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Exámenes resueltos 2012-2016

2° Materiales Aeroespaciales I

Grado en Ingeniería Aeroespacial

Escuela Politécnica Superior
Universidad Carlos III de Madrid



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Universidad Carlos III de Madrid

EXAM

June 2015

Aerospace Materials I (2nd Year)

Surname: **Name:** **Group:**

Information:

- Read the questions carefully before answering. Use the space given for answering each question.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 4 over 10.

1. **(1 mark)** For the following pair of polymers, do the following: (1) state whether it is possible to decide if one polymer has a higher tensile strength than the other; (2) if this is possible, note which has the higher tensile strength and then cite the reasons for your choice; and (3) if it is not possible to decide, then state why not. (A)
   a) Syndiotactic polystyrene having a number-average molecular weight of 600,000 g/mol and Isotactic polystyrene having a number-average molecular weight of 500,000 g/mol. (B) (A)
   b) Poly(styrene-butadiene) random copolymer having a number-average molecular weight of 100,000 g/mol and 10% of the available sites crosslinked and Poly(styrene-butadiene) random copolymer having a number-average molecular weight of 120,000 g/mol and 15% of the available sites crosslinked. (B)
   c) Isotactic polystyrene that has a density of 1.12 g/cm^3 and a weight-average molecular weight of 150,000 g/mol and Syndiotactic polystyrene that has a density of 1.10 g/cm^3 and a weight-average molecular weight of 125,000 g/mol. (B)

a) (A) > (B) ↑ molecular weight → ↑ tensile strength

b) (B) > (A) ↑ molecular weight → ↑ tensile strength

c) (A) > (B) Same

Apuntes descargados de wuolah.com

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Importance

① Mw → Tacticity density → tacticity

2. **(2 marks)** Use the Fe-C phase diagram to answer the questions.

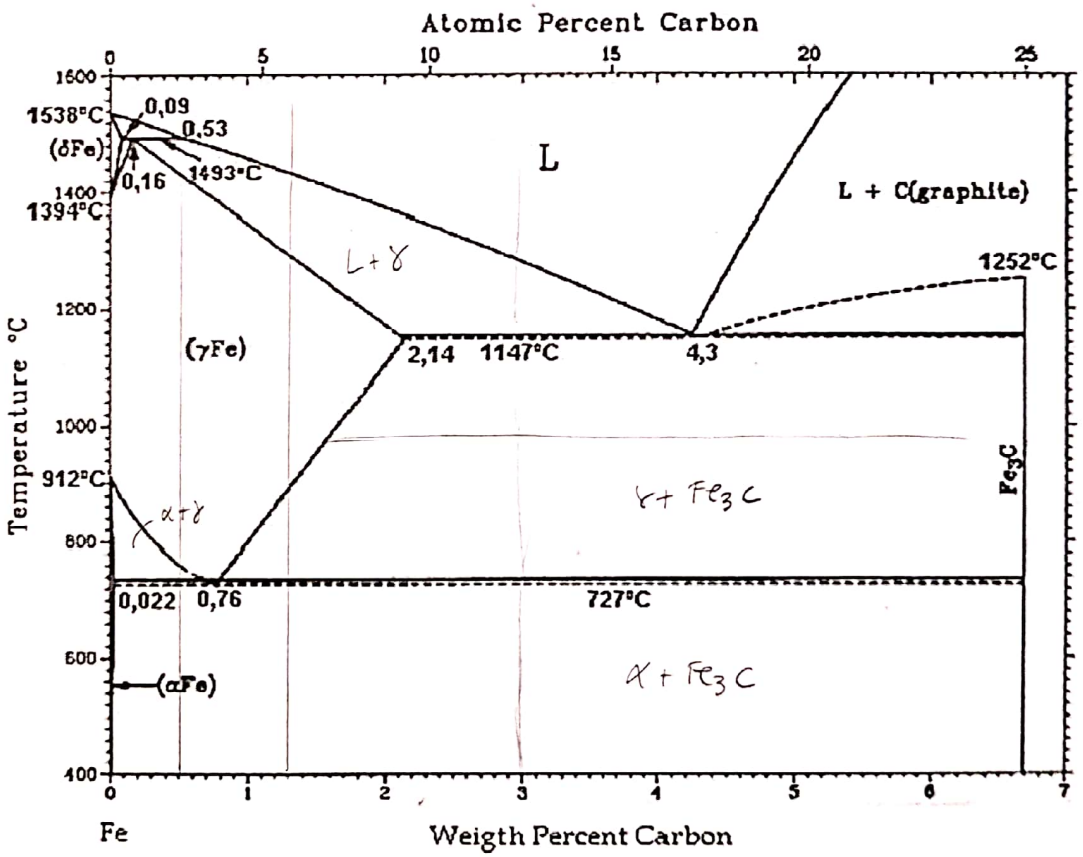
a) **(0.5 marks)** Mark as true (T) or false (F) the following statements:

T	Pure Iron has three allotropic modifications α, γ, δ
→ F	Cementite melts congruently
F	At 1493ºC the reaction is monotectic Peritectic
T	Maximum solubility of C in α phase of Fe at 727ºC is 0.022%
F	Microconstituents of an alloy with 3 wt%C at 1000ºC are primary austenite and cementite ledeburite

b) **(0.5 marks)** For an alloy with 0.5 (wt.)%C at 727+ΔTºC, indicate the phases present, their mass fraction and their chemical composition

c) **(0.5 marks)** Consider 250g of an alloy with 1.3 wt% C and calculate the amount of cementite in each microconstituent at 600ºC

d) **(0.5 marks)** If we add 8% of Mn to the alloy from part c): how will the eutectoid temperature change with respect to the studied alloy? How much carbon will the pearlite have? Justify your answers.



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b) $C_0 = 0.5\%.C$ phases: α and γ

$T = 727 + \Delta T$ $C_\alpha = 0.022\%$. $W_\alpha = \frac{0.76 - 0.5}{0.76 - 0.022} = 0.35$

$C_\gamma = 0.76\%$. $W_\gamma = 0.65$

c) $C_0 = 1.3\%.C$

$T < 727°C$

Fe_3C'

L → $\alpha_L + \gamma$ → γ → $\gamma + Fe_3C$ → $\alpha + Fe_3C$ → $(\alpha + Fe_3C)$ pearlite

$T = 600°C$

- phases: Fe_3C and α

$C_\alpha = 0.01\%.C$ $W_\alpha = \frac{6.7 - 1.3}{6.7 - 0.01} = 0.8$

$C_{Fe_3C} = 6.7\%.C$ $W_{Fe_3C} = 0.2$ → (*)

- micro: Fe_3C' and pearlite $(Fe_3C + \alpha)$

$W_{Fe_3C'} = 6.7\%.C$ $W_{Fe_3C'} = \frac{1.3 - 0.76}{6.7 - 0.76} = 0.09$

$W_{pearl} = 0.76\%.C$ $W_{pearl} = 0.91$

$W_{Fe_3C, pearl} = W_{Fe_3C, T} - W_{Fe_3C'} = 0.2 - 0.09 = 0.11$ (*)

d) Mn favour γ phase → displaces eutectoid ↓T, ↓%C

Pearlite ↓% Carbon

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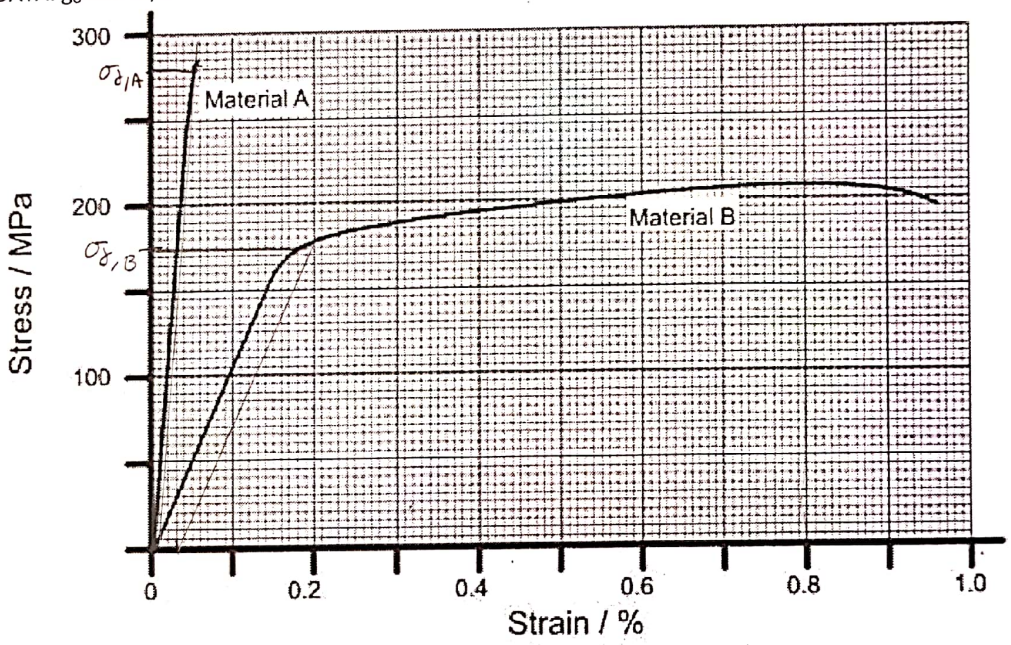
Pídele a los reyes:
El **mejor proyector**
relación calidad/precio
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3. **(2 marks)** A cylindrical rod 3m long and having an initial diameter of 20 mm is subjected to a tensile load of 65000 N and experiences a change in diameter of 0.014 mm, recovering its initial diameter when the load is removed. For this kind of alloy Poisson's ratio is ν= 0.36.
   a) Calculate the length of the cable when it's holding the load mentioned above
   b) Plastic deformation for this alloy begins when it is holding a weight of 26608 kg. Calculate the tensile strength of this alloy. Assuming a safety factor of 2, can it be considered that the rod is working under safe conditions?
   c) Calculate the elastic modulus and the modulus of resilience of this alloy
   d) Calculate the elastic modulus and yield stress for the Materials A and B that have the stress-strain curves represented below. Can Material B replace the alloy rod? Explain why.
   e) If the alloy rod is substituted by Material B and is subjected to the same load calculate the final length of the rod

