11
Wire Drawing

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Drawing: is an operation in which the cross section of a bar, rod, or wire is reduced by pulling it through a die opening, as in Figure 11.1.

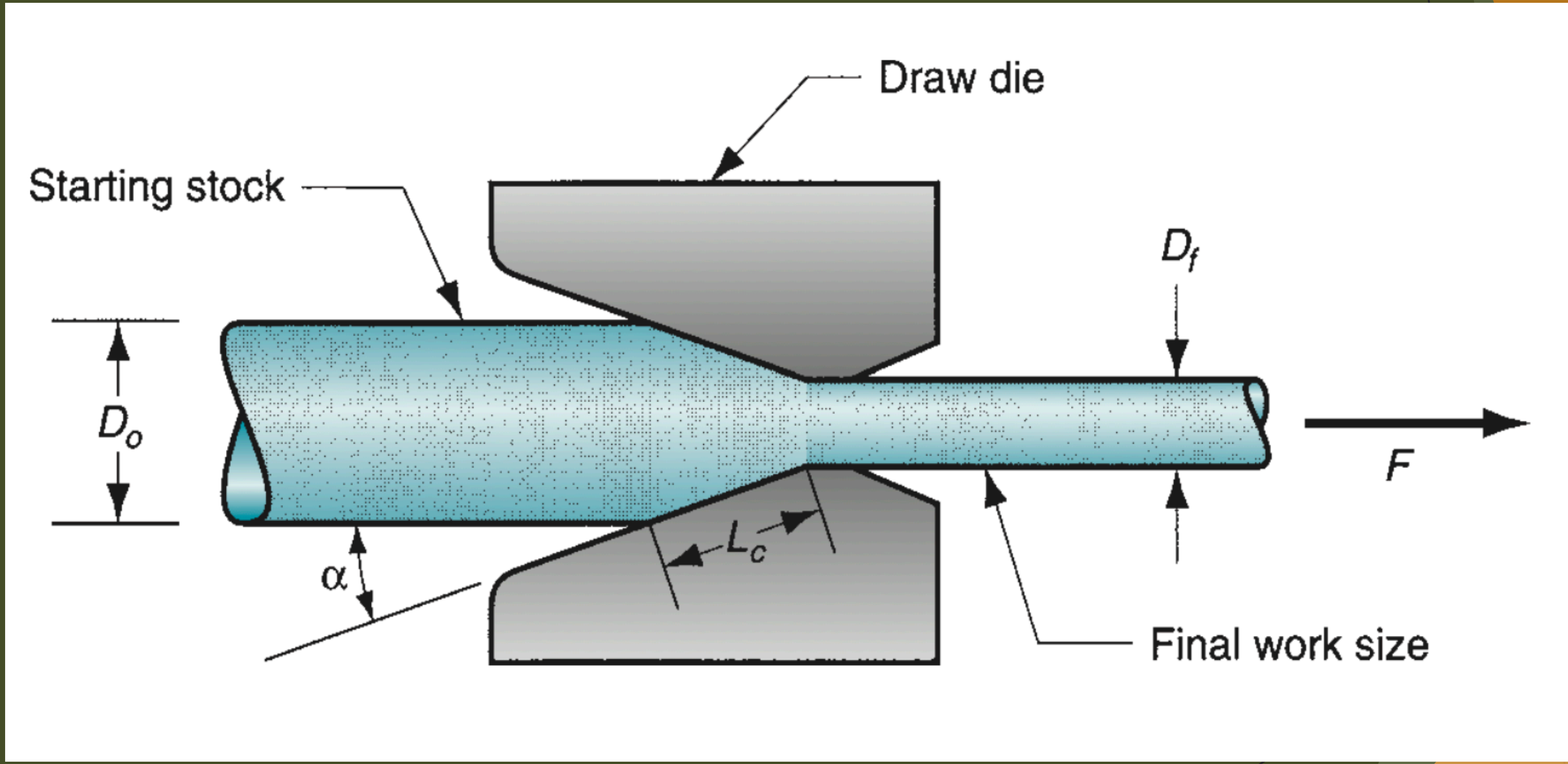

Figure 11.1 Drawing of bar, rod, or wire.

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The general features of the process are similar to those of extrusion. The difference is that the work is pulled through the die in drawing, whereas it is pushed through the die in extrusion.

Although the presence of tensile stresses is obvious in drawing, compression also plays a significant role because the metal is squeezed down as it passes through the die opening.

For this reason, the deformation that occurs in drawing is sometimes referred to as indirect compression.

Wire drawing applies to small diameter stock. Wire sizes down to 0.03 mm are possible in wire drawing.

