Flame spraying. A powder of 60 mesh size is agitated and forced through a flame in front of a spray gun that is surrounded by an inert gas shield. The powder is heated by connection rather than by passage through the flame itself. This avoids denaturing of the powder. The molten globules of plastic fall on the surface to be coated. Final finishing and fusing is achieved by gentle passes of the naked flame.

Vacuum coating. In this method, vacuum is employed to draw the powder on to the surface of the preheated articles. The powder forms a fluidized bed to which vacuum is employed. The absence of air during this process yields a coating having no air entrapped in it. Penton and nylon powder can be used in this method.

17.6 ORGANIC FINISHES

Organic finishing consists in coating a surface with a continuous film of an organic film-forming material. This film may be applied for protecting the surface from corrosive influences, for enhancing the appearance, or a combination of both but it does not allow the holding of close dimensional tolerance and it has only average resistance to abrasion. Its resistance to elevated temperature is also poor. This family of organic coatings includes paints, enamels, varnishes, lacquer, shellac, and rubber base coatings, with vehicles of synthetic resins, rubber, linseed and tung oils. The basic difference between the various types of organic finishes lines in the type of vehicle in each of them.

PRIMERS

In order to secure the proper cohesion of most paints and enamels to metal surfaces, a primer has to be applied first. There are many types. Some are made especially for application to steel, such as on automobile bodies. These are lead primers. Zinc and lead chromate primers can be used on steel, zinc and aluminium with satisfactory results.

OIL PAINT

This paint consists of linseed oil, pigment, and turpentine, or some other solvent to thin the mixture to ; brushing consistency. Drying takes place partially of the solvent, but mainly by oxidation of the vehicle in vegetable oil. Sometimes magnesium silicate is added to impart improved resistance to cracking of the paint film. The drying time, hardness, and elasticity of paint films depend principally on the drying oil or combination of drying oils used. Oil paint makes an excellent coating for wood and is sometimes used on production finishing of metals.

ENAMELS

When paints may be classified as organic finishes where a pigment is dispersed in a drying oil vehicle, enamels represent those organic finishes where the pigment is dispersed in either a varnish or resin or a combination of both. The enamels may dry by either or both oxidation and polymerization. Both air drying and baking type enamels are available.

Baked enamels usually provide a finish that is harder and more abrasion resistant than the typical air drying enamels.

Enamels, because of their availability in all colours, ease of application, and ability to resist corrosive atmospheres and attack of most usually encountered chemical agents, are the most widely used organic coating in the metal processing industry.

VARNISHES

In this, a synthetic or natural resin is used in place of pigments. The resin is cooked in combination with a drying oil such as tung oil which gets partly oxidized and partly polymerized at high temperatures. The resin is dissolved in the oil and a drier is sometimes added at the time of thinning. Varnish characteristics can be changed or modified by changing ratios of resin and oil or by using other resins.

The alkyd types of varnish are quick drying, especially under the application of heat, and have good adherence to smooth surfaces. Their exterior durability is very satisfactory, making them suitable for vehicle finishes.

LACQUERS

By definition, lacquer is a "film forming material which dries by the evaporation of solvent". Since it dries very quickly, it is used in auto industry. Most lacquers are made of nitrocellulose dissolved in volatile organic solvents, with pigment added for color.

Their poor adherence to metal surface requires the use of priming coat for best results. Poor exterior durability is another drawback of this group, although, when well pigmented, lacquers have better durability than varnishes. Clear lacquers are used for protection against indoor atmospheres, while pigmented lacquers are suitable for outdoor protections as well.

Vinyl lacquers have properties that make them useful for lining food and beverage containers. They are impermeable to water, chemical resistant, and free from odor, taste, and toxicity.

SHELLAC

It is a solution of a natural resin in an alcohol. It gets hardened by the evaporation of the thinner used. Quite often it is used as a sealing coat on wood, since it gives a durable film. Since shellac is soluble only in alcohol, lacquers are varnishes can be applied over it without causing running together of the two.

RUBBER BASE COATINGS

The three important types of rubber base coatings are : chlorinated rubber, neoprene, and hypalon.

Chlorinated rubber. The outstanding characteristic of good chlorinated rubber materials is resistance to water. These materials are often used on metals that are subjected to splash or spillage or a submerged metal. They are not resistant to animal or vegetable oils and greases. These are used for protective reasons rather then decorative ones as they are limited in colour.

Neoprene. This coating is consist of neoprene dissolved in a solvent. It dries by evaporation of the solvent, leaving a film that is outstanding in its chemical to alkalies, many acids, alcohols, salts and natural oils.

Hypalon. Hypalon is chlorosulfonated polyethylene. The most outstanding characteristic is resistance to oxidizing agents. The available colours are almost unlimited.

ORGANIC FINISHES–METHODS OF APPLICATION

Organic finishes are applied by brushing, spraying electrocoating, dipping and the centrifugal process. In all these methods a prime coat is first applied, followed by a light sanding to form a surface for good cohesion.

Brushing. Brushing is performed by means of a brush made of animal hair or fibre fixed on a wooden handle. Brushing requires the greatest amount of labour and the least amount of material.

Spraying. Spraying with a spray gun is rapid and gives a smooth coat, but is wasteful of material. While this method is used to a great extent and does produce good results with skilled operators, it is a costly operation due to high labour costs today.

The cost of spray-painting by industry can be reduced considerably by use of automatic spray-painting equipment.

Electro-coating. In electro-coating, the product to be painted is an electrode of a high-voltage circuit. A grid, which is positioned close to and between the spray nozzles and the part, is used as the other electrode. A *dc* current applied to the two electrodes and the part is sprayed through the grid. The paint particles pick up ions and become charged electrostatically.

Dipping. One of the most economical methods of painting is dip painting. Dipping can be done by hand or automatically on conveyors. The part must drain easily and must not accumulate paint and cause fatty edges and tears. Some advantages in favour of its use are :

1. is an economical method.
2. can be used for any complex shape.
3. can be used for small parts without loss of paint.

Centrifugal finishing. This process is primarily used for painting small parts. Such parts are placed in a strongly made wire basket, dipped, and then put in the centrifuge and whirled. This throws the excess paint from the surface of the parts. The parts are finally removed and hung to dry.

17.7 INORGANIC COATINGS

Inorganic coatings are made up of refractory compounds. They include the porcelain enamels and ceramic coatings composed of inorganic mineral materials which are fused to these metals. They may be readily applied to both ferrous and nonferrous surfaces. These coatings provide excellent resistance to corrosion and elevated temperature. They also provide good appearance and resistance to abrasion and maintain close tolerances.

ENAMELLING OF METALS

Vitreous enamel coatings are basically films of glass opacified with inorganic pigments. Such coatings have the best chemical resistance and inertness of glass.

Enamelling is prepared by glass former (SiO_2 + borax), flux (potassium and sodium oxides), stabilizer (CeO and Al_2O_3), opaque agents (TiO_2 and ZrO_2), and coloured pigments (coloured metal oxides, such as cadmium, iron, oxides for red, chromium for green, etc.). All these chemicals are smelted together at 1200 to 1300°C and the molten mass is ground in pebble or grannule and cooled in water. Afterwards, this product is finely milled in ball mills along with water, clay, and sodium silicate to a and then burnt at 500 to 800°C for 4 to 10 minutes, depending upon the kind and thickness of the base metal. The enamel, which is partly molten in this process, is strongly bonded to the base metal and forms a shining surface.

Vitreous enamel has good corrosion resistance towards alkali (not very strong), acids (except hydrofluoric acid), boiling water, and various organic solvents. It has also pleasing colours, permanence in form, electrical properties and good resistance to wear. However, high brittleness limits its use.

CERAMIC COATING

Ceramic coated metals essentially form a composite system which combine the characteristic feature of metals and ceramics. They are, therefore, stable at both room and elevated temperatures, less susceptible to corrosive attack and they posses choicest chemical reactivity. Because of these properties ceramic coated products play a very important role in the making of rocket propulsion systems, air crafts, gas turbines, etc., and articles of day-to-day living, such as kitchen-wares, cans for food stuffs, sanitary-wares and craft-work, jewellery, decorative articles, etc. In between these two extremes, ceramic coated metals play a functional role as thermal insulators, corrosion resistant materials electrical insulators, grinding and cutting media, etc.

The materials commonly used for coating are refractory compounds, such as oxides, silicides, aluminides, beryllides, platinum group metals and cermet type materials. Of these silicides and aluminides occupy top positions due to their excellent performance. There are at present different methods employed to produce ceramics on base metal is mainly dependent on the characteristics of coating material and that of base metal. A technique useful for one system may not prove viable, economical or efficient for other system with different characteristics.

17.8 ELECTROLESS PLATING

In electroless plating (also known as *autocatalytic plating*) metals are deposited on to the surface of a part without using an external source of electricity. A standard electroless plating solution contains the following: metal salts (as source metal), a reducer which is an electron-donor to the metal ion, a catalyst to accelerate the reaction allowing metal deposition, a complexing/chelating agent that allows the metal to stay in solution. Common chelating agents include ethylenediaminetetraacetic acid (EDTA), citrates, oxalates, cyanides, and 1,2 diaminocyclohexanetetraacetic acid (DCTA). The metallic ions in the plating solution are reduced to superfine metallic particles and deposit evenly on the surface of the part, independent of the part geometry. The even plating thickness is a major advantage in this type of plating over the conventional electroplating.

The most common electroless plating is done in the printed circuit board industry where a lot of copper and nickel is plated using this method.

Some advantages of this process include:

1. Uniform deposition without variation in thickness.
2. Palatable on non-conducting materials such as plastics.
3. Solderability.
4. Good wear.
5. Corrosion resistance.

Immersion plating is a process similar to electroless plating. In this process, the base metal from the workpiece is displaced with another metal ion in the plating solution. The metal ions in the plating solution have a lower oxidation potential than the displaced metal. This process, like electroless plating, uses chemical reactions to apply a metal finish to the substrate. Immersion plating differs from electroless plating in that the reducing agent is the base metal of the workpiece and not a chemical additive, as is the case in electroless plating.

The thickness of deposits obtained in immersion plating is limited because deposition stops when the entire surface of the base metal is coated.

REVIEW QUESTIONS

1. What are the ways in which a metallic surface can be cleaned?
2. Name different mechanical and chemical cleaning processes.
3. (a) What methods may be used for removing oil, grease and buffing compounds from a metal surface, (b) What methods may be used for removing sand, oxides, dust, dirt, scale from metal surfaces, and (c) What method is almost always used to clean parts for electroplating ?
4. Why is pickling coating be applied ? What treatment must be used previous to pickling ?
5. How many metallic coatings be applied. State their advantages and disadvantages.
6. Where is metallizing used ?
7. Write short notes on : (a) galvanizing, (b) anodizing (c) phosphate coating and (d) spray painting.
8. State briefly electroplating with its advantages and limitations.
9. Why plastic coating is prepared on metals ? State the various methods used in coating plastics.
10. What are the various organic coating on metals ? Also state briefly 'Enamelling of metals' giving the areas of its application.
11. What is electroless plating? Write its advantages over electroplating.

18

SHEET METAL WORK

18.1 INTRODUCTION

Sheet metal work is generally regarded as the working of metal from 16 gauge down to 30 gauge, with hand tools and simple machines into various forms by cutting, forming into shape, and joining. It has its own significance as a useful trade in engineering works and also for our day-to-day requirements. Common examples of sheet metal work are hoppers, cannisters, guards, covers, pipes, hoods, funnels, bends, boxes, etc. Such articles are found less expensive, lighter in weight, and at many places they easily replace the use of the castings or forgings.

In sheet metal work the knowledge of geometry, mensuration and properties of metal is most essential since nearly all patterns come from the development of the surfaces of a number of geometrical models such as cylinder, prism, cone, and pyramid. A good pattern properly drawn means saving of time and money.

18.2 METALS USED IN SHEET METAL WORK

In sheet metal work, the sheet metal used is black iron, galvanised iron, stainless steel, copper, brass, zinc, aluminium, tin plate and lead. The sheets are specified by standard gauge numbers. Each gauge designates a definite thickness. The larger the gauge number, the lesser the thickness. Most of the metals being described in Chapters 4 and 5, the metals that are extensively used for this work are reviewed here again.

BLACK IRON

The cheapest sheet metal is black iron, which is sheet iron rolled to the desired thickness, annealed by placing in a furnace until red hot, and then set aside to cool gradually. It has a bluish-black appearance and is often referred to as uncoated sheet. Since it is uncoated, it corrodes rapidly. The use of this metal is limited to articles that are to be painted or enameled such as tanks, pans, stove pipes, etc.

GALVANISED IRON

Zinc-coated iron is known as "galvanised iron". This soft steel sheet is popularly known as GI sheet. The zinc coating resist rust, improves the appearance of the metal and permits it to be soldered with greater ease ; but welding is not so easy as zinc gives toxic fumes and residues. Because it is coated with zinc, galvanised sheet iron withstands contact with water and exposure to weather. Articles such as pans, buckets, furnaces, heating ducts, cabinets, gutters, etc. are made mainly from GI sheets.

STAINLESS STEEL

This is alloy of steel with nickel, chromium, and traces of other metals. It has good corrosive resistance and can be welded easily. The cost of stainless steel is very high. Stainless steel used in the sheet metal shop can be worked as galvanised iron sheets, but is tougher than GI sheets. This is used in canneries, dairies, food processing and chemical plants, kitchen wares, etc.

COPPER

Copper sheets are available either as cold-rolled or hot-rolled sheets. Cold-rolled sheets being worked easily are commonly used in sheet metal shop, and are resistant to corrosion. They have a better appearance than other metals. Copper being a costly metal, cost of copper sheets is higher in comparison to GI sheets. Gutters, expansion joints, roof flashing and hoods are some of the common examples of copper sheet.

ALUMINIUM

Aluminium cannot be used in pure form, but is used with a very small amount of copper, silicon, manganese and iron. It is highly resistant to corrosion and abrasion, whitish in colour and light in weight. It is now widely used in the manufacture of a number of articles such as household appliances, refrigerator trays, lighting fixtures, windows, in the construction of airplanes, in the fitting and fixtures used in doors, window and building requirements, and in many electrical and transport industries.

TIN PLATE

Tin plate is sheet iron coated with the tin to protect it against rust. This is used for nearly all soldered work, as it is the easiest metal to join by soldering. The size and thickness of tin plates are denoted by special marks, not by gauge numbers, and can be very confusing to the uninitiated. If larger or heavier sheets of tinned iron are required, the material used is known as "tinned steel", and this may be obtained in all sizes and gauges in which sheet iron is obtainable.

However, this metal has a very bright silvery appearance and is used principally in the making of roofs, food containers, dairy equipments, furnace fittings, cans and pans, etc.

LEAD
Lead sheets are used in highly corrosive acid tanks. Lead is very soft and heavy. Lead sheet can be worked by hand without the use of any mechanical device.

18.3 SHEET METAL HAND TOOLS

There is a fairly large number of hand tools used by sheet metal workers. The tools most commonly used are listed in Table 18.1.

TABLE 18.3 BASIC TOOLS USED IN SHEET METAL WORK

1.	Measuring tools :	5.	Divider
	a) Steel rule	6.	Trammel points
	b) Folding rule	7.	Punches
	c) Circumference rule	8.	Chisel
	d) Vernier caliper	9.	Hammers
	e) Micrometer	10.	Snips or shears
	f) Thickness gauge	11.	Pliers
	g) Sheet metal gauge	12.	Stakes
2.	Straight edge	13.	Groovers
3.	Steel square	14.	Rivet set
4.	Scriber	15.	Soldering iron

Since most of them are described and illustrated in Chapters 14 and 16, a brief survey of the tools is made in the following lines.

MEASURING TOOLS
Steel rule. This is particularly useful in measuring and laying out small work. It can be measure with an accuracy of 0.5 mm (Fig. 16.3).
Folding rule. This is very useful in measuring and laying out larger work, the accuracy being 0.5 mm.
Steel circumference rule. This is used to find out directly the circumference of a cylinder.
Swing blade protractor. This is used for marking and measuring angles.
Vernier caliper. This is used for measuring dimensions up to 0.02 mm (Fig.16.12).
Micrometer caliper.. This is used to measure the thickness of metal sheets accurately up to 0.01 mm (Fig. 16.18).
Thickness Gauge. This is also called slip gauge and is used to measure the clearance between the parts during assembly (Fig. 16.51).
Sheet metal gauge. This is used to measure the thickness of sheets (Fig. 16.52)

STRAIGHT EDGE AND STEEL SQUARE

Straight edge. This is a flat graduated bar of steel with one longitudinal edge beveled. This bar comes in a variety of lengths ranging from 1 to 3 meter. It is useful for scribing long straight lines.

Steel square. It is a L-shaped piece of hardened steel with marks graduated on the edges for measuring. The narrow arm of the square is called *tongue* and the wide part is known as the *body*. It is used for marking in the perpendicular direction to any base line.

SCRIBER, DIVIDER AND TRAMMEL POINTS

Scriber. This is sometimes called the metal worker's pencil. It is a long wire of steel with its one end sharply pointed and hardened to scratch lines on sheet metal in laying out patterns.

Dividers. Dividers are used for drawing circles or arcs on sheet metal. They are also used to mark a desired distance between points and to divide lines into equal parts (Refer Fig. 16.9).

Trammel points. The trammel points consists of a bar with two movable heads. It is used to draw large circles or arcs that are beyond the limit of the dividers.

PUNCHES

A *punch* is used in sheet metal work for marking out work, locating centres, etc. in a more permanent manner. Two types of punches are generally used: (1) prick punch, (2) centre punch (Fig. 14.28). The *prick punch* is used to make small marks on lay out lines in order to make the prick-punch marks longer whilst the *centre* punch is used only to make the prick punch markers larger at the centres of holes that are to be drilled. Besides, there are *solid and hollow punches* very similar to other two punches the inner and outer faces of the punch meeting at an angle of 40°. These are used for making small holes from 2.5 mm to 10 mm.

A *hand lever punch* is sometimes used for making holes with a punch and die incorporated in the tool when a large number of holes are to be punched.

CHISEL AND HAMMERS

Chisels. Chisels are generally used in sheet metal work for cutting sheets, rivets, bolts and chipping operations. A good number of cold chisels are used and these are similar to those illustrated in chapter 14. The *flat chisel* (Fig. 14.7) and *round nose chisel* (Fig. 14.9) are most widely used in sheet metal works.

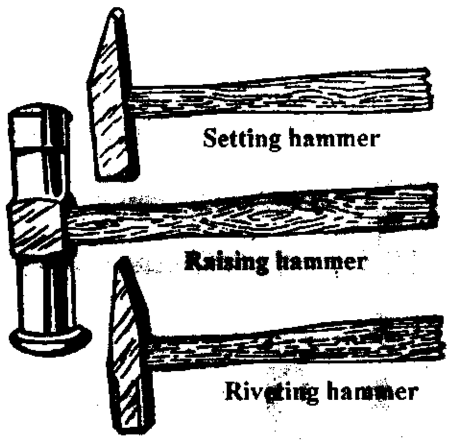


Figure 18.1 Hammers for sheet metal works

Hammers. Hammers are used for forming shapes by hollowing, raising, stretching or throwing off. There are many types of hammers, but the most commonly used hammers are:

(1) *riveting hammer* used for riveting;

(2) *setting hammer* specially useful for setting down the edge when making a double seam; and

(3) *raising hammer* used for forming of a flat sheet of metal into a curved or hollow shape such as a saucer, bowl, tray or spoon. These are illustrated in Fig. 18.1

Mallet. These are soft hammers, and made of raw hide, hard rubber, copper, brass, lead or mostly of wood, used to strike a soft and light blow on the metal.

SNIPS OR SHEARS

A *snip*, also called a *hand shear* (Fig. 18.2) is used like a pair of scissors to cut thin, soft metal. It should be used only to cut 20 gauge or thinner metal. There are several types of snips available for making straight or circular cuts, the most common being straight snips and curved snips.

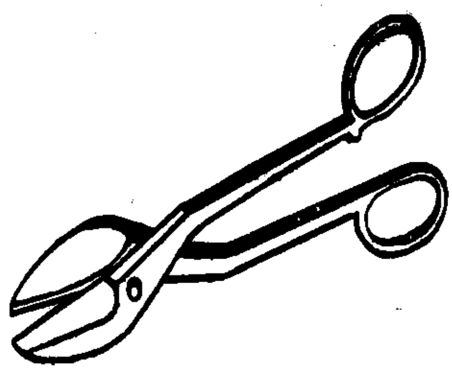


Figure 18.2 A hand shear

The *straight snip* have straight blades for straight line cutting while curved or bent snips have curved blades for making circular cuts. Both these snips are very light and can be easily handled by only one hand. These are also *double cutting shear, squaring shear, ring shear* and *circular shear* used for particular requirements as the name indicates. The heavier classes are known as *bench shears* and *block shears* where one handle may be held in vice or bench plate while the other handle is moved up and down to do the cutting.

