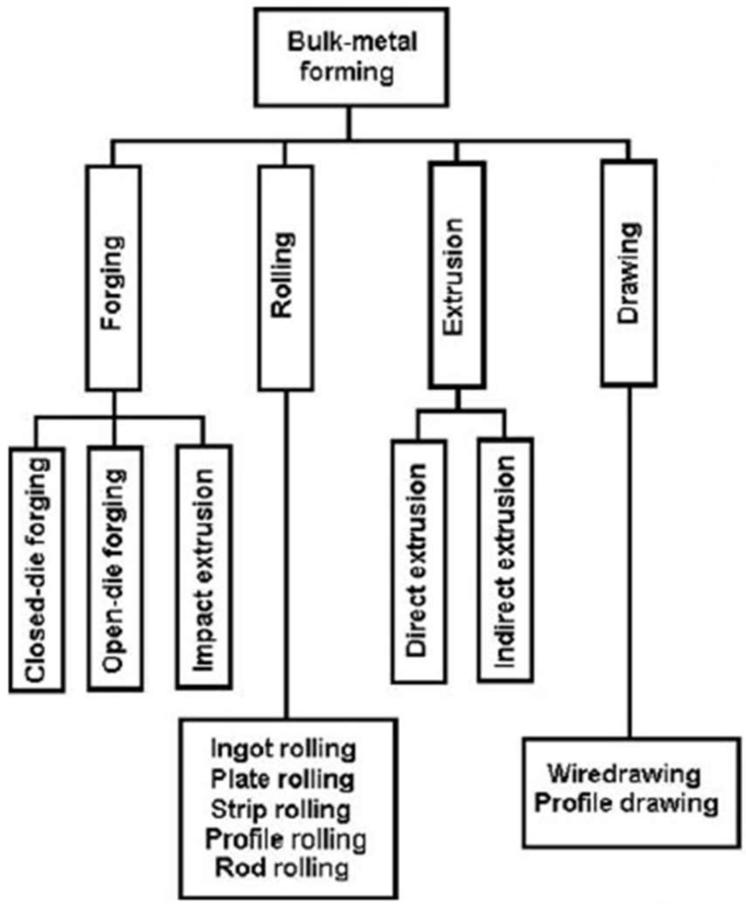
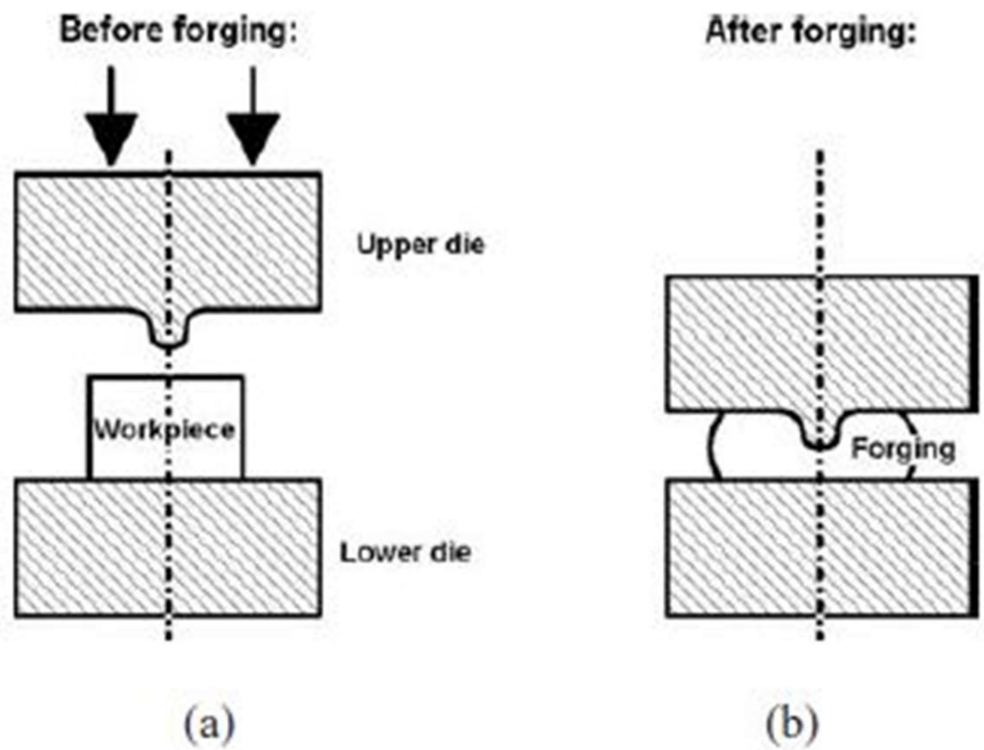
Tutorial 2