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In wire drawing, wire is drawn from coils consisting of several hundred (or even several thousand) meters of wire and is passed through a series of draw dies. The number of dies varies typically between 4 and 12.

The term continuous drawing is used to describe this type of operation because of the long production runs that are achieved with the wire coils

In a drawing operation, the change in size of the work is usually given by the area reduction, defined as follows:

$$r = \frac{A_o - A_f}{A_o} \qquad \text{----------------} \quad (11.1)$$

where r = area reduction in drawing; A_o = original area of work, mm^2; and A_f = final area, mm^2. Area reduction is often expressed as a percentage.

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Mechanics of Drawing: If no friction or redundant work occurred in drawing, true strain could be determined as follows:

$$\epsilon = \ln \frac{A_o}{A_f} = \ln \frac{1}{1-r} \quad \text{---} \quad (11.2)$$

where A_o and A_f are the original and final cross-sectional areas of the work, and r = drawing reduction.

The stress that results from this ideal deformation is given by:

$$\sigma = \bar{Y}_f \epsilon = \bar{Y}_f \ln \frac{A_o}{A_f} \quad \text{---} \quad (11.3)$$

and, $\bar{Y}_f = \frac{K\epsilon^n}{1+n}$ ------- (11.4)

$where\ \bar{Y}_f = average\ flow\ stress\ N/mm^2$, K=strength coefficient N/mm^2 , ϵ = true strain, and n = strain hardening exponent.

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Because friction is present in drawing and the work metal experiences inhomogeneous deformation, the actual stress is larger than provided by equation (11.3).

In addition to the ratio A_o/A_f, other variables that influence draw stress are die angle and coefficient of friction at the work–die interface.

A number of methods have been proposed for predicting draw stress based on values of these parameters:

the equation suggested by Schey:

$$\sigma_d = \bar{Y}_f\left(1 + \frac{\mu}{\tan\alpha}\right)\phi \ln\frac{A_o}{A_f} \quad ---- \quad (11.5)$$

where σ_d = draw stress, MPa; μ = die-work coefficient of friction; α = die angle (half-angle) as defined in Figure (11.1).

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And ϕ is a factor that accounts for inhomogeneous deformation which is determined as follows for a round cross section:

$$\phi = 0.88 + 0.12\frac{D}{L_c} \quad \text{--------------} \quad (11.6)$$

where D = average diameter of work during drawing, mm; and Lc = contact length of the work with the draw die in Figure (11.1), mm.

Values of D and Lc can be determined from the following:

$$D = \frac{D_o + D_f}{2} \quad \text{-----------} \quad (11.7)$$

$$L_c = \frac{D_o - D_f}{2\sin\alpha} \quad \text{----------} \quad (11.8)$$

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The corresponding draw force is then the area of the drawn cross section multiplied by the draw stress:

$$F = A_f \sigma_d = A_f \bar{Y}_f \left(1 + \frac{\mu}{\tan \alpha}\right) \phi \ln \frac{A_o}{A_f} \quad \text{----} \quad (11.9)$$

where F = draw force, N; and the other terms are defined above.

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Example 11.1

Wire is drawn through a draw die with entrance angle = 15^o . 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.

Solution:

$$D = \frac{D_o + D_f}{2} \quad \text{-----------} \quad (11.7)$$

$$D = \frac{2.5 + 2.0}{2} = 2.25 \text{ mm.}$$

$$L_c = \frac{D_o - D_f}{2 \sin \alpha} \quad \text{-----------} \quad (11.8)$$

$$L_c = \frac{2.5 - 2.0}{2 \sin 15} = 0.966 \text{ mm.}$$

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$$\phi = 0.88 + 0.12\frac{D}{L_c} \quad \text{-------} \quad (11.6)$$

$$\phi = 0.88 + 0.12\frac{2.25}{0.966} = 1.16$$

The areas before and after drawing are computed as:

$$A_o = \frac{\pi}{4}D_o^2 = \frac{\pi}{4}2.5^2 = 4.91\ mm^2$$

$$A_f = \frac{\pi}{4}D_f^2 = \frac{\pi}{4}2.0^2 = 3.14\ mm^2$$

The resulting true strain:

$$\epsilon = \ln\frac{A_o}{A_f} = \ln\frac{4.91}{3.14} = 0.446$$

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and the average flow stress in the operation is computed:

$$\bar{Y}_f = \frac{K\epsilon^n}{1+n}$$

$$\bar{Y}_f = \frac{205(0.446)^{0.2}}{1+0.2} = 145.4 \ N/mm^2$$

Draw stress is given by:

$$\sigma_d = \bar{Y}_f(1 + \frac{\mu}{\tan\alpha})\phi \ln\frac{A_o}{A_f}$$

$$\sigma_d = (145.4)\left(1 + \frac{0.07}{\tan 15}\right)(1.16)(0.446) = 94.1\, N/mm^2$$

