Metal Forming Processes (ME5807)

Dr. Yogesh Kumar
Assistant Professor
Mechanical Engineering Department
National Instiute of Technology Patna
Bihar - 800 005, India
yogesh.me@nitp.ac.in

Wire and Bar Drawing

- **Drawing:** is an operation in which the cross section of a bar, rod, or wire is reduced by pulling it through a die opening.
- The difference between drawing and extrusion: the work is pulled through the die in drawing, whereas it is pushed through the die in extrusion.

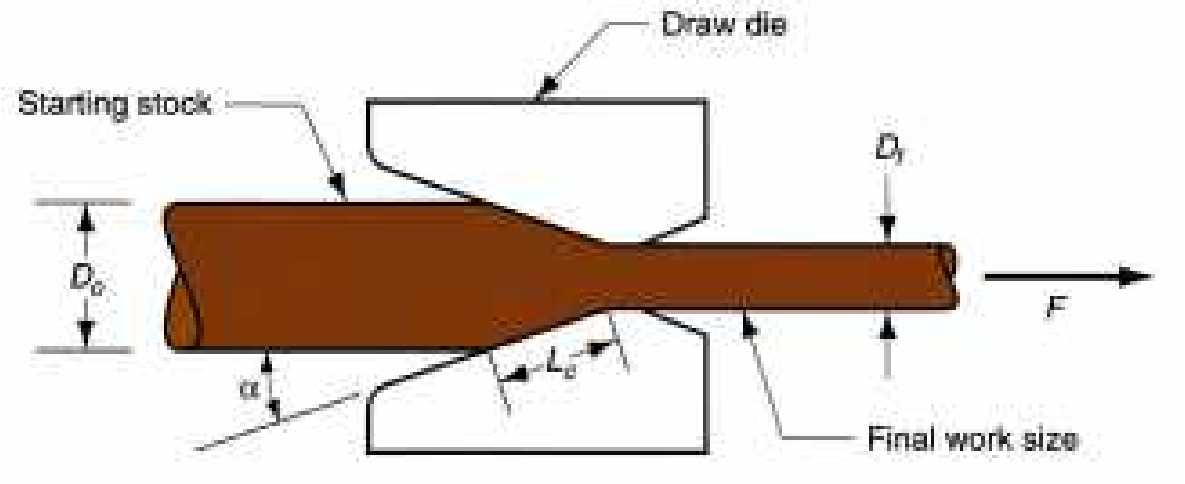

Figure: Drawing of bar, rod, or wire

Wire and Bar Drawing

- **Bar drawing:** the term used for large diameter bars.
- **Wire drawing:** applies to small diameter bars (wire sizes down to 0.03 mm are possible in wire drawing).
- Two stress components are present is drawing; **tensile stresses** due to the pulling action and **compressive stresses** because the metal is squeezed down as it passes through the die opening.
- Change in size of work (given by area reduction): $r = \frac{A_o - A_f}{A_o}$
- Draft: difference between original and final diameter: $d = D_o - D_f$

Analysis of Drawing

- **Mechanics of Drawing:** assume no friction
- True strain: $\epsilon = ln\frac{A_o}{A_f} = ln\frac{1}{1-r}$
- Stress: $\sigma = \overline{Y}_f\epsilon = \overline{Y}_f ln\frac{A_o}{A_f}$
  Where, $\overline{Y}_f = \frac{K\epsilon^n}{1+n}$

Analysis of Drawing

- **Mechanics of Drawing:** assuming friction
  $\sigma_d = \overline{Y}_f \phi (1 + \frac{\mu}{tan\alpha}) ln \frac{A_o}{A_f}$
  where, $\sigma_d =$ draw stress, MPa; μ = die-work coefficient of friction; $\alpha =$ die angle; and ϕ is a factor that accounts for inhomogeneous deformation.

  $\phi = 0.88 + 0.12 \frac{D}{L_c}$
  where $D =$ average diameter of work during drawing, mm; and $L_c =$ contact length of the work with the draw die.

  $D = \frac{D_o + D_f}{2}$ and $L_c = \frac{D_o - D_f}{2 sin\alpha}$

  Accordingly $F = A_f \sigma_d$
  where $F =$ drawing force, N

Analysis of Drawing

- **Maximum Reduction per Pass:** why entire reduction is not taken in one pass?
  - As the reduction increases, draw stress increases.
  - If the reduction is large enough, draw stress will exceed the yield strength of the exiting metal.
  - When that happens, the drawn wire will simply elongate instead of new material being squeezed through the die opening.
  - For wire drawing to be successful, maximum draw stress must be less than the yield strength of the exiting metal.

