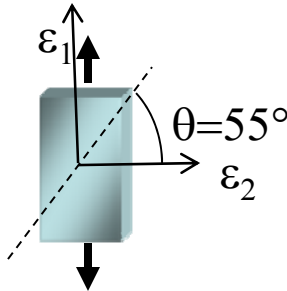


SHEET METALWORKING

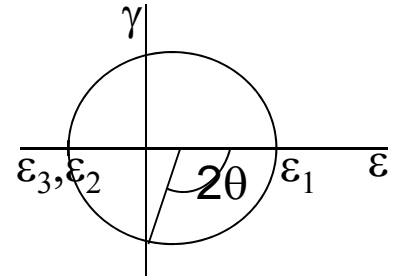
1. Cutting Operation
2. Bending Operation
3. Drawing
4. Other Sheet-metal Forming
5. Dies and Presses
6. Sheet-metal Operation
7. Bending of Tube Stock

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,
 $\epsilon_1 = -2\epsilon_2 = -2\epsilon_3$

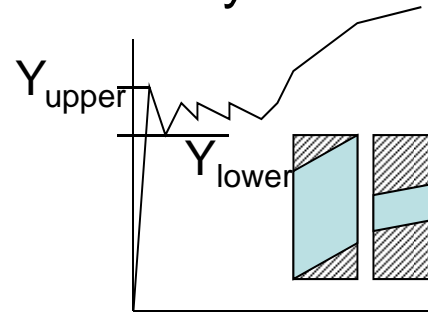


Sheet Metalworking Terminology

- “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

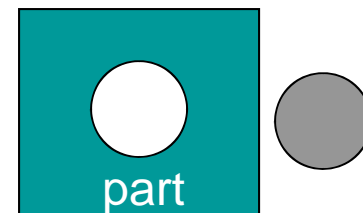
- Elongation – the capability of the sheet metal to stretch without necking and failure.
- Yield-point elongation
 - Lüder's bands on Low-carbon steels and Al-Mg alloys. Lüder's bands can be eliminated by cold-rolling the thickness by 0.5-1.5%.



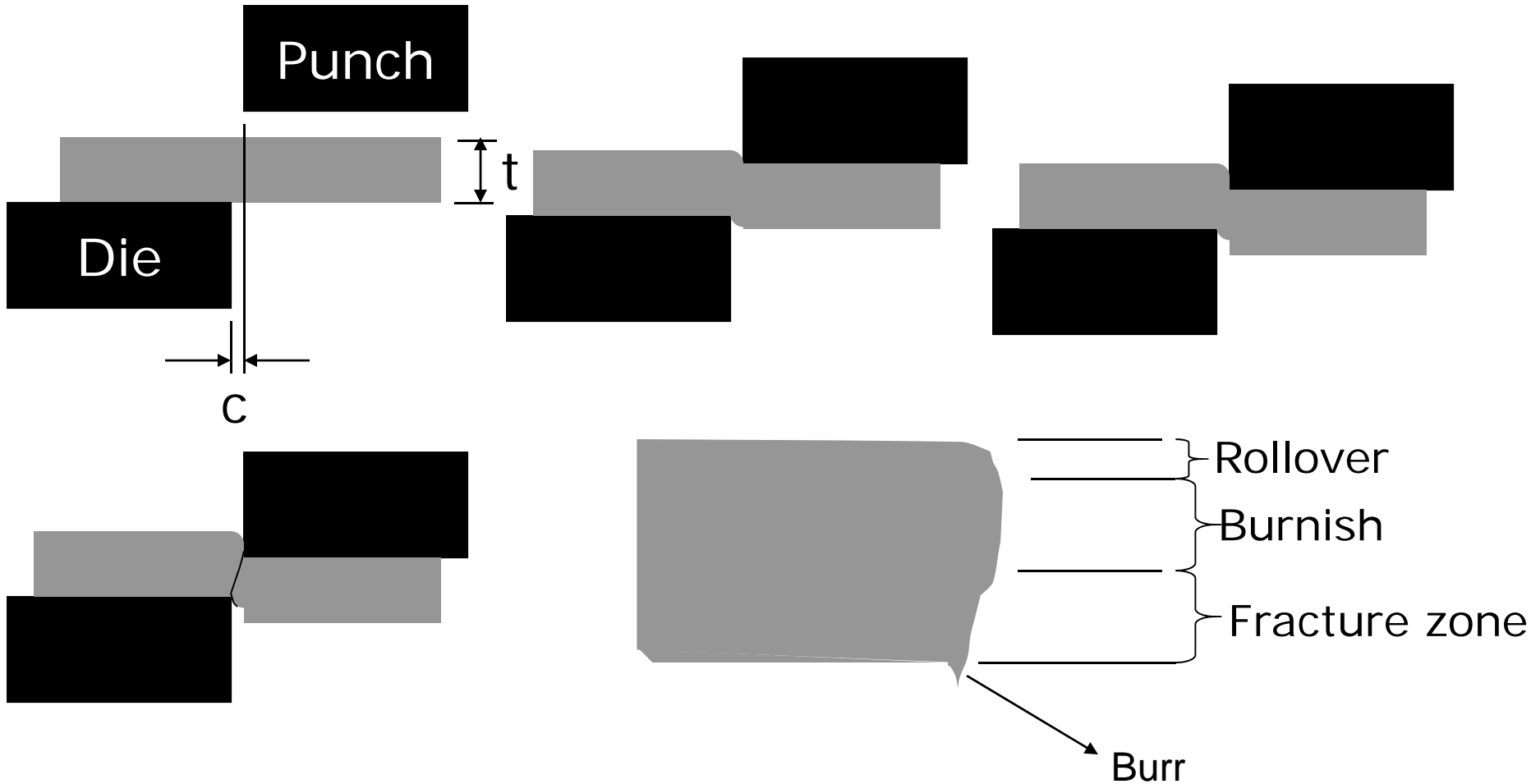
- Anisotropy
 - Crystallographic and mechanical fibering anisotropy
- Grain Size effect on mechanical properties
- Residual Stress, Springback and Wrinkling
- Testing method
 - Cupping test
 - Forming Limit Diagram

