ESO 205T

Nature and Properties of Materials

Interaction session: 11-12 Monday
Tutorial: 11-12 Thursday

Assignment 8

Due by 19 November 2020 11 am

Question 1

Determine the critical radius and activation free energy for homogeneous nucleation of molten iron with latent heat of fusion of 3 x 10^9 J/m^3 and surface free energy of 0.25 J/m^2 for a critical undercooling of 300 ˚C.

Calculate the number of atoms in the critical radius considering the lattice parameter of BCC iron to be 0.3 nm at the melting point 1538 ˚C

$$r^* = \left(-\frac{2\gamma T_m}{\Delta H_f}\right)\left(\frac{1}{T_m - T}\right)$$

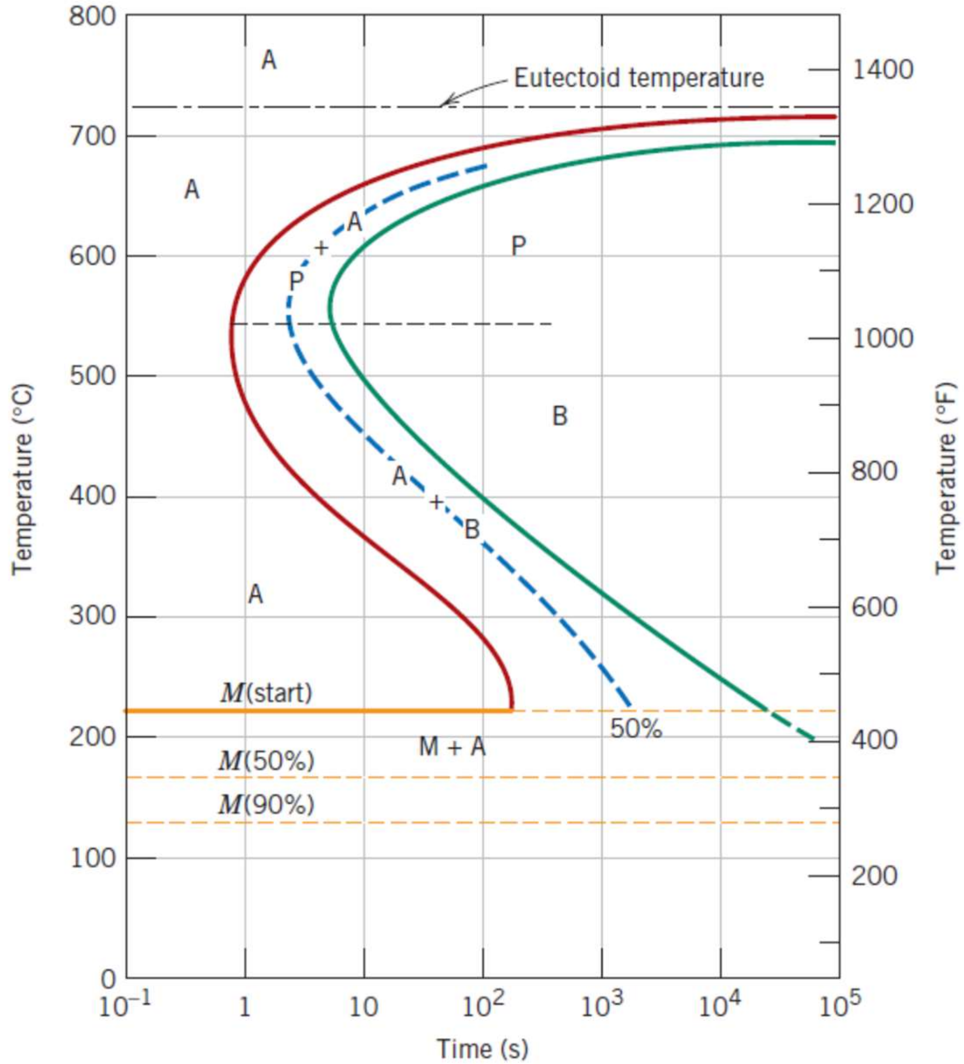
$$\Delta G^* = \left(\frac{16\pi\gamma^3 T_m^2}{3\Delta H_f^2}\right)\frac{1}{(T_m - T)^2}$$

Question 2

Determine the microstructure and fraction of phases for the following heat treatments for the eutectoid steel composition. TTT curve for the eutectoid steel is provided on the next slide. The steel samples were at a temperature of 775 ˚C before the heat treatment and were quenched to respective temperatures in 0.5 second and held for different duration

(i) Quenched to 600 ˚C and held for 500 s followed with quenching to room temperature
(ii) Quenched to 500 ˚C and held for 500 s followed with quenching to room temperature
(iii) Quenched to 300 ˚C and held for 500 s followed with quenching to room temperature
(iv) Quenched to room temperature
(v) Quenched to 150 ˚C held for 100 s followed with quenching to room temperature

Question 2



A – austenite

P – pearlite

B – bainite

M - martensite

Question 3

Pole vault is one of the most difficult athletics event in the Olympics and the design of the pole has undergone significant change from the ancient times to the present day. Materials like wood, bamboo, steel and glass fibre reinforced polymer have been employed to prepare the pole. The figure of merit for the pole is the ratio of square of specific yield strength to specific modulus. Arrange the materials in order of suitability for the manufacture of the pole for best performance by an athlete. Remember that the pole is hollow to reduce the weight.

