Sheet metal Forming

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5.1 Introduction
- Sheet metal work is very useful trade in engineering work and for our day-to-day needs.
- Many articles (household and engineering) whose production by other methods will be uneconomical and complicated are made from metal sheets.
- It is necessary to understand the construction and working of hand tools, sheet metal working machines and basic principles of different operations, to attain proficiency in the trade.
- For successful working in the trade, we must have a good knowledge of projective geometry, development of surfaces and properties of different metals.

5.2 Metals used in Sheet Metal Working
- There are different types of metals used in sheet metal work in the form of sheets and plates.
- The specifications of metal sheets are given in terms of their gauge numbers, length and width. Gauge number represents a thickness of metal sheets.
- The higher the gauge number, the smaller the thickness.
- Some of the important sheet metals are as follows:
  1. Black iron:
     - Black iron or uncoated sheet carries no artificial coating on its surface, but it is cheaper than other types of metal sheets.
     - Components made from this type of metal are pans, tanks, cabinets, almirahs, stove pipes, etc.
  2. Galvanised iron:
     - It is soft iron sheet carries zinc coating on its surface which make the surface good looking and rust resistant.
     - Components made from this type of metal are storage tanks, buckets, heating ducts, furnaces, gutters, pans, trunks, etc.
  3. Aluminium sheets:
     - Due to low strength of aluminium sheets they are not used in their pure form, hence suitable amount of silicon manganese, copper and iron are added.
     - It offers high resistance to corrosion and abrasion.
     - They are used in the manufacture of aero plane bodies, kitchenware and cabinets, doors, windows and building work, electrical appliances, etc.
  4. Copper sheets:
     - Copper sheets are costlier but offers good resistance to corrosion and relatively good in appearance.
     - They are reddish in colour, highly ductile and malleable.
     - They are used in applications like radiators of automobiles, heating appliance, gutters, hoods and components in chemical plants.
  5. Stainless steel:
     - Stainless steel offers high resistance to corrosion and exhibits a bright surface.
It is used in the manufacture of food containing equipments, dairy equipments, food processing plant, chemical plant, etc.

6. **Tin plates**
   - Tin plates are used for those iron sheets which are coated with pure tin.
   - Tin plates are used for making food containers, containers for cooking oils and ghee, cans, etc.

### 5.2.1 Hand Tools used in Sheet Metal Work

There are various types of hand tools used in sheet metal work. Some of them are as follows:

1. **Hammers**: Hammers of different shapes and sizes are used in sheet metal work. To avoid damage to the metal sheet, generally the face of hammers is made of soft materials.
2. **Mallet**: The purpose of wooden mallet is similar to hammer but used for light blows.
3. **Swages**: Swages are made to have curved surfaces. They are made in different sizes so as to suit any required curvature.
4. **Tongs**: Tongs are generally flat types and used for holding metal sheets during the Process.
5. **Punches and shears**: They are made in different shapes to suit the requirement like hollow punch for cutting circular blanks, grooving punch for locking grooves, etc.
6. **Stakes**: Stakes are used to form the metal sheets into different shapes. They work as supporting as well as forming tool.
7. **Tri square and scribers**: They are used to meet the marking requirements, similar to
8. **Wing compass**: It is used for drawing arcs and circles.
9. **Pliers**: Flat nose and round nose pliers are used for holding the workpiece and forming various shapes.
10. In addition to all the above tools some other type of commonly used tools are as follows:

    - Steel square
    - Bumping hammer
    - Mandrel
    - Straight edge
    - Chisels
    - Files

### 5.3 Sheet Metal Operations

Press operations may be grouped into two categories i.e. cutting operations and forming operations. In cutting operations, the sheet metal is stressed beyond its ultimate strength whereas; in forming operations the stresses are below the ultimate strength of the metal.

#### 5.3.1 Metal Cutting Operations

- In sheet metal cutting operations, the metal gets sheared hence these operations are also called as shearing operations.
- In these operations, the metal sheet is stressed beyond its ultimate strength.
- Metal cutting operations include following operations:
  1. Blanking
  2. Punching (Piercing)
  3. Notching
  4. Perforating
1. **Blanking**
   - Blanking is the cutting operation of a flat metal sheet and the article punched out is known as blank.
   - Blank is the required product of the operation and the metal left behind is considered as a waste. Refer Fig. 5.1 and Fig. 5.4 (a).

![Fig. 5.1: Blanking.](image1)

2. **Punching (Piercing)**
   - It is the cutting operation with the help of which holes of various shapes are produced in the sheet metal.
   - It is similar to blanking; only the main difference is that, the hole is the required product and the material punched out to form a hole is considered as a waste. Refer Fig. 5.2 and Fig. 5.3 (b).

![Fig. 5.2: Punching (Piercing](image2)
3. **Notching**
   - It is similar to blanking operation, but in this full surface of punch does not cut the metal.
   - In this operation, metal pieces are cut from the edges of a sheet. Refer Fig. 5.4.