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



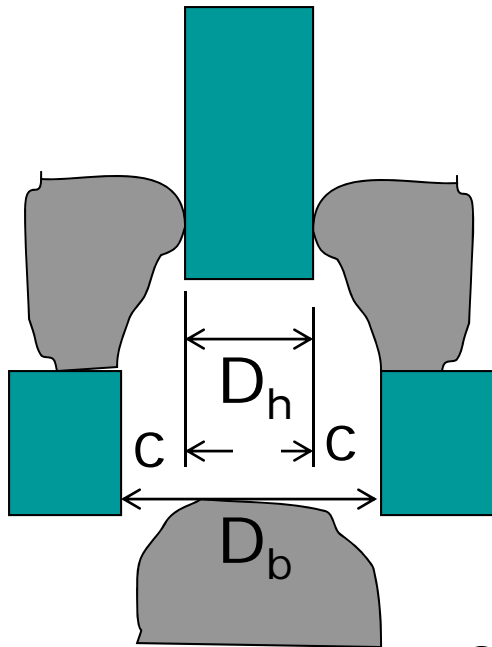
Cutting Operation



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°

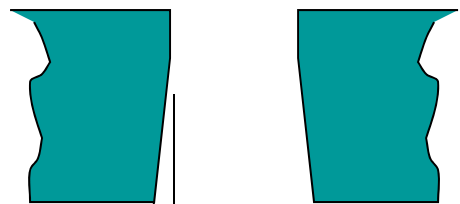
Cutting forces: $F = S * t * L = 0.7 * TS * t * L$

where $S =$ Shear strength

$t =$ thickness

$L =$ length of cutting edge

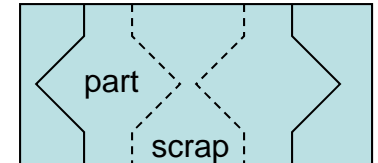
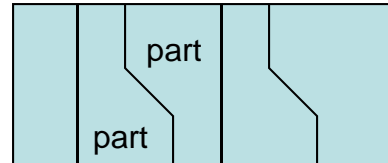
$TS =$ Ultimate tensile strength



