ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Wednesday 30 April 2003 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.*

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) A billet of brass (70 wt% Cu, 30 wt% Zn) is required to have a fine grain-size and uniform composition. Describe two possible ways in which this could be produced, starting with a casting process. What are the advantages and disadvantages of these two methods? [25%]

(b) (i) Describe carefully the process of zone refining, and give one example of its application. [20%]

(ii) A long bar of impure silicon, with constant cross-section and of composition C_0, is to be processed by moving a single liquid zone of length L along the bar, as shown in Fig. 1. The system has a partition coefficient k ($k < 1$), so that liquid of composition C is in equilibrium with solid of composition kC. Sketch the composition profile in the bar and the liquid zone after the furnace has moved a short distance x along the bar, indicating the liquid composition and the compositions of the solid at distances 0, x and $(x+L)$ from the end of the bar. Show that the composition of the solid $C(x)$ in the initial transient is related to the distance x from the end of the bar by:

$$C(x) = C_0\left\{1 - (1-k)\exp\left(-\frac{kx}{L}\right)\right\}$$

[55%]

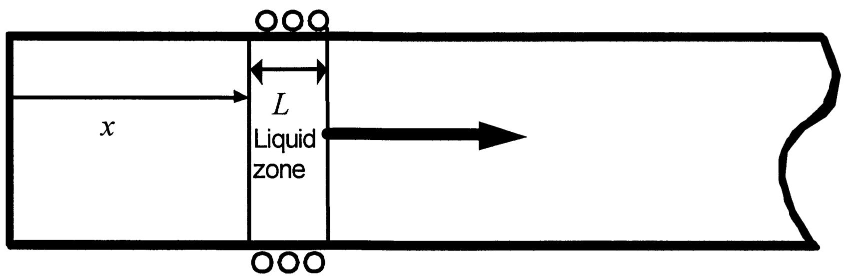


Fig. 1.

2 (a) Metal spectacle frames incorporating a designer logo are to be made in large numbers via a powder route involving Metal Injection Moulding (MIM). Describe the process, indicating the steps which are critical for quality control. What features of MIM make it particularly suitable for this application? [20%]

(b) 150 mm diameter ceramic pipes with an internal screw thread are to be manufactured from alumina. Briefly describe *two* possible processing routes, indicating the advantages and disadvantages of each. [20%]

(c) The following articles are to be made from polymers or polymer-matrix composites. In each case, list the properties sought in the product, briefly describe a processing route and indicate a suitable material, justifying your choices.

(i) Bathtubs for domestic use.

(ii) Two-litre bottles for carbonated drinks.

(iii) Supermarket carrier bags. [60%]

3 (a) Define the term *equivalent diameter*, D_e, in the context of the heat treatment of steels. Schematic curves for equivalent diameter for oil-quenched steel tubes are shown in Fig. 2, which also defines the dimensions x, y and z.

(i) Why does D_e become independent of y/z as this ratio tends to zero?

(ii) The factor f is defined by $D_e = f\,y$. Show that the limiting value of f, marked in Fig. 2 as f_{lim}, is 2.0. [25%]

(b) Define the term *critical diameter*. Estimate the critical diameter for each quenching medium (air, oil and water) from the CCT diagram for 0.5% Ni-Cr-Mo steel shown in Fig. 3. Sketch the microstructure expected at the centre of a bar of 0.5% Ni-Cr-Mo steel with diameter equal to the critical diameter. [35%]

(c) A component of diameter 50 mm is to be heat-treated in 0.5% Ni-Cr-Mo steel, with the following property requirements: hardness at centre 300–320 HV; hardness at surface 450–500 HV. Select a heat treatment schedule which will achieve the required hardness at the centre, and explain why a separate surface treatment will be required. Discuss whether laser transformation hardening is suitable for this treatment, and suggest one other alternative surface treatment. [40%]

