1.4 INTRODUCTION TO CASTING PROCESS

Casting or *Founding* is one of the oldest manufacturing process that has been practiced for over 5000 years. Pre-historic man found copper and shaped it to use as a weapon (arrowhead) for his defense. Later he found that weapons could be easily made by melting and pouring copper in moulds (cast) than they could be beaten (forged) to size and shape. Progress in civilization made man to discover different metals and process for casting them.

Casting involves melting metal and pouring it into a mould cavity whose shape resembles the shape of the desired object, and then allowing the molten metal to solidify in the cavity. The solidified part is taken out of the mould, cleaned and finished to make it suitable for use. Casting is not restricted to metals. Glass and plastics can also be cast using a variety of processes. Also, products ranging from a few millimeters to meters and a few grams to several tons can be cast efficiently and economically thereby making it a versatile method for shaping objects. Casting which was once practiced as an art has emerged to a science, and a major manufacturing process to shape objects.

1.5 STEPS INVOLVED IN MAKING A CASTING

The basic steps in making a casting include:

(a) Pattern making
(b) Mould preparation (including gating and risering)
(c) Core making
(d) Melting and Pouring
(e) Cleaning and Inspection

Note Readers can refer figure 1.2 for clear understanding of the casting process.

a) Pattern making

A pattern is a *replica* of an object to be cast. It is used to prepare a cavity into which the molten metal is poured. A skilled *pattern maker* prepares the pattern using wood, metal, plastic or other materials with the help of machines and special tools. Many factors viz., durability, allowance for shrinkage and machining etc., are considered while making a pattern.

b) Mould preparation

Mould preparation involves forming a cavity by packing sand around a pattern enclosed in a supporting metallic frame called *flask* (*mould* box). When the pattern is removed from the mould, an exact shaped cavity remains into which the molten metal is poured. Gating and risering* are provided at suitable locations in the mould.

* *Gating – Passage through which molten metal flows and enter the mould cavity.*

c) Core making

In some cases, a hole or cavity is required in the casting. This is obtained by placing a core in the mould cavity. The shape of the core corresponds to the shape of the hole required. The mould is cleaned, finished and made ready for pouring molten metal.

d) Melting and Pouring

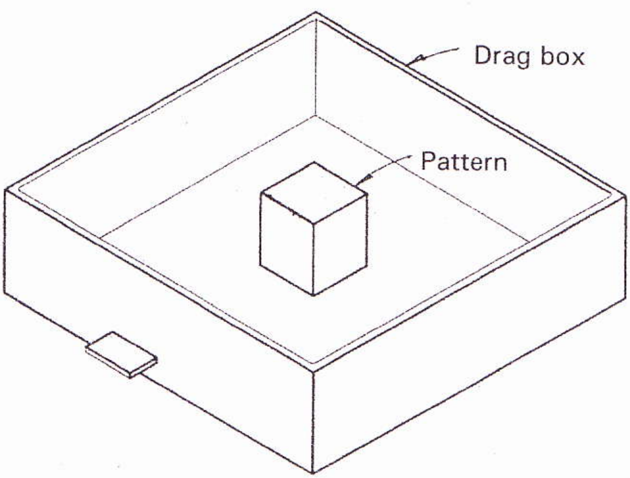
Metals or alloys of the required composition are melted in a furnace and then transfered (poured) into the mould cavity. Many factors viz., temperature of molten metal, pouring time, turbulence etc., should be considered while melting and pouring.

e) Cleaning and Inspection

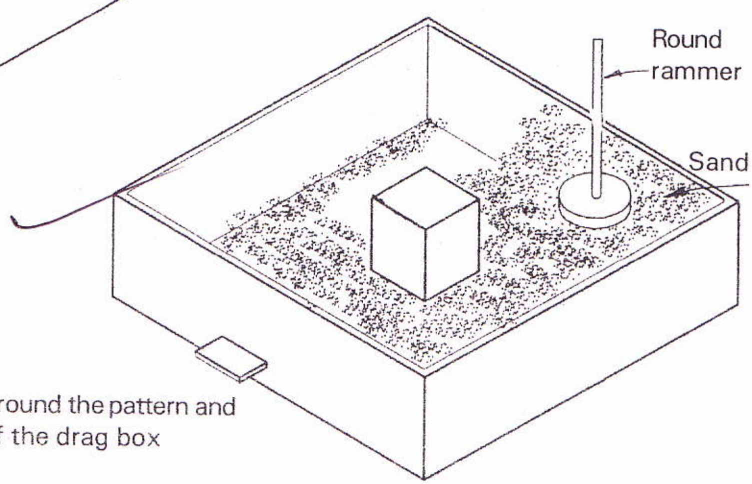
After the molten metal has solidified and cooled, the rough casting is removed from the mould, cleaned and dressed (removing cores, adhered sand particles, gating and risering systems, fins, blisters etc., from the casting surface) and then sent for inspection to check for dimensions or any defects like blow holes, cracks etc.

1.5.1 Procedure for Making a Casting

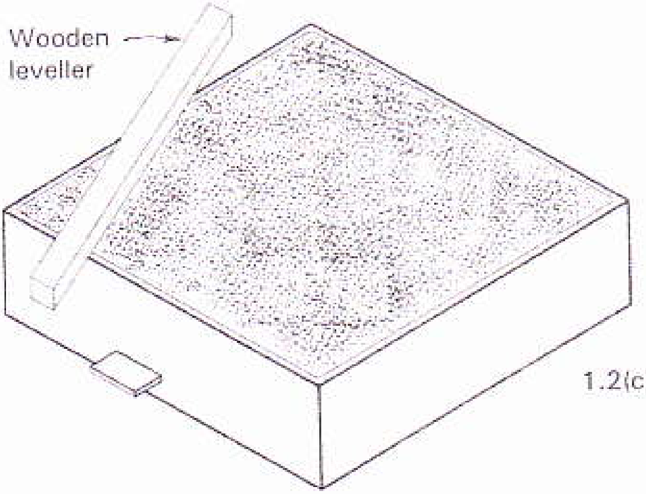
To understand and appreciate casting process, a detailed step-by-step procedure for the benefit of readers is shown in figure 1.2



