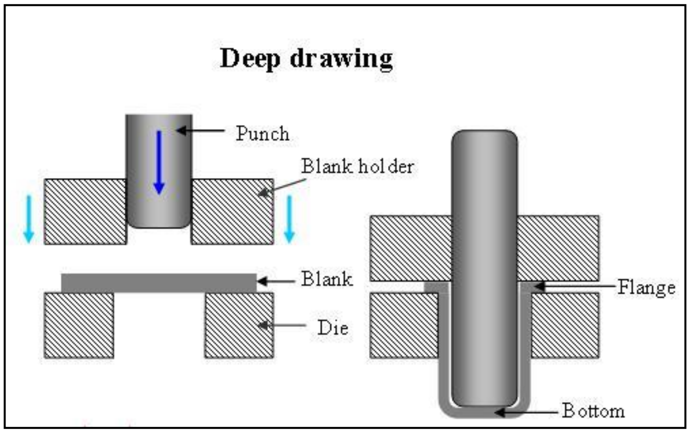
Unit Four: Drawing Processes

Drawing is a metal forming process (cold working process). In this process rod or tube is pulled through a tapered hole in a die which results in reduction in cross section area. The shape of die determines the final product shape. Quality of product obtained is excellent. This process increases strength and hardness of the metal.
Cold drawing is performing important functions in hydraulic system of vehicles, aero planes, ships, industries, etc.….
*When the metal is forced through the die by a **tensile force** applied to the metal at **exist** of die it is called **drawing**, while when a **compressive force** is applied at the **entry** of the die it is called **extruding**.*

Drawing Types:

1- Deep Drawing:

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a **punch**. It is thus a shape transformation process with material retention. *The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter*. This is achieved by redrawing the part through a series of dies. The flange region (sheet metal in the die shoulder area) experiences a radial drawing stress and a tangential compressive stress due to the material retention property. These compressive stresses (hoop stresses) result in **flange wrinkles** (wrinkles of the first order). *Wrinkles can be prevented by using a blank holder*, the function of which is to facilitate controlled material flow into the die radius.



In pure deep drawing there is no reduction of sheet metal thickness, forming is achieved in stretch forming purely because of a decrease in sheet metal thickness.

The recommended metals for Deep Drawing are: Aluminum, Brass, Bronze, cold rolled steel, Copper, Iron, Molybdenum, Nickel, Silver, Stainless steel, and others.

Deep Drawing Advantages:

1. Tool construction costs are lower in comparison to similar manufacturing processes.
2. The technique is ideal for products that require significant strength and minimal weight.
3. The process is also recommended for product geometries that are unachievable through other manufacturing techniques.
4. Deep drawing is especially beneficial when producing high volumes since unit cost decreases considerably as unit count increases.

Deep Drawing Disadvantages:

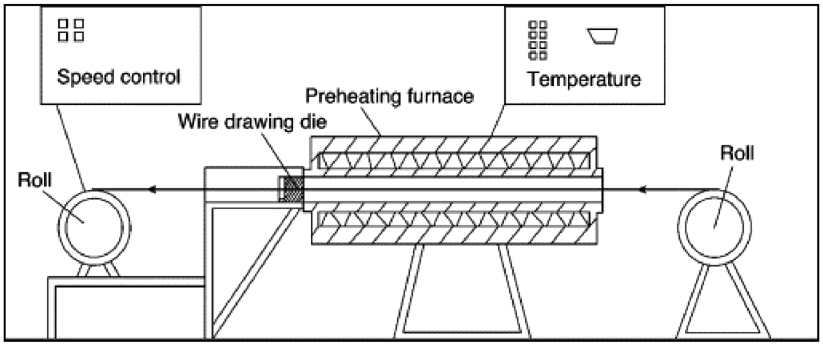
1. Material thickness has a large effect on processing price.
2. Special sleeves required to assist in driving the parts into the dies.
3. This process is costly for low production rate.
4. Limited shapes

2- Wire drawing:

*To begin the wire drawing process, a **spool** of wire is placed at beginning of the machine on a spool*. To feed it through the machine, the end of wire must be cut or flattened. It is fed through the machine and through a series of dies to achieve its final cross-sectional area. The end of the machine usually has a spool or coiler, so the finished product is a coil of wire at the desired cross-sectional area. The end process may also be a barrel packer where a barrel is placed, and the coiled wire is spooled directly into the barrel using a turntable.

