srivenkateshwaraa College of Engineering & Technology
(Approved by AICTE, New Delhi & Affiliated to Pondicherry University, Puducherry)
13-A, Pondy - Villupuram Main Road, Ariyur, Puducherry - 605 102.
ASPIRE TO EXCEL

21001

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT NOTES

SUB NAME: INDUSTRIAL CASTING TECHNOLOGY

SUBCODE : MEE54 **YEAR & SEM :** III/V

PREPARED BY,

Mr. G.PALANIVEL., B.E., M.E., MISTE..

ASSISTANT PROFESSOR

SVCET

UNIT-I

PATTERNS AND MOULDING SANDS

INTRODUCTION TO CASTING

Casting is a process in which molten metal flows by gravity or other force into a mould where it solidifies in the shape of the mould cavity.

The term casting is also applied to the part that is made by this process.

The principle of casting seems simple:

- melt the metal
- pour it into a mould
- and let it cool and solidify

Yet there are many factors and variables that must be considered in order to accomplish a successful casting operation.

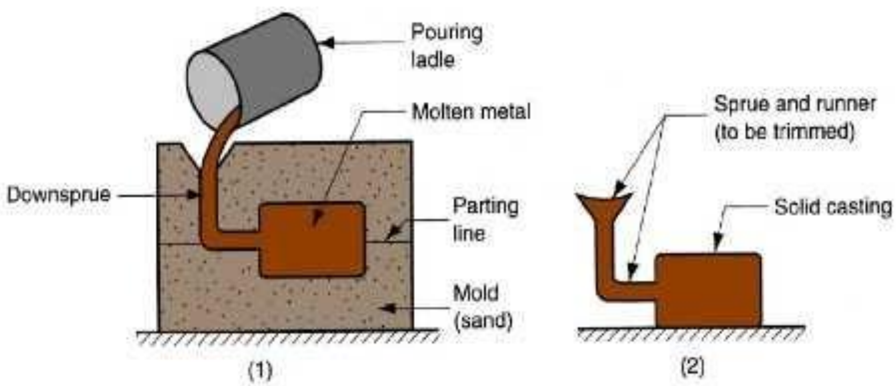


Fig 1.1 Casting Process

Advantages of Casting

- Casting can be used to create complex part geometries, including both external and internal shapes.
- Some casting processes are capable of producing parts to net shape.
- No further manufacturing operations are required to achieve the required geometry and dimensions of the parts.
- Casting can be used to produce very large parts.
- Castings weighing more than 100 tons have been made.
- The casting process can be performed on any metal that can be heated to the liquid state.
- Some casting methods are quite suited to mass production.

Disadvantages of casting

- Limitations on mechanical properties, porosity
- Poor dimensional accuracy and surface finish for some casting processes.
- Safety hazards to humans when processing hot molten metals, and environmental problems

STEPS IN CASTING

- Pattern and Mould
- Melting and Pouring
- Solidification and Cooling
- Removal, Cleaning, Finishing and Inspection

PATTERN

The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints.

If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction. The costs of the pattern and the related equipment are reflected in the cost of the casting. The use of an expensive pattern is justified when the quantity of castings required is substantial.

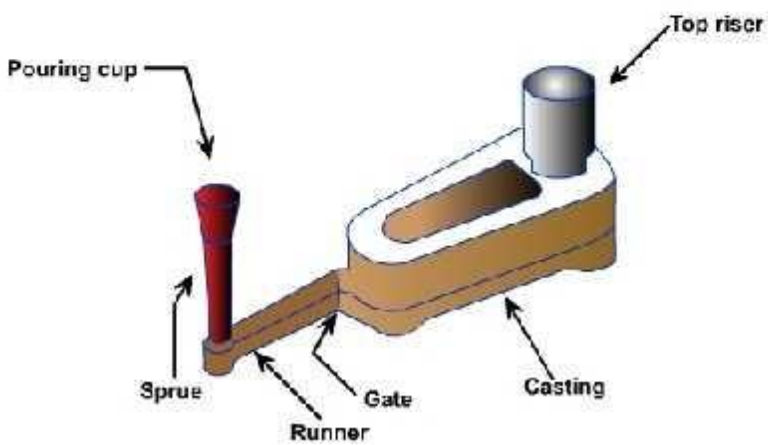


Fig 1.2 a typical pattern attached with gating and risering system

Functions of the Pattern

1. A pattern prepares a mould cavity for the purpose of making a casting.
2. A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
3. Runner, gates, and risers used for feeding molten metal in the mould cavity may form a part of the pattern.
4. Patterns properly made and having finished and smooth surfaces reduce casting defects.
5. A properly constructed pattern minimizes the overall cost of the castings.

PATTERN MATERIAL

Patterns may be constructed from the following materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. To be suitable for use, the pattern material should be:

1. Easily worked, shaped and joined
2. Light in weight
3. Strong, hard and durable
4. Resistant to wear and abrasion
5. Resistant to corrosion, and to chemical reactions
6. Dimensionally stable and unaffected by variations in temperature and humidity
7. Available at low cost

The usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight. Also, it can be easily shaped and is relatively cheap. The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes. Hence, proper seasoning and upkeep of wood is almost a pre-requisite for large-scale use of wood as a pattern material.

COMMON PATTERN MATERIALS

The common materials used for making patterns are wood, metal, plastic, plaster, wax or mercury. The some important pattern materials are discussed as under.

1. WOOD

Wood is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface. Wood can preserve its surface by application of a shellac coating for longer life of the pattern.

But, in spite of its above qualities, it is susceptible to shrinkage and warpage and its life is short because of the reasons that it is highly affected by moisture of the moulding sand. After some use it warps and wears out quickly as it is having less resistance to sand abrasion. It cannot withstand rough handily and is weak in comparison to metal. In the light of above qualities, wooden patterns are preferred only when the numbers of castings to be produced are less. The main varieties of woods used in pattern-making are shisham, kail, deodar, teak and mahogany.

a) Shisham

It is dark brown in color having golden and dark brown stripes. It is very hard to work and blunts the cutting tool very soon during cutting. It is very strong and durable. Besides making pattern, it is also used for making good variety of furniture, tool handles, beds, cabinets, bridge piles, plywood etc.

b) Kail

It has too many knots. It is available in Himalayas and yields a close grained, moderately hard and durable wood. It can be very well painted. Besides making pattern, it is also utilized for making wooden doors, packing case, cheap furniture etc.

c) Deodar

It is white in color when soft but when hard, its color turns toward light yellow. It is strong and durable. It gives fragrance when smelled. It has some quantity of oil and therefore it is not easily attacked by insects. It is available in Himalayas at a height from 1500 to 3000 meters.

It is used for making pattern, manufacturing of doors, furniture, patterns, railway sleepers etc. It is a soft wood having a close grain structure unlikely to warp. It is easily workable and its cost is also low. It is preferred for making pattern for production of small size castings in small quantities.

d) Teak Wood

It is hard, very costly and available in golden yellow or dark brown color. Special stripes on it add to its beauty. In India, it is found in M.P. It is very strong and durable and has wide applications. It can maintain good polish. Besides making pattern, it is used for making good quality furniture, plywood, ships etc. It is a straight-grained light wood. It is easily workable and has little tendency to warp. Its cost is moderate.

e) Mahogany

This is a hard and strong wood. Patterns made of this wood are more durable than those of above mentioned woods and they are less likely to warp. It has got a uniform straight grain structure and it can be easily fabricated in various shapes.

It is costlier than teak and pine wood, It is generally not preferred for high accuracy for making complicated pattern. It is also preferred for production of small size castings in small quantities. The other Indian woods which may also be used for pattern making are deodar, walnut, kail, maple, birch, cherry and shisham.

Advantages of wooden patterns

1. Wood can be easily worked.
2. It is light in weight.
3. It is easily available.
4. It is very cheap.
5. It is easy to join.
6. It is easy to obtain good surface finish.
7. Wooden laminated patterns are strong.
8. It can be easily repaired.

Disadvantages

1. It is susceptible to moisture.
2. It tends to warp.
3. It wears out quickly due to sand abrasion.
4. It is weaker than metallic patterns.

2. METAL

Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence possess longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio.

The main disadvantages of metallic patterns are higher cost, higher weight and tendency of rusting.It is preferred for production of castings in large quantities with same pattern. The metals commonly used for pattern making are cast iron, brass and bronzes and aluminum alloys.

a) Cast Iron

It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, and brittle and get rusted easily in presence of moisture.

Advantages

1. It is cheap
2. It is easy to file and fit
3. It is strong
4. It has good resistance against sand abrasion
5. Good surface finish

Disadvantages

1. It is heavy
2. It is brittle and hence it can be easily broken
3. It may rust

b) Brasses and Bronzes

These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern

Advantages

1. Better surface finish than cast iron.
2. Very thin sections can be easily casted.

Disadvantages

1. It is costly
2. It is heavier than cast iron.

c) Aluminum Alloys

Aluminum alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength. They also possesses good resistance to corrosion and abrasion by sand and thereby enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

Advantages

1. Aluminum alloys pattern does not rust.
2. They are easy to cast.
3. They are light in weight.
4. They can be easily machined.

Disadvantages

1. They can be damaged by sharp edges.
2. They are softer than brass and cast iron.
3. Their storing and transportation needs proper care.

d) White Metal (Alloy of Antimony, Copper and Lead)

Advantages

1. It is best material for lining and stripping plates.
2. It has low melting point around 260°C
3. It can be cast into narrow cavities.

Disadvantages

1. It is too soft.
2. Its storing and transportation needs proper care
3. It wears away by sand or sharp edges.

3. PLASTIC

Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non-sticky to moulding sand, durable and they are not affected by the moisture of the moulding sand. Moreover they impart very smooth surface finish on the pattern surface. These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement.

The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used. These are originally in liquid form and get solidified when heated to a specified temperature. To prepare a plastic pattern, a mould in two halves is prepared in plaster of Paris with the help of a wooden pattern known as a master pattern. The phenolic resin is poured into the mould and the mould is subjected to heat. The resin solidifies giving the plastic pattern.

Recently a new material has stepped into the field of plastic which is known as foam plastic. Foam plastic is now being produced in several forms and the most common is the expandable polystyrene plastic category. It is made from benzene and ethyl benzene.

4. PLASTER

This material belongs to gypsum family which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting. The main advantages of plaster are that it has high compressive strength and is of high expansion setting type which compensate for the shrinkage allowance of the casting metal.

Plaster of Paris 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. It is also preferred for production of small size intricate castings and making core boxes.

5. WAX

Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives which act as polymerizing agents, stabilizers, etc. The commonly used waxes 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 general practice of making wax pattern is to inject liquid or semi-liquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength. Waxes use helps in imparting a high degree of surface finish and dimensional accuracy castings.

Wax patterns are prepared by pouring heated wax into split moulds or a pair of dies. The dies after having been cooled down are parted off. Now the wax pattern is taken out and used for moulding.

Such patterns need not to be drawn out solid from the mould. After the mould is ready, the wax is poured out by heating the mould and keeping it upside down. Such patterns are generally used in the process of investment casting where accuracy is linked with intricacy of the cast object.

FACTORS EFFECTING SELECTION OF PATTERN MATERIAL

The following factors must be taken into consideration while selecting pattern materials.

1. Number of castings to be produced. Metal pattern are preferred when castings are required large in number.
2. Type of mould material used.
3. Kind of moulding process.
4. Method of moulding (hand or machine).
5. Degree of dimensional accuracy and surface finish required.
6. Minimum thickness required.
7. Shape, complexity and size of casting
8. Cost of pattern and chances of repeat orders of the pattern

MACHINES AND TOOLS FOR PATTERNMAKING

Machines for Wood Patternmaking

Most of the machines used for the patternmaking are the same as those for other jobs in woodworking. However, some of the operations otherwise done by a group of machine for instance, boring, milling, slotting, shaping, grooving, and cutting special profiles such as gear teeth are more efficiently performed on a special purpose machine called the ***pattern miller*.**

The size and the capacity of the machines used depend on the size of the general run of work to be performed. The machines chosen for the pattern shop should not only be sturdily built and of sizeable proportions so that they can cope with a variety of jobs, but should also have dependable accuracy. The ones favoured for patternmaking are:

- woodworking lathe
- circular saw
- band saw
- jig saw or scroll saw
- jointer
- planer
- shaper
- pattern-milling machine
- disc and bobbin sander
- Machines for tool grinding.

(1) Woodworking Lathe

The woodworking lathe is one of the most important machines to the patternmaker since patterns and core boxes often involve some sort of cylindrical work. It is designed chiefly for turning jobs, both external and internal. However, by suitably manipulating the tool, tapers, and radii, other irregular shapes can also be easily turned.

The woodworking lathe (Fig 1.3) consists of four major parts are the head stock, which has a spur or live centre fitted in a hollow spindle; the tail stock, carrying a dead centre; a tool rest, which is stationary and adjustable; and a bed to which are fastened the other three parts.

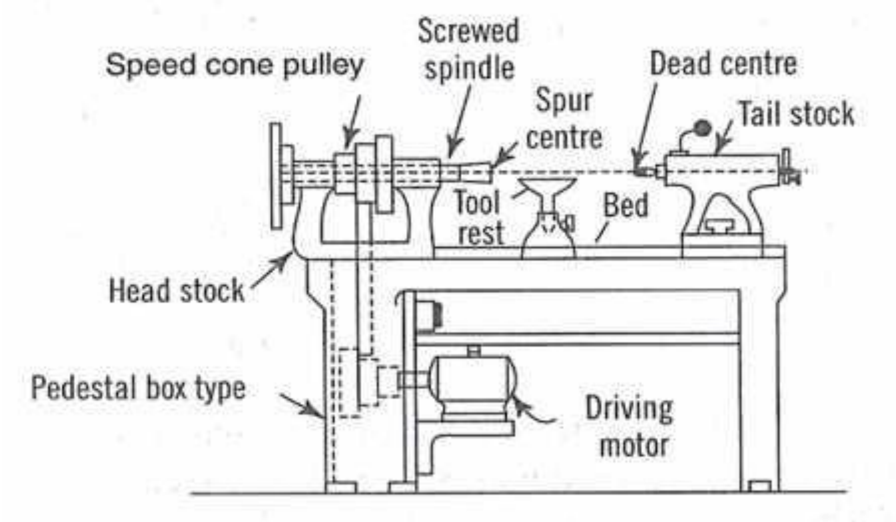


Fig 1.3 Woodworking lathe

- ✓ Pattern shops are equipped with a special type of woodworking lathe, known as the patternmaker's lathe. This lathe is a modified version of the woodworking lathe and in many respects resembles the centre lathe used for metal-working operations. The design of its various parts makes it more robust and sturdy and therefore more dependable than the woodworking lathe.
- ✓ First, the patternmaker's lathe has a back gearing arrangement by means of which the available number of spindle speeds is doubled. Secondly, it is equipped with a feed shaft and a sliding carriage in place of the fixed-type tool rest. On the carriage is fitted a cross slide, a compound slide, and a tool post. Thus, in this lathe, the tool traverse, both parallel to the work axis as well as across it, can be precisely regulated for better size control.
- ✓ The size of woodworking lathes is usually specified in terms of the swing or height-of-centre of the lathe and the maximum distance between the centres. The height-of-centre is taken as the distance from the lathe centre to the upper surface of the bed, and the swing is double that of the height-of-centre.
- ✓ Generally, the woodworking lathe is supplied together with a number of accessories, which considerably increase its usefulness and adaptability. Some of the typical accessories include different types of centres, such as drive centre, cup centre, and screw centre, a face plate, a 4-jaw independent chuck, a 3-jaw self-centring chuck, a tool holder, and a set of wood turning tools. The types of tools commonly

used on these lathes are illustrated in Fig 1.4. The material of these tools is high carbon steel containing about 0.8-1.0% carbon.

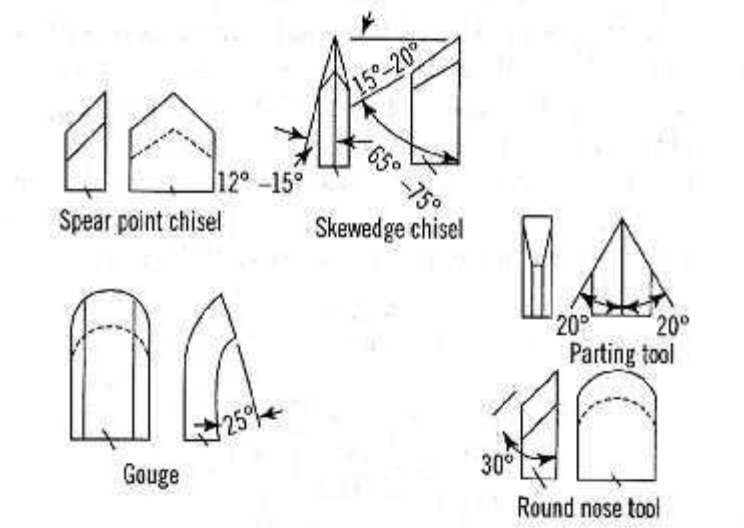


Fig 1.4 woodworking lathe tools

(2) Circular Saw

The circular saw is also an essential machine in the pattern shop. It can be used for all cutting operations, such as ripping, cross-cutting, beveling, rabbeting, grooving, and mitering. The principal parts of the circular saw are a cast-iron table upon which the work is supported and from where it is fed into the saw.

A circular saw blade supported in bearing on the underside of the table and rotating at high speed, a driving arrangement for the saw blade, consisting of an electric motor and a set of pulleys mounted on shafts.

A cut-off guide, which is used during cross-cutting to steer the piece towards the saw blade and a ripping fence, which acts as a guide while sawing along the grains of wood. The circular saw usually has provision for tilting the table, thus enabling cutting at an angle as required during mitering, beveling, etc. The tilting can be done up to an angle of 45°.

The size of the circular saw is specified by the diameter of the saw blade. A 300-mm saw is commonly used for small and medium-sized work. The cutting speeds for sawing vary from 1000 metres to 3000 metres per minute according to the hardness of the wood.

(3) Band Saw

The band saw makes use of an endless metal saw band, which travels over the rim of two rotating pulleys. Although the number of operations that can be performed on a band saw is less than those on a circular saw, it is favoured for curved or irregular cuts in wood.

The main parts of a band saw are the following:

(i) A set of cast-iron pulleys or wheels carrying the saw band on their periphery; of the two wheels, one is adjustable and the other is fixed so that the centre-to-centre distance can be slightly varied to maintain proper tension of the band

(ii) A cast-iron table on which the workpiece is placed and from where it is fed into the saw band for cutting; the table, which can be tilted as in the case of the circular saw, carries a slot in the centre through which the band passes

(iii) A roller guide, fixed to an adjustable arm, which helps in keeping the saw band in position while cutting

(iv) A heavy cast-iron frame or body to which all the other parts are fitted

(v) A driving arrangement, consisting of an electric motor and a set of pulleys, to transmit power to the driving wheel

(vi) A ripping fence as in the circular saw

The band saw is available in two models are horizontal and vertical. In the former, the two wheels are arranged alongside each other and the table is underneath. In the latter model, the more popular of the two, the wheels are arranged one above the other and the band thus has to pass through the table, which is mounted in a central position between the two wheels.

The size of the band saw is specified as the distance from the saw band to the inner side of the frame. This distance is roughly equal to the diameter of the wheels. The width of the saw band varies from 6 mm to 50 mm and is dependent on the size of the machine. Narrow bands are usually employed on small machines where cutting is to be done along a small radius.

(4) Jig Saw or Scroll Saw

The jig saw, which is also known as a scroll saw, is ideal for cutting small size work to an intricate profile. It is actually a diminutive type of band saw and is specially adapted to regular work. The table of the jig saw too can be tilted for angular work. The special characteristic of this saw is its ability to cut inside curves as well. This is done by first threading the blade through a previously bored hole and then working along the desired layout. This internal sawing facility is not available in any other traditional woodworking machine and is invaluable in patternmaking, such as for preparing strickle boards and core boxes. The width of the jig saw blades varies from 1.5 mm to 9 mm.

(5) Jointer

The wood jointer is designed for planing the straight edges and surfaces of boards. Its use, therefore, eliminates the labour involved in hand planing. The jointer (Fig 1.5) consists of a revolving cutter head to which three or more cutter knives are fitted; a table on which the board to be planed is kept pressed and fed by hand against the revolving cutter head; and an adjustable fence for guiding the board at a predetermined angle to the surface of the table. By means of the adjustment provided, the fence may be kept either at 90° to the table or inclined at any other angle for angular and bevel cuts. For regulating the depth of the cut, the cutter head can be raised or lowered by moving a hand wheel.

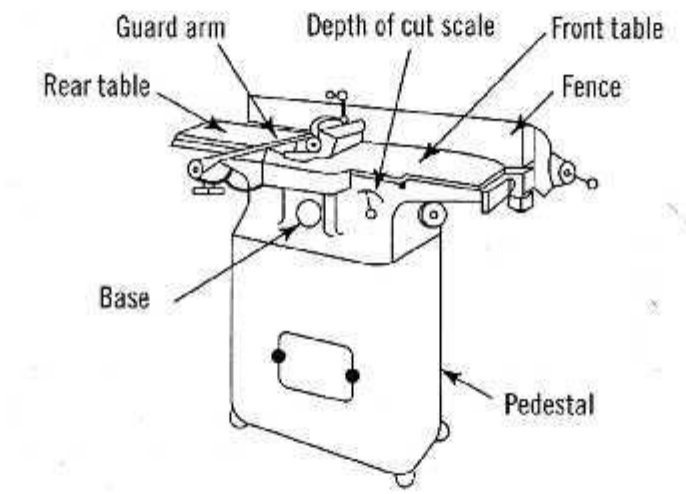


Fig 1.5 Wood Jointer

(6) Planer

The purpose of a wood planer is similar to that of a jointer, but it is designed primarily for planing large and heavy stock at a comparatively faster rate and involving a lesser amount of manual labour (Fig. 2.8). The boards to be planed are fed into the machine by means of feed rolls along a table against a revolving cutter head, thus eliminating the labour of hand feeding. The cutter head is mounted on an overhead shaft which is adjustable for regulating the depth of the cut (Fig 1.6). The table of the planer is generally much wider and longer than that of a jointer and more accommodating for large plants. The planer is also usually equipped to automatically surface the wood to desired thicknesses.

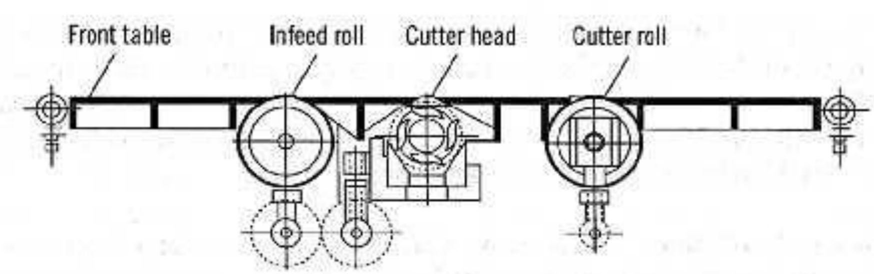


Fig 1.6 Principle parts of a wood Planer

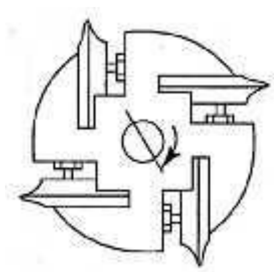
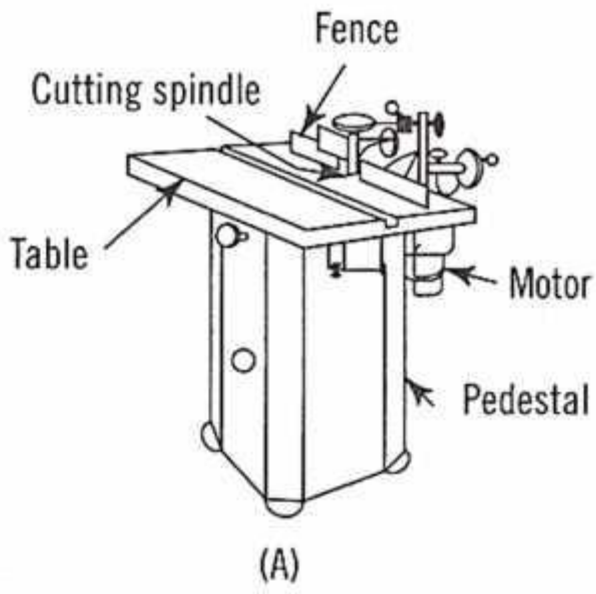


Fig 1.7 Cross section of cutter

(7) Shaper

The machine consists of a cutter head, carrying a cutter and rotating about a vertical axis, and a horizontal table similar to that of a jointer. The wood is fed by hand along the table against the cutter and guided by an adjustable fence, Fig. 1.8(A). The shape of the cut on the surface of the wood is the same as that of the profile of the teeth on the cutter. By suitably designing the cutter, a variety of shapes can be produced. The types of cut that can be taken by a shaper are shown in Fig. 1.8(B).



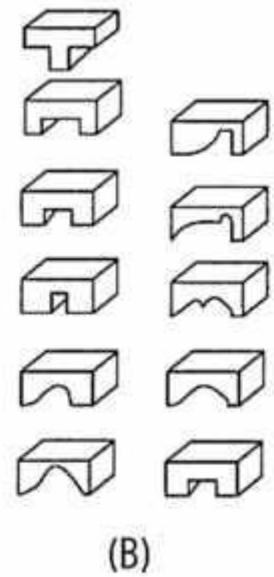


Fig. 1.8 (A) Wood shaper; *Fig. 1.8 (B) Types of cut taken by a wood shaper*

(8) Pattern Milling Machine

This machine has a large base on which a broad column is supported as shown in Fig 1.9. At the front of the base is a table support, which slides on rails and can be locked in the desired position. The workpiece is mounted on the table and it can be moved along both X-X and Y-Y axes, all the three movements being usually hand-operated. The column carries an overhanging arm which can be raised or lowered, both manually and by power operation.

At the outer end of the arm is the spindle head, and cutter spindle. The spindle can be raised, lowered, and canted on both sides through 45° on the right and 30° on the left, working in vertical, horizontal, and any angular position. Six spindle speeds are provided varying from 850 to 4200 rpm. The machine is equipped with several tools and cutters, such as a pattern cutter, core box cutter, fillet cutter, and boring cutter, and gauging and recessing tools.

The pattern-milling machine, by virtue of its expansive table movements, the long vertical movement of its arm, the flexibility of its spindle, and its wide range of tools, cutters and accessories, is capable of numerous operations. These operations include boring, drilling, milling, facing, slotting, grooving, shaping, fillet cutting, gear-cutting, worm-cutting and forming the radius, angular cuts and other shapes as required in the core box.The speeds and feeds needed for woodworking machines are as shown in Table 2.2.

The workability of wood on the machines depends on its specific gravity, moisture content, and the directional arrangement of grains. For instance, low moisture content (about 6%) offers excellent conditions for machining. The type of operation has considerable influence on the quality of work. Surface cutting speeds, also regulated by the foregoing factors, range from 1200 metres per minute to 3000 metres per minute. For a given speed, the feed and I he depth of cut control the amount of material removed and the finish produced. The cutting angle used on woodworking tools varies from 15° to 30°.

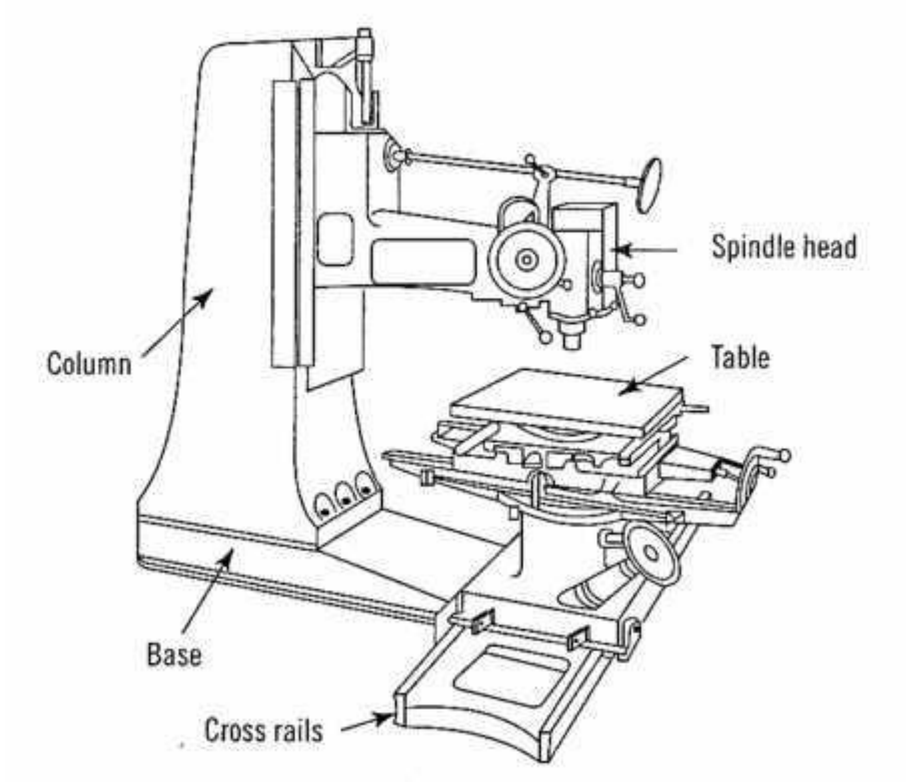


Fig 1.9 Block diagram of pattern milling machine

Speeds and feeds for woodworking machines

MACHINE	RANGE OF SPINDLE SPEEDS	RANGE OF FEEDS
Jointer	4000-5000 rpm	Manual feed
Planer	4000-5000 rpm	5-20 m/min
Lathe	240-2880 rpm	Manual feed
Band saw	1500-1800 m/min	Manual feed
Circular saw	2000-3600 m/min	Manual or automatic, 12- 45 m/min
Borer	1200-3600 rpm	2-35 strokes/min
Pattern miller	850-4200 rpm	Manual

(9) Disc and Bobbin Sander

Sanding is an operation of finishing the surfaces of the wooden items after they have been machined. Essentially, the work involves sandpapering the job to present a uniformly sanded surface. Mechanical operation is provided for sandpaper movement. A disc sander has a large disc, about 450 mm in diameter, rotated by .in electric motor at 3000 rpm. A sandpaper of suitable grade is glued and fixed on the outer face of the disc. An adjustable table is provided against the disc on which the job to be sanded is placed and pressed.

A bobbin sander consists of a cylindrical bobbin of 75-mm diameter and 200-mm length around which again sandpaper can be attached. The bobbin, while it rotates at high speed, also moves up and down through a short stroke of about 50 mm. A work support or table is provided around the bobbin. Curved surfaces, which cannot be sanded on the disc sander, can be finished on the bobbin sander.

Disc and bobbin mechanisms are often combined in a single unit called the disc-cum-bobbin sander in which one electric motor drives both the disc and the bobbin. Special sandpapers in different grades of fine nesses are available for the machine.

Dust Exhaust System Woodworking machines, such as saws and sanders produce very fine dust which, if left uncollected, stays suspended in the atmosphere. Sawdust from the sander is also hot and can be dangerous. Dust exhaust systems should be installed on all such machines so that the dust is collected and disposed of in a convenient manner. A proper dust-collection system helps in maintaining a clean working environment and thus improves efficiency, besides preventing fire hazards and protecting the health of the workers. There should be an exhaust system, either one for each machine or a central exhaust system, which collects dust from various machines by means of a common suction fan.

The exhaust system consists of a hood or some other suitable arrangement to collect the dust and shavings, suction fan, a filtering arrangement for exuding clean air, a chamber for the collection of dust, and suitable pipelines. The filtering arrangement is usually of the 'bag-filter' type, which allows only clean air to pass through a series of bags and then escape to the atmosphere, thus separating it from dust. There is also a vibratory system which periodically shakes the bags to rid them of the dust particles sticking to their linings. Modern woodworking machines are equipped with a built-in dust exhaust system, which is cleaner and more compact than the system installed as an appendage.

(10) Machines for Tool Grinding

In order to efficiently use the woodworking machines, their tools and cutters have to be periodically sharpened and kept trim. It is not possible to grind or sharpen all the diverse types of tools by hand grinding. Equipment that is essential includes a circular saw and band saw blade sharpener (either in two separate machines or in the same machine); a band saw blade butt welder; a planer knife grinder; a tool and cutter grinder; and a double- ended tool grinder.

Hand Tools for Wood Patternmaking

Wood patternmaking is basically a woodworking process since a majority of the patterns used in the foundry are made in wood. Most of the tools required by the patternmaker are therefore the same as those used by the woodworker. A few of the tools are however specially suited to pattern construction work. The various tools commonly used (Figs 1.10) may be broadly classified as follows:

- *Measuring and Marking Tools Rule, contraction rule, scriber, try square, bevel square, marking gauge, trammels, calipers, dividers, vernier calipers, and combination set*

- *Sawing Tools*: Hand saw; tenon saw, dovetail saw, compass saw, coping saw, and keyhole saw
- *Planing Tools* Jack plane, smoothening plane, foreplane, block plane, rabbet plane, router plane, spoke shave, circular plane, and core box plane
- *Boring Tools* Hand drill; breast drill, ratchet brace along with auger bits, twist drill, twist bits, centre bits, expansion bits, and countersink
- *Clamping Tools* Carpenter's vice; bar clamp; 'C' clamp, pinchdogs; and handscrew
- *Miscellaneous Tools* File, mallet, firmer, mortise and paring chisels, internal and external gouges and oilstone

The tools specially adopted for pattern work are the following:

(1) Patternmaker's Contraction Rule:

This rule has suitably oversized graduations marked on it so as to make allowance for the contraction of the canting. A separate rule is available for four common cast metals, namely, iron, steel, brass, and aluminium. A single rule may also have all the four graduations, two on each side. Contraction rules are also available with marked contraction rates, such as 0.6 mm per metre, 1.0 mm per metre, 1.5 mm per metre, and 2.0 mm per metre. These rules are made of stainless steel.

(2) Core box Plane:

This tool is specially designed for the planing of semicircular grooves and hollow portions, as required often in core boxes. The tool has two beds at right angles to each other, which guide a shaped cutter.

(3) Patternmaker's Saw:

This saw is designed particularly for the fine and accurate work required in patternmaking. It has a thin steel blade, 0.7 mm thick, 300 mm long, and 200 mm wide.

(4) Gouges:

Though gouges are used in all wood work, these have special application in patternmaking, particularly for making cavities, grooves, recesses, fillets, etc., in patterns and core boxes. They are made in different shapes and are both in convex and concave form.

(5) Pattern Fillet Irons:

Fillets, in wood, leather, wax, plastic, metal or fibre, are provided on the patterns to avoid sharp corners at the junction of two surfaces. Wooden fillets have to be shaped separately and then attached by gluing. Leather fillets are favoured for costly patterns. These fillets are first pasted on the patterns and then pressed with a spherical tool, called the fillet iron, so that the exact radius as given on the tool is obtained on the fillet. The fillet iron is used similarly on wax fillets. Fillet irons are available in a range of sizes varying from 5 mm to 15 mm radius (Fig. 1.10).

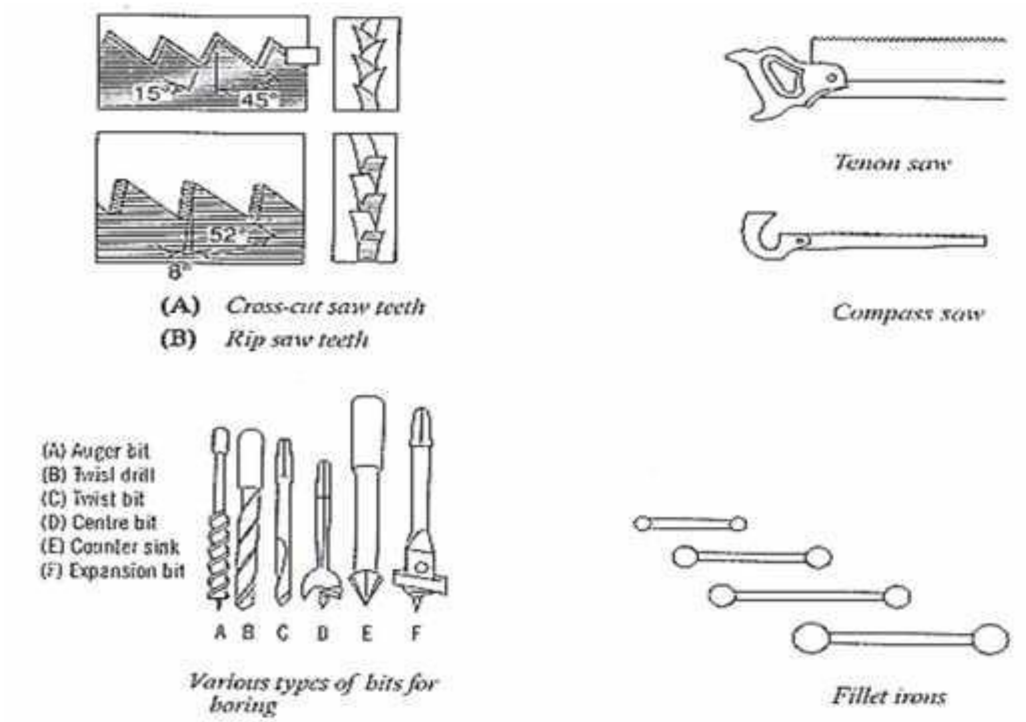


Fig 1.10 Hand Tools for Wood Patternmaking

MACHINES FOR METAL PATTERNMAKING

The production of metallic patterns is an entirely different activity from that of wooden patterns. After the patterns are cast in a foundry, they have to be machined and finished in the metal pattern shop. This shop should have adequate facilities for machining and hand finishing. The machine tools desirable to produce good quality patterns are

(1) Universal milling machine, table size of 1200 mm x 400 mm
(2) Vertical milling machine, copy milling machine or CNC milling machine
(3) Shaping machine, 600 mm stroke
(4) SS and SC lathe, 450 mm swing and 1500 mm bed
(5) Vertical boring machine, 1000-mm table diameter
(6) Column type drilling machine, 50-mm drilling capacity
(7) Radial drilling machine, 50-mm capacity
(8) Hydraulic hacksaw machine, 200 mm capacity
(9) Metal band saw
(10) Surface grinding machine, 450 mm x 200 mm table traverses
(11) Tool-and-cutter grinder and
(12) Coordinate marking and measuring machine for inspection of pattern equipment.

TOOLS AND INSTRUMENTS FOR METAL PATTERNMAKING

The metal-pattern shop should be equipped with various types of hand tools for measuring, marking, fitting, finishing, and fabrication. These include the following:

(1) Measuring Tools and Instruments

Standard rules, 300 mm and 600 mm; contraction rules, rigid and flexible; combination set; vernier bevel protractor; fixed and adjustable squares, straight edges of 300 mm and 600 mm; micrometers up to 150 mm; inside micrometer set, 25 mm to 300 mm, Vernier height gauge, 300 mm and 600 mm; micrometer depth gauge, 300 mm; sine bar, 150 mm and 300 mm; dial gauge with stand and accessories: set of slip gauges with holders and accessories (87-piece set); radius gauge: feeler gauge; screw pitch gauge; wire gauge; surface roughness tester or profilometer.

(2) Marking Tools

Marking table; surface plates; angle plates; vee blocks; rule clamp, calipers, dividers, trammels, marking gauge, scriber, punch, screw jacks (100 mm), engineer's level, sine table, rotary table, dividing head; steel stencils, and obverse and reverse punches for figures and letters

(3)Cutting and Finishing Tools

Chisels, flat and diamond point; punches; electric hand drill; pneumatic drill; electric hand grinder; neumatic grinder; drill hits; grinding wheels; files; reamers; rotary files; rotary burrs and rotary cutters for pneumatic operation; dies and taps; scrapers; hack-saw; countersinks and counterbores

(4)Fabrication Equipment

Oxyacetylene gas-welding set; air compressor; electric arc welding set (dc type); metallising kit: soldering and brazing tools

RAPID TOOL MANUFACTURING TECHNIQUES

1. Rapid Prototyping (RP)

Rapid prototyping (RP) or free form fabrication techniques were initially intended for creating prototypes of complex shaped products to verify their form, fit and to some extent, their function. Recently, these techniques have also been successfully used to create the tooling, and have been enthusiastically embraced by several foundries, tool rooms and service bureaus. This has enabled significant reductions in the lead time to manufacture cast products.

The RP technology is based on the philosophy of converting a 3-dimensional computer-aided design (CAD) model of the part into a series of 2D cross-sectional layers stacked on top of one another (Fig. 1.11). Each layer is created using one of the several techniques available, such as photocuring, cutting, fusing and deposition. The layers are created bottom-up and are joined to each other during the process itself. This approach enables complex shaped parts to be manufactured directly from a 3D CAD model without using part-specific tooling.

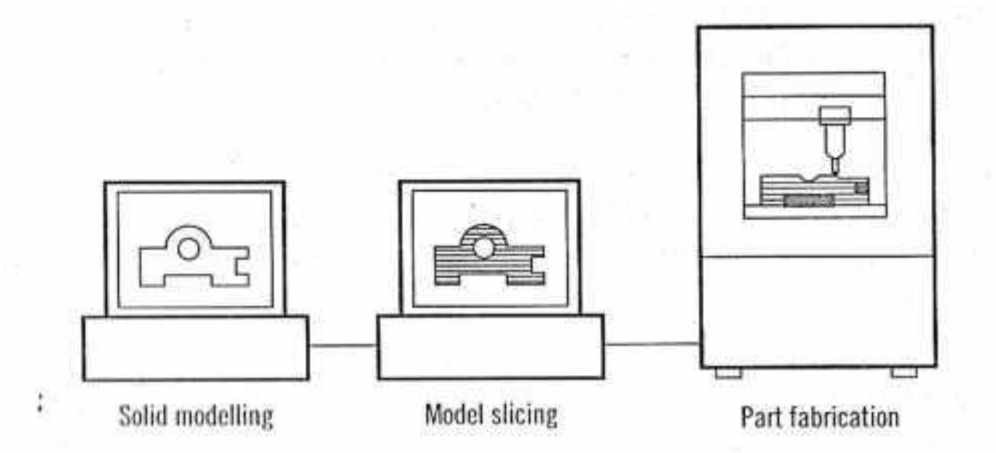


Fig 1.11 Main steps in rapid prototyping

2. Modelling and Slicing

The CAD model of the part can be created by any of the solid modelers available today, which includes Pro-Engineer, I-DEAS, Unigraphics, CATIA and AutoCAD Designer. These packages can differ from one another in terms of user interface, modeling facilities, hardware platform, operating system and other programmes available in the family.