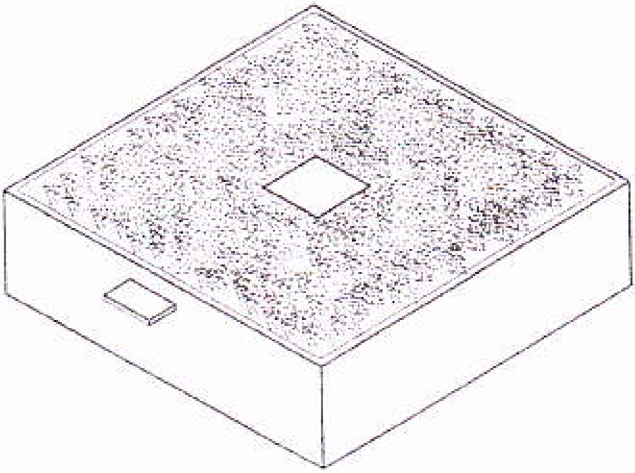
1.2(a) Place pattern in drag box



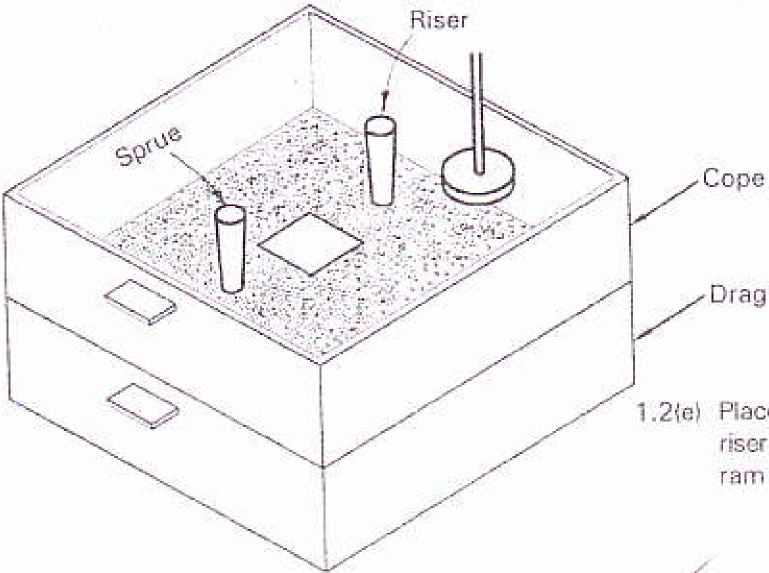
1.2(b) Ram moulding sand around the pattern and till the top surface of the drag box



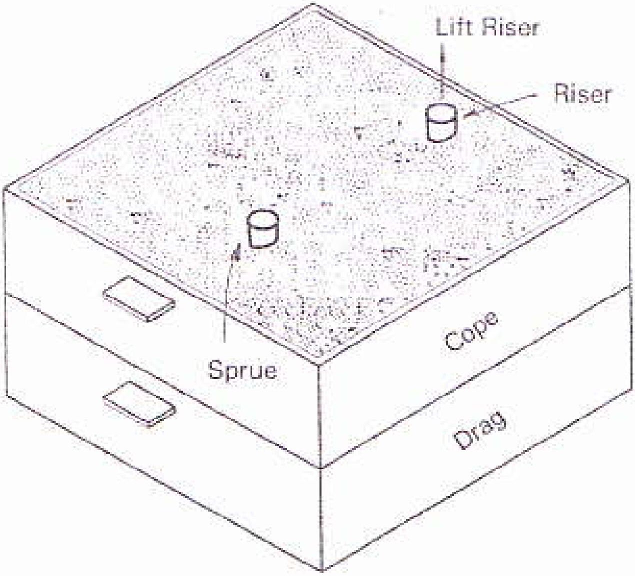
1.2(c) Level the sand in the drag box



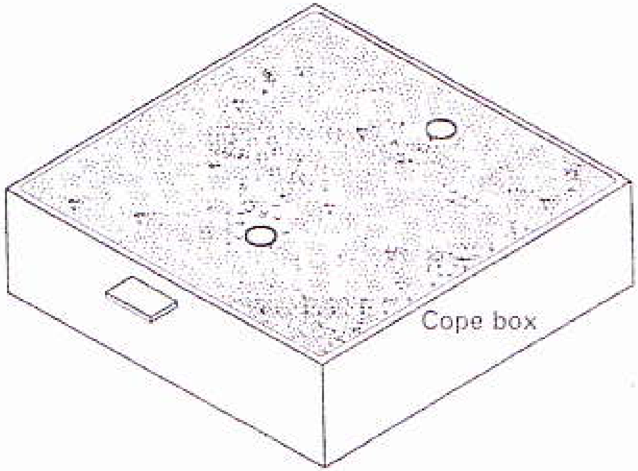
1.2(d) Drag box is inverted, so that pattern is visible at the top surface



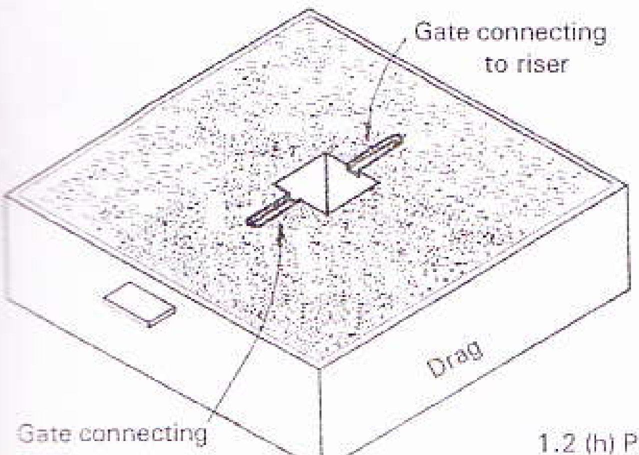
1.2(e) Place cope on top of drag box. Place riser and sprue at proper location and ram sand into the cope box



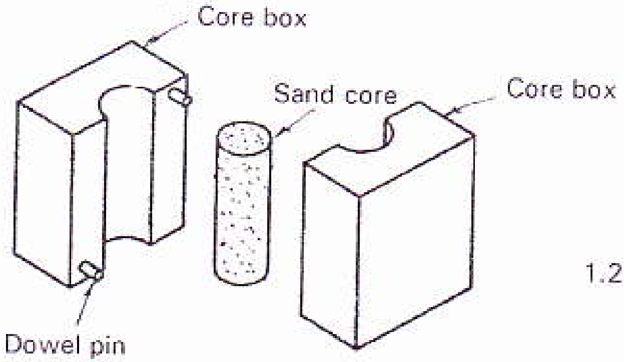
1.2(f) Cope box is rammed till its top surface. Riser & sprue are removed



