Bar, Wire and tube drawing

1.Analysis of wire drawing:

1.1 Analysis of wire drawing

Consider the drawing of a wire through a conical shaped draw die, as shown below, schematically:

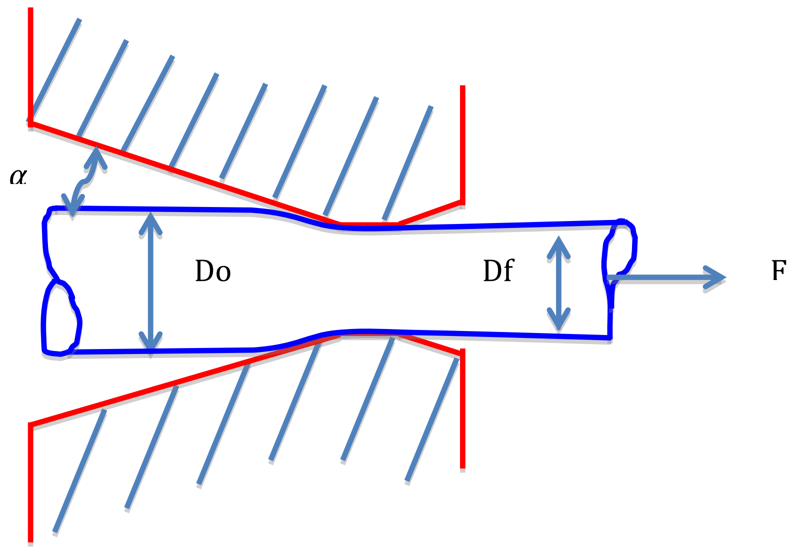

Fig. 1.1.1: Schematic of wire drawing process

Some of the important terms associated with wire drawing are to be understood first. They are:

Area reduction r is defined as (Ao-Af)/Ao -----2.1

The drawing ratio R is defined as Ao/Af = 1/(1-r) ------------2.2

The important parameters which affect the wire drawing force are the drawing ratio, die angle, material flow stress, friction etc.

Approximate expression for drawing force can be written based on plastic work or strain energy. Ignoring friction and redundant work we can write the draw pressure as:

Draw pressure p = $\bar{Y}\ln(\frac{A_0}{A_f})$ = $\bar{Y}\ln R$ = $\bar{Y}\ln(\frac{1}{1-r})$ ----------------2.3

The draw pressure is dependent on draw ratio R. As draw ratio is increased the draw pressure increases.

$\bar{Y}$ is the average flow stress of the material.

1.2 Analysis of wire drawing with friction:

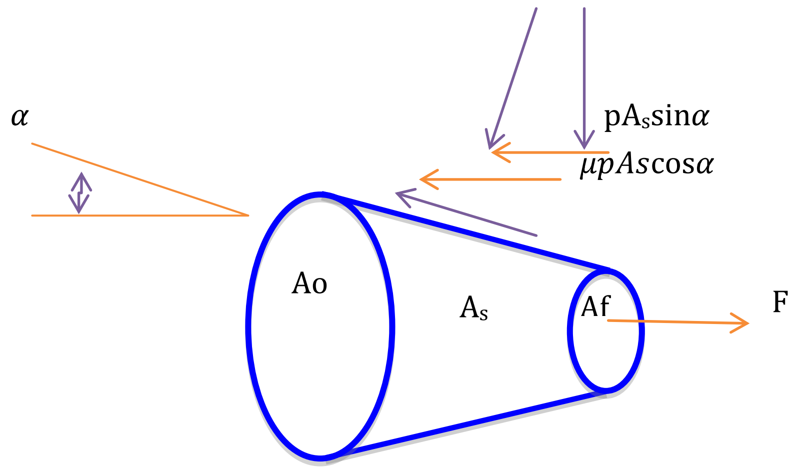

Fig. 1.2.1: Stresses acting on elemental section of the drawn wire during drawing

Consider a conical element of the workpiece inside the die. The surface area of the element is taken to be As. Let α be the semi-cone angle of the die. A_o is the cross sectional area of the work piece at entry of the die. A_f is the exit cross-section area. We can write the surface area of the element A_s as:

$A_s = \frac{A_o - A_f}{sin\alpha}$ ---------------2.4

The forces acting on the elemental work piece are:

Force due to normal die pressure = pAs sinα

frictional force = $\mu pAs\ cos\alpha$

Draw force = F,

Making force balance on the element:

$pA_s sin\alpha + \mu pAs\ cos\alpha$ = F --------2.5

Substituting for A_s from 4, we get:

$p(A_o\text{-}A_f) + \mu p(A_o\text{-}A_f)\cot\alpha = F$

$F = (A_o\text{-}A_f)p\ [1+\mu\cot\alpha)$ ---------2.6

We can eliminate p from the above equation by considering a frictionless drawing. In the absence of friction:

Draw force = $F = (A_o\text{-}A_f)p = \bar{Y}'\ln(\frac{A_0}{A_f})Ao$

From this, we can write: $p = \frac{Ao}{Ao-Af}\bar{Y}'\ln(\frac{Ao}{Af})$ -------2.7

Substituting 7 in 6, we get:

$F = A_o\bar{Y}'\ln(\frac{Ao}{Af})(1+\mu cot\alpha)$ ------------2.8

Or, the draw stress with friction can be written as:

$p = \bar{Y}'\ln(\frac{Ao}{Af})(1+\mu cot\alpha)$ -------------2.9

As seen from the above equation, the draw stress depends on the die angle. Higher the die angle, higher the draw stress.

A simple equation proposed by Schey can also be used for the draw stress. It is given as:

$\sigma_d = \bar{Y}'(1+\frac{\mu}{tan\alpha})\theta\ln(\frac{A_0}{A_f})$ ----------2.9A

where$\theta = 0.88 + 1.2\frac{D}{L_c}$. which accounts for redundant deformation. It is called inhomogeneity factor.

D is average diameter of the billet,L_c is contact length of the wire in the die.

$L_c = \frac{Do-Df}{2sin\alpha}$ and $D = \frac{D0+Df}{2}$

We can determine the draw force from 2.9A as:

F = $A_f\sigma_d$

1.3 Strip drawing – slab analysis:

Strip drawing is a process of drawing in which, metal of large thickness gets reduced in thickness and increase in length through a converging die.

Consider a rectangular strip of initial thickness ho and uniform width. This strip is passed through a convergent die, so that its thickness gets reduced to hf. The semi-die angle is taken to be α.

