

PATTERN AND CORE MAKING

10.1 PATTERN

A pattern is a model or the replica of the object (to be casted). It is embedded in molding sand and suitable ramming of molding sand around the pattern is made. The pattern is then withdrawn for generating cavity (known as mold) in molding sand. Thus it is a mould forming tool. Pattern can be said as a model or the replica of the object to be cast except for the various allowances a pattern exactly resembles the casting to be made. It may be defined as a model or form around which sand is packed to give rise to a cavity known as mold cavity in which when molten metal is poured, the result is the cast object. When this mould/cavity is filled with molten metal, molten metal solidifies and produces a casting (product). So the pattern is the replica of the casting.

A pattern prepares a mold cavity for the purpose of making a casting. It may also possess projections known as core prints for producing extra recess in the mould for placement of core to produce hollowness in casting. It may help in establishing seat for placement of core at locating points on the mould in form of extra recess. It establishes the parting line and parting surfaces in the mold. It may help to position a core in case a part of mold cavity is made with cores, before the molding sand is rammed. It should have finished and smooth surfaces for reducing casting defects. Runner, gates and risers used for introducing and feeding molten metal to the mold cavity may sometimes form the parts of the pattern. The first step in casting is pattern making. The pattern is a made of suitable material and is used for making cavity called mould in molding sand or other suitable mould materials. When this mould is filled with molten metal and it is allowed to solidify, it forms a reproduction of the, pattern which is known as casting. There are some objectives of a pattern which are given as under.

OBJECTIVES OF A PATTERN

- 1 Pattern prepares a mould cavity for the purpose of making a casting.
- 2 Pattern possesses core prints which produces seats in form of extra recess for core placement in the mould.
- 3 It establishes the parting line and parting surfaces in the mould.
- 4 Runner, gates and riser may form a part of the pattern.

- 5 Properly constructed patterns minimize overall cost of the casting.
- 6 Pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.
- 7 Properly made pattern having finished and smooth surface reduce casting defects.

Patterns are generally made in pattern making shop. Proper construction of pattern and its material may reduce overall cost of the castings.

10.2 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 molding sand. After some use it warps and wears out quickly as it is having less resistance to sand abrasion. It can not withstand rough handling 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.

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.

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.

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.

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.

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.

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, 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

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.

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 there by 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.

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 molding sand, durable and they are not affected by the moisture of the molding 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 molding. 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.

10.3 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 molding process.
4. Method of molding (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

10.4 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. 10.1.

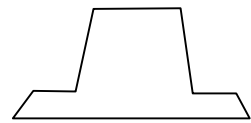


Fig. 10.1 Single piee pattern

2. Two-piece or split pattern

When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern. A typical example is shown in Fig. 10.2.

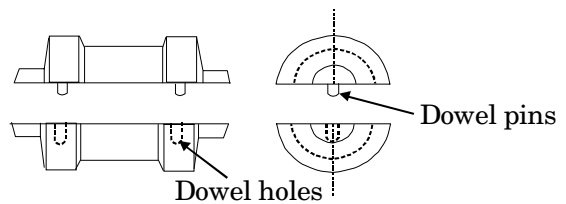


Fig. 10.2 Two piece pattern

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. 10.3.

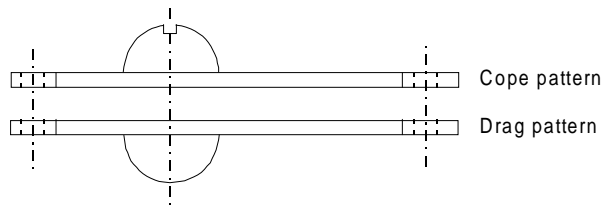


Fig. 10.3 Cope and drag pattern

4. Three-piece or multi-piece pattern

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

5. Loose-piece Pattern

Loose piece pattern (Fig. 10.4) 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.

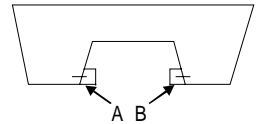


Fig. 10.4 Loose piece pattern

6. Match plate pattern

This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine molding. A typical example of match plate pattern is shown in Fig. 10.5.

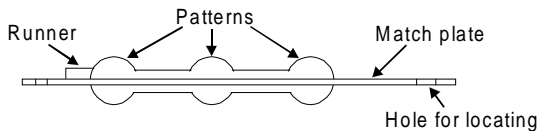


Fig. 10.5 Match plate pattern

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 molding board for the first molding operation as shown in Fig. 10.6.

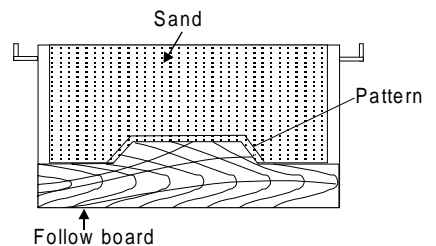


Fig. 10.6 Follow board pattern

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. 10.7. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.

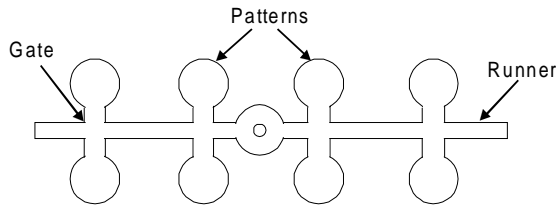


Fig. 10.7 Gated pattern

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. 10.8. 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.

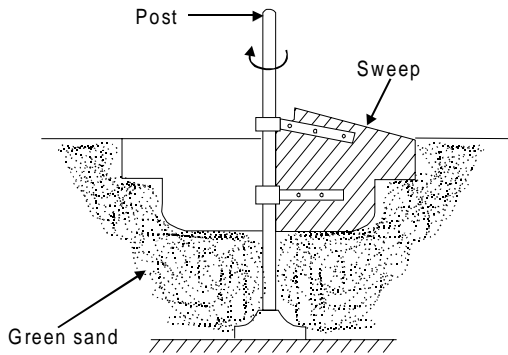


Fig. 10.8 Sweep pattern

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. 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. 10.9.

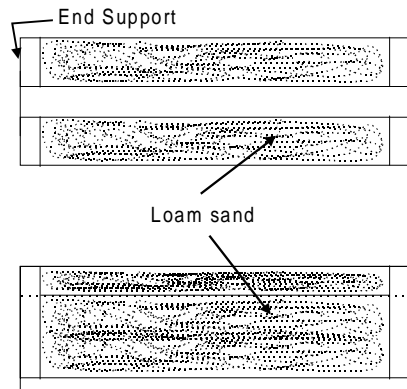


Fig. 10.9 Skeleton pattern

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. 10.10.

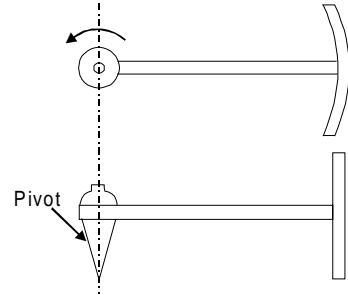


Fig. 10.10 Segmental or part pattern

10.5 PATTERN ALLOWANCES

Pattern may be made from wood or metal and its color may not be same as that of the casting. The material of the pattern is not necessarily same as that of the casting. Pattern carries an additional allowance to compensate for metal shrinkage. It carries additional allowance for machining. It carries the necessary draft to enable its easy removal from the sand mass. It carries distortions allowance also. Due to distortion allowance, the shape of casting is opposite to pattern. Pattern may carry additional projections, called core prints to produce seats or extra recess in mold for setting or adjustment or location for cores in mold cavity. It may be in pieces (more than one piece) whereas casting is in one piece. Sharp changes are not provided on the patterns. These are provided on the casting with the help of machining. Surface finish may not be same as that of casting.

The size of a pattern is never kept the same as that of the desired casting because of the fact that during cooling the casting is subjected to various effects and hence to compensate for these effects, corresponding allowances are given in the pattern. These various allowances given to pattern can be enumerated as, allowance for shrinkage, allowance for machining, allowance for draft, allowance for rapping or shake, allowance for distortion and allowance for mould wall movement. These allowances are discussed as under.

1. Shrinkage Allowance

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

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

The first two of the above are taken care of by proper gating and risering. Only the last one, i.e. the solid contraction is taken care by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals. The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt., Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special

rule known as the pattern marks contraction rule in which the shrinkage of the casting metals is added. It is similar in shape as that of a common rule but is slightly bigger than the latter depending upon the metal for which it is intended.

2. Machining Allowance

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

3. Draft or Taper Allowance

Taper allowance (Fig. 10.11) is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt. These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.

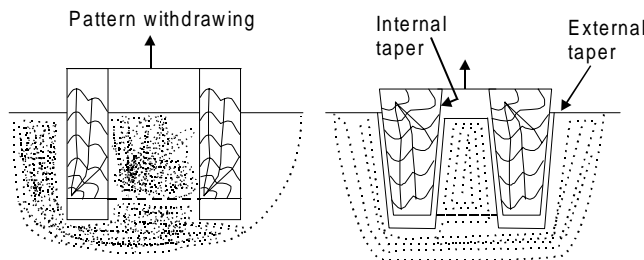


Fig. 10.11 Draft allowance

4. Rapping or Shake Allowance

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

5. Distortion Allowance

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

6. Mold wall Movement Allowance

Mold wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mold cavity depends upon the mold

density and mould composition. This effect becomes more pronounced with increase in moisture content and temperature.

10.6 CORE AND CORE BOX

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 mold. In fact the core (Fig. 10.12) has to withstand the severe action of hot metal which completely surrounds it. Cores are classified according to shape and position in the mold. There are various types of cores such as horizontal core (Fig. 10.13), vertical core (Fig. 10.14), balanced core (Fig. 10.15), drop core (Fig. 10.16) and hanging core (Fig. 10.17).

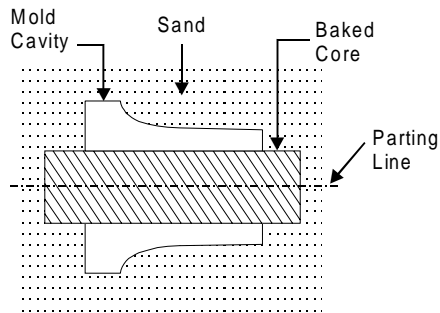


Fig. 10.12 Horizontal core

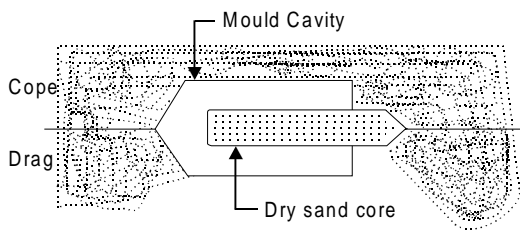


Fig. 10.13 Vertical core

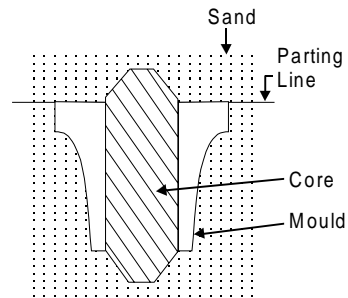


Fig. 10.14 Balanced core

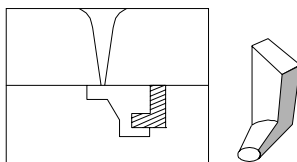


Fig. 10.15 Drop core

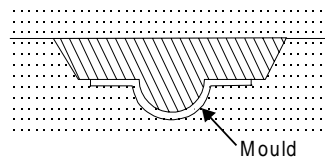


Fig. 10.16 Hanging core

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 mold

3. It may be deployed to improve mold surface.
4. It may provide external under cut features in casting.
5. It may be used to strengthen the mold.
6. It may be used to form gating system of large size mold
7. It may be inserted to achieve deep recesses in the casting

10.6.1 Core Box

Any kind of hollowness in form of holes and recesses in castings is obtained by the use of cores. Cores are made by means of core boxes comprising of either single or in two parts. Core boxes are generally made of wood or metal and are of several types. The main types of core box are half core box, dump core box, split core box, strickle core box, right and left hand core box and loose piece core box.

1. Half core box

This is the most common type of core box. The two identical halves of a symmetrical core prepared in the half core box are shown in Fig. 10.17. Two halves of cores are pasted or cemented together after baking to form a complete core.

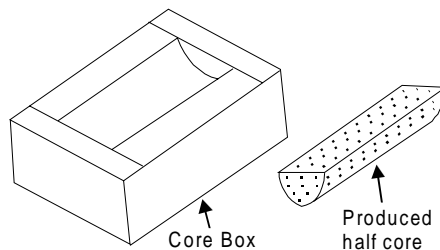


Fig. 10.17 Half core-box

2. Dump core box

Dump core box is similar in construction to half core box as shown in Fig. 10.18. The cores produced do not require pasting, rather they are complete by themselves. If the core produced is in the shape of a slab, then it is called as a slab box or a rectangular box. A dump core-box is used to prepare complete core in it. Generally cylindrical and rectangular cores are prepared in these boxes.

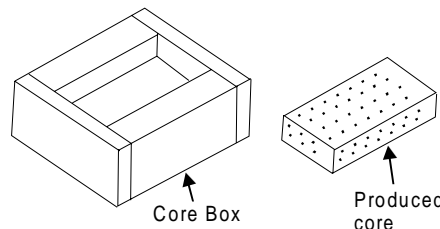


Fig. 10.18 Dump core-box

3. Split core box

Split core boxes are made in two parts as shown in Fig. 10.19. They form the complete core by only one ramming. The two parts of core boxes are held in position by means of clamps and their alignment is maintained by means of dowel pins and thus core is produced.

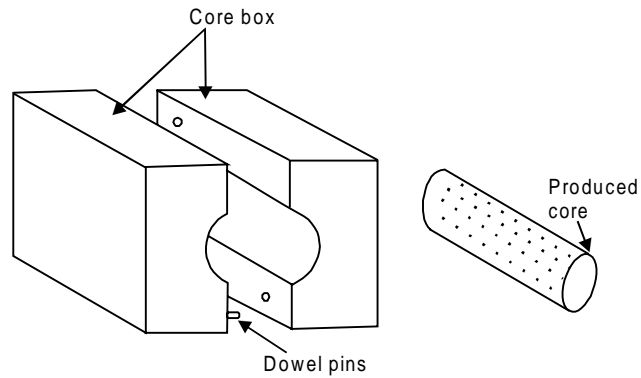


Fig. 10.19 Split core-box

4. Right and left hand core box

Some times the cores are not symmetrical about the center line. In such cases, right and left hand core boxes are used. The two halves of a core made in the same core box are not identical and they cannot be pasted together.

5. Strickle core box

This type of core box is used when a core with an irregular shape is desired. The required shape is achieved by striking oft the core sand from the top of the core box with a wooden piece, called as strickle board. The strickle board has the same contour as that of the required core.

6. Loose piece core box

Loose piece core boxes are highly suitable for making cores where provision for bosses, hubs etc. is required. In such cases, the loose pieces may be located by dowels, nails and dovetails etc. In certain cases, with the help of loose pieces, a single core box can be made to generate both halves of the right-left core.

10.7 CORE BOX ALLOWANCES

Materials used in making core generally swell and increase in size. This may lead to increase the size of core. The larger cores sometimes tend to become still larger. This increase in size may not be significant in small cores, but it is quite significant in large cores and therefore certain amount of allowance should be given on the core boxes to compensate for this increase the cores. It is not possible to lay down a rule for the amount of this allowance as this will depend upon the material used, but it is customary to give a negative allowance of 5 mm /mt.

10.8 COLOR CODIFICATION FOR PATTERNS AND CORE BOXES

There is no set or accepted standard for representing of various surfaces of pattern and core boxes by different colors. The practice of representing of various pattern surfaces by different colors varies with from country to country and sometimes with different manufactures within the country. Out of the various color codifications, the American practice is the most popular. In this practice, the color identification is as follows. Surfaces to be left unfinished after casting are to be painted as black. Surface to be machined are painted as red. Core

prints are painted as yellow. Seats for loose pieces are painted as red stripes on yellow background. Stop-offs is painted as black stripes on yellow base.

10.9 CORE PRINTS

When a hole blind or through is needed in the casting, a core is placed in the mould cavity to produce the same. The core has to be properly located or positioned in the mould cavity on pre-formed recesses or impressions in the sand. To form these recesses or impressions for generating seat for placement of core, extra projections are added on the pattern surface at proper places. These extra projections on the pattern (used for producing recesses in the mould for placement of cores at that location) are known as core prints. Core prints may be of horizontal, vertical, balanced, wing and core types. Horizontal core print produces seats for horizontal core in the mould. Vertical core print produces seats to support a vertical core in the mould. Balanced core print produces a single seat on one side of the mould and the core remains partly in this formed seat and partly in the mould cavity, the two portions balancing each other. The hanging portion of the core may be supported on chaplets. Wing core print is used to form a seat for a wing core. Cover core print forms seat to support a cover core.

10.10 WOODEN PATTERN AND WOODEN CORE BOX MAKING TOOLS

The job of patternmaker is basically done by a carpenter. The tools required for making patterns, therefore do not much differ from those used by a carpenter, excepting the special tools as per the needs of the trade. In addition to tools used by a carpenter, there is one more tool named as the contraction rule, which is a measuring tool of the patternmaker's trade. All castings shrink during cooling from the molten state, and patterns have to be made correspondingly larger than the required casting in order to compensate for the loss in size due to this shrinkage. Various metals and alloys have various shrinkages. The allowance for shrinkage, therefore, varies with various metals and also according to particular casting conditions, and hence the size of the pattern is proportionally increased. A separate scale is available for each allowance, and it enables the dimensions to be set out directly during laying out of the patterns. The rule usually employed the one that has two scales on each side, the total number of scales being four for four commonly cast metals namely, steel, cast iron, brass and aluminum. To compensate for contraction or shrinkage, the graduations are oversized by a proportionate amount, e.g. on 1 mm or 1 per cent scale each 100 cm is longer by 1 cm. The general tools and equipment used in the pattern making shop are given as under:

1. Measuring and Layout Tools

- | | |
|----------------------------------|------------------|
| 1. Wooden or steel scale or rule | 2. Dividers |
| 3. Calipers | 4. Try square |
| 5. Caliper rule | 6. Flexible rule |
| 7. Marking gauge | 8. T-bevel |
| 9. Combination square | |

2. Sawing Tools

- | | |
|----------------|-----------------|
| 1. Compass saw | 2. Rip saw |
| 3. Coping saw | 4. Dovetail saw |

5. Back saw
7. Miter saw

6. Panel saw

3. Planning Tools

1. Jack plane
3. Router plane
5. Block plane
7. Core box plane

2. Circular plane
4. Rabbet plane
6. Bench plane

4. Boring Tools

1. Hand operated drills
3. Twist drill
5. Brace
7. Bit gauge

2. Machine operated drills
4. Countersunk
6. Auger bit

5. Clamping Tools

1. Bench vice
3. Bar clamp
5. Pattern maker's vice

2. C-clamp
4. Hand screw
6. Pinch dog

6. Miscellaneous Tools

1. Screw Driver
3. Chisel
5. File
7. Screw driver
9. Brad pusher

2. Various types of hammers
4. Rasp
6. Nail set
8. Bradawl
10. Cornering tool

10.11 WOODEN PATTERN AND WOODEN CORE BOX MAKING MACHINES

Modern wooden pattern and wooden core making shop requires various wood working machines for quick and mass production of patterns and core boxes. Some of the commonly machines used in making patterns and coreboxes of various kinds of wood are discussed as under.

1. **Wood Turning Lathe.** Patterns for cylindrical castings are made by this lathe.
2. **Abrasive Disc Machine.** It is used for shaping or finishing flat surfaces on small pieces of wood.
3. **Abrasive Belt Machine.** It makes use of an endless abrasive belt. It is used in shaping the patterns.
4. **Circular Saw.** It is used for ripping, cross cutting, beveling and grooving.
5. **Band Saw.** It is designed to cut wood by means of an endless metal saw band.
6. **Jig or Scroll Saw.** It is used for making intricate irregular cuts on small work.
7. **Jointer.** The jointer planes the wood by the action of the revolving cutter head.

8. **Drill Press.** It is used for drilling, boring, mortising, shaping etc.
9. **Grinder.** It is used for shaping and sharpening the tools.
10. **Wood Trimmer.** It is used for mitering the moldings accurately.
11. **Wood Shaper.** It is used for imparting the different shapes to the wood.
12. **Wood Planer.** Its purpose is similar to jointer but it is specially designed for planing larger size.
13. **Tennonner.** These are used for sawing (accurate shape and size).
14. **Mortiser.** It is used to facilitate the cutting of mortise and tenon.

10.12 DESIGN CONSIDERATIONS IN PATTERN MAKING

The following considerations should always be kept in mind while designing a pattern.

1. All Abrupt changes in section of the pattern should be avoided as far as possible.
2. Parting line should be selected carefully, so as to allow as small portion of the pattern as far as possible in the cope area
3. The thickness and section of the pattern should be kept as uniform as possible.
4. Sharp corners and edges should be supported by suitable fillets or otherwise rounded of. It will facilitate easy withdrawal of pattern, smooth flow of molten metal and ensure a sound casting.
5. Surfaces of the casting which are specifically required to be perfectly sound and clean should be so designed that they will be molded in the drag because the possible defects due to loose sand and inclusions will occur in the cope.
6. As far as possible, full cores should be used instead of cemented half cores for reducing cost and for accuracy.
7. For mass production, the use of several patterns in a mould with common riser is to be preferred.
8. The pattern should have very good surface finish as it directly affects the corresponding finish of the casting.
9. Shape and size of the casting and that of the core should be carefully considered to decide the size and location of the core prints.
10. Proper material should always be selected for the pattern after carefully analyzing the factors responsible for their selection.
11. Try to employ full cores always instead of jointed half cores as far as possible. This will reduce cost and ensure greater dimensional accuracy.
12. The use of offset parting, instead of cores as far as possible should be encouraged to the great extent.
13. For large scale production of small castings, the use of gated or match- plate patterns should be preferred wherever the existing facilities permit.
14. If gates, runners and risers are required to be attached with the pattern, they should be properly located and their sudden variation in dimensions should be avoided.
15. Wherever there is a sharp corner, a fillet should be provided, and the corners may be rounded up for easy withdrawal of patterns as well as easy flow of molten metal in the mould.

16. Proper allowances should be provided, wherever necessary.
17. As far as possible, the pattern should have a good surface finish because the surface finish of the casting depends totally on the surface finish of the pattern and the kind of facing of the mold cavity.

10.13 PATTERN LAYOUT

After deciding the molding method and form of pattern, planning for the development of complete pattern is made which may be in two different stages. The first stage is to prepare a layout of the different parts of the pattern. The next stage is to shape them. The layout preparation consists of measuring, marking, and setting out the dimensions on a layout board including needed allowances. The first step in laying out is to study the working drawing carefully and select a suitable board of wood that can accommodate at least two views of the same on full size scale. The next step is to decide a working face of the board and plane an adjacent edge smooth and square with the said face. Select a proper contraction scale for measuring and marking dimensions according to the material of the casting. Further the layout is prepared properly and neatly using different measuring and making tools specifying the locations of core prints and machined surfaces. Finally on completion of the layout, check carefully the dimension and other requirements by incorporating all necessary pattern allowances before starting construction of the pattern.

10.14 PATTERN CONSTRUCTION

On preparing the pattern layout, the construction for making it is started by studying the layout and deciding the location of parting surfaces. From the layout, try to visualize the shape of the pattern and determine the number of separate pieces to be made and the process to be employed for making them. Then the main part of pattern body is first constructed using pattern making tools. The direction of wood grains is kept along the length of pattern as far as possible to ensure due strength and accuracy. Further cut and shape the other different parts of pattern providing adequate draft on them. The prepared parts are then checked by placing them over the prepared layout. Further the different parts of the pattern are assembled with the main body in proper position by gluing or by means of dowels as the case may be. Next the relative locations of all the assembled parts on the pattern are adjusted carefully. Then, the completed pattern is checked for accuracy. Next all the rough surfaces of pattern are finished and imparted with a thin coating of shellac varnish. The wax or leather fillets are then fitted wherever necessary. Wooden fillets should also be fitted before sanding and finishing. The pattern surface once again prepared for good surface and give final coat of shellac. Finally different parts or surfaces of pattern are colored with specific colors mixed in shellac or by painting as per coloring specifications.

10.15 QUESTIONS

1. Define pattern? What is the difference between pattern and casting?
2. What is Pattern? How does it differ from the actual product to be made from it.?
3. What important considerations a pattern-maker has to make before planning a pattern?
4. What are the common allowances provided on patterns and why?
5. What are the factors which govern the selection of a proper material for pattern- making?

6. What are master patterns? How does their size differ from other patterns? Explain.
7. Discuss the utility of unserviceable parts as patterns.
8. What are the allowances provided to the patterns?
9. Discuss the various positive and negative allowances provided to the patterns.
10. Discuss briefly the match plate pattern with the help of suitable sketch. ?
11. Where skeleton patterns are used and what is the advantage?
12. Sketch and describe the use and advantages of a gated pattern?
13. Give common materials used for pattern making? Discuss their merits and demerits?
14. Write short notes on the following:
 - (i) Contraction scale,
 - (ii) Uses of fillets on patterns, and
 - (iii) Pattern with loose pieces
 - (iv) Uses of cores
15. Discuss briefly the various types of patterns used in foundry shop?
16. Define the following?
 - (a) Core prints
 - (b) Mould or cavity
 - (c) Core boxes
 - (d) Shrinkage allowance
 - (e) Chaplets
 - (f) Chills
17. Discuss briefly the various functions of a pattern?
18. Write the color coding for patterns and core boxes?

FOUNDRY TOOLS AND EQUIPMENTS

11.1 INTRODUCTION

There are large number of tools and equipments used in foundry shop for carrying out different operations such as sand preparation, molding, melting, pouring and casting. They can be broadly classified as hand tools, sand conditioning tool, flasks, power operated equipments, metal melting equipments and fettling and finishing equipments. Different kinds of hand tools are used by molder in mold making operations. Sand conditioning tools are basically used for preparing the various types of molding sands and core sand. Flasks are commonly used for preparing sand moulds and keeping molten metal and also for handling the same from place to place. Power operated equipments are used for mechanizing processes in foundries. They include various types of molding machines, power riddles, sand mixers and conveyors, grinders etc. Metal melting equipment includes various types of melting furnaces such as cupola, pit furnace, crucible furnaces etc. Fettling and finishing equipments are also used in foundry work for cleaning and finishing the casting. General tools and equipment used in foundry are discussed as under.

11.2 HAND TOOLS USED IN FOUNDRY SHOP

The common hand tools used in foundry shop are fairly numerous. A brief description of the following foundry tools (Fig. 11.1) used frequently by molder is given as under.

Hand riddle

Hand riddle is shown in Fig. 11.1(a). It consists of a screen of standard circular wire mesh equipped with circular wooden frame. It is generally used for cleaning the sand for removing foreign material such as nails, shot metal, splinters of wood etc. from it. Even power operated riddles are available for riddling large volume of sand.

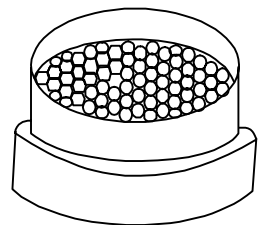


Fig. 11.1 (a)

Shovel

Shovel is shown in Fig. 11.1(b). It consists of an steel pan fitted with a long wooden handle. It is used in mixing, tempering and conditioning the foundry sand by hand. It is also used for moving and transforming the molding sand to the container and molding box or flask. It should always be kept clean.

Rammers

Rammers are shown in Fig. 11.1(c). These are required for striking the molding sand mass in the molding box to pack or compact it uniformly all around the pattern. The common forms of rammers used in ramming are hand rammer, peen rammer, floor rammer and pneumatic rammer which are briefly described as

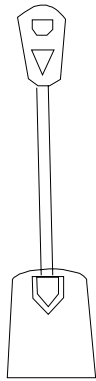


Fig. 11.1 (b)

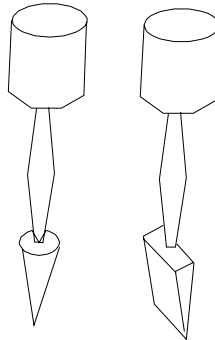


Fig. 11.1 (c)

(i) Hand rammer

It is generally made of wood or metal. It is small and one end of which carries a wedge type construction, called peen and the other end possesses a solid cylindrical shape known as butt. It is used for ramming the sand in bench molding work.

(ii) Peen rammer

It has a wedge-shaped construction formed at the bottom of a metallic rod. It is generally used in packing the molding sand in pockets and comers.

(iii) Floor rammer

It consists of a long steel bar carrying a peen at one end and a flat portion on the other. It is a heavier and larger in comparison to hand rammer. Its specific use is in floor molding for ramming the sand for larger molds. Due to its large length, the molder can operate it in standing position.

(iv) Pneumatic rammers

They save considerable time and labor and are used for making large molds.