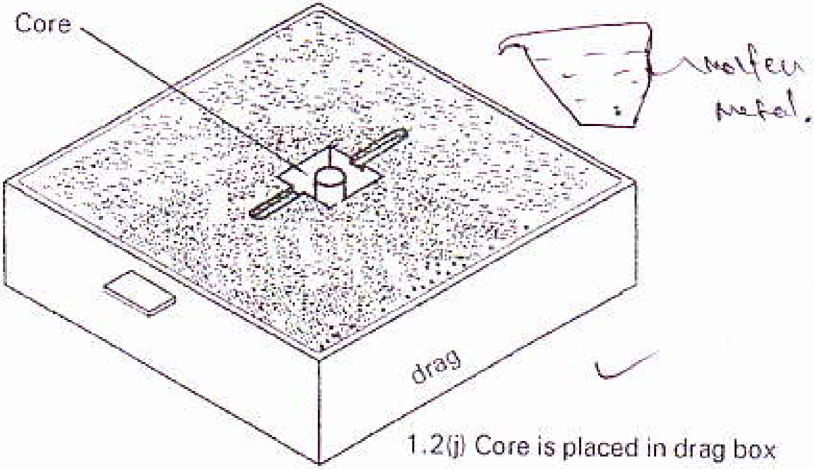
1.2(g) Cope box is lifted and placed aside



1.2 (h) Pattern is removed from the drag box. Gates are cut

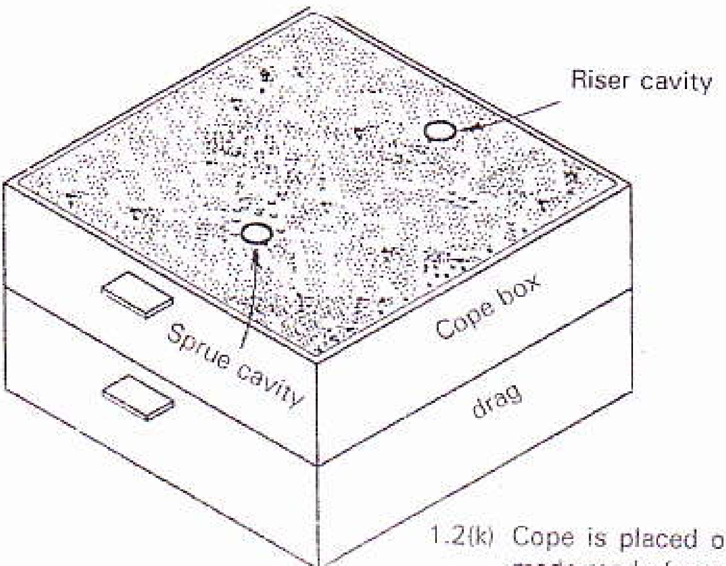


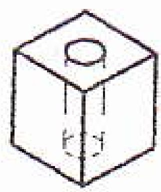
1.2(i) Sand core prepared in core box



1.2(j) Core is placed in drag box

Molten metal is
poured into cavity.





1.2(*l*) Finished casting

1.2(k) Cope is placed on drag & mould made ready for pouring

Figure 1.2 Casting process

1.5.2 Terms Involved in Casting

Figure 1.3 shows the cross-section of the mould shown in figure 1.2(k) ready for pouring.

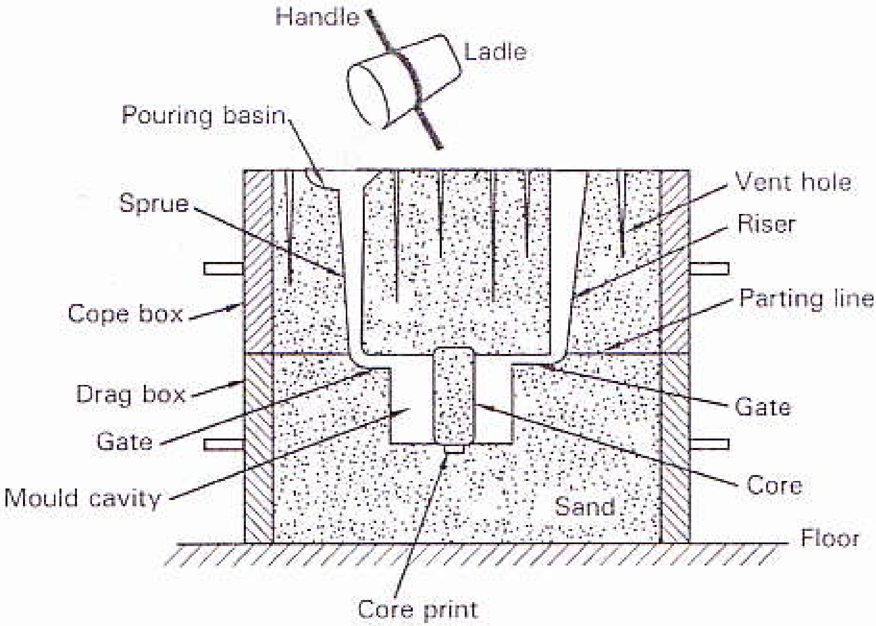


Figure 1.3 Cross-section of a mould

Following are a few important terms involved in casting process.

a) **Mould box (flask) :** It is usually a metallic frame used for making and holding a sand mould. The mould box has two parts: the upper part called *cope*, and the lower part called *drag*.

b) **Parting line/parting surface:** It is the zone of separation between cope and drag portions of the mould in sand casting.

c) **Sprue:** It is a vertical passage through which the molten metal will enter the gate, and then into the mould cavity.

d) **Pouring basin:** The enlarged portion of the sprue at its top into which the molten metal is poured.

e) **Gate/ingate:** It is a short passageway which carries the molten metal from the runner/ sprue into the mould cavity.

h) **Riser:** A riser or feedhead is a vertical passage that stores the molten metal and supplies (feed) the same to the casting as it solidifies.

i) **Mould cavity:** The space in a mould that is filled with molten metal to form the casting upon solidification.

1.6 COMPONENTS PRODUCED BY CASTING PROCESS

Casting is the first step and the primary process for shaping any material. All materials have to be cast before it is put to use. The ingots* produced by casting process are used as raw material for secondary processes like machining, forging, rolling etc. More than 90 % of all manufactured goods and capital equipment use castings for their manufacture. To list the components produced by casting is an endless process. A few major components produced by casting are given below.

- Automotive sector - Nearly 90 % of the parts in automobiles are manufactured by castings. A few parts include brake drum, cylinder, cylinder linings, pistons, engine blocks, universal joints, rocker arm, brackets etc.,
- Aircraft – Turbine blades, casing etc.
- Marine propeller blades.
- Machining – Cutting tools, machine beds, wheels and pulleys, blocks, and table for supports etc., are produced by casting process.
- Agriculture and rail road equipments.
- Pumps and compressors frame, bushings, rings, pinion etc.
- Valves, pipes and fittings for construction work.
- Camera frames, parts in washing machine, refrigerators and air-conditioners.
- Steel utensils and a wide variety of consumer products.

1.7 ADVANTAGES AND LIMITATIONS OF CASTING PROCESS

Following are a few advantages and limitations of casting process.

