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.

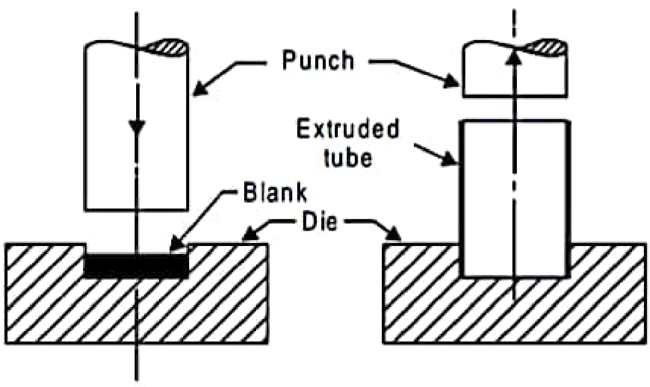

Fig. 16.1 Impact extrusion

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.

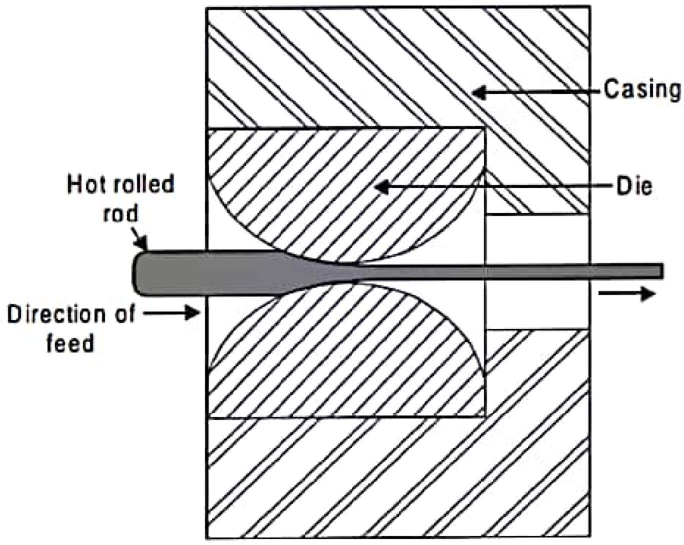

Fig. 16.2(a) Wire drawing

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.

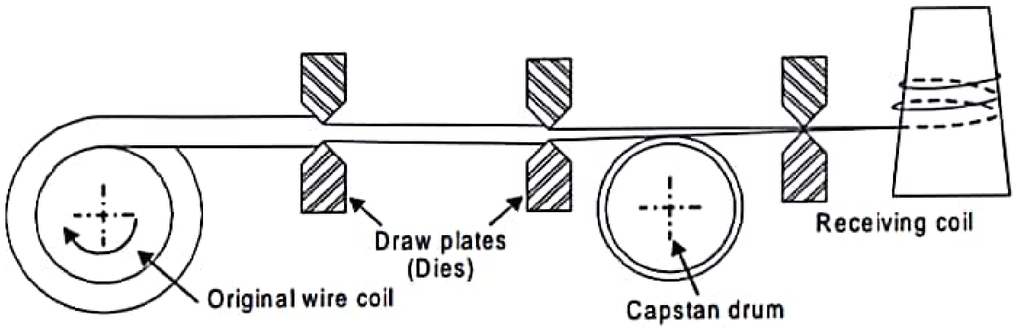

Fig. 16.2(b) Wire drawing

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.

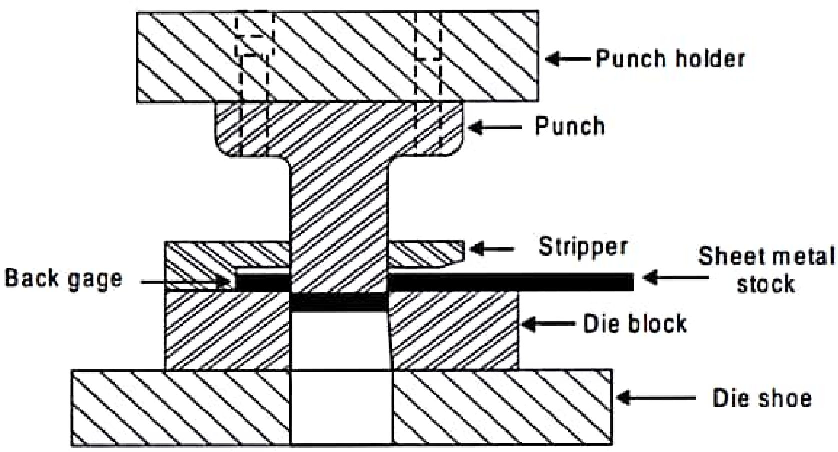

Fig. 16.3 Typical simple press tool

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.

