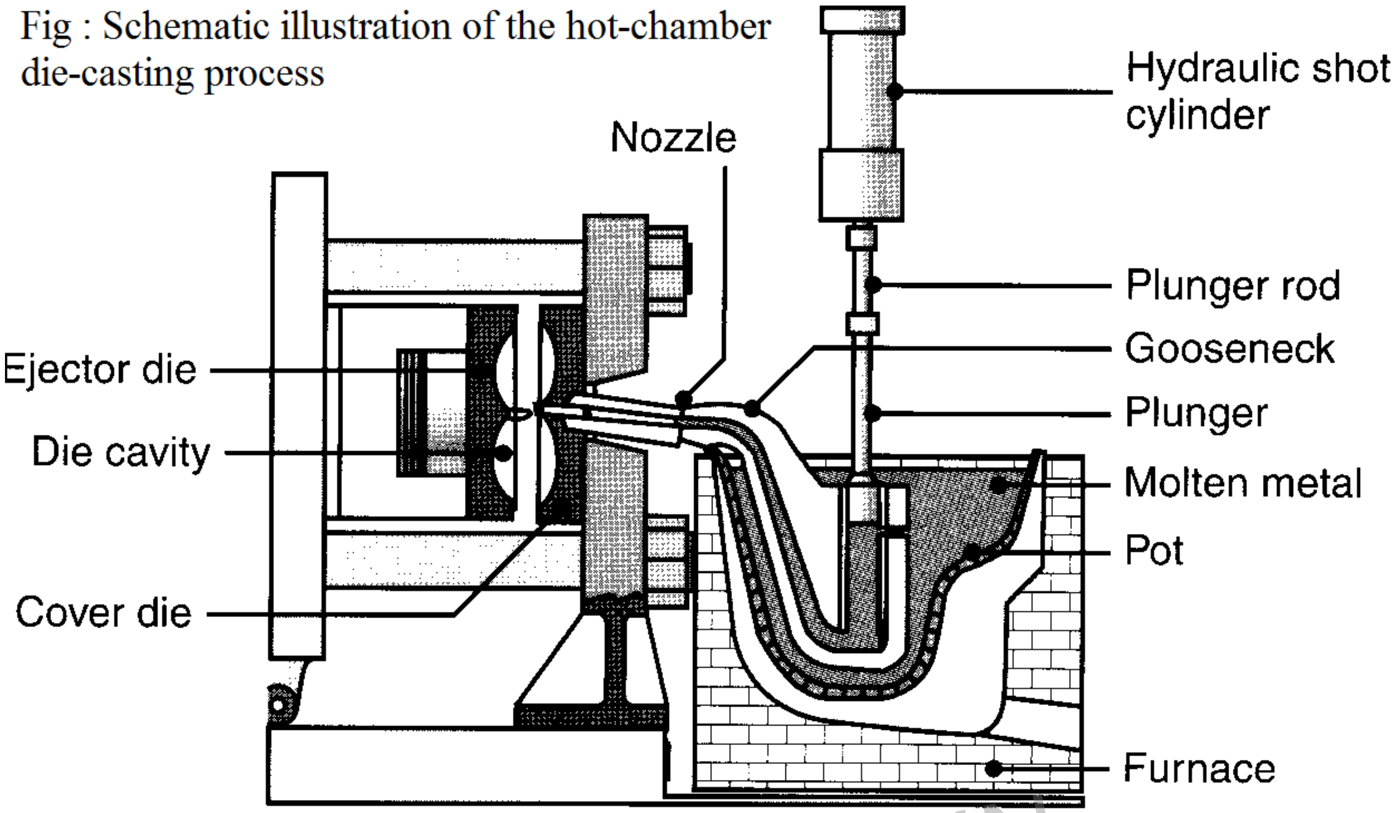
Die Casting

Typical parts made by die casting are housings, business-machine and appliancecomponents, hand-tool components, and toys. The weight of most castings rangesfrom less than 90 g to about 25 kg. Equipment costs, particularly the cost of dies,are somewhat high, but labor costs are generally low, because the process is semi-orfully automated. Die casting is economical for large production runs.

In the die-casting process, molten metal is forced into the die cavity at pressuresranging from 0.7 to 700 MPa. There are two basic types of die-casting machines:hot-chamber and cold-chamber machines.

The hot-chamber process involves the use of a piston, which forcesa certain volume of metal into the die cavity through a gooseneck and nozzle.Pressures range up to 35 MPa, with an average of about 15 MPa. The metal is heldunder pressure until it solidifies in the die. To improve die life and to aid in rapid metalcooling (thereby reducing cycle time) dies usually are cooled by circulating water or oilthrough various passageways in the die block. Low-melting-point alloys (such as zinc,magnesium, tin, and lead) commonly are cast using this process. Cycle times usuallyrange from 200 to 300 shots (individual injections) per hour for zinc, although verysmall components, such as zipper teeth, can be cast at rates of 18,000 shots per hour.

Fig : Schematic illustration of the hot-chamber die-casting process



In the cold-chamber process, molten metal is poured into theinjection cylinder (shot chamber). The chamber is not heated-hence the term coldchamber. The metal is forced into the die cavity at pressures usually ranging from 20to 70 MPa, although they may be as high as 150 MPa.