Advantages

a) Large hollow and intricate shapes can be easily cast.

b) Quick process, and hence suitable for mass production.

c) No limit to size and shape. Parts ranging from few millimeters to meters and few grams to tons can be cast efficiently and economically.

d) Better dimensional tolerances and surface finish can be obtained by good casting practice.

e) Castings exhibit uniform properties in all the directions – longitudinal, lateral and diagonal.

Limitations

a) Presence of defects in cast parts is a major disadvantage.

b) Casting process is not economical for small number of parts.

c) Properties of cast materials are generally inferior when compared to those made by machining or forging process.

1.8 PATTERNS

Primitive man discovered the art of melting copper and found that the molten metal would take the form of the impression or cavity into which it had been poured. The impression was obtained by hollowing out the sand/clay with his hands or crude tools. He soon learned that he must have some object to use as a *model or pattern*, if accurate impression were to be made. This led to the art of making *pattern*.

A pattern is the replica of the object to be cast. It is used to prepare a cavity into which the molten metal is poured. Pattern making is a highly skilled trade translating the 2D (Two dimensional) design plan to a 3D (Three dimensional) object. A skilled *pattern maker* builds the pattern from wood, metal, plastic or other materials with the help of machines and special tools.

Functions of pattern

a) A pattern is used to prepare a cavity whose shape resembles the shape of the desired object.

b) Patterns help to position a core in the mould. They are provided with projections known as *core prints* that helps for support and correct location of the core in the mould cavity. Figure 1.3 depicts the use of core print.

c) Patterns help to establish the parting line and parting surfaces in the mould.

d) In some cases, gating and risering are incorporated in the pattern itself. Hence, patterns support gating and risering system also.

1.9 MATERIALS USED FOR PATTERN

Patterns may be made of wood, metal, plastic or other materials. Before selecting a particular material, a few factors are to be considered. They are:

a) Number of castings to be produced.

b) Degree of accuracy and surface finish of the casting required.

c) Shape and size of the casting.

d) Re-usability of patterns, so that they will provide a repeatable dimensionally acceptable castings.

e) Type of mould material used *i.e.,* clay or resins.

f) Type of moulding selected *i.e.,* green sand moulding, investment process etc.

A few commonly used materials for making patterns are discussed below.

(i) Wood

Wood is the widely used material for making pattern. Different types of wood viz., pine wood, teak wood, mahogany, deodar, compressed wood laminates (ply wood) etc., are generally used.

Advantages of wooden patterns

a) Wood is available in plenty compared to other materials.

b) Inexpensive.

c) Light in weight

d) Can be easily worked.

Disadvantages

a) They are poor in strength.

b) Affected by moisture of the moulding sand causing swelling and distortion.

c) Less resistant to wear and chemical actions.

d) Not suitable for long production runs.

(ii) Metal

Various metals like cast iron, aluminum alloys, steel etc., are used as materials for making patterns.

Advantages

a) Metals are strong.

b) Wear resistant.

c) Dimensionally stable under changing humidity.

d) Gives good surface finish to castings.

e) Suitable for mass production.

Disadvantages

a) Metals are heavy.

b) Costlier.

c) Tendency to rust during long storage periods.

d) Initially they have to be cast or machined to the desired shape and size. This leads to the increase in cost of the final cast product.

(iii) Plastics

Plastic material is a compromise between wood and metal. Thermosetting resins like phenolic resin, epoxy resin, foam plastic etc., are used as materials for making pattern.

Advantages

a) Moderately strong and light in weight.

b) Does not absorb moisture during its use and storage.

c) Gives good surface finish to castings.

Disadvantages

a) Initially plastic patterns have to be cast and finished to desired shape and size. This leads to the increase in cost of the final cast product.

b) Thin sections are difficult to cast using plastics.

(iv) Gypsum (Plaster)

Gypsum or Plaster of Paris is another pattern material capable of producing intricate castings to close dimensional tolerances. They are strong, light in weight, easily shaped, gives good surface finish. However, they are used for small castings only.

(v) Wax

Wax is a re-usable material. It is light in weight, gives good surface finish and suitable for complex shapes. Withdrawal of wax pattern from the mould is easier compared to other pattern materials. This is done by inverting the mould box and heating it to a suitable temperature. The wax melts and drops down leaving a fine finished cavity in the mould. Wax patterns are used in investment casting process. They an suitable for small castings only.

1.11 CLASSIFICATION OF PATTERNS

Patterns are of various types. But the selection of a particular type of pattern depnds on the type of moulding process employed, and the shape and size of the casting required. Some of the commonly used patterns are discussed below.

(a) Single piece pattern

Single piece pattern also called *solid pattern,* is the simplest type made in one piece without any joints, partings or loose pieces. It is suitable for simple shape and large size castings. Figure 1.6 shows a solid pattern. The pattern can be located either in the cope or drag box.

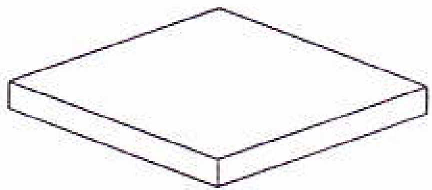
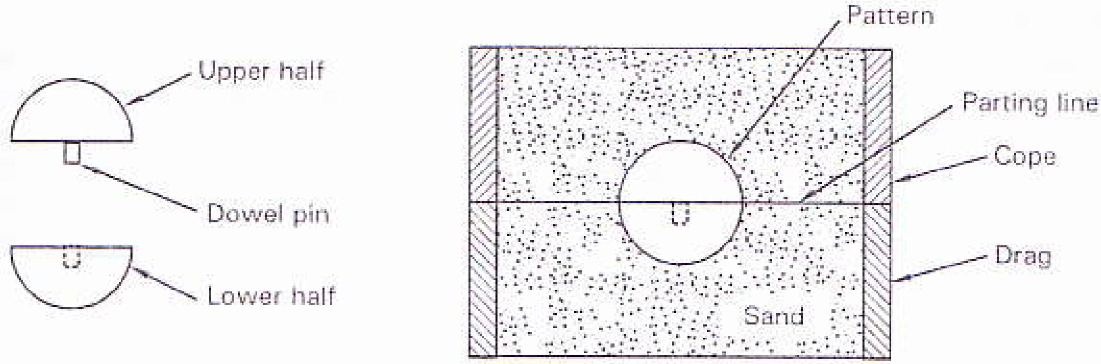


Figure 1.6 Single piece (solid) pattern

(b) Split pattern

Split pattern also called *cope and drag* pattern, is made in two halves/pieces as shown in figure 1.7(a). One half of the pattern is moulded in the cope box while the other half in the drag box. Both the halves are aligned or assembled together with the help of dowel pins. Refer figure 1.7(b). Split types are required for those patterns that are difficult to withdraw from the mould and also for castings with curved surfaces.