Sprue pin

Sprue pin is shown in Fig. 11.1(d). It is a tapered rod of wood or iron which is placed or pushed in cope to join mold cavity while the molding sand in the cope is being rammed. Later its withdrawal from cope produce a vertical hole in molding sand, called sprue through which the molten metal is poured into the mould using gating system. It helps to make a passage for pouring molten metal in mold through gating system

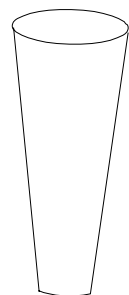


Fig. 11.1 (d)

Strike off bar

Strike off bar (Fig. 11.1(e)) is a flat bar having straight edge and is made of wood or iron. It is used to strike off or remove the excess sand from the top of a molding box after completion of ramming thereby making its surface plane and smooth. Its one edge is made beveled and the other end is kept perfectly smooth and plane.

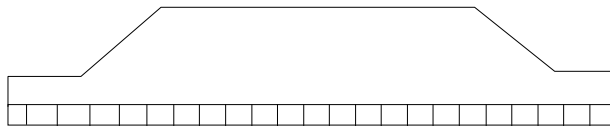


Fig. 11.1 (e)

Mallet

Mallet is similar to a wooden hammer and is generally as used in carpentry or sheet metal shops. In molding shop, it is used for driving the draw spike into the pattern and then rapping it for separation from the mould surfaces so that pattern can be easily withdrawn leaving the mold cavity without damaging the mold surfaces.

Draw spike

Draw spike is shown Fig. 11.1(f). It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other. It may have screw threads on the end to engage metal pattern for its withdrawal from the mold. It is used for driven into pattern which is embedded in the molding sand and raps the pattern to get separated from the pattern and finally draws out it from the mold cavity.

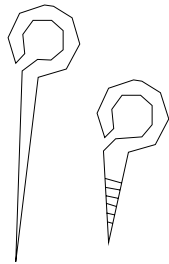


Fig. 11.1 (f)



Fig. 11.1 (g)

Vent rod

Vent rod is shown in Fig. 11.1(g). It is a thin spiked steel rod or wire carrying a pointed edge at one end and a wooden handle or a bent loop at the other. After ramming and striking off the excess sand it is utilized to pierce series of small holes in the molding sand in the cope portion. The series of pierced small holes are called vents holes which allow the exit or escape of steam and gases during pouring mold and solidifying of the molten metal for getting a sound casting.

Lifters

Lifters are shown in Fig. 11.1(h, i, j and k). They are also known as cleaners or finishing tool which are made of thin sections of steel of various length and width with one end bent

at right angle. They are used for cleaning, repairing and finishing the bottom and sides of deep and narrow openings in mold cavity after withdrawal of pattern. They are also used for removing loose sand from mold cavity.



Fig. 11.1 (h)

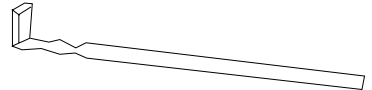


Fig. 11.1 (i)

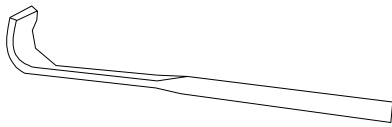


Fig. 11.1 (j)

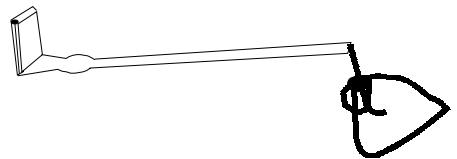


Fig. 11.1 (k)

Trowels

Trowels are shown in Fig. 11.1(l, m and n). They are utilized for finishing flat surfaces and joints and partings lines of the mold. They consist of metal blade made of iron and are equipped with a wooden handle. The common metal blade shapes of trowels may be pointed or contoured or rectangular oriented. The trowels are basically employed for smoothing or slicking the surfaces of molds. They may also be used to cut in-gates and repair the mold surfaces.



Fig. 11.1 (l)



Fig. 11.1 (m)



Fig. 11.1 (n)

Slicks

Slicks are shown in Fig. 11.1(o, p, q, and r). They are also recognized as small double ended mold finishing tool which are generally used for repairing and finishing the mold surfaces and their edges after withdrawal of the pattern. The commonly used slicks are of the types of heart and leaf, square and heart, spoon and bead and heart and spoon. The nomenclatures of the slicks are largely due to their shapes.



Fig. 11.1 (o)



Fig. 11.1 (p)



Fig. 11.1 (q)



Fig. 11.1 (r)

Smoother

Smothers are shown in Fig. 11.1(s and t). According to their use and shape they are given different names. They are also known as finishing tools which are commonly used for repairing and finishing flat and round surfaces, round or square corners and edges of molds.

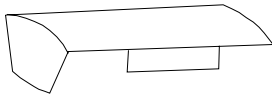


Fig. 11.1 (s)



Fig. 11.1 (t)

Swab

Swab is shown in Fig. 11.1(u). It is a small hemp fiber brush used for moistening the edges of sand mould, which are in contact with the pattern surface before withdrawing the pattern. It is used for sweeping away the molding sand from the mold surface and pattern. It is also used for coating the liquid blacking on the mold faces in dry sand molds.

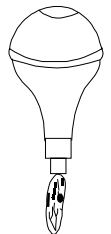


Fig. 11.1 (u)

Spirit level

Spirit level is used by molder to check whether the sand bed or molding box is horizontal or not.

Gate cutter

Gate cutter (Fig. 11.1(v)) is a small shaped piece of sheet metal commonly used to cut runners and feeding gates for connecting sprue hole with the mold cavity.



Fig. 11.1 (v)

Gaggers

Gaggers are pieces of wires or rods bent at one or both ends which are used for reinforcing the downward projecting sand mass in the cope are known as gaggers. They support hanging

bodies of sand. They possess a length varying from 2 to 50 cm. A gagger is always used in cope area and it may reach up to 6 mm away from the pattern. It should be coated with clay wash so that the sand adheres to it. Its surface should be rough in order to have a good grip with the molding sand. It is made up of steel reinforcing bar.

Spray-gun

Spray gun is mainly used to spray coating of facing materials etc. on a mold or core surface.

Nails and wire pieces

They are basically used to reinforce thin projections of sand in the mold or cores.

Wire pieces, spring and nails

They are commonly used to reinforce thin projections of sand in molds or cores. They are also used to fasten cores in molds and reinforce sand in front of an in-gate.

Bellows

Bellows gun is shown in Fig. 11.1(w). It is hand operated leather made device equipped with compressed air jet to blow or pump air when operated. It is used to blow away the loose or unwanted sand from the surfaces of mold cavities.

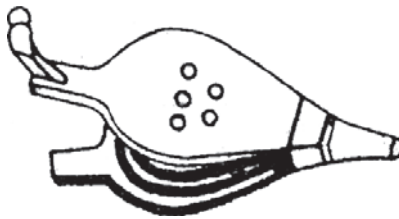


Fig. 11.1 (w)

Fig. 11.1 (a-w) Common hand tools used in foundry

Clamps, cotters and wedges

They are made of steel and are used for clamping the molding boxes firmly together during pouring.

11.3 FLASKS

The common flasks are also called as containers which are used in foundry shop as mold boxes, crucibles and ladles.

1. Moulding Boxes

Mold boxes are also known as molding flasks. Boxes used in sand molding are of two types:

(a) Open molding boxes. Open molding boxes are shown in Fig. 11.2. They are made with the hinge at one corner and a lock on the opposite corner. They are also known as snap molding boxes which are generally used for making sand molds. A snap molding is made of wood and is hinged at one corner. It has special applications in bench molding in green sand work for small nonferrous castings. The mold is first made in the snap flask and then it is

removed and replaced by a steel jacket. Thus, a number of molds can be prepared using the same set of boxes. As an alternative to the wooden snap boxes the cast-aluminum tapered closed boxes are finding favor in modern foundries. They carry a tapered inside surface which is accurately ground and finished. A solid structure of this box gives more rigidity and strength than the open type. These boxes are also removed after assembling the mould. Large molding boxes are equipped with reinforcing cross bars and ribs to hold the heavy mass of sand and support gagers. The size, material and construction of the molding box depend upon the size of the casting.

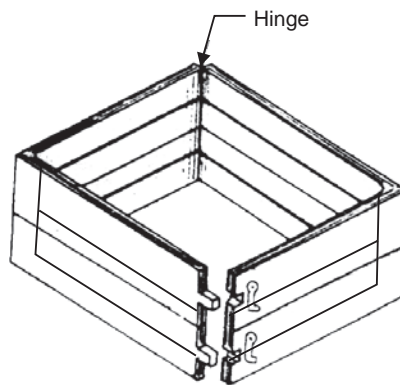


Fig. 11.2 Open molding box

(b) Closed molding boxes. Closed molding boxes are shown in Fig. 11.3 which may be made of wood, cast-iron or steel and consist of two or more parts. The lower part is called the drag, the upper part the cope and all the intermediate parts, if used, cheeks. All the parts are individually equipped with suitable means for clamping arrangements during pouring. Wooden Boxes are generally used in green-sand molding. Dry sand moulds always require metallic boxes because they are heated for drying. Large and heavy boxes are made from cast iron or steel and carry handles and grips as they are manipulated by cranes or hoists, etc. Closed metallic molding boxes may be called as a closed rectangular molding box (Fig. 11.3) or a closed round molding box (Fig. 11.4).

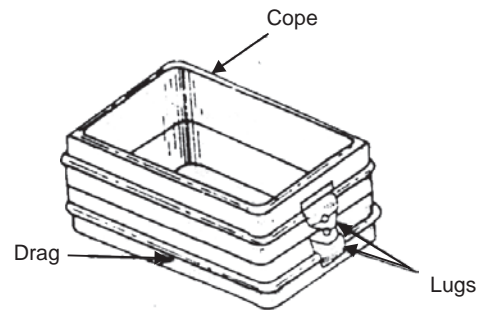


Fig. 11.3 Closed rectangular molding box

2. Crucible

Crucibles are made from graphite or steel shell lined with suitable refractory material like fire clay. They are commonly named as metal melting pots. The raw material or charge is broken into small pieces and placed in them. They are then placed in pit furnaces which are coke-fired. In oil-fired tilting furnaces, they form an integral part of the furnace itself and the charge is put into them while they are in position. After melting of metals in crucibles, they are taken out and received in crucible handle. Pouring of molten is generally done directly by them instead of transferring the molten metal to ladles. But in the case of an oil-fired furnace, the molten metal is first received in a ladle and then poured into the molds.

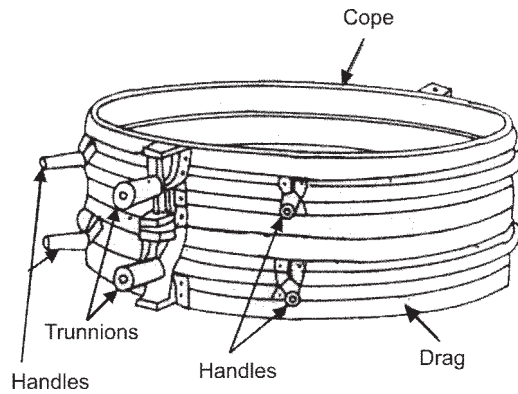


Fig. 11.4 Closed round molding box

3. Ladle

It is similar in shape to the crucible which is also made from graphite or steel shell lined with suitable refractory material like fire clay. It is commonly used to receive molten metal from the melting furnace and pour the same into the mold cavity. Its size is designated by its capacity. Small hand shank ladles are used by a single foundry personal and are provided with only one handle. It may be available in different capacities up to 20 kg. Medium and large size ladles are provided with handles on both sides to be handled by two foundry personals. They are available in various sizes with their capacity varying from 30 kg to 150 kg. Extremely large sizes, with capacities ranging from 250 kg to 1000 kg, are found in crane ladles. Geared crane ladles can hold even more than 1000 kg of molten metal. The handling of ladles can be mechanized for good pouring control and ensuring better safety for foundry personals workers. All the ladles consist of an outer casing made of steel or plate bent in proper shape and then welded. Inside this casing, a refractory lining is provided. At its top, the casing is shaped to have a controlled and well directed flow of molten metal. They are commonly used to transport molten metal from furnace to mold

11.4 POWER OPERATED EQUIPMENTS

Power operated foundry equipments generally used in foundries are different types of molding machines and sand slingers, core making, core baking equipment, power riddles, mechanical conveyors, sand mixers, material handling equipment and sand aerators etc. Few commonly used types of such equipments are discussed as under.

11.4.1 Moulding Machines

Molding machine acts as a device by means of a large number of co-related parts and mechanisms, transmits and directs various forces and motions in required directions so as to help the preparation of a sand mould. The major functions of molding machines involves ramming of molding sand, rolling over or inverting the mould, rapping the pattern and withdrawing the pattern from the mould. Most of the molding machines perform a combination of two or more of functions. However, ramming of sand is the basic function of most of these machines. Use of molding machine is advisable when large number of repetitive castings is to be produced as hand molding may be tedious, time consuming, laborious and expensive comparatively.

11.4.2 Classification of Moulding Machines

The large variety of moulding machines that are available in different designs which can be classified as squeezer machine, jolt machine, jolt-squeezer machine, slinging machines, pattern draw machines and roll over machines. These varieties of machines are discussed as under.

11.4.2.1 Squeezer machine

These machines may be hand operated or power operated. The pattern is placed over the machine table, followed by the molding box. In hand-operated machines, the platen is lifted by hand operated mechanism. In power machines, it is lifted by the air pressure on a piston in the cylinder in the same way as in jolt machine. The table is raised gradually. The sand in the molding box is squeezed between plate and the upward rising table thus enabling a uniform pressing of sand in the molding box. The main advantage of power operated machines in comparison hand operated machines is that more pressure can be applied in power operated.

11.4.2.2 Jolt machine

This machine is also known as jar machine which comprises of air operated piston and cylinder. The air is allowed to enter from the bottom side of the cylinder and acts on the bottom face of the piston to raise it up. The platen or table of the machine is attached at the top of the piston which carries the pattern and molding box with sand filled in it. The upward movement of piston raises the table to a certain height and the air below the piston is suddenly released, resulting in uniform packing of sand around the pattern in the molding box. This process is repeated several times rapidly. This operation is known as jolting technique.

11.4.2.3 Jolt-squeezer machine

It uses the principle of both jolt and squeezer machines in which complete mould is prepared. The cope, match plate and drag are assembled on the machine table in a reverse position, that is, the drag on the top and the cope below. Initially the drag is filled with sand followed by ramming by the jolting action of the table. After leveling off the sand on the upper surface, the assembly is turned upside down and placed over a bottom board placed on the table. Next, the cope is filled up with sand and is rammed by squeezing between the overhead plate and the machine table. The overhead plate is then swung aside and sand on the top leveled off, cope is next removed and the drag is vibrated by air vibrator. This is followed by removal of match plate and closing of two halves of the mold for pouring the molten metal. This machine is used to overcome the drawbacks of both squeeze and jolt principles of ramming molding sand.

11.4.2.4 Slinging machines

These machines are also known as sand slingers and are used for filling and uniform ramming of molding sand in molds. In the slinging operations, the consolidation and ramming are obtained by impact of sand which falls at a very high velocity on pattern. These machines are generally preferred for quick preparation of large sand moulds. These machines can also be used in combination with other devices such as, roll over machines and pattern draw machines for reducing manual operations to minimum. These machines can be stationary and portable types. Stationary machines are used for mass production in bigger foundries whereas portable type machines are mounted on wheels and travel in the foundry shop on a well planned fixed path. A typical sand slinger consists of a heavy base, a bin or hopper to carry sand, a bucket elevator to which are attached a number of buckets and a swinging arm which

carries a belt conveyor and the sand impeller head. Well prepared sand is filed in a bin through the bottom of which it is fed to the elevator buckets. These buckets discharge the molding sand to the belt conveyor which conveys the same to the impeller head. This head can be moved at any location on the mold by swinging the arm. The head revolves at a very high speed and, in doing so, throws stream of molding sand into the molding box at a high velocity. This process is known as slinging. The force of sand ejection and striking into the molding box compel the sand gets packed in the box flask uniformly. This way the satisfactory ramming is automatically get competed on the mold. It is a very useful machine in large foundries.

11.4.2.5 Pattern draw machines

These machines enable easy withdrawal of patterns from the molds. They can be of the kind of stripping plate type and pin lift or push off type. Stripping plate type of pattern draw machines consists of a stationary platen or table on which is mounted a stripping plate which carries a hole in it. The size and shape of this hole is such that it fits accurately around the pattern. The pattern is secured to a pattern plate and the latter to the supporting ram. The pattern is drawn through the stripping plate either by raising the stripping plate and the mould up and keeping the pattern stationary or by keeping the stripping plate and mould stationary and moving the pattern supporting ram downwards along with the pattern and pattern plate. A suitable mechanism can be incorporated in the machine for these movements.

11.4.2.6 Roll-over machine

This machine comprises of a rigid frame carrying two vertical supports on its two sides having bearing supports of trunnions on which the roll-over frame of the machine is mounted. The pattern is mounted on a plate which is secured to the roll-over frame. The platen of the machine can be moved up and down. For preparation of the mould, the roll-over frame is clamped in position with the pattern facing upward. Molding box is placed over the pattern plate and clamped properly. Molding sand is then filled in it and rammed by hand and the extra molding sand is struck off and molding board placed over the box and clamped to it. After that the roll-over frame is unclamped and rolled over through 180° to suspend the box below the frame. The platen is then lifted up to butt against the suspending box. The box is unclamped from the pattern plate to rest over the platen which is brought down leaving the pattern attached to the plate. The prepared mold is now lowered. The frame is then again rolled over to the original position for ramming another flask. Other mechanisms are always incorporated to enable the above rolling over and platen motion. Some roll-over machines may carry a pneumatic mechanism for rolling over. There are others mechanism also which incorporate a jolting table for ramming the sand and an air operated rocking arm to facilitate rolling over. Some machines incorporate a mechanically or pneumatically operated squeezing mechanism for sand ramming in addition to the air operated rolling over mechanism. All such machines are frequently referred to as combination machines to carry out the molding tasks automatically.

11.5 QUESTIONS

1. How do you classify the different tools and equipment used in foundries?
2. Name the different tools used in hand molding stating their use.
3. Sketch and describe the different types of molding boxes you know.
4. What are ladles and crucibles? How do they differ from each other?

5. Describe the working principles and uses of different molding machines.
6. Describe, with the help of sketches, how a mould is rammed on a diaphragm molding machine.
7. What is a molding machine? What main functions does it perform?
8. Describe the principle of working of different pattern draw machines.
9. Describe the principle of working of a rollover machine.
10. What is sand slinger and how does it differ from other molding machines?



MOLD AND CORE MAKING

12.1 INTRODUCTION

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

12.2 MOLDING SAND

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

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

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

12.3 CONSTITUENTS OF MOLDING SAND

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

12.3.1 Silica sand

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

12.3.1.1 Effect of grain shape and size of silica sand

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

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

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

12.3.2 Binder

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

12.3.3 Moisture

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

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

12.3.4 Additives

Additives are the materials generally added to the molding and core sand mixture to develop

some special property in the sand. Some common used additives for enhancing the properties of molding and core sands are discussed as under.

12.3.4.1 Coal dust

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

12.3.4.2 Corn flour

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

12.3.4.3 Dextrin

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

12.3.4.4 Sea coal

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

12.3.4.5 Pitch

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

12.3.4.6 Wood flour

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

12.3.4.7 Silica flour

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

12.4 KINDS OF MOULDING SAND

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

12.4.1 Green sand

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

12.4.2 Dry sand

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

12.4.3 Loam sand

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

12.4.4 Facing sand

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

12.4.5 Backing sand

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

12.4.6 System sand

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

12.4.7 Parting sand

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

12.4.8 Core sand

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

12.5 PROPERTIES OF MOULDING SAND

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

12.5.1 Refractoriness

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

12.5.2 Permeability

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

12.5.3 Cohesiveness

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

12.5.4 Green strength

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

to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

12.5.5 Dry strength

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

12.5.6 Flowability or plasticity

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

12.5.7 Adhesiveness

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

12.5.8 Collapsibility

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

12.5.9 Miscellaneous properties

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

12.6 SAND TESTING

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

increased production resulting from sound castings. Generally the following tests are performed to judge the molding and casting characteristics of foundry sands:

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

Some of the important sand tests are discussed as under.

12.6.1 Moisture Content Test

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

12.6.2 Clay Content Test

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

12.6.3 Grain Fineness Test

For carry out grain fineness test a sample of dry silica sand weighing 50 gms free from clay is placed on a top most sieve bearing U.S. series equivalent number 6. A set of eleven sieves having U.S. Bureau of standard meshes 6, 12, 20, 30, 40, 50, 70, 100, 140, 200 and 270 are mounted on a mechanical shaker (Fig. 12.1). The series are placed in order of fineness from

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

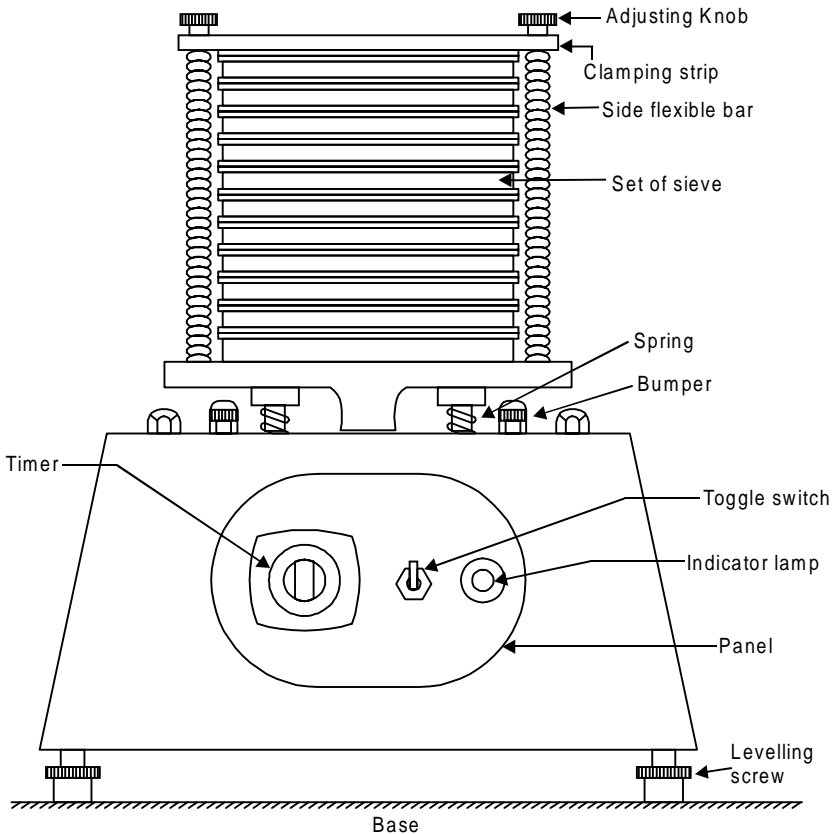


Fig. 12.1 Grain fitness testing mechanical shaker

12.6.4 Refractoriness Test

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

12.6. 5 Strength Test

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

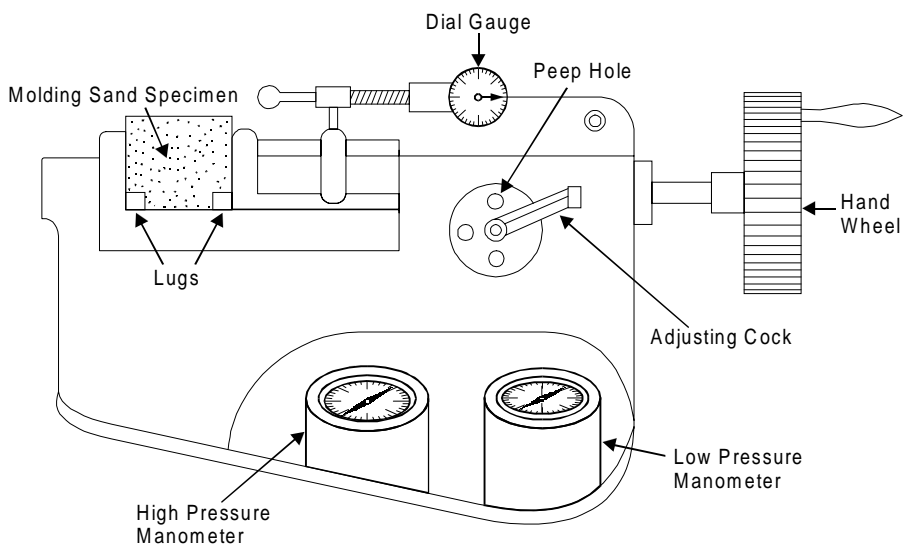


Fig. 12.2 Strength testing machine

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

12.6.6 Permeability Test

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

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

$$P = vh/pat$$

Where, P = permeability

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

h = height of specimen in cm

p = pressure of air in gm/cm^2

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

t = time in minutes.

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

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

12.6.7 Flowability Test

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

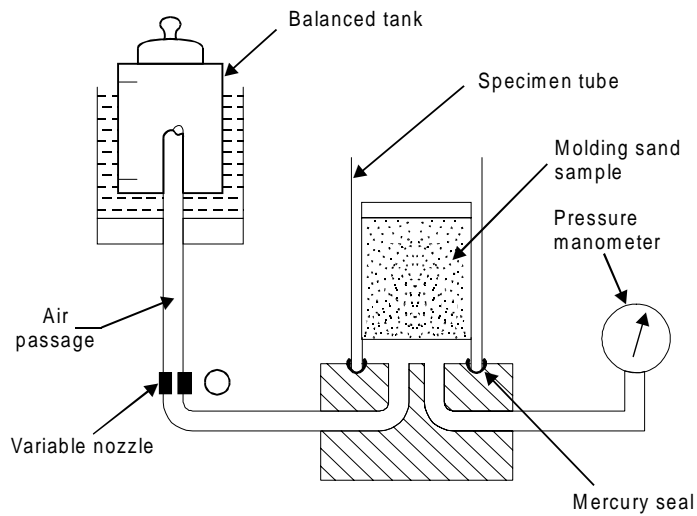
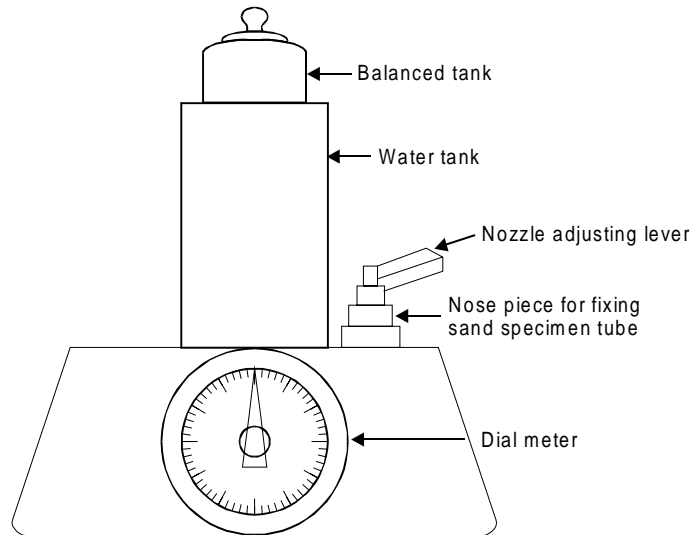


Fig. 12.3 Permeability meter

12.6.8 Shatter Index Test

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

12.6.9 Mould Hardness Test

This test is performed by a mold hardness tester shown in Fig. 12.4. The working of the tester is based on the principle of Brinell hardness testing machine. In an A.F.S. standard hardness tester a half inch diameter steel hemi-spherical ball is loaded with a spring load of 980 gm. This ball is made to penetrate into the mold sand or core sand surface. The penetration

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

12.7 SAND CONDITIONING

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

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

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

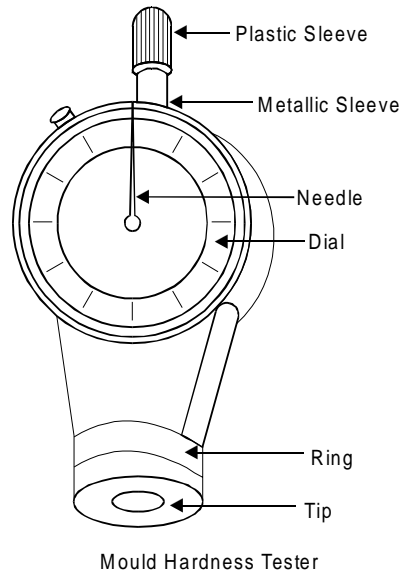


Fig. 12.4 Mould harness tester

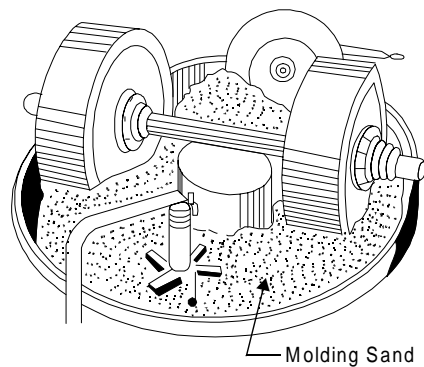


Fig. 12.5 Sand mixing muller

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 followed by clay, while in the other method, clay addition is followed by 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 the rollers. 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 over a one fourth inch mesh screen or by spraying the sand over the sand heap by flipping the shovels. The aeration separates the sand grains and leaves each grain free to flow in the direction of ramming with less friction. The final step in sand conditioning is the cooling of sand mixture because of the fact that if the molding sand mixture is hot, it will cause molding difficulties.

