SECOND EDITION

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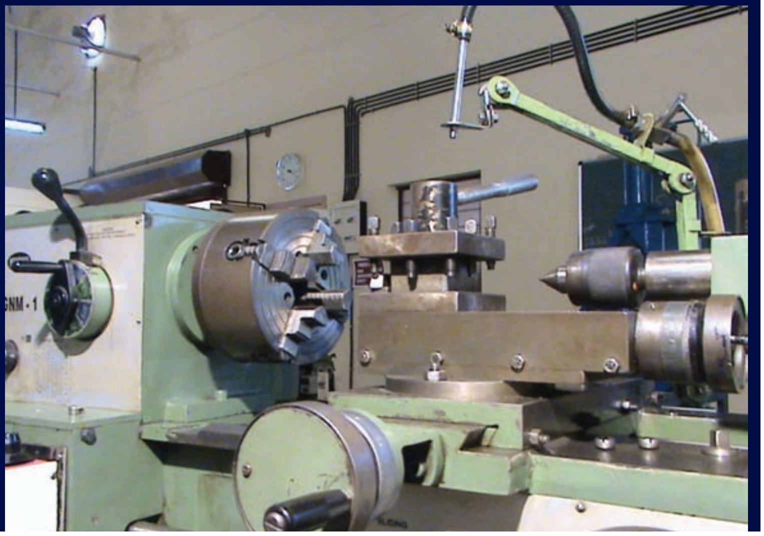
MECHANICAL WORKSHOP PRACTICE

K.C. JOHN



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MECHANICAL WORKSHOP PRACTICE

SECOND EDITION

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MECHANICAL WORKSHOP PRACTICE, Second Edition
K.C. John

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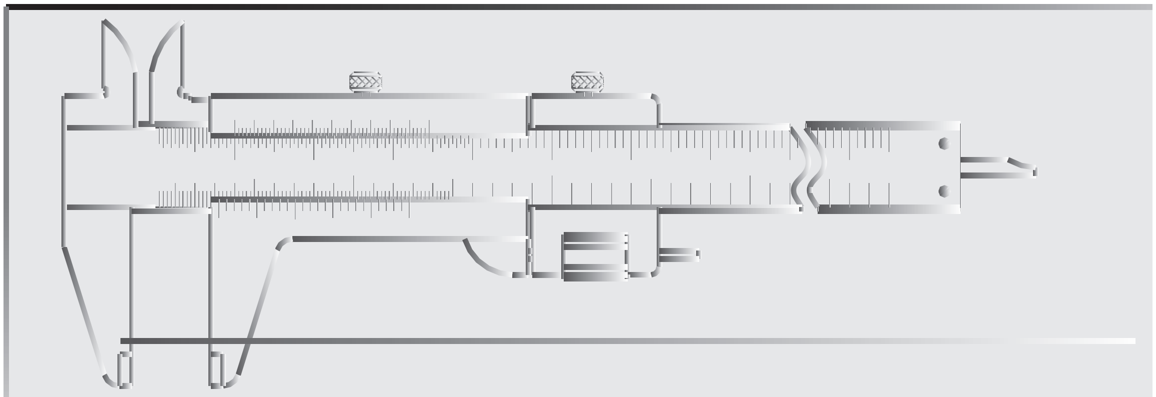

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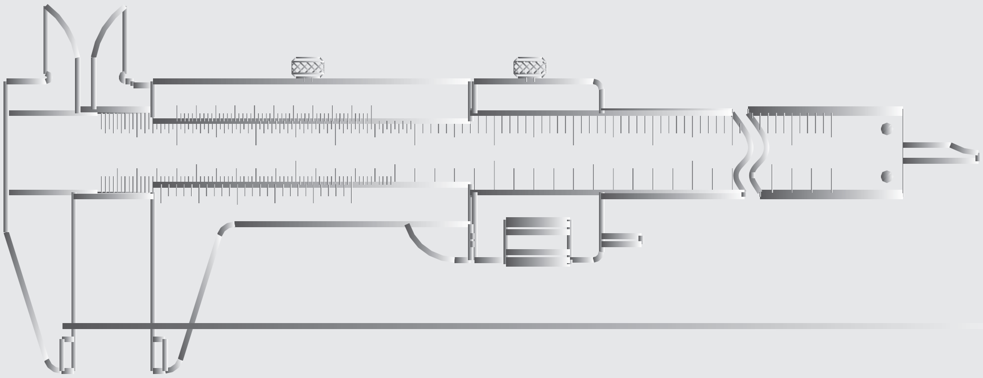


Preface

In the modern engineering curriculum, with the emphasis on engineering science, workshop and laboratory practices have acquired greater importance in the recent years. With major advancements in precise instrumentation and computerized manufacturing techniques, the same has become more sophisticated and specialized field. To gain a basic knowledge of manufacturing process, a student entering the first year of degree or diploma must undertake a course on workshop practice. This gives him/her an overall knowledge about various engineering materials, tools, equipment and processes which are common in the engineering field. Multiple requests from my students and colleagues for a good supporting textbook were my motivation to write the book *Mechanical Workshop Practice*.

The favourable and warm reception of first edition of the book “*Mechanical Workshop Practice*” gave me satisfaction and encouragement to bring out the second edition. I have utilized this opportunity to revise the book little and add one chapter on Plumbing.

This book consists of three modules. Module A is an introduction to workshop practice. Its first chapter explains general principles and layout of workshop processes such as primary and secondary shaping processes, metal joining methods, surface finishing, heat treatments and the materials for workpieces and tools. The second chapter describes the importance of safety measures to be followed as well as the procedure of writing the work and fair records of the practice.

Module B deals with the hand working processes such as fitting, arc welding, sheet metal work, carpentry, blacksmithy and foundry. Each chapter in this module initially explains the tools and equipment used and then the process. Drawings of models and the construction procedures are given at the end as examples.

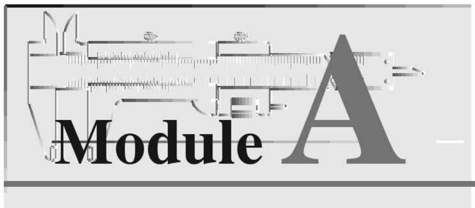
The revised first year syllabus of many Indian Universities includes Plumbing as a new trade for practice. Hear the trade is added as Chapter 9 in the book under the Module B *"Hand Working Processes"*. Enough figures and examples have been added in the chapter in order to understand the topic clearly and to practice the trade. The method of sketching isometric single line piping layout is also added to prepare the details of plumbing.

Module C describes the machining processes and model making. The working principle of engine lathe and turning of cylindrical machine components are covered in this module. Each chapter of the book ends with exercises having enough questions for viva voce and drawings for making models. The process chart and the related tables for tolerances and fits are also given as an Appendix for advanced level practice and the assessment of work.

I am greatly indebted to many specialists on this subject, whose publications have contributed to my knowledge on the subject and to my teachers devoted to the engineering profession. I am especially thankful to Dr. K. Balakrishnan, Principal (Rtd.), Govt. Engineering College, Thrissur, who was kind enough to review the book and give his valuable suggestions for the betterment of the book. I express my deep gratitude to my colleagues who have directly and indirectly helped me to make this attempt a great success. My heartfelt thanks are also due to my son Simon K. John (M.Tech.) for preparing the drawings using CAD.

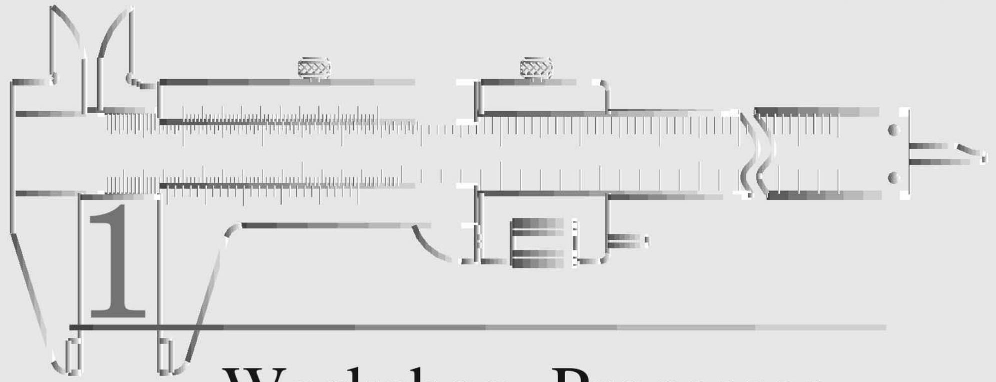
I sincerely thank the students and teaching community who have used the first edition of the book and gave me valuable suggestions for improvement. Finally I thank the PHI Learning group once again for their timely and careful processing of the second edition.

K.C. John



Module A

Introduction to Workshop Practice



1

Workshop Processes

The workshop technology gives the basic working knowledge for the production of various engineering products. It explains the construction, function and the use of various working tools, measuring tools, equipment and machines as well as the technique of manufacturing a product from its raw material. To understand the subject and to develop the skill, one has to practice the workshop processes, starting from simple models to complicated products.

Many of the aspects of workshop technique can only be acquired by experience, by studying on the spot and by establishing contacts with experienced craftsmen. There is much, however, that may be learned by reading prior to or along with the workshop practice. The objective of this part of the book is to provide a preliminary insight into the subject for easy understanding and to give direction for fast progress in the practice. It is to be noted that the basic knowledge of composition, properties and use of different materials, fundamentals about the process of manufacturing, use of hand tools and operations, and allied techniques converts an ordinary student of science into an engineer. Also, the basic knowledge and experience in workshop processes facilitate a sound foundation for further advanced engineering studies.

1.1 Classification of Manufacturing Processes

Metal is considered as the most important material for engineering objects and machines. The term, manufacturing process is considered as the general name for the method of processing metal in order to obtain various shapes. The whole manufacturing processes can be broadly classified into the following five groups:

1. Primary shaping processes
2. Secondary shaping (machining) processes
3. Joining processes
4. Surface finishing processes
5. Processes changing the metal properties

The above-mentioned manufacturing processes can also be grouped as *hot working* and *cold-working* processes. In hot-working process, the metal is processed in hot condition, i.e, above the recrystallization temperature, whereas in cold-working process, the processing is done below this temperature.

1.2 Primary Shaping Processes

Metal obtained by extraction of ores is refined and cast to form big blocks, called *ingots*. These ingots are reduced to smaller size and shape by one or more of the primary shaping processes. A list of the important primary shaping processes is given below.

1. Metal casting
2. Rolling
3. Forging
4. Extrusion
5. Metal drawing
6. Powder metallurgy
7. Oxy-gas cutting
8. Press work
9. Sheet metal work
10. Metal spinning

1.2.1 Metal Casting

Casting or founding is the process of forming metal objects by melting and pouring into moulds. A foundry is a commercial establishment for founding or producing metal castings. Metal casting can be broadly divided into types:

1. Conventional sand casting process.
2. Special casting processes.

The best known and still widely used method of metal casting is the conventional sand casting process. Sand casting consists basically of pouring molten metal into appropriate cavities, formed in a sand mould. Whichever may be the metal poured into the sand moulds, the product is called *sand casting*. The process of sand casting includes the following operations:

1. Pattern making
2. Core making
3. Moulding
4. Melting and pouring
5. Fettling and cleaning
6. Testing and inspection

Figure 1.1 shows an example to sand mould used for casting a single component. The sand casting methods can also be grouped according to the metal cast as shown herein below:

1. Grey iron castings
2. Steel castings
3. Nonferrous castings

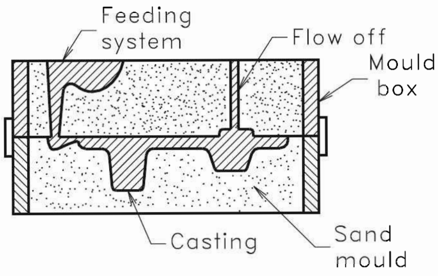


FIGURE 1.1
Sand mould with casting.

The metal casting methods other than the conventional sand casting process are grouped as special casting processes. They include the following:

1. Shell mould casting
2. Investment mould casting
3. Permanent mould casting
4. Die casting
5. Slush casting
6. Plaster mould casting
7. Centrifugal casting
8. Continuous casting

Foundry practice is explained in Chapter 8.

1.2.2 Rolling

Rolling is a process of shaping metals and alloys into semi-finished products by passing them between two rolls rotating in opposite directions [Figure 1.2(a)]. Rolling involves plastic deformation of the metal in which the thickness of the outgoing metal is reduced and the length is increased. The rolling processes can be broadly divided into two sections as mentioned below:

1. *Breaking down processes:* to produce semi-finished products called *blooms, slabs,* and *billets* from the heavy initial metal block called *ingot.*
2. *Finish rolling processes:* to produce rails, beams, plates, sheets, structural sections, rods, etc., from the blooms, slabs and billets.

The rolling process is basically a hot-working process but, thin sheets and foils are rolled in clod (at room temperature) state. Cross sections of some commonly used rolled products are shown in Figure 1.2(b). These products are used as the basic raw material for further shaping processes like welding, forging, sheet metal work, machining, etc.

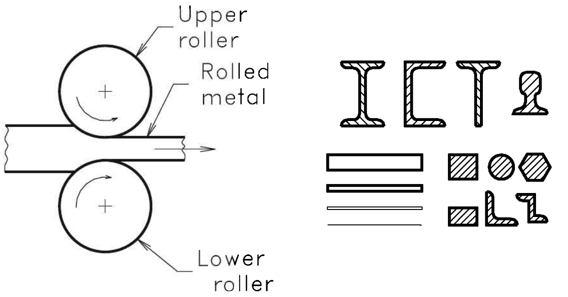


FIGURE 1.2
Rolling.
(a) Rolling process (b) Rolled sections

1.2.3 Forging

Forging is basically a hot-working process of metal, performed by means of hammer blows or the pressure applied by a press. Various types of machine parts of different shapes and sizes are made by forging or stamping operations. Figure 1.3 shows the principle of open die forging. Forging operation can be done by hand or by using machines. Depending on the method of production, forging processes are classified into the following types:

1. Hand forging

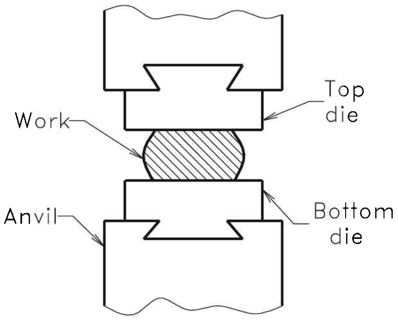


FIGURE 1.3
Open die forging.

2. Power hammer forging
3. Drop forging or closed die forging
4. Press forging

Hand forging is carried out on an anvil with the aid of hand forging tools. Heavy components are forged by using power hammers. To change the shape and control the dimensions of a workpiece, various blacksmith's tools are used. Shaping of metal with the help of hand hammers or power hammers is called *smith forging*. In drop forging or stamping, the flow of metal is limited by the space of the recess in the dies, in which the metal takes its predetermined shape and dimensions. Every part manufactured by drop-forging process requires a separate die or a set of dies. Very heavy components are forged by squeezing the hot metal between dies using presses. Such forging is called *press forging*. Here, instead of suddenly applying the force as a blow, the force is applied gradually like squeezing.

The forging operation is associated with a change in the microstructure of the metal that leads to a rearrangement of fibres and alters the grain size. The layout of grains of a crank shaft made by casting, machining from a solid piece and forging is shown in Figure 1.4 for comparison. The forging process gives the best fibre grain flow layout resulting better strength against dynamic loads. Parts like crank shafts, connecting rods, machine livers, spanners, etc., are manufactured by the drop-forging process. The hand-forging process is explained in Chapter 7.

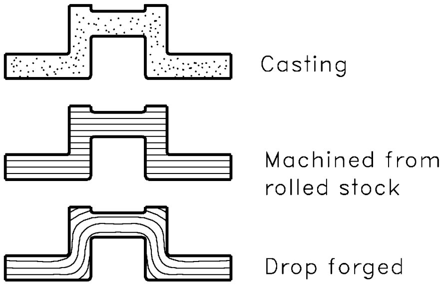


FIGURE 1.4
Grain flow lines in a crank shaft.

1.2.4 Extrusion

Extrusion is the process of forcing metal enclosed in a container and forming the shape by passing out through the opening of a die. The cross-section of the extruded metal is that of the contour and dimension of the opening of the die. Extrusion process is very well used to produce nonferrous metal sections. The initial material for extrusion is cast or rolled billets. Figure 1.5 explains the principle of extrusion. Extrusion processes can be classified as:

1. Direct extrusion
2. Indirect extrusion

In the direct extrusion, both the ram and the extruded metal move in the same direction as shown in Figure 1.5 while in indirect extrusion they move in opposite

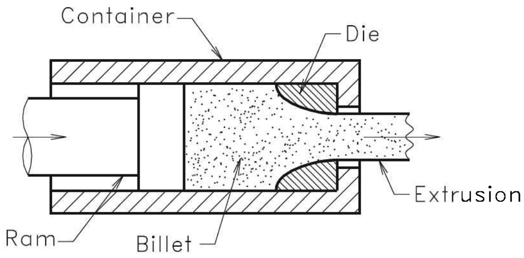


FIGURE 1.5
Extrusion (direct).

directions. The extrusion process can be done in both hot or cold state of metal. Long sections of various shapes and tubes can be manufactured by the direct extrusion process. For the extrusion of tubes, a mandrel is pierced first through the billet and then they are extruded together through the die, producing the tube. Extrusion of aluminium is a very commonly used process to produce material for doors and windows, furniture, automobile body, etc.

1.2.5 Metal Drawing

Metal drawing is a process in which wire, bar stock or tube is drawn in tension through the hole of a drawing die. The hole has a conical shape built in such a way that the inlet side is slightly larger and the outlet side is slightly smaller than the object drawn. Figure 1.6 explains the principle of wire drawing.

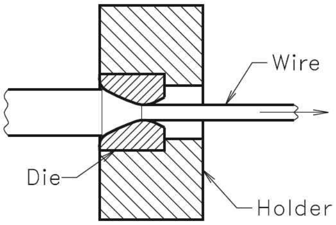


FIGURE 1.6
Wire drawing.

The drawing process is usually done in the cold state and is applied to nonferrous metals and low-carbon steels. The operation is done on powerful drawing benches with high pulling capacity.

1.2.6 Powder Metallurgy

Powder metallurgy can be described as an art of manufacturing commercial articles from powdered metals by placing the powder in moulds and applying pressure. These compressed components are then heated to bind the particles together to get improved strength and other properties. This process is known as *sintering*. In sintering the temperature is kept below the melting point of the powder. Powder metallurgy enables the production of alloys from both metallic and nonmetallic powders. This enables to produce parts which are having unusual characteristics. A few examples of such products are cemented carbide tools, oil-less bearings, special electrical contacts, etc.

1.2.7 Oxy-Gas Cutting

The oxy-gas cutting is based upon the ability of certain metals to burn in the presence of oxygen, expelling heavy heat to melt and form oxides. The metals which are having melting points above the ignition temperature of the metal, form oxides. Carbon steels with carbon percentage up to 0.7 and low alloy steel can be cut by this process. The oxy-gas cutting is performed by means of ordinary gas welding equipment except that the welding torch is replaced by the cutting torch. A gas mixture for pre-heating (oxy-acetyline) is passed through the outer ring-holes of the nozzle, while the cutting oxygen at higher pressure is delivered through the central hole. The oxy-gas cutting can be manual, semiautomatic or automatic. The mechanization of cutting process enables more uniform motion of the torch resulting good quality cut at higher speeds. Oxy-gas cutting process is very well used in structural steel industries to shape metal for welding, fabrication and allied processes.

1.2.8 Press Work

Press work is a term applied to a large variety of operations in connection with the metallic and nonmetallic articles. The operations are done generally in cold state. The press work operations can be broadly grouped as shearing and forming processes (Figure 1.7).

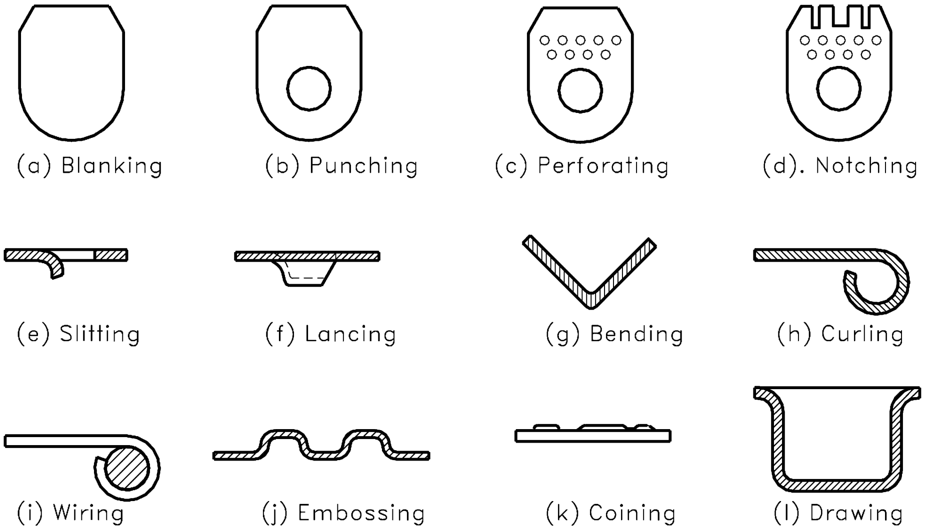

(a) Blanking
(b) Punching
(c) Perforating
(d). Notching
(e) Slitting
(f) Lancing
(g) Bending
(h) Curling
(i) Wiring
(j) Embossing
(k) Coining
(l) Drawing

FIGURE 1.7
Shearing and forming operations in press work.

Shearing operations

(a) *Blanking:* This is the process of cutting a closed outside contour of a shape.

(b) *Piercing:* This is the process of cutting holes of any shape or size inside the contour.

(c) *Perforating:* This is the process of cutting a number of small holes inside the contour.

(d) *Notching:* This is the cutting of relatively small indentation on the edge of a part.

(e) *Trimming:* This is a process of cutting of the excess metal from a piece.

(f) *Shaving:* This is a secondary cutting operation in which the surface of a previously cut edge is finished for bringing close dimensional accuracy.

(g) *Slitting:* This is a process of making incomplete cut in a sheet so that a projected portion is obtained.

(h) *Lancing:* This is the process of cutting along a line in the workpiece, without producing a detached portion.

Forming operations

(a) *Bending:* This is a process of forming bends in one plain only.

(b) *Forming:* This is a process of bending into complicated shapes in more than one plane.

(c) *Curling:* This is a process of shaping an edge to circular cross section along the edge of a sheet or at the end of a shell or tube.

(d) *Wiring:* This is a curling process in which a wire is inserted within the curled edge.

(e) *Embossing:* This is a forming process in which projections like letters, designs etc. are made on a thin metal sheet.

(f) *Coining:* This is a forming process by which the surface is deformed into fine detail by compression.

(g) *Drawing:* This is a forming process by which a flat blank is converted into a cup or a cylindrical form with one end closed.

The press used for shearing or forming may be hand operated, foot operated, hydraulic operated, air operated or power operated. For light works, hand presses are sufficient. For cutting and forming processes, dies and punches of hard steel material are used. The finish and accuracy of object formed by press work depends mainly on the size, shape, dimension and material of die blocks. The types of articles produced by press work range from a small flat blank to a large one roof panel of a saloon car. The size of the object is limited by the size of the die block and the capacity of the power press. In modern times, most of the sheet metal parts of small machines like washing machine, typewriter, electronic equipment, steel furniture, cycle parts, electrical fittings, automobile body parts, etc., are produced by various press-working operations.

1.2.9 Sheet Metal Work

Sheet metal work is basically a hand process of making objects of sheets of metal with the help of hand tools and equipment. The object to be made is developed and drawn on a plane sheet of metal. Then it is cut and folded to form the shape. The joints are made by folding, riveting or soldering.

Ferrous, nonferrous and coated metallic sheets are used for the production of the sheet-metal objects. Machines like shearing machine, folding machine, bending machine etc. are also used for large-scale production of sheet metal objects. Examples for sheet metal works are hoppers, trays, guards, covers, funnel, bucket, measuring can, hoods, boxes, pipes, etc. Sheet metal work is explained in Chapter 5.

1.2.10 Metal Spinning

Metal spinning is a forming process in which the metal sheet is rotated on a chuck or former or die. The deformation of the metal sheet is obtained by a combination of bending and stretching due to the application of pressure using the forming tool (see Figure 1.8).

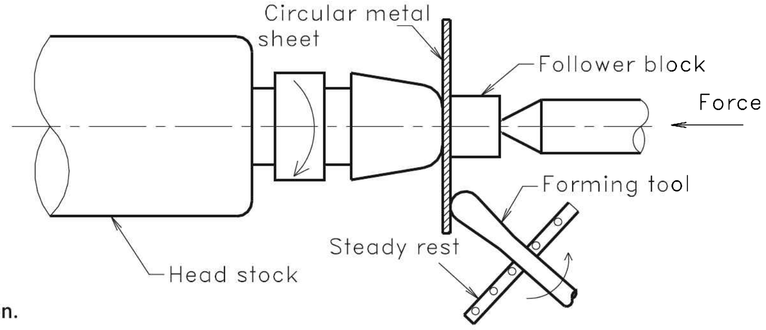


FIGURE 1.8
Principle of spinning operation.

The spinning process can be done in both hot and cold state of metal. Hot spinning is used to produce large and heavy objects like pressure vessels, cylindrical tank ends, etc. The machine used for the process is called *spinning lathe*. The metals that are available in sheet form, can be spun. Hand spinning is successfully done in many small-scale industries to produce aluminium utensils. The objects produced by spinning includes conical shapes, utensils, ornaments, components used for chemical industries, pressure vessel cylinder ends, etc.

1.3 Secondary Shaping Processes

The components or parts produced by primary shaping processes may not have the required accuracy in shape, dimension and surface finish due to the limitations of the process used. A secondary shaping process called *machining* is applied on these components for obtaining the desired finish. Machining is defined as metal-cutting process in which metal is removed from a surface in the form of chips using a tool.

A list of the commonly used machining processes is given below.

1. Turning
2. Drilling
3. Shaping
4. Planing
5. Slotting
6. Milling
7. Grinding
8. Boring
9. Broaching
10. Hobbing
11. Unconventional machining processes.

Turning

Turning is a metal-cutting process performed in a machine tool called *lathe*. Here, the workpiece clamped on a spindle is rotated and the tool is pressed against the moving surface to remove the metal [Figure 1.9(a)]. Turning is the most common machining process used to produce cylindrical objects. More about turning is discussed in Chapter 9.

Drilling

Drilling is a metal cutting process in which holes are produced by pressing a rotating cylindrical tool called *twist drill* against a stationary workpiece. The machine used for this is called *drilling machine* [Figure 1.9(b)]. Drilling is the simplest conventional machining process and is discussed in Chapter 3.

Shaping

Shaping is a metal-cutting process in which plane surfaces or grooves are produced by horizontal reciprocating motion of a tool against a stationary workpiece [see Fig. 1.9(c)]. Shaping is done in a machine tool called *shaper* and the process is suitable to produce plane surfaces or grooves of relatively short lengths on small or medium-size objects.

Planing

Planing is a metal-cutting process in which plane surfaces or grooves are produced by horizontal reciprocating motion of the workpiece against a stationary tool [Figure 1.9(d)]. Planing is done in a machine tool called *planer* and the process is used to produce plane surfaces or grooves of relatively large objects.

Slotting

Slotting is a metal-cutting process in which slots or grooves like keyways are produced by vertical reciprocating motion of the tool against a stationary workpiece

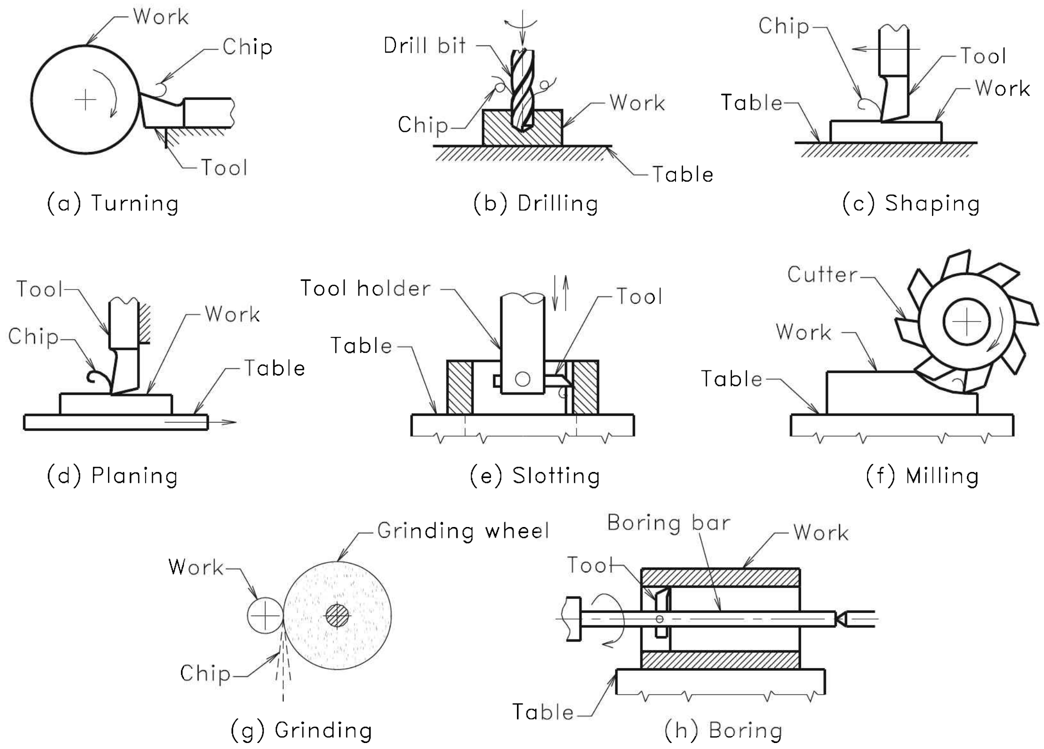


FIGURE 1.9
Secondary shaping (machining) processes.

[Figure 1.9(e)]. Slotting is done in a machine tool called *slotting machine* and the process is generally used to cut keyways or grooves inside holes.

Milling

Milling is a metal-cutting process in which a rotating disc or cylindrical-shaped multiple point cutter is brought against a horizontal moving workpiece. Almost all types of geometrical surfaces with better accuracy and finish can be produced by this process [Figure 1.9(f)]. Milling is done in a machine tool called *milling machine* and the process is commonly used to make very accurate machine-parts having complicated shapes with good surface finish.

Grinding

Grinding is a metal-cutting operation in which metal is removed in the form of fine chips by means of an abrasive wheel rotating at high speed [Figure 1.9(g)]. Grinding is done in a machine tool called *grinding machine* and the process is used to get high surface finish, accuracy of shape and dimension.

Boring

Boring is a metal-cutting process like turning in which the large-sized cylindrical holes are machined. Here the tool fixed on a boring bar, which is supported at two ends, rotates inside the stationary workpiece to affect machining [Figure 1.9(h)]. This boring process is conducted in machines similar to lathe called *boring machines*.

Broaching

Broaching is also a metal-cutting process in which a typical cutter called *broach* is drawn or pulled against a surface in order to cut a hole or groove. Broaching is commonly used to produce components having special-shaped holes.

Hobbing

Hobbing is another metal-cutting process in which a cutter called *hob* revolves and removes metal from the workpiece like milling process. Hobbing is commonly used process to cut large-sized gears.

Unconventional machining processes

The unconventional or non-traditional machining processes are the metal-removing processes other than the above-explained metal-cutting processes. In these processes, the object is shaped by removing metal, using some form of energy. A list of popular unconventional machining processes is given below:

1. Ultrasonic machining (U.S.M.)
2. Abrasive jet machining (A.J.M.)
3. Electro-chemical machining (E.C.M.)
4. Plasma arc machining (P.A.M.)
5. Electrical discharge machining (E.D.M.)
6. Electron beam machining (E.B.M.)
7. Laser beam machining (L.B.M.)

Unconventional machining processes are economical and have wide application when the metal machined is very hard or is of special alloy. Intricate shapes of dies used for injection moulding are produced by these processes.

1.4 Joining Processes

Different metallic pieces are joined together to get the required shape or assembled form of parts. The joints, produced may be of permanent or temporary nature. The different joining processes used in workshop practice are as follows:

1. Welding
2. Brazing and soldering
3. Screwing

4. Riveting
5. Shrink fitting
6. Adhesive bonding

1.4.1 Welding

Welding is the process of joining metallic parts by bringing them into intimate proximity and heating the places of contact to the state of fusion or plasticity. This leads to inter penetration of atoms of the metals in the weld zone and a strong inseparable joint is formed after the metals have cooled. The popular welding processes are mentioned below:

(a) *Arc welding*
  1. Shielded metal arc welding
  2. Submerged arc welding
  3. Gas-metal-arc (MIG) welding
  4. Tungsten-arc (TIG) welding
  5. Automatic hydrogen welding
  6. Flux coated arc welding
  7. Carbon arc welding
  8. Electro-slag welding
  9. Stud welding.

(b) *Resistance welding*
  1. Spot welding
  2. Seam welding
  3. Projection welding
  4. Butt and upset welding
  5. Flash welding
  6. Percussion welding.

(c) *Gas welding*
  1. Oxy-acetylene welding
  2. Oxy-hydrogen welding
  3. Air-acetylene welding
  4. Oxy-other fuel gas welding.

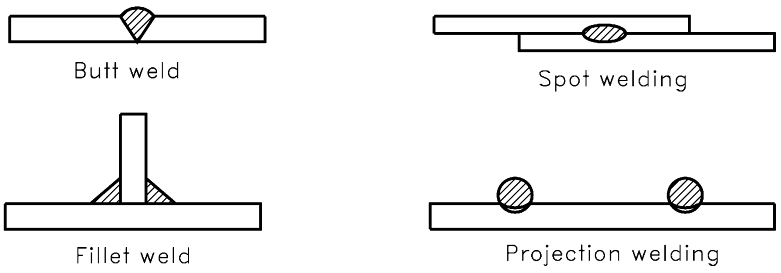
(d) *Miscellaneous welding processes*
  1. Thermit welding
  2. Forge welding
  3. Modern welding processes.

Arc welding

Among the various arc welding processes, *shielded metal arc welding* (manual metal arc welding) is the most widely used and less expensive welding process. Shielded metal arc welding is a manual arc welding process in fusion state, in which the heat required for melting the surfaces to be joined is generated by maintaining an electric arc between a flux-coated consumable electrode and the base metal. More about the process is explained in Chapter 4. Submerged arc welding is also popular in industries due to its suitability for welding thick metals. The remaining arc welding processes given above are generally selected to join metals which are difficult to weld or when special requirements are existing. Figure 1.10(a) shows examples of arc-welded joints. Since the shielded metal arc welding (manual metal arc welding) is so popular, less expensive and suitable to weld mild steel of reasonable thickness, the process is also called in short form *arc welding*.

Resistance welding

In resistance welding, the heat for joining is obtained by resistance offered by the work-pieces to the flow of electric current in a circuit in which the work is a part. The most common resistance welding processes are spot, seam and projection welding. Sheet metal components, wire meshes, welded pipes, etc. are produced by this process. Figure 1.10(b) shows the examples for resistance welded joints.



(a) Welding in fusion state (arc or gas welding)

(b) Welding in plastic state (resistance welding)

FIGURE 1.10 Welded joints.

Gas welding

In gas welding, the heat generated by the combustion of various gases in a stream of oxygen is used to melt the welding area and filler metal. The most popular gas-welding process is oxy-acetylene welding. This is a fusion welding process used to join thin metallic sheets or pieces. Since the oxy-acetylene welding is very popular, this method of welding is also known as *gas welding*.

Miscellaneous welding processes

Other than the above-explained groups of processes, there are other welding processes which are used for special situations, joints, metals, etc. Thermit welding, for example, makes use of the heat supplied by an exo-thermic reaction involving combustion of thermit which is a mixture of powdered aluminium and iron oxide. This process is used to join rails in railway tracks. Forge welding is the oldest form of welding process done in blacksmith shop. In this process, the work-pieces are heated to plastic state and the superimposing ends are hammered to get the joint. The modern welding processes developed to join metals, which are difficult to weld or the welding conditions, size, etc., are not suitable for conventional processes. These processes include electron beam welding, laser welding, plasma arc welding, ultrasonic welding, explosive welding, etc.

1.4.2 Brazing and Soldering

Brazing and soldering are the processes for joining solid metal components similar to welding by introducing a molten alloy between them which has a low melting point than the base metal. Brazing and soldering are used to join ferrous and nonferrous metals and their alloys.

Brazing

Brazing is a metal joining process in which the joint is produced by heating the base metal pieces to a suitable temperature above 430°C and applying a filler metal (brazing alloy) which has melting point below that of the base metal. This filler metal is distributed between closely-fitted surfaces of joint by capillary action. Figure 1.11 gives an example for the brazed joint. Brazing process is classified according to the type of heating of the base metal as mentioned below:

1. Furnace brazing.
2. Torch brazing.
3. Induction brazing.
4. Salt-bath brazing.
5. Infra-red brazing.
6. Electric block brazing.

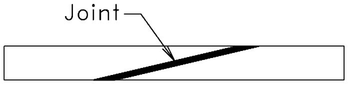


FIGURE 1.11
Braced point.

The commonly used filler metals are the alloys of copper, silver, aluminium, magnesium and nickel. The flux for brazing is selected according to the type of brazing alloy used. They are used to prevent oxidation, to dissolve oxides and to promote capillarity of the filler metal.

Soldering

Soldering is defined as a metallurgical bonding method in which a filler metal has a melting point below 430°C. Most engineering metals such as iron, steel, copper, brass, etc. can be joined by this process. Soldering is extensively used to make electrical and electronic connections, hermetic sealing of metal containers, joining of copper tubing, etc. Figure 1.12 gives a typical joint made by soldering. The soldering metal is basically an alloy of tin and lead of standard proportion of 40:60 by weight. Flux is to be applied at the joining area for making the joint.

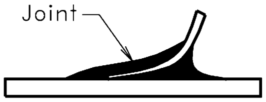


FIGURE 1.12
Soldered joint.

1.4.3 Screwing

Screwed joints are temporary joints made by using threaded fasteners like bolts, nuts, screws, studs, etc. These joints are very common for assembly of parts in machines and equipment. The threads provided on the screwed fasteners join the parts together, transmit power and locate the parts in relation to each other. Figure 1.13 shows a typical screwed joint. A screw thread can be described as a helical or spiral groove or ridge formed on a cylindrical surface, such that the angular displacement of any two corresponding points on the counter of the groove is proportional to their displacement along the axis of the thread. The thread form cut externally on a male member such as, bolt, stud, etc., is known as *external thread*. The thread form cut internally on a female member like nut, socket, etc., is known as *internal thread*. To make a screwed joint, the internal and external thread forms should match each other. The helical form of thread can be of *right-hand* or *left-hand* type. In the case of a right-hand thread, a bolt head or nut is rotated clockwise, it moves forward to tighten the joint. For left-hand type, the opposite action occurs. Most of the threaded fasteners are of right-hand type. Left-hand threads are not common and used only for special purposes. The most common thread forms in use are as follows:

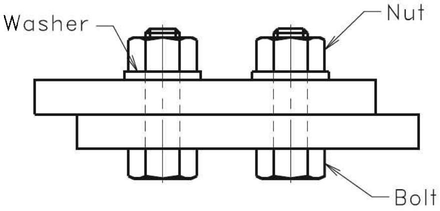


FIGURE 1.13
Screwed joint.

1. British Standard Withworth (B.S.W.) threads in F.P.S. system
2. I.S.O. thread in metric system
3. Square thread for heavily loaded parts

The types of threaded fasteners used to make joints, include the following items:

1. *Bolts*
    - (i) Hexagonal headed bolt
    - (ii) Square-headed bolt
    - (iii) Round or cup headed bolt
    - (iv) T-headed bolt
    - (v) Hook bolt
    - (vi) Eye bolt

2. *Nuts*
   - (i) Hexagonal nut
   - (ii) Square nut
   - (iii) Wing nut
   - (iv) Knurled nut
   - (v) Castle nut
   - (vi) Slotted nut
3. *Studs*
   - (i) Plain stud
   - (ii) Stud with square central part
   - (iii) Stud with collar
4. *Screws*
   - (i) Screws with different forms of heads.
   - (ii) Allen screw
   - (iii) Machine screw
   - (iv) Set screw
   - (v) Screw without head
5. *Washers*
   - (i) Standard washer
   - (ii) Spring washer
   - (iii) Lock washer

When the screwed joints are subjected to vibrations, they have a tendency to get loose and screw off. The machine parts which are subjected to frequent vibration are joined by nuts with locking arrangements. Nuts with screws and spilt pin or lock washers are used for locking the nut. Usually a washer is inserted between the nut or head of bolt and the surface on which it is tightened. This enables easy tightening of nut or bolt and better distribution of clamping pressure on the machine body. The tools used to tighten and loosen the threaded fasteners are as follows:

1. C-spanner
2. Ring spanner
3. Box spanner
4. Adjustable spanner
5. Screw driver
6. Allen key

1.4.4 Riveting

Riveting is a permanent fastening method to join two or more pieces of plates or sheets. Riveting is done by using a cylindrical metal piece called *rivet.* It consists of a cylindrical body and a head. To make a joint by riveting, holes of diameter equal to that of the body of rivet is made on the plates in the joining position and the rivet body is inserted through the hole. The projecting tail-end is deformed to form the second head by the application of pressure using riveting tool or by hammering. Figure 1.14 shows a typical riveted joint. The rivets can be of solid or hollow type. They are grouped according to the shape of head. The common riveted joints are mentioned below:

1. Lap joint.
2. Butt joint with single cover plate.
3. Butt joint with double cover plate.

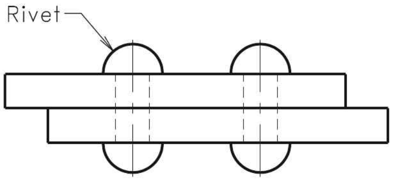


FIGURE 1.14
Riveted joint.

1.4.5 Shrink Fitting

Two components can be joined rigidly by shrink fitting. In shrink fitting process, the inner part is made slightly larger in dimension than the hole of the outer part; i.e. with slight interference. This interference can be eliminated for a short time by heating the outer (female) part and the inner (male) part is inserted. While cooling, the outer part shrinks making a strong joint by shrink fitting. The same joint can also be made by cooling the inner part in order to reduce the dimension slightly. Such a fit is some times called *expansion fit.* To produce a good shrink fit, the parts should be properly designed and machined perfectly to get the required interference at room temperature. The shrink fitting methods are used for lining of heavy shells, fixing of bearing on the shaft, etc.

1.4.6 Adhesive bonding

Adhesive bonding is a method of joining materials by the use of adhesive between the surfaces to be joined. The type of adhesive used may be glue, cement or similar bonding agents. The process of adhesive bonding includes the following steps:

1. The surface preparation.
2. Applying the primer.
3. Applying the adhesive.
4. Assembling of various components to be joined.
5. Curing the bonded joint.

Depending on the type of adhesive, the curing procedure varies. This process may include heating, application of pressure, etc. The joint is prepared in various forms based on the requirement. Generally, for better strength more area of contact of the joining pieces is required. The common types of adhesives used are thermoplastic or thermosetting plastics. The thermosetting plastics cannot be re-melted, if once hardened. The adhesives are available as liquid, paste, tape form, film or powder form. Adhesive bonding is successfully used in wood products, plastics, concrete, paper products, etc. Adhesive bonding cannot give good joint strength for metals; therefore it is seldom used for joining metallic parts.

1.5 Surface Finishing Processes

The surface finishing processes primarily intended to give good finish or protective coating to metal surfaces. In some cases a negligible amount of metal is removed from the surface. Anyhow, an appreciable amount of dimensional change does not occur. The finishing processes in which a very small layer of metal is removed are as follows:

1. Honing
2. Lapping
3. Buffing
4. Deburring
5. Sanding
6. Super finishing
7. Tumbling
8. Polishing

The surface finishing processes include coating of the metallic surface for finish, decoration or protection. They are as follows:

1. Galvanizing
2. Metal spraying.
3. Anodizing
4. Electro plating.
5. Inorganic coating
6. Painting.

The above-mentioned finishing operations are applied only towards the end of the shaping processes of a component.

1.6 Processes Changing the Material Properties

The components of machines and equipment are mainly made up of metals. While shaping them, if the strength of the metal is low at that stage, the production process will be easy. But, after the production of the parts, they have to be converted into their full strength and wear resistance of the required level. This is possible for steel and its alloys by the process called *heat treatment*. Other processes which change the material properties are cold-working, hot-working and shot-peening (Figure 1.15).

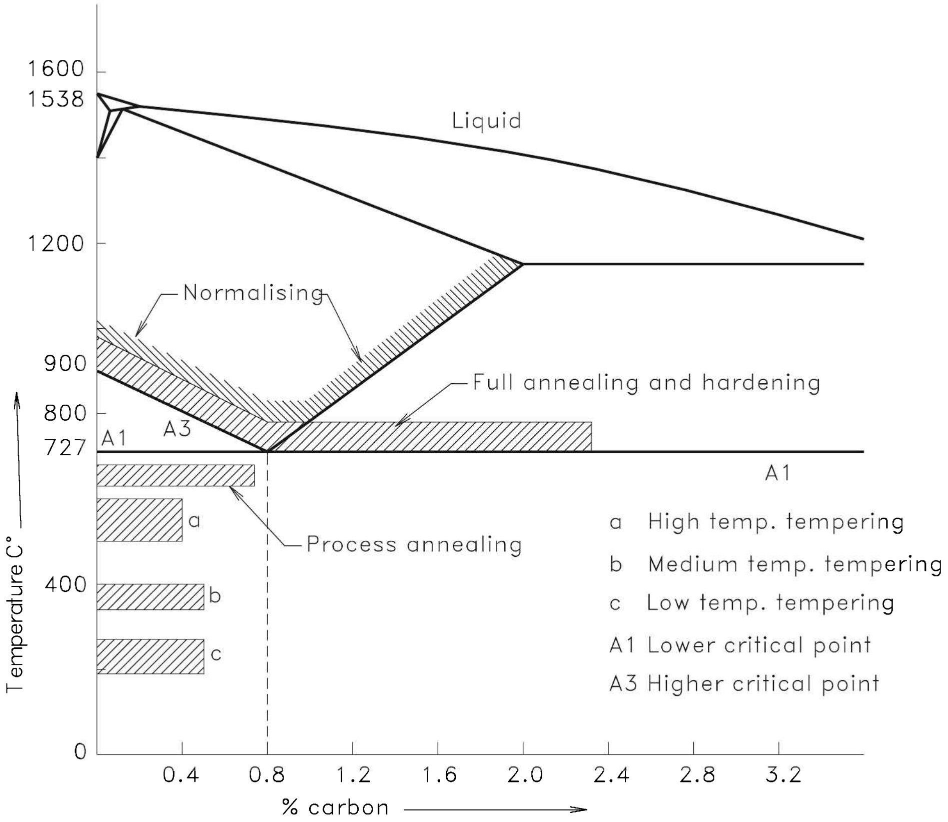


FIGURE 1.15 Simplified iron-carbon diagram showing the temperature ranges for heat treatment.

1.6.1 Heat Treatment of Ferrous Metals

Heat treatment of a metal includes the following three stages:

1. Heating the metal to a predetermined temperature.
2. Holding the metal at that temperature for a specified time so that the structure of the metal becomes uniform throughout the part.
3. Cooling the metal at a predetermined rate to acquire the required property. The commonly used heat treatment processes applied to steel can be broadly classified into the following categories:
   (a) Annealing
   (b) Normalizing.
   (c) Hardening
   (d) Tempering.
   (e) Case hardening
   (f) Surface hardening.

Annealing

Annealing is the process of heating the metal to a temperature that will remove the distortion of grains of the metal and then cooling at a slower rate so that, at room temperature it has no grain distortion or strain. Depending on the temperature, sustaining time, cooling rate, the composition of metal, etc., the annealing process can be grouped as:

1. Full annealing
2. Process annealing
3. Spheroidize annealing
4. Diffusion annealing
5. Isothermal annealing

Figure 1.15 gives the simplified *iron-carbon equilibrium diagram* showing the approximate temperature ranges for heat treatment of steel.

Normalizing

The normalizing process consists of heating the workpiece about 50°C above its upper critical temperature and then cooling in still air at room temperature. If necessary, the metal may be held at the elevated temperature for a short period. Normalizing differs from annealing in the sense that the holding time at the elevated temperature is very short or zero and the cooling rate is rapid for the process. The normalizing process removes the internal stresses, refines the grains to smaller size and improves the mechanical properties such as impact strength, yield point, ultimate tensile strength, etc.

Hardening

Hardening is a heat treatment process in which the metal is heated about 50°C above the higher critical point (A3 line) for steels having less than 0.8% carbon content. For steels having more than 0.8% carbon content, this range is taken above the lower critical point (A1 line). Then the metal is held at that temperature for sufficient time to change into austenite structure and cooled very rapidly by quenching in a suitable medium like water or oil. This process gives the maximum hardness for the metal, hence suitable for tools, dies, machine parts, etc.

Tempering

The subsequent heat treatment for reducing the hardness obtained by hardening process is called *tempering*. In this process the hardened steel is reheated to a temperature below the lower critical point (A1line), retained at that temperature for sufficient time and then cooled slowly to the room temperature. Depending on the holding temperature range, tempering process can be classified as:

1. Low temperature tempering (150° to 250°C).
2. Medium temperature tempering (350° to 450°C).
3. High temperature tempering (500° to 650°C).

In Figure 1.15, the shaded areas a, b, and c represent the tempering regions in iron-carbon diagram. A tempering process relives residual stresses, improves ductility, gives toughness by the reduction of hardness.

Case hardening

Case hardening is a heat treatment process in which the low carbon steel (0.1%C) is heated to red hot and the content of carbon or nitrogen or both on the outer shell of the workpiece is increased by forcing to absorb from the surrounding to the surface for certain depth by diffusion. The outer shell is hardened as done in the hardening process. Thus, by getting the hardened surface and a ductile core, a machine part gets high wear resistance as well as heavy dynamic load bearing capacity. The commonly used case hardening processes are as follows:

1. Carburizing
2. Nitriding
3. Cyaniding
4. Carbo-nitriding

In carburizing process the percentage of carbon in the outer shell is increased to about 1%. The nitriding process adds nitrogen to the outer shell of certain steels containing aluminium and chromium. In cyaniding process both carbon and nitrogen are added to the surface by using a liquid bath, whereas in carbo-nitriding, the same is added by gas atmosphere.

Surface hardening

In surface hardening, only the selected surface is subjected to heating, whereas in case hardening the whole object is brought to the hardening temperature. The hardening property to the surface is obtained to the steel by adding carbon and nitrogen. The heating of surface is done by the following methods.

1. Induction hardening
2. Flame hardening.
3. Laser beam hardening
4. Electron beam hardening.

1.6.2 Heat Treatment of Nonferrous Metals

The heat treatment of nonferrous metals is done for strengthening the metal. Single-phase metals can be strengthened by solid solution hardening process, while strain hardening is used to strengthen ductile metals. The most widely used and effective method for nonferrous metals and alloys is precipitation hardening or age hardening. To understand the various heat treatment processes clearly and to practice them, one must have deep knowledge in metallurgy and the related processes.

1.6.3 Cold Working of Metals

Shaping of metal by plastic deformation can be done in cold state or hot state. If the mechanical working of metals is done below the recrystallization temperature, it is named as *cold working*. For steel, the mechanical working below the lower critical temperature (A1 line in Figure 1.15) of about 700°C is considered as working in cold state. Remember, only a few metals and alloys can be reasonably cold worked.

To understand the behaviour of metal in cold working, one must know about the structure of metal. A metal is made up of irregular grains of different size. In cold working of metals, the grain structure changes resulting the grain fragmentation and distortion. The change of shape of metal can occur only if the stress exceeds the elastic limit. In cold state, metal has higher elastic limit, hence much force has to be applied to affect deformation. There is no recrystallization of distorted grains during a cold working, but results increase of tensile strength, hardness and reduction of ductility of metal. This phenomenon of cold working is known as *work hardening* or *strain hardening*. In order to bring the metal back to its initial state, heat treatment is to be applied. Annealing is the heat treatment used to reduce the work hardening of metal. Cold working has the following advantages.

1. There is no need of heating of metal, so working expense is reduced.
2. Since the workpiece is at room temperature, the work handling, inspection and other related activities are simple and easy.
3. Very good surface finish with no scale is obtained.
4. The hardness and tensile strength of the metal are increased.
5. Better accuracy in dimension can be maintained.

Compared to the advantages, the drawback of cold working is the work hardening. Distortion of grains removes ductility and fracture starts after certain level of deformation. Annealing is the only process to remove this hardness. Cold working is very well used as a finishing process to get better surface finish, dimensional accuracy and hardness. Cold rolling, cold extrusion, press working, wire drawing, tube drawing, cold heading, etc., are some of the popular cold working processes.

1.6.4 Hot Working of Metals

Hot working is conducted at a temperature above the recrystallization point of the metal. For steels, this temperature is about 100°C above the higher critical point (A3) i.e. slightly above 800°C. Since the temperature is above the recrystallization point, the resistance to deformation is lowered considerably and grain recovery occurs continuously as the grains are elongated. High section reduction against less force application is possible in short time. The advantages of hot working are as follows:

1. Less force is to be applied and large deformation of section is obtained.
2. Porosity of metal is largely eliminated by welding of metal in the hot plastic state.

3. Directional properties resulting fibre structure is obtained (Example is drop forging).
4. The full range of deformation is completed in the shortest time.
5. Hot working is economical for shapes requiring more reduction, even though there is the expense for heating.

Compared to the above advantages, hot working has some limitations. They are as follows:

1. Heating is an expensive process and care should be taken to avoid burning of metal.
2. Scale formation is severe and reduces the metal surface finish, hence hot working is difficult for objects having more surface area like plates and sheets.
3. Due to the shrinkage during cooling and the scale formation, the dimensional accuracy of a hot worked product is less.
4. In hot working, the handling of metal is difficult and maintenance expense of machines are high due to working at high temperatures.

The advantages of hot working are always prominent than the limitations, for large and heavy products. So, hot working is very well used for shaping metal, especially steel from the initial metal ingot to the customer sections like angle, channel, beam, rod, etc. The hot working method is used in rolling, forging, extrusion, deep drawing, spinning, etc.

1.6.5 Shot Peening

Shot peening is one among the processes which change the material properties, effectively on the surface. The process basically consists of directing a blast of metal shots to the surface of a workpiece. The throwing of shots at high velocity is done by either the use of a pressurized air jet or high speed rotation of a wheel as in pumping. The peening action of shots gives compression of the surface of the workpiece. This develops hardness to the surface, improves the strength and adds fatigue resistance of the workpiece.

1.7 Materials for Workshop Practice

A material can be defined as that out of which anything is or may be made. A large number of materials are used in engineering. These can be broadly grouped as metals and nonmetals. To select the appropriate material for a job, the engineer must know about the properties, cost, availability, etc., of engineering materials. The following sections give a brief introduction to the materials used for workshop processes.

1.7.1 Classification of Engineering Materials

The materials used for engineering can be broadly classified into the following categories:

1. *Metals*
    - (a) Ferrous metals
        - (i) Wrought iron
        - (ii) Cast iron
        - (iii) Plain carbon steels
        - (iv) Low alloy steels
        - (v) High alloy steels
    - (b) Nonferrous metals and alloys
        - (i) Copper
        - (ii) Aluminium
        - (iii) Lead
        - (iv) Magnesium
        - (v) Nickel
        - (vi) Tin
        - (vii) Zinc
        - (viii) Cadmium, antimony, etc.
2. *Organic materials*
    - (a) Plastics
        - (i) Thermo plastics
        - (ii) Thermosetting plastics
    - (b) Rubber
        - (i) Natural rubber
        - (ii) Synthetic rubber
    - (c) Wood
    - (d) Miscellaneous organic materials like fuels, lubricants, paints, textiles, adhesives, explosives etc.
3. *Ceramic materials*
    - (a) Sand
    - (b) Glass
    - (c) Refractories
    - (d) Insulators
    - (e) Miscellaneous ceramic items, like abrasive, bricks, cement, asbestos, etc.

Ferrous and nonferrous metals

The metals that are commonly used in workshops can be broadly classified as ferrous metals and nonferrous metals.

Ferrous metals

1. Grey cast iron
2. Low carbon (mild) steel
3. Medium carbon steel
4. High carbon steel
5. Alloy steel
6. Stainless steel

Nonferrous metals

7. Copper
8. Brass
9. Bronze
10. Aluminium and its alloys

1. Grey cast iron: Grey cast iron is the commonly used material for machine body, base plates, pump casing, electric motor casing, etc. In grey cast iron, the carbon of about 2 to 4% is found in the form of graphite. The graphite form gives grey appearance and hence the metal is called *grey cast iron*. Cast iron is the outproduct of the furnace called *cupola*. There are other furnaces like pit furnace, induction furnace or arc furnace which are used to melt cast iron. The machine parts produced using this metal is initially cast by foundry process and then machined to the required dimension and finish. In cast iron there are constituents like silicon (1 to 3%), sulphur (0..02 to 0.15%), phosphorus (1%), etc., other than the carbon. Depending on them, the cast iron is graded and selected for various duties. Cast iron is brittle and has low capacity to take tensile loads, but very good for handling compressive stresses. Grey cast iron has good machinability and no ductility. The melting point is low compared to steel, at the same time intricate shapes can be cast without difficulty at low expense. Because of all these properties grey cast iron is very well used for heavy machine bodies and parts, which are subjected to high compressive loads.

2. Low carbon (mild) steel: Low carbon steel which is also called as *mild steel* (MS) is an alloy of iron and carbon. The carbon content varies from 0.05 to 0.15 percentage for *dead mild steel* and 0.15 to 0.3 percentage for *mild steel*. The dead mild steel is very much ductile and is used for making various components like sheets, strips, wires, rods etc. The mild steel (0.15 to 0.3%C) is used for making various structural sections like angles, channels, beams, rods, boiler plates, pins, axles, etc. This family of steel is the most common metal used by engineers for manufacturing, such as steel structures, steel furniture, steel for reinforced concrete, various welded fabrications, forgings, machine parts, etc. The relative use comes to about 50% of the total worldwide use of metal.