(a) Two halves of split pattern (b) Split pattern placed in mould

Figure 1.7 Split pattern

(c) Loose piece pattern

Patterns with complex shapes as shown in figure 1.8(a) cannot be made in one piece, as it is difficult to withdraw from the mould. In such cases, two or more loose pieces are assembled together to form a single pattern. Refer figure 1.8(b). As shown in figure, 1.8(b), *A* and *B* are loose pieces attached to the main body of the pattern with the help of dowel pins. While withdrawing the pattern, the main body is first removed by slowly rapping it, and then the loose pieces are removed. Refer figure 1.8(c). Loose piece pattern consume more time and labour for preparing moulds.

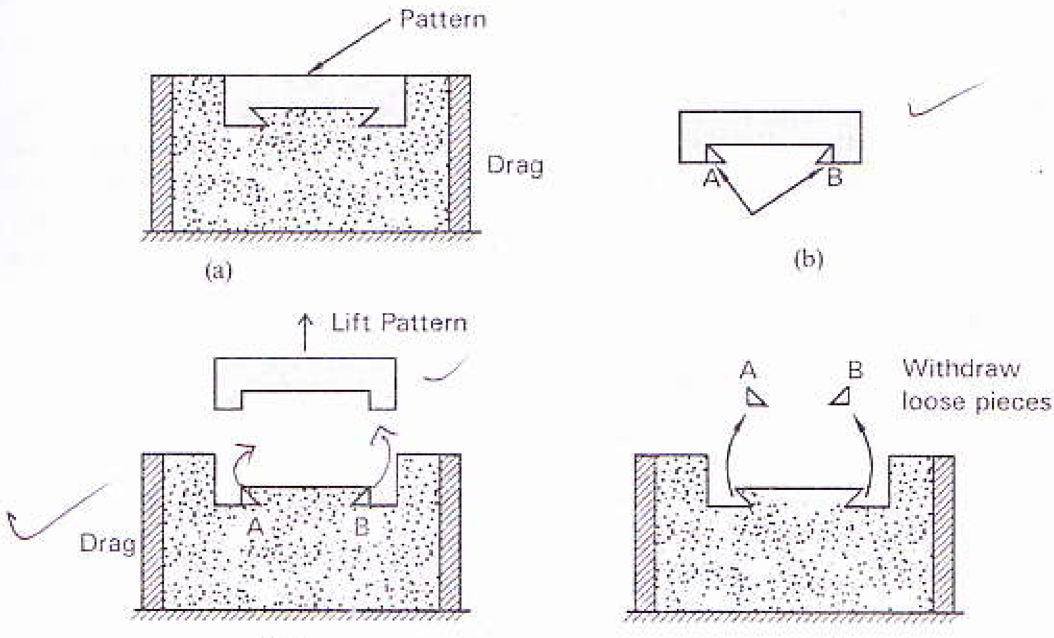
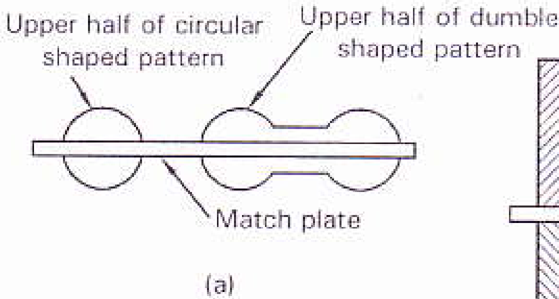


Figure 1.8 Loose piece pattern

(d) Match plate pattern

A match plate is a thin flat plate on either side of which each half of a number of split patterns with different size and shape are attached. Refer figure 1.9 (a). On one side of the match plate there is cope impression and on the other side is the drag impression. The match plate is provided with runner and gates and is placed between the cope and the drag box. Refer figure 1.9 (b). After ramming the cope and drag with moulding sand, the match plate is removed, the cope and drag are assembled and made ready for pouring. Match plate patterns are used in machine moulding process.



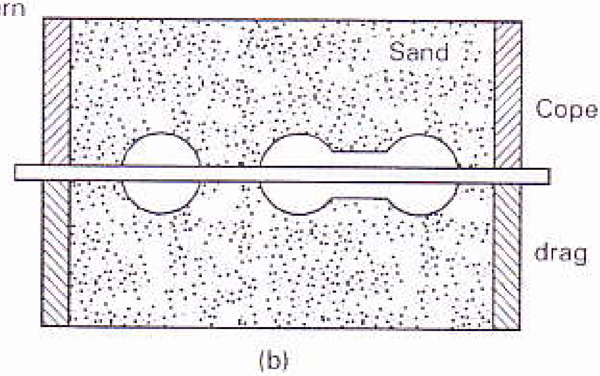


Figure 1.9 Match plate pattern

(e) Gated pattern

Gated patterns are used when parts to be cast are of simple shape and produced in large quantities (mass production). Refer figure 1.10. In this type, a number of patterns are attached to a single runner by means of gates. Generally, patterns are made from metals to remain stronger so that they can be reused to prepare many moulds. Gated patterns provide many advantages like rapid moulding, reduction in skilled labour, mass production and eliminating errors while cutting gates and runners.

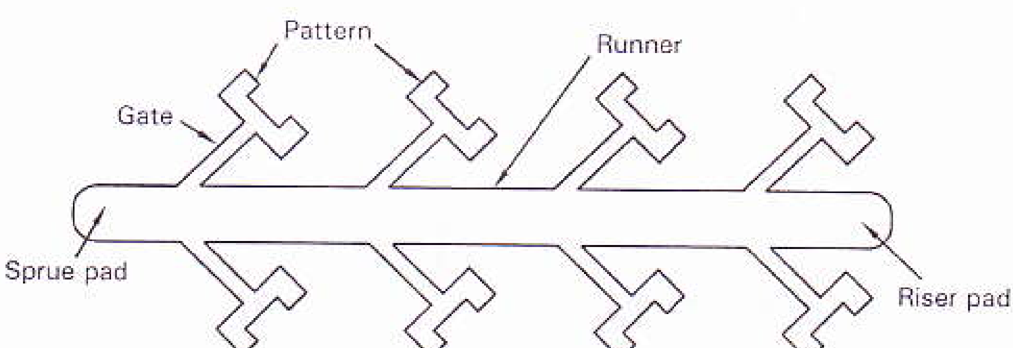


Figure 1.10 Gated pattern

(f) Sweep pattern

Sweep patterns are used for preparing large circular shaped moulds by revolving a sweep (wooden board) attached to the spindle as shown in figure 1.11. One edge of the sweep is attached to the spindle, while the other edge has a contour of the casting desired. The sweep pattern and the spindle located at the center of the mould are removed after the desired shape of cavity is obtained. Sweep patterns are preferred for large castings with circular and symmetrical shapes.

