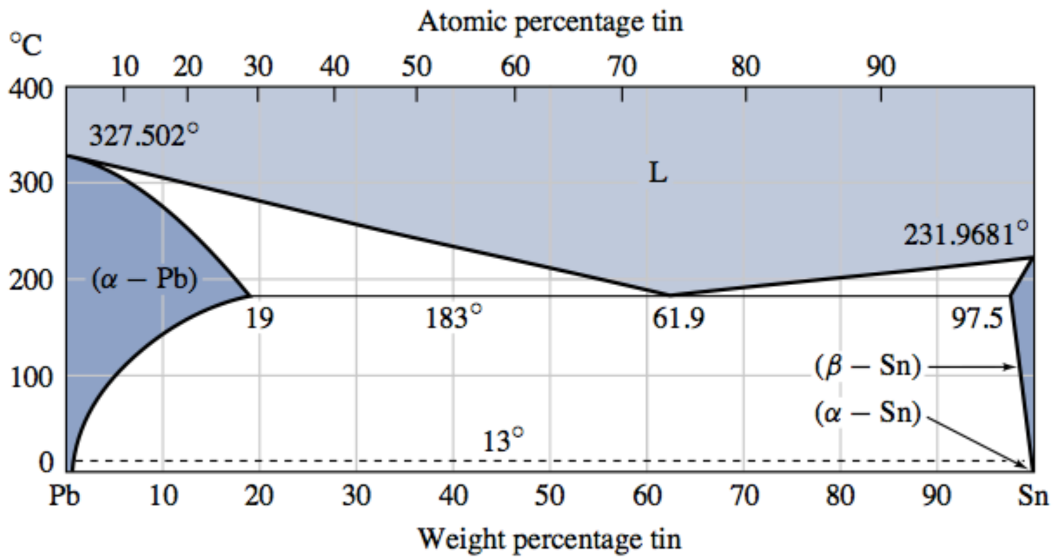
AUB-Spring 2013 MECH340: (Quiz II-1H15)

Problem 1. 30 pts One kilogram of an alloy of 60 weight % Pb and 40 weight % Sn is slowly cooled from 300° C. Refer to the lead-tin phase diagram of the Figure 1 and calculate the following:



a) The weight percent of the liquid and proeutectic alpha just above the eutectic temperature (183° C) and the weight in kilograms of these phases.
b) The weight in kilograms of alpha and beta formed by the eutectic reaction.

Problem 2-30 pts

The Fe-Fe_3C binary phase diagram is given in your textbook.

a) What is the melting temperature of pure Fe? (ii) What is the maximum solid solubility of C in austenite? (iii) At what temperature(s) does pure FCC-Fe transform into pure BCC Fe? (iv) What is the melting temperature of Fe_3C?

b) Consider an Fe-1.0 wt% C alloy equilibrated at 728 °C i) indicate the phase or phases present; ii) indicate the composition of each phase; iii) determine how much of each phase is present; iv) provide a well-labeled sketch of a possible microstructure.
c) Suppose one sample of this steel is slowly cooled in air from 728 °C to room temperature. Sketch a possible (well-labeled) microstructure.

Problem 3. 40 pts. A structural application in a large building calls for loading a column (rod) under a tensile stress of 200 MPa at temperatures that can reach 200 °C. The design lifetime of the building is 75 years. The maximum applied load cannot exceed 60% of the yield strength. The properties of several candidate materials are summarized in the table below. Non-destructive evaluation equipment is available to detect an internal defect with one dimension greater than 500 μm and a surface defect of 250 μm.

Material	**σ_y (MPa)**	**K_{IC} (MPa-m$^{1/2}$)**	**density (g/cm^3)**	**$T_{melting}$ (^{o}C)**
2024-T3 Al alloy	345	44	2.8	650
Sintered silicon nitride	500	5.3	3.3	1850
1040 steel	260	54	7.8	1520
4340 steel tempered@425 ^{o}C	1420	87	7.8	1427

A. One consulting engineer is advocating for sintered silicon nitride, primarily because of its high-temperature properties. Is this a good choice? Justify your answer. Be quantitative where possible.

B. Another consulting engineer is advocating for 2024-T3 Al alloy, primarily because of its low density. Is this a good choice? Justify your answer. Be quantitative where possible.

C. Another consulting engineer is advocating for 1040 plain-carbon steel, primarily because of its relatively low cost. Is this a good choice? Justify your answer. Be quantitative where possible.

D. A final consulting engineer is advocating for 4340-tempered steel, primarily because of its strength. Is this a good choice? Justify your answer. Be quantitative where possible.