3. Medium carbon steel: For medium carbon steel, the carbon percentage varies from 0.3 to 0.8 percent. These steels have better strength and not very easy to shape as mild steel. The hardness is slightly higher and the ductility is poor. The machine parts requiring strength like springs automobile parts, shafts, dies for forging, etc., are made from medium carbon steels. About 20% of the worldwide use of metal is covered by this family of steel.

4. High carbon steel: In high carbon steel, the carbon percentage varies from 0.8 to 1.5. A high percentage of carbon gives hardness and strength to the metal. They can be heat-treated to get the required properties. High carbon steels are used mainly for tools like chisels, hammers, dies, punches, broaches, reamers, drills, taps, etc., and machine parts like springs, mandrels and similar parts requiring high strength and hardness.

5. Alloy steels: In addition to carbon, other elements like nickel, chromium vanadium, tungsten, etc., are added in small percentages to attain certain special properties to the steel. Such steels are called *alloy steels.* According to the Indian standards, alloy steels are classified into the following categories:

(i) Low alloy steels which are having alloying elements up to 5%.
(ii) Medium alloy steels, which are having 5 to 10% alloying elements.
(iii) High alloy steels, which are having alloying elements more than 10%.

Nickel, chromium and manganese are the principal alloy elements in these steels. Tungsten, molybdenum, titanium, vanadium, etc., are added in small proportions. Alloy steels are used for various structures and machine parts subjected to heavy static and dynamic loads.

6. Stainless steel: Corrosion resistant steels are generally known as *stainless steels.* The alloying element (chromium) is added for about 4 to 6% to low carbon steels for producing fairly good corrosion resistant steels. For high resistance to corrosion and fine appearance the chromium percentage has to be increased to a range of 11 to 27%. Sometimes other elements like nickel, manganese, silicon are also added in small percentages to get various desired properties. Stainless steels with chromium content above 12% is used for utensils, diary equipment, food processing units, chemical industries, surgical equipment, etc.

7. Copper: Copper containing impurities up to 0.1% is used for electrical purposes. This copper has high electrical as well as thermal conductivity and good corrosion resistance. The metal is easy to shape and has moderate strength. The inherent properties of copper direct to wide applications, such as electrical conductors, steam pipes, containers, house hold utensils, etc.

8. Brass: The alloy of copper and zinc is called *brass.* The alloy containing up to 37% zinc is called *alpha brass* and it is very ductile and can be easily cold-worked. Alpha brass can be used for producing sheets, wires, deep drawn tubes and shapes. As the zinc percentage increases (from 33 to 47%) the strength increases, but the ductility reduces. Such a brass is called *alpha beta brass* and is used for hot-working. Brasses have high resistance to corrosion, reasonable electrical conductivity and satisfactory thermal conductivity. It is easily machinable and can work as good bearing material giving less friction. Because of these inherent properties, brasses of various proportions are very well used for electrical connectors, bearings, corrosion resistant material for various chemical equipment, household utensils, etc.

9. Bronze: Bronze is considered basically as an alloy of copper and tin. It has superior mechanical properties and corrosion resistance than brass. Bronze is comparatively hard and resists surface wear. It can be shaped by mechanical working or machining similar to brass. Bronze of various compositions containing other alloying elements of small percentages are widely used for engineering purposes. Phosphor bronze, gun metal, bell metal, silver bronze, aluminium bronze, etc. are some of the common types of bronzes in use. For example, a type of phosphor bronze containing 11% tin and 0.3% phosphor, is used for bearings, gears, nuts, machine screws, etc. Gun metal is the best quality of bronze and contains 88% copper, 10% tin 2% zinc and small percentages of other alloys like phosphorus, lead, etc. It is highly resistant to corrosion and is used for small size valves, bearings, pipe line fittings, glands, marine castings, etc. This particular types of brass was used earlier as the gun barrel material and hence, it was called as *gun metal.* The bronze group of alloys has several advantages but is an expensive material than cast iron, steel and even brass.

10. Aluminium and its alloys: Aluminium is a light metal having density of about 2.7. It is highly malleable and ductile and is a good conductor of heat and electricity. Shaping of aluminium products by mechanical working and machining are easy. To improve the properties and strength, aluminium is alloyed with various elements like copper, chromium, nickel, iron, zinc, manganese, silver, etc. Duralumin is a type of aluminium alloy used for automobile parts, aircraft parts, light weight structures, extruded sections, sheets, bars, tubes, rivets, etc. It contains approximately 4% Cu, 0.5% Mg. 0.5% Mn, 0.5% Fe or Si and the balance aluminium. A general purpose aluminium casting alloy has a proportion of 13.5% Zn, 3% Cu and the balance Al. Being a light metal of low cost, the use of aluminium for aircrafts, automobiles, portable equipment, moving machine parts like piston, etc. is increasing day by day in the modern world.

Cutting tool materials

The tool materials used in workshops are of different types depending on the requirements. In general, a cutting tool material may have the following properties.

1. It should have high hardness more than that of the material being cut.
2. It should have toughness to resist fracture and cutting stresses.
3. It should have ability to keep the strength at high temperatures at the cutting point.
4. It should have ability to absorb shocks without permanent deformation.
5. It should have strength to resist disintegration of fine cutting edges.

The types of cutting tool materials are as follows:

1. High carbon steels
2. High speed steels

3. Cast nonferrous alloys
4. Carbides
5. Ceramic tools
6. Diamond

1. High carbon steels: This is the oldest form of cutting tool material having carbon 0.8 to 1.2%. They have poor metal cutting ability at high speed. They are suitable to cut wood and soft metals only.

2. High speed steel (H.S.S.): This is a high alloy steel which can be used to cut metal at a cutting speed of 2 to 3 times that of high carbon steel. The most commonly used H.S.S. has a composition called 18-4-1 (tungsten 18%, chromium 4% vanadium 1%, carbon 0.7% and balance iron.) The H.S.S. is used for cutting tools in lathes, shapers, planers, milling machines, drilling machines, broaching machines, etc. There is another composition called *super* or *cobalt high speed steel* (cobalt 12%, tungsten 20%, chromium 4% vanadium 2%, carbon 0.8% and the balance iron). This super H.S.S. has better hardness and can be safely cut at high temperatures like 620°C.

3. Cast nonferrous alloys: Nonferrous alloys are used as cutting tool material, after casting the tool shape and sharpening by grinding. Some of the popular trade names of these tool materials are mentioned below:

1. Stellite
2. Gormet
3. Crobalt
4. Tantung

The ingredients of the tool material having trade name stellite are chromium 25 to 35%, Tungsten 4 to 25%, carbon 1 to 3% and the balance is cobalt 40 to 50%. The cast nonferrous alloys are strong tool material and can be used for cutting speeds two times higher than that of H.S.S. The cutting temperature at tool tip can go up to 900°C. The mechanical properties are largely determined by the degree of chilling given in casting.

4. Carbides: Carbide tools are nonferrous alloys having tungsten as the main ingredient. A typical composition of carbide tool is tungsten carbide 82%, titanium carbide 10%, and cobalt 8%. This tool is very good for machining steel. The tool tips are shaped as bits of shapes like triangle, square, round, etc., by sintering process as in powder metallurgy. Then the bits are brazed or mechanically fixed on the tool shank.

Carbide tool tips are extremely hard and can retain hardness up to 1200°C. They have less friction against cutting and the cutting speeds can be of high values of 2 to 2.5 times that of H.S.S. Carbide tools are excellent for heavy cuts in steel and cast iron. Their higher wear resistance makes them suitable for use as dies and punches in press working.

5. Ceramic tools: Ceramic tools are made as bits using various boron-nitride powders. The tool bits are shaped by sintering process at 1700°C. Ceramic tools can be operated at cutting speeds 2 to 3 times that of tungsten carbide tools. They are very hard and extremely brittle. Ceramic tools are used as throwaway bits for high speed finish turning operations. For getting long tool life for ceramic tools, the machine should not produce shock loads and vibrations.

6. Diamond: Diamond is the hardest material and is used as single point cutting tool for light and finish machining at high speeds. Materials that are difficult to cut due to high hardness are machined using diamond tools. Diamond tools can give very high finish and dimensional accuracy in machining.

EXERCISES

Questions for Viva Voce

Answer the following questions

(A) Primary shaping processes

1. What are the primary shaping processes as done on metals?
2. Give a list of different casting processes.
3. Describe briefly the process of making sand castings in a factory.
4. What is meant by rolling? What are the end-products of rolling?
5. Explain the terms ingot, blooms and billets related to rolling.
6. What are the advantages of machine parts produced by forging?
7. Give the names of 3 machine parts produced only by forging. Why they are shaped by forging?
8. Explain the process, extrusion.
9. What is meant by wire drawing? Give the areas of application of the process.
10. Describe the term, powder metallurgy.
11. Explain the oxygen cutting process.
12. Give a list of press working operations done on sheet metal.
13. Explain the procedure of making sheet metal objects?
14. Describe the term metal spinning. Give the names of two products produced by this method.

(B) Secondary shaping processes

1. Explain the term, secondary shaping processes related to the manufacturing technology.
2. Define the terms, turning and boring.
3. Compare the following machining processes: (a) Shaping, (b) planing and (c) slotting.
4. What is milling? For the production what types of components, this process is generally used?
5. Explain the use of grinding process in workshops.
6. What is meant by broaching? Give some areas of application.
7. Define the term, hobbing. Write the areas of application.
8. What are the unconventional machining processes?

(C) Joining processes

1. What are the metal joining processes employed in manufacturing?
2. Define the term, arc welding. Give a list of different arc welding processes.
3. Explain the principle of resistance welding.
4. Compare gas welding and gas cutting processes.
5. Explain the term, soldering. What are the materials used for the process?
6. Describe the process of brazing. Give the areas of application of the process.
7. Define the term, screwing. Explain the importance of right-hand and left-hand thread forms.
8. Explain the process of riveting.
9. Describe the process of shrink fitting.
10. Give a brief explanation about adhesive bonding.

(D) Surface finishing processes

1. What is meant by a surface finishing process in manufacturing?
2. Give a list of surface finishing processes in which a small layer of metal is removed.
3. What are the surface-coating processes used to produce finished surfaces?

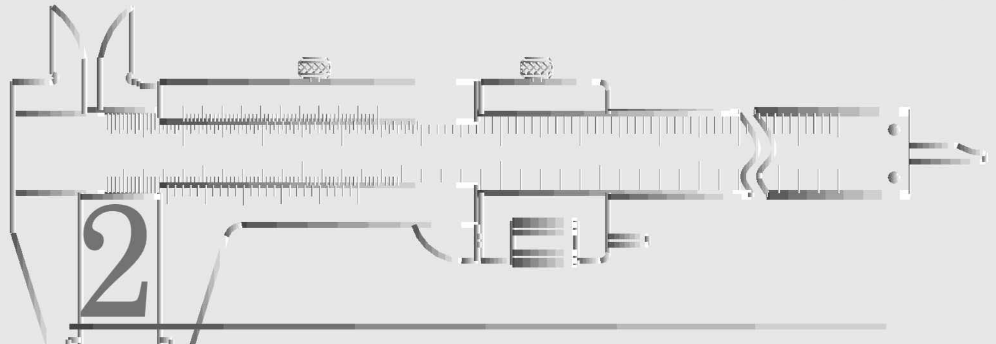
(E) Processes changing the material properties

1. Give a list of the heat treatment processes used to change the material properties.
2. What is meant by annealing of metal?
3. Explain the process of hardening of steel.
4. Compare normalizing and tempering processes applied to steel components.
5. What is case hardening? Compare it with surface hardening.

6. Explain the term cold working of metals.
7. What are the advantages and limitations of hot working processes?
8. Describe the process, shot peening.

(F) Materials for workshop practice

1. Classify the materials used for engineering practice.
2. Give a list of metals generally used in workshops.
3. What is meant by cast iron? Explain the useful properties of this metal.
4. What is meant by mild steel? Give the areas of application and the importance of this metal.
5. Distinguish between high carbon steels and alloys steels.
6. What is meant by stainless steel?
7. Explain briefly about copper and its alloys.
8. Describe the importance of aluminium and its alloys in engineering.
9. Give a list of cutting tool materials used in workshops.
10. What is meant by H.S.S.? Give the uses of the metal.
11. Explain the term, carbides related to tool material.
12. Describe briefly about ceramic tools, cast nonferrous alloy tools and diamond tools.



2

Workshop Practice and Record Writing

An engineering student has to study various theory topics in manufacturing technology and machining processes during his course. Many of the workshop techniques involved in these areas can only be familiarized by practical experience, study on the spot, and by contacts with experienced craftsmen. The theory part that a student has studied, can be physically experienced in a good workshop practice to a reasonable extent. The behaviour of materials, use of tools, methods of operations, control procedures, etc., can be realized by this practice. These experiences add confidence to solve many engineering problems and to make decisions in his future career.

2.1 Workshop Processes for Practice

The areas in which the engineering students are given workshop practice, can be broadly divided into two sections as mentioned below.

1. Hand-working processes
2. Machining processes

1. Hand working processes: The shaping of a part of an equipment or machine by hand operations using hand tools or equipment, can be considered as *hand-working process*. The commonly practized hand-working processes are mentioned below:

1. Fitting
2. Welding

3. Steel metal works
4. Carpentry
5. Smithy
6. Foundry

2. Machining processes: Using metal-cutting machine tools, the machining operations are executed to shape parts. The loading of the workpiece, control of the machining operations, the unloading and inspection are done manually. The conventional machining operations practised are as follows:

1. Turning
2. Drilling
3. Shaping
4. Slotting
5. Milling
6. Grinding

The theory and practice of various hand-working processes as well as machining processes are explained in the Modules B and C respectively.

2.2 Safety Measures

Safety is the primary requirement that a worker or student should learn before he starts working in a workshop. A worker or student can easily learn how to work safely. Rules and regulations, mechanical guards and devices, posters and lectures about safety measures are very important, but they will never replace intelligent precautions taken by the worker or student in doing his work. A good and safe worker is the one, who is safety-conscious and always adopts safe and accepted procedures. The following are the types of safety measures to be considered in a workshop.

1. Safety of the worker
2. Safety of the job
3. Safety of machines, tools and equipment

To maintain safe working conditions and to avoid accidents, different types of safety measures are taken, depending upon the type and seriousness of accident that may happen. A student, who is going to practice in workshops, has to know the following important safety measures.

Wear safe clothing

Wear tight shirt or dress while working inside the workshop. For good protection of the clothing, shop apron may be worn. Wear shoes with thick soles. Do not wear rings, watches, bracelets, or other jewellery that could get caught in moving machine.

Maintain good housekeeping habit

Keep the workshop floor free of oil, grease or any other liquid. Store materials in such a way that they cannot cause hazards. Do not leave tools or workpieces on the work bench or table of machine. They should be kept in the places allotted for them. Clean the work bench or machine after a work and place the scrap in the scrap box.

Follow the general safety measures

While working with machines, the guards should be in position. Replace them immediately after repairs, if any. Do not try to clean or repair a machine, if it is in motion. Cutting tools and workpiece on any machine should be clamped securely before starting. An operator of a machine should not lean against a machine. He should avoid unnecessary talking, while operating the machine. Sufficient light should be provided at the working area.

Take precaution while using hand tools

1. Hammers: Do not use a hammer, unless the head is tightly fixed to the handle. Place the hammer on the bench carefully in the proper position. A falling hammer can cause serious foot injuries. Never strike two hammers together, because the faces of hammers are very hard and blow may cause a chip to break off, while hammering.

2. Chisels: While hammering on a chisel, care should be taken to get the blow correctly on the striking head (back) of the chisel, otherwise, it may cause injury to the chisel holding hand. Mushroomed striking head of the chisel should be removed by grinding. The cut edges are often sharp and may cause injury to hand. They may be removed by filing or grinding.

3. Files: Never use files without proper handles. The surface of the file should be clean and dirt-free. Never hammer on a file or use the file for hammering, because files are made of very brittle material.

4. Saw: Do not test the sharpness of the blade of a saw by running a finger across the teeth. While using a saw, check whether there is proper tension of the blade. Do not apply heavy pressure or sideways force on the saw, because it may break the blade and even cause injury to hand.

Take precaution while operating machine tools

1. Drilling machine: Fix the drill bit tightly on the chuck and remove the tightening key. Clamp the workpiece on the machine vice before starting drilling. The drilling surface should be perpendicular to the axis of rotation of the bit. A punch mark at the position of drilling can give accuracy in hole location. While drilling of small diameters, (less than 5 mm) the axial load should be low in order to protect the bit from breaking. Clean the chips from the machine table using a brush.

2. Lathe: Before starting the machine, clamp the work on the chuck solidly. Turn the chuck or face plate by hand to inspect the working, prior to the starting of machine.

Keep the machine clear of tools and then start. Do not stop the rotation of chuck by hand. Take measurements only after stopping the machine. Do not remove chips by hand; use brush or pliers if necessary, to remove long chips. While working on the lathe, only the operator has to switch on/off the machine, and not by a second person.

3. Grinding machine: Wear goggles or a face shield while grinding on a grinding machine. The wheel-guard and tool-rest should be fitted on the machine properly. While grinding, do not press the work or tool too much on the wheel and it should be held firmly by hand. Never operate a grinding wheel at speeds higher than that recommended by the manufacturer.

2.3 Preparing for the Workshop Practice

An engineering student who is going to do workshop practice, has to prepare the following prior to practice:

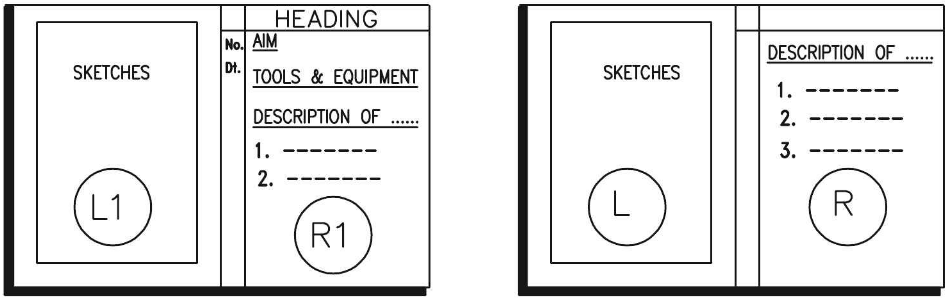
1. The student has to posses the following materials:
   (a) Work record of A4 size.
   (b) Fair record approved by the workshop authorities.
   (c) Pen, clutch pencil, eraser and a straight edge.
2. Students are advised to wear tight dress, preferably pants and shirts. Girl, students have to tie their hair and tuck neatly as a precaution against being caught against moving machine parts. For good protection of clothing, a shop apron of dark colour may also be worn. Wearing of shoes instead of slippers is also recommended for the safety of legs from sharp and hot chips and material other waste.
3. Study the relevant theory about the process, tools, equipment and the material being used for the practice. Usually the students are given a study of the workshop tools and equipment prior to the practice.

2.4 Writing of the Work Record

A work record is the write-up and sketches prepared by the student along with the study of tools and equipment or workshop practice.

2.4.1 Writing of Work Record for a Study

Before starting the actual practice in a workshop, the instructor gives description about the different types of tools and equipment used for cutting, holding, measuring, etc. Students are allowed to handle the tools and thus to become familiar with the shape, name of parts, and the method of using them. After the study, the students are required to prepare the work record of the study. The suggested layout of the work record is shown in Figure 2.1.



1st left side page **1st right side page** **Remaining left and right side pages**

FIGURE 2.1
Layout of work record/fair record for a study.

1. *Heading:* It should be written by using capital letters on the top portion of the 1st right side (facing) page.
2. *Serial number and date:* It should be written in the top portion of the left side margin of the 1st right side page.
3. *Aim:* Objective of the study is to be written on the right side page as the first paragraph.
4. *Tools and equipment:* The list of tools and equipment studied showing the detailed specification, has to be furnished as the second paragraph under the title.
5. Neat sketches of the tools and equipment have to be prepared using pencil on the left hand pages. The name of parts should be marked on them. The appropriate caption should be written below each drawing.
6. A brief description of each tool or equipment studied has to be prepared on the right side pages, under an underlined subheading.

Each student has to prepare the work record on the lines indicated above after conducting the study and get it approved by the instructor, after correction.

2.4.2 Writing of Work Record for a Practice

Similar to study, a work record has to be prepared for workshop practice also. In this work record, a student copies the drawing of the model to be completed and prepares a sketch of the raw material piece to be used for the model. The list of tools to be used and other raw materials, special requirements, etc., if any, are also noted. The procedure is written after completing the model. The suggested layout of the work record for a practice is shown in Figure 2.2.

1. *Heading, serial number with date,* and *aim* are similar to that given in the study.

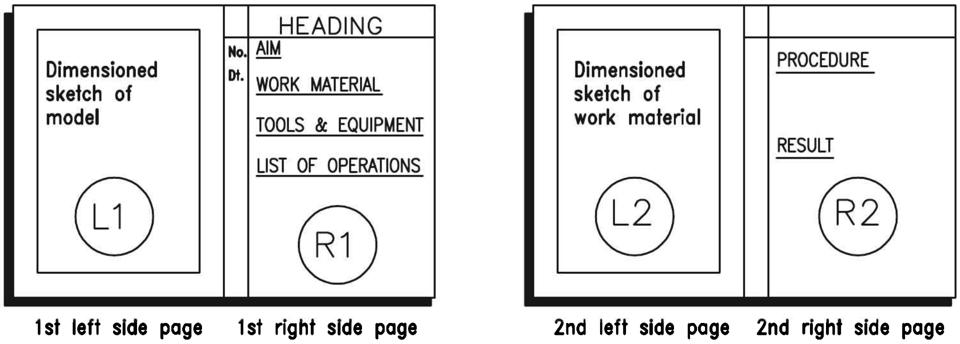


FIGURE 2.2 Layout of work record/fair record for a practice.

2. *Work material:* Details about the work material and other requirements are written under this subheading. This should include the size, number of pieces or quantity, material specification, etc.
3. *Tools required:* A list of tools and equipment required for the practice is given under this subheading.
4. *List of operations*: The operations to be carried out for making the model have to be given as a list, below the subheading.
5. *Procedure:* After completing the work on the model, the procedure followed for making the model has to be written in the second right page, using past tense and in third person. This should contain all details about operations, controls, safety measures, etc., related to the making of model.
6. *Result:* It is a custom to write the result of the practice as the last paragraph of the record. This includes the statement that whether the content of the aim is achieved or not by the practice.

2.5 Writing of the Fair Record

Fair record of a workshop study or practice is actually a fair copy of the work record, approved and signed by the instructor. As in the case of work record, the fair record should contain the following:

Study (as shown in Figure 2.1)

Right side pages	*Left side pages*
Page 1 Heading, Serial. No. and date *Aim* *Tools and equipment* (list) Name and description of tools	Page 1 Sketches of tools and equipment
Page 2, 3, etc. Name & description	Page 2, 3, etc. Sketches of tools and equipment

Practice (as shown in Figure 2.2)

Right side pages	*Left side pages*
Page 1 Heading, Serial. No. & date *Aim* *Work material* *Tools required* *List of operations*	Page 1 Sketch of the model
Page 2 *Procedure* *Result*	Page 2 Sketch of the work material

The fair record should be written in good handwriting. Corrections, over writing, etc., should be avoided. The main and subheading can be written using colour pen. The running matter has to be written using blue ink pen and the sketches using clutch pencil of HB lead. A fair record is the proof of the nature of the work done in the workshop and it has to be submitted at the time of examination for valuation. Hence, a student is advised to prepare the fair record in the most perfect manner to get the maximum benefit from it.

EXERCISES

Questions for Viva Voce

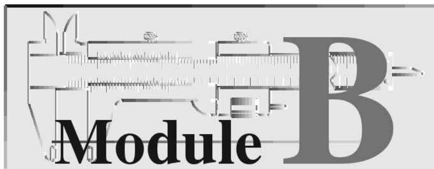
Answer the following questions

(A) Safety measures

1. Classify the types of safety measures to be taken in a workshop.
2. What is the preferred clothing, for a workshop practice? Why importance is given for this?
3. Explain the points to be considered for good housekeeping in a workshop.
4. What are the precautions to be taken while using hand tools in a workshop?
5. Describe the important safety measures to be followed, while operating machine tools.

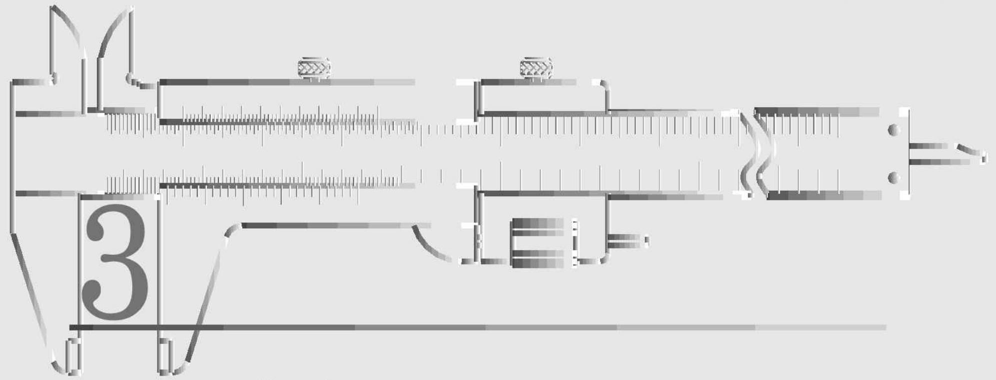
(B) Record writing

1. What are the materials to be possessed by a student as preparation for workshop practice?
2. Explain how a work-record for a study is written. Give the details regarding the writing of title and subtitles.
3. Describe how a work-record for a practice is written. Give details.
4. How the procedure of doing a workshop model is written in a work-record?
5. What is the difference between work-record and fair record? Distinguish the salient features.
6. What are the subtitles to be contained in a fair record?
7. Explain the important points to be considered while writing a fair record for a study as well as a model making practice.



Module B

Hand Working Processes



3

Fitting

The term *fitting*, is related to assembly of parts, after bringing the dimension or shape to the required size or form, in order to secure the necessary fit. The operations required for the same are usually carried out on a work bench, hence the term *bench work* is also added with the name *fitting*.

As a part of the workshop practice, fitting process is studied by all engineering students. This gives the basic knowledge about engineering materials, cutting tools, measuring tools, different fitting operations, behaviour of metals, importance of geometry of shapes, etc.

3.1 Introduction to Bench Work and Fitting

The fitting operations are generally done by using hand tools, after holding and placing the workpiece on a work bench. The tools and related equipment used for fitting processes can be classified as given below.

(a) *Work holding devices:*

1. Work bench
2. Bench vice
3. Hand vice
4. V-block with clamp

(b) *Cutting tools:*

1. Files
2. Hack saws
3. Chisels
4. Hammers
5. Scrapers
6. Drills
7. Reamers
8. Tap and die
9. Drilling machine
10. Tool grinding machine

(c) *Measuring and marking tools:*

1. Surface plate
2. Engineer's try-square
3. Scribers
4. Punches
5. Steel rule
6. Vernier caliper
7. Outside and inside calipers
8. Dividers
9. Combination set
10. Micrometers
11. Vernier height gauge
12. Miscellaneous gauges

(d) *Tools for assembling and inspection:*

1. Spanners
2. Pliers
3. Screw drivers
4. Allen keys

The operations done in fitting processes can be classified as given below:

1. Marking out
2. Hack sawing
3. Chipping
4. Filing
5. Scraping
6. Drilling and reaming
7. Tapping and dieing
8. Assembling

3.2 Work Holding Devices

3.2.1 Work Bench

A fitting process can be done at various places, but most of the important operations of fitting are generally carried out on a table called *work bench.* The work bench is a strong, heavy and rigid table made up of hard wood. The size of the work bench required is about 150 to 180 cm length, nearly 90 cm width and approximately 76 to 84 cm height. *Bench vice,* is the device used to hold the workpiece and it is rigidly clamped on the top of the table as shown in Figure 3.1. Lockup drawers, to keep the tools used for fitting, are also usually provided below the table top.

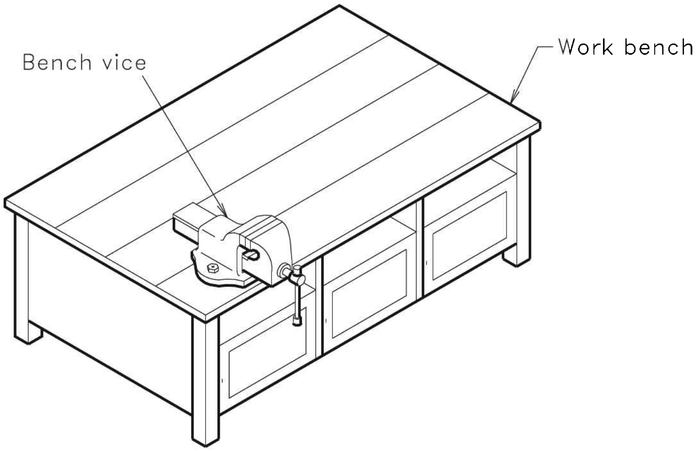


FIGURE 3.1
Work bench with vice.

3.2.2 Bench Vice

Bench vice is the most widely used device for holding the workpiece in position during various operations which are carried out in a fitting shop. It consists of one movable jaw and one fixed jaw as shown in Figure 3.2. The body of the vice is made up of iron or steel by casting. The threaded screw which is made to pass through the movable jaw at the outer end carries a handle at its end. Cast steel plates (known as *jaw plates*) are screwed to the jaw for holding the work rigidly. The gripping property of the jaw plates is increased by serrations provided with them. The base of the vice is bolted on the top of the work bench, nearby the edge.

A work is gripped between the parallel jaws by rotating the screw inside the nut, using the handle. The desired pressure is obtained by tightening or loosening the screw. In order to avoid the gripping marks on a finished surface of the workpiece, soft liners may be used on the jaw surfaces. The size of the vice is usually specified by the width of the jaws. The jaw size varies from 80 to 140 mm and the maximum opening ranges from 95 to 180 mm.

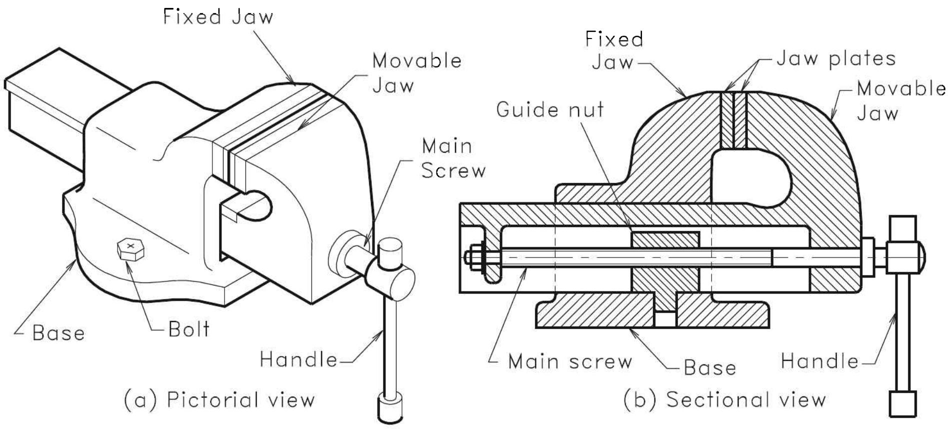


FIGURE 3.2
Bench vice.

3.2.3 Hand Vice

For gripping small objects like screws, rivets, keys, etc., a hand vice is used. The commonly used type of hand vice is shown in Figure 3.3. It basically consists of two steel legs hinged at the bottom and two jaws at the other ends. To keep the jaws separate, a leaf spring is provided nearby the hinged end. The jaws can be opened and closed by operating a wing nut and the screw.

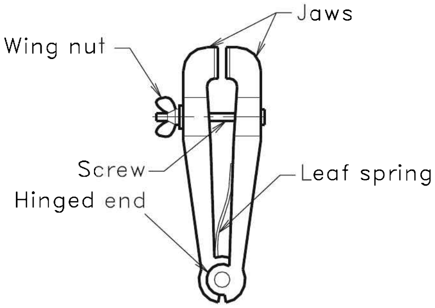


FIGURE 3.3
Hand vice.

3.2.4 V-block with Clamp

Cylindrical objects can be clamped for drilling or similar operations by using a V-block and a U-clamp as shown in Figure 3.4. By keeping the round bar on the

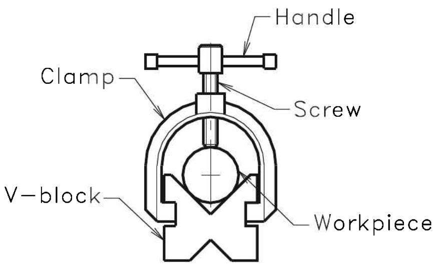


FIGURE 3.4
V-block with clamp.

V-groove, the longitudinal axis of the bar coincides with that of the grove. This enables the marking of centre line, drilling of holes along the centre, etc., accurately.

3.3 Cutting Tools

3.3.1 Files

A file is a hardened piece of steel containing a high percentage of carbon or tungsten. Fine teeth are cut on the surface of the piece in slanting rows. Figure 3.5 shows the standard form of a file with wooden handle in detached position. The end called heal has a pointed portion called *tong*, which is used to fix the wooden handle. Files are classified according to the following factors:

1. The cut and spacing of teeth on file.
2. The shape and form of the cross-section of file.
3. The length of file.

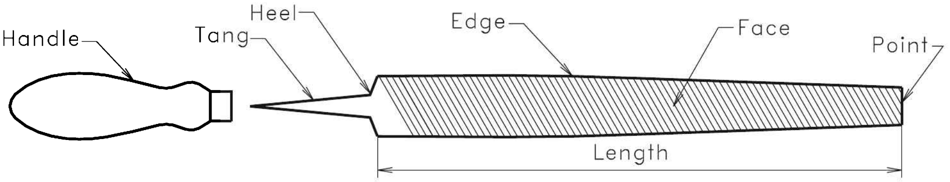
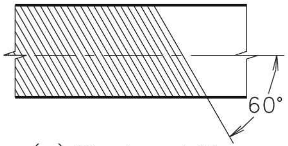


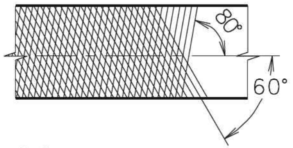
FIGURE 3.5
Parts of a file.

Cut and spacing of teeth on file

The teeth on a file may be of single cut or double cut. A single cut file will be having parallel teeth at 60° inclination to the centre line and is also known as flat files. Double cut files have two times cut-teeth; one similar to those of single cut (at 60°) and the other running diagonally across, making an angle of 80° to the centre line as shown in Figure 3.6. The spacing between teeth is known as the *pitch* and that has importance



(a) Single cut file



(b) Double cut file

FIGURE 3.6
Types of cutting on files.

in the performance of the file. According to the spacing of teeth, files are classified into the following types:

1. Rough (R) 8 teeth/cm
2. Bastard (B) 12 teeth/cm
3. Second cut (Sc) 16 teeth/cm
4. Smooth (S) 24 teeth/cm
5. Dead smooth (DS) 35 teeth/cm
6. Super smooth (SS) 50 teeth/cm

Shape or form of cross section of file

Files are also grouped according to the cross section of them. Different cross sections are required for shaping contour of different forms. For example, a round hole can be shaped only by a round file. Figure 3.7 gives the common cross sections of the files used.

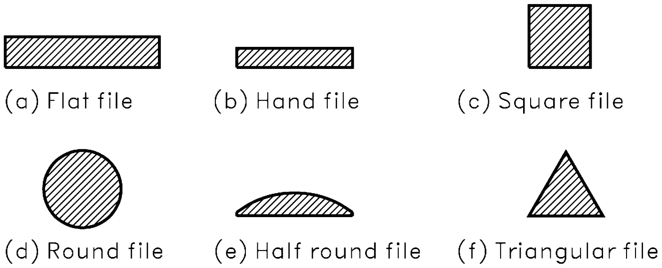


FIGURE 3.7
Types of cross section of files.

The type of files that are generally used for workshop practice are:

1. *Flat file:* This file has parallel edges for about two-thirds of the length and then it tapers in width and thickness. The faces are double cut while the edges are single cut.
2. *Hand file:* For a hand file the width is constant throughout, but the thickness tapers as given in flat file. Both faces are double cut and one edge is single cut. The remaining edge is kept uncut in order to use for filing a right-angled corner on one side only.
3. *Square file:* A square file is parallel for two-thirds of its length and then tapers off like a flat file. The four faces are double cut and is used to file corners and slots.
4. *Round files:* Round files are used for filing round holes, corners, slots, etc. They are also tapered towards the point. Round files are usually double cut, but single cut teeth are used for smooth files.
5. *Half round files:* For these files one side is flat while the other side is a portion of a circle. The flat side of the file is always double cut, while the curved surface is single cut for smooth files.

6. *Triangular (three-square) file:* For filing corners of angles less than 90°, triangular files are used. The three faces are double cut.
7. *Needle files:* These files are miniature forms of the above types avilable in sets, used for smaller size precision jobs.

Effective length of files

The size of a file is its effective length. The distance from the point to the heal (excluding the tang) is considered as the effective length of a file. The length of files used for heavy works varies from 200 to 450 mm, while that for medium works varies from 150 to 250 mm. For fine works, files of length 100 to 150 mm are preferred.

3.3.2 Hack Saw

For cutting off and for making thin cuts, a hack saw is frequently used by a fitter. It mainly consists of a metal frame with a wooden handle on one end, a metal clip with a wing nut on the other end and the cutting blade as shown in Figure 3.8. The hack saw blade is the most important part for the cutting process. It is specified by its length (distance between pin holes) width, thickness and the pitch of teeth. The specification of a hack saw blade commonly used is given below.

Length = 250 and 300 mm	Width = 13 mm and 16 mm
Thickness = 0.63 and 0.80 mm	Pitch of teeth = 1.8 and 1.4 mm

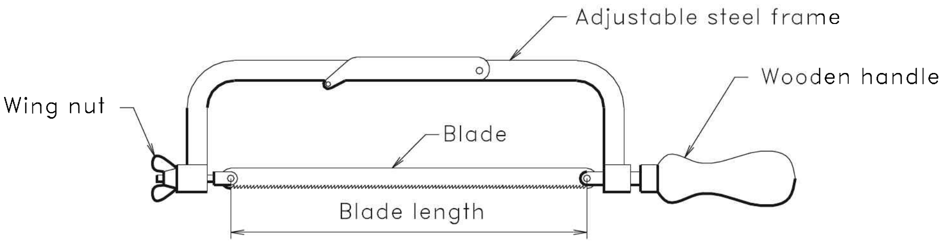


FIGURE 3.8
Hack saw.

The material used for hack saw blade is high carbon steels, H.S.S. or low alloy steels. They are made as *all hard* or *flexible*. All hard blades are hard for the whole body and can cut hard metals without difficulty. But they may break very easily. Flexible blades are made with hard teeth on a soft body, so that a slight bending cannot break them. They are suitable to cut comparatively soft metals like mild steel or aluminium. The breaking of the blade will be less and even an unskilled worker can use it. The sharp points of the teeth are bent alternately to sides to cut wide groove and thus provide clearance for the blade to move. This bending of teeth to sides is called the *set* of the blade.

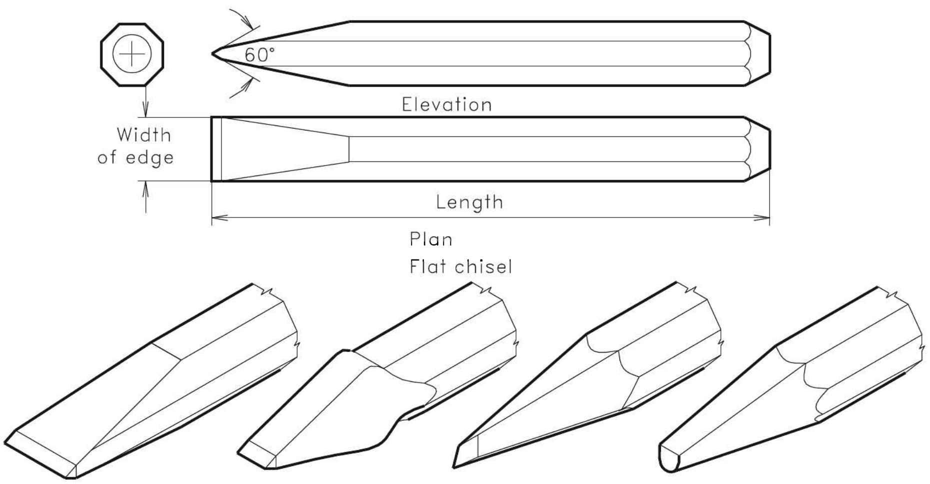
3.3.3 Chisels

Chisels are used to cut or chip off metal from workpiece. If the metal is cut in the cold state (below the recrystallization temperature), the chisel used for that is called *cold chisel*. Cold chisels usually have rectangular, hexagonal or octagonal cross section of body. They are made of high carbon steel and shaped by forging process. Depending on the shape of the cutting end, the commonly used cold chisels are classified into the following types:

1. Flat cold chisel
2. Crosscut cold chisel
3. Diamond-pointed cold chisel
4. Half-round cold chisel

The included angle for the cutting edge usually varies from 40° to 70° (from aluminium to steel) depending on the strength of metal. An angle of 60° in the most common one.

1. Flat cold chisel: This is the most common type of chisel used in fitting shop. It is used to chip off excess metal from the surface of the job. It can also be used for cutting sheets, rods, bars, wires and similar metallic pieces. The length varies from 100 to 400 mm while the cutting edge length is kept between 16 to 32 mm [Figure 3.9(a)].



(a) Flat chisel (b) Cross–cut chisel (c) Diamond–pointed chisel (d) Half–round chisel

FIGURE 3.9
Cold chisels.

2. Crosscut cold chisel: A cross cut chisel is also known as *cape chisel*. It has a slightly wider cutting end than the body but narrow in thickness as shown in figure. It is used to cut groves, key ways, etc. The size is similar to flat chisel but, the width of cutting edge varies from 4 to 12 mm.

3. Diamond pointed cold chisel: This is a special purpose chisel used to cut V-grooves, cleaning of corners and squaring of holes. The cutting edge has a diamond shape as shown in Figure 3.9(c). The size of the chisel is similar to the flat one, but width of cutting edge varies from 6 to 16 mm.

4. Half round cold chisel: This chisel has a half round end as shown in figure. They are used to cut curves, bottom grooves used for oil circulation in bearings or for cleaning rounded corners. The half round chisel is also known as *round nose chisel.* The length of the chisel varies from 150 to 250 mm.

There are cold chisels of various shapes other than the specified above and they are made to suit the special requirement. The chisels are sharpened by grinding on a tool grinding machine. A tool grinder mainly consists of a high speed motor fitted with two grinding wheels of different diameters and grain size on both ends of the extended shaft.

3.3.4 Hammers

Hammers are used to strike on a tool, fastener or workpiece. They are made up of steel by forging process. Wooden or bamboo handle is fitted in the elliptical eye hole of the hammer. Figure 3.10 shows the parts of a hammer used by a fitter. One end of the hammer head, called face, is hardened and polished well. It is having a slightly convex surface. Depending on the shape, weight and the use, the hammers for fitting work are classified as below:

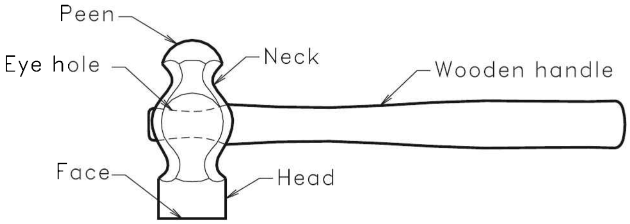


FIGURE 3.10
Hand hammer nomenclature.

1. Ball peen hand hammer
2. Cross peen hand hammer
3. Straight peen hand hammer
4. Soft hammer (mallet)

1. Ball peen hand hammer: This is the most common form of hammer used for fitting works [Figure 3.11(a)]. The peen has the shape of a ball and the other end called face has cylindrical shape. The weight of the hammer varies from 0.11 to 0.91 kg. A ball peen hammer is used for hammering during the operations like chipping, riveting, nailing, etc.

2. Cross peen hand hammer: The hammer is similar to the above with a difference that the ball peen is replaced by a peen in the cross direction of the edge hole. This hammer is used for bending, straightening, hammering inside curves, etc. The size varies from 0.22 to 0.91 kg [Figure 3.11(b)].

3. Straight peen hand hammer: This hammer is similar to the cross peen type. The peen is positioned parallel to the axis of the eye hole. The use of the hammer is similar to that of cross peen type. The size of hammer varies from 0.11 to 0.91 kg [Figure 3.11(c)].

4. Soft hammer (mallet): For giving soft blows which cannot damage the machined surfaces, soft hammers or mallets are used. The material used may be lead, copper, brass, plastic, hard rubber or wood. Wooden mallets of this type are widely used for sheet metal work [Figure 3.11(d)].

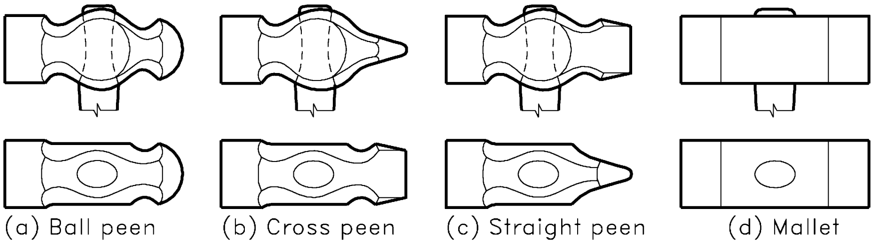

(a) Ball peen (b) Cross peen (c) Straight peen (d) Mallet

FIGURE 3.11
Types of hand hammers.

3.3.5 Scrapers

Scrapers are tools like a file or knife which have very hard cutting edges. Scraping means removal of a very thin layer of metal similar to shaving. The Figure 3.12 shows the types of scrapers commonly used. They are made in variety of lengths from 100 mm and above and in many shapes depending on the work to be executed. The shape of scrapers usually used are given below:

1. *Flat scraper*—for scraping flat surfaces.
2. *Triangular scraper*—for curved surfaces and corners.
3. *Half round scraper*—for round and curved surfaces.

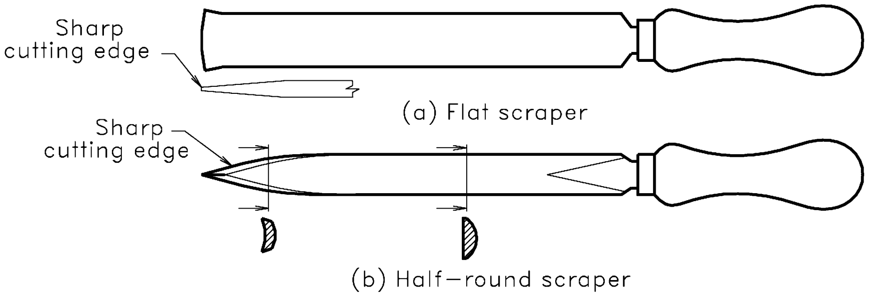
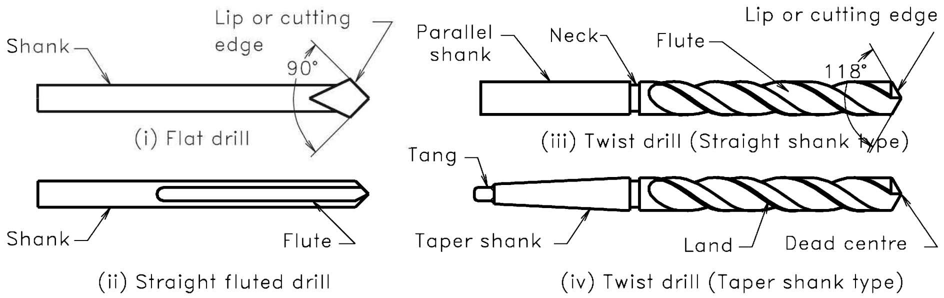


FIGURE 3.12
Types of hand scrapers.

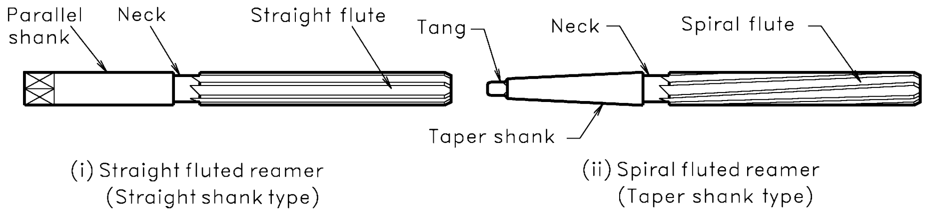
3.3.6 Drills and Reamers

Drill is a tool used to make cylindrical holes by rotating and pressing the tool against a work piece. The two-cutting edges positioned at an angle of about 59° to the axis, remove metal simultaneously while it rotates. Depending on the shape, there are three types of drills [see Figure 3.13(a)].

1. Flat drill
2. Straight fluted-drill
3. Twist drill



(a) Types of drills



(b) Types of reamers

FIGURE 3.13
Types of drills and reamers.

Flat drill and straight-fluted drill are not usually used in a fitting shop. Twist drill of straight shank and taper shank are commonly used for drilling. The included angle between the cutting edges of a twist drill is kept at 118°. The parallel shank type twist drill bits are made for diameter 0.20 to 40 mm size. The taper shank type twist drills range from 3 to 100 mm diameter. The taper of the shank is made as per *Morse Standard Taper* and it keeps the tool tightly inside the socket by friction. To take the drill bit out from the socket, a taper cotter called *drift key* is used. For larger size drills, the drill diameter is marked on it, but for small size drills, the size is determined by inserting it in gauges having standard hole diameters.

Drilled surface of hole may not be smooth and may have dimensional variation. To correct this a process called *reaming* is done using the tool called *reamer*. A reamer is a tool similar to drill, which removes a very thin layer of metal about 0.05 to 0.15 mm from the hole surface using long cutting edges on the reamer, which forms the cylindrical shape [see Figure 3.13(b)]. The cutting edge forming the flutes on the cylindrical surface may be of straight or spiral type. Similar to drills, reamers may have straight or taper shank. The reaming process can be done by hand or by using the drilling machine.

3.3.7 Taps and Dies

Internal and external threads are cut on machine parts by using taps and dies respectively. They can also be used to correct the damaged threads. For each size of thread and thread forms, a set of taps and dies is required. They are made of hard steel similar to other tools.

Taps

A tap is used to cut internal threads on a hole drilled to the core diameter of the thread. It is a screw-like tool (Figure 3.14) which has external threads and flutes (3 or 4 in numbers) cut across the threads. The lower part of the tap is slightly tapered, so that it can enter easily to the drilled hole. The upper part has a cylindrical shank portion, after the thread cutting area. This end has a square shape for holding the tap with the tap wrench during threading. The taps are usually made in the sets of three numbers as mentioned below:

1. First tap, or rougher—to start threading
2. Second tap or intermediate—to cut the thread
3. Bottoming tap or finisher—to finish the thread

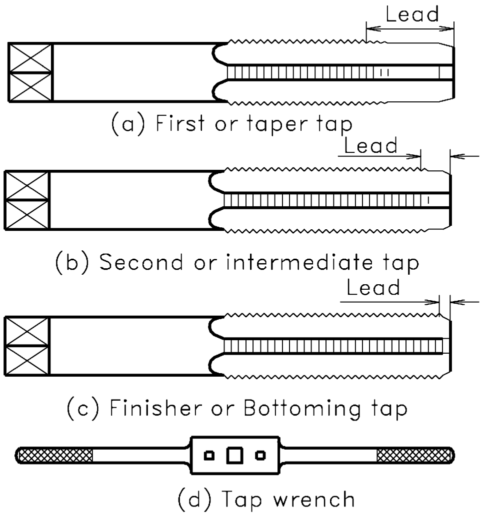


FIGURE 3.14
Taps.

The taps are inserted and rotated inside the drilled hole by holding it in the tap wrench. The tap wrench can be of solid type or adjustable type.

Dies

Dies are used to cut external threads on round rods. A die is a round block of hardened steel with a hole having internal threads and flutes across the threads. The die is fitted inside a die holder called *die stock* and is used for cutting external threads

(Figure 3.15). In the case of cutting external threads, only one die is enough to finish the thread. To cut threads on diameter, slightly varying from the nominal diameter, an adjustable die can be used. Here, the die is split into two and a screw can be used to adjust the gap between the die pieces.

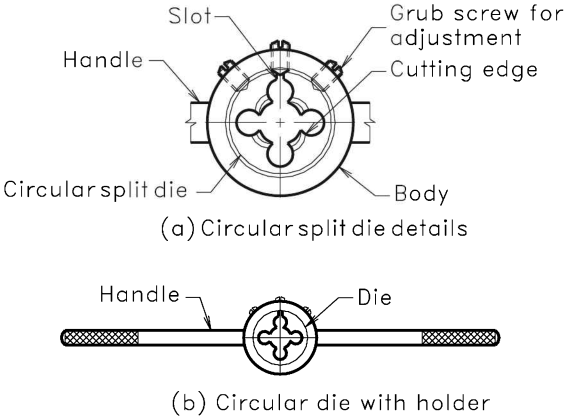


FIGURE 3.15
Die.

3.4 Measuring and Marking Tools

3.4.1 Surface Plate

It is a cast iron plate having perfectly smooth and flat surface, used as a reference surface for measuring and marking (Figure 3.16). The flat surface is finished by grinding and scraping. The bottom legs of the plate are also machined to keep the surface of the plate in perfect horizontal plane. To protect the surface of the plate from dust and dirt, it is kept covered, when out of use.

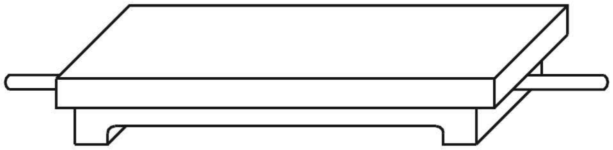


FIGURE 3.16
Surface plate.

3.4.2 Engineer's Try Square

The try square of shape shown in Figure 3.17 is used in fitting shops for scribing straight lines at right angles to a true surface. It can also be used to test the trueness of mutually perpendicular surfaces. It consists of a steel stock of rectangular cross section and a steel blade fitted perpendicular to it.

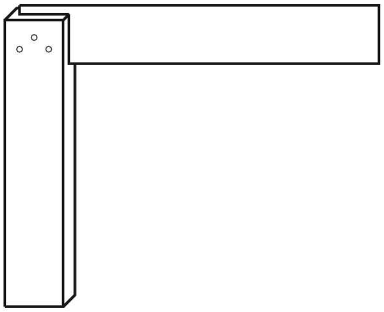


FIGURE 3.17
Try square.

3.4.3 Scribers

A scriber is a piece of hardened steel pointed at ends as shown in Figure 3.18. The length ranges from 150 to 300 mm and diameter 3 to 5 mm. It is used like a pencil to mark scratch lines on the workpiece for transfering the drawing on it. The scriber fitted on an iron rod in vertical position with a cast iron base, is called *scribing block* or *surface gauge*. It can be used for marking as well as checking.

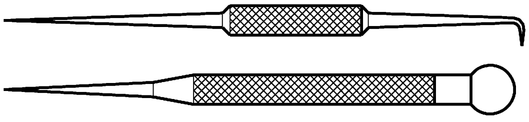


FIGURE 3.18
Scribers.

3.4.4 Punches

A punch is a tool similar to a chisel, but the cutting edge is replaced by a pointed edge. Punches are used to locate the line drawn by a scriber as a permanent mark. Depending on the use and the shape of the marking edge, punches can be classified as (Figure 3.19):

1. Prick punch
2. Centre punch

The prick punch has a sharply pointed marking edge having included angle approximately equal to 40°. It is used to make light punch marks on layout lines. The centre punch has an included angle of about 60°. They are usually used to mark heavy punch indentation to start drilling a hole. The size of the punch varies from 90 to 150 mm length and diameter 8 to 13 mm.

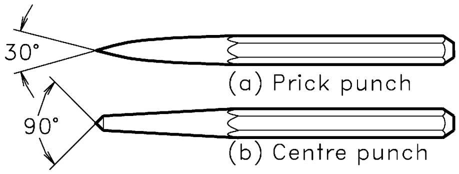


FIGURE 3.19
Punches.

3.4.5 Steel Rule

Steel rule is the scale used in fitting shops for taking measurements up to 0.5 mm accuracy. One side is marked in millimetre and the other side in inches. The material used for making the scale is stainless steel. Steel rules are usually of 150 mm or 300 mm in length (Figure 3.20). For large length measurements, rules of length 600 mm or above are also available in the market. It is to be noted that the marking on scale starts exactly from the left end. This enables to measure the distance by an outside or inside caliper from that end for better accuracy.

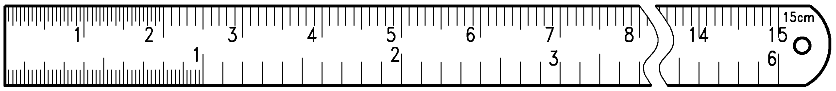


FIGURE 3.20
Steel rule.

3.4.6 Vernier Caliper

For more precise measurement of length, vernier calipers are used. There are vernier calipers to measure length with an accuracy of 0.02 mm or 0.001 inch. Figure 3.21 shows a vernier caliper to measure length in mm and inch.

A vernier caliper basically consists of a bar having the main scale marked on it and the fixed jaw for external and internal measurements. The adjustable vernier head having the vernier scale, is positioned over the main scale and carries the movable jaw as shown in Figure 3.21. There is an auxiliary head, connected to the main head by micrometering screw for fine adjustments. Both the heads are provided with locking screws to lock them firmly at any desired position.

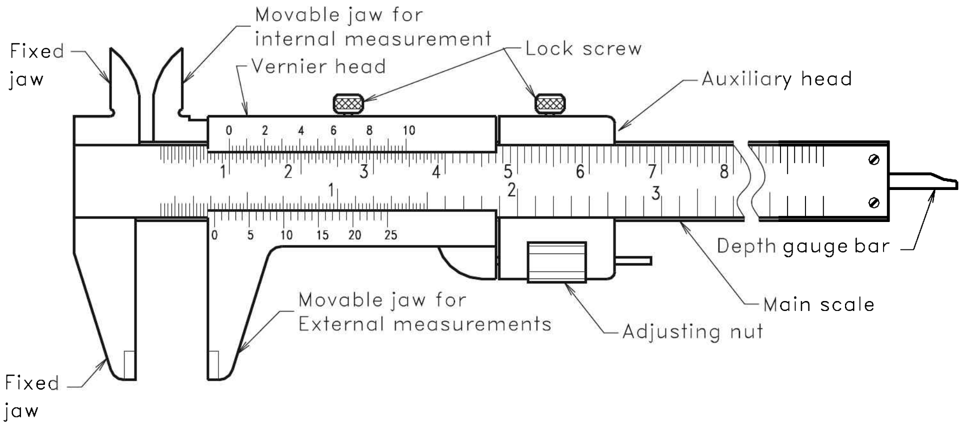


FIGURE 3.21
Vernier caliper.