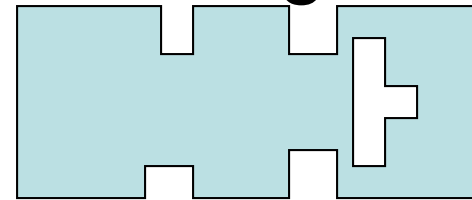
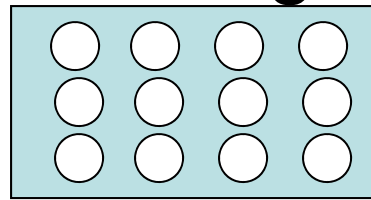
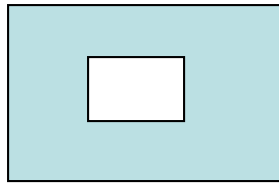
Angular clearance

Other Cutting Operations

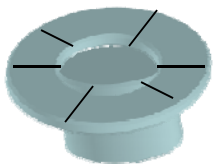
- Cutoff and Parting



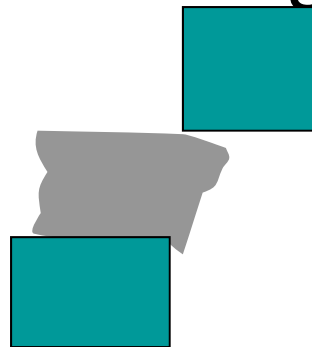
- Slotting, Perforating and Notching



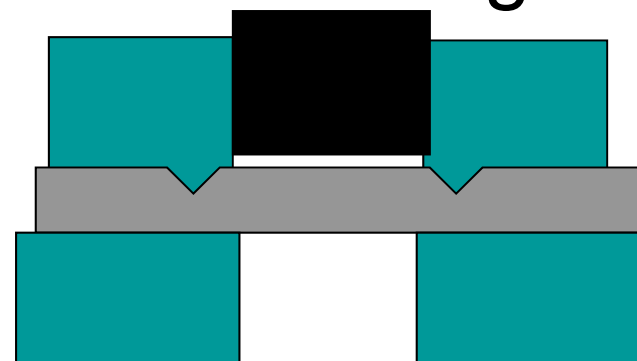