After creating the solid model, it is converted to a faceted representation and stored in the STL format, which is supported by most RP systems. Some RP systems have a provision for converting the solid model created by one or more of the above packages to the STL format. Sometimes, errors can creep in during the conversion process, requiring interactive 'fixing' of these.

The next step involves 'slicing' the solid model into a number of 2D layers. This is automatically performed by the slicing software available with the RP system. For each layer, instructions for the movement of the machine elements are generated and transferred to the RP machine.

If there is an undercut in the part then the layer on top will have inadequate support during its creation, leading to sagging. This is prevented by creating support structures to fill up undercut regions during the layer formation. The support material is later removed by heating to melt it away, washing it in a solvent or simply breaking it off. The orientation of the model can influence the number and volume of support structures required.

3. Prototype Fabrication

A number of RP systems are available today, each incorporating a different technique for creating the part layers. This influences the size and complexity of the machine, range of part materials and quality characteristic.

Stereo lithography Apparatus (SLA) uses an ultraviolet solid state laser beam moving in a criss-cross fashion to cure photocurable polymer resin contained in a vat. The polymer layer is lowered by a platform attached to it to enable generating the next layer on top.The system is available in a wide range of sizes. The automatic resin-dispensing arrangement refills the vat between the builds. Vats are interchangeable for rapid and easy resin exchange. The resolution is about 0.05 mm.

Solid Ground Curing (SGC) is similar to stereo lithography, the difference is that the entire layer of polymer within the specified boundary is cured by a flood of ultraviolet light passing through a glass mask containing a negative image of the cross section.

Fused Deposition Modeling (FDM) technique relies on melting and depositing a thin filament of thermoplastic polymer to form each layer. A separate head deposits the support material in each layer, which can be broken off later. It is used for the final design and prototyping phase of product development. It generates 3D prototypes from 3D CAD software data.

Selective Laser Sintering (SLS) process uses a high-power laser beam to melt thermoplastic powder spread on a layer. A roller spreads the next layer of powder on the previous layer. The unsintered powder serves the function of supports for undercuts.

Laminated Object Manufacturing (LOM) involves laser beam cutting of cross-section contours out of sheets of heat sensitive or polymer coated paper. The adjacent layers are joined by heating and compression by a roller.

4. Rapid Tooling

The CAD model of the part can be converted into the corresponding model of the pattern, by splitting across the parting line, removing the holes, adding core prints, applying draft, fillets and various allowances. The master pattern can also be similarly generated. In addition, feeders and gates can be modelled and attached to the pattern model. The entire casting model can be analyzed on computer to ensure product quality before investing in tooling manufacture (Ravi, 1996).

The range of RP techniques and materials, coupled with different casting processes, provide several routes for producing metal castings. Some of these are useful for creating one-off parts or master patterns. Others are useful for creating patterns that can be used for short, medium or long runs.

Most RP systems can produce patterns out of investment casting wax or a similar polymer. This can be invested to create a single casting or a master metal pattern for large runs. The polymer parts created by most RP systems can be used as patterns for shell moulding. Some RP machines produce parts using ABS plastic, which are harder and may even be used in green sand casting for short runs. RP machines based on LOM technique can produce patterns which look and feel like wood. These can be used either as regular or as master patterns. The pattern life can be increased by coating with resins. Other routes to tooling include metal or ceramic spray techniques to create a shell around the polymer pattern, which can be used for shell moulding or creating master patterns.

5. Criteria for Selection RP

Systems are useful to foundries, tool rooms and service bureaus in rapid tool manufacturing. Since each company may have a unique set of immediate and medium-term requirements, these should be carefully determined and then matched against the capabilities of the various systems available. One or more parts may be selected for benchmarking the systems for a detailed comparison. Finally, an economic analysis can help in pinpointing the right choice.

TYPES OF PATTERN

The types of the pattern and the description of each are given as under.

1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern
7. Follow board pattern
8. Gated pattern
9. Sweep pattern
10. Skeleton pattern
11. Segmental or part pattern

1. Single-piece or solid pattern

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern. Typical single piece pattern is shown in Fig. 1.12.

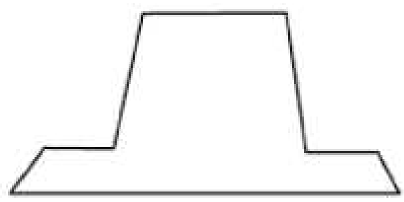


Fig. 1.12 Single piece pattern

2. Two-piece or split pattern

When solid pattern is difficult for withdrawal from the mould cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern. A typical example is shown in Fig. 1.13.

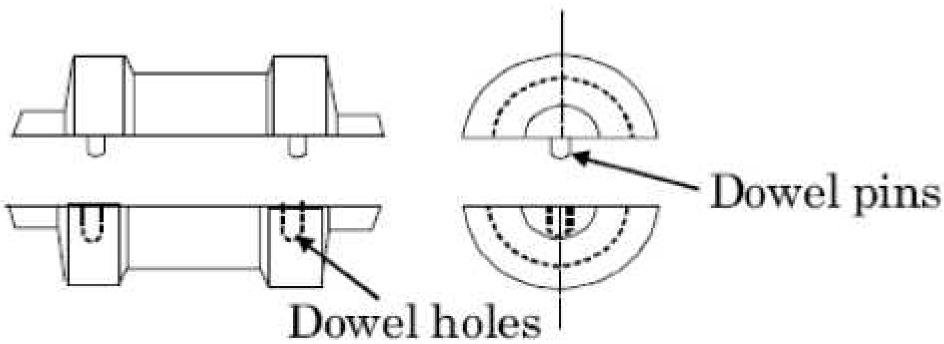


Fig. 1.13 Two piece pattern

3. Cope and drag pattern

In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates. A typical example of match plate pattern is shown in Fig. 1.14.

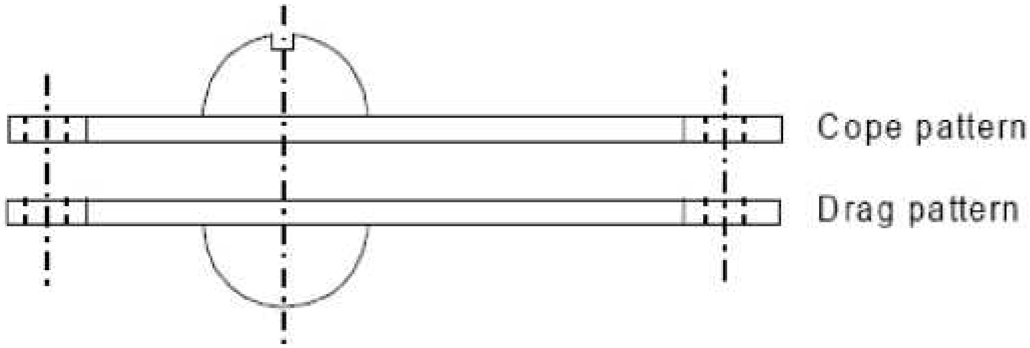


Fig. 1.14 Cope and drag pattern

4. Three-piece or multi-piece pattern

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

5. Loose-piece Pattern

Loose piece pattern (Fig. 1.15) is used when pattern is difficult for withdrawal from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.

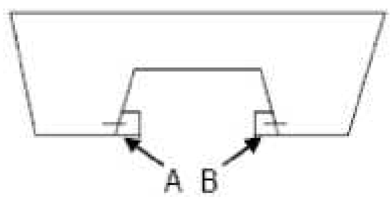


Fig. 1.15 Loose piece pattern

6. Match plate pattern

This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine moulding. A typical example of match plate pattern is shown in Fig. 1.16.

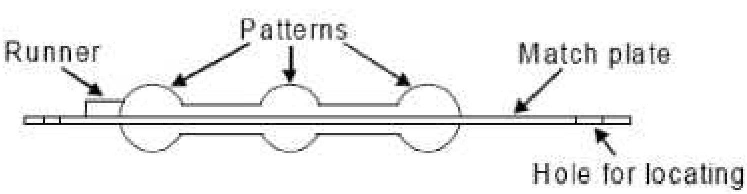


Fig. 1.16 Match plate pattern

7. Follow board pattern

When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a moulding board for the first moulding operation as shown in Fig. 1.17.

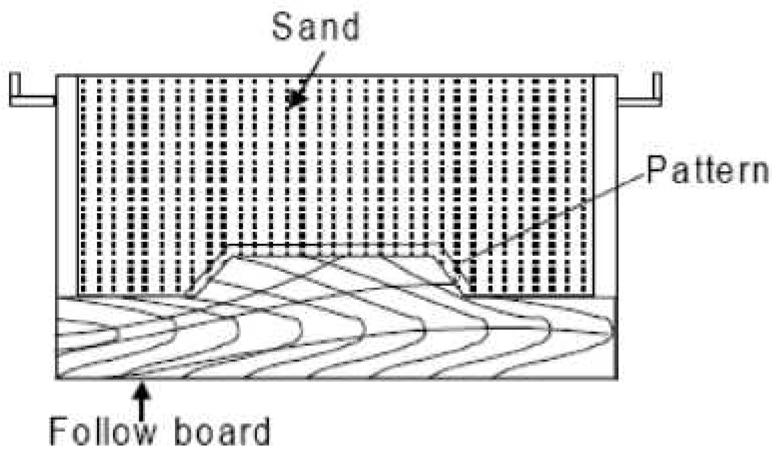


Fig. 1.17 Follow board pattern

8. Gated pattern

In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig. 1.18. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.

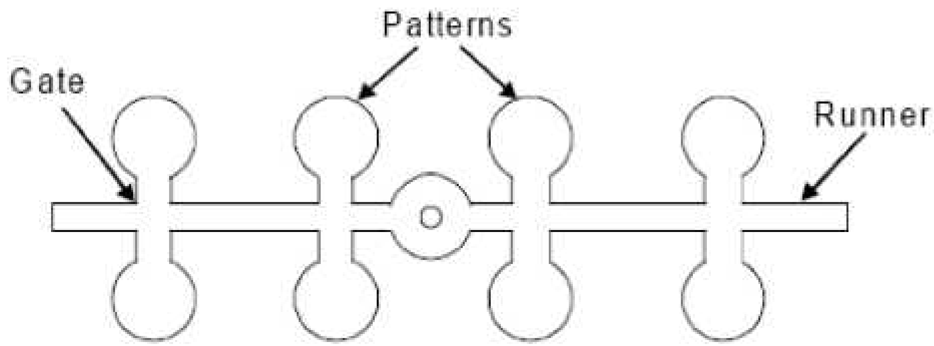


Fig. 1.18 Gated pattern

9. Sweep pattern

Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig. 1.19. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the center of the mould.

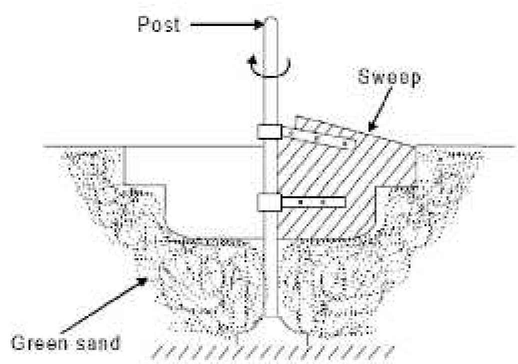


Fig. 1.19 Sweep pattern

10. Skeleton pattern

When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made.

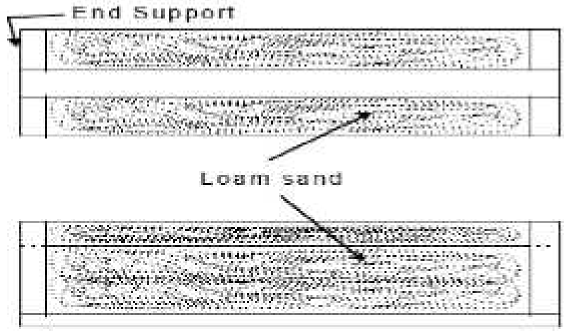


Fig. 1.20 Skeleton pattern

This frame work is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc. A typical skeleton pattern is shown in Fig. 1.20.

11. Segmental pattern

Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown in Fig. 1.21.

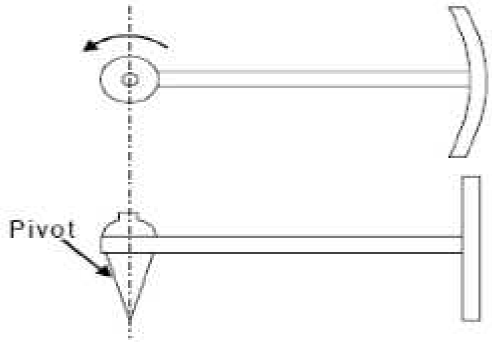


Fig. 1.21 Segmental or part pattern

PATTERN ALLOWANCES

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows:

1. Shrinkage or contraction allowance
2. Machining or finish allowance
3. Draft or taper allowance
4. Rapping or Shake allowance
5. Distortion or camber allowance
6. Mould wall Movement Allowance

1. Shrinkage or Contraction Allowance

All most all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:

i. **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mould.

ii. **Solid Shrinkage:** it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

The rate of contraction with temperature is dependent on the material. For example steel contracts to a higher degree compared to aluminum. To compensate the solid shrinkage, a shrink rule must be used in laying out the measurements for the pattern.

A shrink rule for cast iron is 1/8 inch longer per foot than a standard rule. If a gear blank of 4 inch in diameter was planned to produce out of cast iron, the shrink rule in measuring it 4 inch would actually measure 4 -1/24 inch, thus compensating for the shrinkage. The various rate of contraction of various materials are given in Table 1.

Table 1 : Rate of Contraction of Various Metals

Material	**Dimension**	**Shrinkage allowance** (inch/ft)
Grey Cast Iron	Up to 2 feet 2 feet to 4 feet over 4 feet	0.125 0.105 0.083
Cast Steel	Up to 2 feet 2 feet to 6 feet over 6 feet	0.251 0.191 0.155
Aluminum	Up to 4 feet 4 feet to 6 feet over 6 feet	0.155 0.143 0.125
Magnesium	Up to 4 feet Over 4 feet	0.173 0.155

2. Machining Allowance

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

3. Draft or Taper Allowance

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

These values are greatly affected by the size of the pattern and the moulding method. In machine moulding its, value varies from 10 mm to 50 mm/mt.

4. Rapping or Shake Allowance

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

5. Distortion Allowance

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

6. Mould wall Movement Allowance

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

LIFE EXPECTANCY OF PATTERNS

The life of patterns and core boxes can be expressed in terms of the number of moulds or cores that can be produced. The material of the pattern, type of construction, method of moulding and core-making, care with which patterns are handled, and type of storage affect the life expectancy. Table 2.11 gives the expected life of patterns for guidance purposes.

Table 2.11 Life expectancy of patterns

SL. No.	METHOD OF USING PATTERN	PATTERN MATERIAL	TYPE OF CONSTRUCTION	EXPECTED LIFE IN NUMBER OF MOULDS
1.	Loose	Soft wood	Skeleton	10
2.	Loose		Segmental, disc, box, etc.	50
3.	Loose	Hard wood	Ring, tongue and groove, header and stave, disc, box and composite	200
4.	Mounted			1000

5.	Mounted	Epoxy resin	Cast in plaster or plastic moulds	2000
6.	Mounted	Epoxy resin with filler	Gel coat, lamination with glass fibre	5000
7.	Mounted	Aluminium pressure cast	As cast artd cleaned	3000-5000
8.	Mounted	Aluminium, sand cast	Machined all over and polished	30,000
9.	Mounted	Brass, SG iron, grey iron, steel	Machined all over	50,000

PATTERN STORAGE AND REPAIR

In order to be able to use the patterns for a long time, it is essential to give due consideration to storage and repair requirements. It is advisable that the patterns, after use in the foundry, are carefully inspected for any breakage or loss, adequately repaired, and sent for safe storage. Similarly, when a pattern is requisitioned by the foundry, it should be obtained from storage, inspected, repairs, if any, carried out, and then issued to the foundry.

It is also desirable to maintain a complete history of each pattern by recording, date-wise on a card, the issue and return of patterns to and from the foundry, number of moulds produced, inspection carried out, and nature of repairs done.

The principal factors governing space requirements for pattern storage are

- Quantity and volume of patterns
- Rate of acquisition of new patterns to be added to storage
- Types Of Patterns
- General rate of obsolescence due to changes in casting design, or design of product.

Pattern-storage areas should be so designed that they are weather-proof and fireproof, with adequate arrangements for extinguishing fires. For expensive patterns, it is also desirable to have temperature and humidity controls. Separate areas or floors should be earmarked for light, medium and heavy patterns. Small patterns are kept in racks, and large ones are placed on the floor with proper identification marks.

Repair of patterns is often required for various reasons. It is relatively easier to manufacture new patterns than repair old ones. It needs skill, hard work and experience to correctly repair the pattern equipment. Pattern repair may be required due to normal wear and tear during use, breakage during transportation and handling, careless moulding work, falling of slag or molten metal, seasonal effects, improper placement when not in use, use of sub-standard material, wrong designs and weak construction.

In case of foundries with a large turnover of patterns, it is preferable to have a repair section attached to the storage area and separate from the main pattern shop. A properly organized pattern-repair facility can help improve the technological discipline amongst patternmakers, keep a constant check on undesirable and careless practices during manufacture, and even guide in improving moulding and core-making practices.

MOULDING SANDS

Sand is the principal moulding material in the foundry shop where it is used for all types of castings, irrespective of whether the cast metal is ferrous or non-ferrous, iron or steel. This is because it possesses the properties vital for foundry purposes. The most important characteristic of sand is its refractory nature due to which it can easily withstand the high temperature of molten metal and does not get fused. Moulding sand has chemical resistivity.

It does not chemically react or combine with molten metal and can therefore be used time and again. Sand has a high degree of permeability; it allows gases and air to escape from the mould when molten metal is poured without interfering with the rigidity and strength of the mould. The degree of strength, hardness, and permeability can also be adjusted, as desired, by varying the composition or the ingredients of the sand. Such flexibility is extremely difficult to achieve with any other moulding material.

But the properties vary from one sand to another, and it should be noted that only those sands, characterized by the foregoing features, are considered suitable for moulding work.

PRINCIPAL INGREDIENTS OF MOULDING SANDS

The principal ingredients of moulding sands are

- silica sand grains
- clay (bond)
- moisture

(1) Silica Sand Grains

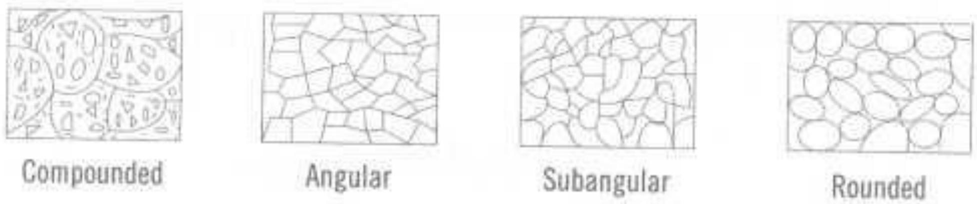
Silica sand grains are of paramount importance in moulding sand because they impart refractoriness, chemical resistivity, and permeability to the sand. They are specified according to their average size and shape. The finer the grains, the more intimate will be the contact and lower the permeability. However, fine grains tend to fortify the mould and lessen its tendency to get distorted. The shapes of the grains may vary from round to angular (Fig. 3.1). The grains are classified according to their shape.

(i) Rounded Grains These grains have the least contact with one another in a rammed structure, thereby making the sand highly permeable to gases. Sand having rounded grains, however, lacks strength and does not pack up to the optimum extent. The binder requirements are minimum.

(ii) Subangular Grains These grains have comparatively lower permeability and greater strength than the rounded ones.

(iii) Angular Grains These grains have defined edges, and the surfaces are nearly flat. They produce higher strength and lower permeability in the mould than sub- angular grains. The binder consumption is likely to be high.

(iv) Compounded Grains In some cases, the grains are cemented together such that they fail to separate when screened. They may consist of rounded, subangular, or angular grains or a combination of the three. Such grains are called compounded grains and are least desirable due to their tendency to break down at high temperature.



In practice, sand grains contain mixed grain shapes, depending on origin. A subangular-to-rounded grain mixture would be the best combination.

(2) Clay

Clay imparts the necessary bonding strength to the moulding sand so that after ramming, the mould does not lose its shape. However, as the quantity of the clay is increased, the permeability of the mould is reduced.

Clay is defined by the American Foundrymen's Society (AFS), 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 of mineral deposit and has no bonding power.

True clay supplies the necessary bond. Under high magnification, true clay is found to be made up of extremely minute aggregates of crystalline particles, called clay minerals. These clay minerals are further composed of flake-shaped particles, about 2 microns in diameter, which are seen to lie flat on one another.

(3)Moisture

Clay acquires its bonding action only in the presence of the requisite amount of moisture. When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of each Hake. The molecules of water forming this film are not in the original fluid state but in a fixed and definite position.

As more water is added, the thickness of the film increases up to a certain limit after which the excess water remains in the fluid state. The thickness of this water film varies with the clay mineral. The bonding quality of clay depends on the maximum thickness of water film it can maintain.

When sand is rammed in a mould, the sand grains are forced together. The clay coating on each grain acts in such a way that it not only locks the grains in position but also makes them retain that position. If the water added is the exact quantity required to form the film, the bonding action is best. If the water is in excess, strength is reduced and the mould gets weakened. Thus, moisture content is one of the most important parameters affecting mould and core characteristics and consequently, the quality of the sand produced.

CONSTITUENTS OF MOULDING SAND

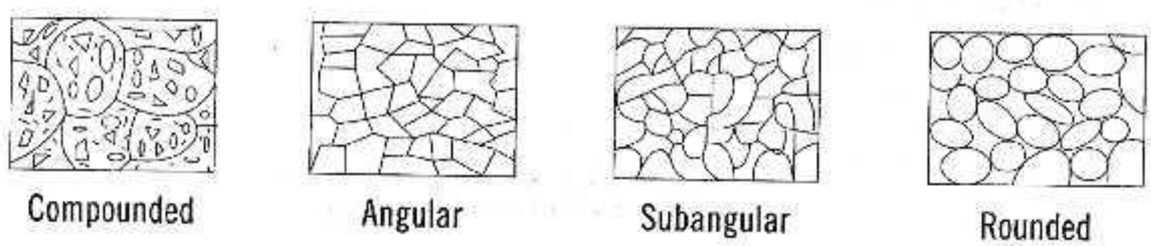
The main constituents of moulding sand involve silica sand, binder, moisture content and additives.

Silica sand

Silica sand in form of granular quarts is the main constituent of moulding sand having enough refractoriness which can impart strength, stability and permeability to moulding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities.

The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present. The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable.

The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, subangular and rounded).



Types of Sand Grains

Binder

In general, the binders can be either inorganic or organic substance. The inorganic group includes clay sodium silicate and port land cement etc. In foundry shop, the clay acts as binder which may be Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller's earth and Bentonite. Binders included in the organic group are dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc.

Organic binders are mostly used for core making. Among all the above binders, the bentonite variety of clay is the most common. However, this clay alone cannot develop bonds among sand grins without the presence of moisture in moulding sand and core sand.

Moisture

The amount of moisture content in the moulding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them. This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand.

The effect of clay and water decreases permeability with increasing clay and moisture content. The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing. For increasing the moulding sand characteristics some other additional materials besides basic constituents are added which are known as additives.

Additives

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

Coal dust

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

Corn flour

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

Dextrin

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

Sea coal

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in moulding sand and core sand. When heated, it changes to coke which fills the pores and is unaffected by water.

Because to this, the sand grains become restricted and cannot move into a dense packing pattern. Thus, sea coal reduces the mould wall movement and the permeability in mould and core sand and hence makes the mould and core surface clean and smooth.

Pitch

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

Wood flour

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

Silica flour

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

KINDS OF MOULDING SAND

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

Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure.

Moulds prepared by this sand are not requiring backing and hence are known as green sand moulds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

Dry sand

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

Loam sand

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

Facing sand

Facing sand is just prepared and forms the face of the mould. It is directly next to the surface of the pattern and it comes into contact molten metal when the mould is poured. Initial coating around the pattern and hence for mould surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness.

It is made of silica sand and clay, without the use of used sand. Different forms of carbon are used to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times as much fine moulding sand to make facings. The layer of facing sand in a mould usually ranges from 22-28 mm. From 10 to 15% of the whole amount of moulding sand is the facing sand.

Backing sand

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

System sand

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

Parting sand

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

Core sand

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

PROPERTIES OF MOULDING SAND

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

Refractoriness

Refractoriness is defined as the ability of moulding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of moulding sands. Refractoriness can only be increased to a limited extent. Moulding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained.

The degree of refractoriness depends on the SiO_2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO_2 content and the rougher the grain volumetric composition the higher is the refractoriness of the moulding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its melting point.

Permeability

It is also termed as porosity of the moulding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective.

Permeability is a function of grain size, grain shape, and moisture and clay contents in the moulding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mould can be further increased by venting using vent rods

Cohesiveness

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

Green strength

The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. they must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the moulding box.

Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

SAND TESTING

Moulding sand and core sand depend upon shape, size composition and distribution of sand grains, amount of clay, moisture and additives. The increase in demand for good surface finish and higher accuracy in castings necessitates certainty in the quality of mould and core sands. Sand testing often allows the use of less expensive local sands. It also ensures reliable sand mixing and enables a utilization of the inherent properties of moulding sand.

Sand testing on delivery will immediately detect any variation from the standard quality, and adjustment of the sand mixture to specific requirements so that the casting defects can be minimized. It allows the choice of sand mixtures to give a desired surface finish. Thus sand testing is one of the dominating factors in foundry and pays for itself by obtaining lower per unit cost and increased production resulting from sound castings.

Generally the following tests are performed to judge the moulding and casting characteristics of foundry sands:

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

Some of the important sand tests are discussed as under.

Moisture Content Test

The moisture content of the moulding sand mixture may be determined by drying a weighed amount of 20 to 50 grams of moulding sand to a constant temperature up to 100°C in an oven for about one hour. It is then cooled to a room temperature and then reweighing the moulding sand. The moisture content in moulding sand is thus evaporated. The loss in weight of moulding sand due to loss of moisture, gives the amount of moisture which can be expressed as a percentage of the original sand sample.

The percentage of moisture content in the moulding sand can also be determined in fact more speedily by an instrument known as a speedy moisture teller. This instrument is based on the principle that when water and calcium carbide react, they form acetylene gas which can be measured and this will be directly proportional to the moisture content. This instrument is provided with a pressure gauge calibrated to read directly the percentage of moisture present in the moulding sand. Some moisture testing instruments are based on principle that the electrical conductivity of sand varies with moisture content in it.

Clay Content Test

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

Grain Fineness Test

For carry out grain fineness test a sample of dry silica sand weighing 50 gms free from clay is placed on a top most sieve bearing U.S. series equivalent number 6. A set of eleven sieves having U.S. Bureau of standard meshes 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 are mounted on a mechanical shaker (Fig. 1.22).

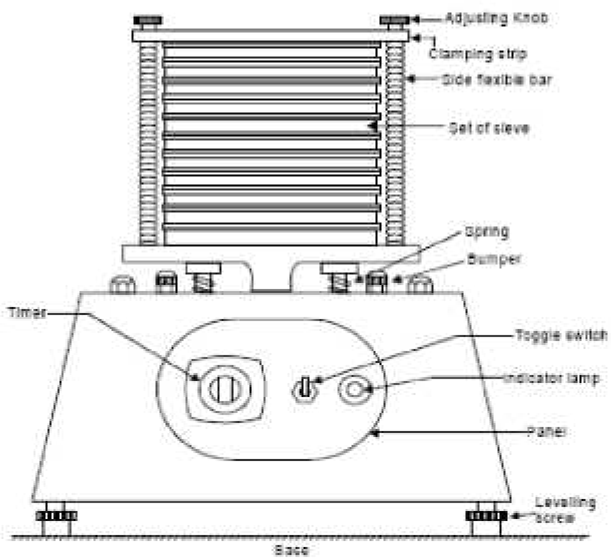


Fig. 1.22 Grain fitness testing mechanical shaker

The series are placed in order of fineness from top to bottom. The free silica sand sample is shaked in a mechanical shaker for about 15 minutes. After this weight of sand retained in each sieve is obtained sand and the retained sand in each sieve is multiplied by 2 which gives % of weight retained by each sieve. The same is further multiplied by a multiplying factor and total product is obtained. It is then divided by total % sand retained by different sieves which will give G.F.N.

Refractoriness Test

The refractoriness of the moulding sand is judged by heating the American Foundry Society (A.F.S) standard sand specimen to very high temperatures ranges depending upon the type of sand. The heated sand test pieces are cooled to room temperature and examined under a microscope for surface characteristics or by scratching it with a steel needle. If the silica sand grains remain sharply defined and easily give way to the needle. Sintering has not yet set in.

In the actual experiment the sand specimen in a porcelain boat is placed into an electric furnace. It is usual practice to start the test from 1000°C and raise the temperature in steps of 100°C to 1300°C and in steps of 50° above 1300°C till sintering of the silica sand grains takes place. At each temperature level, it is kept for at least three minutes and then taken out from the oven for examination under a microscope for evaluating surface characteristics or by scratching it with a steel needle.

Strength Test

Green strength and dry strength is the holding power of the various bonding materials. Generally green compression strength test is performed on the specimen of green sand (wet condition). The sample specimen may of green sand or dry sand which is placed in lugs and compressive force is applied slowly by hand wheel until the specimen breaks. The reading of the needle of high pressure and low pressure manometer indicates the compressive strength of the specimen in kgf/cm2. The most commonly test performed is compression test which is carried out in a compression sand testing machine (Fig. 1.23).

Tensile, shear and transverse tests are also sometimes performed. Such tests are performed in strength tester using hydraulic press. The monometers are graduated in different scales. Generally sand mixtures are tested for their compressive strength, shear strength, tensile strength and bending strength. For carrying out these tests on green sand sufficient rammed samples are prepared to use. Although the shape of the test specimen differs a lot according to the nature of the test for all types of the strength tests can be prepared with the of a typical rammer and its accessories.

To prepare cylindrical specimen bearing 50.8 mm diameter with for testing green sand, a defined amount of sand is weighed which will be compressed to height of 50.8 mm. by three repeated rammings. The predetermined amount of weighed moulding sand is poured into the ram tube mounted on the bottom. Weight is lifted by means of the hand 1ever and the tube filled with sand is placed on the apparatus and the ramming unit is allowed to come down slowly to its original position. Three blows are given on the sample by allowing the rammer weight to fall by turning the lever. After the three blows the mark on the ram rod should lie between the markings on the stand. The rammed specimen is removed from the tube by means a pusher rod. The process of preparing sand specimen for testing dry sand is similar to the process as prepared before, with the difference that a split ram tube is used. The specimen for testing bending strength is of a square cross section.

The various tests can be performed on strength tester. The apparatus can be compared with horizontal hydraulic press. Oil pressure is created by the hand-wheel and the pressure developed can be measured by two pressure manometers. The hydraulic pressure pushes the plunger. The adjusting cock serves to connect the two manometers. Deformation can be measured on the dial.

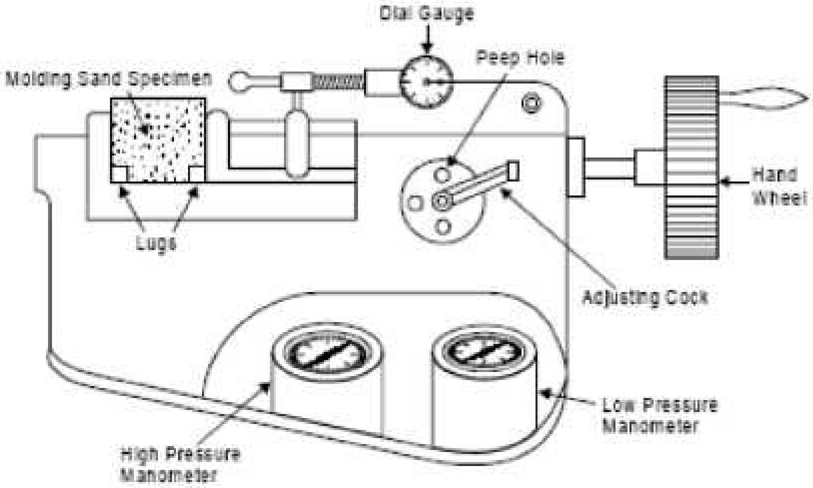


Fig. 1.23 Strength testing machine

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

Permeability Test

Initially a predetermined amount of moulding sand is being kept in a standard cylindrical tube, and the moulding sand is compressed using slightly tapered standard ram till the cylindrical standard sand specimen having 50.8mm diameter with 50.8 mm height is made and it is then extracted. This specimen is used for testing the permeability or porosity of moulding and the core sand. This test is applied for testing porosity of the standard sand specimen. The test is performed in a permeability meter consisting of the balanced tank, water tank, nozzle, adjusting lever, nose piece for fixing sand specimen and a manometer.

A typical permeability meter is shown in Fig. 12.3 which permits to read the permeability directly. The permeability test apparatus comprises of a cylinder and another concentric cylinder inside the outer cylinder and the space between the two concentric cylinders is filled with water. A bell having a diameter larger than that of the inner cylinder but smaller than that of outer cylinder, rests on the surface of water. Standard sand specimen of 5.08 mm diameter and 50.8 mm height together with ram tube is placed on the tapered nose piece of the permeability meter. The bell is allowed to sink under its own weight by the help of multi-position cock. In this way the air of the bell streams through the nozzle of nosepiece and the permeability is directly measured.

Permeability is volume of air (in cm3) passing through a sand specimen of 1 cm2 cross-sectional area and 1 cm height, at a pressure difference of 1 gm/cm2 in one minute. In general, permeability is expressed as a number and can be calculated from the relation

$P = vh/pat$

Where, P = permeability

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

h = height of specimen in cm

p = pressure of air in gm/cm2

a = cross-sectional area of the specimen in cm2

t = time in minutes.

For A.F S. standard permeability meter, 2000 cc of air is passed through a sand specimen (5.08 cm in height and 20.268 sq. cm. in cross-sectional area) at a pressure of 10 gms/cm2 and the total time measured is 10 seconds = 1/6 min. Then the permeability is calculated using the relationship as given as under.

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

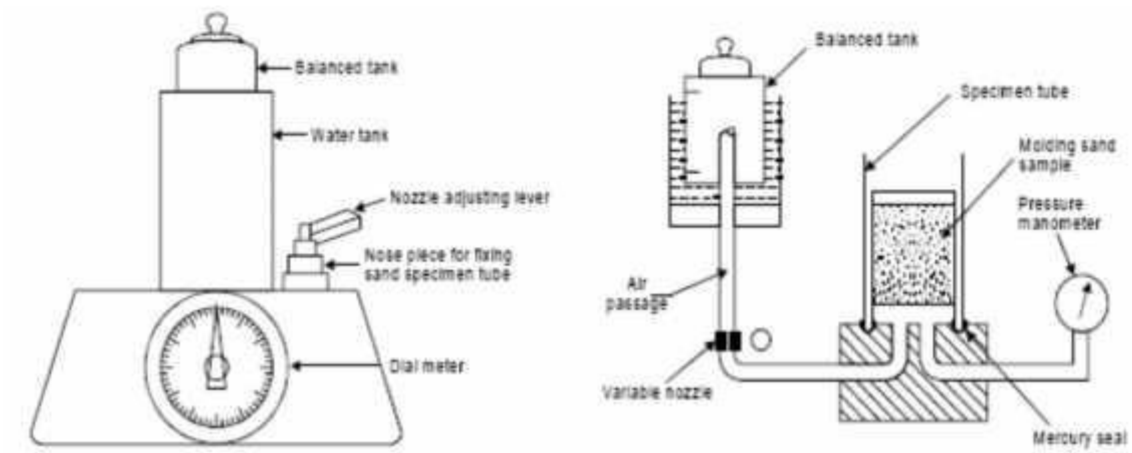


Fig. 1.24 Permeability meter

Flowability Test

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

Shatter Index Test

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

Mould Hardness Test

This test is performed by a mould hardness tester shown in Fig. 1.25. The working of the tester is based on the principle of Brinell hardness testing machine. In an A.F.S. standard hardness tester a half inch diameter steel hemi-spherical ball is loaded with a spring load of 980 gm. This ball is made to penetrate into the mould sand or core sand surface. The penetration of the ball point into the mould surface is indicated on a dial in thousands of an inch.

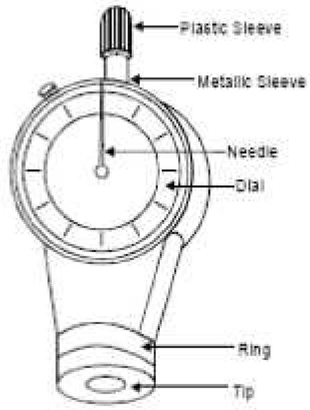


Fig. 1.25 Mould hardness tester

The dial is calibrated to read the hardness directly i.e. a mould surface which offers no resistance to the steel ball would have zero hardness value and a mould which is more rigid and is capable of completely preventing the steel ball from penetrating would have a hardness value of 100. The dial gauge of the hardness tester may provide direct readings.

SAND CONDITIONING

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

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

The sand constituents are then brought at required proper proportion and mixed thoroughly. Next, the whole mixture is mulled suitably till properties are developed. After all the foreign particles are removed from and the sand is free from the hard lumps etc., proper amount of pure sand, clay and required additives are added to for the loss because of the burned, clay and other corn materials. As the moisture content of the returned sand known, it is to be tested and after knowing the moisture the required amount of water is added. Now these things are mixed thoroughly in a mixing muller (Fig. 1.26).

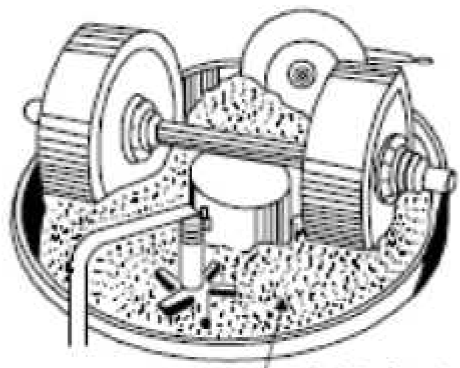


Fig. 1.26 Sand mixing muller

The main objectives of a mixing muller is to distribute the binders, additives and moisture or water content uniformly all around each sand grain and helps to develop the optimum physical properties by kneading on the sand grains. Inadequate mulling makes the sand mixture weak which can only be compensated by adding more binder. Thus the adequate mulling economizes the use of binders. There are two methods of adding clay and water to sand.

In the first method, first water is added to sand follow by clay, while in the other method, clay addition is followed water. It has been suggested that the best order of adding ingredients to clay bonded sand is sand with water followed by the binders. In this way, the clay is more quickly and uniformly spread on to all the sand grains. An additional advantage of this mixing order is that less dust is produced during the mulling operation. The muller usually consists of a cylindrical pan in which two heavy rollers; carrying two ploughs, and roll in a circular path.

While the rollers roll, the ploughs scrap the sand from the sides and the bottom of the pan and place it in front of For producing a smearing action in the sand, the rollers are set slightly off the true radius and they move out of the rollers can be moved up and down without difficulty mounted on rocker arms. After the mulling is completed sand can be discharged through a door. The mechanical aerators are generally used for aerating or separating the sand grains by increasing the flowability through whirling the sand at a high speed by an impeller towards the inner walls of the casting.

Aerating can also be done by riddling the sand mixture oil on a one fourth inch mesh screen or by spraying the sand over the sand heap by flipping the shovels. The aeration separates the sand grains and leaves each grain free to flow in the direction of ramming with less friction. The final step in sand conditioning is the cooling of sand mixture because of the fact that if the moulding sand mixture is hot, it will cause moulding difficulties.

STEPS INVOLVED IN MAKING A SAND MOULD

1. Initially a suitable size of moulding box for creating suitable wall thickness is selected for a two piece pattern. Sufficient care should also be taken in such that sense that the moulding box must adjust mould cavity, riser and the gating system (sprue, runner and gates etc.).
2. Next, place the drag portion of the pattern with the parting surface down on the bottom (ram-up) board as shown in Fig. 1.27 (a).
3. The facing sand is then sprinkled carefully all around the pattern so that the pattern does not stick with moulding sand during withdrawn of the pattern.
4. The drag is then filled with loose prepared moulding sand and ramming of the moulding sand is done uniformly in the moulding box around the pattern. Fill the moulding sand once again and then perform ramming. Repeat the process three four times,
5. The excess amount of sand is then removed using strike off bar to bring moulding sand at the same level of the moulding flask height to completes the drag.
6. The drag is then rolled over and the parting sand is sprinkled over on the top of the drag [Fig. 1.27 (b)].
7. Now the cope pattern is placed on the drag pattern and alignment is done using dowel pins.
8. Then cope (flask) is placed over the rammed drag and the parting sand is sprinkled all around the cope pattern.
9. Sprue and riser pins are placed in vertically position at suitable locations using support of moulding sand. It will help to form suitable sized cavities for pouring molten metal etc. [Fig. 1.27 (c)].
10. The gaggers in the cope are set at suitable locations if necessary. They should not be located too close to the pattern or mould cavity otherwise they may chill the casting and fill the cope with moulding sand and ram uniformly.
11. Strike off the excess sand from the top of the cope.
12. Remove sprue and riser pins and create vent holes in the cope with a vent wire. The basic purpose of vent creating vent holes in cope is to permit the escape of gases generated during pouring and solidification of the casting.
13. Sprinkle parting sand over the top of the cope surface and roll over the cope on the bottom board.
14. Rap and remove both the cope and drag patterns and repair the mould suitably if needed and dressing is applied
15. The gate is then cut connecting the lower base of sprue basin with runner and then the mould cavity.
16. Apply mould coating with a swab and bake the mould in case of a dry sand mould.
17. Set the cores in the mould, if needed and close the mould by inverting cope over drag.
18. The cope is then clamped with drag and the mould is ready for pouring, [Fig. 1.27 (d)].

