11

PATTERNMAKING AND FOUNDRY

11.1 INTRODUCTION

Pattern is the principal tool during the casting process. It may be defined as a model of anything, so constructed that it may be used for forming an impression called *mould* in damp sand or other suitable material. When this mould is filled with molten metal, and the metal is allowed to solidify, it forms a reproduction of the pattern and is known as casting. The process of making a pattern is known as *pattern making.*

Foundry engineering deals with the process of making casting in moulds prepared by patterns. The whole process of producing castings may be classified into five stages : (1) pattern making, (2) moulding and coremaking, (3) melting and casting, (4) fettling, and (5) testing and inspection. Except pattern making, all other stages to produce castings are done in foundry shops.

11.2 PATTERN MATERIALS

The selection of pattern materials depends primarily on the following factors.

1. Service requirements, e.g. quantity, quality and intricacy of casting i.e., minimum thickness desired, degree of accuracy and finish required.
2. Type of production of castings and the type of moulding process.
3. Possibility of design changes.
4. Number of castings to be produced, i.e., possibility of repeat orders.

To be good of its kind, pattern material should be :

1. easily worked, shaped and joined ;

2. light in weight ;
3. strong, hard and durable, so that it may be resistant to wear and abrasion, to corrosion, and to chemical action ;
4. dimensionally stable in all situation ;
5. easily available at low cost ;
6. repairable and reused ;
7. able to take good surface finish.

The wide variety of pattern materials which meet these characteristics are wood and wood products ; metals and alloys ; plasters ; plastics and rubbers ; and waxes.

Wood. Wood is the most common material for pattern as it satisfies many of the aforesaid requirements. It is easy to work and readily available. Wood can be cut and fabricated into numerous forms by glueing, bending, and curving ; it is easily sanded to a smooth surface, and may be preserved with shellac, which is the most commonly used finishing material for wooden pattern. Wood has its disadvantage as a pattern material. It is readily affected by moisture : it changes its shape when the moisture dries out of it, and when it picks up moisture from the damp moulding sand. It wears out quickly as a result of sand abrasion, and, if not stored properly, it may warp badly. Owing to these reasons wooden patterns do not last long, and they are generally used when a small number of castings are to be produced.

Wood used for pattern making should be properly dried before it is used. It should be straight–grained, free from knots, and free from excessive sapwood. The most common wood used for pattern is teak wood–both Burma and C. P. Teak. This wood is straightgrained, light, easy to work, has little tendency to break and warp and has reasonable cost. When a more durable wood is necessary for fragile patterns which are to be used as so-called "masters", mahogony is preferred. It is more costly than C. P. Teak. This, has a uniform grain, and is also easy to curve and shape. Other woods which may also be used in making patterns are sal, shisham, pine, deodar, and few other indigenous variety.

The wood products gaining more popularity for pattern work in recent times includes compressed wood laminates and laminated wood impregnates. The laminates are available as plywoods and as laminated boards, plain or veneered. Laminated wood impregnates are simply impregnated with resins so as to fill up the cell cavities or are impregnated and compressed to increase density and hardness.

Metal. Metal is used when a large number of casting are desired from a pattern or when conditions are too severe for wooden pattern. Metal patterns do not change their shape when subjected to moist conditions. Another advantage of a metal pattern is freedom from warping in storage. Metal patterns are very useful in machine moulding because of their accuracy, durability and strength. Commonly, a metal pattern is itself cast from a wooden pattern called *master pattern*. When metal patterns are to be cast from master patterns, double shrinkage must be allowed. For example, if the metal pattern is to be made of brass and the castings are to be of cast iron, the shrinkage allowed on the wood master pattern will have to be 14 mm per metre for brass, plus 10 mm per metre for cast iron, making a total of 24 mm per metre. Metals used for patterns include cast iron, steel brass, aluminium, and white metal.

Cast iron is used for some highly specialised types of patterns. It is strong, gives a good smooth mould surface with sharp edges and is resistant to the abrasive action of the sand. But cast iron patterns are heavy and are easily broken. Iron patterns rust too much and require a dry storage area.

Brass is used in patterns, particularly when metal patterns are small. It is strong, does not rust, takes a better surface finish than cast iron, and is able to withstand the wear of the moulding sand. But brass patterns are heavier than cast iron. This is why they are restricted to small size patterns.

Aluminium is probably the best all round metal because it melts at a relatively low temperature, is soft and easy to work, light in weight, and resistant to corrosion. Aluminium, being rather soft, is liable to be damaged by rough usage.

White metal is not much used for patterns but is the best material that can be used for making intricate and fine shapes. These alloys are used in most die-casting production and, therefore, are often called die-casting alloys. They have a low melting point, about 200°C, and have little appreciable shrinkage. A comparative evaluation of these metals is given as Table 11.1.

Plastics. Plastics are now finding their place as a modern pattern material because they do not absorb moisture, are strong and dimensionally stable, resistant to wear, have a very smooth and glossy surface, and are light in weight. Because of its glossy surface it can be withdrawn from the mould very easily without injuring the mould, and no dry or liquid parting compound is necessary. Furthermore, the plastic material has a very low solid shrinkage.

When a plastic pattern is required, a wooden pattern is first made to serve as a master pattern which forms the mould into which the plastic resin is poured. These moulds may be made of variety of materials including wood, rubber, plastics, metal or plaster of paris, the last being the one most commonly used.

Two types of plastic materials are used in pattern shops, namely thermosetting and thermoplastic. In the *thermosetting* varieties, epoxy resin has become very popular because of its good production qualities. Of the *thermoplastic* varieties, which tend to become soft and subsequently gasify on heating, the most common is polystyrene foam. The material is available in different densities in foamed or expanded form. It can be easily shaped, machined, and fabricated by glueing to form the pattern.

Rubbers. Certain types of rubbers, such as silicon rubber, are favoured for forming a very intricate type of die for investment casting. This material like epoxy resin, is available in two parts, binder and hardener. When the two parts, originally in liquid form, are mixed together, poured over a master pattern or into a die, and cured, a solid shape, i.e., a pattern, is produced.

Plasters. Gypsum cement known as plaster of paris is also used for making patterns and core boxes. It has a high compressive strength, e.g., up to 300 kg/cm^2, and it can be readily worked with wood tools. When talc and cement are mixed with water, it forms a plastic mass capable of being cast into a mould.

TABLE 11.1 COMPARATIVE EVALUATION OF METALS FOR PATTERNS*

Factors	*G.Cast iron*	*Steel*	*Aluminium*	*Brass*
Availability	Good	Good	Good	Good
Castability	Good	Difficult	Less difficult	Good
Machinability	Good	Good	Very good	Very good
Surface finish	Good	Good	Very good	Very good
Lending to modification	Good	Good	Good	Very good
Weight	Very heavy	Very heavy	Very light	Heavy
Brittleness	High	Low	Low	Low
Tendency to oxidation	Yes	Yes	No	No
Requiring machining	Yes	Less	Not much	Not much
Cost	Low	Low	Medium	High

*Courtesy : *Principles of Foundry Technology, P. L. Jain*, Tata McGraw Hill.

Plaster can also be conveniently used for preparing follow-boards for moulding work. Proprietary varieties of gypsum plasters such as Ultracal, Hydrocal, Hydrostone, and pattern shop Hydrocal, are also available.

Gypsum plaster pattern can be prepared either by directly pouring the slurry of plaster and water in moulds prepared earlier from a master pattern or by sweeping it into desired shape or form by the sweep-and-strickle method.

Waxes. Wax patterns are excellent for *investment casting process.* The materials generally used are blends of several types of waxes, and other additives which act as polymerising agents, stabilisers, etc. The waxes commonly chosen are paraffin wax, shellac wax, bees-wax, cerasin wax, and micro-crystalline wax. The properties desired in a good wax pattern include low ash content (up to 0.05 per cent), resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength.

The normal practice of forming wax pattern is to inject liquid or semiliquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength.

11.3 PATTERNMAKING TOOLS

The patternmaker is basically a wood worker. The tools employed in making patterns, therefore do not differ from those used by a wood worker, excepting the special tools that the particular needs of the trade have developed.

In addition to those used by a wood worker or carpenter, there is one tool in the equipment, *viz.* the *contraction rule,* which is a measuring tool typical of the patternmaker's trade. All castings contract in cooling from the molten state, and patterns have to be made correspondingly larger than the required casting in order to compensate for the loss in size due to this contraction.

Different metals and alloys have different contractions. The allowance for shrinkage, therefore, varies with different metals and also according to particular casting conditions, and it increases in proportion to the size of the pattern.

A separate scale is available for each allowance, and it enables the dimensions to be set out directly during laying out of the patterns. The rule usually used is the one that has two scales on each side, the total number of scales being four for four commonly cast metals namely, steel, cast iron, brass and aluminium. To compensate for shrinkage, the graduations are oversized by a proportionate amount, e.g. on 1 mm or 1 per cent scale, each 100 cm is longer by 1 cm. The rates of contraction for important cast metals are listed in Table 11.2.

TABLE 11.2 RATES OF CONTRACTION FOR IMPORTANT CAST METALS

Cast metal	*Dimension (mm)*	*Contraction (mm/m)*	*Remarks*
Cast iron			
	Upto 600	10.5	
	600-1200	8.5	
	Over 1200	7.5	
Cast steel	Upto 600	21.0	
	600-1800	16.0	
	Over 1800	13.0	
Aluminium	Upto 600	17.0	
	600 1200	13.0	
	1200-1800	12.0	1.5 mm less for cored construction
	Over 1800	10.5	
Magnesium	Upto 1200	14.5	1.5 mm less for cored construction
	Over 1200	13.5	
Brass		16.0	
Bronze		10.5-21	depends on composition
Malleable iron		11.8	6 mm section thickness
		10.5	9 mm section thickness
		9.2	12 mm section thickness
		7.9	15 mm section thickness
		6.6	18 mm section thickness
		4.0	22 mm section thickness
		2.6	25 mm section thickness

11.4 TYPES OF PATTERNS

The type of pattern selected for a particular casting will depend upon several conditions. Among these, one is the anticipated ease or difficulty of the moulding operation to come. Others are whether a small or large number of castings is wanted, the type of moulding process and other factors which may enter the situation because of characteristics peculiar to the casting. Several of the more commonly used types of pattern are listed and described below :

1. Single-piece pattern
2. Split pattern
3. Match plate pattern
4. Cope and drag pattern
5. Gated pattern
6. Loose-piece pattern
7. Sweep pattern
8. Skeleton pattern
9. Segmental pattern
10. Shell pattern
11. Built-up pattern
12. Boxed-up pattern
13. Lagged-up pattern
14. Left- and right-hand pattern

Single-piece or solid pattern. A pattern that is made without joints, partings, or any loose pieces in its construction is called a single-piece or solid pattern. A single-piece pattern is not attached to a frame or plate and is, therefore, sometimes known as a *loose pattern.* These patterns are cheaper. When using such patterns, the moulder has to cut his own runners and feeding gates and risers. This operation takes more time, and they are not recommended except for limited production. Single-piece patterns are usually used for large castings of simple shapes.

The simplest type of pattern classified under this heading is the *flat-back* as shown in Fig. 11.1. It may have few or no irregularities, may not have a core print, but very seldom does it have loose pieces. When completed, the mould cavity will be either entirely in the drag or entirely in the cope. The flat-back has the largest horizontal cross-sectional area and it serves as the parting surface in the mould. Soil temper, stuffing-box and gland of a steam engine are few examples of casting which are made by making solid patterns.

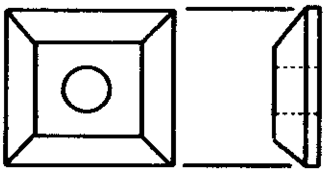


Figure 11.1 Solid pattern

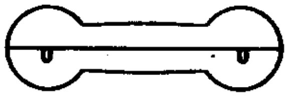


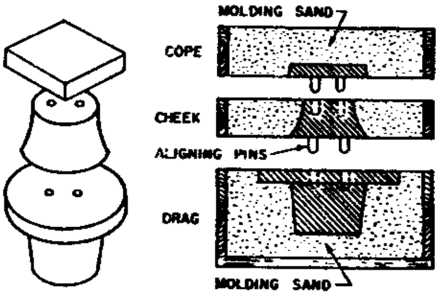
Figure 11.2 Two-piece split pattern

Split pattern. Many patterns cannot be made in a single piece because of the difficulties encountered in moulding them. To eliminate this difficulty, and for castings of intricate design or unusual shape, split patterns are employed to form the mould. These patterns are usually made in two parts, as shown in Fig. 11.2, so that one part will produce the lower half of the mould, and the other, the upper half. The two parts, which may or may not be of the same size and shape, are held in their proper relative positions by means of dowel-pins fastened in one piece and fitting holes bored in the other. The surface formed at the line of separation of the two parts, usually at the centreline of the pattern, is called the *parting surface or parting line.* It will also be the parting surface of the mould.

It is sometimes necessary to construct a pattern for a complicating casting that requires three or more parts instead of two to make the completed pattern (Fig. 11.3). This type of pattern is known as *multi-piece pattern.* A three-part pattern may necessitate the use of a flask having three parts, although it is possible to mould some types of three-part patterns in a two-part flask.

Spindles, cylinders, steam valve bodies, water stop cocks and taps, bearings, small pulleys and wheels are few examples of castings that require the use of split patterns.

Match plate pattern. When split patterns are mounted with one half on one side of a plate and the other half directly opposite on the other side of the plate, the pattern is called a match plate pattern. A single pattern or a number of patterns may be mounted on a match plate. The pattern is made of metal, and the plate which makes the parting line may be either wood or metal. Aluminium is commonly used for metal match plates. Patterns for gates and runners are fastened to the drag side of the plate in their correct positions to from the complete match plate. When the match plate is lifted off the mould all patterns are drawn, and the cope or upper half of the mould matches perfectly with the drag or lower half of the mould. The gates and runners are also completed in one operation.



(a) THREE-PART PATTERN

(b) THREE-PART MOLD

Fugure 11.3 Three-piece split pattern

Fig. 11.4 shows such a plate, upon which are mounted the patterns for two small dumbbells. Match plate patterns are used for producing small castings in large quantities in moulding machines which give accurate and rapid production. They are expensive to construct, but the initial cost is justified when quantity production is desired.

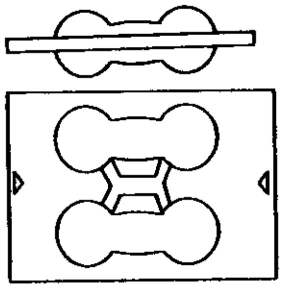


Figure 11.4 Match plate pattern

Cope and drag pattern. In the production of large castings, the complete moulds are too heavy to be handled by a single operator. Therefore, cope and drag patterns are used to ease this problem to efficient operation. The patterns are made in halves, split on a convenient joint line, and separate cope and drag patterns are built and mounted on individual plates or boards. This arrangement permits one operator or group of operators to prepare the cope half of the mould while another operator or group worked on the drag half. This planned distribution of labour increases production appreciably.

Gated pattern. To produce good casting, it is necessary to ensure that full supply of molten metal flows into every part of the mould. Provision for easy passage of the flowing metal into the mould is called gating which cannot be made by hand operations for volume high production particularly because of the time involved. In mass production, a number of castings are produced in a single multicavity mould by joining a group of patterns, and the gates or runners for the molten metal are formed by the connecting parts between the individual patterns. The time ordinarily is spent by the moulder in cutting gates and drawing patterns is eliminated by this arrangement. Such groups of patterns with gate formers attached to the pattern proper are called gated patterns as shown in Fig. 11.5.

Gated patterns may be made of wood or metal and are used for mass production of small castings.

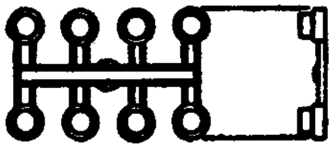


Figure 11.5 Gated pattern

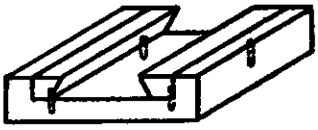


Figure 11.6 Loose-piece pattern

Loose-piece pattern. Some patterns are produced as assemblies of loose component pieces. The loose-piece patterns are needed when the part is such that the pattern cannot be removed as one piece, even though it is split and the line is made on more than one plane. In this case, the main pattern is usually removed first. Then the separate pieces, which may have to be turned or moved before they can be taken out are removed. Completed patterns of this type usually require more maintenance and are slower to mould. Fig. 11.6 show a loose-piece pattern.

Sweep pattern. Symmetrical moulds and cores, particularly in large sizes, are sometimes shaped by means of sweep patterns. The sweep pattern consists of a board having a shape corresponding to the shape of the desired casting and arranged to rotate about a central axis as illustrated in the Fig. 11.7. The sand is rammed in place and the sweep board is moved around its axis of rotation to give the moulding sand the desired shape. Sweep patterns are employed for moulding part having circular sections. The curved sweep might be used to form part of the mould for a large cast-iron kettle and the straight sweep for any shape of groove or ridges. The principal advantage of this pattern is that it eliminates expensive pattern construction.

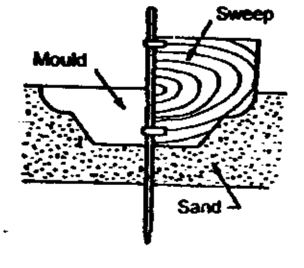


Figure 11.7 Sweep pattern

Skeleton pattern. Patterns for very large castings would require a tremendous amount of timber for a full pattern. In such cases a skeleton pattern as in Fig. 11.8 may be employed to give the general contour and size of the desired casting. This is a ribbed construction with a large number of square or rectangular openings between the ribs which form a skeleton outline of the pattern to be made. The framework is filled and rammed with clays, sand or loam, and a *strike- off board* known as a *strickle board* is

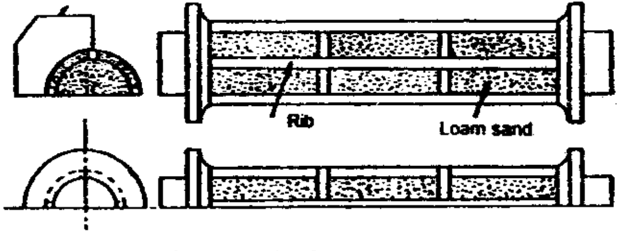


Figure 11.8 Skeleton pattern

used to scrape the excess sand out of the spaces between the ribs so that the surface is even with the outside of the pattern. It is usually built in two parts : one for the cope and the other for the drag.

Soil and water pipes, pipe bends, valve bodies, and boxes are few examples of castings which are made by making skeleton patterns.

Segmental pattern. Segmental patterns or *part patterns* are generally applied to circular work such as rings, wheel rims, gears, etc. They are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. When making a mould using this pattern, a vertical spindle is firmly fixed in the center of drag flask (Fig. 11.9). The bottom of the mould is rammed and swept level. Then the segmental pattern is fastened to the spindle. Moulding sand is rammed between the outside of the pattern and the flask, and in the inside, but not at the ends of the pattern. After ramming one section, it goes forward to the next section for ramming ; and so on, until the entire mould perimeter has been completed.

