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UNIVERSITY OF CALIFORNIA
Departments of Mechanical Engineering and Materials Science &
Engineering

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C-ME 124/C-MSE 113
Mechanical Behavior of Materials
Midterm Exam #2

Name:

SID No.:

No	Total Credit	Credit
1	40	
2	30	
3	30	

Problem 1:

You are given a piece of ductile polycrystalline metal, such as virgin copper, with uniform cross-sectional area that behaves according to the following constitutive behaviour:

$$\sigma_{11} = k\epsilon_{11}^n$$

where σ_{11} and ϵ_{11} are respectively the uniaxial(true) stress and plastic strain.

a) If this material is pulled in uniaxial tension, draw and label the following on a Stress-Strain graph:

- i) variation in engineering stress vs. engineering strain
- ii) the corresponding variation in true stress vs. true strain
- iii) indicate where necking occurs
- iv) label the ultimate tensile strength, σ_u

b) Briefly explain (3 sentences or less) the difference between the true stress-strain and the engineering stress-strain diagrams.

c) By stating your assumptions clearly, derive the following relationships:

- i) An expression relating true stress to engineering stress and engineering strain only
- ii) an expression relating true strain to engineering strain only

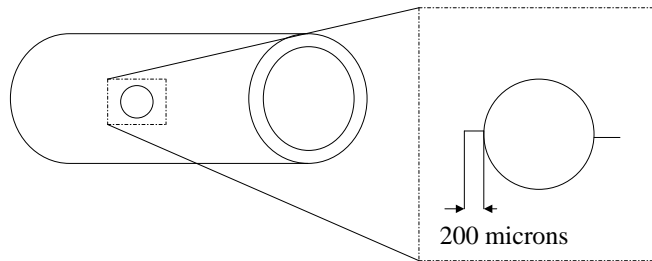
d) Briefly describe (3 sentences or less) what occurs microstructurally at the onset of:

- i) Plastic Deformation
- ii) Necking

e) Based on the constitutive law stated above, derive the true and engineering strains at the onset of necking. Again, state your assumptions clearly.

Problem 2

A pressure tube is being put in service and the users wish to monitor the gas flux through the tube using a flow-meter. A 1 mm diameter hole is therefore drilled into the side of the tube to accommodate the flow-meter inlet. When removing the drill bit, the machinist accidentally nicked the edges of the hole to form microscopic cracks of length, 200 μm , oriented in the longitudinal direction of the tube. (see diagram below). A high strength ferritic steel is used to make the tube, which has the following mechanical properties: yield stress $\sigma_y = 830$ MPa, modulus of elasticity $E = 200$ GPa, Poisson's ratio $\nu = 0.32$, and a fracture toughness K_{Ic} of $30 \text{ MPa}\sqrt{\text{m}}$. The tube dimensions are 15 m long, 12 cm outer diameter, and 2.5 mm wall thickness. Pressure in the tube is at 30 MPa (you may assume that the pressure source can be maintained constant within the tube despite the possible pressure release through the cracks). By considering the stress concentration around the hole, calculate the stress intensity factor developed at the machining cracks. Will the tube fail upon pressurization? Is your answer conservative? Support your answer mathematically.



Problem 3

A nuclear pressure tube, made of annealed Zircaloy 2 alloy, is pressurized with helium gas at 300 psi for 60 days at 700°F. It is then subjected to an increase in internal pressure to 600 psi for 30 days at 650°F. If the tube has an initial wall thickness of 1/8 inches and an outer diameter of 3 inches, calculate the final dimensions (diameter and wall thickness) after this 90 day period. You may neglect elastic and primary creep strains and assume a constitutive law for Zircaloy 2 between 600 and 800°F to be:

$$\dot{\epsilon} = [(\sigma/\sigma_0)^{16}] \exp[(-Q)/kT]$$

where $\sigma_0 = 5.5$ ksi and $Q = 1.065 \times 10^{-18}$ in.lb., $k = 6.79 \times 10^{-23}$ in.lb/°R is Boltzmann's Constant and T is absolute temperature (in °Rankine) °R = °F + 460.

Hint: use $\epsilon_{\theta\theta} = \ln(r/r_o) = \dot{\epsilon}_{\theta\theta} t$