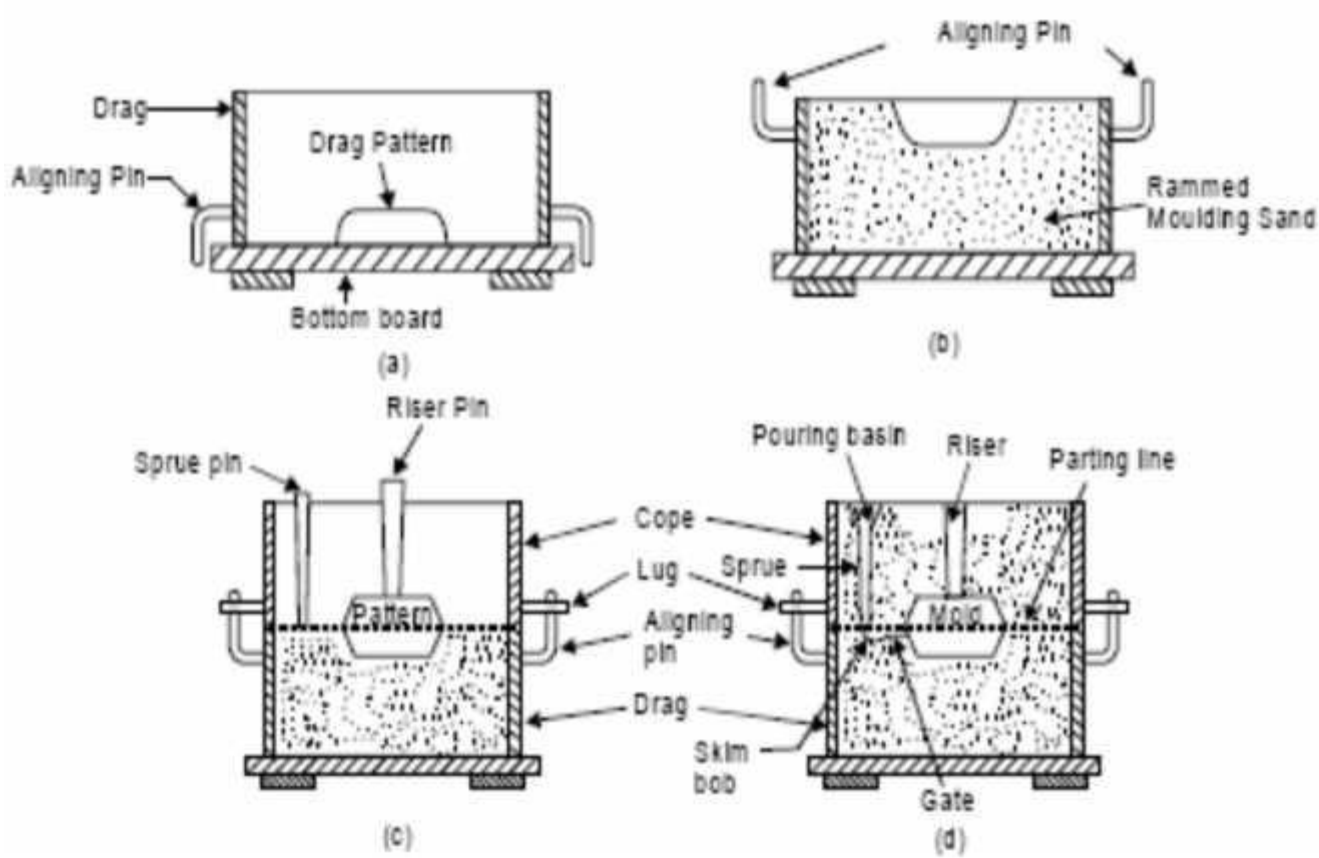


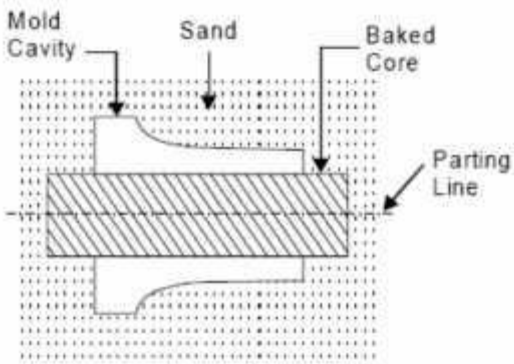
Fig. 1.27 Mould making

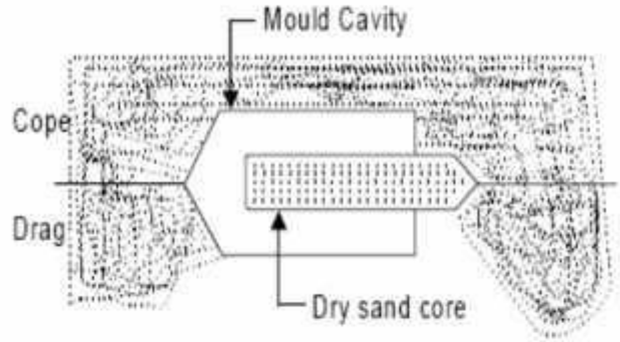
CORE

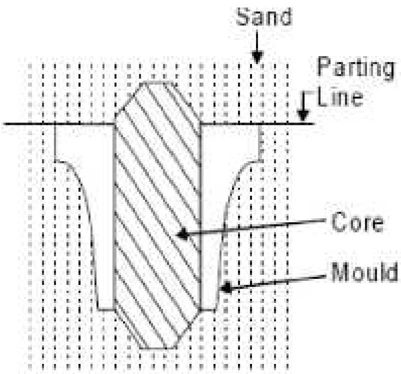
Cores are compact mass of core sand that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting.

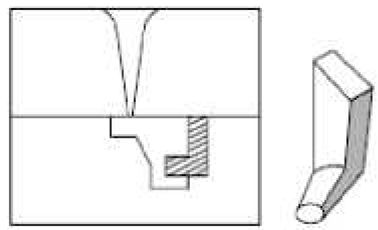
The environment in which the core is placed is much different from that of the mould. In fact the core has to withstand the severe action of hot metal which completely surrounds it.

Cores are classified according to shape and position in the mould. There are various types of cores such as horizontal core (Fig. 1.28), vertical core (Fig. 1.29), balanced core (Fig. 1.30), drop core (Fig. 1.31) and hanging core (Fig. 1.32).









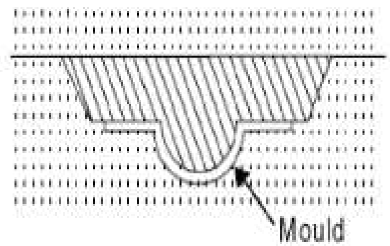


Fig. 1.28 Horizontal core

Fig. 1.30Balanced core

Fig. 1.29 Vertical core

Fig. 1.31 Drop core

Fig. 1.32 Hanging core

There are various functions of cores which are given below:

1. Core is used to produce hollowness in castings in form of internal cavities.
2. It may form a part of green sand mould
3. It may be deployed to improve mould surface.
4. It may provide external undercut features in casting.
5. It may be used to strengthen the mould.
6. It may be used to form gating system of large size mould
7. It may be inserted to achieve deep recesses in the casting

CORE SAND

It is special kind of moulding sand. Keeping the above mentioned objectives in view, the special considerations should be given while selecting core sand. Those considerations involves

- The cores are subjected to a very high temperature and hence the core sand should be highly refractory in nature
- The core sand should not possess such materials which may produce gases while they come in contact with molten metal

- The permeability of the core sand must be sufficiently high as compared to that of the moulding sands so as to allow the core gases to escape through the limited area of the core recesses generated by core prints
- The core sand should be collapsible in nature, i.e. it should disintegrate after the metal solidifies, because this property will ease the cleaning of the casting.

The main constituents of the core sand are pure silica sand and a binder. Silica sand is preferred because of its high refractoriness. For higher values of permeability sands with coarse grain size distribution are used. The main purpose of the core binder is to hold the grains together, impart strength and sufficient degree collapsibility. Beside these properties needed in the core sand, the binder should be such that it produces minimum amount of gases when the molt metal is poured in the mould.

Although, in general the binder are inorganic as well as organic ones, but for core making, organic binders are generally preferred because they are combustible and can be destroyed by heat at higher temperatures thereby giving sufficient collapsibility to the core sand. The common binders which are used in making core sand as follows:

1. Cereal binder

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

2. Protein binder

It is generally used to increase collapsibility property of core.

3. Thermo setting resin

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

4. Sulphite binder

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

5. Dextrin

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

6. Pitch

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

7. Molasses

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

CORE MAKING

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

Core Sand Preparation

Preparation of satisfactory and homogenous mixture of core sand is not possible by manual means. Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type mechanisms.

In the case of roller mills, the rolling action of the mulling machine along with the turning over action caused by the ploughs gives a uniform and homogeneous mixing. Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders. These machines perform the mixing of core sand constituents most thoroughly.

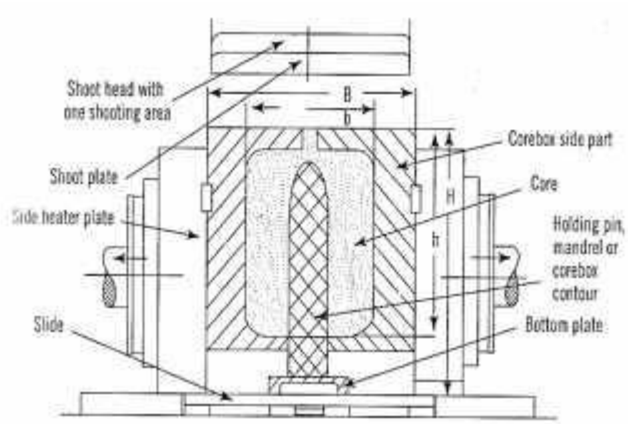
CORE-MAKING MACHINES

A number of types of machines have been developed for the rapid production of cores as well. Suitability of a particular type depends on factors such as the number of cores required, the size of the cores, and the intricacy and design of the cores. The commonly used core-making machines are now discussed.

1. Core-blowing Machine:

The core-blowing machine is indispensable for core making in a production foundry. The core sand is forced into the core box from a sand reservoir with a stream of high velocity air at a pressure of about 6-8 kg/cm2. The core box has a number of vent holes suitably located so that as the sand is introduced, the air is ejected through these holes. Due to the high velocity air, the sand is passed instantly in the core box.

A core shooter is another version of a core blower in which the core sand is ejected from the shooter head and is made to impinge into the core box cavity under impact (Fig. 1.33).



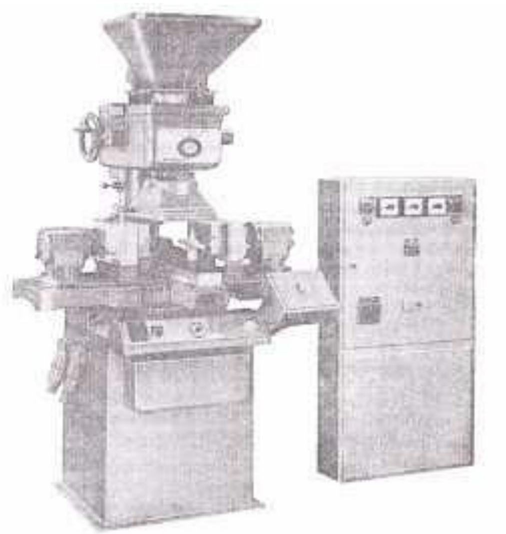


Fig. 1.33 Core shooting and curing machine

2. Core-drawing Machine:

The core-drawing machine facilitates in drawing off the cores from the boxes especially for core boxes having deep draw. The core box, with core sand duly rammed in, is placed on a core plate, which is supported on the machine bed.

From one side, the core box is placed in contact with another vertical plate and this vertical plate is vibrated so as to produce a rapping action on the core box. After rapping the core box is raised leaving the core on the core plate. The ramming of the sand in this case is done by hand either with a hand rammer or a pneumatic rammer.

3. Continuous Core-Making Machine:

A continuous core-making machine is used for preparing cylindrical cores of uniform section in various sizes which are called stock cores. Cylindrical cores, which are most commonly used, are prepared in long length on these machines and are kept in stock.

When a core of a certain diameter and length is required, it is taken out of the stock, cut to the desired length, and used after tapering down the ends. For preparing the stock cores, the core sand is filled in the hopper of the core-making machine from where it comes into a cylinder. It is then forced from the cylinder through a die of the size desired by means of a horizontally rotating screw.

4. Roll-over Core-Box Draw Machine:

This machine is similar to the roll-over pattern-draw hand moulding machine, except that it is smaller and is used for withdrawing the core box from the core.

5. Jolt Roll-over or Jolt Pin-lift Core-Box Draw Machine:

These machines again are similar to the corresponding moulding machines described earlier. In general, these machines are smaller in size and often the various operations such as jolting, roll over, and drawing, are performed manually.

6. Sand Slinger:

For medium- and large-sized cores, sometimes a sand slinger, similar to the one used for moulding work, is required. This is usually of the stationary type and smaller than the one used for making moulds.

CORE BAKING

Once the cores are prepared, they will be baked in a baking ovens or furnaces. The main purpose of baking is to drive away the moisture and harden the binder, thereby giving strength to the core. The core drying equipment's are usually of two kinds namely core ovens and dielectric bakers.

The core ovens are may be further of two type's namely continuous type oven and batch type oven. The core ovens and dielectric bakers are discussed as under.

(1) Continuous type ovens

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

(2) Batch type ovens

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

(3) Dielectric bakers

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

CORE FINISHING

The cores are finally finished after baking and before they are finally set in the mould. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing. The dimensional inspection of the cores is very necessary to achieve sound casting.

Cores are also coated with refractory or protective materials using brushing dipping and spraying means to improve their refractoriness and surface finish. The coating on core prevents the molten metal from entering in to the core. Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand. For handling bulky cores, lifting rings are also provided.

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 some moulding machine. Hand moulding is generally found to be economical when the castings are required in a small number.

On the other hand, when the castings are required in large quantities, hand moulding is more time-consuming and laborious and becomes expensive. Considerable skill is also needed to make good moulds by hand. In such cases, machine moulding is generally employed.

The main advantages of machine moulding are as follows:

(i) It affords great saving in time, especially when a large number of similar castings in small sizes are required.

(ii) When the number of castings is substantial, the additional cost of metallic patterns and other equipment is compensated by the high rate of production, and the overall cost per piece works out lower than in the case of hand moulding.

(iii) The castings obtained are more uniform in size and shape and more accurate than those obtained by hand moulding due to steadier lift of the pattern.

(iv) A semi-skilled worker can do the machine job whereas hand moulding requires skilled craftsmanship.

Moulding Machines

Moulding machines may be broadly classified as

(1) hand-operated moulding machines (2) power-operated moulding machines

1. Hand-operated Moulding Machines

In the case of a hand-operated moulding machine, generally referred as a hand moulding machine, one or more of the operations, such as ramming, pattern drawing, and mould rolling-over, are performed by the machine which is manually operated either by a hand lever or a pedal control. These machines do not make use of any external power.

Depending on the type of operation performed, the hand moulding machines may be of the pattern-draw type or the pattern-draw and squeeze type. The pattern-draw machines make use of a plain stripper type, a pin-lift type or a roll-over type of mechanism for withdrawing the pattern from the mould after the sand has been rammed. Figure 3.34 shows a pattern-draw and squeeze-type hand moulding machine.

2. Power-operated Moulding Machines

The power-operated moulding machines make use of hydraulic or pneumatic action to perform various operations during the moulding process, such as raising or lowering the table for pattern withdrawal, ramming the sand by squeeze, jolt, or combined squeeze and jolt actions, and rolling over the moulding boxes. Owing to the use of external power, manual labour and fatigue are markedly reduced and the production rate of moulds is increased.

Like the hand-moulding machines, the power-operated machines are also named after their principal functions. For example, a pneumatic jolt roll-over moulding machine is I hat in which the sand is packed or rammed by a jolting action with the help of compressed air, the mould is inverted by rolling it over, and the pattern is drawn out mechanically.

Moulding machines that work on a pre-set automatic cycle are also available. Various operations needed to prepare the mould are performed automatically one after the other in proper sequence, and the moulds ready for assembly are passed on from the machine to a conveyer, which transports them to the mould assembly and pouring floor.

For pattern-draw, the arrangement used in these machines is basically similar to that used in hand moulding machines, e.g., pin-lift type, stripper type, or roll-over type. For ramming the sand, three principal methods are employed: *(i) squeezing, (ii) jolting, and (iii) slinging*.

Squeezing:

In the squeeze method, the flask is filled with the moulding sand, and the sand is squeezed against a pressure board pneumatically or hydraulically until the mould attains the desired density. In some cases, the squeeze action may be obtained by means of electromagnets.

The main limitation of this method is that, by squeezing, the sand is packed more densely at the top where the squeeze board presses against the sand and the density decreases uniformly with the depth. At the parting plane, the density is found to be the lowest. The variation of density affects the hardness of the mould which thus varies according to the depth. The squeeze method is therefore restricted ID moulds not more than 150 mm in depth.

The squeeze pressures used vary from 3000 to 20,000 kg according to the size of the machine. Where the moulds contain green sand cores, this method is not at all satisfactory as the sand cannot flow into the core cavities of the pattern and may remain loose near these cavities.

Jolting:

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 sand gets packed and rammed. This action of raising and dropping the table is called jolting. The density and hardness of the sand can be controlled by varying the height of the stroke, the amount of sand heaped above the mould, and the number of strokes.

The drawback in the jolting method is that the sand is rammed hardest at the parting plane and around the pattern and remains less dense in the top layers. This necessitates hand ramming of the mould at the back after the jolting action is completed.

In a jolting machine working on compressed air, the table supporting the flask is mounted on a cylinder called the jolt cylinder which is raised and dropped in succession by the entry and exit of compressed air underneath its base. When the cylinder is dropped, it presses against a valve which causes it to open and allow the air to enter the space beneath the base of the cylinder. The high-pressure air induces the cylinder to rise till it uncovers an exhaust port when the air rushes out and pressure falls down.

Due to the fall in pressure, the cylinder drops down and it again presses against the valve and opens the air entry. The jolt cylinder together with the table are thus raised and lowered in quick succession producing the desired jolting action. The jolting load exerted during moulding varies from 200 kg to 1000 kg according to the size of the machine.

Slinging:

In the slinging operation, the consolidation and ramming of sand is achieved by means of impact with the pattern. Basically, the sand slinging machines, commonly known as sand slingers, are equipped for throwing a stream of sand downward, through a slinging head, onto the pattern at high velocity. Due to the rapid ejection, the sand particles settle down instantly and get rammed.

The design of the sand slinger incorporates a high-speed rotary impeller, pipes, band conveyer, bucket elevator, and an ejecting head attached to a swiveling arm. The ejecting head can be moved all over the moulding box so as to attain uniform density of sand in the mould. The sand slinger may be either the stationary or the travelling type. The latter may again be the motive or the console type.

The ramming capacity of sand slingers varies from 0.15 m3/min for a small size to 0.85 m3/min for a large size. Similarly, the ramming range varies from 4500 mm to 10,000

UNIT II

MELTING FURNACES

Before pouring into the mould, the metal to be casted has to be in the molten or liquid state. Furnace is used for carrying out not only the basic ore refining process but mainly utilized to melt the metal also. A blast furnace performs basic melting (of iron ore) operation to get pig iron, cupola furnace is used for getting cast iron and an electric arc furnace is used for re-melting steel. Different furnaces are employed for melting and re-melting ferrous and nonferrous materials.

The following are the factors which are responsible for the selection of furnace

- ✓ Considerations of initial cost and cost of its operation
- ✓ Relative average cost of repair and maintenance
- ✓ Availability and relative cost of various fuels in the particular locality
- ✓ Melting efficiency, in particular speed of melting
- ✓ Composition and melting temperature of the metal
- ✓ Degree of quality control required in respect of metal purification of refining,
- ✓ Cleanliness and noise level in operation
- ✓ Personnel choice or sales influence

Heat in a melting furnace is created by combustion of fuel, electric arc, electric resistance, etc. A furnace contains a high temperature zone or region surrounded by a refractory wall structure which withstands high temperatures and being insulating minimizes heat losses to the surroundings. For refining and melting the ferrous and non-ferrous materials, various furnaces are used.

FURNACES FOR MELTING DIFFERENT MATERIAL

1. Grey Cast Iron

(a) Cupola
(b) Air furnace (or Reverberatory Furnace)
(c) Rotary furnace
(d) Electric arc furnace

2. Steel

(a) Electric furnaces
(*b*) Open hearth furnace

3. Non-ferrous Metals

(a) Reverberatory furnaces (fuel fired) (Al, Cu)
 (i) Stationary
 (*ii*) Tilting
(b) Rotary furnaces
 (i) Fuel fired
 (*ii*) Electrically heated
(c) Induction furnaces (Cu, Al)
 (i) Low frequency
 (*ii*) High frequency.

(d) Electric Arc furnaces (Cu)

(e) Crucible furnaces (AI, Cu)

(i) Pit type

(ii) Tilting type

(iii) Non-tilting or bale-out type

(iv) Electric resistance type (Cu)

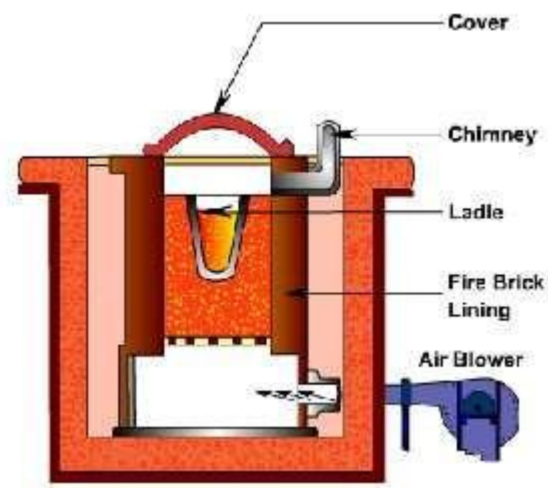
(f) Pot furnaces (fuel fired) (Mg and Al)

(i) Stationary

(ii) Tilting

Some of the commonly used furnaces in foundries are discussed as under.

CRUCIBLE FURNACES



Crucible furnaces are small capacity typically used for small melting applications. Crucible furnace is suitable for the batch type foundries where the metal requirement is intermittent. The metal is placed in a crucible which is made of clay and graphite. The energy is applied indirectly to the metal by heating the crucible by coke, oil or gas. The heating of crucible is done by coke, oil or gas.

Coke-Fired Furnace

- Primarily used for non-ferrous metals
- Furnace is of a cylindrical shape
- Also known as pit furnace
- Preparation involves: first to make a deep bed of coke in the furnace
- Burn the coke till it attains the state of maximum combustion
- Insert the crucible in the coke bed
- Remove the crucible when the melt reaches to desired temperature

Oil-Fired Furnace.

- Primarily used for non-ferrous metals
- Furnace is of a cylindrical shape

- Advantages include: no wastage of fuel
- Less contamination of the metal
- Absorption of water vapour is least as the metal melts inside the closed metallic furnace

PIT FURNACE

Pit furnace is a type of a crucible furnace bath which is installed in the form of a pit and is used for melting small quantities of ferrous and nonferrous metals for production of castings. It is provided with refractory inside and chimney at the top.

Generally coke is used as fuel. It is provided with refractory lining inside and chimney at the top. Natural and artificial draught can be used for increasing the capability towards smooth operation of the furnace. Fig. 2.1 shows the typical pit furnace.

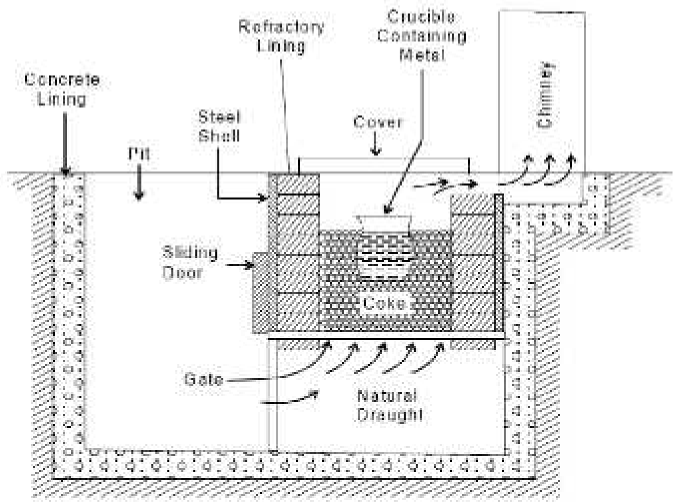


Fig. 2.1 Pit furnace

OPEN HEARTH FURNACE

In open hearth furnace, pig iron, steel scrap etc. are melted to obtain steel. This furnace is widely used in American foundries for steel production. The hearth is surrounded by roof and walls of refractory bricks as shown in Fig. 2.2. The charge is fed through a charging door and is heated to 1650°C mainly by radiation of heat from the burning of gaseous fuels above it. This heat is obtained by the burning of sufficiently pre-heated air and gas.

Such pre-heated air of gas is obtained by passing them though arc shaped hot regenerators at a lower level. This contains fire bricks which are arranged to extract heat from exhaust gases. In the furnace air and fuel are passed through a honeycomb of hot firebrick, called checkers. It preheats the air and fuel so that they are ready for combustion when they enter the hearth. The products of combustion at the same time pass through the checkers at the other end of the furnace. The hot gases heat the checkers. The process then reverses itself, and the newly heated checkers now are used to heat the air and the fuel. It is said as a regenerative process.

The products of combustion after giving up their heat to the checkers pass up through the stack. On firing of coke, the charge is heated. Part of the heat necessary, results from radiation from the low hot roof of the chamber. The furnace is raised bricked in with the charging platform, at the rear, also raised so that the charge may be put into the furnace. The melt is tapped off the front into large ladles. The chemical composition of the end product depends upon the lining, the charge, and the control impurities added during the melt after the melt has been tapped off into the ladle.

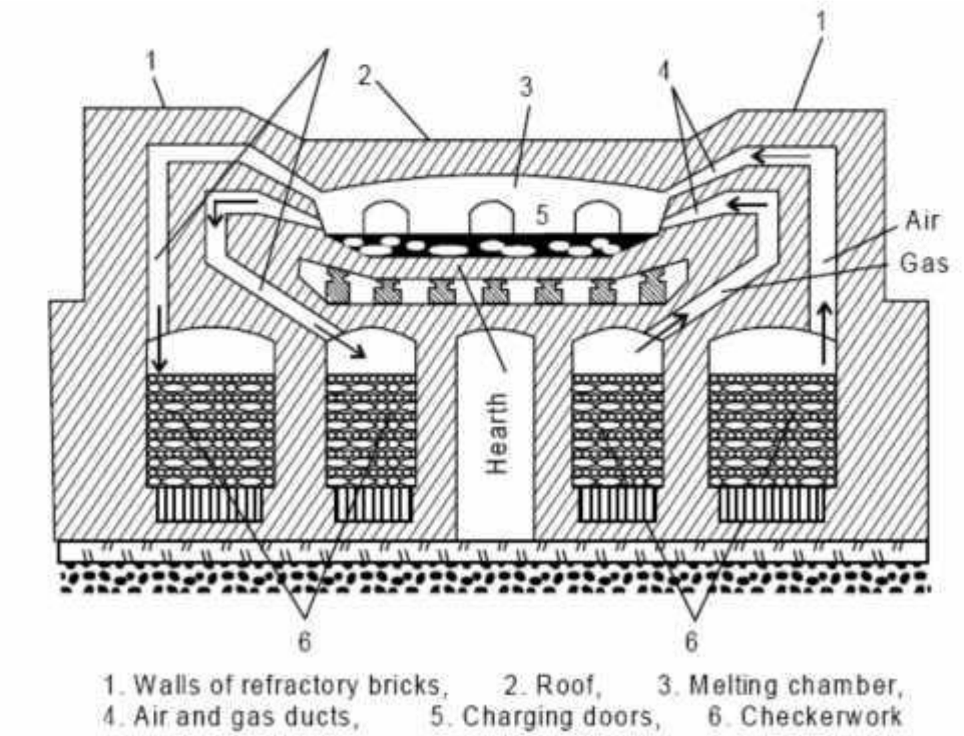


Fig. 2.2 Open hearth furnace

The lining plays a major role in the control of impurities. For magnesite lined furnace, the charge consists of pig iron, limestone, and scrap iron. The limestone forms a slag. This slag and the oxygen in the air combine to remove impurities. The slag reacts with the sulfur and the phosphorus in the metal, while the bubbling air causes oxidation of the carbon and silicon. If too much carbon is present in the melt, iron ore is added. The oxygen from the iron oxide burns out the excess carbon. If the carbon content is too low, pig iron is added. This replenishes the carbon. Other alloying elements like Cr, Ni. Co, W, Mo, V etc. are added as needed.

Ferromanganese may be added to the crucible after tapping. For acid lining furnace, the charge should be scrap iron and low-phosphorus pig iron. Limestone is required to keep the slag fluid. As described above, the basic lining burns phosphorus, silicon, and carbon. The slag is tapped off by the molten metals being allowed to overflow the sides of the crucible into a slag pot. Oxygen is one of the most important elements used in the reduction of the molten metal. Rust, scale, slag, and limestone are some of the sources of oxygen. Oxygen is introduced into the furnace with oxygen lances through the roof of the furnace. Twice the oxygen input will double the carbon reduction. This increases the steel production of the furnace.

AIR FURNACE

This furnace is also known as puddling or reverbratory furnace. It is used for making wrought iron. Fig. 2.3 shows the construction of this type of furnace.

A furnace or kiln in which the material under treatment is heated indirectly by means of a flame deflected downward from the roof. Reverberatory furnaces are used in copper, tin, and nickel production, in the production of certain concretes and cements, and in aluminum.

Reverberatory furnaces heat the metal to melting temperatures with direct fired wall-mounted burners. The primary mode of heat transfer is through radiation from the refractory brick walls to the metal, but convective heat transfer also provides additional heating from the burner to the metal.

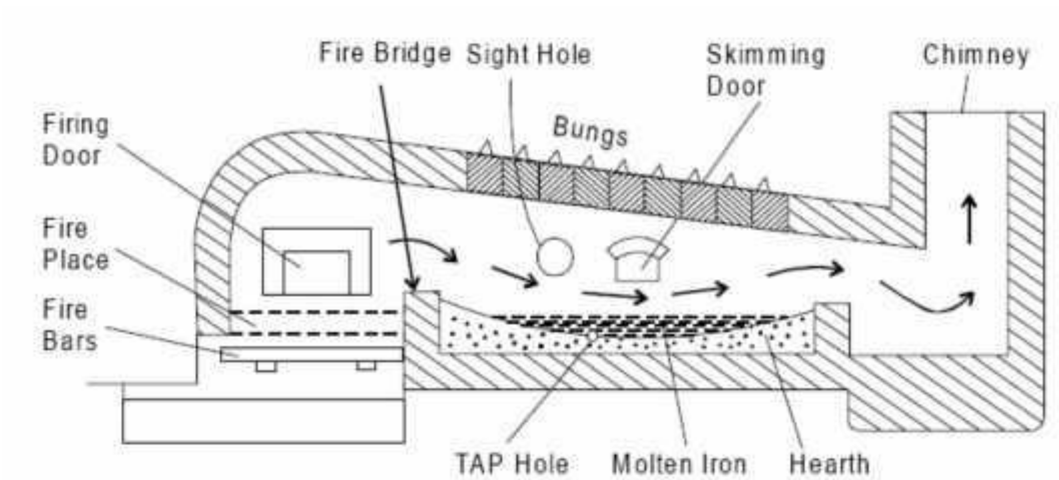


Fig. 2.3 Air Furnace

Advantages provided by reverberatory melters:

- ✓ High volume processing rate
- ✓ Low operating
- ✓ Maintenance costs

Disadvantages of the reverberatory melters:

- ✓ High metal oxidation rates
- ✓ Low efficiencies
- ✓ Large floor space requirements

CUPOLA FURNACE

A cupola is a vertical cylindrical furnace equipped with a tapping spout near its base. Cupolas are used only for melting cast irons, and although other furnaces are also used, the largest tonnage of cast iron is melted in cupolas. General construction and operating features of the cupola are illustrated in Fig.

It consists of a large shell of steel plate lined with refractory.

The ‘‘charge,’’ consisting of iron, coke, flux, and possible alloying elements, is loaded through a charging door located less than halfway up the height of the cupola. The iron is usually a mixture of pig iron and scrap (including risers, runners, and sprues left over from previous castings). Coke is the fuel used to heat the furnace.

Forced air is introduced through openings near the bottom of the shell for combustion of the coke. The flux is a basic compound such as limestone that reacts with coke ash and other impurities to form slag. The slag serves to cover the melt, protecting it from reaction with the environment inside the cupola and reducing heat loss.

As the mixture is heated and melting of the iron occurs, the furnace is periodically tapped to provide liquid metal for the pour.

Description of Cupola

- The cupola consists of a vertical cylindrical steel sheet and lined inside with acid refractory bricks. The lining is generally thicker in the lower portion of the cupola as the temperature are higher than in upper portion
- There is a charging door through which coke, pig iron, steel scrap and flux is charged
- The blast is blown through the tuyeres
- These tuyeres are arranged in one or more row around the periphery of cupola
- Hot gases which ascends from the bottom (combustion zone) preheats the iron in the preheating zone
- Cupolas are provided with a drop bottom door through which debris, consisting of coke, slag etc. can be discharged at the end of the melt
- A slag hole is provided to remove the slag from the melt
- Through the tap hole molten metal is poured into the ladle
- At the top conical cap called the spark arrest is provided to prevent the spark emerging to outside

Operation of Cupola

The cupola is charged with wood at the bottom. On the top of the wood a bed of coke is built. Alternating layers of metal and ferrous alloys, coke, and limestone are fed into the furnace from the top. The purpose of adding flux is to eliminate the impurities and to protect the metal from oxidation.

Air blast is opened for the complete combustion of coke. When sufficient metal has been melted that slag hole is first opened to remove the slag. Tap hole is then opened to collect the metal in the ladle.

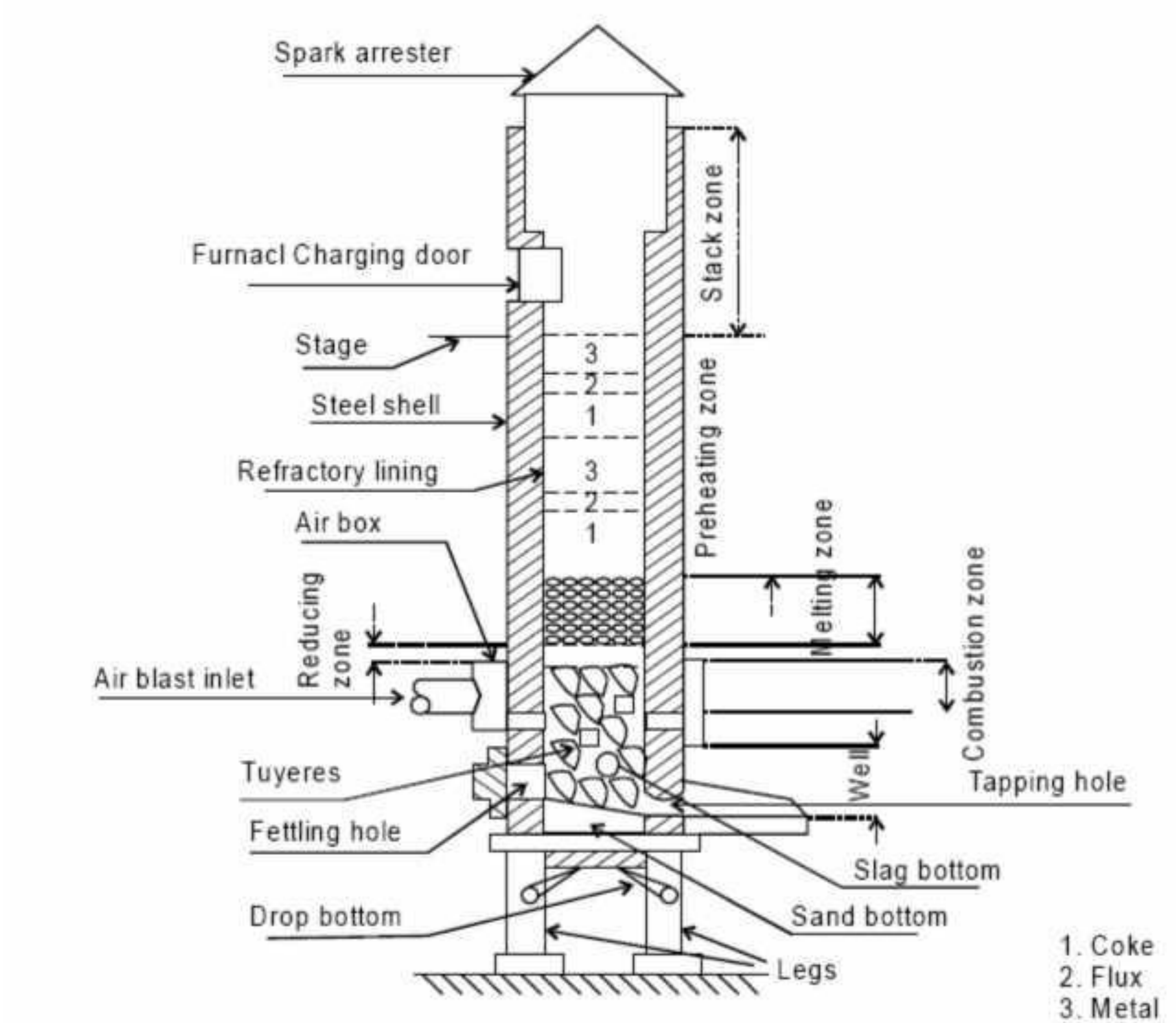


Fig. 2.4 Cupola Furnace

Working of Cupola Furnace

Initially the furnace prop is opened to drop the existing earlier charge residue. The furnace is then repaired using rich refractory lining. After setting the prop in position, the fire is ignited using firewood and then small amount of coke is used to pick fire. The little oxygen is then supplied for combustion. Lime, coke, and metal in balanced proportions are charged through the charging door upon the coke bed and at proper time on starting the blower.

Air is forced from wind box through tuyers into furnace. The forced air rise upward rough the stack furnaces for combustion of coke. Besides being fuel, the coke supports the charge until melting occurs. On increase of temperature, the lime stone melts and forms a flux which protects the metal against from excessive oxidation. Lime also fuses and agglomerates the coke ash.

The melting occurs and proceeds and molten metal is collected at the bottom. Molten metal may be tapped at intervals before each skimming, or the tap-hole may be left open with metal flowing constantly.

In most cupolas slag is drained from the slag hole at the back of furnace. When metal is melted completely the bottom bar is pulled sharply under the plates and bottom is dropped.

All remaining slag, un-burned coke or molten metal drops from the furnace. When the melt charge has cooled on closing furnace, it is patched and made ready for the next heat.

ROTARY FURNACE

Rotary Melting Furnace is a very flexible and universal equipment used for recycling many non-ferrous metals. It is the major lead production technology used in India and many other countries for Secondary Lead Production.

Characteristics such as:

- Equipment scalable for installing higher capacities
- Recovers all lead in one production cycle
- Plates & powder from scrap battery as well as slag from Mini Blast Furnace can be used as raw material
- Requires addition of certain consumables
- Can be fired with various fuels
- Generates high Pollution both as Flue Gases & Fugitive Emissions

Description of Rotary Furnace

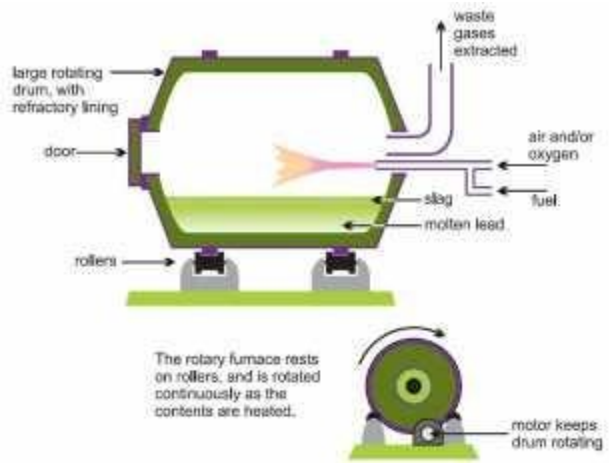
It is a Rotary kiln in the form of a metallic cylinder with conical sides on both ends. Mild steel plate is used for construction of this shell and its thickness varies depending upon the capacity of the equipment. This shell is rotated on its own axis at 1-2 rpm. For this purposes tyres (also called riding rings) are fitted on the shell.

These are fabricated from MS squares or flats, machined for a smooth finish. These tyres ride on steel rollers which are again machined finely. These rollers are fitted on a robust MS structural frame and driven by a gear & motor arrangement. The shell is lined inside with insulation and fire bricks of suitable Alumina content.

Conical ends of the furnace are open on both sides. The furnace is charged with Raw material along with additives from the front end. This side is provided with a movable door on which a burner is mounted. The burner can be a conventional one or a fully automatic one depending upon the fuel used.

At the other end, an exhaust block lined with refractory bricks is provided. A tapping hole is provided in the center of the shell from where molten metal & slag are discharged.

Flue gases generated are sucked from the exhaust block side of the furnace.



Rotary Furnace

Process:

Rotary Furnace can be obtained directly from scrapped batteries or as slag from Mini Blast Furnace. In case of former, batteries are cut open or broken to segregate lead scrap, plastic and other materials from them; lead scrap in the form of lead powder/ plates etc. is charged in the furnace along with a proportionate charge of additives. In the case of latter, slag produced from Mini Blast Furnaces is charged into the Rotary Furnace, again with proportionate additives.

This process is a batch type process. After filling the required quantity of raw material (either manually or mechanically), the lid of the furnace at the front is closed. The burner attached to the moving door is then fired.

Material along with additive chemicals is heated at high temperature inside the furnace. After some time, molten lead is collected at the bottom of the furnace by puncturing the central opening of the Rotary Furnace. Lead is collected either directly into Jumbo Ingot Moulds or in receiving channels from which they are poured into Jumbo Ingot Moulds.