STAKES

Stakes are the sheet metal worker's anvils used for bending, seaming or forming, using a hammer or mallet. They actually work as supporting tools

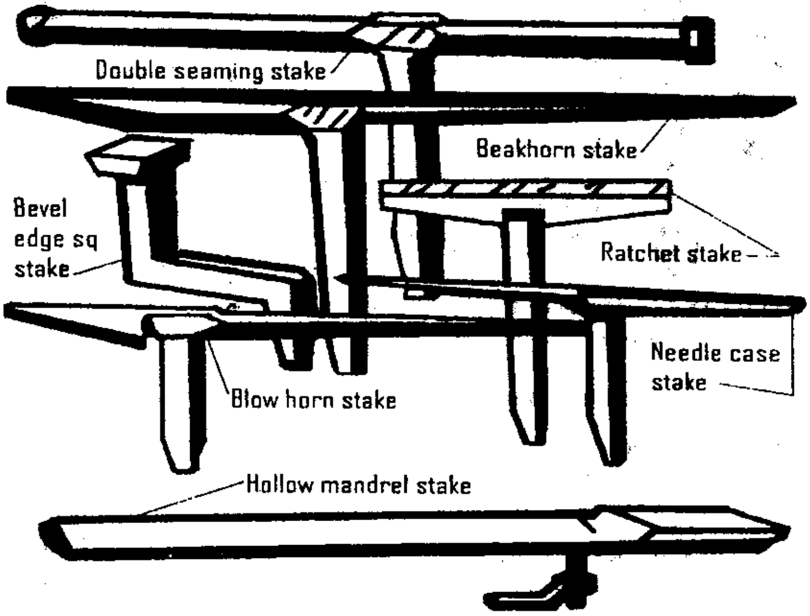


Figure 18.3 Common form of stakes

as well as forming tools. They also help in bending operation. They are made in different shapes and sizes to suit the requirements of the work. Some useful forms are shown in Fig. 18.3. The *double seaming stake* is used to make the double seam. The *beakhorn stake* is used for riveting, forming around and square surfaces, bending straight edges, and making corners. The *bevel edge square stake* is used to form corners and edges. The *hatchet stake* is used to make straight, sharp bends and for folding and bending edges. Small tubes and pipes are performed on the *needle case stake.* Cone-shaped articles may be formed on the *blow-horn stake. Hollow mandrel stakes are* used for riveting, seaming and forming.

PLIERS

Pliers are used for holding, cutting and bending work. *Flat nose pliers* are used for forming and holding work while *round nose* pliers are used for holding and forming various shape and patterns.

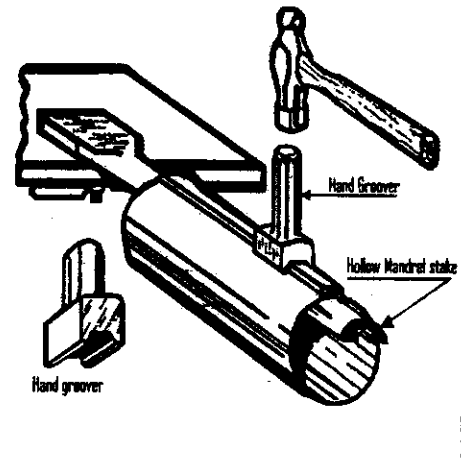


Figure 18.4 Grooving with hand groover

GROOVERS AND RIVET SETS

Hand groover. This is used for groove and flatten a seam as shown in Fig. 18.4. This is available in many shapes.

Rivet set. This is a *hardened steel* tool with a hollow in one end as shown in Fig. 18.5. It is used to shape the end of a rivet into a round, smooth head.

Figure 18.5 A rivet set

SOLDERING IRON

Soldering irons are used for soldering work and consist of a forged piece of copper joined to an iron rod with a wooden handle. These are also called soldering coppers. They are made in various shapes and sizes as shown in Fig. 18.6.

18.4 SHEET METAL OPERATIONS

The practical art of sheet metal lies in the making of different shapes by adopting different operations. The major types of operations are given below (See also in Chapter 7).

1. Shearing.
2. Bending.
3. Drawing.
4. Squeezing.

SHEARING

Shearing is a general name for most sheet-metal cutting but in a specific sense designates a cut in a straight line across a strip, sheet, or bar. This procedure leaves a clean edge on the piece of metal that is sheared or cut.

Shearing action has three basic stages : plastic deformation, fracture, and shear. When the metal is placed between the upper and lower blades of the shear and pressure is applied, plastic deformation first takes place. This extends into the interior of the metal from 5 to 40 per cent of its thickness. As continued pressure is applied to the cutting blade, the fracture or crack start at the cutting edge of each blade. The fracture or crack starts at the cutting edge of each blade, the points of the greatest stress concentration. As the blade descends further, the small fractures meet and the metal is then sheared. The same shearing action takes when a punch and die are used. The quality of the cut surface is greatly influenced by the *clearance* between the two shearing edges.

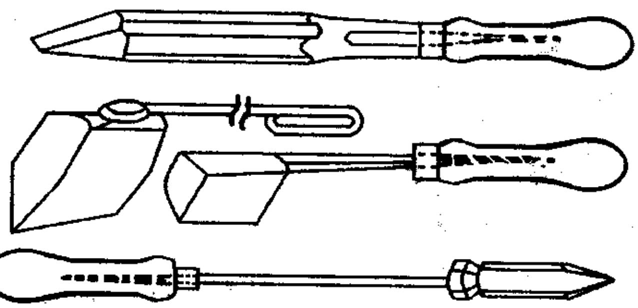


Figure 18.6 Common forms of soldering iron

However, the basic shearing operations are illustrated in Fig. 18.7 and described in the following lines.

Cutting off. This means severing a piece from a strip with a cut along a single line.

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

Blanking. This means cutting a whole piece from sheet metal just enough scrap is left all around the opening to assure that the punch has metal to cut along its entire edge.

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

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

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

Lancing. This makes a cut part way across a strip.

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

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

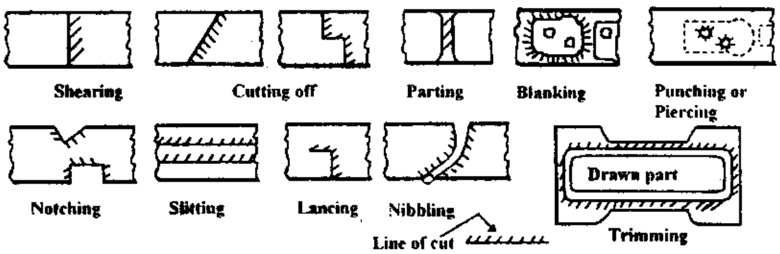


Figure 18.7 Common sheet metal cutting operations

BENDING

Bending and *forming* are sometimes thought to be synonymous terms. However, *bending* occurs when forces are applied to localised areas, such as in bending a piece of metal into a right angle, and *forming* occurs when complete items or parts are shaped.

In all metal bends, the metal is stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the *neutral line* which retains its original length. The neutral axis is at a distance of $0.3t$ to $0.5t$ (where t is the thickness of the stock) from the inside of the bend in most cases. This is depicted in Fig. 18.8. Stretching of the metal on the outside makes the stock thinner.

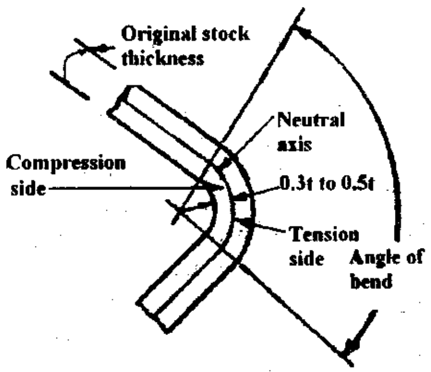


Figure 18.8 Bending in sheet metal

Bending incorporates *angle bending, roll bending, roll forming* (see Art. 7.11) and *seaming*. A special variety of bending is spinning a rotationally symmetrical part. The starting blank is held against a male die (form) which in turn is rotated by some mechanism such as a lathe spindle as described in Art. 7.12.

However, some common kinds of sheet metal bends are illustrated in Fig. 18.9.

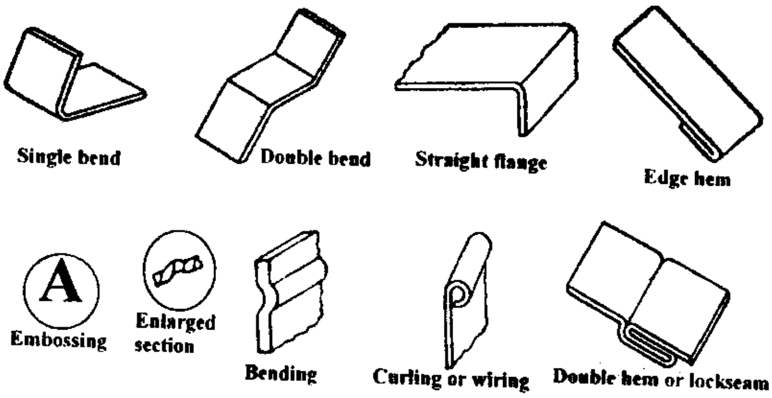


Figure 18.9 Common kinds of sheet metal bends

DRAWING

Drawing is the operation of producing thin-walled hollow or vessel shaped parts from sheet metal (see Chapter 7). The drawing process can be divided into two categories, deep drawing and shallow drawing. In *deep drawing* the length of the object to be drawn is deeper than its width, while in *shallow*, or *box drawing* the length of the object to be drawn is less than the width. Examples are seamless pots, tubs, cans and covers ; automobile panels, tops and hoods etc. The sheet metal is stretched in at least one direction but is often compressed also in other direction in these operations. The work is mostly done cold but sometimes is done hot.

The drawing operations is mostly performed by placing a metal blank over a stationary die and exerting a calculated pressure from a punch against the blank shown Fig. 18.10. The lubricants which are extremely important provide a film between the work piece and die facilitating forming and reducing friction and wear on blank, punch and die.

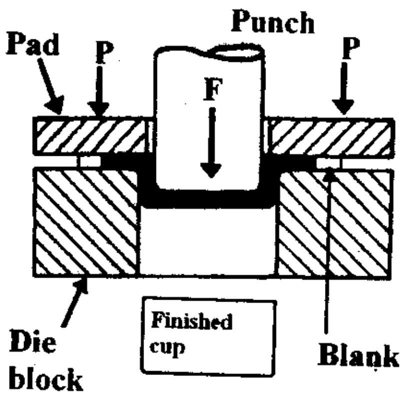


Figure 18.10 The way a cup is drawn

SQUEEZING

Squeezing is a quick and widely used way of forming ductile metal. The squeezing operations of sizing, coining, hobbing, ironing, riveting, etc. mostly used on sheet metals are described in Art. 7.15 and illustrated in Fig. 7.14.

18.5 SHEET METAL JOINTS: HEMS AND SEAMS

Sheet metal working incorporates a wide variety of hems and seams.

A *hem* is an edge or border made by folding. It stiffens the sheet of metal and does away with the sharp edge. A *seam* is a joint made by fastening two edges together. Different kinds of hems and seams are shown in Fig. 18.11.

Hem. Three common types of hems are : (1) single hem, (2) double hem, and (3) wired edge.

The *single hem* is made by folding the edges of the sheet metal over to make it smooth and stiff.

The *double hem* is made by folding the edges over twice to make it stiff and smooth.

The *wired edge* is smooth and very strong. Step by step process of making it is shown in Fig. 18.11.

Seams. Most common types of seams are : (a) lap seam. (b) grooved seam, (c) single seam, (d) double seam, (e) dovetail seam, and (f) burred bottom seam. The type of seam, of course, is determined by the thickness of metal, and the purpose for which the object is to be used.

The *lap seam* is the simplest type of seam and can be prepared as lap joint by means of soldering.

The *grooved seam* is made by hooking two single hems together and then locking them by a groover.

The *single seam* is used to join a bottom to vertical bodies of various shapes.

The *double* seam is similar to single seam with the difference that its formed edge is bent upward against the body.

The *dovetail* seam is similar to dovetail joint in carpentry and is used to join flat plate to a cylindrical piece.

The *burred bottom* or *flanged seam* is used to join the bottom of a container to its body. The flange on cylindrical jobs is often referred to as a *burr* and the process of making a narrow flange is known as burring.

18.6 SHEET METAL ALLOWANCE

An important consideration which calls particular attention is the allowance that is to be given for making joints. These allowances are necessary to obtain following criteria :

1. Correct size of finishing .
2. Part.
3. Better strength at joints of all edges.
4. To avoid cracking or warping.
5. Smooth finish.

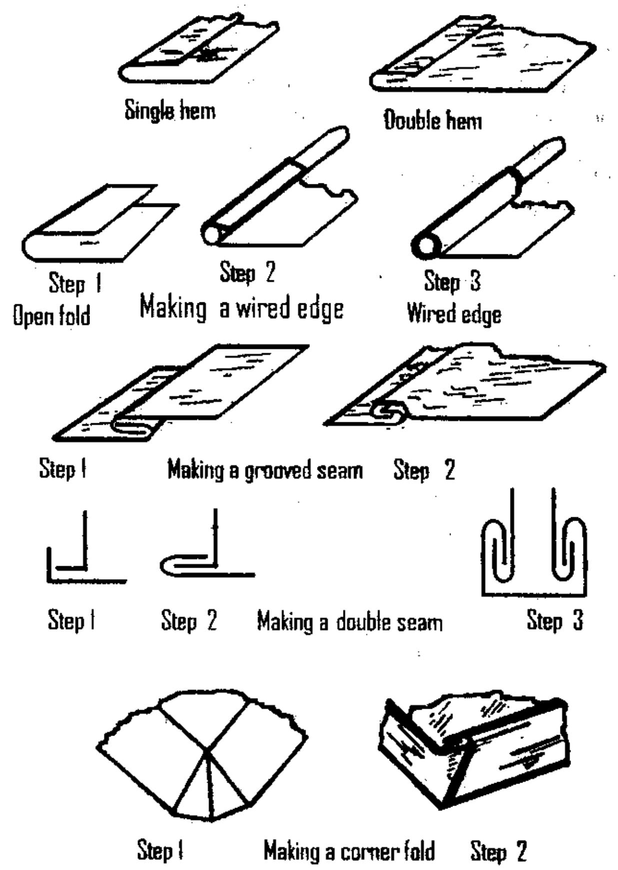


Figure 18.11 Hems and seams

Due allowance must be provided for preparation of edges and seams, and an extra metal called *tab* as shown in Fig. 18.12 is provided for the same. In the making of the various types of hems and seams no allowance is necessary for thinner sheets of 26 gauge or more, while a certain allowance is necessary for thicker and heavier sheets. The usual practice is to provide an additional metal equal to 2.5 to 3 times the thickness of the sheet for wired edges, and 3 times the thickness for seam objectives. General allowance for hem is 6 to 9 mm.

18.7 SHEET METAL WORKING MACHINES

When a large number of jobs are made, particularly in heavier types of sheets, hand operation like shearing, punching, bending, etc. is difficult time consuming and uneconomical. To cope with this problem, both hand and power operated machines have been developed. These machines are designed and perform a wide variety operation, such as forming, bending, edging, grooving, setting down, burring, turning, cutting, punching, drilling, and many others required in a sheet metal shop. Smaller machines are usually referred as to as "bench machine" while the others as "floor machines" which are particularly useful in mass production of identical parts.

The various machines commonly used to perform different operation are listed as follows:

1. Shearing machine.
2. Bar folder.
3. Burring machine.
4. Turning machine.
5. Wiring machine.
6. Setting down machine.
7. Forming machine.
8. Brake.

SHEARING MACHINE

Shearing machines are used to cut or shear metal sheets in very many ways. The particular method chosen depends on several factors such as the size and shape of the parts required and the numbers needed.

There are a large number of machines available for shearing sheet metal but the common ones may be placed into one or two main groups of machines: (a) those using flat blades for the cutting and (b) those using rotary cutters. The most commonly used of all the machines using flat blades are, of course, the *guillotines*.

BAR FOLDER

A *folder* is used for bending and folding the edges of the metal sheets to form the joint at the seam. This is used for shaping metal sheets into cylindrical objects.

BURRING MACHINE

The *burring machine* is used o make a burr of the edges of the bottom for a can and on the end of a cylinder. The making of such burrs is the first step in making a double seam with a double seaming machine.

TURNING MACHINE

This is similar to the burring machine but produces a rounded edge for wiring operations, bodies of cylinders and for double seaming.

WIRING MACHINE

After the edge of the work has been made rounded in the turning machine, the wire is placed into the rounded edge which is then hammered over a little with mallet. The edge of the metal may then be completely pressed over the wire with a wiring machine.

SETTING DOWN MACHINE

After the burr have been made on a burring machine the seams are closed or set down on a setting down machine. This facilitates the operation of double seaming to do a better seaming job.

FORMING MACHINE

Stove pipes, cans, etc. are formed out of flat sheet metal on a forming machines. It has three rolls which can be set at different distances apart and between which the curves are made. This is indispensable for making pipes.

BRAKE

A *brake* is a machine for bending and folding sheet metal. A bar folder only bends or folds the metal near the edges but the brakes can bend or fold the metal any distance from the edge. The *pan brake* and *cornice brake* are the two types of brakes generally available.

18.8 LAYING OUT A PATTERN

Before starting of any project in sheet metal, a pattern should be developed to ensure the accuracy of the finished article. The pattern is nothing but a flat outline of the job. Almost all the patterns are obtained form the development of surfaces of some common geometrical solids, such as cylinder, prism, pyramid and cone.

Most sheet metal and plate objects are formed into three dimensional shapes by squeezing, bending, or forming a predetermined pattern stretch-out. The purpose of the pattern stretch out is to determine the exact amount of sheet metal or plate that is necessary to fabricate the product. The pattern or outline of the object to be fabricated may be drawn on a paper and then transferred to the metal or it may be laid out directly on the sheet metal. For reception work, a pattern is developed and cut from metal; the metal pattern is then used as a *template* from which the actual job is marked off.

Both stretch-outs and patterns are originated by the following three methods of development.

1. Parallel line method.
2. Radial line method.
3. Triangulation method.

PARALLEL LINE METHOD

Parallel-line development derives its name from the parallel lines used in the construction of stretch-outs. This is used for stretchouts or patterns of *Y* shapes, *T* shapes, and elbows. It is also used for areas where pipes intersects flat surface at an angle.

The following steps may be followed in laying out a pattern or stretch-out for a cylinder connector as shown in Fig. 18.12.

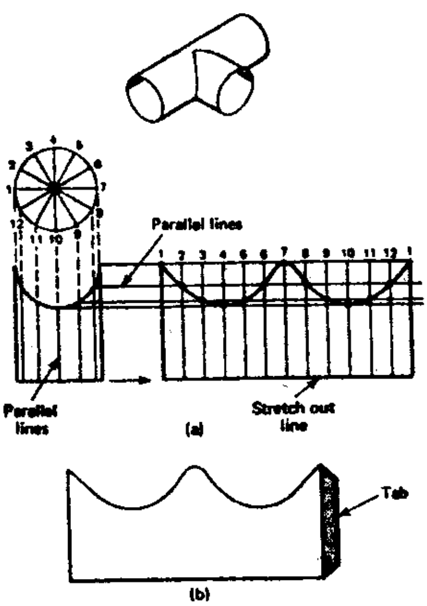


Figure 18.12 Parallel–line development
(a) procedure, (b) stretch-out

1. Draw the plan and elevation of the connector pipe. Divide the plan into 12 number of equal parts and project them in the elevation.
2. Draw the stretch-out line equal to the circumference of the circle at an angle of 90° to the plan.
3. Divide the stretch-out line in 12 equal arc lengths of the plan.
4. Draw perpendicular lines from each division of the stretch-out line and locate the top and bottom points of these lines by projecting the corresponding points from the elevation.
5. Join the points together by sketching freehand from point to point and complete the stretch-out or a pattern as shown in Fig. 18.12 (b).

RADIAL LINE METHOD

Radial line development is used to develop items in which the slant edges radiate like spokes of a wheel from a point known as centre or apex as in the case of pyramids or cones. The bases may be round, square, hexagonal, octagonal, or any other regular polygons.

The following steps may be followed in laying out a pattern of a right cone cut by an inclined plane.

1. Draw the elevation of the cone and on the base line 1, 7 describe the semi-circle representing the half perimeter of the cone base.
2. Divide the semicircle into six equal parts at point 1, 2, 3, 4, 5, 6, 7 and from each point produce vertical lines to intersect base of one cone. From each point of intersection on the base draw the radial lines or the apex.
3. Using the cone apex, describe an arc of radius equal to the slant side *AB* and on it mark off twelve division equal to these in the perimeter 1, 2, 3, 4–1. Join these points to the apex.
4. In the elevation, transfer the points 2, 3, 4, 5, and 6 on the slant side of the cone for the *true distances* on the respective lines in the sector.

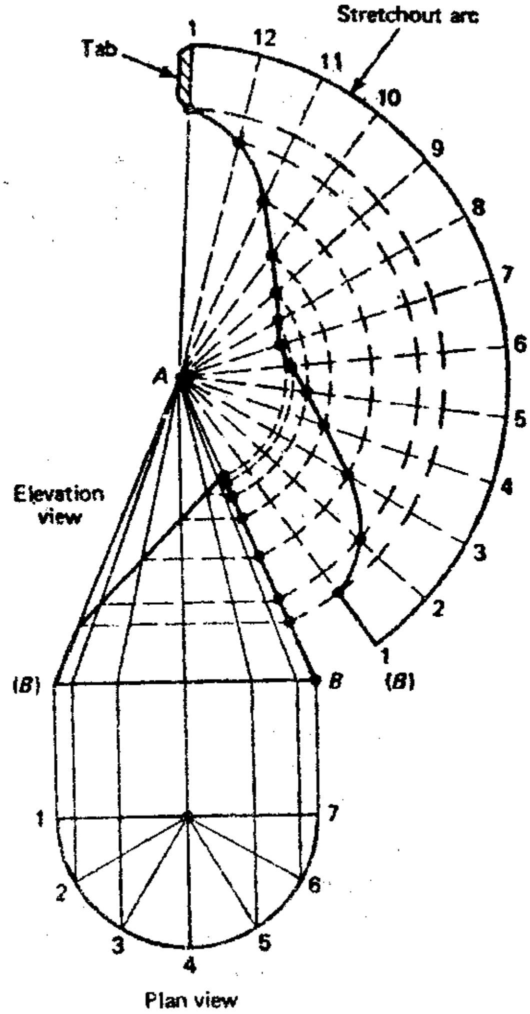


Figure 18.13 Radial–line development

5. Transfer these point on the respective lines in the development.
6. Join these points together to obtain the pattern as shown in 18.13(b).

TRIANGULATION METHOD

Triangulation method is used to develop articles which cannot be developed exactly as in the case of transition piece. A *transition piece* is a connecting piece which connects openings of different shapes and sizes. These pieces are used in ventilating, heating and similar pipes. Necessarily the surfaces are made of planes, cylindrical and conical surfaces. The principle of this method is to divide an object into a series of triangles, to find the true lengths of the sides. and then to place the triangles in their true position in the pattern.