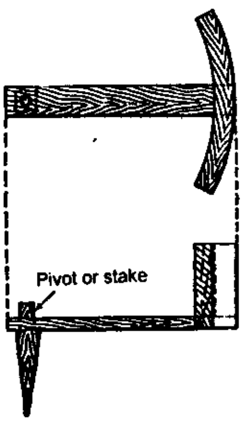


Figure 11.9 Segmental pattern

Shell pattern. The shell pattern is used largely for drainage fittings and pipe work. A typical example is shown at Fig. 11.10. The pattern is usually made of metal, mounted on a plate and parted along the centre line, the two sections being accurately doweled together. These short bends are usually moulded and cast in pairs. The shell pattern is a hollow construction like a shell and the outside shape is used as a pattern to make the mould, while the inside is used as a core-box for making cores.

Sometimes, a pattern of the entire shape of the casting is termed a shell pattern, and a pattern that is of the required shape outside, but having the inside cored out is termed a *block pattern.*

Built-up pattern. As the name implies, built-up patterns or parted patterns are composed of two or more pieces. Patterns for special pulleys are built-up segments of wooden strips. These segments are made by cutting strips of wood to the curvature required, and the thickness desired is built up by glueing them in layers. Flanges are also made similarly. The building up is sometimes necessary because it is difficult to make an intricate shape on a block of wood for constructing a pattern, but it is easier to build up the shape by glueing or joining number of segmental pieces together.

Boxed-up pattern. In a boxed-up pattern the planks or strips of wood are so joined together either by glue, nails, or screws that a pattern is made like a box. Not only this method economises wood for large patterns but makes them lighter on weight. The box construction is employed in making many patterns specially for a casting having a regular outline and rectangular form.

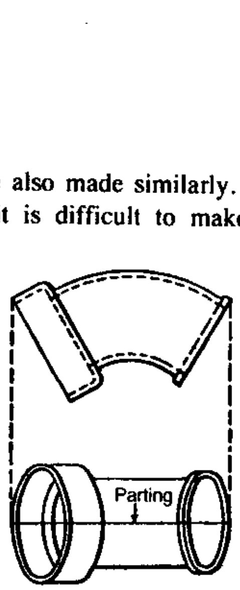


Figure 11.10 Shell pattern

Lagged-up pattern. Cylindrical works such as cylinders pipes or columns are built up with lag or stave construction which ensures permanence of form. "Lags" or "Staves" are longitudinal strips of wood which are bevelled on each side to make the joint tight outside, and glued and nailed or screwed to the end pieces of wood called "heads". The illustration of Fig. 11.11 shows the staves fastened to heads that are half a regular polygon, the object being to make a cylinder or barrel that is to be parted longitudinally through the centre. Such a construction gives the maximum amount of strength and permits building close to the finished outline of the pattern so that there is comparatively little excess stock to be removed to bring it to the required form.

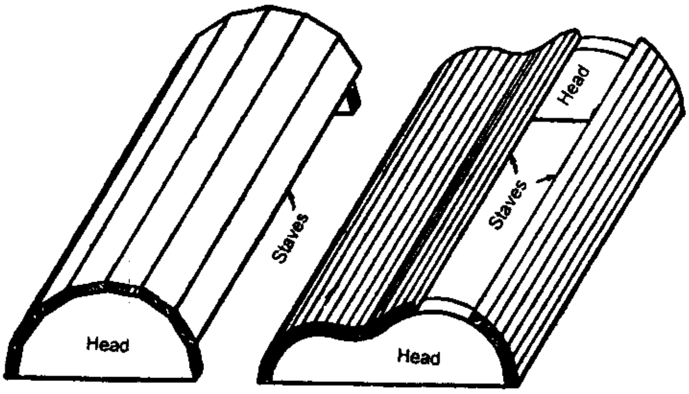


Figure 11.11 Lagged-up pattern

Left-and right-hand patterns. Many patterns are required to be made in pairs, and when their form is such that they cannot be reversed and they have the centres of hubs, bosses, etc., opposite and in line, they must be made right- and left hand. 'J' hangers for overhead shaft line, legs for wood-turning lathe, or garden bench or for paddle type sewing machine, and brackets for luggage racks in the railway carriages are few examples where a pair of right- and left-hand patterns are required. In such instances, on many occasions, pattern makers are supplied with drawings which show either a right- or left-hand casting. From this he is requested to make pattern equipment for both the right- and left-hands. This often presents considerable difficulties especially on the more complicated drawings as to what constitutes the difference between left-and right hand patterns.

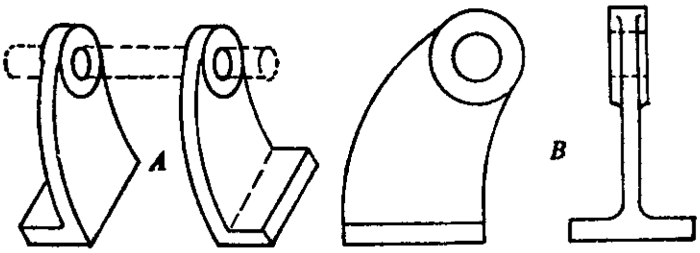


Figure 11.12 Left- and right-hand pattern

The bracket show at *A* in Fig. 11.12 is an example of left- and right-hand patterns. It will be noticed that the only variations between these two patterns is in their base position. If, however, the design could have been made with a base equal on each side of the vertical part (Fig. 11.12*B*), the necessity for two patterns would have eliminated.

METAL PATTERNS

Metal patterns are used for large scale production of castings and they are rarely required as loose patterns. As the patterns are cast, there is no need to make joints or segments. However, the method of manufacture is intricate and requires immense skill. The patternmaker must be practised in metal cutting, finishing, and fabrication methods in addition to inspection technique. Metal patterns, when used, are normally mounted on one or both sides of a pattern plate. When patterns are small, several patterns can be mounted on the same plate.

11.5 PATTERN MAKING ALLOWANCES

Patterns are not made the exact same size as the desired casting for several reasons. Such a pattern would produce castings which are undersize. Allowance must therefore be allowed for shrinkage, draft, finish, distortion, and rapping.

Shrinkage allowance. As metal solidifies and cools, it shrinks and contracts in size. To compensate for this, a pattern is made larger than the finished casting by means of a shrinkage or contraction allowance. In laying measurements for the pattern the patternmaker allows for this by using shrink or contraction rule which is slightly longer than the ordinary rule of the same length. For example, when constructing a pattern for cast iron, the pattern maker uses a shrink rule measuring about 10 mm longer per metre than the conventional rule since cast iron shrinks 10 mm per metre. Different metals have different shrinkages, therefore, there is a shrink rule for each type of metal used in a casting. Typical shrinkage allowances are shown in Table 11.2. A master pattern from which metal patterns are cast may have double shrinkage allowance.

Draft allowance. When a pattern is drawn from a mould, there is always some possibility of injuring the edges of the mould. This danger is greatly decreased if the vertical surfaces of a pattern are tapered inward slightly. This slight taper inward on the vertical surfaces of a pattern is known as the draft. Draft may be expressed in millimeter per metre on a side, or in degrees, and the amount needed in each case depends upon (1) length of the vertical side, (2) intricacy of the pattern, and (3) the method of moulding. Under normal conditions the draft is about 10 to 20 mm per metre on exterior surfaces and 40 to 60 mm per metre on interior surfaces. Fig. 11.13 shows how a draft is provided in a pattern.

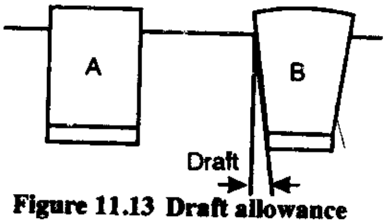
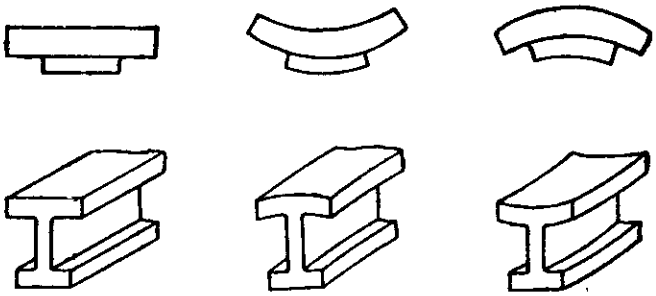


Figure 11.13 Draft allowance

Machining allowance. Rough surfaces of castings that have to be machined are made to dimensions somewhat over those indicated on the finished working drawings. The extra amount of metal provided on the surfaces to be machined is called machine finish allowance and the edges of these surfaces are indicated by a finish mark *V*, or *F*. The amount that is to be added to the ;pattern depends upon (1) the kind of metal to be used, (2) the size and shape of the casting and (3)method of moulding. The standard finish (machining) allowance for different cast metals in mm for hand moulding is given in Table 11.3

Distortion or camber allowance. Some castings, because of their size, shape and type of metal, tend to warp or distort during the cooling period. This is a result of uneven shrinkage and is due to uneven metal thickness or to one surface being more exposed than another, causing it to cool more rapidly. The shape of the pattern is thus bent in the opposite direction to overcome this distortion. This feature is called *distortion* or *camber allowance*. As an example, a casting shaped like the letter *U* will be distorted with the legs diverging, instead of parallel (Fig. 11.14). To compensate for this condition, the pattern is made in such a manner that the legs converge but as the casting cools after its removal from the mould, the legs straighten and remain parallel. Although no distortion data in published form is available, the distortion allowance ranges from the standard finish allowance upto 20 mm when large castings are considered.



Required shape of casting　Distorted casting　Cambered pattern

Figure 11.14 Distortion in casting

TABLE. 11.3 STANDARD MACHINING ALLOWANCE

Diameter of hole / distance from locating point	*Cast iron*		*Cast steel*		*Nonferrous*	
	Bore	*Surfaces*	*Bore*	*Surfaces*	*Bore*	*Surfaces*
200	3	3	4	4	1.5–2.0	1.5
200—400	4.5	4	5.5	5	2.0	1.5
400—700	6	5	7	6	3.0	2.0
700—1100	7	6	9	7	3.5	2.5
1100—1600	9	7	11	9	4.0	3.0
1600—2200	10	8	13	11	—	—
2200—3000	12	9	15	13	—	—

Rapping allowance. When a pattern is rapped in the mould before it is withdrawn, the cavity in the mould is slightly increased. In every cases where castings must be uniform and true to pattern, rapping or shake allowance is provided for by making the pattern slightly smaller than the actual size to compensate for the rapping of the mould.

11.6 METHODS OF CONSTRUCTING PATTERNS

After the moulding procedure and the form of the pattern have been decided upon, a layout of the pattern is made.

PREPARATION OF PATTERN LAY OUT

Layouts are, in general, reproductions of the blue prints laid out to full-size scale on a flat smooth wooden board. The boards for laying out large work are sometimes blackened on the face, and the drawings set down in the chalk lines. If more than one view is required, the additional views are set down on the top of the first view ; the lines being coloured differently for distinction. The patternmaker's drawings are often used by the moulder for reference until the castings are made. In such instances they are wholly or partly varnished with shellac varnish to preserve them.

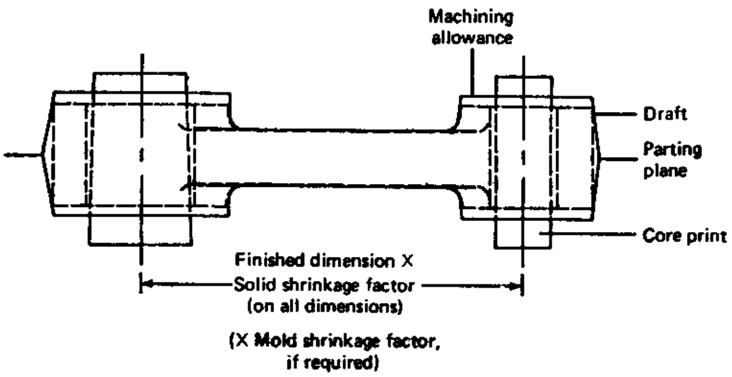


Figure 11.15 Pattern layout giving allowances (finished part shown in broken line)

After the patternmaker has completed the pattern lay out, making allowances–shrinkage, finish, draft, etc. (Fig. 11.15), the next step is the shaping of the pieces that are to be used in the construction of the pattern. The particular method to be used in any given case depends upon the size and shape of the pattern and to a large degree upon the number of castings required. In making patterns it is particularly desirable that the grain of the wood will run in the direction of the greatest length of the piece being shaped. This provides strength and reduces the chance of inaccuracy due to change in size of the pattern lumber.

Fillets. In finishing pattern all the angled corners are filled in with fillets as illustrated in Fig. 11.16. The leaving of sharp corners on a pattern causes the mould to be very weak due to the concentration of stresses at these parts, and if not filled by the moulder, these corners often wash away with the flow of the metal, and thus spoil the casting. It is a good practice, therefore, to fill in the corners of the pattern as this gives a stronger and cleaner mould, and also adds considerably to the strength and appearance of the casting. The fillet may be removed afterwards by machining, if required. The fillets may be made of wood, leather, metal or wax, but fillets made of wood are mostly used.

Flat pattern. A flat pattern may be made by cutting a solid piece of wood to the desired shape, or it may be built up with a number of very thin pieces which are so glued together that their grains run at right angles to the adjacent pieces. As one thick piece is more liable to shrink and alter in shape than several thin pieces well jointed and glued, it will be at once apparent that the latter method has a great advantage over the former.

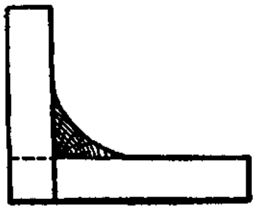


Figure 11.16 Fillet joint

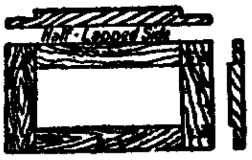


Figure 11.17 **Construction of rectangular pattern**

Rectangular pattern. The pattern of a rectangular outline is built up in the form of a box. Fig. 11.17 is the first part of the construction in boxing up–namely "grounds" or "bridges" which form the foundation of this job. These grounds are framed up with the joints half lapped together. The grounds can then be "checked" or recessed out (see dotted lines in Fig. 11.17) to receive longitudinal stays. The stays fix the grounds in position. The grounds and stays are now properly screwed, squared and leveled together, to form a framing, strong and rigid, to receive the covering boards. The top and bottom pieces of the covering are first placed on. They are screwed to the grounds and stays, with the outer edges flush with the framing. Lastly, the sides are placed on. The pattern now boxed up is trimmed off and the faces finished with the trying plane.

Cylindrical pattern. A cylindrical work that is to be finished by hand or by turning is built up with lag or stave construction as illustrated at *A* in Fig. 11.18. In this construction two or more end pieces called heads in the form of two half regular polygons are used, and lags are fastened to the heads.

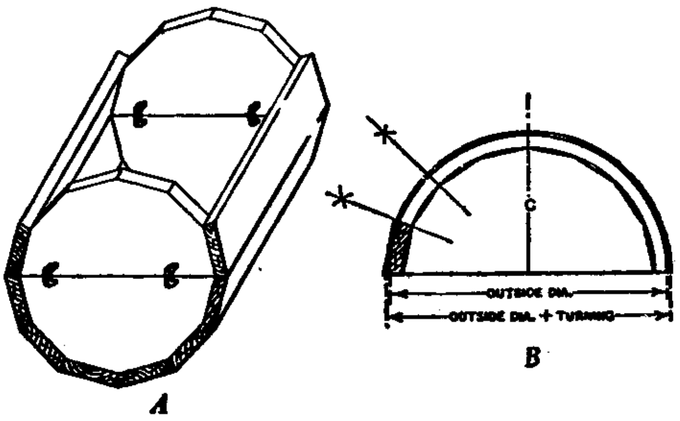


Figure 11.18 Construction of a cylindrical pattern

In laying out the heads for a cylinder, a circle is scribed on a layout corresponding to the outside diameter of the cylinder plus the amount allowed for pattern turning and a centre line is drawn dividing the head into two half sections. The semicircle is divided into a number of equal parts depending on the number of staves to be used as illustrated at B. The staves are fastened to the heads by glue, and nails or screws.

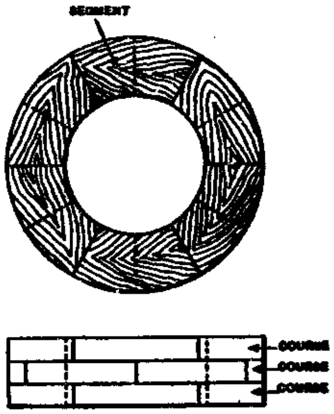


Figure 11.19 Construction of a ring-shaped pattern

Ring-shaped pattern. Ring and disc-shaped patterns are built up by glueing a number of segments of sectors together as shown in Fig. 11.19. These segments or sectors are built up of successive layers of wood called "courses", their sum being equal to the thickness of the required piece. In each segment the long grains of wood are kept parallel to the chord of the circle to be first constructed. By constructing the pattern in this way, the grains of wood will follow the circle as nearly as possible and the shrinkage of each segment will be uniform.

Wheel and pulley pattern. There are two general classes of wheels–one has the plate or solid centre and is called a "webbed" wheel, and the other has spokes or arms. In building webbed wheels with segment rims, as is the usual practice, the segments should run in continuous courses to form the face, a recess being turned in the central course to receive the web which is circular in form. The web should fit the recess turned to receive it and should be glued and nailed in place. When making patterns for armed wheels which have spokes that radiate from the centre as illustrated at *B* in Fig. 11.20, the spokes are worked to form as at *A*, usually before they are assembled. The spokes are fastened to the rim by being built in during the turning process or after the rim is finished. The assembled arms are called a "spider", and there are a number of ways of fastening them together at the hub or centre.

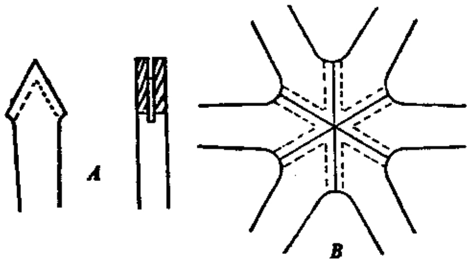


Figure 11.20 Construction of a wheel and pulley pattern

Another way of forming the rim, and the one most commonly used, is by means of a segment or part pattern that is moved in a circle as section of the mould is rammed as described in Article 11.4 under the heading "segmental pattern".

Gear pattern. The rims of large gears are usually built up of segments of the same flywheels or pulleys, and the blocks for the teeth are fitted and fastened to the rim. The simplest way to fasten the blocks is to glue and nail them into place, as at *A* in Fig. 11.21, but the methods illustrated at *B* and *C* are generally employed. Teeth formed by jig are illustrated at *D*. Jigged teeth are fastened to the rim with glue and nails, and are not turned.

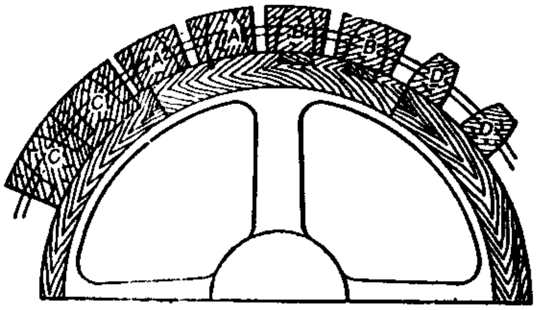


Figure 11.21 Construction of a gear pattern

11.7 OTHER TECHNOLOGICAL CONSIDERATIONS

Follow-board. Patterns that have thin sections, such as the one shown in Fig. 11.22, tend to become distorted considerably or possibly to collapse, under the stress of ramming. This problem of sagging can be easily overcome by constructing a block which will fit inside the pattern to serve as a support during the ramming operation. This support block is known as follow-board. A great many stove and furnace patterns are made on follow-boards, and these are often "masters" for casting metal patterns.