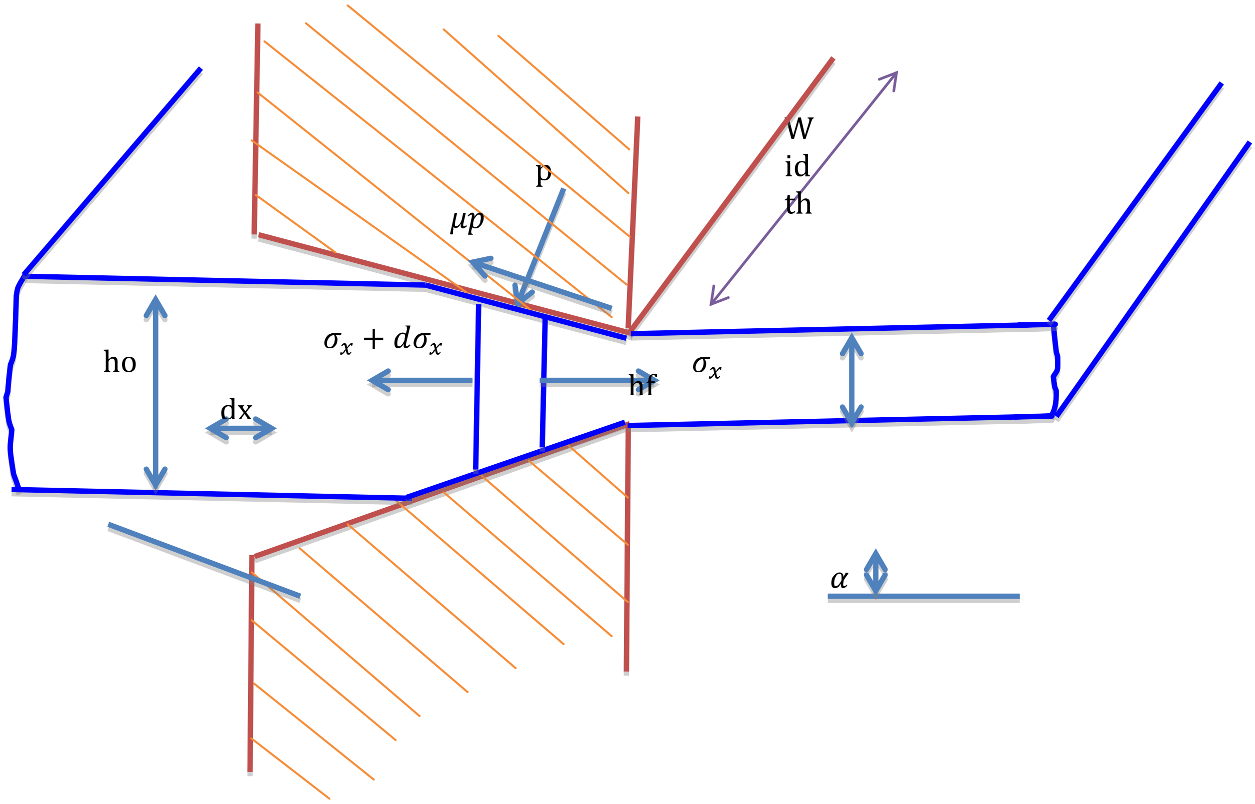

Fig. 1.3.1: Strip drawing – stresses acting

In the analysis, we may assume plane strain compression of the strip, as the width of the strip does not change during the process.

Consider a strip of thickness dx within the die. Let the strip of initial thickness h+dh be reduced in thickness to h after the deformation. We can write the force balance on the elemental strip.

The slant area of the strip = dx/cosα (Width is taken as unity)

Resolving the forces along the direction of drawing and writing the force balance,

$\sigma_x dh + hd\sigma_x + 2\mu pdx + 2pdxtan\alpha$ = 0 -----------2.10

Dividing by dh on both sides,

$\sigma_x + \frac{hd\sigma_x}{dh} + p(1 + \mu cot\alpha)$=0 ----------------2.11

Applying Tresca yield criterion, we have

σ_x+p = $\bar{Y}'$ where $\bar{Y}'$is plane strain yield strength and is = 2Y/$\sqrt{3}$ ------2.12

p = $\bar{Y}' - \sigma_x$ ----------2.13

Substituting in 2.11, and letting B = $\mu cot\alpha$we get:

$\frac{d\sigma_x}{B\sigma_x - Y'(1+B)}$ = $\frac{dh}{h}$ ------2.14

Integrating and applying the boundary condition:
At h = h_o, σ_x =0

We get:

$\sigma_x = \bar{Y}' \frac{1+B}{B}(1 - \left[\frac{h_f}{h_o}\right]^B)$ --------2.15

By applying the same procedure, we can derive a similar expression for the draw stress of wire drawing process.

The draw stress for wire drawing process is given by:

$\sigma_x = \bar{Y}' \frac{1+B}{B}(1 - \left[\frac{d_f}{d_o}\right]^{2B})$ -------2.16

Example: A steel wire is drawn to 24% reduction from initial diameter of 10mm. The flow stress of the material is given by: $\sigma = 1200\varepsilon^{0.28}$MPa. The semi die angle is 6o and μ=0.1. Calculate the draw stress and the power required for the deformation if the wire moves at a speed of 2.5 m/s.

Solution:

Given: r = 0.24 = (Ao-Af)/Ao

We can calculate the strain from the expression: $\varepsilon = ln\frac{1}{1-r}$ = 0.274

The average flow stress is given by: $\overline{Y}'$= k$\frac{\varepsilon^n}{1+n}$ = 1200(0.274)$^{0.28}$ / 1.28 = 652.73 MPa

We can use equation 9 for calculating the draw stress:

p = $\overline{Y}'\ \ln\left(\frac{Ao}{Af}\right)(1+\mu cot\alpha)$ = 349.86MPa

Now, the final area of cross-section of the wire, Af = Ao(1-r) = 59.66 sq.mm

To determine power required, we can use the formula:

Power = Draw force X speed of drawing = Draw stress X A_f X speed = 52180.93 W

Source:
http://nptel.ac.in/courses/112106153/27