8. Shearing

It is a process of cutting a straight line across a strip, sheet or bar. Shearing process has three important stages:

i) Plastic deformation ii) Fracture (Crack propagation) iii) Shear

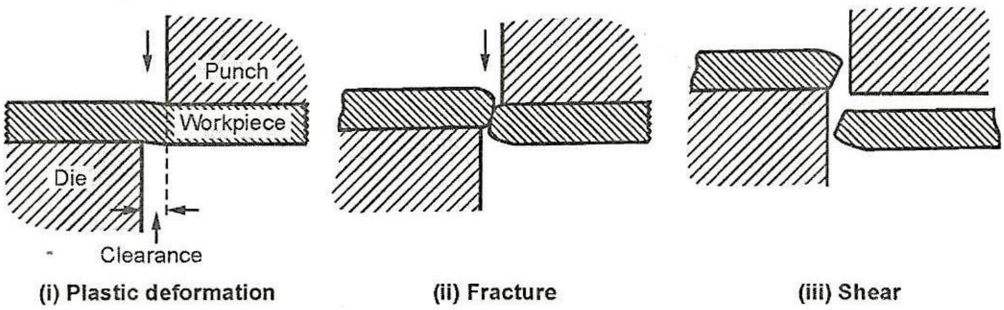

Fig. 4.11 : Steps in shearing process

When the metal is placed between upper and lower blades of the shear and pressure is applied, plastic deformation of metal takes place. As the pressure is continued, the fracture or crack start at the cutting edge of the blade. As the blade descends further, the small fractures meet and the metal is then sheared. Shearing is performed either by using hand or by using machines also.

9. Nibbling

This operation is generally substituted for blanking. It is designed for cutting out flat parts from sheet metal. The flat parts range from simple to complex contours. It is used only for small quantities of components.

4.5.2 Metal forming operations

In metal forming operations, the sheet metal is stressed below the ultimate strength of the metal. In these operations, no material is removed hence there is no wastage. Metal forming operations include following operations:

1. Bending 2. Drawing 3. Embossing
4. Forming 5. Coining (Squeezing)

1. Bending

It is a metal forming operation in which the straight metal sheet is transformed into a curved form. In bending operations, the sheet metal is subjected to both tensile and compressive stresses. During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.

The bending methods which are commonly used are as follows:

a) U-bending b) V-bending c) Angle bending
d) Curling e) Roll bending f) Bending in a 4-slide machine

g) Edge bending

a) U-bending

Figure shows U-bending operation which is also called as channel bending. In this operation, the die cavity is in the form U, due to which component forms the shape of U.

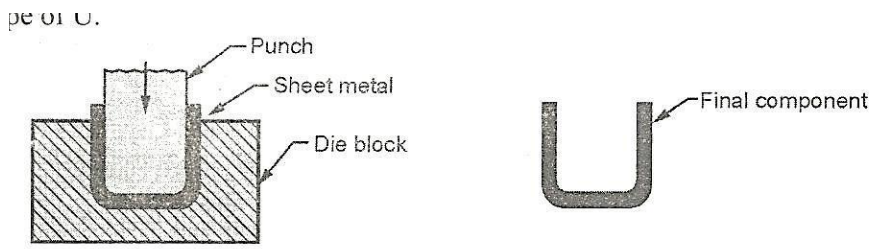

Fig. 4.12 : U-bending

b) V-bending

Figure shows V-bending operation in which wedge shape punch is used. The angle of V may be acute, 90° obtuse.

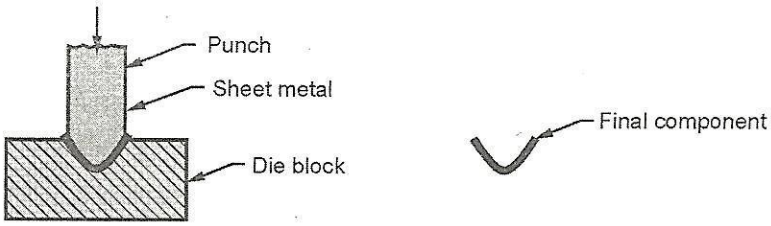

Fig. 4.13 : V-bending

c) Angle bending

In this operation, there is a bending of a sheet metal at a sharp angle.