Analysis of Drawing

- **Maximum Reduction per Pass:** assuming perfectly plastic material; then ($n = 0$ hence $\overline{Y}_f = Y$), and no friction:
  $\sigma_d = \overline{Y}_f ln\frac{A_o}{A_f} = Yln\frac{A_o}{A_f} = Yln\frac{1}{1-r} = Y$
- This means that $ln\frac{A_o}{A_f} = ln\frac{1}{1-r} = 1$. Hence, $\frac{A_o}{A_f} = \frac{1}{1-r}$ must equal the natural logarithm base e. that is, the maximum possible strain is 1.0:
  $\epsilon_x = 1.0$
- The maximum possible area ratio is: $\frac{A_o}{A_f} = e = 2.7183$
- The maximum possible reduction is: $r_x = \frac{e-1}{e} = .632$

Drawing Practice

- Drawing is usually performed as a cold working operation.
- Most frequently used to produce round cross sections, but other shapes are also drawn.
- Drawn products include:
  - Electrical wire and cable; wire stock for fences, coat hangers, and shopping carts.
  - Rod stock to produce nails, screws, rivets, springs, and other hardware items.
  - Bar drawing is used to produce metal bars for machining, forging, and other processes.

Drawing Practice

- **Advantages include:**
  - Close dimensional control.
  - Good surface finish.
  - Improved mechanical properties such as strength and hardness.
  - Adaptability to mass production.

Drawing Practice

- **Drawing Equipment:** (Bar Drawing)
  - Draw bench: consists of an entry table, die stand, carriage, and exit rack.
  - The carriage is used to pull the stock through the draw die.
  - Powered by hydraulic cylinders or motor-driven chains.

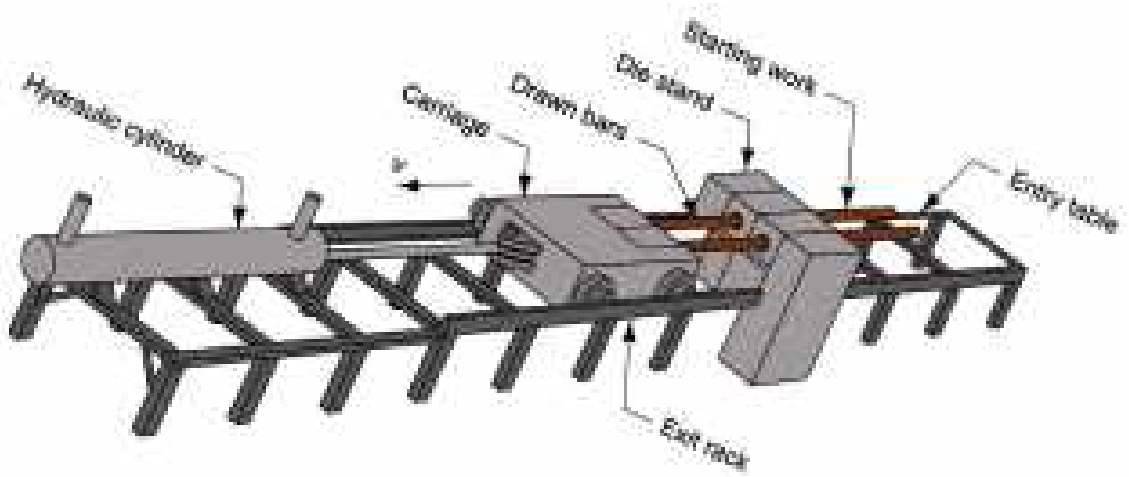

Figure: Hydraulically operated draw bench for drawing metal bars.

Drawing Practice

- **Drawing Equipment:** (Wire Drawing)
  - Done on continuous drawing machines that consist of multiple draw dies, separated by accumulating drums between the dies.
  - Each drum, called a capstan, is motor driven to provide the proper pull force to draw the wire stock through the upstream die.
  - It also maintains a modest tension on the wire as it proceeds to the next draw die in the series.
  - Each die provides a certain amount of reduction in the wire, so that the desired total reduction is achieved by the series.

Drawing Practice

- **Drawing Equipment:** (Wire Drawing)

