ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Tuesday 3 May 2005 9 to 10.30

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

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1 (a) Explain the principles underlying the transformation hardening of the surface of a low-alloy steel component. What factors control the depth to which hardening is achieved? What limits the maximum hardness which can be achieved in a steel by transformation hardening? Briefly describe two other surface treatment processes for steels (not involving the application of coatings) which may be used to produce higher hardness levels than transformation hardening. [35%]

(b) In the heat treatment of steel, define what is meant by the term *equivalent diameter*.

A steel bicycle crank is shown in simplified form in Figure 1, with important dimensions indicated. The circular ends blend tangentially into the flat side faces. The crank is to be oil-quenched and tempered. Use the curves in Figure 2 to estimate equivalent diameters for the steel at the points A, B and C shown in Figure 1.

Explain how the Jominy curves for a given steel would be used to find the tempered hardness at point A, and also the surface hardness. Sketch any relevant curves which would be used in this analysis.

If the crank were air-cooled, would you expect the surface hardness to differ from that at point A? Explain your reasoning. [65%]

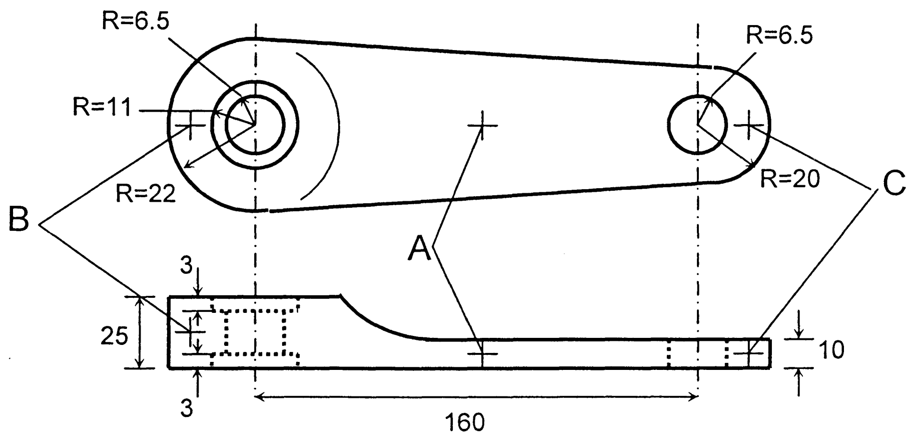

Fig. 1 Dimensions in mm. Not to scale

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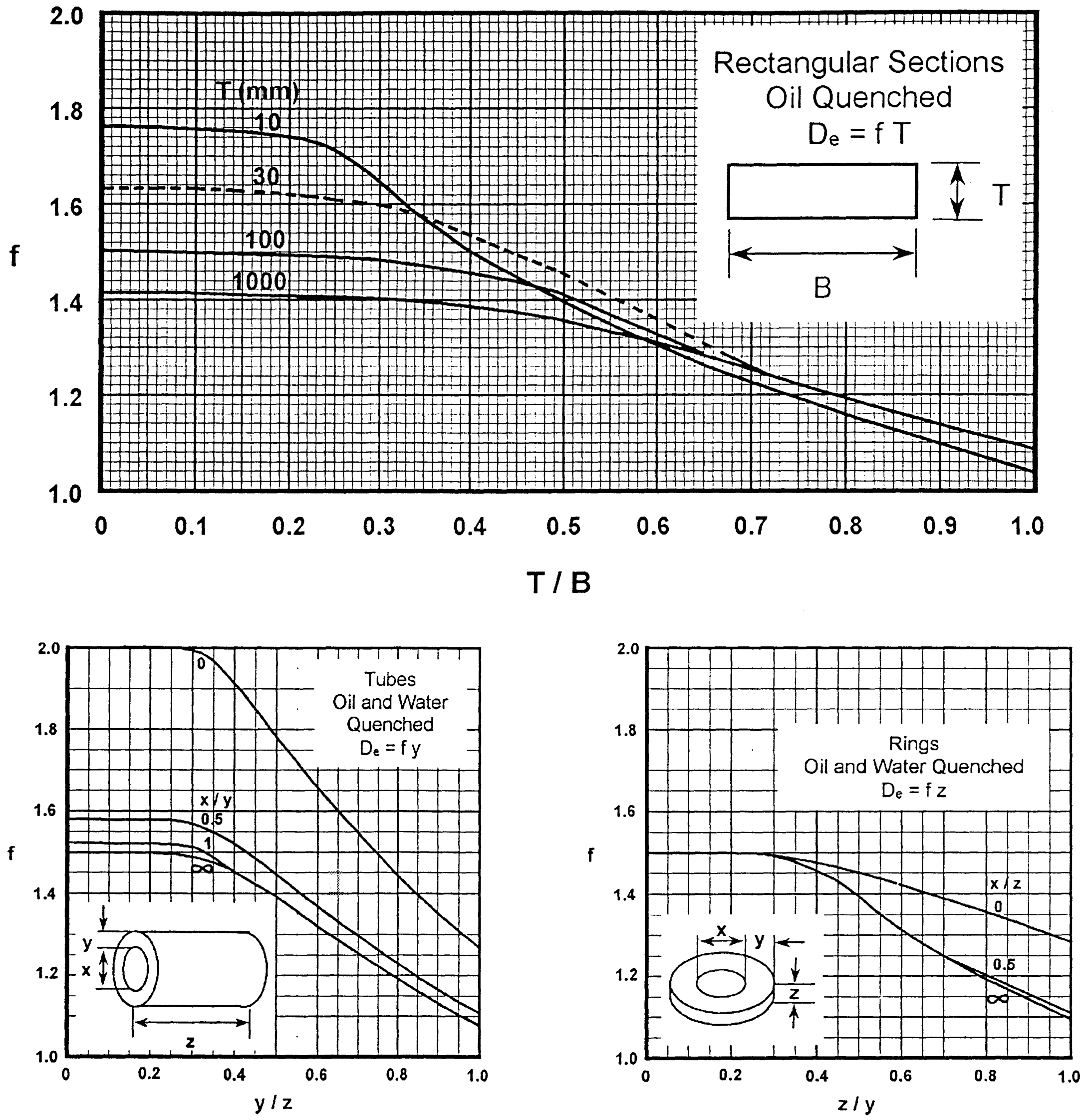