12.8 STEPS INVOLVED IN MAKING A SAND MOLD

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

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

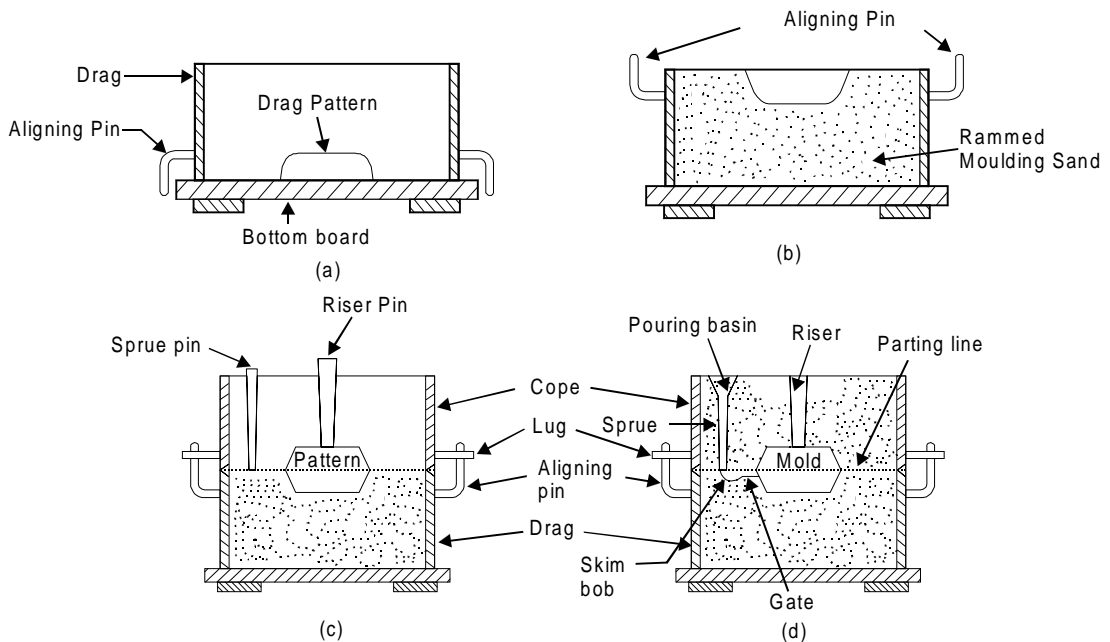


Fig. 12.6 Mold making

Example of making another mold is illustrated through Fig. 12.7

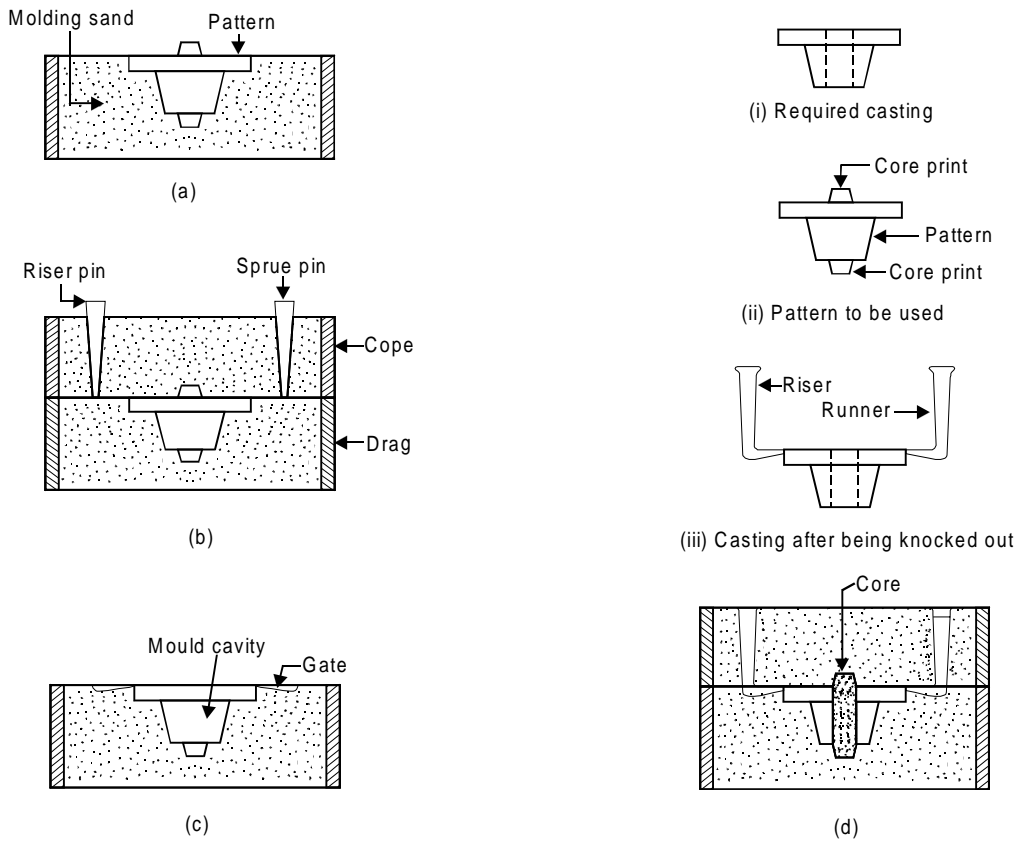


Fig. 12.7 Example of making a mold

12.9 VENTING OF MOLDS

Vents are very small pin types holes made in the cope portion of the mold using pointed edge of the vent wire all around the mold surface as shown in Fig. 12.8. These holes should reach just near the pattern and hence mold cavity on withdrawal of pattern. The basic purpose of vent holes is to permit the escape of gases generated in the mold cavity when the molten metal is poured. Mold gases generate because of evaporation of free water or steam formation, evolution of combined water (steam formation), decomposition of organic materials such as binders and additives (generation of hydrocarbons, CO and CO₂), expansion of air present in the pore spaces of rammed sand. If mold gases are not permitted to escape, they may get trapped in the metal and produce defective castings. They may raise back pressure and resist the inflow of molten metal. They may burst the mold. It is better to make many small vent holes rather than a few large ones to reduce the casting defects.

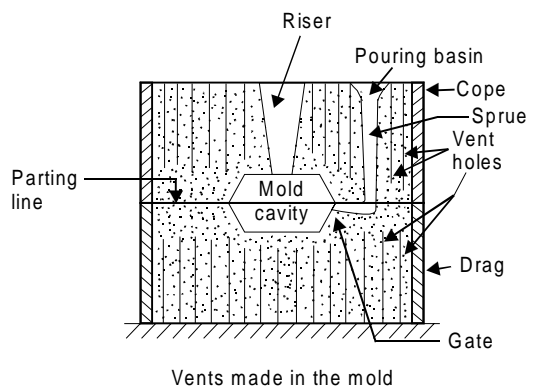


Fig. 12.8 Venting of holes in mold

12.10 GATING SYSTEM IN MOLD

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

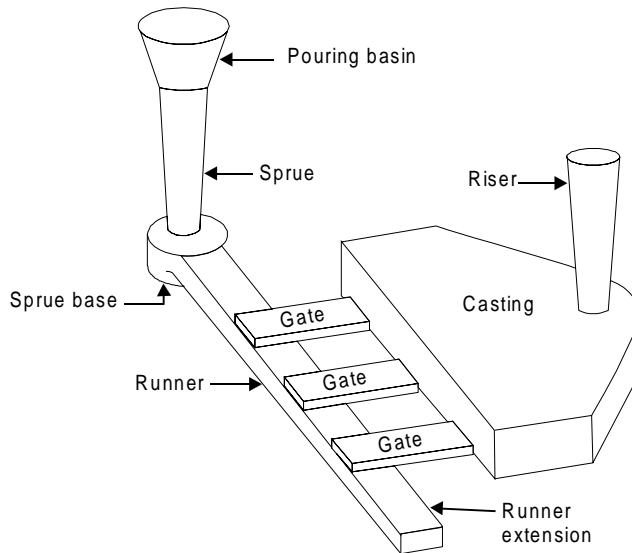


Fig. 12.9 Gating System

1. Pouring basin

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

2. Sprue

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

3. Gate

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

4. Choke

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

5. Runner

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

6. Riser

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

7. Chaplets

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

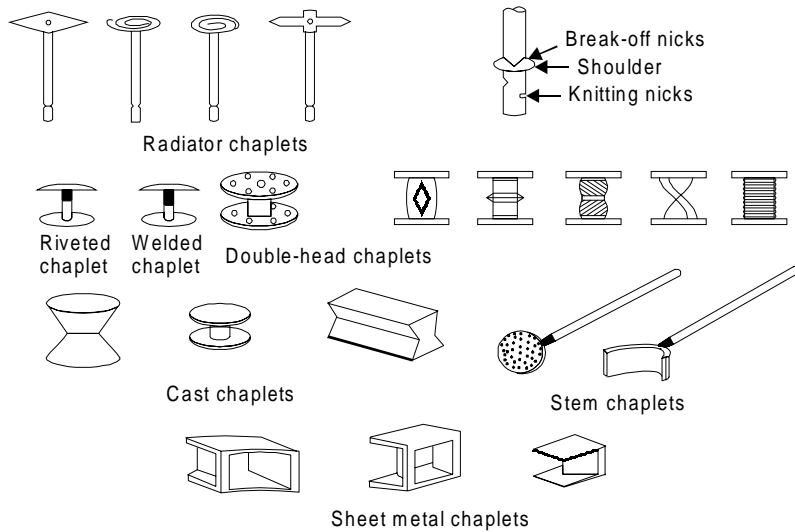
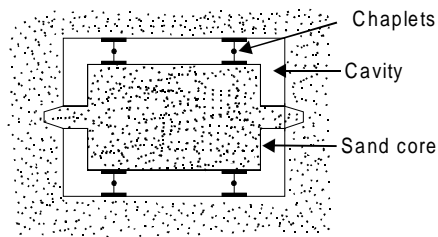


Fig. 12.10 Types of chaplets



Use of chaplets to support a core

Fig. 12.11 Use of chaplets

8. Chills

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

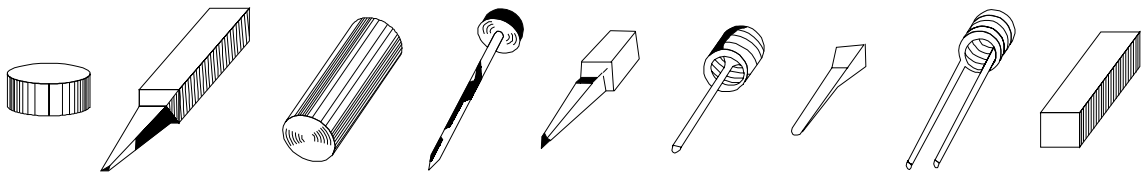


Fig. 12.12 Types of chills

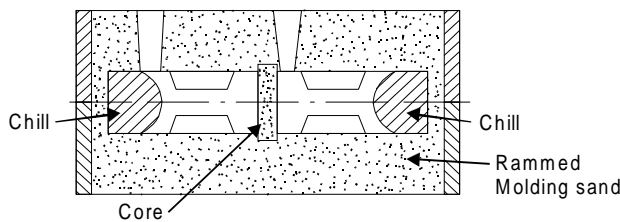


Fig. 12.13 Use of a chill

12.11 FACTORS CONTROLLING GATING DESIGN

The following factors must be considered while designing gating system.

- (i) Sharp corners and abrupt changes in at any section or portion in gating system should be avoided for suppressing turbulence and gas entrapment. Suitable relationship must exist between different cross-sectional areas of gating systems.
- (ii) The most important characteristics of gating system besides sprue are the shape, location and dimensions of runners and type of flow. It is also important to determine the position at which the molten metal enters the mould cavity.
- (iii) Gating ratio should reveal that the total cross-section of sprue, runner and gate decreases towards the mold cavity which provides a choke effect.
- (iv) Bending of runner if any should be kept away from mold cavity.
- (v) Developing the various cross sections of gating system to nullify the effect of turbulence or momentum of molten metal.
- (vi) Streamlining or removing sharp corners at any junctions by providing generous radius, tapering the sprue, providing radius at sprue entrance and exit and providing a basin instead pouring cup etc.

12.12 ROLE OF RISER IN SAND CASTING

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

12.12.1 Considerations for 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 mold till it solidifies completely. This can be achieved when molten metal in riser should freeze at slower rate than the casting.
- 2 Freezing time of molten metal should be more for risers than casting. The quantitative risering analysis developed by Caine and others can be followed while designing risers.

(B) Feeding range

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

(C) Feed Volume Capacity

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

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

12.12.2 Effect of Riser

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

12.13 GREEN SAND MOLDING

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

Advantages

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

12.14 CORE

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

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

12.15 CORE SAND

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

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

1. Cereal binder

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

2. Protein binder

It is generally used to increase collapsibility property of core.

3. Thermo setting resin

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

4. Sulphite binder

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

5. Dextrin

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

6. Pitch

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

7. Molasses

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

8. Core oil

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

12.16 CORE MAKING

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

12.16.1 Core Sand Preparation

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

12.16.2 Core Making Process Using Core Making Machines

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

12.16.2.1 Core blowing machines

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

12.16.2.2 Core ramming machines

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

12.16.2.3 Core drawing machines

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

12.16.3 Core baking

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

12.16.3.1 Continuous type ovens

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

12.16.3.2 Batch type ovens

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

12.16.3.3 Dielectric bakers

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

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

12.16.4 CORE FINISHING

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

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

12.17 GREEN SAND CORES

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

12.18 DRY SAND CORES

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

12.19 CLASSIFICATION OF MOLDING PROCESSES

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

- (i) Classification based on the method used
 - (a) Bench molding.
 - (b) Floor molding,
 - (c) Pit molding.
 - (d) Machine molding.
- (ii) Classification based on the mold material used:
 - (a) Sand molding:
 - 1. Green sand mould
 - 2. Dry sand mould,
 - 3. Skin dried mould.
 - 4. Core sand mould.
 - 5. loam mould
 - 6. Cement bonded sand mould
 - 7. Carbon-dioxide mould.
 - 8. Shell mould.
 - (b) Plaster molding,
 - (c) Metallic molding.
 - (d) Loam molding

Some of the important molding methods are discussed as under.

12.20 MOLDING METHODS

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

12.20.1 Bench Molding

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

12.20.2 Floor Molding

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

12.20.3 Pit Molding

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

12.20.4 Machine Molding

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

12.19.5 Loam Molding

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

12.19.6 Carbon-Dioxide Gas Molding

This process was widely used in Europe for rapid hardening the molds and cores made up of green sand. The mold making process is similar to conventional molding procedure except the mould material which comprises of pure dry silica sand free from clay, 3-5% sodium silicate as binder and moisture content generally less than 3%. A small amount of starch may be added to improve the green compression strength and a very small quantity of coal dust, sea coal, dextrin, wood floor, pitch, graphite and sugar can also be added to improve the collapsibility of the molding sand. Kaolin clay is added to promote mold stability. The prepared molding sand is rammed around the pattern in the mould box and mould is prepared by any conventional technique. After packing, carbon dioxide gas at about 1.3-1.5 kg/cm² pressure is then forced all round the mold surface to about 20 to 30 seconds using CO₂ head or probe or curtain as shown in Fig. 12.14. The special pattern can also be used to force the carbon dioxide gas all round the mold surfaces. Cores can be baked this way. The sodium silicate presented in the mold reacts with CO₂ and produce a very hard constituents or substance commonly called as silica gel.

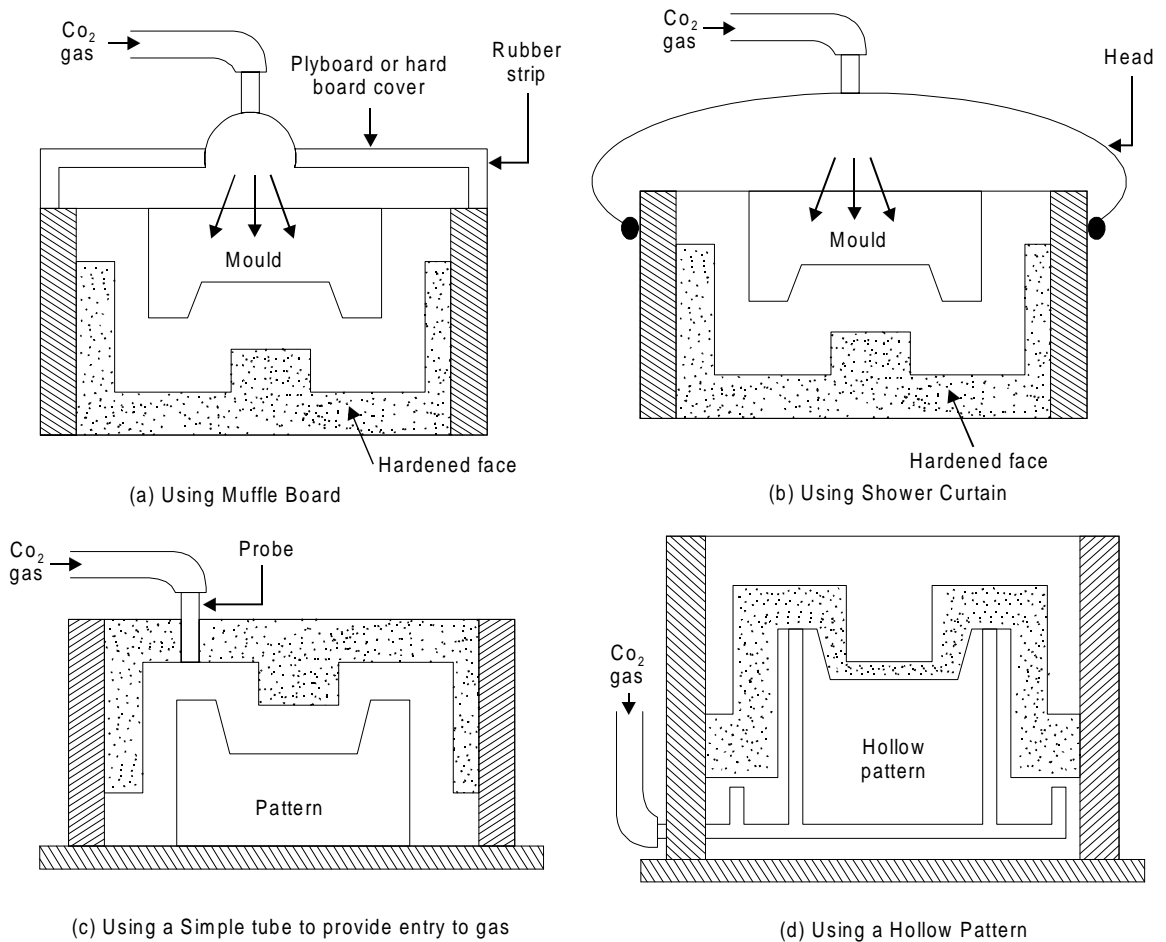
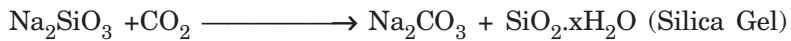


Fig. 12.14 Carbon dioxide molding

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

Few other special molding methods are also discussed as under

12.20.6 Shell Molding

Shell mold casting is recent invention in molding techniques for mass production and smooth finish. Shell molding method was invented in Germany during the Second World War. It is also known as Carning or C process which is generally used for mass production of accurate thin castings with close tolerance of ± 0.02 mm and with smooth surface finish. It consists of making a mould that has two or more thin lines shells (shell line parts, which are moderately hard and smooth. Molding sand is prepared using thermosetting plastic dry powder and fine sand are uniformly mixed in a muller in the ratio 1: 20. In this process the pattern is placed on a metal plate and silicon grease is then sprayed on it. The pattern is then heated to 205°C to 230°C and covered with resin bonded sand. After 30 second a hard layer of sand is formed over the pattern. Pattern and shell are then heated and treated in an oven at 315°C for 60 sec. Then, the shell so formed as the shape of the pattern is ready to strip from the pattern. The shell can be made in two or more pieces as per the shape of pattern. Similarly core can be made by this process. Finally shells are joined together to form the mold cavity. Then the mold is ready for pouring the molten metal to get a casting. The shell so formed has the shape of pattern formed of cavity or projection in the shell. In case of unsymmetrical shapes, two patterns are prepared so that two shell are produced which are joined to form proper cavity. Internal cavity can be formed by placing a core. Hot pattern and box is containing a mixture of sand and resin. Pattern and box inverted and kept in this position for some time. Now box and pattern are brought to original position. A shell of resin-bonded sand sticks to the pattern and the rest falls. Shell separates from the pattern with the help of ejector pins. It is a suitable process for casting thin walled articles. The cast shapes are uniform and their dimensions are within close limit of tolerance ± 0.002 mm and it is suitable for precise duplication of exact parts.

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

Advantages

The main advantages of shell molding are:

- (i) High suitable for thin sections like petrol engine cylinder.
- (ii) Excellent surface finish.
- (iii) Good dimensional accuracy of order of 0.002 to 0.003 mm.
- (iv) Negligible machining and cleaning cost.
- (v) Occupies less floor space.

- (vi) Skill-ness required is less.
- (vii) Moulds formed by this process can be stored until required.
- (viii) Better quality of casting assured.
- (ix) Mass production.
- (x) It allows for greater detail and less draft.
- (xi) Unskilled labor can be employed.
- (xii) Future of shell molding process is very bright.

Disadvantages

The main disadvantages of shell molding are:

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

12.20.7 Plaster Molding

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

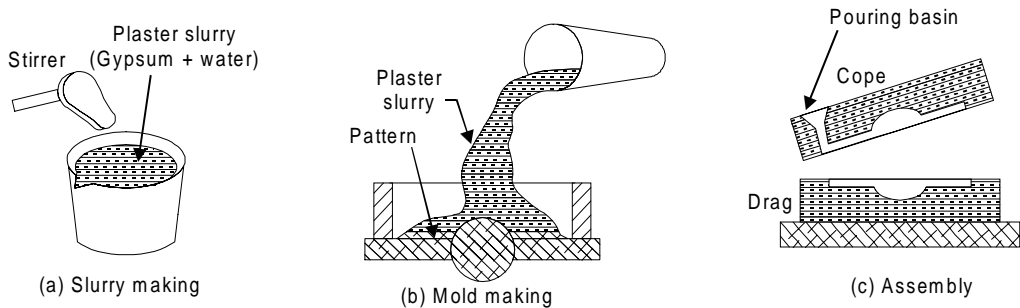


Fig. 12.15 Plaster molding

Advantages

- (a) In plaster molding, very good surface finish is obtained and machining cost is also reduced.
- (b) Slow and uniform rate of cooling of the casting is achieved because of low thermal conductivity of plaster and possibility of stress concentration is reduced.
- (c) Metal shrinkage with accurate control is feasible and thereby warping and distortion of thin sections can be avoided in the plaster molding.

Limitations

- (a) There is evolution of steam during metal pouring if the plaster mold is not dried at higher temperatures avoid this, the plaster mold may be dehydrated at high temperatures, but the strength of the mould decreases with dehydration.
- (b) The permeability of the plaster mold is low. This may be to a certain extent but it can be increased by removing the bubbles as the plaster slurry is mixed in a mechanical mixer.

12.20.8 Antioch Process

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

12.20.9 Metallic Molding

Metallic mold is also known as permanent mold because of their long life. The metallic mold can be reused many times before it is discarded or rebuilt. Permanent molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold. Usually the metallic mould is called as dies and the metal is introduced in it under gravity.

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

conventional sand molds. The mold walls of a permanent mold have thickness from 15 mm to 50 mm. The thicker mold walls can remove greater amount of heat from the casting. This provides the desirable chilling effect. For faster cooling, fins or projections may be provided on the outside of the permanent mold. Although the metallic mould can be used both for ferrous and nonferrous castings but this process is more popular for the non-ferrous castings, for examples aluminum alloys, zinc alloys and magnesium alloys. Usually the metallic molds are made of grey iron, alloy steels and anodized aluminum alloys. There are some advantages, dis-advantages and applications of metallic molding process which are discussed as under.

Advantages

- (i) Fine and dense grained structure in casting is achieved using such mold.
- (ii) No blow holes exist in castings produced by this method.
- (iii) The process is economical.
- (iv) Because of rapid rate of cooling, the castings possess fine grain structure.
- (v) Close dimensional tolerance is possible.
- (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 surface of casting becomes hard due to chilling effect.
- (ii) High refractoriness is needed for high melting point alloys.
- (iii) The process is impractical for large castings.

Applications

- 1 This method is suitable for small and medium sized casting.
- 2 It is widely suitable for non-ferrous casting.

12.21 QUESTIONS

1. Explain briefly the main constituents of molding sand.
2. How do the grain size and shape affect the performance of molding sand?
3. How natural molding sands differ from synthetic sands? Name major sources of obtaining natural molding sands in India?
4. How are binders classified?
5. Describe the process of molding sand preparation and conditioning.
6. Name and describe the different properties of good molding sand.
7. What are the common tests performed on molding sands?
8. Name and describe briefly the different additives commonly added to the molding sand for improving the properties of the molding sand.
9. What are the major functions of additives in molding sands?
10. Classify and discuss the various types of molding sand. What are the main factors which influence the selection of particular molding sand for a specific use?

11. What is meant by green strength and dry strength as applied to a molding sand?
12. What is grain fineness number? Explain how you will use a sieve shaker for determining the grain fineness of foundry sand.
13. How will you test the moisture content and clay content in molding sand?
14. Using the neat sketches, describe procedural steps to be followed in making dry sand mold.
15. Differentiate between the process of green sand molding and dry sand molding.
16. Sketch a complete mold and indicate on it the various terms related to it and their functions.
17. Discuss briefly the various types of molds.
18. Explain the procedure of making a mold using a split pattern.
19. Write short notes of the following:
 - (i) Floor molding
 - (ii) Pit molding
 - (iii) Bench molding
 - (iv) Machine molding
 - (v) Loam molding.
 - (vi) Plaster molding.
 - (vii) Metallic molding.
20. Describe the following:
 - (i) Skin dried molds
 - (ii) Air dried molds
 - (iii) CO₂ molds
 - (iv) Plaster molds.
21. What do you understand by the term gating system?
22. What are chaplets and why are they used?
23. Using neat sketches, describe various types of chaplets.
24. What do you understand by the term gating system?
25. What are the main requirements expected of an ideal gating system?
26. What are different types of gates? Explain them with the help of sketches stating the relative merits and demerits of each.
27. What is chill? Explain in brief its uses.
28. What is meant by the term 'risering'?
29. Discuss the common objectives of risers.
30. What advantages are provided by a riser?
31. What is the best shape of a riser, and why?
32. Why is cylindrical shape risers most commonly used?
33. What are the advantages of blind riser over conventional type riser?
34. Write short notes on the following terms:
 - (i) Use of padding
 - (ii) Use of exothermic materials and
 - (iii) Use of chills to help proper directional solidification.

35. Describe the process of shell molding indicating:
 - (i) Composition of sand mixture
 - (ii) Steps in molding
 - (iii) Advantages
 - (iv) Limitations and
 - (v) Applications.
36. Describe the CO₂-gas molding process in detail using suitable sketches and state its advantages, disadvantages and applications.
37. What is a core? What purposes are served by cores?
38. What are the characteristics of a good core?
39. Classify the types of cores? Explain them with the help of sketches specifying their common applications.
40. What is a core binder?
41. What is core print?
42. Describe different types of core sand.
43. Describe hand core making and machine core making.
44. How are the cores finished and inspected?
45. What is the function of the core in sand molding? How are cores held in place in mold? And how are they supported?
46. Distinguish between green sand cores and dry sand cores?
47. Name the different steps in core-making? Describe the operation of making a dry sand core?
48. What are the different stages in core making?
49. What are the different types of machines used in core-making?
50. Describe the following terms used in core-making.
 - (i) Core drying,
 - (ii) Core finishing
 - (iii) Use of rods, wires, arbors and lifting rings.