It is vitally important the temperature of the machinery does not get too hot (primarily caused by the energy released while deforming of the metal) and the wire has a constant tension and speed as it moves through the series of dies.

There are many applications for wire drawing, including electrical wiring, cables, tension-loaded structural components, springs, paper clips, spokes for wheels, and stringed musical.



Wire drawing Advantages

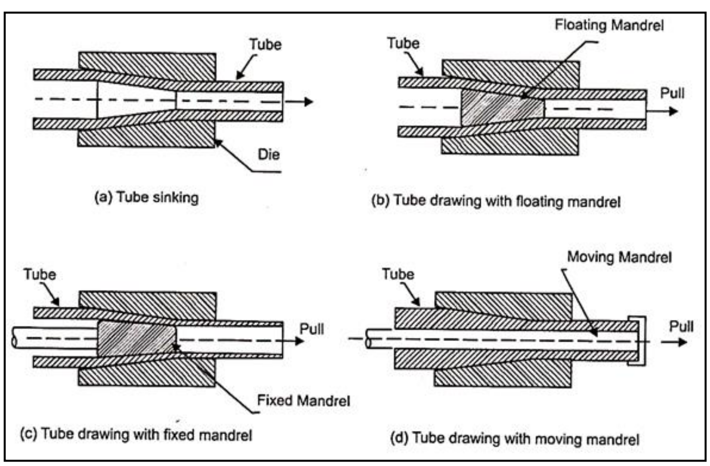
1. Close dimensional control
2. Improved mechanical properties such as strength and hardness.
3. Adaptability to economical batch or mass production

Wire and Tube Drawing Disadvantages:

1. That lengths are limited by the length of the mandrel, usually no more than 100 feet (30 m), and that a second operation is required to remove the mandrel, called reeling. This type of process is usually used on heavy walled or small (inner diameter) tubes.

3- Tube Drawing:

Tube producers often use tube drawing to change tube IDs, ODs, and wall thicknesses. Drawing also can improve the surface finish and refine the grain structure. Tubing is used in applications as varied as aircraft hydraulic lines, diesel fuel lines, thermocouple sheathing, chromatography, and semiconductor manufacture.



a- Tube Sinking:

In this process, tube is simply pulled through the die. The outer diameter is regulated by the die diameter but there is no regulation of inner diameter or thickness of tube. The surface finish on inner diameter is also not good. During the drawing operation the thickness of tube generally changes.

b- Tube Drawing with Floating Mandrel:

The process of tube drawing with a floating mandrel. The position of mandrel with respect to the die gets adjusted by the normal and tangential forces exerted by tube material on the mandrel. The frictional force tends to pull the mandrel into the die while the normal force tries to it push out. Since there is no external control on the position of the mandrel, it may change its position if the frictional condition changes, thus resulting in change in tube thickness.

c- Tube Drawing with Fixed Mandrel:

The tube is drawn through a die and a mandrel. The position of mandrel may be adjusted by the bar attached to its rear end to change the thickness of tube and the internal diameter. The external diameter is determined by the die diameter. The surface quality of both the surfaces, internal as well as external gets improved. The pull required is certainly more than that in tube sinking because of the additional deformation in the thickness of tube and due to frictional force between the tube and the mandrel.

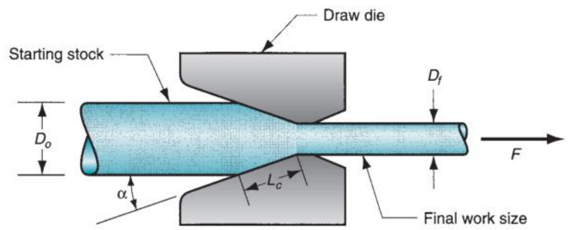
d- Tube Drawing with Moving Mandrel:

The process is illustrated the cylindrical mandrel and the tube are pulled together through the die. The process is generally used to reduce the thickness of tube. Since the area of cross section of tube increases towards the entry side its speed decreases while the mandrel being rigid moves with the same speed as the speed of tube at the exit. Therefore, in the deformation zone the mandrel moves faster than the tube. The frictional force between the tube and the mandrel pulls the tube inside the die while the frictional stress between the tube and die acts in the opposite direction.

