ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Tuesday 2 May 2006 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.

STATIONERY REQUIREMENTS
Engineering Tripos:
Single-sided script paper

Manufacturing Engineering Tripos:
20 page booklet, rough work pad

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

1 (a) (i) Explain briefly why databases for initial process selection need to be subdivided into generic process classes, whereas material selection can be conducted with a single database for all materials.

(ii) After initial screening of unsuitable processes, further refinement of process selection usually requires detailed information about the materials being processed and features of the design. Explain why this is so, giving examples of the information which may be needed for shaping, joining and surface treatment. [25%]

(b) The manufactured cost per part, C, may be estimated using the equation

$$C = C_m^* + \frac{C_t^*}{n} + \frac{C_{oh}^*}{\dot{n}}$$

(i) Define each variable in the equation, and outline the various contributions to the parameters C_m^*, C_t^* and C_{oh}^*.

(ii) Sketch (on log axes) the typical variations of C with the material cost and the batch size, assuming in each case that the other parameters are fixed. Indicate on the first sketch where the material cost dominates the manufactured cost. [25%]

(c) Explain what is meant by a 'supercooled' liquid. Describe two different circumstances in which an impure, non-eutectic liquid metal can be supercooled. In each case, briefly explain the consequences of these types of supercooling for the structure of a casting. [25%]

(d) Distinguish between heterogeneous and homogeneous nucleation of solids from liquids. How is heterogeneous nucleation used to control the microstructures of cast metals? Illustrate your answer by describing how the following structures can be achieved:

(i) a single-crystal turbine blade;

(ii) an ingot with a fully equiaxed microstructure. [25%]

2 (a) Describe (i) a process which can be used to make metallic powders with rounded particle shapes, and (ii) two processes which can be used to make metallic powders with irregular particle shapes. List the basic process steps involved in making a metallic component by a straightforward powder metallurgical (PM) route (involving uniaxial compaction). Discuss the influence, if any, of particle shape on each process step. [35%]

(b) Explain why a uniform density is desirable throughout a component produced by a straightforward PM route, and describe the methods used to achieve this. Discuss whether these methods would also be useful in hot isostatic pressing. [30%]

(c) Explain why:

(i) for certain applications, it may be desirable to produce PM components with large amounts of interconnected porosity;

(ii) incorporation of a small amount of low melting-point material can speed up PM processing;

(iii) the overall processing time is shorter for PM products made from powder with a smaller particle size. [35%]

(TURN OVER

3 (a) Define the terms ‘critical cooling rate’ and ‘critical diameter’ in the context of the heat treatment of steels. [20%]

(b) Figure 1 shows a CCT diagram for a ½NiCrMo steel. Explain what the two lines marked X and Y in the diagram signify. Use the diagram to determine the following:

(i) an estimate of the critical cooling rate (at 750 °C);

(ii) the critical diameters for air, oil and water quenching;

(iii) the microstructures at the centres of bars of diameter 10 mm, quenched in air and in water;

(iv) the diameter of a bar which will have a hardness of 270 HV at its centre after oil quenching and tempering for 1 hour at 600 °C;

(v) the as-quenched surface hardness of bars of diameter 20 mm, for both air and water quenching. [50%]

(c) Explain what is meant by the ‘hardenability’ of a steel, and give two quantitative measures of hardenability. List the factors which influence hardenability and discuss the effect of each factor. Explain why hardenability is an important consideration in the selection of a welding process for a given steel, and illustrate your answer with reference to the processes of oxy-acetylene and laser welding. [30%]

(cont.