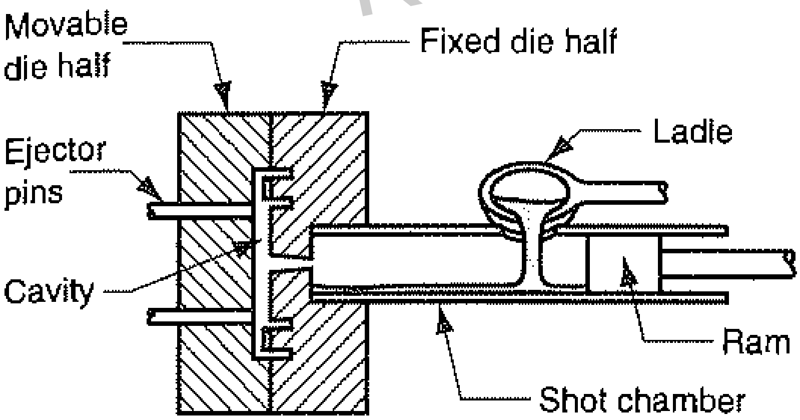


Fig:Schematic illustration of cold chamber process

Centrifugal Casting

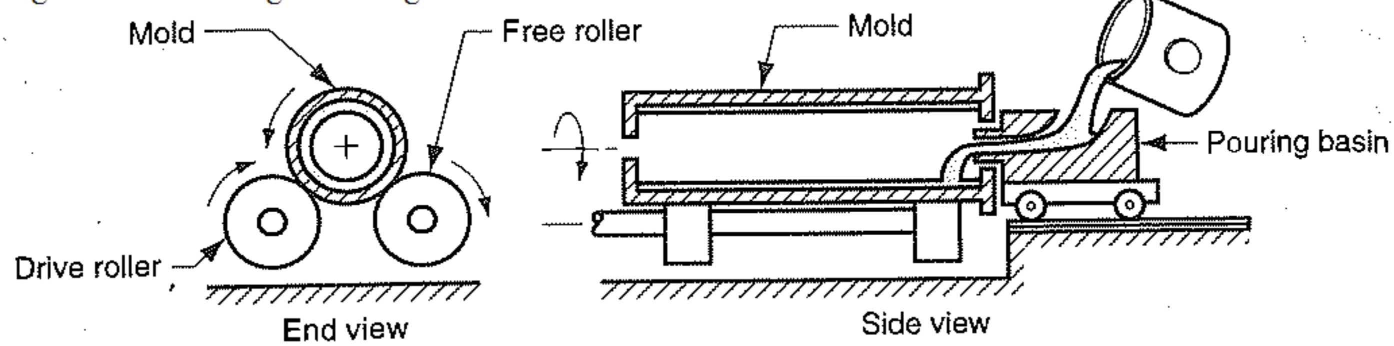
There are three types of centrifugal casting: true centrifugal casting, semicentrifugal casting, and centrifuging.

True Centrifugal Casting.

In true centrifugal casting, hollow cylindrical parts (suchas pipes, gun barrels, bushings, engine-cylinder liners, bearing rings with or withoutflanges, and street lampposts) are produced by the technique shown in Fig. Inthis process, molten metal is poured into a rotating mold. The axis of rotation is usuallyhorizontal, but can be vertical for short workpieces. Molds are made of steel,iron, or graphite and may be coated with a refractory lining to increase mold life. Themold surfaces can be shaped so that pipes with various external designs can be cast.The inner surface of the casting remains cylindrical, because the molten metal is distributeduniformly by the centrifugal forces. However, because of density differences,lighter elements (such as dross, impurities, and pieces of the refractory lining) tend tocollect on the inner surface of the casting. Consequently, the properties of the castingcan vary throughout its thickness.

Cylindrical parts ranging from 13 mm to 3 m in diameter and 16 m long canbe cast centrifugally with wall thicknesses ranging from 6 to 125 mm. The pressuregenerated by the centrifugal force is high (as much as 150 g); such high pressureis necessary for casting thick-walled parts. Castings with good quality,dimensional accuracy, and external surface detail are produced by this process.

