Sheet metal operations - Other sheet metal forming processes

R. Chandramouli
Associate Dean-Research
SASTRA University, Thanjavur-613 401
# Table of Contents

**1. Other sheet metal forming processes:** ........................................ 3

1.1 Stretch forming: .............................................................................................................. 3
1.2 Rubber forming and hydroforming: ................................................................. 4
1.3 Spinning: ...................................................................................................................... 6
1.4 Tube spinning: ......................................................................................................... 8
1.5 Unconventional forming of sheet metal: ...................................................... 8
   1.5.1 Explosive forming: ............................................................................................ 8
   3.5.2 Magnetic pulse forming: ................................................................................ 9
   3.5.3 Electrohydraulic forming: ............................................................................... 9
   3.5.4 Superplastic forming: ...................................................................................... 10
   3.5.5 Blow forming / vacuum forming: ................................................................. 11
   3.5.6 Thermo forming: ........................................................................................... 12
   3.5.7 Laser/Plasma forming: ................................................................................... 12
1. Other sheet metal forming processes:

In this lecture we primarily focus on sheet metal operations that may not require forming press. Stretch forming, hydro forming, spinning are some of such processes.

1.1 Stretch forming:

Stretching of a sheet metal, by holding its ends or edges and bending it over a form block, simultaneously is called stretch forming. It is a process involving tensile force. Rigid die is used in the process. Materials with good ductility alone can be stretch formed. Further, in this process there is very little springback because of absence of nonuniform deformation or due to constant stress gradient across the thickness. This is due to high tensile stress applied. Aircraft wing panels, automobile door panels, window frames are some of the parts produced by this process. Tensile forces as high as 9 MN are used in forming aluminium skins for aircrafts. A single form block or punch is used alongwith gripping jaws. The forming is performed using hydraulically operated ram. First the sheet is bent around the form block. Then it is gripped and stretched applying large tensile force until it plastically deforms. The force required for the operation can be roughly calculated from the expression:

\[ F = Y_f L t \]

Where \( L \) is length of the sheet perpendicular to direction of stretching and \( t \) is thickness of sheet.

It can be shown that the strain gradient during stretch forming is:

\[ \frac{d\varepsilon}{dr} = -\frac{\varepsilon}{n} \]

From this expression we understand that the regions where strain is higher get more work hardened. This renders the less strain hardened neighborhood to
undergo larger strain thereby reducing the strain gradient and keeping constant strain gradient. This enables processing of highly strain-hardenable materials with ease.

**Stretch forming**

![Start of process](image)

**Fig. 3.1.1: Stretch forming**

### 1.2 Rubber forming and hydroforming:

In rubber forming, a polyurethane or rubber pad is used as the die material instead of a rigid material. Such materials have resistance to abrasion, good fatigue life. Pressures of the order of 10 MPa are typical in rubber forming. It is also known as Guerin process. A form block made of rigid material is used. The blank is placed over the form block. The rubber pad, which is attached to the ram, is then forced down on the sheet metal. Scratches on the sheet metal are avoided because the sheet is not in direct contact with the tool.

In hydroforming, fluid pressure acting over a flexible membrane is utilized for controlling the metal flow. Fluid pressure upto 100 MPa is applied. The fluid pressure on the membrane forces the sheet metal against the punch more effectively. Complex shapes can be formed by this process. In tube hydroforming, tubes are bent and pressurized by high pressure fluid. Rubber forming is used in aircraft industry.
Fig. 3.2.1: Tube hydro forming
1.3 Spinning:

Forming deeper axi-symmetric parts from a blank against a rotating mandrel is known as spinning. Rigid rollers are used as the spinning tool. The shaping of the circular blank over a rotating mandrel is done using rigid roller tool. In conventional spinning, the blank is bent around the rotating mandrel using a roller. Spun parts may have diameter as large as 6 m. Utensils are made by
conventional spinning, as this process is cheaper. Blank diameter is larger than the diameter of finished part in conventional spinning.

Shear spinning: Otherwise known as flow turning or hydrospinning, shear spinning involves reduction of thickness and the finished part has same diameter as the blank. Blanks upto 3m diameter can be shear spun. Large plastic deformation of the blank is involved in this process. The process involves thinning of the blank. The maximum spinning reduction $r$ is given by:

$$r = \frac{(t_0 - t_f)}{t_0}$$

where $t_f$ is the final thickness after spinning. It is obtained from the expression:

$$t_f = t_0 \sin \alpha$$

where $\alpha$ is semi-cone angle of the mandrel.

The tangential force during spinning is given by:

$$F_t = u t_0 \sin \alpha f$$

where $f$ is the feed.

The maximum reduction in thickness to which a blank can be subjected to by spinning without any crack is defined as spinnability. It is determined by spinning a circular blank over an ellipsoid mandrel. The maximum spinnability corresponds to a maximum reduction in area of 50%.