The vernier scale for 0.02 mm least count has the scale length of 49 mm and it is divided to 50 equal divisions. Hence, one division of vernier scale is 1/50 mm less than 1 mm. This gives a least count of 0.02 mm. The reading of the vernier caliper is similar to any vernier scale. For example, if a dimension measured contains the main scale divisions (say, 12) and the vernier scale division coinciding with main scale (say 42), then the measured dimension

$$= 12 + (0.02 \times 42) = 12 + 0.84 = 12.84 \text{ mm}$$

3.4.7 Outside and Inside Calipers

To measure the size of or to transfer a dimension to a component, calipers are used. A reasonable accuracy in dimension is obtained by using calipers. The precision in the measurement depends mainly on the skill of the person. The commonly used outside and inside calipers are shown in Figure 3.22.

1. Outside caliper
2. Inside caliper
3. Outside spring caliper
4. Inside spring caliper
5. Hermaphrodite (Jenny or odd leg) caliper

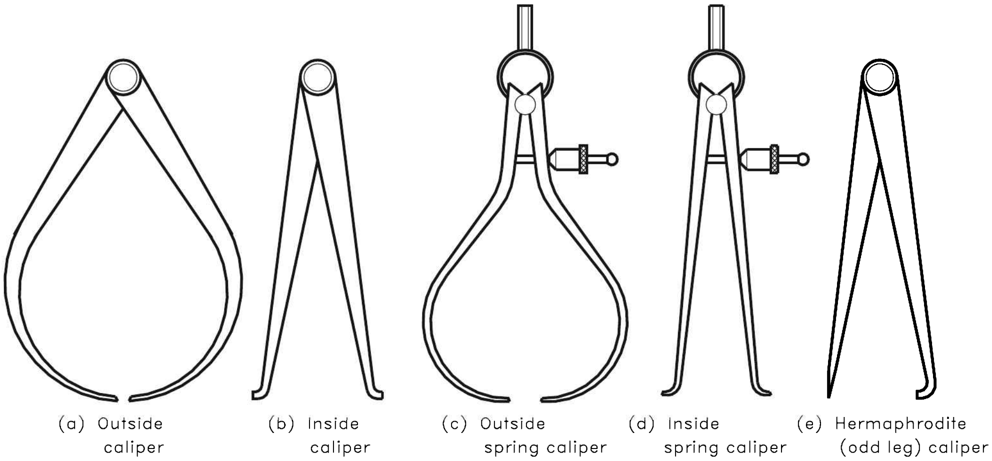

(a) Outside caliper (b) Inside caliper (c) Outside spring caliper (d) Inside spring caliper (e) Hermaphrodite (odd leg) caliper

FIGURE 3.22 Calipers.

Outside caliper is a measuring instrument having the two-curved legs, bent inwards, so that it can be used to measure outside dimensions like diameter of rods, thickness, etc. with the help of a steel rule. The two legs are joined stiff at the hinge of the legs. Inside the caliper has comparatively straight legs with the ends bent outwards. It is used to measure the inside dimensions of holes, shoulders, parallel surfaces, etc. Spring-loaded calipers are also used for the same purpose as of the above calipers. The screw controlled spring calipers are more easy to adjust measurement. The odd leg caliper is used in the same way as that of outside caliper. It is extremely useful for scribing parallel lines about a straight edge of the workpiece or to find the centre of a cylindrical work.

3.4.8 Dividers

A divider used in a fitting shop is similar to that of an inside spring caliper, except that both legs are straight and sharp (Figure 3.23). This tool is used to transfer dimensions, scribing circles and for laying out the drawing in a work.

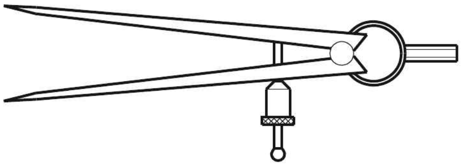


FIGURE 3.23
Divider.

3.4.9 Combination Set

This is an instrument used in fitting shops for measuring, marking or checking angles, perpendicularity, centre, etc. The combination set consists of a marked steel rule with a slot along the centre line and carries three heads (Figure 3.24).

1. Square head
2. Bevel protractor
3. Centre head

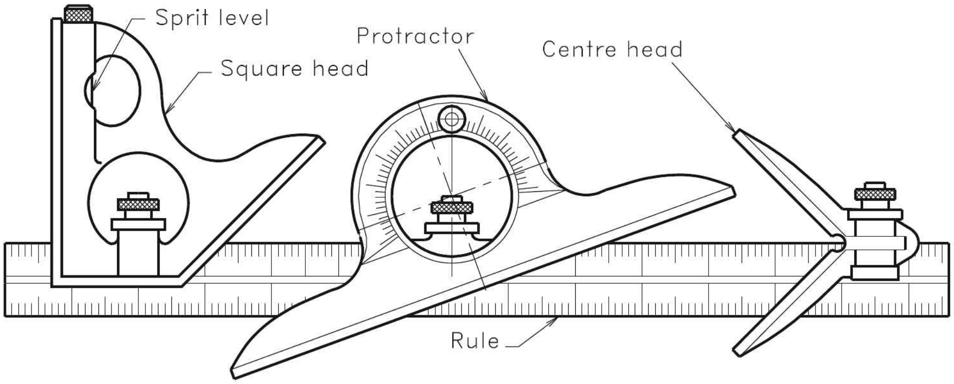


FIGURE 3.24
Combination set.

The square head is used to measure or mark the 90° and 45° angles. There is a spirit level provided on this head and this enables to check the horizontality of a surface. The bevel protractor head is used for measuring angles. With the help of the spirit level fitted with it, the slope of a surface can be determined. The vernier attached to the bevel protractor gives better accuracy in angle measurement. The centre square which is the third part has two arms at right angles. This is used to find the centre of a round rod or shaft. Each head can be moved to the required position and fixed by a clamping screw on the main scale for measurements.

3.4.10 Micrometer

Micrometer is a precision instrument used to measure the size up to an accuracy of 0.01 mm. It consists of a semicircular frame having a cylindrical extension at its right end and hardened anvil inside at the left end (Figure 3.25). To measure the size of a part using the micrometer, the part is placed between the measuring face (anvil) and the spindle. Then the spindle is advanced slowly by screwing the thimble forward. As the anvil is about to touch the object, the further movement of it and the pressure of touching is applied by rotating the ratchet stop. The reading on the barrel as well as thimble are noted to get the size.

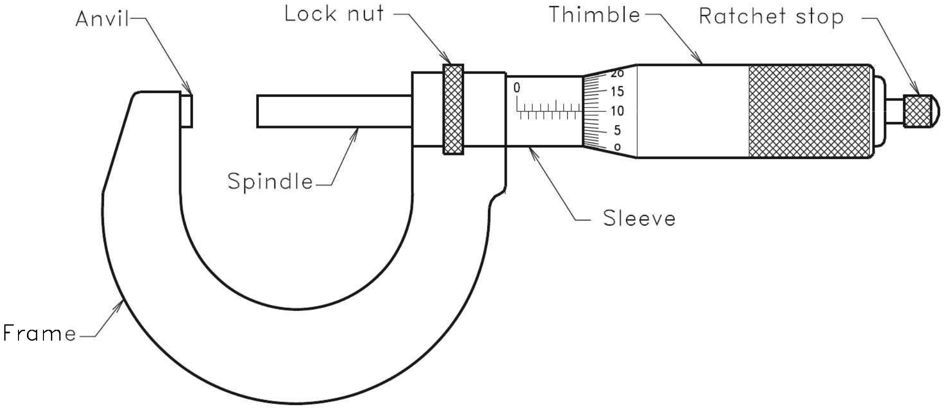


FIGURE 3.25
Micrometer (For out side measurement).

The graduation on the barrel is for 0.5 mm distance. The thimble will move forward or backward for 0.5 mm by one rotation of it. The barrel portion of thimble is further divided into 50, so that rotation for one division gives a movement 0.5/50 = 0.01 mm, which is the least count. To get accuracy in reading, the micrometer should show ‘0’ at the closed position of the measuring surfaces. If it is not at zero but shows some values, (positive or negative) that correction has to be applied in the reading as zero error.

The standard external micrometer (for 25 mm) used in a workshop is shown in Figure 3.25. There are micrometers for measuring external dimensions 25, 50, 75, etc., up to 600 mm, available in the market. Similarly there are micrometers of different designs for measuring the inside diameter, depth, etc., in use.

3.4.11 Vernier Height Gauge

To measure the height of parts or to mark height accurately on an object, vernier height gauges are used. It mainly consists of a base, a vertical main scale, a sliding head with vernier and an auxiliary head. Depending on the type of measurement, the jaw can be replaced by another type. The base of the height gauge has flat and smooth surface. Usually measurement and marking are conducted after placing the workpiece and the gauge on a surface plate. The method of measurement is similar to that of a vernier caliper (Figure 3.26).

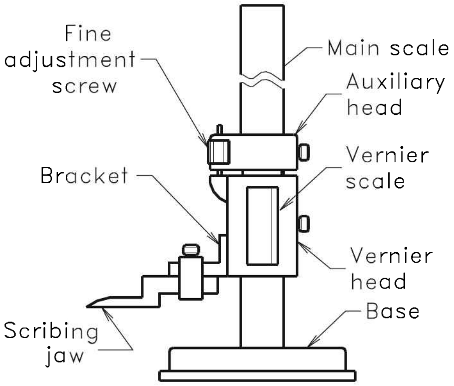


FIGURE 3.26
Vernier height gauge.

3.4.12 Miscellaneous Gauges

For comparing the dimensions of machine parts like thread pitch, thickness, diameter, gap, radius, etc., different types of gauges of standard dimensions are used in workshops.

1. *Screw pitch gauge:* This consists of a set of blades having standard thread forms for comparison of the pitch and the thread shape on screws.
2. *Plate and wire gauges:* These are circular discs having slots for comparing plate thickness and circular holes for comparing wire diameters.
3. *Feeler gauge:* This consists of blades of standard thickness to compare the gap between mating parts.
4. *Radius and fillet gauges:* These are gauges of blades similar to that of feeler gauge and are used to compare the radii of a curved surfaces and fillets.

3.5 Tools for Assembling

3.5.1 Spanners

To tighten and loosen nuts, bolts and studs, spanners are used. They are tools made of forged steel. The size of a spanner is specified by the width across flats of a nut in mm or the diameter of the bolt in inches. Figure 3.27(a) gives the sketch of a double-end C-type spanner. Spanners can be grouped as given below:

1. Single-end C-type spanner
2. Double-end C-type spanner
3. Ring spanner
4. Box spanner

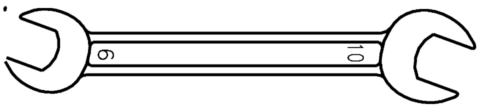


FIGURE 3.27(a)
Spanner.

3.5.2 Pliers

Pliers are mainly used to hold a workpiece or small articles. They are also used to cut or bend wire or similar thin components. Plier basically consist of a pair of steel arms, each having a jaw at one end as shown in Figure 3.27(b). There are different forms of pliers. The jaws are shaped according to the use. Two common types of pliers are:

1. Cutting pliers
2. Nose pliers.

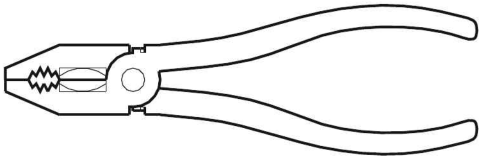
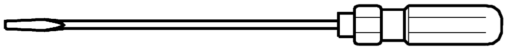


FIGURE 3.27(b)
Plier.

3.5.3 Screw Drivers

To tighten or loosen different types of screws, screw drivers are used. It consists of a hard steel rod flattened at one end and a wooden or plastic handle on the other end (Figure 3.28). The flat end of the tool is inserted into the slot provided on the head of the screw for rotating it. The length of the screw driver is made larger to get high screwing loads without slipping. Very small size screw drivers are sometimes called connecters, since they are used to tighten small screws of electrical fittings.

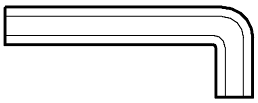
FIGURE 3.28
Screw driver.



3.5.4 Allen Keys

Screws or bolts with allen heads (hexagonal sockets) are tightened or loosened by using L-shaped tool called *allen key*. They are made of hard steel and have hexagonal cross-section (Figure 3.29).

FIGURE 3.29
Allen key.



3.6 Fitting Processes

3.6.1 Marking Out

Marking out is the process of scribing on the surface of the component to indicate the position of edges, centres, shape limit, etc., for cutting, drilling and finishing operations. This marking assists the machinist or fitter in setting up the work for various processes and the limit to which he may allow the removal of metal to proceed. Hence, the geometrical accuracy of the workpiece basically depends on the accuracy of the marking.

The tools used for marking out jobs in fitting shops include surface plate, V-block, scriber, measuring instruments, divider trisquare centre punch, hammers, etc. The surface on which the lines are marked, is prepared by cleaning. For cast surfaces, white washing is done in the marking areas. For machined surfaces copper sulphate solution is brushed to get a thin coating. For simple works, rubbing of white chalk on the surface will do the purpose of coating. The lines up to 0.2 mm thickness is drawn using scribers. Round objects are held in V-blocks while flat objects are placed on the surface plate and lines are marked.

Lines in horizontal directions are scribed using the scribing block or surface gauge. The lines perpendicular to them can be drawn easily after turning the workpiece for 90°. If machined straight surface is available, a trisquare can be used to draw a perpendicular line. The centres of round bar ends can be located by means of a hermaphrodite (odd leg) caliper. Dividers are used to scribe circles and arcs on the flat surfaces. The lines marked are converted into permanent indications by light punching at intervals exactly on the line, using a centre punch and a hammer. The metal is removed up to half of the circumferences of the punch mark for dimensional accuracy.

3.6.2 Hack Sawing

A workpiece can be cut to the approximate size by sawing using a hack saw. The workpiece or blank to be cut is rigidly clamped on the bench vice keeping the line of cut, a few millimetres outside the vice jaws. The hack saw, after tightening the blade, is placed over the cutting line of workpiece in such a way that the wooden handle in the right hand and the other end of the frame is on the left hand. The sawing is started with a backward stroke.

The first backward stroke makes a mark on the job surface. Along that mark the forward stroke is applied with slight pressure. The forward and backward strokes are repeated, giving more pressure during forward movement. This makes a cut called *kerf* on the work. Much care should be taken during the first few strokes for keeping the cutting without deviation from line. After forming the kerf, the cutting can be made fast as about 50 strokes per minute. During heavy cuts, care should be taken not to bend the blade side ways. Since the blade is hard and brittle, it may break. For easy starting of sawing, a sharp line can be filed at the cutting mark using a triangular file. To get better life of hack saw blade and for easiness in cutting, soap water is applied by squeezing a wet cotton waste over the cutting region.

3.6.3 Chipping

Thick layers of metal can be removed by the process called *chipping*. In this process the workpiece is fixed on the bench vice firmly and metal is removed by striking a cold chisel on the surface of the workpiece using hand hammer. The method of chipping is shown in Figure 3.30. The surface to be chipped is kept horizontal. The chisel is held at the middle at an angle of 35° to 70° to the surface by the left hand and the hammering is done in the same direction by right hand. In every blow of hammer a layer of metal is separated in the form of chips. Different types of cold chisels are used to produce various shapes like keyways, grooves, corners, etc. While chipping is ending nearby an edge, care should be taken not to have heavy blows in order to avoid damage of edge. In such cases, the direction of chipping can be reversed or turned 90° to the previous direction.

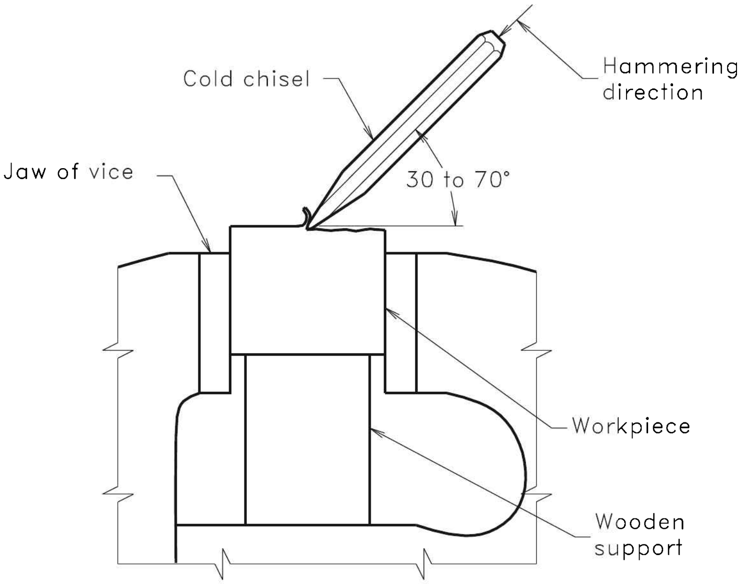


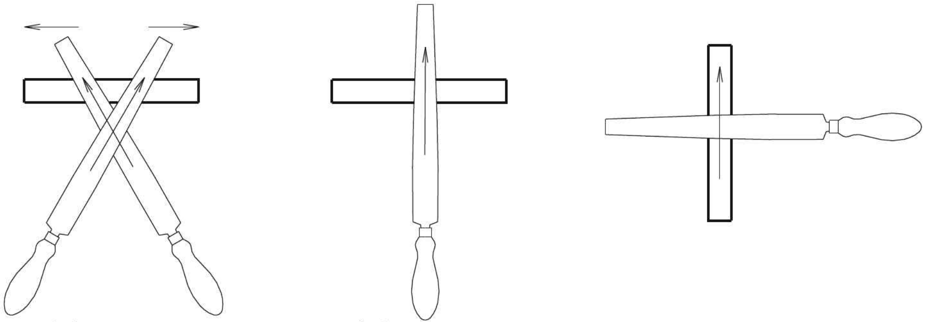
FIGURE 3.30
Chipping.

3.6.4 Filing

Filing is basically the production of flat surfaces by removal of metal in the form of fine chips using a tool called *file*. Filing is considered as the most important part of the fitting process and the skill of the operator in filing governs the geometrical accuracy and finish of the work. This process is applied after bringing the size of the job close to the required dimension by sawing or chipping. The allowance given for filing is about 0.6 mm. By perfect filing process an accuracy of 0.05 to 0.02 mm can be easily obtained.

To start filing, the job is fixed on the bench vice keeping the filing surface perfectly horizontal. The handle of the file is gripped by the right hand and the end of the file blade by the left hand, keeping the ball of the left hand thumb on the blade end. The right hand pushes the file in the forward direction while the left hand exerts pressure downwards in the forward motion. For light cuts, less pressure is to be applied. Hence, the end of the file blade is held by left hand finger tips. It is to be noted that the file cuts only in the forward strokes. The number of strokes of filing is maintained usually 50 to 60 per minute. Depending on the method of filing, the filing processes can be classified as:

1. *Cross filing:* In this filing the file strokes are made in diagonal form from right to left and then from left to right as shown in Figure 3.31(a). This is the most common type of filing and is used for medium and heavy cuts.
2. *Straight filing:* In this filing the file is pressed and moved forward approximately right angles to the length of the work as shown in Figure 3.31(b). On back stroke the file is lifted. This type of filing is suitable to the narrow pieces of work.
3. *Draw filing:* In this filing both the hands are kept on the two ends of the file blade and the blade is kept at right angles to the length of the work. The forward and backward strokes of the file will smoothen the surface produced by cross or straight filing [Figure 3.31(c)].



(a) Cross filing (b) Straight filing (c) Draw filing

FIGURE 3.31
Types of filing processes.

3.6.5 Scraping

Scraping is a process of removing a very thin layer of metal by using the tool called *scraper* (Figure 3.12). After filing, a small irregularity of flat surface can be corrected by pressing and rubbing the cutting edge of the scraper. In order to identify the areas to be scraped, the smoothly finished surface is coated by a thin film of prussian blue or red lead oil. Then a perfectly flat surface is rubbed over it gently. This will identify the areas to the scraped. After scraping and removing a layer from theses areas, again the coating and scraping are repeated until the whole area is approximately rubbed off by the flat surface. During the scraping process, the tool is held in the right hand and the left hand is placed on the lower end of the scraper for controlling the pressure. Machine beds, surface plates, etc., are made perfectly flat by this hand process.

3.6.6 Drilling and Reaming

Drilling is the process of producing circular holes by pressing a rotating tool called *drill* against the workpiece. This is done with the help of a machine called *drilling machine*. For making holes up to 12 mm diameter, bench type drilling machines are used (Figure 3.32). Bench type drilling machine consists of a column fixed on the base. The spindle of drill head and the motor are connected by cone pulley and V-belt arrangement. The spindle is rotated when the motor is switched on and the downward movement of the rotating spindle is obtained by moving the handle in the anti-clock wise direction.

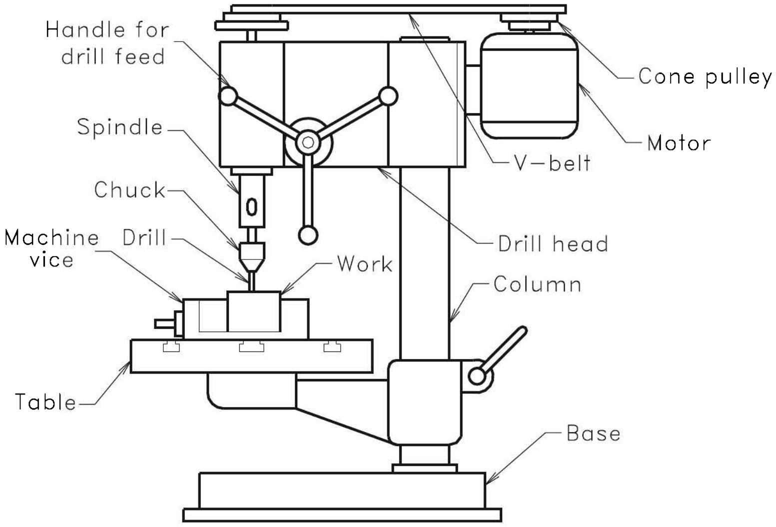


FIGURE 3.32
Bench type drilling machine.

Drilling process

To make a hole on a workpiece, the location of the centre of the hole is marked and a deep punch indentation is made using a centre punch. Then the twist drill of the required size is fixed on the drill chuck. The workpiece is clamped on the machine vice keeping the drilling surface horizontal and the drill bit is brought down to the exact drilling location by adjusting the drill table and rotating the handle for spindle movement. After completing the machine setting, the motor is switched on. The drill tip is brought slowly to the punch mark and gradually pressed to make the hole. As the nose of the drill bit enters the metal, check the accuracy of location. If correction is required, cut a groove with the round-nosed chisel towards that direction. This will help to bring the drill to the correct position. After starting the hole, the rotating drill is pressed gradually to complete the hole. While drilling hard metals, coolants like oil or soap water is applied at the cutting point to reduce the damage of the cutting edge due to friction and heat.

Reaming

To finish a drilled hole for more smoothness as well as dimensional accuracy, reaming is done. Reamers of required size are used for the purpose. The reaming process can be executed by hand or with the help of a drill press. The layer of metal removed may be about 0.1 mm for rough reaming and about 0.05 mm for finish reaming. The object is clamped on a vice and the end of reamer is inserted and rotated. As it is removing metal, it is fully inserted to the other end while in rotation, to get the final dimension and surface finish.

3.6.7 Tapping and Dieing

The process of cutting internal threads using a *tap*, is called *tapping*. A hole of the diameter equal to the core diameter of the screw thread is initially drilled. The work is clamped on the bench vice and the first tap end is inserted and rotated, applying slight downward pressure with the help of the tap wrench (Figure 3.14). This makes a rough thread form and moves forward making the thread of incomplete depth. Frequent forward and backward rotation of the tap is required for easy progress of the thread cutting. After completing the threading with the first tap, the second tap is inserted through the threaded hole to finish the thread size. If the hole is a blind one, the third finishing tap is to be used next in order to correct the thread at the bottom side of the hole. It is to be noted that, the application of the pressure and radial load on the wrench should be even and proportional to the thread size. Otherwise the tap may break very easily, because they are made of very hard and brittle steel.

Similar to tapping, dieing is the cutting of external thread on round rod using a tool called *die* (Figure 3.15). The rod called blank is made to the correct size of the thread diameter and the end is slightly tapered for easy entrance of the die. To start the thread cutting, the rod is clamped on the bench vice keeping the axis vertical and the die with the holder is kept over the rod keeping the holder horizontal.

Then the die is turned forward applying slight pressure from the top similar to the tapping process. When the cutting is started, the die should be turned backward and forward several times until threading is complete. Using an adjustable type split die, the depth of thread can be initially adjusted to a lower value and then to the full size.

3.6.8 Assembling

The process of assembling is joining of finished parts together to form the required component or subassembly of a machine or equipment. The parts produced may be in a batch production or mass production shop. The assembly process may be of any one of the types given below.

1. Assembly of interchangeable parts
2. Assembly by selection of matching parts
3. Assembly with the use of compensating elements
4. Assembly by individual fitting

Here, the last type of assembly (individual fitting) requires full use of the various fitting processes. The assembly process may involve slight modification of dimensions, cleaning of surfaces and burs of holes, threading, drilling of small holes, tightening of screwed fasteners, bending of split pins, etc. Various assembling tools like spanners, pliers, allen keys, etc., are used for tightening the screwed fasteners. After the assembly, the machine part is checked for its geometrical accuracy and working using various measuring tools. If any correction or modification is necessary, it is completed in the fitting shop using various fitting tools.

3.7 Models for Fitting Practice

In engineering institutions the practice in fitting is obtained by doing different types of models from simple to difficult ones. After studying the fitting tools and processes, students start doing models. The following example explains the usual practice of completing one model in fitting.

Example

Make a square joint of the dimensions given in Figure 3.33 using the given MS flat. The time alloted is 3 hours.

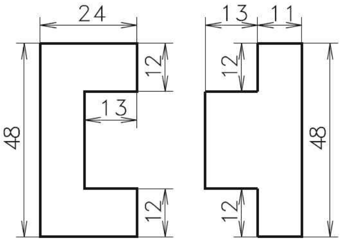


FIGURE 3.33
Square joint.

Aim

To make a square joint using the given mild steel flat piece.

Work material

Material:	Mild steel flat
Size:	Size 50 × 50 × 6 mm

Tools required

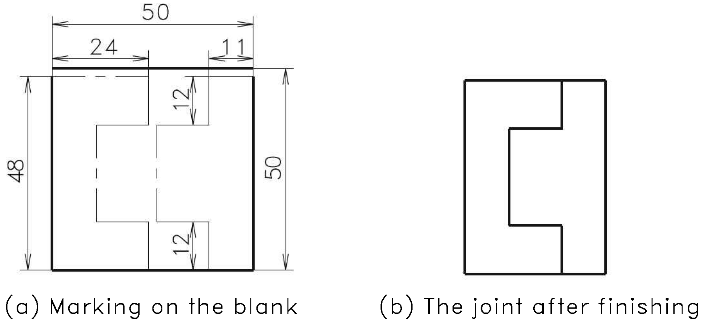
1. Steel rule, 2. Scriber, 3. Centre punch, 4. Ball peen hammer, 5. Hack saw, 6. Try square, 7. Bench vice, 8. Surface plate, 9. Flat file, 10. Triangular file and 11. Surface gauge.

List of operations

1. Rough filing, 2. Marking, 3. Punching, 4. Sawing, 4. Smooth filing to correct dimension.

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools and the blank piece.
3. Check the size of the blank for its suitability to make the model as per drawing.
4. Plan the layout of the pieces to be cut as shown in Figure 3.34.
5. File the edges to form a perfect rectangle so that one side of rectangle AB = 48 mm.
6. File the flat sides to bring the thickness to 6 mm.
7. Mark the dimensions of the model as shown in Figure 3.34(a). and punch along the lines.
8. Cut the shape using hack saw, after giving allowance for filing.
9. File the edges of square to correct the dimension and geometrical accuracy.
10. Finish the joint as shown in the Figure 3.34(b).



(a) Marking on the blank (b) The joint after finishing

FIGURE 3.34
Square joint (Fitting procedure).

EXERCISES

Questions for Viva Voce

Answer the following questions

(A) Fitting tools

1. What is meant by *bench work* related to fitting in work shops?
2. Give a list of the types of tools used in fitting operations.
3. Explain the types of work-holding devices used in fitting.
4. Describe briefly the types of files used in fitting.
5. Explain the construction of a hack saw.
6. What are the types of cold chisels and for what purposes they are used?
7. Describe briefly the types of hammers used.
8. Define the term twist drill. Distinguish a drill from a reamer.
9. Explain the tools used for cutting threads internally and externally.
10. What is a surface plate? For what purpose it is used?
11. What are the types of tools used for marking?
12. Describe briefly the use of a steel rule and a vernier calliper.
13. Explain the use of the different types inside and outside callipers.
14. What is meant by a combination set? What are the uses of them?
15. Describe how a micrometer is used for measuring a size.
16. Give a list and brief explanation of the tools used for machine parts assembly.

(B) Fitting processes

17. Explain the method of marking out the dimensions on a workpiece.
18. What are the important points to be considered while saw cutting?
19. Describe the process of chipping using cold chisels.
20. What are the types of fitting processes? Where they are used?
21. Explain the process of scraping.
22. Describe how a hole is drilled using a bench drill.
23. How the internal and external threads are cut?
24. Give a brief explanation about assembling of machine parts.

Models for Fitting Practice

Make the following models, the allotted time for each model is 3 hours:

1. Figure 3.35 gives drawing of a V-joint. Copy the figure and make the model using the given MS flat piece.

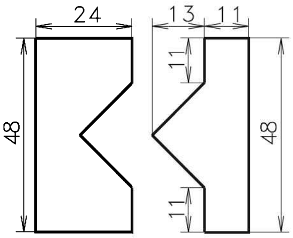


FIGURE 3.35
V-joint.

2. Make a dove-tail joint of size shown in Figure 3.36, using the MS flat piece. Also prepare a dimensioned neat sketch of the joint.

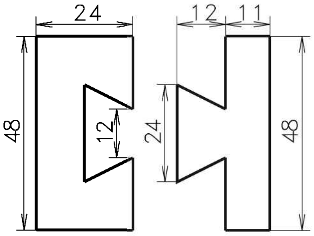


FIGURE 3.36
Dove-tail joint.

3. Copy the sketch of the stepped joint given in Figure 3.37. Then make the joint using the given MS flat piece.

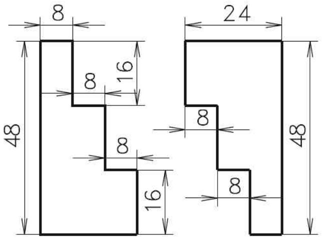


FIGURE 3.37
Stepped joint.

4. Figure 3.38 gives drawing of a trapezoidal joint. Copy the figure and make the model using the given MS flat piece.

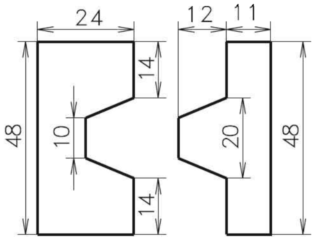


FIGURE 3.38
Trapezoidal joint.

5. Make a V-joint with rectangular cut of size shown in Figure 3.39, using the MS flat piece. Also prepare a dimensioned neat sketch of the joint.

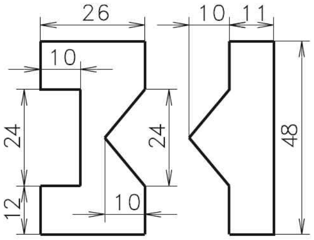


FIGURE 3.39
V-joint with rectangular cut.

6. Copy the sketch of the V-joint with circular cut given in Figure 3.40. Then make the joint using the given MS flat piece.

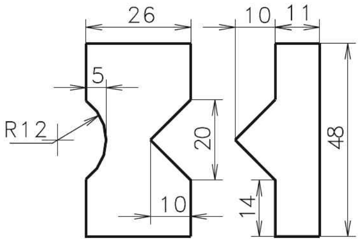


FIGURE 3.40
V-joint with circular cut.

7. Figure 3.41 gives drawing of a N-joint. Copy the figure and make the model using the given MS flat piece.

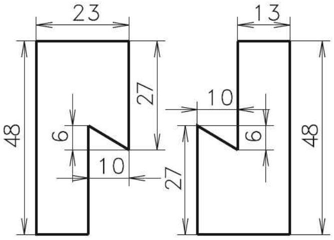


FIGURE 3.41
N-joint.

8. Make an arrow joint of size shown in Figure 3.42, using the MS flat piece. Also prepare a dimensioned neat sketch of the joint.

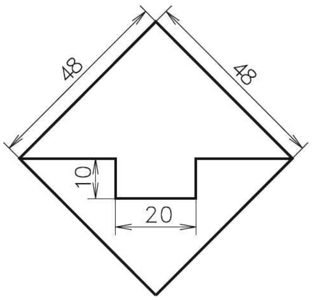


FIGURE 3.42
Arrow joint.

9. Copy the sketch of the square joint given in Figure 3.43. Then make the joint using the given MS flat piece.

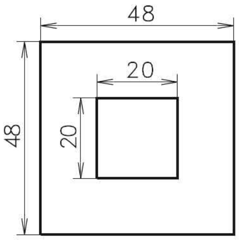
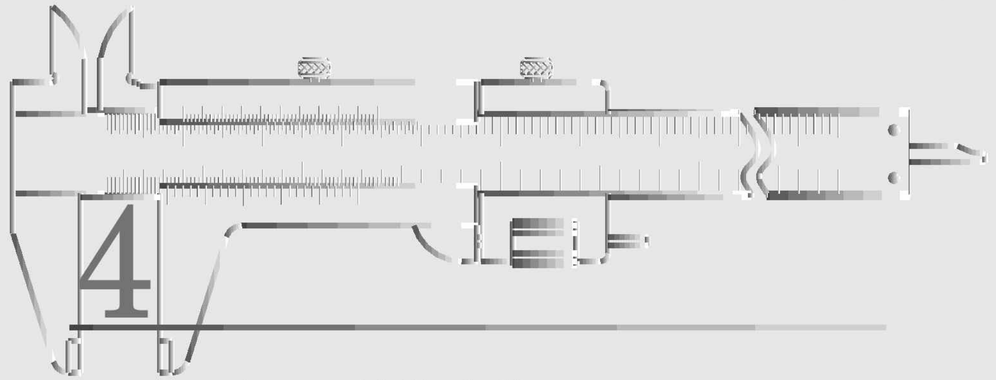


FIGURE 3.43
Square joint.



4

Arc Welding

Arc welding is the term generally used to represent *shielded metal arc welding*, because of its popularity in general engineering works. It is a manual welding process applicable to most of the metals. With the use of suitable electrodes and power supply, joints of good quality can be produced easily on metal parts of thickness ranging from about 2 mm to higher values. The cost of welding is also low compared to other welding processes.

4.1 Principle of Shielded Metal Arc Welding

4.1.1 Arc Welding Principle

Shielded metal-arc welding is a manual arc welding process in which the heat required for melting the joining surfaces is generated by maintaining an electric arc between a flux-coated consumable electrode and the base metal. The flux coating burns along with melting of the tip of the electrode and produces a gaseous shield to protect the electric arc, weld puddle and the neighbouring areas from atmospheric contamination. (Figure 4.1). The flux additionally forms a blanket over the molten weld bead in the form of slag which can be removed later by gentle peening.

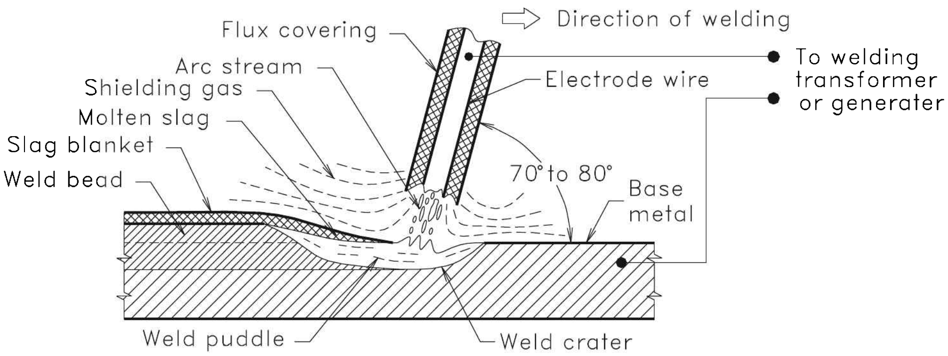


FIGURE 4.1
Shielded metal arc welding.

4.1.2 Power Supply

The electric power used for arc welding process is of low voltage and high current either AC or DC. To convert the standard three-phase line supply to the required form, any one of the following equipment is used.

1.	AC Transformer set	for A.C. output
2.	DC Motor generator set	for D.C. output
3.	DC Transformer-rectifier set	for D.C. output

The AC transformer sets are commonly used for manual arc welding. The primary side of the transformer is connected to the supply mains and the secondary side to the electrode and the workpiece. Usually welding transformers are designed to have an open circuit voltage between 45 and 90 volts of AC. Drooping voltage (approximately constant current) characteristic of shape as shown in Figure 4.2 is preferred for manual arc welding.

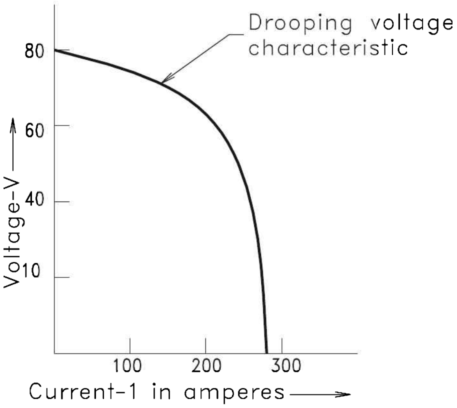
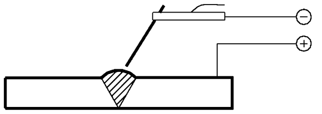
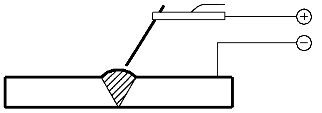


FIGURE 4.2
Current and voltage of power supply.

Direct current supply is obtained either by using a motor generator set or a transformer-rectifier set. DC supply may be of straight polarity (DCSP) or reverse polarity (DCRP) as shown in Figure 4.3. The voltage varies from 45 to 80 and a drooping voltage characteristics is preferred for D.C. also. The polarity selection can improve the welding conditions like welding of metals which are difficult to weld, overhead position of welding, etc. AC supply gives a mixed performance of DCSP and DCRP



D.C.S.P. (DC straight polarity)



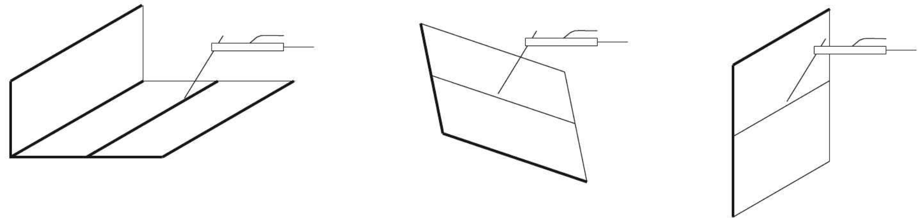
D.C.R.P. (DC reverse polarity)

FIGURE 4.3
Polarity of electrodes.

4.1.3 Welding Positions

There are five recognized positions for welding and are shown in Figure 4.4.

1. Flat or downhand position
2. Inclined position
3. Horizontal-vertical position
4. Vertical position
5. Overhead position



(a) Flat (down hand) position (b) Inclined position (c) Horizontal–vertical position

(d) Vertical position (e) Over head position

FIGURE 4.4
Welding positions.

Among the five positions, the flat or down hand position is considered as the easiest position for welding. Overhead position is the most difficult one in welding because the molten metal and slag flow downward due to gravity. Special electrode coating and use of direct current of suitable polarity can reduce this difficulty in welding. The remaining welding positions are coming in between the two extremes.

4.2 Welding Electrodes

A manual arc welding electrode consists of a metallic wire called *core wire* which is coated uniformly with flux. Electrodes can be classified into several types according to the wire material, flux coating and dimensions. They are selected depending on the position of welding, base material thickness, base material composition and the type of welding current available.

Core wire material

Mild steel is the most commonly used core material for electrodes. To suit the base metal composition, steels and other metal alloys are also used as electrodes. The coatings are provided according to the requirements.

Electrode coverings

Flux coating over the core wire of an electrode perform the following important functions to produce good welded joints.

1. To strike and maintain the arc.
2. To produce a protective gaseous shield around the arc.
3. To produce a slag blanket on the weld metal.
4. To deoxidize and refine the weld metal.
5. To add alloying elements to the welded metal.
6. To concentrate the arc for better penetration.
7. To prevent spatter of metal and thus to get rounded appearance to the weld bead.

The common ingredients of a flux which help in slag formation and metal refining are asbestos, mica, silica, fluorspar, stealite, titanium dioxide, iron oxide, magnesium carbide, calcium carbonate and different aluminas. Iron powder is added for better weld deposition rate. For stabilizing the arc, potassium silicate and potassium titanate are added. Electrodes of different flux compositions are available in the market and they have to be selected as per the directions given on the packet by the manufacturer.

Electrode size

Electrodes are usually produced in lengths of 250, 300, 350 and 450 mm. About 20 mm of core wire length is kept as bare at one end for inserting into the electrode holder to give the power supply. The size of the electrode is measured and designated mainly by the diameter of the core wire. The common size of electrodes (diameter) in mm is given below. The value in bracket shows the standard wire gauge in British system corresponding to the size used.

1.6 mm (16), 2 mm (14), 2.5 mm (12), 3.2 mm (10), 4 mm (8), 5 mm (6), 6 mm (4).

IS code for electrodes

For convenience of reference, the electrodes are given a code number with the help of which it is possible to identify the type of electrode, the welding position in which it may be used under different current conditions and the weld metal strength. In Indian system, the code number for covered electrodes consists of the prefix letter **M** to indicate the suitability of the electrode for metal arc welding of mild steel and of low alloy steels. This is followed by six digits. In addition to this, there may be a suffix letter **P** to indicate that the electrode is suitable for deep penetration in welding. Figure 4.5 shows an example of the marking on a welding rod packet as per BIS. For more details refer IS:815-1956 and IS 814-1963.

IS: 815–1956 Coding		M 325241P
Specification	Position	Current condition
Ref: IS: 814–1963	F. H.	$D+A_{95}$

FIGURE 4.5 Marking on a welding rod packet.

4.3 Arc Welding Equipment and Accessories

The equipment and accessories required for manual arc welding other than the electrode are given below:

1. An equipment to provide high current ranging from 100 to 300 or 600 amperes at an open circuit voltage of about 80 to 100 volts. This is obtained either by a welding transformer or a motor generator set connected to the AC power line.
2. Cables to convey the welding current from the equipment to the electrode holder and workpiece.
3. Electrode holder to grip the electrode and also to convey the current to the electrode.
4. Accessories which the welder has to use during and after welding.

4.3.1 Welding Equipment

Figure 4.6 shows the layout of an arc welding unit. The cables (leads) that carry the welding current are very flexible and generally are made of copper or aluminium wire. The cable is made of very fine and flexible wires. The number strands may range from

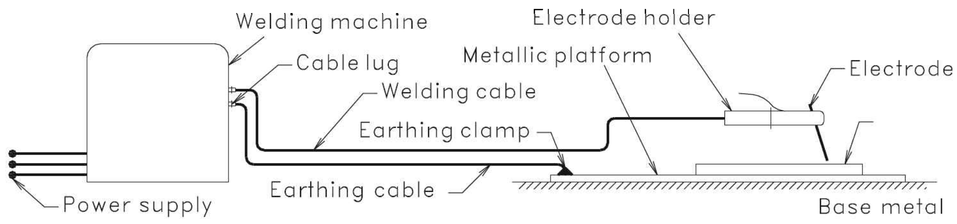
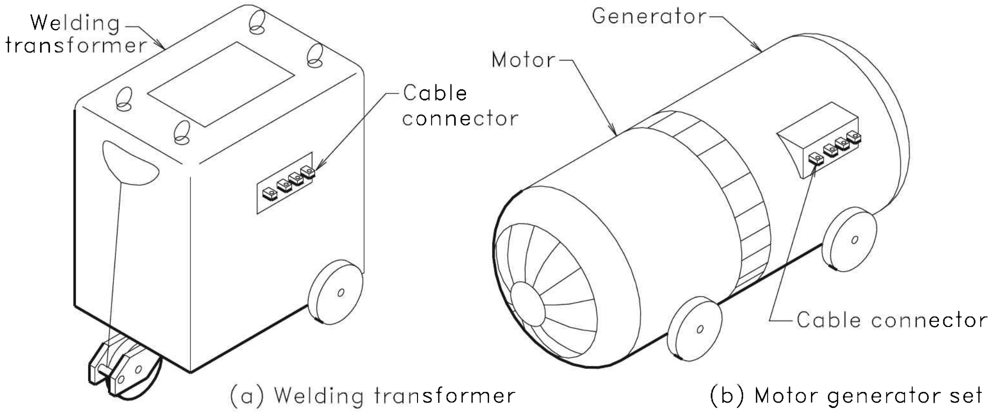
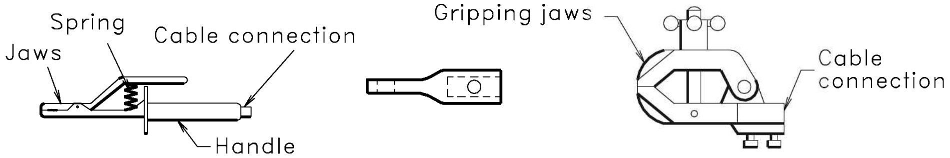


FIGURE 4.6
Layout of arc welding equipment.

800 to 2500. They are insulated by rubber covering and reinforced by fibre and rubber coating. These leads are connected to the machine mechanically through the cable lug. Figures 4.7(a) and (b) show pictorial views of a welding transformer set and a motor generator set.



(a) Welding transformer (b) Motor generator set



(c) Electrode holder (d) Cable connector (e) Earth clamp

FIGURE 4.7
Arc wedling equipment details.

The welding current in a transformer set is controlled by any one of the following method.

1. Tapped choke method
2. Moving core method
3. Moving coil method
4. Magnetic amplifier method.

The tapped choke method is the best and most simple method of control of the current output. Hence, such equipment are commonly used in welding shops.

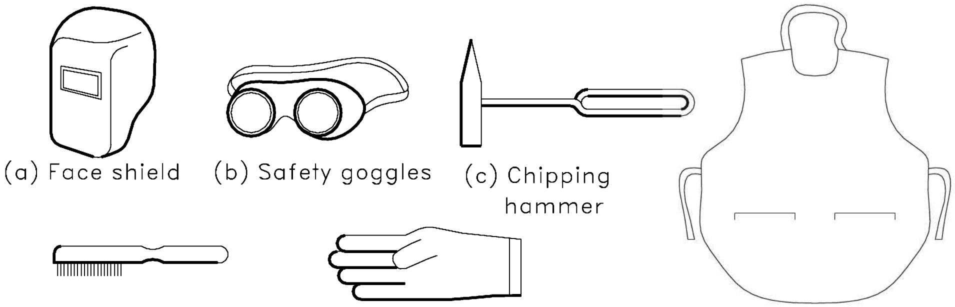
The electrode holders (stingers) [Figure 4.7(c)] come in a variety of sizes ranging the capacity from 150 to 500 amperes. Figure 4.7(a) shows a popular type of electrode holder, the ground clamp (earthing clamp or connection to the workpiece) that completes the circuit between the electrode and the welding machine [Figure 4.7(e)]. This clamp, connected at one end of the cable [Figure 4.7(d)] is bolted to the work or to the metallic platform on which the work is placed for welding.

4.3.2 Operator Accessories

The accessories used by an electric arc welder are given below:

1. *Hand screen (face shield):* It is used for protection of operator's eyes and face from arc light and molten metal spatter [Figure 4.8(a)].
2. *Safety goggles:* This is a pair of eye glasses to protect welder's eyes from light and spatter of molten metal, similar to face shield [Figure 4.8(b)].
3. *Chipping hammer:* It is used for removing the slag from the weld [Figure 4.8(c)].
4. *Wire brush:* This is used for cleaning the weld [Figure 4.8(d)].
5. *Hand gloves:* It is used to protect hand from heat and arc [Figure 4.8(e)]. They are usually made of chrome leather.
6. *Apron:* For protecting operator's clothes and body from heat and arc [Figure 4.8(f)]. It is usually made of heat resistant chrome leather.

The tools used in welding shops other than the accessories are fitting tools like hammers, cold chisels, bench vice, files, hack saw, V-block, outside and inside callipers, try square, steel rule, etc. Details about these tools are given in Chapter 3 of this book.



(a) Face shield (b) Safety goggles (c) Chipping hammer

(d) Wire brush (e) Hand gloves (f) Apron

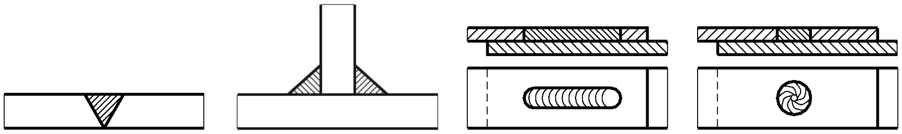
FIGURE 4.8 Arc welding accessories.

4.4 Types of Welds

The welds made in arc welding can be classified into the following categories:

1. *Butt weld:* This weld is formed by joining the end surfaces of two plates or rods [Figure 4.9(a)].

2. *Fillet weld:* This weld is formed by joining surfaces of plates usually at right angles by filling metal [Figure 4.9(b)].
3. *Slot weld:* To join two plates of large area, slots are made on one plate and welding is done inside these slots to fill the gap [Figure 4.9(c)].
4. *Plug weld:* This joint is similar to slot weld. Here, the slots are replaced by round holes to form the plugs by welding [Figure 4.9(d)].



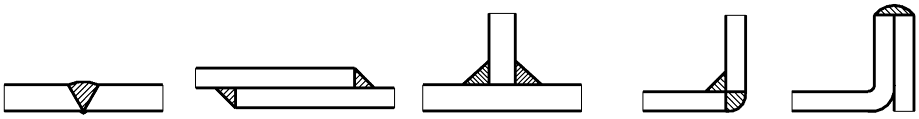
(a) Butt weld (b) Fillet weld (c) Slot weld (d) Plug weld

FIGURE 4.9
Types of welds.

4.4.1 Types of Welded Joints

The welded joints usually produced can be classified into the following types:

1. Butt joint [Figure 4.10(a)].
2. Lap joint [Figure 4.10(b)].
3. Tee joint [Figure 4.10(c)].
4. Corner joint [Figure 4.10(d)].
5. Edge joint [Figure 4.10(e)].

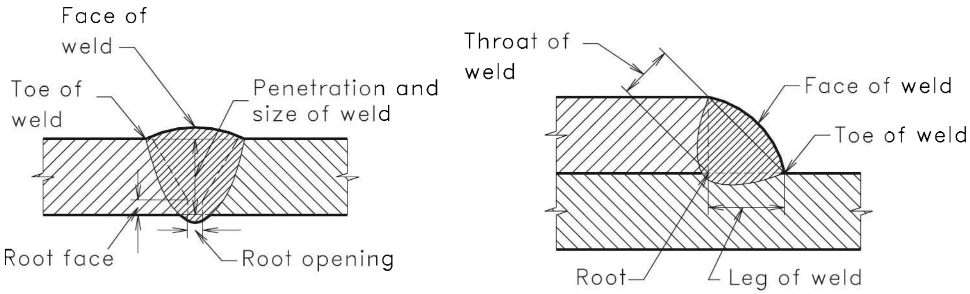


(a) Butt joint (b) Lap joint (c) Tee joint (d) Corner joint (d) Edge joint

FIGURE 4.10
Types of welded joints.

Among the above five types of joints, the butt weld is used for a butt joint and a fillet weld is used for lap joint, tee joint and corner joint. The butt and fillet welds are commonly used to produce welded structures.

The nomenclature of butt and fillet welds are given in Figure 4.11. The size of a fillet weld is specified by its leg. The size of an equal leg fillet weld is the leg length



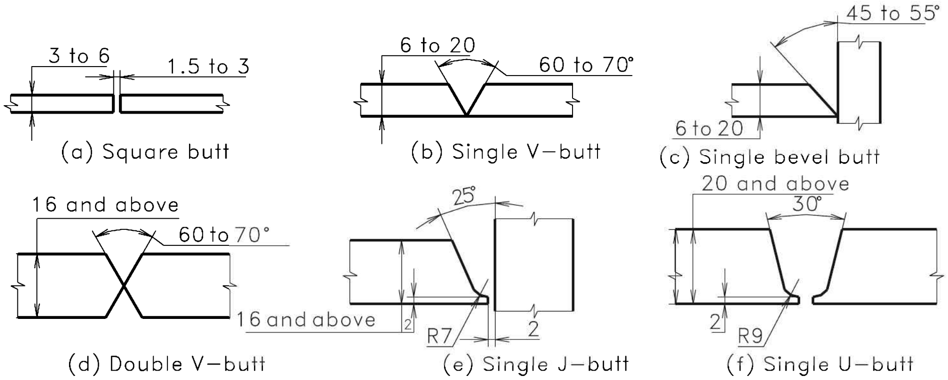
(a) Single V—butt weld (b) Fillet weld

FIGURE 4.11
Nomenclature of weld.

of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet weld, it is the leg lengths of the largest right angled triangle which can be inscribed within the fillet weld cross section.

4.4.2 Edge Preparation

Depending on the thickness of plates and the size of joint made, the edges of plates are prepared before welding. Suitable edge preparation ensures proper fusion at the root of the weld and use of minimum weld metal. The edge preparation is required mainly for butt welds of plates having thickness ranging from 6 mm to above. Figure 4.12 gives the edges prepared for butt welds. For small rates of production, hand chipping process can be used. For a large-scale production, gas cutting method is commonly employed. Machining process like shaping or planing can also be used for this purpose.



(a) Square butt (b) Single V–butt (c) Single bevel butt (d) Double V–butt (e) Single J–butt (f) Single U–butt

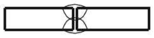
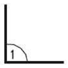
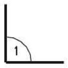
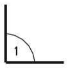
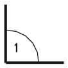
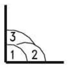
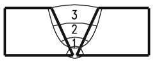
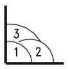
FIGURE 4.12 Edge preparation for butt welds.

4.4.3 Number and Arrangement of Runs

For thickness of plates measuring 6 mm and above, usually more than one layer of welding is required to get a butt weld of good quality. Each layer of welding is known as a *run of weld*. For producing a better joint with less distortion of base metal, the number of runs and electrode size are selected as given in the Figure 4.13. For fillet welds, the number of runs are increased, if the thickness of plate reaches 10 mm or above. It is to be noted that, for butt welds the back sealing run is to be done in down hand position, in addition to the number of runs marked in the table. All slag and irregularities should be removed before starting the next run of weld.

4.5 Welding Symbols

A weld can be represented in a drawing by a combination of welding symbols. They are elementary symbols (Figure 4.14) and supplementary symbols (Figure 4.15). The

Plate thickness in mm	Butt weld				Fillet weld			
		R	E	C		R	E	C
3		1	3.2	90		1	4	160
4		1	4	170		1	5	200
6		1 1	4 5	170 200		1	5	200
8		1 1	5 6	200 320		1	5	200
10		1 1	5 6	200 320		3	5	200
12		1 2	5 6	200 320		1 2	5 6	200 320

R=Number of runs, E=Size of electrode in mm,
C=Approximate current in amperes

FIGURE 4.13
Number and arrangement of run in butt and fillet welds.

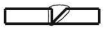
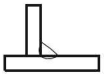
Designation	Illustration	Symbol	Designation	Illustration	Symbol
1. Square butt weld		||	5. Single J–butt weld		J
2. Single V–butt weld		V	6. Backing run		◡
3. Single bevel butt weld		|/	7. Fillet weld		◺
4. Single U–butt weld		∪			

FIGURE 4.14
Elementary welding symbols.

method of positioning welding symbol on a drawing is shown in Figure 4.16. A leader line to identify the joint, a reference line-1 (horizontal continuous) to show the arrow side symbol and a reference line-2 (horizontal line of short dashes) to show the other side symbol form the layout of the arrow unit. The welding symbols are placed on these horizontal reference lines 1 and 2. If the weld is required on the arrow side of the joint, the symbol for the joint should be placed on the continuous line. If the weld

FIGURE 4.15 Supplementary welding symbols.

Shape of weld surface	Symbol
1. Flush surface	—
2. Convex surface	⌒
3. Concave surface	‿

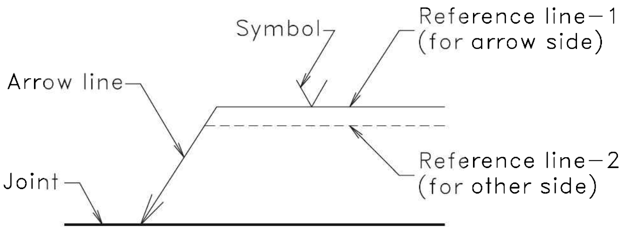


FIGURE 4.16 Positioning of welding symbols.

is required on the other side of the joint, the weld symbol should be placed on the dashed line. Figure 4.17 shows examples for the use of symbols. If the weld is of same type on both sides, the symbols can be shown on the continuous reference line symmetrically.

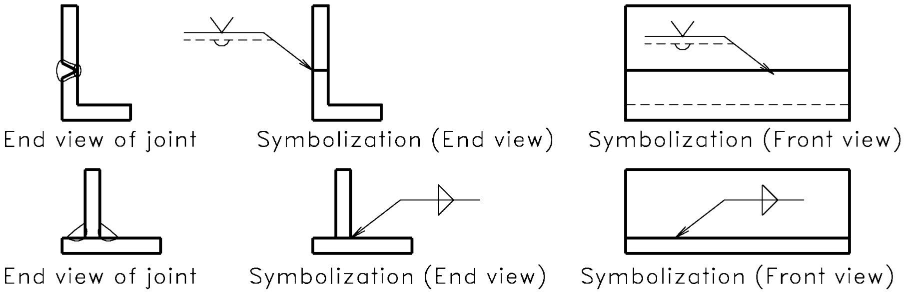


FIGURE 4.17 Use of wedling symbols.

