15
CHAPTER

HOT WORKING OF METALS

15.1 METAL FORMING

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

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

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

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

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

15.2 RECRYSTALISATION

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

15.3 HOT WORKING

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

15.4 EFFECT OF HOT WORKING ON MECHANICAL PROPERTIES OF METALS

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

15.5 MERITS OF HOT WORKING

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

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

15.6 DEMERITS OF HOT WORKING

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

15.7 CLASSIFICATION OF HOT WORKING PROCESSES

The classification of hot working processes is given as under.

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

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

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

15.8 PRINCIPAL HOT WORKING PROCESSES

15.8.1 Hot Rolling

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

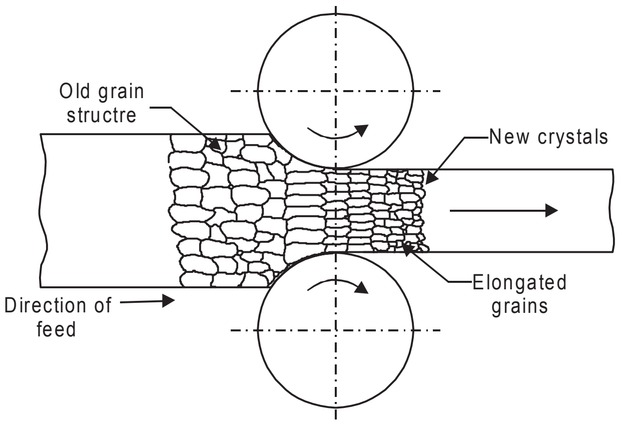

Fig. 15.1 Grain refinement in hot rolling process

15.8.1 Two-High Rolling Mill

A two-high rolling mill (Fig 15.2(a)) has two horizontal rolls revolving at the same speed but in opposite direction. The rolls are supported on bearings housed in sturdy upright side frames called stands. The space between the rolls can be adjusted by raising or 1owering the upper roll. Their direction of rotation is fixed and cannot be reversed. The reduction in the thickness of work is achieved by feeding from one direction only. However, there is another type of two-high rolling mill, which incorporates a drive mechanism that can reverse the direction of rotation of the rolls. A Two- high reverse arrangement is shown in Fig. 15.2(b). In a two-high reversing rolling mill, there is continuous rolling of the workpiece through back-and-forth passes between the rolls.