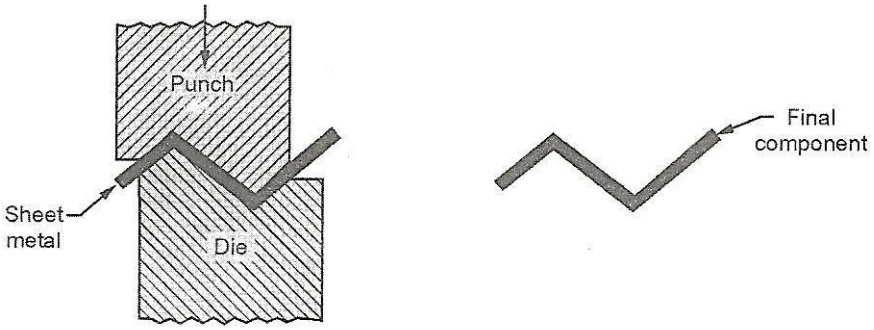

Fig. 4.14 : Angle bending

d) Curling

In this operation, the edge of a sheet metal is curled around. The punch and die both are made to contain the cavity for cutting partially. After the operation, punch moves up and workpiece is ejected out with the help of plunger as shown in figure. This process is used in the manufacturing of drums, pots, vessels, pans, etc.

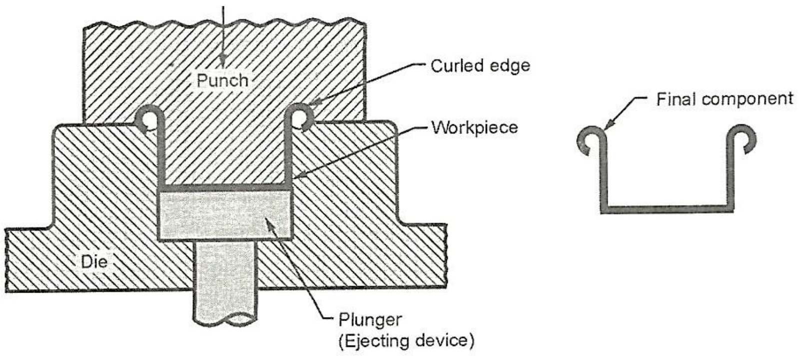

Fig. 4.15 : Curling

e) Roll bending

It is an operation in which generally large sheet metal parts are formed into curved sections with the help of rolls. When the sheet passes between the rolls, the rolls are brought towards each other to a configuration that achieves the required radius of curvature on the workpiece. It is used for fabrication of large storage tanks, pressure vessels, etc. Also used to bend metal plates, tubes, structural shapes etc.

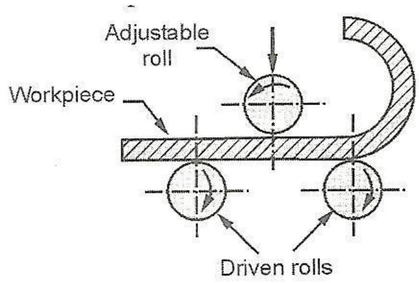

Fig. 4.16 : Roll bending

f) Bending in a 4-slide machine

This type of machine is used for bending of relatively short pieces. These type of machines are available in different designs. The lateral movements of the dies are controlled with the vertical die movement of form the part of desired shapes.

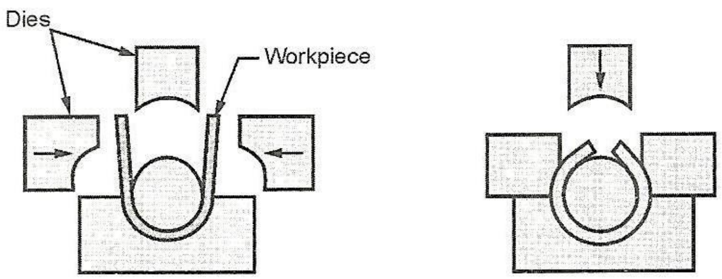

Fig. 4.17 : Bending in a 4-slide machine

g) Edge bending

It involves cantilever loading of sheet metal. In this method a pressure pad is used to hold the base of the workpiece against the die whereas the punch forces the workpiece to yield and bend over the edge of the die. The edge bending operation is limited to bends of 90° or less. The dies used for edge bending is called as wiping dies. They can also be designed for bend angles greater than 90°. Due to pressure pad, wiping dies are more complicated and costly than the V-dies. These dies are used for high production work.