The dimension of a weld can be written on the left-hand side of the symbol, i.e. before the symbol. The number of welds, length of weld, gap between welds etc. are written on the right-hand side of the symbol.

4.6 Defects in Weld

The common defects seen in the shielded metal arc welding can be classified as dimensional discrepancies and structural discontinuity.

(a) *Dimensional discrepancies*

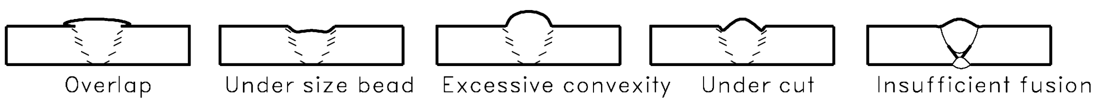
1. Warpage (distortion)

2. Incorrect joint preparation
3. Mismatching
4. Incorrect welding size and profile

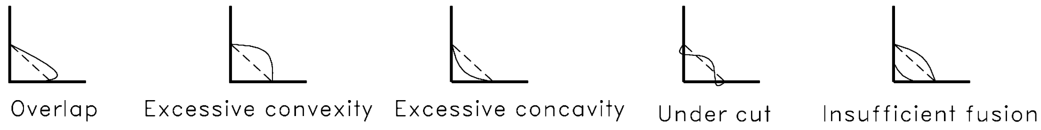
(b) *Structural discontinuity*

1. Porosity
2. Slag inclusion
3. Incomplete fusion
4. Different forms of cracks

In butt welds, the defects in profile are over lap, under size bead, excessive convexity and undercut. In fillet welds, the defects in profile are overlap, excessive convexity excessive concavity and undercut. They are shown in Figure 4.18.



(a) Butt weld



(b) Fillet weld

FIGURE 4.18
Profile defects.

Porosity of weld is caused by impurities in the work metal, contamination of surfaces, excess moisture in electrodes covering, improper arc length, excessive current and too high welding speed. Slag inclusions may result by incomplete de-slagging of previous pass, wide electrode weaving, use of too large size electrode, etc. Gaps from incomplete fusion may occur between weld metal and base metal due to excessive travel speed, bridging, excessive electrode size, insufficient current or poor joint preparation. Undercuts are usually seen due to excessive welding current, arc length and electrode tip weaving speed.

Different types of cracks are seen externally and internally in welds and base metal. They may be longitudinal cracks, transverse cracks, crater cracks, underbead cracks and micro cracks. Figure 4.19 gives the common types of cracks, porosity, slag inclusion, etc., seen in welded joints.

4.7 Welding Practice

To get good results in welding works, it is essential to lay down the correct welding procedure for a particular job. The operator has to follow the correct technique in carrying out the practice. The choice of the procedure and technique for making a particular weld depends on the material, its thickness, the type of work and the mechanical properties required at the joint.

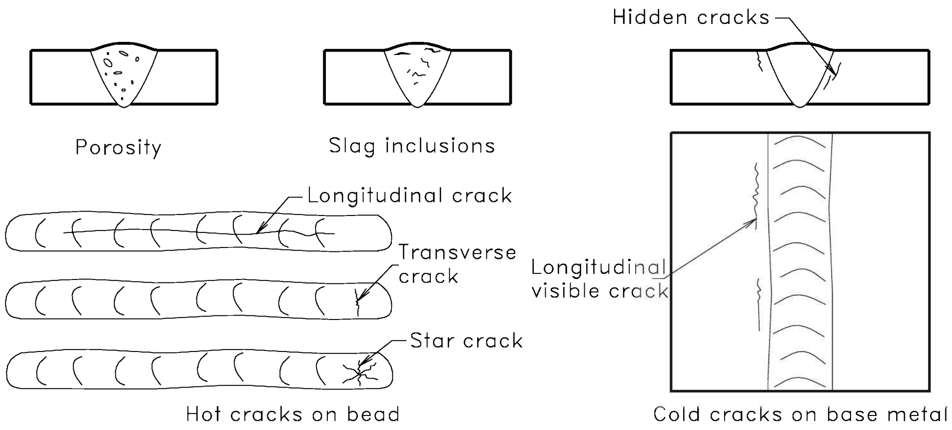


FIGURE 4.19
Cracks, inclusions and porosity in welds.

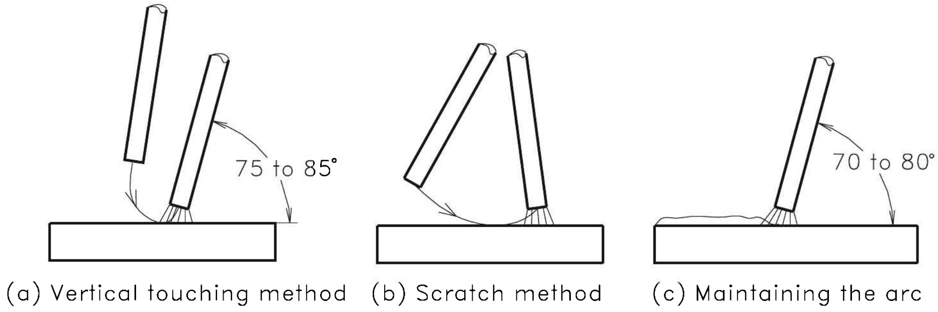
4.7.1 Welding Procedure

The steps to be followed to obtain a good weld are given below:

1. Study the given drawing for welding.
2. Prepare the edges of parts as per the type of weld.
3. Select the type of electrode depending on the quality of weld and position of weld required.
4. Select the size of the electrode suitable to the thickness and the type of weld.
5. Find the approximate length of run per electrode or the speed of travel. Also fix the number of runs, if a multirun weld is required.
6. Finalize the welding sequence.
7. Assemble the pieces to be welded on the welding table or welding floor.
8. Fix the earthing clamp to the base metal or to the metal plate of the welding floor.
9. Select the required voltage and current in the welding machine.
10. Grip the electrode on the electrode holder and check the welding arc by welding on a waste piece. The arc is to be viewed through the handscreen.
11. Make the tack welds at intervals on the joint.
12. Check the alignment of the pieces, after the tack weld.
13. Make the complete welding from one end to the other.
14. Remove the slag using the chipping hammer.
15. Inspect the weld for finding the defects, if any.

4.7.2 Striking and Maintaining the Arc

To strike the electric arc, the work is touched with the electrode and the electrode is quickly withdrawn, a small distance not exceeding that required to maintain the arc under welding conditions. The distance is about 3 mm for medium size electrodes [Figure 4.20(a)]. There is a second method in which a scratching is done with the electrode tip across the plate with a slight circular motion, so that at the bottom of its travel the arc is struck. Further motion of the electrode draws the arc to the required length [Figure 4.20(b)]. The second method is better for a beginner, who is usually in trouble with sticking of the electrode to the plate. If the electrode sticks to the plate, it should be freed with a sharp twist. If this fails, the electrode should be removed from the electrode holder and then from the work by chipping.



(a) Vertical touching method (b) Scratch method (c) Maintaining the arc

FIGURE 4.20
Striking and maintaining the arc.

After the arc has been struck, it is maintained by uniform continuous movement of the electrode towards the welding point. At the same time the electrode is also progressively advanced or moved in the direction of welding. At the instant of striking the arc, the operator should place the face shield in position and observe the arc through the brown glass. When the arc has been drawn, the electrode should be held at an angle of about 70° to 80° to the plate and then moved slowly and evenly towards the operator Figure 4.19(c). The approximate current rating for different electrode sizes, which can easily maintain the arc are given below.

1.6 mm (45 A)	2.5 mm (90 A)	32 mm (130 A)
4 mm (170 A)	5 mm (200 A)	6 mm (320 A)

4.7.3 Tack Welding

Tack welding is used to ensure the correct line up to the components to be welded. A tack weld is the smallest weld as a spot or short length weld made by smaller size electrode. The tacks are made in intervals so that the components are kept in alignment and correct position during the full welding. The tacks should be carefully deslagged and if there is any imperfection, that should be removed by chipping and remade.

4.7.4 Weaving the Electrode

While depositing weld metal, it is often desirable to make the width of the deposit wider than that obtained by a string bead. In such cases a weaving motion is applied to the electrode as it is advanced along the line of weld (Figure 4.21). By weaving,

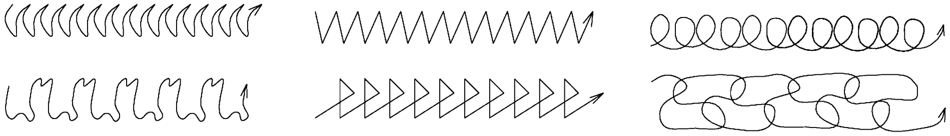


FIGURE 4.21
Typical electrode weaving motions.

it is possible to deposit more metal at a single pass. There are a number of weaving motions which are used according to the position of weld and metal filling rate required.

4.7.5 Safety Precautions

The safety precautions to be taken in a welding shop are given below:

1. Avoid keeping inflammable materials in the welding shop.
2. Use hand screen (face shield) while welding.
3. Welding gloves should be worn during welding and handling of welded components.
4. Do not chip or deslag metal unless glasses are worn.
5. Do not weld while standing on a damp floor.
6. Switch off the welding machine when it is not in use.
7. Make sure that welding return leads make good contact, thus improving welding conditions and reducing fire risk.

Example

Make a single-V butt joint of the dimensions given in Figure 4.22 using the given MS flat.

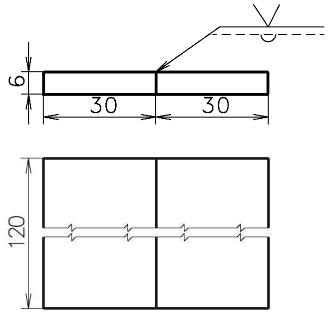


FIGURE 4.22
Single-V butt joint (Symbolic representation).

Aim

To make a single-V butt joint using the given mild steel flat piece.

Materials required

Work piece:	Mild steel flat of size: 120 × 30 × 6 mm — 2 Nos
Electrode:	10 SWG (3.2 mm) MS electrode — 1 No

Tools required

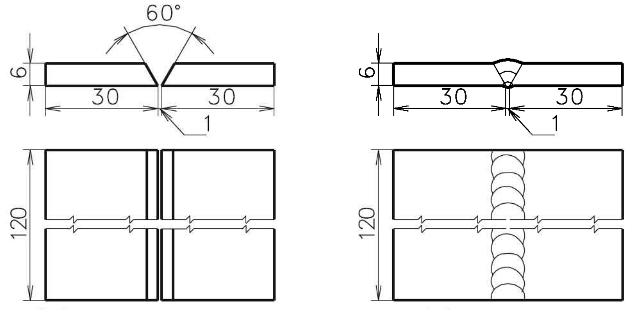
1. Steel rule, 2. Ball peen hammer, 3. Hack saw, 4. Try square, 5. Bench vice, 6. Flat file, 7. Cold chisel, 8. Welding transformer unit, 9. Face shield, 10. Chipping hammer, 11. Wire brush, and 12. Gloves.

List of operations

1. Marking, 2. Sawing, 3. Chipping, 4. Rough filing, 5. Welding, 6. Deslagging, and 7. Cleaning.

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools, the blank piece and the electrode.
3. Check the size of the blank for its suitability to make the model as per drawing.
4. Chip the edges, file them to form the single V as shown in Figure 4.23(a).
5. Place the workpieces on the welding table keeping the V upside down and the gap between them as 1 mm for tack welding.
6. Grip the electrode on the electrode holder and check the earth connection to the table.
7. Set the output current of transformer as 130 A and switch it on. Check the arc by welding on a waste piece.
8. Do the tack weld at ends and check the alignment of the pieces.
9. Complete the backing run welding and remove the slag.
10. Turn the workpiece upside down and do the first run on welding to fill the V-groove up the half depth.
11. Remove the slag and do the second run of welding to complete the filling of the V-groove as given in Figure 4.23(b).
12. Remove the slag and check the dimensional accuracy and also the defects, if any.



(a) Joint preparation (b) Finished joint

FIGURE 4.23
Single-V butt joint (Actual shape of joint).

EXERCISES

Questions for Viva Voce

(A) Welding theory

1. Explain the principle of shielded metal arc welding.
2. What are the types of currents used for producing the arc?
3. Distinguish between DCSP and DCRP.
4. What is meant by welding position?
5. What are the functions of flux covering on an electrode.
6. How an electrode is specified?
7. What are the types of welds?
8. Explain the types of joints made in arc welding.
9. Describe the method of specifying size of a weld.
10. With the help of sketches explain the edge prepared for butt welding.
11. What is meant by welding symbol? Where it is used?
12. What are the types of weld defects seen in welded joints? Explain them briefly.

(B) Welding practice

13. Explain the preparations required before arc welding.
14. Describe the conduct of welding from the beginning to the end.
15. How the welding arc is struck and maintained?
16. Explain the method of weaving the electrode tip to get the required bead size.
17. What is meant by tack welding? Why it is required?
18. What are the precautions to be taken while conducting a welding process?

Models for Welding Practice

Make the following models:

1. Make a straight line weld bead of size shown in Figure 4.24, using MS flat piece. Also prepare a dimensioned neat sketch of the piece.

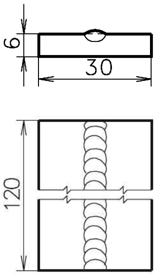


FIGURE 4.24
Straight line welding.

2. Figure 4.25 gives drawing of a square butt joint. Copy the figure and make the model using the given MS flat pieces.

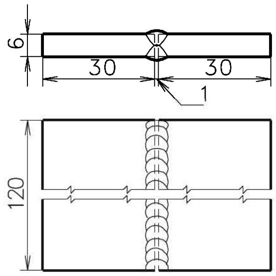


FIGURE 4.25
Square butt joint.

3. Copy the sketch of the single-V butt joint given in Figure 4.26. Then make the joint by welding the given MS flat pieces.

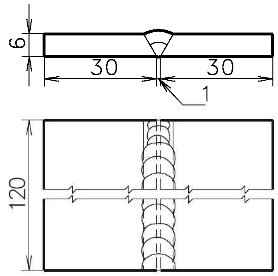


FIGURE 4.26
Single-V butt joint.

4. Make a double-V butt joint of size shown in Figure 4.27, using MS flat pieces. Also prepare a dimensioned neat sketch of the joint.

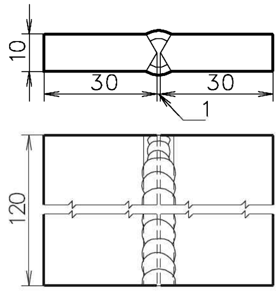


FIGURE 4.27
Double-V butt joint.

5. Figure 4.28 gives drawing of a Tee joint. Copy the figure and make the model by welding the given MS flat pieces.

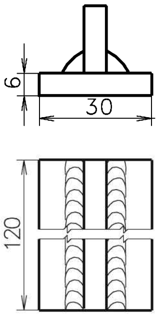


FIGURE 4.28
Tee joint.

6. Copy the sketch of the lap joint given in Figure 4.29. Then make the model of the joint by welding the given MS flat pieces.

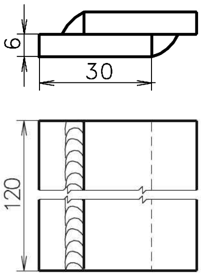
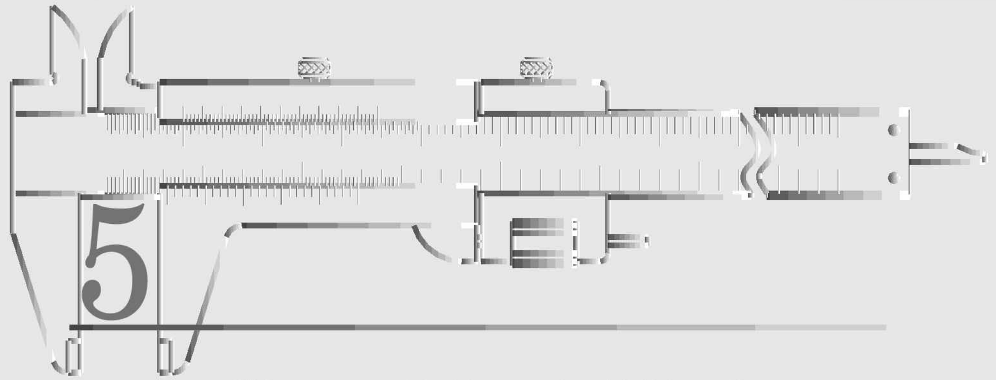


FIGURE 4.29
Lap joint.



5

Sheet Metal Work

Hand working of metal sheets of thickness ranging from 0.31 mm to 1.63 mm (Standard wire gauge 30 to 16) using hand tools and simple machines, is generally considered as sheet metal work. Many engineering components like hoppers, trays, guards, covers, pipes, hoods, bends, boxes, household equipment, steel furniture, etc., are made in small and medium quantities by this process. Sheet metal work basically consists of laying out the pattern by development of surfaces, cutting the sheets, folding and joining them to produce the required three-dimensional shapes.

5.1 Metals Used

A metal plate of thickness less than 4 mm is considered as sheet. The size of the sheet is specified by its length, width and thickness in mm. In British system, the thickness of sheet is specified by a number called *Standard Wire Gauge* (SWG). The commonly used gauge numbers and the equivalent thickness in mm are given below.

SWG (No.)	16	17	18	19	20	22	24	27	30
Thickness (mm)	1.62	1.42	1.22	1.02	0.91	0.71	0.56	0.42	0.37

As the gauge number increases, the thickness decreases. The metals used commonly for sheet metal works are:

1. Black iron (uncoated) sheets
2. Galvanized iron (GI) sheets

3. Copper sheets
4. Aluminium sheets
5. Tin plates
6. Stainless steel sheets

Black iron (uncoated) sheets

Mild steel sheets rolled to desired thickness are annealed (heating in a furnace to red hot temperature and cooling gradually) to convert them to soft metal. This process gives a blue black appearance to the surface and hence, they are known as *black iron sheet*. The sheets are used to make components like tanks, trays, covers, pipes, etc., by sheet metal work or welding. Then they are painted with enamel to protect them from corrosion.

Galvanized iron (GI) sheets

Iron sheets coated with zinc are known as G.I. sheets. The zinc coating protects the iron sheet from corrosion and gives better appearance. They cannot be welded since they produce toxic fume and residues. Many components which are in contact with water are made using G.I. sheets. The material used for sheet metal work in classrooms is G.I. sheets of thickness about 24 gauge (0.56 mm).

Copper sheets

Copper sheets are available in the cold rolled or hot rolled form. Cold rolled copper sheets are commonly used to produce special components like hoods, expansion joints, trays, etc., for chemical processes and for making utensils.

Aluminium sheets

Aluminium having a very small amount of alloying elements like copper, silicon, manganese, iron, etc., is rolled to form sheets. Aluminium sheets are very well used to make articles such as household appliances, building requirements, trays, hoods, hoppers, etc.

Tin plates

Iron sheets coated with pure tin are called tin *plates*. The coating gives bright silvery appearance and corrosion resistance. They are mainly used to make containers for packed food, oil, ghee, etc. and for making dairy equipment, cans and similar products.

Stainless steel sheets

Stainless steel is a metal basically containing iron, nickel, chromium and traces of other metals. It is highly corrosion resistant and can be welded easily. Stainless steel sheets are used similar to G.I. sheets. The areas of application include dairies, food processing units, chemical plants, kitchen utensils, etc.

5.2 Hand Tools

For measuring, marking cutting and forming, various types of hand tools are used in sheet metal work. A list of them is given below:

1. Measuring tools
2. Marking tools
3. Cutting tools
4. Forming tools
5. Joining tools

5.2.1 Measuring Tools

The following types of tools are commonly used in sheet metal shops to measure the dimensions of work pieces:

1. Steel rule
2. Vernier calliper
3. Micrometer
4. Sheet metal gauge

For description and figures regarding the above tools, refer Chapter 3—Fitting.

5.2.2 Marking Tools

In order to mark the patterns and their details on sheet metal, the following marking tools are generally used.

1. Straight edge
2. Steel square
3. Scriber
4. Divider
5. Centre punch

For marking the straight lines on sheet metal, straight edges [Figure 5.1(a)] are used. The use of steel square [Figure 5.1(b)] is similar to that of try square in bench work. The scribers, dividers, and punches are described with figures in Chapter 3.

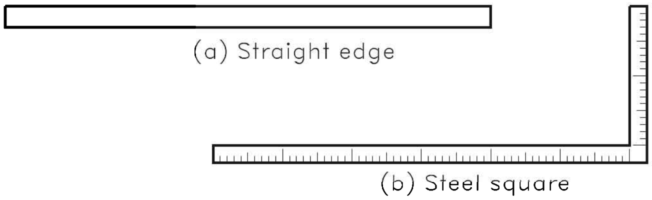


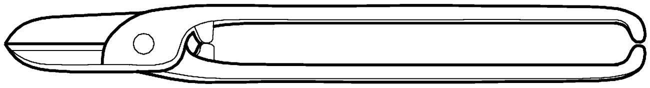
FIGURE 5.1
Tools to mark straight line and rectangle.

5.2.3 Cutting Tools

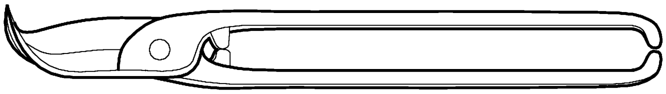
To cut the sheet metal as per the pattern drawn and to make holes for rivets etc., the following types of tools are used.

1. Straight snips (shears)
2. Bent snips (shears)
3. Solid punches
4. Hollow punches
5. Cold chisels
6. Files

A snip is a hand shear used to cut thin sheets of gauge size number 20 or above. It works like ordinary scissors. There are several types and sizes of snips available to cut along straight lines or curved lines. Figure 5.2(a) shows a straight snip having straight blades to cut along straight lines. Figure 5.2(b) shows a bent snip having curved blades to cut along curved lines. These snips are used for cutting thin sheets. The heavier types are known as bench shear and block shear. Solid punches are used to make small holes (2.5 to 10 mm) in sheets for riveting and similar works. Hollow punches are used to make large size holes (10 mm or larger) or to cut circular blanks. They are shown in Figures 5.2(c) and (d). To cut thicker sheets, rivets, rods, wires etc., cold chisels are used. To finish the edges to the required form, files of various shapes are used. The details about files and cold chisels are given in Chapter 3.



(a) Straight snip



(b) Bent snip

(c) Solid punch (d) Hollow punch

FIGURE 5.2
Cutting tools.

5.2.4 Forming Tools

Shaping of the sheet metal such as folding, bending, curling, etc., are done by using the following types of forming tools.

1. Stakes
2. Hammers
3. Mallet

4. Hand groovers.
5. Pliers
6. Bench vice

The types of anvil (support) on which the sheet metal operations are done are called *stakes*. They are of various shapes and sizes as shown in Figure 5.3. The stakes act as supporting as well as the forming tool for the shaping operations like bending, seaming, cutting, folding etc. The common forms of stakes are mentioned below:

(a) Half moon stake
(b) Beak horn stake
(c) Hatchet stake
(d) Funnel stake
(e) Horse head stake
(f) Convex stake
(g) Square stake

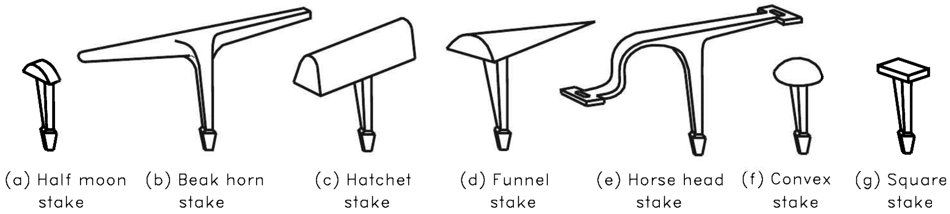

(a) Half moon stake (b) Beak horn stake (c) Hatchet stake (d) Funnel stake (e) Horse head stake (f) Convex stake (g) Square stake

FIGURE 5.3
Different types of stakes.

The sheet metal is shaped by hammering or striking with mallet, after keeping the work on suitable form of stake. The hammers used for sheet metal work are (a) *Setting hammer*, for setting down the edge while making double seam, (b) *Raising hammer* for forming curved or hollow shape from flat piece, and (c) *Riveting hammer* for riveting purpose. *Mallets* are soft hammers used to give soft blows which will not damage the sheet at the same time will shape them. The commonly used types of hammers and mallets are shown in Figure 5.4.

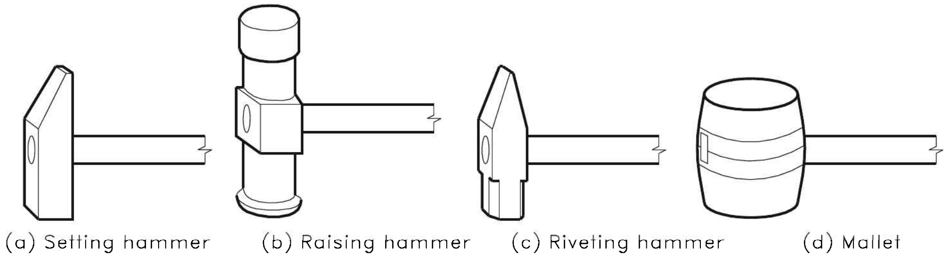

(a) Setting hammer (b) Raising hammer (c) Riveting hammer (d) Mallet

FIGURE 5.4
Different types of hammers.

5.2.5 Joining Tools

The tools exclusively used for making and finishing joints are:

(a) Hand groovers
(b) Rivet set
(c) Soldering irons

Hand groovers are used to flatten and shape joints made in sheet metal. The tool has a groove of required width and depth like a die. This groover is placed over the joint (double hem or lock seam) and hammered from the top of it, to shape the joint as that of the groove (Figure 5.5). For shaping the second head of a rivet, a riveting tool called *rivet set* is used. This can convert the rough shape of a rivet formed by hammering to a smooth round head by final hammering over the tool.

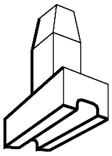


FIGURE 5.5
Hand groover.

A *soldering iron* consists of a copper block, fixed on an iron rod with a wooden handle. It is made in various shapes and sizes to suit the use as shown in Figure 5.6. The purpose of the copper block is to act as a heat source for melting and spreading the *solder* (filler metal) at the joining area. The soldering iron (copper) is heated using furnace, blower or by electrical resistance.

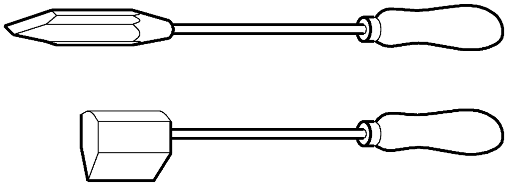


FIGURE 5.6
Forms of soldering iron (copper).

5.3 Sheet Metal Operations

The standard size sheets of required thickness available in the market, are converted to sheet metal products by various hand operations using the sheet metal working tools. The sheet metal operations commonly used are as follows:

1. Laying out of patterns
2. Cutting or shearing
3. Bending and forming
4. Drawing
5. Edge forming

6. Joint making
7. Soldering
8. Riveting

5.3.1 Laying Out of Patterns

The first operation for a sheet metal work is the preparation of the development of the object to be made. The development with the allowances for joints, is called the *pattern stretch out* of the object to be shaped. The accuracy of the shape of the object mainly depends on the accuracy of geometry of the pattern.

The pattern stretch out may be drawn on a drawing paper and then, after corrections if any, can be transferred to or can be laid directly on the sheet metal by scribing. For repetition works, a *template* of the pattern can be prepared and the outline of it can be marked on the sheet metal for reducing the time requirement.

To find the development-patterns of objects, basically there are four methods.

1. *Parallel line method:* Suitable to prisms and cylinders.
2. *Radial line method:* For pyramids and cones.
3. *Triangulation method:* For transition pieces.
4. *Approximate method:* For spherical surfaces.

The method of drawing of development of surfaces is explained in books dealing the subject *Engineering Graphics*. After developing the outer skin of the object to a plane surface, the allowances for joints, edges, etc. are added to the size to get the final pattern for shearing.

5.3.2 Cutting or Shearing

The cutting or shearing operations are conducted to convert the shape of the sheet to that of the pattern. The different types of shearing operations used are mentioned below:

1. *Cutting off:* To cut along a straight line to get or remove a piece; snips are used for this.
2. *Parting:* To cut into two pieces by removing the scrap; snips are used for this.
3. *Blanking:* To remove a large area of sheet metal along a closed boundary, generally a large circular shape; large size hollow punches are used for this.
4. *Punching:* This is an operation of making small size holes with a solid punch by hammering on it, after keeping the sheet over a die hole of same diameter of the punch.
5. *Notching:* This is a process of removing metal to the desired shape from an edge of the sheet. Snips or clod chisels are used for this.
6. *Slitting:* This is a process of cutting along a number of parallel lines to form the slits using snips.

7. *Lancing:* This is a cutting operation partly across a strip.
8. *Trimming:* This is the operation of cutting away the excess metal by snips or chisel.

5.3.3 Bending and Forming

The bending and forming operations shape the metal into angles or curvatures. These operations involve stretching of metal on the outer surface, at the same time compressing the metal on the inner side. The bending and forming operations are done by hammering, with mallets or hammers.

5.3.4 Drawing

This is an operation to produce hollow shapes like vessels from flat thin sheets. Usually a drawing punch and a die of correct size are required for this. Drawing operations are successfully done using hand-operated or power-operated machines.

Vessels or shallow trays can be made by a hand drawing process called *hollowing*. In this process, the metal is beaten into hollow indentation by stretching due to hammering. Similar to hollowing, raising is another process of forming. Here, the metal is beaten over a spherical head using hammers, so that the metal is raised at the middle of a blank forming a spherical projection.

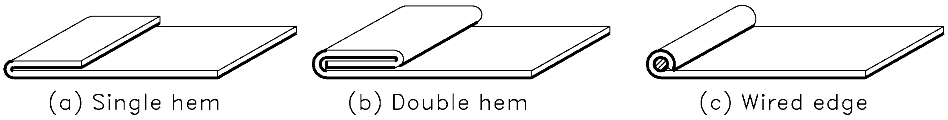
5.3.5 Edge Forming

For sheet metal objects strength is given to the edge and the sharpness is eliminated by folding the edge. The common types of foldings used in sheet metal work are as follows:

1. Single hem
2. Double hem
3. Wired edge

Figure 5.7 shows the three types of edge foldings. A wired edge consists of an edge wrapped around a steel wire for better strength.

FIGURE 5.7
Types of folded edges.


(a) Single hem
(b) Double hem
(c) Wired edge

5.3.6 Joint Making

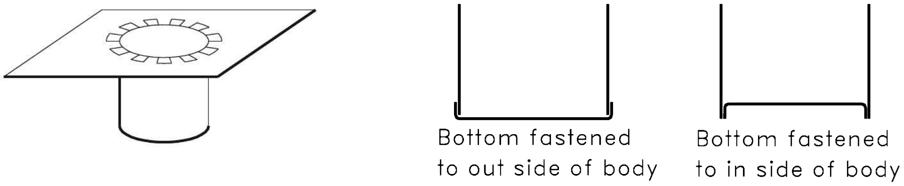
The line of joint on a sheet metal pieces is called *seam*. The most common types of seams are as follows:

1. Lap seam
2. Grooved Seam
3. Single seam
4. Double seam
5. Dove tail seam
6. Flanged (burred) bottom seam

1. *Lap seam:* This is the simplest seam used in sheet metal work [Figure 5.8(a)]. This consists of one edge lapping over the other and joint is made by soldering or riveting.
2. *Grooved seam:* A grooved seam is made by hooking two-folded edges together and then off setting them as shown in Figure 5.8(b). This joint is self-locking and stronger to some extent than lap seam.
3. *Single seam:* This seam is used to join a bottom portion to a vertical body as shown in Figure 5.8(c). The bottom edge is hooked over the bent edge of the vertical body. This method of joint can be used for square, rectangular or round containers.
4. *Double seam:* This seam is similar to single seam with the difference that the formed edge is bent upwards against the body as shown in Figure 5.8(d).
5. *Dove-tail seam:* This seam is used to connect a cylindrical piece to a flat as shown in Figure 5.8(e). The edge of the cylindrical part to be joined is slit at short distance and is bent so that alternate pieces come inside and outside of the joint. Permanent joint is obtained by soldering or riveting.
6. *Flanged (burred) bottom seam:* This seam is used to fasten the bottom of a container to its body. The flange of a cylindrical job is often called a *burr*. The joint consists of a narrow flange which may be joined to inside or outside of the vessel [Figure 5.8(f)].

(a) Lap seam (b) Grooved (Locked) seam

(c) Single seam (d) Double seam



(e) Dovetail seam (f) Flanged (burred) bottom seam

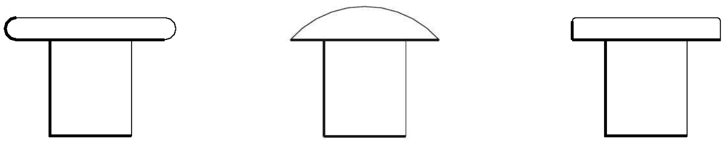
FIGURE 5.8
Types of seam

5.3.7 Soldering

Soldering is the process of fastening two or more pieces of metal by means of an alloy which has lower melting point than the base metal being joined. To solder sheet metal, the items required are soldering iron (copper), the furnace to heat the soldering iron, solder and a flux. The solder used is of the composition of tin and lead of equal quantity. The flux used is a paste or solution of zinc chloride. After applying the flux to the joining region, heated soldering iron is rubbed over the area and the solder is added to the region to get the joint. For thicker sheets, the joining area is to be heated nearby the soldering temperature using blow lamp or furnace heating.

5.3.8 Riveting

Sheet metal objects are joined permanently by riveting. Special rivets called *tinner's rivets* are used for such purpose. These rivets are made of soft iron and are usually coated with tin. For riveting aluminium or joints of less strength, aluminium rivets are used. Figure 5.9 shows the common shapes of rivets used for sheet metal work.


(a) Tine's' rivet

(b) Aluminium rivet

FIGURE 5.9
Types of rivets.

To make a riveted joint, drill or punch the holes of correct size of rivet. The size of rivet is taken as about 2 to 3 times the total thickness of the metal pieces to be joined. Insert the rivet in the hole and set the head on some metal bar or stake. Slip the deep hole of the *rivet-set* over the rivet tail and strike the rivet-set a few sharp blows. This draws the metal and rivet together. Then blow on the rivet tail to form a rough head using the hammer for riveting. To finish the head, place the cup-shaped *rivet-set* over the flattened rivet tail and strike the rivet set until the head is shaped.

5.4 Sheet Metal Work Practice

Example

Make a square tray of given dimensions in Figure 5.10 using GI sheet.

Aim

To make a square tray of given dimensions using the given GI sheet.

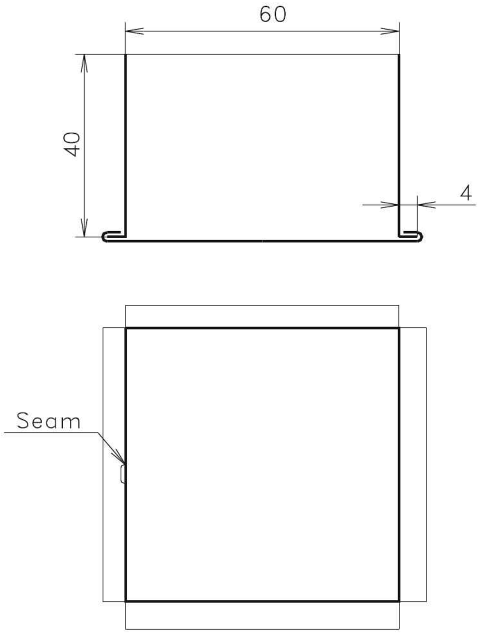


FIGURE 5.10
Square tray.

Materials required

GI sheet of (SWG 26) of size : 253 mm × 44 mm, 1 No.
78 mm × 78 mm, 1 No.

Tools required

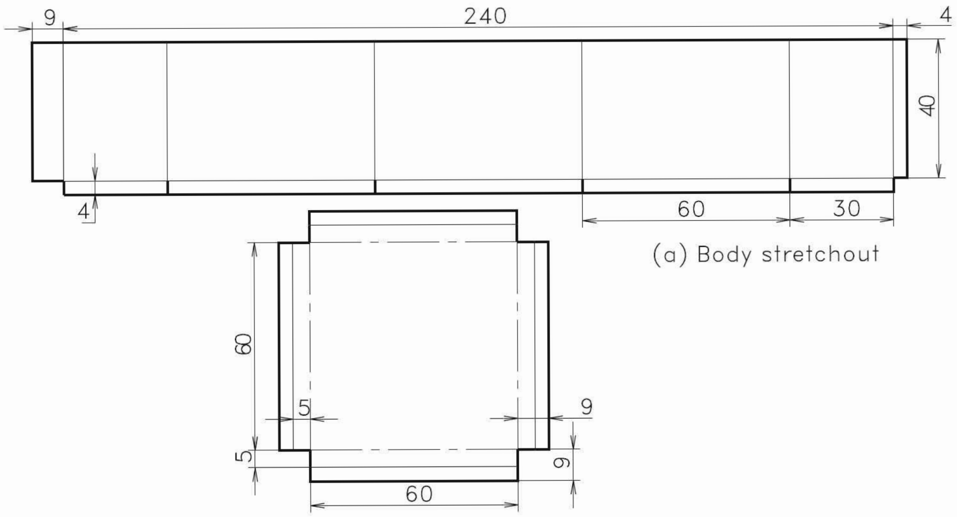
1. Steel rule, 2. Setting hammer, 3. Straight snip, 4. Try square, 5. Bench vice, 6. Flat file, 7. Square stake, 8. Scriber, 9. Hand groover, 10. Mallet.

List of operations

1. Laying out and Marking, 2. Cutting, 3. Bending, 4. Filing, 5. Joint making,

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools, and sheet metal.
3. Sketch the layout of pattern by drawing the development of the tray and add the allowances for joints as shown in Figure 5.11.
4. Mark the layout on the sheet metal using the scriber.
5. Cut the sheet along the marked lines using the snips.
6. Do all bending operations on the sidepiece to get the square-shaped vertical sides and make the grooved seam using the hand groover.
7. Place the sidepiece over the bottom stretch out and bend the four edges to form the single seam as given in the drawing.
8. File the top edge and the sharp corners to get the finished model.



(a) Body stretchout

(b) Bottom stretch

FIGURE 5.11
Square tray (layout).

EXERCISES

Questions for Viva Voce

(A) Tools and equipment

1. What is meant by sheet metal? How a sheet is distinguished from a plate?
2. Give a list of materials used for sheet metal work.
3. What is meant by G.I. sheet? Give a brief explanation.
4. Describe how a sheet metal is specified.
5. What are the measuring and marking tools used for sheet metal work?
6. Give a list of forming tools used.
7. What is meant by a stake? Describe the use of stakes.
8. Why mallet is used mainly for forming the sheets?
9. Give a list of the types of hammers used.
10. What is the use of hand groover? Explain how it is used?
11. Explain the use of soldering iron for sheet metal works.
12. Describe the method of making small and large size holes on sheets.

(B) Practice

13. How the pattern of an object for sheet metal work is prepared?
14. Explain the term stretch out related to development of an object.
15. Explain the different types of shearing operations conducted in sheet metal work.

16. Explain the operations: bending, forming and drawing.

17. What are the types of hems? When a wired edge is required for an object?

18. Give a list of the joints made in sheet metal. Describe them briefly with examples.

19. Explain the process of soldering in sheet metal.

20. Describe the process of making riveted joints in sheet metal.

Models for Sheet Metal Work Practice

Make the following models:

1. Figure 5.12 gives drawing of a model for marking and cutting practice. Copy the figure and make the model using the given GI sheet.

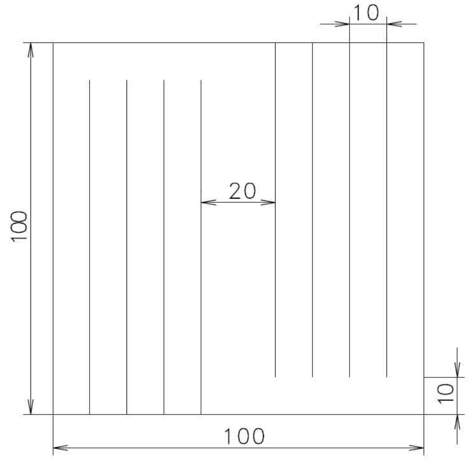


FIGURE 5.12
Model for marking and cutting practice.

2. Copy the sketch of the locked—grooved seam joint given in Figure 5.13. Then make the joint using the given GI sheet.

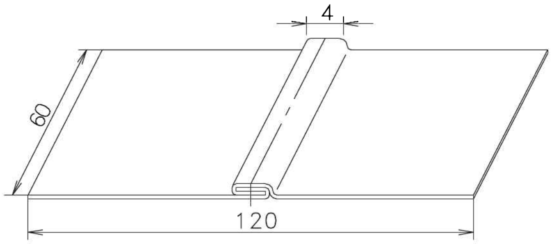


FIGURE 5.13
Locked grooved seam.

3. Make a locked—grooved seam with hemming joint of size shown in Figure 5.14, using the given GI sheet. Also prepare a dimensioned neat sketch of the joint.

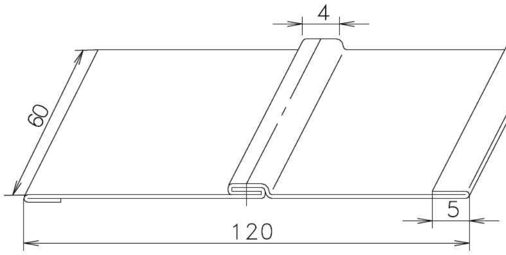


FIGURE 5.14
Locked grooved seam with hemming.

4. Figure 5.15 gives locked up seam joint. Copy the figure and make the model by using the given GI sheet.

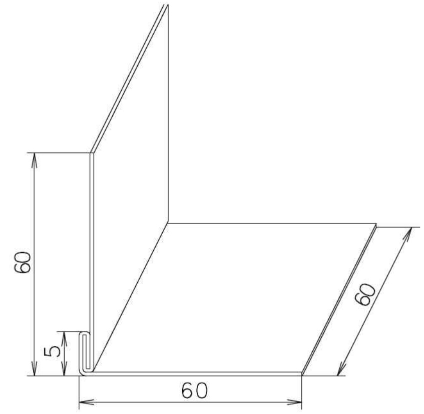


FIGURE 5.15
Locked up seam

5. Copy the sketch of the double—grooved seam joint given in Figure 5.16. Then make the joint using the given GI sheet.

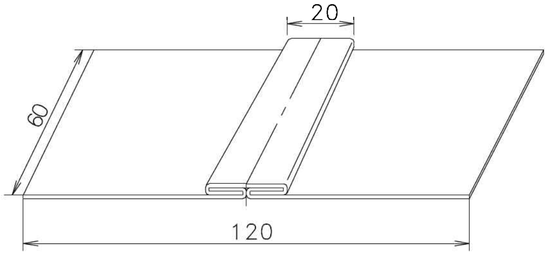


FIGURE 5.16
Double grooved seam.

6. Make a square tray of size 110 × 110 × 25 mm shown in Figure 5.17, using the given GI sheet. Also prepare a dimensioned neat sketch of the tray.

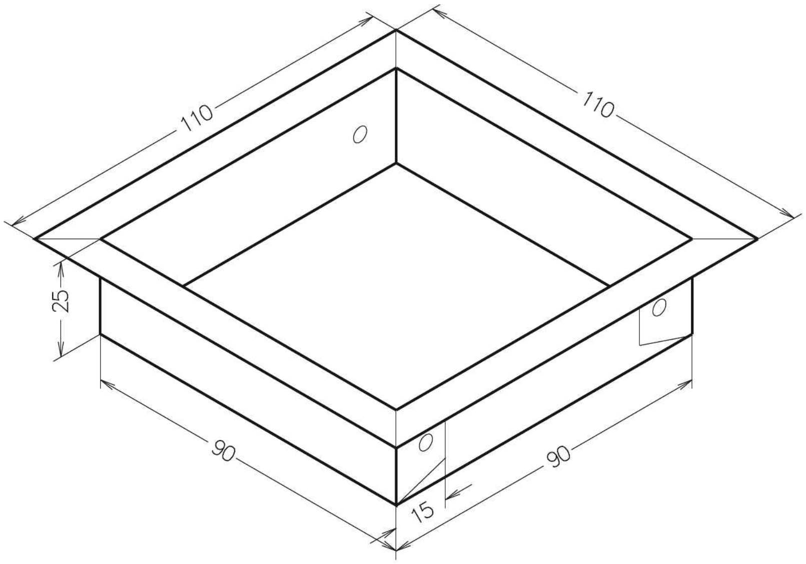


FIGURE 5.17
Square tray.

7. Figure 5.18 gives pictorial view of a dust pan. Copy the figure and make the pan by using the given GI sheet.

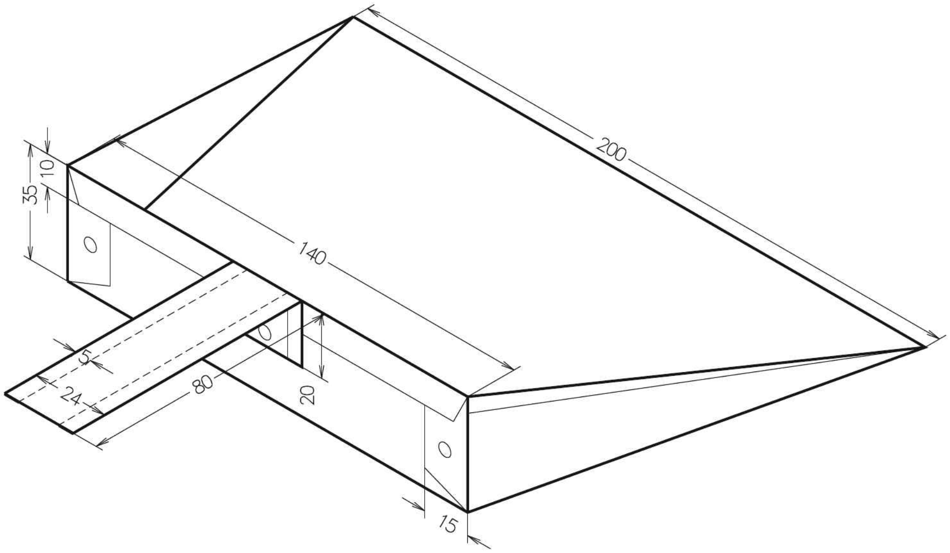
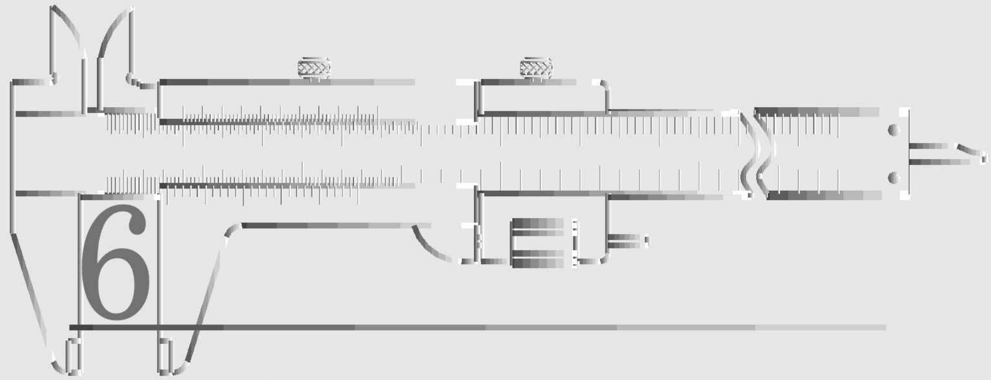


FIGURE 5.18
Dust pan.



6

Carpentry

Carpentry is the process of shaping timber, using hand tools. The products produced are used in building construction, such as doors and windows, furniture manufacturing, patterns for moulding in foundries, etc. Carpentery work mainly involves the joining together of wooden pieces and finishing the surfaces after shaping them. Hence, the term *joining* is also used commonly for carpentry. A student studying the fundamentals of wood working has to know about timber and other carpentry materials, wood working tools, carpentry operations and the method of making common types of joints.

6.1 Materials Used in Carpentry

Basic materials used in carpentry shop are timber and plywood. Auxiliary materials used are nails, screws, adhesives, paints, varnishes, etc.

6.1.1 Timber

Timber is the name given to wood obtained from exogenous (outward growing) trees. In these trees, the growth is outward from the centre, by adding almost concentric layers of fresh wood every year known as *annual rings*. After the full growth, these trees are cut and sawed to convert into rectangular sections of various sizes for engineering purposes.

Timber is available in market in various shapes and size. The common shapes and sizes are given below:

1. *Log:* This is the trunk of the tree which is free from branches.
2. *Balk:* This is the log after sawing roughly to square cross section.
3. *Deal:* This is the log after sawing into rectangular cross section of width about 225 mm and thickness up to 100 mm.
4. *Plank:* This is the timber piece having width more than 275 mm and thickness 50 to 150 mm.
5. *Board:* This is the timber piece below 50 mm in thickness and above 125 mm in width.
6. *Batten:* This is the timber piece below 175 mm in width and thickness between 30 mm to 50 mm in thickness.
7. *Scantlings:* These are timber pieces of various assorted and nonstandard sizes other than the types given above.

6.1.2 Classification of Wood

The timber used for commercial purposes can be divided into two classes *as soft wood* and *hard wood.*

Soft wood

A soft wood is light in weight and light coloured. They may have distinct annual rings but the medullary rays (radial lines) are not visible and the colour of the *sap wood* (outer layers) is not distinctive from the *heart wood* (inner layers). These woods cannot resist stresses developed across their fibres; hence, not suitable for wood working.

Hard wood

In this type of wood the annual rings are compact and thin, and the medullary rays (radial lines) are visible in most cases Figure 6.1. Hard woods are nearly equally strong both along and across the fibres. Hard wood is the material used for wood working.

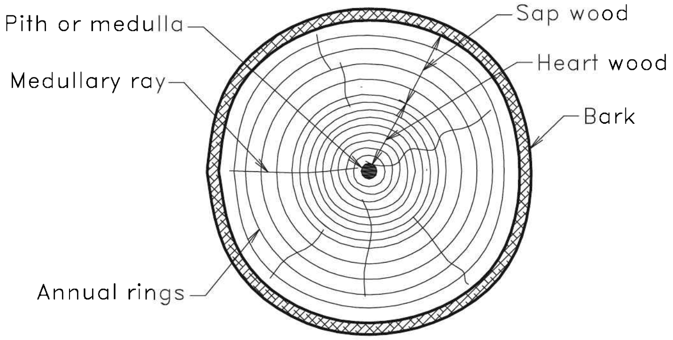


FIGURE 6.1
Cross-section of a hexogenous tree.

6.1.3 Indian Timber

There are a number of types of hard wood and soft wood available in India, which are suitable for carpentry work. Some of the popular names and a brief description of them are given below.

Teak: This is a strong hard wood suitable for almost all important carpentry works. It has brown colour, is comparatively light in weight and easy to work. Shrinking during drying is little and can be easily seasoned. Highly finished and polished surfaces can give very good smoothness and appearance. Due to all these advantages, teak wood is commonly used for costly furniture, doors and windows. Teak is available in all over India and has small difference in material, properties and appearance from place to place.

Sissu: This is a dark brown, tough and durable hard wood. It is considered as one of the best Indian woods suitable for furniture. This wood is available in northern and central India.

Sal: This is a heavy, dark-coloured, close-grained hard wood. It is extensively used for building works as well as for railway spleepers. They grow abundantly in forests all over India. Seasoning of this wood is very slow and the wood working is hard.

Mahogany: This is a hard wood having red brown colour. The grains are fine and have wavy shape. Since the wood contains resinous oil, insects cannot attack the wood. They are largely found growing in Himalayas. For pattern making and cabinet work, mahogany is very commonly used.

Deodar: This is a light-coloured coarse grained wood used for carpentry work. Furniture, doors and windows, railway sleepers, etc. are built using this wood. They are seen in central and northern parts of India.

Babul: This wood is pale red to brown in colour, hard and close-grained. It is used for making agricultural implements, body of carts, tool handles, etc. The wood grows all over India and is readily available for use.

Mango: This is a soft wood of inferior quality. It can decay when exposed to wet weather and is affected by white ants. The wood is cheap and available all over India and used for making low cost doors, windows and furniture.

6.1.4 Plywood

Plywood is a thick sheet formed by pasting veneers of wood called *plys* together using glues. There will be three or more plys in a sheet and the grains of adjacent layers are kept at right angles to each other in order to get better strength in both directions. The outer layers are called *facing plys* and good hard wood veneers are used for that. The inner ones are called *core plys* and low quality wood is used for them. The plywood is made by either cold pressing or hot pressing.

Plywood can be used as solid board or stock which are having uniform thickness. Since the grains are oriented in perpendicular directions, plywood has better strength in both directions. It can be made in very large sheet size without joints. Plywood sheets can be bent to shapes of different designs. Decorative surfaces can be obtained by using costly attractive facing plys like teak wood. Due to the above advantages plywood sheets are very widely used for making furniture, boxes, doors, cupboards, etc.

6.1.5 Auxiliary Materials

There are a number of materials, other than timber, used in carpentry work. A brief description of them are given below:

1. *Screws:* Screws of different sizes and head forms are commonly used for fixing metallic fittings like hinges, tower bolts, etc. and for screwing parts strongly. They are made in steel or brass and is screwed to wood using screw drivers.
2. *Bolts and nuts:* To join heavy wooden parts, bolts and nuts of standard size are commonly used.
3. *Nails*: Wire nails having different head forms are used for reinforcing glued joints and fastening different parts. They may be made of brass, copper or mild steel.
4. *Dowels:* A dowel is a wooden pin made out of bamboo or similar wood by the carpenter. It is used to secure wooden joints tightly by inserting through drilled holes across them.
5. *Adhesives:* To join parts having large area of surfaces, glues of different types are used. After applying the glue on the surface to be joined, the parts are kept in assembled position and secured tightly using clamps till drying or curing is complete. Some of the adhesives used in wood work are animal glue, casein glue, resin glue, vegetable glue, contact cement, etc.
6. *Surface coatings:* After finishing the carpentry work, the surfaces of wooden parts are protected from moisture and weather by applying varnish, polish or oil paint. They can give better appearance also. *French polish* is the coating material commonly used for fine finished wooden parts. This consists essentially of *shellac* dissolved in methylated spirit. Synthetic enamel is the oil paint generally used to coat semi-finished wooden surfaces. A primer of this is applied initially, followed by enamel paint to get the finished surface.

6.2 Tools for Wood Working

There are a number of hand tools used in carpentry shops. They can be classified according to their uses mentioned below.

1. Measuring and marking tools
2. Cutting tools
3. Striking tools
4. Planing tools
5. Work holding devices
6. Miscellaneous tools

6.2.1 Measuring and Marking Tools

Rules

For measuring and setting out dimensions, various types of rules are used in carpentry shops. They include the following:

1. *Steel rule:* A stainless steel rule of length 30 cm or 60 cm.
2. *Fourfold box-wood rule:* This is a wooden scale consisting of four pieces joined together by hinges. The total length is usually 60 cm.
3. *Flexible measuring rule:* For measuring large dimensions as well as curved or angular surface dimensions, these tape type rules are used. When they are not in use, the tape is coiled into a small compact circular case.

Straight edge and squares

To measure straightness as well as the perpendicularity of surfaces or edges, the following types of tools are used.

1. *Straight edge:* This is a machined flat piece of wood or metal having perfectly straight and parallel edges.
2. *Try square:* This consists of a rectangular steel blade fixed rigidly to a hard wood stock or cast iron stock. The size varies from 150 to 300 mm according to the length of blade (Figure 6.2).

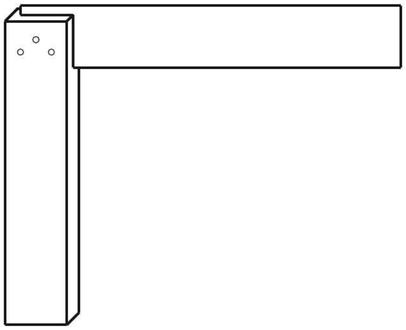


FIGURE 6.2
Try square.

3. *Mitre square:* For measuring 45°, a mitre square made of metal is used. The length of the blade is usually 200 to 300 mm.

4. *Bevel square:* For setting, duplicating, testing or comparing angles, a bevel square is used. It is similar to try square with a difference that the blade can be swivelled to any angle and fixed by screwing a wing nut.
5. *Combination square:* This is a combination of a square, 45° bevel, set square, rule, straight edge and centre finder, similar to the one used in fitting shops (Refer to Chapter 3).

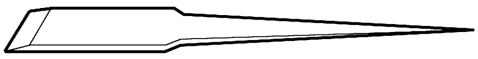
Scriber or marking knife

To convert the pencil lines drawn on the wooden surface into deep scratch lines on the surface, the marking knife is used. They are made of steel with a sharp point at one end and a flat blade at the other end as shown in Figure 6.3(a).

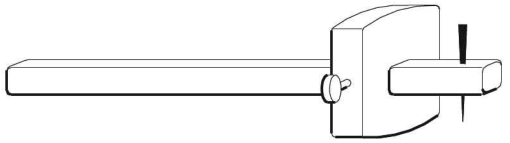
Gauges

Gauges are used to mark lines parallel to the edge of a wooden piece. It mainly consists of a wooden stem sliding inside a wooden stock. The stem carries one or more steel marking points at one end. The stock position on the stem can be varied and fixed rigidly by tightening the thumb screw. To mark a line parallel to an edge, the gauge stock is held firmly against the edge and pushed along it, pressing the steel pointer to the surface. Depending on the purpose, the gauges can be grouped as mentioned below:

1. *Marking gauge:* [Figure 6.3(b)] To mark single line.
2. M*ortise gauge:* To mark two parallel lines.
3. *Cutting gauge:* To cut thin section to get straight strips (up to 3 mm) instead of marking parallel to the edge.



(a) Marking knife



(b) Marking gauge

FIGURE 6.3
Marking tools.

Miscellaneous measuring tools

In carpentry shops there are many measuring and marking tools other than the types explained above. Some of the frequently used tools are given below:

1. *Wing compass:* It is used to mark circles, arcs etc.
2. *Trammel:* This is a beam compass to mark large size radius.
3. *Divider:* It is used to divide and mark dimensions.