15.8.2 Three-High Rolling Mills

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

15.8.3 Four-High Rolling Mill

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

15.8.4 Cluster Mill

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

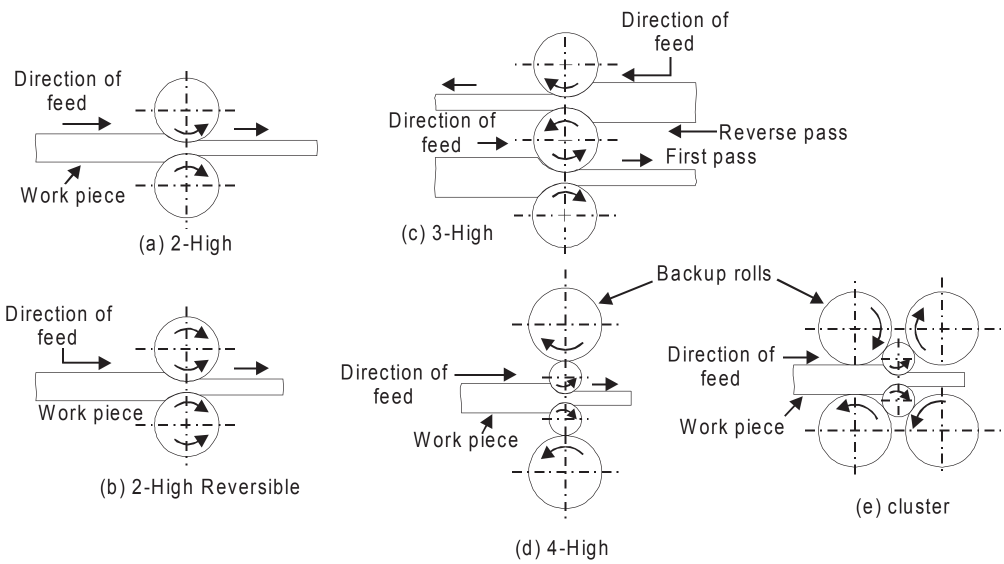

Fig. 15.2 Hot rolling stand arrangements

15.8.5 Continuous Rolling Mill

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

15.8.6 Applications of Rolling

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

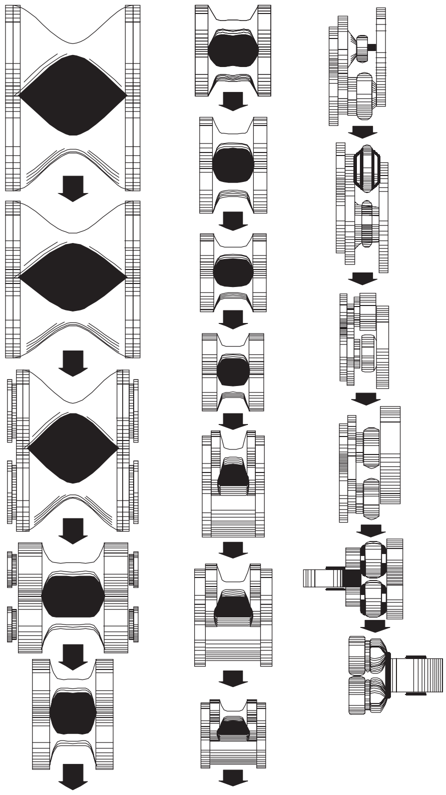

Fig. 15.2(f) Hot rolling stand arrangements

15.9 Hot Piercing or Seamless tubing

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

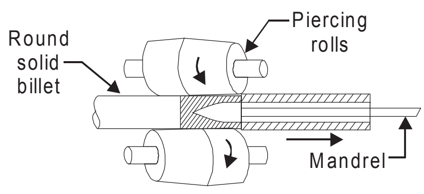

Fig. 15.3 Hot piercing or seamless tubing

Hot pircing includes rotary piercing to obtain formed tube by piercing a pointed mandrel through a billet in a specially designed rolling mill. The rotary piercing can be performed either on a two-high rolling mill or on a three-high rolling mill. In the former, the two rolls are set at an angle to each other. The billet under the rolls is deformed and a cavity formation is initiated at the centre due to tensile stressing. The carefully profiled shape of the mandrel assists and controls the formation of cavity. In a three-high rolling mill, the three shaped rolls are located at 1200 and their axes are inclined at a feed angle to permit forward and rotary motion of the billet. The squeezing and bulging of the billet open up a seam in its center pass makes a rather thick-walled tube which is again passed over plug and through grooved rolls in a two-high roll mill where the thickness is decreased and the length is increased. While it is still up to a temperature, it is passed on to a reeling machine which has two rolls similar to the piercing rolls, but with flat surfaces. If more accuracy and better finish are desired, the run through sizing dies or rolls. After cooling, the tubes are used in a pickling bath of dilute sulphuric acid to remove the scale.

