Høgskolen i Østfold

EKSAMEN

Emnekode: IRM34513	Emnenavn: Advanced materials
Dato: 27.11.2019 Sensurfrist: 18.12.2019	**Eksamenstid:** KL 0900-1300
Antall oppgavesider: 7 Antall vedleggsider: 1	Faglærer: Litian Wang 472 88 765 Anna-Lena Kjøniksen 919 91 942 Oppgaven er kontrollert: Ja
Hjelpemidler: - Calculator, pen or pencils. - All printed og written	
Om eksamensoppgaven: All parts have the same weighting factor, 33% each. All answers must be reasoned.	
The candidate must check for possible lacking page of the present papers.	

Part 1 Metalliske materialer og materialvalg

Question 1

The figure below shows the phase diagram of Al-Cu alloy. We will now examine the following fire alloys (see also four vertical lines in the phase diagram) ::

1. Al-4,5%Cu
2. Al-10%Cu
3. Al-32,7%Cu
4. Al-40%Cu

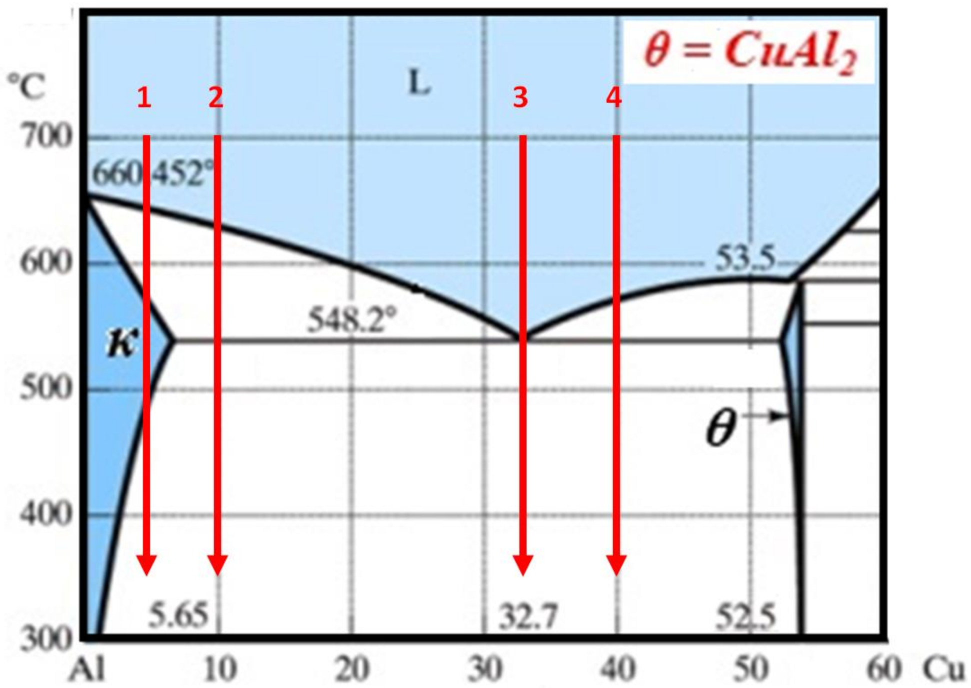


Fig. 1: Phase diagram for Al-Cu.

a) What is the θ-phase in the Al-Cu alloy?
b) Explain the difference between the strengthening mechanisms for alloy 1 and alloy 2.
c) Explain the difference between microstructures for alloy 3 and alloy 4 at room temperature.
d) Why Cu-content in the Al-Cu alloys (classified as 2000 series) is always less than 6% ?
e) Propose one Al-Cu alloy, together with the scheme for heat treatment and explain the corresponding strengthening mechanism.

Question 2

A beam with length L og rectangular cross-section (b, h) is subjected to a load F on the end (see Fig. 2below).

- Dimension for the beam is given by $L = 1.5\ m$ and $b = 50\ mm$.
- Technical requirement for bending is given by $\delta_m = 5.0\ cm$ under load 100 kg.
- Requirement for maximal weight for the beam is $m_{max} = 5.0\ kg$.

