MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING
CAMBRIDGE, MASSACHUSETTS 02139

3.22 MECHANICAL PROPERTIES OF MATERIALS
PROBLEM SET 8

Due in 8 days from its assigned date

Reading
Hertzberg, *Deformation and Fracture Mechanics of Engineering Materials* (John Wiley & Sons, Inc.) Chapter V.
Ashby, M.F., *Mechanical Behaviour of Materials* (Course Notes). Section 8.

1. Consider metals and polymers. Which of these classes of materials generally exhibits strong recovery of creep strain after unloading, and which do not? Briefly explain in terms of the physical mechanisms of creep why the strains are generally recovered, or why they are not recovered, for both classes of materials.

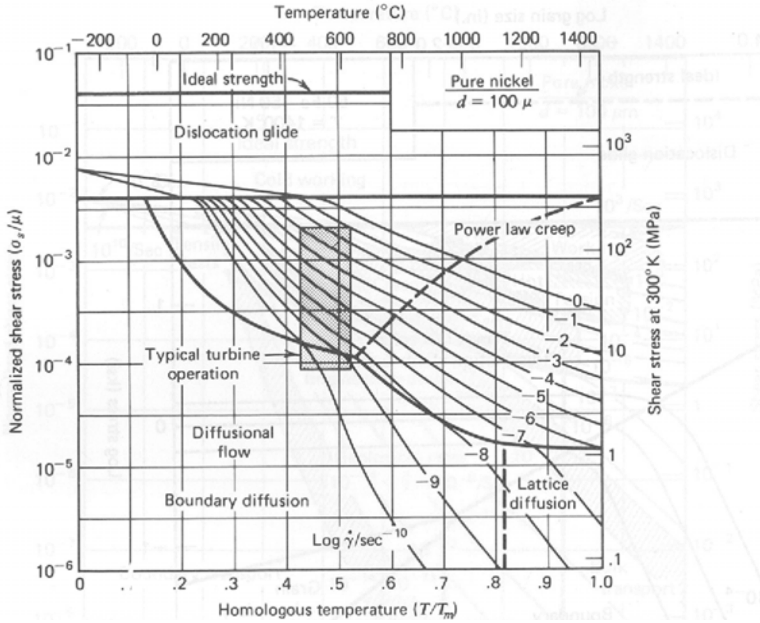
2. A 20 kg screw made from a high-strength steel (E = 210 GPa, σ_o = 200 MPa) holds two rigid plates together at 300°C. The design states that the screw be tightened to a preload of 100 MPa, which may not decrease by more than 10% while in service. To determine the maximum service life of the screw, a creep test at 300°C with a stress of 50 MPa is performed and yields a strain rate of 9.5×10^{-15} s^{-1}.
   a. Assuming that the stresses in the screw are high enough that power law creep is the dominant mechanism of deformation (n = 4), what is the maximum service life of the screw based on the conditions given above?
   (*Hint:* The rigid plates prevent any tensile strain in the bolt.)
   b. If the temperature increases dramatically (1000°C), can we use the data above to estimate how long the screw will maintain the designed preload? Explain.

3. Below is a table of self-diffusion values for silver single crystals and polycrystals over a range of temperatures.

Temperature (K)	$D_{Single\ Crystal}$ (m^2s^{-1})	$D_{Polycrystal}$ (m^2s^{-1})
773	1.26×10^{-17}	1.26×10^{-16}
873	3.16×10^{-16}	1.00×10^{-15}
973	5.00×10^{-15}	6.31×10^{-15}
1073	5.00×10^{-14}	5.00×10^{-14}
1173	3.16×10^{-13}	3.16×10^{-13}
1273	1.26×10^{-12}	1.26×10^{-12}

   a. Make an Arrhenius plot of the diffusion rate as a function of temperature.
   b. Calculate the activation energy for diffusion in a single crystal of silver.
   c. Qomment on the differences in diffusion rate between single crystalline and polycrystalline silver.

4. Consider a pure nickel component with a mean grain diameter of 0.1 mm. If the component is subjected to a shear stress of $\tau = 100$ MPa and creep deformation must not exceed 10^{-8} s^{-1}, what is the maximum operating temperature? If the safety factor is increased such that creep deformation cannot exceed 10^{-10} s^{-1}, what is the maximum operating temperature?



5. (Extra Credit) Turbine engines in jets can reach temperatures of 1300 K. How is creep prevented in turbine blades rotating at 10,000 rpm?