The following steps may be followed in laying out a pattern for a hood as shown in Fig. 18.14.

1. Draw the plane and elevation of the hood.
2. Draw in the plan, four triangles *ABCD* and four part-oblique cones *u,v,w* and *x*. The vertex of each triangle is point on a circular and its base is the side of the square. The base of the part-oblique cone is equal to one-fourth of the circular end and the apex is at one corner of the square end.
3. Divide the circular ends into a number of equal parts 1, 2, 3, 4–1 as shown in the plan. Draw lines from corners of the square to the division to represent elements of the cone and draw elevation of these elements.
4. Find out the true length of all the sides of the triangles and elements of the cones from the corresponding plan and elevation.

   In T.L. diagram *a1* is the plan of one side of the triangle *A* and *a2* and *a3* are the two elements of the cone. So 01, 02, 03, are the true length of these lines.
5. Take a point as vertex and draw triangle *A* in its true size by taking the true length of all the sides.
6. Draw an arc taking one corner of the triangle as centre and raise equal to true length of the elements connecting the point 2. Draw another with the vertex as centre and the length between the division 1, 2 as radius. Repeat the same process to get other points.
7. Draw a smooth line through these points and obtain the pattern. Only half of the pattern is shown in Fig. 18.14, the other half will be exactly the same.

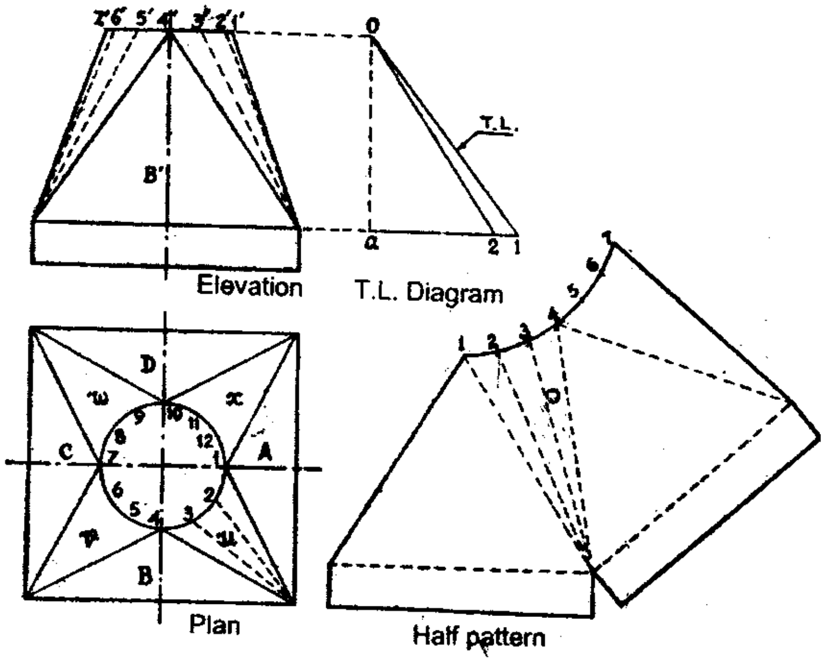


Figure 18.14 Development by triangulation method

REVIEW QUESTIONS

1. Name the metals commonly used in sheet metal work.
2. Give a detail list of hand tools used in sheet metal work.
3. What do you mean by stakes ? Name the different types of the stakes with sketches giving their uses.
4. Why snips are used ? Give a description of some of them with sketches.
5. What are punches and shears used for ?
6. Name the common sheet metal working machines giving their uses.
7. Describe the common sheet metal operations or processes with suitable sketches.
8. Sketch and describe the joints used in sheet metal work stating their uses.
9. What are (a) hems and (b) seams ? Give the uses of some of them with neat sketches ?
10. What do you mean 'lay out a pattern'? Why allowances are provided on the lay outs prepared and how they vary ?
11. State briefly the various methods used in laying out a pattern with their uses.

19

PLUMBING, THREADING FASTENERS AND JOINTS

19.1 PLUMBING

Plumbing is concerned to join and repair of pipes that carry fluids and gases. In modern urban life water and drainage pipe, baths, toilets etc. have become integrated parts of any building. In industrial undertakings, pipe lines are used for supplying compressed air, gas, steam, water, oil, chemical fluids, refrigerants or any other item, capable of flowing through them. Previously clay pipes were used for drainage and sewerage works. A Babcock and Wilcox boiler contains many copper tubes (pipes) which transfer heat from furnace to the drum. Galvanized iron pipes supply water for household purposes.

As the pipes are supplied in standard lengths, these are joined, cut, bent, fitted to carry out the intended engineering functions. Certain accessories like taps, control valves, nipples etc. are also needed to control the flow of the liquid or gas to or from the container.

19.2 SPECIFICATION OF PIPES

Pipes can be specified by ;

1. Material.
2. Inside diameter.
3. Wall thickness.
4. Length.
5. Surface treatment (e.g. plating, galvanizing etc.)

19.3 MATERIALS USED FOR PIPES

The material of the pipe is dependent on the nature of the fluid or gas that flows through it. The following table (Table 19.1) gives the list of materials required for pipes and the use of such pipes ;

TABLE 19.1 PIPE MATERIAL AND ITS USE

Pipe Material	*Use*
1. Galvanized iron	Supply line for water.
2. Clay	Sewerage system.
3. Steel or Chrome plated wrought iron	Fabrication, furniture making.
4. Copper	Boilers, machine tools.
5. Brass	Decorative, household work.
6. Aluminium	Furniture manufacturing.
7. Stainless steel	Carrying chemicals.
8. Glass	Laboratory work.
9. Cast iron	Drainage work, main water pipe lines.
10. Cement concrete & asbestos cement	Sewerage work.
11. PVC (Flexible)	General purposes for water, oil etc.
12. PVC (Hard)	Electric conduit.
13. Rubber	General purposes, connector to LPG.

19.4 PIPE FITTINGS AND JOINTS

Fittings are used for joining two or more sections of pipes for required length, for changing the diameter or direction of flow of the line, or for controlling the flow in the line. Fittings are usually rated as low-pressure, standard, extra-heavy, and hydraulic. Pipe fittings in common use are bend, spring, elbows, round and square, tee, cross, coupler, reducing shocket, cap, plug and nipple. Some of these are shown in Fig.19.1. Fittings are specified by the nominal sizes of pipes for which they are used, as a 20 mm elbow or a 30 mm tee.

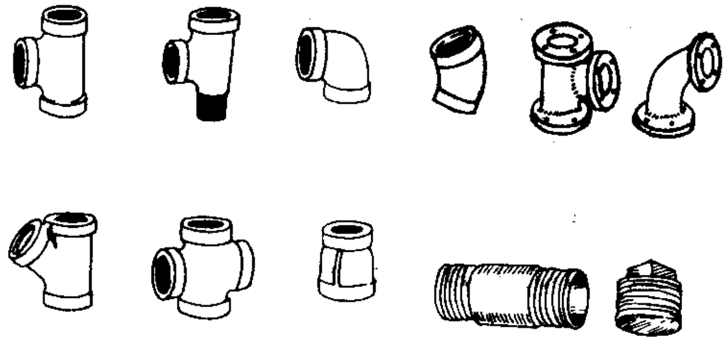


Figure 19.1 Pipe fittings

Screwed joints : Screwed joints (shown in Fig. 19.2) are made with standard pipe threads, and are very similar to one made by coupling. Water, gas and air pipes of small diameters are frequently joined by screwed socket or couplers. This joining consists of a short sleeve with an internal standard pipe thread at each end.

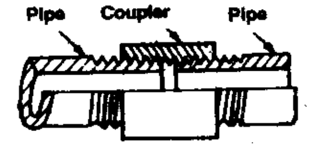


Figure 19.2 Screwed joints

Expansion joints : Expansion joints are used to provide for the alternations of length and change that may happen due to varying temperatures in steam and hot-water pipes. The simplest form of expansion joint consists of a length of copper pipe (or of lap-welded or weldless steel pipe, with riveted flanges) bent in the form of a horse-shoe, which may take the place of a short length in a pipe. It offers little resistance to the ends (Fig. 19.3) being moved closer together or further apart by expansion and contraction.

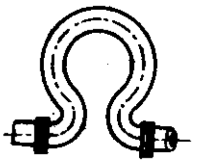


Figure 19.3 Expansion joint

19.5 TAPS AND VALVES

Taps are used to draw water from the pipe lines in regulated way and also can be used to stop or start the flow. They are mostly used for domestic water supply. Taps can be made out of brass or cast iron. In domestic taps washers are often worn out and requires periodic replacement.

Valves and cock are used to regulate and control the supply of fluids in pipe lines, a number of pipe lines are used to distribute fluids / gases from the same reservoir. Pipe lines supplying water from a single overhead tank to a number of flats must contain valves to control external supply of water. Small valves are made of brass while the large valves are made of cast iron. Fig. 19.4 shows a brass wheel valves having female ends. It is necessary to operate the valves through their full range of operation once in a while to keep them in good shape. When installing

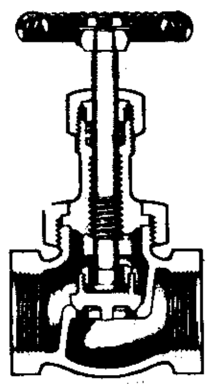


Figure 19.4 Brass wheel valve

valves, direction of flow must be considered. Float valve forms an essential part in flush cisterns and overhead storage tanks. It automatically regulates the water supply and does not allow overflow of water from the tank. A PVC or metallic hollow ball is used as a float. A mechanism disconnects the flow of water by moving the sliding rod in the closing position when the ball floats to the maximum permissible water level. When the water level falls the ball goes down thus the slide moves to the other end to start water flow in the cistern / water tank.

19.6 PLUMBER'S TOOLS

A plumber requires a number of tools and equipment when working. A few of important items are described.

Pipe vice : Pipe vices are used to clamp pipes in position for threading, cutting, fitting or performing any other type of pipe operation. Fig.14.2 shows a general purpose pipe vice.

Pipe bending equipment : Fig. 19.5 shows a pipe bending equipment.

The equipment is a simple time saving device for bending small diameter (up to 40 mm) pipes. The device consists of a base plate which is either fixed on a bench or supported by a structure consisting of four cast iron legs. The operating lever is stopped at the extreme left by stopper pin 'X'. The pipe is inserted between guide roller of the operating handle and the main roller at this position. The lever is then rotated to the right, bending the pipe to the desirable amount. Lower part of the pipe is supported by the guide pin 'Y'.

Though this operation is simple, the curvature is limited to the radius of the main roller. It is not possible to make sharp bend by this device.

The other method of bending consists of localize heating of the pipe, making the material at the part plastic and then bend it. Bending may generate unevenness on the bent portion of the pipe. Further cracking may appear at the point of bending.

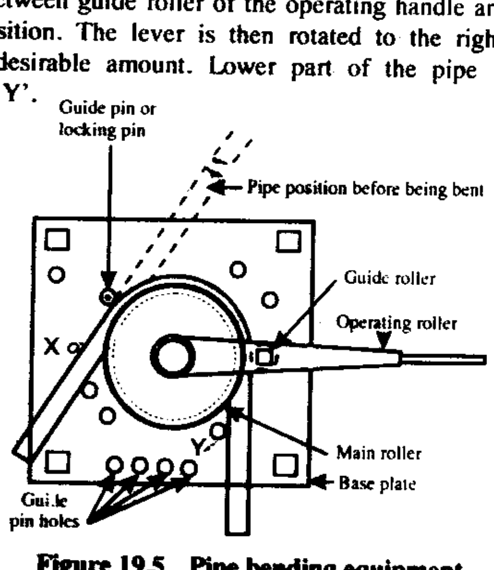


Figure 19.5 Pipe bending equipment

Pipe threading dies and taps : Special piping taps and dies are employed to cut internal and external threads of pipes. Conventional thread cutting methods can be applied if the pipe wall thickness is more than 2.5 mm.

A *pipe cutter* has a hook type cutter used to cut GI and steel pipes. The unit consists of a body and handle. Two sharp and extremely hard cutters are permanently fixed on the body. The other cutter is mounted on the projected part of the handle. A pipe can be inserted between the tips of the three cutters. The handle is tightened and rotated on the pipe to cut it in two pieces.

Pipe wrenches : Pipe wrenchs are used to turn pipes, round bars etc. or either connecting or separating them from fittings. It has a movable part and a main body. The jaws are serrated and a pipe can be fixed by tightening it through the rack. Fixer adjustment can be made by using the adjusting screw. A wrench is shown in Fig. 19.6.

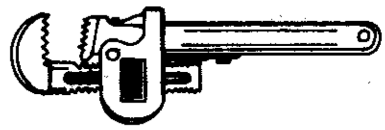


Figure 19.6 Pipe wrench

19.7 THREADED FASTENERS

In all kinds of joining, the various parts are held together by devices known as fastening, and the elements by which the parts are so joined are called *fasteners* or *fastening elements*. There are two types of fasteners used in engineering practice :

1. Temporary. 2. Permanent.

Temporary fasteners are those in which repeated assembly or disassembly is possible without injury or destruction to the fasteners or to the parts. In temporary fastenings, the parts are held together by fasteners such as screw, bolts, nuts, keys, cotters, pins, etc. Bolts and nuts, studs and nuts, and, screws are common examples of *threaded fasteners* engaged in threaded holes of a machine part. Threaded fasteners are further classified as a male and a female threaded fasteners, and threaded rods are examples of the former type, while nuts and threaded holes are examples of the latter type.

Permanent fasteners are those in which either the fastener or the members joined together must be destroyed in dismantling the members. Permanent fastenings may be riveting or welding.

19.8 SCREW THREADS AND THEIR USES

Screw thread may be considered as a raised form known as helix produced on the outside of a cylindrical hole, like a piece of string wrapped around a cylinder or the sides of a cylindrical hole.

They are applied to many devices for various purposes as follows :

1. To transmit power.
2. To increase the effect of the applied effort as in an auto–jack.
3. To control movement as in a micrometer.
4. To convey materials as in a gravity conveyor.
5. To hold parts together as in the case of fastening.

Single- and multi- start threads : In a piece of work it is possible to have several separate and independent threads running along it. Accordingly, there are single threaded screw and multiple or multi-start threaded screw. The independent threads are called starts, and they may be single-start, two-start, three-start, etc. (Fig. 19.7)

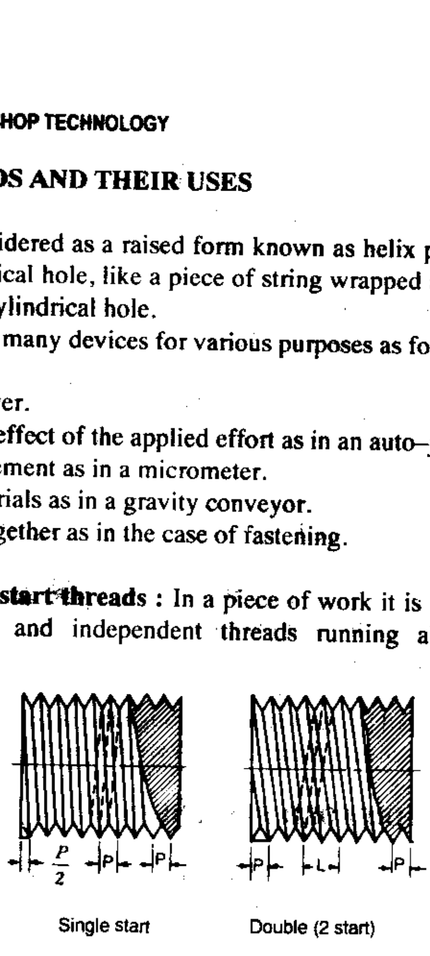


Figure 19.7 Single and multi – start threads

For one complete turn round the screw or bolt when there is a movement of one thread the screw is called *single threaded screw*; and when there is a movement of more than one thread, the screw is called multiple or *multi-start threaded screw*.

Multi-start threads are used in those cases where rapid movement or motion is required. Fountainpen cap, screw press, etc. are good examples where they are widely employed.

RIGHT–HAND AND LEFT–HAND THREADS

Screw threads may be made either right or left handed. A *right-hand thread* is one in which the nut must be turned in a right-handed direction to screw it on, a *left-handed thread* being in which the nut would be screwed on by turning it to the left.

FORMS OF SCREW THREADS

Forms of screw threads vary according to the purpose for which they are to be used, and also according to the country in which they are manufactured. Most threads are *V*-form, but some are square, and some are modifications of either or both. The forms of thread generally used are shown in Fig. 19.8.

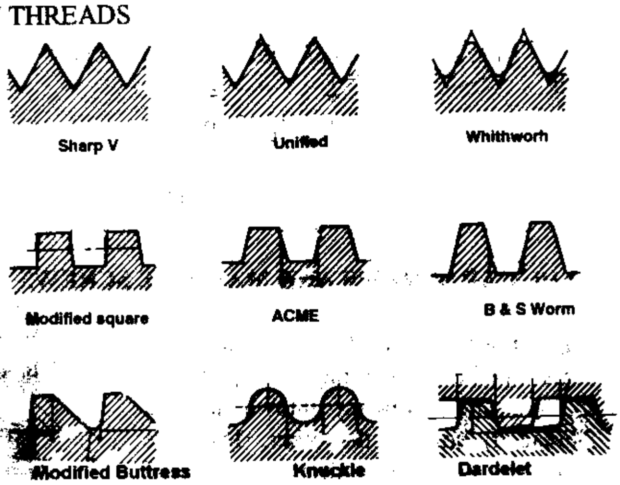


Figure 19.8 Forms of screw threads

19.9 INDIAN STANDARD THREAD

The Indian Standard Institution adopted metric screw thread with ISO profile (diameter range 0.26 to 300 mm) as the Indian Standard thread for various applications (*IS :1330-1958*). It is based on a draft general plan for screw threads with triangular profile, for the diameter range 0.25 to 300 mm., prepared by Technical Committee No. 1, Screw Threads, of the International Organization for standardization (ISO).

This is shown in Fig. 19.9.

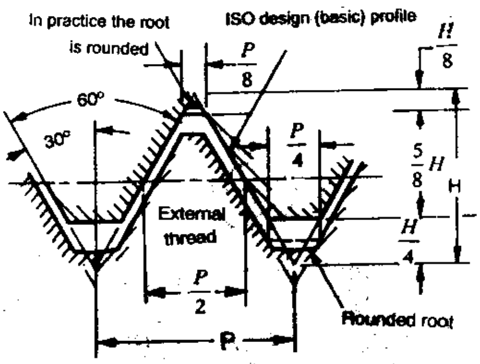
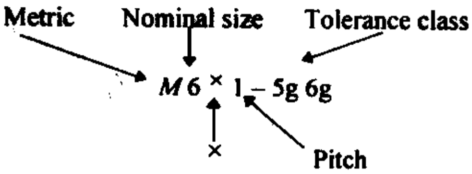


Figure 19.9 ISO thread profile

The threads covered in this standard (*IS :1330-1958*) shall be designated by the letter *M* followed the diameter and the pitch, separated by the sign × and tolerances.



where there is no indication of pitch, it shall mean that a coarse pitch is intended, e.g. $M\,6$ means $M\,6 \times 1$.

19.10 CAP SCREWS AND MACHINE SCREWS

Cap screws are used for connecting two parts together by passing through a hole in one and screwing into a tapered (threaded) hole in the other. They are available in either unified or national coarse and fine thread series.

There are various types of cap screws which are shown in Fig. 19.10.

Machine screws are similar to cap screws in all respects but are generally smaller in diameter. They are primarily used for light duty work where great strength is not required

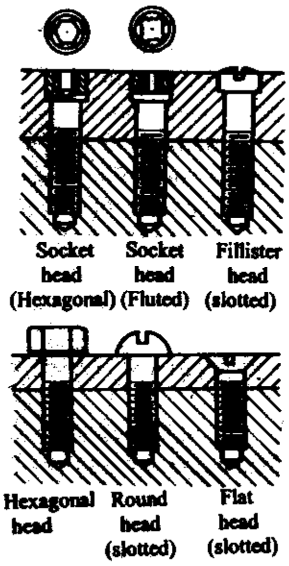


Figure 19.10 Types of cap screws

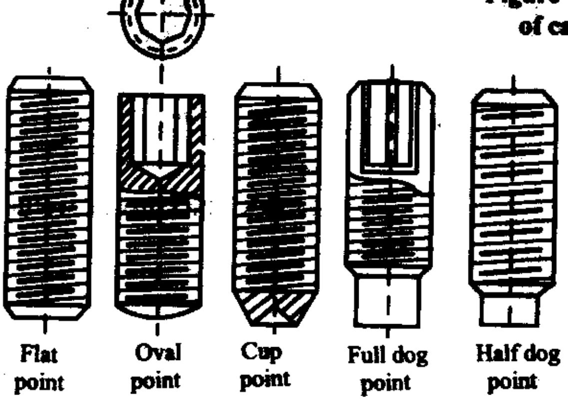


Figure 19.11 Set screws

19.11 SET-SCREWS

Set-screws are similar to cap screws, but is threaded practically throughout its length. They are used for holding two machine parts in a desired position to prevent relative movement. Fig. 19.11 shows different types of set screws.

19.12 METHODS OF PRODUCING SCREW THREADS

Screw threads may be produced (1) by hand with taps and dies,(2) on a lathe with specially shaped cutting tools,(3) on special machines using dies, and (4) on thread grinding machines.

19.13 BOLTS

A bolt comprises of two parts : (*i*) shank, and (*ii*) head. The cylindrical portion of the bolts is known as the shank. This is threaded at the tail end for a sufficient length so as to effectively engage with a nut. The shape of the head depends upon the purpose for which the bolt is required.

Specification of a bolt : To completely specify a bolt it is necessary to mention eight features, namely ; (1) shape or form of the thread, (2) pitch, (3) shape of the head, (4) outline of the body, barrel or stem, (5) size or diameter, (6) direction of thread (as right hand or left hand,) (7) length, and (8) material as steel or brass, etc.

Forms of bolts : Some of the most commonly used bolts are described hereunder.

