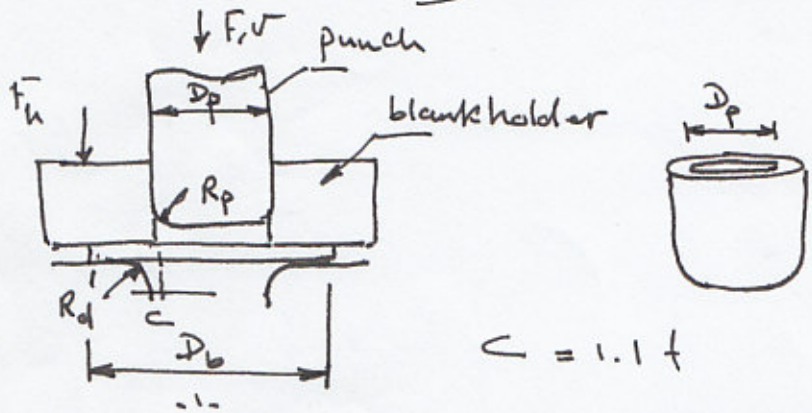
Drawing

Drawing is a sheet-metal operation used to make cup-shaped.

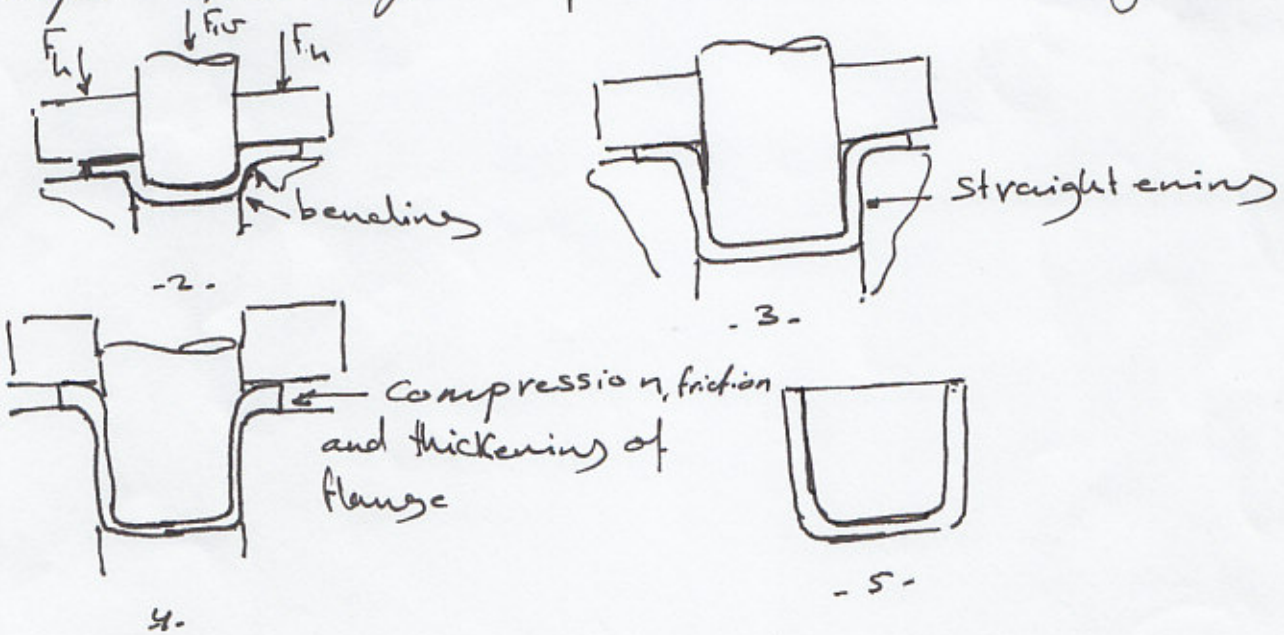
It is performed by placing a sheet-metal blank over a die cavity and then pushing the metal into the opening with a punch as in Fig. 1. The blank must usually be hold down flat against the die by a blank holder.



-1-

$c = 1.1\,t$

- As the punch proceeds downward toward its final bottom position, the work experiences a complex sequence of stresses and strain as it is gradually formed into the shape defined by the punch and die cavity.



- stages in deformation of the work in deep drawing

Lubrication is generally used to reduce friction force.