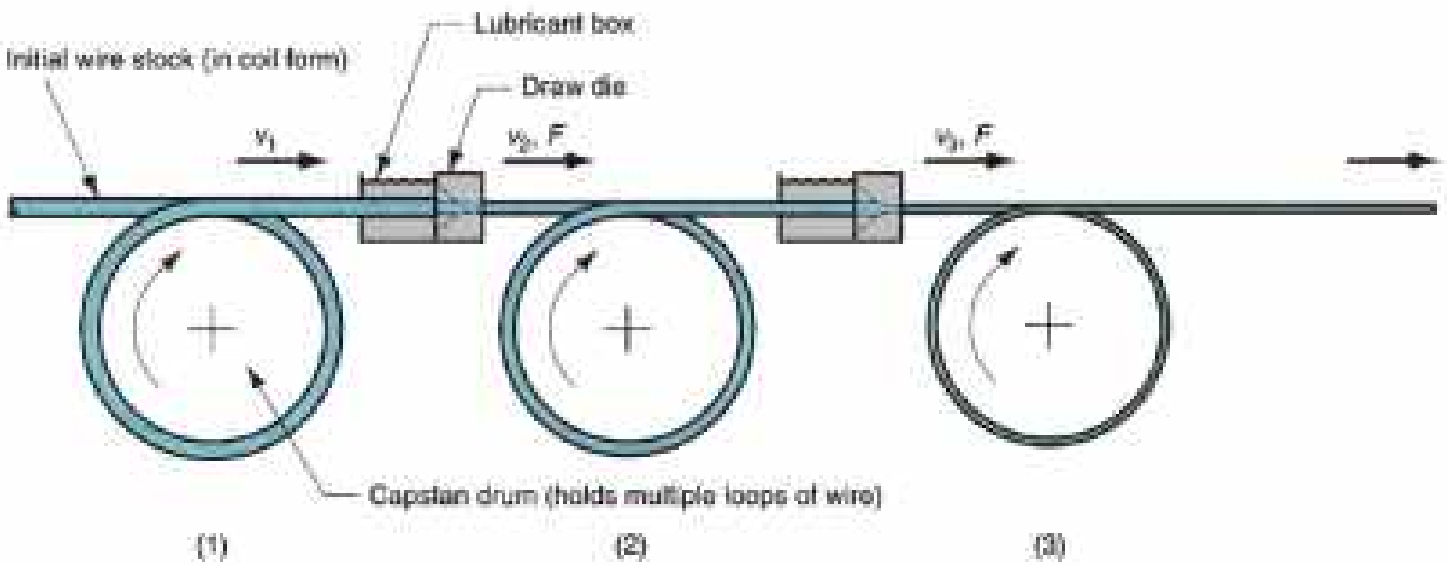

Figure: Continuous drawing of wire

Drawing Practice

- **Drawing Dies** are made of tool steel, cemented carbides or diamond and they consist of 4 regions:
  1. **Entry Region:** usually a bell-shaped mouth that does not contact the work. Its purpose is to funnel the lubricant into the die and prevent scoring of work and die surfaces.
  2. **The Approach Region:** is where the drawing process occurs. It is cone-shaped with an angle (half-angle) normally ranging from about 6 to 20^o.
  3. **The Bearing Surface (Land):** determines the size of the final drawn stock.
  4. **The Back Relief:** is the exit zone. It is provided with a back relief angle (half-angle) of about 30^o

Drawing Practice

- **Drawing Dies**

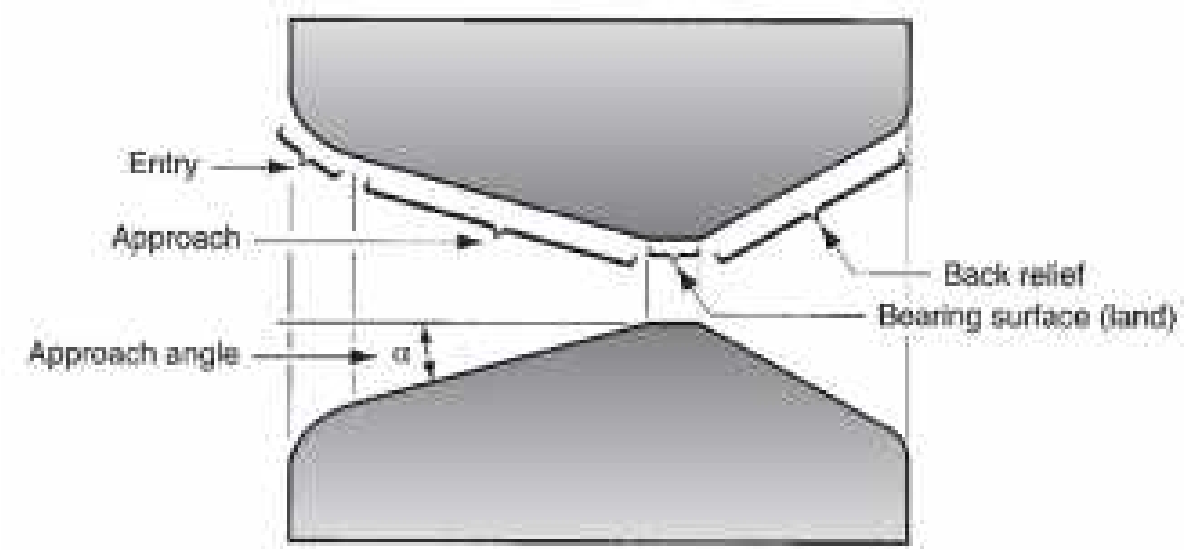

Figure: Draw die for drawing of round rod or wire.

Drawing Practice

- **Preparation of work:** involves three steps: (1) annealing, (2) cleaning, and (3) pointing.

  1. **Annealing:** done to increase the ductility of the stock.
  2. **Cleaning:** required to prevent damage of the work surface and draw die.
  3. **Pointing:** involves the reduction in diameter of the starting end of the stock so that it can be inserted through the draw die to start the process. This is usually accomplished by swaging, rolling, or turning.

Thank You