After draining the Furnace of the first batch, production of next batch is undertaken and the Furnace is again charged with raw material. After three such batches, one batch of slag collected in Rotary Furnace is executed.

Advantages

- Recovers 100% lead in the first operation.
- Slag produced is lead free.
- Equipment can be scaled up for higher production capacities.

Disadvantages

- Many chemicals are required for operation.
- High power consumption.
- Difficult to produce low Antimony lead suitable for soft lead purposes.
- Fugitive Emissions need to be captured in addition to flue gases.

- Need skilled operators and careful maintenance

REFRACTORIES FOR MELTING UNITS

Refractories are materials that can withstand high temperatures and resist the action of slags. These materials should not show any sign of fusion below 1580°C because they are used to serve as receptacles for molten metal. Refractories form a vital part of all melting furnaces in foundries. Good refractory materials:

i. Do not fuse and soften at the temperature at which they are used
ii. Are able to withstand thermal shock due to sudden change in temperature
iii. Resist abrasion
iv. Do not get crushed under the heavy pressure of the charge when used at high temperature
v. Have a low thermal coefficient
vi. Are chemically inert and resist corrosion
vii. Do not allow gases to permeate through them and
viii. Have high electrical resistance if used for electric furnaces.

In actual practice, no refractories fulfil all these requisites, but there are some materials that satisfy many of the conditions.

Refractory materials are classified as acid, basic, or neutral, according to their reactivity with acidic or basic slags formed in the furnaces.

Acid Refractories

Acid refractories are those that are not attacked by acid slags. The common acid refractory materials are silica and fire clay. Silica, in the pure state, fuses at a temperature of 1710°C; when heated in contact with some basic material, it forms a silicate.

Silica bricks are hard and refractory and can withstand 3 kg/cm2 load at I600°C. The thermal shock resistance is low and a tendency to spall is shown during rapid fluctuations of temperature. Fire clays are composed of hydrated aluminium silicate (A1203 2Si02 2H:0).

The properties of fire clay bricks differ markedly due to variations in chemical composition. The thermal expansion of these bricks is low, but the resistance to spalling is high. The fusion temperature is well over 1700°C, but, under load conditions, it gets lowered (1380°C under about 1.5 kg/cm2).

The general requirements of fire bricks, classified into two types as per IS: 1871-1958, are as shown in Table below.

Property	Type I	Type II
Pyrometric cone equivalent, minutes (ASTM Cone No.)	30 minutes	31 minutes
Apparent porosity (% max.)	25	22
Cold crushing strength (kg/cm^2, min.)	200	200
Permanent linear change after reheating (% max.)	For 5 hrs at 1350°C ± 1.0	For 2 hrs at 1400°C ± 0 . 5

Basic Refractories

Basic refractories are those that do not react with basic slags. They are suitable for lining furnaces operating on the basic slag practice. Common basic refractories are magnesite, chrome-magnesite and dolomite. Magnesite has a high fusion point of 2800°C and good resistance to the corrosive action of basic slags. Magnesite bricks have poor thermal shock resistance and low resistance to abrasion whereas chrome- magnesite bricks have superior refractoriness under load and better thermal shock resistance.

These consist of 20-30% MgO and 70-80% chromite. Both magnesite and chrome-magnesite bricks are expensive and are used only where slags are highly basic in nature. Dolomite, a double carbonate of calcium and magnesium ($CaC0_3$ $MgC0_3$), serves as a cheaper substitute for magnesite. Stabilized dolomite, which consists of 3Ca0-$Si0_2$ and MgO, is a better refractory than ordinary dolomite as it is not over prone to expansion and cracking.

Bauxite ($A1_20_3$-$3H_20$) is also highly refractory when pure and is basic in nature. Its utility is, however, limited owing to the presence of many impurities which lower its refractory value.

Neutral Refractories

Neutral refractories neither react with acid nor with basic slags and they permit the use of both acid and basic processes on the same lining. Common neutral refractory materials are carbon, graphite, chromite, and sillimanite. Carbon bricks do not form a liquid phase on heating and thus retain strength at high temperatures.

Their resistance to thermal shock is high and the coefficient of thermal expansion low. They are not melted by molten metal and slag. The oxidation in air as well as in other oxidising gases is rather high at temperatures above 1400°C.

Chromitc bricks are manufactured from chromite ore, which is composed of 32% FeO and 68% Cr_20_3. The fusion temperature of chromite bricks is about 2180°C.

Sillimanite contains 63% A1203 and 37% SiO_2. Its fusion temperature is 1900°C. It has a low coefficient of thermal expansion, and good resistance to abrasion, spalling and corrosive action of slags. The strength retained at high temperature is also fairly high.

Zircon, composed of 100% zirconium oxide, is also suitable as neutral refractory.

Neutral refractories, though ideal in properties, are very expensive and their use is therefore limited to special applications.

Selection of Refractory Materials for Different Furnaces

1. Cupola:

In the hearth area of the cupola, refractory lining is in contact with molten metal, slag, and relatively static coke. The effect of abrasion is therefore not serious, but the lining is prone to the chemical attack of slag. In the melting zone, the lining encounters high temperature and chemical reactions, and thermal shock too as cold air rushes through the opening when the base is dropped.

The choice of refractories in the hearth and melting areas depends on slag practice. Acid slag practice requires a lining of fire bricks, silica, or alumina. Basic slag practice needs magnesite, chrome-magnesite, or burnt dolomite lining; carbon lining is also used occasionally. Lining in the charging zone is not subject to high temperature or attack by the action of slag, but it withstands severe abrasion when the charge moves downwards. Hard burnt fire clay of low porosity is quite suitable for this region.

Cast iron blocks are also used in the upper part near the charging door. The area above the charging door serves only to protect the shell from the heat of stack gases. It is also lined with fire bricks.

2. Electric Arc Furnace:

The type of refractory used in this furnace depends on the type of operating practice, viz. acid or basic. If the lining is acid, the roof and side walls are built of silica bricks. The hearth has first a layer of fire bricks next to the shell, followed by two courses of silica bricks. The brickwork is rammed finally with a hearth mixture comprising silica sand mulled with about 4% ball clay. In the case of basic practice, the roof is constructed of silica bricks or silhmanite.

Sometimes, the outer circle is made of chrome-magnesite bricks and the side walls are lined with silica bricks. However, it is more advisable to use magnesite bricks. Chrome-magnesite bricks are also used for side walls. The hearth shell is lined with magnesite bricks. Stabilized dolomite bricks are also suitable for the hearth. The brickwork is thoroughly dried before the working hearth is rammed with magnesite or dolomite powder.

Maintenance A good refractory maintenance aimed at balanced wear is important to get optimum performance of an electric arc furnace. The slag line including the hot spots and the banks are the areas where most of the repair is necessary. Hot repairs to the furnace lining, in contrast to those made after shutdown, have potential advantages such as increasing the operating efficiency and preventing loss of heat. Eroded spots on the banks or hearth of the furnace are filled up immediately after tapping each heat by throwing furnace bottom sand or crushed ganister in the case of acid lining.

For basic lining the refractory maintenance materials are usually basic products but they differ substantially from the basic materials used for manufacturing of basic bricks. A maintenance material must have adequate refractoriness, but at the same time it must contain a percentage of low melting phases which promote sintering in the temperature of 925 to 1425 °C. In addition, a chemical binder must be included to impart sufficient strength after drying and prior to sintering.

However, this binder lowers the refractoriness of the maintenance material. Regarding grain size of the maintenance material, it may be noted that although a compact layer may give maximum wear resistance, the grade suitable for maximum compactness will not flow satisfactorily through the spray machine and will give rise to segregation. Moreover, if a wet maintenance material is used, excessively compact layer hinders escape of water vapour during drying. The large size grain fraction contributes to the rebound loss whereas the fine fractions lead to down flow.

For this reason, fairly even grain size distributions are generally selected. The maintenance materials are usually magnesia, doloma, doloma magnesia or magnesia chrome products. The range of minor constituents added as binding, sintering and plasticising agents include silicates, alkaline phosphates, sulphates, chromates and clays.

The machines used for application of the maintenance material include pressure chamber spray guns, rotary valve guns or centrifugal spinners.

3. Induction Furnace:

A high frequency current is carried by a water-cooled coil in the induction furnace. The inside of the coil is rammed with a thin layer of sillimanite refractory to form a melting chamber. The thin tayer is rammed by hand around a core which is made in the form of a steel or asbestos cylinder. The core can be either withdrawn or melted with the first charge. When the lining is acid, rammed ganister bonded with clay or sodium silicate is used. For basic lining, sintered magnesite, fused alumina, and zircon give best results.

The refractories for lining must have the following characteristics:

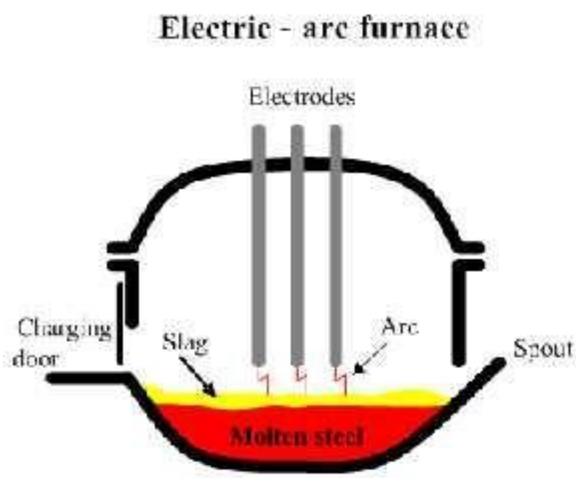
- ✓ Compatibility with Alloys and Oxides: The life of the furnace lining depends upon its compatibility with the metals and alloys being melted and the oxides formed during melting.
- ✓ Retention of Strength at Steelmaking Temperature This is a desirable characteristic, because at this temperature, the lining is subject to mechanical abuse when putting scrap into the furnace and when using crowbars to prevent scrap from bridging over.
- ✓ Low Thermal Conductivity The refractory should have low thermal conductivity for prolonged life of the induction coils and less heat loss.
- ✓ Low Electrical Conductivity Electrical conductivity of the refractory material should be low for efficient induction heating.
- ✓ Resistance to Slag Corrosion and Erosion The refractory lining should be resistant to slag corrosion and erosion to minimize the chance of metal breakthrough and repair between relining's.
- ✓ Low Reheat Shrinkage The lining should undergo small volume changes during heating up and cooling down of the furnace such that chances of development of cracks and subsequent metal breakthrough to the coil is minimum.

ELECTRIC ARC FURNACE (EAF)

Electric Arc Furnace (EAF) is a steel making furnace, in which steel scrap is heated and melted by heat of electric arcs striking between the furnace electrodes and the metal bath.

Two kinds of electric current may be used in Electric Arc Furnaces: direct (DC) and alternating (AC).Three-phase AC Electric Arc Furnaces with graphite electrodes are commonly used in steel making.

The main **advantage of the Electric Arc Furnaces** over the Basic Oxygen Furnaces (BOF) is their capability to treat charges containing up to 100% of scrap. About 33% of the crude steel in the world is made in the Electric Arc Furnaces (EAF).



Structure of an Electric Arc Furnace

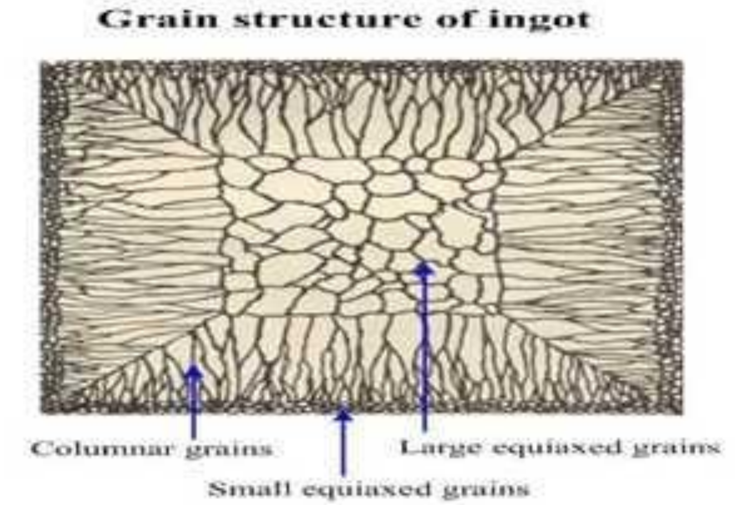
- ✓ The furnace consists of a spherical hearth (bottom), cylindrical shell and a swinging water-cooled dome-shaped roof.
- ✓ The roof has three holes for consumable graphite electrodes held by a clamping mechanism. The mechanism provides independent lifting and lowering of each electrode.
- ✓ The water-cooled electrode holders serve also as contacts for transmitting electric current supplied by water-cooled cables (tubes). The electrode and the scrap form the star connection of three-phase current, in which the scrap is common junction.
- ✓ The furnace is mounted on a tilting mechanism for tapping the molten steel through a tap hole with a pour spout located on the back side of the shell.
- ✓ The charge door, through which the slag components and alloying additives are charged, is located on the front side of the furnace shell. The charge door is also used for removing the slag (de-slagging).
- ✓ The scrap is charged commonly from the furnace top. The roof with the electrodes is swung aside before the scrap charging.
- ✓ The scrap arranged in the charge basket is transferred to the furnace by a crane and then dropped into the shell.

SOLIDIFICATION OF METALS

Solidification is a comprehensive process of transformation of the melt of an alloy into a solid piece of the alloy, involving crystallization of the liquid phase, segregation of impurities and alloying elements, liberation of the gases dissolved in the melt, shrinkage cavities and porosity formation.

- Structure of ingots and castings
- Segregation
- Gas pores
- Shrinkage

Structure of ingots and castings



Fine and homogeneous grain structure is the most desirable for the common castings and ingots. It is achieved when the **crystallization** proceeds under the following conditions:

- Formation of a large number of stable nuclei;
- Fast extraction of latent crystallization heat and the superheat of the liquid.

These conditions are realized when a melt comes to a contact with a wall of a cold metallic mould. Small equiaxed grains (chill crystals) form at this stage. Latent crystallization heat, liberating from the crystallizing metal, decreases the undercooling of the melt and depresses the fast grains growth.

At this stage some of small grains, having favorable growth axis, start to grow in the direction opposite to the direction of heat flow. As a result columnar crystals (columnar grains) form. Length of the columnar grains zone is determined by the constitutional undercooling. When the temperature of the melt, adjacent to the solidification front, increases due to the liberation of the latent heat, constitutional undercooling will end and the columnar grains growth will stop. Further cooling of the molten alloy in the central zone of the ingot will cause formation of **large equiaxed grains**. Formation of the grain zones of an ingot is presented in the figure.

The crystals, growing as a result of solidification of ordinary alloys, are in dendrite form.

Segregation

Composition of solidified alloy is not uniform. Concentrations of impurities and alloying elements are different in different parts of the casting. This difference is a result of different solubility of impurities in liquid and solid phases at the equilibrium temperature.

Segregation is a result of separation of impurities and alloying elements in different casting regions. *Micro segregation* is a segregation of impurities between the dendrite arms. This kind of segregation may be considerably diminished by diffusion of the impurities atom into the dendrite arms during homogenizing annealing.

Macro segregation

Advancing the solidification front towards the ingot center causes enrichment of the liquid in the central zone by impurities and alloying additives, rejected by the solidifying metal and pushed by the solidification front. Segregated impurities are arranged as V-shape marks on the vertical section of the ingot. This effect is called normal macro segregation.

Gravity segregation is a segregation caused by precipitation of primary crystals, which are heavier, than the melt.

Gas pores

Gas pores, entrapped in the solid structure of a casting, arise from different origins:

- Gas (Hydrogen) dissolved in the liquid during melting (from damp materials, atmosphere, oils, etc.). When the melt cools down and solidifies hydrogen solubility decreases and it is forced out from the melt. The gas bubbles are trapped by the dendrites, forming gas porosity.
- Gas pores, called blowholes, may be a result of chemical reaction occurring in the solidifying alloy. If a liquid steel was not deoxidized by deoxidizers (aluminum, silicon), Oxygen and carbon, which are solved in the steel, form carbon monoxide by the reaction: C + O = CO. The bubbles of CO, trapped by the dendrites, form blowholes.
- Surface blowholes may form as a result of the decomposition of some constituents of mould dressing.

Shrinkage

Shrinkage is a contraction of alloy volume caused by:

- Contraction of the melt when it cools down to the liquidus temperature
- Contraction of the alloy owing its solidification (cooling from liquidus temperature to solidus temperature). All metals except bismuth have higher density in solid state, than in liquid.
- Contraction of the solid alloy cooling from the solidus temperature to the ambient temperature.

Shrinkage cavity

When a large isolated region of liquid phase remains within solid, surrounding it, shrinkage cavity will form in this region. The common mould structure includes a riser a "head", in which the melt solidifies last and "feeds" the main casting with liquid alloy, compensating the casting shrinkage.

Shrinkage porosity

This shrinkage defect is a characteristic for the central regions of castings (ingots) of the alloys with a wide temperature range of solidification. In these castings “feeding” melt is not able to infiltrate through the interlacing dendrites. The local micro-spaces between the dendrites arm remain isolated from the melt in riser forming micro-cavities or shrinkage porosity.

UNIT III

GATING AND RISERING

The term 'gating' or 'gating system' refers to all the passageways through which metal enters a mould cavity. It thus mainly includes parts such as a pouring basin, sprue, runner, and gates.

The chief requisites of a gating system are the following:

(i) Metal should be able to flow through the gating system with a minimum of turbulence and aspiration of mould gases so as to prevent sand erosion and gas pick-up. Turbulence is the most important single factor affecting the design of the gating. Excessive turbulence results in the aspiration of air and the formation of dross.

(ii) The metal should be so introduced in the mould cavity that the temperature gradients established on the mould surfaces and within the metal facilitate directional solidification towards the riser.

(iii) The mould cavity should be completely filled with molten metal in the shortest possible time; the gating system should therefore be so designed that the rate of entry of metal into the mould cavity is well regulated.

(iv) The casting should be produced with a minimum of excess metal in gates and risers.

(v) Loose sand, oxides, and slag should be prevented from entering the mould cavity by providing a proper skimming action on the metal as it flows through the gating system.

(vi) Erosion of the mould walls should be avoided.

Fig. 3.1 shows the different elements of the gating system. Some of which are discussed as under.

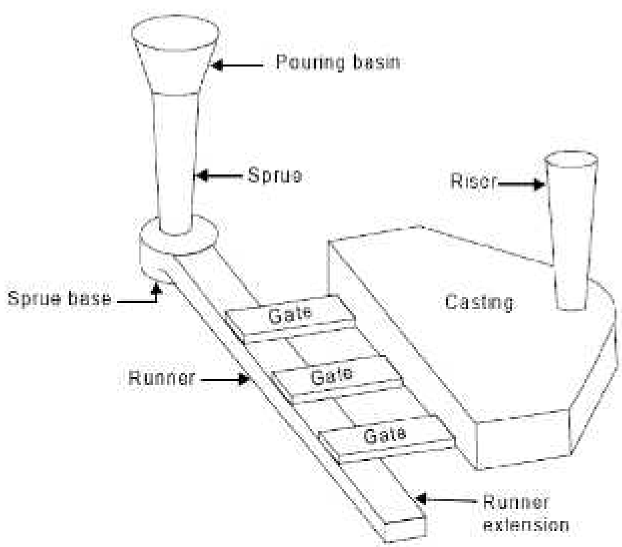


Fig. 3.1 Gating System

1. Pouring basin

It is the conical hollow element or tapered hollow vertical portion of the gating system which helps to feed the molten metal initially through the path of gating system to mould cavity. It may be made out of core sand or it may be cut in cope portion of the sand mould. It makes easier for the ladle operator to direct the flow of molten metal from crucible to pouring basin and sprue.

It helps in maintaining the required rate of liquid metal flow. It reduces turbulence and vertexing at the sprue entrance. It also helps in separating dross, slag and foreign element etc. from molten metal before it enters the sprue.

2. Sprue

It is a vertical passage made generally in the cope using tapered sprue pin. It is connected at bottom of pouring basin. It is tapered with its bigger end at to receive the molten metal the smaller end is connected to the runner. It helps to feed molten metal without turbulence to the runner which in turn reaches the mould cavity through gate.

It sometimes possesses skim bob at its lower end. The main purpose of skim bob is to collect impurities from molten metal and it does not allow them to reach the mould cavity through runner and gate.

3. Gate

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

4. Choke

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

5. Runner

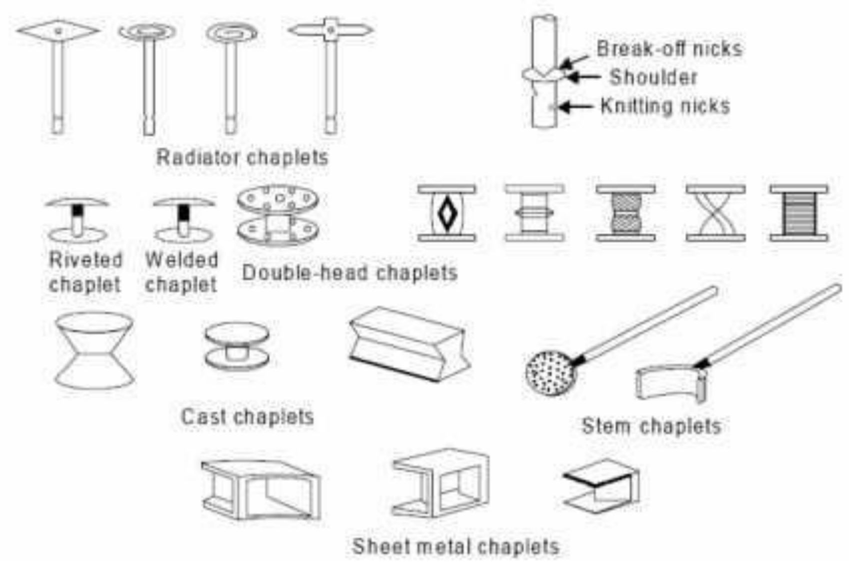
It is a channel which connects the sprue to the gate for avoiding turbulence and gas entrapment.

6. Riser

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

7. Chaplets

Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces. The distances pieces in form of chaplets are made of parent metal of which the casting is. These are placed in mould cavity suitably which positions core and to give extra support to core and mould surfaces. Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification. When the molten metal is poured in the mould cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material. Various types of chaplets are shown in Fig. 3.2. The use of the chaplets is depicted in Fig. 3.3.



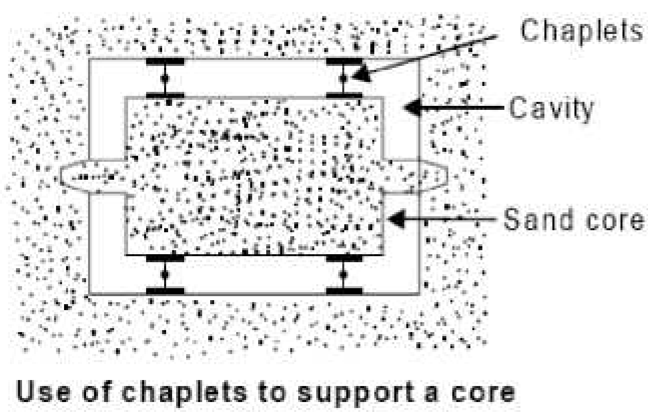


Fig. 3.2 Types of chaplets

Fig. 3.3 Use of chaplets

8. Chills

In some casting, it is required to produce a hard surface at a particular place in the casting. At that particular position, the special mould surface for fast extraction of heat is to be made. The fast heat extracting metallic materials known as chills will be incorporated separately along with sand mould surface during moulding. After pouring of molten metal and during solidification, the molten metal solidifies quickly on the metallic mould surface in comparison to other mould sand surfaces.

This imparts hardness to that particular surface because of this special hardening treatment through fast extracting heat from that particular portion. Thus, the main function of chill is to provide a hard surface at a localized place in the casting by way of special and fast solidification.

Various types of chills used in some casting processes are shown in Fig. 3.4. The use of a chill in the mould is depicted in Fig. 3.5.

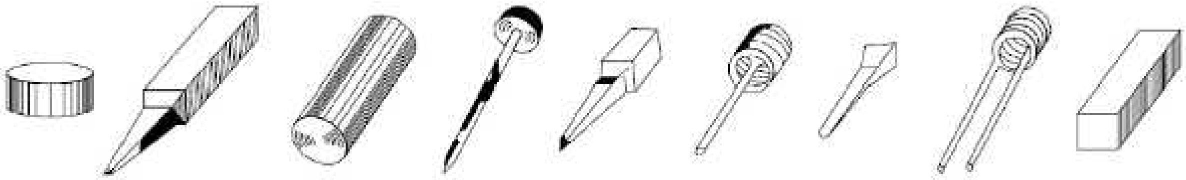


Fig. 3.4 Types of chills

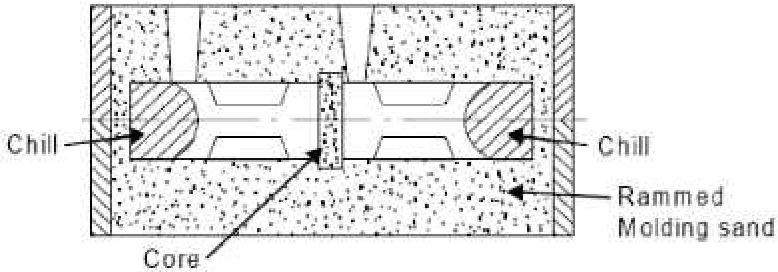


Fig. 3.5 Use of a chill

FACTORS CONTROLING GATING DESIGN

The following factors must be considered while designing gating system.

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

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

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

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

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

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

GATES

The gate is the passage that finally leads molten metal from the runner into the mould cavity. The location and size of the gates are so arranged that the mould can be filled in quickly with a minimum amount of cutting of the mould surfaces by the flowing metal. The gates should be so placed that cracks do not develop when the metal cools. The gate connections should be located where they can be readily removed without damaging the castings. In-gates should not be placed too near the end of the runner. If necessary, a well may be provided at the runner end.

According to their position in the mould cavity, gates may be broadly classified as

(1) Top gates
(2) Parting gates
(3) Bottom gates

(1) TOP GATES:

Molten metal is poured down the head or riser of the casting. Since the metal falls directly into the mould cavity, the mould should be hard and strong enough to resist erosion by the dropping metal. The advantage of top gating is that since all the metal enters the casting at the top, the hottest metal remains in this region. As such, proper temperature gradients are formed, and directional solidification towards the riser, located at the top of the casting, can be achieved. The gates themselves may be made to serve as risers (Fig. 3.6).

To prevent loose sand and drops from entering the mould cavity and to allow the metal to fall in a small stream, a large-sized pouring basin may be fixed on top of the sprue-cum-riser (Fig. 3.6A). A strainer core may also be fitted in the pouring basin for better results. In the case of light castings, wedge shaped gates called wedge gates may be provided (Fig. 3.6B).

Pencil gates, as shown in Fig. 3.6D, are used for massive iron castings where a minimum weight of head is desired and the slag is to be effectively checked from collecting in the mould cavity. In the finger gate (Fig. 3.6E), a modification of the wedge gate, the metal is allowed to reach the mould in a number of streams. The ring gate (Fig. 3.6F) also uses a core to break the stream of molten metal besides directing the metal into the desired position in the mould and, at the same time, retaining the slag.

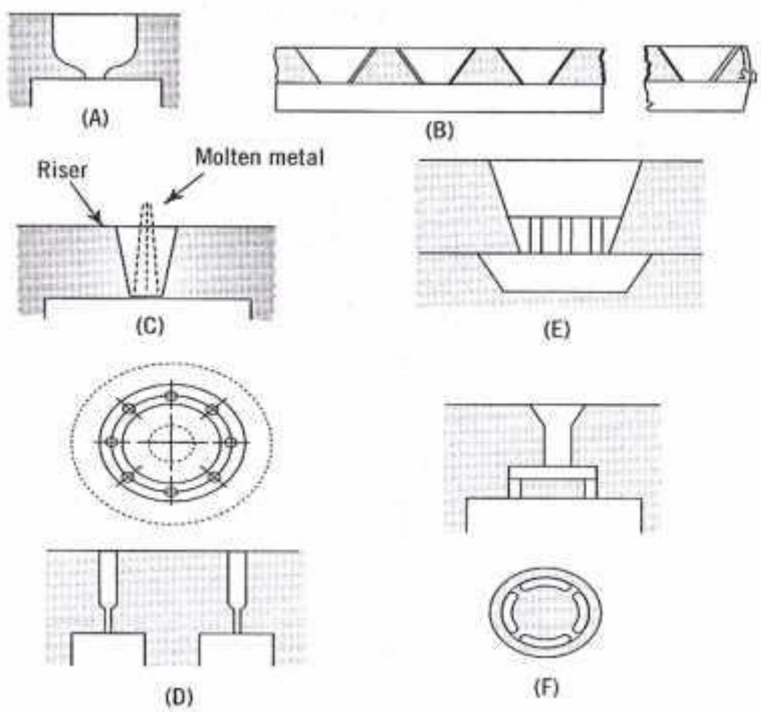


Fig. 3.6 Types of top gates (A) Top gate with pouring basin (B) Wedge gate

(C) Top run gate (D) Pencil gate (E) Finger gate (F) Ring gate

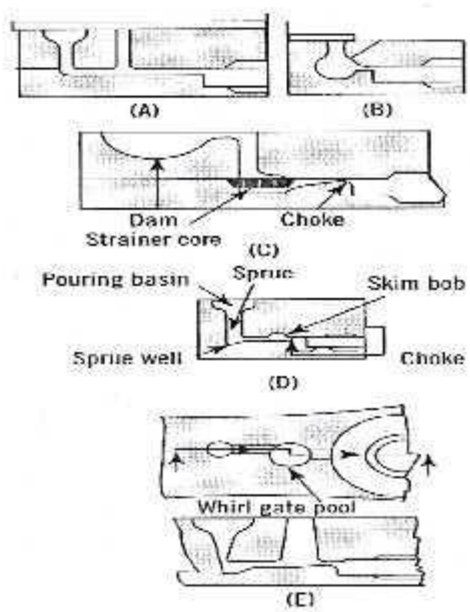
(2) PARTING GATES:

In the case of parting gates (Fig. 3.7), metal enters the mould cavity at the same level as the mould joint or parting line. Molten metal enters through the sprue and reaches the parting surface where the sprue is connected to the gate in a direction horizontal to the casting. The arrangement of providing a gate at the parting line allows the use of devices that can effectively trap any slag, dirt, or sand, which passes with the metal down the sprue. Fig. 3.7D shows the use of a skim-bob, which is a hollow or recess in the cope, to trap the slag and foreign matter in the metal.

This figure also indicates the use of a choke, which serves as a restriction to control the rate of flow of the metal. The choke may he placed in the gate either close to the casting, or away from it so as to prevent squirting of metal in the mould cavity and erosion of sand. Fig. 3.7A illustrates the use of a skimming gate, the purpose of which is similar to that of a skim-bob, viz., trapping the foreign matter which, here being lighter in weight than the metal, can rise up through the vertical passage. Fig. 3.7C depicts the use of a dam-type pouring basin, formed in the upper part of the cope, and a strainer core.

The purpose of both the dam and the strainer core is to separate the impurities and refine the metal. The metal, however, must be very fluid when a strainer core is used. If there is a tendency of shrinkage near the in-gate, a shrink-bob as shown in Fig. 3.7B may be required. At the bottom of the sprue, a dry sand core is sometimes fixed to prevent the sand from getting washed away.

In the case of large castings, molten metal flows through a common runner, which is laid around the mould cavity, and the metal is uniformly distributed to the casting through a number of branch gates. To trap the slag, etc., another effective method is to use a skimming gate with a whirlpool (Fig. 3.7E).The slag, due to whirlpool action, comes to the centre from where it rises up in the skimming gate.



<u>Fig. 3.7 Types of parting gates</u> (A) Skimming gate (B) Parting gate with shrink-bob (C) Parting gate with dam type pouring basin (D) Parting gate with skim-bob (E) Whirlpool gate

(3) BOTTOM GATES:

In the case of bottom gates, usually favoured for large-sized casting, especially those of steel, molten metal flows down the bottom of the mould cavity in the drag and enters at the base of the casting. These are used to keep the turbulence of metal at a minimum while pouring and to prevent mould erosion. Metal is allowed to rise gently in the mould and around the cores.

The disadvantages of bottom gating are the following:

(i) The metal continues to lose its heat as it rises in the mould cavity, and, by the time it reaches the riser, it becomes much cooler. As such, directional solidification is difficult to achieve.

(ii) It is difficult to place the riser near the gate entrance where the metal is hottest.

Two types of bottom gates are shown in Fig. 3.8. The horn type (Fig. 3.8A) enables the mould to be made in two boxes only, thus eliminating the necessity of a 'cheek'. The pattern for this gate is rammed in the drag and later extracted by turning it out of the sand.

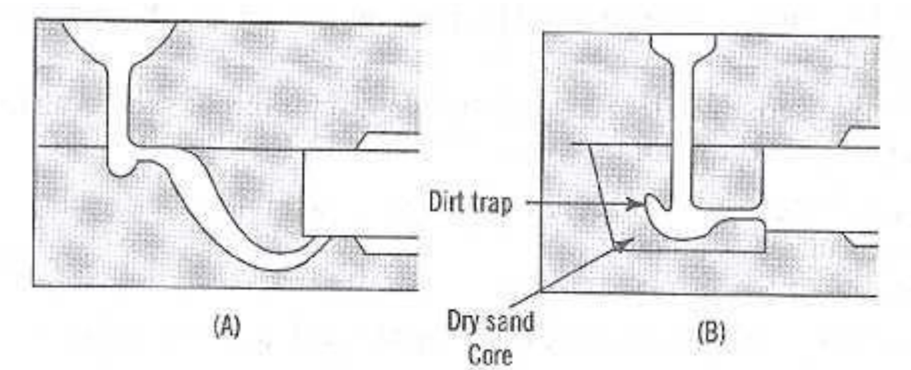


Fig. 3.8 Types of bottom gates (A) Horn gate (B) Bottom gate with dry sand core

Fig. 3.8B shows a bottom gate using a dry sand core. The sprue is curved at the bottom end to form a dirt-trap for slag, dirt, etc. This type of gate also enables the mould to be made in two boxes. Bottom gating can be provided with ease in case of three-part moulds by keeping the in-gates on the parting face of drag und middle part. A draw-in type of runner gate can also be used for simplicity in moulding.

The runner-gate pattern is tapered and can be pulled into the mould cavity after the main pattern for the casting has been withdrawn. The gate is generally placed tangentially on the casting so as to impart a spinning action to the incoming metal. The spinning and whirling action tends to move the slag and scum to the centre from where it can ascend into the riser.

RISERING OF CASTINGS

A riser is a hole cut or moulded in the cope to permit the molten metal to rise above the highest point in the casting. The riser serves a number of useful purposes. It enables the pourer to see the metal as it falls into the mould cavity. If the metal does not appear in the riser, it signifies that either the metal is insufficient to fill the mould cavity or there is some obstruction to the metal flow between the sprue and riser.

The riser facilitates ejection of the steam, gas, and air from the mould cavity as the mould is filled with the molten metal. Most important, the riser serves as a feeder to feed the molten metal into the main casting to compensate for its shrinkage.

The use of several risers may be necessary in the case of an intricate or large casting with thin sections.

The main requisites of an effective riser are the following:

i. It must have sufficient volume as it should be the last part of the casting to freeze.
ii. It must completely cover the sectional thickness that requires feeding.
iii. The fluidity of the molten metal must be adequately maintained so that the metal can penetrate the portions of the mould cavity freezing towards the end.
iv. It should be so designed that it establishes and effects temperature gradients within the castings so that the latter solidifies directionally towards the riser.

ROLE OF RISER IN SAND CASTING

Metals and their alloys shrink as they cool or solidify and hence may create a partial vacuum within the casting which leads to casting defect known as shrinkage or void. The primary function of riser as attached with the mould is to feed molten metal to accommodate shrinkage occurring during solidification of the casting.

As shrinkage is very common casting defect in casting and hence it should be avoided by allowing molten metal to rise in riser after filling the mould cavity completely and supplying the molten metal to further feed the void occurred during solidification of the casting because of shrinkage.

Riser also permits the escape of evolved air and mould gases as the mould cavity is being filled with the molten metal.

It also indicates to the foundry man whether mould cavity has been filled completely or not. The suitable design of riser also helps to promote the directional solidification and hence helps in production of desired sound casting.

CONSIDERATIONS FOR DESIGNING RISER

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

(A) Freezing time

1. For producing sound casting, the molten metal must be fed to the mould till it solidifies completely. This can be achieved when molten metal in riser should freeze at slower rate than the casting.
2. Freezing time of molten metal should be more for risers than casting. The quantative risering analysis developed by Caine and others can be followed while designing risers.

(B) Feeding range

1. When large castings are produced in complicated size, then more than one riser are employed to feed molten metal depending upon the effective freezing range of each riser.

2. Casting should be divided into divided into different zones so that each zone can be feed by a separate riser.
3. Risers should be attached to that heavy section which generally solidifies last in the casting.
4. Riser should maintain proper temperature gradients for continuous feeding throughout freezing or solidifying.

(C) Feed Volume Capacity

1. Riser should have sufficient volume to feed the mould cavity till the solidification of the entire casting so as to compensate the volume shrinkage or contraction of the solidifying metal.
2. The metal is always kept in molten state at all the times in risers during freezing of casting. This can be achieved by using exothermic compounds and electric arc feeding arrangement. Thus it results for small riser size and high casting yield.
3. It is very important to note that volume feed capacity riser should be based upon freezing time and freezing demand. Riser system is designed using full considerations on the shape, size and the position or location of the riser in the mould.

EFFECT OF RISER

Riser size affects on heat loss from top at open risers. Top risers are expressed as a percentage of total heat lost from the rises during solidification. Risers are generally kept cylindrical. Larger the riser, greater is the percentage of heat that flows out of top.

Shape of riser may be cylindrical or cubical or of cuboids kind. If shape is cylindrical i.e. 4″ high and 4″ dia, insulated so that heat can pass only into the circumferential sand walls, with a constant K value of min./sq.ft. Chvorinov’s rule may be used to calculate the freezing time for cylinder as 13.7 min. The freezing time of a 4″ steel cube of same sand is 6.1 minutes and the freezing time of a 2″, 8″ and 8″ rectangular block is also 6.1 min.

Since the solidification time as calculated of the cylinder is nearly twice as long as that of either the block of the cube. Hence cylindrical shape is always better. Insulation and shielding of molten metal in riser also plays a good role for getting sound casting.

TYPES OF RISERS

Risers may be classified as *open risers and blind risers*. In the open riser, the upper surface is open to the atmosphere and the riser is usually placed on the top of the casting or at the parting plane. The open riser seldom extends downwards into the drag, i.e., below the parting plane. This riser, therefore, derives feeding pressure from the atmosphere and from the force of gravity on the metal contained in the riser. In case a certain thickness of metal solidifies in the upper part of the riser, atmospheric pressure no longer remains effective, rendering metal flow from the riser to the casting difficult.

The blind riser, on the other hand, is surrounded by moulding sand on all sides and is in the form of a rounded cavity in the mould placed at the side or top of the casting. It may be located either in the cope or in the drag. Since this riser is closed from all sides, atmospheric pressure is completely shut out. The pressure due to the force of gravity is also reduced due to the formation of vacuum within its body.

In some of the improved designs, a permeable dry sand core, fitted at the top of the blind riser, extends up through the cope to the atmosphere. Due to its permeable nature, air is able to enter the riser and exert some pressure. There is also less chilling effect, due to the use of dry sand core, and the solidification of the riser is slowed down, thus making it more effective.

Sometimes, artificial pressure is created in blind risers by putting some explosive substance in the riser cavity. When the substance comes in contact with the molten metal, it explodes, creating high pressure within the riser.

DIRECTIONAL SOLIDIFICATION

Directional solidification is the solidification of molten metal from the sprue to the mould cavity and then to the riser to produce a casting which is free from voids and internal cavities.

As the molten metal cools in the mould and solidifies, it contracts in volume. The contraction of the metal takes place in three stages:

(i) Liquid contraction;

(ii) Solidification contraction; and

(iii) Solid contraction.

Liquid contraction occurs when the molten metal cools from the temperature at which it is poured to the temperature at which solidification commences. Solidification contraction takes place during the time the metal changes from the liquid state to the solid, e.g., when the metal loses its latent heat. Solid contraction spans the period when the solidified metal cools from freezing temperature to room temperature.

Only the first two of these shrinkages are considered for risering purposes, since the third is accounted for by the patternmaker's contraction allowance. Of the first two types, liquid shrinkage is generally negligible but solidification contraction is substantial and should therefore be considered.

Since all the parts of the casting do not cool at the same rate, owing to varying sections and differing rates of heat loss to adjoining mould walls, some parts tend to solidify more quickly than others. This contraction phenomenon causes voids and cavities in certain regions of the casting.

These voids must be filled up with liquid metal from the portion of the casting that is still liquid and the solidification should continue progressively from the thinnest part, which solidifies, first, towards the risers, which should be the last to solidify. If the solidification takes place in this manner, the casting will be sound with neither voids nor internal shrinkage. This process is known as directional solidification, and ensuring its progress should be a constant endeavor for the production of sound castings.

In actual practice, however, it may not always be easy to fully achieve directional solidification owing to the shape and design of the casting, the type of casting process used, and such other factors. In general, directional solidification can be controlled by

- ✓ Proper design and positioning of the gating system and risers
- ✓ Inserting insulating sleeves for risers
- ✓ The use of padding to increase the thickness of certain sections of the casting
- ✓ Adding exothermic material in the risers or in the facing sand around certain portions of the castings
- ✓ Employing chills in the Moulds
- ✓ Providing blind risers

DESIGN AND POSITIONING OF RISERS

(1) *Riser Shape and Size* The most efficient shape a riser can assume is that which will lose a minimum of heat and thereby keep the metal in a molten state as long as possible. This condition can be met when the riser is spherical in shape so that its surface area is a minimum. For the same volume, the next best shape is a cylinder, and then a square. As it is difficult in practice, to mould a spherical riser, a cylinder is the best shape to employ for the general run of castings.