15.10 HOT EXTRUSION

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

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

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

15.10.1 Methods of Hot Extrusion

Hot extrusion process is classified as

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

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

15.10.1.1 Direct or Forward Hot Extrusion

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

15.10.1.2 Indirect or Backward Hot Extrusion

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

15.10.1.3 Tube Extrusion

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

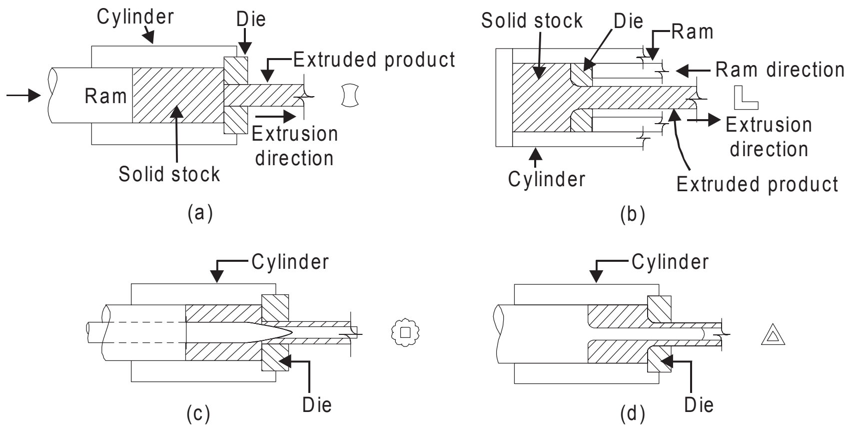

Fig. 15.4 Method of hot extrusion

15.11 HOT DRAWING

Drawing is pulling of metal through a die or a set of dies for achieving a reduction in a diameter. The material to be drawn is reduced in diameter. Fig. 15.5 is another method used in hot drawing or shaping of materials where the heated blank is placed over the die opening the punch forces the blank through the die opening to form a cup or shell. The multiple dies are also used to accomplish the stages in drawing process. Kitchen utensils and components of food processing industries are manufactured by this process.

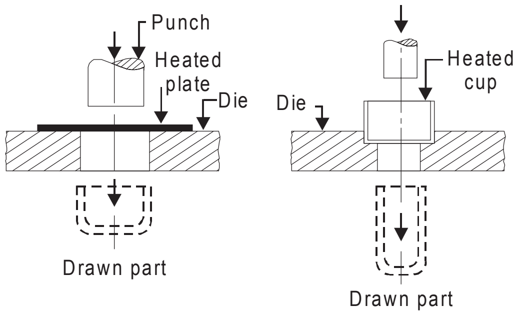

Fig. 15.5 Hot drawing

15.12 HOT SPINNING

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

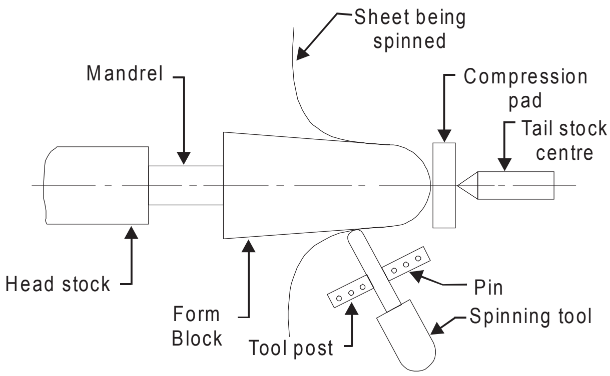

Fig. 15.6 Hot spinning

QUESTIONS

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

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

16

CHAPTER

COLD WORKING

16.1 INTRODUCTION

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

16.2 PURPOSE OF COLD WORKING

The common purpose of cold working is given as under

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

16.3 PRECAUTIONS FALLOWED IN COLD WORKING

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

16.4 CHARACTERISTICS OF COLD WORKING

The main characteristics of cold working are given as under.

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

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

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

Cold working process increases:

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

Cold working processes decreases:

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

16.4 LIMITATIONS OF COLD WORKING

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

16.5 ADVANTAGES OF COLD WORKING

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

16.6 DISADVANTAGES OF COLD WORKING

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

16.7 COMPARISON OF HOT WORKING WITH COLD WORKING

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

Table 16.1 Comparison of Hot Working with Cold Working

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

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

16.8 COLD WORKING PROCESSES

Commonly employed cold working processes are:

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

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

16.9 COLD-ROLLING

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

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

16.10 COLD EXTRUSION

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

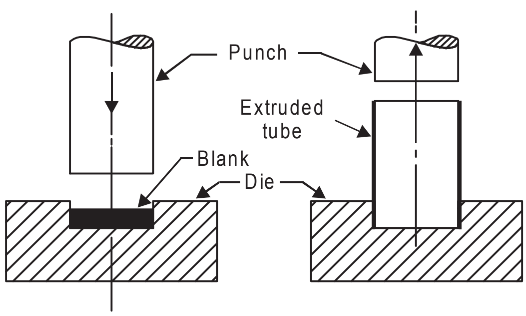

Fig. 16.1 Impact extrusion

16.11 WIRE DRAWING

The wire drawing die setup is shown in Fig.16.2(a). The process of producing the wires of different diameters is accomplished by pulling a wire through a hardened die usually made up carbide. However a smaller diameter wires are drawn through a die made of diamond. The larger diameter oriented wire is first cleaned, pickled, washed and then lubricated. Cleaning is essentially done to remove any scale and rust present on the surface, which may severely affect the die. It is normally done by acid pickling. The hot rolled steel is de-scaled, pickled in acid, washed in water and coated with lime and other lubricants. To make for an easier entrance of wire into the die, the end of the stock is made pointed to facilitate the entry. A pointed or reduced diameter at the end of wire duly lubricated is pushed or introduced through the die which is water cooled also. This pointing is done by means of rotary swaging or by simple hammering. It is then gripped and pulled for attaching it to a power driven reel. The wire diameter is reduced in die because of the ductility property of the material to the smaller diameter through one set of die. However for more reduction in diameter of the wire, various sets of dies can be used in line for subsequent reduction in diameter at each stage as shown in Fig 16.2(b). The reduction in each pass through the die range about 10% for steel and 40% for ductile materials such as copper.

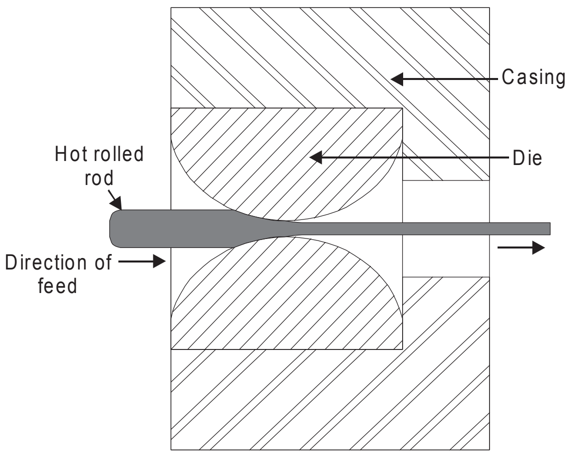

Fig. 16.2(a) Wire drawing

The drawing of the wire starts with a rod or coil of hot rolled steel, which is 0.8 to 1.6 mm larger than the final size required. In this process, there is no force is applied for pushing the wire into the die from the entrance side. The material should be sufficiently ductile since it is pulled by the tensile forces. Hence, the wire may have to be annealed properly to provide the necessary ductility. Further, the wire is to go through the conical portion and then pulled out through the exit by the gripper. The other aspect of preparation needed is the cleaning of the wire and lubricating it as it flows through the die. The pressures acting at the interface of the die and the metal being very high, the lubrication of the die is a serious problem. Therefore, to carry the lubricant through the die, special methods such as gulling, coppering, phosphating and liming are used. The wire is coated with a thin coat of ferrous hydroxide which when combined with lime acts as filler for the lubricant. This process is called sulling. In phosphating, a thin film of manganese, iron or zinc phosphate is applied on the wire, which makes the lubricant to stick to the wire, thereby reducing the friction and consequently, the drawing load. Another lubricant vehicle that is used in wire drawing is a coating of lime. After acid pickling, lime is applied and then allowed to dry. The lime neutralizes any amount of acid left on the surface and adsorbs the lubricant for carrying it to the die. The lubricant normally used is the soap solution. For very thin wires, electrolytic coating of copper is used to reduce friction. The dies used for wire drawing are severely affected because of high stresses and abrasion. The various die materials that are used are chilled cast iron, tool steels, tungsten carbide and diamond. The cast iron dies are used for small runs. For very large sizes, alloy steels are used in making the dies. The tungsten carbide dies are used most commonly for medium size wires and large productions. The tungsten carbide dies are referred because of their long life that is 2 to 3 times that of alloy steel dies. For very fine wires, diamond dies are used. Wire drawing improves the mechanical properties because of the cold working. The material loses its ductility during the wire drawing process and when it is to be repeatedly drawn to bring it to the final size, intermediate annealing is required to restore the ductility.

