ENGINEERING TRIPOS PART IIA

Tuesday 30 April 2013 9.30 to 11

Module 3C1

MATERIALS PROCESSING AND DESIGN

*Answer not more than **three** questions.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

Final Version

1 (a) Briefly describe, illustrating your answer with sketches, the following processes for the fabrication of products from long-fibre polymer composites:

(i) wet lay-up;

(ii) vacuum bagging;

(iii) filament winding. [30%]

(b) Define the term 'pre-preg' and explain why the use of pre-preg has advantages. In which of the processes listed in part (a) would pre-preg be used? [20%]

(c) Which of the processes listed in part (a) would be most suitable to manufacture each of the following products? In each case, justify your answer.

(i) A lightweight cylinder to contain compressed gas at high pressure;

(ii) a prototype seat for a lightweight wheelchair;

(iii) a nearly flat wing component for a passenger aircraft. [30%]

(d) A wind turbine blade was fabricated from glass-fibre epoxy composite. Over a long period of use, including exposure to rain and extremes of temperature, the stiffness of the blade was found to decrease. Describe the mechanisms which may be responsible for this change in the properties of the composite. [20%]

2 (a) The outer casing of a domestic refrigerator was formed from mild steel sheet, with lap joints formed by resistance spot welding. After welding, the casing was coated with paint. After a couple of years of use, corrosion was observed locally within the lap joint. Explain the process by which the corrosion occurred. Suggest changes in joint design, materials or manufacturing method which might be made to avoid corrosion in this location, and comment on their suitability for this application. [30%]

(b) Two pipes made from austenitic stainless steel (type 304, Fe-18%Cr-8%Ni-0.06%C) were joined by arc welding. After exposure to sea water, pitting corrosion occurred close to the weld region. Explain the process by which the corrosion occurred. Suggest changes which could be made to avoid this degradation process. [30%]

(c) High strength steel bolts were electroplated with nickel and exposed to high tensile stress. After some time, they failed suddenly, showing an intergranular fracture surface. What mechanism is likely to have been responsible for this behaviour, and how might it be prevented? [30%]

(d) Explain why it is forbidden to take liquid mercury on board a passenger aircraft. [10%]

3 A long rectangular bar of commercial purity aluminium of width $2w$ and height $2h$ is hot forged in plane strain between parallel platens. The forging load F for a bar of length L is given by

$$F = \frac{2hLY}{\mu}\left(\exp\left(\frac{\mu w}{h}\right) - 1\right)$$

where μ is the coefficient of friction between the workpiece and the platens and Y is the material yield stress.

A bar of length 500 mm, and initial cross-sectional dimensions $2w_0 = 100$ mm and $2h_0 = 200$ mm is forged in a single stroke at a constant platen speed to a final height of 100 mm. The material yield stress $Y = 50$ MPa, which may be assumed constant, and the coefficient of friction $\mu = 0.2$.

(a) Find the values of w and w/h for the final cross-section at the end of the stroke, and for two equally-spaced intermediate values of h. Evaluate the forging load F for each value of h and hence sketch the variation of F with the distance moved by the platen, $(2h_0 - 2h)$. Hence, assuming a piecewise-linear variation between these points, estimate the work done in the forging process. Estimate the average temperature rise in the forging, stating any assumptions made. Comment on the likely uniformity of heating in the billet. The specific heat capacity of aluminium $C_p = 950$ J kg^{-1} K^{-1}. [60%]

(b) What microstructural evolution do you expect to be taking place during forging? Explain whether it is reasonable to assume that Y is constant in this analysis. After forging the bar is subsequently held at a high temperature for 15 minutes. What further microstructural evolution may then occur? Summarise the factors that affect the scale of this microstructure. Give two reasons for conducting this subsequent heat treatment. [40%]

4 (a) Distinguish between *permanent mould* and *permanent pattern* casting processes in terms of how they work, their versatility to make different shapes, and process economics. Give an example of each process type. [25%]

(b) Explain briefly what is meant by a dendrite, and outline the circumstances in which dendrites may form in: (i) pure liquids; (ii) alloys. How does dendrite formation influence impurity segregation and porosity in a casting? Illustrate your answers with sketches as appropriate. [40%]

(c) Give two examples of common impurities in carbon steels, explaining where they come from and how they are rendered harmless by using small alloying additions. [20%]

(d) Distinguish between grey and white cast iron in terms of the distribution of carbon in the microstructure. Outline and explain two useful characteristics of grey cast iron. [15%]

END OF PAPER