- Trimming, Shaving and Fine Blanking



Trimming



Shaving



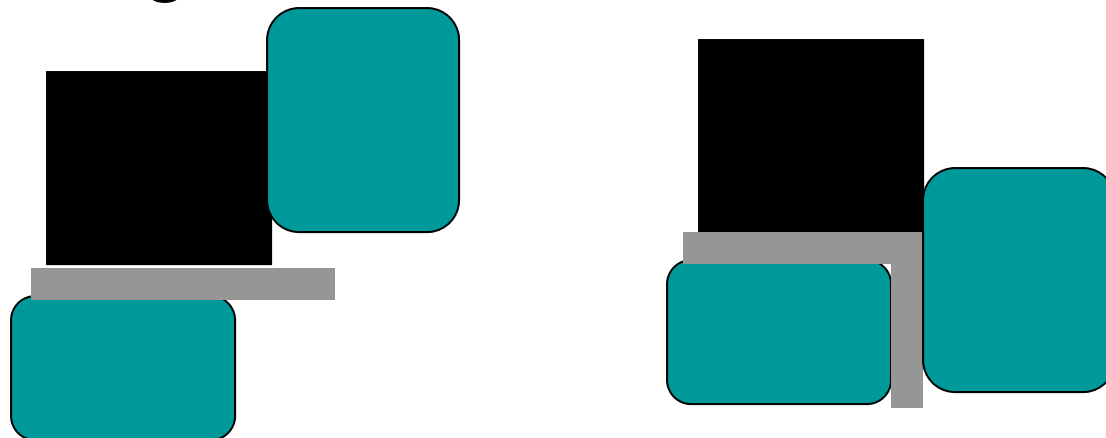
Fine Blanking

2. Bending Operations

- V-bending

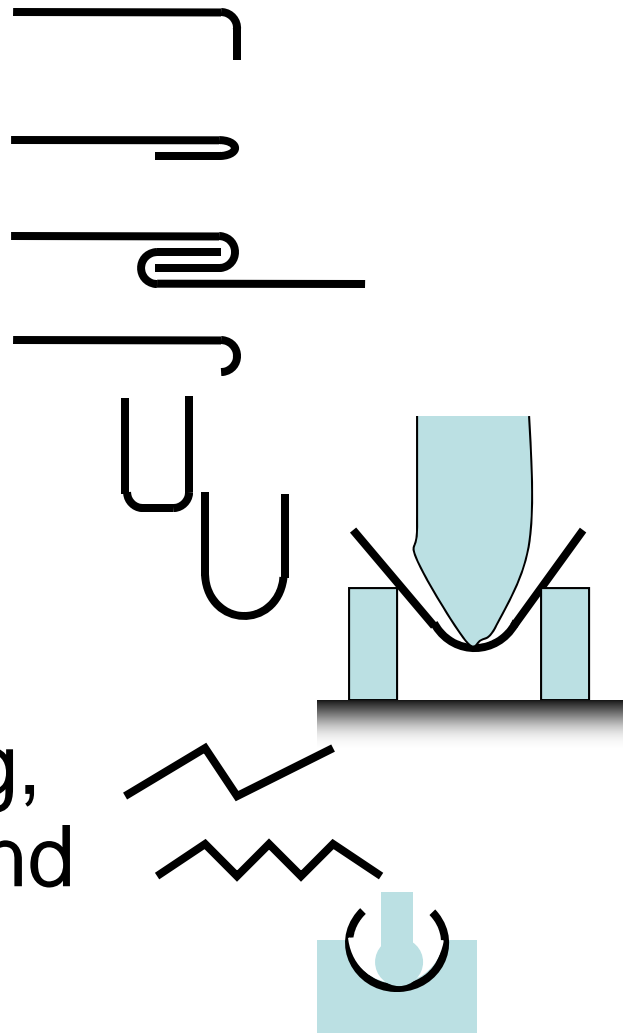


- Edge Bending



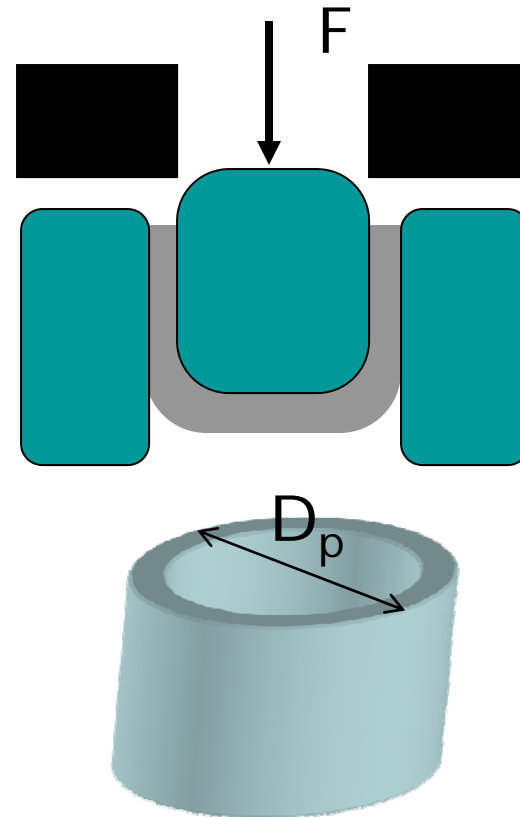
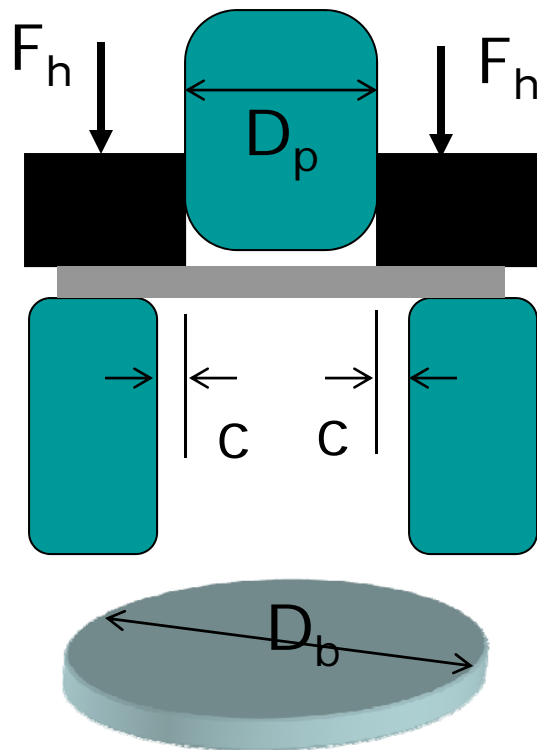
Other Bending Operation