4. *Spirit level:* It is used to check the horizontality of flat surfaces.
5. *Plumb bob:* It is used to check the verticality of a surface.

6.2.2 Cutting Tools

Saws

Saw is a cutting tool which has teeth on one edge and cutting is effected by reciprocating motion of the edge relative to the workpiece. There are different types of saws depending on the shape, size, use and direction of cutting motion. If the cutting occurs during the forward motion, such a saw is called *push type*, whereas in pull type the cutting occurs during backward motion. Commonly used types of saws are briefly explained below.

1. *Cross cut saw (Hand saw):* It is used to cut thick wooden pieces across the grains (Figure 6.4). Cross cut saw has about 3 to 4 teeth per cm with a saw length of about 650 mm.

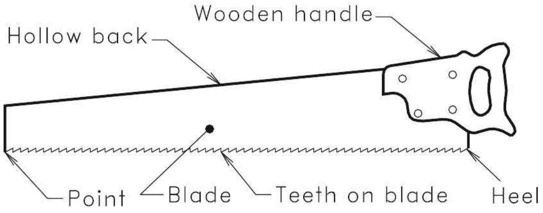


FIGURE 6.4
Cross cut saw.

2. *Tenon saw (Back saw):* This saw is used for short straight cuts (Figure 6.5). It has a parallel blade of 25 to 40 cm length and 6 to 10 cm width. The number of teeth per cm length ranges from 5 to 8. In order to avoid bending of blade during sawing, the blade is provided with a reinforcing strip at the top.

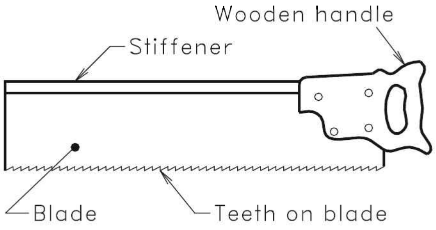


FIGURE 6.5
Tenson saw.

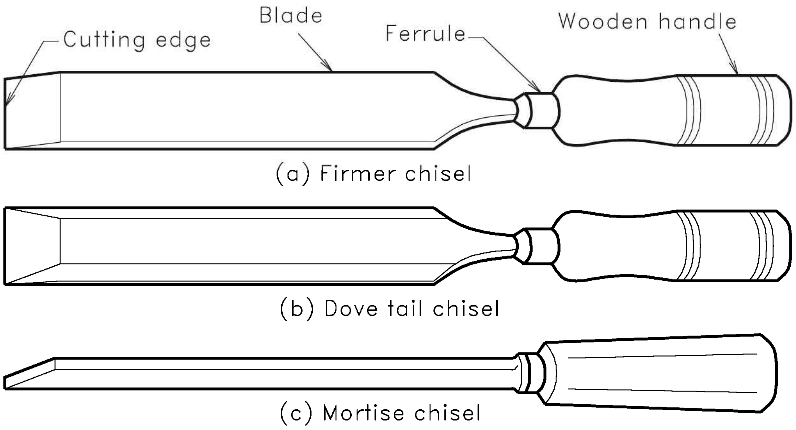
3. *Rip saw:* It is a saw similar to hand saw used to cut wood along the grains.
4. *Panel saw:* This is similar to cross cut saw having finer blade and teeth, used for cutting panels of doors or similar pieces.
5. *Compass saw:* This is a saw having tapered blade which is narrow, long and flexible. It is used to cut along straight or curved lines.

6. *Dove-tail saw:* This is a saw of fine type like tenon saw, used to take fine and accurate cuts. The back side stiffener is provided in the saw.
7. *Key hole saw (pad saw):* This is the smallest type of saw used to cut key holes or the starting of any interior cut.
8. *Bow saw:* This saw has a narrow blade on a wooden frame of the shape of a bow. It is used to cut along sharp curves.
9. *Coping saw:* This saw has a narrow blade held in tension by a spring metal frame. It is used to cut small radius curves in thin wooden pieces.

Chisels

A large number of chisels are used in carpentry shops for cutting wood to get different desired shapes. The common types of chisels used are briefly explained below.

1. *Firmer chisel:* They are the most common and general purpose chisel used by a carpenter [Figure 6.6(a)]. They have flat blade of about 15 to 50 mm width and 125 mm length.
2. *Bevelled edge firmer (dove-tail) chisel:* These chisels are used for fine and delicate works as well as for cutting corners [Figure 6.6(b)].
3. *Mortise chisel:* These chisels are used for heavy and deep cuts to remove a large quantity of wood. These chisels have width of about 15 mm, but the blade thickness may range from 6 to 15 mm [Figure 6.6(c)].
4. *Gouges:* These are chisels with curved sections. They are used to cut curved shapes of internal or external type.



(a) Firmer chisel

(b) Dove tail chisel

(c) Mortise chisel

FIGURE 6.6
Chisels.

6.2.3 Striking Tools

1. *Mallet:* This is a wooden-headed hammer of round or rectangular cross section. The striking face is made flat as shown in Figure 6.7(a). Mallet is used for striking the cutting tools and has wooden handle.

2. *Claw hammer:* This is a hammer having steel head and wooden handle. The flat face of the head is used to drive nails and the claw portion for extracting nails out of the wood [Figure 6.7(b)].

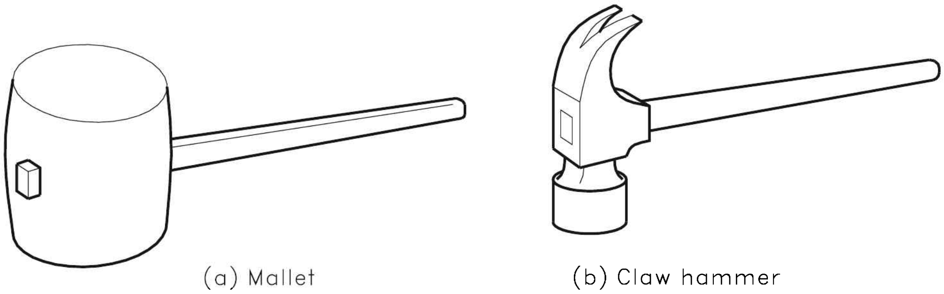


FIGURE 6.7
Striking tools.

6.2.4 Planing Tools

To smoothen the flat wooden surfaces, planing tools are used. Depending on the size and construction and the surface finish obtained, planes are classified into the following categories.

1. *Wooden jack plane:* This is the most commonly used plane in carpenters shops. The main part of a wooden jack plane is a wooden block called *sole,* to which a steel blade having knife edge is fixed at an angle with the help of a wooden wedge. The angle of the blade is kept about 45° to the bottom surface of the blade (Figure 6.8). The size of the blade is taken as 50 to 75 mm. The knife edge of the blade is kept projecting 0.8 to 1.6 mm for roughing and 0.8 mm to lower value for finishing.

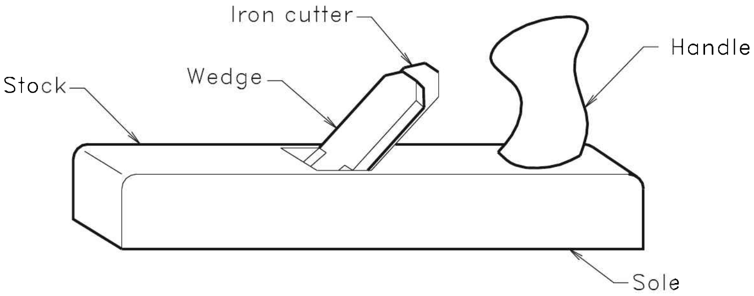


FIGURE 6.8
Wooden jack plane.

2. *Iron jack plane:* In an iron jack plane the wooden sole is replaced by a cast iron channel-shaped body. A wooden knob in the front side and a wooden handle at the back side are fixed on the sole for pushing with two hands. The working principle is the same as that of wooden jack plane. Iron jack plane can give better finish, more life and fast stock removal, but the cost is higher than that of a wooden jack plane.

3. *Smoothing plane:* A smoothing plane is practically a wooden plane of smaller size, used for smoothening and finishing operations. Its length varies from 200 to 250 mm.

4. *Special planes:* There are a number of types of planes used for special applications. A list of the important ones are given below:

(a) *Trying plane:* It is a large size plane to get fine flat surface.
(b) *Rebate plane:* It is used to make recess along the edge of a piece.
(c) *Plough plane:* It is used to make groove for fitting panels.
(d) *Router plane:* It is used to finish the bottom of a groove.
(e) *Circular plane:* It is used to smoothen circular surfaces.

6.2.5 Work Holding Devices

1. *Work bench:* This is a table of heavy size and rigid construction made of hard wood. The size ranges from 50 to 180 cm in length and about 90 cm in width. Two or four carpenters can work at a time on this work bench. Carpenter's vice and bench-hook are fixed on the edge and top respectively as shown in Figure 6.9.

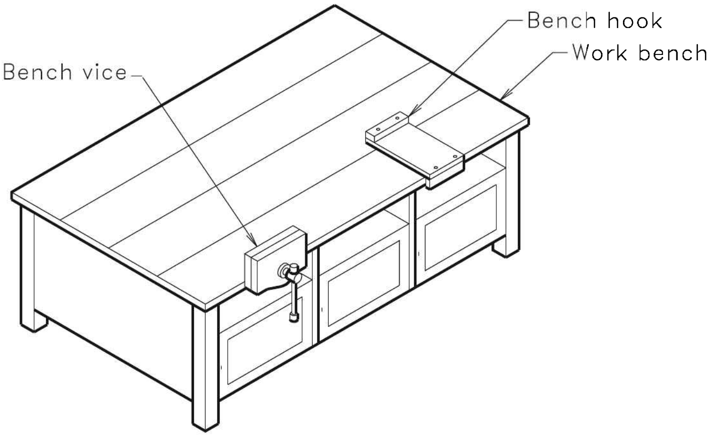


FIGURE 6.9
Work bench.

2. *Carpenter's bench vice:* The most common type of bench vice used in a carpentry shop is shown in Figure 6.10. It consists of a jaw fixed on the table side and a movable jaw kept in position by means of a screw and a handle. The body of vice is made of cast iron or steel. The jaws are lined with hard wood which can be renewed when it is damaged. The screw works inside a fixed half nut which can be engaged or disengaged by operating the lever. By pulling the lever the nut is disengaged from the screw allowing the jaw to move fast. When the lever is released, the nut engages and the screwing action is obtained.
3. *Bench stop (hook):* A bench stop or hook is a wooden block of shape as shown in Figure 6.11. This is placed on the edge of the work bench in order to prevent the workpiece moving forward, while planing or chiselling.

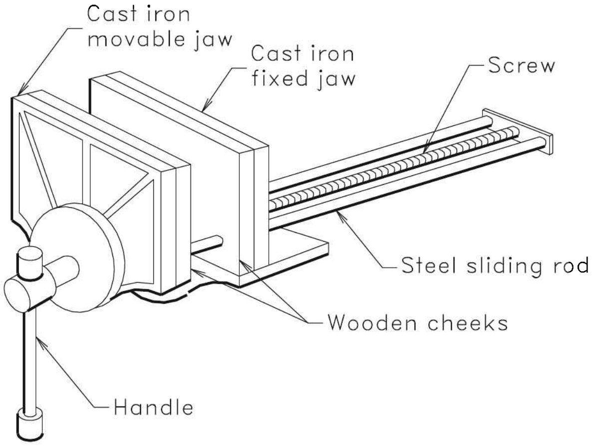


FIGURE 6.10
Bench vice.

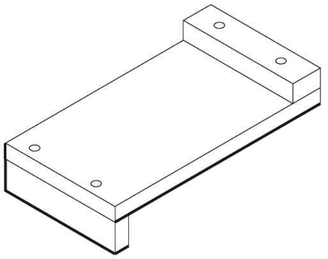


FIGURE 6.11
Bench hook.

4. *Bench hold fast:* The bench hold fast shown in Figure 6.12 is made up of steel and is used to hold the work piece on the table, while doing cutting or similar operations.

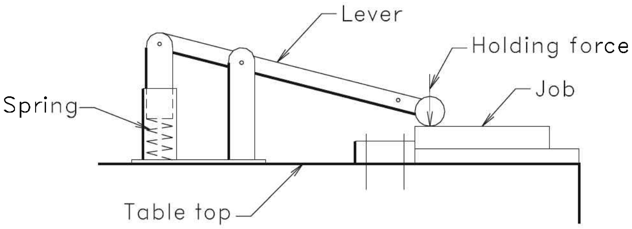


FIGURE 6.12
Bench hold fast.

5. *Sash (bar) cramp:* This is made of a bar of steel, two jaws and a screw as shown in Figure 6.13. The work is clamped between jaws by rotating the screw using the handle. It is used for clamping glued pieces tightly or holding the workpieces of large size together for various operations.
6. *C or G clamp:* The clamp of the shape of letter C or G is used to clamp short pieces together as the bar cramp. Figure 6.14 shows a typical form of the clamp.

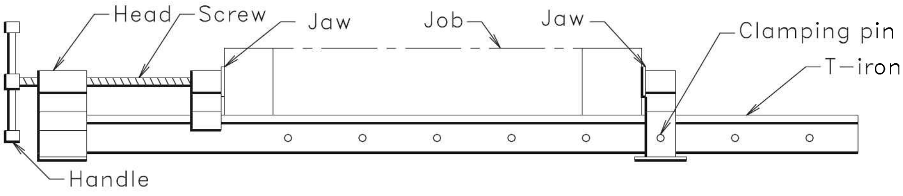


FIGURE 6.13
Sash (Bar) cramp.

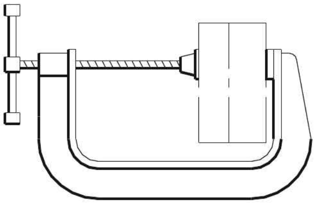


FIGURE 6.14
C or G clamp.

7. *Hand screws:* Figure 6.15 shows the general form of a hand screw. It is used for clamping or holding pieces tightly for various carpentry operations or pasting sheets together.

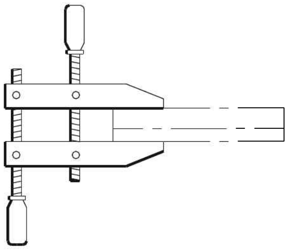


FIGURE 6.15
Hand screw.

6.2.6 Miscellaneous Tools

There are a number of tools other than the types explained above, which are used in carpentry shops to meet the requirements. The frequently used tools of this group are given below.

1. *Rasps and files:* Rasp is a rough file used to remove wood from the surface, corners, etc., resulting very rough surface. Ordinary files are used to smoothen such surfaces.
2. *Sand paper:* This is a thick paper coated with sharp-edged sand or glass particles of fine type on one side of it. When the sand paper is rubbed on the surface, a thin layer of wood is removed resulting smooth surface. The grades of them are denoted by numbers as 00, 1, etc.
3. *Pincer:* This is a tool similar to pliers and is used while screw is extracted from or driven into the wood.
4. *Screw drivers:* They are used to drive wood screw into or from the workpiece.

5. *Hand drill:* To make small size holes of less depth, hand drills are commonly used. Drill bits of suitable designs are used as the cutting tool. The hand drill can be of hand operated or electrically operated type.
6. *Auger:* For making large size deep holes of diameter from 8 mm to 25 mm, augers of suitable size and length are used in carpentry shops. It consists of a steel bar carrying a fluted body in the lower half and a rod on the upper half Figure 6.16. The bottom end of the fluted body is provided with a screw point, which acts as a pivot. Near the pilot screw, there are two cutting edges formed by the end of the twisted body. On the top end there is the wooden handle. To make a hole, the auger screw point is pressed to the wood and rotated with two hands slowly to drive it in like a screw and form the hole.

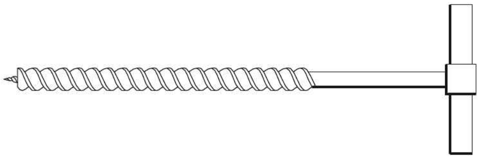


FIGURE 6.16
Auger.

7. *Tools for sharpening:* To sharpen chisels, oil stone is commonly used. For sharpening the saw teeth, triangular files are sufficient. The teeth are set (bending the alternate teeth on each side) using the tool called *saw-set*. This tool is basically a steel plate with gaps or gates of size equal to the thickness of the saw blade. By bending the teeth on both sides, the cutting slot become slightly wider than the thickness of blade, resulting in easy movement of saw.

6.3 Wood Working Processes

The wood working processes usually practised for shaping the wood and making joints are the following:

1. Marking
2. Sawing
3. Planing
4. Chiselling
5. Mortising
6. Tenoning
7. Grooving and tongueing
8. Rebating
9. Recessing
10. Boring
11. Moulding

Marking

The process of setting out dimensions on a rectangular block of wood is known as *marking* and *laying out*. Each dimension is set with the help of steel rule and different measuring as well as marking tools like try square, calliper, marking knife, marking gauge, etc. The wooden pieces should be planed to true rectangular cross section whenever necessary before marking. The marking may be required at several stages of the work, depending on the product shape.

Sawing

It is the basic operation carried out for cutting the wood along the grains or across the grains to get different shapes. To start a cut, the thumb of the left hand is placed nearby the cutting line so that it steadies the blade, enabling to start the cut in the correct place. After one or two short movements, a groove is formed and then the full stroke is given. Light pressure has to be applied during rest of the cutting time, so that the blade is moving steadily for nearly its full length.

Planing

Planing is the process of making wood surface smooth and plane by removal of a small layer of wood from it. Planes of suitable type are to be used for that. Direction of the wood grains should be checked before starting the process and the planing has to be done along the grains. While planing, pressure is applied to each forward stroke which is released in the return stroke. Usually the plane is gripped in the right hand and the downward pressure as well as the forward movement are applied. The left hand is used to grip the front top portion of the plane for supporting the action. As the planing proceeds, the work piece should be checked for its flatness as well as squareness using a try square.

Chiselling

Chiselling is the process of removal of wood in very small quantities by cutting like scraping process, using a chisel alone after holding the chisel in the two hands. The workpiece is usually gripped on a *vice* or *bench hold fast*. To make the required shape from a wood piece, chiselling has to be done very carefully and in the proper way. The skill of chiselling has to be developed by practice. Some guidelines for better results are given below.

1. To cut along horizontal plane, the chisel is held slightly tilted to one side and pushed forward in the direction of the grain. The bevel side is kept down for roughening, while for finishing, the straight side is kept down.
2. The handle of the chisel is slightly lowered down and chiselled from both sides to avoid splintering the edges and corners.
3. In vertical chiselling across the grains, the chisel is controlled with the left hand pressing firmly on the blade of the chisel.
4. The chisel is tilted slightly to one side to give a shearing cut.

5. While rounding a corner, the chiselling should start at the edge near the corner, keeping the direction of cutting towards the corner. This will avoid the biting of the chisel corner into the grain and splitting of the wood.

For heavier cuts, firmer chisels are used and the cutting action is obtained by hitting the wooden mallet on the chisel handle.

Mortising

A cavity or slot made in a wood piece is called *mortise*. The process of making a mortise is called *mortising*. To produce a mortise, firmer and mortise chisels are used. Mallet is used to strike over the chisel handle for heavier cuts. The wood is excavated from about half the depth of the cavity from one side and the other half from the opposite side. This can prevent the splitting of the wood on the surface, while making a mortice. Figure 6.17 shows three types of mortises generally used in carpentry joints.

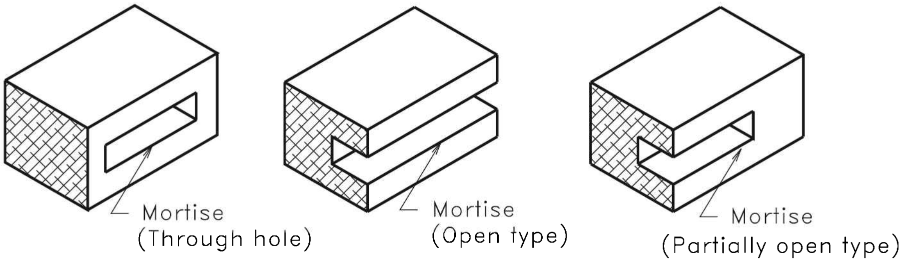


FIGURE 6.17
Types of mortises.

Tenoning

Tenon is the projection made on a wood piece to fit inside a mortise for getting a joint and the process of making the projection is called *tenoning*. The assembly is called a *mortise* and *tenon joint*, which is very commonly used in carpentry. A tenon saw is used to remove the excess wood to produce the tenon. The finishing of the tenon is done using chisel as explained earlier in chiselling. Figure 6.18 shows three types of tenons used in carpentry.

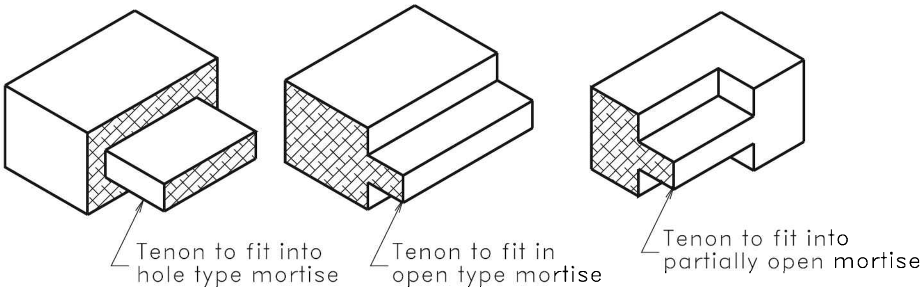


FIGURE 6.18
Types of tenons.

Grooving and tongueing

To make wide planks, rectangular pieces have to be joined by taking groove on one edge and projection on the mating edge. The process of making a rectangular groove on a long edge is called *grooving* and the process of making a rectangular projection on the long edge to fit in the groove is called *tongueing*. Table tops, large size drawing boards, etc., are made like this. A groove is a channel cut along the long edge and a tongue is a corresponding projection to fit into the groove (Figure 6.19). The groove is cut with a plough plane and tongue with tongueing (or moulding) plane.

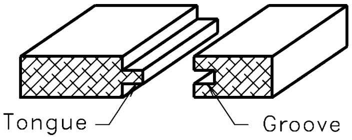


FIGURE 6.19
Groove and tongue of a joint.

Rebating

This is the process of making a rebate or undercut (step) along the edge of a piece of wood as shown in Figure 6.20. Rebates are used on door frames to fit the door panel or on window panel to fit the glass. Rebating is done using a rebating plane or plough plane. Chisel and mallet can also be used for cutting this.

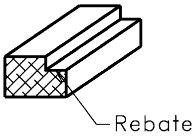


FIGURE 6.20
Rebate on a piece.

Recessing

This is the process of making a depression or recess along a wood piece as shown in Figure 6.21. It is actually a mortising operation in which the hole is blind and not much deep. Recessing is done using chisel and mallet as explained in mortising.

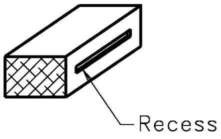


FIGURE 6.21
Recess on a piece.

Boring

The process of production of round through or blind holes is called *boring*. They are made using drills or augers.

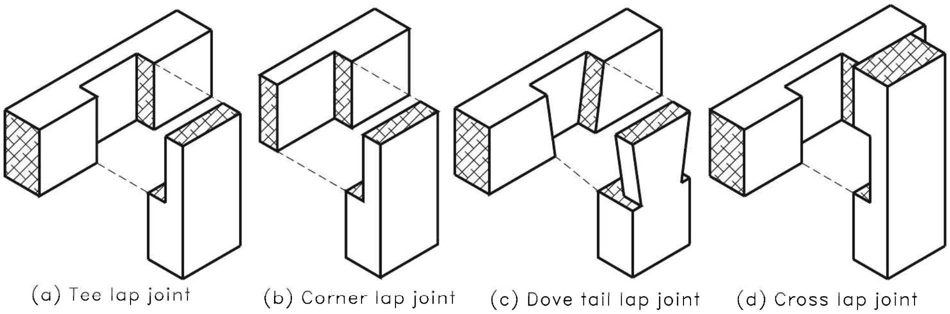
Moulding

Curved projections or grooves along the length of piece of wood are made using moulding planes which has the cutter blade of the shape required. The process of making long grooves and projections by planing is called *moulding*.

6.4 Carpentry Joints

To make various wooden items like doors, windows, furniture etc., wood has to be joined in different forms. The types of joints which are frequently used in carpentry work are given below. The pictorial views give the method of formation of the joints.

1. *Halving (Lap) joints* (Figure 6.22)
   (a) Tee-lap joint
   (b) Corner-lap joint
   (c) Dove-tail lap joint
   (d) Cross lap joint



(a) Tee lap joint (b) Corner lap joint (c) Dove tail lap joint (d) Cross lap joint

FIGURE 6.22
Halving joints.

2. *Mortise and tenon joint* (M&T joint, Figure 6.23)
   (a) Plain (through tenon) M&T joint
   (b) Bare faced tenon M&T joint
   (c) Double tenon M&T joint
   (d) Twin tenon M&T joint

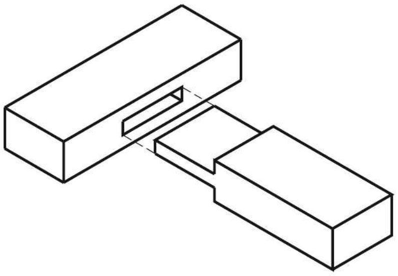


FIGURE 6.23
Mortise and tenson joint.

3. *Briddle joints* (Figure 6.24)
   (a) Tee briddle joint
   (b) Corner bridle joint (open M&T joint)
   (c) Mitre-faced bridle joint
   (d) Dove-tail bridle joint

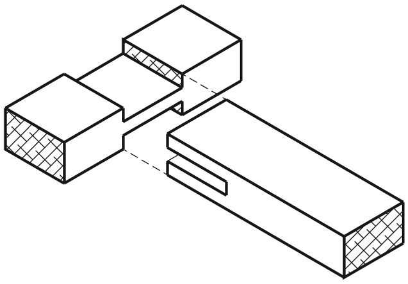


FIGURE 6.24
Briddle joints.

4. *Corner joints* (Figure 6.25)
   (a) Butt joint
   (b) Rebated joint
   (c) Mitred joint
   (d) Cross tongued joint

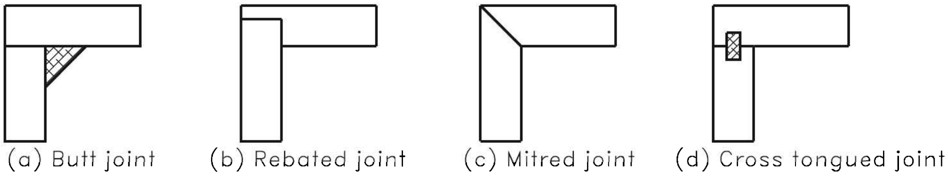


FIGURE 6.25
Corner joints.

5. *Miscellaneous joints* (Figure 6.26)
   (a) Butt or rubbed joint
   (b) Dovel joint
   (c) Loose tongue joint
   (d) Dove-tail joint

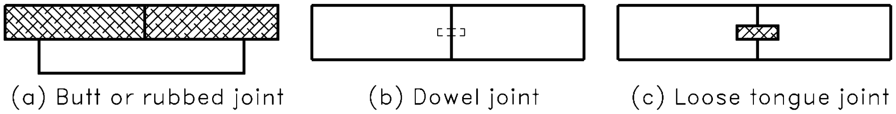


FIGURE 6.26
Miscellaneous joints.

6.5 Wood Working Machines

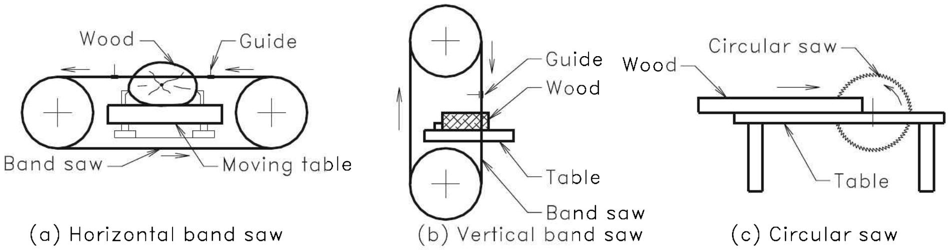
Wood working machines are commonly used in modern carpentry shops in addition to the hand tools explained earlier. The popular types of machines are listed below.

1. Band saw

2. Circular saw
3. Wood working lathe
4. Wood planer
5. Mortiser
6. Sanding machines

Band saw

Band saw is a machine designed to cut wood into blocks, planks, boards or battens. It has an endless metal saw band that travels over the rims of two or more rotating wheels. There are horizontal band saw for slicing heavy logs and vertical band saw for reslicing to small sections. Figures 6.27(a) and (b) show the principle of working of the two types of saws.



(a) Horizontal band saw (b) Vertical band saw (c) Circular saw

FIGURE 6.27
Types of machine saws.

Circular saw

Circular saw (also called table saw) basically consists of a rotating saw of the shape of a circular disc and a table on which it is fitted as shown in Figure 6.27(c). This saw is used for cross cutting as well as for small cutting operations like grooving, rebating, tenoning, bevelling, etc.

Wood working lathe

Wood working lathe is generally used in carpentry shops for turning jobs to produce cylindrical shapes. This machine is similar to a lathe used for turning metal in machine shops (Figure 6.28). It consists of a cast iron bed, a head stock to hold and give the rotational motion to the work at one end, a tail stock to support the work at the other end and a tool rest to feed the cutting tool relative to rotating work for cutting action.

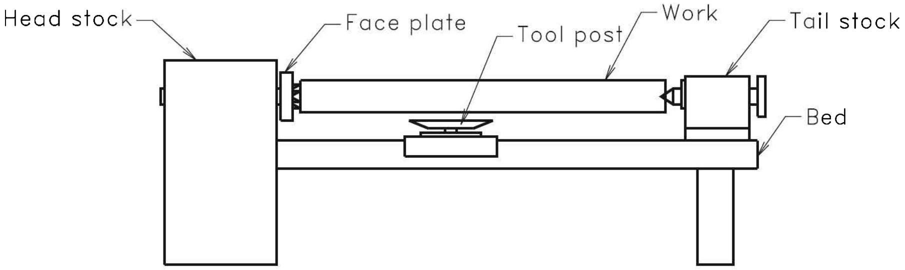


FIGURE 6.28
Wood working lathe.

Wood planer

To plain large and heavy stocks, wood planers are used. The boards to be planed are fed by means of feed rolls along a table against a cutting head. A single surfacer machine has only one cutter head and cuts only from top side. The double surfacer carries two cutter heads on the top and bottom so that it can finish board surfaces by single pass through them. The capacity of a planner is designed by the maximum thickness and maximum width of stock that it can plane.

Mortiser

Motiser is a machine used to produce mortise on wooden pieces to make joints. There are three types of mortising machines.

1. *Hollow chisel mortiser:* This machine has a revolving spindle which carries an auger bit which rotates at high speed inside a hollow chisel of square section. When the chisel is forced into the wood, the bits makes a square hole by the sharp end of the chisel. This machine is more popular.
2. *Chain mortiser:* This machine has an endless chain which has saw teeth on its outer surface. This machine can make a long slot or hole having round bottom corresponding to the profile of the revolving chain.
3. *Oscillating bit mortiser:* This machine carries an oscillating router bit and produces comparatively small mortises suitable for small cabinets.

Sanding Machines

To finish the machined wooden surfaces to the required smoothness, sanding machines are used. The type of sanding machines which are generally used in shops are as follows:

1. *Belt sander:* It uses an endless cloth backed abrasive belt running over two drums.
2. *Disc sander:* It uses of a rotating disc of abrasive like grinding wheel for smoothening curved surfaces.

6.6 Carpentry Practice

Example

Make a Tee (halved) joint of the dimensions given in Figure 6.29 using the given wood piece. The time allotted is 3 hours.

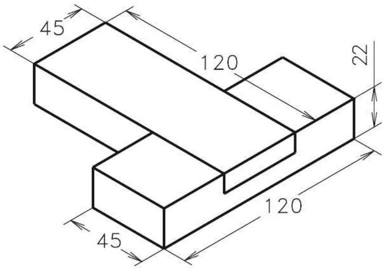


FIGURE 6.29
T-(Halved) joint.

Aim

To make a Tee (halved) joint using the given wood piece.

Work material

Material:	Hard wood.
Size:	Size 48 × 25 × 250 mm.

Tools required

1. Steel rule, 2. Try square, 3. Tenon saw, 4. Firmer chisel, 5. Mallet, 6. Jack plane, 7. Bench vice, 8. Bench hold fast, 9. Bench hook, 10. Marking gauge, 11. Scriber.

List of operations

1. Marking, 2. Planing, 3. Sawing, 4. Chiselling.

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools and the wood piece.
3. Check the size of the wood piece for its suitability to make the model as per drawing.
4. Plane the wood piece to bring to the required cross section using jack plane. The geometrical accuracy is checked by using a try square.
5. Cut the wood piece into two using tenon saw and layout the dimensions of the model.
6. Remove the excess wood by saw cutting keeping a thin layer of wood for finishing the joining surfaces.
7. Finish the halved tee joint surfaces by chiselling as per dimensions and complete the model as shown in Figure 6.30.

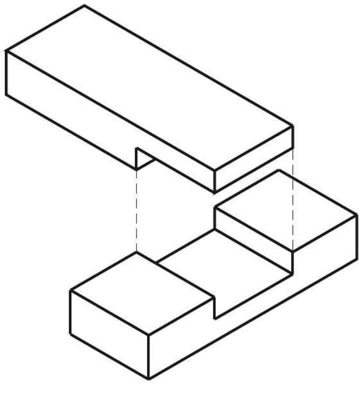


FIGURE 6.30
T-(Halved) joint details.

EXERCISES

Questions for Viva Voce

(A) Tools and equipment

1. What is meant by timber? On what form it is available in market?

2. Differentiate between soft wood and hard wood.

3. What is meant by exogenous trees? Give examples to them.

4. Give a list of the common names of timber available in India, suitable for carpentry work.

5. Describe the term plywood. How it is obtained as large size sheets?

6. Give a list of the auxiliary materials used in carpentry shops.

7. What are the marking tools used in wood working?

8. What is meant by marking gauge. How it is used for marking?

9. Give a list of the saws used for cutting wood.

10. Describe briefly about cross cut saw and tenon saw.

11. What are the types of chisels used for wood working? Describe briefly about them.

12. What is meant by mallet? Explain the use of mallet.

13. Give a list of the plaining tools used in carpentry shops.

14. Describe briefly the construction and use of a wooden jack plane.

15. Name the types of work holding devices used for carpentry work.

16. Explain the use of bench vice, bench hold fast and bench hook.

17. Describe the working principle of band saw and circular saw.

18. Explain briefly how a wood working lathe is used to shape cylindrical objects.

(B) Practice

19. Explain the method of marking out the dimensions for making joints.

20. Describe the process of saw cutting, using a tenon saw.

21. How a jack plane is used to make smooth flat surfaces?

22. What is meant by chiselling?

23. Explain the method of mortising using chisel.

24. What is tenoning?

25. Describe the terms grooving tongueing, rebating and recessing.

26. Explain how large size holes are made in wood? Describe the use of auger.

27. What are the common types of joints made in carpentry work.

28. Explain how a halved joint is made.

Models for carpentry practice

Make the following models, the allotted time is 3 hours:

1. Figure 6.31 shows drawing of a dove-tail (halved) joint. Copy the figure and make the joint using the given wooden piece.

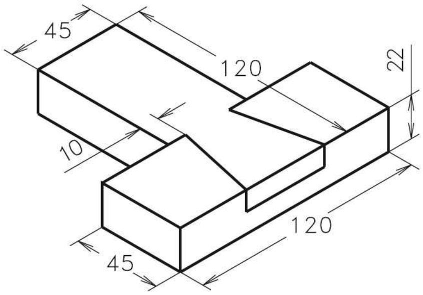


FIGURE 6.31
Dove-tail (Halved) joint.

2. Copy the sketch of the cross (halved) joint given in Figure 6.32 and then make the joint using the given wooden piece.

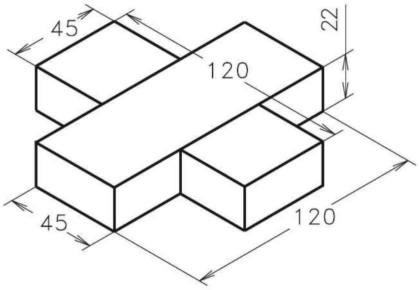


FIGURE 6.32
Cross (Halved) joint.

3. Make a mortise and tenon joint of size shown in Figure 6.33, using the given wooden piece. Also prepare a dimensioned neat sketch of the joint.

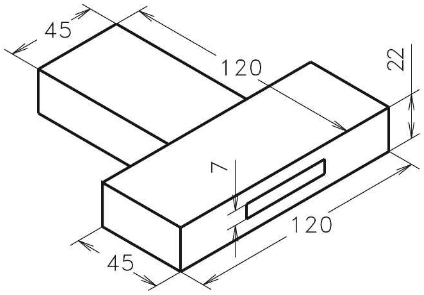


FIGURE 6.33
Mortise and tenon joint.

4. Figure 6.34 shows drawing of a bridle joint. Copy the figure and make the joint using the given wooden piece.

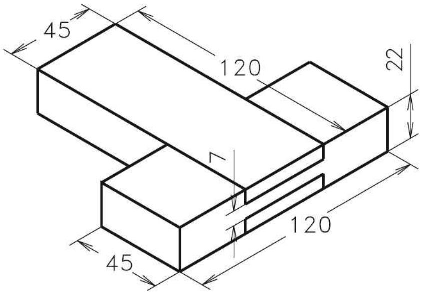
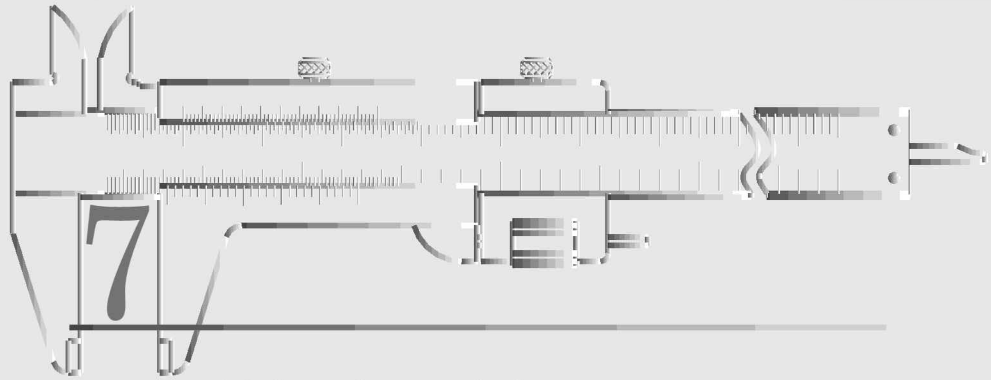


FIGURE 6.34
Briddle joint.



7

Blacksmithy

The process of shaping steel by hand hammering at red hot temperature, after placing on an anvil is called *smithing*. It is considered as one of the oldest methods of shaping metals.

7.1 Principle of Smithing and Forging

Smithing and machine forging are the metal-shaping processes. Smithing is used to shape relatively small jobs by hand hammering. Medium and large size components are shaped using machine forging process. In both cases the metal is heated to red hot temperature (i.e. above the recrystalization temperature) to make it soft and plastic. In smithing the heating is done in open fire or hearth while for machine forging the metal is heated in closed furnaces. In hand forging, hand tools and hammers are used to shape metal. The skill of the operator is the primary part to produce the required shape and dimensions.

A component made by hammering gives high strength to resist dynamic loads than that made by any other processes. Hence, forging process is the only one used to make parts like hooks, levers, cranks, connecting rods, spanners, hammers, hand tools, agricultural implements, etc.

7.2 Heating Equipment

The heating equipment used for smithing is called *open hearth* or *smith's forge.*

Figure 7.1 shows a commonly used smith's forge. It basically consists of a robust cast iron or steel table on which the fuel (coke) is burned. Air at low pressure coming from a blower, is supplied to the fire place (hearth) through a nozzle called *tuyere*. A hood and a chimney are provided above the hearth to collect hot gases and fumes coming from the fire place. The hearth (the table top) and the vertical wall are lined with fire bricks to resist heat. The tuyere connected to the pipeline supplying low-pressure air, is regulated by a valve. A small water tank is provided around the tuyere (at the back of the wall) to cool it. For quenching and cooling of the workpiece and tools, a small water tank of rectangle shape is also provided on the front side of the hearth.

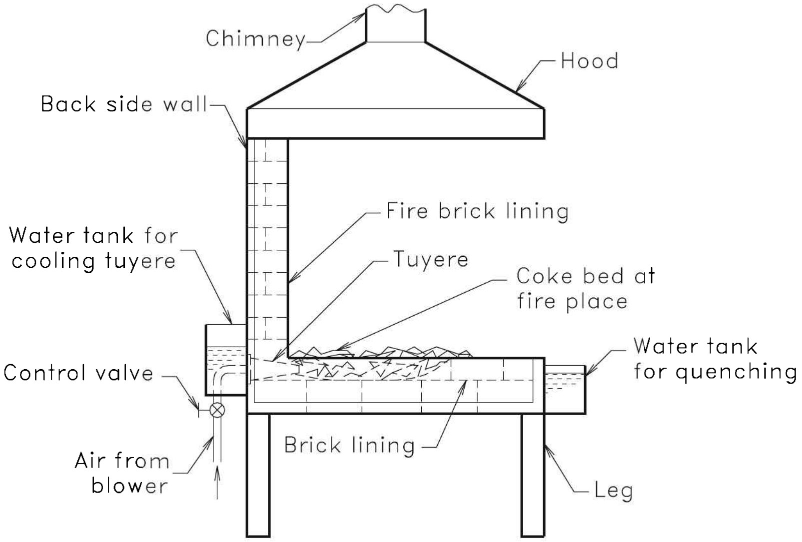


FIGURE 7.1
Smith's forge or hearth.

7.3 Tools and Appliances

The types of tools and appliances used commonly for smithing are given below:

(a) Work supporting tools
(b) Hammers
(c) Tongs
(d) Metal shaping tools
(e) Measuring tools

7.3.1 Work Supporting Tools

Anvil

Anvil is used to support the workpiece while it is being struck with hammer (Figure 7.2). The body of anvil is made of cast steel or wrought iron with hardened

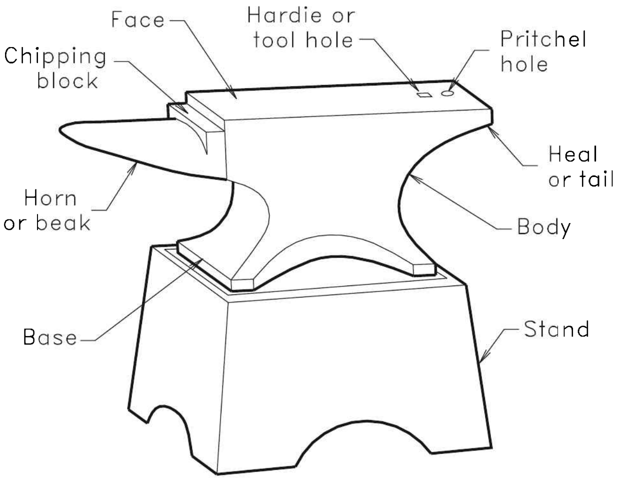


FIGURE 7.2
Anvil.

plate welded to the top. The horn or beak is used to bend or form curved shapes. The commonly used size of anvil is of 150 kg. The anvil is supported by an iron stand.

Swage block

This is a heavy block of cast steel or cast iron with a number of slots and holes of different shapes (Figure 7.3). It is used to support in punching holes and forming different shapes.

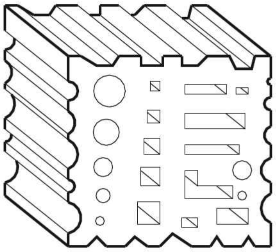


FIGURE 7.3
Swage block.

Bick iron

This is a small anvil which can support workpieces of small size for smithing operations. The bick iron is made of tool steel and the shank of it is fitted with the hardie hole of anvil while in use (Figure 7.4).

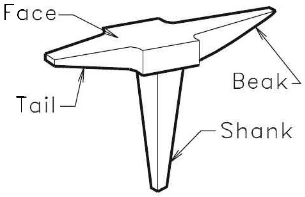
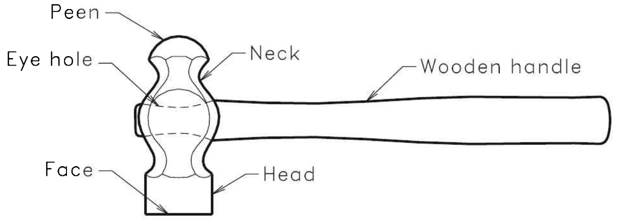


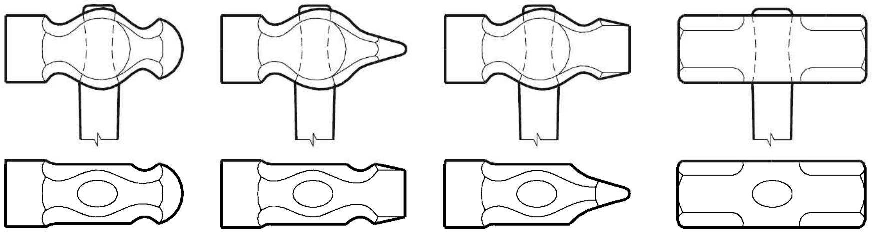
FIGURE 7.4
Bick iron.

7.3.2 Hammers

Different types of hammers are used to apply blow directly on the metal or on the shaping tools (Figure 7.5). The eye hole of the hammer is normally made to oval shape and accommodates the handle of wood or bamboo. The weight of a hammer used varies from 1 to 2 kg for peen hammers and 2 to 8 kg for sledge hammers.



Hand hammer nomenclature

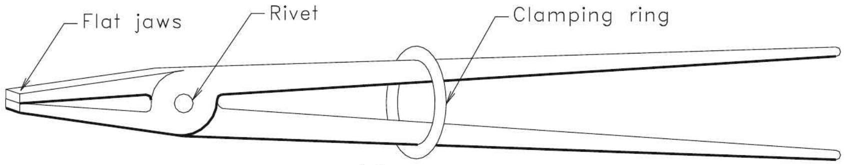


(a) Ball peen (b) Cross peen (c) Straight peen (d) Sledge

FIGURE 7.5
Types of hand hammers.

7.3.3 Tongs

To grip and turn hot workpieces, different types of holding tools called *tongs* are used (Figure 7.6). A tong consists of two bars jointed by a rivet or a pin. The total length of a tong varies from 450 to 650 mm. Different shapes are given to the mouth of the tong in order to hold jobs of different forms.



(a) Flat tong

(b) Side bit tong (c) Round hollow tong

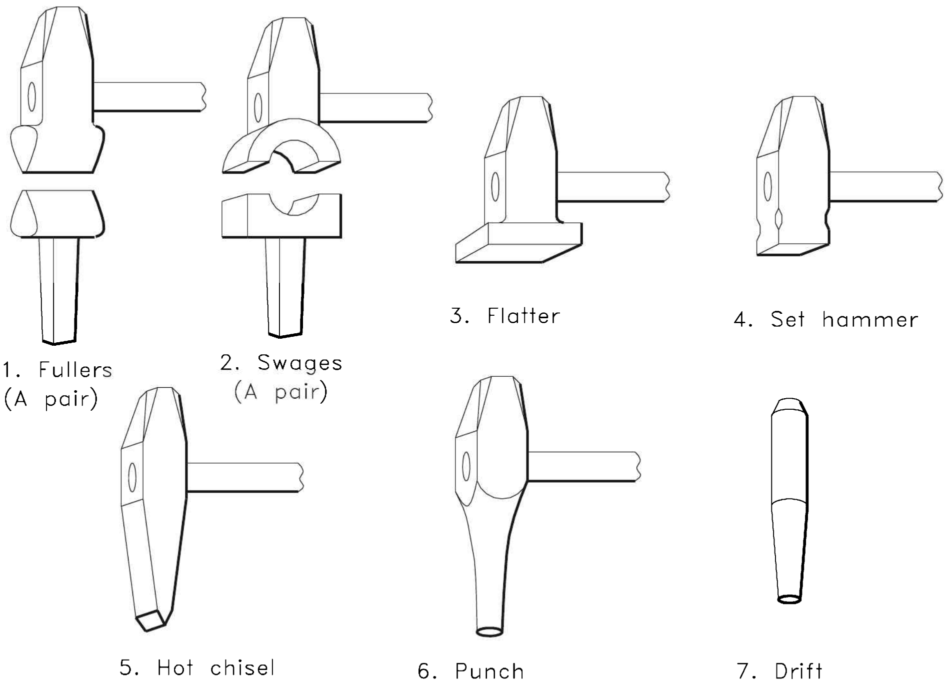
(d) Square hollow tong (e) Pickup tong

FIGURE 7.6
Smith's tongs.

7.3.4 Metal Shaping Tools

Tools like fullers swages, chisels, etc., are used to shape hot metal (Figure 7.7). These tools are placed over the area to be shaped and blows are applied over them using hammers. The shaping tools are made of high carbon steel in different sizes to suit the various types of jobs.

1. *Fuller:* It is used to make necks and drawing out a section.
2. *Swage:* It is used to reduce and shape circular jobs.
3. *Flatter:* It is used to level and finish flat surfaces.
4. *Set hammer:* It is used to level and finish corners of flat surfaces.
5. *Chisel:* It is used to cut metal in hot and cold state.
6. *Punch:* It is used to produce hole in hot state.
7. *Drift:* It is used to expand the size of a hole after punching.



1. Fullers (A pair)
2. Swages (A pair)
3. Flatter
4. Set hammer
5. Hot chisel
6. Punch
7. Drift

FIGURE 7.7
Metal shaping tools.

7.3.5 Measuring Tools

Simple measuring tools are used during smithing operations. The dimension or shape of a hot workpiece has to be inspected between forging operations and after finishing. The following are the measuring instruments usually required in smithy.

1. Steel rule of 30 cm or 60 cm length
2. Outside and inside callipers

3. Gauges
4. Templates

These tools are explained with figures in Chapter 3.

7.4 Heating of Metal

Various types of steels such as mild steel, carbon steel, structural steel and tool steels are the common raw materials for forging. Nonferrous metals and alloys like brass, bronze, copper and aluminium can also be forged. The temperature ranges for forging steels are given below:

Material	*Forging temp. in* °C
Mild steel	750–1300
Medium carbon steel	750–1250
High carbon steels and alloys	800–1150
Stainless steels	940–1180

For smithing the temperature of steel is estimated by the colour of the heated zone. Dark red colour is obtained at about 700°C and cherry red at 900°C. The colour becomes orange at 1100°C and white hot at 1300°C.

Heating of steel improves softness and reduces tensile strength resulting its plasticity and malleability. Proper heating gives easiness for shaping of metal and good surface finish. If the metal is overheated and kept for long time in a furnace, burning due to oxidation may occur resulting cracks on surface or melting of the heat-effected zone.

7.5 Forging Operations

A given metal piece (blank) can be converted to the required shape by one or more of the following forging operations.

1. Upsetting or Jumping
2. Drawing out or drawing down
   (i) Fullering
   (ii) Swaging
3. Punching and drifting
4. Bending and twisting
5. Setting and finishing.
6. Cutting.

7.5.1 Upsetting or Jumping

Upsetting, jumping or heading is a process of forging in which the cross section of the workpiece is increased by reducing its length. The heated metal piece is kept vertical over the anvil with the help of tongs and blows are given at the end, so that the hot portion swells to increase its dimension (Figure 7.8). Initially the bar stock will be of a round or square uniform section. Different cross sections larger than the bar stock are produced by this upsetting operation.

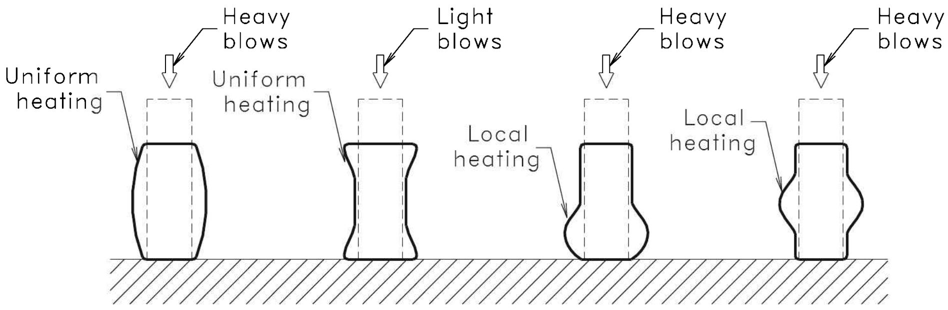


FIGURE 7.8
Upset forging operations.

7.5.2 Drawing Out or Drawing Down

This is a process of reducing the cross section of the workpiece and hence is the reverse of upsetting. Fullering and swaging are the two basic types of drawing processes (Figure 7.9). In fullering, the rectangular cross sections are reduced in thickness and the length of the portion increases proportionally. Fullering can also be used to increase width of the portion. If a round portion is to be drawn, swages are used for that and the operation is called *swaging*. To get a round cross section of smaller diameter form a bar stock of square section, the portion is first converted to octagon and then to round using swages.

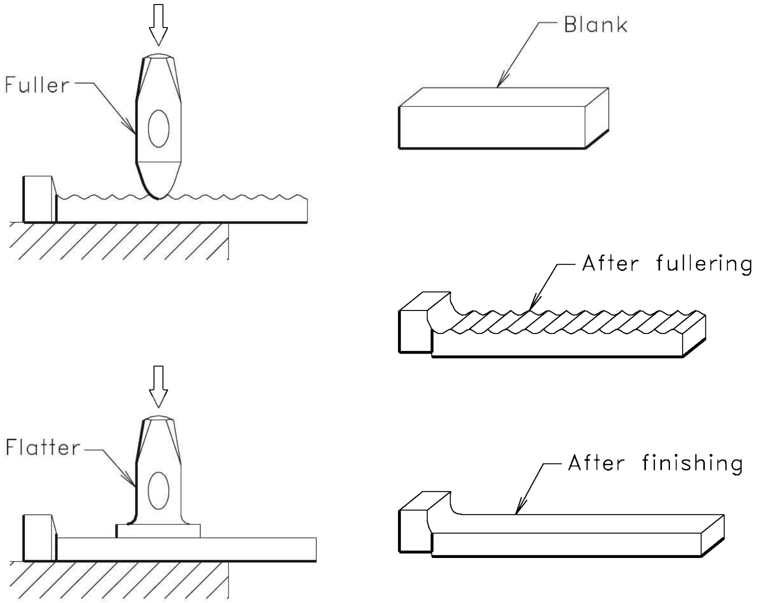


FIGURE 7.9
Drawing out or drawing down operations.

7.5.3 Punching and Drifting

Punching is a process of forcing a punch through hot metal to produce a hole. To make a hole in hot metal piece, it is placed over the anvil flat and the punch is forced to half of thickness (Figure 7.10). Then the job is turned upside down and placed over a *bolster* having a hole on the *prithel* hole of anvil. The punch is forced again to get the hole. In order to increase to punch hole size, a drift (tool like a punch) is forced through the hole and the process is named *drifting*.

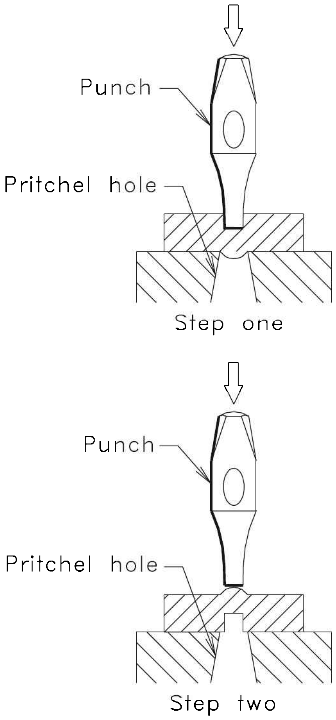


FIGURE 7.10
Punching.

7.5.4 Bending and Twisting

With the help of anvil horn or bick iron, bars, flats, strips, wires, etc., can be bent by hammering. Similarly twisting of flat strips can be done by using tongs and a rectangular hole or vice as given in Figure 7.11.

7.5.5 Setting Down and Finishing

Setting down is a process of making the round corners to square shape by the use of set hammer (Figure 7.12). Even though a set hammer is the form of a sledge hammer with square corners, it is not used for applying blows. It is used just like a *fuller* to

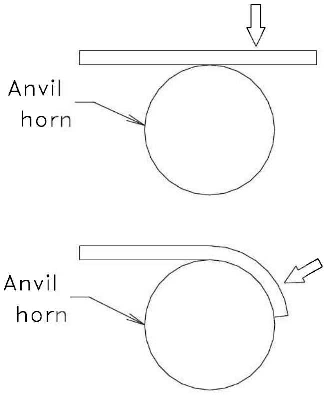


FIGURE 7.11
Bending.

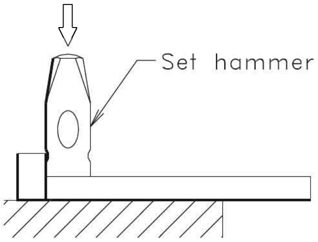


FIGURE 7.12
Setting down.

correct the corners. Finishing is the operation of running unevenness of surfaces by the use of flat fuller or set hammer. Roughly-shaped round surfaces are converted to finished form by using swages.

7.5.6 Cutting

Metal in hot or cold condition is cut by using chisels. This operation is used to remove excess metal from a job or to split a part or to make pieces from a long bar stock Refer (Figure 7.13).

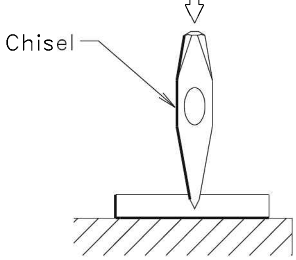


FIGURE 7.13
Cutting.

7.6 Smithing Practice

In smithing, the metal piece heated to the forging temperature is placed in position on anvil using a tong in left hand and is struck by a hammer holding in right hand. Usually a helper is also required for making complicated shapes. In such cases, the operator holds the workpiece with his left hand and places the shaping tool like fuller swage, etc., in right hand. The helper strikes on the shaping tool with sledge hammer in both hands.

The skill of the operator plays major part in producing finished forgings. The number of heatings (passes) may be six or more, but a skilled person requires minimum number of reheating.