Tube drawing Advantages:

1. Low equipment and tooling cost
2. Good surface finish and dimensional accuracy
3. High production rate
4. Long lengths of rounds, tubing, square, angles, etc. can be produced.

Drawing Analysis



Area Reduction

$$r = \frac{A_o - A_f}{A_o}$$

where r area reduction in drawing; A_o original area of work, and A_f final area

Draft

$$d = D_o - D_f$$

where d draft; D_o original diameter; and D_f final work diameter.

True strain: $\epsilon = \ln\frac{A_o}{A_f} = \ln\frac{1}{1-r}$

Average flow stress(Y_f): $\overline{Y}_f = \frac{K\epsilon^n}{1+n}$

Stress (ideal deformation) $\sigma = \overline{Y}_f \epsilon = \overline{Y}_f \ln\frac{A_o}{A_f}$

Draw Stress $\sigma_d = \overline{Y}_f\left(1 + \frac{\mu}{\tan\alpha}\right)\phi\ln\frac{A_o}{A_f}$

where σ_d draw stress; μ die-work coefficient of friction; α die angle (half-angle) φ factor that accounts for inhomogeneous deformation:

$$\phi = 0.88 \pm 0.12\frac{D}{L_c}$$

Average diameter (D) $D = \frac{D_o + D_f}{2}$

Contact length (Lc) $L_c = \frac{D_o - D_f}{2\sin\alpha}$

Draw Force $F = A_f\sigma_d = A_f\overline{Y}_f\left(1 + \frac{\mu}{\tan\alpha}\right)\phi\ln\frac{A_o}{A_f}$

Ex: *Wire is drawn through a draw die with entrance angle 15°. Starting diameter is 2.5 mm and final diameter 2.0 mm. The coefficient of friction at the work–die interface 0.07. The metal has a strength coefficient K=205 MPa and a strain-hardening exponent n = 0.20. Determine the draw stress and draw force in this operation.*

$$D = \frac{D_o + D_f}{2}$$ = (2.5+2)/2=2.25

$$L_c = \frac{D_o - D_f}{2 \sin \alpha}$$ =(2.5-2)/(2*sin15) = 0.966

$$\phi = 0.88 \pm 0.12 \frac{D}{L_c} \qquad \phi = 0.88 + 0.12 \frac{2.25}{0.966} = 1.16$$

The areas before and after drawing:

A_o=4.91mm^2 and A_f =3.14 mm^2.

True strain $\varepsilon = \ln (4.91/3.14) = 0.446$

Average Flow Stress $$\overline{Y}_f = \frac{K\epsilon^n}{1+n} \qquad \overline{Y}_f = \frac{205(0.446)^{0.20}}{1.20} = 145.4 \text{ MPa}$$

Draw stress $$\sigma_d = \overline{Y}_f \left(1 + \frac{\mu}{\tan \alpha}\right) \phi \ln \frac{A_o}{A_f}$$

$$\sigma_d = (145.4)\left(1 + \frac{0.07}{\tan 15}\right)(1.16)(0.446) = 94.1 \text{ MPa}$$

Draw force

$$F = A_f \sigma_d \qquad F = 94.1(3.14) = 295.5 \text{ N}$$

Questions

Q1: A spool of copper wire has a starting diameter of 2.5 mm. It is drawn through a die with an opening that is 2.1 mm. The entrance angle of the die = 18°. Coefficient of friction at the work die interface is 0.08. The pure copper has a strength coefficient = 300 MPa and a strain hardening coefficient = 0.50. The operation is performed at room temperature. Determine (a) area reduction, (b) draw stress, and (c) draw force required for the operation.

Q2: Aluminum rod stock with a starting diameter = 0.50 in is drawn through a draw die with an entrance angle = 13°. The final diameter of the rod is = 0.375 in. The metal has a strength coefficient = 25,000 lb/in^2 and a strain hardening exponent = 0.20. Coefficient of friction at the work-die interface = 0.1. Determine (a) area reduction, (b) draw force for the operation.

Q3: Bar stock of initial diameter = 90 mm is drawn with a draft = 15 mm. The draw die has an entrance angle = 18°, and the coefficient of friction at the work-die interface = 0.08. The metal behaves as a perfectly plastic material with yield stress = 105 MPa. Determine (a) area reduction, (b) draw stress, (c) draw force required for the operation.

YouTube: https://youtu.be/uCThQTUNdWU