MAE 212: Spring 2001

HW 11

Due Thursday, April 26, 2001

1. (From last year's final exam) **True or False:** State your answers in a Box and in order. Do not show your calculations as credit will only be given to your final selection (T or F) shown in the Box.

   (a) For the same applied load in tension, the true stress is always less in magnitude than the engineering stress.

   (b) For incompressible elastic materials, the bulk modulus B is equal to zero.

   (c) The shear modulus G can be expressed in terms of the Young's modulus E and Poisson's ratio ν as $G = \frac{E}{2(1-\nu)}$.

   (d) For an edge dislocation the Burgers vector is parallel to the dislocation line.

   (e) According to the von Mises yield criterion, a state of pure hydrostatic stress will not induce yielding.

   (f) Both phase diagrams and TTT diagrams define equilibrium phase transformations.

   (g) Since there are no close-packed planes in a FCC crystal, any plane containing a [110] direction can act as a slip plane.

   (h) The Miller indices of a close-packed plane in HCP are $[1\bar{1}00]$.

   (i) The recrystallization temperature increases with the amount of previous cold working.

   (j) One of the forms of Gibb's law used for phase transformations in metallic alloys is $C = F - P + 1$, where F is the number of the independent state variables, P the number of phases present and C the number of components.

   (k) A more ductile material will usually have a larger strain hardening exponent n.

   (l) The Schmid factor is used to define the relation between the yield stress of a polycrystal and the critical resolved shear stress on a slip plane of a single crystal.

   (m) In terms of the principal stresses σ_1, σ_2 and σ_3, a plane stress state is defined as one where one of the principal stresses is the average of the other two, e.g. $\sigma_2 = \frac{1}{2}(\sigma_1 + \sigma_3)$.

   (n) In extrusion processes, the maximum reduction per pass is usually obtained when the extrusion pressure becomes equal to the yield stress of the material.

(o) At the neutral point in flat rolling the frictional forces are maximum assuming sliding frictional conditions.

(p) In the sticking friction assumption used in the analysis of forging processes, the coefficient of friction is defined as $\mu = \kappa/p$, where κ is the yield stress in shear and p the pressure at the die/workpiece interface.

(q) The angle between [111] and [11$\bar{1}$] is $\arccos(\frac{1}{\sqrt{3}})$

(r) There are 3 atoms per unit cell in a BCC crystal.

2. (From last year's final exam) Prove that for any type of uniaxial hardening behavior, the true stress/true strain $\sigma(\epsilon)$ relation satisfies the following condition at the instant in which necking starts:

$$\frac{d\sigma}{d\epsilon} = \sigma \tag{1}$$

3. (From last year's final exam) In plane strain forging, the average pressure distribution was calculated in class using the slab analysis method. The results for sliding friction were:

$$p_{ave} = \frac{\frac{2Y}{\sqrt{3}}}{\frac{\mu b}{h}} \left(e^{\frac{\mu b}{h}} - 1\right) \tag{2}$$

where all symbols were defined and used several times in class. Use the above formula to estimate the average pressure in flat rolling of a sheet (without front or back tension):

(a) Draw a schematic of the flat rolling process and show that the contact length between the workpiece and the rolls is approximately given as:

$$L = \sqrt{R\ \Delta h} \tag{3}$$

where Δh is the thickness reduction and R the roll radius (neglect roll flattening).

(b) Draw a schematic of the plane strain forging process indicating h, b and w. Using the expression for p_{ave} in plane strain forging, derive an approximation of the average pressure between the rolls and the sheet in terms of the yield stresses Y_o and Y_f in the entrance and exit regions, respectively, the workpiece thicknesses h_o and h_f in the entrance/exit, the width w, the roll radius R and the average friction coefficient μ.

4. (From last year's final exam) A forging process of a rectangular slab was approximated in class as 'plane strain compression' ($\epsilon_y = 0$, y=the width direction). Assume that the axes x, y and z are principal stress/strain axes and that the material obeys a hardening law of the form $\bar{\sigma} = K\ \bar{\epsilon}^n$. The initial dimensions of the workpiece are $h_o \times b_o \times w_o$ and during compression we denote the dimensions with $h \times b \times w$.

(a) The workpiece is reduced to a height of $h = \frac{h_o}{2}$. Calculate 'the effective strain' at this reduction.

(b) Calculate the yield strength of the workpiece after the reduction in part (a) above.

(c) A cylindrical specimen of diameter d_o is machined from the forged workpiece. At what load (force) would this specimen yield if it is loaded in uniaxial tension?

5. (From the 1999 final exam) 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 26,846 psi. Neglect roll flattening.

   (a) What is the minimum thickness in which the above material can be rolled?

   (b) What is the exit velocity of the aluminum at its minimum thickness?

   (c) Estimate the roll force for the above case of reduction to minimum thickness.

   (d) 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:

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

6. (From last year's final exam) Find the tool radius necessary to produce a final bend radius of 10-in in a part made from a steel of thickness 0.03-in. Assume a yield stress Y=38,971 psi, Young's modulus of $E = 30 \times 10^6$ psi and Poisson's ratio of $\nu = 0.33$.

   (Hint: $\frac{1}{r} - \frac{1}{r'} = \frac{3\sigma_o}{tE'}$, where σ_o is the 'effective plane strain yield stress' and E' the 'effective plane strain elastic modulus'. If you forgot the expression for σ_o, you may want to re-derive it using the von-Mises criterion and considering 'plane strain' bending of a 'thin sheet'.)

7. A steel sheet, 0.036 inches thick, is bent to a radius of curvature of 5.0 inches. The flow (yield) stress $Y = 28,545$ psi and $E' = 33 \times 10^6$ psi.

   (a) What fraction of the cross section remains elastic?

   (b) What percent error does neglecting the elastic core cause in the calculation of the bending moment?