4. **Perforating**
   - It is similar to piercing but the difference is that, to produce holes the punch is not of round shape.
– In this process, multiple holes which are very small and close together are cut in the sheet metal. Refer Fig. 5.4.

5. **Slitting**
– It is the operation of making an unfinished cut through a limited length only. Refer Fig. 5.5.

![Fig. 5.5: Slitting](image)

6. **Lancing**
– In this operation, there is a cutting of sheet metal through a small length and bending this small cut portion downwards. Refer Fig. 5.7.

![Fig. 5.7: Lancing](image)

7. **Shaving**
– This operation is used for cutting unwanted excess material from the periphery of a previously formed workpiece. Refer Fig. 5.8.

![Fig. 5.8: Shaving](image)

– In this process very small amount of material is removed.

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
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 starts at the cutting edge of the blade.

As the blade descends further, the small fractures meet and the metal is then sheared. Refer Fig. 5.9.

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.

### 5.3.2 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 the 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 curve 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**
   - Fig. 5.10 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. 5.10: U-bending](image)

b. **V-bending**
   - Fig. 5.11 shows V-bending operation in which wedge shape punch is used.
   - The angle of V may be acute, 90° or obtuse.

![Fig. 5.11: V-bending](image)

c. **Angle bending**
   - In this operation, there is a bending of a sheet metal at a sharp angle. Refer Fig. 5.12.

![Fig. 5.12 : Angle bending](image)

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 Fig. 5.13.

![Fig. 5.13: Curling](image)

- This process is used in the manufacturing of drums, pots, vessels, pans, etc.

e. **Roll bending**
- It is an operation in which generally large sheet metal parts are formed into curved sections with the help of rolls. Refer Fig. 5.14.

![Fig. 5.14: Roll bending](image)

- 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.

f. **Bending in a 4-slide machine**
- This type of machine is used for bending of relatively short pieces.
- These types of machines are available in different designs.
The lateral movements of the dies are controlled with the vertical die movement to form the part of desired shapes. Refer Fig. 5.15.

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 bend 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.

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. Refer Fig. 5.17.

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, trade marks specifications, etc. on the sheet metal. Refer Fig. 5.18.

![Fig. 5.18: Embossing](image)

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. Refer Fig. 5.19.

![Fig. 5.19: Forming](image)

   - This operation is used in the manufacturing of door panels, steel furniture, air-craft bodies, etc.

5. **Coining (Squeezing)**
   - In coining operation, the metal having good plasticity and of proper size is placed within the punch and die and a tremendous pressure is applied on the blank from both ends. Refer Fig. 5.20.
5.3.3 Deep Drawing
- It is a process of making the cup-shaped parts from a flat sheet-metal blank.
- To provide necessary plasticity for working, the blank is first heated and then placed in position over the die or cavity. Refer Fig. 5.21.

5.4 Die Classification
a. Based on the types of press operations:
   i. Shearing operations: Blanking, piercing, shearing, punching, perforating, notching, trimming, shaving, slitting, parting dies. All these are known as cutting dies.
ii. **Bending operations:** Angle bending, curling, forming, folding, plunging and reaming dies.

iii. **Drawing operations:** Flanging, embossing, bulging and cupping dies.

iv. **Squeezing operations:** Flattering, swaging, coining, sizing, pressing dies.

b. **Based on the type of die construction:**
   - Simple die
   - Compound die
   - Combination die
   - Progressive die
   - Transfer die
   - Multiple die, etc.

### 5.4.1 Types of Dies

1. **Simple dies:**
   - Simple dies perform single operation for each stroke of the press slide.
   - The operation can be any of the operation listed under cutting or forming operations.

2. **Compound dies:**
   - In this type of dies, two or more operation can be performed at one station.
   - Only cutting operations are carried out hence these dies are considered as cutting dies.

   ![Fig. 5.22: Compound die](image)

   - Fig. 5.22 shows a simple compound die in which a washer is made by one stroke of the press.
   - The washer is produced by simultaneous blanking and piercing operation.
   - These dies are used because they are more accurate and economical in mass production as compared to simple dies.
3. **Combination dies:**
   - In this also, more than one operation can be performed at one station.
   - It differs from compound die in such a way that, a cutting operation is combined with bending or drawing operation. Refer Fig. 5.23.

![Combination die diagram](image)

**Fig. 5.23: Combination die**

- The die ring, which is mounted on the die shoe, is counter bored at the bottom to allow the flange of a pad to travel up and down.
- This pad is held with the face of the die by a spring.
- A drawing punch of required shape is attached to the die shoe.
- The blanking punch is secured to the punch holder.
- A spring stripper strips the skeleton from the blanking punch.
- A knockout extending through the centre opening and through the punch stem ejects the port on the upstroke as it comes in contact with the knockout bar on the press.
- In operation, the blank holding ring descents as the part is blanked, then the drawing punch contacts and force the blank into the drawing die which is made in the blanking punch.