DATA: g_o=9.8 m/s^2



a) $\nu = \frac{-\frac{\Delta\phi}{\phi_o}}{\frac{\Delta l}{l_o}} = \frac{\frac{0.014}{20}}{\frac{l_f - 3}{3}} = 0.36 \rightarrow \frac{2.1\cdot10^{-3}}{0.36} = l_f - 3 \rightarrow \boxed{l_f = 3.0058\ m}$

b) $\sigma_y = \frac{F_y}{A_o} = \frac{26608 \cdot 9.81}{\frac{\pi}{4}(20\cdot10^{-3})^2} \times 10^{-6} = 831\ MPa$ } not needed for this part

$\sigma = \frac{F}{A_o} = \frac{65000}{\frac{\pi}{4}(20\cdot10^{-3})^2} \times 10^{-6} = 206.9\ MPa$

Safety conditions: $F_y > N^{\circ 2} F_w \rightarrow 26608 \cdot 9.81 > 2 \cdot 65000$

$261024.5 > 130000$ ✓ → YES

c) $\sigma = E\varepsilon \rightarrow \boxed{E = \frac{206.9\ MPa}{\frac{0.0058}{3}} = 107018\ MPa = 107\ GPa}$

since I don't know E_x for σ_y yet I know the other data that they give us which correspond to the elastic zone

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$$U_r = \frac{1}{2}\frac{(\sigma_y)^2}{E} = \frac{1}{2}\frac{831^2}{107018} = 3.23$$

d) From graph, $\sigma_{y,A} = 275\,MPa \rightarrow E_A = 7.5\,GPa$

$E_B = 1\,MPa$ $\quad \sigma_{y,B} = 175\,MPa \rightarrow$ It cannot replace the alloy rod because $\sigma_{rod} > \sigma_{y,B} \rightarrow$ It would deform $206.9\,MPa > 175\,MPa$ plastically

hoja

e) $\varepsilon = \varepsilon_p + \varepsilon_e$ (doesn't recover / recover)

$$\sigma_w = \frac{\sigma_{y,B}}{N} = \frac{175}{2} = 87.5 \rightarrow f_w = 87.5\cdot10^6 \frac{\pi}{4}(20\cdot10^{-3})^2 = 26\,700\,N$$

needed $\rightarrow$ 65000 N

NO

$$\sigma = \frac{F}{A} = \frac{65000}{\frac{\pi}{4}(20\cdot10^{-3})^2} = 207\,MPa$$

From graph: $\sigma = 207\,MPa \rightarrow \varepsilon = 0.8 = \frac{\Delta l}{l_0} = \frac{l-3}{3} \rightarrow l = 5.4\,m$

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4. **(1 mark)** Answer the following question and explain briefly:
   a) What are Bravais lattices and how many are there?
   b) What are the 3 most common structures of metallic materials and which one has the smallest packing factor?
   c) For closed packed structures, what is the relation between number of possible interstitial sites (n) and number of atoms in the cell (N) for both types of interstitials?
   d) Is the solubility of Carbon higher in ferrite or austenite? Why?