1. **Hexagonal-headed bolt :** This is most common form of bolt and is used for general fastening purposes. The hexagonal head is chamfered at its upper end. To prevent rotation of the bolt while screwing the nut on or off, the bolt-head is held

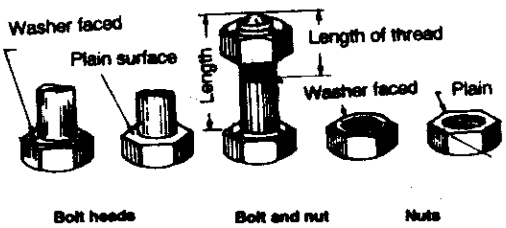


Figure 19.12 Bolts and nuts

by another spanner. A bolt and nut and their combination are shown in Fig. 19.12.

2. **Square-headed bolt :** This bolt is generally used when the head is to be accommodated in recess. This recess is also made of square shape so that the bolt is prevented from turning when the nut is screwed on or off. When a square-headed bolt is to be used with its head projecting outside, it is provided with a neck of square cross-section. This prevents rotation of the bolt. This bolt is commonly used in bearings for shafts.

3. **Cylindrical or cheese-headed bolt :** This bolt is used where projecting corners are undesirable, and where the space for accommodating the bolt-head is comparatively limited. The rotation of the bolt is prevents by means of a pin inserted into the shank just below the head. The projecting part of this pin fits into a corresponding grooves in the adjacent piece. This bolt is commonly used in big ends of connecting rods, eccentrics, etc.

4. **Cup-headed or round-headed bolt :** This bolt is used when projecting corners are undesirable and where better appearance is required. It is usually provided with a snug forged on the shank just below the head.

5. **T-headed bolt :** This type of bolt is used for securing clamps, vices, and other accessories to the tables of machine tools. The tables are provided with *T*-slots to accommodate the *T*-heads.

19.14 STUDS

Studs are threaded on both ends. The nut-end is threaded for a length slightly more than the thickness of a nut or nuts to be used. The other end called the metal end is threaded for a length at least equal to the diameter of the stud. The stud is used in place of a bolt, the parts joined by the fastener are removed frequently or to avoid unnecessary long bolt. Studs are commonly used to cylinder covers to engine cylinders.

10.15 FORMS OF NUT

In order to make bolt and studs into effective fastenings, nuts are required. Nuts are generally in the form of hexagonal or square prisms. Besides these, cylindrical and other forms are used in particular requirements.

Hexagonal nut : This is the most common form of the nut used for general fastening purposes in conjunction with a hexagonal-headed bolt.

Square nut : A square nut, is used in conjunction with a square-headed bolt. The spanner used for the nut can have a better hold on a square nut than on a hexagonal nut.

Ring nut : It is in the form of a ring provided with slots in the curved surface for a special C-spanner. These nuts are generally used in pairs, one nut acting as a lock nut for the other.

Cap nut : It is a hexagonal nut provided with a cylindrical cap at the top to protect the end of the bolt from corrosion. It also prevents leakage through the threads. Cap nuts are commonly used in smoke-boxes of locomotives.

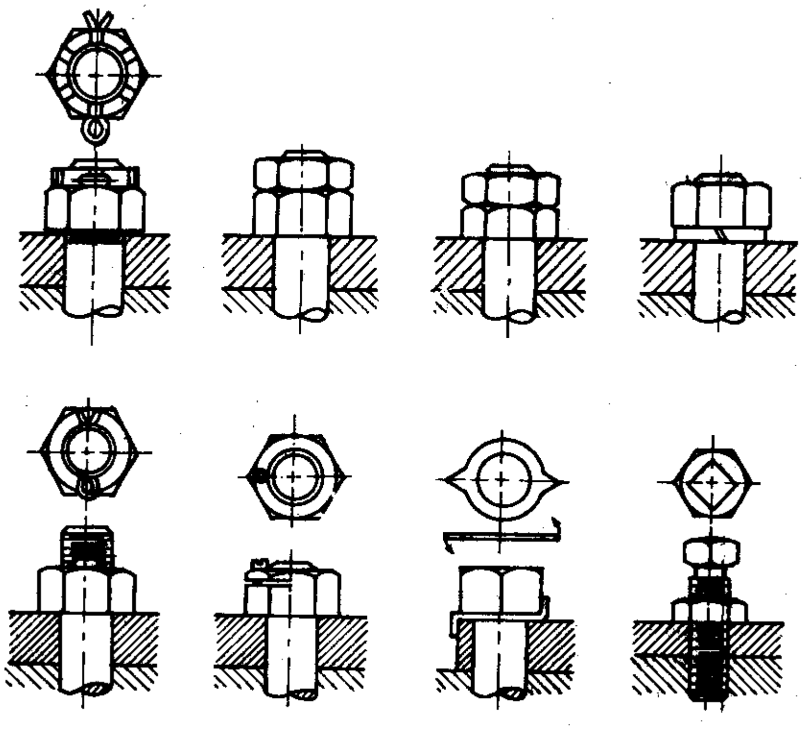


Figure 19.13 Locking nuts

Cylindrical or capstan nut : This nut is cylindrical in shape and has holes drilled in the curved surface for turning it with a Tommy bar.

Dome nut : It is a form of a cap nut having a special dome at the top.

Wing nut or thumb nut : A wing nut can be easily operated by the thumb and a finger, and is used where it is required to be adjusted frequently.

Locking nuts : During vibration in moving parts of machines, there is always a tendency for the nuts to get slack and to screw off the bolts slightly. It is, therefore, necessary to secure the nut in some way as to prevent it from getting loose. Nuts employed to do so are called locking nuts, a few of which are shown in Fig 19.13.

INDIAN STANDARD SPECIFICATION FOR BOLTS AND NUTS

The Indian Standard *(IS 1364-1960)* covers the requirements of precision, and turned hexagonal bolts (diameter 6 to 39 mm) of coarse and fine pitches.

19.16 RIVETING JOINTS

Rivets are permanent fasteners, used for joining two or more members to form a permanent joint. Riveting is extensively used on boiler work, shipbuilding and structural construction.

CLASSIFICATION OF RIVETS

Rivets are classified according to the shape of their heads. The usual types are : (1) cup head or snap head, (2) pan head, (3) conical head, and (4) countersunk head.

METHODS OF RIVETING

Rivets are made in special machines from special round iron or steel bar, with head either cup-shaped or pan-shaped, formed while red hot by dies of these shapes.

In riveting plates, wherever particable, riveting machines are used. The rivet is made red hot, passed through the holes in the plates already drilled and pressed between two dies by hydraulic or steam pressure. The heads are then usually made and are said to be machine riveted. A pneumatic riveter is used in most of the cases which closes the end of the rivet by a quick succession of blows.

When machines are not available, the rivets are hand riveted. In hand riveting, the rivets are heated in special rivet heating furnaces or in forge fire, the holes in the plates are made by drilling and rivets put in and riveted up hot. The tail is hammered and formed into a head by a riveting hammer, a cup-head or pan–head tool being inter-posed to give the head the required shape. At this time the head already formed is held up by an assistant with the aid of a tool called *dolly*, cupped to receive the head of the rivet (Fig 19.14).

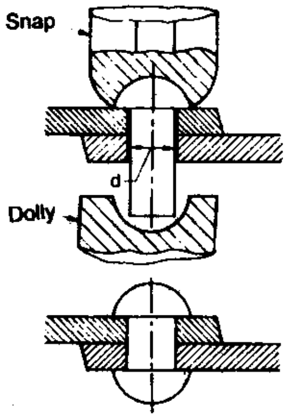


Figure 19.14 Making of rivets

In many cases of work, such as the skin of ships, the seatings of girders, etc., the heads must not project out and the plates are then

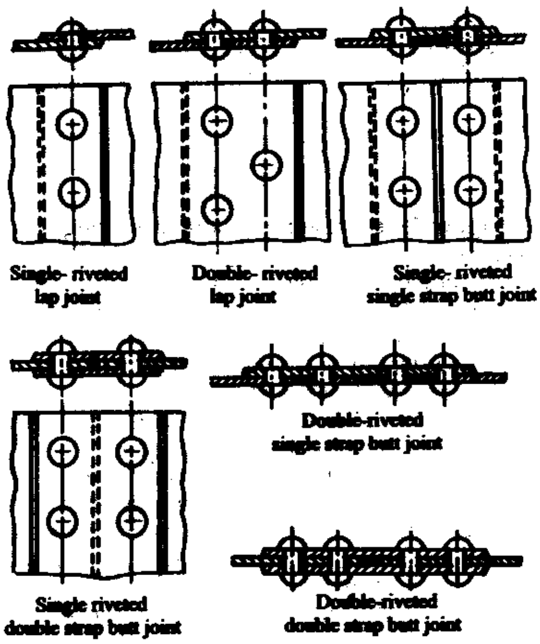


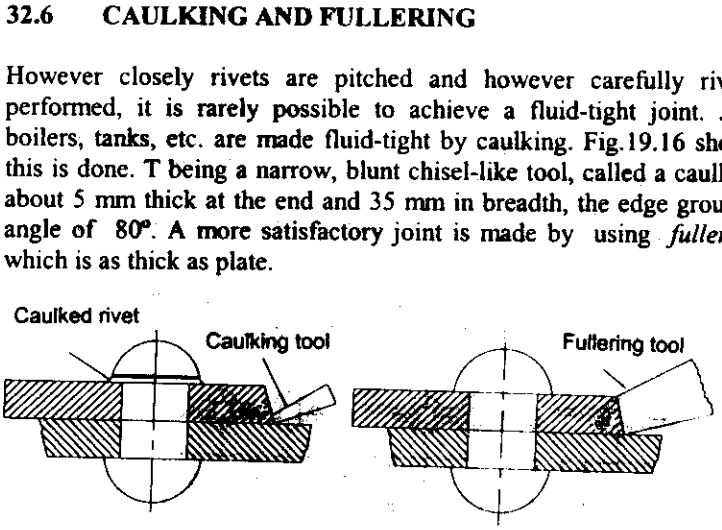
Figure 19.15 Riveted joints

countersunk to provide contersunk headed rivets.

The joining may be single riveted, double riveted, triple riveted, and so on, according to the number of rows of rivets used in the joint. In the case of butt joint, the square edges of the plates butt together, i.e. placed edge to edge and the joint is covered by one or two parallel strips of plate called cover plates, thickness of the plates being from (5/8)t to t. Various riveted joints are shown in Fig. 19.15.

32.6 CAULKING AND FULLERING

However closely rivets are pitched and however carefully riveting is performed, it is rarely possible to achieve a fluid-tight joint. Joints in boilers, tanks, etc. are made fluid-tight by caulking. Fig.19.16 shows how this is done. T being a narrow, blunt chisel-like tool, called a caulking tool about 5 mm thick at the end and 35 mm in breadth, the edge ground to an angle of 80°. A more satisfactory joint is made by using *fullering* tool which is as thick as plate.



Caulking Fullering

Figure 19.16 Caulking and Fullering

REVIEW QUESTIONS

1. What are screw threads and state their uses.
2. What is meant by : (a) single and multi-start threads, and (b) right-hand and left-hand threads ? Explain them with neat sketch.
3. (a) Sketch a screw thread and level the designation of their different parts, (b) Explain clearly (i) pitch and (ii) lead.
4. State the various forms of screw threads used in general engineering with suitable sketches and give their specific uses.
5. Name the various methods of producing screw threads.
6. State where bolts and nuts are used, and specify each of them.
7. Describe with neat sketches the types of bolts and state their uses.
8. Describe the various forms of commonly used nuts and state their uses.
9. What are locking nuts ? State their uses.
10. Distinguish between : (a) a stud and a bolt (b) a screw and a bolt. State the different types of cap screws commonly used.
11. Explain how riveting is made ? Show some of the rivet joints.

20

QUALITY CONTROL

20.1 INTRODUCION

The basic purpose of manufacturing is to produce engineering materials and parts to specified shape, size and finish. The specifications for the shapes, sizes and finishes are furnished to the shop by part drawings or manufacturing drawings. These specificatios are often called *quality characteristics*.

It has already been explained in Chapter 15 that meausred quality of manufactured product is always subject to a certain amount of variation as a result of chance. Some stable 'system of chance causes' is inherent in any particular scheme of production and inspection. The reasons for variation outside this stable system should be discovered and corrected to avoid wastage and, finally to improve quality. This chpater is written to give the reader a basic idea of how this is done in a manufacturing concern.

20.2 INSPECTION AND QUALITY CONTROL

Inspection is very closely associated with quality control. So they should be explained side by side.

Inspection: It is often said that no two things can ever be exactly alike. This also holds true with manufactured parts. Even though certain variations are accepted, parts are liable to rejection if the deviations go beyond the specified quality.

Some procedure must, therefore, be set up to detect errors so that the manufacutre of faulty parts does not go uncorrected.

The philosophy of inspection is only 'preventive' and not 'remidial'. In short, inspection is the method of measuring and/or checking the quality of a product in terms of specified standard.

There are three basic areas of inspection : (1) receiving inspection, (2) inprocess inspection and (3) final inspection.

In the *receiving inspection*, inspections are performed on all incoming materials and purchased parts. In the *inprocess inspection* the products are inspected as they are in process. In the *final inspection*, all finished products are finally inspected prior to sending them to the customer.

Quality control : The word 'quality' as used in manufacturing implies 'the best for the money invested' and does not necessarily mean the 'best'. Quality is a relative term and generally explained with reference to the end use of a product. A component is said to be of good quality if it works well in a particular situation for which it is meant while in other situation it may not work well and it is said to be of bad quality. The word 'control' implies regulation, and regulation implies observations and manipulation. It suggests when to inspect, how often to inspect and how much to inspect.

The basic philosophy of quality control is both 'preventive and remedial'. It is through quality control that some measures are taken to see that defective items are not produced at all. When they do occur, corrective action must be taken to prevent further recurrence.

Inspection is considered to be a tool of quality control. It checks the products while quality control attempts to bring the variable factors under control.

20.3 STATISTICAL QUALITY CONTROL

Any attempt to inspect quality in the finished product by usual inspection devices is time consuming and costly. Besides, in a continuous production process this 100 per cent inspection may not be found practicable.

Certain statistical techniques have been devised to evaluate machines, materials and processes by observing capabilities and trends in variations so that continual analysis predictions may be made to control the desired quality level. These statistical techniques are called statistical quality control methods. These methods or tools are :

1. The Shewhart Control Charts for measurable quality characteristics. These are described as charts for variables, or as charts for $\overline{X}$ and R (average and range) and charts for $\overline{X}$ and σ (average and standard deviation).
2. The Shewhart Control Chart for fraction defective. This is described as the *p* chart.
3. The Shewhart Control Chart for number of defects per unit. This is described as *c* chart.

4. Sampling plans dealing with the quality protection.

20.4 FUNDAMENTALS OF STATISTICS

To understand control charts it is necessary to understand some fundamentals of statistics associated with them. These are briefly explained below :

1. Variables and attributes : All manufactured products must meet certain requirements, either express or implied. All these requirements may be stated either as variables or attributes.

When a record is made on an actual measured quality characteristic such as dimension, hardness, temperature, etc., expressed in their units, the quality is said to be expressed by *variables*. Most specifications of variables give both upper and lower limits for the meausred value. Inspection using variables is mostly done on the shop floor and is important in quality control. Variables are dealt within the control chart for averages of measurement, i.e., for $\overline{X}$ and R, and $\overline{X}$ and σ.

Many requirements are necessarily stated in terms of *attributes* rather than variables. This applies to things that may be judged only by visual examination. For example, the surface finish of a piece of furniture either presents a satisfactory appearance or it does not. In general, the thing examined either conforms or does not conform to the specifications and implies good or bad, acceptable or unacceptable.

2. Variability : Variation seems inevitable in nature. Manufactureing processes are no exception to this. Variability thus appears to be an inherent characteristic of all processes. The amount of this basis variability depends on various characteristics of production process such as machines, the materials, the operators. The purpose of statistical analysis is to examine this variability and to detect when and to what extent external factors enter into the process to alter the variability pattern.

There are two types of variation :

1. Variations due to chance factors.
2. Variations due to assignable causes.

The *chances variations* occur in a random way. For example, a little play between a nut and screw may lead to back-lash in a machine causing the cutting tool to operate differently and producing thereby different measurements of a specified size. The non-homogeneity in a material may result different surface quality or finish in machining. As a result, if a particular phenomenon or physical object is observed or measured with sufficient accuracy, there will be as many different values as there are number of observations. So it is said that chance variation is inherent with the system and very difficult to control even under best conditions of productions. In the quality control, chance variations are seldom considered since variations in measurements are usually small compared to actual variations in quality characteristics. It has been established that if the variations are only due to chance factors, the observations will follow 'normal curve' described in the next article.

Various *assignable causes* leading to variations in dimensions may due to poor quality raw material, machine condition, changing working condition, mistake on the part of a worker, difference in the skill of operators etc. Variations due to assignable causes possess greater magnitude as compared to those due to chance causes, of course, they can be readily controlled by eliminating the causes from the system. The control chart tells when and in some instances suggests where to look.

3. Probability : Probability generally refers to totality of possible happenings. This is a mathematical measure of the likelihood of an happening. It may be noted that probability is meausred on a scale having limits of 0 and 1, where 0 represents absolute impossibility, and 1 represents the absolute certainty. If p is used for probability of an event *happening*, and q for *not happening* the sum of p and q will be unity, i.e. $p + q = 1$. The probability of events happening may be defined as :

$$p = \frac{\text{Number of outcomes favourable to the event}}{\text{Total number of possible events}}$$

In industry, theories of probability are frequently used in connection with sampling since acceptance of a lot is based on inspection of a sample from it.

4. Patterns of variations : In a manufacturing process no two parts can be produced with identical measurements and there will be variations in the measured sizes of parts. It follows that it is necessary to have a simple method of describing patterns of variation. This simple methods involves a frequency distribution.

Frequency distribution : The first step, in a frequency distribution, is to count the number of times (known as frequency) each value occurs. When the various values of a variable are arranged in ordered groups or classes, with their frequency of occurrence a frequency distribution is obtained. A check sheet for 125 measurements is shown in Fig. 20.1. This gives a graphic picture of a frequency distribution that is good enough for practical purposes. Frequency distributions are often used to judge the capability of a manufacturing process. By studying the pattern, the observer can make the amount of correction needed to bring the process back to best performance.

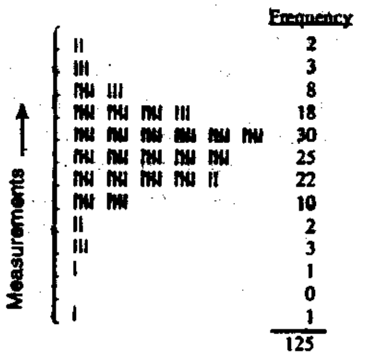


Figure 20.1 Check sheet for frequency distribution

If the results are plotted on a *bar-diagram* having the measured dimension (class) on the horizontal ordinate, and the frequency of occurrence of each dimension on vertical ordinate, a *histogram* as shown in Fig. 20.2 can be constructed. The difference between each value on the horizontal ordinate is called a 'class-interval' and each value is represented at the centre of the class-interval. If a smooth curve is drawn through the top centre points of the histogram a *frequency distribution curve* is obtained. The distribution curve is shown in Fig.20.2

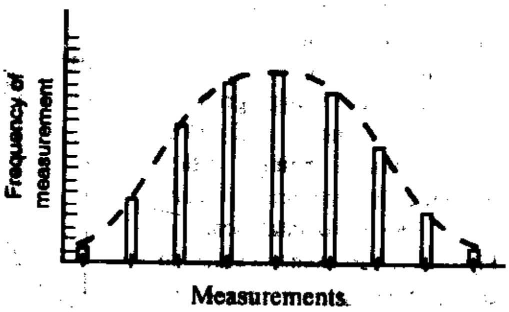


Figure 20.2 Histogram and frequency distribution curve

Averages and measures of dispersion : A frequency curve can be completely defined by (a) the average value and (b) measure of dispersion.

The word *average* applies to any measure of central tendency, called the *arithmetic mean*. This may be expressed as :

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \ldots\ldots\ldots\ldots + X_n}{n} = \frac{\Sigma X}{n}$$

where the symbol $\overline{X}$ represents the arithmetic mean, X_1, X_2, X_3, etc. represent the specific measurements in question and n represents the number of measurements.

Some other important measures of central tendency are the median and the mode. The *median* is the magnitude of the meddle class, i.e., the value that has half the observation above it and half below it. The *mode* is the value that occurs most frequently.

For many purposes, the most useful measure of *dispersion* of a set of numbers is *standard deviation*. This is expressed as :

$$\sigma = \sqrt{\frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \ldots\ldots\ldots\ldots + (X_n - \overline{X})^2}{n}} = \sqrt{\frac{\Sigma(X - \overline{X})^2}{n}}$$

Another important measure of dispersion used particularly in the control chart, is the *range*. This is the difference between the largest observed value and the smallest observed value. This is sometime called *spread*. The symbol R or ω is used to represent the range. Still another measure of dispersion is the *variance*. This is the square of the standard deviation.

Normal curve : Frequency curves of may different shapes may be found. The most useful of these curve is the normal curve shown in Fig. 20.3. This curve is popularly known as probability curve or *normal distribution curve*. This symmetrical bell-shaped type of distribution is typical of many engineering processes, the majority of the component measurements being grouped close to the mean, and fewer measurements being either smaller or larger than the mean.