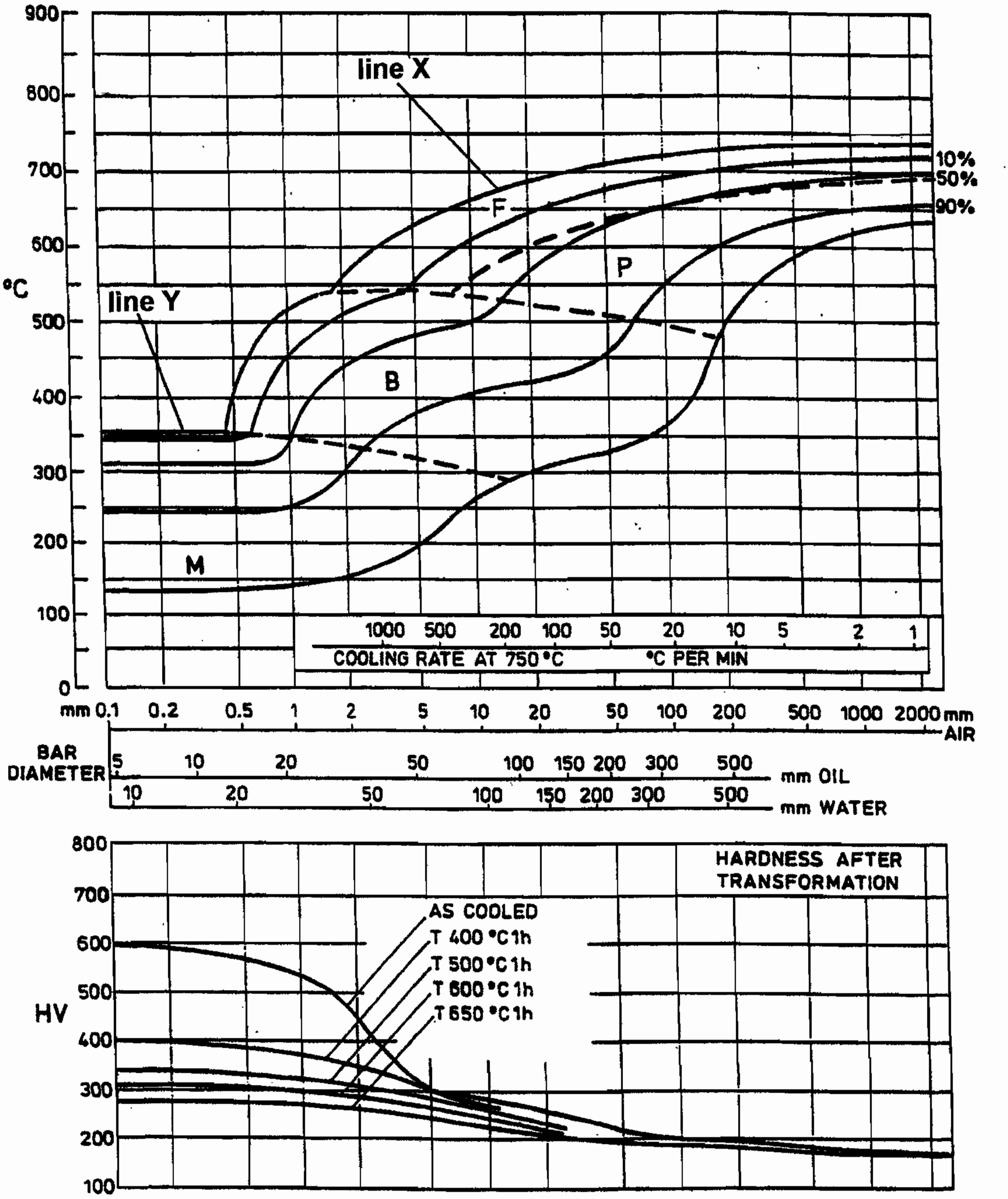

Figure 1 Diagram for question 3

4 (a) The following are two pairs of analogous processes used for metals and polymers:

- pressure die casting and injection moulding;
- centrifugal casting and rotational moulding.

For each pair:

(i) briefly describe each process in the pair, and indicate their similarities and differences;

(ii) give examples of materials and products which are typically processed by each method;

(iii) describe the types of defects which can occur and suggest how they can be avoided;

(iv) compare and contrast any limitations in the shapes produced by the two processes.

[80%]

(b) Explain carefully why:

(i) there is no process for polymers which is analogous to investment casting for metals;

(ii) there is no process for metals which is analogous to film blowing for polymers.

[20%]

END OF PAPER

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Numerical answers

3(b) (i) (very approximately) 10000 °C/min

(ii) air 1 mm; oil 22mm; water 30 mm.

(iii) air: 30% ferrite, 10% pearlite, 57% bainite, 3% martensite (approximate values); oil: 100% martensite.

(iv) 50mm.

(v) air, surface and centre hardness the same, HV = 260; water, surface hardness HV = 600.