Spring 2005 **Engineering Material**

Exam II

Wednesday, 4, April 2005

Duration: 60 minutes
Closed Book Exam
Write clearly your derivations and answers on the question sheet

Name:

ID#:

I Phase Diagram

With reference to the Pb-Sn phase diagram:

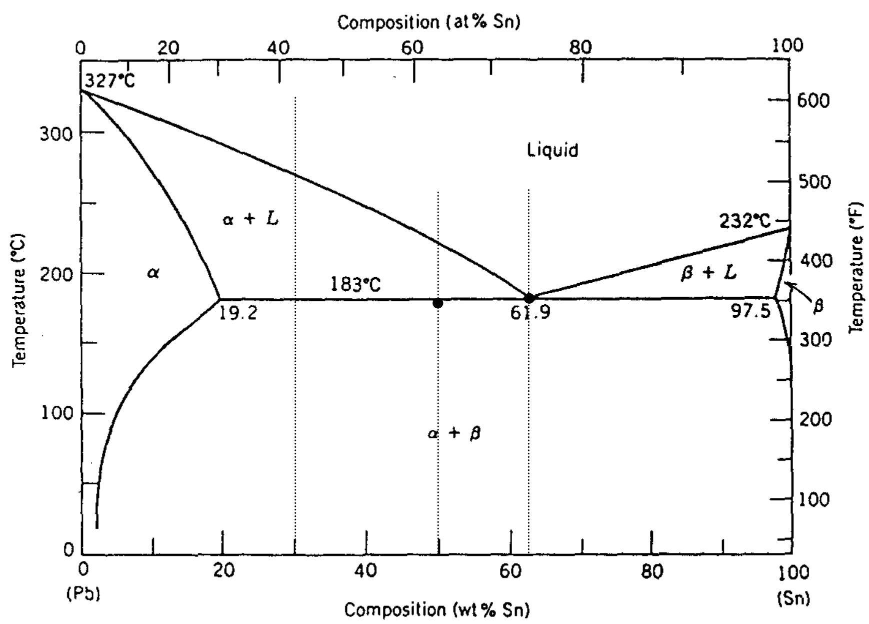
(a) Calculate the relative proportions of the α and β phases present in the eutectic mixture.

(b) Calculate the relative proportions of proeutectic α and eutectic mixture in an alloy containing 50% Sn at a temperature just below the eutectic temperature.

(c) Show that the total proportion of α obtained by adding together the proeutectic α and the α in the eutectic mixture is equal to the α obtained by constructing the tieline across the (α + β) region.

(d) Construct a thermal analysis cooling curve for an alloy containing 30% Sn. Discuss the relationship between the discontinuities on the cooling curve and the respective phase changes that occur.

Solution



(a) eutectic mixture: Pb-61.9wt%Sn at T = 183°C.

$$\%\alpha = \frac{97.5 - 61.9}{97.5 - 19.2} = 45.5\%$$

$$\%\beta = \frac{61.9 - 19.2}{97.5 - 19.2} = 54.5\% \text{ (or 1-45.5\%=54.5\%)}$$

(b) $$\%\alpha \text{ (proeutectic)} = \frac{61.9 - 50}{61.9 - 19.2} = 27.9\%$$

$$\%\text{eutectic phase} = \frac{50 - 19.2}{61.9 - 19.2} = 72.1\%$$

(c) from (a) and (b)

proeutectic α: $\%\alpha_{pro} = 27.9\%$

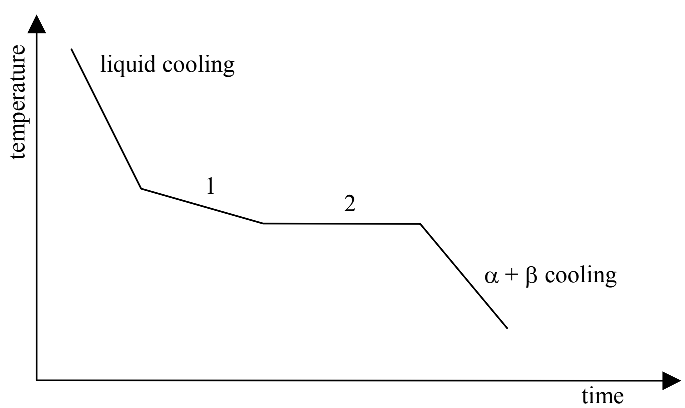
α in eutectic mixture: $\%\alpha_{eut} = 72.1\% \times \frac{45.5}{100}$

