Spring 2020: Mechanical Properties Materials Science (MPMS)

Take Home Exam II: (Plasticity)
Given out on Friday 03/06/2020, due in class on Monday 03/16/2020

Each question carries equal points; Please give your answers on the enclosed pages.

I strongly request you to think very carefully about the questions and your answers before you start writing. In particular please note:

•When a derivation is requested, please do not simply copy from the notes. Underline the assumptions in the analysis that are of a fundamental nature.

•Often the response is required to be descriptive. If you quote equations then they should be clearly described in words.

•Keep you answers as short as possible without losing the essence of your answer. You are advised to redo your answer sheet the second time before you submit. You will realize how much better and clearer your response is.

New for this Take Home Exam: Unnecessary verbiage, equations and derivations will reduce your grade for the question, even though the rest of your answer is correct.

Please write your answers on the pages in the print-out of this problem set.

1. Give three iconic examples, in the form of a figure and/or an equation, along with a couple of sentences to explain, of phenomena related to plastic deformation.

2. Why is the Poisson’s ratio equal to 0.5 in plastic deformation. What influence does this have on the “effective bulk modulus” for plastic deformation.

3. The forming limit diagram refers to multiaxial deformation of a metal sheet. The deformation strains on the surface is measured by the change in the shape of circles along the major and the minor axes, which are called major and minor strains.

(i) What will be the relative values of the strains along the major and the minor axes which leaves the thickness of the sheet unchanged.

(ii) Draw the change in the shape of the circles for three cases: equibiaxial, plane-strain and simple-uniaxial states of stress.

(iii) Which one of the three stress states in (ii) applies to the case of deformation as in (i) above.

4.

(i) How does the definition of slip systems in a given crystal structure, that is, combinations of slip planes and slip vectors, relate to the fact that plastic deformation leaves the crystal structure intact despite large scale movements of atoms?

(ii) Identify all the “most favored” slip systems (how many are there?) in a body centered cubic structure. Why are they “most favored”.

(iii) Why does the possibility of ductile deformation in polycrystals increase with multiplicity of slip systems within one group of slip vectors and slip planes – usually the one that has the lowest yield stress?

5. Describe a mechanism for the increase in the dislocation density with plastic strain. Please use no more than one or two figure and one or two equations in your answer.

6. The yield stress of engineering materials is designed by introducing hard precipitates in the path of the dislocations, which pin them.

(i) Using the following equation for the equilibrium between applied shear stress, σ, and R is the radius of curvature of the circular bowing-out of the dislocation in response to the applied stress

$$\sigma = \frac{Gb}{2R} \qquad (1)$$

show with the aid of one or two figures and a few words, that the dislocations will uncouple from the hard particles if the applied stress, σ^*, is greater than

$$\sigma = \frac{Gb}{\lambda} \qquad (2)$$

where λ is the average spacing between these hard precipitates. Please note that the effective pinning distance is somewhat less than the point-to-point spacing between the particle, as emphasized in the problem just below.

(ii) Heat treatment of aluminum leads to the dispersion of hard particles of size p and volume fraction v_f. Assuming that the particles are in the shape of cubes, with an edge equal to p, arranged as if in a simple cubic lattice show that the face-to-face spacing, λ^* ,that is the width of the metal ligament between the particles (which is somewhat less than λ) is given by

$$\lambda^* = p\left[\frac{1}{v_f^{1/3}} - 1\right] \qquad (3)$$

(iii) Explain why the effective value of λ^* continues to decrease with plastic strain leading to the phenomenon called "strain hardening".