SHEET METALWORKING

1. Cutting Operation
2. Bending Operation
3. Drawing
4. Other Sheet-metal Forming
5. Dies and Presses
6. Sheet-metal Operation
7. Bending of Tube Stock
Introduction

- Cutting and forming thin sheets of metal usually performed as cold working
- Sheet metal = 0.4 (1/64) to 6 mm (1/4in) thick
- Plate stock > 6 mm thick
- Advantage - High strength, good dimensional accuracy, good surface finish, economical mass production (low cost).
- Cutting, bending, drawing

Localized necking

Because $\nu=0.5$ in plasticity,

$$\varepsilon_1 = -2\varepsilon_2 = -2\varepsilon_3$$
Sheet Metalworking Terminology

• “Punch-and-die”
  – Tooling to perform cutting, bending, and drawing

• “Stamping press”
  – Machine tool that performs most sheet metal operations

• “Stampings”
  – Sheet metal products
Sheet-metal Characteristics

• Elongation – the capability of the sheet metal to stretch without necking and failure.
• Yield-point elongation
  – Lüder’s bands on Low-carbon steels and Al-Mg alloys. Lüder’s bands can be eliminated by cold-rolling the thickness by 0.5-1.5%.
• Anisotropy
  – Crystallographic and mechanical fibering anisotropy
• Grain Size effect on mechanical properties
• Residual Stress, Springback and Wrinkling
• Testing method
  – Cupping test
  – Forming Limit Diagram
1. Cutting Operation

• Cutting operation
  – Plastic deformation
  – Penetration (1/3 thickness)
  – Fracture

• **Shearing** using a machine called power shear or square shear.

• **Blanking** – shearing a closed outline (desired part called blank)

• **Punching** – sheared part is slag (or scrap) and remaining stock is a desired part
Cutting Operation

- Punch
- Die
- Rollover
- Burnish
- Fracture zone
- Burr
Analysis

• Clearance - 4-8% but sometime 1% of thickness
  – Too small – fracture does not occur requiring more force.
  – Too large – Get pinched and cause an excessive burr

• Clearance: c=a*t
  – Metal group
    a
  – 1100S and 5052S aluminum alloys, all tempers  0.045
  – 2024ST and 6061ST aluminum alloys;
    brass, soft cold rolled steel, soft stainless steel  0.060
  – Cold rolled steel, half hard; stainless steel,
    half hard and full hard  0.075
Die, blank and punch size

For a round blank,
Blank punch diameter = $D_b - 2c$
Blank die diameter = $D_b$

For a round hole,
Hole punch diameter = $D_h$
Hole die diameter = $D_h + 2c$

Angular clearance of 0.25° to 1.5°

Cutting forces: $F = S \times t \times L = 0.7 \times TS \times t \times L$

where $S$ = Shear strength
$t$ = thickness
$L$ = length of cutting edge
$TS$ = Ultimate tensile strength
Other Cutting Operations

• Cutoff and Parting

• Slotting, Perforating and Notching

• Trimming, Shaving and Fine Blanking
2. Bending Operations

• V-bending

• Edge Bending
Other Bending Operation

• Flanging
• Hemming
• Seaming
• Curling
• Channel,
• U-bending
  Air bending,
  Offset bending,
  Corrugating and
  Tube forming
3. Drawing

- Basic drawing operation – a cup-shape part
Detail Steps of Drawing

1. Initial Contact
2. Bending
3. Straightening
4. Friction & Compression
5. Final Shape
Analysis of Drawing

• Measure of Drawing
  – Drawing ratio: \( DR = \frac{D_b}{D_p} \) feasible if \( DR < 2 \)
  – Reduction: \( r = \frac{D_b - D_p}{D_b} \) feasible if \( r < 0.5 \)
  – Crude measures of the severity of a deep drawing operation

• Drawing Forces: \( F = \pi D_p t (TS) \left( \frac{D_b}{D_p} - 0.7 \right) \)
  Max at 1/3 length

• Holding Force: \( F_h = 0.015Y\pi \left[ D_b^2 - \left( D_p + 2.2t + 2R_d \right)^2 \right] \)
Other Drawing Operation

- Redrawing
- Drawing without a Blankholder
- Not cylindrical cups
- Defects
  - Wrinkling in the flange
  - Wrinkling in the wall
  - Tearing
  - Earing – Anisotropy in sheet metal
  - Surface scratch
Forming-Limit Diagram

- A grid pattern of circles, typically 2.5 to 5mm in diameter, produced by electrochemical or photoprinting.
- After drawing, the circles are observed for failure.
- The major strain is on the major direction and magnitude of strain.
4. Other Sheet-Metal Operations

- With Metal Tooling
  - Ironing
  - Coining and Embossing
  - Lancing

- Using hydrostatic pressure
  - Guerin Process – Rubber pad
  - Hydroforming - Hydraulic fluid
5. Dies and Presses

• Stamping Die
  – Punch
  – Die
  – Stripper

• Types
  – Simple
  – Compound
  – Progressive

• Press
  – Hydraulic
  – Mechanical