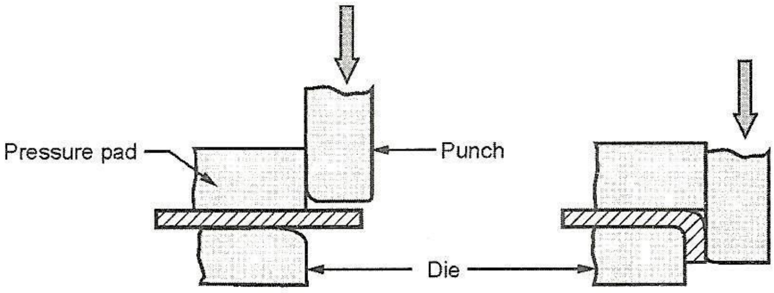

Fig. 4.18 : Edge bending

2. Drawing

In this operation, punch forces a sheet metal blank to flow plastically into the clearance between the punch and die. Finally, the blank takes a shape of cup.

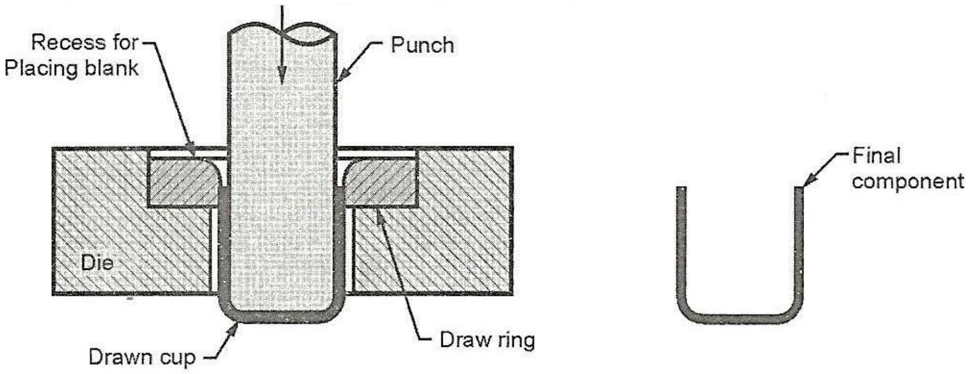

Fig. 4.19 : Drawing

3. Embossing

With the help of this operation, specific shapes or figures are produced on the sheet metal. It is used for decorative purposes or giving details like names, trademarks, specification, etc. on the sheet metal.

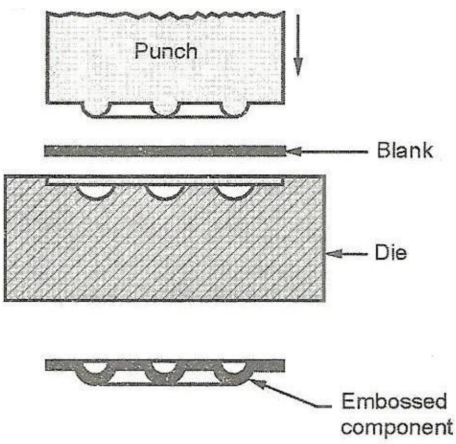

Fig. 4.20 : Embossing

4. Forming

In forming operation, sheet metal is stressed beyond its yield point so that it takes a permanent set and retains the new shape. In this process, the shape of punch and die surface is directly reproduced without any metal flow. This operation is used in the manufacturing of door ponels, steel furniture, air-craft bodies, etc.

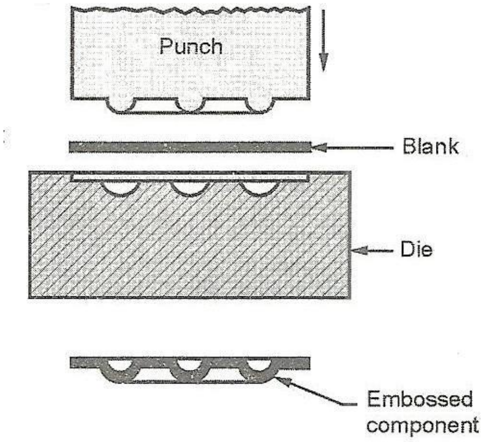

Fig. 4.20 : Embossing

5. Coining (Squeezing)

In coining operation, the metal having good plasticity and of proper size is place within the punch and die and a tremendous pressure is applied on the blank from both ends.