As regards the height of the riser, it must be tall enough to ensure that any pipe formed in it does not penetrate casting. The ratio of height to diameter usually varies from 1 : 1 to 1.5 : 1. The size of the riser, i.e., its diameter, is still largely a matter of experience. For general guidance, the empirical formulae derived by Chvorinov, Caine, etc., can also be used.

Chvorinov's rule is based on the assumption that freezing time is governed by its $(V/A)^2$ ratio, where V/A is the ratio of the volume of the casting to its surface area and is known as modulus. Chvorinov has stated that the freezing time of a casting,

$$t = \left(\frac{1}{q^2}\right)\left(\frac{V}{A}\right)^2$$

where q is a solidification constant, depending on the composition of cast metal and the positioning of the mould cavity, i.e., along a horizontal or vertical axis. For steel, it may be assumed that q = 2.09. Values of $(V/A)^2$ and freezing time for different cylinder diameters and various metals and alloys have been ascertained in actual experiments and noted in handbooks on cast metals. To determine a suitable riser diameter, the $(V/A)^2$ ratio of the given casting is computed and a riser whose $(V/A)^2$ is slightly larger than that of the casting (say 10-15% larger) is chosen.

Caine's method of evaluating riser size is based on the relative freezing time of the casting and the riser. It defines the relative freezing time to complete solidification as

$$\frac{(s \quad a \quad o \ c \quad)}{(vc \quad o \ c \quad)} : \frac{(s \quad a \quad o \ r \quad)}{(vc \quad o \ r \quad)}$$

According to Caine, if the casting solidifies very rapidly, the feeder volume need be only equal to the solidification shrinkage of the casting. On the other hand, if the feeder and casting solidify at the same rate, the feeder must be infinitely large. This signifies that hyperbolic relationship exists between relative freezing time and relative volume. The relative freezing time, X is given by

$$X = \frac{L}{Y - B} + C$$

where Y is (volume of riser/volume of casting), B is the relative contraction on freezing, and L and C are constants, depending on the metal to be cast.

<u>(2)</u> *<u>Riser Location</u>* The location of the riser should be chosen keeping in view the metal to be cast, the design of the casting, and the feasibility of directional solidification. The riser may be located either at the top of the casting or at the side. Top risering is extensively used for light metals as it enables the benefit of metallostatic pressure in the riser. Frequently, the number of users has to be more than one so as to derive its most effective use. In such cases, their spacing should be carefully arranged so as to minimize the shrinkage. The feeding range, which is the distance a riser can feed the metal in a casting, thus becomes an important consideration in riser design. It is found that the casting thickness is the main parameter affecting the feeding range. The riser diameter and the riser height have only a limited effect on it. It is usual practice to maintain a feeding range of about 4.5 times the thickness (T) for plate-type castings and 2-2.5T or $\overline{T}$ for bar-type castings. Where an exothermic riser is used, the feeding distance can be 50 - 75% more. It is advisable to reduce the diameter of the riser at the neck by about 30 - 45%. This improves the feeding range and helps in easy knocking-off of the riser from the casting. The neck area can be further reduced by using wash-burn core or exothermic material around the neck.

<u>(3)</u> *<u>Types of Risers</u>* Risers may be classified as open risers and blind risers. In the **open riser**, the upper surface is open to the atmosphere and the riser is usually placed on the top of the casting or at the parting plane. The open riser seldom extends downwards into the drag, i.e., below the parting plane. This riser, therefore, derives feeding pressure from the atmosphere and from the force of gravity on the metal contained in the riser. In case a certain thickness of metal solidifies in the upper part of the riser, atmospheric pressure no longer remains effective, rendering metal flow from the riser to the casting difficult.

The **blind riser**, on the other hand, is surrounded by moulding sand on all sides and is in the form of a rounded cavity in the mould placed at the side or top of the casting. It may be located either in the cope or in the drag. Since this riser is closed from all sides, atmospheric pressure is completely shut out. The pressure clue to the force of gravity is also reduced due to the formation of vacuum within its body. In some of the improved designs, a permeable dry sand core, fitted at the top of the blind riser, extends up through the cope to the atmosphere. Due to its permeable nature, air is able to enter the riser and exert some pressure. There is also less chilling effect, due to the use of dry sand core, and the solidification of the riser is slowed down, thus making it more effective. Sometimes, artificial pressure is created in blind risers by putting some explosive substance in the riser cavity. When the substance comes in contact with the molten metal, it explodes, creating high pressure within the riser.

<u>(4)</u> *<u>Riserless Design</u>* As the use of risers on castings decreases the yield, efforts should always be made to reduce the size of risers to the barest minimum. There are instances when risers are completely

eliminated through proper mould design, right selection of moulding materials and following correct moulding and casting techniques. For example, in SG iron casting, a riserless design can be achieved if the modulus of the casting is greater than 25 mm, pouring temperature is between 1300 and 1360°C, moulds are highly compacted, rigid, and well vented, pouring is fast, thin in-gates of maximum 15-mm thickness are used, and the iron poured is of high metallurgical quality.

(5) Use of Padding

When, despite the use of standard remedies, shrinkage is found to occur and directional solidification is not fully achieved, padding sometimes proves useful. The padding is simply extra metal added to the original uniform section of the casting. This extra metal, if not desired, can later be removed by machining.

(6) Use of Exothermic Materials

Exothermic materials serve to produce directional solidification by the generation of heat. The exothermic material may be added either to the surface of the molten metal in the riser just after pouring or to the sand in the riser walls. Due to its contact with molten metal, chemical reaction takes place, producing substantial heat. The metal in the riser thus gets superheated and remains molten for a longer time. It also forms a refractory insulating top on the riser to conserve this heat.

The exothermic material is a mixture of the oxide of the metal to be cast and aluminium metal in powder form. Each cast metal requires exothermic material which contains its own oxides. A binder-like gelatinous starch is generally used to prepare a self-made mix.

The exothermic material also serves as an insert in the mould at the desired position to help in controlling directional solidification. The material may be moulded in the form of a core by mixing it with water and then baking it. The exothermic-core is then inserted at a given location. The core retains its shape after the reaction and provides heat insulation to the metal. Another method of using exothermic material is to mix it with the facings and apply the mixture around those portions of the casting where greater heat is required. IS: 10504-1983 covers the use of exothermic feeding aids for foundry.

(7) Use of Chills

When the casting consists of both thick and thin sections, the thinner sections tend to solidify earlier than the thicker ones. This differential cooling rate produces uneven contraction of parts and gives rise to internal strains in the metal. It may even produce cracks if the cooling of thinner parts is too severe. For rapid solidification of heavy sections and the achievement of directional solidification, which ensures controlled freezing towards the riser, chills are commonly used. Chills, which may be external or internal, also help in making the metal dense, thereby avoiding internal Haws.

External Chills These are placed in the mould wall facing the cavity and become part of the same. External chills may be direct or indirect. The direct type forms a section of the mould face that comes into direct contact with the molten metal. If it is embedded behind the mould wall, so as not to have any direct contact with the molten metal, it is called an *indirect chill*. These are made in numerous shapes so that they can merge into the mould contour. External chills are made of metals such as cast iron, steel, and copper. Owing to its extreme heat conductivity and high specific heat, copper makes the most effective chill.

Internal Chills These are placed within the mould cavity and go into the casting when the metal is poured. They may be in the form of a helical spring with a straight shank. The shank is pushed into the sand wall so that the chill, in the form of a spring, projects into the mould cavity. The chills may also be in the form of a nail with a large head. The head, in this type, protrudes into the mould cavity.

The metal for internal chills should obviously be the same as the one being cast.

The chill used must be of the correct size. If a chill is oversized, the excessive chilling will tend to prevent directional solidification. On the other hand, if it is undersized, it will fail to serve its purpose. Internal chills must be thoroughly clean and free of moisture and foreign matter when placed in the mould. They are often coated with tin, copper, or zinc.

The size of the chill is determined according to the thickness of the cast portion where it is used and the chilling capacity. The latter depends on the heat conductivity of the material of the chill. Also, the greater the chill thickness, the more the chilling effect. The effect of chill thickness is, however, limited to a certain value beyond which it does not have any marked influence on the chilling effect. Effective chill thickness is given as 0.7-1.0 times the casting thickness where chill is to be applied. While designing the shape of the chill and fixing its location, care should be taken to reduce the temperature gradient between thesolidified and the solidifying metal sections so as to prevent hot tears at the edges

UNIT IV

MOULDING PROCESSES

METAL MOULD- CASTING PROCESSES

Metal mould-casting processes are different from sand casting in that the moulds, being metallic, are of a permanent nature and are used repeatedly. These metal moulds are also called dies. Unlike sand moulds, metal moulds have superior surface characteristics and can produce castings to close tolerances and with distinctive surface finish. Besides, the processes using metal moulds have been remarkably mechanized with the result that extremely high rates of production are achieved with as small as 15 seconds as cycle time.

The types of metal mould casting processes briefly discussed here are permanent mould casting; pressure die casting; low-pressure casting; squeeze casting; centrifugal casting and continuous casting.

PERMANENT MOULD OR GRAVITY DIE CASTING

This process is commonly known as permanent mould casting in U.S.A and gravity die casting in England. A permanent mould casting makes use of a mould or metallic die which is permanent. A typical permanent mould is shown in Fig. 4.1. Molten metal is poured into the mould under gravity only and no external pressure is applied to force the liquid metal into the mould cavity.

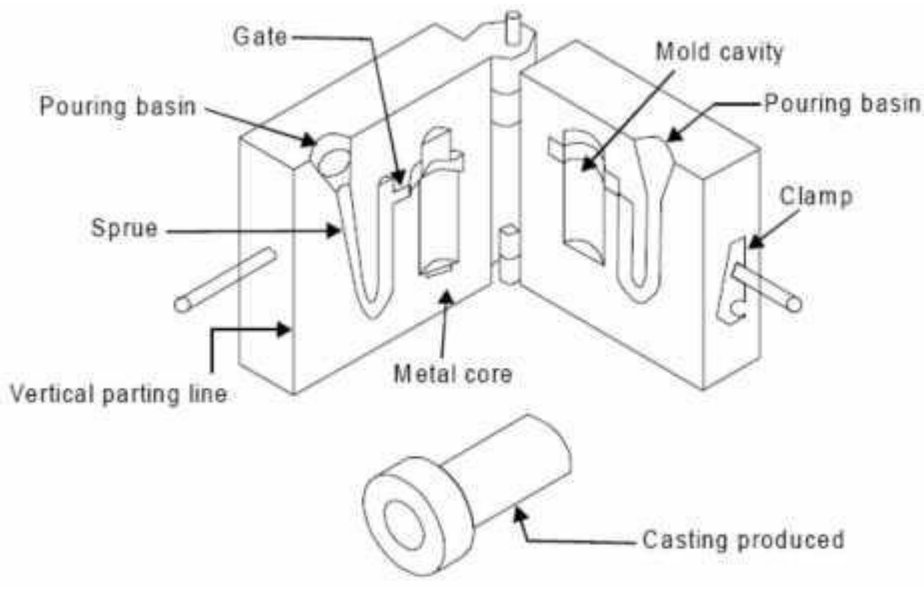


Fig. 4.1 A typical permanent mould

However, the liquid metal solidifies under pressure of metal in the risers, etc. The metallic mould can be reused many times before it is discarded or rebuilt. These moulds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mould is made in two halves in order to facilitate the removal of casting from the mould. It may be designed with a vertical parting line or with a horizontal parting line as in conventional sand moulds. The mould walls of a permanent mould have thickness from 15 mm to 50 mm. The thicker mould walls can remove greater amount of heat from the casting. For faster cooling, fins or projections may be provided on the outside of the permanent mould. This provides the desirable chilling effect. There are some advantages, disadvantages and application of this process which are given as under.

Advantages

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

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

(iii) The process is economical for mass production.

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

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

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

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

(viii) Fast rate of production can be attained.

(ix) The process requires less labor.

Disadvantages

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

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

(iii) Refractoriness of the high melting point alloys.

Applications

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

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

HIGH PRESSURE DIE CASTING

Unlike permanent mould or gravity die casting, molten metal is forced into metallic mould or die under pressure in pressure die casting. The pressure is generally created by compressed air or hydraulically means. The pressure varies from 70 to 5000 kg/cm2 and is maintained while the casting solidifies. The application of high pressure is associated with the high velocity with which the liquid metal is injected into the die to provide a unique capacity for the production of intricate components at a relatively low cost. This process is called simply die casting in USA. The die casting machine should be properly designed to hold and operate a die under pressure smoothly. There are two general types of molten metal ejection mechanisms adopted in die casting set ups which are:

(i) Hot chamber type

(a) Gooseneck or air injection management

(b) Submerged plunger management

(ii) Cold chamber type

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

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

Types of Die-Casting Machines

The machines for feeding metal into dies under pressure are

(1) hot-chamber machine;

(2) cold-chamber machine; and

(3) Air-blown or goose-neck machine.

1) ***Hot-Chamber Machine*** This machine (Fig. 4.2) has a suitable furnace for melting and holding the metal. Submerged below the surface of the molten metal, a plunger operates within a cylinder. When the plunger is raised, it uncovers an opening or port in the cylinder wall through which the metal spills into the cylinder.

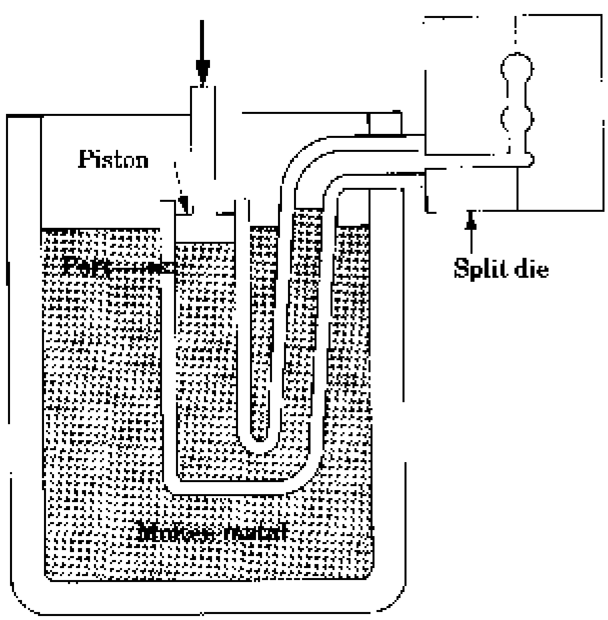


Fig. 4.2 Plunger type hot-chamber die-casting Machine

After the cylinder is filled, the plunger is forced downwards, pneumatically or hydraulically closing the opening and then forcing the confined metal up through a channel and nozzle into the die. After a predetermined time, the plunger is again raised, allowing the surplus molten metal in the channel and nozzle to drop back into the cylinder. The die is then opened and the solidified die casting ejected. Metal-injection speeds and pressures are controllable to suit different metals and casting.

Generally, these machines work at pressures below 150 kg/cm2 as higher pressures have not proved advantageous. In order to attain uniformity and maximum speed of operation, it is necessary to use a predetermined and automatically controlled cycle for various operations. The operator is however required to manually remove the casting from the die, and inspect and sometimes lubricate it.

(2) Cold-Chamber Machine The cold chamber is a horizontal steel cylinder into which molten metal is quickly introduced (Fig. 4.3). This metal is normally ladled by hand from a nearby holding furnace. After feeding the chamber with slightly more metal than is needed to fill the die, the operator pushes a button which starts an automatic-cycle. First, the plunger rapidly advances, forcing the metal into the die; after allowing sufficient time for solidification, the die is automatically opened; as the die opens, the plunger pushes out the so-called biscuit of excess metal from the cold chamber; finally, the die casting is removed. The cold-chamber machine is ideal for metals such as aluminium alloys which cannot be cast in hot-chamber machines due to the high reactivity of molten aluminium with steel. High melting temperature alloys of the non-ferrous type are also best die cast in cold-chamber machines. The pick-up of iron by aluminium in the cold chamber is negligible as the actual contact between the molten metal and the chamber and its plunger is only momentary. Pressures in cold-chamber machines range from 300 kg/cm2 to 1600 kg/cm2.

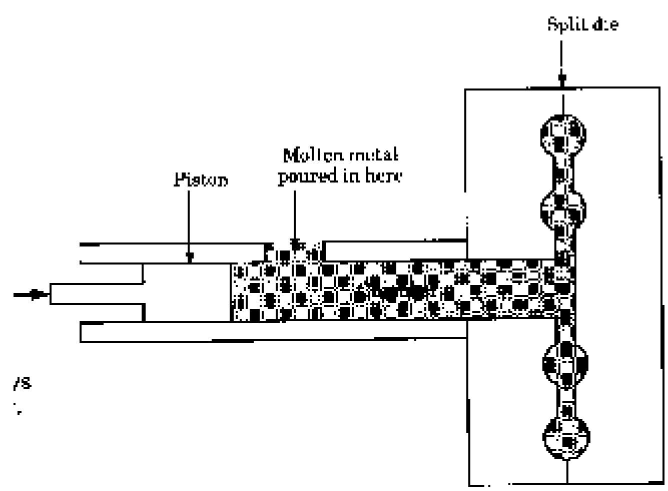


Fig. 4.3 Cold-chamber die casting machine

Modern cold-chamber machines usually provide for multiphase injection of molten metal (Fig. 4.4) to ensure complete and uniform filling of die cavity and preventing porosity in castings. Injection speeds and pressures are variable. Regulation of locking force is done automatically and ladling of metal from the furnace to the die-casting machine is also arranged mechanically to work on a closed cycle operation. Figure 4.4 shows an automatic ladle operated electro-mechanically, fitted to a cold chamber die-casting machine. All these features result in better-quality castings, maximum reliability, high production and high standards of operator safety.

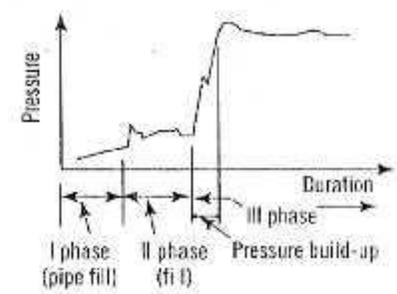


Fig. 4.4 Multi-phase injection

(3) Air-blown or Goose-neck Machine This machine differs from the hot-chamber machine in that it makes use of compressed air to force the liquid into the dies (Fig. 4.5). Since the bottle has a goose-neck shape, it can be tilted about trunnions from the air-blowing position to the filling position and vice versa. The metal can thus be simply filled into the bottle.

The air-blown machine is much simpler in operation and construction than the plunger type as it has no moving parts. However, it requires greater attention from the operator since the work is mostly manual. It is being largely replaced by the hot chamber machine which currently records a much higher rate of production and is favoured primarily because of its easy adaptability to mass production.

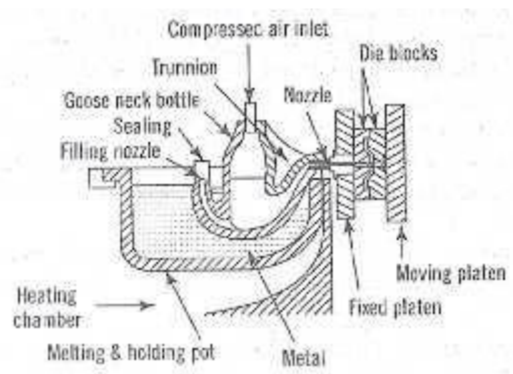


Fig. 4.5 Air-blow type die-casting machine

ADVANTAGES OF DIE CASTING OVER SAND CASTING

1) Die casting requires less floor space in comparison to sand casting.
2) It helps in providing precision dimensional control with a subsequent reduction in machining cost.
3) It provides greater improved surface finish.
4) Thin section of complex shape can be produced in die casting.
5) More true shape can be produced with close tolerance in die casting.

6) Castings produced by die casting are usually less defective.

7) It produces more sound casting than sand casting.
8) It is very quick process.
9) Its rate of production is high as much as 800 casting / hour.

S.No	Permanent Mould Castings	Die Casting
1	Permanent mould casting are less costly	Die casting dies are costly
2	It requires some more floor area in comparison to die casting	It requires less floor area.
3	It gives good surface finishing	It gives very fine surface finishing
4	It requires less skill	It requires skill in maintenance of die or mould
5	Production rate is good	Production rate is very high
6	It has high dimensional accuracies	It also have very high dimensional Accuracies
7	This is suitable for small medium sized non-ferrous	There is a limited scope of non- ferrous alloys and it is used for small sizes of Castings
8	Initial cost is high hence it is used for large production	Initial cost is also high hence used for large production
9	Several defects like stress, surface hardness may be produced due to surface chilling effect	This phenomenon may also occur in this case.

LOW-PRESSURE DIE CASTING

Low-pressure die casting has been lately developed to enable production of castings that are flawless, have very thin sections, and register a yield approaching 100% even in metals such as aluminium and magnesium. The mould, which is made in metal (usually cast iron), is filled by upward displacement of molten metal from a sealed melting pot or bath (Fig. 4.6). This displacement is effected by applying relatively low pressure of dry air (0.5-1.0 kg/mm2) on the surface of the molten metal in the bath. The pressure causes the metal to rise through a central cast iron tube and move into the die cavity. The dies are provided ample venting to allow the escape of air. The pressure is maintained till the metal is solidified; then it is released enabling the excess liquid metal to drain down the connecting tube back into the bath. Since this system of upward filling requires no runners and risers, I here is hardly any wastage of metal. As positive pressure is maintained to force the metal to fill recesses and cavities, casting with excellent surface quality, finish, and soundness are produced. Low pressure on the metal completely eliminates turbulence and air aspiration. Cores, if required, can be used in the dies: they may be of sand or shell.

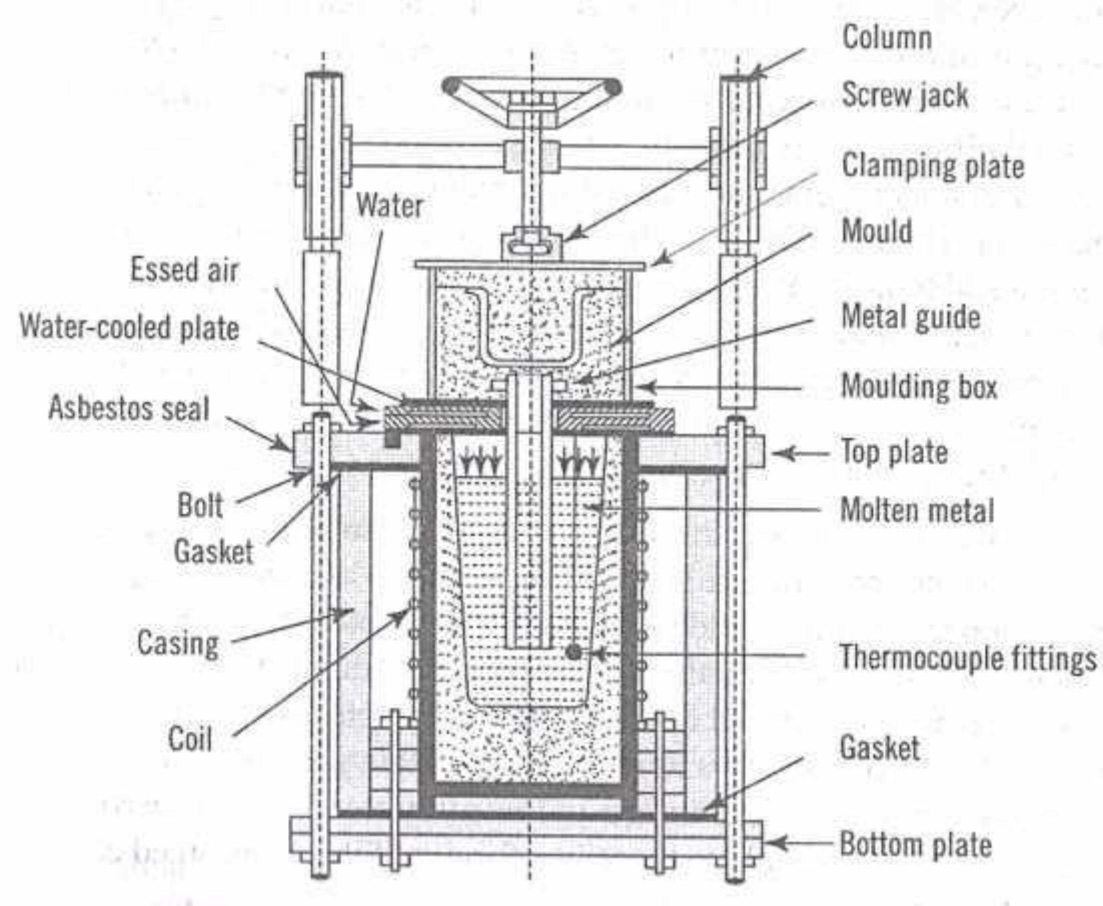


Fig. 4.6 Low-pressure die-casting machine

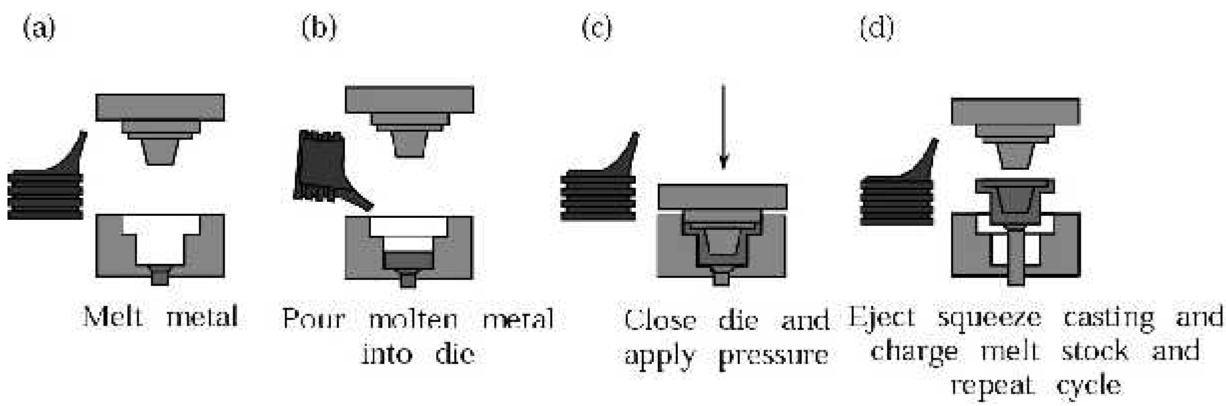
Low-pressure casting is applied in the manufacture of automobile and aircraft components, impellers for pumps, and rain-water fittings. For example, in a plant where aluminium alloy pump impellers of about 250-mm diameter are produced, a pressure of 0.75 kg/mm2 is maintained for a period of 30-45 seconds. The dies and cores are pre-heated to about 250°C before use. The holding down pressure on the dies, about 30 kg/mm2, is applied pneumatically. The cores are made in plaster. This results in castings with vanes of 1-mm thickness, a high degree of quality, accuracy, and finish, and hardly 2% rejection rate.

Low-Pressure Die-Casting Machine In case of the standard machines manufactured these days, the working of the machines is fully automated and simplified, giving accurate and reliable results. In the machine, a strong vacuum instantaneously evacuates all air from the cavities and feed channels. In about two seconds, the desired amount of molten alloy is drawn from the centre of the melt, through the transfer tube, and into the injection cylinder. The first movement of the plunger shuts off the metal flow from the feed tube to control the amount of metal ladled. The molten alloy is then smoothly injected into the air-free die cavities and high pressure is brought to bear on the freezing metal, while the vacuum remains active. After a dwell time, the die opens and the part is automatically ejected onto a shuttle tray for transfer out of the die area.

SQUEEZE CASTING

The squeeze casting process incorporates the advantage of forging or mechanical deformation into the casting process. Molten metal is poured into a die whose half parts are initially separated and then brought together to squeeze the casting while it solidifies. Simultaneously, pressure is applied from a punch in a direction lateral to the movement of the dies, thereby triggering squeeze action from all directions. The pressure is applied on to the molten metal at the precise time when the metal temperature at the interface of metal and die has reached solidus. Delay may necessitate the use of higher pressures, and premature application of pressure may produce coarse and uneven surfaces and ragged edges. Compression time should be such that complete solidification takes place without any air gap. After withdrawal from the die, the casting is cooled in hot sand.

Squeeze casting requires extremely accurate control of a number of variables, such as pressures applied, compression temperature of metal, compression time, die and punch temperature, and type of lubricant used. For any given casting and its composition, the correct values of these variables must first be decided. The process has therefore been put to restricted commercial use and laboratory investigations and research on ways to refine it are still in progress. In one case, it has been used to form forging die inserts in low alloy steel. The properties achieved have been found comparable to those in a forging. Fibre reinforced castings with SiC or Al_2O_3 fibres interspersed in metal matrix have been successfully squeeze cast and commercially used to produce automobile pistons.



Sequence of operations in the squeeze-casting process.

CENTRIFUGAL CASTING

In centrifugal casting process, molten metal is poured into a revolving mould and allowed to solidify molten metal by pressure of centrifugal force. It is employed for mass production of circular casting as the castings produced by this process are free from impurities. Due to centrifugal force, the castings produced will be of high density type and of good strength. The castings produced promote directional solidification as the colder metal (less temperature molten metal) is thrown to outside of casting and molten metal near the axis or rotation. The cylindrical parts and pipes for handling gases are most adoptable to this process. Centrifugal casting processes are mainly of three types which are discussed as under.

(1) True centrifugal casting

(2) Semi-centrifugal casting and

(3) Centrifuged casting

True Centriugal Casting

In true centrifugal casting process, the axis of rotation of mould can be horizontal, vertical or inclined. Usually it is horizontal. The most commonly articles which are produced by this process are cast iron pipes, liners, bushes and cylinder barrels. This process does not require any core. Also no gates and risers are used. Generally pipes are made by the method of the centrifugal casting. The two processes namely De Lavaud casting process and Moore casting process are commonly used in true centrifugal casting. The same are discussed as under:

De Levaud Casting Process

Fig 4.7 shows the essential components of De Levaud type true centrifugal casting process. The article produced by this process is shown in Fig 4.8. In this process, metal moulds prove to be economical when large numbers of castings are produced. This process makes use of metal mould. The process setup contains an accurately machined metal mould or die surrounded by cooling water. The machine is mounted on wheels and it can be move lengthwise on a straight on a slightly inclined track. At one end of the track there is a ladle containing proper quantities of molten metal which flows a long pouring spout initially inserted to the extremity of the mould. As pouring proceeds the rotating mould, in the casting machine is moved slowly down the track so that the metal is laid progressively along the length of the mould wall flowing a helical path. The control is being achieved by synchronizing the rate of pouring, mould travel and speed of mould rotation. After completion of pouring the machine will be at the lower end of its track with the mould that rotating continuously till the molten metal has solidified in form of a pipe. The solidified casting in form of pipe is extracted from the metal mould by inserting a pipe puller which expands as it is pulled.

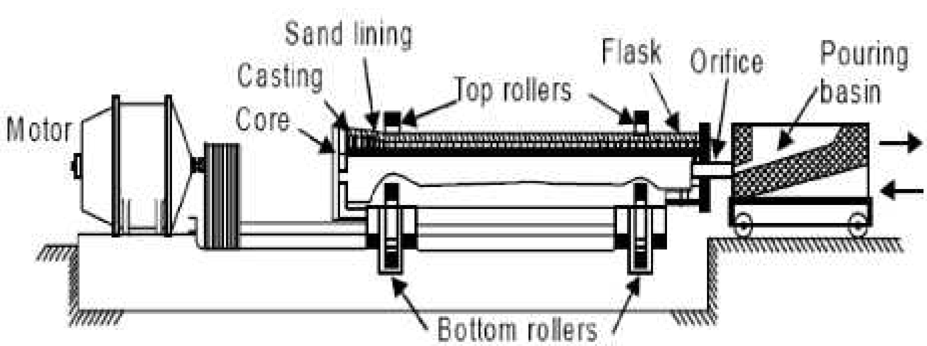


Fig. 4.7 De Levaud type true centrifugal casting process.

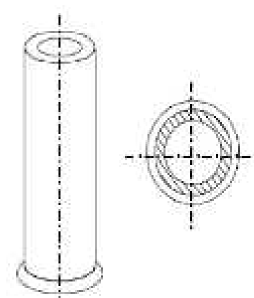


Fig. 4.8Article produced by true centrifugal casting process

Moore Casting System

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

Semi-Centrifugal Casting

It is similar to true centrifugal casting but only with a difference that a central core is used to form the inner surface. Semi- centrifugal casting setup is shown in Fig. 4.9. This casting process is generally used for articles which are more complicated than those possible in true centrifugal casting, but are axi-symmetric in nature. A particular shape of the casting is produced by mould and core and not by centrifugal force. The centrifugal force aids proper feeding and helps in producing the castings free from porosity. The article produced by this process is shown in Fig. 4.10. Symmetrical objects namely wheel having arms like flywheel, gears and back wheels are produced by this process.

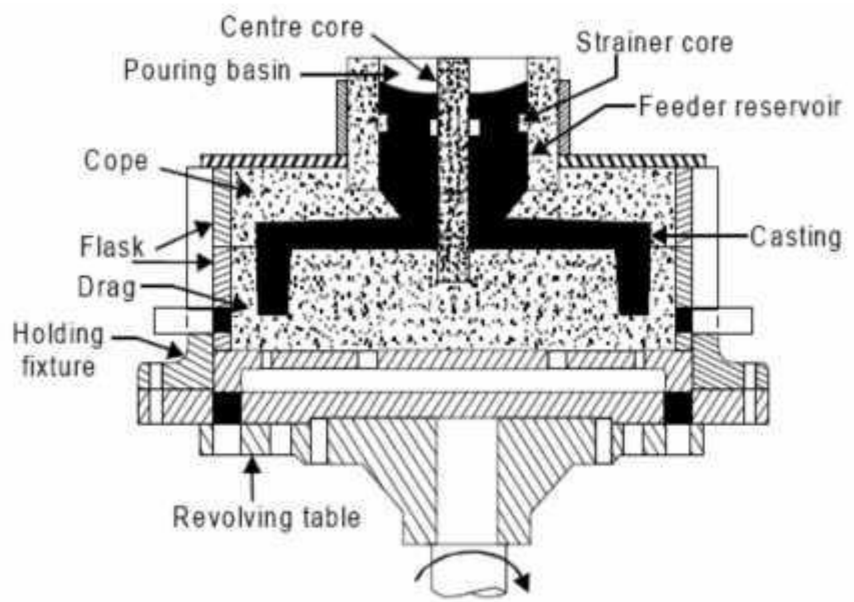


Fig. 4.9 Semi-centrifugal casting setup

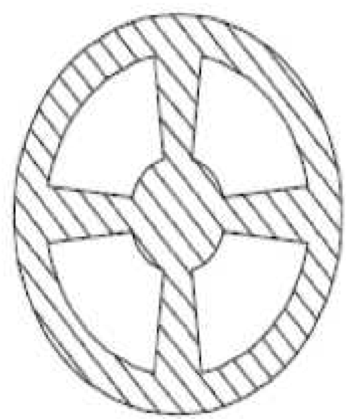
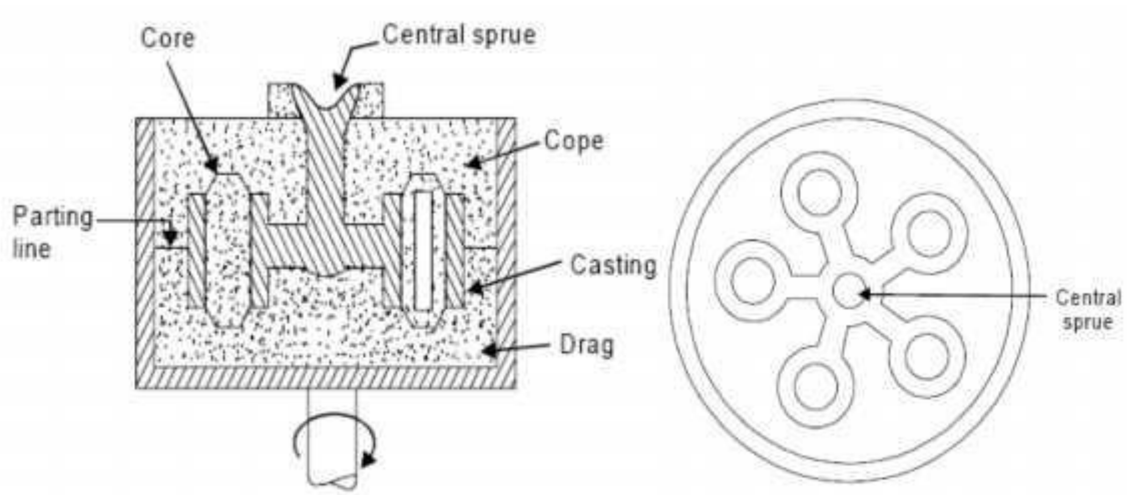


Fig. 4.10 Article produced by semicentrifugal casting process

Centrifuging Casting

zCentrifuging casting setup is shown in Fig. 4.11. This casting process is generally used for producing non-symmetrical small castings having intricate details. A number of such small jobs are joined together by means of a common radial runner with a central sprue on a table which is possible in a vertical direction of mould rotation. The sample article produced by this process is depicted in Fig. 4.12.



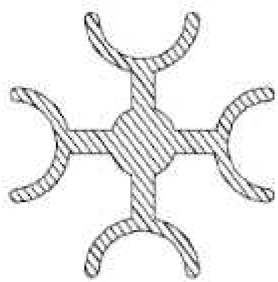


Fig. 4.11 Centrifuging casting setup

Fig. 4.12 Article produced by centrifuging casting process

CONTINOUS CASTING

In this process the molten metal is continuously poured in to a mould cavity around which a facility for quick cooling the molten metal to the point of solidification. The solidified metal is then continuously extracted from the mould at predetermined rate. This process is classified into two categories namely Asarco and Reciprocating. In reciprocating process, molten metal is poured into a holding furnace. At the bottom of this furnace, there is a valve by which the quantity of flow can be changed. The molten metal is poured into the mould at a uniform speed.

The water cooled mould is reciprocated up and down. The solidified portion of the casting is withdrawn by the rolls at a constant speed. The movement of the rolls and the reciprocating motion of the rolls are fully mechanized and properly controlled by means of cams and follower arrangements.

Advantages of Continuous Casting

(i) The process is cheaper than rolling

(ii) 100% casting yield.

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

(iv) Casting surfaces are better.

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

Applications of Continuous Casting

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

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

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

ELECTRO-SLAG CASTING

This process, developed originally in the erstwhile USSR, is based on the principle of the electro-slag welding process. It dispenses completely with the risering and gating system and also with the need for a separate melting unit, pouring ladle and transportation arrangements.

The process consists of a water-cooled iron or steel mould (C) which itself acts as a melting unit, and one or more consumable steel electrodes (E) to produced molten metal under a protective slag. Heat is produced by the passage of electric current between the electrodes and mould, through the conductive slag (D). As the temperature rises above the melting point of the electrode, it melts at the tip and flows through the basic slag into the molten metal pool (B) in the mould cavity. As the electrode gets consumed, it is continuously lowered at a controlled rate (G). Solidification takes place without any contact with the atmosphere. Besides refining action, the slag absorbs non-metallic impurities from the molten metal and protects it from atmospheric contamination. The electrode maintains a continuous pool of metal on top of the solidifying layer and therefore, feed metal is always available to guarantee a sound structure (Fig. 4.13).

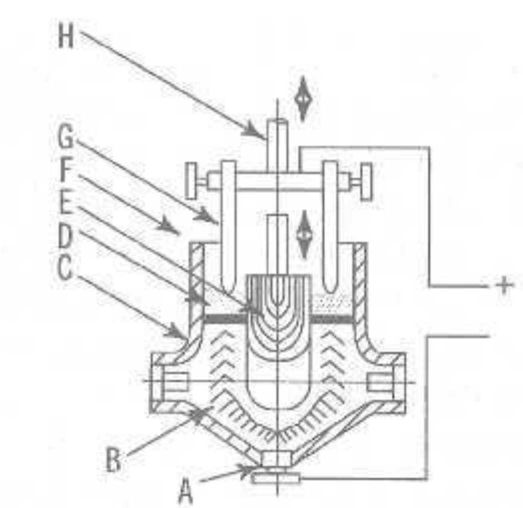


Fig. 4.13 Electro-slag Casting Process

Graphite and ceramic moulds have also been used in place of metallic ones. The transfer technique has also been adopted, in which metal is melted under cover of a protective slag in a separate chamber on the side of the mould, and molten metal flows continuously from the chamber into the mould cavity. This technique makes it possible to produce castings of complex shapes and composite forms. The typical items cast by this process are crankshafts, connecting rods, nozzles, valve bodies, high-pressure vessels, etc. There is no limit to the size and weight of castings that can be produced. The casting yield is almost 100%. However, the process is expensive owing to the high initial cost and high cost of electrodes which have first to be formed in suitable sizes and compositions.

VACUUM MOULDING

Vacuum moulding was developed a few years ago in Japan. Its main advantage is that it does away with the use of binders and moisture as sand ingredients. The mould is prepared with dry sand and the required compaction and the shape of mould cavity are obtained by using vacuum. The procedure used to prepare the mould is shown schematically in Fig. 4.14. As neither binder nor water is required in the mould, a clean environment is possible, fettling problems are eliminated, and no sand conditioning is necessary. Mould production is quite fast and moulding machines can produce 90 to 100 moulds per hour.