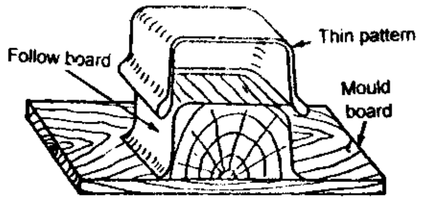


Figure 11.22 Follow-board

The purpose of the follow-board is, in some cases, not only to serve as a support to the fragile pattern, but to form an irregular parting line in the mould when the outlines of the pattern are not regular. Follow-boards for making partings are very often made of plaster-of-paris or litharge.

Strickle board. The strickle board, also called *strike-off* board, is a thin piece of wood or metal to scrape off excess sand from a skeleton pattern. It is also used for cutting sand cores in halves, and sand moulds for large concentric castings such as flywheels, gear wheels, cone pulleys, etc. The strickle may be a straight edge for flat surfaces or shaped to the required contour of outline. All strickles should be levelled on their working edge. A strickle board is shown in Fig. 11.39.

Stop-off pieces. A *stop-off* is a piece of stock placed on the drag of a thin pattern to add support. Very frequently it becomes necessary to construct a thin pattern which will naturally have a tendency to warp out of its true shape. This tendency to warp out can be overcome by adding narrow strips of materials known as stop-offs (Fig. 11.23). When the pattern is drawn from the mould, the impressions it makes are later filled in with sand, rammed, and smoothed off, and the resulting casting will not show the position of stop-off.

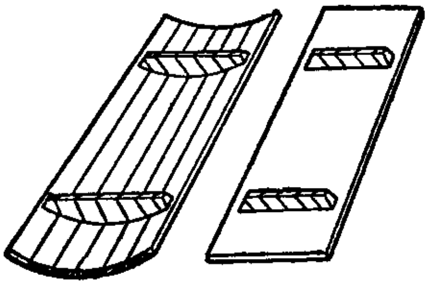


Figure 11.23 Stop-off pieces to strengthen flimsy pattern

Stop-off is a term which is also used to describe the process of reducing the size of a mould for the purpose of making a shorter casting. For doing so, the pattern maker provides a stop-off piece to enable the moulder to adjust the length of the mould to the correct length required. The extra length in the cavity produced by a longer pattern is filled up and rammed with moulding sand. A stop-off piece may, thus, be used as a part of a longer pattern enabling the patternmaker to avoid making of another pattern for a shorter casting. This is illustrated in Fig. 11.24.

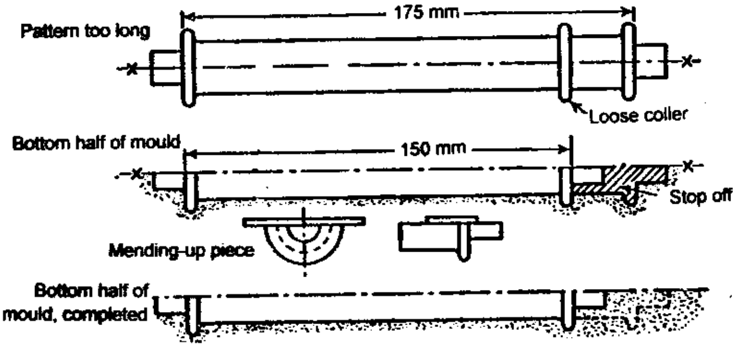


Figure 11.24 Stop-off pieces

Loose-pieces. The pattern which cannot be drawn from the sand owing to the projections can be drawn by making these projections as loose-pieces. The loose-pieces are fixed to the pattern by means of pins, which are removed as soon as sufficient sand has been rammed round the loose-pieces to hold them in position. The mould is then completed and the main body of the pattern is lifted out of the sand in the usual way, following which the loose-pieces are removed separately by a tool known as *skewer* as shown in Fig. 11.25.

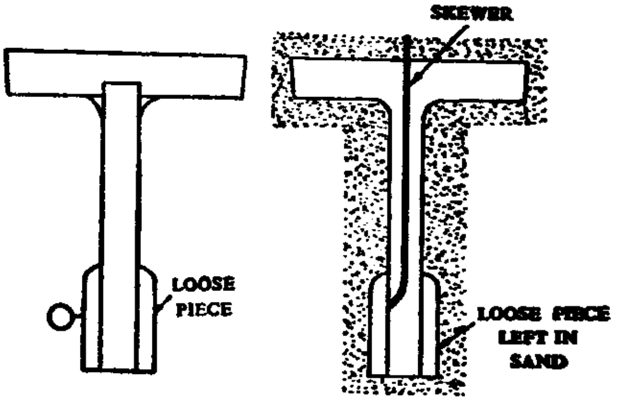


Figure 11.25 Pattern showing loose-pieces

11.8 COREPRINTS

Castings are often required to have holes, recesses, etc. of various sizes and shapes. These impressions are obtained by using sand cores which are separately made in boxes known as coreboxes. For supporting the cores in the mould cavity, an impression in the form of a recess is made in the mould with the help of a projection suitably placed on the pattern. This projection on the pattern is known as the coreprint. A coreprint

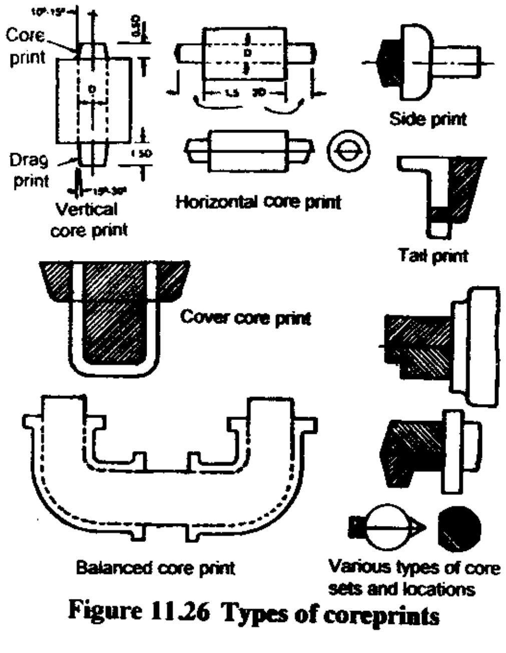


Figure 11.26 Types of coreprints

is, therefore, an added projection on a pattern, and it forms a seat which is used to support and locate the core in the mould. There are several types of coreprints, viz., horizontal or parting line coreprint, vertical or cope and drag coreprint, balancing coreprint, cover or hanging core-print, wing or drop core-print. (Fig. 11.26).

Horizontal coreprint. This is laid horizontally in the mould and is located at the parting line of the mould. The coreprint is often found on the split or two-piece pattern. When it is important that certain core be located at a desired angular relationship with respect to the central axis, a flat portion at one end is made to coincide with a flat portion of the coreprint.

Vertical coreprint. This stands vertically in the mould. This is why this type of core is referred to as a vertical coreprint. The coreprint is located on the cope and drag sides of a pattern and is constructed with considerable taper specially on the cope side (about 10-15°)so that they are easily moulded. The taper on drag print is only 1.5–3°.

Balancing coreprint. This is used when a horizontal core does not extend entirely through the casting, and the core is supported at one end only. An important feature of this coreprint is that the print of the core in the mould cavity should balance the part which rests in the core seat.

Hanging or cover coreprint. This is used when the entire pattern is rammed in the drag and the core is required to be suspended from top of the mould. In this case, the core serves as a cover for the mould, and also as a support for hanging the main body of a core.

Wing or drop coreprint. This is used when the cavity to be cored is above or below the parting line in the mould. Wing coreprints are also known as "chair", and "tail" coreprints.

11.9 CORE BOXES

A core box is essentially a type of pattern made of wood or metal into which sand is rammed or packed to form a core. The types of core boxes, in common use, in foundry work, are described below.

- **Half box.** A half box, as shown in Fig. 11.27, is used to form two identical halves of a symmetrical core. After they are shaped to form and baked, the core halves are pasted together to form a completed core.

Dump box. A dump box, illustrated in Fig. 11.28, is designed to form a complete core that requires no pasting. If the core thus made is in the shape of a slab or rectangle, it is called a rectangular box. The box is made with open one side and the sand is rammed up level with the edges of this opening.

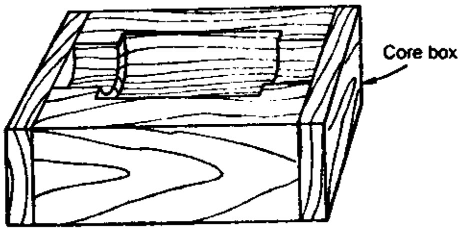


Figure 11.27 Half core box

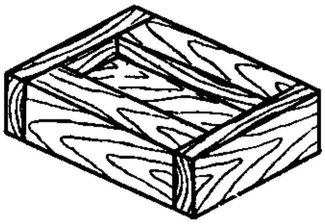


Figure 11.28 Dump core box

Split box. An example of a split core box is shown in Fig. 11.29. It consists of two halves which are clamped together. One half of the box has two or more dowels to hold the parts in correct alignment. It is arranged with opening at one or both ends for filling and ramming the sand. After ramming and striking off the excess sand, the core box is unclamped and rapped. This type of core box moulds the entire core.

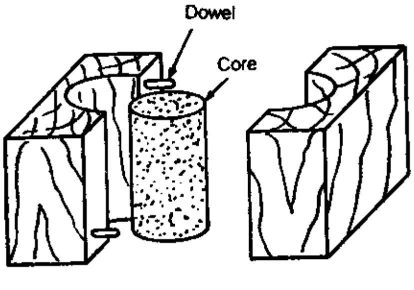


Figure 11.29 Split core box

A booked type core box is somewhat similar to a split core box. It consists of two halves, hinged together, opening and closing like a book to form a complete core.

Strickle box. A strickle box is often used when a core with an irregular shape is required. In a strickle box, the shape of the core is produced by striking off the core sand from the top of the core box with a piece of stock called strickle board made to correspond to the contour of the required core as shown in Fig. 11.30.

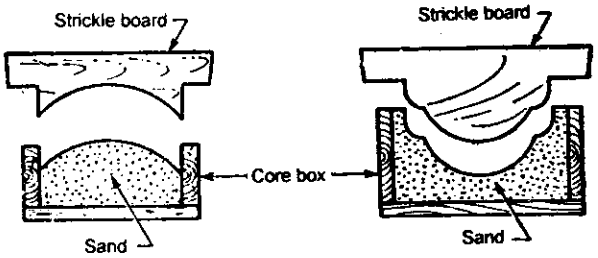


Figure 11.30 Strickle core box

Right- and left-hand box. Right- and left-hand core boxe, illustrated in Fig. 11.31, are necessary when two-half cores made in the same box cannot be pasted together to form an entire core. The core halves are made in these two boxes and pasted together.

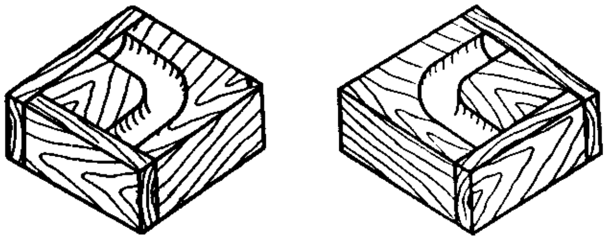

(a) Left-hand box (b) Right-hand box

Figure 11.31 Right- and left-hand core box

Gang box. In instances where large number of cores are to be made, a gang core box, in which several core cavities are rammed in a single operation, is employed. A gang core box is illustrated in Fig. 11.32.

Core box with loose pieces. The joints and devices used for fastening loose-pieces to patterns are also used for the same purpose in core-box work. Bosses, hubs, etc. are skewered to the sides or ends. The skewers, where possible, drawing through the sides or ends form the outside of the box.

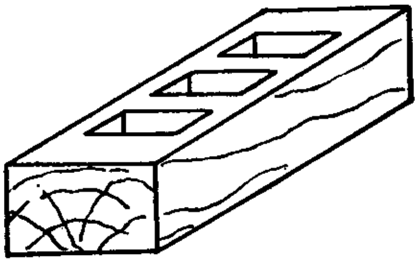


Figure 11.32 Gang core box

Sweep and skeleton box. A sweep and a skeleton core box looks like a sweep and a skeleton pattern. They are used for large cores required in small quantities.

11.10 COLOUR CODING FOR PATTERNS AND CORE-BOXES

All surfaces of a wooden pattern are coated with shellac to keep out moisture and important parts of a pattern and core-box are coloured for identification of their different parts. A widely accepted colour code for general use is given below.

1. Surfaces to be left unfinished are to be painted *black*.
2. Surfaces to be machined are to be painted *red*.
3. Seats for loose-pieces are to be marked by *red stripes on a yellow* background.
4. Coreprints are to be painted *yellow*.
5. Stop-offs are to be marked by diagonal *black stripes on yellow base*.

For IS Colour code see Appendix.

FOUNDRY

Foundry or casting is a process of forming metallic products by melting the metal, pouring it into a cavity known as the mould, and allowing it to solidify. When it is removed from the mould it will be of the same shape as the mould. Almost any article may be cast with proper technique and design, and there is practically no limit as to the size and shape of the castings that may be made.

11.11 MOULDING TOOLS AND EQUIPMENT

Foundry tools and equipment may be classified into three groups, namely, hand tools, flasks, and mechanical tools.

Hand tools. The hand tools a moulder uses are fairly numerous. A brief description of the most important tools is given here.

Shovel: A shovel (Fig. 11.33) is used for mixing and tempering moulding sand and for moving the sand from the pile to the flask.

Figure 11.33 Shovel

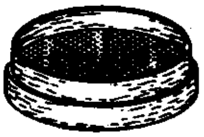


Figure 11.34 Riddle

Riddle: A riddle, sometimes called a *screen*, consists of a circular or square wooden frame fitted with a standard wire mesh at the bottom as shown in Fig. 11.34. It is used for removing foreign materials such as nails, shot metal, splinters of wood, etc., from the moulding sand. Both hand and power riddles are available, the latter being used where large volumes of sand are to be riddled.

Rammer : A hand rammer (Fig. 11.35) is a wooden tool used for packing or ramming the sand into the mould. One end, called the *peen*, is wedge shaped, and the opposite end, called the *butt*, has a flat surface. Floor rammers are similar in construction but have long handles. Pneumatic rammers are used in large moulds saving considerable labour and time.

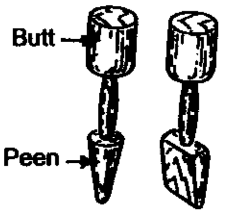


Figure 11.35 Hand rammer

Trowel : A trowel consists of a metal blade fitted with a wooden handle (Fig. 11.36). Trowels are employed in order to smooth or sleek over the surfaces of moulds. A moulder also uses them in repairing the damaged portions of a mould. The usual trowel is rectangular in shape and has either a round or square end.

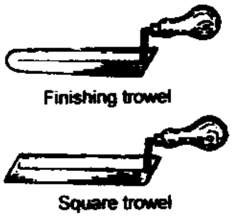


Figure 11.36 Trowel

Slick : It is a small double-ended tool having a flat on one end and a spoon on the other end (Fig. 11.37). This tool is also made in a variety of shapes. The type most commonly used is the oval spoon. Slicks are used for repairing and finishing small surfaces of the mould.

Figure 11.37 Slick

Lifter: Lifters are made of thin sections of steel of various widths and lengths with one end bent at right angles as shown in Fig. 11.38. They are used to clean and finish the bottom and sides of deep, narrow openings in moulds.

Figure 10.38 Lifter

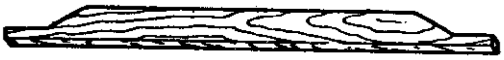


Figure 11.39 Strike-off bar

Strike-off bar : The strike-off bar is a piece of metal or wood with a straight edge (Fig. 11.39). It is used to strickle or strike-off excess sand from the mould after ramming to provide a level surface.

Sprue pin : A sprue is a tapered peg (Fig. 11.40) pushed through the cope to the joint of the mould. As the peg is withdrawn it removes the sand, leaving an opening for the metal. This opening is called the sprue through which the metal is poured. The sprue pin forms the riser pin.

Figure 11.40 Sprue pin

Figure 11.41 Bellow

Bellow : Bellows are used to blow loose particles of sand from the pattern and the mould cavity. A hand blower is shown in Fig. 11.41. Moulding machines are also provided with a compressed air jet to perform this operation.

Swab : A simple swab is a small brush having long hemp fibres a bulb swab has a rubber bulb to hold the water and a soft hair brush at the open end. A *bulb swab* is shown in Fig. 11.42. Swabs are used for moistening the sand around a pattern or for applying paint.

Gate cutter : It is a small piece of tin plate shaped as shown in Fig. 11.43. This serves as a tool for cutting gates and runners in the mould.

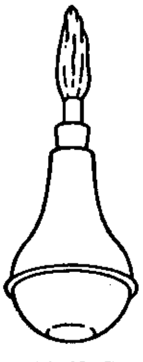


Figure 11.42 Swab

Figure 11.43 Gate cutter

Figure 11.44 Mallet

Mallet : A raw hide mallet (Fig. 11.44) is used to loosen the pattern in the mould so that it can be withdrawn without damage to the mould.

Vent rod : A vent rod or wire, as shown in Fig. 11.45, is used to make a series of small holes to permit gases to escape while the molten metal is being poured.

Figure 11.45 Vent rod

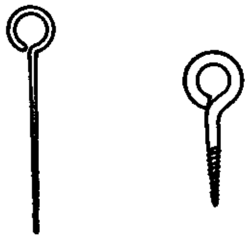


Figure 11.46 Draw spike

Draw spike or screw : The draw spike is a pointed steel rod, with a loop at one end. It is used to rap and draw patterns from the sand. Fig. 11.46 illustrates two kinds of draw spikes. The draw spike is threaded on the end to engage metal patterns.

Rapping plate : A rapping or lifting plate, as shown in Fig. 11.47, is used to facilitate rapping and lifting of the pattern from the mould. The plate must be firmly attached to the pattern by long screws or even bolts in larger patterns. The moulder places a draw spike in the rapping hole and raps it to loosen the pattern, then fixes draw screws into the screw hole on the plate.

Figure 11.47 Rapping plate

Pouring weight : A pouring weight is simply a plate of cast iron with a cross-shaped opening cast in it to give considerable liberty in placing the runner in the mould. It is used on the top of a mould for giving a weight to prevent the pressure of the liquid metal from forcing the mould apart causing a run-out.

Gaggers : Gaggers, sometimes called lifters, are iron rods bent at one end or both ends (Fig. 11.48). They are used for reinforcement of sand in the top part of a moulding box, and to support hanging bodies of sand.

Clamps : Clamps (Fig. 11.49) are used for holding together the cope and drag of the completed mould to prevent he cope from floating or rising when the metal is introduced into the mould.

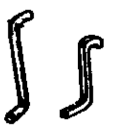


Figure 11.48 Gaggers

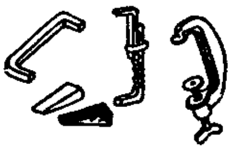


Figure 11.49 Clamps

Figure 11.50 Spirit level

Spirit level : The spirit level in Fig. 11.50 is used by the moulder to ensure that his bed of sand moulding box or moulding machine table is horizontal.

Moulding board and bottom board : A moulding board is a smooth wooden board on which the flask and patterns are placed when the mould is started. When the mould is turned over, the function of this board is ended the mould is placed on a similar board, called a bottom board, which acts as a support for the mould until it is poured.