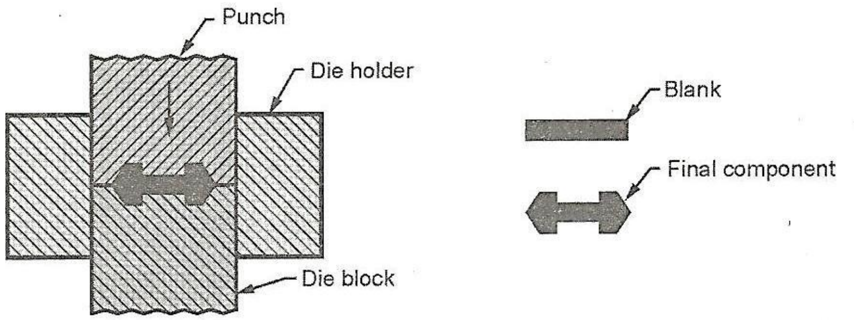

Fig. 4.22 : Coining

Under severe compressive loads, the metals flows in the cold state and fills up the cavity of the punch and die. This operation is used in the manufacturing of coins, medals, ornamental parts, etc.

4.6 Bending Operations

Bending in sheet-metal work is defined as the straining of the metal around a straight axis, as in figure 4.23.

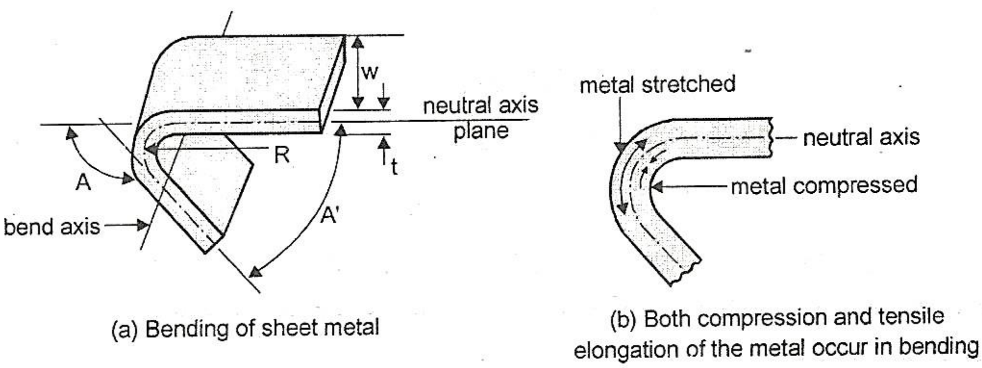

Figure 4.23. Bending Operations

During the bending operation, the metal on the inside of the neutral plane is compressed, while the metal on the outside of the neutral plane is stretched.

These strain conditions can be seen in figure. The metal is plastically deformed so that the ben takes a permanent set upon removal of the stresses that caused it. Bending produces little or no change in the thickness of the sheet metal.

4.6.1 V-bending and Edge bending

Bending operations are performed using punch and die tooling. The two common bending methods and associated tooling are V-bending, performed with a V-die, and edge bending, performed with a wiping die. These methods are illustrated in figure 4.24.