CASTING

13.1 INTRODUCTION

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. The solidified object is taken out from the mold either by breaking or taking the mold apart. The solidified object is called casting and the technique followed in method is known as casting process. The casting process was discovered probably around 3500 BC in Mesopotamia. In many parts of world during that period, copper axes (wood cutting tools) and other flat objects were made in open molds using baked clay. These molds were essentially made in single piece. The Bronze Age 2000 BC brought forward more refinement into casting process. For the first time, the core for making hollow sockets in the cast objects was invented. The core was made of baked sand. Also the lost wax process was extensively used for making ornaments using the casting process. Casting technology was greatly improved by Chinese from around 1500 BC. For this there is evidence of the casting activity found in China. For making highly intricate jobs, a lot of time in making the perfect mold to the last detail so hardly any finishing work was required on the casting made from the molds. Indus valley civilization was also known for their extensive use of casting of copper and bronze for ornaments, weapons, tools and utensils. But there was not much of improvement in the casting technology. From various objects that were excavated from the Indus valley sites, they appear to have been familiar with all the known casting methods such as open mold and piece mold. This chapter describes the fluidity of molten metal, different casting techniques and various casting defects occurring in casting processes.

13.2 SIGNIFICANCE OF FLUIDITY

Fluidity of molten metal helps in producing sound casting with fewer defects. It fills not only the mold cavity completely and rapidly but does not allow also any casting defect like “misrun” to occur in the cast object. Pouring of molten metal properly at correct temperature plays a significant role in producing sound castings. The gating system performs the function to introduce clean metal into mold cavity in a manner as free of turbulence as possible. To produce sound casting gate must also be designed to completely fill the mold cavity for preventing casting defect such as misruns and to promote feeding for establishing proper temperature gradients. Prevent casting defect such as misruns without use of excessively high pouring temperatures is still largely a matter of experience. To fill the complicated

castings sections completely, flow rates must be high but not so high as to cause turbulence. It is noted that metal temperature may affect the ability of molten alloy to fill the mold, this effect is metal fluidity. It include alloy analysis and gas content, and heat-extracting power of the molding material. Often, it is desirable to check metal fluidity before pouring using fluidity test. Fig. 13.1 illustrates a standard fluidity spiral test widely used for cast steel. “Fluidity” of an alloy is rated as a distance, in inches, that the metal runs in the spiral channel. Fluidity tests, in which metal from the furnace is poured by controlled vacuum into a flow channel of suitable size, are very useful, since temperature (super-heat) is the most

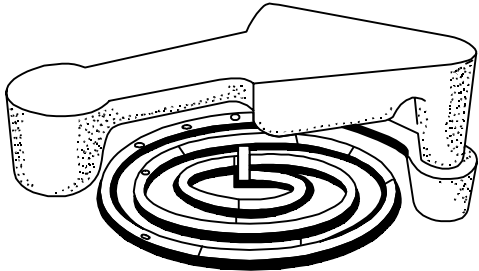


Fig. 13.1 Fluidity spiral test

significant single variable influencing the ability of molten metal to fill mold. This test is an accurate indicator of temperature. The use of simple, spiral test, made in green sand on a core poured by ladle from electric furnace steel melting where temperature measurement is costly and inconvenient. The fluidity test is same times less needed except as a research tool, for the lower melting point metals, where pyrometry is a problem. In small casting work, pouring is done by means of ladles and crucibles.

There are some special casting methods which are discussed as under.

13.3 PERMANENT MOLD OR GRAVITY DIE CASTING

This process is commonly known as permanent mold casting in U.S.A and gravity die casting in England. A permanent mold casting makes use of a mold or metallic die which is permanent. A typical permanent mold is shown in Fig. 13.2. Molten metal is poured into the mold under

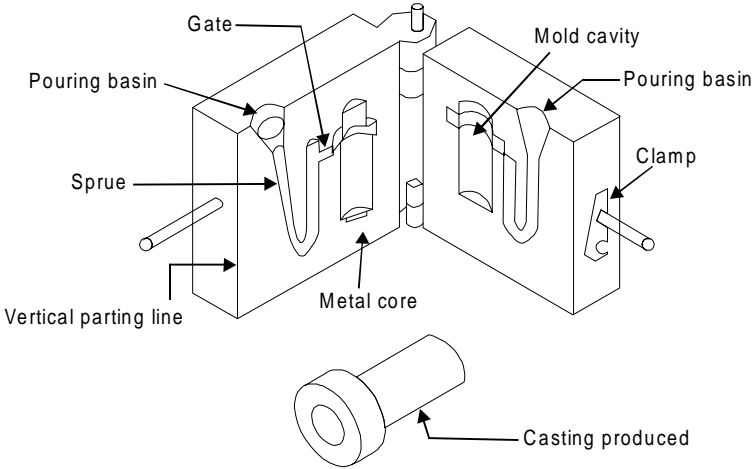


Fig. 13.2 A typical permanent mold

gravity only and no external pressure is applied to force the liquid metal into the mold cavity. However, the liquid metal solidifies under pressure of metal in the risers, etc. The metallic mold can be reused many times before it is discarded or rebuilt. These molds are made of dense, fine grained, heat resistant cast iron, steel, bronze, anodized aluminum, graphite or other suitable refractoriness. The mold is made in two halves in order to facilitate the removal of casting from the mold. It may be designed with a vertical parting line or with a horizontal parting line as in conventional sand molds. The mold walls of a permanent mold have thickness from 15 mm to 50 mm. The thicker mold 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 mold. 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 mold is higher than the sand mold. 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.

13.3 SLUSH CASTING

Slush casting is an extension of permanent mold casting or metallic mold casting. It is used widely for production of hollow casting without the use of core. The process is similar to metallic mold casting only with the difference that mold is allowed to open at an early stage (only when a predetermined amount of molten metal has solidified up to some thickness) and some un-solidified molten metal fall down leaving hollowness in the cast object. The process finds wide applications in production of articles namely toys, novelties, statuettes, ornaments, lighting fixtures and other articles having hollowness inside the cast product.

13.4 PRESSURE DIE CASTING

Unlike permanent mold or gravity die casting, molten metal is forced into metallic mold 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 alloys 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.

There are four main types of die-casting machine which are given as under.

1. Hot chamber die casting machine
2. Cold chamber die casting machine.
3. Air blown or goose neck type machine
4. Vacuum die-casting machine

Some commonly used die casting processes are discussed as under.

Hot chamber die-casting

Hot chamber die-casting machine is the oldest of die-casting machines which is simplest to operate. It can produce about 60 or more castings of up to 20 kg each per hour and several hundred castings per hour for single impression castings weighing a few grams. The melting unit of setup comprises of an integral part of the process. The molten metal possesses nominal amount of superheat and, therefore, less pressure is needed to force the liquid metal into the die. This process may be of gooseneck or air-injection type or submerged plunger type-air blown or goose neck type machine is shown as in Fig. 13.3. It is capable of performing the following functions:

- (i) Holding two die halves finally together.
- (ii) Closing the die.
- (iii) Injecting molten metal into die.

- (iv) Opening the die.
- (v) Ejecting the casting out of the die.

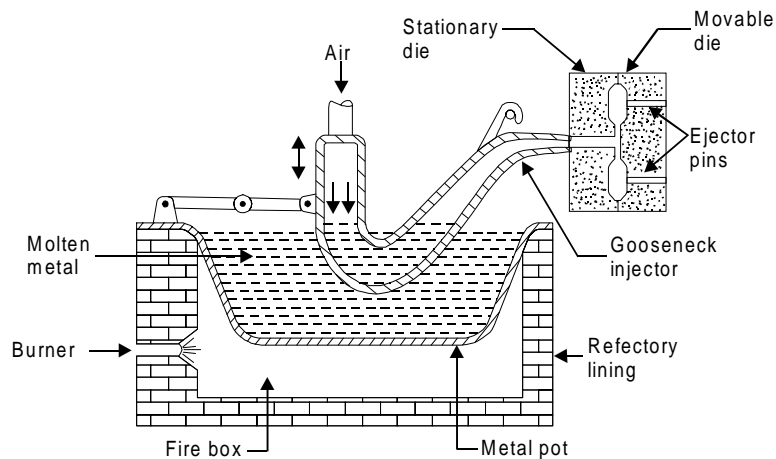


Fig. 13.3 Air blown or goose neck type die casting setup

A die casting machine consists of four basic elements namely frame, source of molten metal and molten metal transfer mechanism, die-casting dies, and metal injection mechanism. It is a simple machine as regards its construction and operation. A cast iron gooseneck is so pivoted in the setup that it can be dipped beneath the surface of the molten metal to receive the same when needed. The molten metal fills the cylindrical portion and the curved passageways of the gooseneck. Gooseneck is then raised and connected to an airline which supplies pressure to force the molten metal into the closed die. Air pressure is required for injecting metal into the die is of the order of 30 to 45 kg./cm². The two mold halves are securely clamped together before pouring. Simple mechanical clamps of latches and toggle kinds are adequate for small molds. On solidification of the die cast part, the gooseneck is again dipped beneath the molten metal to receive the molten metal again for the next cycle. The die halves are opened out and the die cast part is ejected and die closes in order to receive a molten metal for producing the next casting. The cycle repeats again and again. Generally large permanent molds need pneumatic or other power clamping devices. A permanent mold casting may range in weight from a few grams to 150 kg. for aluminum. Cores for permanent molds are made up of alloy steel or dry sand. Metal cores are used when they can be easily extracted from the casting. A dry sand core or a shell core is preferred when the cavity to be cored is such that a metal core cannot possibly be withdrawn from the casting. The sprues, risers, runners, gates and vents are machined into the parting surface for one or both mold halves. The runner channels are inclined, to minimize turbulence of the incoming metal. Whenever possible, the runner should be at the thinnest area of the casting, with the risers at the top of the die above the heavy sections. On heating the mold surfaces to the required temperature, a refractory coating in the form of slurry is sprayed or brushed on to the mold cavity, riser, and gate and runner surfaces. French chalk or calcium carbonate suspended in sodium silicate binder is commonly used as a coating for aluminum and magnesium permanent mold castings. Chills are pieces of copper, brass or aluminum and are inserted into the mold's inner surface. Water passages in the mold or cooling fins made on outside the mold surface are blown by air otherwise water mist will create chilling effect. A chill is commonly used to promote directional solidification.

Cold chamber die casting

Cold chamber die casting process differs from hot chamber die casting in following respects.

1. Melting unit is generally not an integral part of the cold chamber die casting machine. Molten metal is brought and poured into die casting machine with help of ladles.
2. Molten metal poured into the cold chamber casting machine is generally at lower temperature as compared to that poured in hot chamber die casting machine.
3. For this reasoning, a cold chamber die casting process has to be made use of pressure much higher (of the order of 200 to 2000 kgf/cm²) than those applied in hot chamber process.
4. High pressure tends to increase the fluidity of molten metal possessing relatively lower temperature.
5. Lower temperature of molten metal accompanied with higher injection pressure with produce castings of dense structure sustained dimensional accuracy and free from blow-holes.
6. Die components experience less thermal stresses due to lower temperature of molten metal. However, the dies are often required to be made stronger in order to bear higher pressures.

There are some advantages, disadvantages and application of this process which are given as under.

Advantages

1. It is very quick process
2. It is used for mass production
3. castings produced by this process are greatly improved surface finish
4. Thin section (0.5 mm Zn, 0.8 mm Al and 0.7 mm Mg) can be easily casted
5. Good tolerances
6. Well defined and distinct surface
7. Less nos. of rejections
8. Cost of production is less
9. Process require less space
10. Very economic process
11. Life of die is long
12. All casting has same size and shape.

Disadvantages

1. Cost of die is high.
2. Only thin casting can be produced.
3. Special skill is required.
4. Unless special precautions are adopted for evaluation of air from die-cavity some air is always entrapped in castings causing porosity.
5. It is not suitable for low production.

Applications

1. Carburetor bodies
2. Hydraulic brake cylinders
3. Refrigeration castings
4. Washing machine
5. Connecting rods and automotive pistons
6. Oil pump bodies
7. Gears and gear covers
8. Aircraft and missile castings, and
9. Typewriter segments

13.5 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.

13.6 COMPARISON BETWEEN PERMANENT MOLD CASTING AND DIE CASTING

The comparison between permanent mold castings and die casting given as under in Table 13.1.

Table 13.1 Comparison between Permanent Mold Castings and Die Casting

S.No.	Permanent Mold Castings	Die Casting
1.	Permanent mold 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 mold
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.

13.7 SHELL MOLD CASTING

Shell mold casting process is recent invention in casting techniques for mass production and smooth surface finish. It was originated in Germany during Second World War. It is also called as Carning or C process. It consists of making a mold that possesses two or more thin shells (shell line parts, which are moderately hard and smooth with a texture consisting of thermosetting resin bonded sands. The shells are 0.3 to 0.6 mm thick and can be handled and stored. Shell molds are made so that machining parts fit together-easily. They are held using clamps or adhesive and metal is poured either in a vertical or horizontal position. They are supported using rocks or mass of bulky permeable material. Thermosetting resin, dry powder and sand are mixed thoroughly in a muller.

Complete shell molding casting processes is carried in four stages as shown in Fig. 13.4. In this process a pattern is placed on a metal plate and it is then coated with a mixture of fine sand and Phenol-resin (20:1). The pattern is heated first and silicon grease is then sprayed on the heated metal pattern for easy separation. The pattern is heated to 205 to 230°C and covered with resin bounded sand. After 30 seconds, a hard layer of sand is formed over pattern. Pattern and shell are heated and treated in an oven at 315°C for 60 secs.,

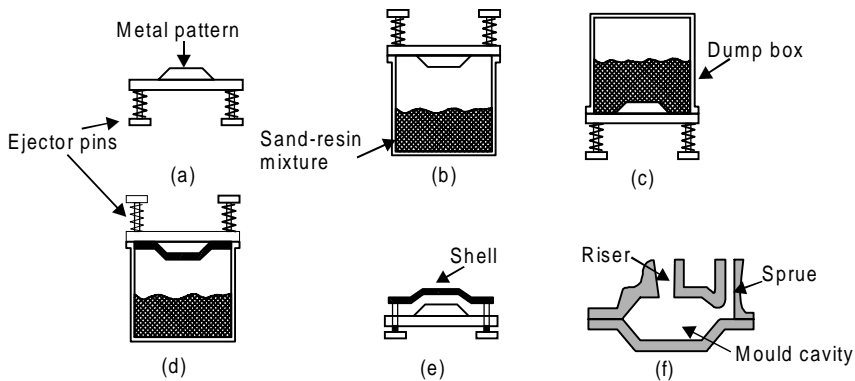


Fig. 13.4 Shell mold casting process

Phenol resin is allowed to set to a specific thickness. So the layer of about 4 to 10 mm in thickness is stuck on the pattern and the loose material is then removed from the pattern. Then shell is ready to strip from the pattern. A plate pattern is made in two or more pieces and similarly core is made by same technique. The shells are clamped and usually embedded in gravel, coarse sand or metal shot. Then mold is ready for pouring. The shell so formed has the shape of pattern formed of cavity or projection in the shell. In case of unsymmetrical shapes, two patterns are prepared so that two shell are produced which are joined to form proper cavity. Internal cavity can be formed by placing a core. Hot pattern and box is

containing a mixture of sand and resin. Pattern and box inverted and kept in this position for some time. Now box and pattern are brought to original position. A shell of resin-bonded sand sticks to the pattern and the rest falls. Shell separates from the pattern with the help of ejector pins. It is a suitable process for casting thin walled articles. The cast shapes are uniform and their dimensions are within close limit of tolerance ± 0.002 mm and it is suitable for precise duplication of exact parts. It has various advantages which are as follows. There are some advantages and disadvantages of this process which are given as under.

Advantages

The main advantages of shell molding are:

- (i) Very suitable for thin sections like petrol engine cylinder.
- (ii) Excellent surface finish.
- (iii) Good dimensional accuracy of order of 0.002 to 0.003 mm.
- (iv) Negligible machining and cleaning cost.
- (v) Occupies less floor space.
- (vi) Skill-ness required is less.
- (vii) Molds can be stored until required.
- (viii) Better quality of casting assured.
- (ix) Mass production.

Disadvantages

- (i) Initial cost is high.
- (ii) Specialized equipment is required.
- (iii) Resin binder is an expensive material.
- (iv) Limited for small size.
- (v) Future of shell molding process is very bright.

Applications

- (i) Suitable for production of casting made up of alloys of Al, Cu and ferrous metals
- (ii) Bushing
- (iii) Valves bodies
- (iv) Rocker arms
- (v) Bearing caps
- (vi) Brackets
- (vii) Gears

13.8 CENTRIFUGAL CASTING

In centrifugal casting process, molten metal is poured into a revolving mold 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 Centrifugal Casting

In true centrifugal casting process, the axis of rotation of mold 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 Levauud Casting Process

Fig 13.5 shows the essential components of De Levauud type true centrifugal casting process. The article produced by this process is shown in Fig 13.6. In this process, metal molds prove to be economical when large numbers of castings are produced. This process makes use of metal mold. The process setup contains an accurately machined metal mold 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 mold. As pouring proceeds the rotating mold, in the casting machine is moved slowly down the track so that the metal is laid progressively along the length of the mold wall flowing a helical path. The control is being achieved by synchronizing the rate of pouring, mold travel and speed of mold rotation. After completion of pouring the machine will be at the lower end of its track with the mold 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 mold by inserting a pipe puller which expands as it is pulled.

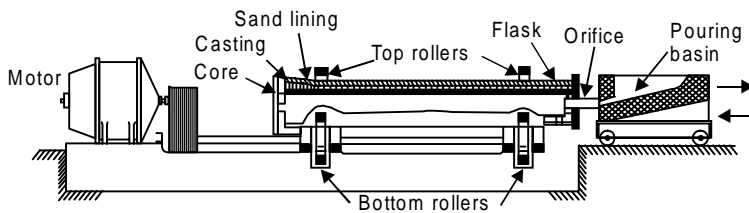


Fig. 13.5 De Levauud type true entrifugal casting process.

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 mold 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 mold is raised as that mold axis gets inclined. As the pouring starts and continues, the end is gradually lowered till the mold is horizontal and when the pouring stops. At this stage, the speed of mold rotation is increased and maintained till the casting is solidified. Finally, the mold rotation is stopped and the casting is extracted from the mold.

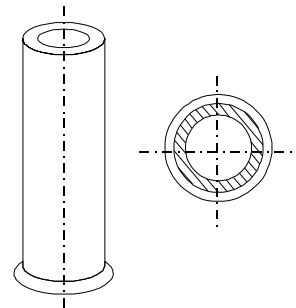


Fig. 13.6 Article produced by true centrifugal casting process

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. 13.7. 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 mold 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. 13.8. Symmetrical objects namely wheel having arms like flywheel, gears and back wheels are produced by this process.

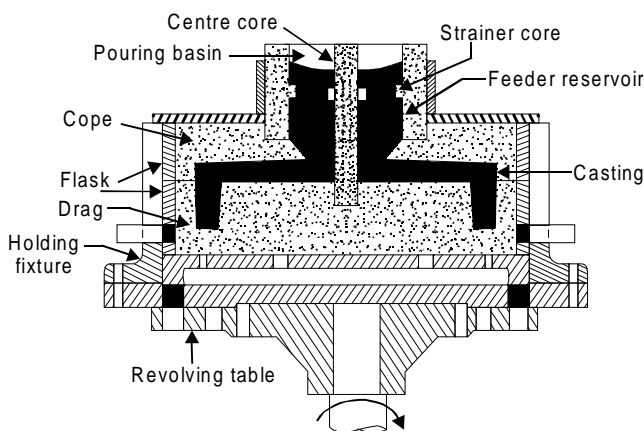


Fig. 13.7 Semi-centrifugal casting setup

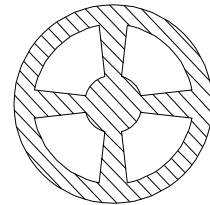


Fig. 13.8 Article produced by semi-centrifugal casting process

Centrifuging Casting

Centrifuging casting setup is shown in Fig. 13.9. 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 mold rotation. The sample article produced by this process is depicted in Fig. 13.10.

13.9 CONTINUOUS CASTING

In this process the molten metal is continuously poured in to a mold 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 mold 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 mold at a uniform speed. The water cooled mold 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

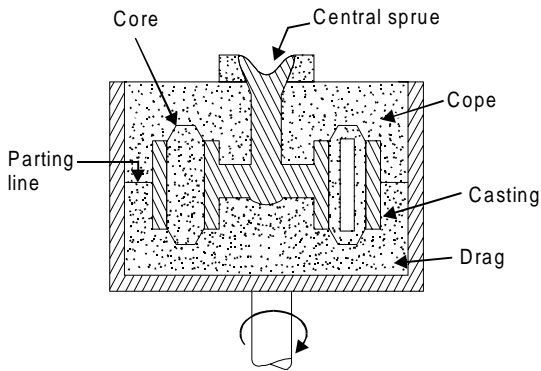
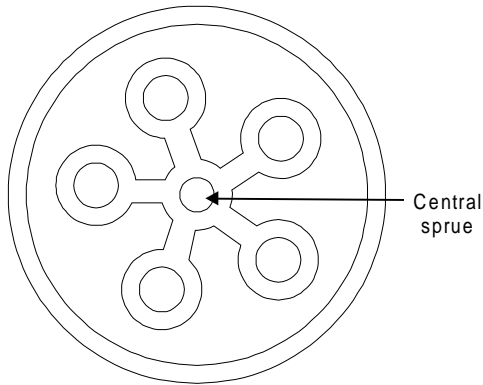


Fig. 13.9 Centrifuging casting setup

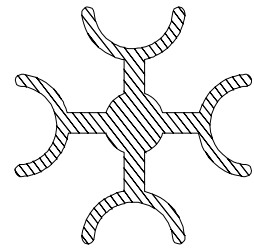


Fig. 13.10 Article produced by centrifuging casting process

- (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, fluted or gear toothed etc.

13.10 PROBABLE CAUSES AND SUGGESTED REMEDIES OF VARIOUS CASTING DEFECTS

The probable causes and suggested remedies of various casting defects is given in Table 13.1.

Table 13.1: Probable Causes and Suggested Remedies of Various Casting Defects

S.No.	Name of Casting Defect	Probable Causes	Suggested Remedies
1.	Blow holes	<ol style="list-style-type: none"> 1. Excess moisture content in molding sand. 2. Rust and moisture on Chills, chaplets and inserts 3. Cores not sufficiently baked. 4. Excessive use of organic binders. 5. Molds not adequately vented. 6. Molds not adequately vented. 7. Molds rammed very hard. 	<ol style="list-style-type: none"> 1. Control of moisture content. 2. Use of rust free chills, chaplet and clean inserts. 3. Bake cores properly. 4. Ram the mold s less hard. 5. Provide adequate venting in mold and cores
2.	Shrinkage	<ol style="list-style-type: none"> 1. Faulty gating and risering system. 2. Improper chilling. 	<ol style="list-style-type: none"> 1. Ensure proper directional solidification by modifying gating, risering and chilling
3.	Porosity	<ol style="list-style-type: none"> 1. High pouring temperature. 2. Gas dissolved in metal charge. 3. Less flux used. 4. Molten metal not properly degassed. 5. Slow solidification of casting. 6. High moisture and low permeability in mold. 	<ol style="list-style-type: none"> 1. Regulate pouring temperature 2. Control metal composition. 3. Increase flux proportions. 4. Ensure effective degassing. 5. Modify gating and risering. 6. Reduce moisture and increase permeability of mold.
4.	Misruns	<ol style="list-style-type: none"> 1. Lack of fluidity ill molten metal. 2. Faulty design. 3. Faulty gating. 	<ol style="list-style-type: none"> 1. Adjust proper pouring temperature. 2. Modify design. 3. Modify gating system.
5.	Hot Tears	<ol style="list-style-type: none"> 1. Lack of collapsibility of core. 2. Lack of collapsibility of mold 3. Faulty design. 4. Hard Ramming of mold. 	<ol style="list-style-type: none"> 1. Improve core collapsibility. 2. Improve mold collapsibility. 3. Modify casting design. 4. Provide softer ramming.
6.	Metal penetration	<ol style="list-style-type: none"> 1. Large grain size and used. 2. Soft ramming of mold. 3. Molding sand or core has low strength. 4. Molding sand or core has high permeability. 5. Pouring temperature of metal too high. 	<ol style="list-style-type: none"> 1. Use sand having finer grain size. 2. Provide hard ramming. 3. Suitably adjust pouring temperature.
7.	Cold shuts	<ol style="list-style-type: none"> 1. Lack of fluidity in molten metal. 2. Faulty design. 3. Faulty gating. 	<ol style="list-style-type: none"> 1. Adjust proper pouring temperature. 2. Modify design. 3. Modify gating system
8.	Cuts and washes	<ol style="list-style-type: none"> 1. Low strength of mold and core. 2. Lack of binders in facing and core stand. 3. Faulty gating. 	<ol style="list-style-type: none"> 1. Improve mold and core strength. 2. Add more binders to facing and core sand. 3. Improve gating

9.	Inclusions	<ol style="list-style-type: none"> 1. Faulty gating. 2. Faulty pouring. 3. Inferior molding or core sand. 4. Soft ramming of mold. 5. Rough handling of mold and core. 	<ol style="list-style-type: none"> 1. Modify gating system 2. Improve pouring to minimize turbulence. 3. Use of superior sand of good strength. 4. Provide hard, ramming.
10.	Fusion	<ol style="list-style-type: none"> 1. Low refractoriness in molding sand 2. Faulty gating. 3. Too high pouring temperature of metal. 4. Poor facing sand. 	<ol style="list-style-type: none"> 1. Improve refractoriness of sand. 2. Modify gating system. 3. Use lower pouring temperature. 4. Improve quality of facing sand.
11.	Drops	<ol style="list-style-type: none"> 1. Low green strength in molding sand and core. 2. Too soft ramming. 3. Inadequate reinforcement of sand and core projections 	<ol style="list-style-type: none"> 1. Increase green strength of sand mold. 2. Provide harder ramming. 3. Provide adequate reinforcement to sand projections and cope by using nails and gagers.
12.	Shot Metal	<ol style="list-style-type: none"> 1. Too low pouring temperature. 2. Excess sulphur content in metal. 3. Faulty gating. 4. High moisture content in molding sand. 	<ol style="list-style-type: none"> 1. Use proper pouring temperature. 2. Reduce sulphur content. 3. Modify gating of system.
13.	Shift	<ol style="list-style-type: none"> 1. Worn-out or bent clamping pins. 2. Misalignment of two halves of pattern. 3. Improper support of core. 4. Improper location of core. 5. Faulty core boxes. 6. Insufficient strength of molding sand and core. 	<ol style="list-style-type: none"> 1. Repair or replace the pins, for removing defect. 2. Repair or replace dowels which cause misalignment. 3. Provide adequate support to core. 4. Increase strength of both mold and core
14.	Crushes	<ol style="list-style-type: none"> 1. Defective core boxes producing over-sized cores. 2. Worn out core prints on patterns producing under sized seats for cores in the mold. 3. Careless assembly of cores in the mold 	<ol style="list-style-type: none"> 1. Repair or replace the pins, for removing defect. 2. Repair or replace dowels which cause misalignment. 3. Provide adequate support to core. 4. Increase strength of both mold and core.
15.	Rat-tails or Buckles	<ol style="list-style-type: none"> 1. Continuous large flat surfaces on casting. 2. Excessive mold hardness. 3. Lack of combustible additives in molding sand. 	<ol style="list-style-type: none"> 1. Break continuity of large flat groves and depressions 2. Reduce mold hardness. 3. Add combustible additives to sand.

16.	Swells	1. Too soft ramming of mold. 2. Low strength of mold and core 3. Mold not properly supported.	1. Provide hard ramming. 2. Increase strength of both mold and core.
17.	Hard Spot	1. Faulty metal composition. 2. Faulty casting design.	1. Suitably charge metal composition. 2. Modify casting design.
18.	Run out, Fins and Fash	1. Faulty molding. 2. Defective molding boxes.	1. Improving molding technique. 2. Change the defective molding boxes. 3. Keep weights on mold boxes.
19.	Spongings	1. Availability of dirt and swarf held in molten metal. 2. Improper skimming. 3. Because of more impurities in molten metal	1. Remove dirt swarf held in molten metal. 2. Skimming should be perfect. 3. Fewer impurities in molten metal should be there.
20.	Warpage	1. Continuous large flat surfaces on castings indicating a poor design. 2. No directional solidification of casting.	1. Follow principle of sufficient directional solidification 2. Make good casting design

13.11 PLASTICS MOLDING PROCESSES

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

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

Two major processes from the above are discussed as under.

13.11.1 Injection die Molding

In this process, thermoplastic materials soften when heated and re-harden when cooled. No chemical change takes place during heating and cooling. Fig. 13.11 illustrates the injection molding process. The process involves granular molding 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 mold 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 mold. The metal cooled in rigid state in the mold. Then mold is opened and piece is ejected out material heating temperature is usually between 180°-280°C. Mold is cooled in order to cool the mold articles. Automatic devices are commercially available to maintain mold temperature at required level. Injection molding is generally limited to forming thermoplastic materials, but equipment is available for converting the machines for molding thermosetting plastics and compounds of rubber.