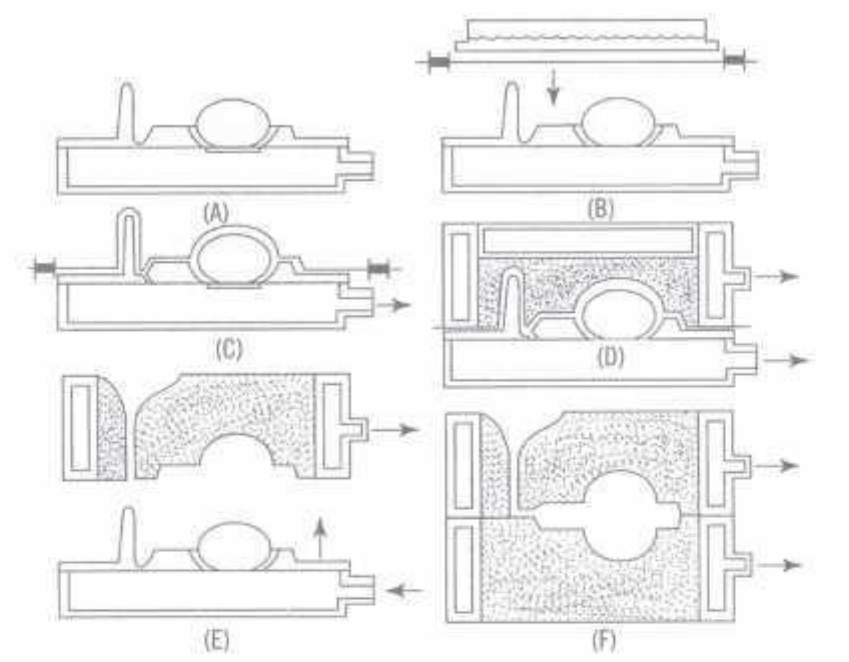


Fig. 4.14 Steps in vacuum moulding process

(A) Pattern set on hollow carrier plate.

(B) Thin plastic sheet softened by heater.

(C) Softened-sheet dropped over pattern and vacuum created in carrier plate.

(D) Double-walled flask set on pattern, flask filled with dry sand and vibrated, sprue formed, mould levelled. Sprue opening and mould top covered with plastic sheet. Vacuum applied to flask. Sand gets compacted.

(E) Vacuum in carrier plate released and mould stripped.

(F) Cope and drag moulds assembled, having plastic-lined cavity. Vacuum in flasks maintained during pouring and later, till casting solidifies. On releasing vacuum, sand drops leaving clean casting.

The process however requires special pattern plates and double-walled flasks for effecting vacuum, efficient venting system in the inner face of flasks to prevent the sand particles from being sucked by the vacuum pump, a device of stretching and heating plastic sheet and a powerful vacuum pump. Sand grains must be carefully selected for successful operation. For maximum compaction, a two screen sand (70% of 70 mesh size and 30% of 270 mesh size) is employed. A vibratory frequency of 3000 cycles per minutes is used for a few seconds to cause compaction.

PLASTICS MOULDING PROCESSES

There are various methods of producing components from the plastics materials which are supplied in the granular, powder and other forms. Various plastics moulding processes are:

1. Compression Moulding.
2. Transfer Moulding
3. Injection Moulding.
4. Extrusion Moulding
5. Blow Moulding.
6. Calendaring.
7. Thermoforming.
8. Casting

Some major processes from the above are discussed as under.

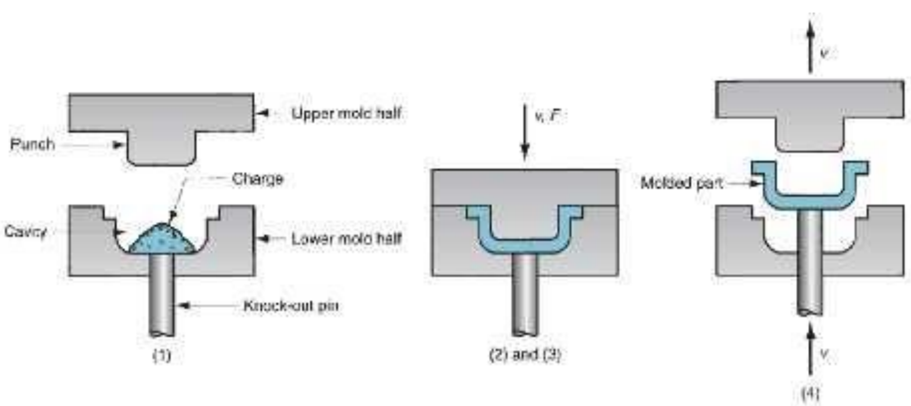
COMPRESSION MOULDING

Compression moulding is an old and widely used moulding process for thermosetting plastics. Its applications also include rubber tires and various polymer matrix composite parts. The process, illustrated in Figure 4.15 for a TS plastic, consists of (1) loading a precise amount of moulding compound, called the charge, into the bottom half of a heated mould; (2) bringing the mould halves together to compress the charge, forcing it to flow and conform to the shape of the cavity; (3) heating the charge by means of the hot mould to polymerize and cure the material into a solidified part; and (4) opening the mould halves and removing the part from the cavity.

The initial charge of moulding compound can be any of several forms, including powders or pellets, liquid, or preform. The amount of polymer must be precisely controlled to obtain repeatable consistency in the moulded product. It has become common practice to preheat the charge before its placement into the mould; this softens the polymer and shortens the production cycle time. Preheating methods include infrared heaters, convection heating in an oven, and use of a heated rotating screw in a barrel. The latter technique (borrowed from injection moulding) is also used to meter the amount of the charge.

Compression moulding presses are oriented vertically and contain two platens to which the mould halves are fastened. The presses involve either of two types of actuation: (1) upstroke of the bottom platen or (2) down stroke of the top platen, the former being the more common machine configuration. They are generally powered by a hydraulic cylinder that can be designed to provide clamping capacities up to several hundred tons.

Moulds for compression moulding are generally simpler than their injection mould counterparts. There is no sprue and runner system in a compression mould, and the process itself is generally limited to simpler part geometries because of the lower flow capabilities of the starting thermosetting materials. However, provision must be made for heating the mould, usually accomplished by electric resistance heating, steam, or hot oil circulation. Compression moulds can be classified as hand moulds, used for trial runs; semiautomatic, in which the press follows a programmed cycle but the operator manually loads and unloads the press; and automatic, which operate under a fully automatic press cycle (including automatic loading and unloading).



<u>Fig. 4.15 Compression moulding for thermosetting plastics:</u> (1) charge is loaded; (2) and (3) charge is compressed and cured; and (4) part is ejected and removed (some details omitted)

Materials for compression moulding include phenolics, melamine, urea-formaldehyde, epoxies, urethanes, and elastomers. Typical mouldings include electric plugs and sockets, pot handles, and dinnerware plates. Advantages of compression moulding in these applications include (1) moulds that are simpler and less expensive, (2) less scrap, and (3) low residual stresses in the moulded parts. A typical disadvantage is longer cycle times and therefore lower production rates than injection moulding.

TRANSFER MOULDING

In this process, a thermosetting charge is loaded into a chamber immediately ahead of the mould cavity, where it is heated; pressure is then applied to force the softened polymer to flow into the heated mould where curing occurs. There are two variants of the process, illustrated in Fig. 4.16: (a) pot transfer moulding, in which the charge is injected from a ‘‘pot’’ through a vertical sprue channel into the cavity; and (b) plunger transfer moulding, in which the charge is injected by means of a plunger from a heated well through lateral channels into the mould cavity. In both cases, scrap is produced each cycle in the form of the leftover material in the base of the well and lateral channels, called the cull. In addition, the sprue in pot transfer is scrap material. Because the polymers are thermosetting, the scrap cannot be recovered.

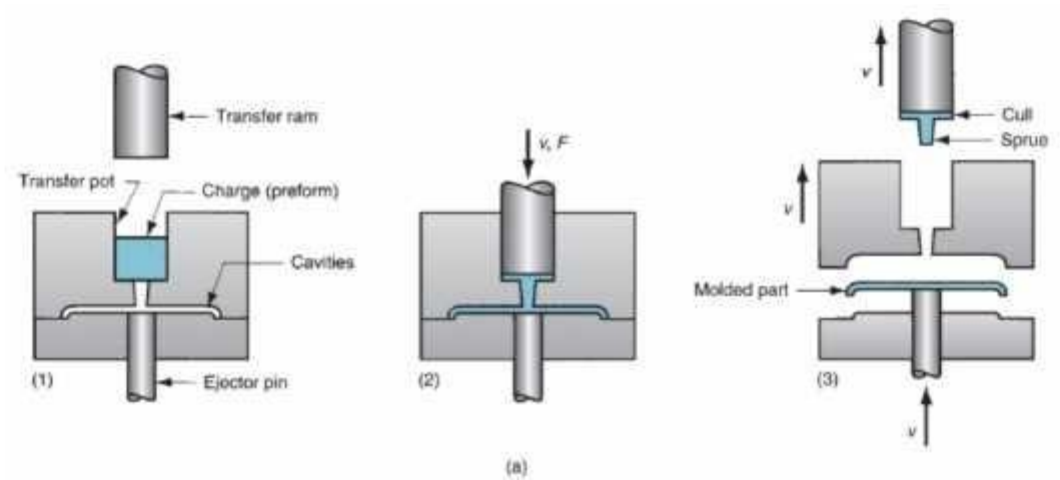
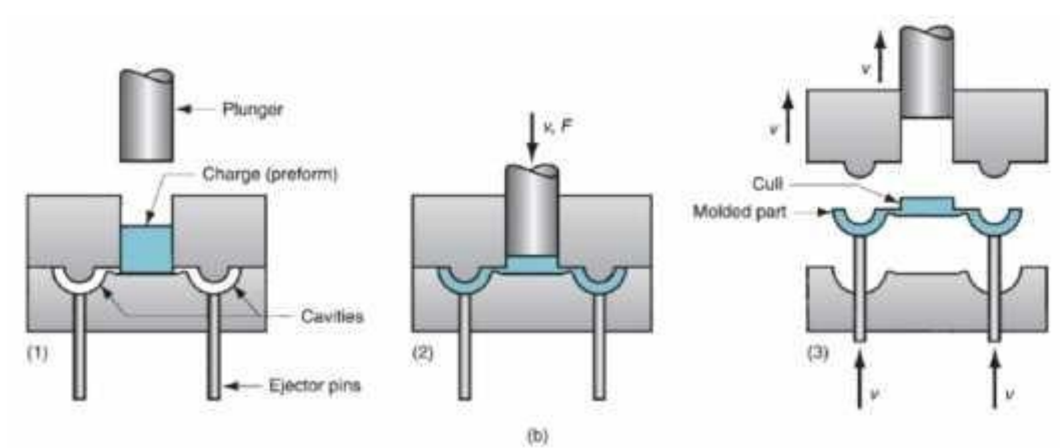


Fig. 4. 16 (a) Pot transfer moulding, and (b) plunger transfer moulding.

Cycle in both processes is: (1) charge is loaded into pot, (2) softened polymer is pressed into mould cavity and cured, and (3) part is ejected.



Transfer moulding is closely related to compression moulding, because it is used on the same polymer types (thermosets and elastomers). One can also see similarities to injection moulding, in the way the charge is preheated in a separate chamber and then injected into the mould. Transfer moulding is capable of moulding part shapes that are more intricate than compression moulding but not as intricate as injection moulding. Transfer moulding also lends itself to moulding with inserts, in which a metal or ceramic insert is placed into the cavity before injection, and the heated plastic bonds to the insert during moulding.

Injection die Moulding

In this process, thermoplastic materials soften when heated and re-harden when cooled. No chemical change takes place during heating and cooling. Fig. 4.17 illustrates the injection moulding process. The process involves granular moulding material is loaded into a hopper from where it is metered out in a heating cylinder by a feeding device. The exact amount of material is delivered to the cylinder which is required to fill the mould completely. The injection ram pushes the material into a heating cylinder and doing so pushing bushes a small amount of heated material out of other end of cylinder through the nozzle and screw bushing and into cavities of the closed mould. The metal cooled in rigid state in the mould. Then mould is opened and piece is ejected out material heating temperature is usually between 180°- 280°C. Mould is cooled in order to cool the mould articles. Automatic devices are commercially available to maintain mould temperature at required level. Injection moulding is generally limited to forming thermoplastic materials, but equipment is available for converting the machines for moulding thermosetting plastics and compounds of rubber.

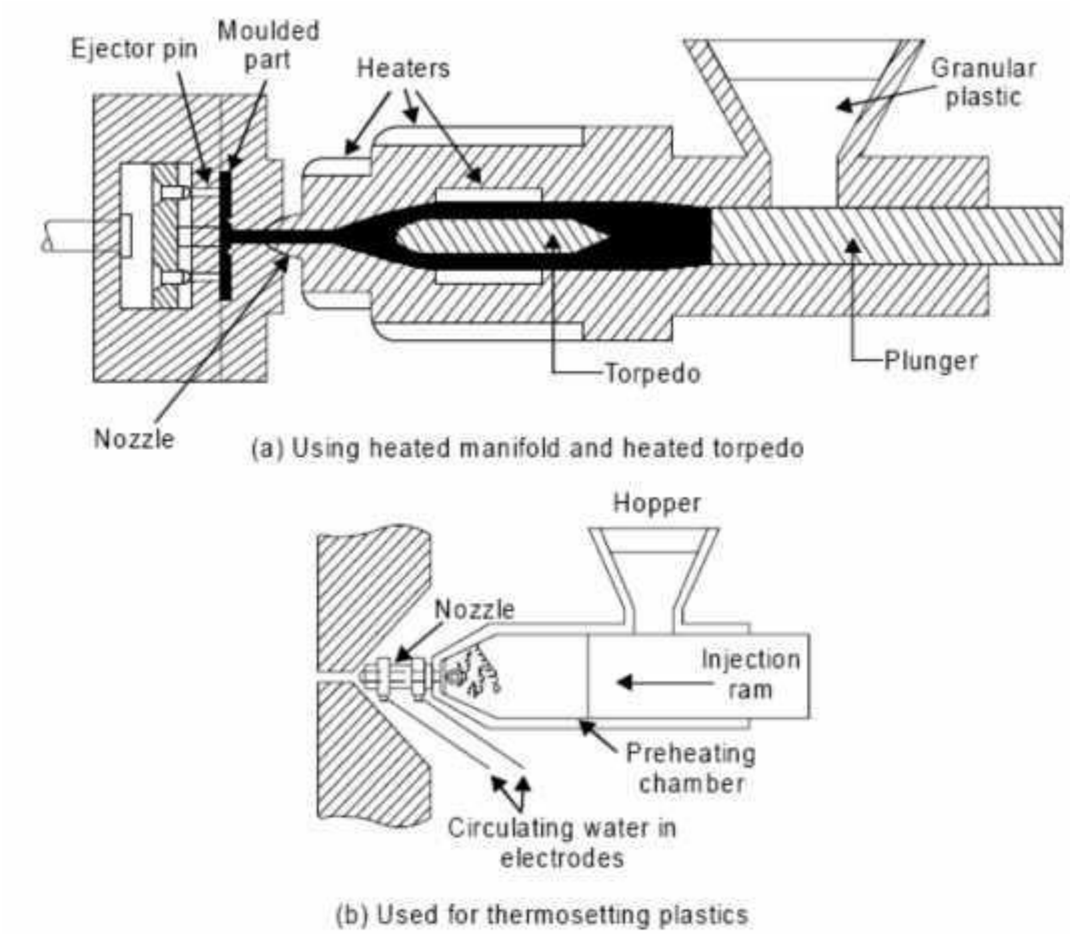


Fig. 4.17 Typical injection moulding

Extrusion Moulding

Generally all thermo plastic materials are highly suitable for extrusion in to various shapes such as rods, tubes, sheets, film, pipes and ropes. Thermosetting plastic is not suitable for extrusion moulding. In this process the powder polymer or monomer is received through hopper and is fed in to the heated chamber by a rotating screw along a cylindrical chamber. The rotating screw carries the plastic powder forward and forces it through the heated orifice of the die. As the thermoplastic powder reaches towards the die, it gets heated up and melts. It is then forced through the die opening of desired shape as shown in the sectional view of the extrusion moulding process through Fig 4.18. On leaving the product from the die, it is cooled by water or compressed air and is finally carried by a conveyor or belt. The process is continuous and involves low initial cost.

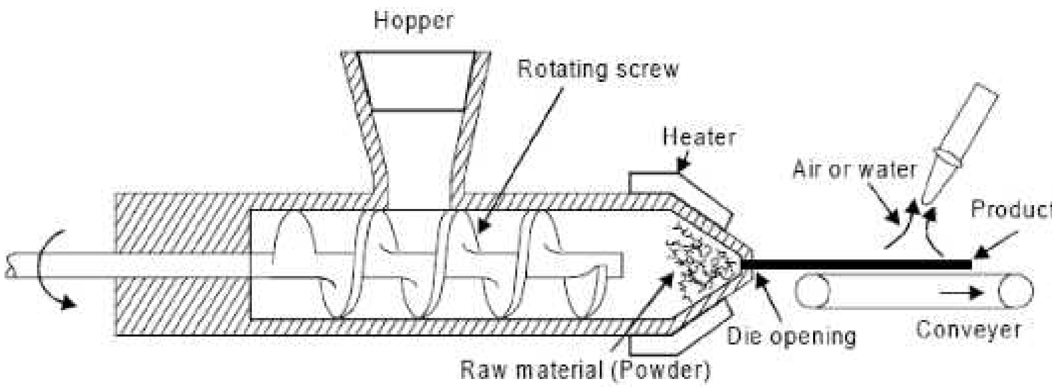


Fig. 4.18 Schematic extrusion moulding

BLOW MOULDING

Blow moulding is a moulding process in which air pressure is used to inflate soft plastic inside a mould cavity. It is an important industrial process for making one-piece hollow plastic parts with thin walls, such as bottles and similar containers. Because many of these items are used for consumer beverages for mass markets, production is typically organized for very high quantities. The technology is borrowed from the glass industry (Section 12.2.1) with which plastics compete in the disposable and recyclable bottle market.

Blow moulding is accomplished in two steps: (1) fabrication of a starting tube of molten plastic, called a parison (same as in glass-blowing); and (2) inflation of the tube to the desired final shape. Forming the parison is accomplished by either extrusion or injection moulding.

Extrusion Blow Moulding This form of blow moulding consists of the cycle illustrated in Figure 13.30. In most cases, the process is organized as a very high production operation for making plastic bottles. The sequence is automated and often integrated with downstream operations such as bottle filling and labeling. It is usually a requirement that the blown container be rigid, and rigidity depends on wall thickness among other factors. We can relate wall thickness of the blown container to the starting extruded parison [12], assuming a cylindrical shape for the final product. The effect of die swell on the parison is shown in Fig 4.19.

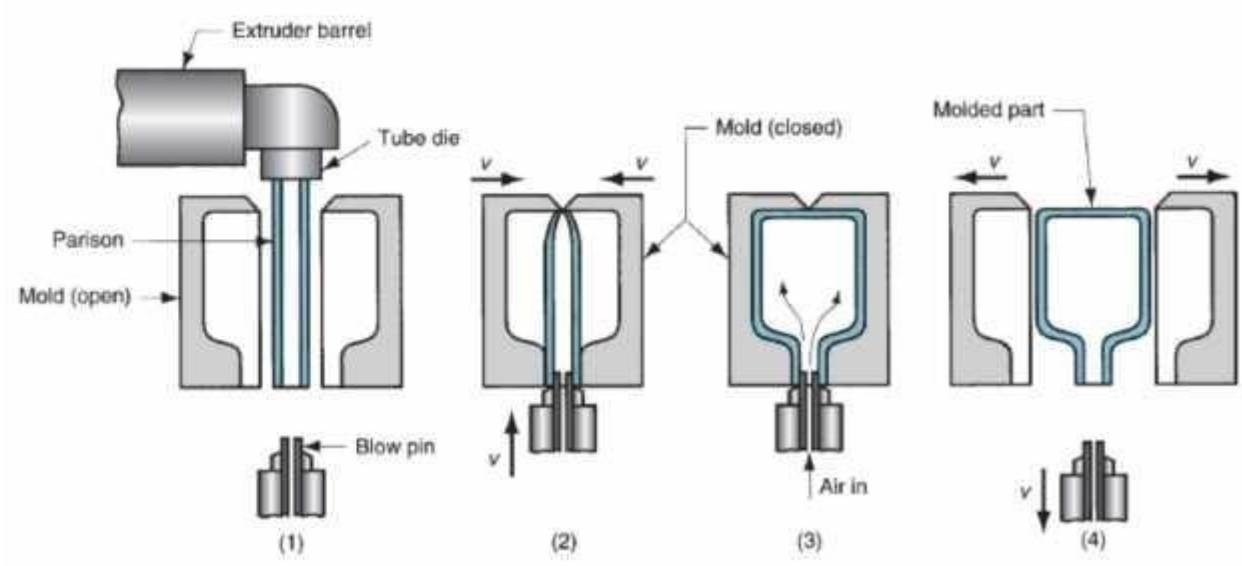
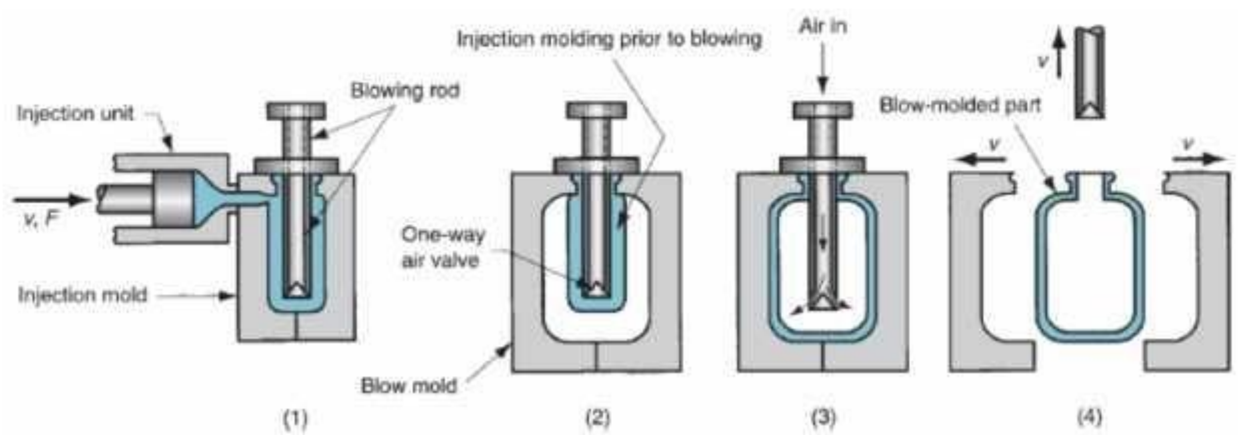


Fig. 4.19 Extrusion blow moulding: (1) extrusion of parison; (2) parison is pinched at the top and sealed at the bottom around a metal blow pin as the two halves of the mould come together; (3) the tube is inflated so that it takes the shape of the mould cavity; and (4) mould is opened to remove the solidified part.

Injection Blow Moulding In this process, the starting parison is injection moulded rather than extruded. A simplified sequence is outlined in Fig 4.20. Compared to its extrusion-based competitor, injection blow moulding usually has the following advantages: (1) higher production rate, (2) greater accuracy in the final dimensions, (3) lower scrap rates, and (4) less wasteful of material. On the other hand, larger containers can be produced with extrusion blow moulding because the mould in injection moulding is so expensive for large parisons. Also, extrusion blow moulding is technically more feasible and economical for double-layer bottles used for storing certain medicines, personal care products, and various chemical compounds.



<u>Fig. 4.20 Injection blow moulding:</u> (1) parison is injected moulded around a blowing rod; (2) injection mould is opened and parison is transferred to a blow mould; (3) soft polymer is inflated to conform to the blow mould; and (4) blow mould is opened, and blown product is removed.

Materials and Products Blow moulding is limited to thermoplastics. Polyethylene is the polymer most commonly used for blow moulding—in particular, high density and high molecular weight polyethylene (HDPE and HMWPE). In comparing their properties with those of low density PE given the requirement for stiffness in the final product, it is more economical to use these more expensive materials because the container walls can be made thinner. Other blow mouldings are made of polypropylene (PP), polyvinylchloride (PVC), and polyethylene terephthalate. Disposable containers for packaging liquid consumer goods constitute the major share of products made by blow moulding; but they are not the only products. Other items include large shipping drums (55-gal) for liquids and powders, large storage tanks (2000- gal), automotive gasoline tanks, toys, and hulls for sail boards and small boats. In the latter case, two boat hulls are made in a single blow moulding and subsequently cut into two open hulls.

UNIT V

CLEANING AND INSPECTION OF CATSING

After the casting is extracted from the mould, it is no longer fit for use as such, as it has sprue, risers, etc., attached to it. Besides, it is not completely free of sand particles. This operation of cutting off the unwanted parts, and cleaning and finishing the casting is known as fettling. The fettling operation may be divided into different stages:

(1) knocking out of dry sand cores;
(2) removal of gates and risers;
(3) extraction of fins and unwanted projections at places where the gates and risers have been removed and also elsewhere;
(4) cleaning and smoothening the surface; and
(5) Repairing castings to fill up blowholes, straightening the warped or deformed castings.

(1) **Knocking out of Dry Sand Cores** Dry sand cores may be removed by rapping or knocking with an iron bar. For quick knocking, pneumatic or hydraulic devices may be employed. These devices, besides knocking the cores, also help in cleaning and smoothening the casting.

(2) **Removal of Gates and Risers** The choice of method for removing gates and risers from the castings depends upon the size and the shape of the casting and the type of the metal. The options for such work are:

(i) knocking off or breaking with a hammer, which is particularly suited in case of grey iron castings and other brittle metals
(ii) sawing with a metal cutting saw, which may be a band saw, a circular saw, or a power hacksaw (a metal band saw of the 'do-all' type is considered suitable for steel, malleable iron, and non-ferrous castings)
(iii) flame cutting with oxyacetylene gas, generally adopted for ferrous metals, especially for large-sized castings where the risers and the gates are very heavy
(iv) using a sprue cutter for shearing of the gates
(v) employing abrasive cut-off machines, which can work with all metals but are specially designed for hard metals, which are difficult to saw or shear
(vi) plasma arc cutting, now being increasingly used to cut sprues and risers of plate-shaped castings with a view to eliminate the manual operation of burning off and to make the work fast, clean and accurate, by using a programmable robot for holding and manipulating the castings.

(3) **Removal of Fins and Unwanted Projections** The operation of removing unwanted metal fins, projections, etc., from the surface of the casting is called snagging. While snagging, care must be exercised to see that a proper casting contour is followed and too much metal is not removed.

The methods for snagging include:

1) using grinders of pedestal, bench, flexible shaft, or swing-frame type;
2) chipping with hand or pneumatic tools;
3) gouging and flame-cutting;
4) removing metal by arc-air equipment; and
5) filing.

(4) Cleaning and Smoothening Castings

In the as-cast state, castings often have sand particles adhering to their surface in a fused form. When the castings are heat-treated, a scale is also formed on the surface. In order that the casting surface be clean and smooth, the adhering sand particles and the scale have to be removed. The various methods available for this purpose are now described briefly.

1. *Tumbling* The castings to be cleaned are put in a large steel shell or barrel, which is closed at its ends by cast-iron lids. The barrel is supported on horizontal trunnions and is rotated at a speed varying from 25-50 rpm. Along with the castings, small pieces of white iron called stars are also charged to help complete the cleaning and polishing operations. When the barrel is rotated, it causes the castings to tumble over and over again, rubbing against each other. Thus, by a continuous preening action, not only do the castings get cleaned and polished but also the sharp edges and fins get eliminated and the internal stresses in the castings are relieved.
   When the barrel is charged, care should be taken to ensure that the castings are packed tight enough to prevent any breakage. At the same time, these should not be so tight as to prevent the relative motion of the adjacent pieces. The capacities of tumbling barrels (Fig. 8.1) may vary from 1-12 cu m. The limitation of this process is that heavy castings cannot be charged with small ones of fragile nature. Generally, small-sized castings, which are not fragile in nature, are best suited for tumbling.
2. *Tumbling with Hydroblast* In this method, the barrel is not horizontal bill is arranged obliquely at an angle of about 30°. One end of the barrel, which is at a higher level than the other, may be kept open to enable observation of the cleaning process. When the castings are tumbled, a high-velocity stream of water and sand is blasted on the castings at a velocity of about 6000 metres per minute. This action results in more efficient cleaning and polishing, and the tumbling time is also considerably reduced.

   The method is better adapted to non-ferrous castings since ferrous ones tend to get corroded due to water treatment. The base of the barrel is perforated to facilitate removal of the sand-and-water mixture. For large castings, hydroblasting chambers are used. The castings are placed on a slowly rotating table and a high-velocity stream is emitted from an adjustable nozzle.

3. *Cleaning with Compressed Air Impact* (Sand Blasting) A high-velocity stream of compressed air along with abrasive particles is directed by means of a blast gun against the casting surface. The blast gun

is designed to convey air at high velocity into a mixing chamber. The abrasive is fed into this chamber through a side tube by suction feed, gravity feed, or direct pressure. Generally, in the case of small guns, the abrasive is drawn in the mixing chamber due to vacuum created by the passage of high-velocity air. The abrasive used is either sand or steel grit. From the mixing chamber, air-borne sand particles are directed towards the casting. Figure 8.2 shows a complete sand-blasting arrangement which has a manually operated blast pipe.

The blasting operation is generally carried out in special cabinets or rooms where the operator directs the blast against the castings to be cleaned. The discharged sand drops through a perforated floor from where it is conveyed to the moulding shop for re-use. The room reserved for sand blasting is provided with an exhaust system for collecting the dust and suitable mechanical means for handling the castings. The small-sized castings are cleaned in cabinets equipped with windows through which the operator can manipulate the gun and direct the blast. While working, the operator must be thoroughly protected against harmful dust. He should wear large rubber gloves, protective clothing on the body, and an air-pressurized helmet.

Unlike tumbling, the sand-blasting method can be adopted for both fragile and large-sized castings. The method is also more efficient and ensures good polish.

4. *Cleaning with Mechanical Impact* (Shot Blasting) Instead of using air pressure for hurling the abrasive grit towards the casting, centrifugal force may be exerted by means of an impeller wheel. The abrasive applied in this case is steel shots. As the shots move from the hub of the impeller towards the periphery, their velocity gets accelerated and they finally leave the impeller at a very high velocity, hitting the casting surface with enormous impact. Large cleaning units may be equipped with one or more blasting impellers strategically positioned at different places all around the casting. The casting may also be mounted on a rotating table (Fig. 8.3). I n some units, the castings are tumbled and at the same time the abrasive is hurled towards them. In a monorail-type shot blast, the castings are carried by a power conveyer into the machine from one side and taken out from the other side.

(5) Repairing the Castings

Defects such as blowholes, gas holes, cracks, etc., may often occur in castings. Sometimes the castings get broken, bent, or deformed during shake-out or because of rough handling. Often the castings get, warped during heat treatment or while they cool down in the mould. Such defective castings cannot be rejected outright for reasons of economy. They are therefore repaired by suitable means and put to use unless the defects are such that they cannot be remedied. The common methods of repair are now dealt with.

(i) *Metal-Arc Welding* Large-sized cracks, blowholes, and other imperfections can be rectified by metal-arc welding. The area to be welded must first be cleaned by chipping, filing, gouging, or grinding. Then the joint must be accurately prepared and, if necessary, widened before welding is commenced. Metals that can be welded by this method include almost all cast metals, except magnesium. A proper selection of welding electrode is vital. AC metal-arc welding is most often selected for welding steel castings. The electrodes used should preferably be coated so that a dense and strong joint is produced. DC arc welding is preferred for welding cast irons and non-ferrous metals as the polarity can be changed and more heat can be obtained on either the electrode or the workpiece, as desired. DC welding can thus give lower electrode consumption, higher metal deposition rates and smoother welds. It is also less dangerous, the arc voltage used being lower than in the case of AC welding.

(ii) *Oxy-acetylene Gas Welding* This method, which is the least expensive and easily portable, is suitable where the sections to be welded are not too heavy and when- slower cooling rates are required, for instance, to prevent hardenable steels from getting hardened. Gas welding can easily allow the use of a broad flame, which can pre-heat the area ahead of the section being welded. This is not possible in arc welding. The flame temperature is also lower than that of the arc, so cooling rates are slow. The flame can be adjusted so as to make it oxidising, reducing, or neutral. An oxidising flame is used for welding brasses and bronzes, reducing flame for high carbon and alloy steels, nickel alloys, and other hard-facing materials, and a neutral flame for low carbon steels. By using the proper technique, almost all cast metals and alloys, except magnesium, can be gas welded. Liquefied petroleum gas (LPG) or natural gas is also used in place of acetylene where a broad flame is desired.

(iii) *Carbon Arc Welding* Here the electrode is not made of consumable metal but of carbon, and a separate filler rod is fed into the arc to acquire deposition. The method is suitable for all foundry alloys except magnesium and particularly suited for welding copper base and aluminium alloys.

(iv) *Inert Gas Tungsten Arc Welding* (TIG Process) This process uses a non-consumable type of tungsten electrode together with a shield of inert gas, such as helium and argon for protection of the welding zone. It is most suitable for metals that tend to get quickly oxidised, for instance, magnesium and magnesium alloys. It is also widely used for welding thin aluminium castings as also for stainless steels and alloys of copper and nickel.

(v) *Inert-Gas Metal-Arc Welding* (MIG Welding) The electrode is made of metal similar to the work metal and is of the consumable type. The method is very fast as the electrode wire is automatically fed, and the inert gas protects the metal from oxidation. The gases used are argon, nitrogen, and carbon monoxide. The method is suitable for the repair and joining of large-sized steel castings and is economical where high speed of operation is required.

(vi) *Submerged Arc Welding* In this case, the entire welding action takes place beneath a granular mineral material which acts as flux (Fig. 5.1). The electrode used is in bare form. The flow of current melts the flux, spreading it over the weld zone and keeping the arc and weld metal submerged. The metal is thus completely protected from oxidation; besides, there is no visible arc, sparks, spatter, or smoke. This enables use of heavy welding currents, high welding speeds, deeper penetration, and superior quality of welds. The method is unsuitable for repair work as it is basically a production process, but it is adopted for building up large pressure vessels or structures by welding together smaller steel castings.

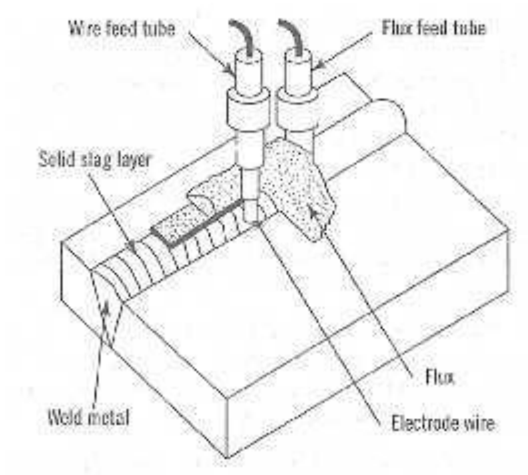


Fig. 5.1 Submerged Arc Welding

(vii) *Atomic Hydrogen Welding* A continuous stream of hydrogen is passed through the arc produced between two tungsten electrodes. Due to the heat of the arc, the gas dissociates from molecular to atomic form. When the atoms of hydrogen strike the cooler work surface, they again re-unite and emit an enormous amount of heat, thus melting the base metals that need to be joined. The heat input thus available is very high; moreover, hydrogen also acts as a shield against the action of atmospheric oxygen and nitrogen. Filler metal is fed separately from a wire. This process is ideal for the repair welding of metal moulds and dies made of alloy steels, and is also used for welding of thin castings in stainless steel, aluminium alloys, etc., It produces a very homogeneous and smooth joint with strength that equals that of the parent metal.

(viii) *Thermit Welding* The high temperature required for melting metal to fill up the joint is attained by employing an exothermic reaction. The method is more like a casting process. It entails igniting in a crucible a mixture of iron oxide and finely divided aluminium in the ratio of 3: 1 and a special powder used to ignite the mixture. Due to the heat of ignition, the mixture explodes at a temperature of about 1540°C, and pure iron with aluminium oxide as slag is produced:

$$8Al + 3Fe_30_4 \rightarrow 9Fe + 4Al_2O_3$$

The joint, crack or cavity to be filled is arranged in a sand mould with a proper gating and feeding system and the metal from the thermit crucible is poured into the mould. Pure metal occupies the space between the pieces to be joined and slag floats at the top. To enable preparation of the sand mould in one piece, wax is placed in the joint space and around, and the gating system, also in wax, is attached. The whole assembly is embedded in moulding sand and the mould inverted and heated to cause the wax to melt and flow out, leaving the cavity around the metal parts to be joined as shown in Fig. 5.2.

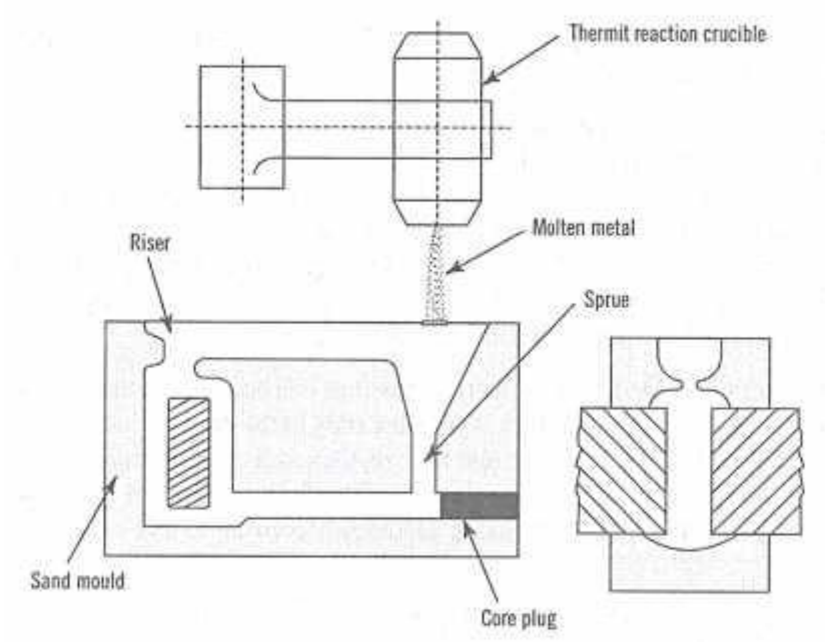


Fig. 5.2 Arrangement of thermit welding for casting repair

Thermit welding is employed for repairing large and heavy steel castings such as steel mill rolls, ship-stern frames, and gears. It is also used for the fabrication of heavy units by joining relatively simple castings. The process is simpler, less time-consuming, and cheaper than other methods and produces good strength and better quality. Also, no stress relief is necessary as the cooling is very slow and the operation itself relieves the stresses.

(ix) *Flow Welding* This entails melting the metal, in the same way as for casting purposes, and then continuously pouring the molten metal directly into the crack or cavity to be filled, till the surrounding area also starts melting. The excess metal is then removed by grinding or machining. This method is not much favoured now as easier and quicker methods of welding are available.

(x) *Braze Welding* This process is applied for such parts that tend to get distorted or cracked when welded by other means. A lower heat input is required as the base metal is not actually melted and the bond is obtained only by diffusion. A non-ferrous copper base or silver base alloy which melts at a temperature above 430°C is employed as filler metal. It is introduced in the liquid state in between the pieces that are to be joined. The method may be used to make castings watertight and to repair pipes and pipe fittings and other thin plate-type castings for filling fine cracks, crevices, porosity, etc.

(xi) *Soldering* This is similar to brazing, the difference being in the filler metal: a tin-lead alloy which melts at a much lower temperature (below 430°C) is preferred for soldering. The process serves to fill up surface imperfections when high strength is not required and porous areas in copper-base alloy castings are to be made pressure tight.

(xii) *Resin Impregnation* Where welding or brazing cannot effectively fill the porous areas of a casting, resin impregnation often admirably serves the purpose. The process entails forcing a resin to enter the pores under pressure while the casting is kept under vacuum. Resin impregnation equipment is expensive but works out worthwhile for foundries where pressure-tight castings, either ferrous or non-ferrous, are regular products. IS: 12799-1989 describes the recommended practice for impregnation of castings.

(xiii) *Epoxy Fillers* Certain epoxy plastic fillers can be used to fill up pinholes, blowholes and cracks, and to impart enough strength to the casting. For good mechanical properties, fillers are also duly charged with metal powders to suit different cast metals. These fillers are of two types, viz., general purpose and fast-curing. The latter takes hardly two hours to harden whereas the former takes longer. Smooth-on cement, which is a pasty mixture of iron filings in a hardening agent, is also widely used to repair iron castings.

(xiv) *Straightening* Deformed or warped castings can be straightened in a press by applying pressure. This operation is possible only in the case of ductile materials, such as steel, aluminium, copper, and bronze. Generally, a hydraulic press is used along with formed dies. Small castings can also be straightened by hammering manually. Both cold and hot pressing are used according to size and material of casting.

(xv) *Metal Spraying* When the casting becomes undersized, it can be built up by providing a coat of metal in the desired thickness by a metal-spraying process. This is a simple and relatively inexpensive way of forming a layer of metal on the cast surface. The sprayed metal may be either the same as the base metal or a dissimilar one. The deposited metal is taken in wire form. The spray gun uses oxygen and acetylene to melt the wire and compressed air to atomise the molten metal in the form of spray. All types of metals and alloys can be sprayed. The bond obtained is of the mechanical type with negligible diffusion. The joint between the parent metal and the sprayed metal is not as strong as that obtained by welding or brazing. This technique is also used for providing an anticorrosive metal layer on iron and steel castings. Fig. 5.3 explains the principle of metal spraying and Fig. 5.4 shows the set-up required for the process.