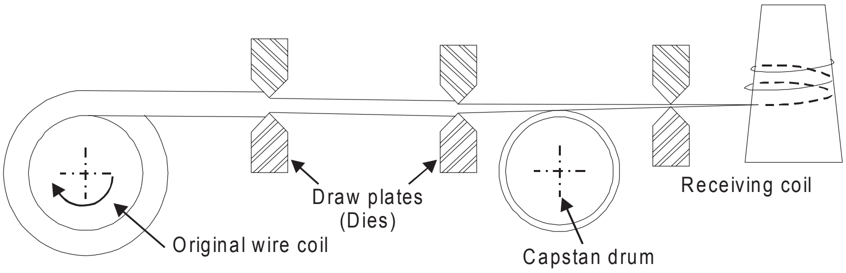

Fig. 16.2(b) Wire drawing

16.12 SHEET METAL PROCESSES

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

16.12.1 General Sheet Metal Operations

Shearing

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

Cutting

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

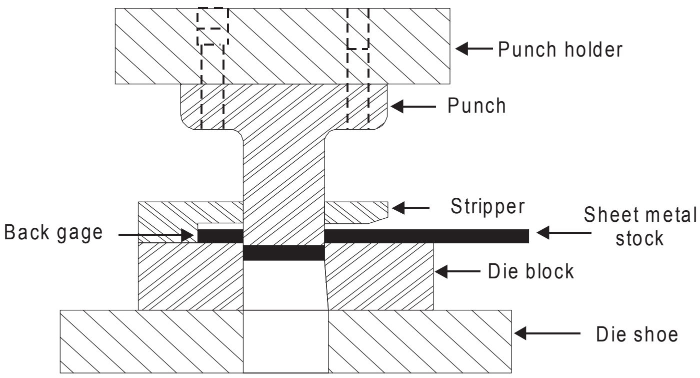

Fig. 16.3 Typical simple press tool

Parting

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

Blanking

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

Punching

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

Notching

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

Slitting

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

Nibbling

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

Trimming

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

Lancing

It makes a cut part way across a strip.

Forming

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

16.12.2 Bending

It is employed for bending into desired shapes various stock materials like sheets, rods, wires, bars, pipes, tubes and various structural shapes. Formed dies are used for bending the articles and the operation is usually performed in many stages. For bending in all sheet material are stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the natural line which retains its original length. The neutral axis lies at a distance of 30 to 50% of thickness of the sheet from the inside of the bend. Stretching of the sheet metal on the outside makes the stock thinner. Bending is sometimes called as forming which involves angle bending, roll bending, and roll forming and seaming and spinning. Well designed fixtures are also used where mass bending of such components is required. Bending occurs when forces are applied to localized areas, such as in bending a piece of metal into a right angle, and forming occurs when complete items or parts are shaped. However, some common kinds of sheet metal bends using by press brake dies are depicted in Fig. 16.4.