Forging

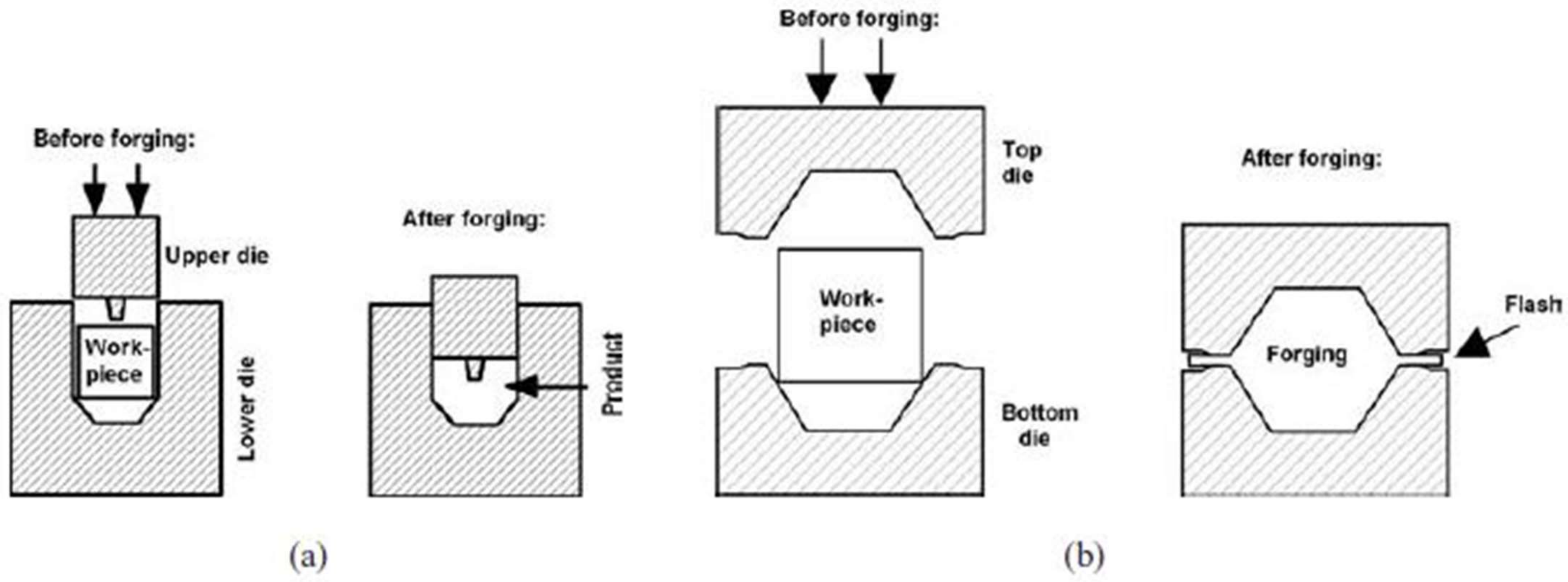
TYPES OF FORGING



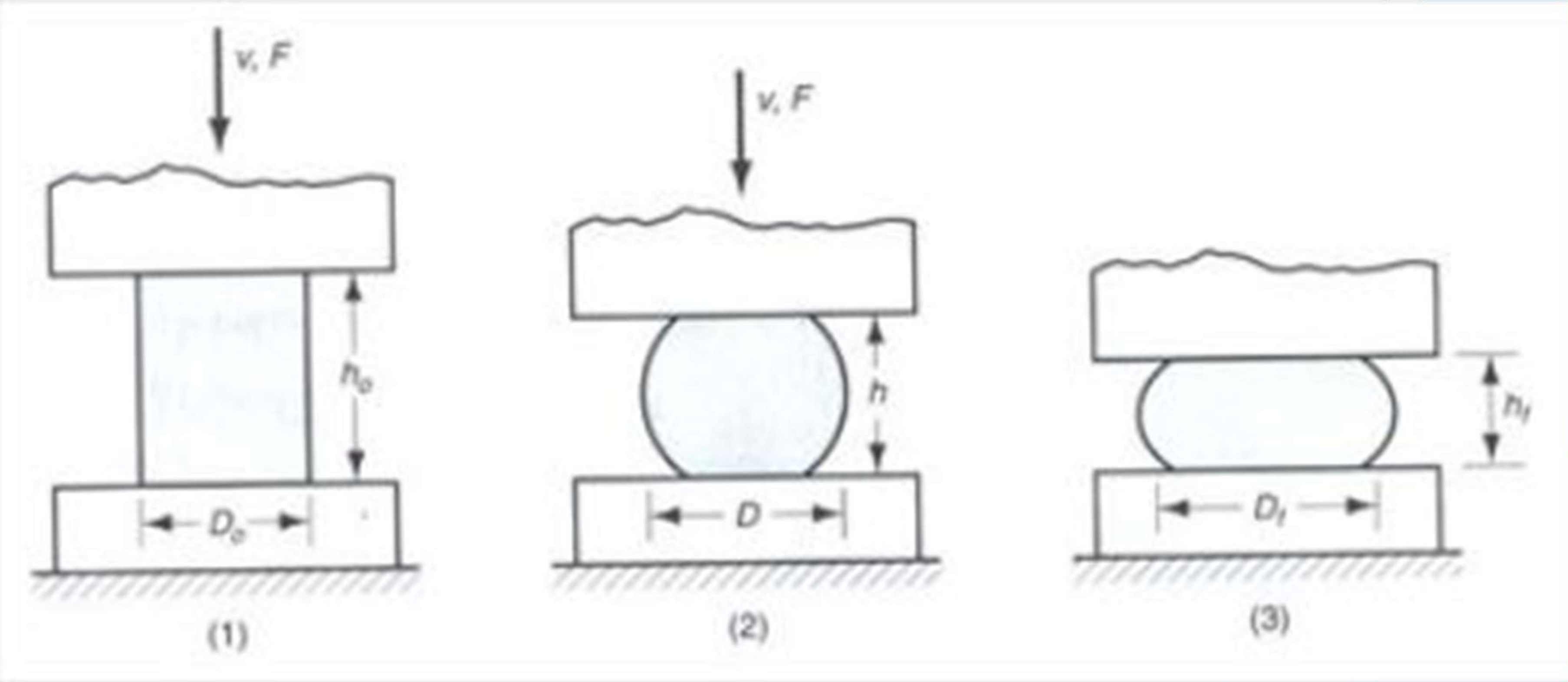
OPEN - DIE FORGING



CLOSED - DIE FORGING



CASE 1: UPSET FORGING OF CYLINDRICAL BILLET



initial height, h_0

final deformed height, h_f

true strain, $\epsilon = \ln\left(\frac{h_0}{h_f}\right)$

Forging force, $F = YA$

Here, by volume constancy,

$A \cdot h = A_0 h_0$

$\Rightarrow A = \frac{A_0 h_0}{h}$

Let Y be flow stress,

average flow stress,

$$\bar{Y} = \frac{k\varepsilon^n}{n+1}$$

where,

k - strengthening factor

n - strain-hardening exponent

$\Rightarrow$ Forging Force, $F = \bar{Y} . A$

Practical case includes assumption of barelling.

∴ for non-homogenous upsetting,

$$F = k_f \bar{Y} A,$$

where, $k_f = 1 + \frac{0.4 \mu d}{h}$,

k_f - forging shape factor

PROBLEM 1

Cold upset forging of a cylindrical billet of initial height 60 mm and initial diameter 30 mm, results in a final reduced height of 40 mm. The material of the billet has flow stress given by the expression=300 ε^0.2 MPa. The coefficient of friction between the billet and die surfaces can be assumed to be 0.1. What is the forging force required at the reduced height?