Material	Strength (MPp)	Modulus (GPa)	Density (g/cc)
Wood	35	8	1.5
Bamboo	20	10	1.16
Steel	375	200	7.85
Glass fibre reinforced polymer	200	50	1

Question 4

True stress – true strain relationship for metallic materials is given by the constitutive relationship $\sigma = K\varepsilon^{n}$
where K is the strength co-efficient and n is the strain hardening exponent. Determine the condition for necking when the load bearing capacity due to strain hardening is equal to the load bearing capacity of the reduced cross section area of the sample.

The constitutive relationship for oxygen free high conductivity copper is given by

$$\sigma = 300\varepsilon^{0.5}$$

Determine the ultimate tensile strength of copper.

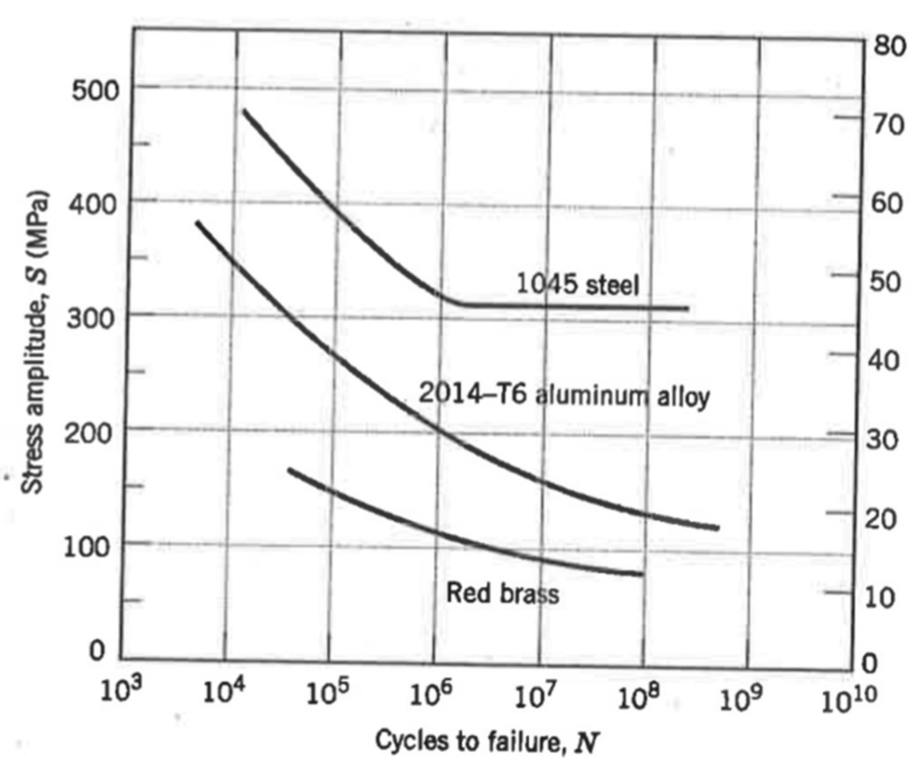
Question 5

Determine the yield strength for nickel with grain size of 25 µm and dislocation density of 10^{14} m^{-2} assuming additive contribution from grain size strengthening and dislocation strengthening. The lattice friction stress which is defined as the stress required for motion of the dislocation through the lattice is 20 MPa.

Hall-Petch co-efficient = 0.16 MPa $m^{0.5}$, Taylor factor = 3, Dislocation screening factor = 0.5, shear modulus of nickel = 72 GPa and lattice parameter of FCC nickel is 3.499 Å

Question 6

A shaft of steel and 2014-T6 aluminium alloy is subjected to a mean stress of 150 MPa with a stress ratio of -0.4. Determine the number of cycles to failure from the S-N curve (stress amplitude vs. number of cycles to failure) provided below.



Question 7

Steady state creep rate for a high temperature alloy is 10^{-6} s^{-1} at 600 ˚C and 5 x 10^{-4} at 900 ˚C for a stress of 200 MPa. Determine the activation energy for creep and the steady state creep rate at 800 ˚C for a stress of 200 MPa.

$$\dot{\varepsilon}_s = A\sigma^n \exp\left(-\frac{Q}{RT}\right)$$