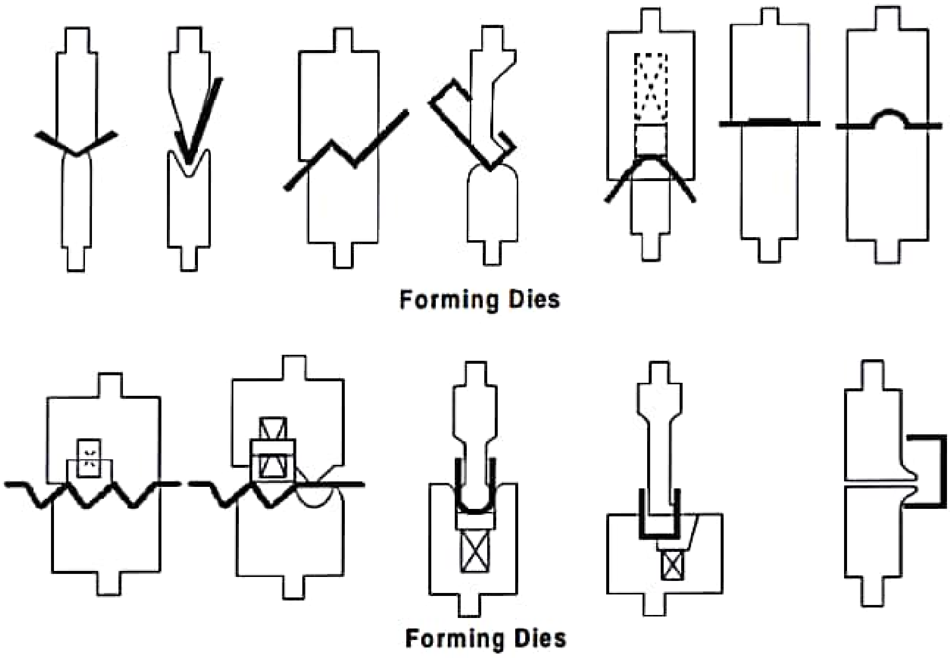

Fig. 16.4 Kinds of sheet metal bends using press brake dies

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.

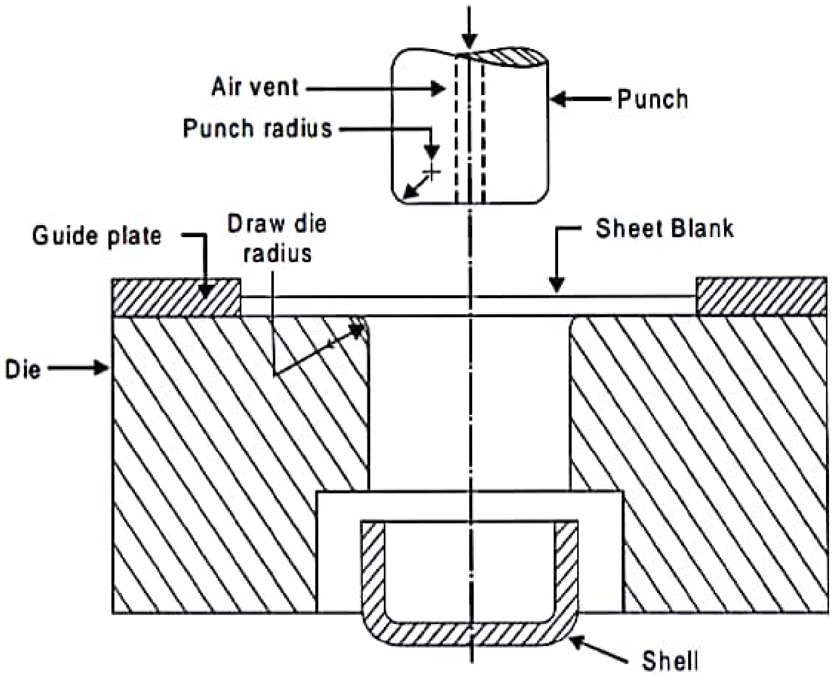

Fig. 16.5 Cold drawing

(*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.