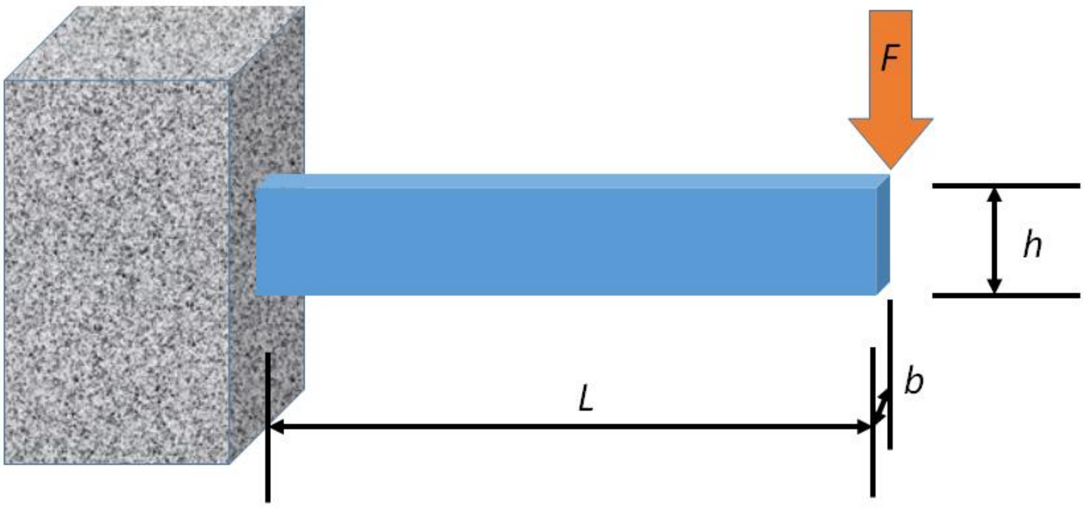


Fig. 2: Beam with load F.

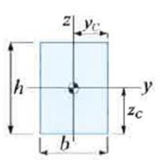
a) How to define the stiffness of the beam?

b) Determine explicit relation between height of the beam (h) and E-modul (E).

c) Show that the material index for selecting light and stiff beam above is M=E^(1/3)/ρ .

d) Determine the minimal value for the material index M .

Formula for Question 2:



$A = bh$ $\quad y_C = b/2$ $\quad z_C = h/2$

$$I_y = \frac{bh^3}{12} \qquad I_z = \frac{hb^3}{12}$$

$$w_B = \frac{PL^3}{3EI}$$

--- Slutt av del 1 ---

Part 2 Composite materials

Question 3: «Rule of Mixture»

The rule of mixture is given by the following two relations

$$\begin{cases} E = V_1 \cdot E_1 + V_2 \cdot E_2 \\ E^{-1} = V_1 \cdot E_1^{-1} + V_2 \cdot E_2^{-1} \end{cases}$$

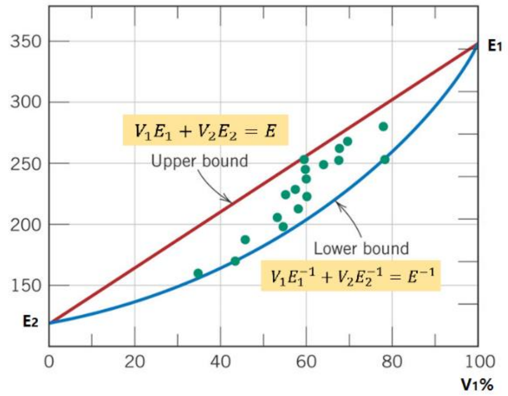


Fig. 3: Illustration for Rule of Mixture.

a) Prove $= V_1 \cdot E_1 + V_2 \cdot E_2$.

b) Explain how the rule can be applied to the mechanical properties of composite materials.

c) In the tensile test, composite materials exhibits two stadiums in the $\sigma \sim \epsilon$ plot. What are mechanisms for these two stadium?

d) In composite materials, the total load $(F_{total} = F_f + F_m)$ is distributed to fibre (F_f) og matrix (F_m) unevenly .

Show that the ratio between F_f and F_m is given by

$$\left(\frac{F_f}{F_m}\right) = \left(\frac{E_f}{E_m}\right)\left(\frac{V_f}{V_m}\right),$$

and the proportion on the fibre is then determined by

$$\left(\frac{F_f}{F_{total}}\right) = \left(\frac{E_f}{E_m}\right)\left[\frac{V_f}{1 - V_f + \left(\frac{E_f}{E_m}\right)V_f}\right].$$

Question 4: Composite

A carbon fibre composite (CFRP) is manufactured with vacuum-infusion method with Epoxy . (see fig. 4)

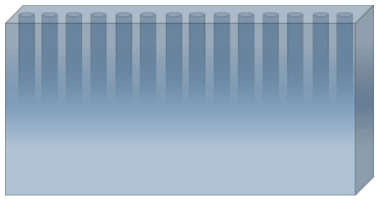


Fig. 4: Carbon Fiber Reinforced Plastic / CFRP.

Elastic property for carbon fibre and Epoxy are as follows.

Fiber: E = 350 GPa	Epoxy: E = 7 GPa

a) Determine volume percent for the fibre V_f when we require the portion of the load on fibre (F_f/F_{total}) must be at least 99%. (Hint: see Question 3d)

b) Determine Young's modulus for the composite.

c) Repeat calculation in (a) og (b) for Glass fibre with E = 70 GPa.

d) Discuss the results from (c).

A CFRP laminate is manufactured and the laminate consists of six layers of fibre. Fibre alignment for each layer are $-45°, 0°, -30°, 30°, 90°, 45°$, respectively.

e) How to determine the Toung's modulus (E) when E for each layer is known as E_K?