total proportion of α phase in Pb-50wt%Sn:
$\%\alpha_{tot} = \%\alpha_{pro} + \%\alpha_{eut} = 60.7\%$

alternatively use tie-lie across the α + β region

$$\%\alpha_{tot} = \frac{97.5 - 50}{97.5 - 19.2} = 60.7\%$$

(d)



1. α phase starts to form at ~ 270°C. The gradient of the cooling curve decreases due to the latent heat of solidification. The α phase continues to form, becoming increasingly richer in Sn as the temperature decreases.

2. At 183°C, the remaining liquid transforms to α + β phases of eutectic composition. The gradient of the cooling curve is horizontal due to the latent heat of solidification of a single composition alloy.

II Phase Diagram

For a steel containing 0.4%C calculate the proportions of

(a) pro-eutectoid ferrite and pearlite, and

(b) ferrite and cementite;

(c) Calculate the percentage carbon in cementite.

Solution

(a) pro-eutectoid ferrite and pearlite, and
(b) ferrite and cementite;

in steels containing (i) 0.2 %C and (ii) 0.4 %C.

(i) steel of 0.2%C (mild steel)

(a) $$\%F_{pro} = \frac{0.77 - 0.2}{0.77 - 0.022} = 76\%$$

$\%P = 1\text{-}74\% = 24\%$

(b) $$\%F = \frac{6.69 - 0.2}{6.69 - 0.022} = 97.3\%$$

$\%Fe_3C = 2.7\%$

(ii) steel of 0.4%C

(a) $$\%F_{pro} = \frac{0.77 - 0.4}{0.77 - 0.022} = 49.5\%$$

$\%P = 1\text{-}49.5\% = 50.5\%$

(b) $$\%F = \frac{6.69 - 0.4}{6.69 - 0.022} = 94.3\%$$

$\%Fe_3C = 5.7\%$

Weight percentage of C in Fe_3C:

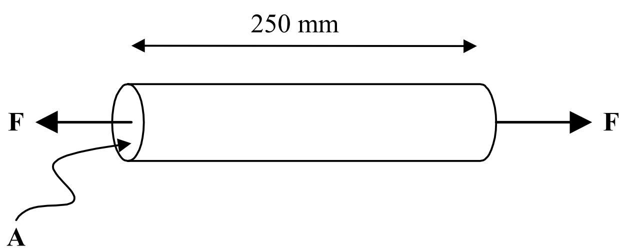
$$\text{wt\%C} = \frac{12}{55.85 \times 3 + 12} = 6.69\%$$

Atomic percentage of C in Fe_3C:

$$\text{at\%C} = \frac{1}{3 + 1} = 25\%$$

III Mechanical Properties

An automobile component of 250 mm in length is designed to carry a tensile load of 44,400N without experiencing any plastic deformation. The property data of four alloys are given in the table. According to these properties, which alloy will give the minimum weight for this component?



$$A = \frac{F}{\sigma_y}$$

alloy	σ_y (MPa)	ρ	A (cm^2) [F = 44.4 kN]	mass (g) [$\rho \times A \times L$]
steel	690	7.9	0.64	126
brass	345	8.5	1.29	274
Al alloy	275	2.7	1.61	109
Ti alloy	480	4.5	0.93	105

IV Dislocations

An FCC crystal is subjected to a tensile stress, σ, of 140 MPa along the $[\bar{1}\,\bar{1}\,2]$ direction. Calculate the force per unit length on dislocations that lie on the $(\bar{1}\,\bar{1}\,1)$ plane and have the following Burgers vectors:

(a) $\frac{a}{2}[\bar{1}\,10]$ and,

(b) $\frac{a}{2}[101]$.

Let a = $2.5\text{x}10^{-10}$ m.