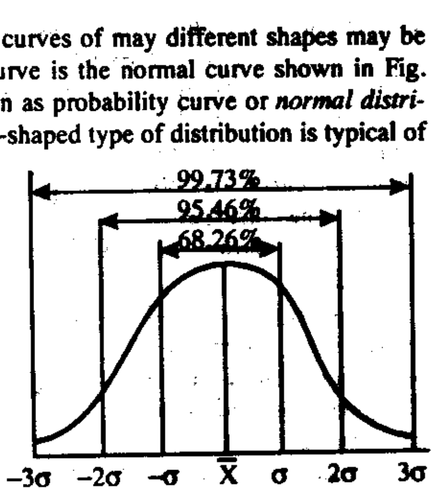


Figure 20.3 Typical normal distribution curve

The horizontal scale in Fig. 20.3, represents values of standard deviation σ above and below the mean $\overline{X}$. If the plot of measurements taken approaches the normal distribution curve, 99.73 per cent of all measured values will fall within $\overline{X} \pm 3\sigma$. Only 0.27 per cent are expected to fall beyond those limits. Similarly, 95.46 per cent of the values fall within the limits $\overline{X} \pm 2\sigma$, and 68.26 per cent within $\overline{X} \pm 1\sigma$. Other values of area for various values of standard deviations may be found in text books on statistics.

For example, in the manufacturing specification of a sample if the standard deviation σ is 0.002, the mean $\overline{X}$ is 0.625 and tolerances is ±0.006 representing 3σ then from the normal distribution curve, only 0.27 per cent will be expected to come under rejection as 99.73 per cent will be expected to fall within this area. If however, a tolerance of ±0.002 or 1σ is given then the expected rejection rate will be 31.74 per cent as 68.26 per cent of all manufactured parts will be expected to fall within this area. Therefore, to keep a tolerance of ±0.002 either the process is to be improved or a more accurate method of manufacture is to be used.

It may be noted that most distributions found in industrial inspection activities are not normal, but many approach normality giving approximately same results.

20.5 CONTROL CHARTS

Process control charts are commonly used in quality control to maintain a continuous evaluation of the manufacturing process. A control chart is simply a frequency distribution of the observed values plotted as points in order of occurrence so that each value has its own identity relative to the time of observation. Points on the control charts may or may not be connected. The chart is provided with limit lines, called control limits, having, in general, one *upper control limit* and one *lower control limit*.

A process is said to be *in control* if the observed values are influenced only by chance causes fall within the limits, and *out of control* when assignable causes seem to be operating in the system and the observed value fall outside the limits. It should be remembered that the control limits of the process control charts do not represent the performance limit or limits of the manufacturing process nor do they represent the specification limits of the manufacturing drawing. The performance limits of the process are the limiting dimensions within which practically all parts fall. If the distribution is normal or near normal, there are $\pm 3\sigma$ limits of the total distribution. In fact, therefore, 3σ limits form the basis of quality control. However, points which fall outside of the control limits do not necessarily represent rejected material but only signal that some corrective action is required to prevent manufacturing faulty parts.

As already said various types of control charts have been developed by the statisticians to improve product quality and to reduce costs of manufacture.

20.6 CONTROL CHARTS FOR VARIABLES ($\bar{X}$ and R Chart)

The chart for average values, the $\bar{X}$ chart and the chart for ranges, the R chart, are used for a manufactured part which the inspector checks by measurement and not by gauging. Fig. 20.4 shows an example of these two charts.

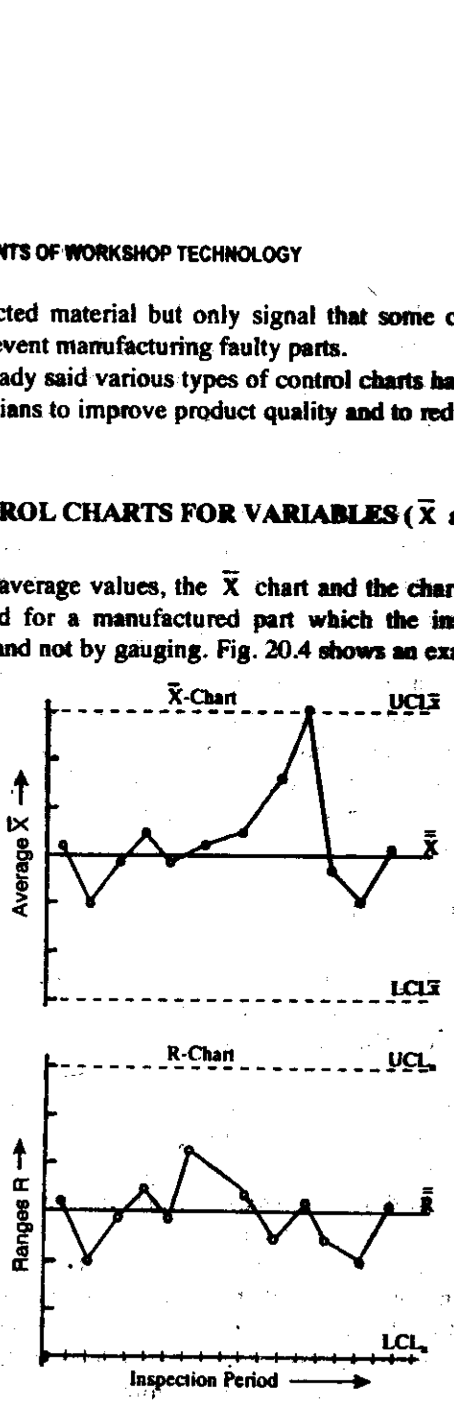


Figure 20.4 Typical $\bar{X}$ and R control charts

$\bar{X}$**-Chart :** Samples of consecutive parts are taken from the machine at frequent time intervals and recorded on the chart in their sequence of manufacture. A sample consists of subgroups, the size of which should be carefully measured. Generally, the subgroup size is five to ten. It is always better to take frequent small subgroups than infrequent large subgroups. The parts are measured and the average of these measurements is plotted on the $\overline{X}$ chart. Average values are plotted instead of individual readings because sample averages tend to approach the normal distribution curve more closely than do individual vales. The central line, $\overline{\overline{X}}$ shown on the $\overline{X}$ chart is average of the averages or grand average of the subgroup (5 to 10) average. This is expressed as

$$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{K}$$

Where $\overline{X}$ is the average value of each subgroup and *K* is the number of subgroups. The control limits are set at three standard deviations (3σ) of the sample averages from the mean $\overline{\overline{X}}$, and are called *upper control limit.* ($UCL_{\bar{x}} = \overline{\overline{X}} + 3\sigma_{\bar{x}}$) and the *lower control limit* ($LCL_{\bar{x}} = \overline{\overline{X}} - 3\sigma_{\bar{x}}$), where

$$\sigma_{\overline{X}} = \sqrt{\frac{\Sigma(\overline{X} - \overline{\overline{X}})^2}{K}}$$

To shorten the calculation of control limits, the formulas for 3-sigma control limits may be replaced as :

$$UCL\bar{x} = \overline{\overline{X}} + A_2 \overline{R}$$

$$LCL\bar{x} = \overline{\overline{X}} - A_2 \overline{R}$$

where A_2 is a constant factor the values of which are found in Table 20.1 and $\overline{R}$ is the average range.

The average value $\overline{X}$ being the arithmetic mean of the values in each group, the control chart detects any change of the arithmetic mean or central tendency which may be caused by tool wear, changed machine adjustments, temperature increase, new work materials, or similar causes.

***R*–chart** : The chart for ranges, the R chart is obtained from the same sample groups that were used in determining the values of $\overline{X}$. The central line or the mean, of the R chart represents the average of the subgroup ranges. Control limits on range charts can be calculated as :

$$UCL_R = D_4\bar{R}$$

$$LCL_R = D_3\bar{R}$$

where D_3 and D_4 are constant factors the values of which are found in Table 20.1 and $\bar{R}$ represents the average of the ranges of each subgroup.

This control chart will help to detect any changes in the process which causes the spread of the curve of normal distribution to increase.

Any change of variability shown on the *R* chart is difficult to account for, but may be due to wear in machine bearings or slides, etc.

In both $\bar{X}$ and R control charts, as already stated, all values will fall within the control limits, if the variations are only due to chance causes. If either the $\bar{X}$ or R values fall outside of the control limits there are assignable causes and some corrective action must be taken.

Observation : The $\bar{X}$ chart in Fig. 20.4 indicates that only at a certain inspection period a point went beyond the upper control limit otherwise the process average remained in a state of statistical control. Investigation into the process showed that the out of control point was due to the cutting action of a worn cutting tool. Replacement of the tool, however, caused subsequent points to fall within the control limits.

Analysis of R chart (Fig 20.4) shows that the entire process remained in a state of statistical control with all points falling inside the control limits. Sudden drifting of two consecutive points well above and below the average range might have been caused by a number of chance causes.

It may, therefore, be concluded from the observations that the process is under control at a satisfactory level and the product meets specification.

Objectives of the charts : In general, where control charts for variables, either $\bar{X}$ or R, are undertaken, some or all of the following purposes are present :

1. To secure information to be used in establishing or changing specifications or in determining whether a given process can meet specification.
2. To secure information to be used in establishing or changing production procedures by either elimination of assignable causes of variation or fundamental changes in the procedure.
3. To secure information to be used in establishing or changing inspection procedures or acceptance procedures or both.
4. To provide a basis for decisions during the process as to when to hunt for causes of variation and take necessary corrective action.

5. To provide a basis for decisions on acceptance or rejection of manufactured or purchased product.

TABLE 20.1 FACTORS USED IN $\overline{X}$ AND R CHARTS

Sample size (Number of samples in a sample)	*Limit average*	*Range lower limit*	*Range upper limit*
n	A_2	D_3	D_4
2	1.88	0.00	3.27
3	1.02	0.00	2.57
4	0.75	0.00	2.28
5	0.58	0.00	2.11
6	0.48	0.00	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
12	0.27	0.28	1.72

Problem 20.1. Subgroups of 5 items each are taken from a manufacturing process at regular intervals. A certain quality is measured, and $\overline{X}$ and R values are computed for each subgroup. After 10 subgroups, $\Sigma \overline{X} = 76$ and $\Sigma R = 26$. Compute the control-chart limits.

$$\overline{\overline{X}} = \frac{76}{10} = 7.6 \quad \text{and} \quad \overline{R} = \frac{26}{10} = 2.6$$

$$UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R} = 7.6 + (0.58 \times 2.6) = 9.11$$

$$LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R} = 7.6 - (0.58 \times 2.6) = 6.09$$

$$UCL_R = D_4\overline{R} = 2.11 \times 2.6 = 5.48$$

$$LCL_R = D_3\overline{R} = 0 \times 2.6 = 0$$

20.7 CONTROL CHARTS FOR ATTRIBUTES (p charts)

Inspite of the advantages of the $\bar{X}$ and R charts, one limitation is that they are charts for *variables*, i.e., for quality characteristics that can be measured and expressed in numbers. Many quality characteristics can be measured only as *attributes*, i.e., by classifying each item inspected into one of two classes : either good or bad, acceptable or unacceptable, conforming or nonconforming to the specification.

The control charts for fraction defective p is used to quality characteristics that can be observed only as attributes–for example, dimensions checked by go and non-go gauges even though they might have been measured as variables. As long as the result of inspection is a classification of an article as accepted or rejected, a single p chart may be applied to one quality characteristic or a dozen or a hundred. As a result, it may also be applied as a tool for saving the cost of computing and charting quality criteria.

The p-chart has somewhat the same objectives as the $\bar{X}$ and R chart. It discloses the presence of assignable causes of variation, even though it is much inferior to those charts as an instrument for actual diagnosis of causes of variation. It is used effectively in the improvement of quality by immediate correction in the process before large quantities of scrap are produced. In effect, the chart gives advance warning of the commencement of a trend toward the production of an increasing number of defective articles. In addition to this, the p-control chart provides management with a useful record of quality history about changes that may occur in the quality level.

Fraction defective, p, may be defined as the ratio of the number of defective articles found in any inspection or series of inspections to the number of articles actually inspected. Fraction defective is nearly always expressed as a decimal fraction. This may be expressed as:

$$p = \frac{\text{number of defectives in subgroup}}{\text{number inspected in subgroup (n)}}$$

and
$$\bar{p} = \frac{\text{total number of defectives during period}}{\text{total number inspected during period } (\Sigma n)}$$

Wherever practicable, it is desirable to have data for at least 25 sub-groups before computing $\bar{p}$ and establishing control limits.

Per cent defective is 100p i.e. 100 times the fraction defective. As for example, if p=0.0092, the per cent defective is 100p=0.92 per cent. For actual calculation of control limits, it is necessary to use the fraction defective. For charting, and for general presentation, the fraction defective is generally converted to per cent defective.

Just as in the case of the control charts for $\bar{X}$ and R, the control chart for *p* has a central line indicating average value $\bar{p}$, and upper and lower control limits which are equally distant from the central line. A typical *p*-chart is shown in Fig. 20.5.

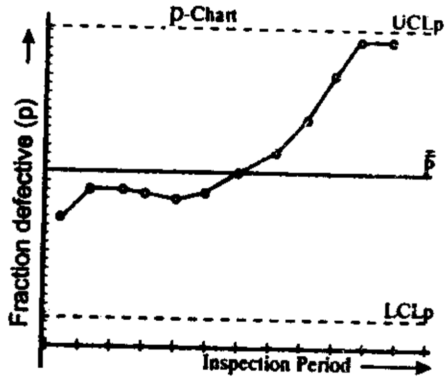


Figure 20.5 Typical p control chart

The formula for 3-sigma control limits are :

$$UCL_p = \bar{p} + 3\sigma_p$$

$$= \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$LCL_p = \bar{p} - 3\sigma_p$$

$$= \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

The value of $3\sqrt{\bar{p}(1-\bar{p})}$ can be computed once to apply to all calculations of control limits. The value of $\sqrt{n}$ is computed for each day and divided into $3\sqrt{\bar{p}(1-\bar{p})}$ to get the value of $3\sigma_p$ for the day.

Observation : The process shows a drift towards running out of control which if continued would require action, thus saving an accumulation of scrap.

Purpose of the p chart : As applied to 100 per cent inspection a control chart for fraction defective may have any or all of the following purposes :

1. To discover the average proportion of defective articles or parts submitted for inspection over a period of time.
2. To bring to the attention of management may changes in the average quality level.
3. To discover those out-of-control high spots that call for action to identify and correct causes of bad quality.
4. To discover those out-of-control low spots that indicate either relaxed inspection standard or erratic causes of quality improvement.
5. To suggest places for the use of $\bar{X}$ and R chart to diagnose quality problems.
6. To afford a basis for judgment whether successive lots may be considered as representative of a process.

Chart for p and chart for np : Whenever subgroup size is variable, the control chart must show the fraction defective or proportion defective rather than the actual number of defectives. However, if subgroup size is constant, the chart for actual number of defectives, called ***np*** or ***pn chart***, may be used.

The construction of *np chart* is identical to *p*. After finding out the value of *p* this is multiplied with *n* to get *np* which indicates the central line. The upper and lower control limits are :

$$UCL_{np} = n\bar{p} + 3\sigma_{np}$$

$$LCL_{np} = n\bar{p} - 3\sigma_{np}$$

where, $$3\sigma_{np} = 3\sqrt{n\bar{p}(1-\bar{p})}$$

20.8 CONTROL CHART FOR DEFECTS (c CHART)

The *p* or *np* chart applies to the number of defectives in subgroups of constant size, while the *c* chart applies to the number of *defects* in subgroups of constant size. A *defective* is an article whereas articles lacking conformity to specification is a *defect*. Every defective may contain one or more defects, for example a cast part may have blow holes and surfaces cracks at the same time.

In most cases, however, each subgroup for the *c* chart consists of a single article; the variables *c* consists of the number of defects observed in one article. But it is necessary that the subgroup for the *c* chart be a single article.

The *c* chart is preferred for large and complex parts. Such parts being few and limited, the use of *c* chart, as compared to *p* charts, is restricted to limited use.

The *c* chart is plotted in the same manner as *p* chart except that the control limits are based on Poisson distribution which describes more appropriately the distribution of defects.

The value of $\bar{c}$ is first computed. The 3-sigma limits are :

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

For example, if there are 200 defects in 25 machines, the average $\bar{c}$ is 200/25=8.0. Control limits computed from the average are as follows:

$$UCL_c = \bar{c} + 3\sqrt{\bar{c}} \quad = 8 + 3\sqrt{8} \quad = 165$$

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}} \quad = 8 - 3\sqrt{8} \quad = 0$$

Whenever calculations give a negative value of the lower control limit of a *c* chart, that limit is recorded as zero.

20.9 APPLICATION OF CONTROL CHARTS

The following examples are given to show the applications of control charts in controlling the quality characteristics of components :

1. Final assemblies (Attribute charts).
2. Manufactured components, such as shafts, spindles, balls, pin holes, slots, etc., (Variable charts).
3. Bullets and shells (Attribute charts).
4. Welded and soldered joints (Attribute charts).
5. Cast and forged parts ; long lengths of cloth, rubber, etc., defects in parts made of glass ; large and complex products like bomber engines, turbines, I.C. engines ; etc., (*c* charts).
6. Punch press works, forming, spot welding, etc., (Attribute charts).
7. Studying tool wear (Variables charts).
8. Incoming materials (Attributes or variable charts).

Problem 18.2. Ten sample of parts were taken from a production line for 100 per cent inspection, each sample containing 300 parts. The total number of defectives was 350. Compute upper and lower control limits.

$$p = \frac{\text{total number of defectives}}{\text{total number of pieces inspected}}$$

$$p = 350/(10 \times 300) = 0.1167$$

$$n = \text{number of pieces inspected every day}$$

$$\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{0.1167 \times 0.8833}{300}} = \mathbf{0.01852}$$

and $$3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 3 \times 0.01852 = \mathbf{0.05556}$$

Thus $$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.1167 + 0.0556 = \mathbf{0.1723}$$

$$LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.1167 - 0.0556 = \mathbf{0.0611}$$

Problem 18.3. Ten castings were inspected in order to locate defects in them. After inspection total 37 defects were found. Compute *c*-control limits.

$$\bar{c} = 37/10 = 3.7$$

Therefore, $UCL_c = \bar{c} + 3\sqrt{\bar{c}} = 3.7 + 3\sqrt{3.7} = \mathbf{9.472}$

$LCL_c = \bar{c} - 3\sqrt{\bar{c}} = 3.7 - 3\sqrt{3.7}$

$= -2.072 =$ **0** (Zero)

20.10 SAMPLING INSPECTION

Acceptance sampling inspection is a necessary part of quality control and may be applied to incoming materials, to particularly finished product at various intermediate stages of manufacturing, and to final product.

The cost of 100 per cent inspection, in most cases, far exceeds the penalty cost of passing of the small number of rejected parts when a suitable inspection procedure is used. Even on many cases 100 per cent inspection will not eliminate all the defective products due to various reasons.

Much of the inspection now-a-days is therefore done by sampling which contributes a means for the best protection against the acceptance of defective parts, provided a few items can be tolerated among a large number of good items. In the sampling procedure, specified number of pieces are selected at random from the entire lot and inspected. Acceptance sampling is usually done by *attributes*. According to previously determined standards, the entire lot is either accepted or rejected on the basis of the inspection of the sample lot. It should be recognized that although modern sampling acceptance procedures are generally superior to the traditional sampling methods, there is always a probability or risk that an unsatisfactory lot or batch will be passed and that a good batch will be rejected. The former is called the *consumer's risk*, and the latter is called the *producer's risk*.

There are a unique number of sampling plans based on single sampling, double sampling, or some form of sequential or group sequential sampling.

In *single sampling plans*, a lot is accepted or rejected on the basis of a single sample drawn from the lot. In the *double sampling plan*, a second sample is drawn and decision is taken on the basis of the combined results of the first and second sample, if it is not possible to decide the fate of the lot on the basis of the first sample. ***Sequential sampling*** is used when a decision is possible after each lot has been inspected and when there is no specified limit on the total number of units to be inspected.

Operating characteristic (OC) curve : The OC curve of an acceptance sampling plan shows the ability of the plan to distinguish between good and bad lots.

For any given fraction defective p in a submitted lot, the OC curve shows the probability P_a that such a lot will be accepted by the given sampling plan. Fig. 20.6 shows as operation characteristic curve for a single sampling plan for $N = 1300$, $n = 100$ and $c = 3$, where N represents number of pieces in a lot, n, number of pieces in a sampling, and c, acceptance number. It means that if 3 or less of the 100 random samples from a lot of 1300 parts are found to be defective, the lot will be accepted. The lot will be rejected if more than 3 defectives are found in the sample of 100.

The curve shows that the quality of material coming into inspection being per cent defective (point p_1), the materials will be accepted by the sampling plan 95 per cent of the time. If the material coming in are 8 per cent defective point (point p_2), it will be accepted only about 10 per cent of the time. Thus, a sampling plan should be selected that will satisfy the demands of both the producer and consumer of the material being manufactured.

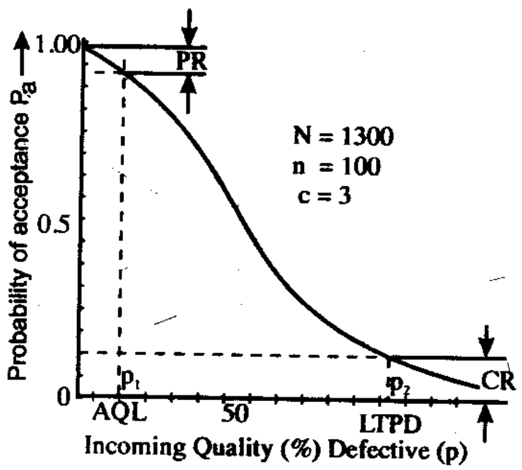


Figure 20.6 OC curves to show sampling inspection

As already stated, the probability of accepting a product of some stated quality is known as consumer's risk (CR), while the probability of rejecting a product of some stated quality is referred to as the producer's risk (PR) and is equated as $1 - P_a$. In the above example in Fig. 20.6 the acceptable quality level (AQL) is 2 per cent, the PR is 5 per cent and the lot tolerance per cent defective (LTPD) is 8 per cent, and CR is 10 per cent.

The shape of an operating characteristic curve depends upon the value of n and c. Accordingly, by changing the parameters (n and c) of an OC curve, one can easily choose the most appropriate curve as per the requirement. The values of P_a for various values of N, n, and c can be found out from quality control tables or nomograph.

20.11 THE ISO 9000

ISO 9000 is a family of international standards for quality management and assurance. ISO 9001, ISO 9002, and ISO 9003 detail the requirements, which must be met. ISO 9000 and ISO 9004 are guidelines. Listed below are the models that make up the ISO 9000 family of standards.