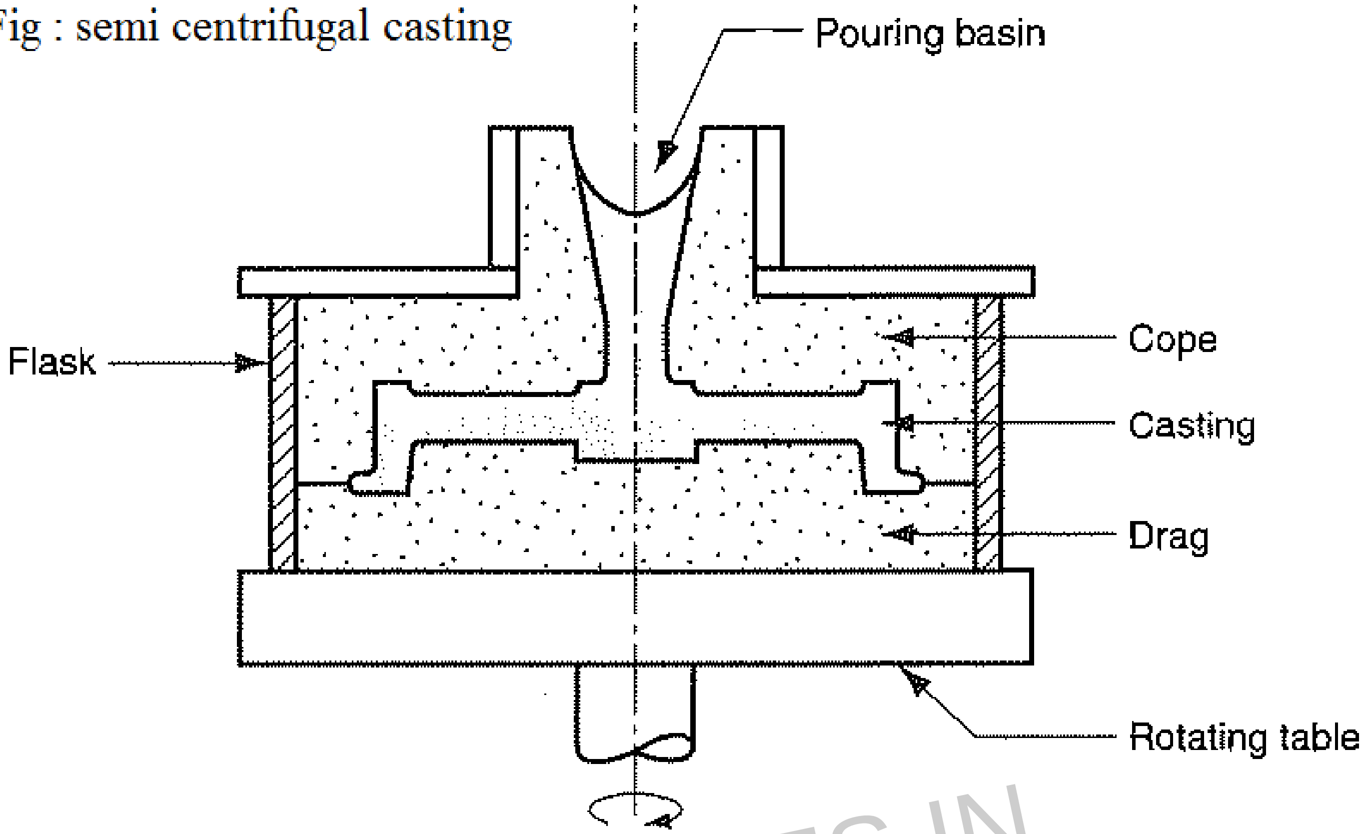
Fig : True centrifugal casting



Semicentrifugal Casting

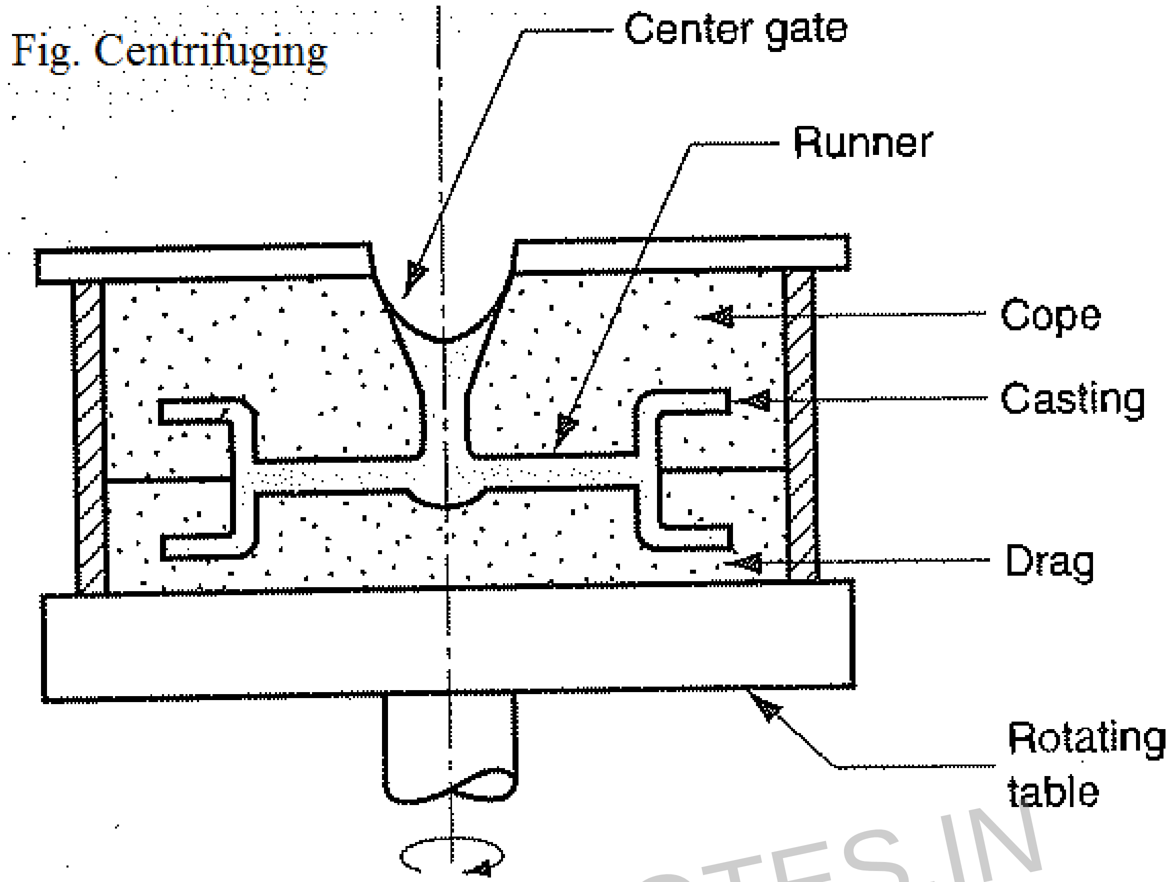
This method is used to cast parts with rotational symmetry, such as a wheel with spokes. Density of metal in the final casting is greater in the outer sections than at the centre of rotation. The process is often used on parts in which the centre of the casting is machined away , thus eliminating the portion of the casting where quality is lowest.