Moulding boxes. Sand moulds are prepared in specially constructed boxes called flasks. The purpose of the flask is to impart the necessary rigidity and strength to the sand in moulding. They are usually made in two parts, held in alignment by dowel pins. The top part is called the *cope* and the lower part the ***drag***. If the flask is made in three sections, the centre is called the ***cheek*** (Fig. 11.3). These flasks can be made of either wood or metals depending upon the size required and the purpose the flasks must serve. Metal flasks are used when production is large, but when only a few castings are needed and a special flask must be obtained, the wooden flask is the most economical.

Two types of flasks are used in a foundry : (1) the snap flask, and (2) the tight or box flask. A *snap flask* (Fig. 11.51) is made with the hinge on one corner and a lock on the opposite corner so that the flask may be removed from the mould before it is poured. The snap flask is of advantage in that many moulds can be made for the same pouring from a single flask.

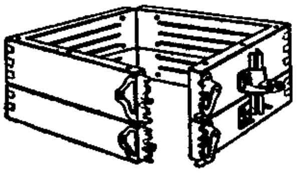


Figure 11.51 Snap flask

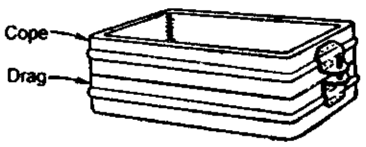


Figure 11.52 Box flask

The *tapered slip flask* is another type of removal flask. It has rigid corners but the sides have a smooth inside surface and a 5-degree taper to allow the flask to be removed upward.

A box flask shown in Fig. 11.52 must remain in the mould until the pouring operation is completed. These boxes are usually made of metal and are very suitable for small and medium sized moulding.

A typical wooden moulding box is shown in Fig. 11.53. The side timbers are continued beyond the ends of the box to form two handles at each end. The sides are held together by strong cross timbers, reinforced with bolts. This is easier to handle and may be employed for large moulding.

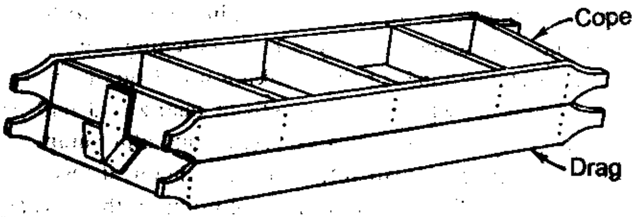


Figure 11.53 Wooden moulding box

Mechanical tools. The mechanical tools in the foundry include the many types of moulding machines that will ram the mould, roll it over, and draw the pattern. Besides, there are power operated riddles, sand mixers, sand conveyors, etc. The mould is even poured and shaken out mechanically, and the casting is taken by machine to the cleaning department. The amount of mechanisation, however, varies considerably from one foundry to the other. Mass-production foundries making large quantities of relatively few types of castings are in a position to mechanise more completely than the job-shop foundries.

11.12 MOULDING SANDS

The principal material used in the foundry shop for moulding is the sand. This is because it possesses the properties vital for foundry purposes.

Sources. All sands are formed by the breaking up of rocks due to the action of natural forces such as frost, wind, rain, heat and water currents. Rocks, however, are very complex in their composition, and sands contain most of the elements of the rocks of which they are fragments. For this reason, moulding sands in different parts of the world vary considerably. Today, sand is obtained from places which probably once were bottoms and banks of rivers and sand dunes.

In India, foundry sands are found in Damodar and Barakar area, Santhal Pargana (Bihar), Batala (Gurdaspur, Punjab), Bhavnagar (Saurashtra), Londha (Maharashtra), Avadi and Veeriyambakam (Madras), Kanpur, Jabalpur, Rajkot, Guntur, in Ganges and many other places.

Principal ingredients. The principal ingredients of moulding sands are : (1) silica sand grains, (2) clay, (3) moisture, and (4) miscellaneous materials.

Silica in the form of granular quartz, itself a sand, is the chief constituent of moulding sand. Silica sand contains from 80 to 90 per cent silicon dioxide and is characterized by a high softening temperature and thermal stability. It is a product of the breaking up of quartz rocks or the decomposition of granite, which is composed of quartz and feldspar. The feldspar, when decomposed, becomes clay (hydrous aluminium silicate). However, silica sand grains impart refractoriness, chemical resistivity, and permeability to the sand. They are specified according to their average size and shape.

Clay is defined as those particles of sand (under 20 microns in diameter) that fail to settle at a rate of 25 mm per minute, when suspended in water. Clay consists of two ingredients : fine silt and true clay. Fine silt is a sort of foreign matter or mineral deposit and has no bonding power. It is the true clay which imparts the necessary bonding strength to the mould sand, so that the mould does not lose its shape after ramming. True clay is found to be made up of extremely minute aggregates of crystalline, usually flake-shaped, particles called clay minerals. Most moulding sands for different grades of work contain 5 to 20 per cent clay.

Moisture, in requisite amount, furnishes the bonding action of clay. When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of flake-shaped clay particles. The bonding quality of clay depends on the maximum thickness of water film it can maintain. The bonding action is considered best if the water added is the exact quantity required to form the film. On the other hand, the bonding action is reduced and the mould gets weakened if the water is in excess. The water should be between 2 and 8 per cent.

Miscellaneous materials that are found, in addition to silica and clay, in moulding sand are oxide of iron, limestone, magnesia, soda, and potash. The impurities should be below 2 per cent.

Classification. Moulding sands may be classified generally into three different types : (1) natural moulding sands, (2) synthetic or high silica sands, and (3) special sands.

Natural moulding sands, called green sands, are taken from river beds or are dug from pits. They posses an appreciable amount of clay which acts as a bond between the sand grains and are used as received with water added. The quantity and type of clay mineral present affect the strength, toughness and refractoriness of the sand.

Natural moulding sands are also obtained by crushing and milling soft yellow sandstone, carboniferrous rocks, etc. During the milling operation, clay aggregates break down and clay particles get uniformly distributed over the sand grains. The grain shape of these sands is required to be subangular to round.

Due to their ease of availability, low cost, and high flexibility of operation natural moulding sands are used for most of the ferrous and nonferrous light castings. The requirements of these sands are satisfied by IS: 3343-1965, which has classified them into three grades *A*, *B* and *C*, according to their clay content and sintering temperature. This is listed in Table 11.4.

TABLE. 11.4 REQUIREMENT OF NATURAL SANDS

	Grade A	*Grade B*	*Grade C*
Clay percentage	5—10	10—15	15—20
Sintering temperature in °C	1350—1450	1200—1350	1100—1200

Synthetic sands are basically *high silica sands* containing little (less than 2 per cent) or no binder (clay) in natural form. They occur as loose or poorly consolidated deposits of sedimentary origin, dunes blown inland from the coast. or accumulated deposits in estuaries and rivers along the coast. They are also made in foundry by first crushing quartzite sandstones and then washing and grading these to yield a sand grade of requisite shape and grain distribution. The desired strength and bonding properties of these sands are developed by separate additions such as bentonite, water and other materials. This allows greater flexibilities in the content of properties such as green and dry strength, permeabilities, and others that can be easily varied at will. In fact, therefore, synthetic sands are more expensive than natural sands.

IS: 1987-1974 covers the requirements of high silica sand for use in foundries and classifies it into three grades according to the silica content (Table 11.5).

TABLE. 11.5 REQUIREMENTS OF HIGH SILICA SAND

Grade	*Silica*	*Alumina (max)*	*Iron oxide (max)*	*Ca & Mg oxides (max)*	*Alkalies (max)*
A	98	1.0	1.0	1.0	0.5
B	95-98	1.5	1.0	1.0	0.5
C	90-95	2.0	1.5	2.0	1.5

A choice of natural moulding sands and synthetic sands is given in Table 11.6.

TABLE 11.6 CHOICE OF MOULDING SANDS

Types of sands	*Application*	*Reasons*
Natural moulding sand	Light castings	Permeability is not important and only good surface finish may be required.
	Jobbing foundry	Only a few castings may be required ; patterns may be of poor quality.
	Mechanised production of castings with few cores	There is little influx of sand from cores.
	Dry sand moulding	High premeability is not necessary as little gas is evolved ; patching is easy.
Synthetic sand	Heavily cored castings	At shake-out, large amount of clay-free core sand enter moulding sand ; regular clay additions are possible.
	Mechanised production	Better hardness and uniform properties can be obtained.
	High pressure moulding	Results in good hardness and permeability, easy stripping, high strength, and toughness in mould.

Special sands are ideal in getting special characteristics, which are not ordinarily obtained in other sands. Zircon, olivine, chamotte, chromite, and chrome-magnesite are often used as special sands. Zircon sands are suitable for cores of brass and bronze castings. Some foundries use olivine sand for nonferrous castings of an intricate nature. Chamotte is valuable for heavy steel castings. Chromite and chrome-magnesite sands are particularly useful where the chilling tendency is to be increased to control solidification. They are also suitable as facing materials in moulds for steel castings.

11.13 TYPES OF MOULDING SAND

Moulding sands may again be classified, according to their use, into a number of varieties. These are described below.

Green sand. It is a mixture of silica sand with 18 to 30 per cent clay, having a total water of from 6 to 8 per cent. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Being damp, when squeezed in the hand, it retains the shape, the impression given to it under pressure. Moulds prepared in this sand are known as green sand moulds.

Dry sand. Green sand that has been dried or baked after the mould is made is called dry sand. They are suitable for larger castings. Moulds prepared in this sand are known as dry sand moulds.

Loam sand. Loam sand is high in clay, as much as 50 per cent or so, and dries hard. This is particularly employed for loam moulding usually for large castings.

Facing sand. Facing sand forms the face of the mould. It is used directly next to the surface of the pattern and it comes into contact with the molten metal when the mould is poured. Consequently, it is subjected to the severest conditions and must possess, therefore, high strength and refractoriness. It is made of silica sand and clay, without the addition of used sand. Different forms of carbon are used to prevent the metal from burning into the sand. They are sometimes mixed with 6 to 15 times as much fine moulding sand to make facings.

The layer of facing sand in a mould usually ranges from 20 to 30 mm. From 10 to 15 per cent of the whole amount of moulding sand used in the foundry is facing sand. A facing sand mixture for green sand moulding of cast iron may consist of 25 per cent fresh and specially prepared sand, 70 per cent old sand, and 5 per cent sea coal.

Backing sand. Backing sand or *floor* sand is used to back up the facing sand and to fill the whole volume of the flask. Old, repeatedly used moulding sand is mainly employed for this purpose.

The backing sand is sometimes called *black sand* because of the fact that old, repeatedly used moulding sand is black in colour due to the addition of coal dust and burning on coming in contact with molten metal.

System sand. In mechanical foundries where machine moulding is employed a so-called system sand is used to fill the whole flask. In mechanical sand preparation and handling units, no facing sand is used. The used-sand is cleaned and reactivated by the addition of water binders and special additives. This is known as system sand. Since the whole mould is made of this system sand the strength, permeability and refractoriness of the sand must be higher than those of backing sand.

Parting sand. Parting sand is used to keep the green sand from sticking to the pattern and also to allow the sand on the parting surface of 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. Sand used for making cores is called core sand, sometimes called *oil sand*. This is silica sand mixed with core oil which is composed of linseed oil, resin, light mineral oil and other binding materials. Pitch or flours and water may be used in large cores for the sake of economy.

11.14 GRAIN SHAPE AND SIZE OF SAND

The shape and size of sand grains has a substantial effect on the processing properties of moulding and core sands. The shape of the grains and number of similar grains in the sand determine the possibility of its application in various types of foundry practice.

Shapes of sand grains vary from angular to sub-angular to rounded and compound. Use of angular grains (obtained during crushing of rocks or hard sand stones) is avoided as these grains have a large surface area. Thus a higher percentage of binders is required to bring in the desired strength. Rounded shape grain sands are best as moulding sand. The grains contribute to higher bond strength in comparison to angular grains. However, rounded grains sands have higher thermal expandibility than angular grain sands. Sub-angular grains can be taken as a better compromise as its characteristics lie in between angular and rounded shape grains. Fig. 11.54 shows the shapes of the sands.

Compound grains are cemented together such that they fail to separate when screened. They may consist of round, subangular, or angular

Figure 11.54 Shape of sands

grains or a combination of the three. Compound grains are least desirable in sand mixtures as they have a tendency to disintegrate at high temperatures. In actual practice, however, sharp, irregular shaped grains are usually preferred because of their ability to interlock and add strength to the mould.

There are again three distinct sizes of sand grains: *fine, medium* and *coarse*. For small and intricate castings the use of a fine sand is desirable, so that all the details of the mould will be brought out sharply. Medium sand is used in bench work and light floor work such as making machinery castings having from 1 to 50 mm sections. As the size of the casting increases, the sand particles likewise would be coarser to permit the ready escape of gases that are generated in the mould. Grain size is determined by passing the sand through screens or sieves with certain opening sizes which are measured in microns. The preferred size of sand for casting is preferably kept in the range of 0.3–0.15 mm. Presently in foundries, preference is given to the finer sands. The finer grain sizes have higher resistance to metal penetration and erosion. However this type is having a higher thermal expansion defects. The foundrymen generally prefer that sands must posses 4 to 5 sieve sands. (Refer Table 11.8). The distribution of a typical general purpose silica sand is shown below :

Description : A washed graded high silica sand of medium grain size.

uses :

Core manufacturing

Average fineness number : 100

Visual grain shape : Sub-angular

Surface by air permeability : 140 cm^3/g

Chemical analysis :

SiO_2 : 99.50 %

Al_2O_3 : 0.15 %

Others : 0.35 %

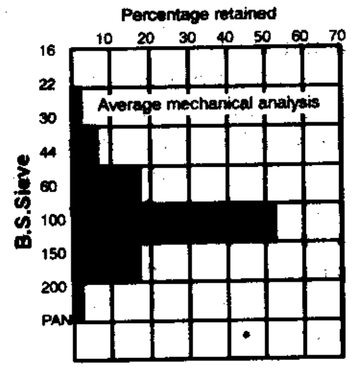


Figure 11.55 Grain distribution of casting sand

11.15 SAND ADDITIVES

Additives are the materials generally added to the sand mixture to develop special properties in the mould and consequently in castings.

Facing materials. The object of using facing materials is to provide a smooth surface on the casting. The material forms a thin, smooth coating on the mould. Various substances may be used for this purpose including charcoal, gas carbon, coke dust, plumbago, black lead, graphite, or sea coal. The principal carbon facings are graphite and sea coal. Graphite is mineral carbon that is mined from the earth, and similar to a lump of clay. Sea coal (known as *coal dust* in U.K.) is a mineral that contains a high per cent of carbon but is less pure than graphite and gives off much more gas. Sea coal is made from the screenings of the soft coal breakers. It is, in fact, finely powdered bituminous coal.

These materials are either applied to or mixed with the moulding sand that comes in contact with the molten metal. They may be applied wet or dry according to the nature of the mould. In the dry state the material is dusted on from a porous bag and applied with a soft brush. For use in the wet state some adhesive is employed, clay, gum and other substance being mixed with water used. They are usually painted on to the mould with a brush, or applied as a spray.

Miscellaneous moulding materials. These are the moulding materials, besides those already described, that are used in foundry procedures. They include fire clay, clay wash, parting materials and core binders.

Fire clay is a mineral product consisting essentially of hydrated aluminium silicate and it comes from the same source that sand does. The purpose of using fire clay is that it offers a good bond when mixed with burnt sand, in the proportion of 1 to 2 for coating the inside of cupolas and pouring ladles.

Clay:wash is a mixture of fire clay and water. It is used in the foundry where a strong bond is required, and for repairing ladle linings with a fresh daubing mixture.

Parting materials are parting sands or parting dusts which must contain no bond. A non-silica parting compound made from powdered phosphate rock is the material that is widely used as a parting dust. This is applied on the parting surface or joint of a mould from a dust bag to prevent the moulding sand from adhering to the moulding box or to the pattern.

Binders can be classified as inorganic and organic. Inorganic binders are clays (kaolinite, illite, bentonites), cements, gypsum, sodium silicate, brown coal ashes etc. Organic binders include carbohydrate (starch, dextrin, dextrose), molasses, various types of oils, pitches, natural resins (calophony, shellac) and synthetic resins (acrylic alkyd, polistyrene, melamine, urea formaldehyde, phenolic etc.)

The primary purpose of binders is to influence the bonding properties of sand. Of all the binders, dextrine is perhaps the best. It increases air-setting strength, toughness, and collapsibility and prevents sand from drying rapidly.

11.16 PROPERTIES OF MOULDING SAND

Proper moulding sand must possess six properties. It must have porosity, flowability, collapsibility, adhesiveness, cohesiveness or strength, and refractoriness. The properties are determined, not only by the chemical composition, but by the amount of clayey matter in the sand, by its moisture content, and lastly by the shape and size of the silica sand grains.

Porosity. Molten metal always contains a certain amount of dissolved gases, which are evolved when the metal freezes, Also, the molten metal, coming in contact with the moist sand, generates steam or water vapor. If these gases and water vapor evolved by the moulding sand do not find opportunity to escape completely through the mould they will form gas holes and pores in the casting.

The sand must, therefore, be sufficiently porous to allow the gases or moisture present or generated within the moulds to be removed freely when the moulds are poured. This property of sand is called porosity or *permeability*.

Flowability. Flowability of moulding sand refers to its ability to behave like a fluid so that, when rammed, it will flow to all portions of a mould and pack all-round the pattern and take up the required shape. The sand should respond to different moulding processes. High flowability is required of a moulding sand to get compacted to a uniform density and to obtain good impression of the pattern in the mould. Good flowability is very essential where energy for compaction during ramming is transmitted through the sand mass as in machine moulding. Flowability increases as clay and water content increase.

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.

Adhesiveness. The sand particles must be capable of adhering to another body, i.e., they should cling to the sides of the moulding boxes. It is due to this property that the sand mass can be successfully held in a moulding box and it does not fall out of the box when it is removed.

Cohesiveness or strength. This is the ability of sand particles to stick together. Insufficient strength may lead to a collapse in the mould or its partial destruction during conveying, turning over or closing. The mould may also be damaged during pouring by washing of the walls and core by the molten metal. The strength of moulding sand must, therefore, be sufficient to permit the mould to be formed to the desired shape and to retain this shape even after the hot metal is poured in the mould.

This property of sand in its green or moist state is known as *green strength*. A mould having adequate green strength will retain its shape and will not distort or collapse even after the pattern is removed from the moulding box.

The strength of sand that has been dried or baked is called *dry strength*. It must have then strength to withstand erosive forces due to molten metal, and retain its shape.

Refractoriness. The sand must be capable of withstanding the high temperature of the molten metal without fusing. Moulding sands with a poor refractoriness may burn on to the casting. Refractoriness is measured by the sinter point of the sand rather than its melting point.

11.17 SAND PREPARATION

Preparation of sand includes: (1) mixing of sand, (2) tempering of sand, and (3) sand conditioning.

Mixing of sand. Foundries use a great deal of moulding and core sands. From 4 to 5 m^3 of moulding sand is expended to make one tonne of sound casting. But very few natural sands have all the qualities that moulding sand should possess. So it is usual to make up the deficiency of sand in any particular characteristic by mixing it with other sands or other substances which possess that characteristic in a high degree. Generally, it is mixed with clay, lime, magnesia, potash, soda, horse manure, sawdust, cowdung, coaldust, etc., in small quantities. Silica is a high fusing material. So sand is capable of withstanding high temperature but it has no bond. Hence, clay is a necessary bond to the moulding sand. But too much clay in sand will crack the mould after drying. The addition of other elements like lime, magnesia, iron oxide, soda, etc. reduces the melting point of silica. Hence smaller amount of these elements are added to make the casting soft.

