SHEET METALWORKING

1. Cutting Operation
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6. Sheet-metal Operation
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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

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
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
    - 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 = Dp - 2c
- Blank die diameter = Db

For a round hole,
- Hole punch diameter = Dh
- Hole die diameter = Dh + 2c
- Angular clearance of 0.25° to 1.5°

Cutting forces: F = S * t * L = 0.7 * TS * t * 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

Analysis of Bending I

- Bend Allowance - length of a neutral axis
  \[ A = 2z \left( \frac{1}{360} (R + K_s t) \right) \]
  \( A \) = Bend Angle
  \( R \) = Bend Radius
  \( t \) = Stock Thickness
  \( K_s \) = A Factor to Estimate Stretch
  \( K_s = 0.33 \) if \( R > 2t \) and \( K_s = 0.5 \) if \( R < 2t \)
- Springback
  \[ SB = \frac{A - A'}{A} \]
  \( A \) = included angle of the sheet metal part
  \( A' \) = included angle of the bending tool

Analysis of Bending II

- Compensate for spring back
  - Overbending
  - Bottoming – squeezing the part at the end of the stroke
- Bending force: \[ F = \frac{K_bf (TS) w t^2}{D} \]
  \( K_bf = 1.33 \) for V-bending
  \( K_bf = 0.33 \) for Edge-bending
  \( w \) = width of part
  \( t \) = stock thickness
  \( D \) = die opening dimension
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

Analysis of Drawing
- Measure of Drawing
  - Drawing ratio: \( DR = \frac{D_p}{D_b} \) 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: \( F = \pi D_p TS \left( \frac{D_p}{D_b} - 0.7 \right) \)
  Max at 1/3 length
- Holding Force: \( F_h = 0.015 \pi F \left( D_p + 2.2r + 2R_i \right)^2 \)

Other Drawing Operation
- Redrawing
- Drawing without a Blankholder
- Not cylindrical cups
- Defects (Fig. 20.24)
  - Wrinkling in the flange
  - Wrinkling in the wall
  - Tearing
  - Earing – anistropy 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

6. Other Types Sheet Metal Operations

- Stretch Forming
- Roll Bending and Forming
- Spinning – make cone, hemisphere, tubes
  - Conventional
  - Shear
  - Tube
- High-Energy-Rate Forming
  - Explosive Forming
  - Electrohydraulic forming
  - Electromagnetic forming

7. Bending of Tube Stock

- Bending without collapse and fold
- To avoid flattening
  - \( R(bend \radius) > 1.5D(tube \ diameter) \) with a mandrel
  - \( R>3D \) without mandrel.

- Types
  - Stretch bending
  - Draw bending (rotating form)
  - Compression bending (form block)
  - Roll bending (similar to sheet metal)