Fig : semi centrifugal casting



Centrifuging

In centrifuging (also called centrifuge casting), mold cavities of anyshape are placed at a certain distance from the axis of rotation. The molten metal ispoured from the center and is forced into the mold by centrifugal forces.The properties of the castings can vary by distance from the axis of rotation, as intrue centrifugal casting. The process is used for smaller parts ,and radial symmetry of the part is not a requirement as it is for the other two centrifugal casting methods.

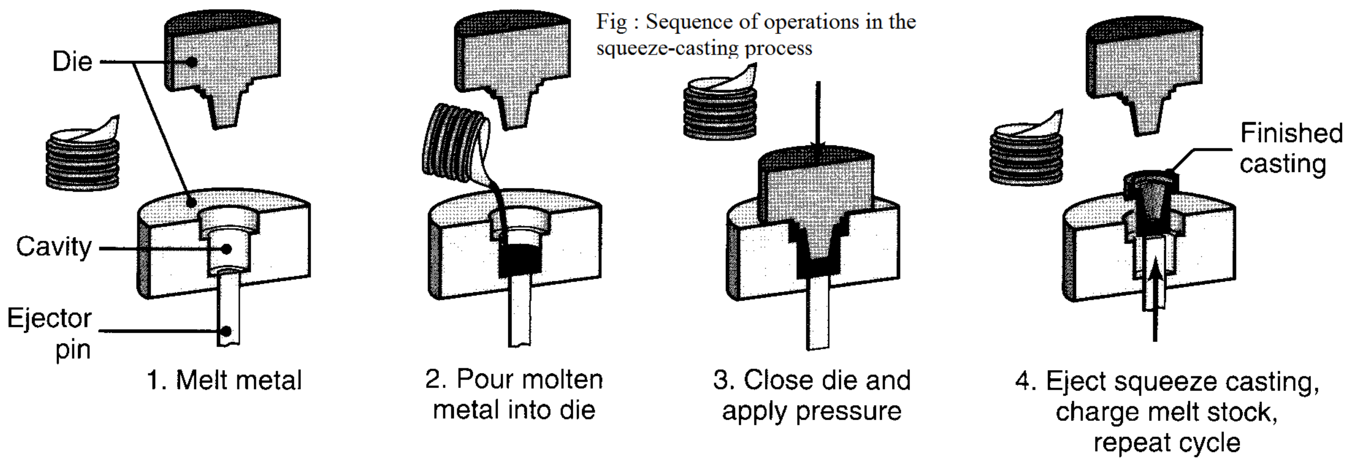


Squeeze Casting and Semisolid-metal Forming

Squeeze Casting

In the *squeeze casting* process, molten metal is introduced into the die cavity of ametal mold, using large gate areas and slow metal velocities to avoid turbulence.Whenthe cavity has filled, high pressure (20 to 175 MPa) is then appliedand maintained during the subsequent solidification.The pressure applied keeps the entrapped gases insolution, and the contact under high pressure at the die-metal interface promotesrapid heat transfer, thus resulting in a fine microstructure with good mechanicalproperties.

Fig : Sequence of operations in the squeeze-casting process



Semisolid-metal Forming

For most alloy compositions, there is a range of temperatures where liquid andsolid coexist, and several techniques have been developed to produce shapes from this *semisolid* material.

In the ***rheocasting*** process, molten metal is cooled to the semisolidstate with constant stirring.The stirring or shearing action breaks up the dendrites, producinga slurry of rounded particles of solid in a liquid melt.This slurry, with about a 30%solid content, can be readily shaped by high-pressure injection into metal dies. Becausethe slurry contains no superheat and is already partially solidified, it freezes quickly.

In the ***thixocasting*** variation, there is no handling of molten metal.The material isfirst subjected to special processing (stirring during solidification as in rheocasting)to produce solid blocks or bars with a nondendritic structure.When reheated to thesemisolid condition, the ***thixotropic material***can be handled like a solid but flows like aliquid when agitated or squeezed. (thixotropic behavior ofalloys is that the viscosity decreases when the liquid metal is agitated)The solid material is then cut to prescribed length,reheated to a semisolid state where the material is about 40% liquid and 60% solid, mechanicallytransferred to the shot chamber of a cold-chamber die-casting machine, andinjected under pressure.