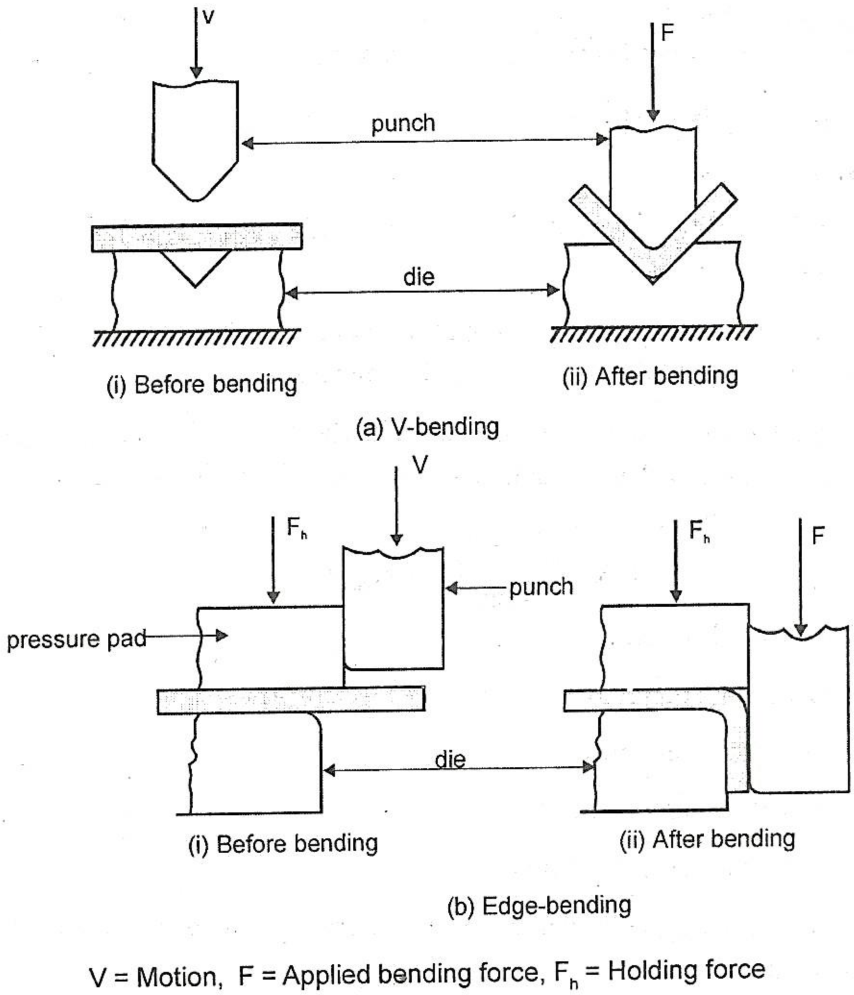

Figure 4.24. Two Common Bending Methods

In V-bending, the sheet metal is bend between a V-shaped punch and die. Included angles ranging from very obtuse to very acute can be made with V-dies.

V-bending is generally used for low-production operation. It is often performed on a press brake and the associated V-dies are relatively simple and inexpensive.

Edge bending involves cantilever loading of the sheet metal. A pressure pad is used to apply a holding force F_h to hold the base of the part against the die, while the punch forces the part to yield and bend over the edge of the die.

In the setup shown in figure 4.24, edge bending is limited to bends of 90° or less. More complicated wiping dies can be designed for bend angles greater than 90°.

Because of the pressure pad, wiping dies are more complicated and costly than V-dies and are generally used for high production work.

4.6.2 Important Factors of Bending

Bend Allowance

If the bend radius is small relative to stock thickness, the metal tends to stretch during bending. It is important to be able to estimate the amount of stretching that occurs, if any, so that the final part length will match the specified dimension. The problem is to determine the length of the neutral axis before bending to account for stretching of the final bent section. This length is called the bend allowance, and it can be estimated as follows:

— ( )

Where BA-Bend allowance, in (mm)

A- Bend angle (degrees)

R-bend radius in (mm)

t-Stock thickness, in.(mm)

– factor to estimate stretching

The values of predict that stretching occurs only if bend radius is small relative to sheet thickness.

Springback

When the bending pressure is removed at the end of the deformation operation, elastic energy remains in the bent part, causing it to recover partially toward its original shape. This elastic recovery is called springback, defined as the increase in included angle of the bent part relative to the included angle of the forming tool after the tool is removed. This is illustrated in figure 4.25 and is expressed as

———

Where SB- Spring back

- Included angle of the sheet-metal part (degrees)

- Included angle of the bending tool (degrees)

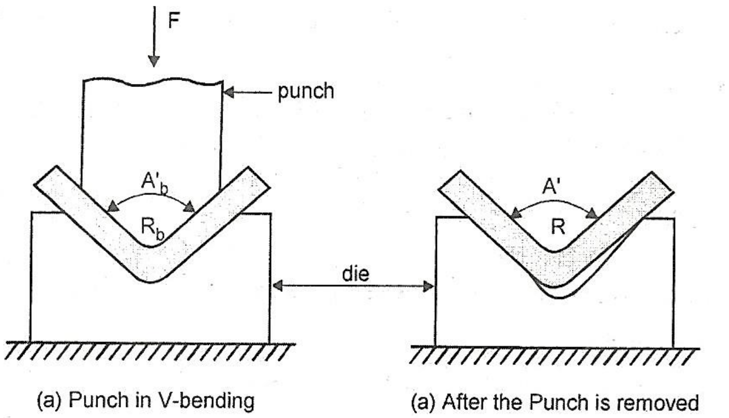

Figure 4.25 Springback Effect in V Bending

Bending force

The force required to perform bending depends on the geometry of the punch and die and the strength, thickness, and width of the sheet metal.