7.6.1 Smithing Procedure

The steps to be followed to produce a component by smithing are given below:

1. Study the drawing of the component to be forged and calculate the approximate volume of metal required.
2. Take a blank of shape suitable to the component, having a total volume of at least 5 to 10% excess. The excess volume is provided for losses due to scaling and trimming.
3. Plan the forging operations and the sequence. Prepare an operation process chart in detail.
4. Collect the forging and measuring tools and keep them ready for use.
5. Place the blank in the hearth for heating as specified in the process chart.
6. Check the temperature of the metal by its colour and take it out, when it reaches the forging temperature using proper shape of tongs.
7. Do the forging operations one by one without delay. If the temperature becomes low, keep it for re-heating.
8. Repeat the above steps several times, till the shape and size of component reaches the required one.
9. Quench the workpiece in water to bring it to room temperature and do the final inspection.

7.6.2 Safety Measures

1. Use only the tongs, whose jaws fit the shape of the forging.
2. See that the hammers are always securely attached to their handles.
3. Clean the hot stock and anvil from scales using steel brush or scraper.
4. Never attempt to forge cold or burnt metal.
5. Wear proper uniform and shoes as specified by the shop rules.
6. Hold the hot metal downward close to the ground, while handling it from forge (hearth) to the anvil.

7. Never keep any hot or cold forgings or waste materials to accumulate around the working place. They should be kept in proper storage locations.

Example

Make a hexagonal chisel of the size shown in Figure 7.14 using the given cylindrical iron piece of diameter 25 mm and length 100 mm.

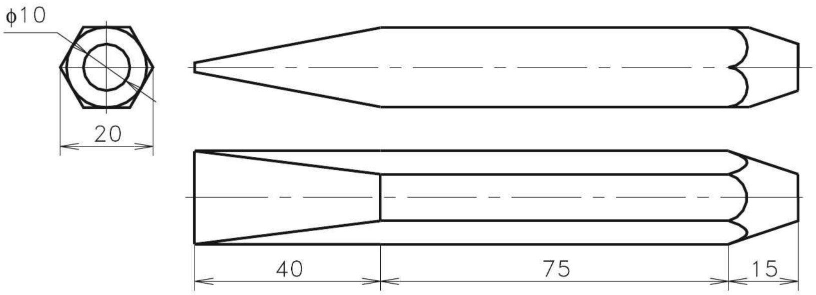


FIGURE 7.14
Hexagonal chisel.

Aim

To make a hexagonal chisel of given dimensions using the given cylindrical iron piece.

Materials required

Cylindrical iron piece of diameter 25 mm and length 100 mm and coke for heating.

Tools required

1. Hammer, 2. Tongs, 3. Flatter, 4. Anvil, 5. Forge, and 6. Steel rule.

List of operations

1. Heating, 2. Hammering to hexagonal prism, 3. Jumping to reduce length, 4. Hammering to shape conical end and 5. Hammering to shape chisel end.

Procedure

1. Heat the given cylinderical piece to red hot temperature using the forge.
2. Take the heated piece using tongs and hammer it after placing lengthwise over the face of the anvil to form hexagonal prism.
3. Reduce the length of the prism to 100 mm by jumping, after holding it vertical over the anvil face.
4. Flatten the six faces using the flatter and finish the hexagonal shape.
5. Shape one end to conical form by hammering.
6. The other end is shaped to chisel form as shown in figure by hammering on the parallel flat faces, after keeping it on the anvil.

EXERCISES

Questions for Viva Voce

(A) Tools and equipment

1. What is meant by blacksmithy?
2. Explain blacksmith's forge used for metal heating.
3. What all types of tools and appliances are used in a smith's shop?
4. What is meant by anvil? Describe its shape and use.
5. Explain the use of a swage block.
6. Describe briefly the use of a bick iron.
7. What are the types of hammers used in smithy?
8. Describe briefly the term tong and the types of them.
9. Explain the use of fullers, swages and flatter.
10. Explain the tools used for making holes in forging.
11. What is meant by a set hammer?
12. Give a list of measuring tools used in smithy.

Processes

13. Explain the process of heating metal for forging.
14. How the temperature of a heated metal piece is judged?
15. Give the approximate forging temperatures of low medium and high carbon steels.
16. Write a list of the forging operations carried out in smithy.
17. What is meant by jumping or upsetting? When this is used?
18. Explain the process of drawing out.
19. Describe the process of making a large size hole by forging.
20. Explain, how a bar is cut in forging.
21. Describe the process of making a simple component by hand forging process.
22. What are the safety measures to be taken in a smithy shop?

Models for smithy practice

Make the following models, the allotted time is 3 hours:

1. Figure 7.15 shows drawing of an MS square prism. Copy the figure and make the model using the given MS round piece.

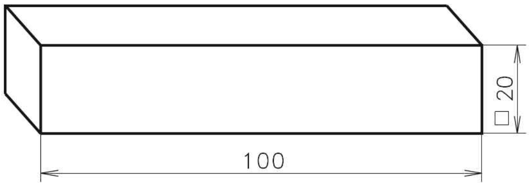


FIGURE 7.15
Square prism.

2. Copy the sketch of the octagonal prism given in Figure 7.16 and then make the model using the given MS round piece.

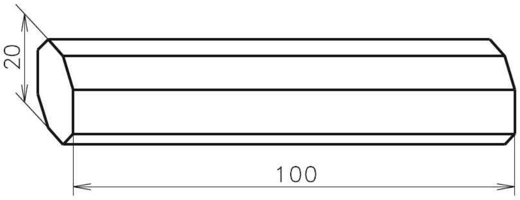


FIGURE 7.16
Octagonal prism.

3. Make a cylindrical model of size shown in Figure 7.17, using the given MS piece. Also prepare a dimensioned neat sketch of the model.

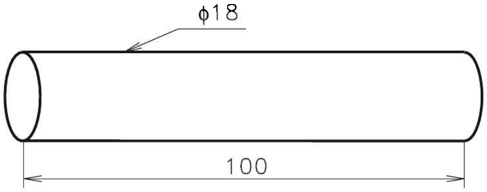


FIGURE 7.17
Cylinder

4. Figure 7.18 shows drawing of an MS hexagonal prism. Copy the figure and make the model using the given MS round piece.

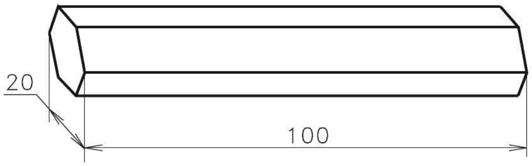


FIGURE 7.18
Hexagonal prism.

5. Copy the sketch of the square bolt given in Figure 7.19 and then make the model using the given MS round piece.

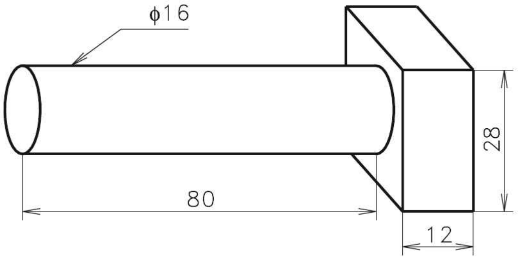


FIGURE 7.19
Square bolt.

6. Make a hexagonal bolt of size shown in Figure 7.20, using the given MS round piece. Also prepare a dimensioned neat sketch of the model.

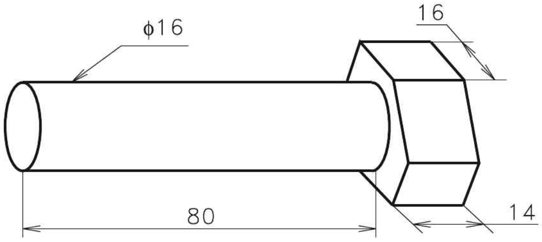
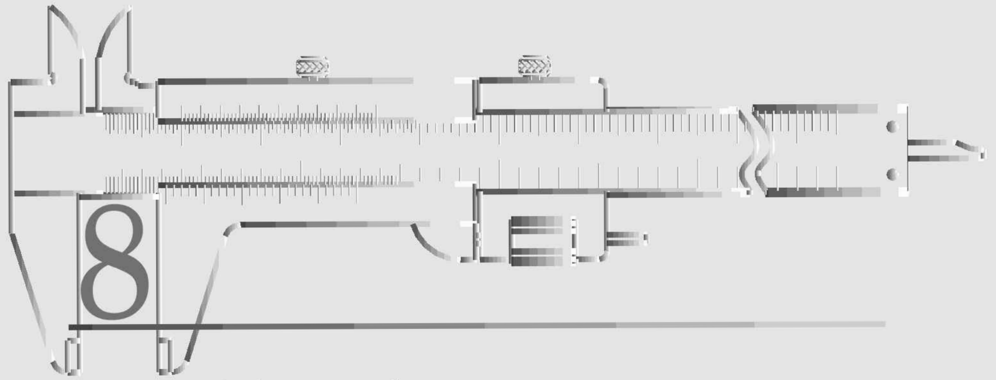


FIGURE 7.20
Hexagonal bolt.



8

Foundry

Founding or casting is the process of forming metal objects by melting the metal and pouring it into mould cavities. A foundry is an establishment for producing castings.

8.1 Introduction to Metal Casting Processes

Metal casting processes can be broadly classified into two types:

1. Conventional sand casting processes
2. Special casting processes

The s*and casting* proces is the most common of all casting processes. Sand moulds are used for this purpose. All the casting processes, other than the conventional sand casting, are called *special casting processes.* They include shell mould casting, die casting, investment casting, centrifugal casting, etc.

8.1.1 Sand Casting Process

The sand casting process consists of basically the making of the sand mould having properly-shaped cavity and pouring molten metal into it to produce a casting. The process of producing sand casting contains the following sections.

1. Pattern making
2. Moulding

3. Melting and pouring
4. Fetling, cleaning and inspection.

The shape of a casting is initially made by using wood or plastic which is called *pattern*. Using the pattern, a cavity is made inside the sand mould and the process is called *moulding*. Metal to be cast is melted in a furnace and poured to the cavity of the mould. After solidification and cooling, the sand mould is broken and the casting is taken out. Unnecessary projections are removed and the surface is cleaned to finish the casting for inspection.

Depending on the condition of the moulding sand, such as wet or dried at the time of pouring molten metal, the casting processes are divided into two categories:

1. Green (wet) sand mould casting
2. Dry sand mould casting

The metals commonly cast in foundries can be grouped as given below:

(a) *Ferrous metals*
  1. Cast iron
  2. Steels

(b) *Nonferrous metals*
  1. Heavy nonferrous metals like copper, zinc, lead and its alloys
  2. Light nonferrous metals like aluminium, and its alloys

8.1.2 Sand Mould

A sand mould can be described as a void created in compact sand using a pattern, when filled with molten metal it will produce a casting. The process of producing the required shape of cavity is called *moulding*. Figure 8.1 shows cross section of a sand mould ready for casting. It consists mainly of three parts:

1. The lower half called *drag* resting on a bench or floor
2. The upper half called *cope*, assembled over the drag
3. The *core* fitted inside the cavity of mould

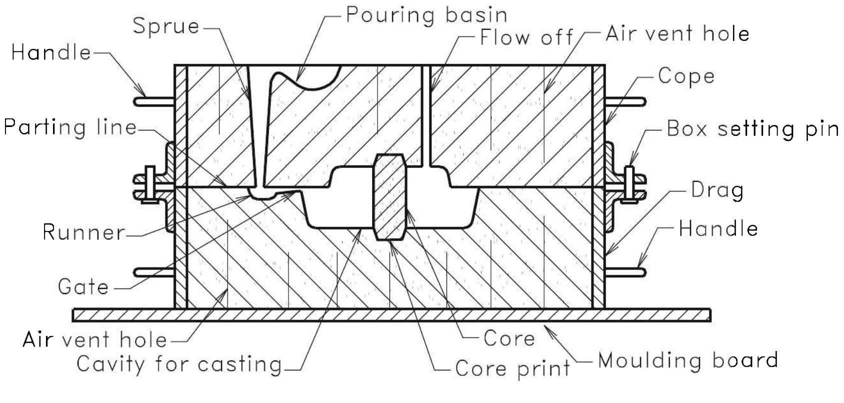


FIGURE 8.1
Flask mould assembly (cross section).

The outer box used for moulding called *flask,* is in two halves (cope and drag) and is made of iron or wood. The cavity at the centre of the sand mould is shaped by initially placing the pattern and ramming the moulding sand around it. Then the pattern is withdrawn, the core is fitted in position and the two halves (cope and drag) are assembled together to form the mould ready for pouring. Various terms related to the parts of a mould are given in Figure 8.1. The molten metal is poured to the pouring basin, so that it flows to the cavity after passing through the vertical sprue. The metal comes out through the flow-off, when the cavity is filled. Solidified casting is taken out by breaking the mould (Figure 8.2).

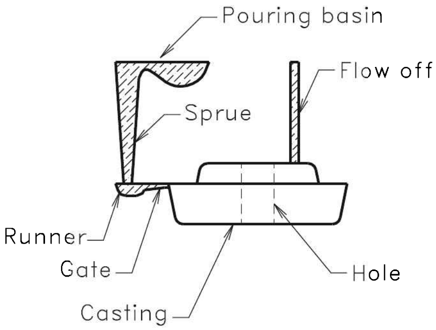


FIGURE 8.2
Casting.

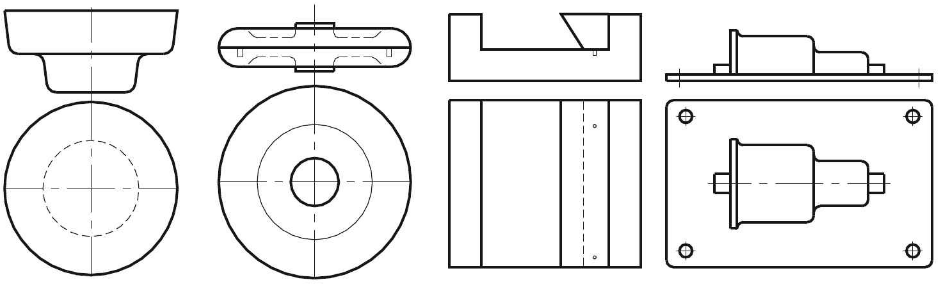
8.2 Patterns

A pattern is a form made of wood, plastic, metal or any other suitable material, around which moulding sand is packed to shape the casting cavity of a mould. Teak wood is the most commonly used pattern material. Plastics, aluminium, brass and cast iron are also used as materials for pattern in special casting processes.

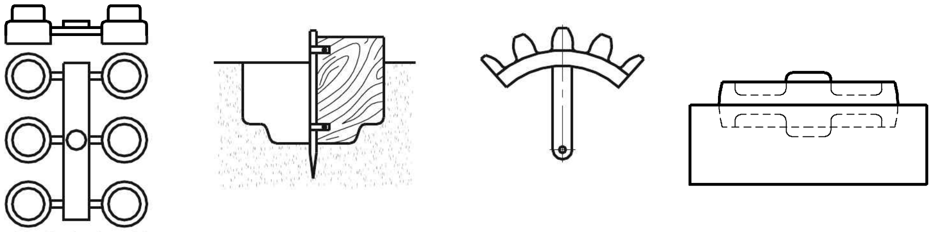
8.2.1 Types of Patterns and Core Boxes

Patterns and core boxes can be classified depending on the shape and size of the casting, number of castings taken and the method of moulding employed. The most commonly used types of wooden patterns for sand casting are given below (Figure 8.3).

1. *Solid (single piece) pattern:* It is a pattern made without joint or parting.
2. *Split pattern:* These patterns are split along the parting surface of mould.
3. *Loose piece pattern:* This is a pattern with a loose piece so that the pattern can be removed from the mould in pieces after moulding.
4. *Match plate patterns:* They are split patterns, the halves of which are separated by a plate of the required thickness and shape. Match plate patterns are generally made of metal or plastic and used for machine moulding of small components.



1. Solid pattern 2. Split pattern 3. Loose piece pattern 4. Match plate pattern



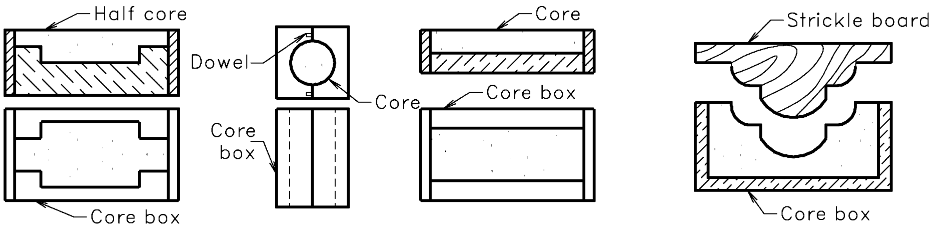
5. Gated pattern 6. Sweep pattern 7. Segmental pattern 8. Follow board pattern

FIGURE 8.3
Types of patterns.

5. *Gated patterns:* The passages for flowing molten metal (gates) are also made using these types of patterns.
6. *Sweep pattern:* Moulds which are symmetrical and regular in shape can be made with the use of a wooden piece called “sweep”.
7. *Segmental pattern:* They are sections of a pattern arranged in such a manner as to form a complete mould by moving from one segment of the mould to the next.
8. *Follow board pattern:* Follow board is a wooden board or seat to support the pattern during moulding so that the function of a split pattern is achieved.
9. *Skeleton pattern:* When the casting size is too big the pattern is made as wooden frame (skeleton).
10. *Shell pattern:* Hollow construction of pattern reduces weight. The inside cavity can be used as a core box in shell pattern.

Core boxes, although are not referred to as pattern, are required for producing cores to make holes or undercuts in castings. Core boxes are constructed in wood or metal (Figure 8.4). The most commonly used types of core boxes are:

1. Half core box
2. Split core box
3. Dump core box
4. Strickle core box.



1. Half core box 2. Split core box 3. Dump core box 4. Strickle core box

FIGURE 8.4
Types of core boxes.

While designing the pattern and cores, provision should be made to support the cores rigidly inside the mould cavity. For this, an extension called *core print* on the core and a similar cavity in the mould are made to support the core.

8.2.2 Pattern Allowances

The allowances commonly considered for patterns and core boxes are given below:

1. *Shrinkage allowances:* 9 to 13 mm per metre length (approximately 1%) for cast iron.
2. *Machine finish allowances:* About 3 mm is given as extra size for machineing surfaces.
3. *Pattern draft or taper allowances:* A taper of 10 to 20 mm per metre (1 in 50) for outside vertical surfaces and 40 to 60 mm per metre (1 in 20) for inside vertical surfaces.

8.2.3 Pattern Making

Basically pattern making is a wood working process. The process is explained in the carpentry section of the book. In pattern finishing, all its angled corners are filled in with fillets. This gives a stronger and cleaner mould and improves strength of the casting. Wooden patterns, after making and finishing, are coated with shellac and painted as per American coding for easy understanding of different parts.

1. *Black:* As cast surface
2. *Red:* Surfaces to be machined
3. *Yellow:* Core prints, and seats
4. *Red strips on yellow background:* Surfaces of loose pieces and their seats.

8.3 Tools and Equipment for Hand Moulding

The tools and equipment used for sand moulding process are grouped as mentioned below:

(a) Sand preparation tools and equipment

(b) Moulding flasks
(c) Moulders tools.

Sand preparation tools and equipment

To prepare the sand for moulding, the following tools are used (Figure 8.5).

1. *Shovel:* Used to mix and condition the foundry sand. It is also used to transfer sand from one place to other.
2. *Hand riddle:* This is a circular frame fitted with a net, so that the sand can be riddled (sieved) to remove lumps and foreign materials.
3. *Muller:* This is a motor operated machine having two stone wheels revolving at slow speed, inside a cylindrical vessel. This can do through mixing of a the moulding sand with clay and moisture.

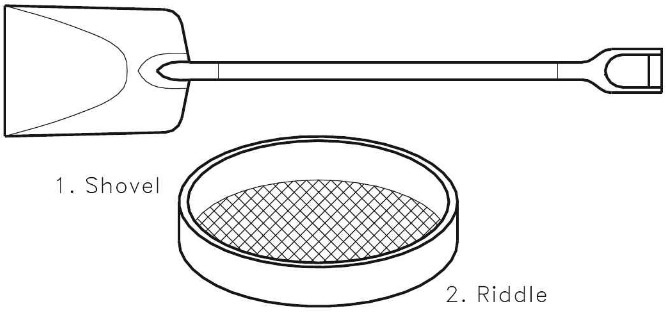


FIGURE 8.5
Tools for sand preparation.

Moulding flasks

They are moulding boxes or flasks used for sand moulding. Wood, steel or cast iron are the materials used for flasks. They can be of closed or open (snap) type. Figure 8.6 shows a wooden flask of closed type. An open type will be hinged at corner and this enables to open the box by side ways. In addition to the drag (bottom part) and the cope (top part), if a third middle box is used for moulding, that box is called *cheek*.

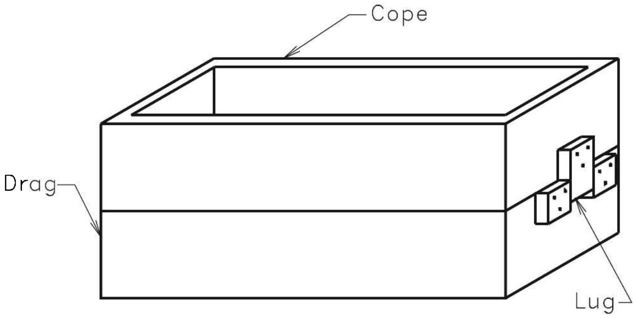


FIGURE 8.6
Wooden flask.

Moulder's tools

In hand moulding, a number of tools are used to construct, repair and finish the mould. The most common tools used are given below (Figure 8.7).

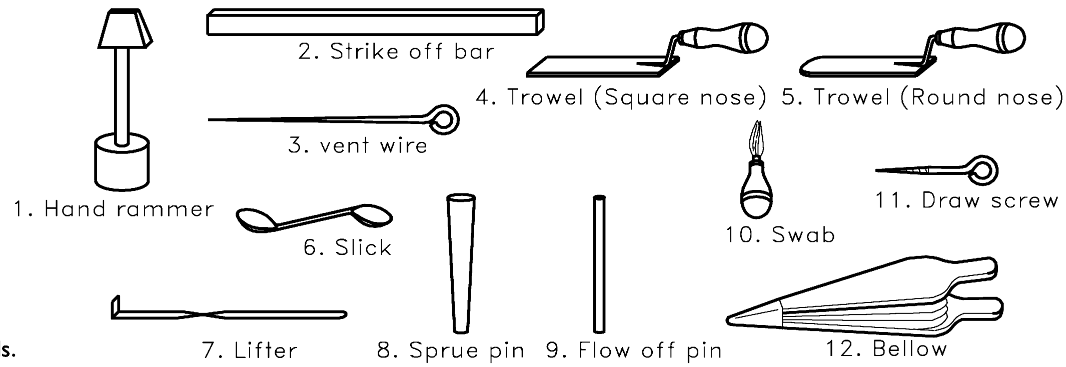


FIGURE 8.7
Moulders' tools.

1. *Moulding board:* It is a wooden board to support flask and patterns while moulding.
2. *Rammers:* It is used to compact the sand by ramming.
3. *Strike off bar:* It is a metal bar to remove excess sand over box.
4. *Vent wire:* It is used for making openings in mould called *air vents*.
5. *Trowels:* It is used to finish the mould surface and corners.
6. *Slicks:* It is used to repair and finish mould surface and corners.
7. *Lifters or cleaners:* It is used to finish vertical surfaces and to remove loose sand from mould.
8. *Sprue and flow off pins:* It is used to make the down sprue (the inlet hole for molten metal) and the flow off passages (the outlet of gases and to check the filling of molten metal).
9. *Swab:* It is a brush to water the mould surface during finishing or repairing.
10. *Bellows:* It is used for blowing off loose sand from mould cavities.

8.4 Hand Moulding

Moulding consists of all operations necessary to prepare a mould for receiving molten metal. Sand moulding usually involves packing the mixed moulding sand around the pattern held within the supporting frame (flask), withdrawing the pattern to leave the mould cavity, setting the cores inside the cavity and closing the mould. These operations can be done either by hand moulding or by machine moulding. The most common hand-moulding process is flask moulding done over a work bench (called *bench moulding*) or on the foundry floor (called *floor moulding*).

8.4.1 Moulding Sand and Its Preparation

Composition

Moulding sand contains the following ingredients:

1. *Sand:* Silica sand of average fineness No: 70 is the major content of moulding sand. This comes about 80 to 85% by weight.
2. *Clay:* Bentonite is the common type of clay used as binder. The percentage varies from 10 to 15 by weight.
3. *Moisture:* Water of about 3 to 6% is added to actuate the clay for developing plasticity and strength.
4. *Additives:* For controlling the mould properties, materials like coal dust, cereals, iron oxide, wood flour, etc., are added in small percentages as additives.

Sand conditioning

The used moulding sand from the foundry floor is added with sufficient quantity of moisture. This process of spraying water to make it wet is called *sand tempering*. The tempered sand is sieved using hand operated or mechanically operated sieves to remove iron pieces or any large size particles. New sand and additives are added in sufficient quantity and moisture is added if required. The mixture is then rammed and mixed several times (2 to 4 times) by shawl to coat sand particles with clay. The sand mixture is tested for its quality and is used for moulding, if it is OK. In mechanised foundries muller is used for the mixing operation.

Sand testing

Moulding sand properties like moisture content, permeability, strength, etc., are tested after taking samples from batches of conditioned moulding sand. This is done in sand-testing lab of the foundry. For small foundries only the physical test is conducted by an expert moulder to judge the quality. For this kind of testing, a handful of prepared sand is taken, gripped well with fingers and then released. The sand mass thus produced is broken into two pieces by hand and the edges found at the broken sections are carefully observed. No deformation of edges shows that the sand conditioning is proper. Gradual setting down of top edge indicates high moisture. Gradual separation of sand grains from the edge shows low moisture and weak bond. By experience, a moulder can judge the quality of the moulding sand by the physical test.

Types of moulding sand

The moulding sand with perfect composition and thorough mixing is used as *facing sand* (sand near by the pattern) in large size moulds. The rest of the space is filled with lower quality moulding sand and it is called the *backing sand.* To separate the cope and drag along the mould surface, dry silica sand is used as *parting sand.* Facing sand with additives added in required proportion is used for cores and is known as *core sand.*

8.4.2 Bench Moulding

Moulds for making small castings are made in flasks placed over a bench and that is called *bench moulding*. For medium size casting the same moulding process is followed in foundry floor and that is called *floor moulding*. Moulding processes using two boxes (the drag and the cope) are called *two box moulding* and this is the most common type of moulding process. If a third box is used in between the cope and the drag, that box is called *cheek* and the moulding is called *three box moulding*. The boxes are fitted with locating and clamping devices in order to keep alignment and to prevent lifting of the cope while pouring molten metal. A two-box moulding process is explained in steps (Figure 8.8).

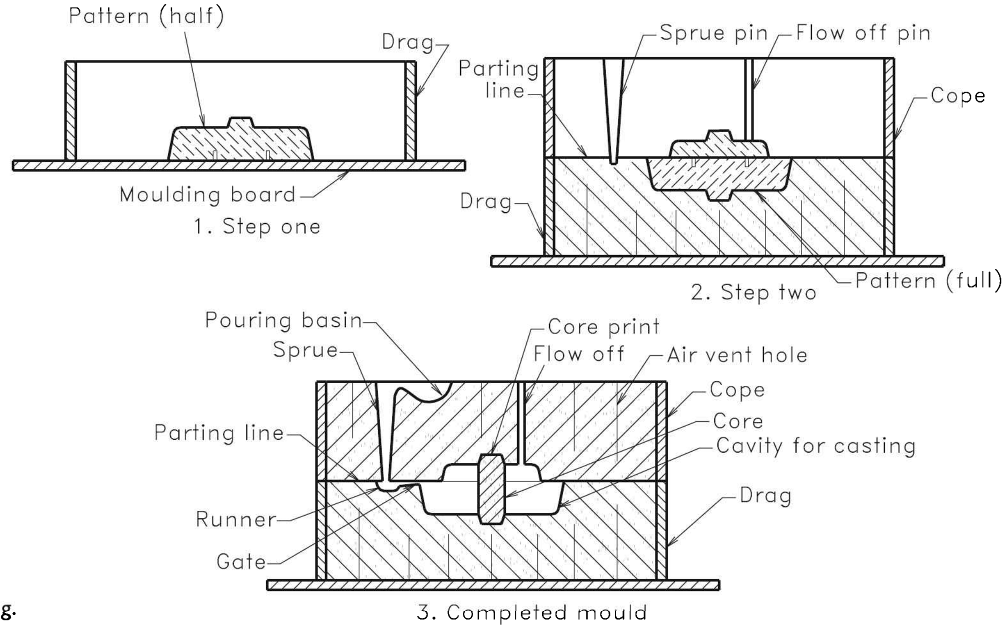


FIGURE 8.8
Bench moulding.

Moulding procedure:

1. Place the moulding board on the work bench and keep the pattern over it with its flat surface down.
2. Set the drag (bottom part of the flask) over the board keeping the upside down, so that the pattern is located approximately at the centre.
3. Fill about 15 to 20 mm layer of facing sand over the pattern and compact it by hand around the pattern.
4. Then fill the backing sand in two to three layers followed by a ramming, to fill the drag slightly in excess level.
5. Remove the excess sand using the strike-off bar to get a level surface and finish it by using trowel.
6. Make small pin holes with the help of vent wire, so that permeability is improved for removal of gases during casting.

7. Turn the drag box upside down, so that the parting line face of the pattern comes to the top.
8. Finish the top surface with trowel and sprinkle the parting sand over the surface to form a very thin layer for separation.
9. Fit the cope over the drag in alignment and place the top part of the pattern in position.
10. Place the sprue pin in vertical position on the parting face of mould, nearby the pattern and place the flow off pin on the top most point of the pattern. A layer of facing sand is filled and compacted with hand over pattern for holding the pins in position.
11. Fill the backing sand in two to three layers followed by ramming so that the cope is filled to a slightly excess level.
12. Remove the excess sand using strike off bar and level the surface with a trowel.
13. Make vent holes using vent wire.
14. Remove the sprue and flow off pins carefully and cut the sprue funnel (pouring basin).
15. Detach the cope from drag and lift it carefully. Place the cope over the board or bench keeping the parting plane upwards.
16. Cut the runner and gate (opening to mould cavity) from sprue hole to the pattern using pointed small trowels, slicks and lift.
17. Moisture the sand around the pattern with the help of swab and draw out the pattern using a draw screw or spike.
18. Clean the mould cavity and surface using bellows. Inspect the finish and filling of corners of the cavity. If it is not satisfactory, repair them using moulding tools.
19. Dust the two-halves of mould cavity with graphite or coal powder for better finish of casting.
20. Assemble the two-halves carefully, after keeping the core in position, and bolt them to keep ready for pouring metal.

If dry sand moulds are required, the mould halves are dried in sun light or in ovens. They are assembled at the time of pouring of metal.

8.5 Melting and Pouring

Metal is melted in furnaces. Commonly used furnaces in foundries can be grouped as mentioned below:

1. Crucible furnaces
2. Cupola furnace
3. Electrical furnaces

Crucible furnace

Crucible is a pot placed inside the furnace in which metal is melted, using the heat produced by burning coke, oil or gas. Metal weighing up to 150 kg can be melted in large size crucible furnaces. Figure 8.9 shows schematic diagram of an oil fired tilting type crucible furnace. Usually nonferrous metals are melted using these types of furnaces.

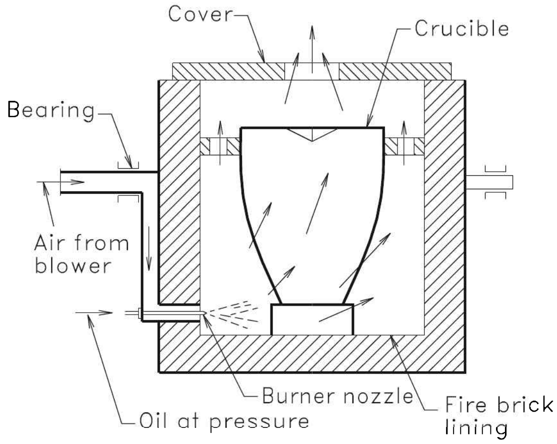


FIGURE 8.9
Oil fired tilting furnace.

Cupola furnace

This is the most widely used furnace in small and medium size foundries, suitable for melting cast iron. It is a cylindrical type vertical furnace erected on four legs or columns (Figure 8.10). The shell of cupola is made of 8 to 10 mm thick steel plates and the interior is lined with fire clay bricks. Coke is the material used to burn for producing heat. Pig iron (raw material for cast iron) and pieces of old castings, coke and limestone are charged (filled) from the top side of the furnace in layers. During burning of coke, the metal melts and comes out as molten cast iron through the metal spout. The molten metal is collected in ladles and is poured in moulds.

Electrical furnaces

Types of electric furnaces used in foundries are as follows:

1. *Induction furnaces:* These are suitable for melting all metals and used in large size foundries.
2. *Arc furnaces:* These are usually used to melt steel in steel foundries.
3. *Resistance type furnaces;* These are usually used to melt nonferrous metals.

Metal pouring

The handling of molten metal from melting furnace to the mould for pouring is done using ladles. Ladles are constructed of steel plates and is coated with refractory

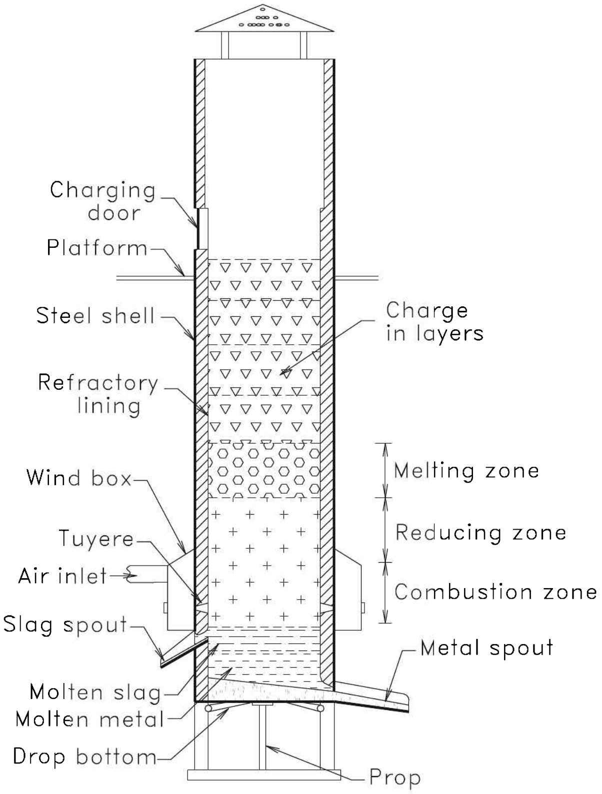


FIGURE 8.10
Copola furnace.

material. The large size ladles are handled by overhead travelling cranes. For small and medium size castings, the metal is poured using hand ladles. Figure 8.11 shows a two-men shank ladle used in small foundries.

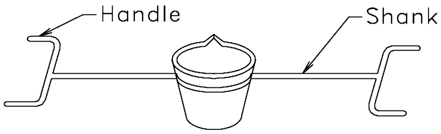


FIGURE 8.11
Shank ladle for two men.

The molten metal, after tapping from the furnace, should be poured in moulds within seconds. For better fluidity of metal and to get defect-free castings of correct composition, certain chemicals are added to the ladle carrying the molten metal. This process is called *inoculation*.

8.6 Moulding Practice

Example

Construct a sand mould using the wooden pattern given in Figure 8.12.

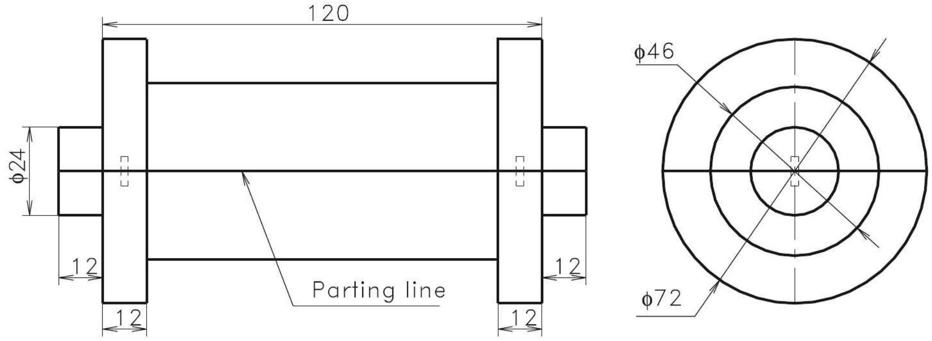


FIGURE 8.12
Split pattern of pipe.

Aim

To make a sand mould using the given pattern.

Materials required

Moulding sand, parting sand, graphite or coal dust, and water.

Tools required

1. Flask (Cope and Drag), 2. Moulding board, 3. Shovel, 4. Hand rammer, 5. Strike-off bar, 6. Vent wire, 7. Trowel, 8. Slick, 9. Lift, 10. Sprue and flow off pins, 11. Swab, 12. Hand riddle.

List of operations

1. Preparation of moulding sand, 2. Compacting of sand over pattern. 3. Withdrawal of pattern, 4. Cutting of gating system, 5. Finishing of the mould surface, and dusting.

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools required and the pattern.
3. Prepare the moulding sand and check its quality by physical test.
4. Place the moulding board on work bench and set the drag keeping upside down.
5. Place the pattern at the centre of drag, keeping the parting line touching on the board.
6. Fill the moulding sand, ram it and remove the excess sand by strike off bar.
7. Finish the top surface by trowel and make the air vent holes.
8. Keep the drag box in its normal position, finish the top face with trowel, and springle the parting sand over the surface, after keeping the top half of the pattern above the lower half.
10. Fit the cope over the drag in alignment and bolt it.
11. Place the sprue and flow off pins in position and fill the moulding sand after compacting a layer of the sand over the pattern.

12. Ram the sand with hand rammer and remove the excess sand with strike off bar.
13. Finish the top surface with trowel and make air vent holes.
14. Remove the sprue and flow off pins carefully. Detach the cope from drag and place it keeping upside down.
15. Cut the gating system on the drag surface and withdraw the pattern carefully from the mould.
16. Clean the mould cavity and dust the surface with graphite or coal powder on the surfaces of the halves. Now the mould is ready for inspection and valuation.

EXERCISES

Questions for Viva Voce

(A) Tools and equipment

1. What is called a pattern? Explain its functions?

2. What are the materials used for pattern-making?

3. Distinguish between a solid pattern and a split pattern.

4. What is meant by match plate pattern? What are the uses of them?

5. In which condition a loose piece pattern is used?

6. Explain the use of sweep pattern, segmental pattern and skeleton pattern.

7. What is a core? How they are made?

8. Explain the term *core print* and its use.

9. What is meant by pattern allowances?

10. Explain the American colour coding system followed for painting patterns.

11. What are the tools used to prepare moulding sand.

12. Explain briefly about *cope* and *drag*.

13. Give a list of moulding tools.

14. What is meant by sprue pin. Explain the functions of sprue and flow off pins.

15. Name the types of furnaces used in a foundry.

16. Describe briefly the working of a crucible furnace.

17. What is *cupola*? For what purpose it is used in a foundry?

18. Explain briefly the principle of working of cupola furnace.

19. What are the materials changed in cupola to get molten metal?

20. What are the types of electrical furnaces used in foundry shops?

21. What is meant by ladle? How it is used in a foundry?
22. Explain the term *inoculation* in a foundry shop.

(B) Practice

23. What is meant by sand casting?
24. Explain the principle of making a sand casting.
25. Distinguish between green sand moulding and dry sand moulding.
26. What is the composition of moulding sand?
27. Give the use of additives in moulding.
28. What is meant by sand conditioning before moulding?
29. Explain shortly the process of sand testing.
30. Describe the terms facing sand, backing sand and parting sand.
31. Explain the principle of bench moulding.
32. Explain the procedure of filling moulding sand in a flask while moulding.
33. What are the important points to be considered while moulding?
34. What is the importance of *parting line* in a mould?
35. Explain the term *gate* in connection with a mould.
36. Why the vent holes are made on cope and drag?
37. Explain how a core is supported inside a mould.
38. Describe briefly, the process of finishing a mould.

Models for Foundry Practice

Make the following sand moulds, the allotted time for each is 3 hours:

1. Figure 8.13 shows drawing of a wooden pattern (cylindrical disc). Copy the figure and make a sand mould for casting the disc in cast iron.

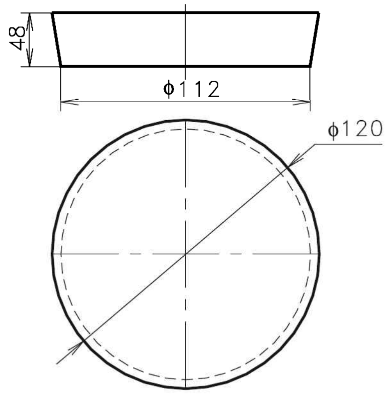


FIGURE 8.13
Cylindrical disc.

2. Copy the sketch of the pattern of dumb bell type given in Figure 8.14. Make a sand mould using the given wooden pattern to pour molten cast iron.

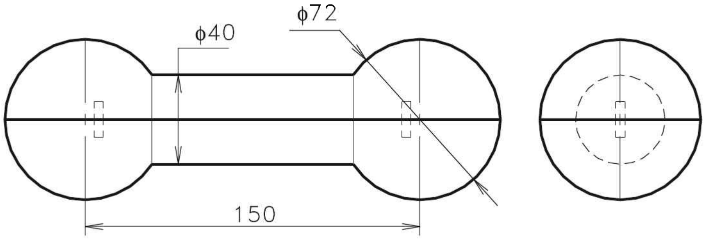


FIGURE 8.14
Dumb bell.

3. Figure 8.15 shows drawing of a wooden pattern to mould stepped cone pulley. Copy the figure and make a sand mould to cast the shape in cast iron.

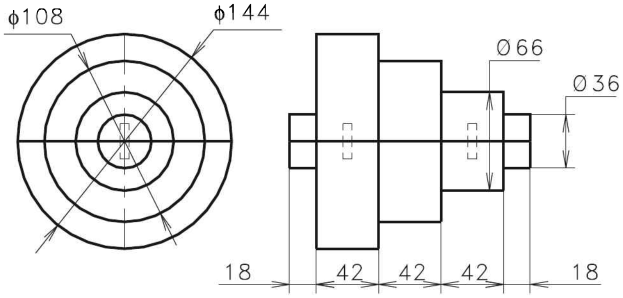


FIGURE 8.15
Cone pulley.

4. Make a sand mould to cast a square disc with hole of size shown in Figure 8.16. Also prepare a dimensioned neat sketch of the wooden pattern.

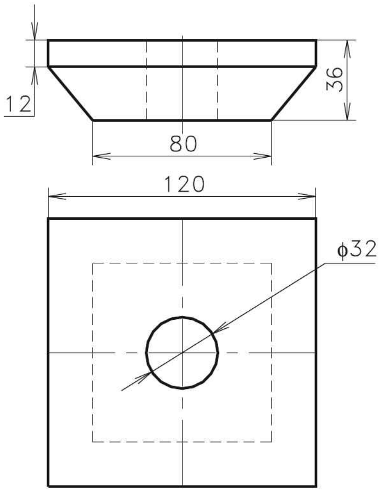


FIGURE 8.16
Square disc with hole.

5. Copy the sketch of the pattern for journal bearing given in Figure 8.17. Make a sand mould using the given wooden pattern to cast in brass.

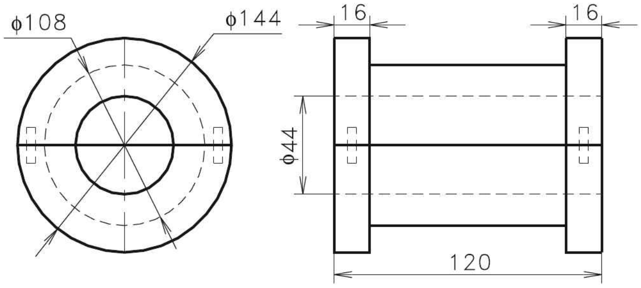
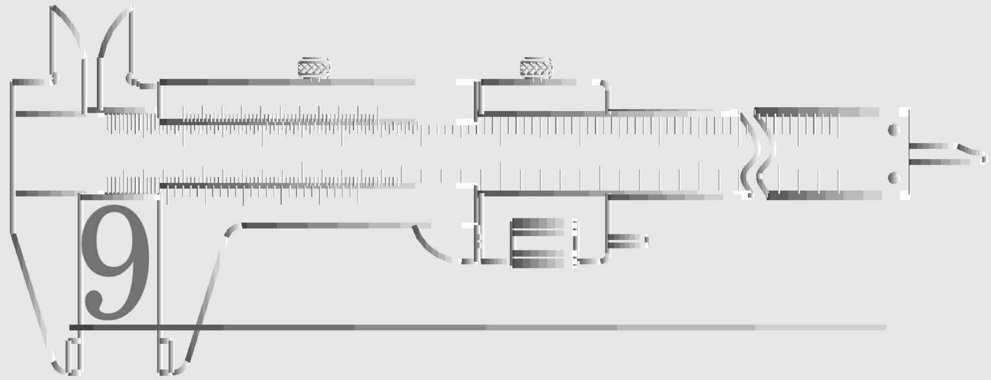


FIGURE 8.17
Journal bearing.



9

Plumbing

Plumbing is a skilled trade of working with pipes or tubes and plumbing fixtures. The process is mainly used for the supply of drinking water and the drainage of waste water, sometimes mixed with waste floating materials, in a living or working place. A *plumber* is someone who installs or repairs piping systems, plumbing fixtures and equipment such as valves, washbasins, water heaters, water closets, etc. Thus it usually refers to a system of pipes and fixtures installed in a building for the distribution of water and the removal of waterborne wastes.

9.1 Introduction

The Latin word *plumbum,* means metal lead pipe, is the origin for developing the term plumbing. Plumbing process was originated during the ancient civilizations such as the Greek, Roman, Persian, Indian, and Chinese civilizations as they developed public baths and needed to provide potable water, and drainage of wastes carried by water. Improvement in plumbing systems was very slow, until the 19th century. Eventually, the development of separate underground water and sewage systems eliminated open sewage ditches and cesspools. Most large cities today pump waste water mixed with solid wastes to treatment plants in order to separate and partly purify the water before emptying into streams or other bodies of water.

Plumbing services required in modern buildings and working places can be broadly grouped as:

(a) Installation of plumbing systems
(b) Maintenance of the systems

These systems can be further classified as conventional and special types:

Conventional plumbing systems

1. Water supply system
2. Rain water disposal system
3. Sewage/wastewater disposal system

Special plumbing systems

1. Hot water supply system
2. Garden hydrant system
3. Gas supply system
4. Solar water heating system
5. Swimming pool water filtration
6. Water treatment for domestic use
7. Fountains, cascades and water bodies
8. Plumbing for industries
9. Fire suppression system

In the above systems the main items used are pipes, pipe fittings and fixtures. The pipes are cut to the required lengths, and the pipe fittings, sanitary fixtures, etc., are installed in position using different plumbing tools. A student practicing the plumbing process should gather sufficient knowledge about these items and their use.

9.2 Pipes and Their Joints

Pipes are manufactured by using different types of materials like steel, cast iron, galvanized iron, brass, copper, aluminum, lead, plastic, concrete, asbestos, etc. They are usually classified according to the material. They are also grouped as cast, welded, seamless, extruded, etc. For conveying large quantity of water, cast iron, steel or concrete pipes having large diameter are usually used. Galvanized iron pipes (GI pipes) are popular for medium and low pressure water supply lines. Plastic pipes are preferred for household uses at low pressure. Pipes are generally specified by their inner diameter (Nominal diameter specified in inches). Hence, the pipe fitting size is also based on this dimension. But for plastic pipes, this rule is not strictly followed because threading is not usually required for them. For engineering uses, along with the nominal diameter, the pipe thickness is also specified as light, medium or heavy.

Types of pipe joints

According to the pipe material, size and application, different methods are used to join pipes. The most common types of pipe joints are:

1. Screwed pipe joint—for GI pipes
2. Welded pipe joint—for steel, copper, aluminum and lead pipes
3. Flanged pipe joint—for cast iron and steel pipes
4. Soldered pipe joint—for brass and copper tubes
5. Glued or cemented pipe joint—for PVC pipes

Pipes made up of iron (GI pipes) and brass of small and medium diameters (10 mm to 100 mm) are usually joined by screwing the pipe specials with internal or external threads. Welding is used to make permanent joint of medium and large diameter steel pipes. Flanged pipe joints are common in medium and large diameter pipes of cast iron and steel, along with rubber/CAF (Compressed Asbestos Fibre) gaskets. The flanges are screwed to the pipe for smaller diameters but made integral for large diameters. Pipes of copper and brass are usually joined by soldering.

PVC (Poly Vinyl Chloride) pipe is the most popular choice in plastic group. It is rigid, and uses *thread* or *solvent weld* (glue) connections. It also can be heat fused. PVC pipes are available in various pressure ratings for water supply and waste water disposal. Standard PVC can only be used for cold water supply, and is a very popular choice for landscape irrigation. The reasons for the popularity are the economy, no corrosion and easiness to work. CPVC is a different type of plastic, which has an extra chlorine atom in the compound, can be used for the hot water supply, and in industry.

To join plastic pipes, gluing or cementing method is used. *Solvent cement* is the gluing material and it partially melts the surface of the plastic pipe to make the joint. As the glue evaporates within two minutes, a strong joint is obtained.

9.3 Pipe Fittings

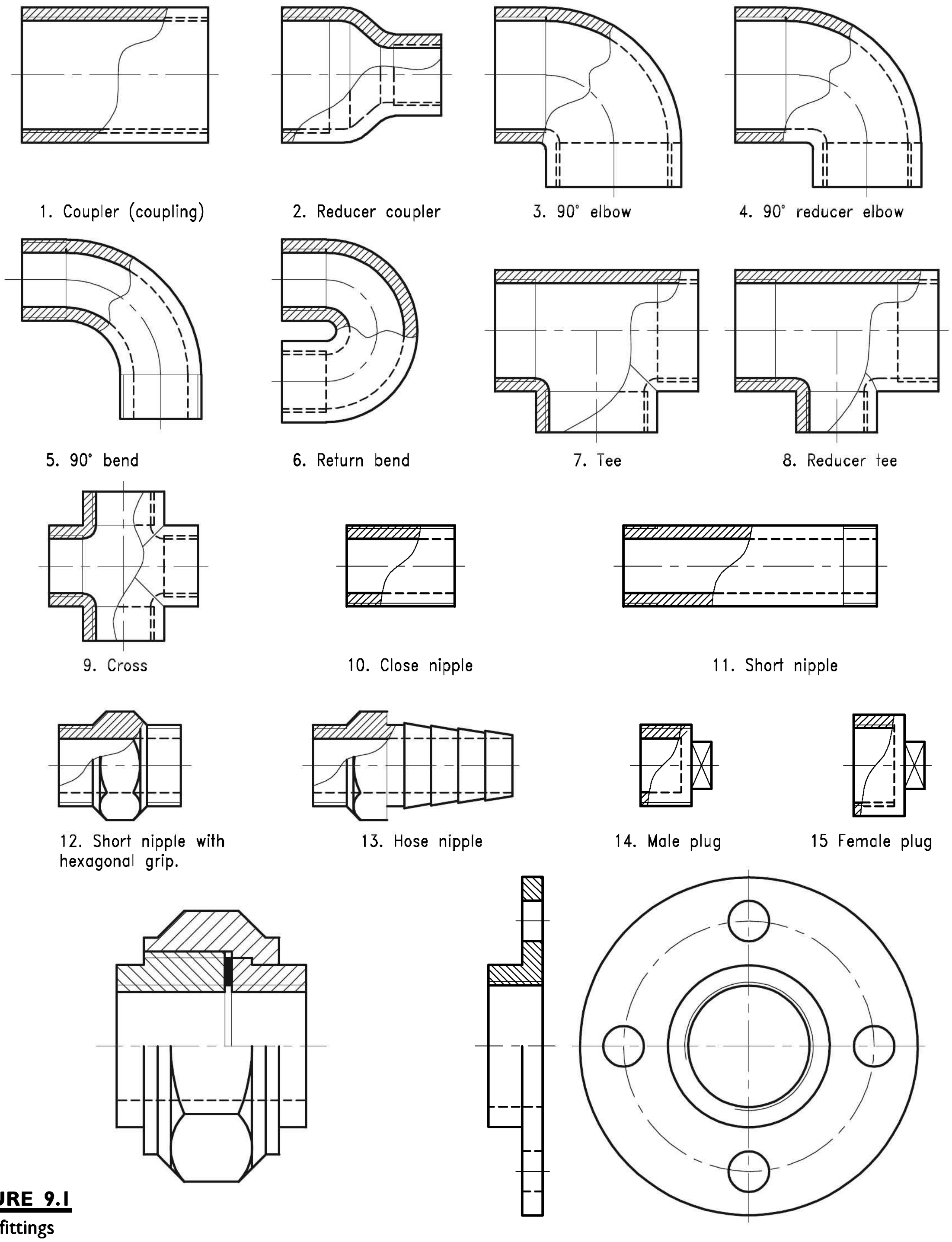
Screwed pipe fittings, (pipe specials) are removable or temporary pipe connections which permit necessary dismantling or reassembly for the purpose of installation, maintenance, cleaning, repair, etc. The functions of pipe fittings can be broadly classified as:

1. To join two or more pipe lines together
2. To effect change in diameter or direction
3. To close the end of a pipe line

The most common types of screwed pipe fittings used in galvanized iron (GI) pipe lines and plastic (PVC) pipe lines are shown in Figure 9.1 (1 to 17). A brief description of these fittings is given below.

1. ***Coupler (coupling):*** Two pipe lines of equal diameter and in axial alignment can be joined by a coupler (coupling). It is a short sleeve with internal thread.

2. ***Reducer coupler (Reducer coupling):*** This is a coupler to join two pipe lines of different diameters in axial alignment.



1. Coupler (coupling)
2. Reducer coupler
3. 90° elbow
4. 90° reducer elbow
5. 90° bend
6. Return bend
7. Tee
8. Reducer tee
9. Cross
10. Close nipple
11. Short nipple
12. Short nipple with hexagonal grip.
13. Hose nipple
14. Male plug
15 Female plug
16. Screwed union
17. Flange

FIGURE 9.1
Pipe fittings (specials)

3. ***90° Elbow:*** This is a pipe special used for effecting abrupt change in direction through 90°. Internal threads are provided on both ends. An elbow brings twice the head loss than a bend.

4. ***90° Reducer elbow:*** This is an elbow with outlet diameter less than that of inlet diameter. It is used to join two pipe lines having different diameters and meeting at right angle.

5. ***Bend:*** This is a pipe special used to effect gradual change in direction (usually 90°). The two ends of the bend are externally threaded.

6. ***Return bend:*** This bend is used to return the direction of pipe line through 180°. The ends are internally threaded for fitting the pipe lines.

7. ***Tee:*** This pipe special is used to make a branch connection of same diameter to the main pipe line at right angle. A Tee is internally threaded and it connects three ends of pipes.

8. ***Reducer Tee:*** This is a pipe special similar to Tee used to take a branch connection of reduced diameter from the main pipe line.

9. ***Cross:*** This pipe special is used to take two branch connections at right angles to the main pipe line. The threads are provided internally.

10. ***Close nipple:*** A nipple is a short straight piece of pipe with external thread on both ends. A close nipple is the shortest one of this category with external thread for the full length. They are used to join two internally threaded pipe specials and valves.

11. ***Short nipple:*** A short nipple has the same shape and function of a close nipple, but it has a short unthreaded portion at the middle of its length for gripping.

12. ***Short nipple with hexagonal grip:*** This nipple has an additional hexagonal nut shape at the middle portion for easy screwing with spanner. It is similar to an ordinary short nipple, except that difference.

13. ***Hose nipple:*** A hose nipple is used to connect a hose (flexible pipe-usually plastic or rubber) to a pipe line. One end of the hose-nipple has a stepped taper to fit the hose, while other end has thread. A hexagonal nut shape is given to the middle portion for gripping with a spanner.

14. ***Male plug:*** A male plug is used to close an internally threaded end of a pipe line or pipe special. It has external thread and a grip of square shape at the end.

15. ***Female plug (cap):*** A female plug is used to close an externally thread end of a pipe or pipe special. It has internal thread and a grip of square shape at the end.

16. ***Screwed union:*** It consists of three pieces as shown in the drawing. The two end pieces have internal threads at their ends which are connected to the pipe ends. The central hexagonal (or octagonal) piece (union nut) has internal thread at one end and a collar at the other end. After the end pieces are screwed on to the pipes, the central piece (union nut) is tightened to draw the end pieces together to get a water tight joint.

17. ***Flange:*** This is a disc type pipe special having threaded hole at the centre for screwing to the externally threaded end of a pipe line. It will have holes around the central hole at equal angular spacing (3, 4, 6, or 8 Nos.) for joining to another similar flange or flat surface using bolt or stud. Example for the use of various pipe fittings in pipe line is given in Figure 9.2.

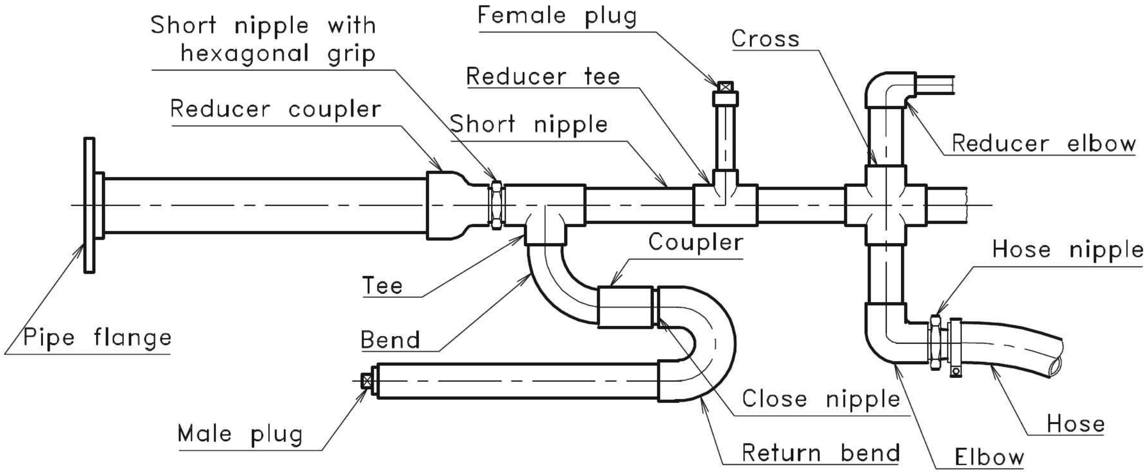


FIGURE 9.2
Use of pipe fittings.

