Outline

- Introduction
- Cutting Operations
  - Shearing
  - Blanking
  - Piercing (punching)
- Sheet Metal Cutting Analysis
- Bending Operations
- Types of bending
- Bending analysis

Historically

Sheet metal stamping was developed as a mass production technology for the production of bicycles around the 1890's. This technology played an important role in making the system of interchangeable parts economical (perhaps for the first time).

Sheet Metalworking

- Cutting and forming operations performed on relatively thin sheets of metal which are produced by rolling
- Thickness of sheet metal = 0.4 mm (1/64 in) to 6 mm (1/4 in)
- Thickness of plate stock > 6 mm
- Operations usually performed as cold working (except when the stock is thick or the metal is brittle then warm working is performed)

Sheet and Plate Metal Products

- Sheet and plate metal parts for consumer and industrial products such as:
  - Automobiles and trucks
  - Airplanes
  - Railway cars and locomotives
  - Farm and construction equipment
  - Small and large appliances
  - Office furniture
  - Computers and office equipment

Sheet Metal Processes

1. Cutting
   - Shearing to separate large sheets; or cut part perimeters or make holes in sheets
2. Bending
   - Straining sheet around a straight axis
3. Drawing
   - Forming of sheet into convex or concave shapes

Advantages of Sheet Metal Parts

- High strength
- Good dimensional accuracy
- Good surface finish
- Relatively ............
- For large quantities, economical mass production operations are available
Cutting

just before the punch contacts work

punch begins to push into work, causing plastic deformation

Fracture is initiated at the opposing cutting edges

punch penetrates into work causing a smooth cut surface

Quality of sheared edges

• Depends on process used
  • Edges can be rough, not square, and contain cracks, residual stresses, and a work-hardened layer
  • These are all detrimental to the …………. of the sheet
• Quality can be improved by control of …………, tool and die design

Clearance in Sheet Metal Cutting

Force required for shearing:

\[ F = f \times t \]

- \( f \) is the fraction of the thickness through which the punch has traveled
• Incorrect clearance requires higher ……………
  • and causes excessive burr.

Quality of sheared edges

• Low clearance
  – ……………
  – ……………
  – ……………
• High clearance
  – ……………
  – ……………
  – ……………

As clearance increases, the material tends to be pulled into the die rather than be sheared
Cutting Operations

Shearing
- Typically used to cut large sheets into smaller sections for subsequent operations

Blanking

Punching

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 $D_b$:
- 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 = $D_h + 2c$

Clearance in Sheet Metal Cutting

- Recommended clearance can be calculated by:
  \[ c = at \]
  where $c = \text{clearance}$; $a = \text{allowance}$; and $t = \text{stock thickness}$
- Allowance $a$ is determined according to type of metal

Metal group
- 1100S and 5052S aluminum alloys, all tempers
- 2024ST and 6061ST aluminum alloys; brass, soft cold rolled steel, soft stainless steel
- Cold rolled steel, half hard; stainless steel, half hard and full hard

Angular Clearance

- Purpose: allows slug or blank to drop through die
- Typical values: 0.25° to 1.5° on each side

Other Cutting Operations

Shaving
Fine Blanking
**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

**Cutting Forces**

- Shearing forces can be reduced by ........... cutting tools
- This is analogous to the action of hand scissors, in which the blades close at an angle rather than parallel to each other.
- Angled cutting tools reduce the instantaneous sheared .......... thus reduce the ........... required.

**Bending**

- Straining sheetmetal around a straight axis to take a permanent bend

- Metal on inside of neutral plane is compressed, while metal on outside of neutral plane is stretched

**Types of Sheetmetal Bending**

- **V-Bending**
  - For low production
  - Performed on a press brake
  - V-dies are simple and inexpensive

- **Edge Bending**
  - For high production
  - For angles .........
  - Pressure pad required
  - Dies are more complicated and costly
Types of Sheetmetal Bending

- With intelligent design and multiple press strokes even complex shapes can be produced.
- To successfully design the tooling for operation such as this, it requires a knowledge of the major parameters associated with bending.
- These parameters include: minimum bend radius, the spring back angle and the press force.

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.

\[ BA = 2\pi A \frac{(R + K_{ba}t)}{360} \]

Where,
- \( BA \) = bend allowance
- \( A \) = bend angle
- \( R \) = bend radius
- \( t \) = stock thickness
- \( K_{ba} \) is factor to estimate stretching
  - If \( R < 2t \), \( K_{ba} = 0.33 \)
  - If \( R \geq 2t \), \( K_{ba} = 0.50 \)

Springback in Bending

To compensate for SB:
- **Overbending** – ............ punch angle and ............ punch radius
- **Bottoming** – plastically deform with additional punch pressure

Springback = increase in included angle of bent part relative to included angle of forming tool after tool is removed

Reason for springback:
- When bending pressure is removed, elastic energy remains in bent part, causing it to recover partially toward its original shape

Analysis of Bending

\[ SB = \frac{A' - A_b}{A_b} \]

Where,
- \( A \) = included angle of the sheet metal part
- \( A_b \) = included angle of the bending tool
**Bending Force**

Maximum bending force estimated as follows:

\[
F = \frac{K_{bf} TS wt^2}{D}
\]

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

- For V- bending, \( K_{bf} = 1.33 \)
- For edge bending, \( K_{bf} = 0.33 \)

---

**Next Topic:**

*Deep Drawing*