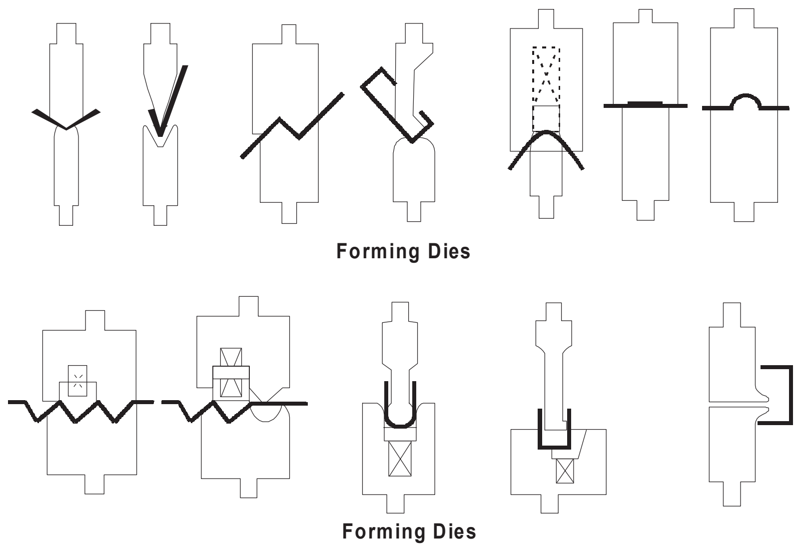

Fig. 16.4 Kinds of sheet metal bends using press brake dies

16.12.3 Cold Drawing

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

16.12.3.1 Metal Flow in Deep Drawing Dies

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

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

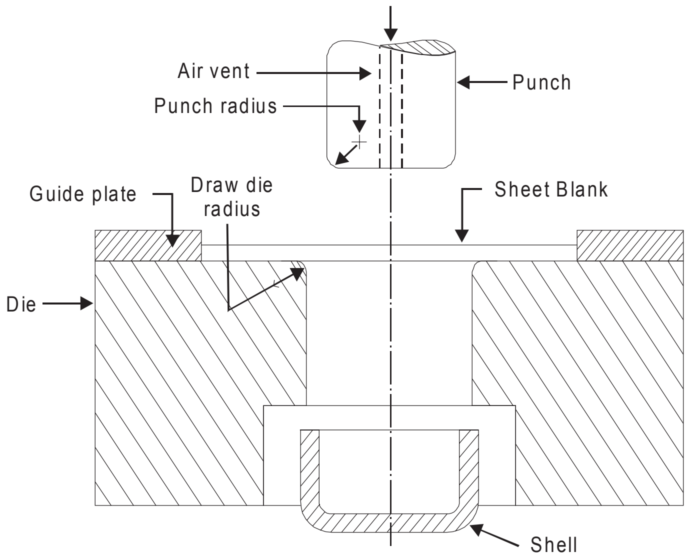

Fig. 16.5 Cold drawing

(*ii*) The metal flow of the volume elements at the periphery of the blank is extensive and involves an increase in metal thickness caused by severe circumferential compression. The increase is usually slight because it is restricted by the clearance between the punch and bore wall of the die ring.

(*iii*) The metal flow taking place during the forming of the cup will uniformly increases with cup height.