Defects in casting

Defects in casting occurs due to defects in the following :

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

Various defects in casting are,

1. **Blow: It** is a fairly large well rounded cavity produced by the gases which displace the molten metal at the cope surface of casting. Blows usually occur on a convex casting surface and can be avoided by having a proper venting and an adequate permeability.

2 . **Scar** : It is a shallow blow , usually found on a flat casting surface .

3. **Blister** : This is a scar covered by thin layer of a metal

4. **Gas holes** : These refer to the entrapped gas bubbles having a nearly spherical shape , and occur when an excessive amount of gases is dissolved in the liquid metal.

5. **Pin holes** : These are nothing but tiny blow holes and occur either at or just below the casting surface. Normally these are found in large numbers and are almost uniformly distributed in the entire casting surface.

6. **Porosity** : It indicates very small holes uniformly dispersed trhoughout a casting.It arises when there is a decrease in gas solubility during solidification.

7. **Drop** : It is an irregularly shaped projection on the cope surface of a casting . This is caused by dropping of sand from the cope or other overhanging projectin into the mould. Adequate strength of sand and use of gaggers can help in avoiding drop.

8. **Inclusion** : It refers to a non metallic particle in the metal matrix, It becomes highly desirable when segregated.

9.**Dross** : Lighter impurities appearing on the top surafce of a casting is called dross.It can be taken care of at the pouring stage by using items such as a stariner and skim bob.

10.**Dirt** : Sand particles dropping out of the cope gets embedded on the top surface of a casting.When removed these leave small , angular holes , known as dirt.

11.**Wash** : A low projection on the drag surface of a casting commencing near the gate is called wash.This is caused by the erosion of sand due to the high velocity of liquid meatl in the bottom gating.

12.**Buckl**e : It refers to a long , fairly shallow , broad , vee shaped depression occuring in the surface od a flat casting of a high temperature metal. At high temperature , an expansion of thin layer of sand at the mould face takes place before the liquid metal at the mould face solidifies.As this expansion is obstructed by the flak , the mould face tends to bulge out forming the vee shape. A proper amount of volatile additive is essential for overcoming this defect.

13.**Scab** : This refers to rough thn layer of a metal protruding above the casting surface ,on top of a thin layer of sand.

14.**Rat tail** : A long , shallow angular depression normally found in a thin casting. The reason for its formation is same as that of buckle. The reason for its formation is the same as that for a buckle. Here, instead of the expanding sand upheaving , the compressed layer fails by one layer , gliding over the other.

15**. Penetration** : If the mold surface is too soft and porous , the liquid metal may flow between the sand particles up to a distance , into the mould. This causes rough ,porous projections and this defect is called penetration.

16. **Swell** : This defect is found on the vertical surfaces of a casting if the molding sand is deformed by the hydrostatic pressure caused by the high moisture content in the sand.

17**. Misrun** : Many a time , the liquid metal may , due to insufficient superheat , start freezing before reaching the farthest point of the mould cavity. This defect is called as misrun.

18. **Cold shut** : For a casting with two gates at its two sides , the misrun may show up at the centre of the casting. When this happens , the defect is called cold shut.

19. **Hot tear** : A crack that develops in a casting due to high residual stresses is called a hot tear.

20. **Shrinkage cavity** : An improper riser may give rise to a defect called shrinkage cavity.

21. **Shift** : A misalignment between two halves of a mold or of a core may give rise to a defective casting. Accordingly this defect is called a mold shift or core shift.

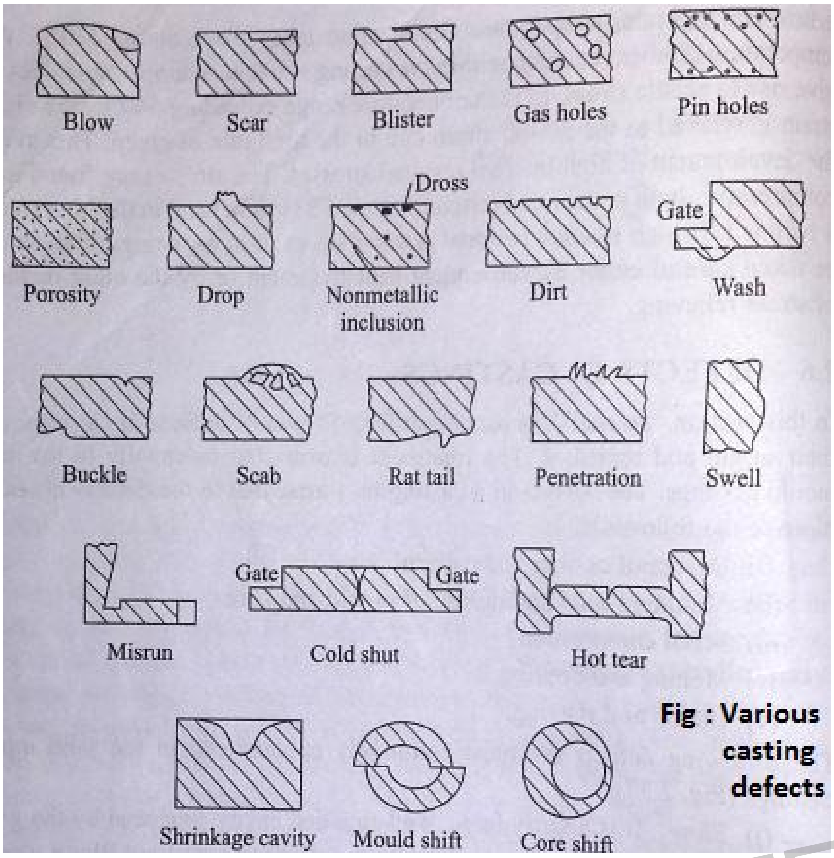


Fig : Various casting defects

Non destructive testing

In nondestructive testing, the product is examined in a manner that retains its usefulness for future service.Tests can be performed on parts during or after manufacture, or even on parts that are already in service.