- The holding force applied by the blankholder is to be a critical factor in deep drawing.
- If it is too small, wrinkling occurs
- If it is too large, it prevent the metal from flowing properly toward the die cavity, resulting in stretching and possible tearing of the sheet metal.
- The thinning near the base of the cup up to 25%.

DR, drawing ratio $= \frac{D_b}{D_p} \leq 2$

r, reduction $= \frac{D_b - D_p}{D_b}$ less than 0.5

- t/D_b, thickness-to-diameter ratio to be greater than 1%

As t/D_b decreases, tendency for wrinkling.

<u>Ex.</u>

A drawing operation is used to form a cylindrical cup with inside diameter = 3 in. and height = 2 in. The starting blank size = 5.5 in. and the stock thickness $= \frac{3}{32}$ in. Based of the data, is the operation feasible?

$DR = \frac{5.5}{3.0} = 1.8\bar{3}$, $r = \frac{5.5 - 3.0}{5.5} = 45.45\%$

$t/D_b = \frac{3/32}{5.5} = 1.7\%$

the drawing is feasible

Drawing Forces

$$F, \text{ Force} = \pi D_p t (TS)\left(\frac{D_b}{D_p} - 0.7\right)$$

constant

(correction factor to account for friction)

$$F_h, \text{ holding force} = 0.015 Y \pi \left[D_b^2 - (D_p + 2.2t + 2R_d)^2\right]$$

Ex.

For the drawing operation of example.

Determine: (a) drawing force and (b) holding force, given that the tensile strength of the sheet metal $= 70{,}000\ lb/in^2$, and yield strength $= 40{,}000\ lb/in^2$. The die corner radius $= 0.25$ in.

$$F = \pi(3.0)\left(\frac{3}{32}\right)(70{,}000)\left(\frac{5.5}{3.0} - 0.7\right) = 70.097\ lb$$

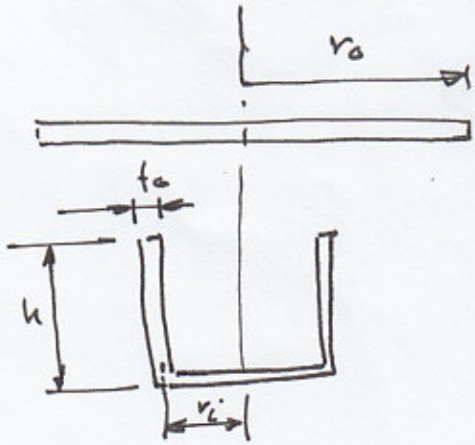
$$F_h = 0.015(40{,}000)\pi\left[5.5^2 - \left(3.0 + 2.2 \times \frac{3}{32} + 2 \times 0.25\right)^2\right]$$

$$= 31.121\ lb$$

Height of cup

$$\pi R_o^2 t_o = \pi r_i^2 t_o + 2\pi r_i \cdot t_o h$$

$$h \approx \frac{r_i}{2}\left\{\left(\frac{R_o}{r_i}\right)^2 - 1\right\}$$



Other drawing operation

Redrawing

- If the drawing ratio is too high ⇒ may required more than one drawing step, refferred to as redrawing.
- For the first drawing, the max reduction of the starting blank should be 40% to 45%
- For the second draw (first redraw), $r_{max} = 30\%$
- For the third draw (second redraw) $r_{max} = 16\%$

Reverse drawing

- The drawing part is positioned face down on the die so that the second drawing operation produces a configuration.

- It may seem that reverse drawing would produce a more severe deformation than redrawing, it is actually easier on the metal.
- The reason is that the sheet metal is bent in the same direction at the outside and inside corners of the die in reverse drawing, whereas in redrawing the metal is bent in two opposite directions at the two corners. Because of this difference, the metal experiences less than hardening in reverse drawing and the drawing force is lower.

Drawing without a blankholder

- The blank holder is to be prevent wrinkling of the flange while the cup is being drawn
- Wrinkling is reduced as t/D_b ratio increases.
- If t/D_b large enough, drawing can be accomplised without blankholder.
- The limiting condition for drawing without a blankholder can be estimate from eq.

