ENGINEERING TRIPOS   PART IIA
MANUFACTURING ENGINEERING TRIPOS   PART I

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Wednesday 28 April 2004   9 to 10.30

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ENGINEERING TRIPOS  PART IIA:  MODULE 3C1
MANUFACTURING ENGINEERING TRIPOS PART I:  PAPER P4A

MATERIALS PROCESSING AND DESIGN

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

*All questions carry the same number of marks.*

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

*There are no attachments.*

> **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**

1    (a)    What are the main factors to consider in the selection of each of the three process classes: shaping, joining and surface treatment?   Explain, with examples, why the processing rate is generally not a simple characteristic of a given process.          [30%]

(b)    Discuss the reasons for intermediate and final annealing in the rolling of sheet aluminium products.  Briefly describe the underlying microstructural mechanisms which occur in the annealing of aluminium alloys.  Give one example in each case of how an annealing mechanism may be influenced by:

(i)    the homogenization process applied to the original cast billet;

(ii)    the rolling conditions prior to annealing.          [35%]

(c)    Explain how the following factors influence the hardenability of steels:

(i)    carbon content (in plain carbon steels);

(ii)    alloy content (e.g. Ni, Cr, Mo);

(iii)    austenitizing temperature.          [35%]

2    The microstructure of a solidified ingot of a binary metallic alloy can contain three distinct regions.

(a)    Sketch a typical ingot structure, identifying and describing the main features of each region and explaining how each is formed.  Are any regions likely to show some crystallographic texture, and if so, why?          [25%]

(b)    Sketch a graph showing how the composition of the solid will vary along a section through the middle of the ingot. Explain the reasons for this variation.          [25%]

(c)    What factors determine the relative proportions occupied by the three regions, and how might these proportions be changed?  Why might this be desirable?   [25%]

(d)    In which regions can the grain size be controlled during solidification, and how can this be achieved?  For what applications might this be desirable?  Describe methods which could be used to make:

(i)    a fine-grained casting; and

(ii)    a single-crystal casting.          [25%]

3    The following processes and materials can be used to make complex aircraft parts:

injection-moulded PEEK (a high-strength crystallizable polymer) reinforced with short carbon fibres; or

hand-layup of long-fibre CFRP with an epoxy matrix.

(a)    Briefly describe both manufacturing processes. Explain any variations in mechanical properties which might occur within the parts.                    [30%]

(b)    In both cases, explain why problems might be encountered as a result of changes in section of the parts, and discuss how these problems can be minimized.    [20%]

(c)    Comment on the relative costs and merits of the two production processes for short and long production runs, and for the ease of making modifications to the design of the parts.                                                              [10%]

(d)    At the final assembly stage, it will be necessary to join the parts to others made from the same material. For each of the two materials, discuss appropriate methods of joining, indicating any constraints on joint geometry. What problems might be encountered with joint integrity and mechanical strength in service?    [30%]

(e)    Discuss the extent to which recycling is likely to be successful for either material.                                                                          [10%]

4    Outline the process steps involved in the fabrication of a steel component by a conventional powder metallurgy route. What are the advantages of this method over machining the part from bar stock? What limits the maximum size of component which can be made by a powder route? Discuss the factors which control the final density of a conventionally-made powder metallurgy component. What other production processes might be used to achieve a higher final density in a powder metallurgy component?    [60%]

The initial sintering rate (rate of change of density $\rho$) for a powder component is given by:

$$\frac{d\rho}{dt} = \frac{A}{a^3} D_0 \exp(-Q/\bar{R}T)$$

where $a$ is the particle diameter, $A$ is a constant, and $D_0 \exp(-Q/\bar{R}T)$ is the standard expression for diffusivity. What physical processes are responsible for the higher sintering rate of smaller particles? Why must this equation cease to be valid at very long sintering times?    [15%]

Two iron powder compacts, initially identical, are sintered under different conditions: one for 30 minutes at 1200 °C, and the other for 45 minutes at 1175 °C. Both have the same final density. Estimate the activation energy $Q$ for self-diffusion of iron;  state clearly any assumptions you make.    [25%]

**END OF PAPER**