Coal dust is perhaps the most widely used substance, which accounts for the fact that most moulding sand is black in colour. The addition of coal dust tends to make the sand more open and helps to cool the mould after it has been poured. As soon as the molten metal comes in contact with the sand containing coal it dries the face of the mould and begins to heat the sand. The coal dust immediately gives off carbon dioxide gas, and water (moisture content) in the sand starts getting converted into steam. The coal dust thus absorbs a fairly high amount of heat and cools the sand, thereby preventing the grains from becoming overheated and fusing. A protective film of carbon monoxide or CO_2 gases obtained from the coal also helps to keep the metal and sand separated from each other.

Mixing of moulding materials should ensure uniform distribution of clay, moisture and other constituents between the sand grains. The more uniform this distribution, the better the main qualities of the sand.

Sand tempering. To prepare foundry sand for making a mould, it must be tempered and cut through. The process by which sufficient moisture is added to the moulding sand is known as sand tempering. To temper the sand, water is thrown over the heap in a sheet by giving a backward swing to the pail as the water leaves it. Then the pile of sand is cut through, a shovelful at a time, letting the air through the clay in the sand and breaking up the lumps. This moistens the clay in the sand, making it adhesive. The pile is thus put in the best condition for working.

Sand conditioning. New sand as well as used sand must be properly conditioned before being used. Proper sand conditioning accomplishes uniform distribution of the binder around the sand grains, controls the moisture content, eliminates foreign particles, and aerates the sand so that it flows readily around and takes up the detail of the pattern. In general, sand conditioning consists of preparing the moulding sand to render it suitable for ramming in flasks.

For limited production such as job-shop production of casting, the handling and conditioning of the moulding sand is done by hand. In a mechanised foundry, appropriate equipment and appliances are provided for this purpose. A popular machine for sand mixing is a *muller* which kneades, shears, slices through, and stirs the sand in a heavy pot by means of several revolving rollers and knives. Before mixing all moulding materials are screened to remove large lumps of clay, pebbles, metal particles, and other foreign matter which may lead to casting spoilage. Shaker, rotary and vibratory screen what is called *riddles*, are used for screening the sand. Metal particles are removed by *magnetic separators*. The moulding sand obtained in the sand muller requires aeration to separate the sand grains by *aerators*. This operation, sometimes called *fluffing*, is performed by aerators of various design.

Proper sand conditioning and preparation has the following advantages :

1. the binder is uniformly distributed around the sand grains ;
2. the moisture is evenly dispersed in the sand mixture and the moisture content properly controlled ;

3. the sand gets aerated, causing the sand grains to separate and increasing the flowability of sand ;
4. the sand is delivered at the proper temperature, and
5. the foreign particles are separated and removed from the sand mass.

11.18 SAND TESTING

In progressive foundries it is recognised that the foundry sand deserves as much attention as the casting metal. The foundry sand may account for one-third of the cost of the finished casting. In modern mass production of sand castings, the moulding sand which constitutes the chief moulding material is therefore, required to be tested periodically in order that control of its composition and properties may be maintained. Test may be either chemical or mechanical. Chemical tests are used only to determine the undesirable elements in the sand, and in most cases mechanical tests are employed. Table 11.7 shows the average demond for moulding sands.

Grain-fineness. Grain size of a sand is designated by a number called "grain-fineness number" that indicates the average size as well as proportions of smaller and larger grains in the mixture. A given grain-fineness number corresponds to a standard sieve of 280 mm diameter

TABLE 11.7 AVERAGE DEMAND OF SAND IN M^3 PERTON OF FERROUS ALLOY CASTINGS[1]

Average weight of casting (kg)	*Type of castings*	*Demand for sand in m^3/ton of sand casting*			
		Facing sand	Backing sand	Core sand	Total
upto 5	light	0.3	5.2	0.5	6.0
5–10	light	0.3	4.7	0.5	5.5
10–30	light	0.3	4.2	0.5	5.0
30–50	medium	0.6	3.5	0.6	4.7
50–100	medium	0.6	3.3	0.6	4.5
100-500	medium	0.6	2.8	0.6	4.0
500–2,000	heavy	0.7	2.2	0.6	3.5
2,000–5,000	heavy	0.7	2.0	0.6	3.3
5,000–10,000	heavy	0.7	1.7	0.6	3.0

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[1] Selection of moulding methods and materials, Panigrahi S.C., Indian Foundry Journal, Nov. 1995.

which has the identical number of meshes in it. The test for fineness is conducted by screening sand grains by means of a set of standard sieves that are graded and numbered according to the fineness of their mesh. For most foundry practice, a bank of sieve with the following apertures is the most convenient (Table 11.8).

The essential mechanical tests include fineness, moisture content, clay content, permeability, strength in compression, and mould hardness. The grain-fineness number is calculated by multiplying the above percentage figures by a constant given, one for each sieve, termed a *multiplier*. The products of this multiplication are added to obtain a total product. The fineness number is then calculated from the formula :

$$\frac{\text{total product}}{\text{total percentage of sand retained on screen}}$$

Test for moisture content. This test is performed by drying 50 gm of the moist sand to constant weight between 105° C and 110°C in a uniformly heated oven, cooling to room temperature in a *desiccator* and then weighing the dry sample. The difference between the moist and dry weights of the sample in grams divided by 50 gm gives the per centage of moisture content in the given sand.

TABLE 11.8 SEIVE AND APERTURE RELATIONSHIPS

Seive No.	*Apperture, mm*
16	1.003
22	0.699
30	0.500
44	0.353
60	0.251
72	0.211
100	0.152
150	0.104

An instrument called the *moisture teller* is widely used in modern foundries. The instrument blows hot air through the moist sand in a pan, the bottom of which is made of 500-mesh metal screen. The sand sample is spread over the pan in a thin layer, and hot air is blown for a period of approximately three minutes through a 50 gm sample. The moisture is effectively removed and a precision balance determines the loss in weight of the sample.

A portable instrument called the *moistmeter* enables the user to determine the moisture content of a sand almost instantly. The two arms of the instrument are inserted in the given sample of moulding sand held in a container, and a small electric current, supplied from a dry battery in the handle, is passed through the moist sand. The wetter the sand, the more easily the current flows, and the deflection of an indicator gives a measure of the moisture content.

Clay-content test. The method for determining the clay-content of moulding sands consists of agitating the sand in water so as to separate the clay from the sand particles and then removing the clay which remains suspended in water. The material which fails to settle within a period of 5 minutes in distilled water at room temperature is designated as a clay substance.

The equipment necessary for determining the percentage of clay in moulding sands consists of a drying oven, a balance and weights, and a sand washer. A small quantity of sand, thoroughly dried out of a sample of 50 gm, is selected and placed in a wash bottle. Then 47 cc of distilled water and 25 cc of a 3 per cent caustic soda solution are added to this sand. The mixture is stirred for 5 minutes in a rapid sand stirrer or 1 hour if a rotating sand washer is used and allowed to stand for 5 minutes to permit the larger particles of sand grains to settle. Next, most of the solution on top is siphoned off and discarded, removing the clay which fails to settle. This operation is repeated until the water is clear after a 5 minutes settling period. The bottle is finally placed in the oven, and after the sand is dried out a sample is weighed. The percentage of clay is determined by the difference in the initial and final weights of the sample.

Permeability test. Permeability is measured by the quantity of air that will pass through a standard specimen of the sand under a given pressure in a prescribed time. The permeability apparatus uses the standard rammed 5.08 cm diameter by 5.08 cm height test piece.

A permeability meter, as shown in Fig. 11.56, has a cylindrical water tank in which an inverted bell or air holder, properly balanced, is floating. By properly opening the three-way valve, air which is trapped under the bell will flow through the sand specimen as shown. Mercury around the bottom of the specimen tube provides an air tight seal. The pressure of this air is obtained with the water manometer and the straight scale. It should be close to 10 cm of water which correspond to a pressure of 10 gm per cm^2.

Permeability number is defined as the volume of air in cc that will pass per minute under a pressure of 1 gm per cm^2 through a specimen which is 1 cm^2 in cross-sectional area and 1 cm deep. The permeability number is calculated using the following formula :

$$\text{Permeability number} = \frac{v \times h}{p \times a \times t}$$

where v = volume of air = 2,000 cc.
h = height of the sand specimen = 5.08 cm.
p = air pressure = 10 gm/cm^2.
a = cross-sectional area of the speimen = 20.268 cm^2.
t = time for 2,000 cc of air in seconds.

Since v, h, p, and a are constant, this formula reduces to :

$$\text{Permeability} = \frac{3{,}007.2}{\text{time.in.sec}}$$

Compression-strength test. Several tests have been devised to test the holding power of various bonding materials in green and dry sand. Compression tests are the most common although tension, shear and transverse tests are sometimes used.

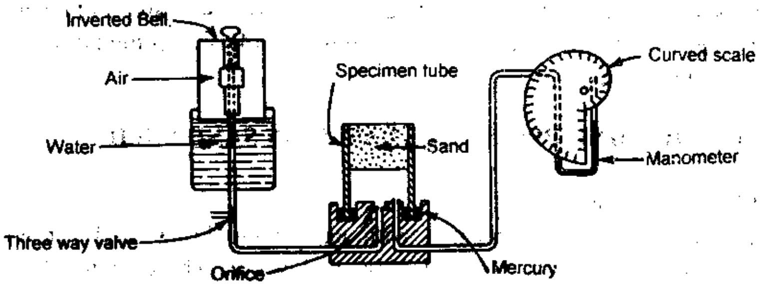

Figure 11.56 Permeability meter

The green compressive strength (kgf/cm^2) of a foundry sand is maximum compressive strength a mixture is capable of developing when moist. The rammed sand specimen 5.08 cm high × 5.08 cm diameter, is pushed out of the specimen tube and placed with the end that was uppermost in ramming against the upper plate of a universal sand strength machine. The machine is so constructed that it registered a continuously increasing load until rupture of the specimen takes place. The load is applied at a rate of about 2 kgf/cm^2 until the specimen breaks. The compression value is read directly on the green compression scale of the testing machine.

Mould and core hardness test. This test is performed by a mould-hardness tester in the foundry to determine how hard a mould has been rammed. The tester is about the size of a pocket watch and the hardness test can be made within a few seconds. It operates on the same principle as a Brinell hardness into the surface of the mould and the depth of penetration is indicated on the dial of the tester in hundredths of a millimeter. The hardness can also be read on another scale in kgf/cm^2.

11.19 MOULDING PROCESSES

Moulding processes in common use may be classified according to different forms. They may broadly be classified as : (1) hand moulding, and (2) machine moulding. In piece and, small-lot production foundry practice, sand moulds are made by hand ; moulding machines are employed in large-lot and mass production.

Moulding processes are often classified according to (1) the type of material of which the mould is made or (2) the methods used in making the mould. Under the first heading the following items are included : (1) green sand moulds, (2) dry sand moulds, (3) skin-dried moulds, (4) loam moulds. Moulds classified as to the methods commonly used are : (1) bench moulding, (2) floor moulding, (3) pit moulding, (4) sweep moulding, and (5) plate moulding.

11.20 MOULDING PROCESSES BASED ON SAND USED

GREEN-SAND MOULD

Green-sand moulds are prepared with natural moulding sands or with mixtures of silica sand, bonding clay, and water. These materials are thoroughly mixed in proportions which will give the desired properties for the class of work being done. Typical sand mixtures for green-sand moulds are given in Table 11.9.

To make the green-sand mould the sand must be properly tempered before it can be used. If the sand is too dry, additional water is added if too wet, dry sand is added until it has the proper temper. To check the sand for proper temper, a handful is grasped in the first. The pressure is released, and the sand is broken in two sections. The sections of sand should retain their shape and the edges of the break should be sharp and firm.

The surface of the mould which comes in contact with the molten metal forms the most important part in green-sand moulds. In order to give the casting a clean and bright surface and to prevent the sand from burning on the face of the mould, a layer of facing sand is given surrounding the pattern. Facing-sand mixtures for iron castings generally contain some finely ground bituminous coal known as sea-coal, and new sand in addition to used moulding sand. One part by volume of sea-coal to ten parts of moulding sand is a common ratio in mixtures for moulds for iron castings. The sea-coal aids in preventing the sand from fusing to the surfaces of the castings, whereas the new sand increases the bond in the facing mixture, and thereby prevents cutting of sand surfaces by the liquid metal.

TABLE 11.9 TYPICAL SAND MIXTURE FOR GREEN-SAND MOULDS

Material	*Light work (Per cent)*	*General work (Per cent)*	*Smooth finish (Per cent)*
Floor sand	6 parts – 80 %	8 parts-59.3 %	10 parts–57.1 %
New sand	1 part – 13.4 %	4 parts-29.6 %	4 parts –22.9%
Coal dust	½ part – 6.6 %	1½ parts-11.%	1½ parts–8.6 %
Carbon blacking			1½ parts–8.6 %
Talc (french chalk)			½ parts–2.8 %

It is common practice to coat the surfaces of sand mould with refractory materiel to produce a smooth skin on the castings. The material ordinarily used for this purpose are graphite, coke, charcoal, gas carbon, plumbago, black lead, silica, mica, and talc. These materials may be placed in two groups ; the carbonaceous materials known as blackings, and the other materials are designated as mineral coatings. They may be applied wet or dry. For use in the wet state some adhesive is employed–clay, gum and other substances being mixed with water are used. Blackings or mineral coatings used dry are dusted over the mould face.

Advantages of green sand mould are listed below :

1. Green-sand moulding is the least expensive method of producing a mould.
2. There is less distortion than in dry sand moulds, because no baking is required.
3. Flasks are ready for reuse in minimum time.
4. Dimensional accuracy is good across the parting line.
5. There is less danger of hot teraing of casting than in other types

of mould.

Disadvantages of green sand mould are listed hereunder :

1. Sand control is more critical than in dry sand moulds.
2. Erosion of the mould is more common in the production of large castings.
3. Surface finish deteriorates as the weight of the casting increases.
4. Dimensional accuracy decreases as the weight of the casting increases.

The Principal methods of green-sand moulding are as follows :

1. Open-sand method
2. Bedded-in method
3. Turn-over method

Open sand method. This is the simplest form of green-sand moulding, particularly suitable for solid patterns. The entire mould is made in the foundry floor or in a bed of sand above floor level for convenience in working and pouring. No moulding box is necessary and the upper surface of the mould is open to air. The sand in the foundry floor is made loose and perfectly levelled to obtain uniform thickness of the casting. As there is no head of metal the sand may be rammed lightly, just hard enough to support the weight of metal only. After proper levelling, the pattern is pressed in the sand bed for making mould. The pouring basin is built up at one end of the mould, and the overflow channel is cut at the sides of the cavity at the exact height from the bottom face of the mould to give the desired thickness.

This method is mainly used for simple castings, floor plates, moulding boxes, grills, railings and gates, weights, i.e., castings with flat tops in which it does not matter if the upper surface is decidedly rough.

Bedded-in method. If the upper surface of a casting is not flat or must be smoother than the rough surfaces produced by open-sand moulds, a solid pattern can also be moulded by using a technique known as "bedded in", in which a sand cover or cope is necessary.

In bedded-in method, the pattern is pressed or hammered down to bed it into the sand of the foundry floor or in a drag partially filled with sand to form the mould cavity. To ensure that the sand is properly compacted, careful ramming of the sand close to the pattern is necessary. As a check, the pattern can be drawn and the mould cavity surface tested for soft spots. All soft spots should be filled in with extra sand and the pattern again pressed downward until properly rammed mould cavity is obtained.

After the joint has been smoothed, and parting sand spread, a cope is placed over the pattern. The cope is rammed up, runners and risers cut, and the cope box lifted, leaving the solid pattern in the floor or in the drag as the case may be. The pattern is drawn out, and the surfaces of both parts of the mould finished and the cope box replaced in its correct position to complete the mould.

Turn-over method. This method is very much used and most suitable for split patterns as well as for solid patterns. One half of the pattern is placed with its flat side on a moulding board, and a drag is rammed and rolled over. It is now possible to place the other half of the pattern and a cope box in proper position. After ramming, the cope is lifted off and the two halves of the pattern are rapped and drawn separately. The cope is next replaced on the drag to assemble the mould. The process is described in Art. 11.21.

DRY SAND MOULD

The moulding process involved in making dry sand moulds are similar to those employed in green-sand moulding except that a different sand mixture is used and all parts of the mould are dried in an oven before being reassembled for casting.

The green sand mould depends upon the moisture and the natural clay binder in the sand to retain its shape. But the sand used for dry sand moulds depends upon added binding material such as flour, resin, molasses, or clay. The materials are thoroughly mixed and tempered with a thin clay water. The amount of binder is determined by the size of the casting being made. Table 11.10 gives some of the typical sand mixture for dry-sand moulds.

Metal flasks must be used for dry sand moulds to withstand the heat in the oven. Before drying, the inside surfaces of a dry sand mould are coated with wet blacking--a mixture of carbon black and water with a small addition of gum. This gives a smoother surface to the casting. These moulds can be held for any length of time before pouring, provided they are kept dry.

TABLE 11.10 TYPICAL SAND MIXTURE FOR DRY SAND MOULDS

Material	*Small and Medium work*	*Ordinary heavy work*	*Extra heavy work*
Floor sand	13 parts	11 parts	10 parts
New sand	8 parts	9 parts	10 parts
Horse manure or sawdust	1 parts	1 parts	1 parts

Advantages of dry sand moulds are :

1. They are stronger than green sand moulds, and thus are less susceptible to damage in handling.
2. Over-all dimensional accuracy of the mould is better than for green sound moulds.
3. Surface finish of castings is better, mainly because dry sand moulds are coated with a wash.

Disadvantages of dry sand moulds are :

1. Castings are more susceptible to hot tears.
2. Distortion is greater than for green sand moulds, because of the baking.
3. More flask equipment is needed to produce the same number of finished pieces, because processing cycles are longer than for green sand moulds.
4. Production is slower than for green sand moulds.

Dry-sand moulds are often used for large work such as engine cylinders, engine blocks, rolls for rolling mills, etc., to avoid spoilage. Castings of intricate design and those requiring special smoothness, soundness, and accuracy are also used in dry-sand moulds.

SKIN-DRIED MOULD

This is a process that dries the moisture from the surface layer of the rammed sand to a depth of about 25 mm or more by using gas torches or heaters. It has the advantages of both green sand and dry sand moulding to a certain extent. Since the time required for drying is less than in the case of dry sand, the method is less expensive. Skin-drying is particularly adapted to very large moulds, or to works which require accurate details.