ISO 9001 Quality System is a model for quality assurance in design/development, production, installation and servicing. ISO 9001 is made up of 20 sets of quality system requirements.

ISO 9002 Quality System is a model for quality assurance in production and installation.

ISO 9003 Quality Systems is the model for quality assurance in final inspection and test.

ISO 9004–1 and the other parts of ISO 9004 are the standards of guidelines on the elements of quality management and a quality system.

In its most basic form it requires that you:

Say what you do: Have documented procedures for performing the work that affects product or service quality.

Do what you say : Work according to the written procedures

Record what you do: Retain records of the activities to provide objective evidence of compliance.

Improvement: Compare what you actually achieve with what is planned and use the information to correct any shortcomings.

REVIEW QUESTIONS

1. Why is inspection of manufactured part necessary, and what is the primary responsibility of the inspection department ?
2. Explain the difference between (1) inspection, (2) quality control and (3) statistical quality control.
3. State briefly what do you mean by (1) variables, (2) attributes, and (3) probability, in statistical concept.
4. State why normal distribution curve is usually taken into consideration for statistical quality control.
5. State why are average values ($\overline{X}$) are plotted instead of individual values (X) on a control chart.
6. In process control for variable why it is necessary to use both a chart for averages and ranges. State what these charts signify ?
7. State why *p* and *c* control chart are used. What they signify ? State the advantages of a *p* chart over a $\overline{X}$ chart.
8. What do you mean by acceptance sampling? State their usefulness over 100 per cent inspection.
9. How can the risk involved in using a particular sampling plan can be determined.
10. Subgroups of 5 items each are taken from a manufacturing process at regular intervals. A certain quality characteristic is measured, and $\overline{X}$ and *R* values are computed for each subgroup. After 25 subgroups, $\Sigma\overline{X}$=357.50 and ΣR=8.80. Compute the control chart limits. All points on both charts fall within these limits. If the specification limits are 14.40±0.40, what conclusions can be draw about the ability of the existing process to produce items within these specifications? Suggest possible ways in which the situation could be improved.
11. The resistance in ohms of a certain electrical device is specified as 200±15. A control chart is run on the manufacturing process with samples of 4 taken from the production line every hour for 20 hr. $\Sigma\overline{X}$=4,140. ΣR=288. What should be the 3-σ control limits on the $\overline{X}$ and *R* charts?
12. A *p* chart is to be used to analyze the September record for 100 per cent inspection of certain radio transmitting tubes. The total number inspected during the month was 2,196, and the total number of defectives was 158. Compute *p*. Compute individual 3-σ control limits for the following 3 days, and state whether the fraction defective fall within control limits for each day.

Date	*Number inspected*	*Number of defectives*
Sep. 14	54	8
15	162	24
16	213	3

21

CERAMIC AND GLASS PROCESSING

21.1 INTRODUCTION

Ceramics are abundant in nature and widely used in our daily life in the form of bricks, pottery, tiles, glass, cement and concrete. They are important engineering materials, widely used in domestic, industrial and building products. Traditional ceramic raw materials include clay minerals such as kaolinite. Silicon carbide and tungsten carbides are subsequently added as modern ceramics and are valued for their abrasion resistance. They are used as wear plates of crushing equipment in mining operations. A wide range of ceramic and glass materials are being used in biomedical applications; ranging from bone implants to biomedical pumps. Dentistry has also advanced with ceramic teeth that can be matched to a patient's natural ones. Ceramics are expected to find applications in gene therapy and tissue engineering also.

Ceramics are more complex than metallic structures. A ceramic has traditionally been defined as "an inorganic, nonmetallic solid that is prepared from powdered materials and is fabricated into products through the application of heat". Most ceramics are made up of two or more elements and are categorized as compound. For example, alumina (Al_2O_3) is a compound made up of aluminum atoms and oxygen atoms. Other examples can be: calcium and oxygen (calcia -CaO), and silicon and nitrogen (silicon nitride-Si_3N_4).

21.2 CLASSIFICATION OF CERAMICS

Ceramics can be classified as (a) crystalline and (b) non-crystalline.

Crystalline ceramic materials are not amenable to a great range of processing. They are hard and brittle. SiO_2 and Al_2O_3 are such examples.

Non-crystalline ceramics, being glasses, tend to be formed from melts. The glass is shaped when fully molten, by casting. It can also be shaped by other methods such as blowing in a mold when it is in a state of toffee-like viscosity. If heat-treatments are carried on this class of processed glasses, it becomes partly crystalline, the resulting material is known as a *glass-ceramic*.

Ceramics can also be classified as the way these materials evolved: (1) *traditional ceramics* like pottery, bricks and cements, (2) *advanced ceramics* consisting of oxides and carbides. These ceramics are having superior mechanical and physical properties over traditional ceramics, and (3) *glasses*. A detailed classification is shown in Fig. 21.1.

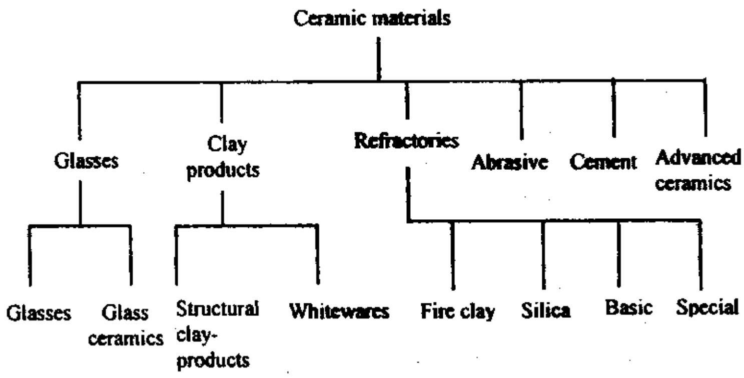


Figure 21,1 Classification of ceramics

Glasses of various types are used for different domestic applications like dinnerware, window panes, bulbs and lenses. *Glass fibers* are used for home insulation, and advanced glass is used as optical fibers.

Clay products include brick, sewer pipe, roofing and wall tile, flue linings, etc.

Whitewares are dinnerware, floor and wall tile, electrical porcelain, etc.

Refractories include brick and monolithic products and are used in metal, glass, cements, ceramics, energy conversion, petroleum, and chemicals industries.

Abrasives are natural ceramics like garnet, artificial diamond, etc. or may be synthetic like silicon carbide, fused alumina, etc. Abrasives are used for grinding, cutting, polishing, lapping, or pressure blasting of materials.

Cements are widely applied in roads, bridges, buildings, and dams.

Advanced ceramics can be used as structural parts like bio-ceramics, cutting tools, and engine components, electrical applications like capacitors, insulators, substrates, integrated circuit packages, piezo-electrics, magnets and superconductors, coatings, used in engine components, cutting tools, and industrial wear parts and in chemical and environmental utilities like filters, membranes, catalysts, and catalyst supports.

21.3 PROPERTIES OF CERAMICS

The atoms in ceramic materials are held together by a chemical bond. The two most common chemical bonds for ceramic materials are covalent and ionic. The bonding of atoms in ceramics is much stronger in covalent and ionic bonding than in metal. That is the reason, metals are ductile and ceramics are brittle. As ceramic materials have wide variations in properties, they are used for a multitude of applications[1]. In general, most ceramics are:

a) hard,
b) brittle,
c) thermal insulators,
d) nonmagnetic,
e) prone to thermal shock,
f) wear-resistant,
g) refractory,
h) electrical insulators,
i) oxidation resistant, and
j) chemically stable.

21.4 PROCESSING OF TRADITIONAL CERAMICS

Processing of traditional ceramics can be carried out in five phases. They are:

a) Preparation of raw material
b) Shaping and forming processes
c) Drying
d) Firing / sintering, and
e) Finishing

PREPARATION OF RAW MATERIALS

Most of the natural source of ceramics are available in the form of lumps and contains impurities. The first step in preparation of raw materials is crushing and removal of impurities. Crushing is carried out either dry or wet using any mechanical method like (a) jaw crusher (b) gyratory crusher (c) cold crusher, and (d) hammer mill. In this process, particle sizes of materials are reduced from a lump to a smaller size in several steps. Fig. 21.2 shows the schematic diagram of a *jaw crusher*. The *double toggle mechanism* makes the movable jaw up and down by eccentric shaft. The jaws are farther apart at the top than at the bottom, forming a tapered chute so that the material is crushed progressively finer as it travels downward until it is small enough to escape from the bottom opening. The movable jaw plate leaves the fixed jaw plate under the function of a drawbar and a spring, and then the crushed materials are discharged from the lower outlet of the crushing cavity.

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[1] http://depts.washington.edu/matseed/mse_resources/Webpage/Ceramics/

Grinding is used further to break up input materials to fine grained particles after it is crushed. *Pulverization* may be carried out using ball mills. Preparation of finer particles can also be carried out by using milling, including *attrition* in which particle-to-particle collision results in agglomerate break up of particles.

SHAPING AND FORMING PROCESS

Prior to shape / forming, ceramic powders are mixed with processing additives (binders, plasticizers, lubricants, deflocculates, water etc.). In this process, the fine grains of particles of ceramics are mixed with any suitable fluid (generally water) to make a paste so as to impart desired shapes, ranging from toilet bowls to spark plug insulators. Clay is the main natural available ceramic materials. With optimum proportions of powder and water, a range of plasticity can be achieved to suit the shaping process. Once the parts are formed from the clay paste, it is dried up. The part is fired subsequently to form the final shape. The ingredients must be thoroughly mixed, wet or dry. Forming can involve: (1) *Extrusion*, such as extruding "slugs" to make clay pipes, (2) *Pressing* to make shaped parts like bricks, (3) *Slip casting*, as in making toilet bowls, wash basins and ornamentals like ceramic statues.

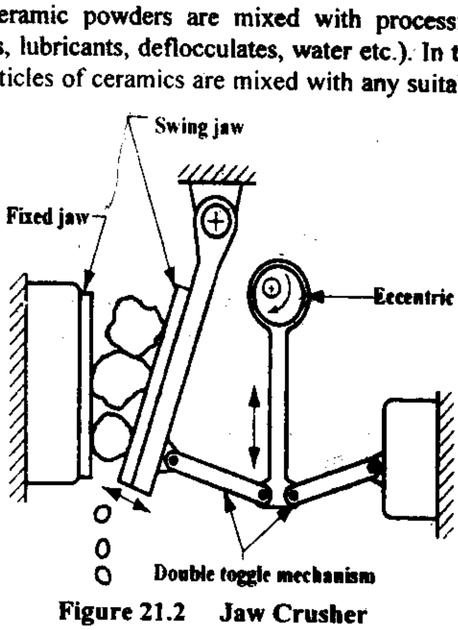

Figure 21.2 Jaw Crusher

Forming produces a "green" part, ready for drying. Green parts are soft, pliable, and will lose shape subsequently if untreated or not dried properly. The ingredients can be divided in three categories[2]: (1) materials that provide good consistency and plasticity and ideal for shaping like *clay*; (2) materials that do not show good plasticity when wet, but do not shrink during firing examples; *alumina* and *silica*, and (3) materials types in which wetting agents improve mixing of ingredients, example; *feldspar* $Al(AlSi)_3O_8$. Feldspar can be vitrified through firing and serves as a flux to form a glassy phase at low temperatures.

[2] *Groover M. P., 2002, Fundamentals of Modern Manufacturing, John, Wiley & Sons, N.Y*

The important shaping processes for natural ceramics may be divided as: (1) slip casting; (2) plastic-forming methods; (3) semi-dry pressing ; and (4) dry pressing.

Slip casting technique is used for forming of "ceramic slurry" which is a stable suspension of ceramic powders, processing additives and 20-50% of liquid (water or solvent). The slurry is poured into a mold made of a micro-porous material (e.g. gypsum), which is capable to soak the liquid from the slurry, consolidating the ceramic part.

Slip casting is used for manufacturing fine china, sinks, sanitary ware, thermal insulation parts. Fig. 21.3 shows the process of slip casting. Water proportion is kept very high in this method and slurry flows like fluid.

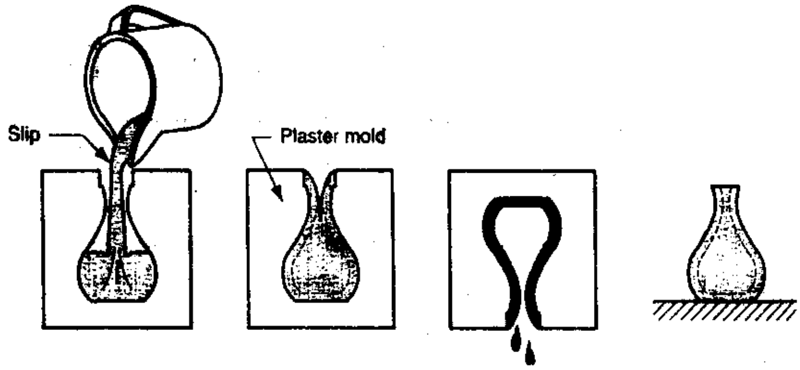

Figure 21.3 Slip Casting (*adapted from Groover M. P.,2002. Fundamentals of Modern Manufacturing, John, Wiley & Sons, N.Y*)

Plastic forming includes a variety of methods; manual and mechanised. Manual methods like *hand modeling* and *hand throwing* on a potter's wheel are widely used. Hand thrown pottery is greatly priced for its unique beauty and is very popular as home decor items. Earthen tea cups are widely used in our country. *Jiggering* is an improvement of hand throwing through mechanization. *Jiggering* is the operation of bringing a shaped tool into contact with the plastic clay meant for the piece under construction. The piece itself being set on a rotating plaster mould on the wheel. The jigger tool shapes one face while the mould shapes the other. Jiggering is used only in the production of flat wares, such as plates. But a similar operation, known as *jolleying*, is used in the production of hollow-wares such as cups. Jiggering and jolleying have been used in the production of pottery since 18th century. In large-scale factory production, jiggering and jolleying are usually automated, and the operations are carried out by semi-skilled labor.

Pressing of ceramic powders in semi-dry and dry form is used in many applications. In semi-dry method, water is mixed in the proportion of 10% to 15%. The moisture content in the dry pressing is kept lower than 5%. Binders or lubricants are usually added in the dry powder to prevent die-sticking. No flash is formed in dry pressing. Also shrinkage does not occur after the component/ part is made. Fig.21.4 shows a dry-pressing operation.

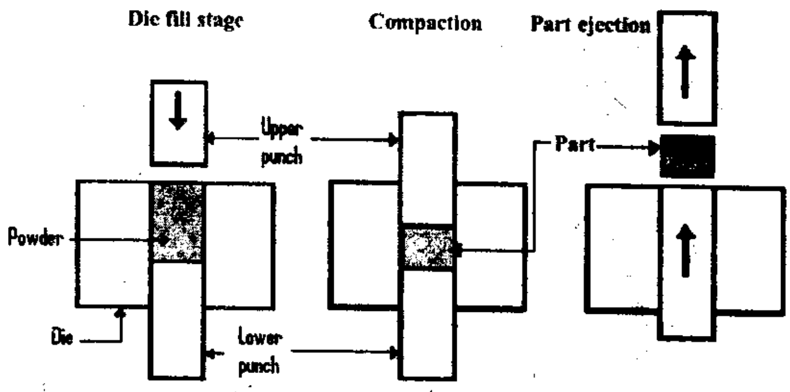

Figure 21.4 Dry press operations for ceramic powder

DRYING

Drying is removal of water or binder off the formed material. Controlled heat is applied in two-stage processes. In the first stage air drying is carried out by passing hot air in a tunnel or by natural drying, using sun rays. When clay starts to dry, water evaporates from it. When it does, the particles of clay are drawn closer together which causes shrinkage. A lot of problems are caused by uneven rates of drying for clays, which creates stress in the clay products. Sometimes the stress shows up right away through cracks or warping. It is very important to make sure that the piece is dried as even as possible. The dried part shrinks and becomes brittle, necessitating careful handling of the part. Any slight impact may cause crumbling and breaking of the part.

FIRING AND SINTERING

Firing must be carried out through a controlled heating process as rapid heating may cause cracks and surface defects. In this stage the part is heated to the boiling point of water. This stage must be carried out slowly or the formation of steam within the body of the clay may cause it to break. That is the reason the early stages of firing is done slowly and with a peephole or lid open for steam to escape.

The principle of *sintering*-is simple ("sinter" has roots in the English "cinder"). In sintering, firing is done at a temperature below the melting point of the ceramic. Once the "green body" (a roughly-held powder body) is made, it is baked in a kiln, where atomic and molecular diffusion processes give rise to significant changes in the primary microstructure as illustrated in Fig. 21.5. The change includes gradual elimination of porosity, which is typically accompanied by a net shrinkage and overall densification of the component. Thus, the pores in the object may close up, resulting in a denser product of significant strength and fracture toughness.

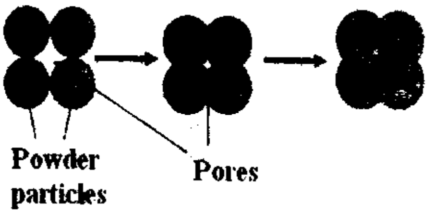

Figure 21.5 Sintering

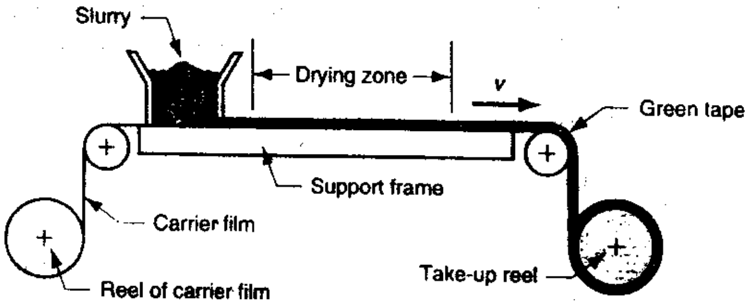

Figure 21.6 Tape casting for Ceramic sheet manufacturing

Tape Casting is a process of forming a thin film of ceramic slurry spread over a flat surface of carrier film. The slurry film thickness is controlled by a knife edge located above the moving carrier surface. The solvent, containing in the slurry, evaporates, resulting in formation of ceramic sheet, which may be stripped from the supporting surface. Fig. 21.6 shows the process of tape casting. Tape Casting is used for manufacturing multilayer ceramics for capacitors and dielectric insulators.

Gel Casting is a process of shape forming of slurry, prepared from ceramic powder mixed with a solution of organic monomer. When the slurry is poured into a mold, the monomer polymerizes, forming a gel that binds ceramic powder particles into a strong complex-shaped part. The part may be machined before firing. The process is economical and it is used for manufacturing large complex shapes for parts such as turbine rotors.

21.5 GLASS

Glass is ceramic but an amorphous (non-crystalline) solid material. Glasses are typically brittle, and often optically transparent. The most familiar type of glass, used for centuries are window panes and drinking vessels. It is known as soda-lime glass, made of about 75% silica (SiO_2) plus Na_2O, CaO, and several minor additives. Often, the term *glass* is used in a restricted sense to refer to this specific use.

21.6 STRUCTURE AND PROPERTIES OF GLASS

The glass has amorphous structure, made up of very long chain of atoms. As in other amorphous solids, the atomic structure of a glass lacks any long range translational periodicity. However, due to chemical bonding characteristics, glasses possess a high degree of short-range order with respect to local atomic polyhedra

There are many different types of glasses with varied chemical and physical properties. A suitable adjustment of chemical compositions brings specific characteristics of the glass. The glasses can be classified as given hereunder:

a) Commercial glass, also known as soda-lime glass
b) Lead glass
c) Borosilicate glass, and
d) Glass fibre

Commercial Glass, also known as Soda-lime glass is utilised in daily lives. The use is seen in the form of bottles and jars, flat glass for windows or for drinking glasses. The main constituent of commercial glass is sand. Sand by itself can be fused to produce glass but the temperature at which this can be achieved is about 1700°C. The melting temperature can suitably be reduced by adding other minerals and chemicals to sand.

Most commercial glasses have chemical compositions of: 70% to 75% SiO_2 (silica), 12% to 16% Na_2O (sodium oxide), 5% to 11% CaO (calcium oxide), 1% to 3% MgO (magnesium oxide), and 1% to 3% Al_2O_3 (aluminium oxide).

Lead glass, commonly known as lead crystal is used to make a variety of decorative glass objects. It contains lead oxide instead of calcium oxide, and potassium oxide instead of sodium oxide. The traditional *English full lead crystal glasses* contain at least 30% lead oxide (PbO) but glasses containing at least 24% PbO are known as *lead crystal*. Glass containing less than 24% PbO, is known as *crystal glass*.

Borosilicate Glass, used as ovenware and other heat-resisting ware, is known under the trade name as Pyrex. Borosilicate glass is made of silica (70-80%) and boric oxide (7-13%) with lesser amounts of alkalis (sodium and potassium oxides) and trace of aluminium oxide. This type of glass has relatively low alkali content and has good chemical durability and thermal shock resistance. Like other types of glasses, it does not crack in temperature variations. It is widely accepted in chemical industries, for making laboratory apparatus, ampoules and pharmaceutical containers.

Fiber glass refers to a group of products made from individual glass fibers combined into a variety of forms. Glass fibers can be divided into two major groups according to their geometry: (a) *continuous fibers* used in yarns, and (b) *discontinuous (short) fibers* used as insulation and filtration. Fiberglass can be formed into yarn much like wool or cotton, and woven into fabric which is sometimes used for draperies. Fiberglass textiles are commonly used as a reinforcement material for molded and laminated plastics. Fiberglass wool, a thick, fluffy material made from discontinuous fibers, is used for thermal insulation and sound absorption. It is commonly found in ship and submarine bulkheads and hulls; automobile engine compartments and body panel liners; in furnaces and air conditioning units; acoustical wall and ceiling panels; and in architectural partitions.

