ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Tuesday 29 April 2008 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

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

Version 3

1 Describe how you would manufacture the following. In each case, state what properties of the product are particularly critical and explain why the processing method you have chosen is suitable for ensuring that these are achieved.

(a) 1 mm diameter HDPE filament for reinforcing concrete beams. [15%]

(b) A structural I-beam made from carbon fibre reinforced plastic. [15%]

(c) 2-litre PET bottles for carbonated drinks. [15%]

(d) A stainless steel clasp for a watch strap, incorporating a designer logo. [35%]

(e) A cylindrical bronze oil-filled bearing. [20%]

2 (a) Casting and homogenisation of aluminium alloys produces a number of second phase particles in the microstructure, such as dispersoids. Briefly describe two examples of the way such particles affect the microstructure evolution during thermomechanical processing of aluminium alloys. Also identify the main influences which these effects have on the resulting properties. [30%]

(b) In the co-selection of processes and compatible alloys, complex coupling occurs between characteristics of the process, the material and the product design itself. For both of the following objectives, summarize the key physical behaviour involved, and identify briefly how characteristics of process, material and product design control this behaviour:

(i) Successful mould filling in casting;

(ii) Avoidance of embrittlement in welding of low alloy steels. [50%]

(c) By referring to particular advantages and disadvantages of the processes concerned, explain the following selection of process for the components given:

(i) Precision-ground ball bearing races are laser hardened, but not coated by thermal spraying;

(ii) internal seams of radiators are spot-welded, but not joined using epoxy resin. [20%]

3 (a) Define the term *hardenability* in the context of heat treatment of steels. Explain briefly what is meant by the *Jominy end quench test* and discuss why is it useful. [15%]

(b) Define what is meant by *equivalent diameter* (D_e). Figure 1 shows the equivalent diameter curves for oil and water quenched tubes. D_e is given by $f\ y$, where y is defined in Figure 1. Explain why the limiting value of f is 2. [15%]

(c) Figure 2 shows a CCT diagram for a 0.5% Ni-Cr-Mo steel. Use the diagram to estimate the critical cooling rate at 750°C. Quenching to room temperature at this rate can lead to surface cracking. Explain why this happens and suggest a heat treatment process to overcome such problems. [15%]

(d) Estimate the diameter of a 0.5% Ni-Cr-Mo steel bar which will have a hardness of 340 HV at its centre after water quenching and tempering for 1 hour at 400 °C. State the proportions of the various microstructures present. [15%]

(e) A tube made from 0.5% Ni-Cr-Mo steel has an external diameter of 96 mm, an internal diameter of 70 mm and a length of 200 mm. The tube is austenitised and then quenched into water. Find the microstructure and estimate the hardness at the position of slowest cooling. [20%]

(f) Find the dimensions of a 0.5% Ni-Cr-Mo steel tube which can be quenched in oil to give the same microstructure as that found in part (e) at the position of slowest cooling. Assume that the tube is scaled in proportion. [20%]

