ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART 1

Tuesday 28 April 2009 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 answer booklet, rough work pad

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

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1 (a) Figure 1 shows a Continuous Cooling Transformation (CCT) diagram for a 1.25 Cr – 0.20 Mo steel.

(i) Define the terms Ac_3, Ac_1, M_s and M_f. Explain how the alloy content influences hardenability. [20%]

(ii) Estimate the critical cooling rate (at 750°C). [10%]

(iii) Estimate the critical diameters for air, oil and water quenching. [10%]

(iv) Cylindrical bars of this steel having diameters 50 and 250 mm are austenitised at 860°C and then quenched into oil. What microstructures are expected at the centres of the bars? Estimate the as-quenched hardnesses at the centres of the bars.

After quenching, the 50 mm diameter bar is tempered at 500°C for 1 hour. Using Figure 2, estimate the variation in hardness you would expect to find across the diameter of the bar.

What microstructural changes take place during tempering? Explain why the mechanical properties change in the way they do. [40%]

(b) Suggest which types of stainless steel would be suitable for manufacturing the following items:

(i) a kitchen knife;

(ii) a container for liquid nitrogen.

In each case, give reasons for your choice. [20%]

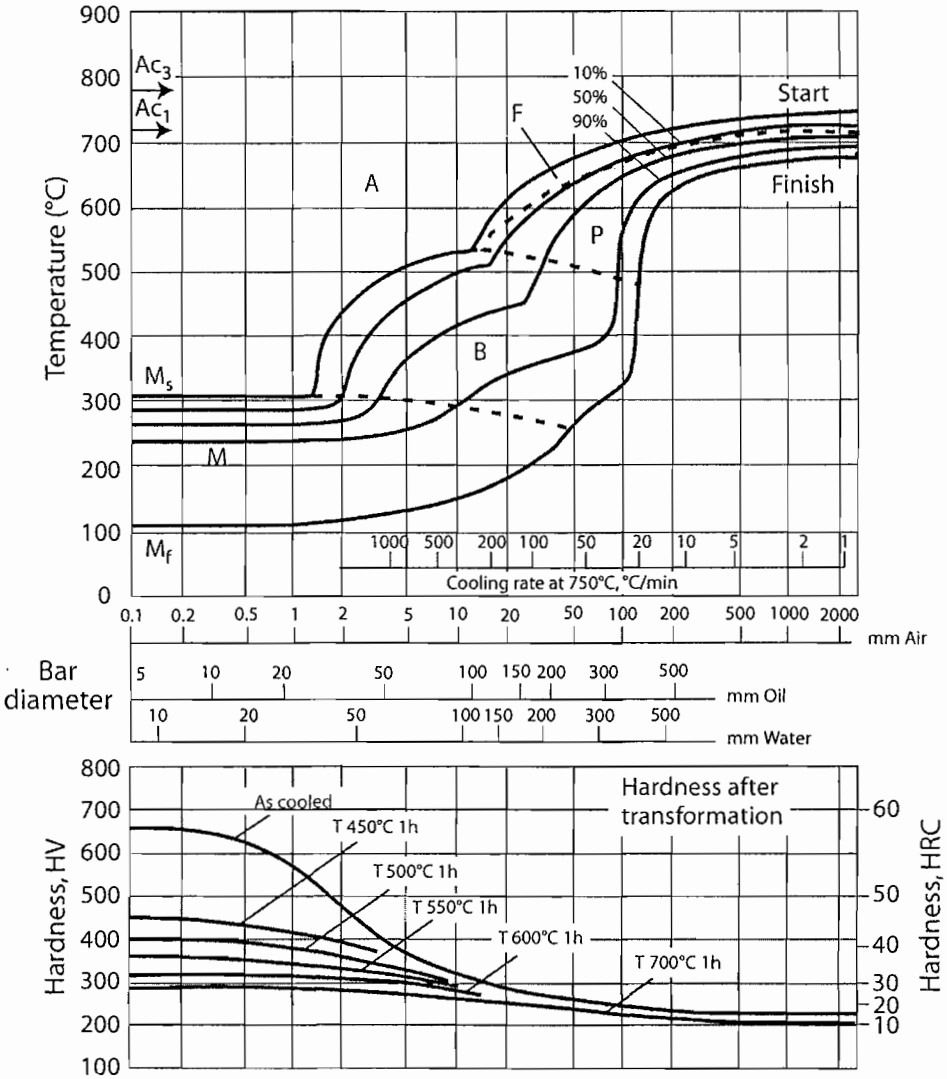

Fig. 1

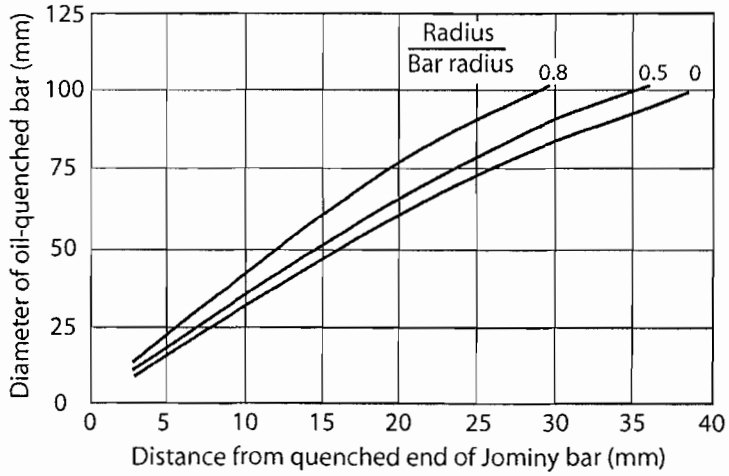

Fig. 2

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2 (a) Screw extrusion forms the basis of a range of production processes for polymer articles. With the aid of a diagram relating pressure at the die to flow rates, show how the output flow rate of the extruder may be estimated. Use your diagram to illustrate the effect of the following on the maximum pressure in the extruder and the output flow rate:

(i) adding short glass fibres to the polymer being extruded;

(ii) reducing the die diameter.

Are there other factors, not shown on your diagram, that influence output rate? [40%]

(b) Discuss what problems you might encounter in making the following products from HDPE using extrusion:

(i) a thick-walled hollow pipe with square section;

(ii) a circular section rod of high dimensional tolerance.