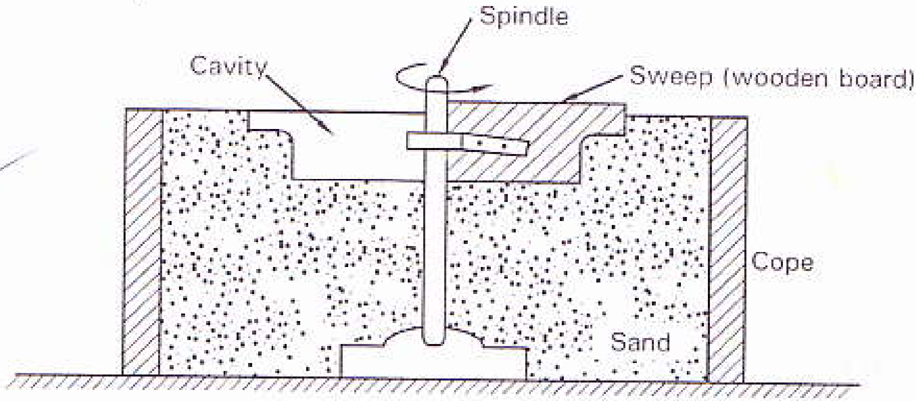


Figure 1.11 Sweep pattern

(g) Skeleton pattern

A skeleton pattern is prepared by joining pieces of wood to form an outline of the pattern to be made. In other words, it is just the skeleton of the desired shape of the casting (like the skeleton of a human body). Refer figure 1.12(a). The skeleton pattern is then filled with loam sand* and rammed. Refer figure 1.12(b). A strickle board is used to remove the excess sand to give the desired shape. Skeleton patterns are used to produce large castings in small quantities.

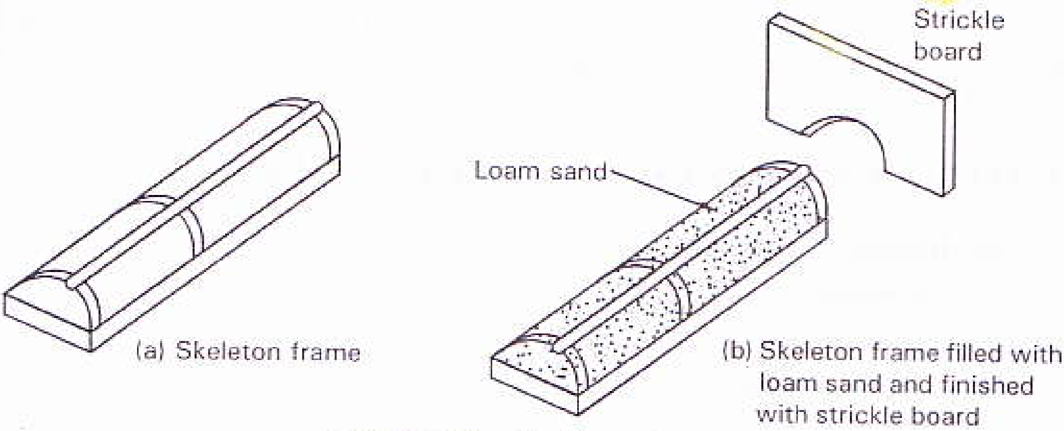


Figure 1.12 Skeleton pattern

* *Loam sand – Contains more clay, around 50 % compared to ordinary moulding sand.*

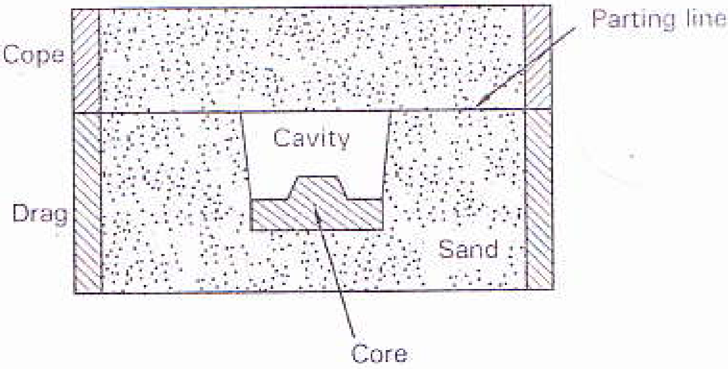


Figure 2.7 Ram-up core

2.8 METHOD OF MAKING CORES

Core making consists of the following four steps:

(i) Core sand preparation
(ii) Core moulding
(iii) Core baking
(iv) Core finishing

(i) Core sand preparation

The core sand of desired type (dry sand, no-bake etc.,) and composition, along with additives is mixed manually or using muller* of suitable type.

(ii) Core moulding or Core making

Cores are prepared manually or using machines depending on the needs. Machines like jolt machine, sand slinger, core blower etc., are used for large scale continuous production, while small sized cores for limited production are manually made in hand filled core boxes.

A core box is similar to a pattern that gives suitable shape to the core. Figure 2.8 (a) shows a core box used to produce rectangular shaped cores. The procedure involved for preparing core is as follows:

- The prepared core sand mixture is rammed manually into the core box.
- The core box is inverted over a core plate and rapped in all directions using wooden mallet. Refer figure 2.8(b).
- The box is lifted vertically to leave the core on the core plate. Refer figure 2.8 (c).
- The core along wi'h the core plate is sent for baking.

