08 Deep Drawing

Deep Drawing: is a sheet-metal-forming operation used to make cup-shaped, box-shaped, or other complex-curved and concave parts. It is performed by placing a piece of sheet metal over a die cavity and then pushing the metal into the opening with a punch, as in Figure 8.1

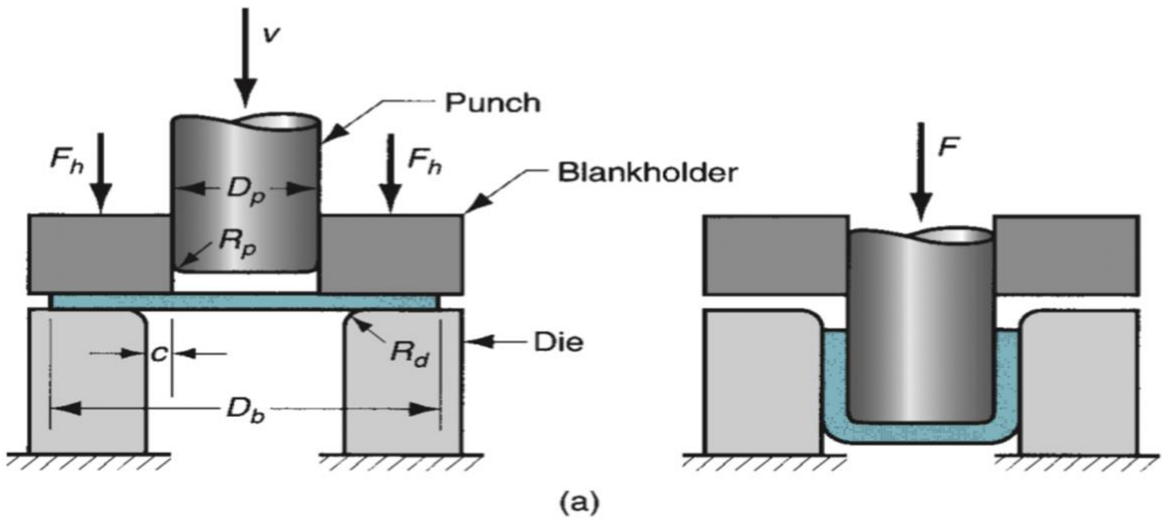


Figure 8.1 (a) Drawing of a cup-shaped part: (1) start of operation before punch contacts work, and (2) near end of stroke.

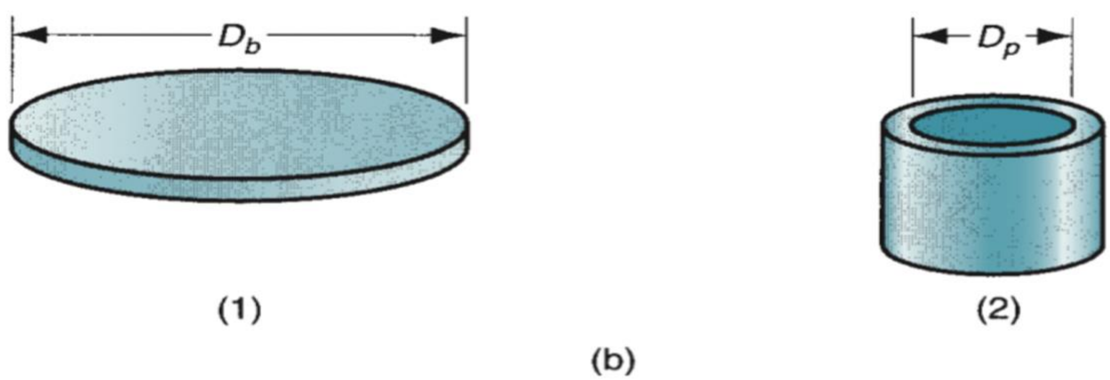


Figure 8.1 (b) corresponding work part: (1) starting blank, and (2) drawn part. Symbols: c = clearance, D_b= blank diameter,D_p= punch diameter, R_d= die corner radius, R_p= punch corner radius, F = drawing force, F_h = holding force.

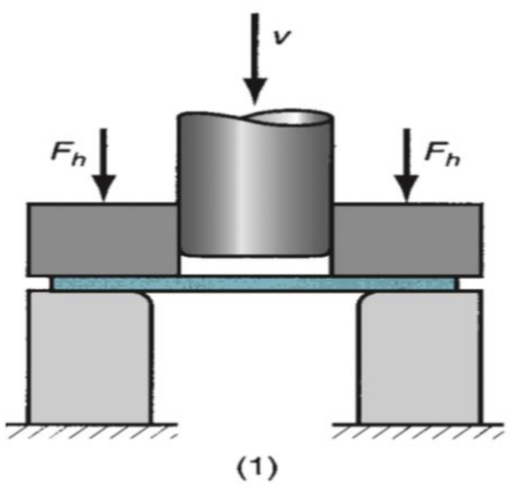
The blank must usually be held down flat against the die by a blank holder. Common parts made by drawing include beverage cans, ammunition shells, sinks, cooking pots, and automobile body panels.