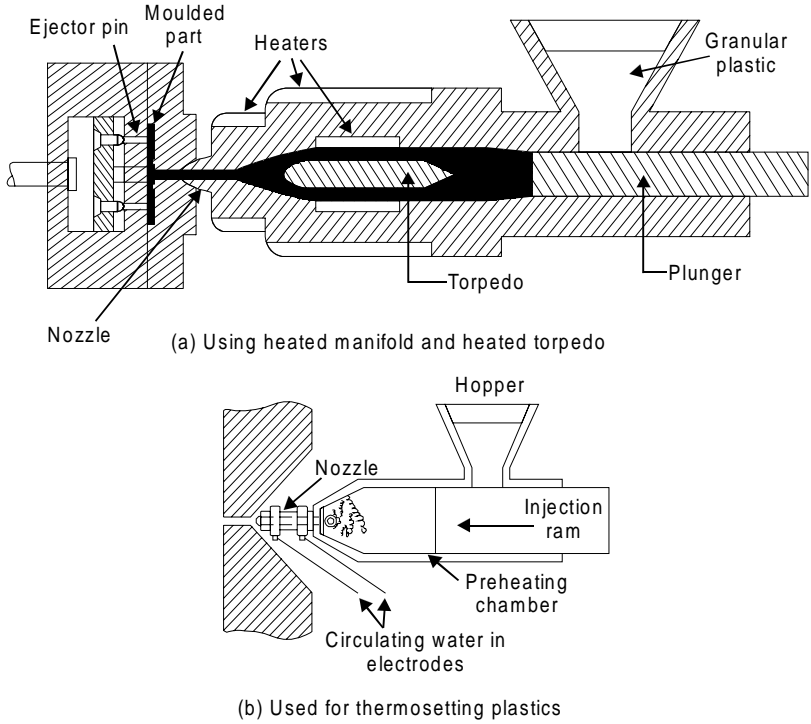


Fig. 13.11 Typical injection molding

13.11.2 Extrusion Molding

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 molding. 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 molding process through Fig 13.12. 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.

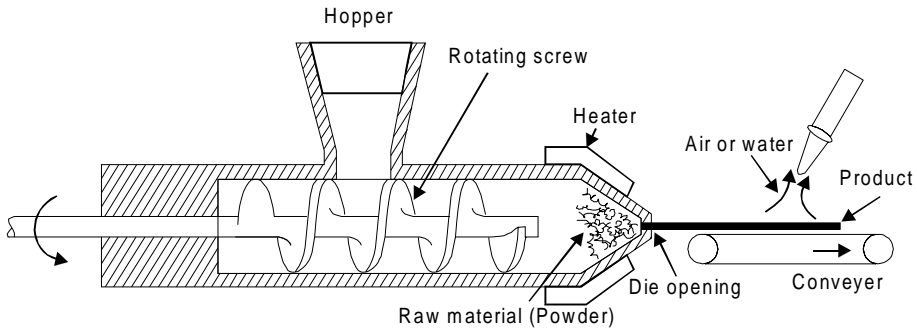


Fig. 13.12 Schematic extrusion molding

13.12 QUESTIONS

1. Describe in detail the terms 'solid zone', 'mushy zone' and 'liquid zone' used in solidification of castings. Using figures explain the term directional solidification used in castings.
2. What is "directional solidification", and what is its influence on casting quality?
3. Is directional solidification necessary in casting? How does it help in the production of sound castings?
4. What are the controlling factors of directional solidification in casting? Name different stages through which the metal contraction takes place during the solidification of the casting?
5. Why do you prefer fabricating of metal parts by casting?
6. Define casting. What four basic steps are generally involved in making a casting?
7. What are the common factors which should be considered before designing a casting?
8. Sketch the cross-section through a permanent mold, incorporating all its principal parts. Describe its construction in detail.
9. Describe the permanent mold casting process and discuss how it differs from the other casting processes.
10. What are the common materials used for making the permanent molds?
11. Describe step by step procedure for casting using a permanent mold. What are the advantages, dis-advantages and applications of permanent mold casting?
12. What different metals and alloys are commonly cast in permanent molds?
13. What is the difference between gravity die casting and pressure die casting?
14. How are die casting machines classified? What are the common constructional features embodied in most of them?
15. Sketch and explain the construction and operation of a hot chamber die casting machine.
16. How does a cold chamber die casting machine differ from a hot chamber machine? Explain the working of a cold chamber machine with the help of a diagram.
17. Make a neat sketch to explain the principal parts of an air blown or goose neck type machine. How does it differ from a hot chamber die casting machine. Discuss their relative advantages, disadvantages and applications.
18. What is a vacuum die-casting machine? How is the vacuum applied to hot and cold chamber machines to evacuate the entrapped air completely. What is the main advantage of this type of machine?
19. Specify features required to be embodied in a successful design of a die-casting die.
20. Describe the various alloys commonly cast through pressure die-casting.
21. What are the general advantages, disadvantages applications of die casting?
22. How does a cold chamber die casting machine differ from a hot chamber die casting machine?
23. Make neat sketch and explain the construction and operation of a hot chamber die casting machine.
24. Make neat sketch and explain the construction and operation of a cold chamber die casting machine.
25. Explain the various steps involved in the investment casting of metals.
26. What is investment casting? What are the main materials used for making the investment pattern?
27. Describe the complete step by step procedure of investment casting. What are the main advantages and disadvantages of investment casting?

28. Describe briefly the shell casting process using neat sketches. State its advantages, disadvantages and generation applications
29. Describe continuous casting process and discuss the important metallurgical features of the billets produced by these methods.
30. Explain with the help of a neat sketch, the process of centrifugal casting.
31. What do you understand from centrifugal casting?
32. How are the centrifugal casting methods classified?
33. With the help of a neat diagram describe the process of true centrifugal casting. How can this method be used for production of pipes?
34. Illustrate and describe the process of semi-centrifugal casting.
35. What is centrifugal casting?. Describe the process, stating its differences with other centrifugal casting methods.
36. What are the advantages and disadvantages of true centrifugal casting?
37. Which materials are commonly used for making the molds for centrifugal casting?
38. Explain the difference with the help of sketches between true centrifugal casting, semi-centrifugal casting and centrifuge casting.
39. What is continuous casting? Name the various processes of continuous casting you know. Describe in detail the reciprocating process of continuous casting.
40. How will you select the vertical and inclined axes of rotation in true centrifugal casting.
41. Write short notes on the following:
 - (i) Slush casting
 - (ii) Pressed casting
 - (iii) De Lavaud process for centrifugal casting
 - (iv) Moore sand spun process for centrifugal casting.
42. What are the general rules and principles to be followed in designing a casting?
43. What do you understand by foundry mechanization? Explain in brief.
44. What are the advantages of mechanization of foundry?
45. Describe the various units for which mechanization can be easily adopted.
46. What are the main factors which are responsible for producing defects in the castings?
47. Name the various defects which occur in sand castings and state their probable causes and remedies?
48. List the defects generally occurring from the following, stating the precautions necessary to prevent them:

(i) Improper pouring technique,	(ii) Use of defective gating system
(iii) Poor or defective cores,	(iv) High moisture content in sand.
49. Discuss briefly the causes and remedies of the following casting defects:

(i) Blow holes,	(ii) Porosity,	(iii) Hot tears
(iv) Shrinkage cavities,	(v) Scabs, and	(vi) Gas porosity
50. Write short notes on the following casting defects:

(i) Sand inclusions,	(ii) Cuts and washes,	(iii) Misrun and cold shuts,
(iv) Honey combing,	(v) Metal penetration,	(vi) Drops,
(vii) Warpage and	(viii) blow holes	

51. Explain the causes and remedies of the following casting defects:
- | | |
|--------------|--------------------------|
| (i) Fins | (ii) Shot metal |
| (iii) Shifts | (iv) Hard spots |
| (v) Run out | (vi) Rattails or buckles |
| (vii) Fusion | (viii) Swells |
| (ix) Crushes | |
52. What are the various operations generally required to be performed after shake out for cleaning the castings?
53. Explain the various methods used for removal of gates and risers etc.
54. What are the common methods used for cleaning the surface of the casting?
55. Why are the castings heat treated?
56. How do you repair the castings? Explain.
57. What do you understand from destructive and non-destructive testing methods of inspecting castings?
58. What are the various non-destructive testing methods used for inspection of castings? State their advantages and limitations:
59. Write short notes on the following inspection methods:
- | |
|-------------------------------|
| (i) Visual inspection |
| (ii) Pressure test |
| (iii) Penetrate testing |
| (iv) Radiography |
| (v) Magnetic particle testing |
| (vi) Ultrasonic testing. |

14
CHAPTER

FORGING

14.1 INTRODUCTION

Forging is an oldest shaping process used for the producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammers. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers, small power hammers, die, press or upsetting machine. It consists essentially of changing or altering the shape and section of metal by hammering at a temperature of about 980°C, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith's shop. A metal such as steel can be shaped in a cold state but the application of heat lowers the yield point and makes permanent deformation easier. Forging operation can be accomplished by hand or by a machine hammer. Forging processes may be classified into hot forging and cold forgings and each of them possesses their specific characteristics, merits, demerits and applications.

Hand forging process is also known as black-smithy work which is commonly employed for production of small articles using hammers on heated jobs. It is a manual controlled process even though some machinery such as power hammers can also be sometimes used. Black-smithy is, therefore, a process by which metal may be heated and shaped to its requirements by the use of blacksmith tools either by hand or power hammer. In smithy small parts are shaped by heating them in an open fire or hearth. Shaping is done under hand control using hand tools. This work is done in a smithy shop. In smith forging or hand forging open face dies are used and the hammering on the heated metal is done by hand to get the desired shape by judgment.

Forging by machine involves the use of forging dies and is generally employed for mass-production of accurate articles. In drop forging, closed impression dies are used and there is drastic flow of metal in the dies due to repeated blow or impact which compels the plastic metal to conform to the shape of the dies. The final shape of the product from raw material is achieved in a number of steps. There are some advantages, disadvantages and applications of forging operations which are given as under.

Advantages of forging

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.
2. Forging refines the structure of the metal.
3. It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it.
4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.
5. Because of intense working, flaws are rarely found, so have good reliability.
6. The reasonable degree of accuracy may be obtained in forging operation.
7. The forged parts can be easily welded.

Disadvantages of forging

Few dis-advantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.
2. The close tolerances in forging operations are difficult to maintain.
3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.
4. Some materials are not readily worked by forging.
5. The initial cost of forging dies and the cost of their maintenance is high.
6. The metals gets cracked or distorted if worked below a specified temperature limit.
7. The maintenance cost of forging dies is also very high.

Applications of forging

Almost all metals and alloys can be forged. The low and medium carbon steels are readily hot forged without difficulty, but the high-carbon and alloy steels are more difficult to forge and require greater care. Forging is generally carried out on carbon alloy steels, wrought iron, copper-base alloys, aluminium alloys, and magnesium alloys. Stainless steels, nickel-based super-alloys, and titanium are forged especially for aerospace uses.

Producing of crank shaft of alloy steel is a good example which is produced by forging. Forging processes are among the most important manufacturing techniques utilized widely in manufacturing of small tools, rail-road equipments, automobiles and trucks and components of aeroplane industries. These processes are also extensively used in the manufacturing of the parts of tractors, shipbuilding, cycle industries, railroad components, agricultural machinery etc.

14.2 FORGEABILITY

The ease with which forging is done is called forgeability. The forgeability of a material can also be defined as the capacity of a material to undergo deformation under compression without rupture. Forgeability increases with temperature up to a point at which a second

phase, e.g., from ferrite to austenite in steel, appears or if grain growth becomes excessive. The basic lattice structure of metals and their alloys seems to be a good index to their relative forgeability. Certain mechanical properties are also influenced by forgeability. Metals which have low ductility have reduced forgeability at higher strain rate whereas highly ductile metals are not so strongly affected by increasing strain rates. The pure metals have good malleability and thus good forging properties. The metals having high ductility at cold working temperature possesses good forgeability.

Cast parts, made up of cast iron are brittle, and weak in tension, though they are strong in compression. Such parts made using cast iron tend to need to be bulky and are used where they will not be subjected to high stresses. Typical examples are machine bases, cylinder blocks, gear-box housings etc. Besides the above factors, cost is another major consideration in deciding whether to cast a component or to forge it. An I.C. engine connecting rod is a very good example of where a forging will save machining time and material, whereas the cylinder block of the same engine would be very expensive if produced by any process other than casting. Another good point associated with casting is that big or small complex shapes can easily be cast. Small parts can directly be machined out from regular section materials economically. A part machined out from the rolled steel stock definitely possesses better mechanical properties than a conventionally cast part. Sometimes the shape and size of a part would mean removing a large amount of material by machining, it is sometimes more economical to forge the part, thereby reducing the machining time and the amount of material required.

The main alloys for cold forging or hot forging are most aluminium and copper alloys, including the relatively pure metals. Carbon steels with 0.25 % carbon or less are readily hot forged or cold-headed. High carbon and high alloy steels are almost always hot forged. Magnesium possessing hexagonal close packed (HCP) structure has little ductility at room temperature but is readily hot forged. Aluminium alloys are forged between 385°C and 455°C or about 400°C below the temperature of solidification. Aluminium alloys do not form scale during hot forging operations, die life is thus excellent. Copper and brasses with 30% or less zinc have excellent forgeability in cold working operations. High zinc brasses can be cold forged to a limited extent but are excellent hot forging alloys. Magnesium alloys are forged on presses at temperature above 400°C. At higher temperatures, magnesium must be protected from oxidation or ignition by an inert atmosphere of sulphur dioxide.

14.3 FORGABLE MATERIALS

Two-phase and multi-phase materials are deformable if they meet certain minimum requirements. The requirement of wrought metals is satisfied by all pure metals with sufficient number of slip planes and also by most of the solid solution alloys of the same metal. Wrought alloys must possess a minimum ductility that the desired shape should possess. To be a forgeable metal, it should possess the required ductility. Ductility refers to the capacity of a material to undergo deformation under tension without rupture. Forging jobs call for materials that should possess a property described as ductility that is, the ability to sustain substantial high plastic deformation without fracture even in the presence of tensile stresses. If failure occurs during forging, it is due to the mechanism of ductile fracture and is induced by tensile stresses. A material of a given ductility may fail very differently in various processes, depending on the deforming conditions imposed

on it. Forgeable metals are purchased as hot-rolled bars or billets with round or rectangular cross the sections. Forgeable materials should possess the required ductility and proper strength. Some forgeable metals are given as under in order of increasing forging difficulty.

- | | |
|---------------------------------|--------------------------------|
| 1. Aluminium alloys | 2. Magnesium alloys |
| 3. Copper alloys. | 4. Carbon and low alloy steels |
| 5. Martensitic stainless steels | 6. Austenitic stainless steels |
| 7. Nickel alloys | 8. Titanium alloys |
| 9. Columbium alloys | 10. Tantalum alloys |
| 11. Molybdenum alloys | 12. Tungsten alloys |
| 13. Beryllium. | |

14.4 HEATING DEVICES

Forgeable metals are heated either in a hearth or in a furnace. The hearths are widely used for heating the metals for carrying out hand forging operations. Furnaces are also commonly used for heating metals for heavy forging. The forging job is always heated to the correct forging temperature in a hearth (Fig. 14.1) or in a furnace (Fig. 14.2) located near the forging arrangements. Gas, oil or electric-resistance furnaces or induction heating classified as open or closed hearths can be used. Gas and oil are economical, easily controlled and mostly used as fuels. The formation of scale, due to the heating process especially on steel creates problems in forging. A non-oxidizing atmosphere should, therefore, be maintained for surface protection. Special gas-fired furnaces have been developed to reduce scaling to minimum. Electric heating is the most modern answer to tackle scaling and it heats the stock more uniformly also. In some cases, coal and anthracite, charcoal containing no sulphur and practically no ash are the chief solid fuels used in forging furnaces. Forge furnaces are built raise temperatures up to 1350°C in their working chambers. They should be sufficiently large to allow proper combustion of the fuel, and to obtain uniform heating of the forging jobs. Each heating furnace consists of parts including firebox, working chamber, chimney, flues, re-cuperator or regenerator, and various auxiliary arrangements. Various types of furnaces are used for heating the metals and some of them are briefly described as under.

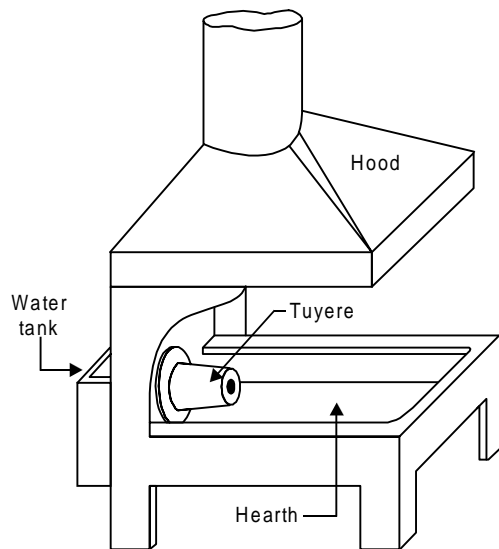


Fig. 14.1 Typical hearth

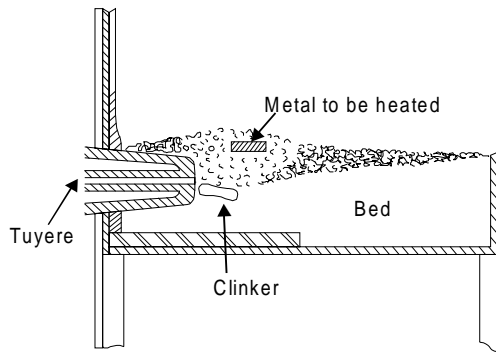


Fig. 14.2 Black smith furnace

14.4.1 Box or batch type furnaces

These furnaces are the least expensive furnaces widely used in forging shops for heating small and medium size stock. There is a great variety of design of box-type furnaces, each differing in their location of their charging doors, firing devices and method, employed for charging their products. These furnaces are usually constructed of a rectangular steel frame, lined with insulating and refractory bricks. One or more burners for gas or oil can be provided on the sides. The job-pieces are placed side by side in the furnace using a slot through a suitable tong. It is therefore sometimes called slot type furnace.

14.4.2 Rotary-hearth furnaces

These are set to rotate slowly so that the stock is red to the correct temperature during one rotation. These can be operated by gas or oil fuels.

14.4.3 Continuous or conveyor furnaces

These furnaces are of several types and are preferred for larger stock. They have an air or oil-operated cylinder to push stock end-to-end through a narrow furnace. The pieces are charged at one end, conveyed through the furnace and moved at other end at the correct temperature for the forging work.

14.4.4 Induction furnaces

These furnaces are very popular because induction greatly decreases scale formation and can often be operated by one person. The furnace requires less maintenance than oil or gas-fired furnaces. In induction furnaces the stocks are passed through induction coils in the furnaces. Delivery to forging machine operator can be effected by slides or automatic handling equipment.

14.4.5 Resistance furnaces

These furnaces are faster than induction furnaces, and can be automated easily. In resistance heating furnace, the stock is connected to the circuit of a step-down transformer. Fixtures are also equipped along with furnace for holding different length, shape, and diameter of stock. However, the fixtures are often quite simple and can be adjusted to handle a family of parts.

14.4.6 Open fire and stock fire furnace

The fire itself plays an important part on the efficient heating of stock and it must be kept clean, free from excess dust or clinkers. Work which is laid on top of the fire will get hot underneath and remain colder on the top use it is exposed to the atmosphere, and uneven heating will result. In the same way, work which is red low in the fire but at the same time against the tuyre will become hot on one side, but will have a blast of cold air blowing against it, from the tuyre on the other side. The correct position for heating the job is in the hearth of the fire. The most common methods of firing in forging are namely open fire and stock fire which are discussed as under.

Open fire

Open fire is shown in Fig.14.3. This type of fire is highly convenient for general heating work and is made up in the hollow space in front of tuyre nozzle with coke left from the last fire, covered with green petroleum. As the fire burns away, coke from the top and sides is drawn into the centre, and its place is taken by more green coal taken from the supply maintained on the front place of the forge or taken from the outside. The jobs or work-pieces must be covered with a layer of coal, and to obtain a flame at single spot, the coal should be slightly damped with water and pressed down with a flat shovel. In the spot where the flame is desired, the coal should be loosened with a pocker. To ensure uniform heating of work on all sides, it must be turned round from time to time.

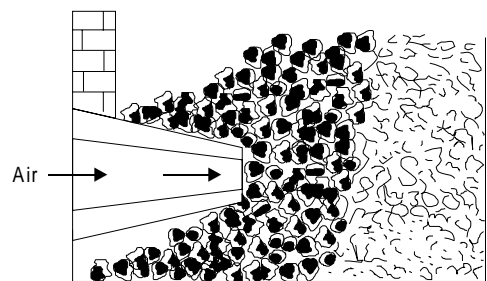


Fig. 14.3 Open fire

Stock fire

A stock fire is depicted through Fig.14.4 which is intended to last for several hours. This type of fire is commonly useful in dealing with large pieces, when a heat may have to be kept for sometime. The job or work has to be turned in all directions to ensure uniform heating of the job. Such fire is made up around a block of the desired size which is placed near the tuyre nozzle and upon which coal damped with water that is closely built into the form of a mound or "stock". Fine coal or pulverized coal is suitable for use in stock fire. The block is then withdrawn from the bed of the hearth with a turning force to prevent the stock from being broken and a tunnel is thus formed with an opening at the top. The fire is then lighted in the hollow space. From the bottom of the tunnel a small amount of coal is removed and a cavity is formed in the place in to which clinker may fall. Here the work is heated, being carefully covered with freshly coke fuel from time to time as the fire burns away.

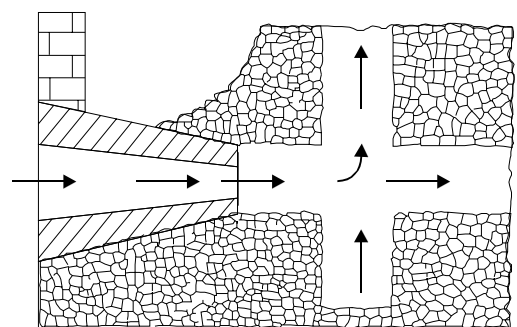


Fig. 14.4 Stock fire

14.4.7 Fuels used in forging shop

The fuels used in forging shop are classified as solid, liquid and gaseous fuels which are discussed as under:

Solid fuels

Wood, coal, anthracite, peat, charcoal, coke, pulverized fuel etc.

Liquid fuels

Crude oil, petroleum, kerosene, tar oil etc.

Gaseous fuels

Natural gas and some artificially produced gases are used generate heat.

A good fuel should always possess the following essential characteristics which are given as under:

1. The fuel should be able to generate the required heat.
2. It should have complete combustion.
3. It should be highly efficient.
4. It should not produce excess smoke and flying ash.
5. It should be easy to fire, cheap and easily available.

14.5 CONTROL OF HEATING DEVICES

For good control of heating devices such as hearth or forging furnace, the following points are always considered.

1. The nozzle pointing into the centre of the hearth is called the tuyre and is used to direct a stream of air into the burning coke. The air is supplied by centrifugal blower.
2. As the hottest part of the fire is close to the tuyre opening, therefore, the tuyre is provided with a water jacket to prevent it from burning away.
3. The hood provided at the top of hearth collects smoke, fumes etc., and directs them away from the workplace through the chimney in form of exhaust.
4. The fuel for the fire may be either black-smithing coal or coke. To light the fire, either use paper and sticks or preferably a gas poker.
5. Impurities will collect as clinker and must be removed from the bottom of the fire when the fire cools.
6. The blowers are used to control the air supply using forced draught. Regulators control the draught and the temperature of the fire.
7. Blower delivers to forge adequate supply of air at proper pressure which is very necessary for the combustion of fuel.
8. A centrifugal blower driven by an electric motor is an efficient means of air supply in forging hearth.
9. Fire tools such as rake, poker and slice are generally used to control or manage the fire and these tools are kept nearby the side of the hearth. Rake is used to take heated workpiece out of the fire. Poker is a steel rod which is used to poke (stir) fire in the hearth.

10. The place of the metal to be heated should be placed just above the compact centre of a sufficiently large fire with additional fuel above to reduce the heat loss and atmospheric oxidation.

14.6 FORGING TEMPERATURES

A metal must be heated to a temperature at which it will possess high plastic properties to carry out the forging process. The metal work piece is heated to a proper temperature so that it gains required plastic properties before deformation, which are essential for satisfactory forging. Excessive temperatures may result in the burning of the metal. Insufficient temperatures will not introduce sufficient plasticity in the metal to shape it properly by hammering etc. Moreover, under these conditions, the cold working defects such as hardening and cracking may occur in the product.

The temperature to start the forging for soft, low carbon steels is 1,250 to 1,300°C, the temperature to finish forging is 800 to 840°C. The corresponding temperatures for high carbon and alloy steels which are hard in nature are 1100 to 1140°C and 830 to 870°C. Wrought iron is best forged at a temperature little below 1,290°C. Non ferrous alloys like bronze and brass are heated to about 600 to 930°C, the aluminium and magnesium alloys to about 340 to 500°C.

Forging temperature should be proper to get good results. Excessive temperature may result in the burning of the metal, which destroys the cohesion of the metal. Insufficient temperature will not introduce sufficient plasticity in the metal. The forging operation in metal is if finished at a lower temperature, it may lead to cold hardening and cracks may develop in it. However, excessive heating of the forgeable part may result in oxidization and hence material is wasted. The temperature of heating steel for hand forging can be estimated by the color of heat and which color of the light emitted by the heated steel. For accurate determinations of forging temperatures of the heated part, the optical pyrometers are generally used.

14.7 ADVANTAGES OF FORGING IN COMPARASION TO CASTING AND MACHINING

Because of inherent improvement in the grain size and introduction of un-interrupted grain flow in the structure of finished forged component forging has the following advantages in comparison to casting and machining. Some of such advantages are given as under.

- (i) Greater strength and toughness.
- (ii) Reduction in weight of the finished part.
- (iii) Saving in the material.
- (iv) Elimination of internal defects such as cracks, porosity, blowholes, etc.
- (v) Ability to withstand unpredictable loads during service.
- (vi) Minimum of machine finish to be carried out on the component especially when it is forged in dies.

14.8 EFFECT OF FORGING ON METAL CHARACTERISTICS

Generally a forging material is selected based on certain desirable mechanical properties inherent in the composition and/or for those which can be developed by forging. Such properties may be one or several, such as strength, resistance to fatigue, shock or bending, good

machining characteristics, durability etc. A continuous and uninterrupted grain flow in a forged component results in higher strength and toughness. In a cast part, there is no grain flow. Cast part is having random orientation of grains so it has weak crystalline structure. In a rolled or machined component, an interrupted grain flow exists. Rolled component is having better ductility in a direction parallel to that of the plastic elongation because of orientation effect of grains. When a component is machined, machining interrupts the continuity of grain flow. In forged parts, the fiber like flow lines of the component are continuous. Forging leads to a re-arrangement of fibers because working is done above recrystallisation temperature.

The original crystals are deformed during forging operation and many of the constituents are precipitated at high temperatures which again become soluble in the solid iron on freezing, thus increasing the local homogeneity of the metal. The properties, like elastic limit, tensile strength of metal are unproved due to the grain flow. If a forged gear blank piece is cut in a plane aligned with the direction and surface is ground smooth and along teeth of the gear blank and immersed in an acid solution, the exposed metal will appear to the naked eye to have a fibre like structure as shown in Fig. 14.5 and Fig.14.6.

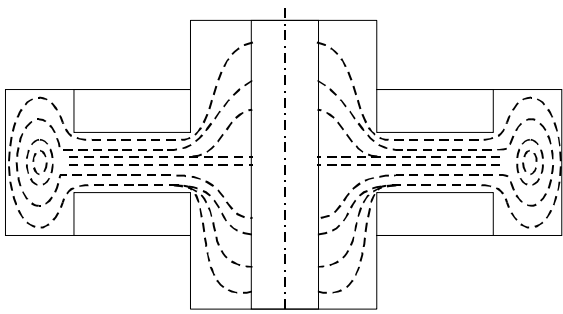


Fig. 14.5 Fibrous forged structure of gear blank

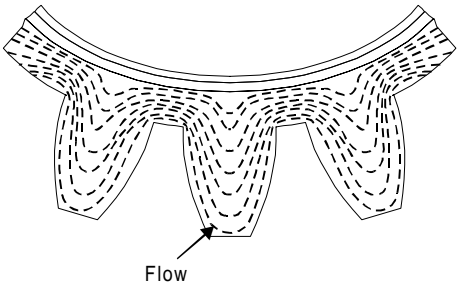


Fig. 14.6

Forging is generally employed for those components which require high strength and resistance to shock or vibrations. It provides fine crystalline structure to the metal, improves physical properties, closes all voids and forms the metal to shapes. It enhances the mechanical properties of metals and improves the grain flow which in turn increases the strength and toughness of the forged component.