The maximum bending force can be estimated by means of the following equation, based on bending of a simple beam:

where F - Bending force, Ib (N)

TS - Tensile strength of the sheet metal, MPa

ω - Width of part in the direction of the bend axis, in mm

t - Stock thickness, in mm

D - Die opening dimension for V-bending

K_{bf} - 1.33 for V bending, and for edge bending, K_{bf}=0.33.

4.7 Drawing operations

Drawing is a sheet-metal forming operation used to make cup-shaped, box-shaped, or other more complex-curved, hollow-shaped parts.

It is performed by placing a sheet-metal blank over a die cavity and then pushing the metal into the opening with a punch, as in figure 4.26.

The blank must usually be held down flat against the die by a blankholder. Common parts made by drawing include beverage cans, ammunition shells, sinks, cooking pots, and automobile body panels.

4.7.1 Mechanics of drawing

Drawing of a cup-shaped part is the basic drawing operation, with dimensions and parameters as pictured in figure 4.26.

Let us examine the parameters of the operation and the mechanics of how it performed. A blank of diameter D_b is drawn into a die by means of a punch of diameter D_p.

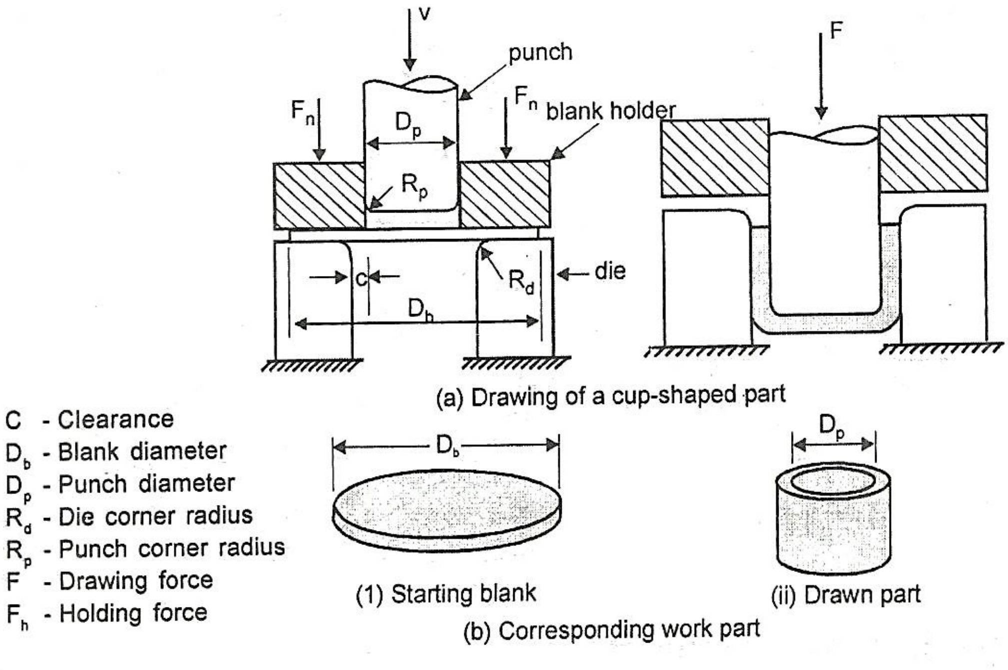

Figure 4.26. Drawing Operations

The punch and die must have corner radii, given by R_p and R_d. If the punch and die were to have sharp corners (R_p and R_d=0), a hole punching operation (and not a very good one) would be accomplished rather a drawing operation. The sides of the punch and die are separated by a clearance c.

This clearance in drawing is about 10% greater than the stock thickness:

$$C=1.1t$$

The punch applies a downward force F to accomplish the deformation of the metal, and a downward holding force F_h is applied by the blankholder, as shown in the sketch.

4.7.2 Stages in the deep drawing operation

As the punch proceeds downward its final bottom position, the work experiences a complex sequence of stresses and strains as it is gradually formed into the shape defined by the punch and die cavity.

The stages in the deformation process are illustrated in figure 4.27. As the punch first begins to push into the work, the metal is subjected to a bending operation.