1.Visual Inspection

Probably the simplest and most widely used nondestructive testing method is *visual inspection.*
The human eye is a very discerning instrument and,with training, the brain can readily interpret the signals. Optical aids such as mirrors,magnifying glasses, and microscopes can expand the capabilities of this system.

2.Liquid penetrant test

Liquid penetrant testing, also called ***dye penetrant inspection***, is an effective method of detecting surface defects in metals and other nonporous materials. The piece to be tested is first subjected to a thorough cleaning and is dried prior to the test.Then a penetrant, a liquid material capable of wetting the entire surface and being drawn into fine openings, is applied to the surface of the workpiece by dipping, spraying, or brushing. Sufficient time is given for capillary action to draw the penetrant into any surface discontinuities, and the excess penetrant liquid is then removed by wiping, water wash, or solvent. The surface is then coated with a thin film of developer, an absorbent material capable of drawing traces of penetrant from the defects back onto the surface. Brightly colored dyes or fluorescent materials that glow under ultraviolet light are generally added to the penetrant to make these traces more visible, and the developer is often selected to provide a contrasting background.

Preheating zone starts from the upper end of the melting zone and continues up to thebottom level of the charging door. This zone contains a number of alternate layers of coke bed,flux and metal charge. The main objective of this zone is to preheat the charges from roomtemperature to about 1090°C before entering the metal charge to the melting zone. Thepreheating takes place in this zone due to the upward movement of hot gases. During thepreheating process, the metal charge in solid form picks up some sulphur content in this zone.

6. Stack

The empty portion of cupola above the preheating zone is called as stack. It provides thepassage to hot gases to go to atmosphere from the cupola furnace.

Operation

A bed of molding sand is first rammed on the bottom to a thickness of about 6 inches (150 mm) or more. A bed of coke about 40 inches (1.0 m) thick is next placed on the sand. The coke is then ignited, and air is blown at a lower-than-normal rate. Next, the charge is fed into the cupola through the charging door. Many factors, such as the charge composition, affect the final structure of the gray cast iron obtained. Nevertheless, it can generally be stated that the charge is composed of 25 percent pig iron, 50 percent gray cast-iron scrap, 10 percent steel scrap, 12 percent coke as fuel, and 3 percent limestone as flux. These constituents form alternate layers of coke, limestone, and metal. Sometimes, ferromanganese briquettes and inoculants are added to the charge to control and improve the structure of the cast iron produced**.**Coke is the fuel used to heat the furnace. Forced air is introduced through openings near the bottom of the shell for combustion of the coke. The flux is a basic compound such as limestones that react with coke ash and other impurities to form slag. The slag serves to cover the melt, protecting if from reaction with the environment inside the cupola and reducing heat loss. As the mixture is heated and melting of the iron takes place , the furnace is tapped periodically to provide liquid metal for the pour.

General Design Considerations for Castings

There are two types of design issues in casting: (a) geometric features, tolerances, etc., that should be incorporated into the part and (b) mold features that are needed to produce the desired casting. Robust design of castings usually involves the following steps:

I. Design the part so that the shape is cast easily. A number of important design considerations are given in this chapter to assist in such efforts.

2. Select a casting process and a material suitable for the part, size, required production volume, mechanical properties, and so on. Often, steps 1 and 2 in this list have to be specified simultaneously and can be a demanding design challenge.

3. Locate the parting line of the mold in the part.

4. Locate and design the gates to allow uniform feeding of the mold cavity with molten metal.

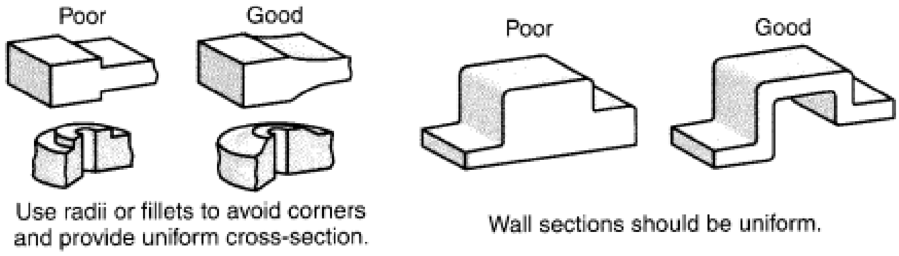
5. Select an appropriate runner geometry for the system.

6. Locate mold features, such as sprue, screens, and risers, as appropriate.

7. Make sure proper controls and good practices are in place.

Design of Cast Parts. The following considerations are important in designing castings, as outlined in Fig.