But there may be certain defects also, like scale inclusions on the surface, misalignment of the dies, crack, etc. These defects can be controlled. The advantages of forging processes are that, although the metal piece has to be heated to the correct forging temperature before shaping, less metal will be used than if the shape were machined from a solid block of metal. All forgings are covered with scale and hence they require cleaning operation. It is done by

pickling in acid, shot peening or tumbling depending upon the size and composition of the forgings. If some distortion has occurred in forging, a sizing or straightening operation may be required. Controlled cooling is usually provided for large forgings. Heat treatment may also be required to provide certain physical properties. However some common characteristics of forged parts are given as under.

- (i) Forged parts have directional properties and hence have good strength.
- (ii) Mechanical properties of materials such as percentage elongation, resistance to stock and vibrations are improved.
- (iii) Forging process confines the structure of metal by closing up the cavities.
- (iv) Cracks and blow-holes are minimized in forged parts.

14.9 COMMON HAND FORGING TOOLS

For carrying out forging operations manually, certain common hand forging tools are employed. These are also called blacksmith's tools, for a blacksmith is one who works on the forging of metals in their hot state. The main hand forging tools are as under.

- | | |
|-------------------------|------------------|
| 1. Tongs | 2. Flatter |
| 3. Swage | 4. Fuller |
| 5. Punch | 6. Rivet header |
| 7. Hot chisel | 8. Hammers |
| 9. Anvil | 10. Swage block |
| 11. Drift | 12. Set-hammer |
| 14. Brass scale | 15. Brass |
| 16. Black smith's gauge | 17. Heading tool |

Some of the hand forging tool are depicted in Fig.14.7- 14.15 and their applications are described as under.

Tongs

The tongs are generally used for holding work while doing a forging operation. Various kinds of tongs are shown in Fig. 14.7.

1. Flat tongs are used for mainly for holding work of rectangular section.
2. Straight-lip fluted tongs are commonly used for holding square, circular and hexagonal bar stock.
3. Rivet or ring tongs are widely used for holding bolts, rivets and other work of circular section.
4. Gad tongs are used for holding general pick-up work, either straight or tapered.

Flatter

Flatter is shown in Fig. 14.7. It is commonly used in forging shop to give smoothness and accuracy to articles which have already been shaped by fullers and swages.

Swage

Swage (Fig. 14.7) is used for forging work which has to be reduced or finished to round, square or hexagonal form. It is made with half grooves of dimensions to suit the work being

reduced. It consists of two parts, the top part having a handle and the bottom part having a square shank which fits in the hardie hole on the anvil face.

Fuller

Fuller (Fig. 14.7) is used in forging shop for necking down a forgeable job. It is made in top and bottom tools as in the case of swages. Fuller is made in various shapes and sizes according to needs, the size denoting the width of the fuller edge

Punch

Punch (Fig. 14.7) is used in forging shop for making holes in metal part when it is at forging heat.

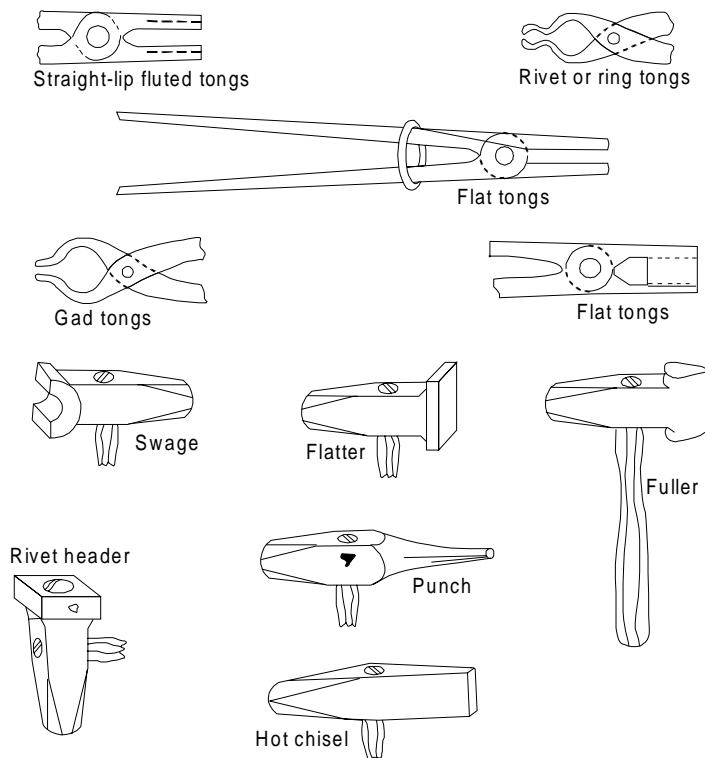


Fig. 14.7 Hand forging tools

Rivet header

Rivet header (Fig. 14.7) is used in forging shop for producing rivets heads on parts.

Chisels

Chisels are used for cutting metals and for nicking prior to breaking. They may be hot or cold depending on whether the metal to be cut is hot or cold. A hot chisel generally used in forging shop is shown in Fig. 14.7. The main difference between the two is in the edge. The edge of a cold chisel is hardened and tempered with an angle of about 60°, whilst the edge of a hot chisel is 30° and the hardening is not necessary. The edge is made slightly rounded for better cutting action.

Hand hammers

There are two major kinds of hammers are used in hand forging: (1) the hand hammer used by the smith himself and (2) the sledge hammer used by the striker. Hand hammers (Fig. 14.8) may further be classified as (a) ball peen hammer, (b) straight peen hammer, and (c) cross peen hammer. Sledge hammers (Fig. 14.8) may further be classified as (a) Double face hammer, (b) straight peen hammer, and (c) cross peen hammer. Hammer heads are made of cast steel and, their ends are hardened and tempered. The striking face is made slightly convex. The weight of a hand hammer varies from about 0.5 to 2 kg where as the weight of a sledge hammer varies from 4 to 10 kg.

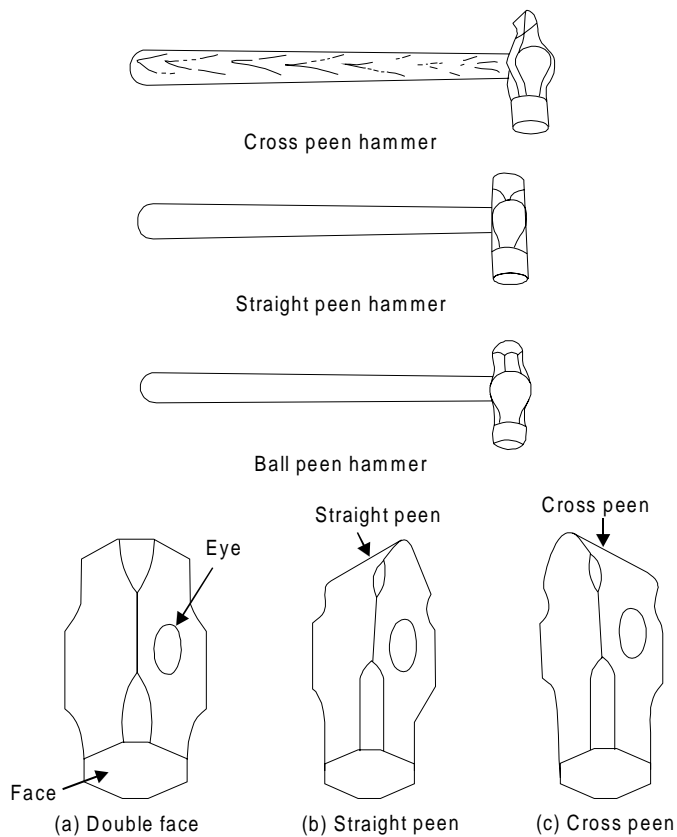


Fig. 14.8 Types of hammers

Set hammer

A set hammer generally used in forging shop is shown in Fig. 14.9. It is used for finishing corners in shouldered work where the flatter would be inconvenient. It is also used for drawing out the gorging job.

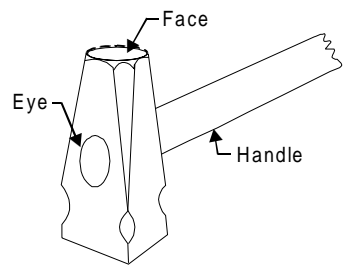


Fig. 14.9 Set hammer

Anvil

An anvil is a most commonly tool used in forging shop which is shown in Fig.14.10. It acts as a support for blacksmith’s work during hammering. The body of the anvil is made of mild steel with a tool steel face welded on the body, but the beak or horn used for bending curves is not steel faced. The round hole in the anvil called pritchel hole is generally used for bending rods of small diameter, and as a die for hot punching operations. The square or hardie hole is used for holding square shanks of various fittings. Anvils in forging shop may vary up to about 100 to 150 kg and they should always stand with the top face about 0.75 mt. from the floor. This height may be attained by resting the anvil on a wooden or cast iron base in the forging shop.

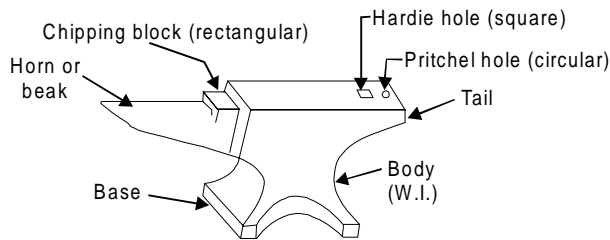


Fig. 14.10 Anvil

Swage block

Swage block generally used in forging shop is shown in Fig. 14.11. It is mainly used for heading, bending, squaring, sizing, and forming operations on forging jobs. It is 0.25 mt. or even more wide. It may be used either flat or edgewise in its stand.

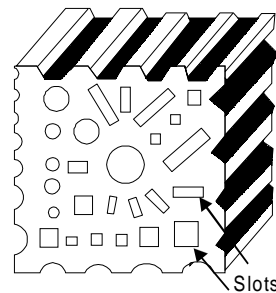


Fig. 14.11 Swage block

Drift

Drift generally used in forging shop is shown in Fig.14.12. It is a tapered rod made of tool steel. Holes are opened out by driving through a larger tapered punch called a drift.

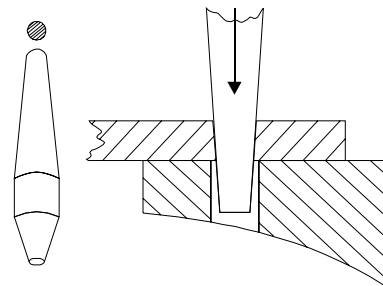


Fig. 14.12 Drift

Hardie

Hardie is a type of chisel used in forging shop. It is shown in Fig. 14.13. Its taper head is fixed into the hardie hole of the anvil, the cutting edge being upward. The part to be cut is kept over the cutting edge of the fixed hardie on anvil and another chisel is placed over the job and the cutting is performed by hammering.

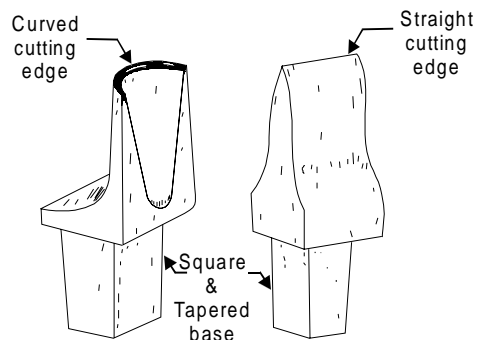


Fig. 14.13 Hardie

Shovel

Shovel generally used in forging shop is shown in Fig. 14.14. It is used to place coal or coke in the furnace. It is also used to set coal pieces in furnace and remove ash from furnace.

Poker

Poker (Fig.14.14) is employed for removing clinker from the furnace and to loose the compact coal pieces in the furnace.

Rake

Rake (Fig. 14.14) is used to put coal pieces on tuyres.

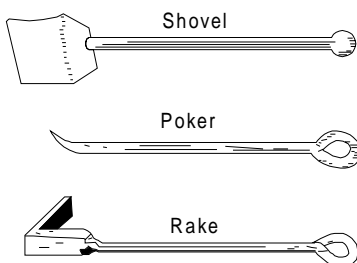


Fig. 14.14 Shovel, Poker and Rake

Beak Iron

Beak iron generally used in forging shop is shown in Fig. 14.15. It is also known as small anvil made of forged steel. Its upper front end consists of horn and upper back end comprises of flat tail. Its taper shank is inserted into the hardie hole of the anvil. It is commonly used as anvil for small forge work.

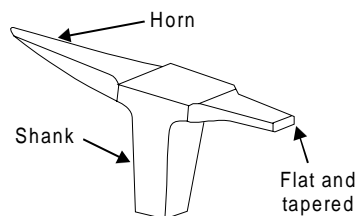


Fig. 14.15 Beak iron

14.10 FORGING METHODS

The forging methods are commonly used for changing the shape of the raw material in to the finished form in the forging shop are generally classified into two categories namely hand forging and power forging. These are being discussed as under

14.10.1 Hand forging

Hand forging is performed in the black smithy shop. The job is heated at the forging temperature in hearth and it is then brought on anvil using tong. It is then forged using hand hammers and other hand forging tools for imparting specific shape.

14.10.1.1 Forging Operations

The hand forging operations (Fig. 14.16) are

- | | |
|------------------|--------------|
| 1. Upsetting | 2. Bending |
| 3. Drawing down | 4. Cutting |
| 5. Setting down | 6. Punching |
| 7. Flattening | 8. Fullering |
| 9. Forge Welding | 10. Swaging |

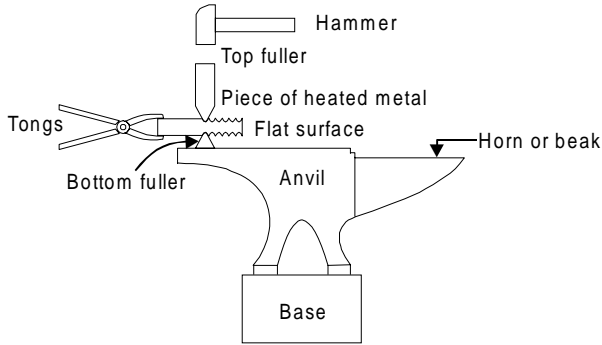


Fig. 14.16 Hand forging

Some important hand forging operations are described as under:

(i) Drawing out

Drawing out is used to reduce the thickness of a bar and to increase its length. It may be carried out by working the metal over the horn the anvil as shown in Fig. 14.17, then by hammering it on the anvil face. The rounded horn of the anvil acts as a blunt edge, which forces the metal to flow lengthwise when struck by the hammer. For drawing down very heavy work, fuller may be used for drawing down a bar over the horn (round portion) of anvil.

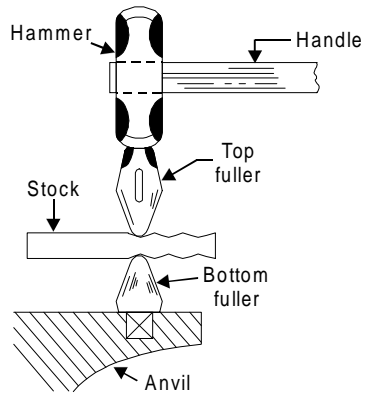


Fig. 14.17 Drawing out

(ii) Fullering

Fullering operation generally used in forging shop is shown in Fig. 14.18. It involves heating the stock in the black smith hearth. Then heated stock is placed on the fuller fixed on anvil. A fuller is put over the sock and hammering is done to reduce the cross section of job at required point.

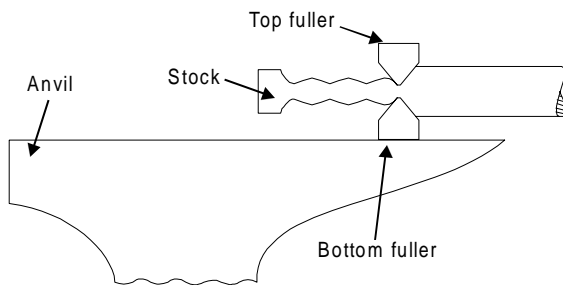


Fig. 14.18 Fullering

(iii) Upsetting

Upsetting is also known as jumping operation which is carried out to increase the thickness (or diameter) of a bar and to reduce its length. Generally, the increase in thickness is only local, for example, when forming a bolt head. This operation is an operation just

opposite to drawing and involves increasing the cross-sectional area usually by hammering or pressing in a direction parallel to the ingot axis. The length of the ingot decreases and following the path of least resistance it spreads out. The required shape is given the ingot by spreading it between two dies. Only that portion of the bar which is to be upset is heated locally. Or, the whole bar is heated and except for the portion to be upset, the rest is quenched in water so that upset will form only on the hot portion of the bar. In one method of upsetting, the bar is held in the tong and supported vertically on the anvil. The top edge of the bar is then hammered to form the upset on the bottom hot end of the bar. For upsetting, the blow of the hammer must be in line with the bar to prevent bending of the bar.

(iv) Bending

Bending is a very commonly used forging operation in forging shop to give a turn to a metal rod or plate. It is accompanied by spreading of the metal in the inside of the bend and narrowing at outside. The simplest method of bending a piece of metal in hand forging is to support it on the anvil and to strike its free end with a hammer. When bent, the metal of the workpiece thins out round bend causing weakness. This can be overcome by upsetting the bar prior to bending.

(v) Cutting

Cutting is a main forging operation to cut out a metal rod or plate into two pieces with the help of a chisel and hammer when the metal is in red hot condition. A hot or cold cut (chisel) is used for cutting heated metal bars in a smithy shop. The hot set does not require hardening and tempering. Its cutting edge is keener than that of a cold set. Hot sets are manufactured from a tough variety of steel in order that they may cut through relatively soft red-hot metal with ease. While cutting, it is best to cut half through the workpiece to turn it over and cut through from the other end.

(vi) Punching

Punching is a main forging operation used for producing hole in metal plate by using a tool known as punch. The metal plate is placed over the hollow cylindrical die and punch is placed above it at required location where hole is being made. For punching a hole, the metal job must be at near welding heat and the punch is driven part way through the job with hammer blows. The work is then turned over and the hole is completed from the other side. The above said practice is adopted for thicker jobs.

(vii) Forge Welding

It is a process of joining two metal pieces to increase the length by pressing or hammering them when they are at forging temperature. It is performed in forging shop and hence sometimes it is called as forge welding.

14.10.2 Power Forging

Hand hammer blows impact will not be always sufficient enough to affect the proper plastic flow in a medium sized or heavy forging. It also causes fatigue to the hammer man. To have heavy impact or blow for more plastic deformation, power hammer are generally employed. These hammers are operated by compressed air, steam, oil pressure, spring and gravity. They are generally classified as spring hammer and drop hammers. The capacity of these hammers is given by the total weight. A 100 kg hammer will be one of which the falling pans weigh 100 kg. The heavier these parts and greater the height from which they fall, the higher will be

intensity of blow the hammer will provide. Power hammers are of different types e.g. spring power hammers, pneumatic power hammers etc. These hammers are named due to their construction, according to their way of operation and according to the type of fuel they use for getting the required power for operation. Besides these, a large number of forging presses are also used in forging work. Typical hammers are discussed in following in following paragraphs.

14.10.2.1 Spring Hammer

Spring hammer is commonly used for small forgings. It is light type of power hammer. The typical design of a spring hammer is shown in Fig. 14.19. It consists of a heavy rigid frame carrying a vertical projection at its top. This projection acts as a housing of bearing in which the laminated spring oscillates. The rear end of this spring carries a connecting rod and the other front end a vertical top which carries weight and moves vertically up and down between fixed guides provided for this purpose. The connecting rod at its lower end is attached to an eccentric sheave, which is further connected to the crank wheel. For operating the hammer the treadle is pressed downwards which makes the sheave to rotate through the crank wheel and thus the laminated spring starts oscillating in the bearing. This oscillation of the spring is responsible for the up and down movement of the tup thus, the required blows are provided on the job to be forged. A hand lever is also equipped with this mechanical kind of hammer to adjust the stroke of the connecting rod and, hence the intensity of blows. Eccentric type of spring hammer is the one in which a rotating eccentric disc is used for producing vibrations in the spring. It can be operated by means of a foot ring, known as treadle provided at the bottom and is connected to the shaft at the top through a vertical bar having a clutch at its end. The shaft at the top of hammer carries a pulley and a solid disc at the end. The pulley is driven by means of a belt from the line shaft or an electric motor. The solid disc, at the, end of the shaft, carries a crank connected eccentrically to it which has a laminated spring at its lower end. The nip carrying the weight is suspended on a toggle joint connecting the two ends of the laminated spring. When the foot treadle is pressed the clutch engages with the shaft and the disc carrying the crank starts rotating which in turn produces fluctuations in the toggle joint of the machine. It makes the tup to move and down in vertical direction. The speed of blows entirely depends upon the speed of the driving pulley.

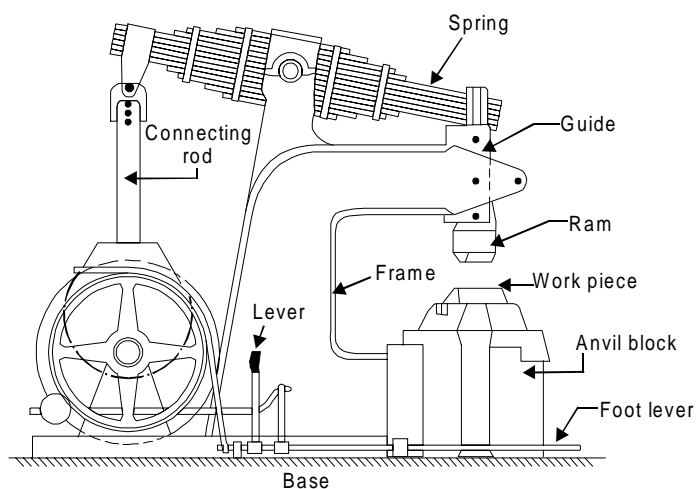


Fig. 14.19 Spring hammer

Spring hammers may be made available in various capacities having the tup weights from 30 to 250 kg. Those having top weights 50 to 100 kg and speed of blows up to 300 per minute are in generally used in forging shop. These hammers have a common drawback in their springs getting broken very frequently due to severe vibrations during forging of the jobs in the forging shop.

14.10.2.2 Drop Hammers

Drop hammers are operated hydraulically and are widely used for shaping parts by drop hammering a heated bar or billet into a die cavity as shown in Fig. 14.20. A drop forging raises a massive weight and allows it to fall under gravity on close dies in which forge component is allowed to be compressed. The die incorporates its shape on to the hot work piece as shown in Fig. 14.21. Drop hammers are commonly used for forging copper alloys and steel.

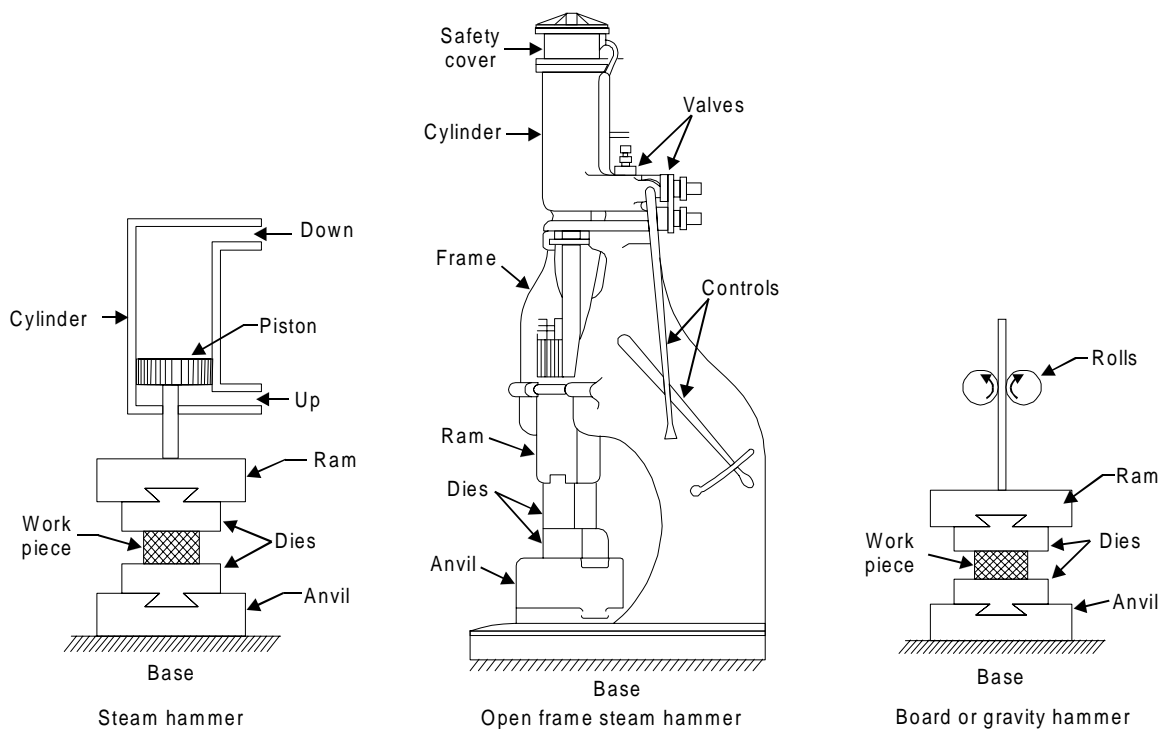


Fig. 14.20 Drop hammers

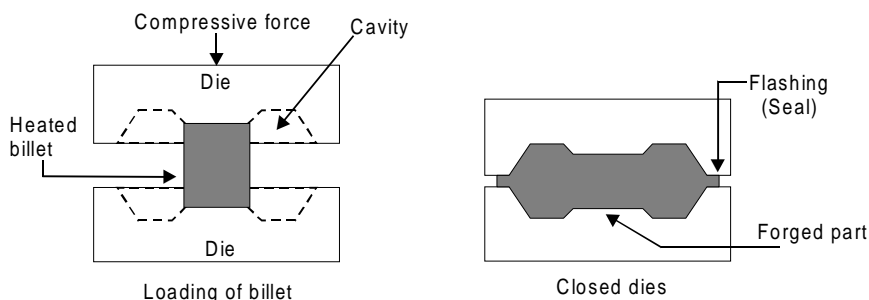


Fig. 14.21 Close die forging

14.10.2.3 Design Principles for drop forging

Certain principles for drop forgings generally followed are given as under:

1. The sections of the forging should be balanced about the parting line. Where this is impossible, design for the simplest irregular parting line which approaches a balanced condition.
2. Generous inside fillets and external radio should be allowed. Minimum radius should be 2 mm for small parts and 4 mm for large parts.
3. Sufficient draft should be allowed for easy removal of: the part, as follows:

14.11 DEFECTS IN FORGED PARTS

Defects commonly found in forged parts that have been subjected to plastic deformation are as follows.

- (i) Defects resulting from the melting practice such as dirt, slag and blow holes.
- (ii) Ingot defects such as pikes, cracks scabs, poor surface and segregation.
- (iii) Defect due to faulty forging design.
- (iv) Defects of mismatched forging because of improper placement of the metal in the die.
- (v) Defects due to faulty design drop forging die.
- (vi) Defects resulting from improper forging such as seams cracks laps. etc.
- (vii) Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

Some well identified common forging defects along with their reason are given as under.

1. Mismatched forging

Reasons

Due to non alignment of proper die halves.

2. Brunt and overheated metal

Reasons

This is caused by improper heating the metal at high temperature or for a long time.

3. Fibred flow lines discontinued

Reasons

This will occur because of very rapid plastic flow of metal.

4. Scale pits

Reason

These are formed by squeezing of scale into the metal surface during forging.

5. Oversize components

Reasons

Due to worn out dies, incorrect dies, misalignment of die halves.

14.12 REMOVAL OF DEFECTS IN FORGING

Defects in forging can be removed as follows:

- (i) Surface cracks and decarburized areas are removed from forging parts by grinding on special machines. Care should also be taken to see that the job is not under heated, decarburized, overheated and burnt.
- (ii) Shallow cracks and cavities can be removed by chipping out of the cold forging with pneumatic chisel or with hot sets.
- (iii) The parting line of a forging should lie in one plane to avoid mismatching.
- (iv) Destroyed forgings are straightened in presses, if possible.
- (v) Die design should be properly made taking into consideration all relevant and important aspects that may impart forging defects and ultimate spoilage
- (vi) The mechanical properties of the metal can be improved by forging to correct fibre line. The internal stresses developed due to heating and cooling of the job can be removed by annealing or normalizing.

14.13 GENERAL CONSIDERATIONS ADOPTED FOR DESIGNING A FORGING JOB

There are some common considerations adopted while designing a forging job and the same are given below.