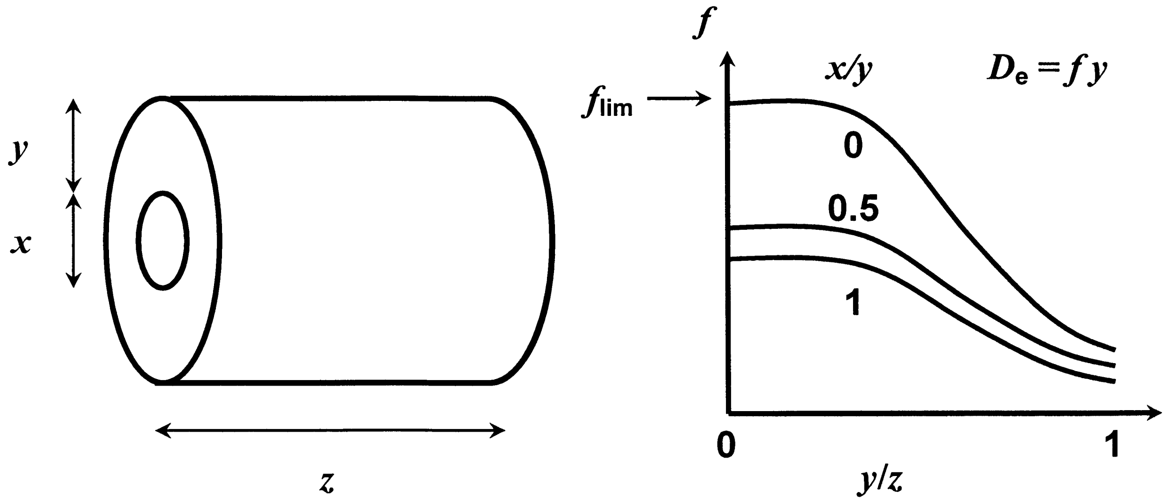
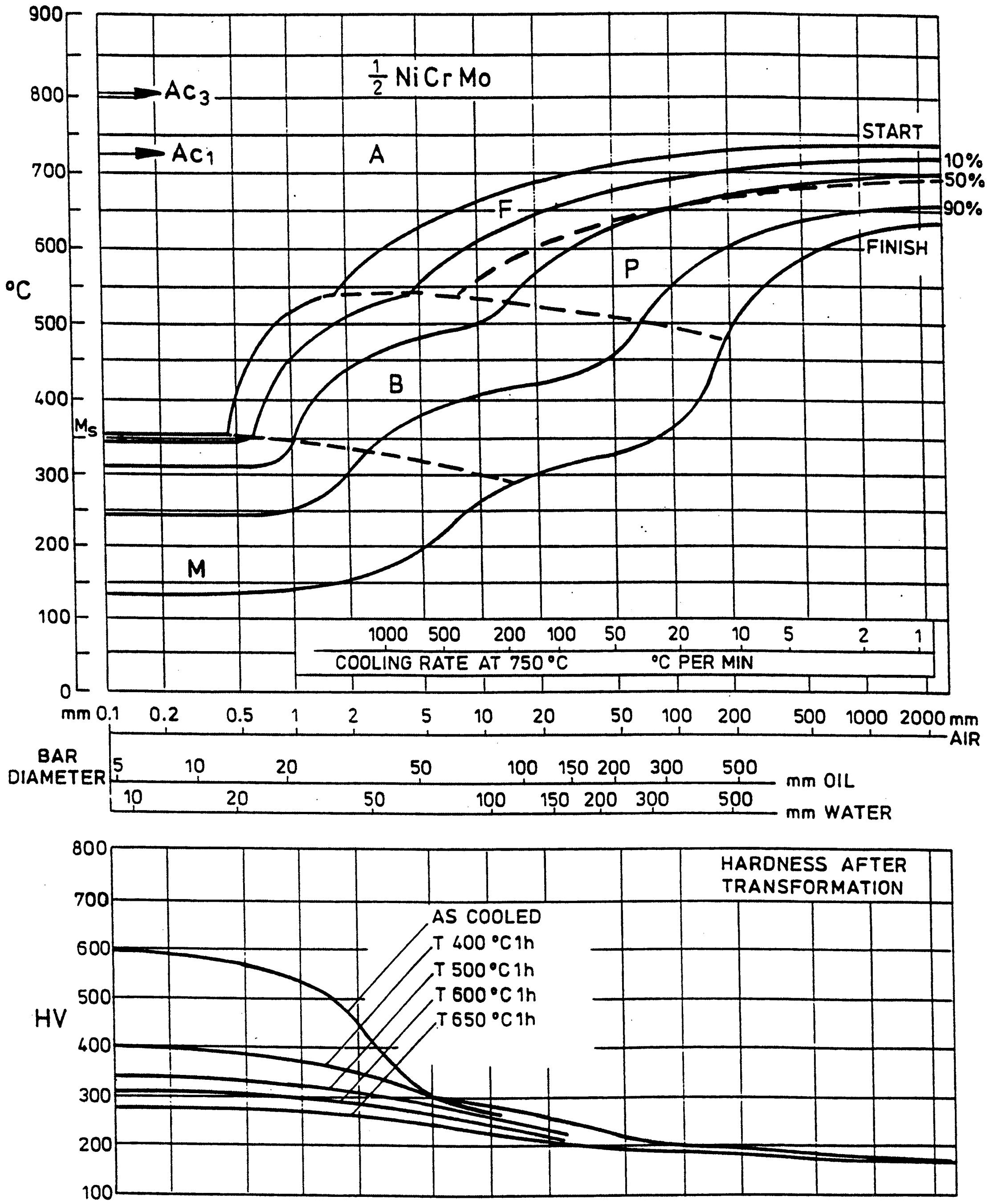


Fig. 2

(cont.



900
800
700
600
500
400
300
200
100
0
°C
Ac3
Ac1
Ms
1/2 NiCrMo
A
F
P
B
M
START
10%
50%
90%
FINISH
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
HV
HARDNESS AFTER TRANSFORMATION
AS COOLED
T 400 °C 1h
T 500 °C 1h
T 600 °C 1h
T 650 °C 1h

Fig. 3

4 (a) In the flat rolling of aluminium, the hot rolling stage typically reduces the metal thickness from 25 mm to 3 mm. Explain why multi-stand tandem mills are used for hot rolling of flat strip. What factors govern the rolling loads and torques, and what are the main control issues in tandem rolling? Define the terms *anisotropy* and *texture* in the context of metal rolling. Why are these properties relevant to subsequent processing of the strip? [50%]

(b) Outline the factors that dominate the selection of a surface treatment method for a metal component. Why is it difficult to predict the wear resistance provided by a given surface treatment? [25%]

(c) The heat-affected zone in low carbon steel welds may show both a grain-refined region and a grain-growth region. Explain the changes in phase and microstructure responsible for this, and comment on the implications for the properties of the welds. [25%]

END OF PAPER