E. As the lead engineer on this aspect of the building design, what will be your recommendation for the material to use? Provide a brief justification.

(Hint: look in your slides/textbook for $T_{melting}$ and its effect on crack propagation)

Good luck

Solution:
Problem 1.

( ) $\text{proeutectic (Pb)} = \dfrac{61.9 - 40}{61.9 - 19.2} = 51.29\%$

$\text{liquid} = 100 - 51.29 = 48.71\%$

( ) $\text{total (Pb)} = \dfrac{97.5 - 40}{97.5 - 19.2} = 73.44\%$

$\text{eutectic (Pb)} = 73.44 - 51.29 = 22.15\%$

So, in 1 Kgr we have:

0.2215 Kgr eutectic (Pb)

0.5129 Kgr proeutectic (Pb)

$1 - 0.7344 = 0.2656$ Kgr (Sn)

Problem 2.
Part a-

(i) What is the melting temperature of pure Fe? 1538°C
(ii) What is the maximum solid solubility of C in austenite? 2.11 wt% C
(iii) At what temperature(s) does pure FCC Fe transform into pure BCC Fe? 912°C AND 1394°C
(iv) What is the melting temperature of Fe_3C? 1227°C

Part b-

B(i) $\gamma + Fe_3C$

(ii) $C_\gamma = $ Fe-0.78 wt% C

$C_{Fe_3C} = $ Fe-6.69 wt% C

(iii)

$$w_\gamma = \frac{6.69-1.0}{6.69-0.78} = 0.96$$

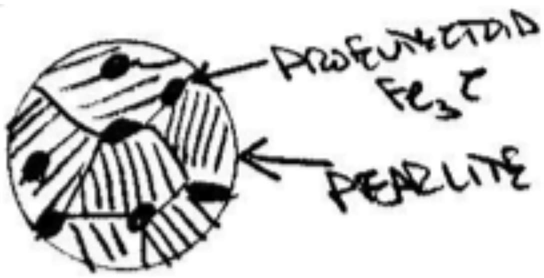
$$w_{Fe_3C} = \frac{1.0-0.78}{6.69-0.78} = 0.04$$

1.00 ✓

(iv)

part c-

(C)



Problem 3.

(A) $0.6 \times 500\,MPa = 300\,MPa > 200\,MPa$ ✓

$473K/2123K = 0.22 \Rightarrow$ CREEP NOT SIGNIFICANT

$K_{Ic} = Y\sigma\sqrt{\pi a} \Rightarrow a = \frac{1}{\pi}\left(\frac{5.3\ MPa\text{-}m^{1/2}}{200\ MPa}\right)^2 = 2.2\times10^{-4}\,m = 220\,\mu m < 250\,\mu m$

∴ SILICON NITRIDE IS NOT A GOOD CHOICE BECAUSE THE CRITICAL CRACK SIZE, AND THE COLUMN WILL BE AT RISK FOR BRITTLE FAILURE

(B) 2024 T3 Al

$0.6 \times 345\,MPa = 207 > 200$

$473K/923K = 0.51 \Rightarrow$ THIS IS A SIGNIFICANT FRACTION OF T_m, AND THIS ALLOY WILL BE SUSCEPTIBLE TO FAILURE BY CREEP OVER A LONG PERIOD OF TIME. HENCE THIS ALLOY IS NOT A GOOD CHOICE.

(C) 1040 PLAIN CARBON STEEL

$0.6 \times 260\,MPa = 150\,MPa < 200\,MPa$

THIS MATERIAL DOES NOT SATISFY THE DESIGN REQUIREMENT OF $\sigma_{APPLIED} < 0.6\,\sigma_y$.

THEREFORE, THIS IS NOT A GOOD CHOICE.

(D) 4340 TEMPERED

$0.6 \times 1420\,MPa = 852\,MPa > 200\,MPa$ ✓

$473K/1700K = 0.28 \Rightarrow$ CREEP IS NOT LIKELY TO BE A PROBLEM.

$a = \frac{1}{\pi}\left[\frac{87\ MPa\text{-}m^{1/2}}{200\ MPa}\right]^2 = 0.060\,m = 6\,cm \gg 250\,\mu m \Rightarrow$ BRITTLE FRACTURE IS NOT A THREAT.

THIS MATERIAL IS A GOOD CHOICE.

(E) BECAUSE DENSITY IS NOT AN ISSUE (THIS IS NOT A TRANSPORTATION APPLICATION) AND BECAUSE IT SATISFIES DESIGN CONSIDERATIONS FOR STRESS, CREEP, AND BRITTLE FRACTURE, THE 4340 STEEL IS THE BEST CHOICE.