LOAM MOULD

Loam is clay and sand mixed with water to form a thin plastic mixture from which moulds are made. Loam sand also contains fire clay or *ganisters*. The loam must be sufficiently adhesive so that it can cling to the vertical surfaces. Loam moulds always require special provision to secure adequate ventilation. The object is to open out pores in the otherwise compact, closely knit mass, by artificial means. Thus various kinds of organic matter such as chopped straw, and particularly horse manure, is mixed up with the sand. A typical loam sand mixture is given below :

1	Silica sand	22 vol.
2	Clay	5 vol.
3	Coke	10 per cent
4	Moisture	18-20 vol.

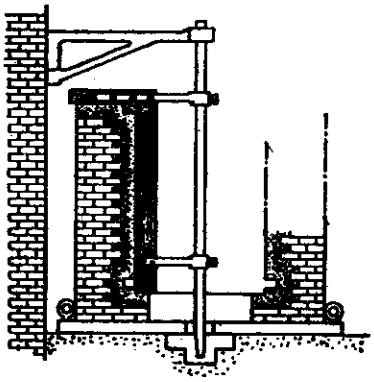

Figure 11.57 Loam moulding with a sweep pattern

This is applied as plaster to the rough structure of the mould usually made of brickwork and the exact shape is given by a rotating sweep around a central spindle as shown in Fig. 11.57. Cast iron plates and bars are used to reinforce the brickwork which retains the moulding material. Loam moulds may also be prepared by the use of a skeleton pattern made of wood. The surfaces of loams are blackened and are dried before being assembled.

Loam moulds are employed chiefly in the making of large castings for which it would be too expensive to use full patterns and ordinary flask equipment. Objects such as large cylinders, round-bottomed kettles, chemical pans, large gears, and other machine parts are produced in loam moulds.

11.21 MAKING A GREEN-SAND MOULD

The general procedure used in making moulds may be acquired by following the operations used in moulding a split pattern.

First, one-half of the pattern is placed with its flat surface on a *mould board*, and the *drag* section of the flask is set over the pattern on the same board as shown in Fig. 11.58. After powdering the pattern with lycopodium, talc, or graphite, a 15 to 20 mm layer of facing sand is riddled over the pattern. The drag is then filled by layers of green sand mixture from 70 to 100 mm thick, compacting each layer with rammer. The top of the mould is *rammed* with the butt end of a rammer. The object of ramming the sand is to consolidate it, thereby preventing the cavity of the mould from being enlarged by the pressure of the metal.

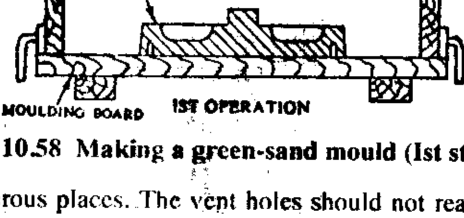

Fig. 10.58 Making a green-sand mould (Ist step)

After the sand is rammed, a *strickle* is used to scrape off the excess sand level with the top of the flask. The mould is then *vented* by sticking it with a fine stiff wire at numerous places. The vent holes should not reach the pattern by 15 to 20 mm as otherwise they may spoil the mould. Moreover, the metal may run into the vent holes during pouring. These vent holes permit the escape of gases generated in the mould when the molten metal comes in contact with moist sand.

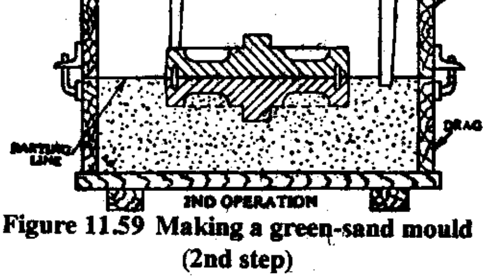

Figure 11.59 Making a green-sand mould (2nd step)

A small amount of loose sand is sprinkled over the mould, and *bottom board* is placed on the top. The drag is rolled over, the moulding board is removed, and the upper surface is sprinkled with parting sand. The parting sand is used to prevent the joints between the halves of a mould from adhering to one another when the two parts of the moulding box are separated.

The remaining half of the pattern and the cope section of the flask are then assembled as shown in Fig. 11.59. Tapered wooden pegs to serve as *sprue* and *riser* are placed in proper position on the pattern which is riddled over with facing sand and then the cope is filled with green-sand.

The operation of filling, ramming, and venting of the cope proceed in the same manner as in the drag. The cope usually carries a series of cross-bars to give support to the moulding sand, which is further supported by pieces of bent iron called *lifters* or *gaggers*.

Following these operations the wooden pegs are withdrawn from the cope and a funnel- shaped opening is scooped out at the top of the sprue to form the *pouring basin*. Next the cope is lifted off and placed on a board with the parting line upward.

An iron bar is now pushed down to the pattern and rapped sideways so as to loosen the pattern in the mould. This *rapping* facilitates the removal of the pattern and prevents any sand from sticking to the pattern. Next the pattern is drawn out and he *runner* and *gate* are cut in the drag from the pattern to the sprue. Also, the core must be set in the print left by the pattern in the drag. Loose particles of sand are removed by a jet of air and the surfaces of the mould are brushed or dusted with foundry blackings so as to give a smooth surface to the casting. Finally, the mould is assembled, the cope being carefully placed on the drag so that the flask pins fit into the bushes. Before pouring the molten metal the cope is sufficiently loaded to prevent it from floating up when the metal is poured. The completed mould is shown in Fig. 11.60.

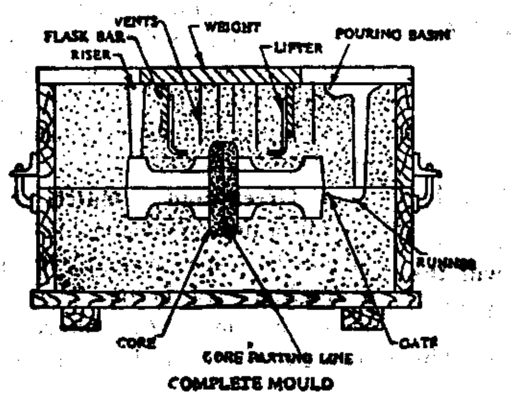

Figure 11.60 Making a green-sand mould (completed mould)

11.22 TYPICAL MOULDING PROBLEMS

Certain types of moulding problems which illustrate different methods of moulding are given here. The examples shown are simple, but these devices may be useful to more difficult and complicated patterns.

False cope. The making of a false cope is very similar to the method used in making a bedded-in mould. The pattern is first bedded into the cope, and a smooth parting surface is made. A drag flask is set on the cope and rammed up in the usual manner. Then the complete flask is rolled over, and the false cope is lifted off, leaving the pattern in place in the drag. Having served its purpose, the sand in the false cope is knocked out. The usual reason for using a false cope is to obtain an irregular parting surface. The real cope, complete with gating system, is then rammed up in the usual manner.

Coping down. The pattern shown in Fig. 11.60 may be moulded by coping down and making a new pattern. The pattern is first supported on a moulding board by placing a suitable piece of wood under the elevated end. The drag is then set on the moulding board and rammed up. After the drag is rolled over an irregular parting surface is formed to the parting line of the pattern. The new parting surface is sloped gradually, what is called coping down, so that the cope may be lifted off without danger of dropping the sand, which projects downwards. After ramming, rolling over, and coping down, the drag should appear as shown in Fig. 11.61. This mould is then completed in the usual manner.

Figure 11.61 A pattern with the parting line not in one plane

Green-sand match. If several castings are required from an irregularly shaped pattern with the parting line not in one plane as shown in Fig. 11.61, the coping down may be largely eliminated by using a green-sand match. Ordinarily a green-sand match is made by first ramming up a drag and coping down to the parting line of the pattern as illustrated in Fig. 11.62. The green-sand match is now rammed up extra hard on this drag without the sprue and riser pins. It is now retained for supporting the pattern and automatically forming the irregular parting surface. The complete green-sand match with

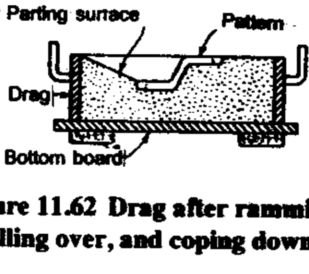

Figure 11.62 Drag after ramming rolling over, and coping down

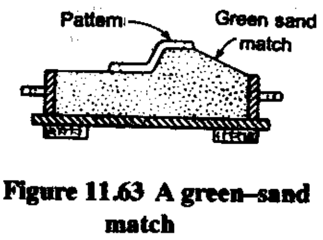

Figure 11.63 A green–sand match

pattern in place and ready for use is shown in Fig. 11.63. Much time is saved by using a sand match since it is necessary to cope down and form a new parting surface on the first drag.

Often other materials more durable than ordinary sand are used for making matches. When a match is made of plaster-of-paris it is called *plaster-of-paris match*. Similarly, there is *portland-cement match* made of portland cement. If the match is made of wood it is known as a *follow board* shown in Fig. 11.22.

Draw–back. Where patterns must be of such a shape that they cannot be drawn from the sand owing to projections, drawbacks are employed to get over the difficulty. This is illustrated in Fig. 11.64.

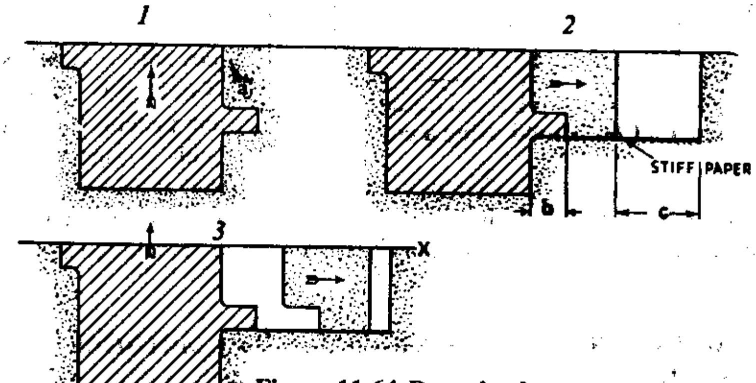

Figure 11.64 Draw back

Sketch *1* shows that the solid pattern cannot be drawn upwards from the mould without dragging out that piece of sand marked *a*. Sketch *2* indicates the cavity dug out of the mould, well away from the pattern. The space *c* behind the draw-back must be greater than the width of the projection *b*. A stiff paper is rammed up in the moulding sand as shown to form parting surface to the flange. Sketch *3* shows that when the draw-back has been slid, the pattern can be withdrawn.

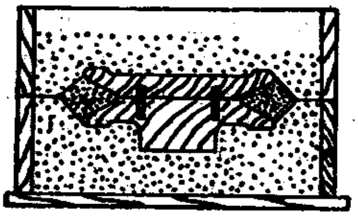

Figure 11.65 Sheave moulding using a dry-sand core

When the pattern is out of the way, the draw-back is brought back in its correct position, and the space behind it is filled up again with sand.

Using a dry sand core. The method of moulding a sheave wheel or similar type of pattern is to use a dry sand core to form the groove in the pulley. A vee-shaped dry sand core known as a false core is placed in the mould cavity to form the groove as shown in Fig. 11.65.

A dry sand core can also be used to form the overhanging portion of a pattern.

Using a cover core. The cover core is a flat core used to cover cavity in a mould. This is illustrated in Fig. 11.66. The pattern having a dovetail face at the top end is placed upside down on a moulding board with a flat cover core conforming the shape of the dovetail at each of the dovetail recesses. The drag is set over the pattern, filled up with sand and rammed. The drag is then rolled over now facing dovetail at the top. Cover cores are removed and the pattern is drawn vertically upward. They are finally replaced in the corresponding impressions in the mould to have the desired casting.

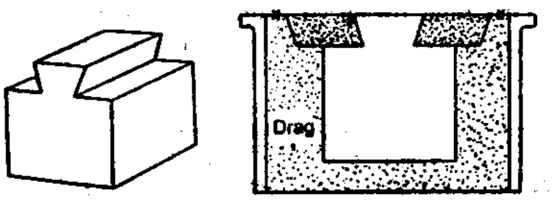

Figure 11.66 Mould using a cover core

11.23 MOULDING PROCESSES BASED ON THE METHODS USED

BENCH AND FLOOR MOULDING

Bench moulding applies chiefly to moulds small enough to be made on a work bench of a height convenient to the moulder.

Very heavy castings or castings of a considerable depth or area may be moulded in the sand of the foundry floor in much the same way as green-sand or dry-sand moulding. In such cases, the floor itself acts as the drag, and this may be covered with a cope or the mould may be cast open.

PIT MOULDING

Moulds of large jobs are generally prepared in a pit dug in the foundry floor which facilitates in lifting the pattern and casting the mould easily. Since a pit which functions as a drag cannot be rolled over, the sand under the pattern may be rammed by bedded-in. The pattern may be suspended in correct location as the sand is rammed under it. In other cases, if the bottom surface of a pattern is flat, the pattern can be placed on a flat level surface rammed up for it.

A bed of coke is laid on the bottom of the pit, covered with straw and then a layer of sand, which is rammed and leveled. The coke bed is connected with atmosphere by vertical vent pipes in the corners of the pit to provide an outlet for the gases generated. If the floor is lightly damp, the inside surfaces of the pit are lined with tar-paper, bricks, or wooden planks. Generally, one box is required to complete the mould. Runners, pouring basins, feeders, are cut in it.

SWEEP MOULDING

Sweep mouldings are employed for moulding parts whose shape is that of a surface of revolution. In the preliminary process, a base *1* and spindle *2* is well placed in the foundry floor. The sand is filled in and rammed until the excavation forms approximately the shape and size of the required casting. This is illustrated in Fig. 11.67(a). A sweep holder *5* is then placed in the spindle land the sweep *6* is attached by bolts and nuts. The surface of the mould is produced by the profile of the sweep as it is rotated about the spindle as shown in Fig. 11.67(b). After sweeping, the spindle is removed and the mould patched at the centre. The gate is then cut and the mould is ready for pouring. This is shown in Fig. 11.67 (c).

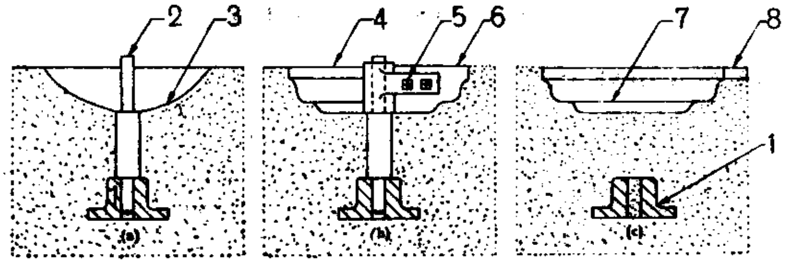

Figure 11.67 Sweep moulding

1. Base, 2. Spindle, 3. Well-rammed excavation, 4. Foundry floor, 5. Sweep holder, 6. Sweep, 7. Mould, 8. Gate

PLATE MOULDING

In this process, the pattern is divided into half across the parting and mounted in halves on to plates with parallel sides of the same shape as the parting (Fig. 11.68). The use of plates gives the following advantages :

1. The patterns can be handled easily and rapidly.
2. The task of making the joint between the two parts of the mould is relieved as the plate provides its own joint when the flask is rammed up.
3. The pattern can be drawn quickly, as the plate overlaps the side

of the box and the pins which hold it in position act as guides during the drawing operation.

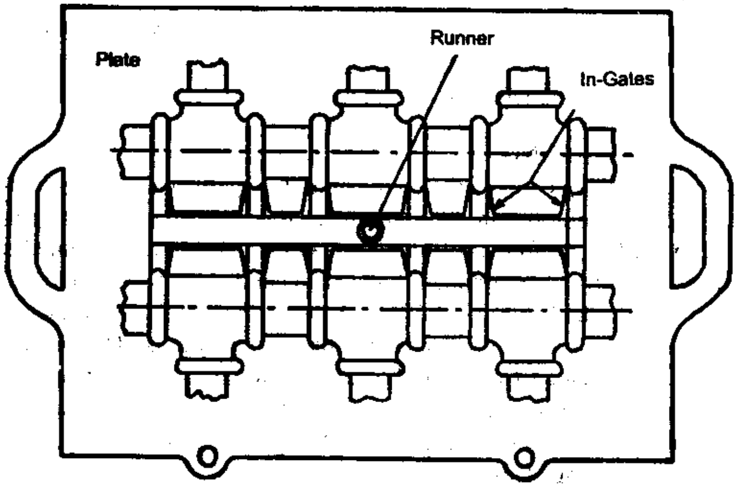

Figure 11.68 Plate moulding

11.24 MACHINE MOULDING

Moulding processes may be classified as hand moulding or machine moulding according to whether the mould is prepared by hand tools or with the aid of moulding machines. Hand moulding is found to be economical when only a few castings are required. Hand moulding is slow and it requires considerable skill to produce good castings.

On the other hand, the use of moulding machine is advisable when large number of repetitive castings are to be produced since hand moulding is more time consuming, laborious and becomes expensive. The dimensions of machine-cast castings are more accurate, in other words, it is possible to produce castings to close tolerances. As a consequence, the weight of castings is reduced and material saved. The working time per mould is similar than that required for hand moulding, this means that, related to the same shop area, the output of castings is increased per unit of time. In fine, machine moulding offers higher production rates and better quality casting in addition to less heavy and lower costs, and no specialized knowledge or skill is required on the part of the operator.

A moulding machine performs two important functions–it packs the sand and draws the pattern. Moulding machines are, therefore, classified according to (1) the method of compacting the moulding sand, and (2) the method of removing the pattern. In any case, one or two patterns are fastened to a pattern plate which is installed in the moulding machine. The patterns are made of metal, plastics or any other suitable material.

Classification of moulding machines according to the methods of compacting the sand.

Squeezer machine. In the squeeze method, moulding sand in the flask is squeezed between the machine table and the overhead squeeze board pneumatically or hydraulically until the mould attain the desired density.

The principle of operation of a top *squeezer machine* is illustrated in Fig. 11.69. The pattern *2* is placed on a mould board which is clamped on the table *1*. The flask *3* is then placed on the mould board and the sand frame *4* on the flask. The flask and frame are filled with moulding sand and leveled off. Next the table is raised by the table lift mechanism against the platen *5* on the stationary squeezer head *6*. The platen enters the sand frame upto the dotted line and compacts the moulding sand. After the squeeze, the table returns to its initial position.

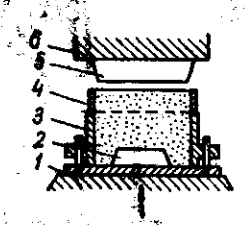

Figure 11.69 Top squeezer machine

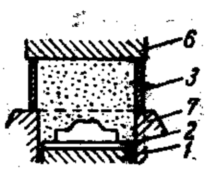

Figure 11.70 Bottom squeezer machine

The principle of a *bottom squeezer machine* is shown in Fig. 11.70. As before, the pattern is placed on the mould board which is clamped to the table. The flask *3* is placed on the frame 7 and is filled with sand. Next the squeeze head is brought against the top of the flask and the table with the pattern is raised upon the dotted line. After squeezing, the table returns to its initial position.

The main limitation of the squeezer method is that, the sand is packed more densely on the top of mould from which the pressure is applied, and the density decreases uniformly with the depth. At the parting plane and around the pattern, the density is found to be the lowest. This variation of density affects the hardness of the mould which thus varies according to the depth. The squeeze method is, therefore, restricted to moulds not more than 150 mm in depth.

Jolt machine. In the jolting method, the flask is first filled with the moulding sand and then the table supporting the flask is mechanically raised and dropped in succession. Due to the sudden change in inertia at the end of each fall, the sands get packed and rammed. The action of raising and sudden dropping the table is called "jolting".

Fig. 11.71 illustrates the principle of a jolt moulding machine in which the table *1*, with the platen and flask *3*, filled with moulding sand, is raised to 30 to 80 mm at short intervals by the plunger *8* when compressed air is admitted through the hose *9* and the channel *10*. The air is next released through the opening *11* and the table drops down suddenly and strikes the guiding cylinder *12* at its bottom. This sudden action causes the sand to pack evenly around the pattern. Springs *13* are used to cushion the table blows and thus reduce noise and prevent destruction of the mechanism and the foundation.