- Flanging
- Hemming
- Seaming
- Curling
- Channel,
- U-bending
- Air bending,
- Offset bending,
- Corrugating and
- Tube forming

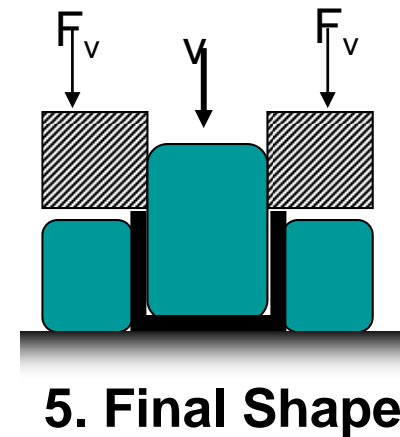
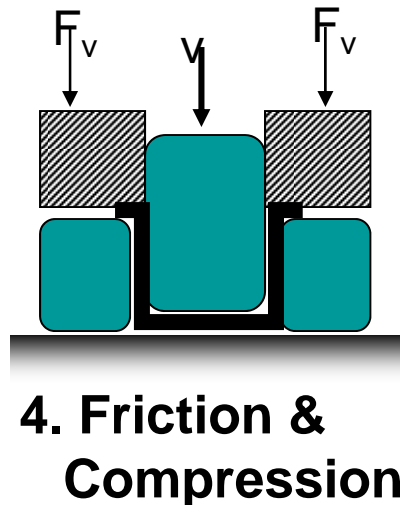
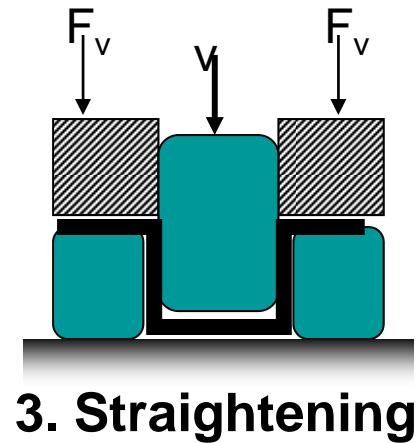
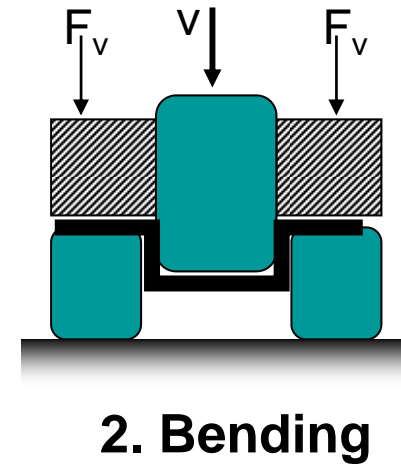
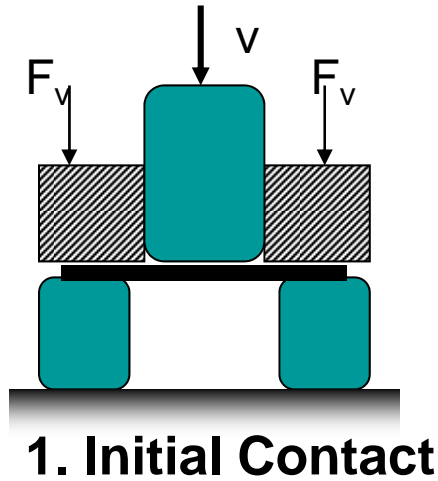