Corners, angles, and section thickness. Sharp corners, angles, and fillets should be avoided as much as possible, because they act as stress raisers and may cause cracking and tearing of the metal (as well as of the dies) during solidification. Fillet radii should be selected to reduce stress concentrations and to ensure proper liquid-metal flow during pouring.



Section changes in castings should be blended smoothly into each other. The location of the largest circle that can be inscribed in a particular region is critical so far as shrinkage cavities are concerned (Figs.a and b). Because the cooling rate in regions vvith larger circles is lower, these regions are called hot spots. They can develop shrinkage cavities and porosity (Figs.c and d). Cavities at hot spots can be eliminated by using small cores. Although they produce cored holes in the casting (Fig.e), these holes do not affect its strength significantly. It is important to maintain (as much as possible) uniform cross sections and wall thicknesses throughout the casting to avoid or minimize shrinkage cavities. Although they increase the cost of production, metal paddings or chills in the mold can eliminate or minimize hot spots (Fig .f)

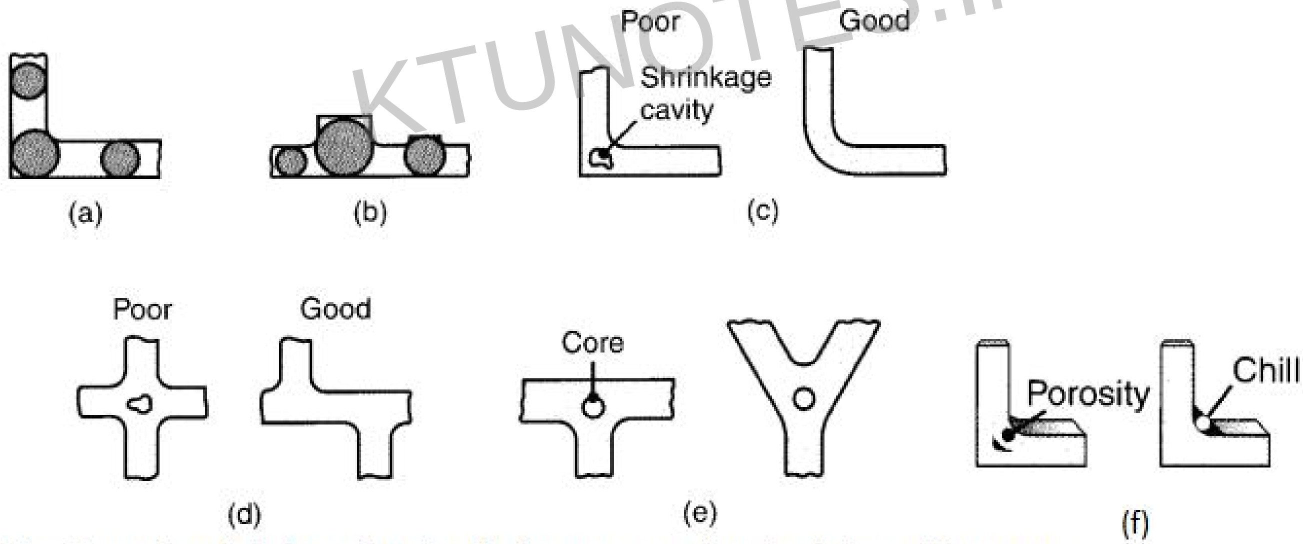


Fig : Examples of designs showing the importance of maintaining uniform cross sections in castings to avoid hot spots and shrinkage cavities.

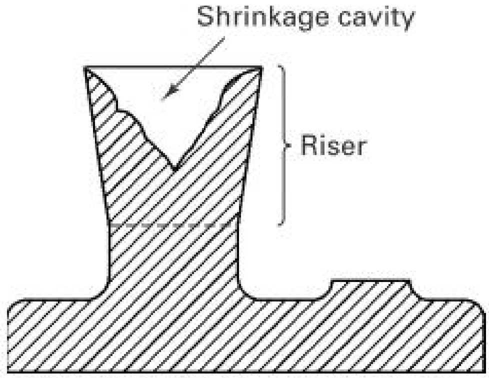


Fig : Attached risers can move the shrinkage cavity external to the actual casting

Flat areas : Large flat areas (plane surfaces) should be avoided, since they may Warp during cooling because of temperature gradients, or they develop poor surface finish because of an uneven flow of metal during pouring. One of the common techniques for avoiding either of these problems is to break up flat surfaces with staggered ribs and serrations.

Shrinkage : To avoid cracking of the casting during cooling, there should be allowances for shrinkage during solidification. In castings with intersecting ribs, the tensile stresses can be reduced by staggering the ribs or by changing the intersection geometry. Allowances for shrinkage, known as patternmaker's shrinkage allowances, usually range from about 10 to 20 mm/m.