Given :

$h_o = 60$ mm

$d_o = 30$ mm

$h_f = 40$ mm

$Y = 300\,\varepsilon^{0.2}$ MPa ; $k = 300,\ n = 0.2$

$\mu = 0.1$

$F = k_f \bar{Y} A$

(i) Finding A_f

$$A_f = \frac{A_o h_o}{h_f}$$

$$= \frac{\frac{\pi}{4} d_o^2 h_o}{h_f}$$

$$= \frac{\pi/4 \cdot (30)^2 (60)}{40}$$

$$= 1060.29 \text{ mm}^2$$

$$A_f = \frac{\pi}{4} d_f^{\,2}$$

$$d_f = \left(\frac{4}{\pi} A_f\right)^{1/2}$$

$$= \left[\frac{4}{\pi} \times 1060.29\right]^{1/2}$$

$$= 36.74 \text{ mm}$$

(ii) Finding $\bar{Y}$

$$\bar{Y} = \frac{k\varepsilon^n}{n+1} = \frac{Y}{n+1}$$

$$\varepsilon = \ln\left[\frac{h_0}{h_f}\right]$$

$$= \ln\left[\frac{60}{40}\right]$$

$$= 0.405$$

$$\bar{Y} = \frac{300\,(0.405)^{0.2}}{0.2+1}$$

$$= 208.65 \text{ MPa}$$

(iii) Finding k_f

$$k_f = 1 + \frac{0.4\mu d_f}{h_f}$$

$$= 1 + \frac{(0.4)(0.1)(36.74)}{40}$$

$$= 1.037$$

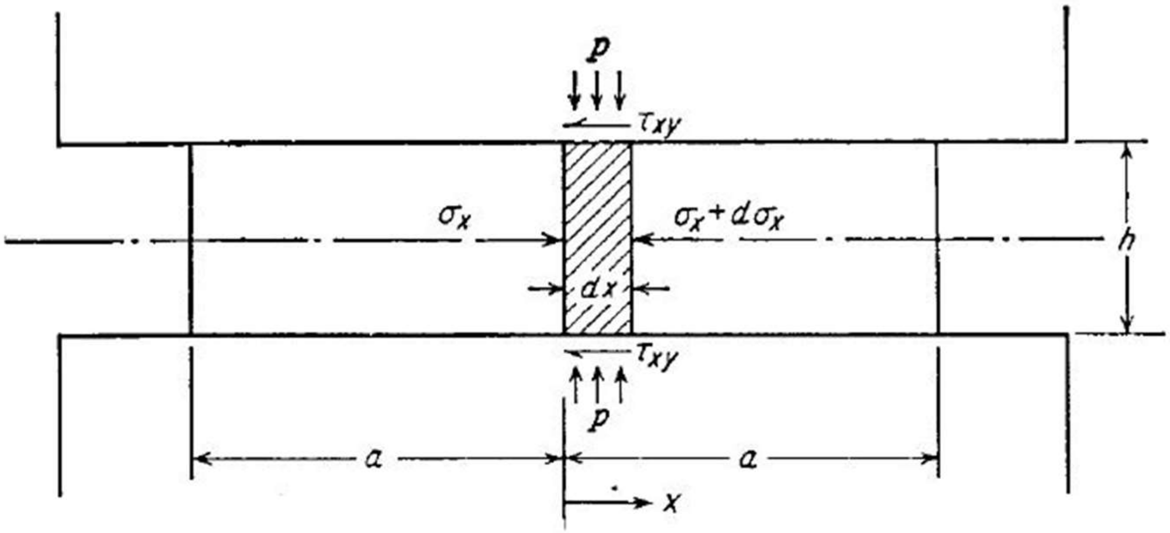
$$\Rightarrow F = k_f \bar{Y} A_f$$

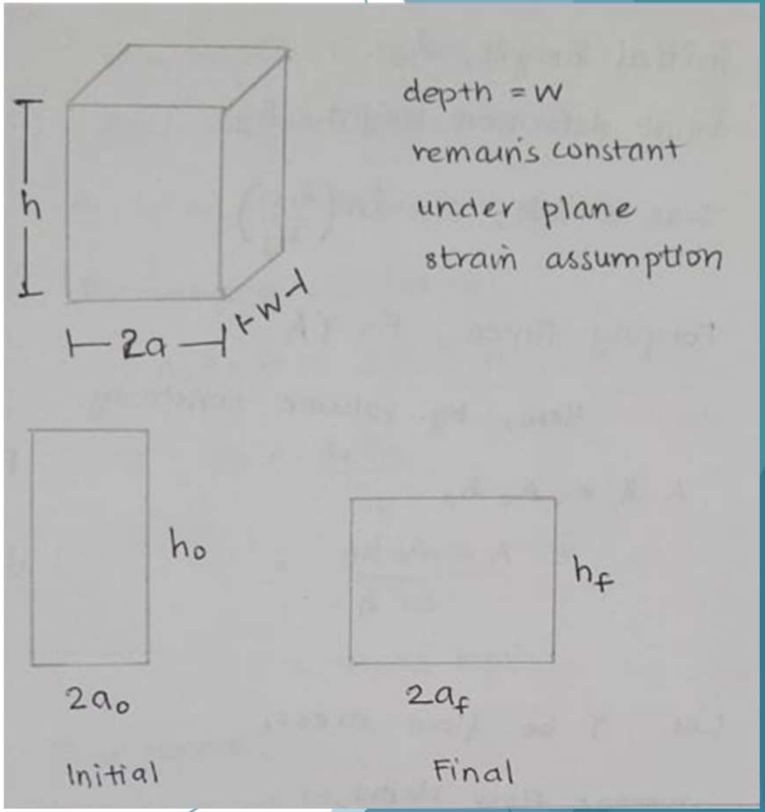
$$= 1.037 \times 208.65 \times 1060.29$$

