Metal Forming Processes (ME5807)

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Drawing

Drawing

Sheet metal forming to make cup-shaped, box-shaped, or other complex-curved, hollow-shaped parts

- Sheet metal blank is positioned over die cavity and then punch pushes metal into opening
- Products: beverage cans, ammunition shells, automobile body panels
- If $h/d > 0.5$, it is called Deep drawing
- If $h/d < 0.5$, it is called Shallow drawing.

Deep Drawing

Difference between wire drawing & deep drawing?

(a) Drawing of cup-shaped part: (1) before punch contacts work, (2) near end of stroke; (b) work-part: (1) starting blank, (2) drawn part.

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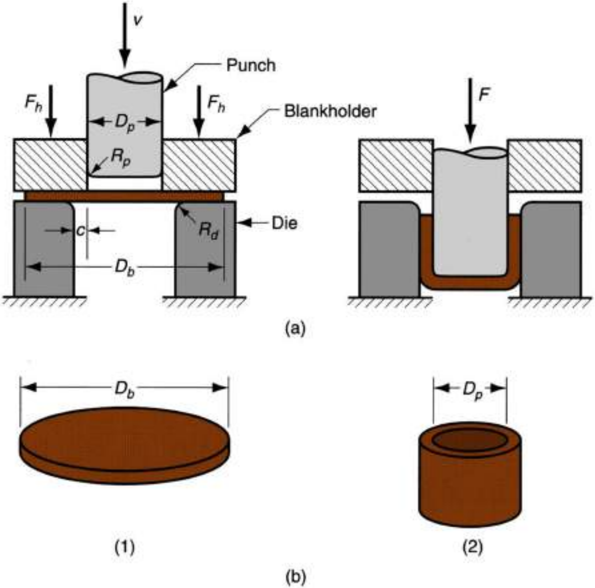
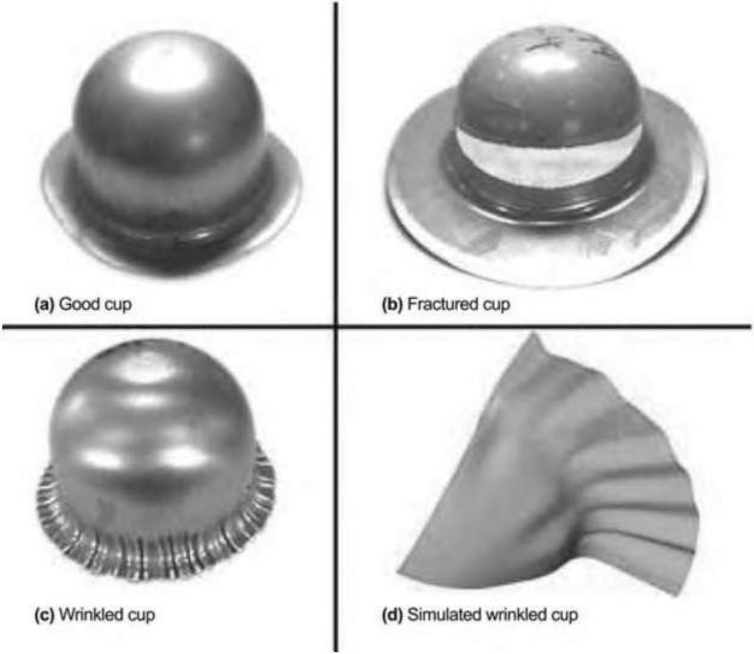
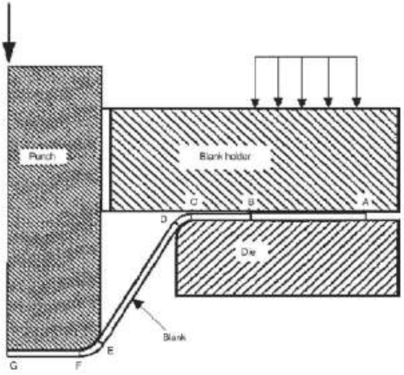



(a) Good cup
(b) Fractured cup
(c) Wrinkled cup
(d) Simulated wrinkled cup

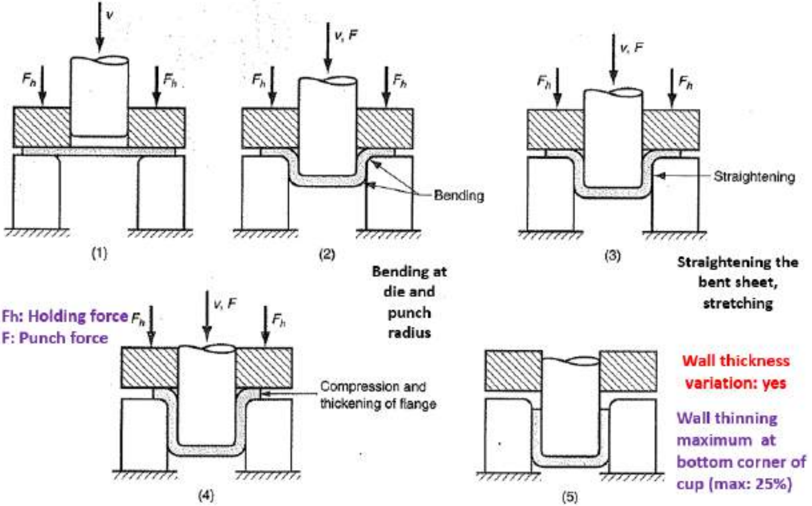
Deformation during Deep Drawing

Deep drawing involves many types of forces and deformation modes, such as tension in the wall and the bottom, compression and friction in the flange, bending at the die radius, and straightening in the die wall.