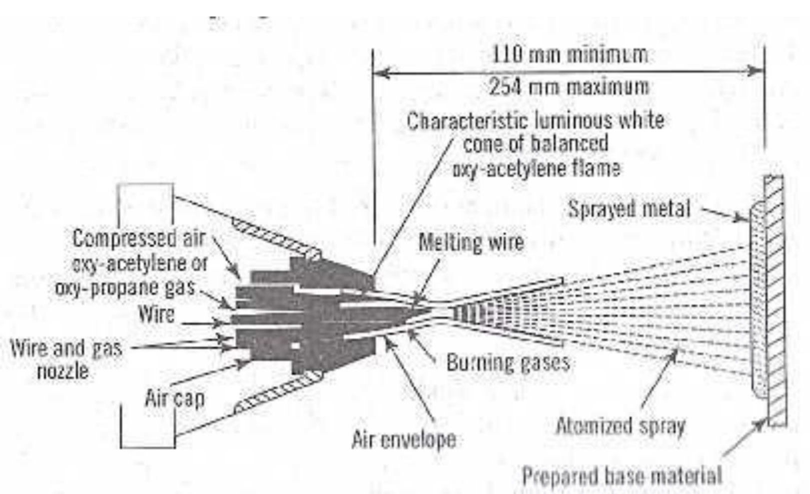


Fig. 5.3 Metal Spraying

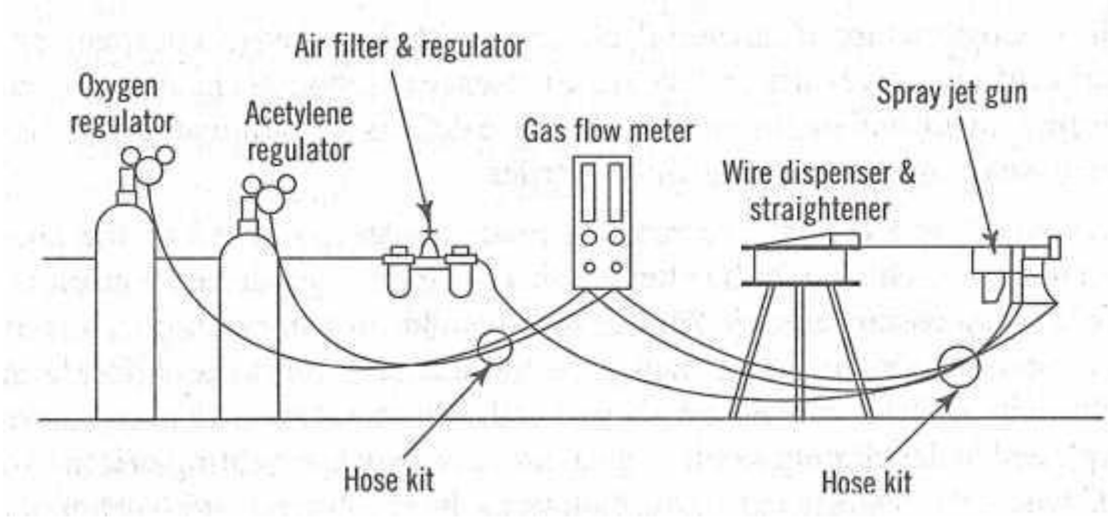


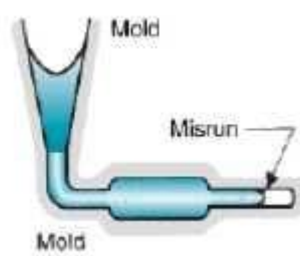
Fig. 5.4 Set-up for metal spraying

HEAT TREATMENT OF CASTINGS

Heat treatment involves the improvement of the properties of materials by bringing about certain permanent structural changes. Modern demands for high-quality castings have made heat treatment an indispensable step between the casting process and the finished product for engineering applications.

DEFECTS IN SAND CASTINGS

There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the cast product. Some defects are common to any and all casting processes. These defects are discussed below:



(1) *Misruns*: castings that solidify before completely filling the mould cavity. This occurs because of (1) low fluidity of the molten metal, (2) low pouring temperature, (3) slow pouring, (4) thinner cross-section of the mould cavity

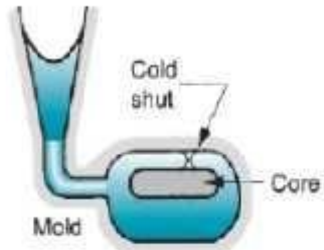
(2) *Cold Shuts*: This defect occurs when two portions of the metal flow together but no fusion occurs between them due to premature freezing. **Causes:**

a) low temperature of molten metal
b) improper gating system
c) too thin casting sections

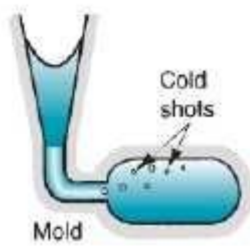
d) slow and intermitted pouring
e) improper alloy composition
f) use of damaged pattern

Remedies:

a) Smooth pouring with the help of monorail.
b) Properly transport mould during pouring.
c) Arrange proper clamping arrangement.
d) providing appropriate pouring temperature.



(3) *Cold shots*: forming of solid globules of metal that are entrapped in the casting. Proper pouring procedures and gating system designs can prevent this defect.



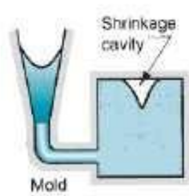
(4) *Shrinkage cavity*: cavity in the surface or an internal void in the casting, caused by solidification shrinkage that restricts the amount of molten metal present in the last region to freeze. It is sometimes called as 'pipe'. Proper riser design can solve this problem.

Causes:

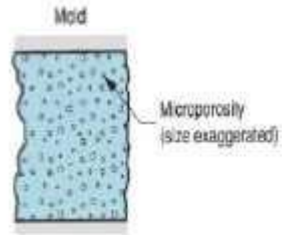
a) Inadequate and improper gating
b) Poor design of casting involving abrupt changes in thickness
c) Too high pouring temperature

Remedies:

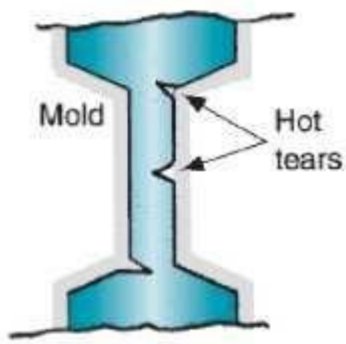
a) Use the suitable composition that is adjusted silicon and (1.80 to 2.10) or carbon equivalent (3.9 to 4.1).
b) Carry out proper ramming and maintain optimum pouring temperature and time.



(5) *Microporosity*: network of small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal.

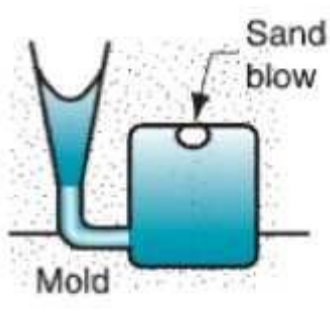


(6) *Hot tearing*, also called hot cracking, occurs when the casting is restrained from contraction by an unyielding mould during the final stages of solidification or early stages of cooling after solidification. The defect is manifested as a separation of the metal (hence, the terms tearing and cracking) at a point of high tensile stress caused by the metal's inability to shrink naturally.



Some defects are related to the use of sand moulds, and therefore they occur only in sand castings. To a lesser degree, other expendable-mould processes are also susceptible to these problems. Defects found primarily in sand castings are discussed below:

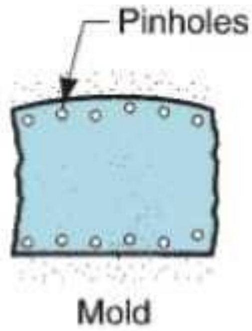
(1) Sand blow is a defect consisting of a balloon-shaped gas cavity caused by release of mould gases during pouring. It occurs at or below the casting surface near the top of the casting. Low permeability, poor venting, and high moisture content of the sand mould are the usual causes.



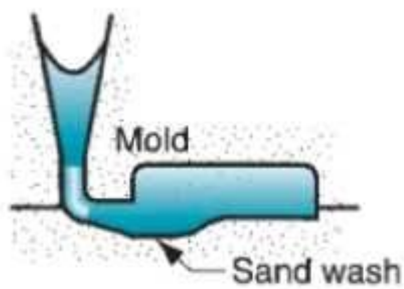
(2) Pinholes, also caused by release of gases during pouring, consist of many small gas cavities formed at or slightly below the surface of the casting.

Causes:
-sand with high moisture content.
-absorption of hydrogen/carbon monoxide gas in the metal.

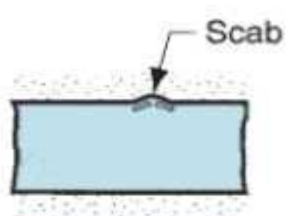
-alloy not being properly degassed.
-steel is poured from wet ladles.
-sand containing gas producing ingredients.
Remedies:
-reducing the moisture content of moulding sand.
-increasing its permeability.
-employing good melting and fluxing practices.
-improving a rapid rate of solidification.



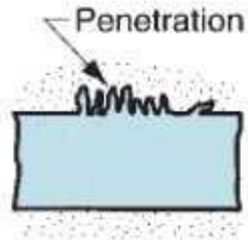
(3) Sand wash: surface dip that results from erosion of the sand mould during pouring. This contour is formed in the surface of the final cast part.



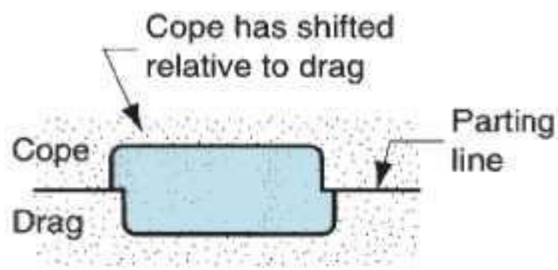
(4) Scab: It is caused by portions of the mould surface flaking off during solidification and gets embedded in the casting surface.



(5) Penetration: surface defect that occurs when the liquid penetrates into the sand mould as the fluidity of liquid metal is high, After solidifying, the casting surface consists of a mixture of sand and metal. Harder ramming of sand mould minimize this defect.

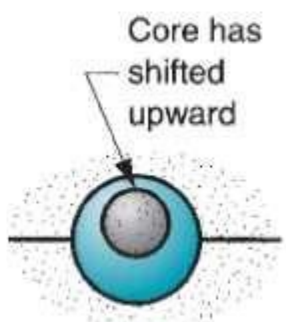


(6) Mould shift: defect caused by displacement of the mould cope in sideward direction relative to the drag. This results in a step in the cast product at the parting line.

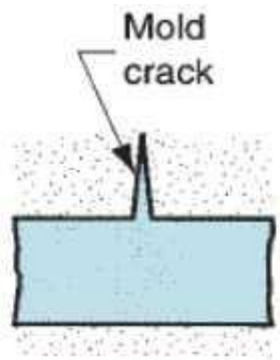


Causes:
-worn dowel in patterns made in halves.
-improper alignment of mould boxes due to worn out/ill fitting mould boxes.
Remedies:
- Properly arrange box warpage.
- Properly move boxes with pins.
- Properly clamp the boxes.

(7) Core shift: displacement of core vertically. Core shift and mould shift are caused by buoyancy of the molten metal.



(8) Mould crack: ‘fin’ like defect in cast part that occurs when mould strength is very less, and a crack develops, through which liquid metal can seep.



INSPECTION AND TESTING OF CASTINGS

Two basic objectives of inspection are (i) to reject castings that fail to meet the customer's requirements, and (ii) to serve as a means of maintaining the quality of workmanship and materials used in the foundry. Inspection of castings broadly covers a large number of methods and techniques used to check the quality of castings. These methods may be classified into five categories:

1. visual inspection;
2. dimensional inspection;
3. mechanical and chemical testing;
4. flaw detection by non-destructive methods; and
5. Metallurgical inspection.

VISUAL INSPECTION

All castings are subjected to a visual inspection to ensure that the surfaces fulfil the requirements of both the customer and the producer. Visible defects that can be detected provide a means for discovering errors in the pattern equipment or in the moulding and casting process. Most of the defects can be discerned by careful visual examination. Visual examination may prove inadequate only in the detection of sub-surface or internal defects in which case more sophisticated methods may be necessary.

DIMENSIONAL INSPECTION

Dimensional control is usually required for all types of castings. Sometimes it is not so critical but at other times it may be vital. When precision castings are produced by processes such as investment casting, shell moulding and die casting, dimensions need to be closely checked. Initially, when the castings are made from a new pattern, a few sample castings are first made which are carefully checked with the drawings to ensure that the sizes obtained conform to those specified and will be maintained within the prescribed tolerances in the lot under production. On testing of the sample lot, deviations from the blueprint are rectified on the pattern equipment. When the castings are found to be consistently within the tolerances, spot checks, together with a regular check of the patterns and dies being used, may be sufficient. In the case of the jobbing type of foundry, each casting produced may be different and, therefore, according to the customer's requirements, each one may have to be thoroughly inspected for dimensional variations.

Dimensional inspection of castings may be conducted by various methods:

(i) *Standard Measuring Instruments* to Check the Sizes Instruments such as rule, vernier calipers, vernier height gauge, vernier depth gauge, micrometers, scribing block, combination set, straight edge, squares, spirit level, and dial indicator are commonly used. For high precision castings or after machining, more advanced measuring instruments, such as auto-collimator, comparator, ultrasonic instruments for measuring wall thickness and projection instruments are also required.

(ii) *Templates and Contour Gauges* for the Checking of Profiles, Curves, and Intricate Shapes Templates act as time-saving aids in measurement and facilitate the entire job. These can be easily prepared in mild steel or brass sheet by marking out, and cutting and finishing the profile that is required to be checked on the castings.

(iii) *Limit Gauges* For toleranced dimensions on casting produced on a repetitive basis, limit gauges are usually used. The type of limit gauges—plug, ring, snap, plate—depends on the shape of the parameter to be checked. Periodical checking and maintenance of limit gauges is very important.

(iv) *Special Fixtures* Special fixtures are required to be designed and used where dimensions cannot be conveniently checked by using instruments, for instance, during the checking of locations, relative dimensions, centre-to-centre distance, angularity of surfaces, and so on.

(v) *Coordinate Measuring and Marking Machine (CMM)* This machine is very useful for measurement and inspection of uneven, undulated, irregular, or curved surfaces which cannot be conveniently or accurately checked by other measuring tools or instruments. The accuracy of measurement of these machine ranges from 0.001 mm to 0.05 mm. Besides measuring, it can be used for marking purposes also in all three dimensions on metallic or non-metallic surfaces. Measurement and marking are accomplished easily without errors in reading in all three dimensions. Once the machine is set, all measurements can be carried out in a programmed sequence automatically. The machine in reality is a multi-axial device providing measurement of output of position and displacement sequentially without a need for changing tools.

The machine essentially consists of a touch probe, usually having a ruby tip, which is mounted on a horizontally sliding arm, movable vertically along a column. The column is fixed to a base which in turn is held on a large accurately machined granite surface plate and is movable in a direction perpendicular to the direction of the movement of arm. Thus, the probe is capable of being moved along all three axes for carrying out measurement of different surfaces of a workpiece. The sliding movements of the arm and column are performed with great precision and are read on an electronic digital read-out unit, attached to the machine. When marking is to be done on surfaces, a scriber is used in place of a probe. A larger variety of probes, scribers and other accessories are available to enable the machine to be highly flexible and accurate in operation. The movements along the three axes may be manual or motorised. The machine can be further equipped with a small computer system for processing the data obtained from measurement and for storing and retrieving the same.

A special software is also available with the computer so that measurement and inspection of different types of surfaces can be carried out automatically without the need for manual control. The drawing data from CAD station can be also transmitted to this machine by interlinking the two systems with the actual value of dimensions. A printer can also be provided with the computer for producing a hard copy of the inspection report. The CMM machines are now getting increasingly popular in inspection departments attached to tool rooms, pattern and die shops, foundry and forging shops, press shops, welding and structural shops and plastic and glass-part manufacturing units.

MECHANICAL AND CHEMICAL TESTING

All foundries should have facilities for determining the mechanical properties of a cast metal and its chemical composition. Mechanical testing methods include certain procedures which require a standard type of equipment. These are:

(i) tensile test to determine the tensile strength, yield strength, percentage elongation, and percentage reduction in area,

(ii) bend, notch bend, and impact transverse tests to evaluate the ductility and resistance to shock of the cast metal;

(iii) hardness test, which can indicate the strength and ductility of the metal (often, only hardness testing is conducted with visual inspection. Other tests are used only when so required);

(iv) fatigue test, applied in cases where an appraisal of the life of the casting in service is to be known; and

(v) tests for damping capacity and wear resistance.

Chemical testing is required to determine allowable limits. In the case of ferrous castings, it is necessary to know the percentage of carbon, silicon, sulphur, manganese, and phosphorus contents. The presence of alloying elements or metallic inclusions, such as Cr, Ni, Cu, Mg, W, V, Mo and Co, may also have to be determined. Chemical analysis can be used in all such cases to accurately ascertain the composition, though certain tests may be too cumbersome and time-consuming.

In many instances, it is necessary to quickly determine the content of carbon, silicon, and sulphur. This may also have to be regularly checked where a close control of the composition of metal is consistently required. Certain quick tests have been developed for such cases. One such test, commonly used in the case of grey iron, malleable iron, and ductile iron, is called *Carbon Equivalent Measurement.*

Carbon equivalent (CE) is given by

$$\text{Total carbon}\,\% + \frac{1}{3}\,S\ \%$$

Since silicon has a predominant effect on the graphitising tendency of iron, the cumulative effect of carbon and silicon can indicate the strength characteristics of the iron produced. For shop floor use, a measuring instrument, known as 'instant carbon sensor' that quickly assesses CE. is available. It works on the principle that CE is directly related to the liquidus arrest temperature of the metal. The instrument is equipped to hold molten metal in a small reservoir over a chromel-alumel thermocouple and the temperature of the metal, as it solidifies in the reservoir, is registered on the chart of the temperature recorder. From this chart the liquidus arrest temperature can be easily determined. A conversion table (Table 7.3) is available for arriving at CE corresponding to the determined value of liquidus temperature.

Similarly, for rapid determination of silicon in cast iron, a special apparatus called the *Strohlein thermoelectrometer* is available. It is equipped to measure the thermal emf produced when a junction between the metal whose silicon is to be determined and another metal, such as copper, is heated. The thermal effect depends on the actual metals involved and on the temperature difference between the junction and the cold ends. Silicon possesses a special position in the thermoelectric series and it is possible to determine its content by means of empirical calibration curves. The equipment is so designed that constant operating conditions are maintained at all times. Calibration curves are first prepared by using samples of known silicon content. The metal under test is then taken in the form of shavings and kept between two anvils on the apparatus. One of the anvils is heated by circulating a thermostatic liquid through it and the thermal emf generated due to the heating of a dissimilar junction is measured on a transistorised micro-voltmeter. From the calibration curves, the percentage of silicon is determined from the emf value.

Conversion table for liquids temperature to carbon equivalent

LIQUIDUS TEMPERATURE	*CARBON EQUIVALENT*
2250	3.60
2230	3.70
2210	3.80
2190	3.90
2170	4.00
2150	4.10
2130	4.20
2110	4.30

Chemical analysis, though the most accurate and reliable method, takes a long time. When metal is melted and refined in an electric furnace, the composition needs to be quickly determined, so that alloys can be added to adjust the constituents to the desired proportions. In such cases, chemical analysis is not suitable.

More rapid methods are available not only for CE or silicon, as mentioned earlier, but also for most of the other elements, which may be present in the metal even in traces. These methods are based on the principles of spectroscopy. Spectroscopic analysis is gaining popularity in foundries for quick determination of the constituent elements including the trace elements. Various types of spectroscopic analyzers are available, the selection depending on the nature of requirements in terms of the elements to be checked, the accuracy desired, the frequency at which tests are to be conducted, and the type of cast metal.

A microprocessor-based system operating on the principle of thermal analysis is also available for quick determination of carbon equivalent, total carbon, silicon and temperature of molten metal. It can be used for various cast metals like grey iron, malleable iron, SG iron, steel and copper-base alloys. The instrument is equipped with a digital display. A print-out is also obtained for permanent record. It has a high degree of accuracy, e.g., within ± 0.05% for carbon equivalent and total carbon and within ± 0.15% for silicon.

FLAW DETECTION BY NON-DESTRUCTIVE METHODS

Non-destructive tests are also required to be conducted in foundries to examine the castings for any sub-surface or internal defects, surface defects, which cannot be detected by visual examination and for overall soundness or pressure tightness, which may be required in service. These tests are valuable not only in detecting but even in locating the casting defects present in the interior of the casting, which could impair the performance of the machine member when placed in service. Parts may also be examined in service, permitting their replacement before the actual failure or breakdown occurs.

The important non-destructive test for castings include:

1. sound or percussion test (stethoscope test);
2. impact test;
3. pressure test;
4. radiographic examination;
5. magnetic particle inspection;
6. electrical conductivity test;
7. fluorescent dye-penetrant inspection;
8. ultrasonic test; and
9. Eddy current test.

1. *Sound or Percussion Test* (Stethoscope Test): This is an old method, which has been refined over the years. Basically, it entails suitably supporting the suspension of the part by chains or other equipment, permitting the part to swing free of the floor and other obstructions, and then tapping it with a hammer. The weight of the hammer blows is so adjusted that vibrations will be set up in the casting producing a certain characteristic tone which may or may not change the wavelength of sound produced by the blows.

The stethoscope test serves to detect relatively large discontinuities in an otherwise homogeneous metal and may be successful when applied to simple shapes and uniform cross sections. The drawback of the method is that it is difficult to judge the extent of the defect and to locate the fault.

2. *Impact Test* This test may be destructive or non-destructive in nature, depending on the quality of casting. Moreover, it cannot be used in all cases as it can damage the casting.

A hammer of appropriate size is used to strike or fall on certain members of the casting where the defect is suspected. It is expected that the casting containing harmful defects will break and will thus be automatically rejected whereas those that are faultless will stand the test.

A variation of this method involves dropping the casting from a specified height onto a steel base. Obviously, the method of testing is not very reliable and sometimes even the defect-free castings may break. This method is therefore sparingly used these days.

3. *Pressure Test* This method is employed to locate leaks and to test overall strength of certain parts, such as cylinders, valves, pipes, and fittings, which are required to hold or carry fluids in service under various amounts of pressure. The fluid used in testing may be water, air, or steam. Water being incompressible is generally preferred since danger is minimized even if the casting should shatter due to pressure. The pressure may vary from one and a half times to two times the working pressure. For safety reasons, the pressure is generally applied by means of a small hand pump. A leak, even if it is not located immediately, may be detected on the pressure gauge. Steam tests have the advantage that steam can press through smaller holes or openings through which water may not readily pass. Besides, the heat of the steam also causes minute cracks to widen due to expansion. While testing pneumatically, the casting is immersed in a tank carrying water and then the air pressure is applied. If there is a leak, air bubbles are formed.

4. *Radiographic Examination* Radiography is a non-destructive test for detection of internal voids in castings. Electromagnetic waves having low wavelengths (varying between 10-6 and 10~10 cm) are used as a means of inspection. These waves, generally called X-rays, have properties similar to those of light waves, but they have much shorter wavelengths, which lie outside the range of human sensitivity. These X-rays can, however, be detected by a sensitive photographic film. Owing to their shorter wavelengths, these waves can penetrate materials that are normally opaque to light. The denser the material, the shorter the wavelength required to penetrate it. The test can be applied to all grades of iron and steel castings, though it is an expensive method of inspection.

The X-rays are produced by an X-ray tube which carries two sealed copper elements, the cathode and the anode. The cathode bears an electrically heated filament which generates electrons; when these electrons strike the tungsten target fixed to the anode they are driven towards the positively charged anode. The striking of the electrons causes their kinetic energy to be partly converted into heat, which is conducted away through the cooling fins provided on the anode and the remainder of the energy is converted into electromagnetic waves, termed X-rays. The X-rays pass out of the tube through a window in the form of a beam. The intensity of these X-rays is controlled by regulating the current passing through the filament. Similarly, the wavelength of the ray is inversely proportional to the voltage applied between the two poles. The shorter the wavelength, the greater the depth of penetration.

If there is a cavity or a hole in the casting under inspection, and, when such a casting is kept against the X-rays, the rays finding less obstruction penetrate more freely than at the place where the metal is more dense and solid. The rays that penetrate and emerge from the casting are absorbed by a photographic plate. Thus the part of the photographic plate opposite the defect will receive more rays and will be more exposed than the rest of the plate. This will produce a contrasting image on the negative. For more accurate results, special films with an emulsion coating are found suitable. Sometimes, in place of a photographic plate, fluoroscopic screens are used; these screens are made of materials that fluoresce when exposed to X-rays in a dark room. To protect the viewer from continuous exposure to the rays, the image of the screen is observed in a mirror, which is so placed that observer is located out of the path of the X-rays. The voltages required for the X-ray machines depend on the density of the metal and its section thickness.

Like X-rays, gamma rays which are emitted during the decomposition of radium, are also suitable for the inspection of castings. The wavelengths of these rays range between 10~75 and 10~105 cm and since these are shorter than X-rays they can penetrate metals more easily. Due to their high penetrating power, the radiation absorbed by the photographic film is negligible and the remainder passes through the film. Further, the difficulty experienced during the observation of thick and thin sections simultaneously is also less than when using X-rays. But due to the high cost of radium and the need for expensive protective equipment, the technique is used to a limited extent.

Radiography does not enable detection of cracks. The position of defects in the section also cannot be easily defined unless special techniques are employed. Interpretation of radiographs depends on a subjective assessment and hence requires proficiency in the work along with experience. Castings which have passed the radiography test may still not be entirely leak-proof. Recommended radiations and their sources are given in Table.

Recommended radiations and their sources

	Radiation	Iron thickness	Exposure
X-rays	100 kV	< 12	
	200 kV	12-40	1-10 min
	400 kV	40-90	
	1000 kV	50-150	
	20,000 kV	60-250	
Y-rays	Cobalt 60	40-100	
	Iridium 192	12-100	3-6 **h**

	Cesium 137	20-200	

5. *Magnetic Particle Inspection* This test is used to reveal the location of cracks that extend to the surface of iron or steel castings, which are magnetic in nature. The casting is first magnetised and then iron particles are sprinkled all over the path of the magnetic field. The particles align themselves in the direction of the lines of force. Their distribution is also in proportion to the strength of the magnetic field. In the case of a faultless casting, particles will be distributed uniformly all over the surface, whereas if a defect exists, the iron particles will jumble round the defect. The reason is that a discontinuity in the casting causes the lines of force to bypass the discontinuity and to concentrate around the extremities of the defect. By studying the concentration of the particles, the depth at which the defect occurs can also be judged. However, considerable experience is necessary for an accurate estimation of the defects. With correct test procedure, cracks longer than 1 mm and a fraction of a millimetre deep can be detected.

Generally, a casting can be magnetised by passing an electric current through it. The current may be either alternating or direct. An alternating current is used when high surface sensitivity is desired, and the direct current is preferred where defects are to be located beneath the surface. Other methods for magnetizing castings include positioning the casting between two magnetic poles or placing the casting in a coil carrying a direct current.

Iron particles may be applied either dry with a handshaker or bulb blower or in wet form by spraying or pouring over the surface. When wet, the particles are carried in suspension form in liquid, for instance, kerosene, gasoline, or carbon tetrachloride. After testing, casting remains magnetised unless subjected to demagnetisation.

(6) *Electrical Conductivity Method* In this method, current is passed through the casting and read on an ammeter. If the casting has imperfections, there is a resistance to the flow of current and this is evident by a drop in the reading. The method is difficult to apply in practice owing to variations in sectional thickness, size and metallurgical structure; also it cannot be used directly unless a suitable standard is developed for a given lot of castings.

(7) *Fluorescent Dye-Penetrant Inspection* Penetrant testing helps to direct small surface cracks in castings, which cannot be observed with the naked eye. Although this method shows up the finest surface defects in a magnified form, interior defects, where the penetrant does not reach, cannot be revealed.

The method is very simple and can be applied to all cast metals. It entails applying a thin penetrating oil-base dye to the surface of the casting and allowing it to stand for some time so that the oil passes into the cracks by means of capillary action. The oil is then thoroughly wiped and cleaned from the surface. If the casting under inspection has any surface cracks, the oil will remain in these cracks and will tend to seep out. To detect the defects, the casting is painted with a coat of whitewash or powdered with talc and then viewed under ultraviolet light. The oil, being fluorescent in nature, can be easily detected under this light, and thus the defects are clearly revealed. By close observation of the amount of penetrant coming to the surface, the form and size of the crack can also be estimated with a fair degree of accuracy. The oils used are water-emulsifiable penetrants and are of proprietary nature.

Fluorescent dye inspection can also disclose those surface defects that are not revealed by radiographic inspection. For this reason, the penetrant test is often used to supplement the radiographic test.

(8) *Ultrasonic Testing* Ultrasonic testing used for detecting internal voids in castings, is based on the principle of reflection of high-frequency sound waves. If the surface under test contains some defect, the high-frequency sound wave, when emitted through the section of the casting, will be reflected from the surface of the defect and return in a shorter period of time. On the other hand, if the section is homogeneous and faultless, the wave will be reflected back after it travels through the whole of the section. In this case, it will take longer to return to its source. For detecting the lengths of time, an oscillograph is used. The path of travel of sound wave is plotted on the CRT screen of the oscillograph where it can also be measured. The advantage this method of testing has over other methods is that the defect, even if in the interior, is not only detected and located accurately, but its dimension can also be quickly measured without in any way damaging or destroying the casting. With a clean metal of small grain size, holes as small as 0.025 mm in diameter can be detected.

Ultrasonic testing can be applied to spheroidal graphite, compacted graphite, malleable and high-grade iron castings. The ease of application depends on casting shape. Proper test procedure can detect almost any hole, cavity or discontinuity. The method can be adopted for measuring wall thicknesses when only one side is accessible. Defects closer than 2 mm to a surface need special techniques to be detected.

The test frequencies used for detection vary from 0.5 to 5.0 MHz, according to the nature of iron and section thickness. For example, for SG iron having 20-50 nun section thickness, 5 MHz frequency is required, whereas for Grade 20 grey iron, 1 to 1.5 MHz is adequate. The equipment is light and portable; weighing 5 to 6 kg and can be taken anywhere at the work sites.

(9) *Eddy Current Test* This test is used for rapidly checking the hardness of iron castings. In this method of non-destructive testing, a coil carrying alternating current induces an eddy current of the same frequency in the test part under investigation. The eddy currents produced are affected by changes in the electrical conductivity, magnetic permeability and physical and metallurgical properties of the test part.

The instrument consists of (i) a main unit, with a cathode ray tube (CRT) video display complete with frequency selector, oscilloscope controls, coil balance and sensitivity controls, and phase-shifting controls, and (ii) a matched pair of coils. The physical or metallurgical characteristics of any two parts kept in these coils are electromagnetically compared by observing their signals on the CRT screen. Before actual testing, the instrument has to be balanced. For this purpose, two similar parts are kept in the two coils and the test frequency is adjusted to the optimum value suiting the parameters of the test. The instrument is then balanced to obtain a horizontal straight line on the screen, showing that both parts are identical. Calibration curves are prepared and used for regular inspection.

One of the two parts kept originally for balancing is replaced by the part under test. The dissimilarity in shape of the signals, as observed on the CRT screen, indicates the variance in the concerned property of the two parts.

The eddy current intensity is greatest at the surface of the specimen and decreases as the depth increases. At high frequencies, eddy currents are produced only in the skin region, enabling the study of case depth, case hardness, and surface flaws or imperfections. Use of lower frequencies can be made to study sub-surface flaws, segregation, grain structure and chemical composition. The depth of penetration also depends on the conductivity and relative permeability of the specimen. Thus, the optimum frequency suiting the conductivity, magnetic permeability and depth of penetration desired must be selected such that the signals are clear and easily interpretable.

The eddy current method is suitable for testing hardness of rolled, forged, extruded, sintered or cast components in ferrous and nonferrous alloys, particularly, heat treated castings, such as malleable iron, nodular iron and CG iron. Hardness can be predicted to ±10 points Brinell. The test is normally limited to castings which will fit inside a 300-mm dia. coil. It is particularly well-suited for inspection of components produced by mass production machines on the shop floor, where the components produced have to be simultaneously inspected and segregated into good or bad lots or into different categories according to the quality.

METALLURGICAL INSPECTION

Metallurgical inspection is very useful for checking grain size, non-metallic inclusions, sub-microscopic pin holes, the type and distribution of phases present in the cast structure, and the response to heat treatment. These features can be appraised by certain methods:

1. chill test;
2. fracture test;
3. macro-etching test;
4. sulphur print test; and
5. microscopic examination.

1) *Chill Test* Wedge test is a common method for chill testing of grey iron. It offers a convenient means for an approximate evaluation of the graphitising tendency of the iron produced and forms an important and quick shop floor test for ascertaining whether this iron will be of the class desired. The depth of chill

obtained on a test piece is affected by the carbon and silicon present and can therefore be related to the carbon equivalent, whose value, in turn, determines the grade of iron.

In practice, a wedge-test specimen (Fig. 5.5) of standard dimensions (IS: 5699-1970) is cast in a resin or oil-bonded sand mould. The test specimen is removed from the mould as soon as it is completely solid, quenched in water and then fractured in the middle by striking with a hammer. The chilled iron at the apex of the wedge usually consists of two zones; the portion nearest the apex entirely free of graphite is 'clear chill' followed by the portion in which spots of cementite or white iron are visible, called 'mottled zone'. The width of the chilled zone, measured parallel to the base and across the wedge is designated as 'total chill'. The value should not exceed more than half the value of the base. Chill width is largely affected by the use of alloy additions or inoculants and therefore the same value should not be expected in all cases.

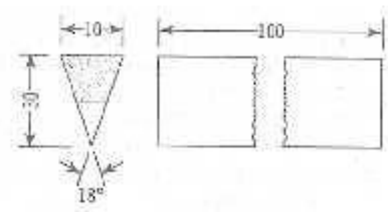


Fig. 5.5 Standard wedge No.2

Wedge No.	Breadth mm	Height mm	Included angle dec.	Length mm
1	5	25	11.5	100
2	10	30	18	100
3	20	40	28	100
4	25	45	32	125
5	30	50	34.5	150

2. *Fracture Test* By examining a fractured surface of the casting, it is possible to observe coarse graphite, mottled graphite or chilled portion and also shrinkage cavity, pin hole, etc., The apparent soundness of the casting can thus be judged by seeing the fracture.

In case of steel casting, fracture test is also used in some foundries to quickly judge the amount of carbon present. A test rod of 25-mm diameter and 75-mm length is cast in a sand mould and quenched in water. The rod is then broken into two pieces and the fracture examined visually. Due to quenching, martensite is formed which is seen in the fractured section in the form of white spots or lines according to the amount of carbon present. Fig. 5.6 shows three types of fractures for varying amounts of carbon.

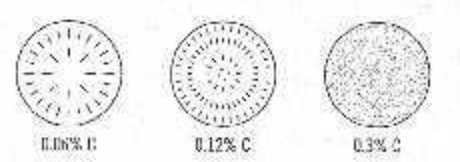


Fig. 5.6 Fractured sections of steel having varying carbon content

3. *Macro-etching Test* (Macroscopic Examination) The macroscopic inspection is widely used as a routine control test in steel production because it affords a convenient and effective means of determining internal defects in the metal. Macro-etching may reveal one of the following conditions:

a) crystalline heterogeneity, depending on solidification;
b) chemical heterogeneity, depending on the impurities present or localised segregation;
c) mechanical heterogeneity, depending on strain introduced on the metal, if any.

The test entails etching the sample piece of casting in a suitable reagent at a particular temperature for a prescribed length of time. The heterogeneity in the metal is revealed by the difference in chemical relations between the structural components of the metal and the selected etching reagent. Surface defects, inclusions, segregated area, etc., are selectively attacked by the reagent, and are therefore easily detected. Macro-etching reagents found suitable for steel and cast iron include hydrochloric acid, nitric acid, and Stead's reagent.

4. *Sulphur Print Test* Sulphur may exist in iron or steel in one of two forms: either as iron sulphide or manganese sulphide. The distribution of sulphur inclusions can be easily examined by this test. The component to be examined for sulphur segregation is sectioned, ground, and polished. A sheet of photographic bromide paper is soaked in 2% solution of sulphuric acid for about five minutes. It is then removed from this acid solution and allowed to drain free from excess solution or is lightly pressed between two pieces of blotting paper. The emulsion side of the paper is then placed on the polished surface of the sample under moderate pressure for about two minutes. Care should be taken to ensure that no air bubbles are trapped. The paper is then removed and found to have brown stains where it was in contact with any sulphides. The reaction of sulphuric acid with the sulphide region of the steel produces H2S gas, which reacts with the silver bromide in the paper emulsion, forming a characteristic brownish deposit of silver sulphide. The darker and the more numerous the markings, the more the sulphur indicated. The paper is finally placed in a fixing solution for ten minutes, washed in running water, and dried. The entire operation can be carried out in daylight.

5. *Microscopic Examination* Microscopic examination can enable the study of the microstructure of the metal or alloy, elucidating its composition, the type and nature of any treatment given to it, and its mechanical properties. In the case of all cast metals, particularly steels, cast iron, malleable iron, and SG

iron, microstructure examination is essential for assessing metallurgical structure and composition.

The sample for examination is first cut to about 12-mm diameter and 9-mm thickness, and filed and ground to erase any deep grooves or marks. The piece should not get overheated at any time as this may alter its structure. The specimen is then polished on a series of emery papers of various grit sizes, the last one being of the finest variety. Sample polishing machines are available for the purpose. It may sometimes be desired to mount the sample in Bakelite, epoxy resin, or some plastic material before it is polished so as to keep edges from getting rounded off. For final polishing, the specimen is rubbed on a special cloth, which has already been impregnated with a polishing medium. It is then thoroughly cleaned and degreased, by washing in hot water, and sprayed with acetone or spirit.

The next step is to etch the specimen so that the etching reagent will first dissolve the thin bright layer produced during polishing and then attack metal at the grain boundaries and make them prominent on the surface. Owing to the nature of the grain boundaries, the rate of chemical solution along the boundaries will be greater than within the grains. Therefore, etching will produce the true underlying microstructure. The specimen is treated with the etching reagent for a few seconds until it acquires a dull matt appearance. It is then washed in hot water and dried in hot-air blast.

Etching Reagents

For steel and cast irons

(i) nital. (2% solution of nitric acid in alcohol);

(ii) picral. (4% solution of picric acid in alcohol); and

(iii) alkaline sodium picrate (2g of picric acid and 25 g of caustic soda added to 100 ml of water).

For copper and its alloys

(i) ferric chloride solution in water or alcohol; and

(ii) ammonium hydroxide-hydrogen peroxide.

For aluminium and its alloys

(i) hydrofluoric acid solution in water (0.5%);

(ii) sodium hydroxide solution in water (1.0%); and

(iii) sulphuric acid.

After the specimen is etched and washed, it is ready for examination under the metallurgical microscope.

Scanning Electron Microscope The use of a scanning electron microscope (SEM) has brought new insights in the field of metallurgical analysis, particularly in the study of fractures (fractography), grain size and grain growth, phase transformations, impurities and trace elements, characteristics of powders and their compaction. No specimen preparation is usually necessary. Even non-conducting materials can be examined by applying a mild conductive coating on the surface. The resolution of SEM being as high as and the depth of field being nearly 300 times that of an optical microscope, this instrument can be extremely valuable in quality control of castings, as also other products.

A fine beam of electrons is allowed to interract with the sample. The low-energy secondary electrons are made to strike a scintillator. The photon image is then fed to a photo multiplier through a light guide. The signal from the photomultiplier is used to influence the scanning in a cathode ray tube in synchronism with the scanning of the specimen by the original electron beam. The image on the tube is a magnified view of the specimen surface with excellent fidelity to topographic details.

POLLUTION CONTROL IN FOUNDRIES

POLLUTANTS IN A FOUNDRY

Foundries are among the industrial plants causing environmental pollution, producing substantial quantities of air pollutants. The numerous processes available for moulding, melting and casting are accompanied by evolution of heat, noise, dust and gases. Dust, fines, fly ash, oxides, etc., which form particulate matter are generated in large quantities when preparing mould and core sands and moulds, melting metals, pouring moulds, knocking out poured moulds and loading and unloading raw materials. Gaseous matter like gases, vapours, fumes and smoke are produced during melting and pouring operations. The major pollutants emitted from various work areas in a foundry are given in Table 9.1. The basic means of controlling the emission of pollutants are changing the production process, sup plying adequate make-up air, proper aeration and ventilation of the shop, reduction of pollutants at source by taking appropriate control measures, dispersion and dilution of pollutants in the air space and good housekeeping.

Major pollutants emitted in a foundry

Work area	Pollutant	Emission concentration g/m3
Pattern shop	Sawdust, wood chips	Heavy
Sand preparation	Dust and fumes,	100-175
	powder materials	75-150
Moulding and core-making	Sand	50-100
	fumes	100-175
	Binder dust	75-150

	Vapours	Light
Mould drying and ladle heating	CO, so_2	Light
Cupola	so_2	Light
	CO	Heavy
	Unburnt hydrocarbons.	Heavy
	smoke	
	Metallic oxides	Moderate
	Coke dust	100-175
	Limestone dust, fly ash	Moderate
Electric arc furnance	Dust, CO, $S0_2$ oxides,	Moderate
	Nitrogen cyanide, fluoride, etc.	Light
Electric induction furance	Dust, oxides, smoke	Light
Pouring and mould cooling	CO	Light
	Binder fumes	Moderate
	Oil vapours	Heavy
Knock-out	Sand, fines and dust	200-350
	Smoke, steam, vapours	Heavy
Fettling	Dust, metal dust, sand fumes	>100
	Abrasive powder	10-50
Heat treatment	CO, SO,, oil vapours	Light

DUST AND FUME CONTROL

It is of utmost importance that the air polluted by foundry work be cleansed to maintain hygienic working conditions. The atmosphere in the pattern shop is charged with fine particles of sawdust. Dust sand particles are exuded when sand is mixed and prepared during moulding, shake-out fettling operations. Fumes are produced during melting, metal-transfer, and pouring operations. It is essential to devise a system for collecting all the dust and fumes so produced and disposing them so that they do not pollute the atmosphere in the foundry and pose a threat to the health of the workers. When a foundry layout is planned, provision should be made for dust and fume control. If this vital aspect is attended to as an afterthought, it becomes difficult to incorporate the necessary equipment.