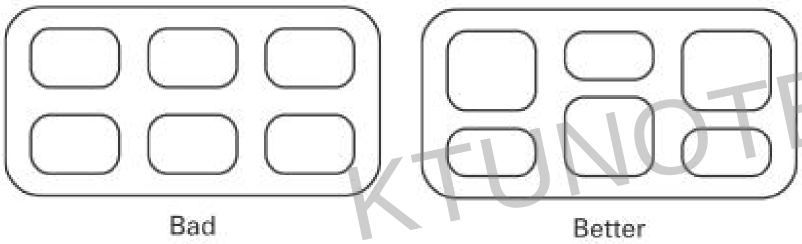
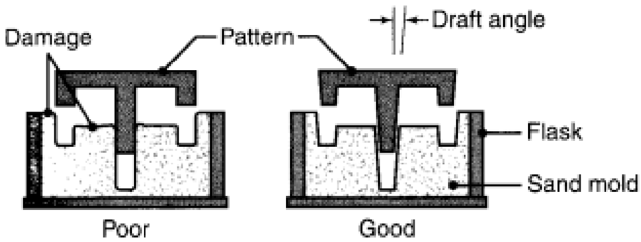


Fig : Using staggered ribs to prevent cracking during cooling

Draft : A small draft (taper) typically is provided in sand-mold patterns to enable removal of the pattern without damaging the mold (see Fig). Drafts generally range from 5 to 15 mm/m. Depending on the quality of the pattern, draft angles usually range from 0.5 ° to 2°.



Locating the Parting Line: A part should be oriented in a mold so that the large portion of the casting is relatively low and the height of the casting is minimized. Part orientation also determines the distribution of porosity. For example, in casting aluminum, hydrogen is soluble in liquid metal, but is not soluble as the aluminum solidifies. Thus, hydrogen bubbles can form during the casting of aluminum, float upwards due to buoyancy, and cause a higher porosity in the top parts of castings. Therefore, critical surfaces should be oriented so that they face downwards.

Avoid the causes of hot tears : Hot tears are casting defects caused by tensile stresses as a result of restraining a part of the casting. Figa and b shows locations where hot tears can occur and a recommended design that would eliminate their formation.

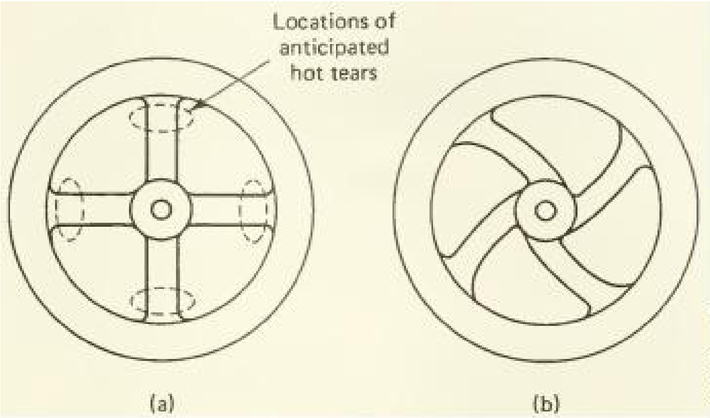


Fig : Hot tears: (a) a casting design that promotes hot tears; (b) recommended design to eliminate hot tears

Casting Yield

Casting yield provides a direct measure of the relative success of individual casting methods in promoting metal economy.

$$\text{Casting yield} = \frac{\text{Weight of finished casting}}{\text{Weight of casting including gating and risering}} \times 100\ \%$$

Economics of Casting

As is the case with all manufacturing processes, the cost of each cast part (unit cost) depends on several factors, including materials, equipment, and labor. Some require more labor than others, some require expensive dies and machinery, and some require a great deal of time to produce the castings.

General Cost Characteristics of Casting Processes

Casting process	Cost* Die	Equipment	Labor	Production rate (pieces/hr)
Sand	L	L	L–M	<20
Shell mold	L–M	M–H	L–M	<50
Plaster	L–M	M	M–H	<10
Investment	M–H	L–M	H	<1000
Permanent mold	M	M	L–M	<60
Die	H	H	L–M	<200
Centrifugal	M	H	L–M	<50

*L = low; M = medium; H = high.

Pouring Practice

Some type of pouring device, or ladle, is usually required to transfer the metal from the melting furnace to the molds. The primary considerations for this operation are (1) to maintain the metal at the proper temperature for pouring and (2) to ensure that only high-quality metal is introduced into the molds.The specific type of pouring ladle is determined largely by the size and number of castings to be poured. In small foundries, a handheld, shank-type ladle is used for manual pouring. In larger foundries, either bottom-pour or teapot-type ladles are used.

Cleaning and Finishing

After solidification and removal from the mold, most castings require some additional cleaning and finishing. Specific operations may include all or several of the following:

1. Removing cores 2. Removing gates and risers 3. Removing fins, flash, and rough spots from the surface

4. Cleaning the surface 5. Repairing any defects

Sand cores can usually be removed by mechanical shaking.At times, however, they must be removed by chemically dissolving the core binder. On small castings, sprues, gates, and risers can sometimes be knocked off. For larger castings, a cutting operation is usually required. Most nonferrous metals and cast irons can be cut with an abrasive cutoff wheel, power hacksaw, or band saw. Steel castings frequently require an oxy- acetylene torch. Plasma arc cutting can also be used.

After the gates and risers have been removed, small castings are often tumbled in barrels to remove fins, flash, and sand that may have adhered to the surface. Metal shot or abrasive material is often added to the barrel to aid in the cleaning. Extremely large castings usually require manual finishing, using pneumatic chisels, portable grinders, and manually directed blast hoses.