Finally, the draw force is this stress multiplied by the cross-sectional area of the exiting wire:

$F = A_f\sigma_d = (3.14)$ 94.1= 295.5 N

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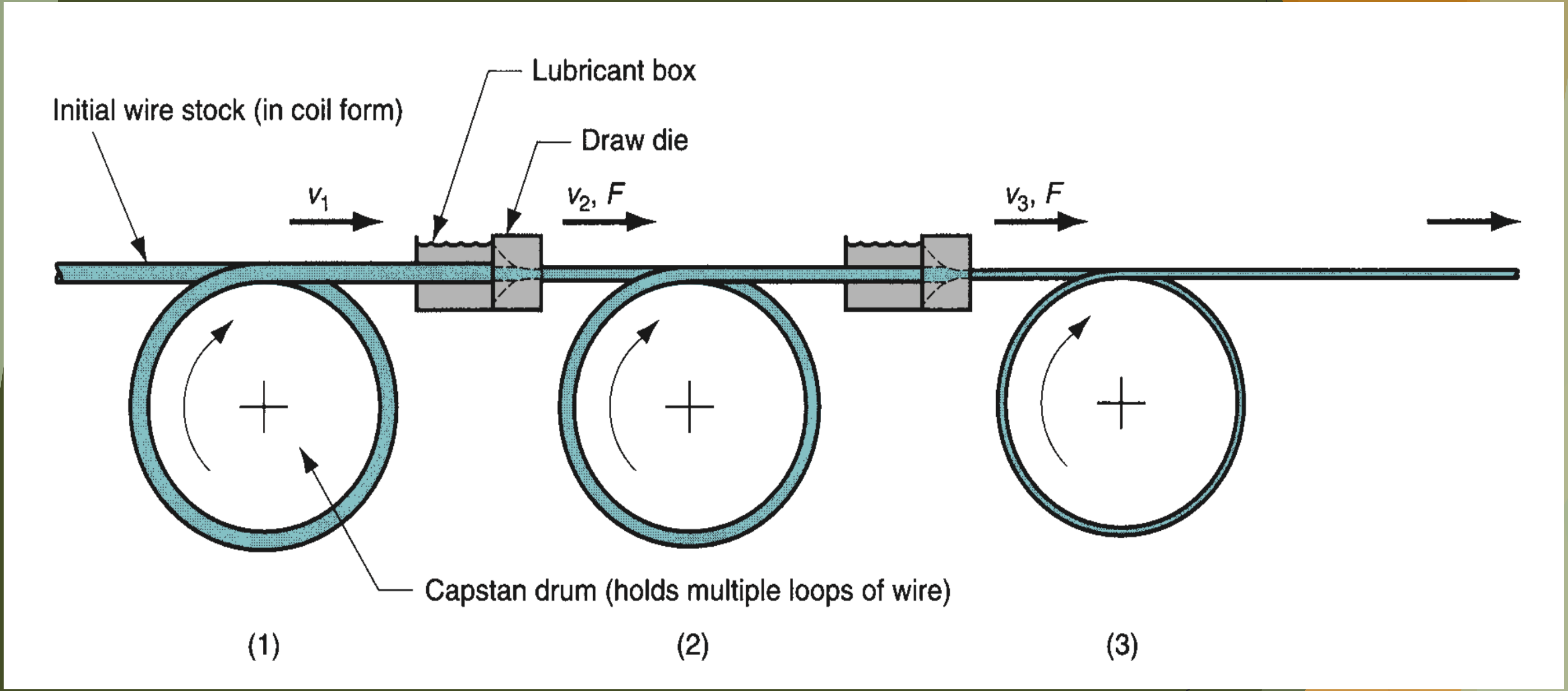

Figure 11.2 Continuous drawing of wire.

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Preparation of the Work Prior to drawing, the beginning stock must be properly prepared. This involves three steps:

(1) annealing.

(2) cleaning.

(3) pointing.

The purpose of ***annealing*** is to increase the ductility of the stock to accept deformation during drawing. As previously mentioned, annealing is sometimes needed between steps in continuous drawing.

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Cleaning of the stock is required to prevent damage of the work surface and draw die. It involves removal of surface contaminants (e.g., scale and rust) by means of chemical pickling or shot blasting. In some cases, prelubrication of the work surface is accomplished subsequent to cleaning.

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. The pointed end of the stock is then gripped by the carriage jaws or other device to initiate the drawing process.