$D_b - D_p < 5t$.

advantages

1. lower-cost
2. Simple press

Drawing

1- Derive a expression for the reduction r in drawing as a function of drawing ratio DR

$$r = \frac{D - D_p}{D} \quad \text{—— (1)}$$

$$DR = \frac{D}{D_p} \quad \text{—— (2)}$$

$$r = D/D - D_p/D = 1 - \frac{D_p}{D} = 1 - \frac{1}{DR}$$

From (2)

$$D_p = \frac{D}{DR} \quad \text{sub in (1)}$$

$$r = \frac{D - \frac{D}{DR}}{D} = \frac{\frac{DDR - D}{DR}}{D} = \frac{DDR - D}{DR} \times \frac{1}{D}$$

$$r = \frac{DDR - D}{DDR} = 1 - \frac{1}{DR}$$

2- A cup is to be drawn in a deep drawing operation. The height of the cup is 75 mm and its inside diameter = 100 mm. The sheet metal thickness = 2 mm. if the blank diameter = 225 mm, determine (a) drawing ratio, (b) reduction, and (c) thickness-to-diameter ratio, (d) Does the operation seem feasible?

Sol. (a) $DR = \frac{D_b}{D_p} = \frac{225}{100} = 2.25$

(b) $r = \frac{D_b - D_p}{D_p} = \frac{225 - 100}{225} = 0.555 \; 55.5\%$

(c) $t/D_b = \frac{2}{225} = 0.89\%$

(d) Feasibility? No! DR is too large (greater than 2.0)

" " " (" " 50%)

t/D_b " " small (less than 1%)

3- Solve problem 2 except that the starting blank size = 175 mm.

(a) DR = 1.75
(b) r = 42.9 %
(c) t/D_b = 1.14 %
(d) Feasibility ? DR < 2.0, r < 50%, and t/D > 1%.

- However, the operation is not feasible because the 175 mm diameter blank size does not provide sufficient metal to draw a 75 mm cup height.

blank area = $\pi D^2/4 = 24.053\ mm^2$

Cup area = $\underbrace{\pi D_p h}_{\text{area of wall}} + \underbrace{\pi D_p^2/4}_{\text{area of base}} = 100\pi h + \pi(100^2)/4$

$= 314.16h + 7854$

Area of cup = area of blank

$314.16h + 7854 = 24{,}053 \Rightarrow h = 51.56\ mm$

This is less than the specified 75 mm height

4. A deep drawing operation is performed in which the inside of the cylindrical cup has a diameter = 4.0 in. and a height = 2.5 in. The stock thickness = $\frac{1}{8}$ in. and the starting blank diameter = 7.5 in. punch and die radii = $\frac{5}{32}$ in. The metal has tensile strength = 60,000 lb/in^2 and yield strength = 30,000 lb/in^2. Determine: (a) drawing ratio (b) reduction, (c) drawing force, and (d) blank-holder force.

(a) 1.875, (b) 1.667%, (c) 110,756 lb, (d) 49,770 lb.

5. Solve the previous problem except $t = 3/16$ in
Estimate F_h then compare with Ex. 4

6. A cup drawing operation is performed in which the inside diameter 80 mm and the height = 50 mm. The stock thickness = 3.0 mm, and the starting blank diameter = 150 mm. punch and die radii = 4 mm. Tensile strength = 400 MPa and a yield strength = 180 MPa for this sheet metal.
Determine: (a) drawing ratio, (b) reduction, (c) drawing force, and (d) blankholder force.

7. A deep drawing operation is to be performed on a sheet-metal blank that is $\frac{1}{8}$ in. thick. The height (inside dimension) of the cup = 3.8 in. and the diameter (inside dimension) = 5.0 in. Assuming the punch radius = 0, compute the starting diameter of the blank to complete the operation with no material left in the flange.
Is the operation feasible (ignoring the fact the punch radius is too small)?

t is constant (deep drawing)

Cup area = wall area + base area

$$= \pi D_p h + \pi D_p^2/4 = 25.25\pi \text{ in}^2$$

Blank area $= \pi D^2/4 = 0.25\pi D^2$

Blank area = cup area : $0.25\pi D^2 = 25.25\pi = 79.32 \text{ in}^2$

$D = 10.050$ in ≈ 81.81 in.

For feasibility, test $DR = \frac{D_b}{D_p} = \frac{10.050}{5.0} = 2.01 > 2.0$

is No.