4. **Progressive die:**
   - A progressive die or follow on die has a series of stations.
   - At each station, an operation is performed on a workpiece during a press stroke.
   - Between the strokes, the piece in the metal strip is transferred to the next station.
   - A finished workpiece is made at each stroke of the press.
   - When the piercing punch cuts a hole in the strip, the blanking punch blanks out portion of the metal in which a hole has been produced at a previous station.
Hence, after each stroke a finished washer is produced. Refer Fig. 5.24.

Fig. 5.24: Progressive die

5. Transfer dies:
- It is similar to progressive dies, where the stock is fed progressively from one station to another.
- In transfer dies, already cut blanks are fed mechanically from station to station.

6. Multiple dies:
- These dies are also called as Gang dies.
- It produces two or more work-pieces at each stroke of the press.
- Number of simple dies and punches are ganged together, to produce more parts at each stroke of the press.

5.5 Spring Back
- In metal working processes, the total deformation of a workpiece will be the sum of elastic deformation and plastic deformation.
- We know that, elastic deformation is recoverable and plastic deformation is permanent.
- Therefore, at the end of a metal working process, when the pressure on the metal is released, there is an elastic recovery by the material.
- Due to this elastic recovery, total deformation of metal will get reduced.
- This phenomenon is called as spring back or elastic recovery.
- It is important in cold working operations like forming, bending, etc.
It depends upon the yield point strength of a metal.

The amount of spring back is difficult to predict hence cut and try methods are used.

To compensate for spring back, the cold deformation must be carried, beyond required limit by an amount equal to the spring back.

Compensation for Spring Back

Following are some techniques to prevent the spring back:

i) Over bending           ii) Bottoming
iii) Stretch forming      iv) Ironing

i. Over bending:
   - In this method, the workpiece is slightly over bent.
   - So, when it springs back it will achieve proper bend angle.
   - Over bending is done by setting the bending die and punch at smaller angle than required. Refer Fig. 5.25.

![Fig. 5.25: Spring back](image)

ii. Bottoming:
   - In this method, the workpiece is subjected to high localized compressive stresses.
   - This results in the high compressive strains in metal that set most of the metals past the yield point.
   - Hence, the spring back is avoided.

iii. Stretch forming:
   - Stretch forming strains the metal beyond elastic limit to give workpiece a permanent set.
   - This prevents the metal from spring back.

iv. Ironing:
   - Ironing can be accomplished by using wiping dies.
   - To iron the bend effectively, the distance between the punch and die should be kept less than the material thickness.

5.6 Riveting

- Riveting is a permanent fastening method.
- Although, in modern manufacturing practices welding has replaced riveting to a considerable extent still it has its own significance and use in several types of works.
Riveting is largely used in the manufacture of boilers, pressure vessels, rail wagons and coaches, furnace bodies, bridges, etc.

Rivets are permanent fastener and the plates joined together by riveting can be separated only either by chipping off the rivet heads or due to the failure of joint.

Rivets are generally classified according to the shapes of their heads.

Some commonly used forms of heads are shown in Fig. 5.26.

The snap or cup head is the most commonly used form and gives a very strong joint.

Pan head provides the maximum strength and is widely used where strength is primary consideration.

Conical head is generally formed by hand hammering and is mainly used in small work.

Countersunk head provides a flush head, as it does not project from the work surface and is used in ship-building.

![Rivet Heads](image)

Wrought iron and mild steel are the most commonly used materials for making rivets used in general engineering work although for very small work brass, copper and aluminium rivets are also used.

These rivets are installed or fitted by following methods:

i) Manually with hammer  ii) Pneumatic hammer
iii) Riveting machines  iv) Handheld squeezers

Rivets which are small enough and soft enough are fitted manually with hammer and bucking bar.

Hard rivets are fixed by riveting machines and pneumatic hammers.
Advantages:
- In case of riveting, there is no uneven heating and cooling of the workpiece and hence, the problem of thermal distortions is avoided.
- As the workpiece is not heated, during the process, additional (thermal) stresses are not developed.
- Less-skilled operator is required for the process.
- Inspection of riveting work is easy than welding work.

Disadvantages:
- Riveted joints require additional cover a plates, straps, clip angles and large number of rivets, which increases the weight of the structure.
- Riveted joints are not tight and leak proof as that of the welded joints.
- The cost of the riveted assembly is more than welded joint.
- The riveting process takes more time than the welding.

5.7 Cold Heading
- Cold forging is a cold upsetting process adapted for large scale production of small cold upset parts from a wire stock. For example, small bolts, rivets, screws, pins, nails and small machine parts, small balls for ball bearings, etc.
- The machine used in the process is similar to hot forging.
- The dies are used for forming the required shapes.
- The rod is fed up to stops through straightening rolls, cut to size and pushed into the header die.

![Fig. 5.27: Cold heading process](image-url)
– The rod is gripped ~the die and a punch operates on the projected part to apply pressure and form the head.
– During the process, a compressive force or impact causes the metal to flow in some determined shape of the die.
– Fig. 5.27 shows the cold forming process in which the head will form in the punch, in the die, in punch and die or in between punch and die.