![Conventional Spinning](image)

**Fig.1.3.1: Sheet spinning**
1.4 Tube spinning:

In this process, reduction in wall thickness and increase in length of tubes is achieved with the help of a rotating mandrel and roller. Both internal and external spinning can be carried out. Roller can be moved forward or backward. Different profiles of the tube can be made in this process. The tangential force required is written as:

\[ \text{F}_t = \text{Y}_f(\text{t}_0-\text{t})f, \text{ where } f \text{ being the feed and } \text{Y}_f \text{ being flow stress of the material.} \]

Tube spinning is used in forming of rocket parts, automotive components etc.

1.5 Unconventional forming of sheet metal:

High energy rate forming processes such as explosive forming, electrohydraulic forming etc are discussed in this section.

1.5.1 Explosive forming:

In this process the high energy released due to explosion of an explosive is utilized for forming of sheets. No punch is required. A hollow die is used. The sheet metal is clamped on the top of the die and the cavity beneath the sheet is evacuated. The assembly is placed inside a tank filled with water. An explosive material fixed at a distance from the die is then ignited. The explosion causes shock waves to be generated. The peak pressure developed in the shock wave is given by:

\[ p = k(\frac{1}{\text{R}})^a \]

\( k \) is a constant, \( a \) is also a constant. \( R \) is the stand-off distance. Compressibility of the medium and its impedance play an important role on peak pressure. If the compressibility of the medium used is lower, then the peak pressure is higher. If the density of the medium is higher, the peak pressure of the shock wave is higher. Detonation speeds as high as 6500 m/s are common. The metal flow is also happening at higherspeed, namely, at 200 m/s. Strain rates are very high. Materials which do not loose ductility at higher strain rates can be explosively formed. The stand off distance also determines the peak pressure during explosive forming. Steel plates upto 25 mm thickness are explosive formed. Tubes can be bulged using explosive forming.
3.5.2 Magnetic pulse forming:

This process is also known as electromagnetic forming. In this sheet metal high velocity forming, the electrical energy stored in a series of capacitors is discharged through a magnetic coil. Mechanical force is induced due to the induced magnetic field on the work by the eddy current of the coil, opposing the original magnetic field. The forces repel each other. The work material is thus forced against the die cavity. Tube swaging, flaring, bulging etc can be made by this process.

3.5.3 Electrohydraulic forming:

A pair of electrodes immersed in water get connected by a thin wire. The high current discharged through the wire from a series of capacitors outside, creates spark. This in turn produces shock waves. The shock waves propagate through the water medium and help in forming the part. It is suitable for small parts as the energy generated in this process is lower than that in electromagnetic forming.

Fig. 3.5.1.1: Explosive Forming
3.5.4 Superplastic forming:

Some metals and alloys are capable of undergoing large uniform elongations – upto 2000% - without localized deformation, under certain conditions. Very fine grain structure is required – grain size of 10-15 microns. Superplastic forming is carried out at elevated temperature of 0.4 Tm. Materials with fine grains as well as resistance to grain growth at elevated temperatures can be superplastically formed. Materials with high strain rate sensitivity (m>0.3) resist necking even at large stresses. Aluminium, zinc alloys, nickel alloys are formed into complex shapes using superplastic forming. It is carried out at slow strain rates-less than 0.01 s⁻¹. Flow stress required during superplastic forming is very low – less than 30 MPa. The alloys, which undergo superplastic forming, have low strength and high ductility. Difficult to form alloys can be formed under superplastic conditions. Moreover, tools required need not have high strength. No residual stresses are induced in formed products. This process along with diffusion bonding is used for fabricating intricate parts. First the sheets are diffusion bonded. Then the unbounded regions are expanded inside a mold using air pressure. Such processes are used in aerospace industries for making stiff structural components. Alloys of titanium and aluminium are superplastically formed for making parts of aircrafts such as fuselage, ducts etc. Superplastic forming does not leave any residual stress on the formed part due to low stresses involved.
Fig. 3.5.4.1: Superplastic forming with diffusion bonding

The technology of superplastic forming involves combination of blow forming or thermoforming and diffusion bonding.

3.5.5 Blow forming / vacuum forming:

In blow forming, a pressure difference, created on both sides of the sheet metal causes the sheet metal to get stretched and formed to the shape of the die. Argon gas is used for pressurizing the sheet metal on one side, whereas on the other side, a low pressure of argon gas is maintained. Such back-pressure avoids cavitation of the sheet metal. Cavitation is the formation of inter-granular voids. Sometimes, vacuum is maintained on the other side of the sheet. This process is called vacuum forming.
3.5.6 Thermo forming:

This process is often used for forming plastics. Firstly, a male die stretches the sheet superplastically. Then gas pressure is used to force the sheet which has been stretched against the die.

3.5.7 Laser/Plasma forming:

If thermal stresses are induced locally in materials, localized deformations can occur. Such deformations can be utilized for forming of sheet metals. Laser or plasma can be used as heat source for causing localized heating. There may not be external stress required for the forming process. However, laser-assisted
forming may require small external forces for forming operations such as bending, tube forming, embossing etc.