Version Final

MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Tuesday 29 April 2014 9 to 10.30

Paper 1

Module 3P1

MATERIALS INTO PRODUCTS

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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
20 page answer booklet
Rough work paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Define the term *carbon equivalent* and explain why the concept is useful in the context of the heat treatment and fusion welding of steels. Reproduction of an equation for carbon equivalent is not required. [10%]

(b) (i) Define the term *equivalent diameter*, in the context of the heat treatment of a component of complex shape. [10%]

(ii) A long strip of BS 817M40 steel has a rectangular cross-section with dimensions 10×50 mm. It is austenitised at 850 °C and then allowed to cool in air. Estimate the microstructure and hardness of the steel at the centre of the cross-section and at the surface of the strip. Data for this geometry and material are provided in Fig. 1 and 2. [25%]

(c) (i) Describe the process of metal inert gas (MIG) welding of steel. Define the parameter Δt_{8-5} and explain its significance in determining the microstructure and hardness of the material in the heat-affected zone. [15%]

(ii) A butt joint is formed between two strips of BS 817M40 steel by MIG welding, for which $\Delta t_{8-5} \approx 100$ s at a particular point in the heat affected zone. Estimate the microstructure of the steel at this point, and comment on the suitability of this process for joining this material. [30%]

(iii) Discuss the measures that could be taken to increase the toughness of the welded region for this material. [10%]

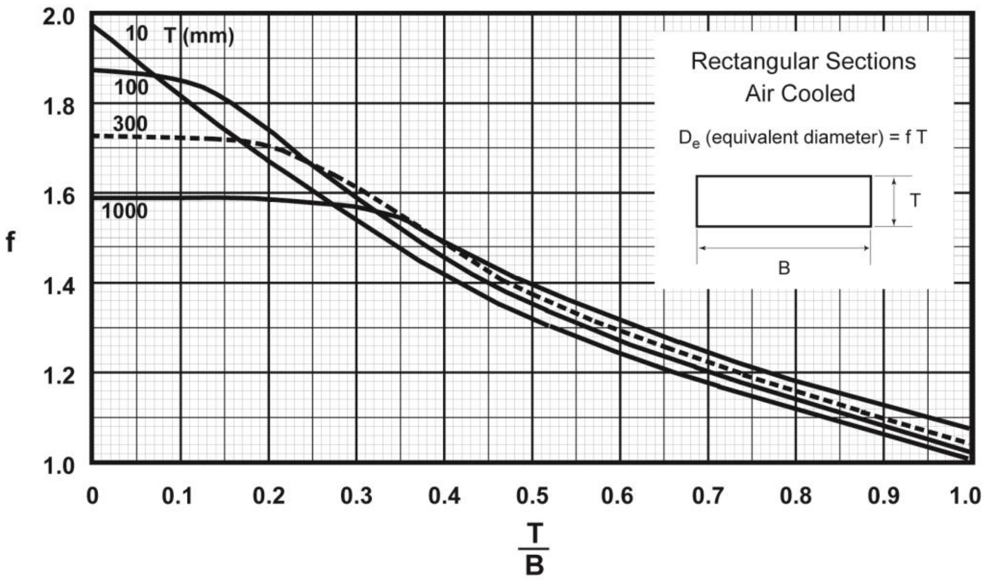

Fig. 1

BS 817M40, AISI 4340 (En24)

