Sheet Metal Forming

Introduction
Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

Metal Forming Process
Forming can be defined as the process in which the desired size and shape of the object are obtained through plastic deformation of material. The stresses induced during the process are greater than yield strength but should be less than the fracture strength. Different types of loading may be used depending on the process.

- Tensile
- Compressive
- Shear
- Bending

Classification of Metal Working Process
Metal working process may be classified as the ease with which metal may be formed into useful shapes by-

- Plastic deformation process
- Metal removal process

  a) PLASTIC DEFORMATION PROCESS
In this the volume and the mass of the metal are conserved and the metal is displaced from one location to another.

  b) METAL REMOVAL PROCESS
In this the material is removed from the stock in order to give it required shape.

Classification of Metal Forming Process
Metal forming process may be classified on the basis of type of forces applied to the work piece as it is formed into direct shape.
Sheet metal processing

The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size. If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized ‘blank’ from larger sheet.

Sheet metal forming processes

Sheet metal processes can be broken down into two major classifications and one minor classification

- **Shearing processes** -- processes which apply shearing forces to cut, fracture, or separate the material.
- **Forming processes** -- processes which cause the metal to undergo desired shape changes without failure, excessive thinning, or cracking. This includes bending and stretching.
- **Finishing processes** -- processes which are used to improve the final surface characteristics.
Shearing Process

1. **Punching**: shearing process using a die and punch where the *interior* portion of the sheared sheet is to be **discarded**.
2. **Blanking**: shearing process using a die and punch where the *exterior* portion of the shearing operation is to be **discarded**.
3. **Perforating**: punching a number of holes in a sheet
4. **Parting**: shearing the sheet into two or more pieces
5. **Notching**: removing pieces from the edges
6. **Lancing**: leaving a tab without removing any material

![Fig. Shearing Operations: Punching, Blanking and Perforating](image_url)

Forming Processes

- **Bending**: forming process causes the sheet metal to undergo the desired shape change by bending without failure. Ref fig.1
• **Stretching**: forming process causes the sheet metal to undergo the desired shape change by stretching without failure. Ref fig.2

![Fig. 2 Schematic illustration of a stretch-forming process.](image)

• **Deep Drawing**: forming process causes the sheet metal to undergo the desired shape change by drawing without failure. Ref fig.3

![Fig. 3 Schematic of the Drawing process.](image)
• **Roll forming:** Roll forming is a process by which a metal strip is progressively bent as it passes through a series of forming rolls. Ref fig.4

![Fig. 4 Eight-roll sequence for the roll forming of a box channel](image)

• **Punching or piercing**: The shearing of the material when the metal inside the contour is discarded. The punch A is piercing the hole for the washer.

![Punching or piercing](image)

• **Blanking**: The shearing of close contours, when the metal inside the contour is the desired part.

![Blanking](image)

• **Notching**: The punch removes material from the edge or corner of a strip or blank or part.

![Notching](image)
• **Shearing**: The separation of metal by the movement of two blades operated based on shearing forces.

**Dies and Punches**

**Simple**: single operation with a single stroke
**Compound**- two operations with a single stroke

**Combination**- two operations at same station.

**Progressive**- two or more operations at two or more stations with each press stroke, creates what is called a strip development Punches and dies are designed so that successive stages in the forming of the part are carried out in the same die on each stroke of the press. Progressive dies are also known as multi-stage dies.

**Limiting draw ratio (LDR)**

Drawability is a ratio of the initial blank diameter (Do) to the diameter of the cup drawn from the blank to punch diameter (DP)

\[
LDR \approx \left( \frac{D_o}{D_p} \right)_{max} \approx e^\eta
\]

Where \(\eta\) is an efficiency term accounting for frictional losses. Normally the average maximum reduction in deep drawing is \(~ 50\%)\.
Forming limit criteria

Tensile test only provides ductility, work hardening, but it is in a uniaxial tension with frictionless, which cannot truly represent material behaviours obtained from unequal biaxial stretching occurring in sheet metal forming. Sheet metal formability tests are designed to measure the ductility of a material under condition similar to those found in sheet metal forming.

Defects in Forming

Cracks
Edge Forming Strain on surface

- Radial cracks in the flanges and edge of the cup due to not sufficient ductility to withstand large circumferential shrinking.
- Wrinkling of the flanges or the edges of the cup resulting from buckling of the sheet (due to circumferential compressive stresses) solved by using sufficient hold-down pressure to suppress the buckling.
- Surface blemishes due to large surface area. EX: orange peeling especially in large grain sized metals because each grain tends to deform independently use finer grained metals.
- Mechanical fibering has little effect on formability.
- Crystallographic fibering or preferred orientation may have a large effect. Ex: when bend line is parallel to the rolling direction, or earing in deep drawn cup due to anisotropic properties.

Simple Calculation Formulas:

**Clearance in Sheet Metal Cutting**

- Distance between the punch and die
- Typical values range between 4% and 8% of stock thickness
  - **If too small, fracture lines pass each other, causing double burnishing and larger force**
  - **If too large, metal is pinched between cutting edges and excessive burr results**

For a round blank of diameter $D_b$:

![Diagram of clearance in sheet metal cutting]
Blanking punch diameter = \( D_b - 2c \)
Blanking die diameter = \( D_b \)
For a round hole of diameter \( D_h \):
Hole punch diameter = \( D_h \)
Hole die diameter = \( D_h + 2c \)
• Recommended clearance can be calculated by: \( c = at \); where \( c \) = clearance; \( a \) = allowance; and \( t \) = stock thickness
• Allowance \( a \) is determined according to type of metal

<table>
<thead>
<tr>
<th>Metal group</th>
<th>( a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1100S and 5052S aluminum alloys, all tempers</td>
<td>0.045</td>
</tr>
<tr>
<td>2024ST and 6061ST aluminum alloys; brass, soft cold rolled steel, soft stainless steel</td>
<td>0.060</td>
</tr>
<tr>
<td>Cold rolled steel, half hard; stainless steel, half hard and full hard</td>
<td>0.075</td>
</tr>
</tbody>
</table>

**Cutting Forces**

\[
F = S \times t \times L;
\]
Where: \( S \) = Shear strength; \( t \) = thickness; \( L \) = length of cutting edge; Important to determine the press capacity (tonnage)
If shear strength is not known cutting force can be estimated as: \( F = 0.7 \times TS \times t \times L \) Where \( TS \) = Ultimate tensile strength

**Stretching during Bending**

• If bend radius is small relative to stock thickness, metal tends to stretch during bending
• Important to estimate amount of stretching, so that final part length = specified dimension
• Problem: to determine the length of neutral axis of the part before bending
Where,
\[
BA = 2\pi \frac{A}{360} (R + K_{ba}t)
\]
- If \( R < 2t \), \( K_{ba} = 0.33 \)
- If \( R \geq 2t \), \( K_{ba} = 0.50 \)

and \( K_{ba} \) is factor to estimate stretching
Bending Force

Maximum bending force estimated as follows:

Where,

\( F \) = bending force

\( TS \) = tensile strength of sheet metal

\( w \) = part width in direction of bend axis

\( t \) = stock thickness

\( D \) = die opening dimension

\[
F = \frac{K_b TS w t^2}{D}
\]

- For V-bending, \( K_b = 1.32 \)
- For edge bending, \( K_b = 0.92 \)