Tutorial Session 23: T73S06 (Creep Rupture / R5V6) - Homework
Last Update: 23/10/14

Mentor Guide K&S Questions

1.1 Explain what is meant by creep and when it is significant.

1.2 Describe the macroscopic symptoms of a creeping structure under primary loading

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1.4 Describe graphically the meaning of primary, secondary and tertiary creep.

1.5 Describe creep rupture data and isochronous creep data.

1.6 State the R5 definition of insignificant creep and give examples of the insignificant creep temperature for common ferritic and austenitic steels.

Numerical Questions

1) The fraction of lattice sites which are vacant assuming thermal equilibrium is given by the Arrhenius, or Boltzmann, factor $\exp\left\{-\frac{U_v}{kT}\right\}$, where U_v is the energy required to create a vacancy (1eV = 1.6×10^{-19} J), k is Boltzmann's constant (1.38×10^{-23} J/K), and T is the absolute temperature (K). Show that the equilibrium vacancy fractions quoted in the session 23 notes are correct (i.e., ~3×10^{-7} at 500°C, and ~10^{-4} at 1000°C).

2) Repeat the above calculations for dislocations (which require 8eV per atom plane) and hence show that the number of dislocations which would be expected to arise spontaneously by thermal motion is essentially zero.

3) Show that a dislocation density of ~ 10^{10} per mm^2 might be expected to arise due to cold work of 20% strain at a stress of ~300 MPa. [Evaluate the plastic work done per cubic-mm, and divide by the energy required to create a mm length of dislocation. Use a dislocation energy of 8eV per atom, and assume atoms of size 2×10^{-7}mm].

4) A very simple model illustrating how tertiary creep can arise from the loss of load bearing area can be formulated as follows. The current load bearing area, A, is found in terms of the engineering creep strain from $\frac{A_0}{A} = 1 + \varepsilon_c$, and the true stress is found from $\sigma = \frac{A_0}{A}\sigma_0$. If the engineering creep strain rate is given in terms of the true stress as $\dot{\varepsilon}_c = C\sigma^n$, then show by integrating that the creep strain for a constant load test as a function of time is $\varepsilon_c = \frac{1}{[1-(n-1)\dot{\varepsilon}_0 t]^\lambda} - 1$, where $\lambda = \frac{1}{n-1}$ and $\dot{\varepsilon}_0$ is the secondary strain rate, i.e., the strain rate at stress σ_0. If $\dot{\varepsilon}_0 = 10^{-6}$/hr, and n = 9, plot a graph of the creep strain against time thus demonstrating that it looks qualitatively as tertiary creep should (i.e., a steeply rising curve).