3. Drawing

- Basic drawing operation – a cup-shape part



Detail Steps of Drawing

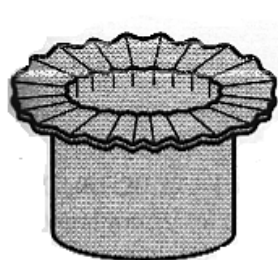
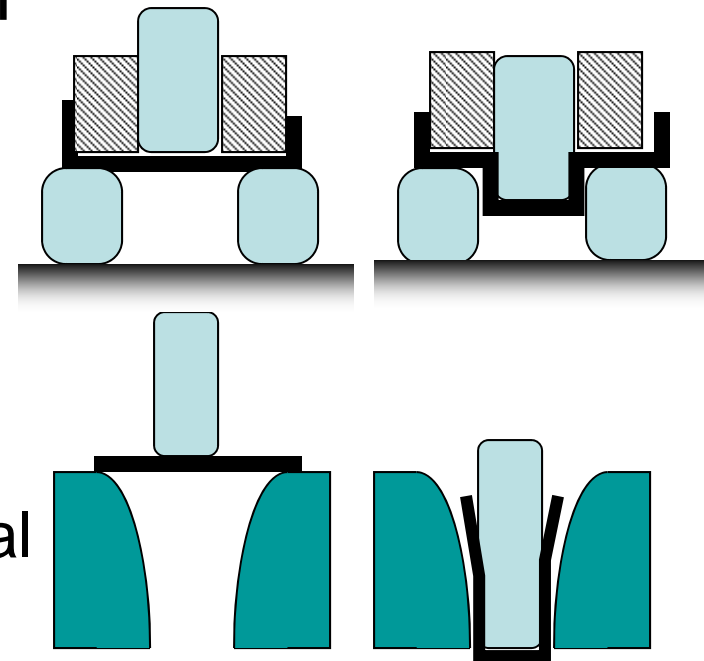


Analysis of Drawing

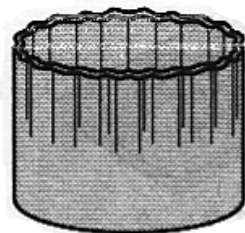
- Measure of Drawing
 - Drawing ratio: $DR = \frac{D_b}{D_p}$ feasible if $DR < 2$
 - Reduction: $r = \frac{D_b - D_p}{D_b}$ feasible if $r < 0.5$
 - Crude measures of the severity of a deep drawing operation
- Drawing Forces: $F = \pi D_p t (TS) \left(\frac{D_b}{D_p} - 0.7 \right)$
Max at 1/3 length
- Holding Force: $F_h = 0.015Y\pi \left[D_b^2 - (D_p + 2.2t + 2R_d)^2 \right]$

Other Drawing Operation

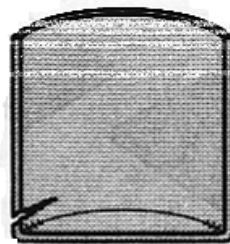
- Redrawing
- Drawing without a Blankholder
- Not cylindrical cups
- Defects
 - Wrinkling in the flange
 - Wrinkling in the wall
 - Tearing
 - Earing – Anisotropy in sheet metal
 - Surface scratch



