MAE 112: Spring 2001

HW 10

Due: Tuesday, April 19

Problem 1

Consider a sheet of metal of 5 inch width and 0.075 inch thickness. It is to be rolled to a thickness of 0.050 inches in one pass using a mill whose steel rolls are of 8 inch diameter; the value of μ in this case is about 0.10, and the average flow stress of the metal sheet is 20 ksi. For the steel rolls you can use $E' = 33 \times 10^6$ psi.

1. Calculate the average roll pressure if roll flattening is ignored.
2. Repeat (a) if roll flattening is considered.
3. Estimate the minimum thickness to which this sheet could be rolled.

Problem 2

Consider (plane-strain) forging of a metal slab from an initial size of 1-in by 1-in by 10-in to a final size of 0.5-in by 2-in by 10-in. This is accomplished using a flat faced drop hammer to supply the necessary force. Sliding friction is assumed with $\mu = 0.1$. For the combination of temperature and strain rate involved, the yield stress of the material is approximately constant, $Y = 2,500$ psi.

1. Find the force required to produce the final thickness.
2. How much work is required to perform the operation?
3. Compute the probable deformation efficiency, η.

(Hint: It is given that at a given height h the average pressure in plane strain forging is equal to : $p_{ave} = \frac{2Y}{\sqrt{3}}[1 + \frac{\mu b}{2h}]$.)

Problem 3

Aluminum ($E_{Al} = 10 \times 10^6$ psi and $\nu_{Al} = 0.31$) is rolled in a mill with 10 -in diameter steel rolls ($E_S = 30 \times 10^6$ psi and $\nu_S = 0.33$). The coefficient of friction between the roll and aluminum is 0.30. The 13 - in wide aluminum strip enters the rolls 0.020 -in thick at 37 ft/sec. The average yield stress of the material is $31,000$ psi. Neglect roll flattening.

1. (3 points) What is the minimum thickness in which the above material can be rolled?
2. (2 points) What is the exit velocity of the aluminum at its minimum thickness?
3. (8 points) Estimate the roll force for the above case of reduction to minimum thickness.
4. (2 points) For the given material, give two significantly different ways to allow rolling to a smaller thickness than that predicted in item (a) above.

Possibly useful formulas:

- $L = \sqrt{R' \Delta h}$
- $R' = R(1 + \frac{16 F_s}{\pi E' \Delta h})$, where $E' = \frac{E}{1-\nu^2}$ and F_s is the force/width.
- $P_{ave} = \frac{h}{\mu L}(e^{\frac{\mu L}{h}} - 1)(\frac{2Y}{\sqrt{3}} - \frac{\sigma_b + \sigma_f}{2})$
- $h_{min} = \frac{7.5\mu\ R'}{E'}(\frac{2Y}{\sqrt{3}} - \frac{\sigma_b + \sigma_f}{2})$

Problem 4

You are asked to estimate the force required to coin a U.S. quarter assuming this is done cold. The method approximates axial compression and the entire quarter flows plastically. The mean flow stress is 25 Ksi, the outer diameter is about 0.95-in and the mean thickness after forming is about 0.06-in. Sticking friction is reasonable.

Problem 5 (from an earlier MAE212 final exam)

Consider axially symmetric wire drawing of a non-hardening material through a conical converging die. For small semi-die angles α, we can assume that inside the deformation zone the radial, circumferential and axial axes are fixed principal axes. To emphasize that σ_r is a compressive stress we use the notation $\sigma_r = -p$ ($p \geq 0$, p=pressure).

- Assume that the yield stress is given as Y. Using the approximation $\sigma_r = \sigma_\theta$, show that according to the von Mises criterion, yielding occurs when

$$\sigma_z \ + \ p = Y \tag{1}$$

where σ_z is the axial stress.

- Assume that the die is well lubricated such that friction can be neglected. Analyze a slab of material in the deformation zone and apply equilibrium in the x-axis to show that:

$$\frac{dD}{D} = \frac{dp}{2Y} \tag{2}$$

- With an appropriate integration of your slab equilibrium equation show that the pressure p in the die-workpiece interface can be expressed as a function of the diameter D in the deformation zone as follows:

$$p = Y[1 - \ell n(\frac{D_o}{D})^2] \tag{3}$$

Problem 6 (from an earlier MAE212 final exam)

Calculate the force required for extrusion of 1100-O aluminum from a diameter of 6 in to 2 in. Assume that the redundant work is 40 percent of the ideal work of deformation and that the friction work is 25 percent of the total work of deformation (The aluminum alloy obeys $\bar{\sigma} = K\bar{\epsilon}^n$, with K$=26,000$ psi and n=0.2).