8. Solve Ex. 7 except use a punch radius = 0.375 inch.

8. The surface area of the cup

$h = 3.80 - 0.375 = 3.425$ in, then A_1

A_2 quarter toroid formed by 0.375 radius at the base of the cup, A_3 base, which has a diameter =

base: $5.0 - 2 \times 0.375 = 4.25$ in

$A_1 = \pi D h = \pi (5.0)(3.425) = \underline{53.807}$ in^2.

$\pi D/4 = 0.25\pi(\underbrace{2 \times 0.375}_{D})$ = 0.589 in.

طول محيط ربع دائرة

The centroid is located at the center of the arc which is

$0.375 \sin 45 = 0.265$ beyond the center of the 0.375 in.

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Thuse, the diameter of the circle described by the centroid is

$4.25 + 2 \times 0.265 = 4.780$ in

$A_2 = \pi(4.78)(0.589) = 8.847$ in^2.

$A_3 = \pi(4.25)^2/4 = 14.188$ in^2

Pappus - Guldin Theorem

Total area of cup $= 53.807 + 14.188 + 8.847 = 76.842$ in^2

Blank area $= \frac{\pi D^2}{4} = 0.7855 D^2 = 76.842$

$D = 9.89$ in

$DR = 1.978$

$t/D = 0.125/9.89 = 0.0126 \le 1.26\% \Rightarrow$ (The operation is feasible)

previous problem

$A = 25.25 \times \pi = ?$ compare with 76.842

9. A drawing operation is performed on 3.0 mm stock. The part is a cylindrical cup with a height = 50 mm and inside diameter = 70 mm. Assume the corner radius on the punch = zero. (a) Find the required starting blank size D_b, (b) Is the drawing operation feasible?

t is constant

Cup area = wall area + base area

$= \pi D_p^2/4 + \pi D_p h = \pi(70)(50) + 0.25\pi(70)^2 = 14.846\ mm^2$

Blank area $= \pi D^2/4 = 0.7855 D = 14.846$

$D = 137.48$ mm

$DR = 1.964$, $t/D_b = 2.18\%$ (feasible) but $R_p = 0$ (the shape would be difficult to draw = like blanking punch)

10. Solve Ex. 9. take $h = 60$ mm.

11. Solve Ex. 10. take $R_p = 10$ mm, answer $D = 143.28$ mm and the operation infeasible.

12. A cup-shaped part is to be drawn without a blank holder from sheetmetal whose thickness = 0.25 inches. The inside diameter of the cup = 2.5 inches, its height = 1.5 inches, and the corner radius at the base = 0.375 inch. (a) what is the min starting blank diameter that can be used, according to ($D_b - D_p < 5t$), (b) Does this blank diameter provide sufficient material to complete the cup.

$D_b < 5t + D_p = 5(0.25) + 2.5 = 3.75$ in

هذا فعل السلك ، بالعموم قانون مع السؤال 8

Volume of walls, $V_1 = (1.5 - 0.375)\frac{\pi}{4}[(2.5 + 2\times 0.25)^2 - (2.5)^2] = 2.430 \text{ in}^3$

$\frac{\pi D^2}{4}$ قطر

V_2 = (cross-section of quarter toroid) × (Circle made by sweep of centroid)

Cross-section of quarter toroid $= 0.25\pi[(0.375 + 0.25)^2 - (0.375)^2] = 0.1964 \text{ in}^2$

قطر πr^2

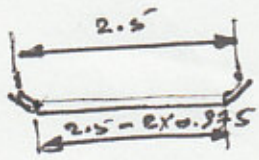
circle made by centroid sweep has diameter:

$(2.5 - 2\times 0.25) + 2\left(\frac{0.375 + 0.25}{2}\right)\sin 45 = 2.457$ in

محيط قاعدة πD مساحة

$V_2 = 2.457\pi(0.1964) = 1.516 \text{ in}^3$ (محيط القاعدة × مساحة)

$V_3 = (2.5 - 2\times 0.375)^2 \pi (0.25)/4 = 0.601 \text{ in}^2$



$V_T = V_1 + V_2 + V_3 = 4.547 \text{ in}^3$

V of blank $= \pi D^2 t/4 = \pi(0.25)D^2/4 = 4.547$

$D = 4.81$ in

- The diamete of 3.75 computed in (a) does not provide sufficient metal to complete the drawing.