Department of Materials Science and Engineering
Massachusetts Institute of Technology
3.14 Physical Metallurgy – Fall 2003

Problem Set #7

Due Wednesday, November 19, 2003

7.1 In class we developed a physical argument for how strain hardening promotes ductility by suppressing necking. In this assignment you will develop a mathematical argument for the same effect. To begin, we will start with the strain hardening law derived earlier in class:

$$\sigma_y = k\varepsilon^n$$

This equation was derived for TRUE stresses and strains after the onset of yield. In a tensile test, the ductility is measured in units of ENGINEERING stress and strain. Engineering and true stresses and strains are related as:

$$\sigma = \sigma_{eng}\left(1 + \varepsilon_{eng}\right) \qquad \varepsilon = \ln\left(1 + \varepsilon_{eng}\right)$$

With these relationships, derive the equation for the engineering stress-strain curve. Plot the curves (with stress normalized by k) for strain hardening exponents n = 0, 0.1, 0.3, and 0.5.

7.2 The ductility of the specimens can be measured by looking at the ultimate tensile strength, UTS, (i.e., the maximum engineering stress in the tensile test). The strain achieved at the UTS is roughly the ductility of the specimen, because the deformation is stable up until this point. Derive analytically an expression for the strain at the UTS.

7.3 Plot the ductility vs. the strain hardening exponent, n. You will now have a renewed appreciation for why strain hardening is a desirable characteristic in structural materials.