(a)
Wrinkling in the flange



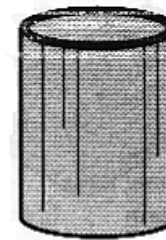
(b)
Wrinkling in the wall



(c)
Tearing



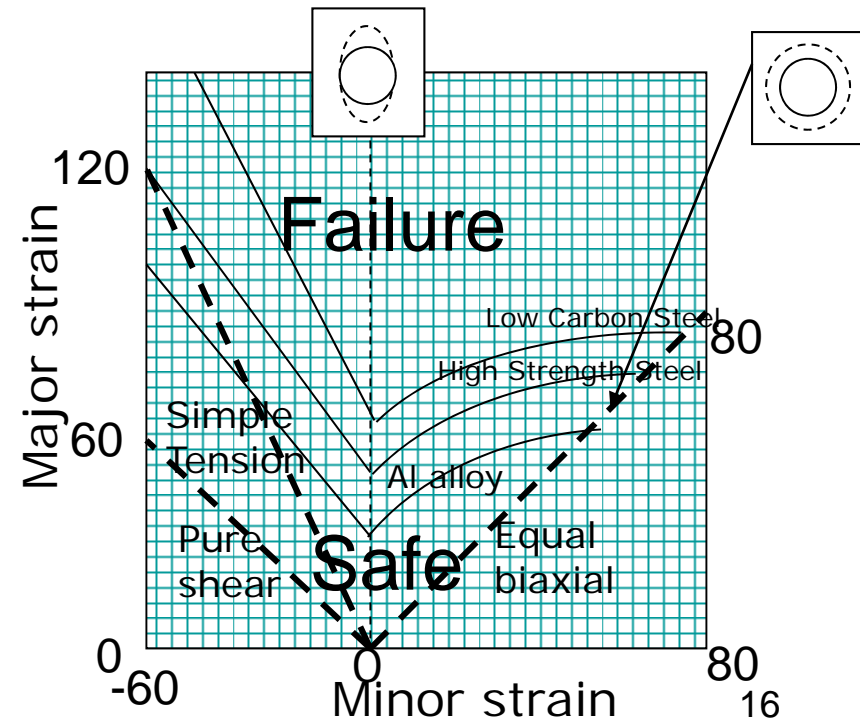
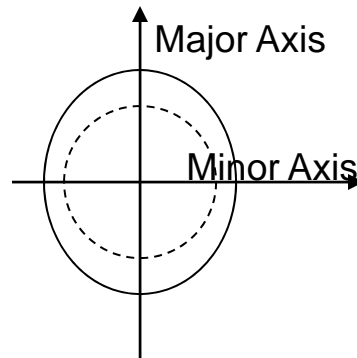
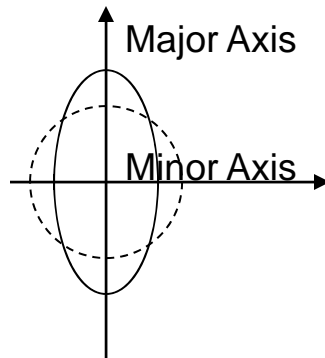
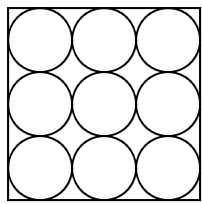
(d)
Earing



(e)
Surface Scratches

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



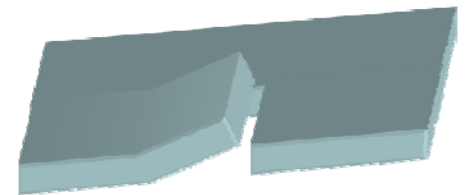
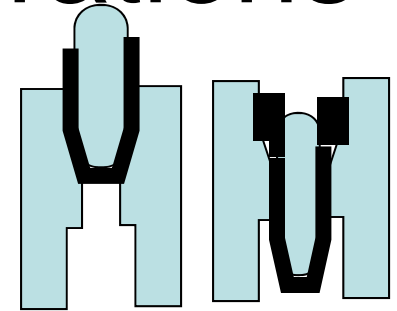
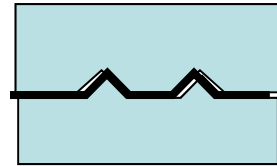
4. Other Sheet-Metal Operations

- With Metal Tooling

- Ironing

- Coining and Embossing

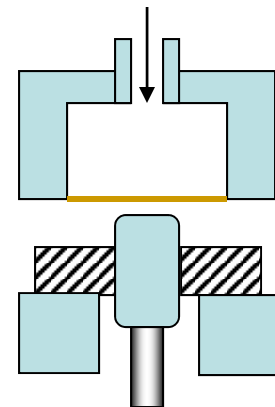
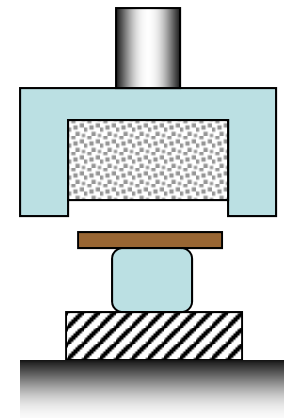
- Lancing



- 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