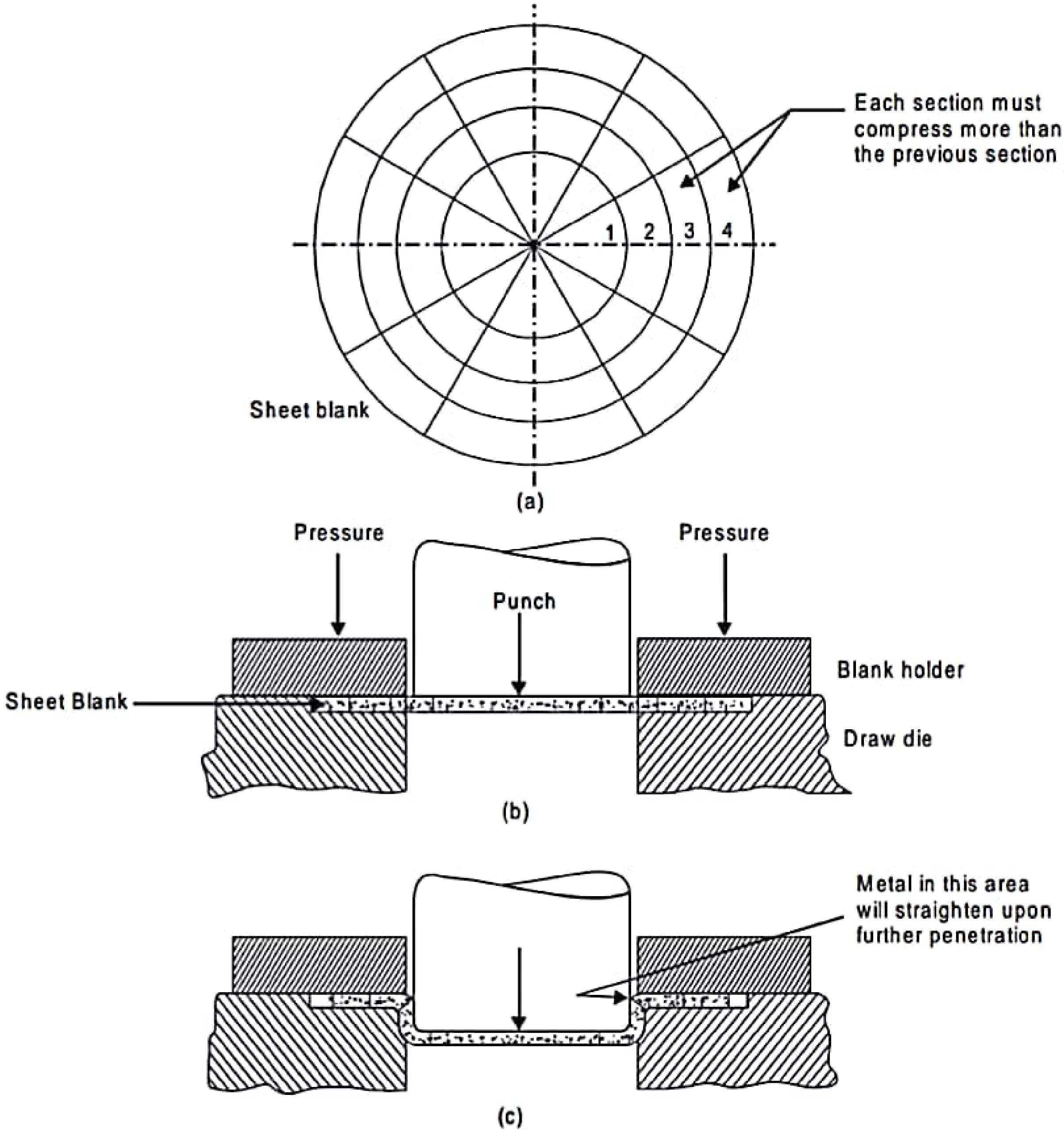

Fig. 16.6 Metal flow in deep drawing

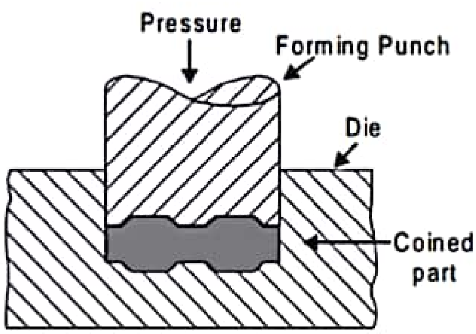

Fig. 16.7 Embossing

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.

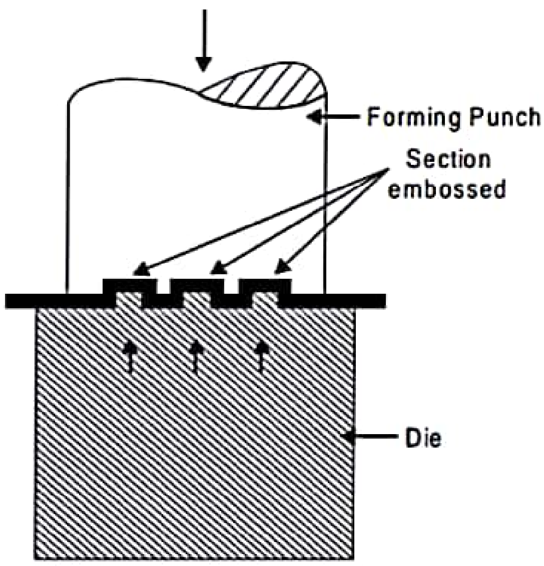

Fig. 16.8 Coining

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.