21.7 PROCESSING OF GLASS

RAW MATERIALS PREPARATION AND MELTING

Silica (SiO_2) is natural quartz in sand and is used as the primary source for preparing glasses. The sand must be washed properly to remove impurities which may cause undesirable coloring of the glass. Subsequently the sand is classified according to grain sizes. The most desirable particle size for glassmaking is in the range 0.1 to 0.5 mm. Most commercial glasses are of the silica–soda–lime variety; the silica is usually supplied as common quartz sand, whereas Na_2O and CaO are added as soda ash (Na_2CO_3) and limestone ($CaCO_3$). For most applications, especially when optical transparency is important, it is essential that the glass product is homogeneous and pore free. Recycled glass (discarded glass) is added in the mixture in modern practice. In addition to preserving environment, recycled glass facilitates easy melting. Recycling old glass uses 40% less energy than manufacturing it from new. The glass making process creates huge fossil fuel emissions. But for every ton of glass when recycled, save up to the equivalent of 30 liters of fuel oil that would otherwise be burned to create new glass products.[3]

Glass is produced by heating the raw materials to an elevated temperature above which melting occurs(around 1500°C to 1600°C). The

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[3] http://www.greenstudentu.com/encyclopedia/recycling/glass

processing time takes around 30 hours to 40 hours per charge. Homogeneity is achieved by complete melting and mixing of the raw ingredients.

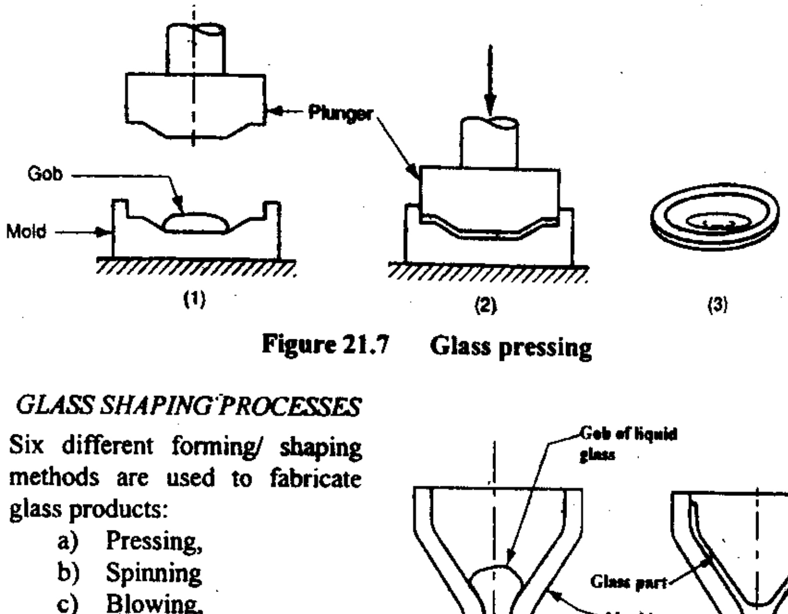

Figure 21.7 Glass pressing

GLASS SHAPING PROCESSES

Six different forming/ shaping methods are used to fabricate glass products:

a) Pressing,
b) Spinning
c) Blowing,
d) Casting
e) Drawing, and
f) Fiber forming.

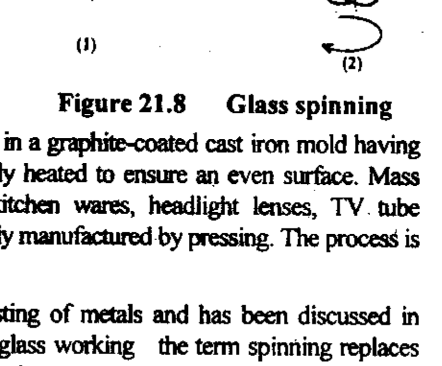

Figure 21.8 Glass spinning

Pressing is used in the fabrication of relatively thick-walled pieces such as plates and dishes. The glass piece is formed by pressure application in a graphite-coated cast iron mold having the desired shape; the mold is ordinarily heated to ensure an even surface. Mass production of glass pieces such as kitchen wares, headlight lenses, TV tube faceplates, and similar items are generally manufactured by pressing. The process is illustrated and described in Fig. 21.7

Spinning is similar to centrifugal casting of metals and has been discussed in Chapter 11.(please refer page 389). In glass working the term spinning replaces the conventional term of centrifugal casting. A gob of molten glass in specified quantity is dropped in a conical mould (shown in Fig. 21.8(1)). The mould is rotated at high speed causing centrifugal force forcing the molten glass to spread upward on the mold surface (shown in Fig. 21.8(2)).

The method is used to produce a funnel-shaped components such as the back sections of cathode ray tubes for televisions and computer monitors. Solidification progresses from the outer surface.

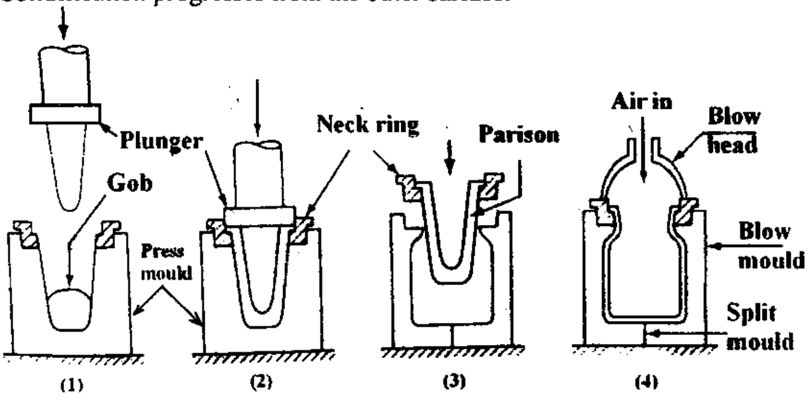

Figure 21.9 Glass blowing process

(*Fundamentals of Modern Manufacturing, M.P. Groover, John Wiley*)

Glass blowing is a process to shape glass. Although originally glass blowing used to be performed by hand, especially for art objects. The process has now been completely automated for the production of glass jars, bottles, and light bulbs which are produced in huge quantities. In order to perform glass blowing, the artist must have a *blowpipe*. The tip of the blowpipe is preheated by dipping it in the molten glass. A gob of the molten glass is accumulated on the blowpipe and rolled onto a tool called a *marver*. A marver is usually a thick sheet of steel that lies flat. The marver is important to the glass blowing process, because it creates a cool exterior layer on the glass and makes it possible to shape it. The artist blows air into the blowpipe in order to form a bubble with the molten glass.

The several steps involved in one such blowing technique is known as *press and blow* method, illustrated in Fig. 21.9. In this case a raw gob of molten glass is placed in a press mould in the first stage. The gob is pressed by a plunger to create a *parison*, or temporary shape. This parison is subsequently inserted into a finishing or blow mold and forced to conform to the mold contours by the pressure created from a blast of air.

Casting is the method in which the molten glass when sufficiently fluid, is poured into a mold. Relatively massive objects, such as astronomical lenses and mirrors, are made by this method. These pieces must be cooled very slowly to avoid internal stresses and possible cracking due to temperature gradients that would otherwise be setup in the glass. After cooling and solidifying, the pieces must be finished by lapping and polishing. Casting is not much used in glass working except for these kinds of special jobs.

Drawing is used to form long glass pieces in the form of sheet, rod, tubing, and fibers, having constant cross section. One such process by which glass tube is formed is known as *Danner process*.

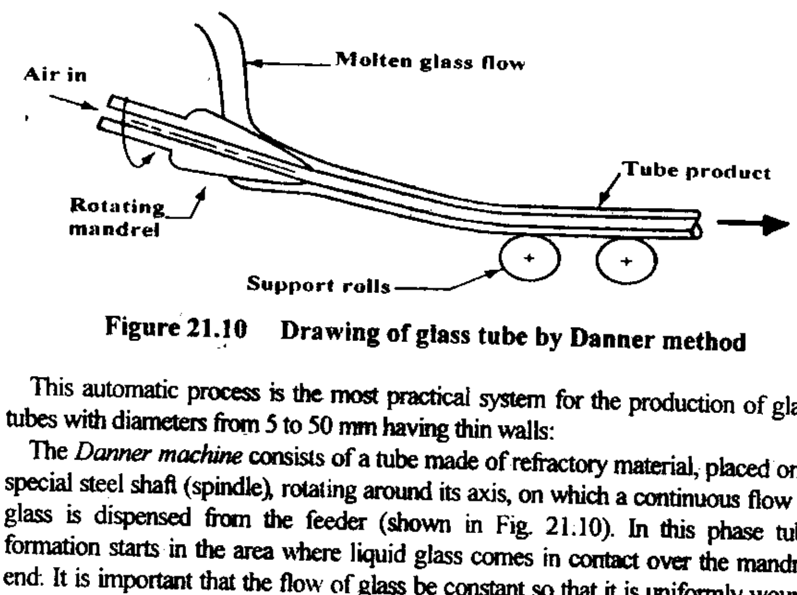

Figure 21.10 Drawing of glass tube by Danner method

This automatic process is the most practical system for the production of glass tubes with diameters from 5 to 50 mm having thin walls:

The *Danner machine* consists of a tube made of refractory material, placed on a special steel shaft (spindle), rotating around its axis, on which a continuous flow of glass is dispensed from the feeder (shown in Fig. 21.10). In this phase tube formation starts in the area where liquid glass comes in contact over the mandrel end. It is important that the flow of glass be constant so that it is uniformly wound around the rotating spindle. The glass which is dispensed from the feeder must be sufficiently fluid to enable it to spread along the tube-shaped spindle and reach the final part, where the glass is blown and moves away from the spindle in the form of a tube with homogenous and uniform appearance. The spindle is placed in a furnace with adjustable temperature to avoid thermal shocks to the glass. To facilitate uniform winding of the molten glass, the spindle must also be inclined (between 12 and 20 degrees) and the rotation speed must be as stable as possible.

Fiber forming of glass: Fibers or filaments of glasses can be formed by drawing strands of molten glass through small apertures. Fibers of glass consist of numerous extremely fine fibers. Glass fiber is used to make fiberglass cloth for use in reinforcing composite materials, such as those used to waterproof boats. Low cost, lightweight cloth is known as *e-glass* fiberglass cloth. Heavier, stronger *s-glass* grade fiberglass cloth is used when a higher tensile strength is required. Fiberglass cloth is used with epoxies and resins to make stiff, high strength composites

Sheet glass manufacturing using Float process: This process was developed in the late 1950s for making flat glass sheets. Its advantage over other methods such as rolling is that it obtains smooth surfaces that need no subsequent finishing. In the *float process* as illustrated in Fig. 21.11, the glass flows directly from its melting furnace onto the surface of a molten tin bath. The highly fluid glass spreads evenly across the molten tin surface, achieving a uniform thickness and smoothness.

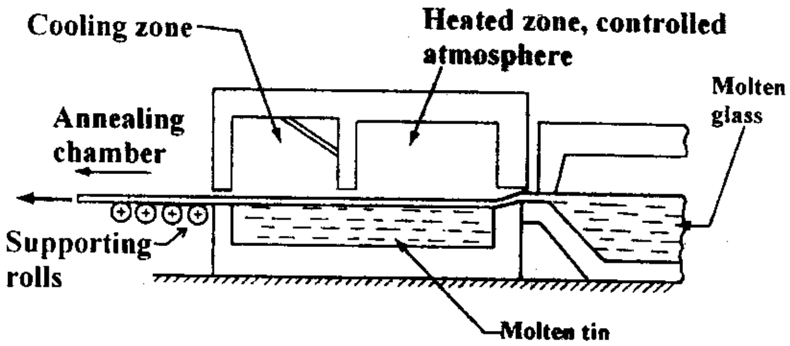

Figure 21.11 Float glass manufacturing process

21.8 CEMENT

The main raw materials used in the cement manufacturing process are limestone, sand, shale, clay, and iron ore. The raw materials are mixed in required proportions to meet a desired chemical composition and are ground in a rotating ball mill with water to make it semi-wet, if needed. The raw materials are ground to a size where the majority of the particle sizes are less than 75 micron meter. Materials exiting the mill are called "slurry" and could be pumped (as it behaves like fluid) to blending tanks to insure the correct chemical composition Next; the fine powder is heated in a kiln, up to 1500°C. This creates hard rock like substance known as *clinker*.

The clinker is combined with small amounts of gypsum and limestone and finely ground in a finishing mill. The mill is a large revolving cylinder containing large sized steel balls. The finished cement, ground appropriately in the order of particle size ranging from 0.1 to 250 micron-meter and filled in bags for use.

21.9 CONCRETE

Concrete is a composite material for construction, composed of cement and other materials like sand , gravel, stone chips, and other materials. Concrete solidifies and hardens after mixing with water due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Concrete is used to make pavements, pipe, architectural structures, foundations, motorways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles.

REVIEW QUESTIONS

1. Define ceramics. Classify ceramics.
2. List different properties of ceramics.
3. List the use of advanced ceramics.
4. Briefly discuss the processing of traditional ceramics.
5. Discuss how jaw crushers can be used for crushing input to ceramics.
6. Discuss about slip casting of ceramic parts.
7. Discuss the dry pressing operations of ceramic powder.
8. What do you understand of sintering?
9. What is glass? Why they are different from other material?
10. List the uses of different types of glasses.
11. Discuss glass pressing process.
12. How sheet glass is manufactured? Discuss.
13. What is cement? Where they are used?
14. How cement is different from concrete?

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9. http://www.essroc.com/default.aspx?pageid=183

22

INTRODUCTION TO MACHINE TOOLS

INTRODUCTION

Machining consists of forcing a cutting tool with one or more cutting edges through excess materials on a work piece. The excess materials, which are progressively separated from the work piece by machining, are known as *chips*. Machine tools take all aspects of chip forming processes. The purpose of metal machining for all products is to finish surfaces more closely to specified dimensions than can be done by other metal forming methods hitherto described. Parts formed roughly by other processes like foundry, forging and like processes normally have some or all of their surfaces refined by machining.

THE LATHE

The main function of a lathe is to remove metal from a piece of work to give it the required shape and size. This is accomplished by holding the work securely and rigidly on the machine and then turning it against cutting tool which will remove metal from the work in the form of chips.

TYPES OF LATHE

Lathes of various designs and constructions have been developed to suit the various conditions of metal machining. The types generally used are:

1. Speed lathe
2. Engine lathe
3. Bench lathe
4. Tool room lathe
5. Capstan and Turret lathe.
6. Special purpose lathe
7. Automatic lathe.

DESCRIPTIONS AND FUNCTIONS OF LATHE PARTS

A modern geared-head lathe consists of a bed made of grey cast iron on which are mounted the headstock, the tailstock, and the carriage (Fig.22.1).

The *headstock*, from which power is transmitted to the different parts of a lathe, consists of the *headstock casting* to accommodate all the parts within it; the *main spindle* to which the work is attached; the work fitted

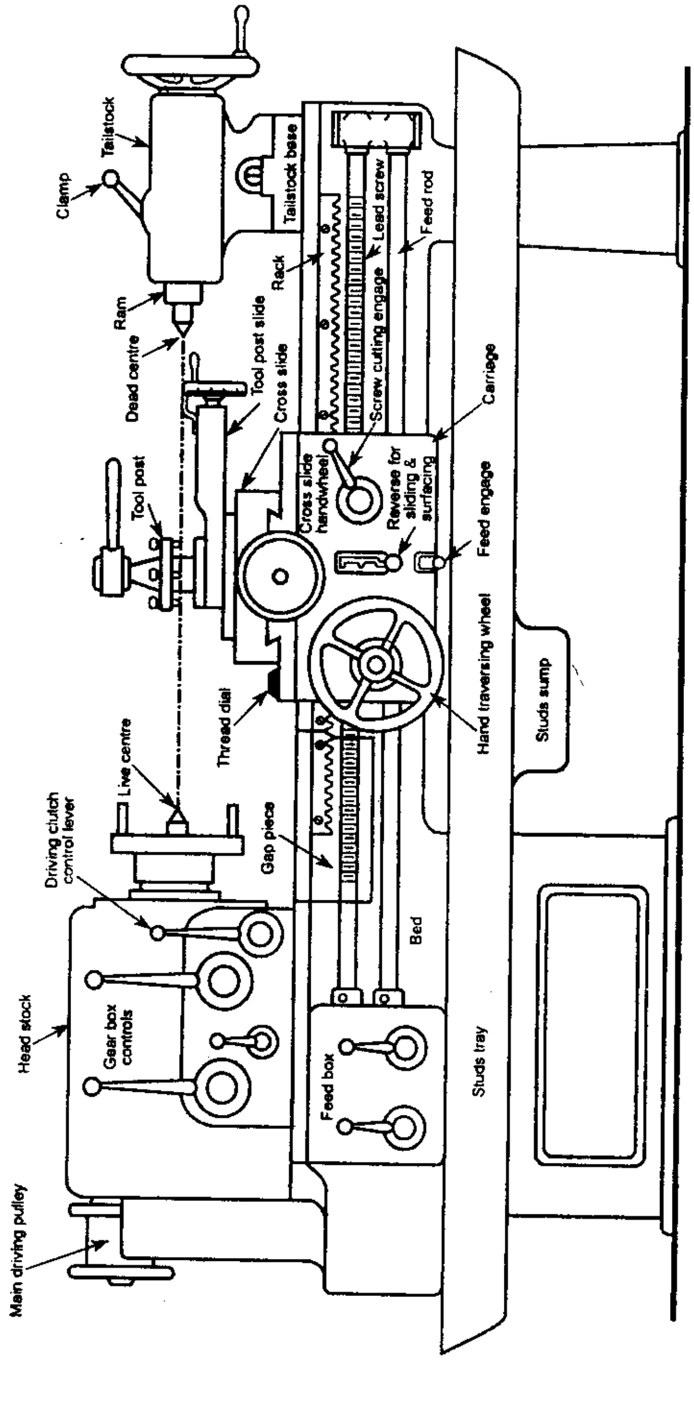

Figure 22.1 The Lathe parts

into the main spindle; the cone pulley used to get various spindle speed; and *back gear* arrangement for obtaining a wide range of slower speeds, and certain gears called *change wheels* used to produce different velocity ratio required for thread cutting.

The *tailstock* is for the purpose of primarily giving an outer bearing and support for work being turned on centres. It can be adjusted for alignment or non-alignment with respect to the spindle centres and carries a centre called *dead centre* for supporting one end of the work. Both live and dead centres have 60^0 conical points to fit centre holes in the work, the other end tapering to allow for good fitting into the spindles. Now-a-days the dead centre is mounted in ball bearing so that it rotates with the job avoiding friction of the job with dead centre. This is especially necessary with heavy jobs.

The *carriage* is supportive on the lathe bed-ways and can move in a direction parallel to the spindle axis. It comprises apron, cross-slide, saddle, compound rest, and tool post. The lower part of the carriage is termed the *apron* in which there are gears to constitute apron mechanism for adjusting the direction of the feed, the *clutch mechanism* and the *split half nut*. The cross-slide is mounted on the carriage and can move at right angles to the spindle axis. The cross-slide is mounted on a *saddle* in which the *compound rest* moves to any desired angle. The compound rest slide is actuated by a screw which rotates in a nut fixed to the saddle. The *tool post* fits in a tee-slot in the compound rest and holds the tool holder in place by the tool post screw.

A chuck is one of the most important devices for holding and rotating a piece of work in a lathe. Work pieces of short length, and large diameter or of irregular shape that cannot be conveniently mounted between centres are held quickly and rigidly in a chunk.

LATHE OPERATIONS

Operations which are performed in a lathe either by holding the work piece between centres or by a chuck are:

(a) Facing.
(b) Taper turning
(c) Forming
(d) Thread cutting
(e) Straight turning
(f) Grooving
(g) Step turning

TAPER AND TAPER TURNING

A *taper* may be defined as a uniform increase or decrease in diameter of a piece of work measured along its length. In a lathe, *taper turning* means to produce a conical surface by gradual reduction in diameter from a cylindrical work piece. This tapering of a part has wide applications in the construction of machines. Almost all machine spindles have taper holes which receive taper shank of various tools and work holding devices.

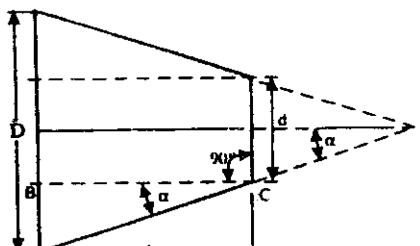

Figure 22.2 Taper elements

D-Large diameter of taper, d- Small diameter of taper, l- length of taper, α -Half angle of taper

Taper elements : A tapered piece shown in the Fig.22.2 may be designated by the following symbols :

D = large diameter of taper in mm.

d = small diameter of taper in mm.

l = length of tapered part in mm.

2α = full taper angle.

α = angle of taper or half taper angle

The amount of taper in the work piece is usually specified by the ratio of the difference in diameters of the taper to its length. This is termed as the *conicity* and its designated by the letter *K*.

$$K = \frac{D-d}{l}$$

Example 22.1: In Fig. 22.2 lot D=90 mm, d=80 mm and l=100 mm, find the value of K.

$$K = \frac{D-d}{l} = \frac{90-80}{100} = \frac{1}{10}$$

This 1/10 means that the amount of taper is 1:10, or in a length of 10 mm, the diameter of the taper is reduced by 1 mm. The amount of taper 1/10may also be expressed as a decimal, i.e. 0.1.

THE DRILLING MACHINE

The drilling machine is one of the most important machine tools in a workshop. As regards its importance it is second only to the lathe. Although it was primarily designed to originate a hole, it can perform a number of similar operations. In a drilling machine holes may be drilled quickly and at a low cost. The hole is generated by the rotating edge of a cutting tool known as the drill which exerts large force on the work clamped on the table. As the machine tool exerts vertical pressure to originate a hole it is loosely called a "drill press".

TYPES OF DRILLING MACHINE

Drilling machines are made in many different types and sizes, each designed to handle a class of work or specific job to the best advantage. The different types of drilling machines are:

1. Sensitive drilling machine.
2. Portable drilling machine.
3. Radial drilling machine.
4. Gang drilling machine.
5. Multiple spindle drilling machine.
6. Automatic drilling machine.
7. Deep hole drilling machine.