a) A Bravais lattice is an infinite array of discrete points generated by a set of discrete translations operations described in 3D space
Ie: The ways that crystalline materials have to arrange themselves. Combination of the 7 crystalline systems and the 4 unit cells → 14 Bravais Lattices

b) BCC: $PF = \frac{2 \cdot \frac{4\pi R^3}{3}}{\left(\frac{4}{\sqrt{3}} R\right)^3} = 0.68$ $4R = \sqrt{3}a$

FCC: $PF = \frac{4 \cdot \frac{4\pi}{3} R^3}{\left(\frac{4}{\sqrt{2}} R\right)^3} = 0.74$ $4R = \sqrt{2}a$

HCP: $PF = 0.74$

c) tetrahedral interstitials: $n = 2N$
octahedral " : $n = N$

Ex 11
d) Austenite: FCC ; Ferrite: BCC
Due to large size, carbon atoms occupy octahedral interstitials, which are bigger in FCC than in BCC → Higher solubility in Austenite (FCC)

5. **(1 mark)** Answer the following question and explain briefly:
   a) What are typical materials used as matrices in ceramic matrix composites (CMC)?
   b) What are the advantages of CMCs?
   c) What is the role of the reinforcements in CMCs?
   d) Name and describe a manufacturing method applicable only to CMCs?

(Composites II slide 35)

a) Silica based glass, silicon carbide, silicon nitride, alumina, carbon matrix.

b) • High temperature oxidation stability
• Enhanced toughness
• Low density
• Ablation resistance
• High fracture toughness or crack resistance

c) Their role is to increase toughness → increase fracture energy through various energy-absorbing mechanisms

d) Sol-gel processing: Infiltration of a preform
1) Pour sol over preform (sol-gel infiltrates preform); 2) Dry (heat treating)
3) Repeat (repeat infiltration and drying until required density); 4) Fire

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6. **(1 marks) a)** Define a ceramic material. What structural defects are the main causes of failure of polycrystalline ceramic materials? Distinguish between traditional and engineering ceramics and give an example of each. **b)** What is the sintering process of ceramic materials? What occurs to the ceramic particles during sintering?

a) A ceramic material is an inorganic material made from metals and non metals united by ionic and/or covalent bonds.

Pores, foreign particles and large grains are the main causes of failure

Traditional ceramics (clay products) → silica (SiO_2)

Engineering ceramics (other products) → MgO → need synthesis

b) Sintering consists of heating the compact part to a high temperature below the melting point, when the material of the separate particles diffuse to the neighboring powder particles. The particles develop strong bonds between them → strength and hardness

Densification and shrinkage occurs

Sergjan: ceramic particles are getting closer, reducing porosity

7. **(1 mark)** Lattice energy for binary ionic compounds depends on the values of some fundamental constants and other parameters that are a function of the nature of the ions.
   a) Enumerate at least two parameters and briefly explain their influence.
   b) In the following table you may find the values of the melting point (ºC), lattice energy (Kcal/mol), hardness (Moh's scale) as well as the formula of several binary compounds. Match each compound with the correct values of T_m, lattice energy and hardness.
   Data r(Na) < r (K), r(Mg) < r(Ba)

Compound	T_m	Lattice energy	Hardness
NaCl	776	747	6.5
KCl	1923	164	2.5
MgO	801	183	3.3
BaO	2800	940	2.25

Compound	T_m	Lattice energy	Hardness
NaCl	801	183	2.5
KCl	776	164	2.25
MgO	2800	940	6.5
BaO	1923	747	3.3

a) ↑ ion size → ↓ lattice energy, ↓ T_m

↑ valence number → ↑ lattice energy, ↑ T_m

↑ lattice energy → ↑ T_m → ↑ hardness

LE: MgO > BaO > NaCl > KCl

T_m

Hardness

Tiene más importancia la valencia

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https://amzn.to/2Lg6wRM

8. **a) (0.5 marks)** For a metallic conductor explain how is electrical resistivity affected by (i) increasing temperature and (ii) impurities, alloying additions, dislocations and grain boundaries

$\rho_{total} = \rho_T + \rho_d + \rho_i$ ← impurity resistivity: ↑ impurities, alloying additions... → ↑ ρ

$\rho_T = \rho_0(1 + \alpha_T T)$ → ↑T → ↑ ρ_T → ↑ ρ_{total}

↓

Carriers scattering of the e⁻

↓

reduces mobility and conductivity

b) (0.5 marks) Explain the relationship between superconducting materials and magnetism. Define the T_c (critical temperature in a superconductor). What is the Meissner effect?

Already explained in other exam

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