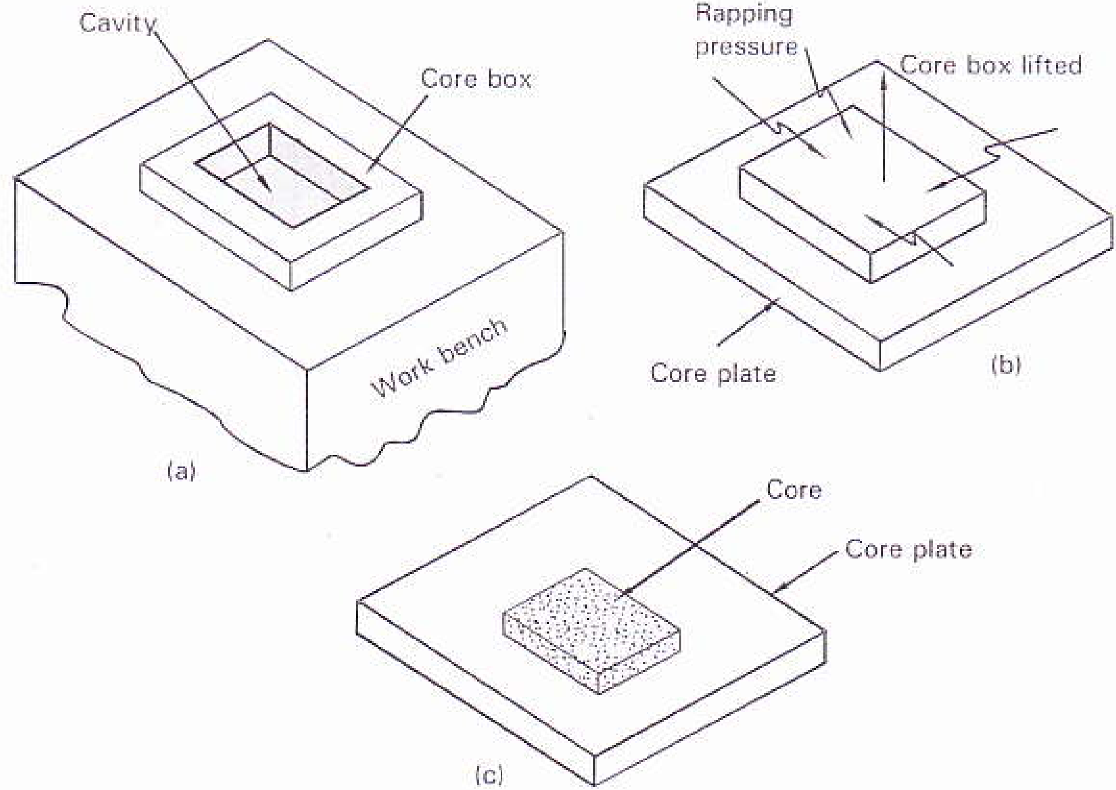


Figure 2.8 Core making

(iii) Core Baking

Cores are baked in ovens in order to drive away the moisture in them, and also to harden the binder thereby imparting strength to the core. The temperature and duration for baking may vary from 200 - 450°F and from a few minutes to hours respectively depending on the size of the core and type of binder used.

(iv) Core finishing

The baked cores are finished by rubbing or filing with special tools to remove any fins, bumps, lose sand or other sand projections from its surface. The cores are also checked for dimensions and cleanliness. Finally, if cores are made in parts, they are assembled by using suitable pastes, pressed and dried in air before placing them in the mould cavity.

2.10 CONCEPT OF GATING AND RISERING

2.10.1 Gating

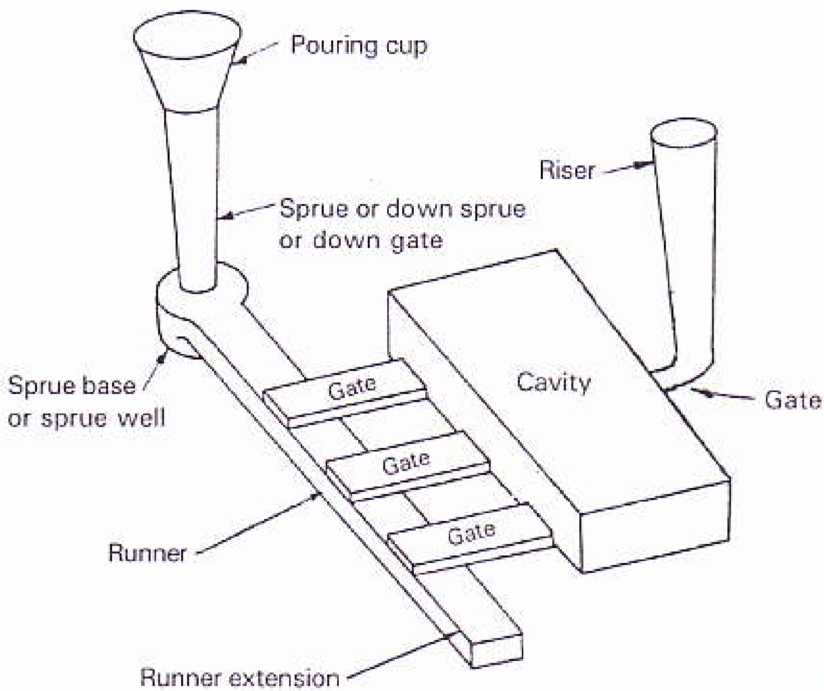
The concept of gating is very important, as it helps one to learn the controlled flow of molten metal from the crucible (ladle) into the mould cavity.

The term *gating* or *gating system* refers to all the channels or cavities through which the molten metal flows to reach and fill the mould cavity. Figure 2.9 shows a simple gating system which consists of the following components.

- Sprue
- Pouring cup
- Runner
- Ingates or gates

(a) Sprue

A sprue is a vertical passage way through which the molten metal will enter the runner. It is also called *down gate* or *down sprue*. The sprue is tapered in cross-section with its bigger end at the top connected to the pouring cup, while its smaller end connected to the runner.

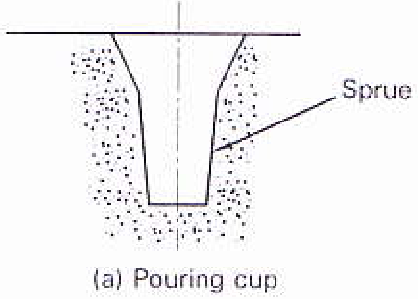


Note Riser is not a part of the gating system

Figure 2.9 Gating system

(b) Pouring cup

The enlarged portion (usually funnel shaped) of the sprue at its top into which the molten metal is poured is called pouring cup. Refer figure 2.10 (a). In some cases, pouring basin is used instead of cup. The pouring basin has a larger opening as shown in figure 2.10 (b). It makes pouring easier, eliminates aspiration,* and reduces the momentum of the liquid flowing into the mould by settling first into it.



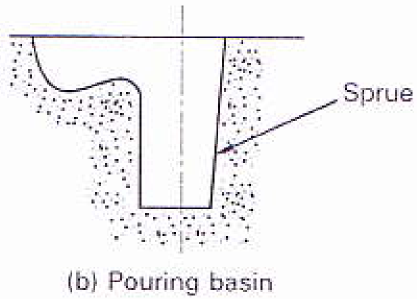


Figure 2.10 Pouring element

(c) Runner

The runner is a horizontal passageway through which the molten metal flows into the gates. The cross-section of the runner may be square or trapezoid, and its length is very large compared to its width.

(d) Runner extension

It is a small portion of the runner that extends beyond the last gate. It is used to trap the slag in the initial molten metal.

(e) Ingates

The *ingate* or *gate* is a short passageway which carries the molten metal from the runner to the mould cavity. The gates used may vary in number and depends on the size of the casting and rate of solidification of molten metal. A gate may be built as a part of the pattern, or it may be cut in the mould using gate cutter tool.