SENSITIVE DRILLING MACHINE

The sensitive drilling machine (shown in Fig. 22.3) is designed for drilling a small holes at high speed in light jobs. The base of the machine may be mounted on a bench or on the floor. It consists of a vertical column, a horizontal table, a head supporting the motor and driving mechanism, and a vertical spindle for driving and rotating the drill. There is no arrangement for any automatic feed of the drill spindle. The drill is fed into the work by purely hand control. High speed and hand feed are necessary for drilling small holes. High speeds are necessary to attain required cutting speed by small diameter drill. Hand feed permits the operator to feel or

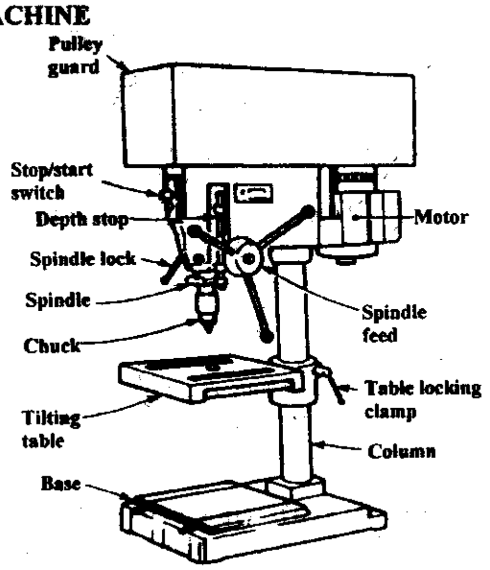

Figure 22.3 Sensitive drilling machine

sense the progress of the drill into the work, so that if the drill becomes worn out or jams on any account, the pressure on the drill may be released immediately to prevent it from breakage. As the operator senses the cutting action, at any instant, it is called sensitive drilling machine. Sensitive drilling machines are capable of rotating drills of diameter from 1.5 to 15.5 mm. Super sensitive drilling machines are designed to drill holes as small as 0.35 mm in diameter.

THE SHAPER

The shaper is the reciprocating type of machine tool intended primarily to produced flat surfaces. The surfaces may be horizontal, vertical, or inclined.

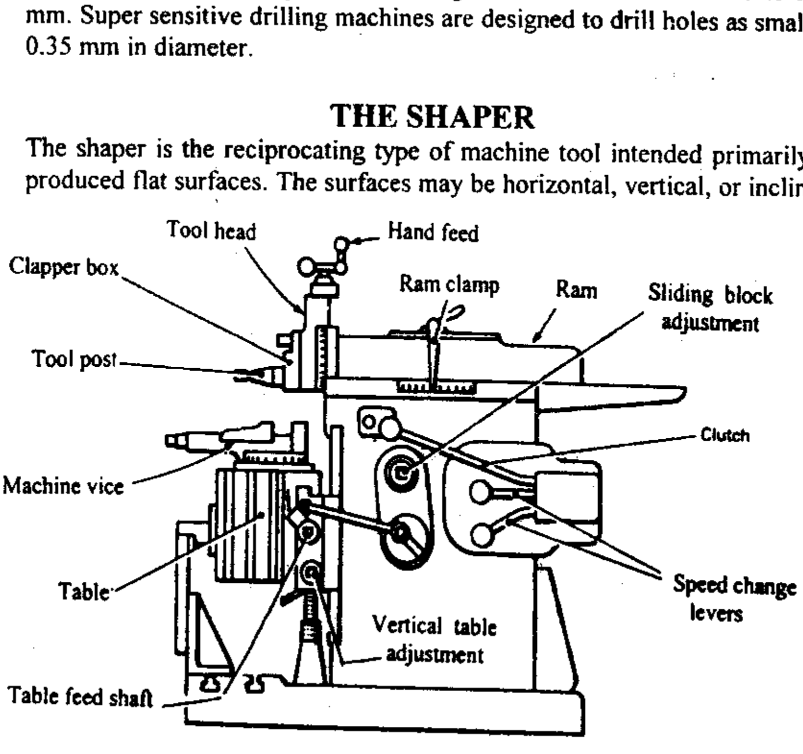

Figure 22.4 A standard shaper

In general, the shaper can produce any surface composed of straight line elements. Modern shapers can generate countered surface. Fig.22.4 shows the schematic diagram of a shaper.

RAM AND TOOL HEAD OF A SHAPER

Ram; The ram is the reciprocating member of the shaper. This is semi-cylindrical in form and heavily ribbed inside to make it more rigid. It slides on the accurately machined dovetail guide-ways on the top of the column and is connected to the reciprocating mechanism contained within the column. It houses a screwed shaft for altering the position of the ram with respect to the work and holds the tool head at the extreme forward end.

Tool head : The tool head of a shaper holds the tool rigidly, provides vertical and angular feed movement of the tool and allows the tool to have an automatic relief during its return stroke.

SHAPER MECHANISM

In a shaper, rotary movement of the drive is converted into reciprocating movement by the mechanism contained within the column of the machine. The ram holding the tool gets the reciprocating movement. In a standard shaper metal is removed in the forward cutting stroke, while the return stroke goes idle and no metal is removed during this period. To reduce the total machining time it is necessary to

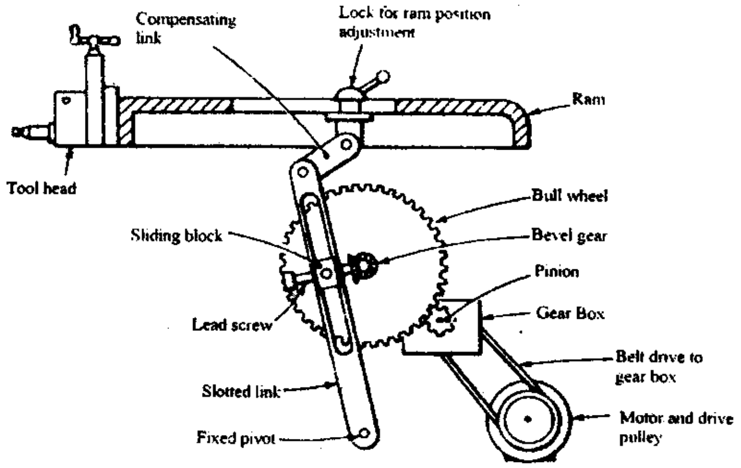

Figure 22.5 Shaper mechanism

reduce the time taken by the return stroke. Thus the shaper mechanism should be so designed that it can allow the ram holding the tool to move at comparatively slower speed during the forward cutting stroke, the cutting speed depending upon the type of material and machining condition, whereas during the return stroke the ram moves at a faster rate to reduce idle return time. This mechanism is known as *quick return mechanism* and is shown in Fig. 22.5.

The *planer* like a shaper primarily produces plane and flat surfaces by a single point cutting tool. A planer is very large compared to a shaper and capable of machining heavy work pieces which cannot be accommodated on a shaper table. The fundamental difference between a shaper and a planer is that in a planer the work is supported on the table, reciprocates past the stationary cutting tool and the feed is supplied by the lateral movement of the tool, whereas in a shaper the tool which is mounted upon the ram reciprocates and the feed is given by the crosswise movement of the table.

The size of a standard planer is specified by the size of the largest rectangular solid that can reciprocate under the tool. The size of the largest solid is known by the distance between the two housings, the height from the top of the table to the cross-rail in its uppermost position, and the maximum length of table travel.

The slotting machine falls under the category of reciprocating type of machine tool similar to a shaper or a planer. It operates almost on the same principle as that of a shaper. The major difference between a slotter and shaper is that in a slotter the ram holding the tool reciprocates in a vertical axis, whereas in a shaper the ram holding the tool reciprocates in a horizontal axis. A vertical shaper and a slotter are almost similar to each other as regards to their construction, operation, and use. The only difference being, in the case of a vertical shaper, the ram holding the tool may also reciprocate at an angle to the horizontal table in addition to the vertical stroke.

GRINDING MACHINES

Grinding is metal operation performed by means of a rotating abrasive wheel that acts as a tool. This is used to finish work pieces which must show a high surface quality, accuracy of shape and dimension. The art of grinding goes back many centuries. Over 5,000 years ago the Egyptians abraded and polished building stones to hairline fits for the pyramids. Columns and statues were shaped and finished with a globular stone which abraded the surface.

Mostly grinding is the finishing operation because it removes comparatively little metal, 0.25 to 0.50mm in most operations and the accuracy in dimensions is in the order of 0.000025 mm. Grinding is also done to machine materials which are too hard for other machining methods that use cutting tools. Many different types of grinding machines have now been developed for handling various kinds of work to which the grinding process is applicable.

PORTABLE AND FLEXIBLE SHAFT GRINDERS

The usual form of portable grinder resembles a portable or electric hand drill with a grinding wheel mounted on spindle. The simplest type of grinder is the floor-stand grinder as shown in Fig. 22.6.

A floor-stand grinder has a horizontal spindle with wheels usually at both ends and is mounted on a base or pedestal. There is provision for driving the wheel spindle by belt from motor at the rear, at floor level. Frequently the wheels are mounted directly on the motor shaft extensions, in which case the motor is on the top of the stand. A small size machine mounted on a bench is called *bench grinder*.

These machines are used for snagging and off-hand grinding of tools and miscellaneous parts. Polishing wheels may be run on these grinders.

Portable grinders are often used in shop floor. These resemble portable or electric hand drills with a grinding wheel mounted on spindle as shown in Fig. 22.6.

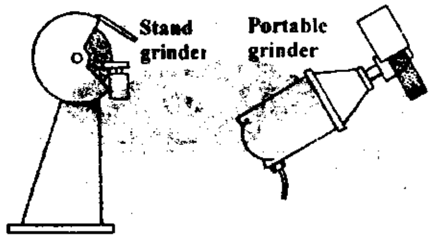

Figure 22.6 Stand and Portable grinder

TOOL AND CUTTER GRINDERS

Tool and cutter grinders (shown in Fig. 22.7) are used mainly to sharpen and recognition multiple tooth cutters like reamers, milling cutters, drills, taps, hobs and other types of tools used in the shop. With various attachments they can also do light surface, cylindrical, and internal grinding to finish such items as jig, fixture, die and gauge details and sharpen single point tools. They are classified according to the purpose of grinding, into two groups :

1. Universal tool and cutter grinders.
2. Single-purpose tool and cutter grinders.

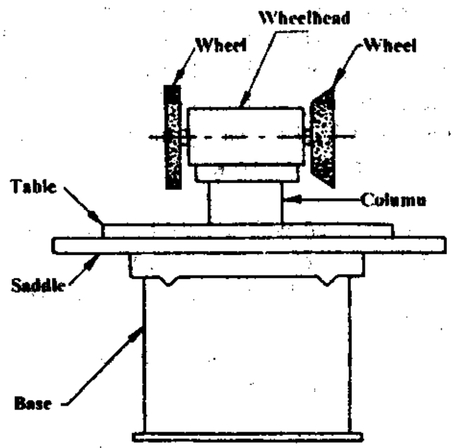

Figure 22.7 A tool and cutter grinder

Universal tool and cutter grinders are particularly intended for sharpening of miscellaneous cutters. Single-purpose grinders are used for grinding tools such as drills, tool-bits, etc. in large production plants where large amount of grinding work is necessary to keep production tools in proper cutting condition. In addition, tools can be ground uniformly and with accurate cutting angles. A typical tool and cutter grinder is shown in Fig.22.7.

GRINDING WHEELS

A grinding wheel is a multi -tooth cutter made up of many hard particles

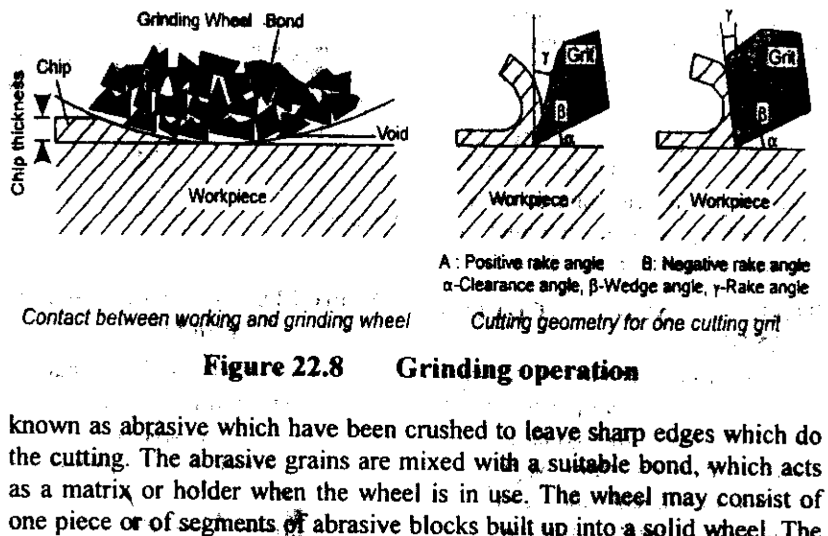

Figure 22.8 Grinding operation

known as abrasive which have been crushed to leave sharp edges which do the cutting. The abrasive grains are mixed with a suitable bond, which acts as a matrix or holder when the wheel is in use. The wheel may consist of one piece or of segments of abrasive blocks built up into a solid wheel. The abrasive wheel is usually mounted on some form of machine adapted to a particular type of work.

The Indian standard marking system for grinding wheels (IS: 551-1954) has been prepared with a view to establishing a uniform system of marking of grinding wheels to designate their various characteristics, to give a general indication of the hardness and grit size of any wheel as compound with another.

Each marking shall consist of six symbols, denoting the following in succession as given below:

1. Abrasive type
2. Grain size
3. Grade
4. Structure
5. Bond type
6. Manufacturer's record

The cutting action of the grinding wheel is shown in the Fig. 22.8.

MILLING MACHINES

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The cutter rotates at a high speed and because of the multiple cutting edges it removes metal at a very fast rate.

The machine can also hold one or more number of cutters at a time. This is why a milling machine finds wide application in production work. This is superior to other machines as regards accuracy and better surface finish, and is designed for machining a variety of tool work.

For general shop work the most commonly used is the column and knee type where the table is mounted on the knee-casting which in turn is mounted on the vertical

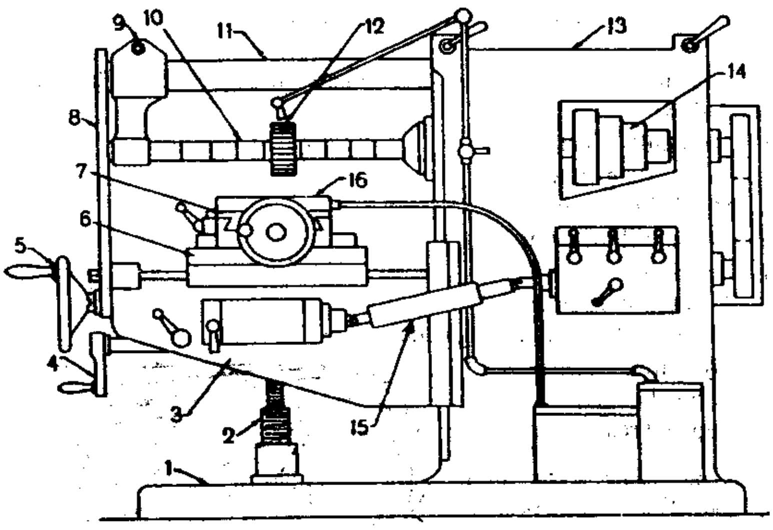

Figure 22.9 Column and knee type milling machine

1. Base, 2.Elevating screw, 3. Knee, 4. Knee elevating handle,
5. Cross feed handle, 6. Saddle, 7. Table, 8. Front brace,
9. Arbor support, 10. Cone pulley, 15. Telescopic feed shaft.

slides of the main column. The knee is vertically adjustable on the column so that the table can be moved up and down to accommodate work of various heights. The column and knee type milling machines are classified according to the various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle. Fig. 22.9 illustrates a column and knee type milling machine.

The size of the column and knee type milling machine is designated by the dimensions of the working surface of the table and its maximum length of longitudinal, cross and vertical travel of the table. The following are the typical size of a horizontal knee type milling machine:

Table length x width = 1100 mm x 310 mm.

Power traverse: longitudinal x cross x vertical

= 650 mm x 235 mm x 420 mm.

In addition to the above dimensions, number of spindle speed, number of feed, spindle nose taper, power available, net weight and the floor space required, etc. should also be stated in order to specify the machine fully.

The milling cutter are revolving tools having one or several cutting edges of identical form equally spaced on the circumference of the cutter. The cutting elements are called teeth which intermittently engages the work piece and remove material by relative movement of the work-piece and cutter.

There are many different types of standard milling cutters. They are classified below:

a) Plain milling cutter.
b) Side milling cutter.
c) Metal slitting saw.
d) Angle milling cutter.
e) End mill.
f) T-slot milling cutter.
g) Woodruff key slot milling cutter.
h) Fly cutter.
i) Formed cutter.
j) Tap and reamer cutter.

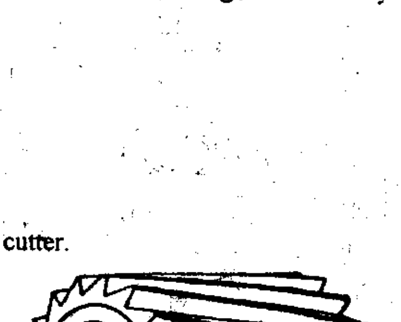

Figure 22.10 Plain milling cutter

Plain milling cutter: The plain milling cutters are cylindrical in shape and have teeth on the circumferential surface only. The cutters are intended for the production of flat surfaces parallel to the axis of rotation of the spindle. The cutter teeth may be straight or helical according to the size of the cutter. Fig.22.10 illustrates a straight teeth plain milling cutter

FUNDAMENTALS OF THE MILLING PROCESSES

The various milling processes performed by the different milling cutters may be grouped under two separate headings: *peripheral milling* and *face milling*. The cutting action of milling cutters to perform the above processes are described below.

Peripheral milling: The peripheral milling is the operations performed by a milling cutter to produce a machined surface parallel to the axis of rotation of the cutter. Two cutting processes in peripheral milling includes *down-milling* and *up-milling*. They are described below:

Down-milling: The down-milling, which is also called climb milling, is the process of removing metal by a cutter which is rotated in the same direction of travel of the work piece. The down-milling is illustrated in Fig. 22.11 (a). The thickness of the chip is maximum when the tooth begins its cut and it reduces to the minimum when the cut terminates.

Up-milling: The up-milling, which is also called conventional milling, is the processes of removing metal by a cutter which is rotated against the direction of travel of the work piece. The up-milling operation is illustrated in Fig. 22.11(b). the thickness of the chip in up-milling is minimum at the beginning of the cut and it reaches to the maximum when the cut terminates.

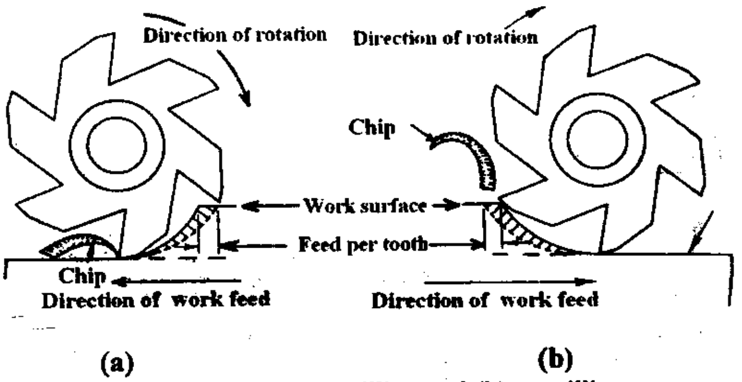

Figure 22. 11 (a)Down-milling and (b)up-milling

The *face milling* is the operation performed by a milling cutter to produce a flat machine surface perpendicular to the axis of rotation of the cutter. The peripheral cutting edges of the cutter do the actual cutting, whereas the face cutting edges finish up the work surface by removing a very small amount of material.

MILLING MACHINE OPERATIONS

The following are the different operations performed in a milling machine:

1. Plain milling.
2. Face milling.
3. Side milling.
4. Straddle milling.
5. Angular milling.
6. Gang milling.
7. Form milling.
8. Profile milling.
9. End milling.
10. Saw milling.
11. Milling key ways, grooves and slots
12. Gear milling.
13. Helical milling.
14. Cam milling.
15. Thread milling.

NUMERICAL CONTROL MACHINE TOOLS

Numerical control (NC) is a technique of automatically operating a productive facility, based on code of letters, numbers and special characters. The complete set of coded instructions, responsible for executing an operation is called part programme. This programme is translated into electrical signals to drive various motors to operate the machine to carry out the required operations. Avoidance of humane interventions, omission of conventional tooling and fixturing, and quick change capability of NC system are the primary factors considered to decide the level of acceptance of machine tools for a particular job. Fig. 22.12 shows the components of a traditional NC system.

Any NC machine can be considered as a general purpose machine tools

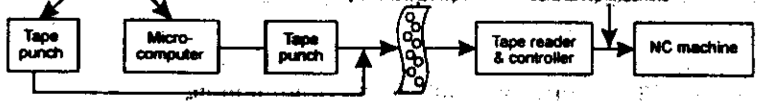

Figure 22.12 Components of NC system

fitted with drive motors and other auxiliary functions of the machine along with the work table, spindle and other hardware of the traditional machine tools.

REVIEW QUESTIONS

1. List different types of lathes. Describe various parts of a lathe.
2. List various lathe operations
3. What is taper? How do you calculate conicity in taper turning?
4. Draw a neat diagram of a shaper. Identify various parts.
5. Draw a sensitive drilling machine showing different parts.
6. Draw a shaping machine indicating various parts.
7. Draw a shaper mechanism with brief description.
8. Explain why grinding machine is important in any machining shop.
9. Draw a schematic diagram of a milling machine and label the parts.
10. Explain the difference between up-milling and down-milling.
11. Draw the components of NC system.