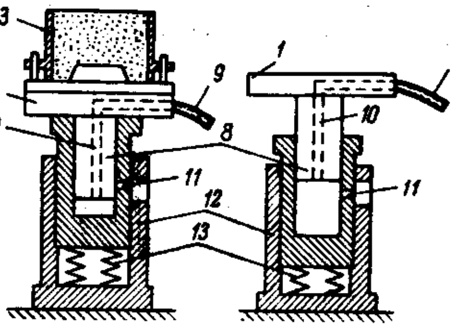

Figure 11.71 Jolt machine

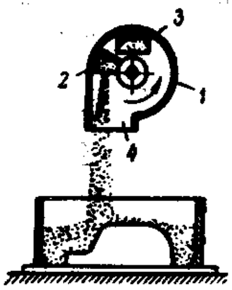

Figure 11.72 Sand slinger

The drawback in this method is that sand is rammed hardest at the parting plane and around the pattern and remains less dense in the top. This necessitates hand ramming of the mould at the back after the jolting action is completed. These machines are preferred for horizontal surfaces.

Jolt-squeeze machine. In order to overcome the drawbacks of both the squeeze and jolt principles of ramming the sand, a combination of squeeze and jolt action is often employed. A jolting action is used to consolidate the sand on the face of the pattern and it is followed by a squeezing action to impart the desired density throughout the mass of the sand.

The jolt-squeeze machine is so constructed that both squeeze and jolt actions can be obtained one after the other. A high pressure jolt-squeeze machine is capable of producing moulds of maximum hardness, rammed uniformly throughout the flask.

Sand slinger. In the slinging operation, the consolidation and ramming are obtained by the impact of sand which falls at a very high velocity.

The principle of a sand slinger is illustrated in Fig. 11.72. The overhead impeller head consists of the housing 1 in which the blade 2 rotates at a very high speed. The sand is delivered to the impeller through the opening *3* by means of conveyor buckets. The impeller head by the rotation of the blade throws the sand through the outlet *4* down into the flask over the pattern at a rate ranging from 500 to 2000 kg per min. The density of the sand can be controlled by the speed of the blade.

Mould produced by this method have adequate strength, since hardness is a function of sand velocity, which is controllable in a sand slinger. These machines are most often used for ramming medium-size to large moulds.

Classification of moulding machines according to the method of removing the pattern from the mould :

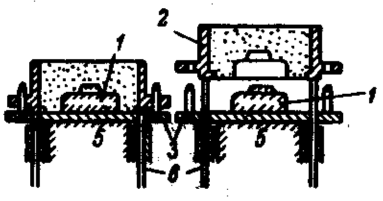

Figure 11.73 Straight draw moulding machine

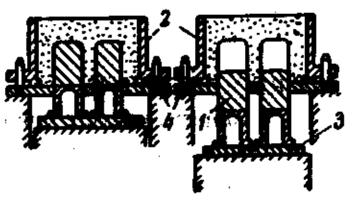

Figure 11.74 Stripping plate moulding machine

Straight-draw moulding machine. In the straight-draw moulding machine (Fig. 11.73), the pattern *1* is fixed on the pattern plate *3* on the table-5, and the flask or moulding box *2* is placed over it and filled with sand. It is then roughly rammed round the edges of the box. The squeeze head is next swung over in position and it squeezes the mould. The flask is then lifted from the pattern by stripping pins *6*.

Stripping-plate moulding machine. The principle of a stripping-plate moulding machine is illustrated in Fig. 11.74. The stripping plate *4* is arranged between the flask *2* and pattern plate *3*. The stripping plate has a recess whose contours equal those of the pattern *1*. When the mould is ready the pattern is withdrawn from the mould downwards through the stripping plate, which supports the mould when the pattern is removed.

Turn-over moulding machine. This is used for large size, high moulds, having parts which might easily break away. In Fig. 11.75, the flask *2* rests on the pattern plate *3* during the moulding operation. Then the flask together with the work table *5* is rotated 180° and pins *6* lift the table *5* together with the pattern *1* out of the mould.

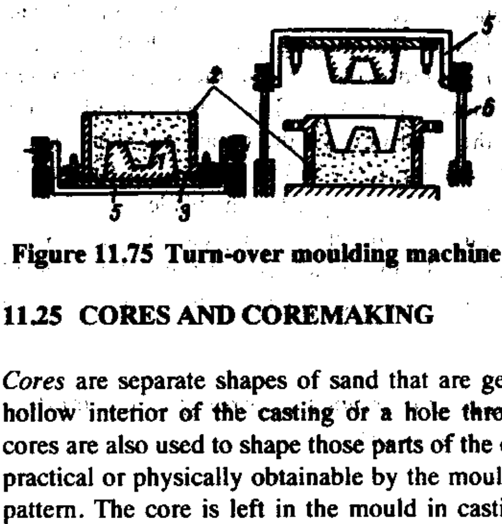

Figure 11.75 Turn-over moulding machine

11.25 CORES AND COREMAKING

Cores are separate shapes of sand that are generally required to from the hollow interior of the casting or a hole through the casting. Sometimes cores are also used to shape those parts of the casting that are not otherwise practical or physically obtainable by the mould produced directly from the pattern. The core is left in the mould in casting and is removed after the casting.

CORE REQUIREMENTS

Cores are subject to severe conditions since after pouring the mould they are surrounded on all sides by molten metal. Consequently, they must possess some special characteristics which are as follows :

1. Cores must be *strong* enough to retain its shape without deforming, to withstand handling and to resist erosion and deformation by metal during filling of the mould.
2. Cores must be *permeable* to allow the core gases to escape easily.
3. Cores should be highly *refractory* in nature to withstand high temperature of the molten metal.
4. Cores must be sufficiently *low in residual gas-forming* materials to prevent excess gas from entering the metal.
5. Cores must be *stable* with a minimum of contraction and

expansion to make a true form of the casting.

6. Cores should be sufficiently *collapsible*, i.e., they should disintegrate and collapse after the metal solidifies, to minimise strains on the casting and to facilitate removal of the core from the casting during shakeout.

CORE SANDS

The ingredients of core sands are *sand* and *binder*. Core sands are usually silica, but zircon, olivine, carbon and chamotte sands are used. Sand that contains more than 5 per cent clay cannot be used for cores. Excessive clay reduces not only permeability but also collapsibility.

The type of sand to be used depends on the size of the core and also on the pouring temperature of the metal. The important facts to be considered are the size, shape, and distribution of sand grains, the clay content, and the mineralogical composition of clay particles. The smaller the grain size of the sand used in cores, the smoother will be the surface of the casting made in contact with these cores. Furthermore, sand with rounded grains is more satisfactory for cores than with angular grains for higher values of permeability.

Core binders. Core sand has no natural bond, as almost pure sand is used for preparing cores. Hence some other materials are added to the sand to act as binders which cement the sand particles together before and after the cores are baked. They impart strength, and sufficient degree of collapsibility in addition to giving good permeability, ample refractoriness and other qualities that cores should possess.

Core binders most commonly used are of three general types: (a) binders that harden at room temperature, (b) binders that require baking to harden, and (c) clays. Various commercial binders are available in the market which consist mainly of oils, cereals, dextrine, resins, sulphite-liquor, molasses and protein.

The action of thermoplasting binders such as rosin and pitch depends on the amount of heat which liquefies and disperses the binder in the sand. *Rosin* is a form of resin and is obtained by distillation and extraction from pinewood. Thermosetting resin binders are also becoming common owing to their high strength, low gas formation, collapsability, and resistance to moisture absorption. The resin binders usually favoured are of phenol, urea, and furan.

Core oils, as mentioned earlier, are more popular as they are very economical and produce better cores. The chief ingredients of these core oils are vegetable oil, for instance, linseed oil and corn oil. Sometimes, specially processed mineral oils are also added to achieve special properties. They are mainly used in making what are called oil sands for cores.

Oil sands can be used for almost any sand casting application. The following is a typical formulation that contain cereal and a small amount of clay (bentonite) ; this mixture, which is mixed in a muller, has proved satisfactory for the casting of gray iron and several other metals.

Sand (by weight)	95.80 per cent
Cereal flour	1.01 per cent
Core oil	1.17 per cent
Water	1.86 per cent
Bentonite	0.16 per cent

Oil sands are very popular because :

1. They are easy to use for core making.
2. An oil-sand core is more collapsible than a clay bonded core known as *loam core*.
3. The green and dry strengths of the oil sand mixture can be controlled by quite simple variations in the proportions of dextrine and oil respectively.
4. The baked cores are very hard and not easily damaged in handling or during closing of the moulds.

CORE MAKING

Core making consists of the following operation : (1) core sand preparation, (2) core moulding, (3) baking, and (4) core finishing.

Core sand preparation. The first consideration in making a core is to mix and prepare the sand properly. The mixture must be homogeneous so that the core will be of uniform strength throughout. The core sands are generally mixed in (1) roller mills, and (2) core mixers. In the case of roller mills, the action of the mullers and ploughs gives a uniform and homogeneous mixing. Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders.

Core moulding. Cores are then made manually or with machines. Normally a core box is required for the preparation of cores. Green sand cores are made by ramming the sand mixtures into boxes, the interiors of which have desired shapes and dimensions (Fig. 11.76). The methods used to ram core are usually done by machines. Core-making machines can be broadly classified as (1) core blowing machines, (2) core ramming machines, e.g., jolting, squeezing, slinging. The principles that they apply for making a sand mould apply also to making a sand core. Except for low-volume production, or very large cores, the sand mixtures is compacted into the core box by core blowing that fills the core sand into the core box by compressed air. The degree of compactness necessary to produce a satisfactory core depends on the type of binder used and on the size and shape of the core.

Fragile and medium-size cores are often reinforced with steel wires and rods so that they will have sufficient strength to resist the forces to which they are subjected within the moulds. In large cores, perforated pipes or arbors are used. In addition to giving the strength, they also serve as a large vent.

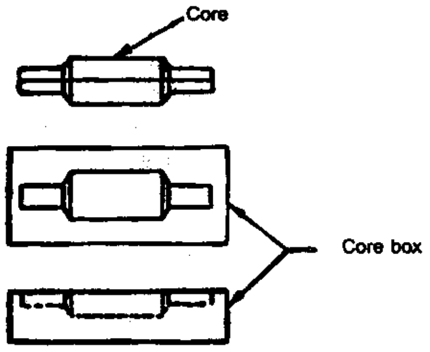

Figure 11.76 Core box and core

Core baking. After the cores are prepared and placed on metal plate or core carriers, they are baked to remove the moisture and to develop the strength of the binder in core ovens at temperature from 150°C to 400°C, depending on the type of the binder used, the size of the cores, and the length of baking time. The core plates called driers are usually perforated to permit the circulation of gases and to lessen the sticking of the cores to the supports. As a rule, one or more vents are provided in cores to assist in the discharge of gases from the interior of the core prints. According to the kind of production, the core-drying ovens are classified as :

1. Core ovens
   (i) batch type (ii) continuous type
2. Dielectric bakers

Batch type ovens are used for baking variety of cores in batches. The cores are generally placed either in drawers or in portable racks which are finally placed in the ovens.

Continuous type ovens are preferred for a high rate production of small and medium-size cores. The core racks move slowly through these ovens on a continuous chair or rail. The loading and unloading is continuous, with backing time controlled by the rate of travel of the conveyor. Because the oven is operated steadily at a fixed temperature and because all cores are in the heated zone for the same length of time, only a fairly narrow range of sizes can be baked properly.

Core-drying ovens are usually heated by coal, coke, oil, gas or electricity.

Dielectric bakers can bake cores in a small fraction of the time required for baking the same cores in conventional ovens. Dielectric heating is employed in modern core ovens for high quality cores made from resin binders. The material to be heated dielectically is placed between the parallel cement bonded asbestos plates or electrodes and a high frequency current is passed through it. The main advantage of these ovens is that they are faster in operation and a good temperature control is possible with them.

Core finishing. After the baking operation, cores are smoothed. All rough places and unwanted fins are removed by filing Some cores are made in two or more pieces which must be assembled usually by pasting together with dextrin or other water-soluble binders.

The last operation in the making of a core is to apply a fine refractory coating or core wash to the surface. This is sometimes called *core-dressing*. This coating prevents the metal from penetrating into the core and provides a smoother surface to the casting. Some materials used for core washes include finely ground graphite, silica, mica, zircon, flour, and a rubber-base chemical spray. Coatings may be applied to the core surfaces by brushing, dipping, or spraying.

TYPES OF CORES

The cores used in foundries are typed according to their shape and their position in the mould. The common types of cores, illustrated in Fig. 11.77, are described below.

Horizontal cores. The most common type is the horizontal core. The core is usually cylindrical in form and is laid horizontally at the parting line of the mould. The ends of the core rest in the seats provided by the core prints on the pattern.

Vertical core. This is placed in a vertical position both in cope and drag halves of the mould. Usually top and bottom of the core are provided with a taper, but the amount of taper on the top is greater than that at the bottom.

Balanced core. When the casting is to have an opening only one side and only one core print is available on the pattern a balanced core is suitable. The core print in such cases should be large enough to give proper bearing to the core. In case the core is sufficiently long, it may be supported at the free end by means of a chaplet (Fig. 11.78).

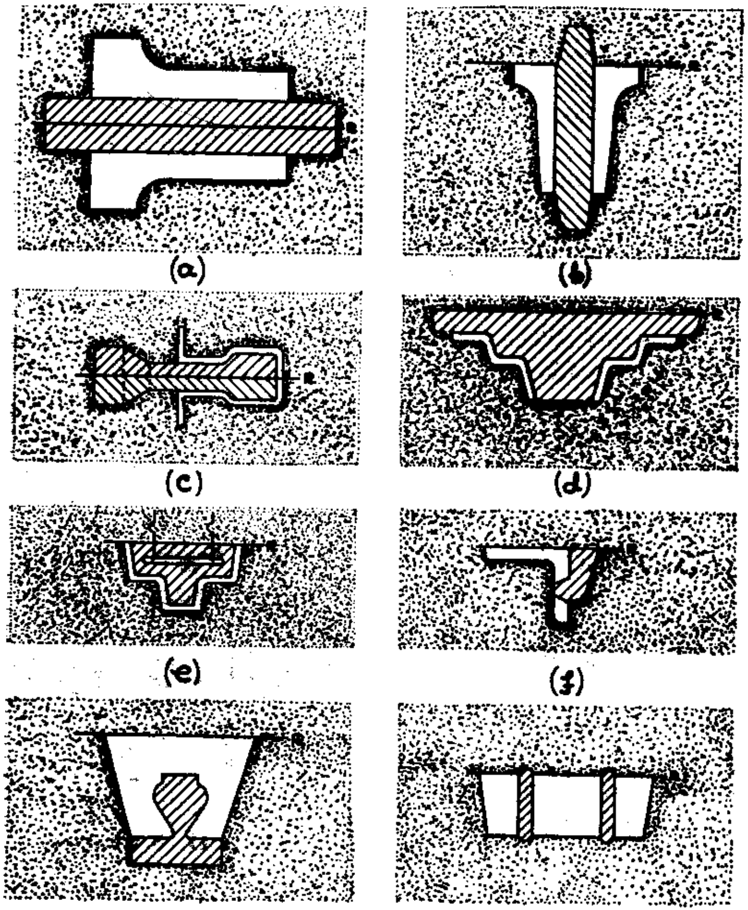

Figure 11.77 Different types of cores

1. Horizontal core, 2. Vertical core, 3. Balanced core, 4. Cover core,
5. Hanging core, 6. Wing core, 7. Ram-up core, 8. Kiss core

Hanging and cover core. If the core hangs from the cope and does not have any support at the bottom of the drag, it is referred to as a *hanging core*. In this case, it may be necessary to fasten the core with a wire or rod that may extend through the cope. On the other hand, if it has its support on the drag it is called *cover core*. In this case, the core serves as a cover for the mould, and also as a support for hanging the main body of the core.

Wing core. A wing core is used when a hole or recess is to be obtained in the casting either above or below the parting line. In this case, the side of the core print is given sufficient amount of taper so that the core can be placed readily in the mould. This core is sometimes designated by other names such as *drop core, tail core, chair core,* and *saddle core,* according to its shape and position in the mould.

Ram-up core. It is sometimes necessary to set a core with the pattern before the mould is rammed up. Such a core is called ram-up core. This is used when the core-detail is located in an inaccessible position in both interior and exterior portions of a casting.

Kiss core. When the pattern is not provided with a core print and consequently no seat is available for the core, the core is held in position between the cope and drag simply by the pressure of the cope. This core is referred to as a kiss core. They are suitable when a number of holes of less dimensional accuracy with regard to the relative position of the holes are required.

CORE SHIFTING

A core must be securely fixed to withstand the upward thrust of the molten metal. If a core does not stay in just the right place in its mould, the walls of the cavity it produces will not be of proper thickness. To keep the cores in place during casting some form of chaplets are required. Chaplets are the supporters of cores. These are rods with flat or curved plates riveted to them. Various types of chaplets are used in supporting different types of cores. Some of the more generally used forms are shown in Fig. 11.78.

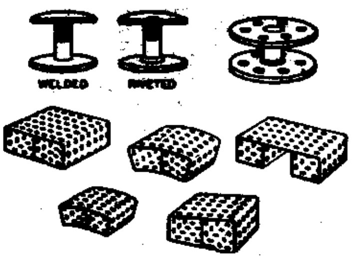

Figure 11.78 Chaplets

11.26 SPECIAL MOULDING PROCESSES

In recent years, special moulding processes have been developed to effect a saving in time and expense, to produce better quality moulds and cores, and to increase productivity with less effort and skill. Generally, these processes do not in all cases require drying or baking of moulds or cores, and rapid hardening action takes place due to chemical reactions in them.

The use of following special moulding processes has considerably increased in recent years.

CARBON DIOXIDE MOULDING

The process is basically a hardening process for moulds and cores. The principle of working of the CO_2 process is based on the fact that if CO_2 gas is passed through a sand mix containing sodium silicate (water glass), the sand immediately becomes extremely strongly bonded as the sodium silicate becomes a stiff *gel*. This gel is responsible for giving the necessary strength to the mould. The chemical reaction can be represented in simplified form as :

$$\underset{\text{(Sodium silicate)}}{Na_2O,(x)SiO_2} + (x)\,H_2O + CO_2 \rightarrow \underset{\text{(Sodium corbonate)}}{Na_2CO_3} + \underset{\text{(Silica gel)}}{SiO_2.(x)\,H_2O}$$

where x is 3, 4 or 5, most often $x = 2$

The sand used for the process must be dry with a maximum moisture content of 0.25 per cent and free of clay. It has been found that there is a rise in the strength as the grain fineness of the sand is increased until about 80 mesh size. When finer sands are used, the maximum strength decreases until with 120 mesh size it reduces to zero. However, this sand is thoroughly mixed with 3 to 5 per cent sodium silicate liquid base binder in a muller for 3 to 4 minutes. Suitable additives such as coal powder, wood flour, sea coal, dextrine may be added to improve certain properties like collapsibility. Kaolin clay, aluminium oxide, and invert sugar or sugar in other forms are sometimes added for certain specific properties. The kaolin clay promotes moulds stability. Aluminium oxide improves the hot strength of the bonded sand, and produces a smooth interface between the mould and the metal. Addition of invert sugar reduces , the retained strength of the mould or core after pouring. Severe shakeout problems may be encountered without additions of sugar. The suitable sand mixture can then be packed around the pattern in the flask or in the core box by standard machines, core blowers, or by hand.