The sides of the punch and die are separated by a clearance c. This clearance in drawing is about 10% greater than the stock thickness:

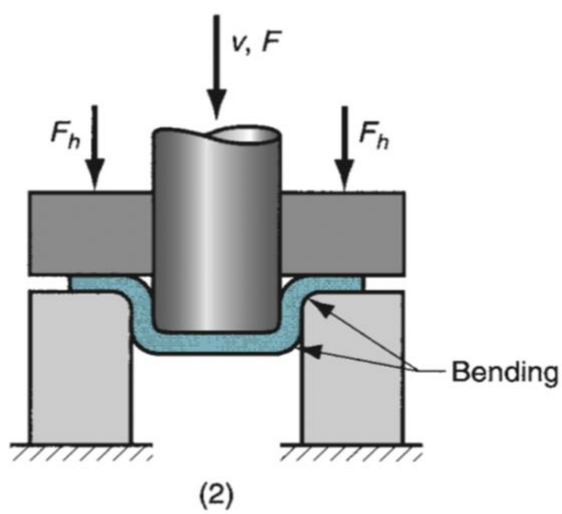
$$c = 1.1\ t$$

The punch applies a downward force F to accomplish the deformation of the metal, and a downward holding force F_h is applied by the blank holder, as shown in the sketch.

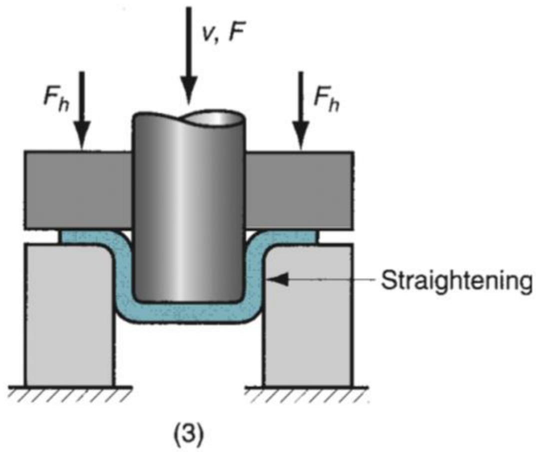
As the punch proceeds downward toward its final bottom position, the work experiences a complex sequence of stresses and strains as it is gradually formed into the shape defined by the punch and die cavity. The stages in the deformation process are illustrated in Figure 8.2.



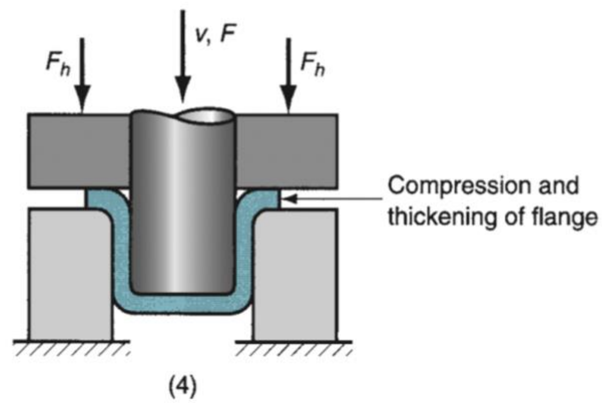
(1) punch makes initial contact with work.



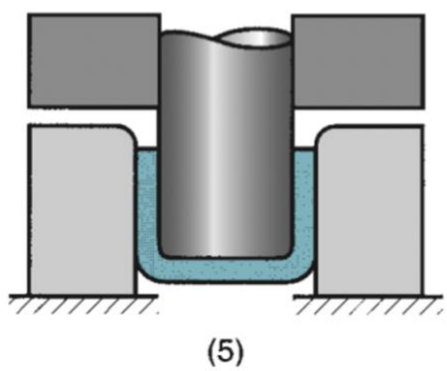
(2) bending.



(3) straightening.



(4) friction and compression.



(5) final cup shape showing effects of thinning in the cup walls.

Figure 8.2 Stages in deformation of the work in deep drawing: Symbols: v = motion of punch, F = punch force, Fh = blank holder force.

The holding force applied by the blank holder is now seen to be a critical factor in deep drawing.

If it is too small, wrinkling occurs. If it is too large, it prevents the metal from flowing properly toward the die cavity, resulting in stretching and possible tearing of the sheet metal.

Determining the proper holding force involves a delicate balance between these opposing factors.

Up to 25% thinning of the side wall may occur in a successful drawing operation, mostly near the base of the cup.

Measures of Drawing: One of the measures of the severity of a deep drawing operation is the drawing ratio DR. This is most easily defined for a cylindrical shape as the ratio of blank diameter Db to punch diameter Dp. In equation form:

$$DR = \frac{D_b}{D_p}$$

An approximate upper limit on the drawing ratio is a value of 2.0.

The actual limiting value for a given operation depends on:

1. Punch and die corner radii (Rp and Rd).

2. friction conditions.

3. Depth of draw.

4. Characteristics of the sheet metal, such as ductility and isotropy.

Example 8.1:

A drawing operation is used to form a cylindrical cup with inside diameter = 75 mm and height = 50 mm. The starting blank size = 138 mm. Based on these data, is the operation feasible?

Solution:

To assess feasibility, we determine the drawing ratio:

$$DR = \frac{D_b}{D_p}$$

DR = 138/75 = 1.84

According to this measure, the drawing operation is feasible. The drawing ratio is less than 2.0.

The drawing force required to perform a given operation can be estimated roughly by the formula:

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

where F = drawing force, N; t = original blank thickness, mm; TS = tensile strength, MPa; and Db and Dp are the starting blank diameter and punch diameter, respectively, mm. The constant 0.7 is a correction factor to account for friction.

This equation estimates the maximum force in the operation. The drawing force varies throughout the downward movement of the punch, usually reaching its maximum value at about one-third the length of the punch stroke.

Example 8.2: A drawing operation is used to form a cylindrical cup with inside diameter = 75 mm and height = 50 mm. The starting blank size = 138 mm and the stock thickness = 2.4 mm. determine drawing force, given that the tensile strength of the sheet metal (low-carbon steel) = 300 MPa.

Solution:

The drawing force required equal:

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

$$F = \pi \, (75) \, (300) \, (2.4) \left(\frac{138}{75} - 0.7\right) = 193.3 \text{ N}$$