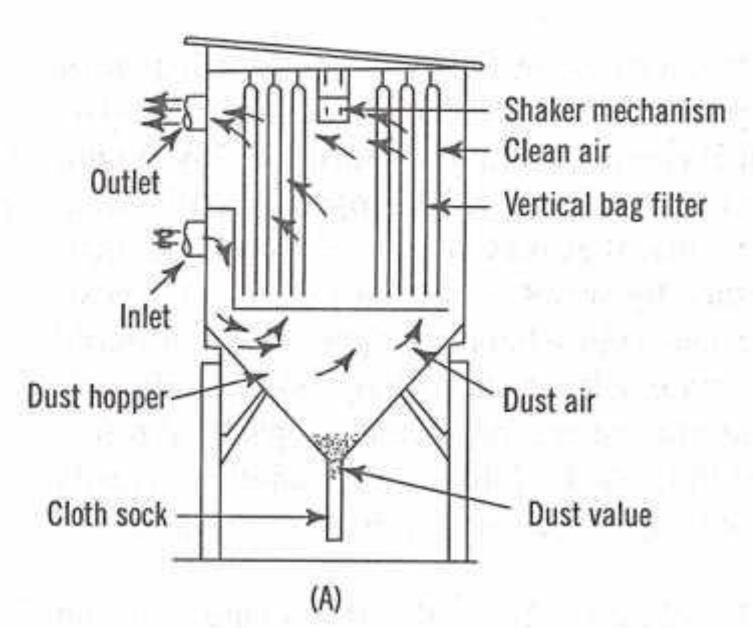
Materials requiring to be separated may be classified into two broad categories: particulate matter, where the particles are either solid, such as dust, fume, smoke, and fly ash, or liquid, such as mist and fog; and gaseous matter, where the contaminant may be either gas over the entire range of atmospheric and process temperatures and pressures, or liquid at lower temperature, and gas at the temperature and pressure of its release into the atmosphere.

The method of separation depends on the category to which the pollutant belongs. Some separation processes are applicable to several types of pollutants whereas others to only one of them. The methods commonly used in foundries are now outlined.

1. *Filter* The filter serves for removing particulate matter from gas or air streams by retaining it in or on the porous structure through which the gas flows (Fig. 5.7.). The porous structure is usually a woven or felted fabric. The filter must be continuously or periodically cleaned, or replaced.

The filtering action may be obtained in various ways, such as direct interception, impaction, diffusion, and electrostatic precipitation. In direct interception, the particle is carried by a streamline of gas, which heads it directly towards a part of the solid surface comprising the filter. In impaction, the particle is in a streamline of gas, which sweeps by the solid material of the filter and allows the particle to touch the filter material. In diffusion, a blow from a molecule of the gas projects the particle to the filter surface. In electrostatic precipitation, electrical charges on the particle and filter attract the particle towards the filter. One or more high-intensity electrical fields are maintained to cause the particles to acquire an electrical charge and be forced to move towards the collecting surface.

Filters are commonly employed in pattern shops on various woodworking machines, such as band saw, circular saw, and sanding machines. They are also used on cupola collection systems in conjunction with other equipment, such as after-burners, gas cooler, recuperators and exhaust blower. Sand-reclamation plants also use bag filters for separating 'fines' from sand grains.



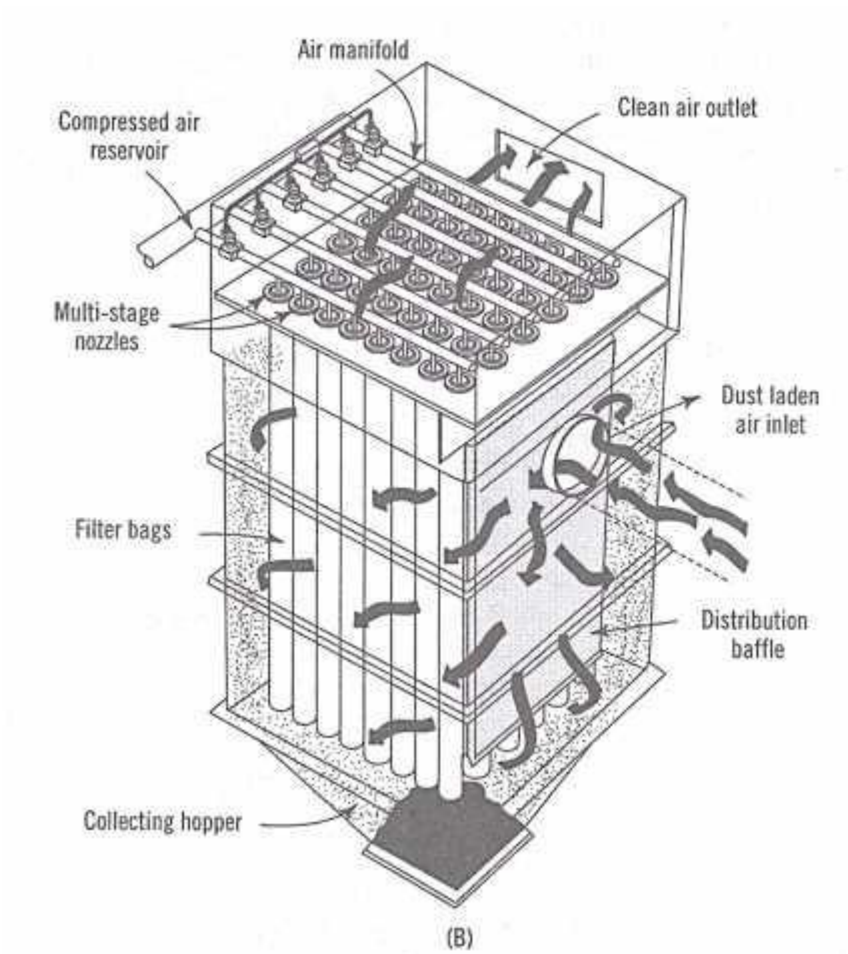


Fig. 5.7 (A) Bag filter (B) Schematic arrangement of an ultra-jet type filter

2. *Cyclone* The cyclone (Fig. 5.8) works on the principle of Vortex core centrifugal separation in which a vortex motion of the particulate matter is created within the collector. This motion provides the

centrifugal force which propels the particles to locations from where they may be removed. Cyclones may be operated either dry or wet. Also, they may either deposit the particulate matter in a hopper or concentrate it into a stream of gas which flows to another separator for ultimate collection. The cyclone is used in sand-preparation plants for separating sand particles from air, in cleaning the cupola exhaust, in moulding shops, and on shake-out stations.

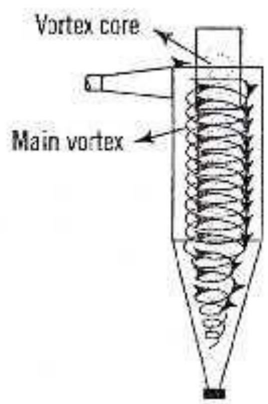


Fig. 5.8 Cyclone

3. *Mechanical Collectors* These devices include settling chambers, baffled chambers, and fan arrangement, which collect particulate matter by gravity or centrifugal force but do not depend upon a vortex as in the case of cyclones. As their efficiency of collection is generally rated low, they are used as precleaning devices before other types of collectors. They also function in combination with filters or scrubbers. Cupola exhaust systems often make use of mechanical collectors (Fig. 5.9).

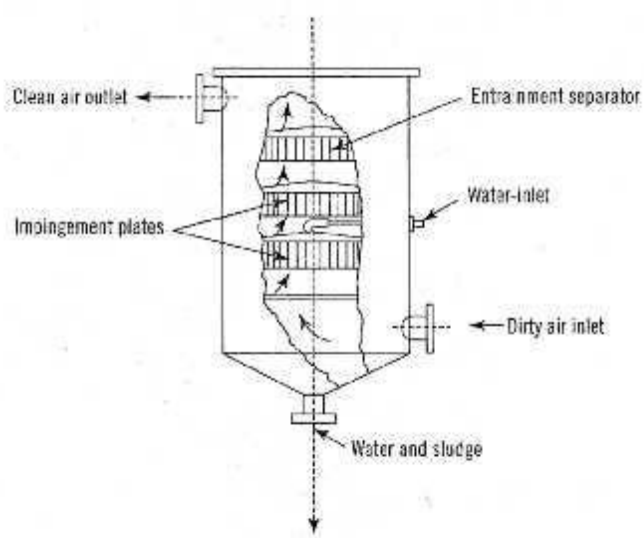


Fig. 5.9 Wet centrifugal dust collector

4. *Scrubbers* The scrubber is employed primarily for removing gases and vapour-phase contaminants from the carrier gas, though it can also remove particulate matter. A liquid, usually water, is introduced into the collector and it either dissolves or chemically reacts with the contaminant collected. Methods used to effect a contact between scrubbing liquid and carrier gas includes (i) spraying the liquid into chambers containing baffles, grille, or packing; (ii) flowing the liquid over weirs; and (iii) bubbling the gas through tanks or troughs of liquid. Scrubbers are ideal for cleaning the exhausts of cupola and arc furnaces.
5. *After Burners* The after-burner assists in oxidising the solid combustible material present in the particulate matter and converts it into gaseous form. It also helps to convert carbon monoxide into carbon dioxide as in the case of cupola gases. After-burning may be accomplished by using furnace oil as a fuel and introducing it along with air into a combustion chamber through which the carrier gas passes.
6. *Combination Devicess* Some devices combine features of the aforementioned equipment so that dust and fumes are controlled most economically and with a minimum pressure drop. For instance, there are cyclones in which liquid is sprayed, and scrubbers in which cyclonic action is used. Packed-bed filters, operated wet, and packed-bed scrubbers are similar to each other, the only difference being that the equipment designed to separate particulate matter is called a filter and the same when designed to separate gaseous contaminants is called a scrubber. Often, equipment of different types are used in series. Fig. 5.10 shows a common arrangement of exhaust cleaning used on large-sized cupolas.

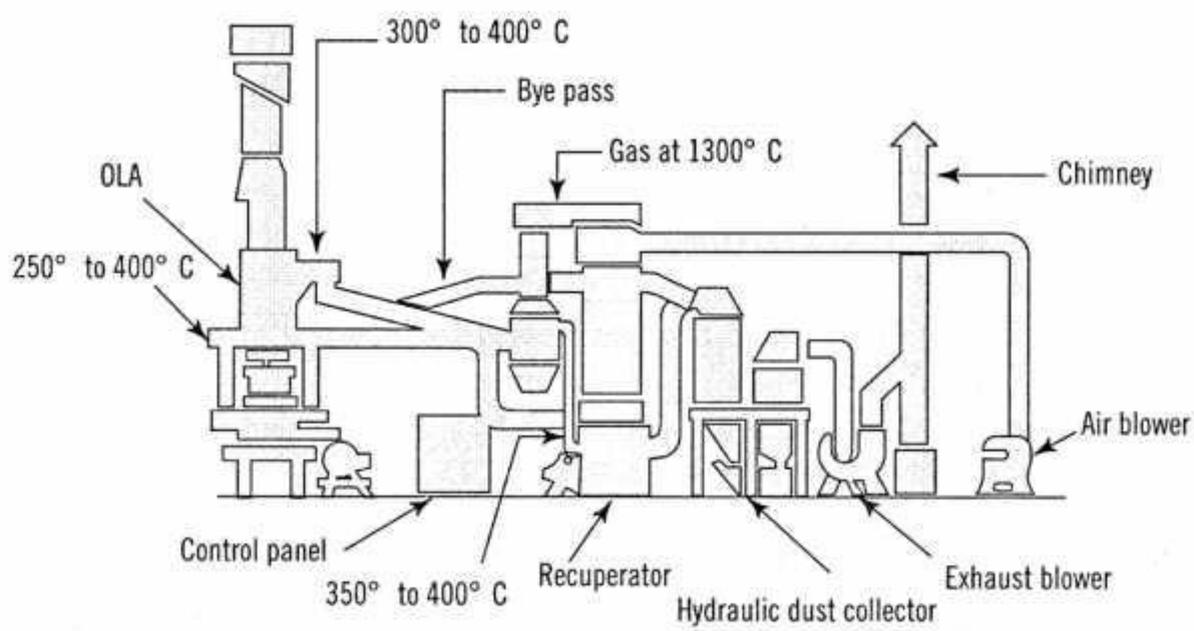


Fig. 5.10 Cupola furnace installation

PLANT LAYOUT FOR FOUNDRIES

Plant layout involves arranging and coordinating the physical plant facilities in a pattern that affects the maximum efficiency in the combination of men, materials, and machines for operation of any unit of a business.

Plant layout has also been defined as a floor plan for determining and arranging the desired machinery and equipment of a plant, whether established or contemplated, in one best place, to permit the quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the time of the receipt of raw materials to the shipment of finished products.

As the foundry industry has moved from a seller's to a buyer's market, it is characterized by stiff competition and reduced profits. Since profits are lower, it is logical that a plant with lower production costs and overheads is better able to maintain its relative production activity.

One of the most effective ways to cut down production costs is to eliminate or reduce to a minimum all non-productive plant activities. A good layout is one that provides for full utilization of available equipment for production, material handling devices and manpower, and that effects maximum saving in process inventory.

Advantage of a Good Layout

Some of the advantages to be gained from good plant layout in a foundry are the following:

1) *Improvement in the Manufacturing Process* These improvements may be both in the method of processing and the control of the process. They may result from

   (a) elimination or reduction of delays through improved arrangement or better work balance between machines or operators;

   (b) smoother materials flow in the process; plant layout allows new analysis of the materials handling problem and incorporation of new methods and equipment; a major factor in this area may be the possibility of incorporating the techniques of automation or automatic handling, thereby reducing interruptions in the flow;

   (c) improved control by incorporating methods for identifying, counting, and inspecting goods in process.

(2) *Improved Quality Control* An analysis of the production necessary for proper plant layout also requires the determination of quality control factors and inspection locations. A good layout incorporates these quality considerations in a manner that ensures maximum control and minimum cost.

(3) *Improved Materials Handling* Materials handling is improved by proper location of equipment, reduced handling distances, and closer coordination of the entire handling activity. The application of the principle of standardisation to material handling reduces the variety of handling units and equipment, permitting

greater flexibility without sacrificing efficiency. Standardisation may also reduce the investment required for materials handling.

(4) *Minimum Equipment Investment* Planned machine balance and location, with minimum handling load distances, and planned machine loading reduces the inclusion of idle or partially loaded units in production areas, thereby reducing investment requirements. The reduction of equipment investment applies to service and maintenance equipment, materials handling equipment, and office equipment, as well as production machines.

(5) *Effective Use of Available Area* In many plants, expansion and growth has taken place in such a manner that plant arrangement has been a matter of immediate convenience. A well-planned plant layout offers an opportunity to place equipment and services in such a manner that the most effective coordination is possible. Locating equipment and services such that they can perform multiple functions, development of up-to-date work areas, and operator job assignment for full utilisation of the labour force, help to improve utilisation of plant areas.

(6) *Improved Utilisation of Labour* Proper plant layout allows the design of individual operations, the process, the flow, and material handling in such a manner that each worker can effectively apply his activities to the best overall plant effort. Balancing of labour to production needs and machine requirements eliminates many situations in which the operator's time is not utilised to the maximum. Layout of equipment for ease of maintenance reduces maintenance personnel requirement. Improved handling, which frequently means further incorporation of mechanical means, minimises both direct and indirect labour requirements.

(7) *Improved Employee Morale* A layout that provides for employee convenience and comfort inevitably boosts employee morale. A design that incorporates such items as correct lighting, proper cooling and ventilation, noise and vibration control, sufficient and convenient rest rooms and lunch facilities leads to efficient job performance and to reduced idle time, otherwise spent in travelling to facilities or in grievance actions that result from dissatisfaction.

(8) *Improved Efficiency in Plant Services* Efficiency is obtained by considering the problems of maintenance and service equipment and buildings during the arrangement and layout planning. New utility distribution systems giving maximum flexibility and capacity become an integral part of the new layout, thereby facilitating future re-arrangement or expansion.

Steps in Planning a Foundry Layout

In order to realise the maximum potential of a layout for a new foundry, a systematic procedure must be followed. The final layout can be no better than the data upon which it is based. Certain steps if followed assure the collection and analysis of the necessary supporting data.

1) *Analyse the Product to be Manufactured* This implies having available or deciding

(a) the annual tonnage;

(b) the type of castings to be produced: their range of sizes, weights, composition, and product mix; and

(c) the maximum piece weight.

(2) *Determine the Process Required to Manufacture the Product* Operation sheets must be prepared or developed for each manufactured product. For layout purposes, only the sequence of operations is required initially.

Castings may be classified as light, medium, and heavy or according to the quantity required. Logical location of workplaces like moulding, core-making, melting, inspection, etc., should be suitably determined. Green sand, skin dried, dry sand, machine moulding, shell moulding, CO, process, etc., are among the various processes to be broadly considered first to suit the casting requirements before the details of layout are decided.

(3) *Prepare Layout Planning Charts* The layout planning chart is of prime importance as it serves as the medium for first tabulating and then combining the various factors to be provided for in the final layout. It incorporates

a) the flow process showing all operations, movements, storages, and inspections in sequence;
b) standard times for each operation obtained from time studies or predetermined time standards;
c) machine selection;
d) machine balance;
e) manpower requirements; and
f) materials handling load, method, and equipment requirements.

To complete the layout planning chart, a full review and analysis is required at each step. Once this is done, the layout of the manufacturing area involves primarily a conversion of the layout planning chart data to the physical plant statistics. To achieve this, three additional jobs require attention:

(4) *Determine Work Stations* The requirements of machine, operator, materials, and service areas must be considered. This is accomplished by using man-machine and/or operation charts and scaled workstation sketches/models.

(5) *Analyse Storage Area Requirements* Before beginning the actual layout both the size and the location of the storage area should be studied with relation to production activities. At least three types of storage should be included in the survey:

(i) storage of raw-materials;

(ii) in-process storage; and

(iii) finished goods storage.

(6) *Establish Minimum Aisle Widths* Clearances around the various pieces of machinery and between departments should be determined before starting the layout. Aisle widths are dependent primarily upon materials handling methods and equipment, workstation clearance requirements, and pedestrian traffic and should be carefully decided to avoid production problems in future.

(7) *Establish Office Requirements* These will depend upon the scope of operational activities. The exact requirements of space should be worked out and provided in the layout.

(8) *Consider Personnel Facilities and Services* Allow for such items as first aid, lunch and refreshment centres, lockers, rest rooms, and parking.

(9) *Survey Plant Services* These include utilities such as compressor room, pump house, waste disposal, equipment maintenance, cooling, dust extraction and ventilation.

(10) *Provide for Future Expansion* This may include sufficient provisions for the addition of new product lines or for increased demand for the existing products.

(11) *Prepare Layout Plan* The location of all plant and equipment, workstations, facilities, storage spaces, aisles etc., should be clearly indicated on this plan.

Fig. 5.11 shows a typical layout for a small grey iron foundry which fulfils the essential requirements of a good plant layout for a small scale unit. Fig. 5.12 shows a layout for a typical steel foundry for producing large-sized castings.

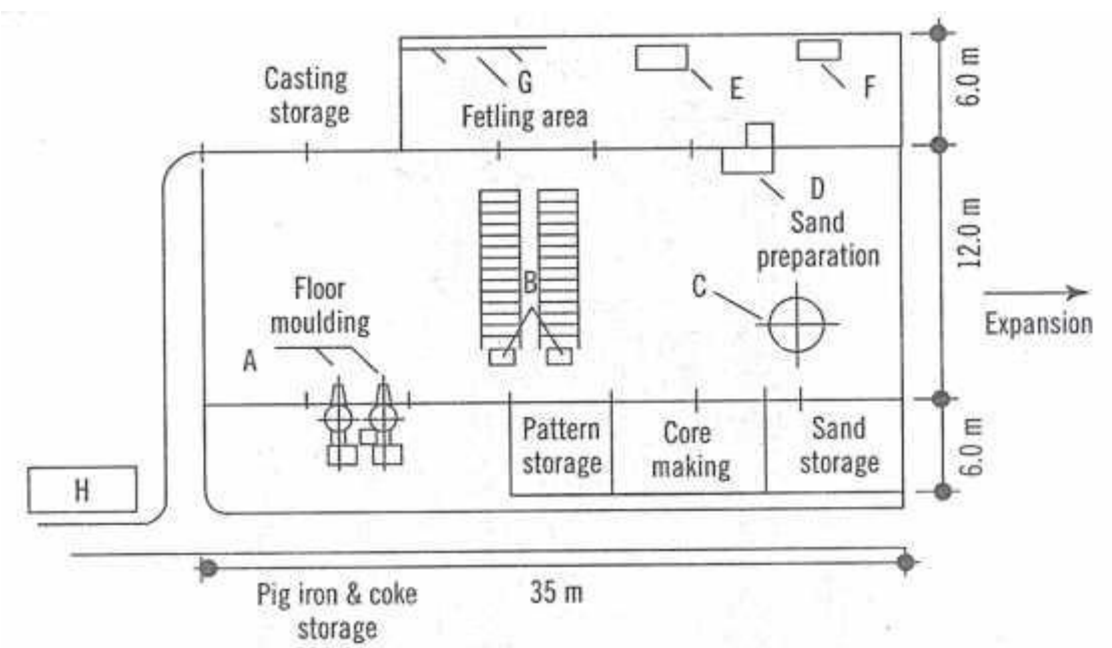


Fig. 5.11 Layout of a small grey iron foundry

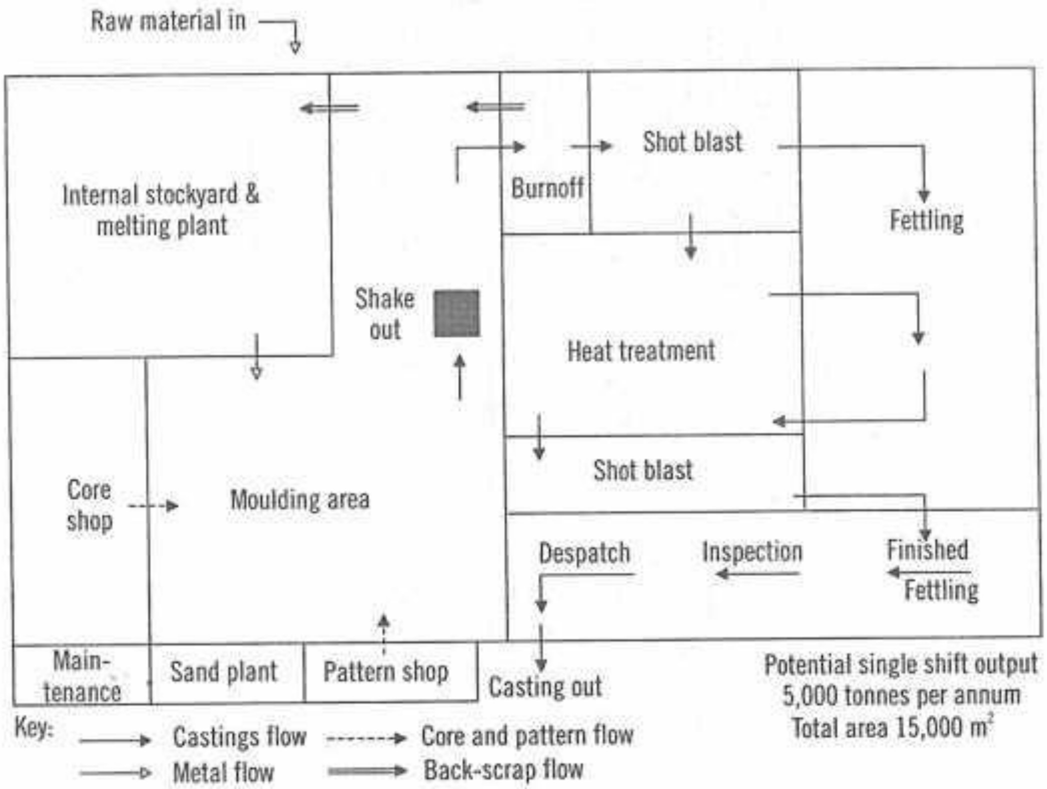


Fig. 5.12 Typical Layout of a grey iron foundry

AREAS FOR MECHANISATION

Mechanisation has a distinct impact on areas concerned with the preparation and control of sand; moulding and core-making; melting, pouring, and shake-out operations and material handling.

Sand Preparation and Control, Moulding and Core-Making

Sand preparation equipment is invaluable in both jobbing and mass-production foundries. The riddle which rids sand of refuse, the muller which kneads the sand for re-use, the magnetic separator which removes iron particles from return sand, the aerator which helps to improve the flowability of sand, hoppers which act as storage for sand before it is sent for mulling, all such equipment are essential for maintaining the homogeneity of sand mixtures. If sand is initially wet, it has to be dried in sand driers. In case the sand gets overheated in the mould, it has to be cooled down to room temperature in special coolers, before it can be re-used.

Continuous Mixer Continuous mixers (Fig. 5.13) are now coming increasingly into use with the development of organic no-bake resin systems based on phenolic binders. These two-part no-bake systems are fast-acting, need less sand, generate low nitrogen, give high productivity and the sands are reclaimed easily. Two types of mixers are used—pivotal type for small to medium sizes, and the mobile type for heavy jobs.

Fig. 5.13 Continuous mixer unit

The mixer consists of a horizontal trough fixed to a column at one end with a rotating shaft with blades around fastened to it. The sand along with resin and hardener are introduced at one end in the trough in measured quantities using a pneumatic metering device. As the constituents travel in the trough from one end to the other, they get thoroughly mixed and the sand grains are uniformly coated with resin. The sand mix is finally discharged from a spout directly into the moulding box placed below on a compaction table. The sand is compacted by means of low amplitude and high-frequency vibrations caused to the table using two unbalanced motors. The moulds are then painted, cores laid in place, closed and poured. The poured moulds after cooling down are transferred on a conveyer line to the shake-out and reclamation.

Integrated systems, now available, consist of a sand-preparation unit supplying mixed resin sand continuously, discharging it into a moulding box placed on a vibratory compaction table, a pattern loop-mould stripping device, and a shake-out with a reclamation plant (Fig. 5.14) The reclamation unit consists of a fluidised sand cooler cum classifier which allows about 80-90% of the used sand to be reclaimed and re-used, thus affecting considerable savings in sand costs. The castings are removed from the mould, the sand lumps are reduced to grain size in a scrubber and oversized grains, lumps, tramp metal and other degradable material along with sand fines are separated. The dust is removed using a bag filter- type dust-extractor unit. The sand is cooled in a cooler unit using cooling water circulating through copper tubes placed in the fluidised bed. The water is cooled continuously in an evaporative type water-cooling tower. The reclaimed sand is conveyed pneumatically to the mixer unit. The new sand is added to reclaimed sand in the desired proportion by adjusting a pneumatic slide-gate valve.

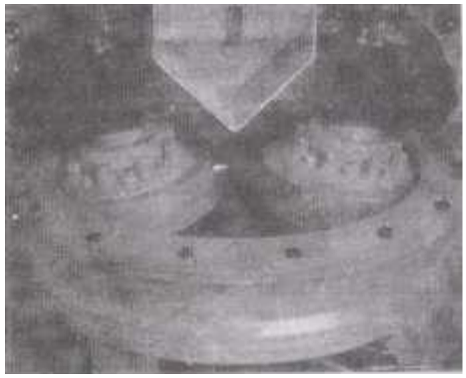


Fig. 5.14 Reclaimer unit

Thus, the use of a continuous mixer enables the quality of castings produced to be much higher than those produced by the CO, process. Also, sand and fettling costs are reduced and labour productivity is greatly increased.

Sand-testing facilities are essential for controlling the characteristics affecting the properties of moulds and cores. The conventional approach to sand control in foundries is to maintain a constant, predetermined moisture level. At constant moisture, however, there is no regulation of the variation in the composition and temperature of sand, in the nature or the amount of additives, all of which affect the working and ramming properties of sand. Consequently, improved methods of sand control have come into vogue. In one method, sand is prepared to a constant degree of mouldability. The apparatus, called the mouldability controller (Fig. 5.15), adjusts the moisture addition to compensate for the variations in sand composition.

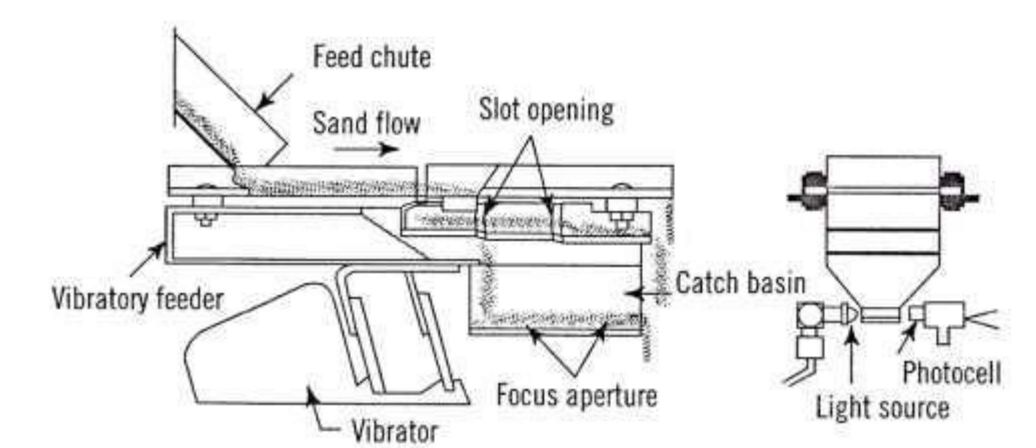


Fig. 5.15 Mouldability Controller

The mouldability controller has a slotted vibratory feeder trough and a system of photoelectric cells. The controller is positioned at the sand mixer from where a small amount of sand enters the controller. The sand falls on to the vibratory feeder and moves towards the slots. When the sand is dry, it falls through the slots and blocks off the focusing apertures through which two light sources are directed towards two photocells. The interruption of these light beams opens two water valves in the mixer to add more moisture to the sand. When the required amount of water has been received by the sand and the desired mouldability level attained, sand moving on the vibratory feeder tends to bridge the slots rather than fall through them. It, therefore, no longer obstructs the light beams, and so the water valves get closed. This system of adjusting water additions by the opening and closing of water valves operates continually according to the requirements of the sand and thus maintains a constant workability, producing moulds of an exceptionally high quality.

Melting, Pouring and Shake-out Equipment

In a mechanized foundry, the attempt is to substitute manual labour by mechanical devices wherever possible. However, the extent to which the machine can be exploited is dependent on factors such as the type and condition of equipment, the economical feasibility of installing such devices, and the floor space available. Although the mechanical gear varies from foundry to foundry, it generally includes a crane, lift truck, turnover truck, belt conveyer, or bucket conveyer system for handling charges, such as pig iron, scrap, and coke and flux, and transporting to the furnace.

Machines are also essential for sending the charge up to the charging door, as in the cupola, and discharging it into the furnace. A skip-hoist type of conveyor is customarily used to send the charge-up. In this arrangement, the charging bucket is mounted on wheels, and guided by a vertical or inclined track. The bucket is raised and lowered along the track by the working of a reversible electric motor through a cable. When the bucket reaches the charging door, it operates an electrical limit switch which brakes the motor instantly and, after some time lag, reverses it. For convenient loading, the bucket is lowered into a pit. The discharge bucket used is usually the top-discharge type which is automatically inverted as it enters the charging door of the cupola.

For large-sized cupolas, the crane type of conveyance is suitable. Here, the bucket is raised by a crane from the loading station and carried horizontally into the charging door. The bottom of the discharge bucket has a hinged door which swings open for discharging.

In the case of other furnaces, such as the open-hearth furnace, air furnace, and electric furnace, the crane arrangement with either the top discharge or the bottom discharge bucket is commonly employed.

The variety of equipment used for melting the metals has already been discussed in Chapter 6. Factors such as the metal to be melted, the quantity of metal required, the quality and purity of metal desired, and the availability of fuel determine the type of equipment needed in the foundry shop.

After the metal is melted, it is scooped into ladles and carried to the pouring floor by means of a crane. The metal may be poured either by keeping the ladle stationary in the crane and moving the moulds one after another on a roller conveyer or by keeping the moulds fixed in a line and shifting the ladle forward every time a mould is filled with the metal.

When the castings are sufficiently cool, the moulds are transported by a crane or conveyer to the shake-out station where they are vibrated or shaken in such a way that the castings along with the sand are eased out of the moulding boxes. The shaking operation is conducted on a grating which has a sand conveyer beneath. The sand duly separated from the castings passes through the grate and is carried away to a sand-reclamation plant whereas the castings and the emptied moulding boxes remain on the grating. The castings are then sent to the fettling and inspection shop and the moulding boxes are returned to the moulding section.

Shake-out machines are of many types. For small-sized moulds, a stationary grating installed at a small incline is most suitable. The moulds break, when jolted and dropped, allowing the sand to pass through the grating and leaving the casting and the moulding box above it. For small- and medium-sized castings, the vibrating type of shake-out is commonly used. It consists of a perforated plate or a heavy grille fastened to a vibrating frame. After the mould is placed on the grille, the frame is vibrated by means of a motor-driven eccentric arrangement to extract the sand from the mould and release it through the grille. The vibrating frame is connected to the machine structure by compression springs, thus largely eliminating the transmission of vibrations into the foundation.

For heavy moulds, the ideal shake-out is the bumper type. The mould is positioned on two heavy beams which are hinged at one end. The free ends of the beams rest on motor-driven cams. When the cams are rotated, the beams get first lifted slightly, then dropped back into place. This action jolts the mould. All shake- outs should be fitted with a hood and a powerful dust-suction device to prevent fine sand and dust particles from escaping into the air around.

Automatic Pouring System During the last ten years, several foundries in the country have installed automatic pouring systems as an adjunct to large-capacity induction furnaces with the objective of maintaining consistent quality of castings produced, and for controlling pouring rate and pouring time of molten metal and reducing metal losses. This has reduced manpower requirements considerably, improving yield of the castings and productivity of the foundry, and, further, the quality of work life. These systems are well-suited in innovative and quality- oriented foundries engaged in large-scale mass production or continuous type of production of gray and ductile iron castings using automatic moulding lines.

Their success is leading the way for more widespread adoption of this modern technology. Thus, increased casting production, higher casting quality and enhanced worker safety is made possible by applying automatic pouring technology. The pouring system uses a high response stopper-rod pouring mechanism and a vision-based control technology, which can allow precise pours mould-after- mould, without any operator intervention or interruption. Ladles bring hot metal from the furnaces at carefully timed intervals to maintain the desired pouring temperature range in the pouring tundish. Automatic pouring continues as the tundish is replenished.

The moulding lines are so arranged that perfectly filled moulds move from the automatic pouring system along the now-empty manual pouring line. Apart from the advantages enumerated above, other savings and efficiencies are obtained in several other areas, such as reduced maintenance requirements, improved working environment, commitment to quality and productivity and finally rapid payback of capital expenditure.

MATERIAL HANDLING

Material handling equipment is an invaluable asset in the rapid and economic production of castings on a large-scale. The foundry which is the receiving centre of huge quantities of diverse materials, requires to be suitably equipped to ensure efficient handling and treatment of items, such as

1) sand;
2) moulds and cores;
3) molten metal; and
4) castings.

1) ***Handling Sands*** Sands are required to be conveyed from one part of the production foundry to another for various purposes. For example, sand is taken from the shake-out station to the riddle for screening; from the screen to the magnetic separator; from the magnetic separator to the reconditioning plant, i.e., muller and aerator or to the hoppers for storage; and from the storage to the mixing or conditioning plant. Reconditioned sand has to be sent to distribution mains and then to workstations. All this travelling to and fro is conducted on a sand conveyer. The wide range of sand conveyers covers specified areas of work in the foundry shop.

   (i) Belt Conveyer The belt conveyer is commonly used for transferring sand from one place to another in travel that requires a horizontal or an inclined direction of movement. It consists of an endless belt, two pulleys (called head and tail pulleys), rollers or idlers for carrying the loaded belt and returning the empty belt, a belt-tightening mechanism, and bell cleaners. The belts are available in various sizes and strengths and are made of cotton plies bonded with synthetic rubber. Since such material cannot withstand more than about 150°C, the belt conveyer can be used only when the temperature of the sand is within the limit. Where hot sand is to be transported, a metal conveyer is used.

   The head pulley is used for driving the belt and is connected to an electric motor through reduction gear. Its diameter should be large enough to ensure full traction. To prevent sand from spilling and to keep it in the centre, the idlers which support the belt are arranged in three pieces, i.e., each set of idlers has three rollers, one horizontal in the centre and two slightly inclined on the sides. These idlers should not be spaced very far apart, otherwise the belt will sag too much under load. When the sand conveyer is used for inclined travel, the angle of incline should not exceed 15° for dry and 25° for tempered sand to keep it from rolling backwards.

(ii) Bucket Elevator When the sand is to be conveyed vertically upwards, a bucket elevator is ideal. There are two pulleys, one at the top and the other at the bottom which carry an endless belt. The belt carries a number of buckets all around and the whole assembly is enclosed in a steel casing which has two openings, one at the bottom for feeding and the other at the top for discharge. The bucket elevator is generally preferred to the inclined belt conveyer owing to a saving in space and cost.

(iii) Apron Conveyer The apron conveyer's overlapping steel plates, hinged at the ends, serve, when assembled, the same purpose as a belt. The advantage of an apron conveyer is that it can be used for transporting materials that are too hot to be carried by a belt. The drawbacks are that it cannot be used at high speeds, there are chances of sand spillage and leakage through the plates, and the cost of maintenance as well as the initial costs are higher.

(iv) Flight Conveyer The flight conveyer is generally used for distributing sand to workstations from an overhead trough. It has two endless chains moving on sprockets, fixed at both ends, and carrying steel plates, called 'flights', at certain intervals. When the chain moves, it causes the flights to shift in the trough and force the sand to enter the openings in the hoppers.

(v) Reciprocating and Oscillating Conveyer Occasionally, the reciprocating and oscillating conveyers are also considered suitable for transporting sand. The reciprocating action is produced by a crank-pin and connecting-rod arrangement. This type of conveyer is used for short travels where the depth of excavation needed for continuous conveyance is not a requisite. The oscillating conveyer is also sometimes selected for transporting hot sand and hot castings. It is made of steel plates which are fastened together and secured by two beams. The oscillating action is produced by means of an eccentric.

(vi) Mono-rail Conveyer The mono-rail conveyer is frequently used for carrying sand and other items, such as castings, molten metal, and furnace charge. The sand is filled in buckets or containers of the drop-bottom type and transported from one place to another on an overhead mono-rail. The conveyer may be either manually or electrically operated.

(vii) Crane For small foundries engaged in jobbing work, an overhead travelling crane may be more convenient for carrying sand. The sand is filled in a bottom discharge type of bucket which is transferred with the help of a crane.

2) ***Handling Moulds*** In a production foundry, moulds may be conveyed from the mould-production section to the storage where they remain stationary for pouring or they may be conveyed past a pouring station where molten metal is poured into them while they are in motion. The moulds when cool are conveyed

to a shake- out station and, after shake-out operation, the emptied flasks, moulding boards, etc., are returned to the mould-production area. All these transport operations in a mechanised foundry are conducted on a suitable conveyer system.

Like sand conveyers, mould conveyers also are of many types, each suited to particular working conditions.

(i) Roller Conveyer The roller conveyer has two beams fixed on trestles of suitable height and supporting laterally arranged rollers above. It may be either of the gravity or the power-driven type. Gravity conveyers are those in which no power is used to drive the rollers and move the moulds. Instead, the ends of the rollers are fitted in sealed bearings and the moulds need to be pushed by the operator to cause them to move on the rollers. The beams may be fixed at a slight incline to facilitate the moulds' movement by the force of gravity.

In the case of power-driven conveyers, some of the rollers at fixed intervals along the length of the conveyer are driven by an electric motor which has a variable speed to enable coordination of the mould movement with mould-production. This type of conveyer is expensive and is, therefore, considered worthwhile only for mass-production foundries whereas the gravity conveyer is suitable for both jobbing and mass-production foundries.

(ii) Pallet (Car- Type) Conveyer The pallet or car-type conveyer is the most efficient means of moving moulds in large-scale foundries from the mould-production area to the pouring department and after allowing adequate time for cooling, to the shake-out station. It has pallets made for cast iron or steel plates mounted on wheels which can roll along a narrow gauge track. The moulds are placed on the pallets and pushed manually. In the case of continuous drives, however, the pallets may be connected by a chain and driven from one end by power. Pallet conveyers have made completely mechanised work possible.

(iii) Overhead Conveyer Sometimes an overhead conveyer of the mono-rail type is also employed for transporting moulds in small foundries. The completed moulds are placed on the platform of the conveyer and the platform is carried to the pouring area by an overhead mono-rail. After the casting has solidified, the same carrier is moved to the shake-out station.

3) ***Handling Molten Metal*** For pouring molten metal into moulds, two systems are commonly followed. Where a continuous conveyer is not used, the moulds after completion are carried on a roller conveyer to the storage area. The molten metal is transferred in ladles to this area with the help of a traveling crane or hoist and is poured into the stored moulds. Where the moulds are constantly moving, the metal is brought on a mono-rail conveyer and poured into the moving moulds.

4) ***Handling Castings*** After the castings are removed from the moulds at the shake-out station, they are transported on a suitable conveyer to the clearing and fettling section. The range of conveyers includes the plate-band, roller, oscillating and overhead varieties.

(i) Plate-band Conveyer A plate-band conveyer is used in many foundries for carrying castings to the fettling or inspection sections. It is excellent for both horizontal and inclined travels and for short as well as long distances. The plates are joined together and mounted on a continuous chain moving on power-driven sprockets.

(ii) Roller Conveyer The roller conveyer can carry castings in the same way as it carries moulds. The gravity type is particularly cheap to install, and satisfies the need of small foundries.

(iii) Oscillating Conveyer The oscillating conveyer, which is the frequent choice for sands, is sparingly used for transferring castings.

(iv) Overhead Conveyer The overhead conveyer is considered suitable for carrying castings from the shake-out station to the shot-blasting rooms for cleaning. It carries the castings by means of hooks suspended from a chain. The conveyer along with the castings enters the shot-blasting chamber from one side and leaves it through the exit on the rear side.

(v) Industrial Trucks Lift trucks and front-end loaders are in use in foundaries for decades. For industrial trucks, a careful evaluation of the factors that limit their efficiency can help in improving the foundry productivity. It can also help to evaluate the function of trucks in the planning of overall materials handling, involving cranes, monorail carriers and belt conveyers, which may lead to saving in time and manufacturing costs.

(vi) Robots Several operations in a foundry shop are assumed to be hazardous, unpleasant, suffocating, tiring and unattractive to workers. Robots are most suitable to operate in such locations to enhance productivity, quality and to decrease manufacturing cost of the operations, which are repetitive in nature requiring consistency in quality and quantity of production. A robot, being a programmable device, is capable of performing complex actions in a wide variety of operations without human intervention.