The combination of sprue, sprue base, runner and ingates completes the total *pouring system* of any casting.

2.10.2 Risering

We know that as the molten metal solidifies, it shrinks in volume. At this stage, if it does not have a source of more molten metal to feed as it shrinks, voids appear leading to defects in castings. This problem is overcome with the use of *riser*. Refer figure 2.9.

A riser or feeder head is a vertical passage made in the cope, to store the liquid metal and supply (feed) the same to the casting as it solidifies. Referring to figure 2.9, molten metal flows into the

Sand Moulding

2.1 TYPES OF BASE SAND

Sand, due to its high refractoriness, and also being inexpensive, is the primary and basic material used for preparing moulds. Nearly 90 – 95 % of the moulding sand mixture is occupied by *sand* and the remaining being *binder* and *additives*. Sand, usually referred to as *base sand* has many sources and compositions. But all sands have their common origin in the fact that they are granular material resulting from the disintegration or crushing of rocks. Four basic types of sand are discussed below:

(i) Silica sand

Silica sand is essentially silicon dioxide (SiO_2) found in nature on the bottoms and banks of rivers, lakes and seashore. Silica deposits tend to have varying degree of organic and mineral contaminants like limestone, magnesia, soda and potash that must be removed prior to its use, otherwise which affect castings in numerous ways.

Silica sand is available in plenty, less expensive and possess favorable properties that are essential to make a good casting. But its high thermal expansion leads to certain casting defects; the reason for which not being used in steel foundries. However, silica sand when mixed with certain additives like wood flour, cereals (corn flour), saw dust etc., defects can be eliminated. These additives burn by the heat of the molten metal thereby creating voids that can accommodate the sand expansion.

(ii) Olivine sand

Olivine sand is typically used in non-ferrous foundries. With its thermal expansion (0.0083″/inch) about half of that of silica sand (0.018″/inch) makes it suitable for production of steel castings also. But the high cost restricts its wide use.

(iii) Chromite

This is African sand with cost being much higher compared to other sands. Due to its superior thermal characteristics, it is generally used in steel foundries for both mould and core making.

(iv) Zircon

Zircon or Zirconium silicate possesses most stable thermal properties of all the above discussed sands. The choice for this type of sand arises when very high temperatures are encountered, and refractoriness becomes a consideration. But the major disadvantage is that, zircon has trace elements of Uranium and Thorium which is hazardous in nature thereby restricting its use in foundries.

2.2 REQUIREMENT (PROPERTIES) OF BASE SAND

Following are a few requirements to be satisfied while selecting the base sand for moulding process.

a) Sand should have a high refractoriness. It should withstand the heat of the molten metal without melting, losing its shape, size etc.

b) Sand grains when packed (rammed) together should be permeable or porous enough to allow the escape of hot gases and water vapour through them. This property called *permeability* is an important requirement of base sand that helps the hot gases or moisture (generated from the molten metal) to pass out of the mould, otherwise which, defects related to gas entrapment occurs in castings.

c) Sand grains when mixed with binder should provide good strength and also distribute and flow easily under the ramming pressure.

d) Sand should be available in plenty, and also should be cheaper.

e) Sand should not fuse or burn out. They should be reusable.

f) Sand should not chemically react with the molten metal.

1.13 BINDERS

The sand used for preparing moulds is a mixture of *silica sand*, *binder* and *additives* in suitable proportions. A hard mould is a primary requirement in making any casting, and binders serve the purpose.

A *binder* is a material used to produce cohesion or bind the sand particles (silica sand) together thereby imparting strength to the sand. Clay binders (Bentonites) are the most widely used for bonding moulding sands. But, clay activates or tends to bind sand particles only in the presence of water (moisture). The amount of water added to clay should be based on experimental trials because, if too little water is added, the sand will lack strength as the bond between the sand particles is low. On the other hand, too much water causes sand to reach semi-liquid state thereby making it unsuitable for moulding. In other words, for a given percentage of clay, there is an optimum percentage of water that gives favorable properties to the moulding sand. For a good moulding sand, clay may vary in the range 6 – 12 % and moisture from 3 – 5 %.

1.14 TYPES OF BINDERS USED IN MOULDING SAND

Binders are classified into two types:

a) Organic binders and

b) Inorganic binders.

Organic group of binders include:

- Dextrin – made from starch.
- Molasses – a by-product of sugar industry.

- Cereal binders – gelatinized starch and gelatinized flour.
- Linseed oil – a vegetable oil.
- Resins – Urea formaldehyde, phenol formaldehyde etc.

Inorganic group of binders include:

- Clay binders – Bentonite, Fire clay etc.
- Portland cement.
- Sodium silicate etc.

1.15 ADDITIVES

Additives are generally added to develop certain new properties, or, to enhance the existing properties of the moulding sand. They do not form a compulsory constituent to the moulding sand. However, its addition improves the quality of the moulding sand and hence the casting obtained.

Note Additives do not impart any binding qualities.

A few commonly used additives and their functions are described below.

(a) Sea coal

- It is a finely powdered bituminous coal.
- Its addition ranges from 2 – 8 % by weight of sand.
- Enhances peeling* property of castings.
- Improves surface finish of castings.
- Prevents sand burn out.

Note Sea coal material is added for casting *cast iron alloys*, but not suitable for *steels*, because the volatile nature of coal produces smoke and gas that adds *lustrous carbon* on the metal surface. However, these gases aid in producing a non-oxidizing atmosphere for cast iron alloys.

(b) Silica Flour

- It is pulverized silica added in ranges of 5 – 10 % based on sand weight.
- Resists metal penetration in the mould walls.
- Improves surface finish.
- Minimizes sand expansion defects.

(c) Wood Flour (Cellulose material)

- It is a pulverized soft wood (fibrous material).
- Added in ranges of 1 – 2 % by weight of sand.

* *Peel – It is a term that describes how a casting separates at the mould metal interface.*

- Controls sand expansion created by temper water.
- Absorbs excess water and improves flowability of sand during moulding process.
- Improves collapsibility of moulds/cores.

(d) Iron oxide

- Develops hot strength to moulding sand.
- Aid in the thermal transfer of heat from the mould-metal interface and provides stability to the moulds dimensional properties.

(e) Graphite

- It may be natural or synthetic graphite.
- Added in ranges of 0.2 – 2% by weight of sand.
- Improves surface finish of castings.
- Improves mouldability of foundry sand mixtures.

(f) Pitch

- Pitch is distilled from soft cool at about 600°F.
- May be added up to 2% by weight of sand.
- Improves hot strength.
- Improves surface finish on ferrous castings.