Hand lay-up and vacuum-infusion are two usual methods for producing laminates. We have gone through the procedures in our workshop.

f) Describe the procedure concisely, and explain why maintaining vacuum is important.

--- Slutt av del 2 ---

Part 3 Plast og Nanomaterialer

Question 5:

You have two dilute polymer solutions of the same polymer in water. These polymer solutions are at good solvent conditions at room temperature, and poor solvent conditions at 37 ^{o}C.

The only difference between the two samples is that one sample has a pH of 4, and the other sample has a pH of 10. At pH 4, the polymer has a high quantity of positive charges along the polymer chain. The polymer is neutral at pH 10.

a) When you heat such a sample up from 20 to 37 ^{o}C, there are two different mechanisms that can change the sizes you measure. Which two mechanisms are this, and how do each of them change the sizes of the sample?

b) Based on the answer in a), what has happened in the sample if the sizes you measure at 20 and 37 ^{o}C are the same?

c) You heat the samples up to 37 ^{o}C, and observe that the neutral sample at pH 10 becomes turbid (milky white) and sediments, while the positively charged sample remains transparent and do not sediment. Why?

d) You add nanoparticles to both samples (at room temperature). The sample with a pH of 10 do not seem to change, but the sample at pH 4 form aggregates that sediment when you add the nanoparticles. What does this tell us about the nanoparticles?

e) Name two methods you can use to determine the sizes of these samples, without drying or diluting them.

Question 6:

The surface tension between water and air is 72.7 mN/m.

The surface tension between Teflon and air is 18.5 mN/m.

The surface tension between mercury and air is 425.4 mN/m.

The interface tension between Teflon and mercury is 312.4 mN/m

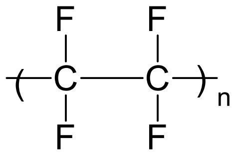
a) You place a water droplet on a smooth Teflon surface, and observe a contact angle of 109.0^{o}.
What is the interface tension between water and Teflon if we assume that the contact angle is at equilibrium?

b) You have a mercury droplet on a rough Teflon surface. It is resting on top of the cavities, and is in contact with 1/8 av of the surface. The drop has a contact angle of 167.8^{o}.
What is the contact angle on a corresponding smooth Teflon surface, if we assume that the contact angles are at equilibrium?

c) Is the drop in b) at equilibrium?

d) You place a water droplet on the same Teflon surface as in b). It has a contact angle of 173.8^o.
Is the drop laying on top of the cavities or wetting down into the cavities? Explain why.
If it is wetting down into the cavities, how much larger surface are is it in contact with compared to the drop on the smooth surface.
Assume that the contact angles are at equilibrium.

e) Even if it can tolerate high temperatures, Teflon (PTFE) is a thermoplastic with linear polymer chains:



Does it exhibit a high or low degree of crystallinity? Why?

--- Slutt av del 3 ---

---Merry Christmas/God jul/Feliz Navidad ---

Formelsamling:

For en dråpe som hviler på en fast overflate gir Youngs ligning:

$$\cos\theta = \frac{\gamma_{SG} - \gamma_{SL}}{\gamma_{LG}}$$

hvor θ er kontaktvinkelen til dråpen, γ_{SG} er overflatespenningen mellom det faste stoffet og luft, γ_{SL} er grenseflatespenningen mellom det faste stoffet og væsken (dråpen) og γ_{LG} er overflatespenningen mellom væsken og luft.

Dersom overflaten er ujevn gjelder Wenzels ligning dersom dråpen væter alle ujevnhetene

$$\cos\theta_{rough} = f \cos\theta_{smooth}$$

og Cassie-Baxters ligning dersom dråpen ligger på toppen av ujevnhetene.

$$\cos\theta_{rough} = -1 + \phi[\cos\theta_{smooth} + 1]$$

$f = A_{rough}/A_{smooth}$ hvor A er arealet av overflaten, og ϕ er fraksjonen av overflaten som dråpen er i kontakt med.

Equations:

Youngs equation, for a drop that is resting on top of a solid surface

$$\cos\theta = \frac{\gamma_{SG} - \gamma_{SL}}{\gamma_{LG}}$$

where θ is the contact angle of the drop, γ_{SG} is the surface tension between the solid surface and air, γ_{SL} is the interfacial tension between the solid surface and the liquid drop, and γ_{LG} is the surface tension between the liquid drop and air.

Wenzel's equation for a rough surface where the drops is wetting down into the rough surface:

$$\cos\theta_{rough} = f \cos\theta_{smooth}$$

Cassie-Baxter's equation for a drop that is resting on top of a rough surface:

$$\cos\theta_{rough} = -1 + \phi[\cos\theta_{smooth} + 1]$$

$f = A_{rough}/A_{smooth}$ where A is the area of the surface, and ϕ is the fraction of the surface the drop is in contact with.