$$= 229415.\ N$$

$$= 229.42 \text{ kN}$$

CASE 2: UPSET FORGING OF RECTANGULAR BILLET





Stresses acting on a plate forged in plane strain,

$$\frac{d\sigma_x}{dx} = -\frac{2\tau_{xy}}{h}$$

von-Mises yield criterion for plane strain condition:

$$\sigma_1 - \sigma_3 = \frac{2}{\sqrt{3}} Y = \bar{Y}$$

Here, $\sigma_1 - \sigma_3 = \bar{Y} = p - \sigma_x$

$\bar{Y}$ doesn't vary w.r.t x.

$$\Rightarrow \frac{dp}{dx} = \frac{d\sigma_x}{dx}$$

$$\Rightarrow \frac{dp}{dx} = -\frac{2\tau_{xy}}{h}$$

By Coulumb's law of sliding friction,

$$\tau_{xy} = \mu p$$

$$\Rightarrow \frac{dp}{p} = -\frac{2\mu}{h}\, dx$$

Integrating on both sides, using first two terms of expansion series to resolve,

$$p = \bar{Y}\left[1 + \frac{2\mu(a-x)}{h}\right]$$

Mean Forging peessure,

$$\bar{p} = \int_0^a p\frac{dx}{a}$$

$$\bar{p} = \frac{\bar{Y}}{\frac{2\mu a}{h}}\left(e^{\frac{2\mu a}{h}} - 1\right)$$

Total Forging Load,

$$F = \bar{p}A$$

$$= \bar{p}(2a)w$$

PROBLEM 2

A rectangular block of height 40 mm, width 100 mm and depth 30 mm is subjected to upset forging under sliding friction condition, with a friction coefficient of 0.2. The material of the billet has flow stress expressed as: Y = 300 e^0.2. Calculate the forging load required at the height reduction of 30%, assuming plane strain compression.

Given:

$h_0 = 40$ mm

$2a_0 = 100$ mm $\Rightarrow a_0 = 50$ mm

$w = 30$ mm = depth

30% height reduction.

$\Rightarrow h_f = (1-0.3)h_0 = 28$ mm

By volume constancy,

$$2a_0 h_0 w = 2a_f h_f w$$

$$\Rightarrow a_f = \frac{a_0 h_0}{h_f}$$

$$= \frac{50 \times 40}{28}$$

$$= 71.43 \text{ mm}$$

True strain,

$$\epsilon = \ln\left(\frac{h_o}{h_f}\right).$$

$$= \ln\left(\frac{40}{28}\right)$$

$$= 0.357$$

Flow stress, $Y = 300\,\varepsilon^{0.2}$

$$\Rightarrow K = 300, \quad n = 0.2$$

$$\bar{Y} = \frac{K\varepsilon^n}{n+1} = 203.7 \text{ MPa}$$

$$\frac{2\mu a_f}{h_f} = \frac{2 \times 0.2 \times 71.43}{28} = 1.02$$

$$\bar{p} = \frac{\bar{Y}}{\frac{2\mu a_f}{h_f}} \left(e^{\frac{2\mu a_f}{h_f}} - 1 \right)$$

$$= \frac{203.4}{1.02} \left(e^{1.02} - 1 \right)$$

$$= 353.59 \text{ MPa}$$

Total Forging Load,

$$F = \bar{p}\,(2a)\,w$$

$$= 353.59 \times (2 \times 71.43) \times 30$$

$$= 1515.42 \text{ kN}$$

THANK YOU!