Fig. 2 Graphs for Question 1

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2 (a) A thick-walled component with a square box section is made from gunmetal (88 wt% Cu, 10 wt% Sn, 2 wt% Zn) by sand-casting. The component is found to contain porosity on both the microscopic and macroscopic scales.

(i) Show on sketches of the microstructure, and of the whole component section, the regions where any porosity might be expected. Explain why it forms there, and suggest how porosity could be avoided. [30%]

(ii) An inoculant is added to the liquid metal just before casting. What effect would this have on the distribution of porosity? [20%]

(iii) What differences in the occurrence and distribution of porosity would you expect if the alloy were Al-12 wt% Si ? [15%]

(iv) How might the amount of micro-porosity in Al-12 wt% Si be reduced by a post-casting treatment? [10%]

(b) The following parts are to be made from alloys chosen from the list below. Choose one alloy for each application, justifying your choice and describing the expected microstructure.

(i) Part of an automotive disc brake unit. This is an intricate casting with considerable surface detail, in which high tolerances are required. The material is required to have a specified minimum strength and toughness. [15%]

(ii) A bed to support a heavy-duty precision lathe. [10%]

List of alloys:

Grey cast iron (Fe + 3 wt% C + 2 wt% Si)
SG cast iron (Fe + 3.5 wt% C + 2 wt% Si, trace Mg)
White cast iron (Fe + 3 wt% C + 1 wt% Si)

3 (a) (i) Briefly describe the following three processes for the manufacture of components from thermoplastic polymers, identifying the similarities and differences between them: injection moulding; extrusion; film blowing. For each process, indicate the shapes of products for which they are appropriate. [25%]

(ii) Explain how molecular alignment may occur in the flow of a polymer melt. Discuss possible advantages and disadvantages of producing high molecular alignment in polymer processing, with examples from two of the three processes listed above. [25%]

(b) The operating equation for a screw extruder for a thermoplastic polymer is given by:

$$A\omega - \frac{B\Delta P}{\eta} = \frac{CP}{\eta}$$

(i) Explain the meaning of each symbol and the significance of each term in the equation. Sketch an appropriate graph to show how the equation may be used to estimate the output from the extruder. What factors are ignored in this analysis? [35%]

(ii) Use your graph to predict the change in output which will be caused by adding a filler to the polymer. [15%]

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4 A butt weld is formed between two plates of medium-carbon steel (0.45 wt% C) by manual metal arc (MMA) welding in a single pass. The filler alloy has the same composition as the plates.

(a) Sketch a diagram illustrating the MMA welding process, and explain the role of each important feature in the diagram. [15%]

(b) Describe how the microstructures in the welded plate will vary from the centre of the weld to the unaffected regions of the plate, and explain their origins by referring to an appropriate phase diagram. Why is it important to control the maximum hardness in the weld region? [25%]

(c) Explain the effects and any possible benefits of:

(i) preheating the plates before welding;
(ii) heat treating the plate after welding. [20%]

(d) How might the structure and properties of the welded region differ if the plates were joined by electron beam welding? [15%]

(e) A similar butt joint is formed between plates in a heat-treatable wrought aluminium alloy by tungsten inert gas (TIG) welding. Show how the hardness is likely to vary across the weld region:

(i) immediately after cooling;
(ii) after several days at room temperature.

Explain fully the reasons for any differences between the two cases. [25%]

END OF PAPER

PART IIA 2005

3C1 Materials processing and design

Principal Assessor: **Prof K Hutchings**

Engineering Tripos Part IIA 2005 Paper 3C1

Manufacturing Engineering Tripos Part I 2005 Paper P4A

Numerical answers

Question 1(a)

Equivalent diameters: A 17.2 mm; B 19.7 mm; C 12.2 mm