- Zone A-C: the flange (axial compression, radial tension, circumferential compression)
- Zone C-D: the die corner radius (bending and friction)
- Zone D-E: the wall of the cup (tension and potential fracture)
- Zone E-F: the punch corner radius (bending and friction)
- Zone F-G: the flat circular bottom (friction and near zero strain)



Mechanics of Drawing



Stages in deformation of the work in deep drawing: (1) punch makes initial contact with work, (2) bending, (3) straightening, (4) friction and compression, and (5) final cup shape showing effects of thinning in the cup walls. Symbols: v = motion of punch, F = punch force, F_h = blankholder force.

Calculation of blank diameter

- Assumptions: No change in thickness

$$\frac{\pi D^2}{4} = \frac{\pi d^2}{4} + \pi d h$$

$$D^2 = d^2 + 4dh$$

$$D = \sqrt{d^2 + 4dh}$$

Where, $D =$ Diameter of the blank before forming

Total Punch Force

$$P = [\pi D_p h(1.1\sigma_o) ln\frac{D_o}{D_p} + \mu(2H\frac{D_p}{D_o})]e^{\mu\pi/2} + B$$

Punch force = 1st Term +2nd Term + 3rd Term

- **1st Term :** Force due to ideal deformation
- **2nd Term:** Force due to friction and blank holder pressure.
- **3rd Term:** Force required to bend and straighten the blank

Total Punch Force

$$P = [\pi D_p h(1.1\sigma_o) ln \frac{D_o}{D_p} + \mu(2H\frac{D_p}{D_o})]e^{\mu\pi/2} + B$$

Where,
P = Total punch load
σ_o = Average flow stress
D_p = Diameter of punch
D_o = Blank diameter
H = Blank hold on pressure
h = Wall thickness
μ = Co-efficient of friction
B = Force required to bend and straighten the blank

Limiting Draw Ratio (LDR)

The draw ratio (DR) of a deep drawing operation is:

$$DR = \frac{d_o}{d_1}$$

Where, $d_o =$ Blank diameter, $d_1 =$ Cup diameter.

The limiting draw ratio (LDR) is defined as the maximum DR that can be obtained while drawing a cup without fracture:

$$LDR = \frac{d_o^{max}}{d_1}$$

Where, $d_o^{max} =$ Maximum blank diameter (without Fracture)

Factors Affecting Limiting Draw Ratio (LDR)

- Decreasing blank holder-sheet friction
- Decreasing sheet-die friction
- Increasing sheet-punch friction
- Increasing relative ratio of blank thickness to diameter $(\frac{s_o}{d_o})$
- Increasing ratio of punch corner radius to punch diameter $(\frac{r_p}{d_p})$
- Decreasing relative punch diameter (ratio of punch diameter to thickness)
- Using a material with high strain-hardening exponent, n

Parameters Affecting the Deep Drawing Process

- Material Properties
  - Strength coefficient, K
  - Strain-hardening coefficient, n
- Geometry
  - Punch corner radius, r_p,
  - Die radius, r_D,
  - Punch-die clearance, u_o
  - Blank diameter, d_o
  - Blank thickness, s_o
- Interface conditions
  - Lubricationl/friction conditions
- Equipment and tooling
  - Press speed
  - Blank holder

Limitations of Deep Drawing

- Wrinkling and tearing are typical limits to drawing operations
- Different techniques can be used to overcome these limitations
  - Draw beads
  - Vertical projections and matching grooves in the die and blankholder
- Trimming may be used to reach final dimensions

Stamping

Stamping / Press Working

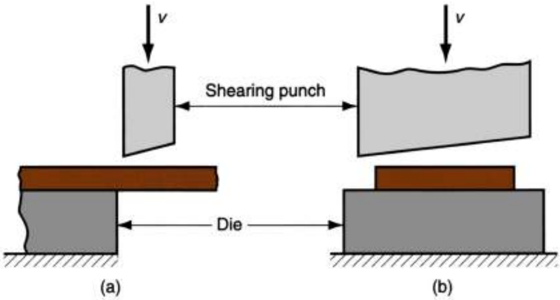
Metal pressing, or metal stamping, is the process of forming a shape from a metal sheet, coil or tube, using a press tool and stamping dies. The metal is manipulated to the shape of the die to produce precise and accurate components. The press forming process lends itself perfectly to the cost effective production of large batches. Three principal operations in pressworking that cut sheet metal:

- Shearing
- Blanking
- Punching

Shearing

Sheet metal cutting operation along a straight line between two cutting edges

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



Blanking and Punching

- Blanking - sheet metal cutting to separate piece from surrounding stock
  - Cut piece is the desired part, called a blank
- Punching - sheet metal cutting similar to blanking except cut piece is scrap, called a slug
  - Remaining stock is the desired part

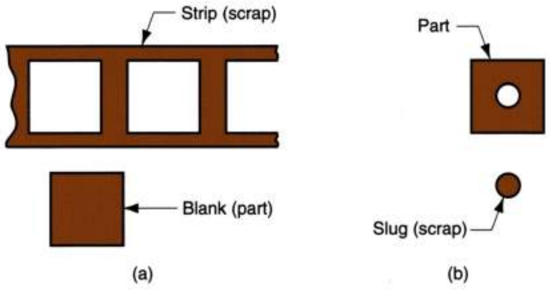


Figure: (a) Blanking, and (b) Punching

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