1. Sufficient draft on surfaces should be provided to facilitate easy removal of forgings from the dies. It depends mainly on the depth of the die cavity. The greater the depth, the larger draft will be the required. Generally, however, a 1 to 5 degrees draft is provided on press forgings and 3 to 10 degrees on drop forgings.
2. Sharp corners where ever occur should always be avoided as far as possible to prevent concentration of stresses leading to fatigue failures and to facilitate ease in forging. The usual practice is to provide fillets of more than 1.6 mm radius. The exact size of the fillet is however decided according the size of the forging. If a perfectly sharp corner is required, the fillet can be removed at later stage.
3. Forgings which are likely to carry flash, such as in drop and press forgings, should preferably have the parting line in such a position that the same will divide them in two equal halves.
4. As far as possible the parting line of a forging should lie in one plane.
5. The forged component should ultimately be able to achieve a radial flow of grains or fibres.
6. Attention should be given to avoid the presence of pockets and recesses in forgings. If they cannot be avoided, their number should be reduced to a minimum as far as possible.
7. High and thin ribs should not be designed. Also, cavities which are deeper than their diameters should be avoided.
8. Metal shrinkage and forging method should be duly taken into account while deciding the forging and finishing temperatures.
9. Although it is possible to achieve quite close tolerances of the order of 0.4 mm on either side through forging and therefore it is adequate to provide allowances to

compensate for metal shrinkage, machining, die wear, trimming and mis-match of dies.

10. Too thin sections in parts should be avoided to facilitate an easy flow of metal.

14.14 HEAT TREATMENT OF FORGING

Heat treatment is carried out for releasing the internal stresses arising in the metal during forging and cooling of work piece. It is used for equalizing the granular structure of the forged metal and improving the various mechanical properties. Generally forged parts are annealed, normalized and tempered to obtain the desired results.

14.15 SAFETY PRECAUTIONS

Some safety precautions generally followed while working in forging shop are given as under.

1. Always avoid the use of damaged hammers.
2. Never strike a hardened surface with a hardened tool.
3. No person should be allowed to stand in line with the flying objects.
4. Always use the proper tongs according to the type of work.
5. The anvil should always be free from moisture and grease while in use.
6. Always wear proper clothes, foot-wears and goggles.
7. The handle of the hammer should always be tightly fitted in the head of the hammer.
8. Always put out the fire in the forge before leaving the forge shop.
9. Always keep the working space clean.
10. Proper safety guards should be provided on all revolving parts.
11. Head of the chisel should be free from burrs and should never be allowed to spread.
12. During machine forging, always observe the safety rules prescribed for each machine.
13. One must have the thorough knowledge of the working of the forging machine before operating it.

14.16 QUESTIONS

1. What is the difference between smithy and forging?
2. What do you understand by open fire and stock fire? Which of the two is more advantageous and why?
3. Explain the various types of furnaces used in forging work?
4. Write Short notes on:
 1. Drop forging
 2. Press forging
 3. Flattening
 4. Smith's Forge
 5. Pedestal grinder
 6. Power hammers

7. Pneumatic riveting machine
8. Layout of smithy or forging shop.
- 5 Sketch and describe the following forging tools
 - (i) Anvil.
 - (ii) Swage Block,
 - (iii) Set hammers
 - (iv) Punches,
 - (v) Drift, and
 - (vi) Hardie
- 6 Explain with neat sketches the following forging operations:
 - (i) Upsetting,
 - (ii) Drawing down,
 - (iii) Bending,
 - (iv) Drifting,
 - (v) Punching,
 - (vi) Welding
 - (vii) Fullering
- 7 Describe press forging. How does it differ from drop forging?
- 8 Describe in brief the various types of forgings?
- 9 Explain in brief the defects in forging?
- 10 Why heat treatment is necessary for forging?
- 11 What are the main considerations in designing a forging?
- 12 Explain in brief the various safety precautions associated with the forging shop?

15
CHAPTER

HOT WORKING OF METALS

15.1 METAL FORMING

Metal forming is also known as mechanical working of metals. Metal forming operations are frequently desirable either to produce a new shape or to improve the properties of the metal. Shaping in the solid state may be divided into non-cutting shaping such as forging, rolling, pressing, etc., and cutting shaping such as the machining operations performed on various machine tools. Non-cutting or non machining shaping processes are referred to as mechanical working processes. It means an intentional and permanent deformation of metals plastically beyond the elastic range of the material. The main objectives of metal working processes are to provide the desired shape and size, under the action of externally applied forces in metals. Such processes are used to achieve optimum mechanical properties in the metal and reduce any internal voids or cavities present and thus make the metal dense.

Metals are commonly worked by plastic deformation because of the beneficial effect that is imparted to the mechanical properties by it. The necessary deformation in a metal can be achieved by application of mechanical force only or by heating the metal and then applying a small force. The impurities present in the metal are thus get elongated with the grains and in the process get broken and dispersed through out the metal. This also decreases the harmful effect of the impurities and improves the mechanical strength. This plastic deformation of a metal takes place when the stress caused in the metal, due to the applied forces reaches the yield point. The two common phenomena governing this plastic deformation of a metal are (a) deformation by slip and (b) deformation by twin formation. In the former case it is considered that each grain of a metal is made of a number of unit cells arranged in a number of planes, and the slip or deformation of metal takes place along that slip plane which is subjected to the greatest shearing stress on account of the applied forces. In the latter case, deformation occurs along two parallel planes, which move diagonally across the unit cells. These parallel planes are called twinning planes and the portion of the grains covered between them is known as twinned region. On the macroscopic scale, when plastic deformation occurs, the metal appears to flow in the solid state along specific directions, which are dependent on the processing and the direction of applied forces. The crystals or grains of the metal get elongated in the direction of metal flow. However this flow of metal can be easily be seen under microscope after polishing and suitable etching of the metal surface. The visible lines are called fibre flow lines. The above deformations may be carried out at room temperature or higher temperatures. At higher temperatures the deformation is faster because the bond

between atoms of the metal grains is reduced. Plasticity, ductility and malleability are the properties of a material, which retains the deformation produced under applied forces permanently and hence these metal properties are important for metal working processes.

Plasticity is the ability of material to undergo some degree of permanent deformation without rupture or failure. Plastic deformation will take place only after the elastic range has been exceeded. Such property of material is important in forming, shaping, extruding and many other hot and cold working processes. Materials such as clay, lead, etc. are plastic at room temperature and steel is plastic at forging temperature. This property generally increases with increase in temperature.

Ductility is the property of a material enabling it to be drawn into wire with the application of tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms percentage elongation and percent reduction in area often used as empirical measures of ductility. The ductile material commonly used in engineering practice in order of diminishing ductility are mild steel, copper, aluminium, nickel, zinc, tin and lead.

Malleability is the ability of the material to be flattened into thin sheets without cracking by hot or cold working. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice in order of diminishing malleability are lead, soft steel, wrought iron, copper and aluminium. Aluminium, copper, tin, lead, steel, etc. are recognized as highly malleable metals.

15.2 RECRYSTALLISATION

During the process of plastic deformation in metal forming, the plastic flow of the metal takes place and the shapes of the grains are changed. If the plastic deformation is carried out at higher temperatures, new grains start growing at the location of internal stresses caused in the metal. If the temperature is sufficiently high, the growth of new grains is accelerated and continuous till the metal comprises fully of only the new grains. This process of formation of new grains is known as recrystallisation and is said to be complete when the metal structure consists of entirely new grains. That temperature at which recrystallisation is completed is known as the recrystallisation temperature of the metal. It is this point, which draws the line of difference between cold working and hot working processes. Mechanical working of a metal below its recrystallisation temperature is called as cold working and that accomplished above this temperature but below the melting or burning point is known as hot working.

15.3 HOT WORKING

Mechanical working processes which are done above recrystallisation temperature of the metal are known as hot working processes. Some metals, such as lead and tin, have a low recrystallisation temperature and can be hot-worked even at room temperature, but most commercial metals require some heating. However, this temperature should not be too high to reach the solidus temperature; otherwise the metal will burn and become unsuitable for use. In hot working, the temperature of completion of metal working is important since any extra heat left after working aids in grain growth. This increase in size of the grains occurs by a process of coalescence of adjoining grains and is a function of time and temperature. Grain growth results in poor mechanical properties. If the hot working is completed just above the recrystallisation temperature then the resultant grain size would be fine. Thus for

any hot working process the metal should be heated to such a temperature below its solidus temperature, that after completion of the hot working its temperature will remain a little higher than and as close as possible to its recrystallisation temperature

15.4 EFFECT OF HOT WORKING ON MECHANICAL PROPERTIES OF METALS

1. This process is generally performed on a metal held at such a temperature that the metal does not work-harden. A few metals e.g., Pb and Sn (since they possess low crystallization temperature) can be hot worked at room temperature.
2. Raising the metal temperature lowers the stresses required to produce deformations and increases the possible amount of deformation before excessive work hardening takes place.
3. Hot working is preferred where large deformations have to be performed that do not have the primary purpose of causing work hardening.
4. Hot working produces the same net results on a metal as cold working and annealing. It does not strain harden the metal.
5. In hot working processes, compositional irregularities are ironed out and non-metallic impurities are broken up into small, relatively harmless fragments, which are uniformly dispersed throughout the metal instead of being concentrated in large stress-raising metal working masses.
6. Hot working such as rolling process refines grain structure. The coarse columnar dendrites of cast metal are refined to smaller equiaxed grains with corresponding improvement in mechanical properties of the component.
7. Surface finish of hot worked metal is not nearly as good as with cold working, because of oxidation and scaling.
8. One has to be very careful as regards the temperatures at which to start hot work and at which to stop because this affects the properties to be introduced in the hot worked metal.
9. Too high a temperature may cause phase change and overheat the steel whereas too low temperature may result in excessive work hardening.
10. Defects in the metal such as blowholes, internal porosity and cracks get removed or welded up during hot working.
11. During hot working, self-annealing occurs and recrystallization takes place immediately following plastic deformation. This self-annealing action prevents hardening and loss of ductility.

15.5 MERITS OF HOT WORKING

1. As the material is above the recrystallisation temperature, any amount of working can be imparted since there is no strain hardening taking place.
2. At a high temperature, the material would have higher amount of ductility and therefore there is no limit on the amount of hot working that can be done on a material. Even brittle materials can be hot worked.
3. In hot working process, the grain structure of the metal is refined and thus mechanical properties improved.

4. Porosity of the metal is considerably minimized.
5. If process is properly carried out, hot work does not affect tensile strength, hardness, corrosion resistance, etc.
6. Since the shear stress gets reduced at higher temperatures, this process requires much less force to achieve the necessary deformation.
7. It is possible to continuously reform the grains in metal working and if the temperature and rate of working are properly controlled, a very favorable grain size could be achieved giving rise to better mechanical properties.
8. Larger deformation can be accomplished more rapidly as the metal is in plastic state.
9. No residual stresses are introduced in the metal due to hot working.
10. Concentrated impurities, if any in the metal are disintegrated and distributed throughout the metal.
11. Mechanical properties, especially elongation, reduction of area and izod values are improved, but fibre and directional properties are produced.
12. Hot work promotes uniformity of material by facilitating diffusion of alloy constituents and breaks up brittle films of hard constituents or impurity namely cementite in steel.

15.6 DEMERITS OF HOT WORKING

1. Due to high temperature in hot working, rapid oxidation or scale formation and surface de-carburization take place on the metal surface leading to poor surface finish and loss of metal.
2. On account of the loss of carbon from the surface of the steel piece being worked the surface layer loses its strength. This is a major disadvantage when the part is put to service.
3. The weakening of the surface layer may give rise to a fatigue crack which may ultimately result in fatigue failure of the component.
4. Some metals cannot be hot worked because of their brittleness at high temperatures.
5. Because of the thermal expansion of metals, the dimensional accuracy in hot working is difficult to achieve.
6. The process involves excessive expenditure on account of high cost of tooling. This however is compensated by the high production rate and better quality of components.
7. Handling and maintaining of hot working setups is difficult and troublesome.

15.7 CLASSIFICATION OF HOT WORKING PROCESSES

The classification of hot working processes is given as under.

1. Hot rolling
2. Hot forging
3. Hot extrusion
4. Hot drawing

5. Hot spinning
6. Hot piercing or seamless tubing
7. Tube Forming and
8. Hot forming of welded pipes

Some of the important hot working processes are described as under.

15.8 PRINCIPAL HOT WORKING PROCESSES

15.8.1 Hot Rolling

Rolling is the most rapid method of forming metal into desired shapes by plastic deformation through compressive stresses using two or more than two rolls. It is one of the most widely used of all the metal working processes. The main objective of rolling is to convert larger sections such as ingots into smaller sections which can be used either directly in as rolled state or as stock for working through other processes. The coarse structure of cast ingot is converted into a fine grained structure using rolling process as shown in Fig. 15.1. Significant improvement is accomplished in rolled parts in their various mechanical properties such as toughness, ductility, strength and shock resistance. The majority of steel products are being converted from the ingot form by the process of rolling. To the steel supplied in the ingot form the preliminary treatment imparted is the reduction in its section by rolling as shown in figure. The crystals in parts are elongated in the direction of rolling, and they start to reform after leaving the zone of stress. Hot rolling process is being widely used in the production of large number of useful products such as rails, sheets, structural sections, plates etc. There are different types of rolling mills, which are described as under.

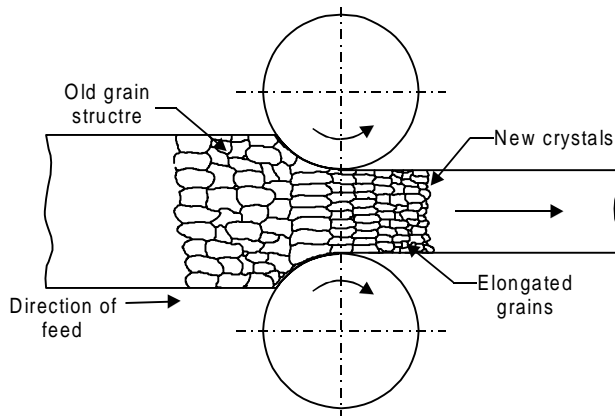


Fig. 15.1 Grain refinement in hot rolling process

15.8.1 Two-High Rolling Mill

A two-high rolling mill (Fig 15.2(a)) has two horizontal rolls revolving at the same speed but in opposite direction. The rolls are supported on bearings housed in sturdy upright side frames called stands. The space between the rolls can be adjusted by raising or lowering the upper roll. Their direction of rotation is fixed and cannot be reversed. The reduction in the thickness of work is achieved by feeding from one direction only. However, there is another

type of two-high rolling mill, which incorporates a drive mechanism that can reverse the direction of rotation of the rolls. A Two-high reverse arrangement is shown in Fig. 15.2(b). In a two-high reversing rolling mill, there is continuous rolling of the workpiece through back-and-forth passes between the rolls.

15.8.2 Three-High Rolling Mills

It consists of three parallel rolls, arranged one above the other as shown in Fig. 15.2(c). The directions of rotation of the upper and lower rolls are the same but the intermediate roll rotates in a direction opposite to both of these. This type of rolling mill is used for rolling of two continuous passes in a rolling sequence without reversing the drives. This results in a higher rate of production than the two-high rolling mill.

15.8.3 Four-High Rolling Mill

It is essentially a two-high rolling mill, but with small sized rolls. Practically, it consists of four horizontal rolls, the two middle rolls are smaller in size than the top and bottom rolls as shown in Fig. 15.2(d). The smaller size rolls are known as working rolls which concentrate the total rolling pressure over the workpiece. The larger diameter rolls are called back-up rolls and their main function is to prevent the deflection of the smaller rolls, which otherwise would result in thickening of rolled plates or sheets at the centre. The common products of these mills are hot or cold rolled plates and sheets.

15.8.4 Cluster Mill

It is a special type of four-high rolling mill in which each of the two smaller working rolls are backed up by two or more of the larger back-up rolls as shown in Fig. 15.2(e). For rolling hard thin materials, it may be necessary to employ work rolls of very small diameter but of considerable length. In such cases adequate support of the working rolls can be obtained by using a cluster-mill. This type of mill is generally used for cold rolling work.

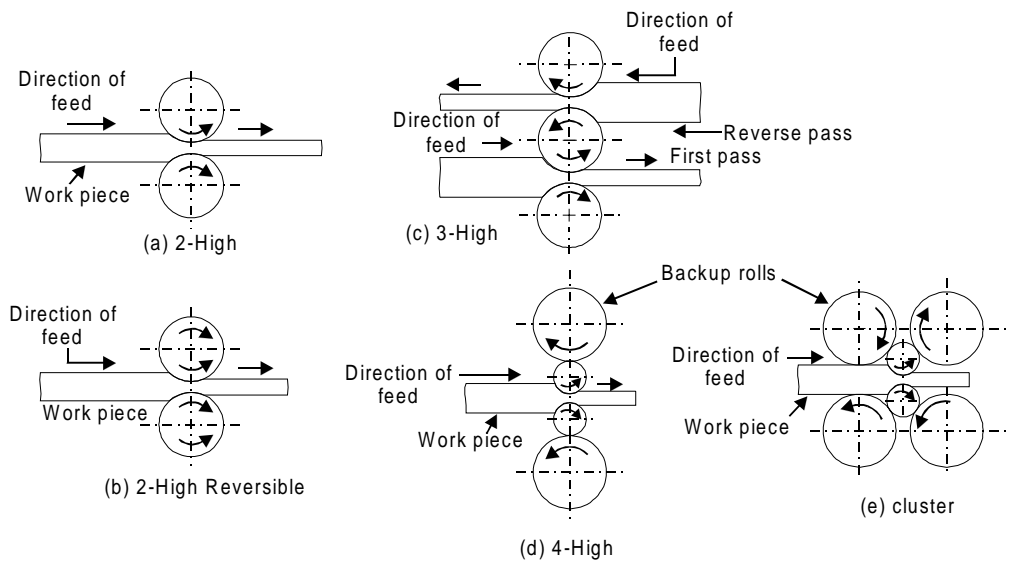


Fig. 15.2 Hot rolling stand arrangements

15.8.5 Continuous Rolling Mill

It consists of a number of non reversing two-high rolling mills arranged one after the other, so that the material can be passed through all of them in sequence. It is suitable for mass production work only, because for smaller quantities quick changes of set-up will be required and they will consume lot of time and labor.

15.8.6 Applications of Rolling

In the rail mill (Fig. 15.2(f)), the heavier structural sections and rails are made. Rolling mills produce girders, channels, angle irons and tee-irons. Plate mill rolls slabs into plates. The materials commonly hot rolled are aluminium, copper magnesium, their alloys and many grades of steel.

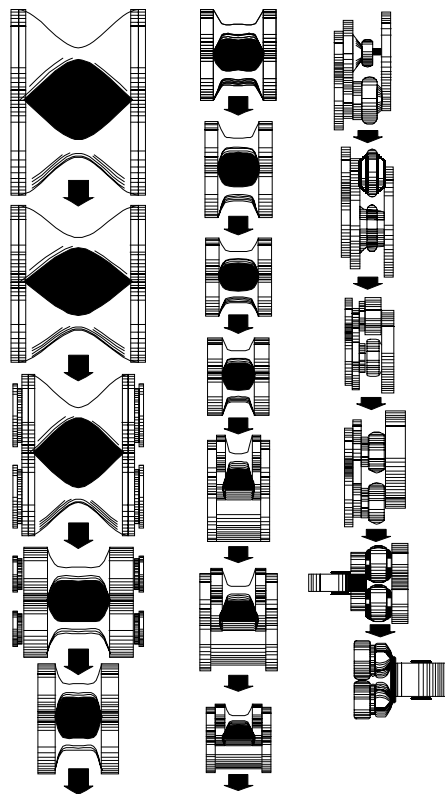


Fig. 15.2(f) Hot rolling stand arrangements

15.9 Hot Piercing or Seamless tubing

Hot piercing is also known as seamless tubing or roll piercing process. The process setup is shown in Fig. 15.3. It is used for making thin-walled round objects. Seamless tube forming is popular and economical process in comparison to machining because it saves material wasted in boring of parts.

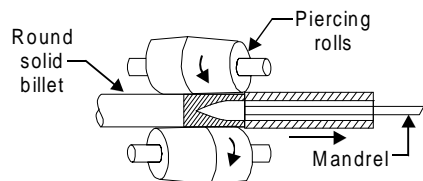


Fig. 15.3 Hot piercing or seamless tubing

Hot piercing includes rotary piercing to obtain formed tube by piercing a pointed mandrel through a billet in a specially designed rolling mill. The rotary piercing can be performed either on a two-high rolling mill or on a three-high rolling mill. In the former, the two rolls are set at an angle to each other. The billet under the rolls is deformed and a cavity formation is initiated at the centre due to tensile stressing. The carefully profiled shape of the mandrel assists and controls the formation of cavity. In a three-high rolling mill, the three shaped rolls are located at 120° and their axes are inclined at a feed angle to permit forward and rotary motion of the billet. The squeezing and bulging of the billet open up a seam in its center pass makes a rather thick-walled tube which is again passed over plug and through grooved rolls in a two-high roll mill where the thickness is decreased and the length is increased. While it is still up to a temperature, it is passed on to a reeling machine which has two rolls similar to the piercing rolls, but with flat surfaces. If more accuracy and better finish are desired, the run through sizing dies or rolls. After cooling, the tubes are used in a pickling bath of dilute sulphuric acid to remove the scale.

15.10 HOT EXTRUSION

It is the process of enclosing the heated billet or slug of metal in a closed cavity and then pushing it to flow from only one die opening so that the metal will take the shape of the opening. The pressure is applied either hydraulically or mechanically. Extrusion process is identical to the squeezing of tooth paste out of the tooth paste tube. Tubes, rods, hose, casing, brass cartridge, moulding-trims, structural shapes, aircraft parts, gear profiles, cable sheathing etc. are some typical products of extrusion. Using extrusion process, it is possible to make components, which have a constant cross-section over any length as can be had by the rolling process. The intricacy in parts that can be obtained by extrusion is more than that of rolling, because the die required being very simple and easier to make. Also extrusion is a single pass process unlike rolling. The amount of reduction that is possible in extrusion is large. Generally brittle materials can also be easily extruded. It is possible to produce sharp corners and re-entrant angles. It is also possible to get shapes with internal cavities in extrusion by the use of spider dies, which are explained later.

The extrusion setup consists of a cylinder container into which the heated billet or slug of metal is loaded. On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening. The extruded metal is then carried by the metal handling system as it comes out of the die.

The extrusion ratio is defined as the ratio of cross-sectional area of the billet to that of the extruded section. The typical values of the extrusion ratio are 20 to 50. Horizontal hydraulic presses of capacities between 250 to 5500 tonnes are generally used for conventional extrusion. The pressure requirement for extrusion is varying from material to material. The extrusion pressure for a given material depends on the extrusion temperature, the reduction in area and the extrusion speed.

15.10.1 Methods of Hot Extrusion

Hot extrusion process is classified as

1. Direct or forward hot extrusion
2. Indirect or backward hot extrusion
3. Tube extrusion

Different methods of extrusion are shown in Fig. 15.4. Each method is described as under.

15.10.1.1 Direct or Forward Hot Extrusion

Fig. 15.4 (a) shows the direct extrusion operational setup. In this method, the heated metal billet is placed in to the die chamber and the pressure is applied through ram. The metal is extruded through die opening in the forward direction, i.e. the same as that of the ram. In forward extrusion, the problem of friction is prevalent because of the relative motion between the heated metal billet and the cylinder walls. To reduce such friction, lubricants are to be commonly used. At lower temperatures, a mixture of oil and graphite is generally used. The problem of lubrication gets compounded at the higher operating temperatures. Molten glass is generally used for extruding steels.

15.10.1.2 Indirect or Backward Hot Extrusion

Fig. 15.4 (b) shows the indirect extrusion operational setup. In indirect extrusion, the billet remains stationary while the die moves into the billet by the hollow ram (or punch), through which the backward extrusion takes place. Since, there is no friction force between the billet and the container wall, therefore, less force is required by this method. However this process is not widely used because of the difficulty occurred in providing support for the extruded part.

15.10.1.3 Tube Extrusion

Fig. 15.4 (c and d) shows the tube extrusion operational setup. This process is an extension of direct extrusion process where additional mandrel is needed to restrict flow of metal for production of seamless tubes. Aluminium based toothpaste and medicated tubes are produced using this process.

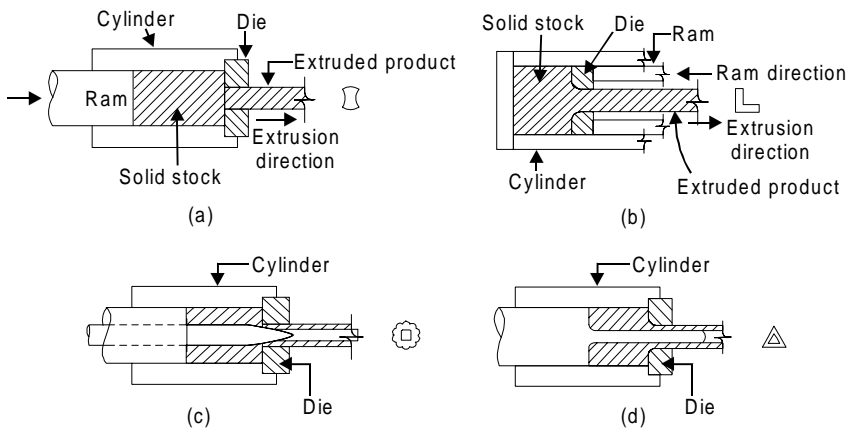


Fig. 15.4 Method of hot extrusion

15.11 HOT DRAWING

Drawing is pulling of metal through a die or a set of dies for achieving a reduction in a diameter. The material to be drawn is reduced in diameter. Fig. 15.5 is another method used in hot drawing or shaping of materials where the heated blank is placed over the die opening

the punch forces the blank through the die opening to form a cup or shell. The multiple dies are also used to accomplish the stages in drawing process. Kitchen utensils and components of food processing industries are manufactured by this process.

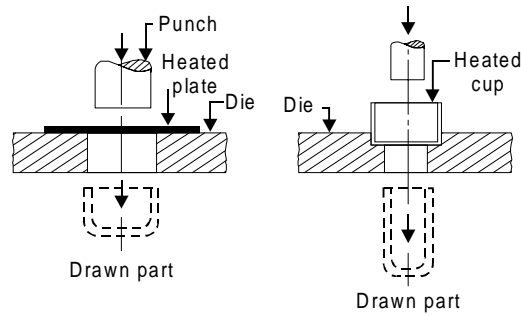


Fig. 15.5 Hot drawing

15.12 HOT SPINNING

Hot spinning is a process in which pressure and plastic flow is used to shape material. Spinning may be either hot or cold and is generally carried over a spinning lathe. In both cases, the metal is forced to flow over a rotating shape by pressure of a blunt tool as shown in Fig. 15.6. The amount of pressure of the blunt tool against the disc controls the generated heat, which helps in forming processes.

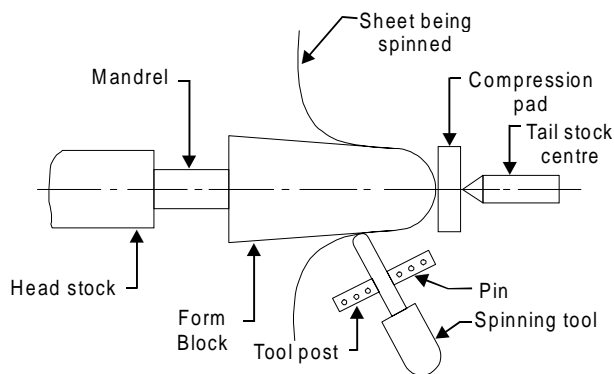


Fig. 15.6 Hot spinning

QUESTIONS

1. What do you understand by mechanical working of metals?
2. Define re-crystalline temperature.
3. Differentiate between hot and cold working.
4. Define hot working of metals. What are its advantages and disadvantages?
5. Describe with sketches the three methods of hot working.
6. Explain briefly the various methods of hot extrusion with neat sketches.

7. What is hot extrusion? In how many ways it can be performed?
8. Describe briefly with neat sketches all the process of extrusions.
9. Discuss their relative merits and demerits of different kind of extrusion.
10. How welded pipes and tubes are manufactured?
11. Describe the process of hot extrusion of tubes.
12. What is roll piercing? And for what purpose is it used?
13. Write Short notes on:
 - (a) Hot spinning
 - (b) Hot Extrusion
 - (c) Hot forging
 - (d) Hot drawing.
14. Explain hot rolling and various type of rolling mills used in hot rolling.
15. Write short notes on the following:
 - (i) Hot piercing
 - (ii) Hot forging
 - (iii) Forging
16. How and why are directional properties obtained in a forged component? Discuss their advantages, dis-advantages and applications.
17. What are the advantages of hot extrusion over rolling and forging?
18. With the aid of a sketch, briefly describe the process of spinning. Why is it called a flow turning process?

COLD WORKING

16.1 INTRODUCTION

Cold working of a metal is carried out below its recrystallisation temperature. Although normal room temperatures are ordinarily used for cold working of various types of steel, temperatures up to the recrystallisation range are sometimes used. In cold working, recovery processes are not effective.