9.4 Valves and Meters

Valves are used in piping systems to control or stop the flow of liquid or gas. The most common types of valves used in low pressure water pipe line are:

1. Water tap
2. Water cock
3. Globe valve
4. Gate valve
5. Ball valve
6. Non-return valve
7. Foot valve

Water tap

To collect water from low pressure pipe line, water tap (screw-down valve) is commonly used. Figure 9.3 gives the cross section of the tap. Its leather or rubber faced valve disc is lifted or lowered by rotating the spindle. Brass or gun-metal is the material used for the valve body and the size is specified by the pipe to which it is fitted, usually ranging from 10 mm to 25 mm.

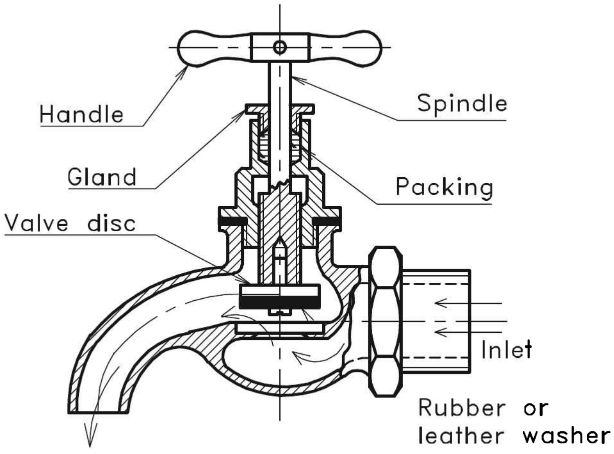


FIGURE 9.3
Water tap.

Water cock

This is the simplest and smallest form of a valve in which a conical plug called cock is inserted into a conical hole having a matching taper. A rectangular hole is provided at the centre across the conical portion so that, in one position it permits flow of water as shown in Figure 9.4. A half turn of the handle will bring the solid portion of the cock to the water ways preventing the flow. Cocks are used for low rate of water flow or for tapping pressure line to a manometer etc.

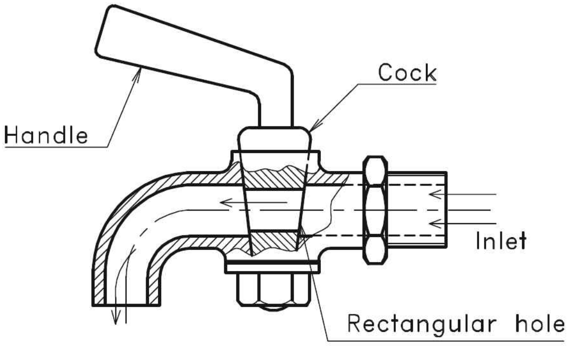


FIGURE 9.4
Water cock.

Globe valve

Globe valves are used as control valves in fluid (gas and liquid) pipe lines. Figure 9.5 shows the simplest and smallest type of globe valve used in water pipe lines. Basically, the valve is a variable opening flow device. The design of a globe valve also creates a slight retardation to the flow because the fluid is forced to make a double turn and passes through the opening at 90° to the axis of the pipe. The valve plug is raised or lowered to stop or regulate the flow through a circular opening. A globe valve can be

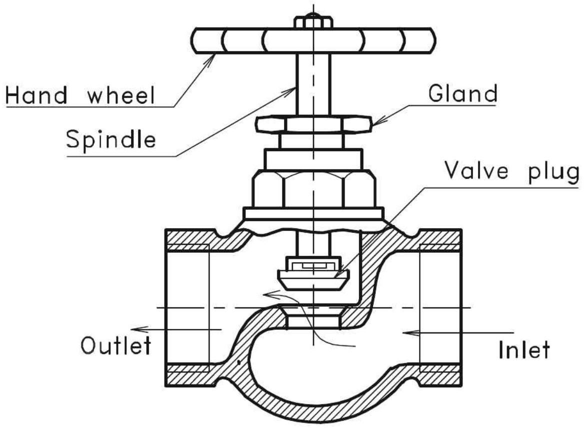


FIGURE 9.5
Globe valve.

identified by the spherical body and the arrow mark for the direction of flow. These valves are used in water pipe lines from 12 mm to 100 mm or even larger diameter for the flow control purpose.

Gate valve

A gate valve is on–off type valve. It allows a straight-line movement of fluid and offer very little resistance to the flow in fully opened position. The central disc moves completely out of the passage and leaves a full opening. Figure 9.6 shows a simple type of gate valve partially opened in position. These valves are very widely used in water pipe lines of diameter ranging from 12 mm to higher values. A gate valve can be identified by its slim body. It is to be noted that there will be no arrow mark or the body of valve because it can be used in both ways.

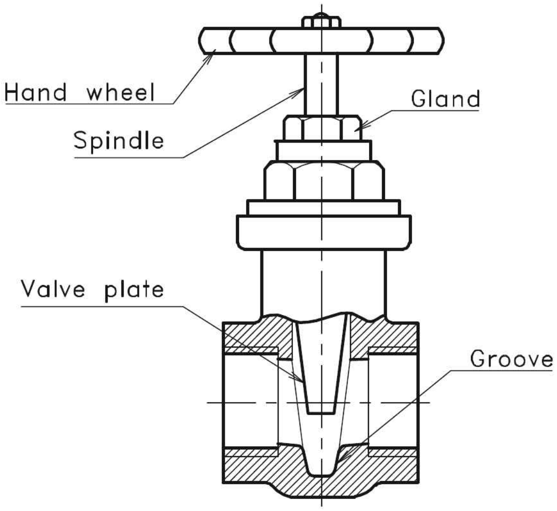


FIGURE 9.6
Gate valve.

Ball valve

A ball valve has a spherical shaped rotating part with a hole at the centre to on or off the flow through the pipe line. Figure 9.7 shows the assembly of the valve, top half in section. The ball is connected to a spindle and the spindle is turned to 90° with the help of a handle (lever) to on or off position. The external surface of the ball is made smooth and it rotates rubbing two PVC washers. The gland packing arrangement stops the leakage. Ball valve can be used as gate valve in pipe lines and offers minimum head loss.

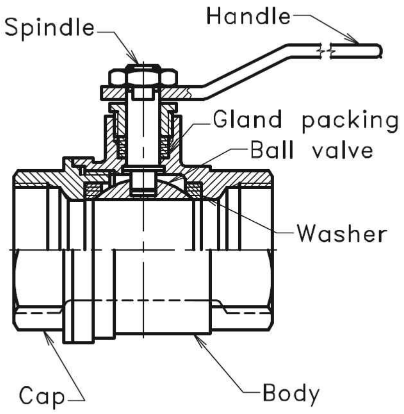


FIGURE 9.7
Ball valve.

Non-return valve

If the fluid flow in the reverse direction is to be stopped automatically in a pipe line, a non-return valve has to be fitted in the line. A type of non-return valve used pipe lines is shown in Figure 9.8. In this valve, the disc-valve portion at the centre is lifted when the pressure of water in the inlet side is greater than that of the outlet side, allowing the forward flow. When the pressure of outlet side exceeds that of inlet, the valve closes automatically stopping the reverse flow.

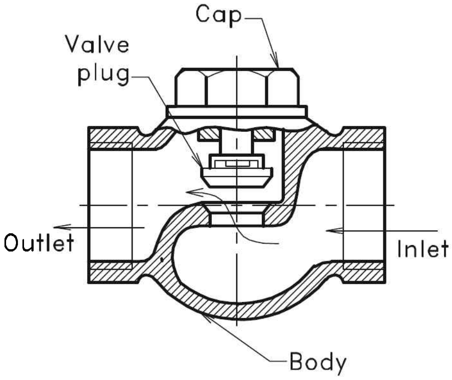


FIGURE 9.8
Non-return valve.

Foot valve

Foot valve is a kind of non-return valve used in centrifugal pumps. It is fitted at the bottom most end of the suction pipe (Foot) to stop flow in the downward direction for priming purpose. The strainer restricts the entry of floating materials to the pipe line. Figure 9.9 gives the details of the foot valve. The material used may be cast iron, brass, or PVC.

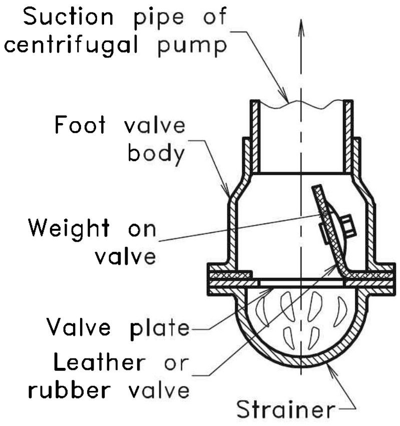


FIGURE 9.9
Foot valve.

Water meter

Water meter is one of the most common type of measuring device used in pipe lines for the measurement of volume of water flowing through it. Figure 9.10 shows the principle of working of a rotary type water meter. When water flows across the meter,

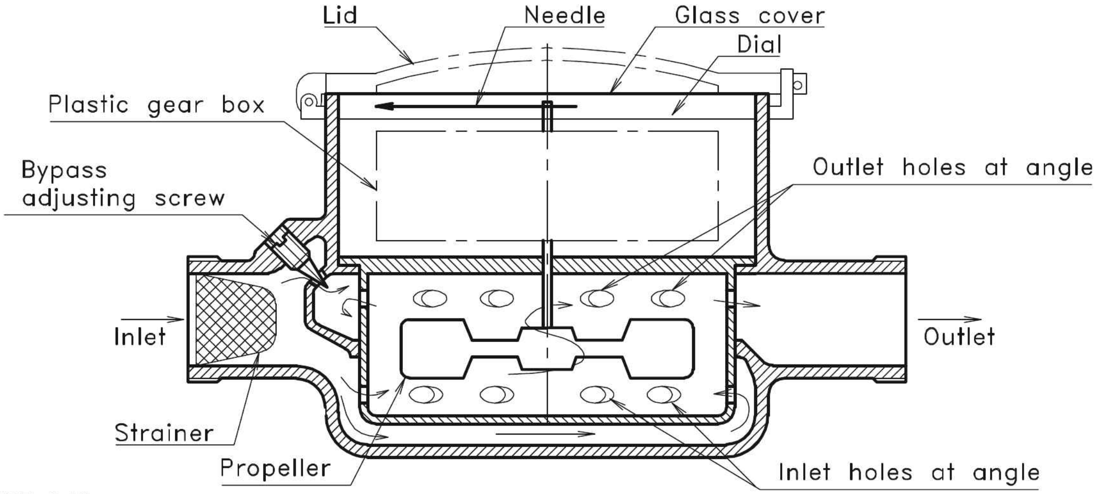


FIGURE 9.10
Water meter.

the flow takes place in a helical path due to the inclined holes. As a result the propeller rotates operating a series of gears. The volume of water flowing through the meter can be directly read from the calibrated circular dial by noting the initial and final readings. The meter reading can be corrected by adjusting the position of the by pass control screw provided in the inlet side of the meter. Water meter is fitted at the entry point of water pipe line to a house or usage area.

9.5 Plumping Fixtures (Sanitary fittings)

The fixtures used in a building for receiving excreta and waste water discharged by the users are called sanitary fittings. They include water closets, wash basins, kitchen sinks, bath tubs, flushing cisterns, shower stall, urinal, floor traps, etc.

Sanitary fixtures are connected to drain pipes of large diameter ranging from 50 mm to 100 mm. In modern types fittings PVC pipes are preferred, although asbestos pipes were the old practice. In order to prevent the reverse flow of foul air or gas through drainage pipes, traps are generally fitted after a fixture before connecting to the outlet pipe. A trap is a water seal with full of water. This collection is formed by a depression or bent fitting in the pipe line as shown in Figure 9.11. The traps can be classified according to the shape of them as P-trap, S-trap, and Q-trap.

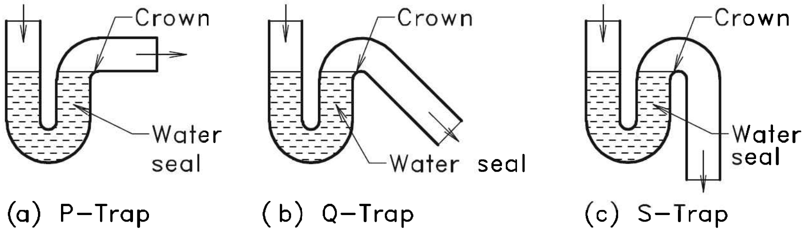


FIGURE 9.11
Types of traps.

(a) P–Trap (b) Q–Trap (c) S–Trap

Water closets

Water closets (WC) are fixtures those receive and dispose off human excreta using water as the medium of conveyance.

There are three types of water closets:

1. European (Pedestal or western) type WC
2. Indian (Squatting or oriental) type WC
3. Universal (Anglo-Indian) type WC

European (Pedestal or western) type WC

This fixture has a bowel form, with oval shaped opening at the top, having 400 mm height to form a chair like structure. S-type or P-type trap is used according to the outlet pipe position. Figure 9.12 gives cross-section of a European WC.

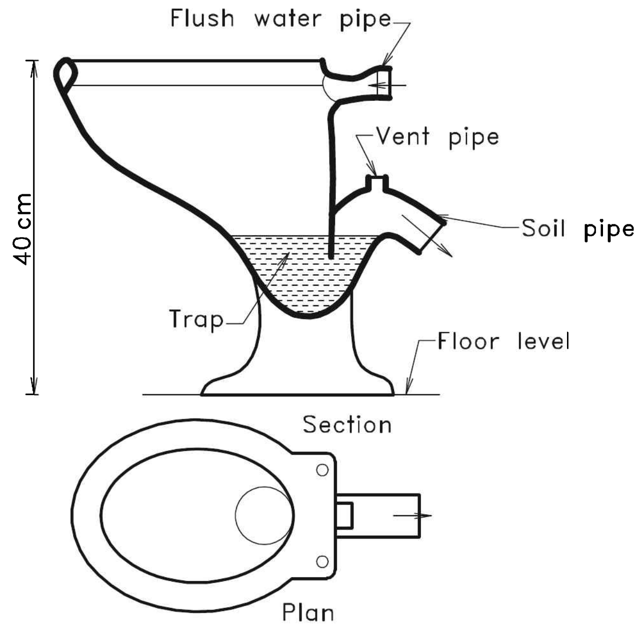


FIGURE 9.12
Water closet (Pedestal or western).

Indian (Squatting or oriental) type WC

These closets are installed at the floor level and enables a person to use it in a squatting position. Figure 9.13 gives cross-section of an Indian WC. Here, P type trap is used.

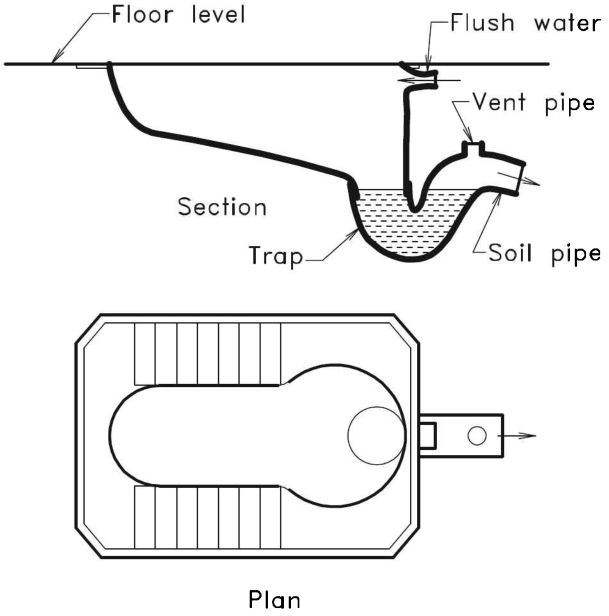


FIGURE 9.13
Water closet (Squatting or oriental).

Universal (Anglo-Indian) type WC

This is a combination of the above two. The top is wider and the user can either sit as a European WC using the plastic seat, or squat on it as on an Indian one.

Flushing systems

Water closets are flushed by discharging water through a suitable mechanism. Water of about 5 litres to 12.5 litres is to be delivered quickly (8–9s) i.e., at a rate of 1.5 l/s. Flush tanks (Flushing cisterns) placed above the WC gives the pressure (head) for efficient flushing. About 1.8 m is the best preferred head for better action. An inverted bell with a mechanism to lift it by a lever is installed above the flush. Siphonic cisterns operate only when the cistern is full of water. Hence, it does not waste water by overflow. Flush tanks are also available with 'beta valve' or similar mechanism which has direct opening from the flush tank and not through the siphon mechanism. This may bring over flow, if the valve is not perfectly working. A float-valve mechanism fitted at the water inlet point of the flush tank stops the inward flow when the tank is full. Flush valves are also available as substitute for flush tanks. They are mechanical valves fitted directly on the pipe line. Here, filling time is not required, so immediate flushing is possible after the previous one. This type is good for public toilets, where continuous use is there.

Wash basins and kitchen sinks

Wash basins (Figure 9.14) used in lavatories are fitted with cold and hot water supply taps with mixing fixture. The waste collected by the basin is disposed using 32 mm diameter waste pipe. An additional stopcock (usually angle valve) is provided at the inlet of each tap to isolate the fixture when required. Basins are usually made up of porcelain-ware or plastic. Kitchen sinks are similar to the wash basins but the shape and dimensions are given suitable to kitchen use. Stainless steel is the material commonly used for the sink. The waste pipe fitted is of 40 or 50 mm diameter in order to facilitate disposal of small amount of solid waste.

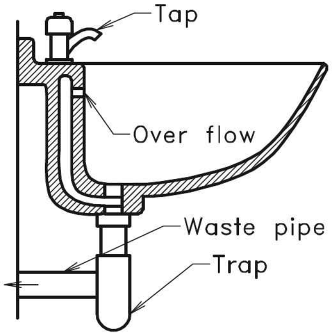


FIGURE 9.14
Wash basin.

Bath tubs and showers

Bath tubs are vessels capable of holding water and allowing a person to soak in, clean and relax. Hot and cold water is supplied and mixed in the tub for use. The water holding capacity of a standard tub is about 200 litres to 225 litres and the requirement of water is about 150 litres to 180 litres. Showers are provided for a spray of water which enables a person to wash himself while standing. The control valve is fitted for hot and cold water mixing at a convenient height.

Geysers

Geyser is the name of hot water springs found in many parts of the world. This term is adopted for the appliance used for hot water supply unit in buildings. Electrically heated individual geysers are popular in India. It mainly contains a heating element wound around the pipe carrying water. When the electric supply is given, it heats the water flowing though it. The whole unit is of cylindrical shape and fitted in the bath room at overhead position to collect water. Centralized hot water supply system is used in hotels and flats to overcome cold season. The heating is done with the help of a boiler using electricity, gas or different types of fuels and the distribution is done through insulated pipelines.

9.6 Sketching of Piping Layouts

A neat line sketch of the piping layout is prepared before starting the plumbing process so that clear information about the layout of fixture, its connections, operating directions, etc. will be clear to all involved in the work.

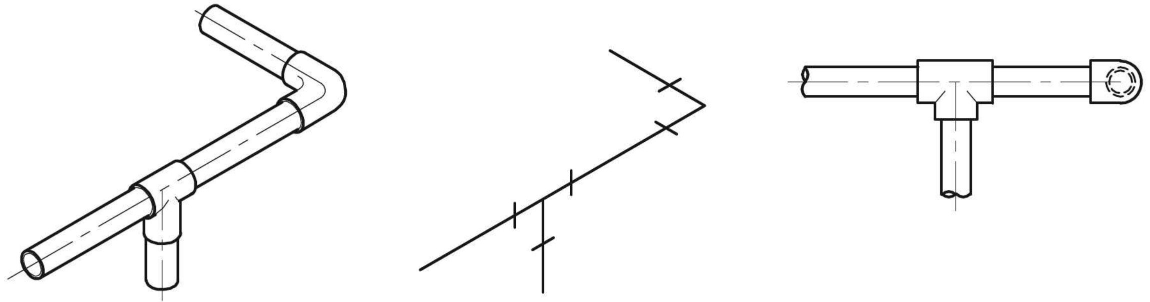
Piping layout drawings can be classified as:

1. Double line pictorial layout
2. Single line pictorial layout
3. Double line orthographic layout
4. Single line orthographic layout
5. Single line developed layout

In double line piping layout all the pipes are represented by two lines and fittings are shown as it is seen. In single line layouts the pipes are shown by single thick line and the fittings by its symbols. In pictorial (Isometric) layouts, a three dimensional pictorial view is drawn. Figure 9.15 gives the example for the five types of piping layouts. Among the five types of layouts the single line isometric layout is the simplest and most suitable for sketching.

Representation of pipe fittings, valves and fixtures

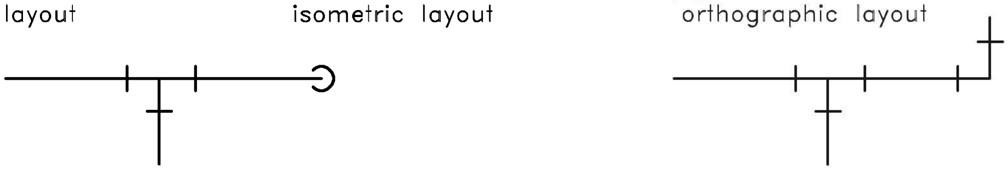
The pipe fittings and valves of screwed type can be represented in piping layouts by graphic symbols. In an isometric view, there are three equal faces as shown in Figure 9.16. In isometric piping layout, the graphic symbols are to be shown in all



(a) Double line isometric layout

(b) Single line isometric layout

(c) Double line orthographic layout



(d) Single line orthographic layout

(e) Single line developed layout

FIGURE 9.15
Types of piping layouts.

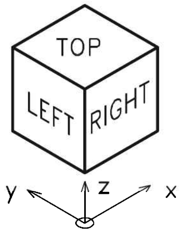


FIGURE 9.16
Principle of Isometric view.

three faces according to the requirement. Figure 9.17 shows a plumbing setup drawn using isometric graphic symbols. Figure 9.18 gives a list of graphic symbols for common pipe specials, drawn as on the right isometric face. It is to be noted that for screwed joints, say for an elbow, two short lines are shown to represent the ends. For a flanged joint, two parallel short lines are shown to represent the flanges. Figure 9.19 shows the graphic symbols for common types of valves. To show the various fixtures other than the pipe specials and valves, simplified forms of the equipment itself may be drawn.

9.7 Water Supply System

Water supply system of different types are in use according to the area of application as residences, hostels, hospitals, industries, swimming pools, fire fighting, gardening, etc. The quantity of water required (per day, per person), the quality, pressure, temperature, etc., are also different. An expert plumber should gather clear idea about

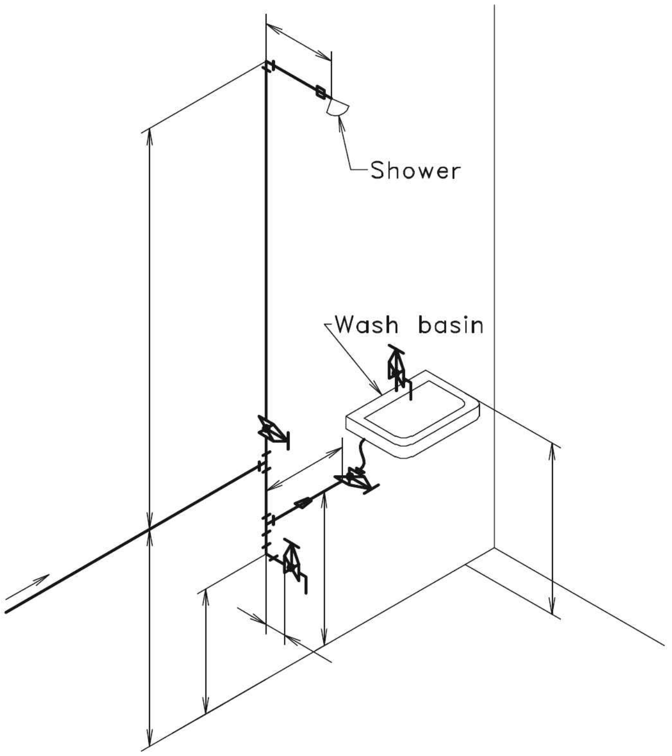


FIGURE 9.17
Sample of plumbing layout.

such things. In residences, the requirement is considered as 135 litres (90 for domestic purposes and 45 for flushing) per day per person. Data about such things are available from tables given in building code of practice. Figure 9.19 gives a sample of the layout of water supply used in a multiple floor residential building using single line developed layout. Water from the city water mains is collected in a ground tank through a water meter and pumped to the overhead tank fitted on the top of the building. From there it is distributed to various floors as shown. Air vent pipe is provided at a height above the tank for the smooth downward flow of water.

9.8 Rain Water Disposal System

Rain water falling on roofs, paved areas and other open areas must be collected and disposed off efficiently and quickly. Plumber has to plan and fit good drainage piping system for a building. Figure 9.20 shows a sample of flat floor drainage system. The number of pipelines and the diameter has to be selected according the possible intensity of rain fall and the catchment area.

The rain water falling on the roof can be collected and used after filtering. The water thus collected is good enough for drinking purpose also than the one obtained from wells and city supply lines. After the starting of a rain, allow five minutes to

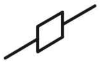
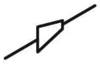
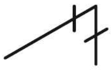
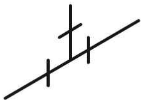
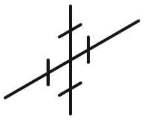
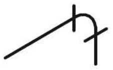
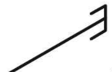
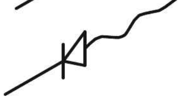
	Description	Isometric symbol (right face)
1	Coupler	
2	Reducer coupler	
3	90° Elbow	
4	Tee	
5	Cross	
6	Bend	
7	Plug (female)	
8	Plug (male)	
9	Union	
10	Hose nipple	

FIGURE 9.18
Isometric graphic symbols for pipe fittings.

drain water to outside through the pipe. This cleans the surface and then the inlet valve can be opened to admit water to the tank through the filter. Figure 9.21 is self explanatory of the procedure. Collection of water by this method is called rain water harvesting for domestic use.

9.9 Sewage/Wastewater Disposal System

The water after its use and the sewage (human excreta or soil) are collected and moved through drain pipes by gravity. Finally they are disposed to a domestic septic tank or to a public sewer. For maintaining healthy conditions in a building, a plumber has to

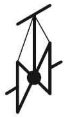
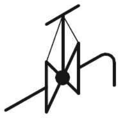
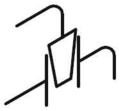
	Description	Isometric symbol (right face)
1	Gate valve	
2	Globe valve	
3	Water tap	
4	Water cock	

FIGURE 9.19
Isometric graphic symbols for valve.

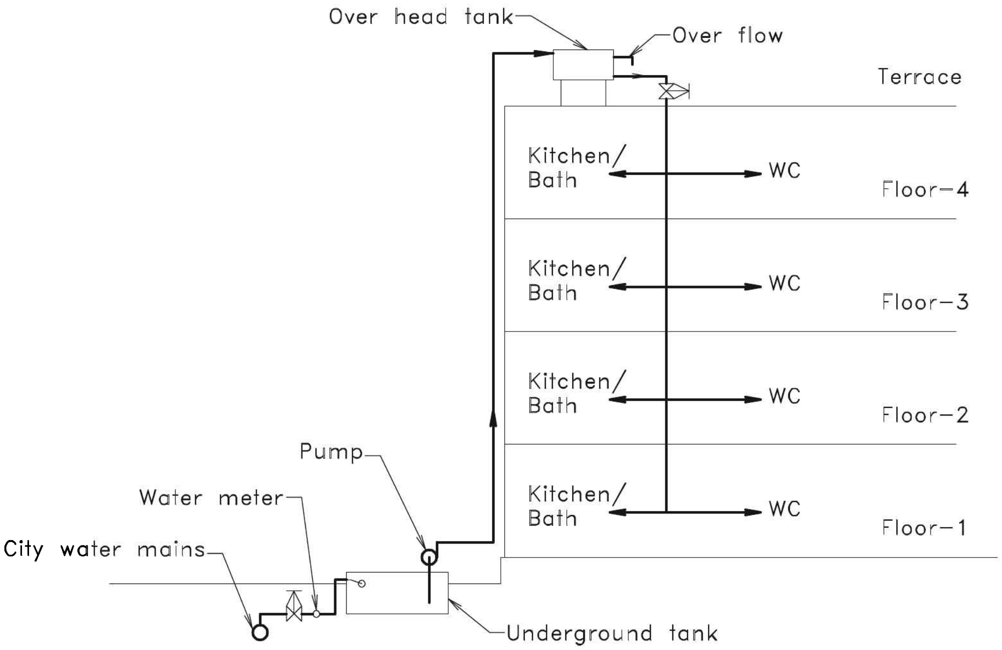


FIGURE 9.20
Water supply system in a multifloor building.

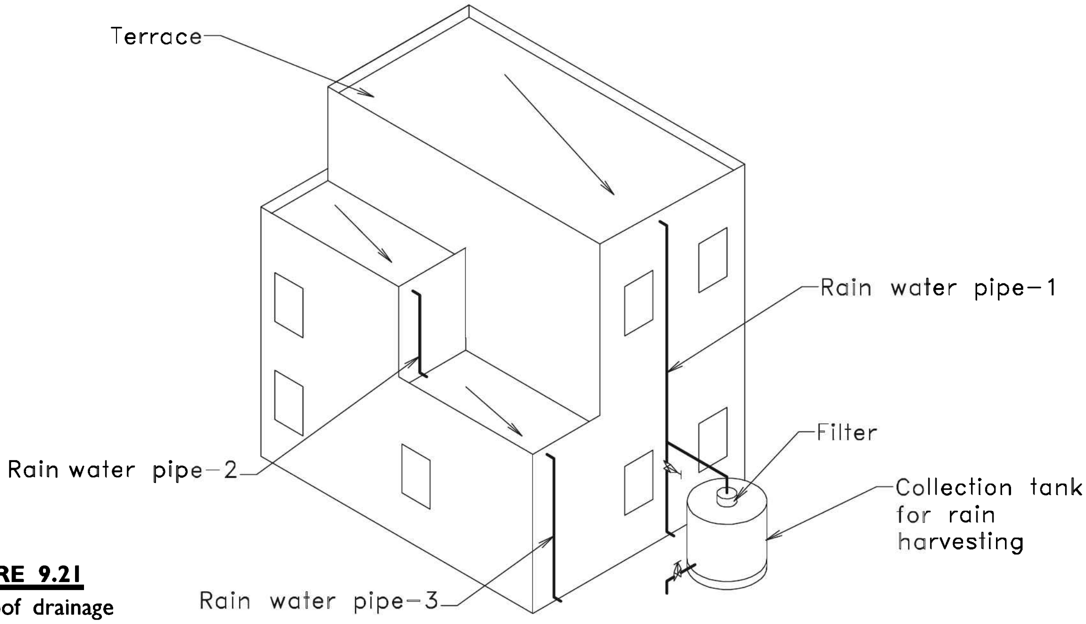


FIGURE 9.21
Flat roof drainage and rain harvesting system.

plan and install the sewage system efficiently. Some of the important points to be considered are:

1. The length of drainage pipe should be minimum in order to reduce the sewage handling problems. This is attained by locating the lavatory blocks at one place and one over the other for a multistoreyed building.
2. Sharp bends and more junctions should be avoided.
3. Sufficient slope for drainage has to be given for pipelines.
4. Larger diameters should be selected for pipes. Examples: 100 mm for soil pipe, 75 mm for rain water and waste water pipes, 50 mm for vent pipe, etc.
5. Enough traps should be fitted in the sewage system at suitable locations.
6. All the connections should be leak proof and manholes have to be provided at bends and intersection.

Septic tank

Solid waste carried by water in pipe lines (Sewage) is disposed in septic tanks. Figure 9.22 shows cross section and plan views of a simple septic tank with two compartments. Septic tanks are made with a minimum width of 75 cm and depth of 130 cm so that 100 cm is depth is available for water. The minimum capacity of liquid storage should be 1000 litres and the length may be 2 to 4 times the width. For circular tanks, the minimum diameter shall not be less than 135 cm. The smallest size of tank is sufficient for 5 users. As the number of users increases the size of tank has to be enlarged proportionally as per the design data. The septic tanks should be plastered inside and outside with cement to make it leak proof.

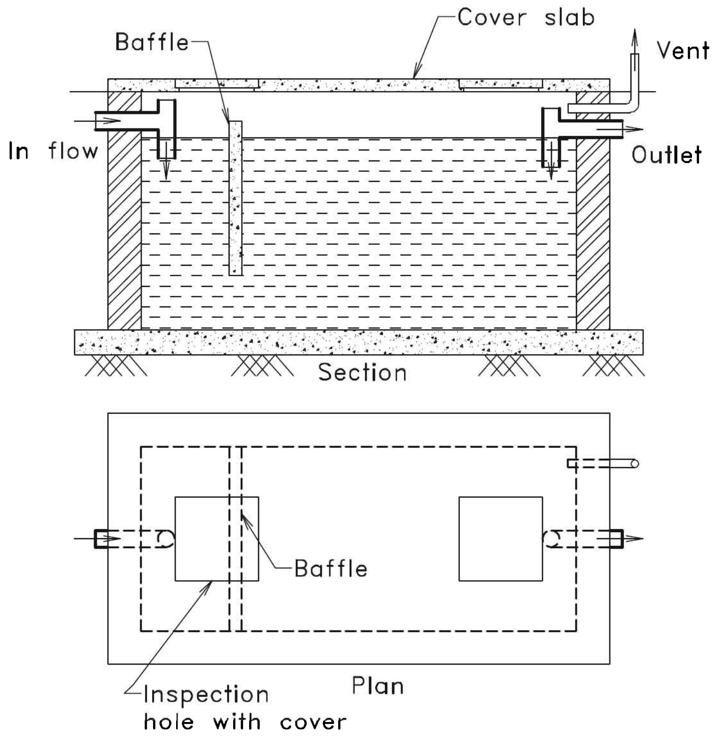


FIGURE 9.22
Septic tank.

A septic tank produces septic action by anaerobic bacteria. Here carbohydrates, cellulose, proteins and fatty matter present in the sewage are broken into simple compounds and finally digested. The water separated out from the digested material is called effluent and it is disposed to below the ground level using soak pit (Seepage pit).

Soak pit (Seepage pit)

Soak pit is a covered one as shown in Figure 9.23 and the effluent is discharged to it. The earth below the tank absorbs the effluent collected in the pit. The sides of the pit may be built with bricks, stone or concrete blocks and lined with 7.5 cm coarse sand. Similar soak pits are built to dispose waste water collected form bath rooms and wash basins. They are called sludge soak pits and used separately from septic tank. Soak pits are to be located far away from the drinking water collecting well.

9.10 Plumbing for Industries

Plumbing has many industrial applications and engineers have to design, plan, erect, test and maintain the pipe lines for various factory uses. It is crucial for moving fluids in chemical and petroleum industries in the form of raw, semi-processed and processed products. The working conditions of the pipes are also may be critical such as high

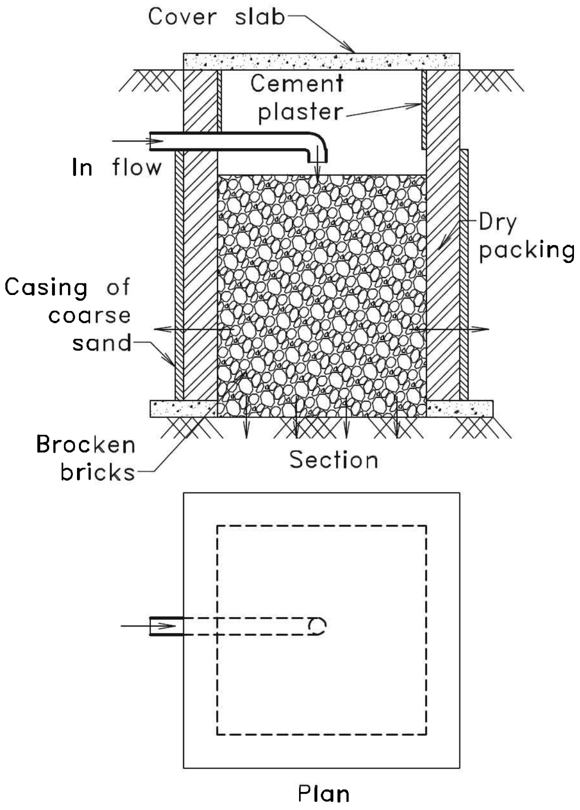


FIGURE 9.23
Soak pit.

pressure, vacuum, hot, cold, heavy, light, corrosive, etc. A list of the important areas of application is given below:

1. Conveyance of oils, chemicals, water and other fluids
2. Handling of compressed air and gases
3. Steam and water handling at high pressure and temperature
4. Fluid handling in refrigeration systems
5. Waste water and chemical waste handling
6. Fire suppression systems

The pipes and fittings used for the above purposes may vary according to the material moved, pressure, temperature and quantity. PVC pipes and fitting are applicable to low pressure and room temperature conditions only. As pressure and temperature increases, the pipe used may be welded G.I. or seamless stainless steel. For chemicals and large quantity supply of water or steam, cast iron pipes having in-built flanges are used. Rubber or plastic coatings of appropriate type may also be provided inside the pipes to control corrosion. Brass, lead or copper may also be selected as material, especially for high pressure low quantity movements. Industrial piping layout drawings are professionally prepared using special soft-wares designed for that. Different types of lines, symbols and colours are assigned as per International Standards to plan the layouts, so that it will be easy to read, record and understand. It is to be noted that, even though the principle of pipe installation and maintenance in industries is more or less similar to that of domestic use, the word plumbing is generally applied for buildings used for residence.

9.11 Plumber's Tools

Plumbing is the process of installing, or repairing of pipes, pipe specials and fixture units for different sanitary appliances, for the supply and drain of water and gas. This includes the cutting of pipes to the required lengths, drilling of holes, threading and making of leak proof joints, etc. Sometimes bending of long pipe line may also be required. For all these operations the following tools are generally used:

General fitting tools for plumbing

1. Pliers
2. Spanners
3. Steel rule
4. Measuring tape
5. Hack saw
6. Screw drivers
7. Spirit level
8. Scriber
9. Punch
10. Electric-hand drill
11. Files

Special tools for plumbing

1. Pipe vice
2. Pipe wrench
3. Chain wrench
4. Pipe cutter
5. Pipe bending machine
6. Pipe threading dies.

Pipe vice

Pipe vice is a device used to hold the pipe firmly while cutting, threading and fixing or loosening of pipe specials. The two jaws are V-shaped in order to grip circular pipes firmly. Figure 9.24 shows a type of pipe vice in common use.

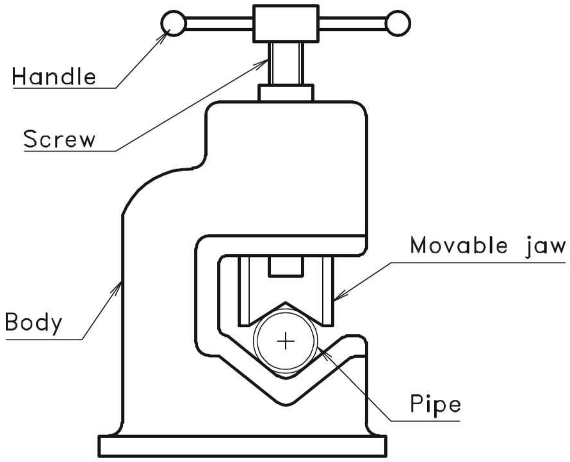


FIGURE 9.24
Pipe vice.

Pipe wrench

Pipe wrenches are made in several designs. The most common type of pipe wrench is shown in Figure 9.25. This wrench can be used for gripping a range of pipe sizes depending upon the rack provided on the movable part of the tool. The overall length of wrench specifies the size of the tool. The commonly used size varies from 30 to 50 cm.

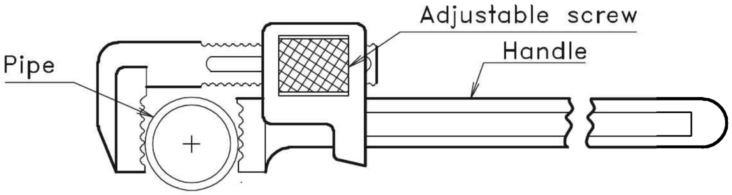


FIGURE 9.25
Pipe wrench.

Chain wrench

This wrench mainly consists of a chain for griping instead of jaws. The chain is wound around the pipe and gripped to the body of the wrench for screwing or unscrewing of large diameter pipe specials. Figure 9.26 shows the use of a chain wrench.

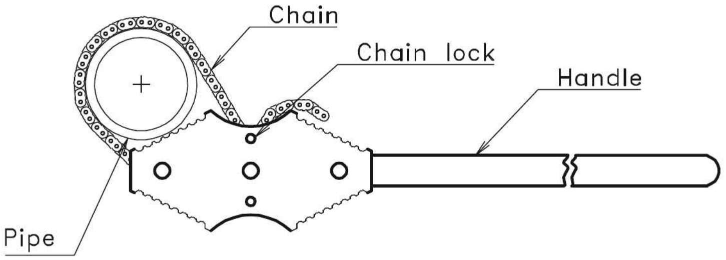


FIGURE 9.26
Chain wrench.

Pipe cutter

A pipe cutter is a type of tool used by plumbers to cut pipe. Besides producing a clean cut, the tool is often a faster, cleaner, and more convenient way of cutting pipe than using a hacksaw, although this depends on the metal the pipe is made out of. There are two types of pipe cutters. Plastic tubing cutters, which really look much like a pair of pruning shears, may be used for thinner pipes and tubes such as a sprinkler pipe. Then there is a pipe cutter with a sharp wheel and adjustable jaw grips for use on thicker pipes. See Figure 9.27. These are used by rotating it around the pipe and repeatedly tightening it, until it cuts all of the way through.

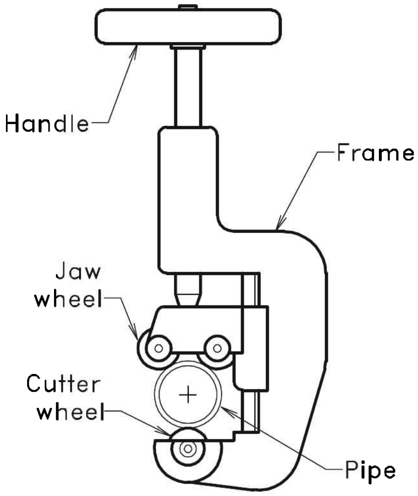


FIGURE 9.27
Pipe cutter.

Pipe bending machine

Bending of pipes is done by means of a pipe bending machine. It is mounted on a tripod stand and can swivel about its axis at any angle so as to give a wide range for operation. The unit can accommodate a number of bending blocks (formers) and dolly blocks to give the desired curvature at the bend. Figure 9.28 shows the top view of a hydraulic, pipe bending machine. In operation, the two outer formers remain stationary while the central former moves during the bending. To get the force for bending a hydraulic pump liver is actuated forward and backward, after closing the oil release valve.

Pipe threading dies

Dies are used to cut external threads on round pipes and rods. A die is a round block of hardened steel with hole having internal threads and flutes across the threads. The die is fitted inside a die holder called *die stock* and is used for cutting external threads. See Figure 9.29. In the case of cutting external threads, only one die is enough to finish the thread. To cut threads on a diameter slightly varying from the nominal

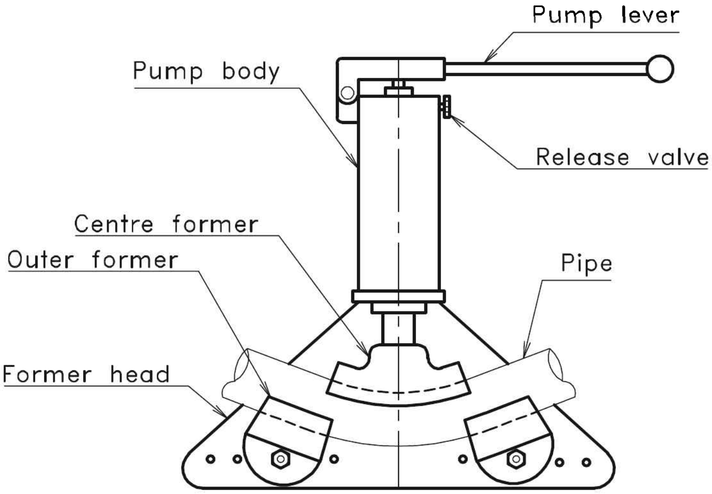
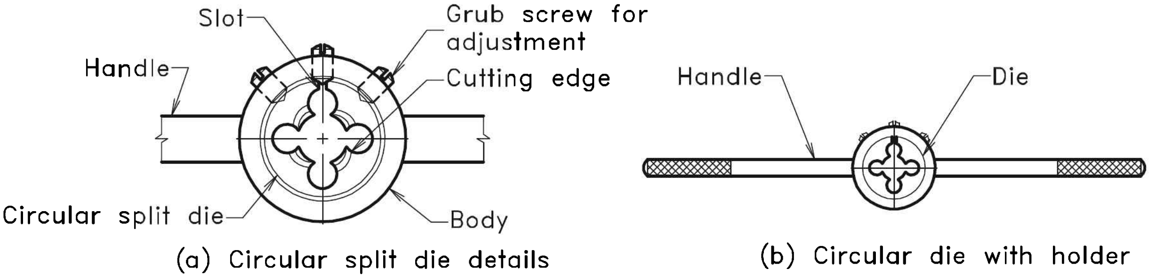


FIGURE 9.28
Pipe bending machine (Hydraulic).



(a) Circular split die details

(b) Circular die with holder

FIGURE 9.29
Die for threading.

diameter, an adjustable die can be used. Here, the die is split into two and a screw can be used to adjust the gap between the die pieces. The thread cutting is done after holding the pipe between the jaws of a pipe vice and screwing the die stock from the end of pipe with force.

9.12 Accessories for Plumbing

Plumbing process requires some accessories other than the pipes, fittings, valves and fixtures for the operation. The common accessories include:

1. ***Solvent Cement Glue:*** It is a PVC resin-based material used for jointing PVC pipes and pipe fittings without the use of thread. The surfaces which are in contact for a joint, are coated first with the glue. Then the parts are tightly assembled together. After drying for two minutes, the joint becomes a plastic seal and permanent leak proof one.

2. ***Teflon (PTFE) Tape:*** It is a trade name of the DuPont company for, a non-stick substance *polytetrafluoroethylene (PTFE)*. This is available in thin tape form, which is wound over a circular ring. Joints of threaded components can be made leak proof by winding the teflon tape over the externally threaded portion, before making the joint.

3. ***Shellac compound:*** It is a resin secreted by the female *lac* bug, on trees in forests. This resin is dissolved in denatured alcohol to make liquid shellac. To make leak proof joints in threaded components, a shellac mixed compound is applied on the threaded surfaces. It is allowed to dry for few minutes after making the joint. For large diameter G.I. pipes, this compound is applied on the threaded portion, after winding a thin fibre (Jute) thread for one layer. This assures a leak proof joint easily even though there is some imperfection in threading. The compound is available in small plastic bottles.

4. ***Gaskets:*** It is a mechanical seal that fills the space between two mating flat surfaces, generally to prevent leakage from or into the joined objects while under compression. Gaskets are commonly produced by cutting from sheet materials, such as gasket paper, rubber, metal, cork, felt, fibreglass, CAF (Compressed Asbestos Fibre) or a plastic polymer. In flanged pipe joints a gasket is placed in between the bolted flanges for controlling the leak. Shellac compound may also be applied on the mating surfaces.

5. ***Brushes:*** Small size brushes up to 25 mm size are used for cleaning as well as application of solvent cement, shellac compound, etc.

6. ***Pipe Clips and Fixings:*** For fixing pipe on wall pipe clips and fixings are used. They are screwed or nailed to wall.

7. ***Backing Rings:*** To support heavy pipes backing rings of MS or plastic are used.

8. ***Wall plug or Rawl plug:*** It is a type of *fixing* used in buildings so that, screws can be fitted into masonry walls. There are many forms of wall plug, but the most common principle is to use a tapered tube of soft material, such as plastic. This is inserted loosely into a drilled hole, then a screw is tightened into the centre. The screwing action wedges the plug firmly in place and the soft material is conforming tightly to the masonry.

9. ***Screws and nails:*** For fixing clamps, fixtures, backing rings, etc. on wooden surfaces and walls, different types of screws and nails of various size are used in plumbing.

9.13 Plumbing Practice

The process of plumbing to supply water to various points in a house involves the following steps:

1. ***Planning the plumbing layout:*** The first step of plumbing is the planning of the piping layout to fulfill the requirements in an efficient manner. For this, the distance from overhead tank to the fixtures should be the minimum as far as possible, with less head loss in pipe specials.

2. ***Preparation of the line sketch:*** After finalizing the requirements and their location, the details are worked out and isometric single line layout is prepared. This should include the dimensions and size of pipes, pipe specials, fixtures etc.

3. ***List of materials and their collection:*** A detailed list of materials with specification is prepared and those items are collected in the site.

4. ***Installation:*** The fixtures are installed in the specified positions and the pipe line paths are marked. Starting from the tank, the pipes are laid by joining the pipe specials one by one. For this the pipes are to be cut to required lengths considering the overlaps. Hacksaw or pipe cutter may be used for this. PVC pipes and specials are joined by solvent cement application. For GI pipes, threading is to be done using dies and they are joined by screwing together with the use of pipe specials. The installation is completed using various tools and accessories.

5. ***Inspection and testing:*** The last step of plumbing is inspection of the installation and testing. After checking each joint and clamping the pipes in position, water line is opened from the tank to section by section, in order to test the working of fixtures and pipe lines. If there is any leak or fault is found, that should be rectified after closing the supply valve.

Plumbing processes and the steps are almost similar for other requirements like rain water disposal and sewage disposal. Here, the pipe diameters are large as 50 mm to 150 mm depending on the use. Proper slope and air vents have to be provided to pipe lines to result defect free working of the system.

Cutting to lengths and end-threading of GI pipes

GI pipes are galvanized mild steel (coated with zinc) pipes and used for conveying raw and treated drinking water. Mostly medium quality GI pipes are used. Their sizes vary from 15 mm to 150 mm. These pipes are manufactured conforming to IS-1239 (pt-I) 1990. Table 9.1 gives the nominal bore size and the corresponding useful data used for plumbing.

Table 9.1 Dimensions, nominal mass and thread size of medium quality steel pipes

Nominal bore		*Outside Dia.* mm	*Thickness (Std.)* mm	*Weight* kg/m	*Thread* per inch	*Major Dia.* mm
mm	inch					
15	1/2	21.3	2.77	1.27	14	20.955
20	3/4	26.7	2.87	1.69	14	26.441
25	1	33.4	3.38	2.50	11	33.249
40	$1^1/_2$	48.3	3.68	4.05	11	47.803
50	2	60.3	3.91	5.44	11	59.614
65	$2^1/_2$	75.9	5.16	8.62	11	75.184
80	3	88.9	5.49	11.29	11	87.884
100	4	114.3	6.02	16.07	11	113.03

To cut a full length pipe to required length, it is gripped horizontally between the jaws of a pipe vise and cut to length using a hack saw or a pipe cutter. The bur formed at the cut end should be removed using a file. For cutting thread on the pipe, the die size of major diameter (suitable to the outside diameter) is selected first as given in Table 9.1. Then the split die diameter is slightly enlarged by adjusting the grub screws on it (Figure 9.29) to accommodate the outside diameter of pipe. The die is screwed forward gradually from the end of pipe so that, a rough thread with less depth is formed first. While cutting, the screwing action may be forward and backward to remove the chip easily. The grub screws of the dies are tightened step by step to get full depth of thread. To check the fitness of thread, a standard coupler of same size may be screwed on the pipe using a wrench. Internal threads are not cut usually on pipes.

Example 1

Prepare a double line piping layout for the given sketch (Figure 9.30) and make the pipe line assembly using PVC pipe fittings as per the given dimensions and size.

Aim

To prepare a double line piping layout of the sketch given and make the pipe line assembly using PVC pipe fittings as per the given dimensions and size.

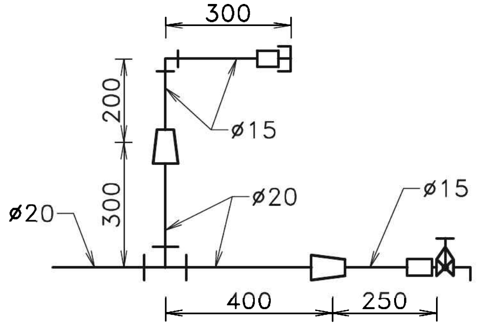


FIGURE 9.30
Single line piping layout.

Materials required

1. PVC pipes of diameters: 3/4" (20 mm) and 1/2" (15 mm) 1 piece each.
2. PVC pipe fittings: Tee 3/4" (20 mm) – 1 No., Reducer coupler 3/4" to 1/2" (20 mm to 15 mm) – 2 Nos., Coupler 1/2" – 1 No., Elbow 1/2" (15 mm) – 1 No., Coupler with thread on one end 1/2" (15 mm) – 1 No., Female plug 1/2" (15 mm) – 1 No., Water tap 1/2" (15 mm) – 1 No.

Tools required

1. Pipe vice
2. Hack saw

3. File
4. Steel rule
5. Scriber
6. Measuring tape
7. Brush.

List of operations

1. Sketching of layout
2. Marking
3. Cutting of pipe into lengths
4. End finishing
5. Assembling

Procedure

1. Copy the given single line sketch in the work record.
2. Convert the sketch to double line piping layout as shown in Figure 9.31.
3. Mark the lengths on pipe after adding the overlaps for specials and cut it into pieces precisely using hack saw. The cut ends should be perpendicular to the axis of pipe and bur free. File may be used for correcting that.
4. Assemble the fittings, check the accuracy and apply corrections if required.
5. Apply solvent cement on the mating surfaces using brush and assemble the components together to complete the required pipe line work.

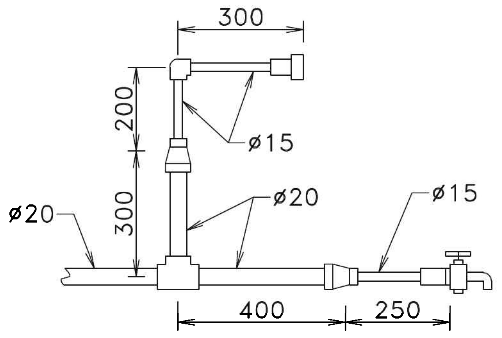


FIGURE 9.31
Double line piping layout.

Example 2

Assemble and fix the given European water closet on the floor and connect the flush tank to the closet after installing on the wall behind.

Aim

To assemble and fix the given European water closet on the floor and connect the flush tank to the closet after installing on the wall behind.

Materials required

1. European water closet with P-trap, PVC seat and cover, fixing screws, etc. complete – 1 set.
2. PVC pipe of diameters 4" (100 mm) – 1 No.
3. PVC coupler 4" (100 mm) 1 No.
4. PVC flush tank with inlet and outlet pipes complete – 1 set.
5. PVC pipe fittings: Angle valve 1/2" (15 mm) – 1 No., coupler with thread on one end 1/2" (15 mm) – 1 No.
6. L-shaped wall clamp with screws and PVC plugs 2 sets.
7. Accessories: Solvent cement and white cement—small quantities.

Tools required

1. Pipe vice
2. Hack saw
3. File
4. Brush
5. Electric hand drill with bit
6. Spanner set
7. Pipe wrench
8. Pliers
9. Steel rule
10. Measuring tape
11. Scriber

List of operations

1. Marking
2. Cutting of pipe into lengths
3. End finishing
4. Fixing of WC in position
5. Drilling and fixing of L-clamps for flush tank
6. Assembly and fixing of Flush tank in position
7. Fixing of angle valve in position
8. Connection of flush tank to WC and angle valve using flexible pipes.

Procedure

1. Prepare a line sketch of the layout in the work record and mark the important parts on them as shown in Figure 9.32.
2. Fix the European water closet on the floor, leaving sufficient space to accommodate the flush tank on the wall. Two holes have to be drilled on the floor for this purpose and screws have to be tightened to the plugs inserted in the holes.

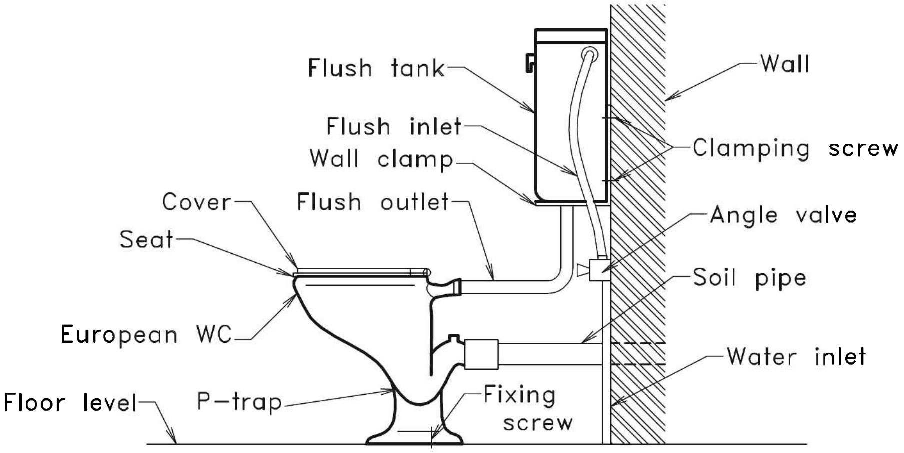


FIGURE 9.32
Assembly of WC and flush tank.

3. Mark the position of the L-clamps on the wall relative to the WC and drill four holes using hand drill. Insert the PVC plugs in the holes and tighten screws to fix the clamps in position. Place the flush tank on the clamp and check the location.
4. Locate the position of angle valve relative to the flush tank and fix the in coming pipe and the valve on it.
5. Connect the incoming and outgoing flexible pipes to the flush tank using tools.
6. The joints are made leak proof by applying solvent cement on mating surfaces of PVC fittings. The connection between WC and waste pipe is sealed using white cement in paste form.
7. Assemble the seat and seat cover over the WC using the fixing screws.
8. After checking the assembly of the WC and the flush tank, including the float setting for its closing at filled position, water line is connected to the angle valve.
9. The assembly is tested for its working.

Example 3

Cut the given GI pipe of diameter 3/4" (20 mm) to 150 mm length and cut standard pipe thread on the cut end. Also check the accuracy of the thread by screwing a GI elbow of the same size on the end.