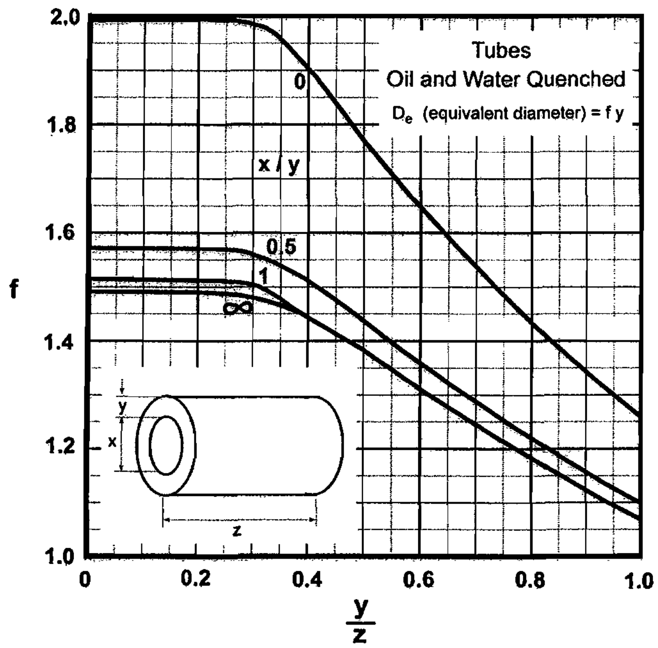
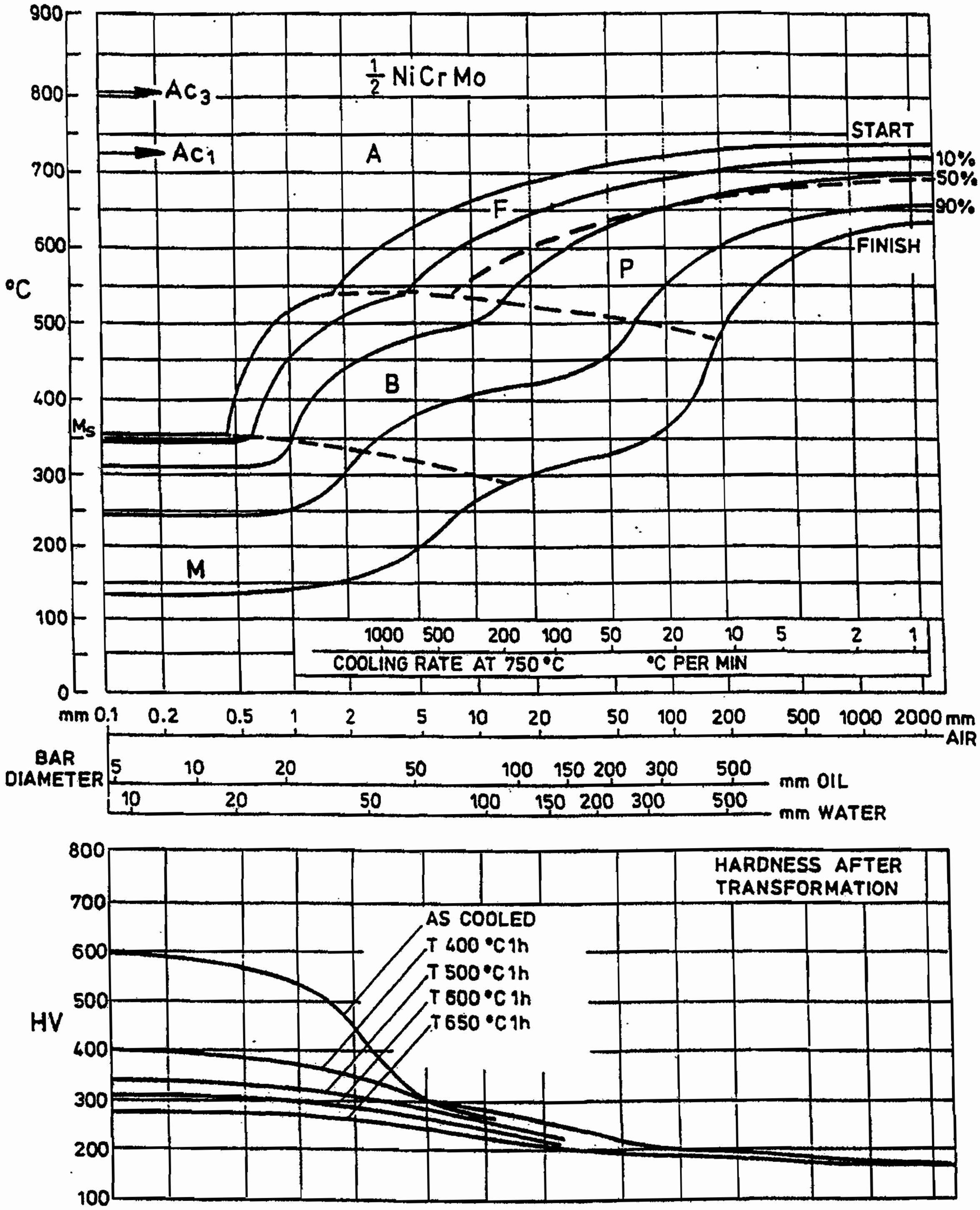


Fig. 1



½ NiCrMo
Ac3
Ac1
A
F
P
B
M
Ms
START
10%
50%
90%
FINISH
°C
900
800
700
600
500
400
300
200
100
0
1000 500 200 100 50 20 10 5 2 1
COOLING RATE AT 750 °C °C PER MIN
mm 0.1 0.2 0.5 1 2 5 10 20 50 100 200 500 1000 2000 mm AIR
BAR DIAMETER
5 10 20 50 100 150 200 300 500 mm OIL
10 20 50 100 150 200 300 500 mm WATER
HARDNESS AFTER TRANSFORMATION
AS COOLED
T 400 °C 1h
T 500 °C 1h
T 600 °C 1h
T 650 °C 1h
HV
800
700
600
500
400
300
200
100

Fig. 2

4 (a) Discuss the role of nucleation in determining the microstructure and mechanical properties of a cast ingot. How do the chill zone, columnar zone and equiaxed zone in a cast structure form? Illustrate your answer by explaining how you would produce the following:

(i) a single-crystal fan blade for a gas turbine engine;

(ii) a steel ingot suitable for rolling into thin strip;

(iii) an ingot in which the grain size and shape are uniform throughout. [50%]

(b) What casting and post-casting treatment would you recommend for producing a chemically homogeneous structure in a statue which is cast in brass containing 70% copper, 30% zinc? Would you propose any different treatments for a bar of brass of the same composition which is to be shaped after casting? Explain your reasoning. [25%]

(c) Explain the following in relation to the casting of aluminium-silicon alloys:

(i) why is there likely to be more porosity in an aluminium alloy containing 2% silicon than in an aluminium alloy containing 12% silicon? Explain how you would minimise the amount of porosity in the 2% silicon alloy, using a post-casting treatment if necessary;

(ii) how you would achieve maximum toughness in an as-cast aluminium alloy containing 12% silicon. [25%]

END OF PAPER