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

16.12.4 Embossing

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

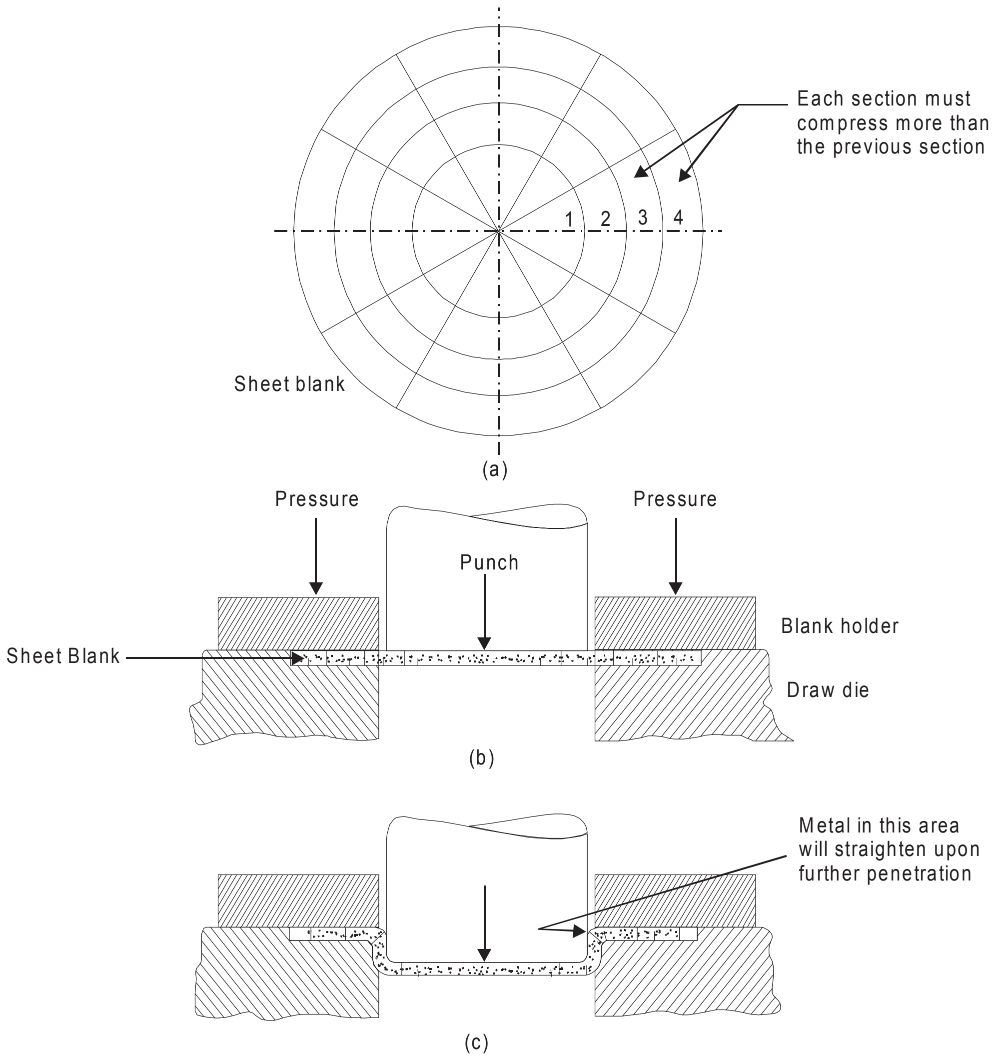

Fig. 16.6 Metal flow in deep drawing

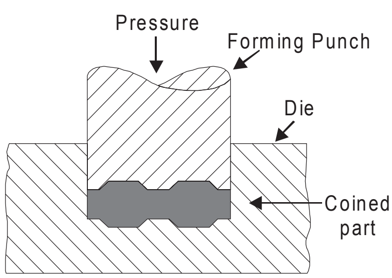

Fig. 16.7 Embossing

16.12.5 Coining

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

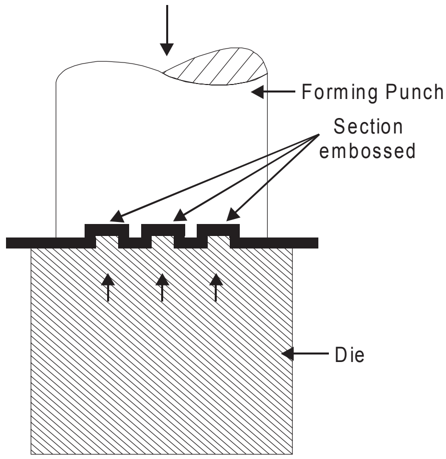

Fig. 16.8 Coining

16.12.6 Roll Forming

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

16.13 SHOT PEENING

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

16.14 QUESTIONS

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

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