Aim

To cut the given GI pipe of diameter 3/4" (20 mm) to 150 mm length and cut standard pipe thread on the cut end. Also check the accuracy of the thread by screwing an elbow of the same size on the end.

Materials required

1. GI pipe of diameters: 3/4" (20 mm) – one piece.
2. GI elbow of diameters 3/4" (20 mm) – 1 No.

Tools required

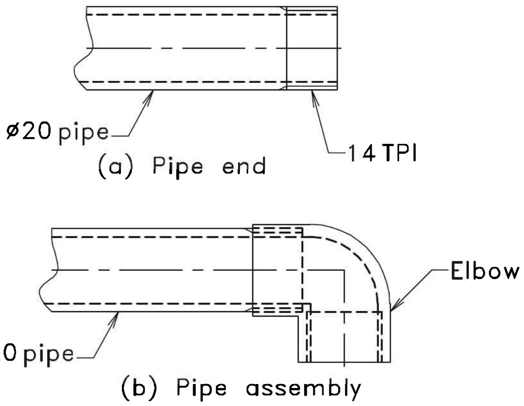
1. Pipe vice
2. Hack saw
3. File
4. Pipe wrench
5. Steel rule
6. Scriber
7. Threading die 3/4" (20 mm) with holder.

List of operations

1. Sketching of the joint
2. Marking of length
3. Cutting of GI pipe into length
4. End finishing
5. Screwing of elbow

Procedure

1. Sketch the pipe assembly view in the work record as shown in the Figure 9.33.



(a) Pipe end

(b) Pipe assembly

FIGURE 9.33 GI pipe with elbow.

2. Mark the length 150 mm on the GI pipe using steel rule and scriber.
3. Hold the pipe on the vice and cut the pipe to the required length using hack saw.

4. File the end of pipe to remove bur as well as to form a slight taper around to admit the die.
5. Select the die for 3/4" (20 mm) thread and fit inside the die holder. Unscrew the grub screws slightly to enlarge the die hole in order to accommodate outer diameter of the pipe.
6. Start cutting of thread gradually from the slightly tapered end of pipe by screwing forward and then backward.
7. Do the same operation for the required full length. Then tighten the grub screws and cut the thread two three times to get the full depth for thread.
8. Screw the elbow to the full length using pipe wrench and get the work finished.

EXERCISES

Questions for Viva Voce

1. What is meant by the term plumbing? Explain.
2. What are the areas coming under conventional and special plumbing systems?
3. How many types of pipe joints are used in plumbing. Give application of each type.
4. What is the meaning of pipe fittings or pipe specials? Name five most popular pipe fittings.
5. Give the expansion of PVC as pipe material. Differentiate the same with G.I. pipes.
6. Where a Screwed Union Joint is used in plumbing? Explain.
7. When a flanged joint is used in piping? Explain the use gasket in a flanged joint.
8. Differentiate a water tap from a water cock. Where they are generally used?
9. Explain the working of gate valve, glob valve and ball valve in piping layouts.
10. What is a non-return valve? Where it required in a pipe line?
11. Explain the use of foot valve in a centrifugal pump.
12. Give the use of water meter in a pipe line. By what principle it is showing the reading?
13. What is meant by a fixture used in plumbing? Give names of five types of fixtures in domestic use.
14. Explain the traps P, S, and Q used in plumbing.
15. Differentiate the use of WC-European and WC Indian.
16. Briefly explain the working of a flushing system.
17. What is the difference between a wash basin and a kitchen sink?
18. How a geyser is working? Explain the use of it.

19. What are the types of piping layouts used in plumbing? Give symbols used for elbow, Tee, coupler and female plug.
20. Sketch isometric symbols for gate valve, globe valve and water tap.
21. What are the important points to be considered while planning a sewage disposal system?
22. Explain the working of a septic tank.
23. Why soak pits are used for waste water disposal? Prepare a line sketch of a simple soak pit.
24. Give a list of special tools used by plumbers.
25. Explain the use of a pipe vice.
26. What is the use of a die? How threading is done on a G.I. pipe using a die?
27. Differentiate a pipe wrench and chain wrench.
28. Give a list of accessories used by a plumber.
29. What is solvent cement? Where it is used in plumbing?
30. Describe the method of threading a G.I. pipe, using a die and a holder.

Questions for Plumbing Practice

1. Figure 9.34 shows a single line piping layout. Convert it to double line piping layout by sketching and make a pipe assembly of it using PVC pipes and specials.

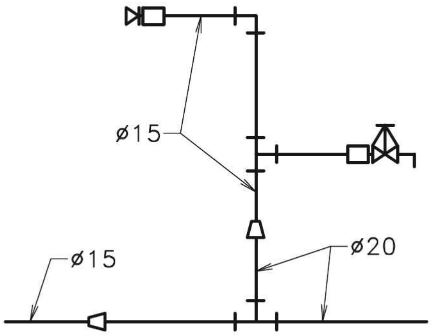


FIGURE 9.34 Single line piping layout.

2. Isometric single line piping layout is given Figure 9.35. Sketch a double line piping layout of it in isometric position. Also make the pipe assembly using PVC pipe fittings.
3. Assemble and fix an Indian WC on a floor and sketch a sectioned side view of it showing the pipe fitting details. The trap used may be P-type.
4. Sketch side view showing the details of fitting a wash basin on a wall with pipe connection through angle valve. Then make the assembly of the same items and check the working of the unit.

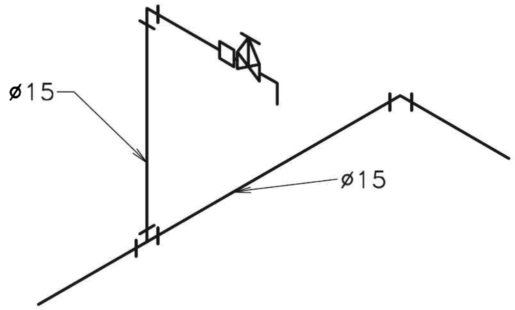
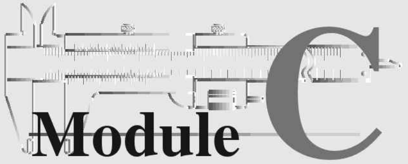


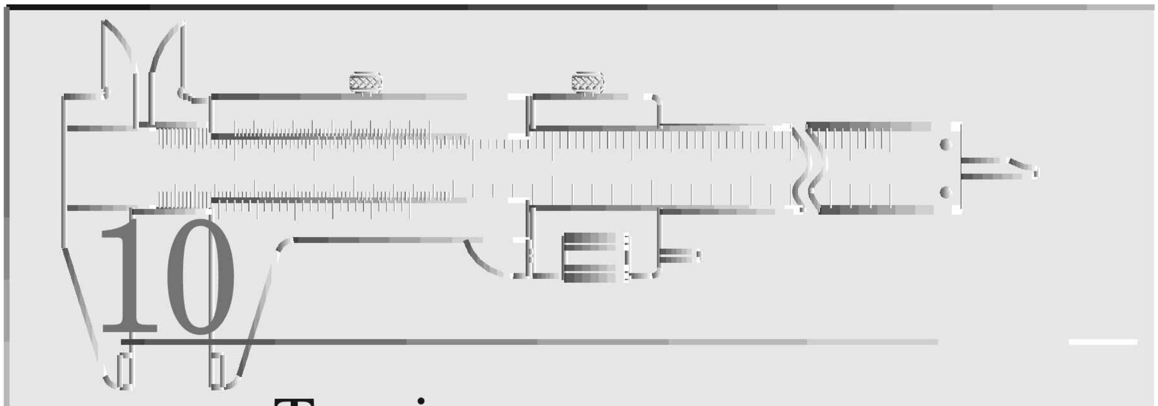
FIGURE 9.35
Single line piping layout.

5. Cut the 1/2" (15 mm) G.I. pipe into 20 cm length and thread one end for 15 mm length using a die to produce standard thread of 14 TPI. Then fit a coupler of the same size on it and sketch the assembly.
6. A G.I. pipe of diameter 3/4" (20 mm) is to be fitted to an elbow (G.I.) of the same size. Cut thread on the end of pipe using standard die set and fit the elbow to the full depth. Also prepare a sketch of the assembly.



Module C

Machining Processes



10

Turning

Turning is a metal-cutting process in which the workpiece is rotated and a single-point cutting tool of hard material is brought to the surface by feed motion resulting the removal of excess metal in the form of chips. Lathe is the name of the machine used for turning process.

10.1 Introduction to Turning

10.1.1 Principle of Turning

Turning is one of the oldest machining operations and the machine used for turning is called *lathe*. The present form of lathe was developed initially by Henry Maudsley in 1800, for cutting threads. The principle of turning is explained Figure 10.1. The

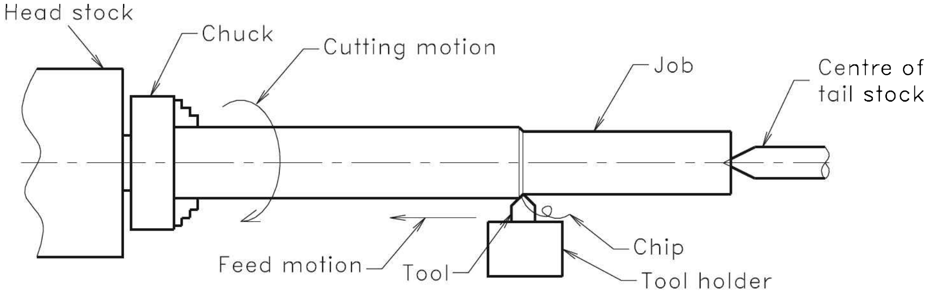


FIGURE 10.1
Principle of turning (Top view).

workpiece is gripped by a rotating fixture called *chuck* fitted on the spindle of the lathe headstock. The other end of the workpiece is supported by the centre fitted on the tailstock of the lathe. A cutting tool is fixed on a tool post, which can move parallel to the axis of rotation for feed motion. By this machining, a cylindrical external surface is formed. Turning is basically the machining of external cylindrical forms. The same process in lathe can be modified by changing the tool position, by changing the type of tool and the tool movements to produce various shapes like step, taper, flat surface, spherical surface, screw thread, groove, hole, undercut, etc.

10.1.2 Metal Cutting and Chip Formation

Metal-cutting operation in turning is explained by Figure 10.2. The workpiece rotates about the centre of it and the sharp tip of the cutting tool is pressed on the cutting surface along the horizontal centre line. This makes a layer of metal to separate from the surface in the form of chips and moves along the rake surface of the tool. The angle made by the top surface of the tool (rake surface) to the horizontal centre line of the work is known as the *rake angle* of cutting. Many cutting properties, including the cutting force, are governed by this rake angle of tool. In order to avoid rubbing of the machined surface on the cutting tool, a small relief angle is given to the end for clearance.

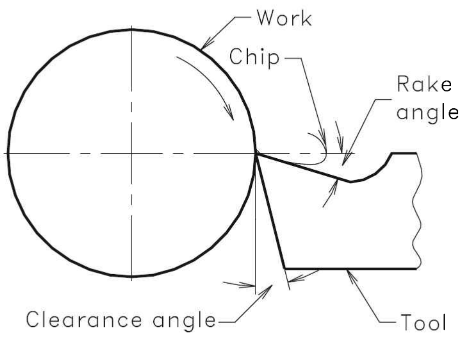


FIGURE 10.2 Metal cutting in lathe.

The type of chip produced during turning depends on the material being cut and the cutting conditions. The conditions include the feed rate, depth of cut, the type of tool, the type of machine tool and the presence of cutting lubricant. The types of chip formed during turning (Figure 10.3) are:

(a) Continuous chip
(b) Discontinuous chip
(c) Continuous chip with built-up edge

A continuous chip is formed by plastic deformation of metal, without fracture, in front of the cutting edge of the tool. It is followed by a smooth flow of the chip along the tool rake face. While machining the ductile materials like mild steel, copper, and aluminium at correct cutting speed and feed, a ribbon like continuous chip is obtained.

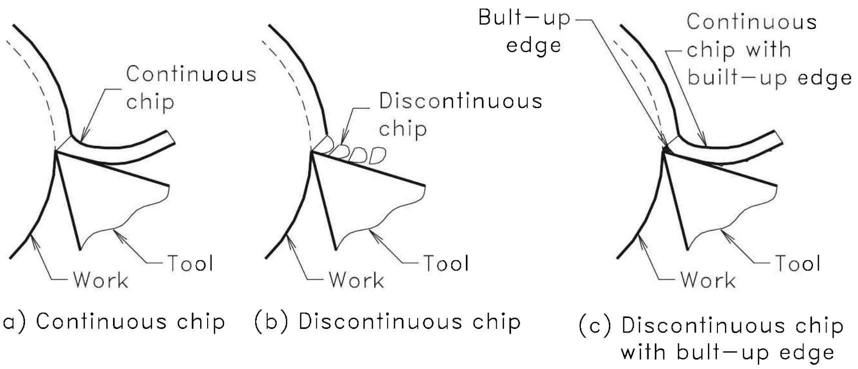


FIGURE 10.3
Types of chips.

(a) Continuous chip (b) Discontinuous chip (c) Discontinuous chip with bult-up edge

While cutting brittle materials like cast iron and cast brass, segmental chips are formed. The built up edge associated with a continuous chip is a result of welding particles of workpiece as hard edge at high pressure and temperature. The formation of built up edge reduces the sharpness of tool resulting high cutting force and temperature. The surface finish of machined surface is also reduced. The formation of built up edge can be minimized or prevented by giving light cuts at high speeds in the presence of a good lubricant.

10.1.3 Cutting Speeds for Turning

The cutting speed (cutting velocity) for machining is represented as the surface velocity of the workpiece in motion.

$$\text{Cutting velocity, V} = \pi \times D \times N/1000 \text{ m/min.}$$

where

D is the diameter of work in mm
N is the rpm of work.

The cutting velocity of workpiece is selected by the following factors.

1. The physical property of the work material like hardness brittleness, ductility, etc.
2. The material property of cutting tool.
3. The feed and depth of cut.
4. The rigidity and capacity of the machine tool to resist the cutting forces.

A calculation method of finding the approximate cutting speed, feed and depth of turning is given as:

$$\text{cutting speed, } V = C \times A^{1/3} \text{ m/min}$$

where,

C = Constant depends on the material cut
A = Area of cut
= (Feed per rev.) × depth of cut mm^2.

The table below gives the value of V, and C for the materials generally turned in lathe using tool of material of High Speed Steel.

Work material	V (m/min)	C (constant)
Mild steel	20 to 28	24
High carbon steel	12 to 18	13
Cast iron	18 to 25	18
Brass	45 to 90	48
Bronze	15 to 21	21

The depth of cut for rough turning can be taken as 0.8 to 6 mm in medium size machine tools and feed per revolution is taken between 0.1 to 1 mm.

10.1.4 Types of Turning Machines

Lathe is the family name for the machine tools used for turning operations. There are many types of lathes by design, size, use automation, etc. A list of the names of lathes used in workshops and production centres is given below:

(a) *General purpose lathes*
  1. Centre (Engine) lathe
  2. Speed lathe
  3. Bench lathe
  4. Tool room lathe

(b) *Special purpose lathes*
  5. Facing lathe
  6. Boring lathe
  7. Turret lathe
  8. Capstan lathe

(c) *Mass-production lathes*
  9. Automatic screw cutting lathe
  10. Swiss-type automatic lathe
  11. Single-spindle automatic lathe
  12. Multi-spindle automatic lathe

Centre lathe or engine lathe is the most common machine tool used for various turning operations. It is popular in work shops for producing or repairing cylindrical parts in small quantities. A student in engineering has to study in detail about and practice in a centre lathe. Speed lathes are similar to the centre lathes working at high speeds. They are generally used for wood turning. Bench lathe is a small size lathe fitted on a work table and used to produce very small size components. Tool room lathes are used in tool rooms for repairing or producing accurate size of tools and small size of components.

Lathes of special category are designed for a particular range of turning operations only. A facing lathe, for example, is used for cutting large size gears, discs, etc. which require mainly the facing operation. Boring lathes are suitable for shaping the large size holes. Turret and capstan lathes are designed for batch production of small and medium size components in a semiautomatic manner. For mass production of cylindrical parts, the production lathes are employed.

10.2 Centre Lathe (Engine Lathe)

Centre lathe is a machine tool used for turning (machining) to produce various cylindrical shapes. The workpiece is placed between two centres of the machine, one is the *driving centre*, which is the nose of a rotating spindle supported inside the headstock. The other one is a *dead centre* called tailstock. In olden times, steam engine was used as the prime mover for running the machine tool and hence this lathe was called as *engine lathe*. Pedal operated small size lathes were also used in those days.

General layout and specification

The general layout of a centre lathe is shown in Figure 10.4. This machine tool mainly consists of a horizontal bed which forms the body of the machine. The driving centre called *head-stock* is mounted on the left end. The head-stock has a horizontal spindle rotated by a prime mover (motor) and it carries a *face plate* or *chuck* to hold the workpiece. On the right side there is the *tailstock* having dead centre to support the end of rotating workpiece. The cutting tool is fixed on a tool post which is mounted above a sliding member called *carriage*. With the help of the carriage, the tool is moved longitudinally parallel to the axis of rotation and in the cross direction of it, to get the cutting action.

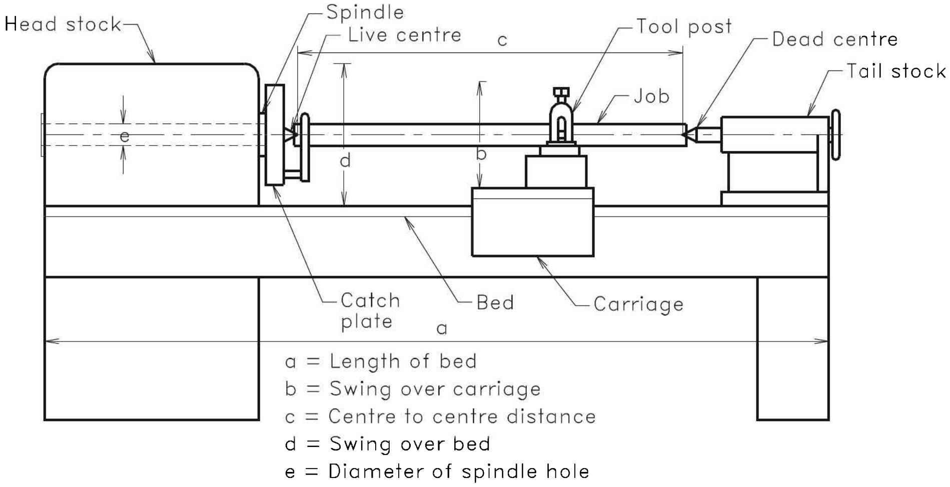


FIGURE 10.4
General layout of a centre lathe.

The size of a centre lathe is specified by giving the following details:

1. The maximum centre to centre distance in mm, i.e., the maximum length of workpiece that can be accommodated between the centres.
2. The swing or maximum diameter that can be rotated over the bed ways.
3. The length of the bed including the head stock and tail stock lengths.
4. The diameter of the hole through the lathe spindle for turning round bars.

Bed

The bed of a lathe is the body of the lathe made up of cast iron. All other parts are fitted on the bed. There are the guideways on the top side of the bed on which the carriage or saddle moves parallel to the axis of rotation of the spindle of lathe. The tailstock is fitted on the right side of it and the headstock on its left end. A detailed layout of a lathe is given in Figure 10.5.

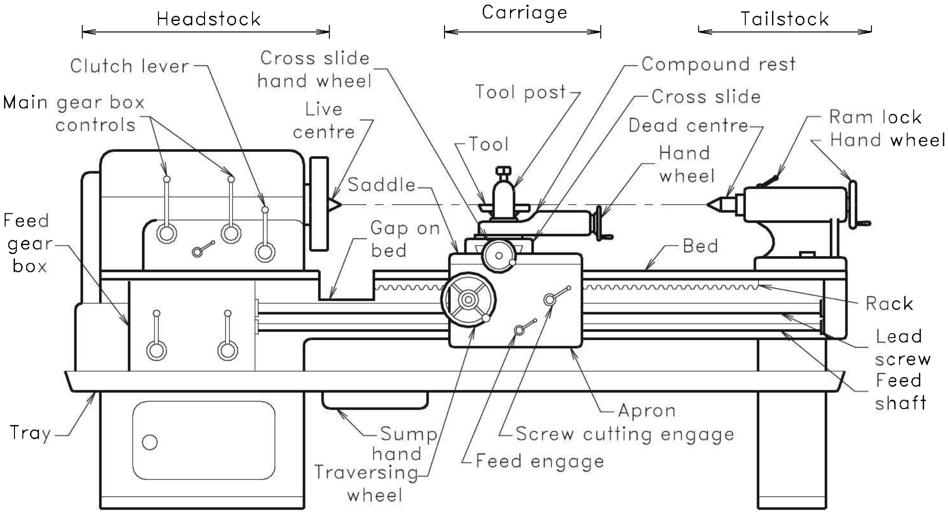


FIGURE 10.5
Centre lathe (Name of parts).

Headstock

Headstock of a lathe is the power source for the machine tool. The prime mover (motor) is usually fitted at the bottom side and is connected to the spindle of lathe using flat or V-belt on stepped pulleys. In modern lathes, gears are also used to get large speed ranges. The spindle carrying the work revolves inside heavy duty bearings in the headstock.

Tailstock

The right end (outer end) of the work is supported by a stationary (dead) centre called tailstock. The main function of a tailstock is to hold the dead centre which supports one end of the work. Its position can be adjusted and clamped on the bed. Figure 10.6 shows cross section of a tailstock.

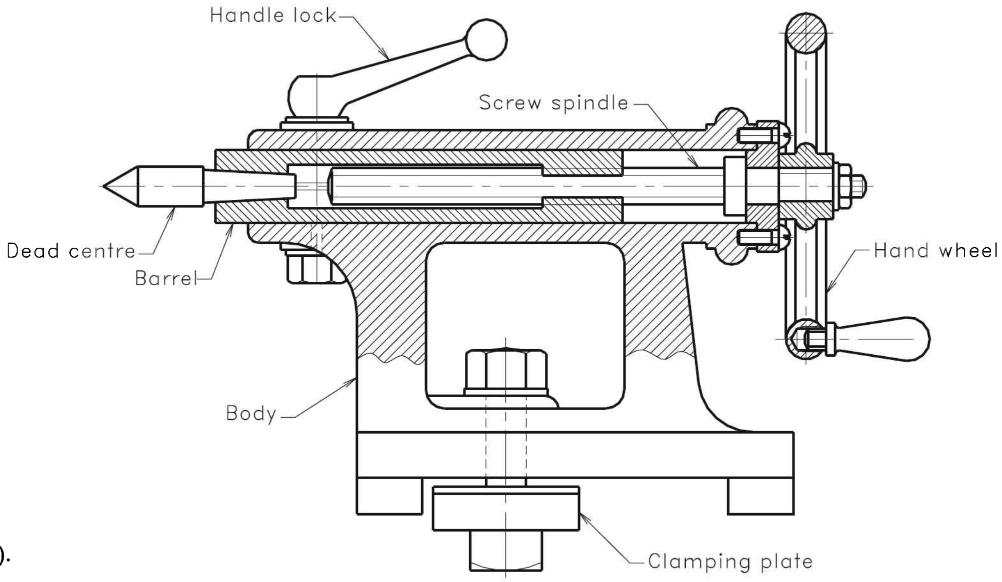


FIGURE 10.6
Tailstock
(Sectional view).

Carriage

The carriage placed on the bed in between the headstock and tailstock supports, guides and controls the movements of the cutting tool. It consists of several sets of parts like apron, saddle, cross slide, compound rest and tool post.

1. Apron: It is the lower vertical portion of the carriage hanging on the saddle and contains the controls for the tool movements and carriage movements. Apron contains gears and clutches for transmitting motion from the feed rod to the carriage. The split nut mechanism which engages with the lead screw, gives the movements of tool for thread-cutting.

2. Saddle: This is an 'H' shaped cast frame which is resting flat over the bed. This part slides directly over the guideways. The apron is hanging from the front edge of it. The cross slide, the compound rest and the tool post are fitted over this. Figure 10.7 gives the layout of the arrangement.

3. Cross slide: The cross slide mounted over the saddle enables the cross movement to the tool post. In order to move the cross slide forward or backward, the screw fitted below it, is turned by rotating the handle provided at the end of it. When the screw rotates, it moves through a nut which is fitted below the cross slide, resulting the cross movement.

4. Compound rest: The compound rest or compound slide is fitted over the cross slide. This has a circular base to obtain angular movements. The compound slide has a screw and nut arrangement to get forward and backward movements for short lengths.

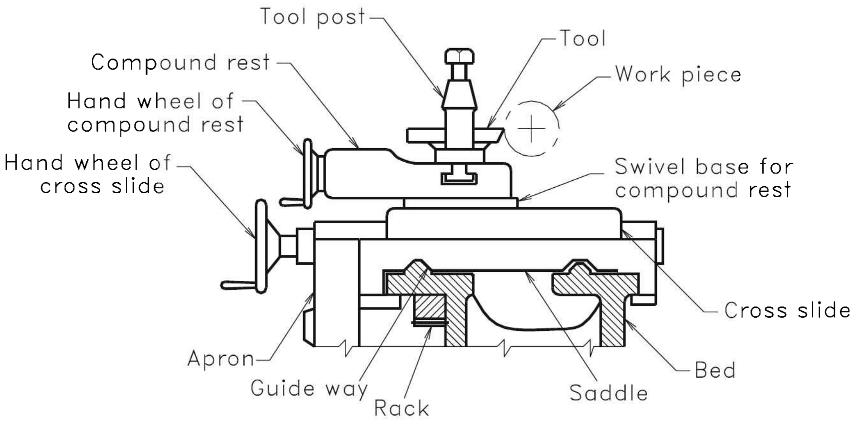


FIGURE 10.7
Carriage assembly.

5. Tool post: The tool post is mounted on the top of the compound rest. The tool is fixed on the tool post for cutting action. There are different types of tool posts in use. They may be grouped as mentioned below:

1. Single screw tool post
2. Four screw tool post
3. Open side tool post
4. Four way tool post

Figure 10.8 shows a single screw tool post used in small and medium-size centre lathes. This mainly consists of a tool post body of round bar with slotted hole for fixing the tool. The tool is fixed over a convex *rocker* which is placed over a concave ring washer, using a tool post screw. The convex rocker and the concave ring enable to fix the cutting point of tool at the horizontal centre line of the workpiece and to adjust the effective rake angle of tool.

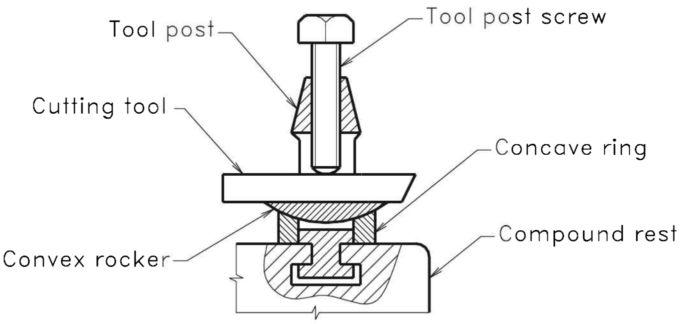


FIGURE 10.8
Single screw tool post.

End of bed gearing

The spindle motion is transferred to the feed gear box through gears fitted at the left end of the lathe bed. The drive is then transmitted through the feed gear box, selectively to the lead screw or the feed shaft, depending on whether the machine is being used for thread-cutting or plain-turning.

10.3 Accessories and Attachments

To use lathe for various turning operations, the accessories are also required in addition to the main parts explained so far. The commonly used accessories are as follows:

1. Face plate
2. Four-jaw chuck
3. Three-jaw chuck
4. Centres
5. Carriers and catch plates
6. Steady rest
7. Follow rest
8. Service tools

The accessories include the following items also, which support the turning operation directly or indirectly:

1. Machine lamp
2. Splash guard
3. Coolant equipment
4. Mandrels
5. Magnetic chuck
6. Collet chuck
7. Drill holder
8. Change gears

The attachments used in a lathe are additional equipment required for special operations. They include the following:

1. Taper turning attachment
2. Hydro-copying attachment
3. Milling attachment

1. Face plate: A face plate basically consists of a circular disc with a central-threaded hole to fit on the spindle nose. There are radial slots and T-slots to fix the clamps (Figure 10.9). Face plate is used to hold workpiece which cannot be held by centres or chucks.

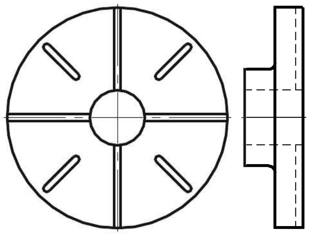


FIGURE 10.9
Face plate.

2. Four-jaw chuck: A chuck is a work-holding device used in lathes. The four-jaw chuck shown in Figure 10.10 has four independent jaws which are usually used to grip the workpiece of shapes other than cylindrical. The body of the chuck is made of cast iron, while the jaws are made of hard steel.

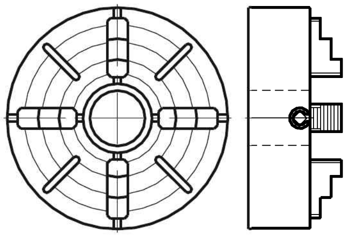


FIGURE 10.10
Four-jaw chuck.

3. Three-jaw chuck: Figure 10.11 shows a self-centring three-jaw chuck. The jaws are moved simultaneously by screwing one jaw. This enables easy clamping of cylindrical jobs at its centre. The scroll disc having spiral grooves enables the simultaneous movement of the jaws.

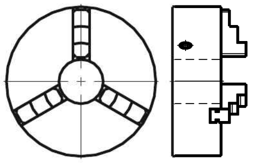
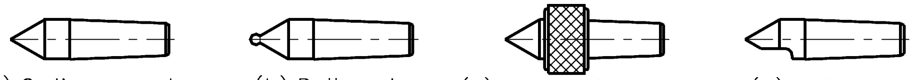


FIGURE 10.11
Three-jaw chuck.

4. Centres: The centre used to support long rods may be of live centre or dead centre. The centres are made of hard material and are machined to smooth surface. The included angle of the centre is usually kept as 60°. Figure 10.12 shows different types of centres used in a lathe.

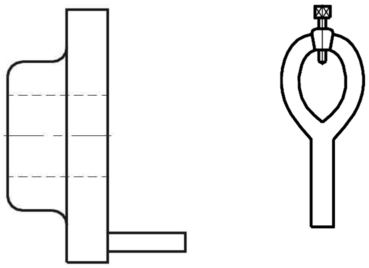


(a) Ordinary centre (b) Ball centre (c) Friction less centre (d) Half centre

FIGURE 10.12
Centres.

5. Carrier and catch plate: Carrier and catch plate arrangement is used while machining jobs between centres. Carrier or driving dog is attached to the end of the workpiece by set screws and catch plate is either screwed or bolted to the nose of the spindle of headstock (Figure 10.13).

6. Steady rest: A rest is a device used to support cylindrical, lengthy, and slender jobs (Figure 10.14). A steady rest is a mechanical frame of the type shown in figure which acts as an intermediate bearing having three-point support to resist the cutting forces. It is mounted on the bed guideways.



(a) Catch plate (single pin type)

(b) Straight tail carrier (driving dog)

FIGURE 10.13
Catch plate and carrier.

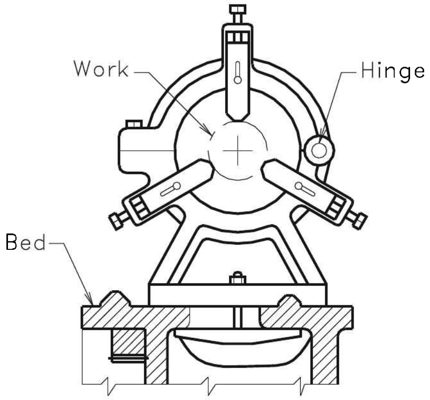


FIGURE 10.14
Steady rest.

7. Fallow rest: This rest is similar to that of steady rest. The unit is clamped on the carriage so that it follows when the carriage moves during cutting operation. This unit has only two points to support the work.

8. Service tools: The service tools used in lathe include spanners, screw drivers, pliers, allen keys, etc. They are explained with figures in Chapter 3 for fitting.

10.4 Tools for Measuring and Machining

10.4.1 Measuring and Marking Tools

The tools used for measuring and marking dimensions on the workpiece during turning are almost the same as that are used for fitting. A list of the frequently used measuring and marking tool are given below:

1. Steel rule
2. Vernier calliper
3. Micro meter

4. Outside and inside callipers
5. Divider
6. Combination set
7. Vernier height gauge
8. Screw gauge
9. Punches
10. Scribers

For explanation and figures, refer Chapter 3 for fitting.

10.4.2 Cutting Tools

Tool geometry

Single-point cutting tools are used for turning operations. There are a number of forms of single-point cutting tools in use. The tool geometry of a standard single-point right hand cutting tool is given in Figure 10.15. It has a shank of rectangular cross section. The cutting point has a radius called *nose radius*. The top face on which the chip is rubbing is called *rake face*. The angle of it with respect to the horizontal centre line of the job is called the effective *rake angle*. The rake angle value has much importance on the cutting forces. The metal is actually removed by the side cutting edge and the nose. The relief angles give clearances, so that rubbing of tool on the cut surface is avoided. The approximate values of the angles and nose radius of a single point HSS tool for cutting mild steel are as follows:

Front as well as side rake angles = 10 to 12°
Front as well as side clearance angles = 6 to 8°
The nose radius = 0.4 mm to 1.6 mm

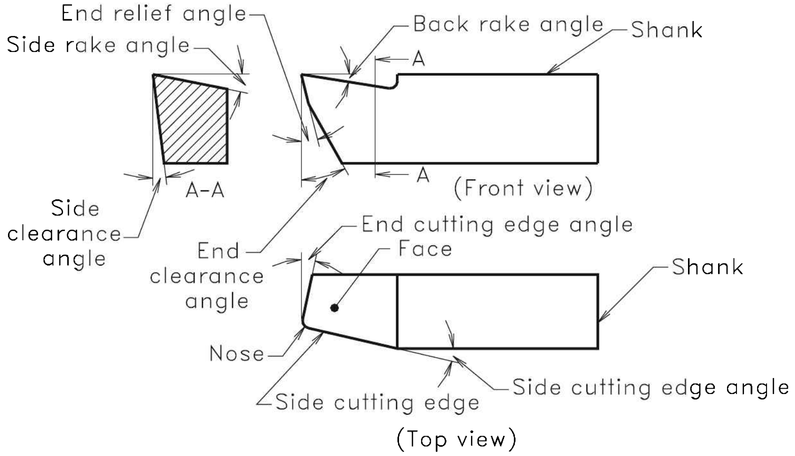


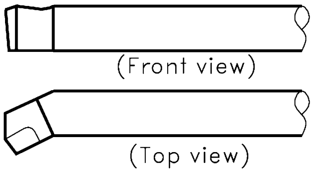
FIGURE 10.15
Single point cutting tool (right hand type).

Types of cutting tools

For producing different shapes in turning, tools in various forms are required. The common forms of cutting tools in use are given below (Figure 10.16).

1. *Cylindrical turning tool:* It is used for rough and finish turning of cylindrical surfaces.
2. *Facing tool:* This tool is used to produce flat face perpendicular to the axis of rotation.
3. *Grooving tool:* It is used to produce grooves of different shapes.
4. *Parting off tool:* It is used to part off the job from the stock by narrow groove cutting.

(a) Parting off tool (b) Thread cutting tool



(c) Boring tool

(d) Turning tool (right hand type)

(e) Turning tool (left hand type)

FIGURE 10.16 Types of turning tools.

5. *Chamfering tool:* It is used to produce chamfer at the required angle.
6. *Shoulder turning tool:* It is used to produce sharp curved or grooved shoulders.
7. *Forming tool:* It is used to produce curved profiles.
8. *External thread cutting tool:* It is used to turn V-shaped external threads.
9. *Square thread cutting tool:* It is used to turn square threads.
10. *Internal thread cutting tool:* It is used to cut internal threads on jobs.
11. *Drilling tool:* It is used to twist drill with taper shank to produce holes by fixing it on the tail stock.
12. *Boring tool:* It is used to enlarge the hole size by internal turning.
13. *Under cutting tool:* It is used to produce undercuts in side holes.
14. *Right hand tool:* Any tool shape which is used to cut from tailstock (right side) to the headstock side is right hand tool.
15. *Left hand tool:* Any tool shape which is used to cut from headstock (left side) to the tailstock side is left hand tool.
16. *Knurling tool:* This tool is used to get knurled surface used for handle grip.

17. *Thread chaser:* This is a multipoint threading tool used to correct the thread shape.
18. *Combination centre drill:* It is used to make a 60° conical hole at the centre of a shaft for supporting at dead centre of the tailstock.
19. *Files:* It is used to make smooth external surfaces by filing during turning.
20. *Emery paper:* It is used to make very smooth surfaces by manual application during turning.

The cutting tools are made by any one of the following methods.

1. *Forged tool:* The shape is made by forging, heat treatment and griding.
2. *Tipped tools by brazing:* Tool tips of higher hardness are brazed to the shank for holding.
3. *Tipped tool by screwing:* The tool tips are fixed to the holder by screwed fasteners.

Tool material

Turning tools are made by using various hard materials of the following types.

1. High carbon steels
2. High speed steels (HSS)
3. Cast nonferrous alloys
4. Carbides
5. Ceramic tools
6. Diamond.

More about these material are given in Chapter 1 under the title *cutting tool materials.*

10.5 Turning Operations

The turning operations which are commonly conducted in a workshop can be grouped according to the work holding method as mentioned below:

1. These are held between the centres and driven by carrier and catch plate.
2. These are held and driven by chuck on one end and the other end supported by tailstock dead centre.
3. These are held and driven by chuck or face plate alone.
4. These are held on a mandrel which is supported by centres and driven by carrier and catch plate.

The turning operations which are performed in a lathe depending on the method of removal of metal can be listed as shown below:

A. *General*
   1. External turning
   2. Shoulder turning

3. Facing
4. Chamfering
5. Grooving
6. Forming
7. Taper turning
8. Parting off

B. *General internal turning*
  1. Boring
  2. Counter boring
  3. Undercutting
  4. Taper boring.

C. *Special turning operations*
  1. External thread cutting
  2. Internal thread cutting
  3. Drilling
  4. Reaming
  5. Knurling
  6. Tapping
  7. Eccentric turning
  8. Filing and polishing

10.6 Turning Practice

Example

Construct the model given in Figure 10.17 by step turning from the given mild steel rod.

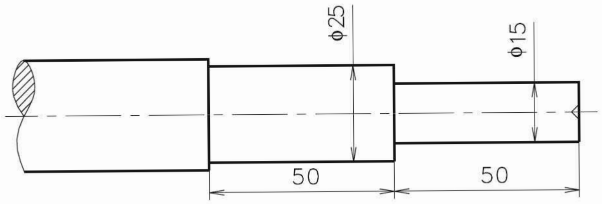


FIGURE 10.17
Model for step turning.

Aim

To construct the model given in Figure 10.17 using the given mild steel rod.

Material required

Workpiece material:	Mild steel round rod
Workpiece size:	30 mm diameter and 150 mm length

Tools required

1. Centre lathe fitted with 3 jaw chuck, 2. Cutting tool, 3. Centre drill, 4. Spanner, 5. Steel rule, 6. Vernier calliper, 7. Outside calliper, 8. Micrometer.

List operations

1. Facing the stock end, 2. Centre drilling, 3. Rough turning of cylindrical surfaces and steps, 4. Finish turning of cylindrical surfaces and steps.

Procedure

1. Copy the given drawing in the work record.
2. Collect the tools and the blank piece.
3. Check the size of the blank using steel rule and outside calliper for its suitability to make the model as per drawing.
4. Grip the blank piece in the three-jaw chuck projecting a short length of about 20 mm from the jaws.
5. Fix the cutting tool on the tool post keeping the cutting point at the height of the axis of rotation. This can be done by setting the tool at the height of nose point of the dead centre.
6. Turn the end face by facing operation and drill at the centre using centre drill, after fixing the drill bit on the tailstock.
7. Re-clamp the workpiece on the chuck such that the blank is projecting approximately 120 mm from the jaws and the other end is supported by the dead centre of the tailstock.
8. Do the rough straight turning of diameter 25 mm at a low rpm (300 rpm to get a cutting velocity of about 25 m/min).
9. Do the rough turning of diameter 15 mm at about 400 rpm.
10. Finish the cylindrical surface and the step face at high rpm (600 rpm to get a cutting velocity of about 50 m/min). Check the dimensions and unclamp the workpiece from the lathe.

EXERCISES

Questions for Viva Voce

Tools and equipment

1. Explain the term machining.

2. Define cutting speed, feed and depth of cut related to metal cutting.

3. What are the types of chips formed during machining?

4. Give a list of the types of lathes used for manufacturing machine parts.

5. Explain the general layout of a centre lathe.

6. How the size of a lathe is specified?

7. Explain briefly the terms *headstock* and *tailstock*.
8. Describe the layout of a carriage.
9. What are the types of tool posts used in lathes?
10. Explain how a tool is set for turning, using a single screw tool post.
11. Give a list of accessories used in centre lathe.
12. Differentiate between four-jaw chuck and three jaw chuck.
13. What are the types of centres used in a lathe?
14. Describe the use of catch plate and driving dog.
15. What is meant by a steady rest?
16. What is meant by rake angle of a single point cutting tool?
17. Give a list of tool forms used for turning.
18. Explain the name H.S.S. related to cutting tool.
19. What are the materials used for making cutting tools?
20. Describe the work-holding methods used for turning.
21. Give a list of turning operations done in a centre lathe.

Models for Turning Practice

Make the following models, the allotted time for each model is 3 hours:

1. Figure 10.18 gives drawing of a cylindrical model for straight turning. Copy the figure and make the model using the given MS rod.

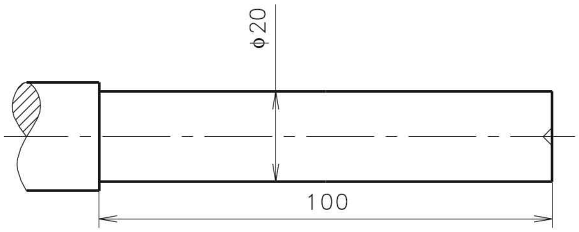


FIGURE 10.18
Model for straight turning.

2. Make a model for collar and step turning of size shown in Figure 10.19, using the given MS rod. Also prepare a dimensioned neat sketch of the model.

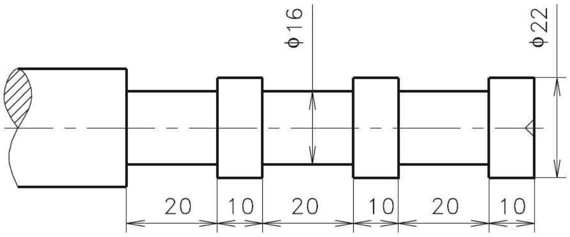


FIGURE 10.19
Model for collar and step turning.

3. Copy the sketch of the model for step and taper turning given in Figure 10.20. Make the model by turning the given MS rod.

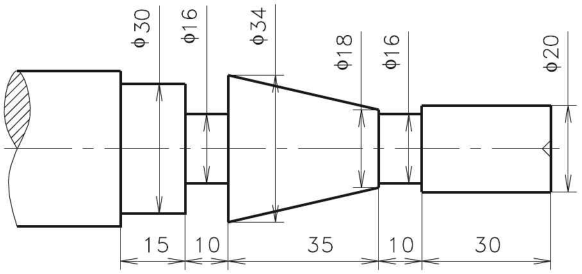


FIGURE 10.20
Model for step and taper turning.

4. Figure 10.21 gives drawing of model for thread-cutting. Copy the figure and make the model using the given MS rod.

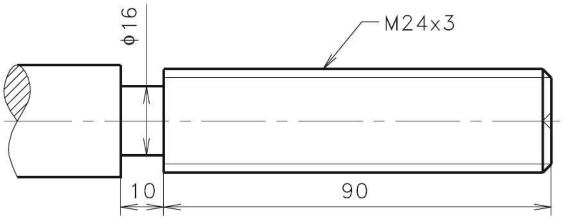


FIGURE 10.21
Model for thread cutting.

5. Make a model for form and taper turning of size shown in Figure 10.22, using the given MS rod. Also prepare a dimensioned neat sketch of the model.

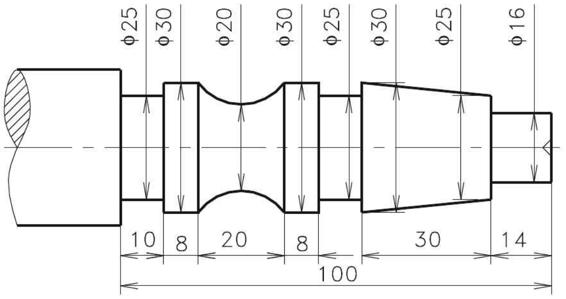


FIGURE 10.22
Model for form and taper turning.

6. Copy the sketch of the model for form, taper and thread cutting given in Figure 10.23. Make the model by turning the given MS rod.

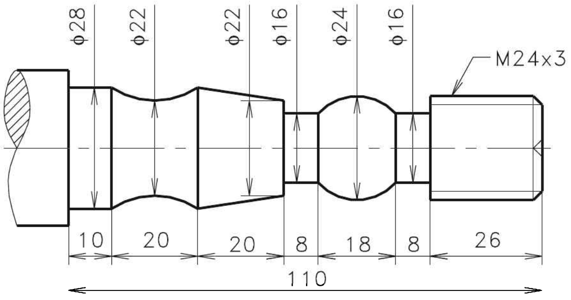
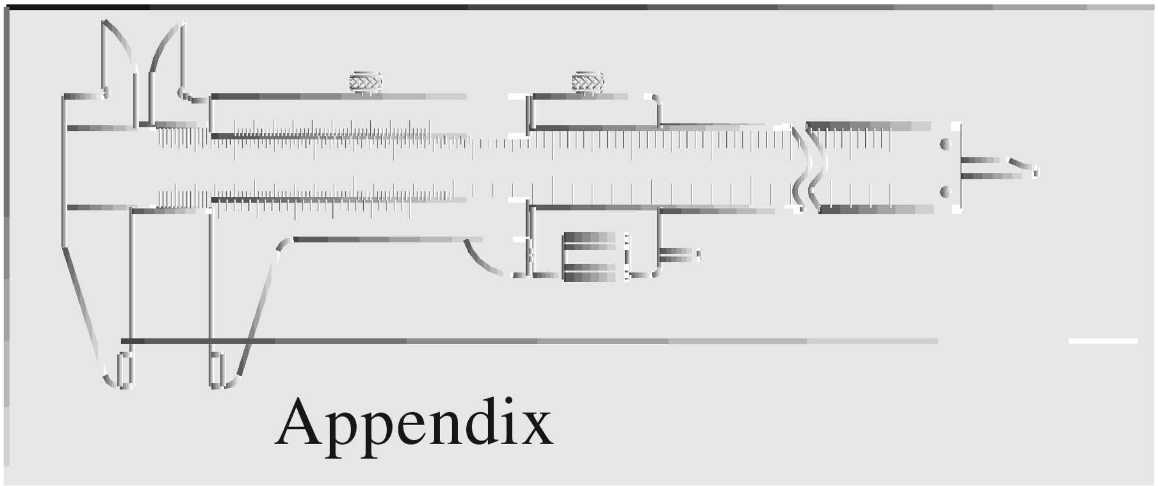


FIGURE 10.23
Model for form, taper and thread cutting.



Appendix

A.1 Process Chart

A process chart is a document in tabular form which furnishes all the operations to be performed on a workpiece. The other names called for the tabular form are *operation process chart, operation sheet, worksheet,* etc. Process charts are commonly used in production shops to give instructions to machine operators.

Table A.1 shows a process chart suitable to prepare a turning model in machine shop. A process chart should contain all the information about the workpiece, like material, blank size, weight, etc. and the details about the machines used, departments, and so on. A drawing of the component with full dimensions, tolerances and surface finish should be attached. The production operations are carried out in sequence as shown in the process chart shown in Figure A.1 and they are numbered as 05, 10, 15, 20, etc. The cycle time and total number of operations should be determined from the details. A student has to copy the drawing of model and prepare the chart in the workbook before starting operations on the machine tool.

Table A.1 Process Chart

Name of part:	M/c No:	Material:	Total operations:
Model No:	Department:	Blank size:	Cycle time:

Operation seq.	Operation details (Clamping, feed, depth of cut, etc.)	Tools/Gauges	Cutting		Set up time (min)	Operational time (min)
			Speed m/min	r.p.m.		
05						
10						
15						
20						

Name of student:	Approved by: (Signature)
Class and Registration No:	Name of staff:

A.2 Quality Assessment Chart

The dimensions on a workpiece can be named as D1, D2, D3,... for diameters and L1, L2, L3,... for lengths. As per the tolerance given (general tolerance or tolerance shown using ISO symbols) the upper and lower limits of each dimension can be calculated and tabulated as displayed in Table A.2. The actual values measured by the student on his model can also be entered, so that the teacher can evaluate the quality of performance.

Table A.2 Quality acessment chart

Model No:
Name of W/s:

Name of student:
Class and Registration No:

Dimensions	D1	D2	D3				L1	L2	L3			
Basic size												
Upper limit												
Lower limit												
Actual size												
Marks												

Total mark:

Valued by: (Signature)
Name of staff:

Table A.3 shows the general tolerance for linear dimension.

Table A.3 General tolerance (mm) for linear dimensions in mm (IS:SP46–1947)

Dimension above		0.5	3	6	30	120	315
Up to and including		3	6	30	120	315	1000
Class of tolerance	Fine	±0.05	±0.05	±0.1	±0.15	±0.2	±0.3
	Medium	±0.1	±0.1	±0.2	±0.3	±0.5	±0.8
	Coarse	–	±0.2	±0.5	±0.8	±1.2	±2

Table A.4 exhibits cutting speeds for turning of carbon and low alloy steel.

Table A.4 Cutting speeds (m/min) for turning of carbon and low alloy steels

Steels Brinnel hardness	HSS tools		Carbide tools	
	Roughing	Finishing	Roughing	Finishing
Depth of cut Feed mm/rev	4 mm 0.4 mm	0.6 mm 0.0 4 mm	4 mm 0.4 mm	0.6 mm 0.04 mm
85–125 (C 07 to C 10)	40	55	140	165
125–175 (C 14 to C 20)	35	45	116	140
175–225 (C 25 to C 40)	30	40	105	135
225–275 (C 45 to C 65)	25	32	95	130
275–325 (law alloy steel)	20	25	83	120

Table A.5 shows cutting speeds for turning cast iron using simple-point cutting tools.

Table A.5 Cutting speeds for turning cast iron using single point cuttingtools:

Cast iron Brinnel hardness	HSS tools		Carbide tools	
	Roughing	Finishing	Roughing	Finishing
Depth of cut Feed mm/rev	4.8 mm 0.4 mm	1.6 mm 0.2 mm	4.8 mm 0.4 mm	1.6 mm 0.2 mm
Up to 160 (GCI–15)	50	80	100	140
160–220 (GCI–20)	25	45	63	110
220–360 (GCI–25)	16	25	56	90

Table A.6 shows commonly used tolerance zones and limits for shafts.

Tabel A.6 Commonly used tolerance zones and limits for shafts of sizes upto 500 mm (in microns)

Diameter steps in mm		d9	e8	f7	g6	h7	h6	js6	k6	n6	p6
Over	to										
–	3	–20 –45	–14 –28	–6 –16	–2 –8	0 –10	0 –6	+3 –3	+6 0	+10 +4	+12 +6
3	6	–30 –60	–20 –38	–10 –22	–4 –12	0 –12	0 –8	+4 –4	+9 +1	+16 +8	+20 +12
6	10	–40 –76	–25 –47	–13 –28	–5 –14	0 –15	0 –9	+4.5 –4.5	+10 +1	+19 +10	+24 +15
10	18	–50 –93	–32 –59	–16 –34	–6 –17	0 –18	0 –11	+5.5 –5.5	+12 +1	+23 +12	+29 +18
18	30	–65 –117	–40 –73	–20 –41	–7 –20	0 –21	0 –13	+6.5 –6.5	+15 +2	+28 +15	+35 +22
30	50	–80 –142	–50 –89	–25 –50	–9 –25	0 –25	0 –16	+8 –8	+18 +2	+33 +17	+42 +26
50	80	–100 –174	–60 –106	–30 –60	–10 –29	0 –30	0 –19	+9.5 –9.5	+21 +2	+39 +20	+51 +32
80	120	–120 –207	–72 –126	–36 –71	–12 –34	0 –35	0 –22	+11 –11	+25 +3	+45 +23	+59 +37
120	180	–145 –245	–85 –148	–43 –83	–14 –39	0 –40	0 –25	+12.5 –12.5	+28 +3	+52 +27	+68 +43
180	250	–170 –285	–100 –172	–50 –96	–15 –44	0 –46	0 –29	+14.5 –14.5	+33 +4	+60 +31	+79 +50
250	315	–190 –320	–110 –191	–56 –108	–17 –49	0 –52	0 –32	+16 –16	+36 +4	+66 +34	+88 +56
315	400	–210 –350	–125 –214	–62 –119	–18 –54	0 –57	0 –35	+18 –18	+40 +4	+73 +37	+98 +62
400	500	–230 –385	–135 –232	–68 –131	–20 –60	0 –63	0 –40	+20 –20	+45 +5	+80 +40	+108 +68

Table A.7 displays commonly used tolerance zones and limits for holes.

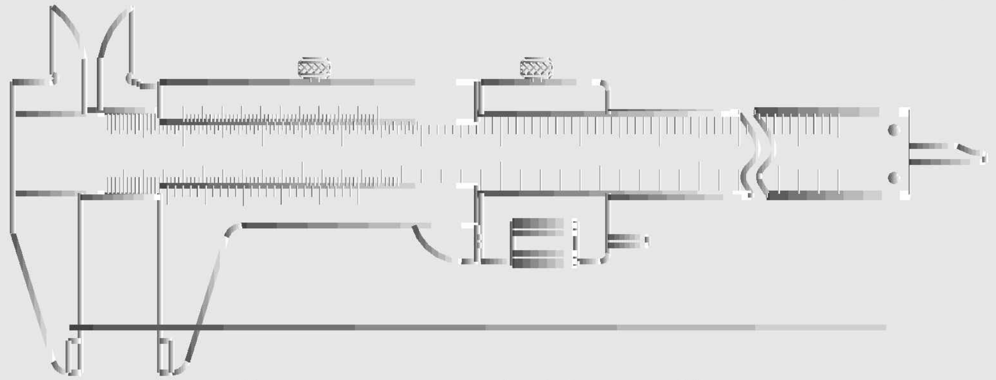
Tabel A.7 Commonly used tolerance zones and limits for holes of sizes upto 500 mm (in microns)

Diameter steps in mm		H6	H7	H8	H9	H11
Over	to					
–	3	+6 0	+10 0	+14 0	+25 0	+60 0
3	6	+8 0	+12 0	+18 0	+30 0	+75 0
6	0	+9 0	+15 0	+22 0	+36 0	+90 0
10	18	+11 0	+18 0	+27 0	+43 0	+110 0
18	30	+13 0	+21 0	+33 0	+52 0	+130 0
30	50	+16 0	+25 0	+39 0	+62 0	+160 0
50	80	+19 0	+30 0	+46 0	+74 0	+190 0
80	120	+22 0	+35 0	+54 0	+87 0	+220 0
120	180	+25 0	+40 0	+63 0	+100 0	+250 0
180	250	+29 0	+46 0	+72 0	+115 0	+290 0
250	315	+32 0	+52 0	+81 0	+130 0	+320 0
315	400	+36 0	+57 0	+89 0	+140 0	+360 0
400	500	+40 0	+63 0	+97 0	+155 0	+400 0

Table A.8 displays commonly used fits in hole basis system.

Table A.8 Commonly used fits in hole basis system (16 fits by BIS)

Name of fit	Symbol and IT grade
Clearance fits	
1. Large clearance fit	H11/a11
2. Slack running fit	H11/c11
3. Loose running fit	H8/d9 or d10, H9/d9 or d10
4. Easy running fit	H7/ e8, H8/e8
5. Normal running fit	H7/f7, H8/f7
6. Sliding and location fit	H7/g6
7. Location fit	H7/h6, H8/h7
Transition fits	
8. Push fit	H7/js6
9. Light keying fit	H7/k6
10. Medium keying fit	H7/m6
11. Heavy keying fit	H7/n6
Interference fits	
12. Light press fit	H7/p6
13. Medium drive fit	H7/r6
14. Heavy drive fit	H7/s6
15. Force fit	H7/t6
16. Shrink fit	H8/u7



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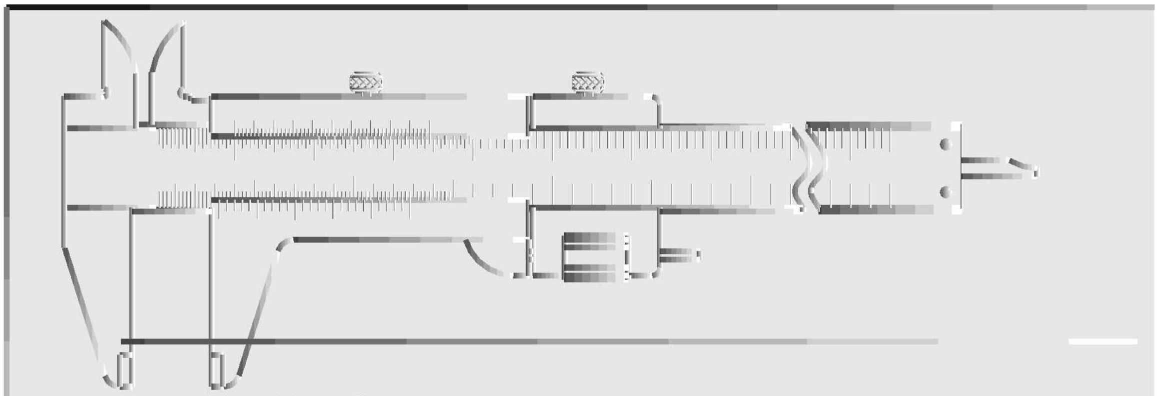

Index

SECOND EDITION

MECHANICAL WORKSHOP PRACTICE

K.C. JOHN

Designed for the core course on Workshop Practice offered to all first-year diploma and degree level students of engineering, this book presents clear and concise explanation of the basic principles of manufacturing processes and equips students with overall knowledge of engineering materials, tools and equipment commonly used in the engineering field.

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