The sheet is simply bent over the corner of the punch and the corner of the die, as in figure 4.27. The outside perimeter of the blank moves in towards the center in this first stage, but only slightly.

As the punch moves further down, a straightening action occurs in the metal that was previously bent over the die radius, as in the figure 4.27 (iii).

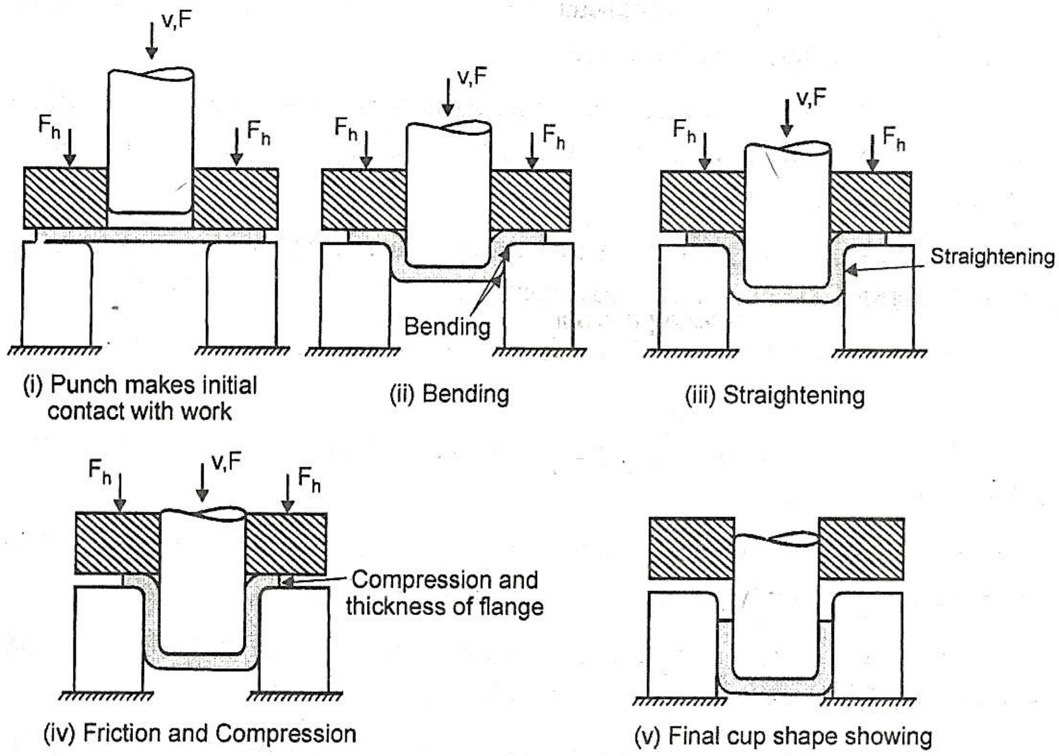

Figure 4.27 Stages in Deformation of the work in Deep Drawing

The metal at the bottom of the cup, as well as along the punch radius, has been moved downward with the punch, but the metal that was bent over the die radius must now be straightened in order to be pulled into the clearance to form the wall of the cylinder.

At the same time, more metal must added to replace that which is now being used in the cylinder wall. This new metal comes from the outside edge of the blank.

The metal in the outer portions of the blank is pulled or drawn toward the die opening to resupply the previously bent and straightened metal now forming the cylinder wall.

It is this type of metal flow through a constricted space from which the drawing process gets its name.

During this stage of the process, friction and compression play important roles in the flange of the blank.

For the material in the flange to move toward the die opening friction between the sheet metal and the surfaces of the blankholder and the die must be over come.

Initially, static friction is involved until the metal starts to move; then, after metal flow begins. Dynamic friction governs the process.

The magnitude of the holding force applied by the blankholder, as well as the friction conditions at the two interfaces, are determining factors in the success of this aspect of the drawing operation.

Lubricants or drawing compounds are generally used to reduce friction forces. In addition to friction, compression is also occurring in the outer edge of the blank.

As the metal in this portion of the blank is drawn toward the center, the outer perimeter becomes smaller.

Because the volume of metal remains constant, the metal is squeezed and becomes thicker as the perimeter is reduced.

This often results in wrinkling of the remaining flange of the blank, especially when thin sheet metal is drawn or when the blankholder force is too low.

It is a condition that cannot be corrected once it has occurred. The friction and compression effects are illustrated in figure 4.27.