Explain what steps you might take in order to reduce the problems. [30%]

(c) Why do HDPE articles made by extrusion often have anisotropic mechanical properties? How could you produce a circular section extrusion in which the anisotropy is a

(i) maximum;

(ii) minimum? [30%]

3 (a) A small complex part (e.g. pump casing or small fan) is to be manufactured by one of the following routes:

A: from aluminium alloy powder using metal injection moulding (MIM);

B: from aluminium alloy using pressure die casting;

C: from nylon using injection moulding.

(i) Briefly explain how each process works, and state the advantages and limitations of each process. [40%]

(ii) Discuss what criteria you would use to decide which material and production process to choose. What information would you need to make a recommendation for the minimum cost component? [30%]

(b) Briefly summarise the advantages and disadvantages of cold working in comparison with hot working for metals. What approximate temperature range would be classified as hot working for Ni alloys? What factors determine the temperature rise in deformation processing? Explain, with examples, why the temperature rise is significant in metal forming. [30%]

4 (a) For each of the following fusion welding processes, describe the source of heat, the source of the weld metal, and the method by which excessive oxidation of the weld metal is prevented:

(i) oxy-acetylene welding;

(ii) resistance spot welding;

(iii) laser welding.

Indicate, explaining your reasoning, which of the above three processes could be used for the following applications:

A: to join 0.8 mm thick sheet steel parts in automated car body assembly;

B: to deposit a 1 mm thick layer of nickel-based alloy onto a steel substrate. [60%]

(b) Fusion welding can be used to join hardened plates of Al-Mg alloys (5000 series), and also of Al-Mg-Si alloys (6000 series). For each material, describe the mechanisms which will determine the final strengths of the weld metal and the heat-affected zone. What information would you need in order to be able to comment further on the suitability of these alloys for use in high-strength welded structures? [40%]

END OF PAPER

3C1 / P4A 2009: Numerical answers

1. (a)
(ii) Approx 3000°/min
(iii) Critical diameters: Air: 2.0-3.5mm, Oil 45-50mm, Water 55-60mm
(iv) 400HV