When the packing is complete, CO_2 is forced into the mould or core at a pressure of about 1.45 kgf/cm^2 (142 kN/m^2) for a predetermined length of time. The reaction proceeds rapidly in the early stages of gasification and the compressive strength of the sand mixture reaches a maximum value when a certain critical amount of gas is passed. The time to harden a small or medium size body of sand will range from 15 to 30 seconds. The volume of CO_2 required can be calculated if the quantity of sodium silicate present is known. As a thumb rule, for every 1 kg of sodium silicate, 0.50-0.75 kg of gas is required. Overgassing is wasteful and results in deteriorating the sand. Gassing can be effective only if the air present in the pores of the sand mass is completely evacuated and this is replaced by CO_2 gas. The gassing can be carried out by a probe having a number of holes at the base. The flow rate of CO_2 gas depends on the depth of penetration desired.

The hardness of moulds and cores can be further increased by exposing them to free atmosphere for a short while after gassing. Sometimes a little heating at about 200°C also helps in increasing the hardness.

Patterns used in this process may be made of wood, metal or plastic. The varnish coating on the wooden pattern causes green sand to stick to the pattern. Varnish can, however, be used if a layer of cellulose lacquer is applied afterwards. A more effective alternative is to provide a zinc coat of 0.05 to 0.13 mm thickness over the pattern followed by spraying a layer of aluminium or brass of about 0.25 mm thickness. Subsequent rubbing it with a smooth emery paper gives good result.

Advantages claimed for this process are :

1. Uses conventional equipment for moulding and sand mixing.
2. Eliminates the need for internal support for cores, and for drag and cope elements.
3. Operation is speedy. Moulds and cores can be used immediately after processing.
4. Suitable for heavy and rush orders.
5. Eliminates baking ovens and core driers.
6. Floor space requirements is minimal.
7. Semi-skilled labour can be used.
8. Indirect labour costs are small.
9. Greater dimensional accuracy can be attained than other moulding or coremaking processes.

The major disadvantages of carbon dioxide process are :

1. Difficulty in reclaiming used sand.
2. Moulds and cores are more expensive compared to conventional processes.
3. Bench life of sand mixtures is much shorter than for most other

mould and core mixes.

4. Moulds and cores deteriorate noticeably after being stored under normal atmospheric conditions for more than 24 hours.
5. Shakeout properties are poor compared with those of conventional moulds and cores.
6. Poor collapsibility of hardened sand normally requires special additives to improve the quality.

FERRO-SILICON MOULDING

This moulding is based on the principal that if sodium silicate and powdered ferro-silicon are mixed in the ratio of 2.25 : 1 by weight, foaming action takes place and the temperature rises by exothermic reaction between them. At room temperature, this reaction takes places slowly but once the temperature is increased, the reaction accelerates. Finally, the silica sand forms a hard spongy mass. No baking of the mould or core is necessary as in the CO_2 process.

Normally, for ferrous casting clean, dry sand of 65 mesh, while for nonferrous casting, sand of 100 mesh is suitable. The moulds have to be coated with a suitable wash before they are closed.

DICALCIUM SILICATE MOULDING

This process is based on the principle that if about 2-3 per cent dicalcium silicate, known to be very effective hardening agent, and 5 per cent sodium silicate are mixed with sand along with suitable foaming chemicals, flowability of sand mass increases. As a result, the sand mix can easily flow in the mould, and there is no need of ramming as required in conventional moulding process. Finally, the sand forms a hard mass having sufficient collapsibility.

The main advantage of this process is the great saving in labour input and moulding equipment since no drying or backing are needed. On the other hand, high quality defect-free castings are produced. This finds wide application in medium and heavy castings, both in grey iron and steel castings.

CEMENT-SAND MOULDING

Portland cement may be used as binding material to bind sand grains together. It is found that a good combination of strength, permeability, and flowability is achieved by using cement along with sodium silicate. Flowable cement slurry can also be produced using foaming chemicals in the sand mix. The ramming of sand is thus considerably reduced. However, a good bond can be developed in sand with the addition of about 2 per cent cement, 4-5 per cent sodium silicate, and 1 per cent pitch or molasses.

These moulds produce smooth and accurate surface, but the main disadvantage with cement bonded sand moulds is that they are difficult to knock out of the flask.

SHELL MOULDING

After the name of its inventor, the shell moulding is also known as Croning process or C-process.

This is variant of the resin bonded sand technique for casting steel, iron or nonferrous alloys.

The mould is formed from a mixture of fine sand (100-150 mesh) and a thermosetting resin binder that is placed against a heated metal pattern, preferably made of grey cast iron. When the mixture is heated on this manner, the resin cures, causing the sand grains to adhere to each other forming sturdy shell that conforms exactly to the dimensions and shape of the pattern and constitutes half of a mould. After the shell has been cured and stripped from the pattern, any cores required are set, the two halves of the mould are secured together, placed in a flask and backup material added ; then the mould is ready for pouring.

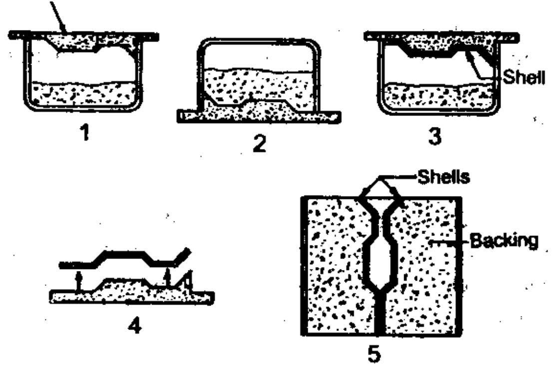

Figure 11.79 Shell moulding process

1. Sand resin in a box, 2. Mix dumped over a heated pattern, 3. Shell formed over the pattern, 4. Shell stripped from the pattern, 5. Shells joined together to form a complete mould

In actual practice, the metal pattern is heated to about 200°C to 300°C, the melting point of resin. Before resin and sand mixture are deposited on the pattern by blowing or dumping, the pattern is pre-conditioned by spraying silicon dissolved in acetone. The process is necessary to ensure that the shells do not stick with the pattern. The resin starts melting and in a few seconds, forms together with the sand a uniform and resin-soaked layer of about 4 to 12 mm in thickness, depending on the heating period. The pattern is then turned over to allow the unbounded sand to be removed, leaving the shell on the pattern. The shell is then stripped mechanically and once more heated for 3 to 5 minutes in a special oven to cure the plastic material. The curing takes place at temperatures of up to about 420°C, depending on the type of resin used. In this way, stable shell moulds are obtained which are made in two sections. Both sections are matched and joined by guides to obtain the casting mould. Finally, they are placed in a metal case, and surrounded by about 37 mm of steel shot, sand, and other backup material to support them during pouring. The gates sprues, and risers are usually a part of the mould. Fig. 11.79 shows the mode of preparing a shell mould and shell core. Machines are available, both for moulding and core making, where the operation can be carried out manually, semiautomatically, or on a fully automatic cycle.

This process is useful for castings that may range in weight from 200 gm to as high as 200 kg in both ferrous and nonferrous metals. It is primarily used for producing castings where greater dimensional accuracy and smoother surface finish than as-cast dimensions are desired as in automobile castings.

For shell moulding coarse sand imparts high shell strength and poor casting finish. A fine sand generates good casting finish but lower shell strength for resin. Resin binder is kept 3.5 to 6 per cent of the weight of the sand used, depending on the shell moulding type.

The main advantages of shell moulding are :

1. Productivity can exceed that of conventional sand-casting practice.
2. Saving of material.
3. Thin sections can be cast.
4. Machining of castings is reduced and in some cases, eliminated.
5. Cost of the tooling processes required are reduced.
6. Closer dimensional tolerances (±0.2 mm) can be obtained.
7. Better surface finishes are realised.
8. Floor space and sand quantity are reduced.
9. Shells can be stored and transported easily.
10. Allows greater detail and less draft.
11. Unskilled labour can be employed.

12. Process can be used for all cast metals.

The main limitations of the process are :

1. High pattern cost.
2. High resin cost.
3. High equipment cost.
4. Uneconomical for small runs.
5. Maximum casting size and weight are limited.
6. Relative inflexibilities in gating and risering as these are provided in the shell itself.
7. Shrinkage factors vary with casting practice.

HOT-AND COLD-BOX MOULDING

The *hot-box process*, particularly adapted in core making, uses basically the same materials as that used in shell moulding, but here the resin is applied for coating the sand grains. The resin-sand mix is then blown over the metal pattern or core box heated to about 200° to 300°C and allowed to form a solid mass instead of allowing shell formation.

Special hot-box machines are now available where the sand mix is blown over the heated pattern, the blown sand cured, and mould or core then stripped from the pattern or core box.

Greater accuracy of dimensions and higher rates of production than in the case of shell moulding are achieved. This is a moulding and core making process essentially for mechanised production of small casting required in big quantities.

The *cold-box process* consists of mixing fine dry sand either polyisocyanate resin binder and alkyd phenolic resin, blowing the mix into a sealed core box and injecting an airborne catalyst triethylamine vapour through the core box. The hydroxyl group of the liquid phenolic resin combines with the isocyanate group to form a stiff urethane resin. The two binder components are usually used in a 1 : 1 ratio with from 1 to 2 per cent by weight of the resin mixture added to the sand.

The process has the advantage that no heating of pattern is required, and the curing takes place in only within 20-30 seconds. So it is a simple, high production coremaking process, and extremely suitable for small-sized castings required in large quantities.

INVESTMENT MOULDING

This process of making casting is often referred to as "lost wax process" and "precision casting process". Casting can be made to very close tolerances in this process and do not require subsequent machining.

It consists mainly of two stages which are illustrated in Fig. 11.80.

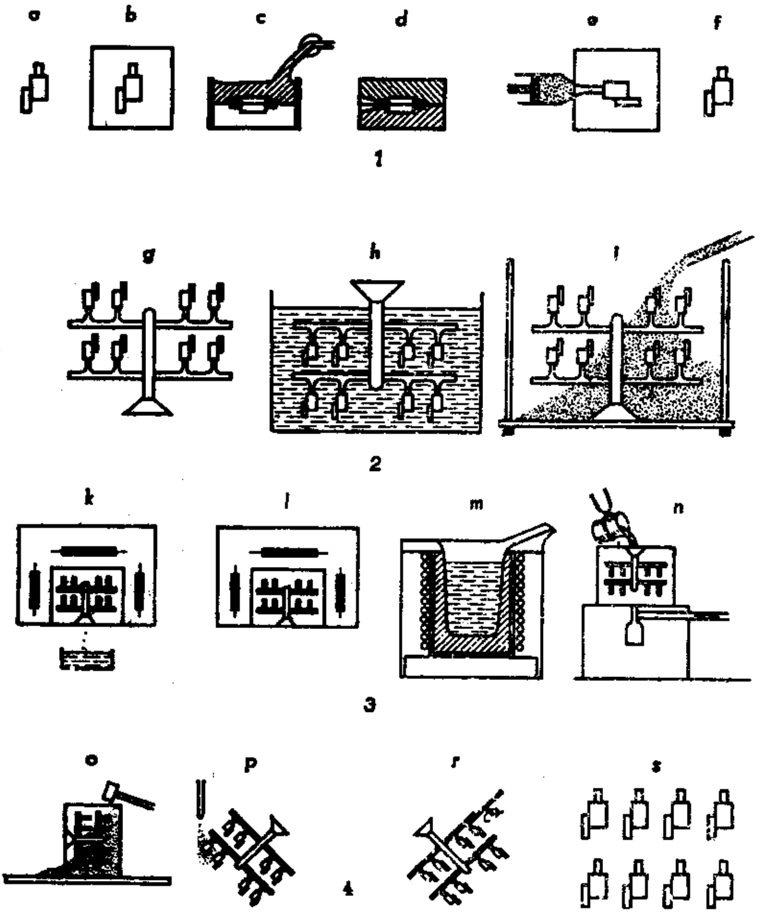

Figure 11.80 Investment moulding in stages

1. Making the pattern, 2. Making the cast mould, 3. Preliminaries of casting and casting process, 4. Separating and cleaning the castings

First, a master pattern is made of wood or metal around which a mould is formed. It does not consist of mould sand but of gelatine or an alloy of low melting point which is poured over the master pattern. This master mould consists of the usual two sections and thus can be opened. It is used for making the "lost pattern".

The master mould is then filled with liquid wax, with a thermoplastic material liquified by heating or with mercury. The heated materials become solid when they are cooled to normal room temperature. If mercury is used, the master mould must be cooled down to about–60° (freezing up) to become solid. The second pattern produced on this way is used for preparing the casting mould properly. The expandable wax pattern is coated with slurry consisting of silica flour and small amounts of kaolin and graphite mixed with water. This process is referred to as the "investment" of the pattern.

However, the pattern is then used to make up moulds similar to those used in conventional moulding process, but the pattern within the mould is not taken out of the mould which is not opened after this moulding process. This is the reason why a high precision is achieved in casting.

The finish mould is dried in air for 2 to 3 hours and then baked in an oven for about 2 hours to melt out the wax. At a temperature of 100° to 120°C the wax melts and runs through a hole in the bottom plate into a tray, thus providing a cavity of high dimensional accuracy for the casting process. After this, the mould is sintered at about 1000°C to improve its resistivity. Finally, it is cooled down to a temperature between 900° and 700°C for casting.

It is possible to combine several hundred lost patterns of small workpieces into what is called a "bunch of patterns" by one common gate, make one combined mould, and cast them in one common process.

Investment castings produced by this process have a good surface finish and are exact reproduction of the master pattern. This is used for casting turbine plates, parts of motor-car, sewing machines, typewriters, and calculating machines, as well as for various instruments.

The advantages of this process are :

1. Machining can be largely reduced or eliminated since tolerances close to ±0.1 mm and surface finish of around 1-5 micron are possible.
2. Extremely thin section, to the extent 0.75 mm, can be cast successfully.
3. Complex shaped parts that cannot be obtained by other process can be conveniently made.
4. Sound and defect-free castings may be obtained.
5. Suitable for mass production of small-sized castings.

The limitations of this process are :

1. Unsuitable for castings of more than about 5 kg weight.
2. Precise control is required in all stages of casting.
3. Expensive in all respects.

FULL MOULDING PROCESS

In this method, a polystyrene foam pattern, complete with sprues, bottom gates, runners, and risers, and coated with a suitable mould wash is rammed up in a flask filled up with no-bake type of sand. For small-sized castings furan or alkyd isocyanate while for medium and large-size castings CO_2, ferrosilicon may be used. When the molten metal is poured through the sprue, the heat from the molten metal vapourises the pattern and consequently displacement of the pattern material takes place by the molten metal. The amount of gas produced is so small that it can easily escape through the sand without causing any back pressure. However, shapes with high dimensional accuracy can be cast quickly and inexpensively by this method.

The advantages of this process are :

1. High dimensional accuracy is obtained.
2. Defects such as blowholes and pinholes are eliminated.
3. There is no limitation as regards size, shape or complexity.
4. Suitable and economical for large-scale production of small castings of both ferrous and nonferrous metals.
5. The rate of production is very quick as a large number of patterns can be moulded together.

Limitations of this process are :

1. Precise control at all stages of production is required.
2. The raw materials, equipment and technology required are expensive.
3. Additional cost of cleaning castings for trimming gates, sprues and risers is involved.

PLASTER MOULDING

In this method, the mould is prepared in gypsum or plaster of paris. In practice, the plaster of paris is mixed with talc, asbestos, fibres, silica flour, and a controlled amount of water to form a slurry. This plaster slurry is poured over the metallic pattern confined in a flask. The mould is vibrated and the slurry allowed to set. The pattern is removed after about 30 minutes when the setting is complete and the mould is dried and backed by slowely heating it to about 200°C in a conveyor oven. Inserts and cores are placed, cope and drag matched by guide pins. Molten metal is then poured into the mould. Finally, the casting is cooled in the mould, shaken out and the mould is destroyed. Castings are then trimmed of gates, sprues, and flash.

Advantages of plaster moulding are :

1. Warping and distortion of thin sections can be avoided since plaster has no chilling tendency due to low rate of heat conductivity.
2. A high degree of dimensional accuracy and surface finish is obtained, and machining cost, is therefore, eliminated.
3. Highly suitable for reproduction of fine form and detail as are necessary for ornamental castings, statues, jewellery, etc. besides being used for engineering components.

Limitations of this process are :

1. Low permeability of plaster of paris.
2. Suitable only for nonferrous castings owing to the fact that plaster of paris destroys at 1200°C.

CERAMIC MOULDING

In ceramic moulding, a thick slurry, consisting of specially developed ceramic aggregates and a liquid chemical binder (alcohol based silicon ester) is pured over the reusable split and gated metal pattern which is usually mounted on a match plate. The slurry fills up all cavities and recesses by itself and no ramming or vibration of the mould is required. The pattern is withdrawn after it sets in about 3 to 5 minutes. The ceramic mass is then removed from the flask, treated with a hardener to promote chemical stabilisation and heated to about 980°C in a furnace to remove the liquid binder. The mould is then ready for pouring molten metal.

Advantages of this process are :

1. Highest precision and extremely high finish are obtained.
2. Suitable for all types of cast metals including highly reactive metals such as titanium and uranium.

3. The castings do not normally require any riser, venting or chilling as the cooling rate is very slow.
4. Any ordinary pattern of wood, metal, or epoxy resin may be employed.
5. Highly suitable for precision parts which include forging dies, dies for plastic moulding, dies for drawing, extrusion, die casting, patterns for shell moulding, impellers of pumps having very narrow passages, parts for aircrafts, atomic reactors etc.

Disadvantages of ceramic moulding are :

1. Impractical to control dimensional tolerances across the parting line to the same tolerance as within one-half of the mould.
2. The process is expensive as the mould materials are high in cost and expendable.

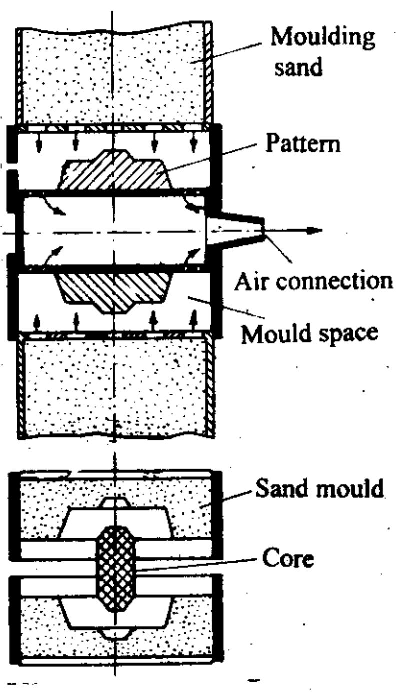

Figure 11.81 Suction moulding

SUCTION MOULDING

In this method, a vacuum is created by withdrawing air from the mould space. Subsequently moulding sand is sucked in, and the cavity is filled up. The sand can thereafter be rammed in the pattern. The processes is used for casting iron, steel and aluminium. The weight of casting ranges from 200 gm to 120 kg. Fig. 11.81 shows the operation. Mould is used once and is made from wet artificial crashed sand. The process is different from *vacuum moulding* where plastic sheet is vacuum moulded to the contour of the pattern, back filled with fine grained binder free quartz sand and sealed with another plastic sheet. The mould is constantly connected to a vacuum source before, during and after the casting.

Advantages of the suction moulding process are :

1. Optimum mould compactation around the pattern.