The holding force applied by the blankholder is now seen to be a critical factor in deept drawing. If it is too small, wrinkling occurs.

If it is too large, it prevents the metal from flowing properly toward the die cavity, resulting in stretching and possible tearing of the sheet metal.

Determining the proper holding force involves a delicate balance between these opposing factors.

Progressive downward motion of the punch results in a continuation of the metal flow caused by drawing and compressions, as described previously.

In addition, some thinning of the cylinder wall occurs, as show in figure 4.27. The force being applied by the punch is opposed by the metal in the form of deformation and friction in the operation.

A portion of the deformation involves stretching and thinning of the metal as it is pulled over the edge of the die opening.

4.7.3 Defects in drawing

A number of defect can occur in a drawn product, some of which we have already alluded to. Following is a list of common defects, with sketches in figure 4.28

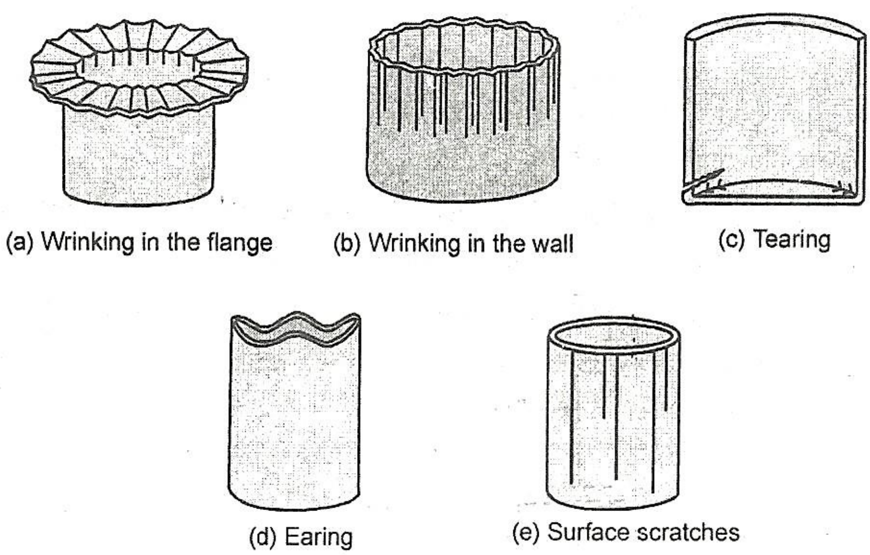

Figure 4.28 Defects in Drawing

a) **Wrinkling in the flange:** wrinkling in a drawn part consists of a series of ridges that form radially in the undrawn flange of the workpart due to compressive buckling.

b) **Wrinkling in the wall:** If and when the flange is drawn into the cup, these ridges appear in the vertical wall.

c) **Tearing:** Tearing is an open crack in the vertical wall, usually near the base of the drawn cup, due to high tensile stresses that cause thinning and failure of the metal at this location. This type of failure can also occur as the metal is pulled over a sharp die corner.

d) **Earing:** This is the formation of irregularities (called ears) in the upper edge of a deep drawn cup, caused by anisotropy in the sheet metal. If the material is perfectly isotropic, ears do not form.

e) **Surface scratches:** Surface scratches can occur on the drawn part if the if the punch and die are not smooth of if lubrication is insufficient.

4.8 Stretch Forming Operations

This method is used for producing large accurately contoured sheets. It has been developed in Second World War period itself.

Stretching is the process of stressing the work blank beyond its elastic limit by moving a form block towards the blank or sheet metal. The form block has projections of exact size required on the blank which is in the form of depressions on the same blank. Stretching is mainly done for straightening a part to obtain a straight axis and uniform cross-section. During stretching the blank, the spring back occurs after completing the stretching process.

Spring back is defined as the movement of the metal to resume its original position causing a decrease in ben angle after the applied force is withdrawn. So, this spring back has to be considered to obtain exact shape and size of the blank after the stretching process. Spring back always depends on material type, thickness of the blank, hardness of the blank and bend radius. Generally large bend radius produces greater spring back on the blank. But, this spring back can be avoided by

i. Over stretching using V-type form blocks, and
ii. By coining the metal slightly at the corners of the blank to remove elastic stresses called corner setting.

4.8.1 Methods of Stretch Forming

The stretch forming process can be done in two methods such as

1. Form – block method
2. Mating – die method