16.2 PURPOSE OF COLD WORKING

The common purpose of cold working is given as under

1. Cold working is employed to obtain better surface finish on parts.
2. It is commonly applied to obtain increased mechanical properties.
3. It is widely applied as a forming process of making steel products using pressing and spinning.
4. It is used to obtain thinner material.

16.3 PRECAUTIONS FALLOWED IN COLD WORKING

Cold working leads to crack formation and propagation if performed in excess and it should therefore be avoided. Residual stresses developed due to inhomogeneous deformation cause warping or distortion when the part is released from the tooling and during subsequent machining. Magnitude and distribution of residual stresses should therefore be controlled. Orange-peel and stretcher strains are material related types of roughness defects found on surfaces not touched by tooling. The former can be avoided by using fine grained sheets and latter is minimized by temper rolling or stretching the strip to prevent localized yielding.

16.4 CHARACTERISTICS OF COLD WORKING

The main characteristics of cold working are given as under.

1. Cold working involves plastic deformation of a metal, which results in strain hardening.
2. It usually involves working at ordinary (room) temperatures, but, for high melting point metals, e.g., tungsten, the cold working may be carried out at a red heat.

3. The stress required for deformation increases rapidly with the amount of deformation.
4. The amount of deformation, which can be performed without introducing other treatment, is limited.
5. Cold rolling process generally distorts grain structure.
6. Good surface finish is obtained in cold rolling.
7. The upper temperature limit for cold working is the maximum temperature at which strain hardening is retained. Since cold working takes place below the recrystallisation temperature, it produces strain hardening.
8. Excessive cold working gives rise to the formation and propagation of cracks in the metal.
9. The loss of ductility during cold working has a useful side effect in machining.
10. With less ductility, the chips break more readily and facilitate the cutting operation.
11. Heating is sometimes required.
12. Directional properties can be easily imparted.
13. Spring back is a common phenomenon present in cold-working processes.
14. For relatively ductile metals, cold working is often more economical than hot working.

There is some increase and some decrease in properties of the cold worked part, which are given as under.

Cold working process increases:

- Ultimate tensile strength
- Yield strength
- Hardness
- Fatigue strength
- Residual stresses

Cold working processes decreases:

- Percentage elongation
- Reduction of area
- Impact strength
- Resistance to corrosion
- Ductility

16.4 LIMITATIONS OF COLD WORKING

1. The cold worked process possesses less ductility.
2. Imparted directional properties may be detrimental
3. Strain hardening occurs.
4. Metal surfaces must be clean and scale free before cold working.
5. Hot worked metal has to be pickled in acid to remove scale, etc.
6. Higher forces are required for deformation than those in hot working.
7. More powerful and heavier equipments are required for cold working.

16.5 ADVANTAGES OF COLD WORKING

1. In cold working processes, smooth surface finish can be easily produced.
2. Accurate dimensions of parts can be maintained.
3. Strength and hardness of the metal are increased but ductility decreased.
4. Since the working is done in cold state, no oxide would form on the surface and consequently good surface finish is obtained.
5. Cold working increases the strength and hardness of the material due to the strain hardening which would be beneficial in some situations.
6. There is no possibility of decarburization of the surface
7. Better dimensional accuracy is achieved.
8. It is far easier to handle cold parts and it is also economical for smaller sizes.

16.6 DISADVANTAGES OF COLD WORKING

1. Some materials, which are brittle, cannot be cold worked easily.
2. Since the material has higher yield strength at lower temperatures, the amount of deformation that can be given to is limited by the capability of the presses or hammers used.
3. A distortion of the grain structure is created.
4. Since the material gets strain hardened, the maximum amount of deformation that can be given is limited. Any further deformation can be given after annealing.
5. Internal stresses are set up which remain in the metal unless they are removed by proper heat-treatment.

16.7 COMPARISON OF HOT WORKING WITH COLD WORKING

The comparison of hot working with cold working is given in Table 16.1.

Table 16.1 Comparison of Hot Working with Cold Working

S. No.	Hot Working	Cold Working
1.	Hot working is carried out above the recrystallisation temperature and below the melting point. Hence the deformation of metal and recovery take place simultaneously.	Cold working is carried out below the recrystallisation temperature. As such, there is no appreciable recovery.
2.	No internal or residual stresses are set-up in the metal in hot working.	In this process internal or residual stresses are set-up in the metal.
3.	It helps in irradiating irregularities in metal composition breaking up the non metallic impurities in to tiny fragments and dispersing them through out the metal and thus facilitate uniformity of composition in the metal	It results in loss of uniformity of metal composition and thus affects the metal properties.

4.	Close tolerance can not be maintained	Better tolerance can be easily maintained.
5.	Surface finish of this process is comparatively not good	Surface finish of this process is better.
6.	It results in improvements of properties like impact strength and elongation	It results in improvements of properties like impact strength and elongation.
7.	Due to re-crystallisation and recovery no or very negligible hardening of metal takes place.	Since this is done below re-crystallisation temperature the metal gets work hardened.
8.	Due to higher deformation temperatures, the stress required for deformation is much less.	The stress required to cause deformation is much higher.
9.	Hot working refines metal grains resulting in improved mechanical properties.	Most of the cold working processes lead to distortion of grains.
10.	If cracks and blow bores are present in the metal, they are finished through hot working.	In cold working the existing cracks propagate and new cracks may develop
11.	If properly performed, it does not affect UTS, hardness, corrosion resistance, yield strength and fatigue strength of the metal.	It improves UTS, hardness, yield strength but reduces the corrosion resistance of strength of the metal.

16.8 COLD WORKING PROCESSES

Commonly employed cold working processes are:

1. Rolling
2. Extrusion
3. Wire drawing
4. Forging
5. Sheet metal operations
 - (a) Shearing etc.
 - (i) Piercing
 - (ii) Blanking
 - (iii) Cutting
 - (iv) Parting
 - (v) Punching
 - (vi) Notching
 - (vii) Slitting
 - (viii) Nibbling
 - (ix) Lancing
 - (x) Trimming
 - (b) Bending
 - (c) Drawing
 - (d) Pressing and deep drawing
 - (e) Squeezing
 - (i) Embossing
 - (ii) Coining
6. Cold spinning
7. Shot peening

Cold working processes are also similar to hot working processes. Some of the important colds working processes are described as under.

16.9 COLD-ROLLING

Cold rolling process setup is similar to hot rolling. Bars of all shapes such as rods, sheets and strips are commonly finished by rolling. Foil is made of the softer metals in this way. Cold-rolling metals impart smooth bright surface finish and in good physical and mechanical properties to cold rolled parts. If the objective is only to give a clean, smooth finishing metal, only a superficial amount of rolling will be needed. On the other hand, where it is desirable that the tensile strength and stiffness be increased substantially, the section thickness is significantly reduced, and then higher roll pressures and deeper kneading are necessary. Cold rolling also improves machinability in the cold rolled part by conferring the property of brittleness, a condition, which is conducive to smooth tool, finishes with broken chips. The preliminary step to the cold-rolling operation, the sheets of pre hot-rolled steel are immersed in an acid solution to remove the washed in water and then dried. The cleaned steel is passed through set of rolls of cold rolling process thereby producing a slight reduction in each the required thickness is obtained.

The arrangement of rolls in a rolling mill, also called rolling stand, varies depending on the application. The various possible configurations of rolls are similar to hot rolling. The names of the rolling stand arrangements are generally given by the number of rolls employed. These stands are more expensive compared to the non-reversible type because of the reversible drive needed. Internal stresses are set up in cold rolled parts which remain in the metal unless they are removed by proper heat-treatment. This process needs more power for accomplishing the operation in comparison to hot rolling.

16.10 COLD EXTRUSION

Principle of cold extrusion is similar to that of hot extrusion, which has been discussed under hot extrusion in section 15.10. The dissimilarity is that material in hot working processes should possess the essential ductility with out the application of heat. Impact extrusion is also a cold extrusion process. It is used for making small components from ductile materials. Impact extrusion process is shown in Fig. 16.1. Impact extrusion of material is accomplished where the work blank is placed in position over the die opening the punch forces the blank through the die opening causing material to flow plastically around the punch. The outside diameter of the tube is same as diameter of the die, and the thickness is controlled by the clearance between punch and die. Collapsible medicare tubes and toothpastes etc. are produced using this impact extrusion.

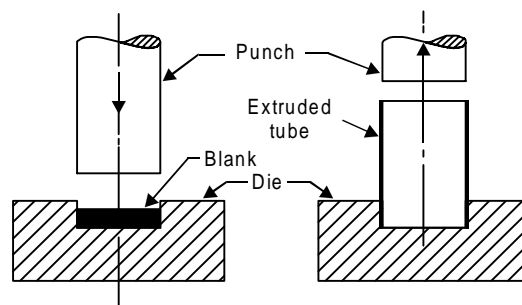


Fig. 16.1 Impact extrusion

16.11 WIRE DRAWING

The wire drawing die setup is shown in Fig.16.2(a). The process of producing the wires of different diameters is accomplished by pulling a wire through a hardened die usually made up carbide. However a smaller diameter wires are drawn through a die made of diamond. The larger diameter oriented wire is first cleaned, pickled, washed and then lubricated. Cleaning is essentially done to remove any scale and rust present on the surface, which may severely affect the die. It is normally done by acid pickling. The hot rolled steel is descaled, pickled in acid, washed in water and coated with lime and other lubricants. To make for an easier entrance of wire into the die, the end of the stock is made pointed to facilitate the entry. A pointed or reduced

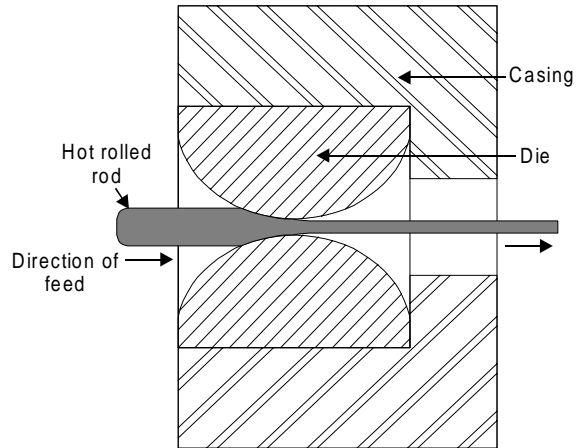


Fig. 16.2(a) Wire drawing

diameter at the end of wire duly lubricated is pushed or introduced through the die which is water cooled also. This pointing is done by means of rotary swaging or by simple hammering. It is then gripped and pulled for attaching it to a power driven reel. The wire diameter is reduced in die because of the ductility property of the material to the smaller diameter through one set of die. However for more reduction in diameter of the wire, various sets of dies can be used in line for subsequent reduction in diameter at each stage as shown in Fig 16.2(b). The reduction in each pass through the die range about 10% for steel and 40% for ductile materials such as copper.

The drawing of the wire starts with a rod or coil of hot rolled steel, which is 0.8 to 1.6 mm larger than the final size required. In this process, there is no force is applied for pushing the wire into the die from the entrance side. The material should be sufficiently ductile since it is pulled by the tensile forces. Hence, the wire may have to be annealed properly to provide the necessary ductility. Further, the wire is to go through the conical portion and then pulled out through the exit by the gripper. The other aspect of preparation needed is the cleaning of the wire and lubricating it as it flows through the die. The pressures acting at the interface of the die and the metal being very high, the lubrication of the die is a serious problem. Therefore, to carry the lubricant through the die, special methods such as gulling, coppering, phosphating and liming are used. The wire is coated with a thin coat of ferrous hydroxide which when combined with lime acts as filler for the lubricant. This process is called sulling. In phosphating, a thin film of manganese, iron or zinc phosphate is applied on the wire, which makes the lubricant to stick to the wire, thereby reducing the friction and consequently, the drawing load. Another lubricant vehicle that is used in wire drawing is a coating of lime. After acid pickling, lime is applied and then allowed to dry. The lime neutralizes any amount of acid left on the surface and adsorbs the lubricant for carrying it to the die. The lubricant normally used is the soap solution. For very thin wires, electrolytic coating of copper is used to reduce friction. The dies used for wire drawing are severely affected because of high stresses and abrasion. The various die materials that are used are chilled cast iron, tool steels, tungsten carbide and diamond. The cast iron dies are used for small runs. For very large sizes, alloy

steels are used in making the dies. The tungsten carbide dies are used most commonly for medium size wires and large productions. The tungsten carbide dies are referred because of their long life that is 2 to 3 times that of alloy steel dies. For very fine wires, diamond dies are used. Wire drawing improves the mechanical properties because of the cold working. The material loses its ductility during the wire drawing process and when it is to be repeatedly drawn to bring it to the final size, intermediate annealing is required to restore the ductility.

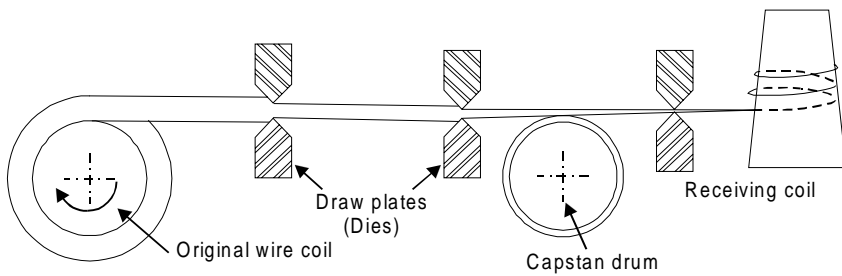


Fig. 16.2(b) Wire drawing

16.12 SHEET METAL PROCESSES

Sheet metal work processing is highly common in manufacturing sheet metal parts using from sheet stock. The various sheet metal operations are performed on press machine of required capacity using press tools or dies. The dies may be single operation die or multi-operation dies. A simple piercing, blanking and shearing die is shown in Fig. 16.3. However the basic sheet metal operations are described in the following lines.

16.12.1 General Sheet Metal Operations

Shearing

It takes place when punch and die are used. The quality of the cut surface is greatly influenced by the clearance between the two shearing edges. However, the basic shearing operations are described in the following lines.

Cutting

It means severing a piece from a strip with a cut along a single line.

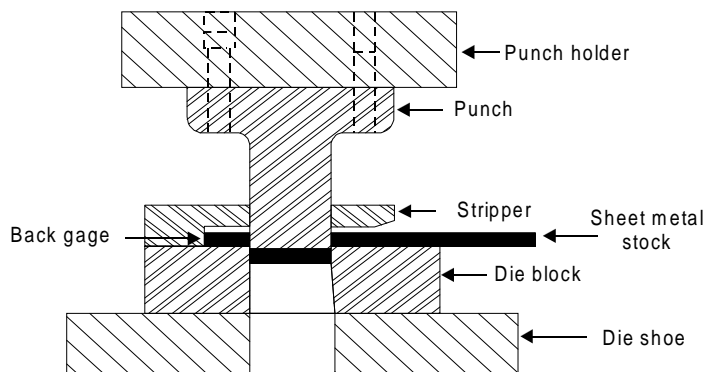


Fig. 16.3 Typical simple press tool

Parting

It signifies that scrap is removed between the two pieces to part them.

Blanking

It means cutting a whole piece from sheet metal just enough scrap is left all around the opening to assure that the punch has metal to cut along its entire edge. The piece detached from the strip is known as blank and is led for further operations. The remaining metal strip is scrap. Blanking is nearly almost the first operation and may be the only one necessary or it may be followed successively by many others. Blanking is often combined with other operations in one tool, all the work being performed at one stroke of the press. A blanking die must have clearance, otherwise the blank would not fall freely, and it might remain struck in the die block.

Punching

It is the operation of producing circular holes on a sheet metal by a punch and die. The material punched out is removed as waste. Piercing, on the other hand, is the process of producing holes of any desired shape.

Notching

It is a process of removing metal to the desired shape from the side or edge of a sheet or strip.

Slitting

When shearing is conducted between rotary blades, the process is referred to as slitting. It cuts the sheet metal lengthwise.

Nibbling

It is an operation of cutting any shape from sheet metal without special tools. It is done on a nibbling machine.

Trimming

It is the operation of cutting away excess metal in a flange or flash from a piece.

Lancing

It makes a cut part way across a strip.

Forming

It is a metal working process in which the shape of the punch and the die is directly reproduced in the metal with little or no metal flow.

16.12.2 Bending

It is employed for bending into desired shapes various stock materials like sheets, rods, wires, bars, pipes, tubes and various structural shapes. Formed dies are used for bending the articles and the operation is usually performed in many stages. For bending in all sheet material are stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the natural line which retains its original length. The neutral axis lies at a distance of 30 to 50% of thickness of the sheet from the inside of the bend. Stretching of the sheet metal on the outside makes the stock thinner. Bending is sometimes called as forming which involves angle bending, roll bending, and roll forming and

seaming and spinning. Well designed fixtures are also used where mass bending of such components is required. Bending occurs when forces are applied to localized areas, such as in bending a piece of metal into a right angle, and forming occurs when complete items or parts are shaped. However, some common kinds of sheet metal bends using by press brake dies are depicted in Fig. 16.4.

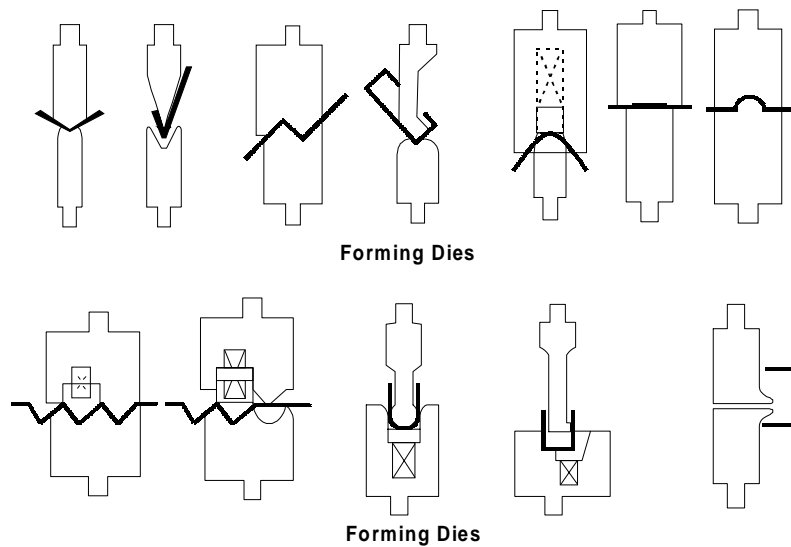


Fig. 16.4 Kinds of sheet metal bends using press brake dies

16.12.3 Cold Drawing

Like hot drawing, it also involves the forcing of a metal through by means of a tensile force applied to the exit side of the drawing die. Most of the plastic flow is accomplished by the compressive force which arises from the reaction of metal with die. It is the operation in which the metal is made to flow plastically by applying tensile stresses to the metal. The blank of calculated diameter is placed on a die and held of it by a blank holder and bottom is pressed into the die by a punch and the walls are pulled in as shown in Fig. 16.5. The efficiency of operation depends upon blank size, reduction factor, drawing pressure, blank holding pressure, punch and die diameters, type of lubricant, die material etc. Therefore, this process is generally used for making cup shaped parts from the sheet blanks, without excessive wrinkling, thinning and fracturing. It can undertake jobs of nearly any size. It is a process of managing a flat precut metal blank into a hollow vessel. Utensils of stainless steel are generally made by this process.

16.12.3.1 Metal Flow in Deep Drawing Dies

When the punch of a deep drawing press forces a portion of metal blank through the bore of the drawing, different forces came into action to cause a rather complicated plastic flow of the material. The volume and thickness of the metal remain essentially constant, and the final shape of the cup will be similar to the contour of the punch. The flow of metal is summarized as follows.

- (i) There is no metal deformation takes place in the blank area which forms the bottom of the cup.

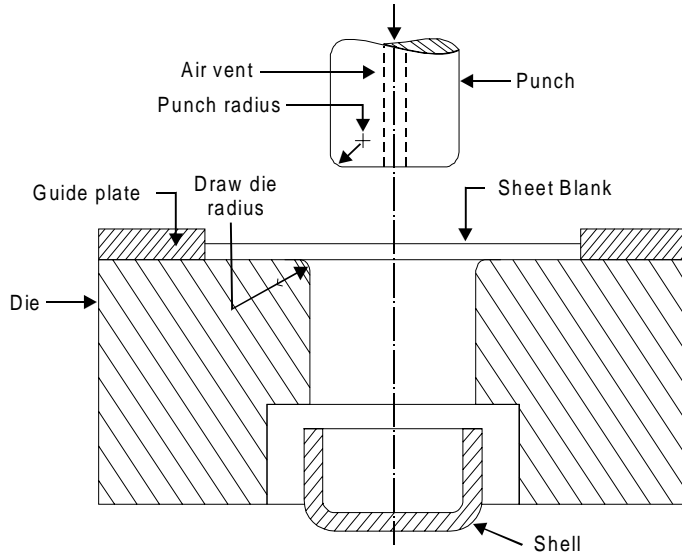


Fig. 16.5 Cold drawing

- (ii) The metal flow of the volume elements at the periphery of the blank is extensive and involves an increase in metal thickness caused by severe circumferential compression. The increase is usually slight because it is restricted by the clearance between the punch and bore wall of the die ring.
- (iii) The metal flow taking place during the forming of the cup will uniformly increase with cup height.

Fig. 16.6 shows the flow of metal in deep drawing.

16.12.4 Embossing

Fig. 16.7 shows the embossing process. It is a process through which blanks of sheet metal are stretched to shape under pressure by means of a punch and a die. Punch operates at a low speed to allow time for proper stretching. The operation gives a stiffening effect to the metal being embossed. Stress in the material may be reduced by producing deep parallel ridges. A large number of ornamental wares, such as plates in sheet metal are produced. A simple form of this process, called open embossing, consists of producing simple shallow shapes by the punch only.

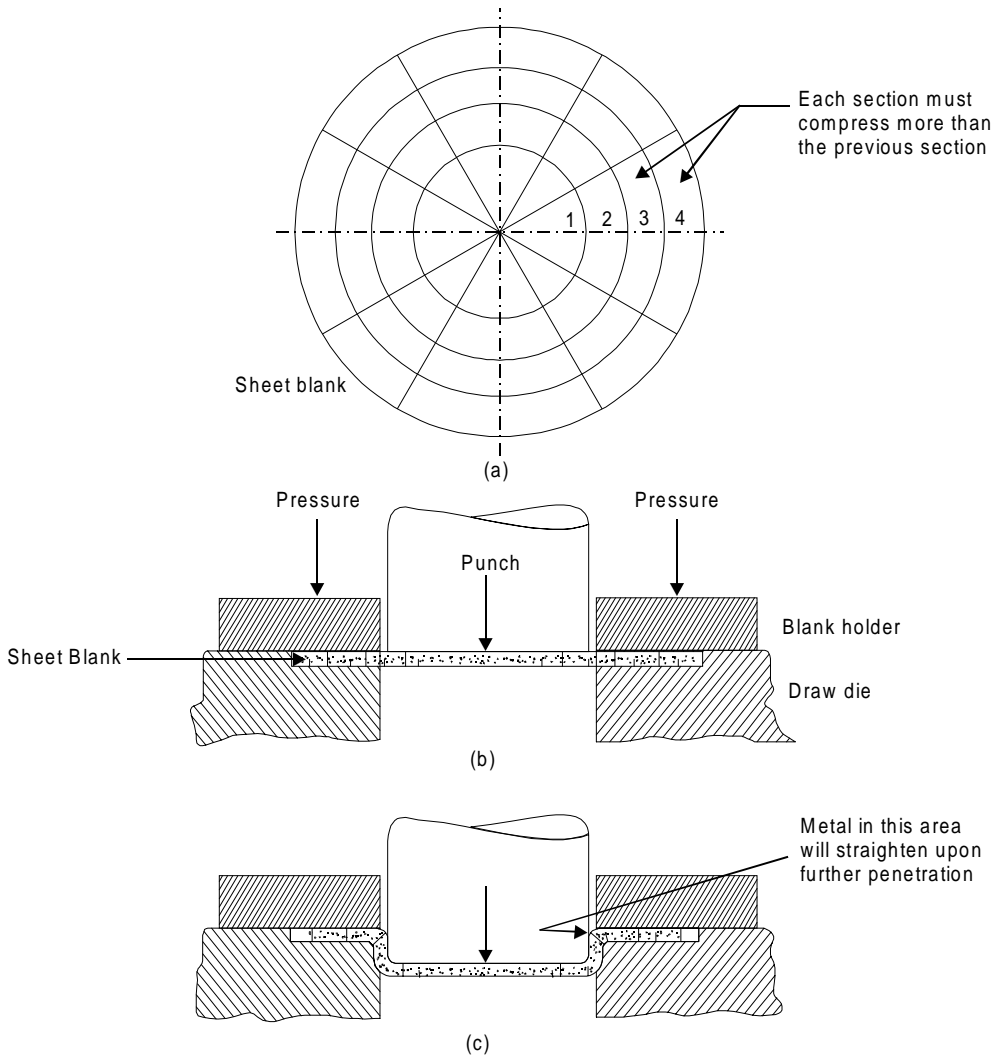


Fig. 16.6 Metal flow in deep drawing

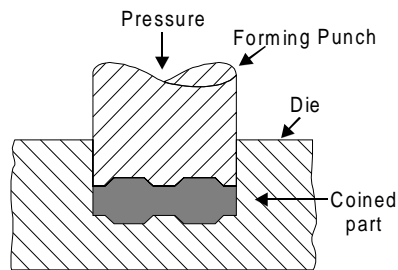


Fig. 16.7 Embossing

16.12.5 Coining

Fig 16.8 shows the coining process used in cold working operations. It is basically a cold working operation, which is performed in dies where the metal blank is confined and its lateral flow is restricted. It is mainly used for production of important articles such as medals, coins, stickers and other similar articles, which possess shallow configurations on their surfaces. The operation involves placing a metal slug in the die and applying heavy pressure by the punch. The metal flows plastically and is squeezed to the shape between punch and the die. The process, on account of the very high pressures required, can be employed only for soft metals with high plasticity.

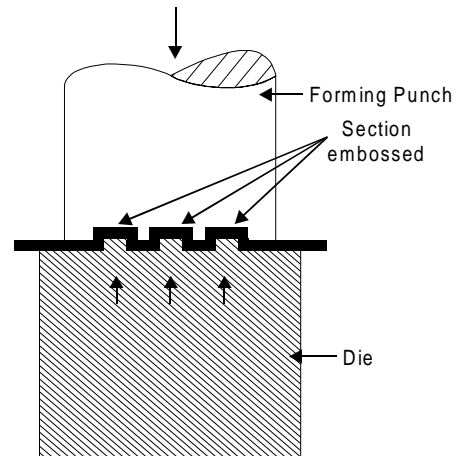


Fig. 16.8 Coining

16.12.6 Roll Forming

It consists of feeding a continuous metal sheet or strip through a series of rolls whereby it is formed into desired shapes. The roll formed sections can be used in as formed condition with their both edges separate from each other. Alternatively, they can be welded to form a closed section such as tubing and pipes. A number of rolls employed in the series depend upon the shape to be formed. The forming arrangement carries guide rolls and straightening devices also.

16.13 SHOT PEENING

It is a process of increasing the hardness and fatigue strength on parts surfaces. The process comprises of throwing a blast of metal shot on to the surface of a component requiring shot peening. It is used to set up a superficial state of surface compression stress, causing the interior of the member to assume an opposite tensile stress. Blast may be thrown either by air pressure or with help of a wheel revolving at high speed. This high velocity blast of metal shot provides a sort of compression over the components surface and increases hardness and strength of the surface and also its fatigue resistance.

16.14 QUESTIONS

1. Differentiate between hot working and cold working.
2. Define cold working of metals. What are its advantages and disadvantages?
3. What are the specific advantages, limitations and applications of cold working?
4. Explain the various cold drawing processes.
5. Using neat sketches explain briefly the process of wire-drawing.
6. Describe the process of cold spinning stating its advantages and specific uses.
7. Explain briefly the stretch forming operation.
8. Write short notes on the cold rolling and cold extrusion.
9. What is cold forging and swaging?
10. What for cold heading is used?
11. Explain the process of rotary swaging with the help of a neat sketch.

12. What is impact extrusion? Explain this process and state its specific applications.
13. Describe the following cold working processes:
 - (i) Embossing
 - (ii) Coining
 - (iii) Roll forming
 - (iv) Roll bending
 - (v) Shot peening
14. Explain the following cold working processes:
 - (i) Cold rolling
 - (ii) Stretch forming
 - (iii) Cold hobbing
 - (iv) Cold bending.
15. Write short notes on the following:
 - (i) Cold forging
 - (ii) Hobbing
 - (iii) Embossing
 - (iv) Staking
 - (v) Ironing
 - (vi) Shot peening.
16. Discuss the methods used for the production of pipes and tubes.
17. Using neat sketch describe briefly the method of extruding a hollow round collapsible tube with help of drawing process.