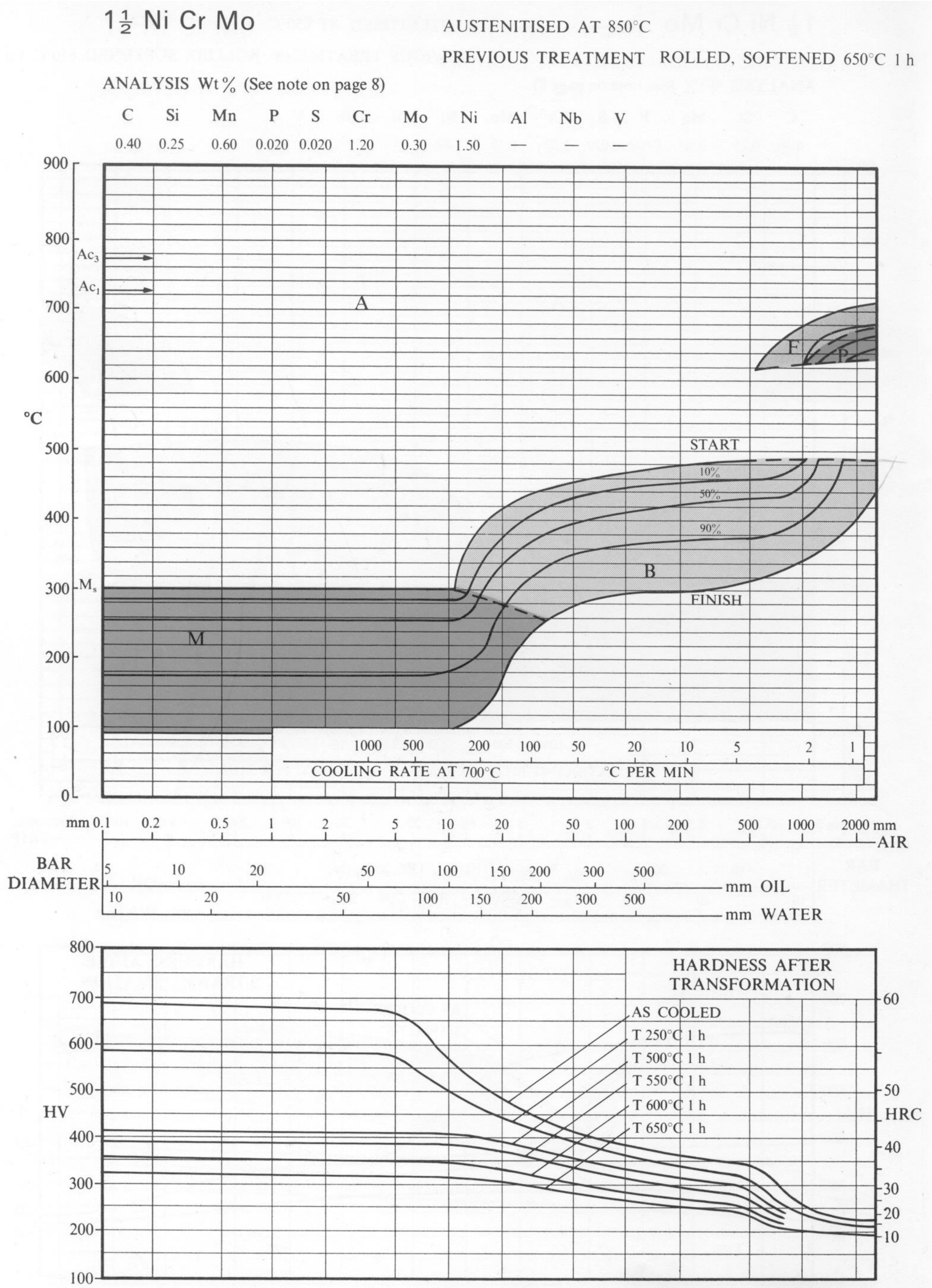

Fig. 2

(TURN OVER

2 (a) *Sink marks* and *weld lines* are defects that can occur in polymer mouldings. In each case:

(i) describe the defect, using sketches to illustrate your answer;

(ii) explain carefully why it has arisen, including a note on how you would expect the problem to be influenced by whether the polymer is crystallisable;

(iii) discuss how the defect might cause problems in service;

(iv) suggest ways in which the defect could be avoided. [60%]

(b) A sheet is made from long glass fibres in an epoxy resin matrix using alternating laminae of uniaxially aligned prepreg sheet, with the fibres aligned at 0° and 90° to the direction of maximum stress in alternate layers.

(i) Why would such a multi-layer composite experience internal stresses in service? Explain how this influences the stacking sequence of the laminae used to make the composite. [20%]

(ii) The composite is used to carry a bending moment in a wet environment where the temperature cycles between 20 °C and 100 °C. Discuss the effects this might have on the composite.

The thermal expansion coefficient of glass fibre is $4.9\times10^{-6}\ \mathrm{K}^{-1}$ and that of epoxy resin is $60\times10^{-6}\ \mathrm{K}^{-1}$. The epoxy resin softens at 200 °C. [20%]

3 (a) Small components with complex geometries are to be manufactured using either powder injection moulding (PIM) or metal injection moulding (MIM).

(i) Describe the process steps involved in producing the 'green' component.

(ii) Outline the advantages of producing the green part using a PIM or MIM process rather than uniaxial pressing.

(iii) Explain how the green component is converted into the finished part.

(iv) How can the porosity of the finished part be controlled? [40%]

(b) A choice of three manufacturing processes is available: powder injection moulding (PIM), metal injection moulding (MIM) and investment casting. For each of the following parts, identify which process or processes could be used, giving your reasons.

(i) Ceramic surgical implant.

(ii) Metal part with intricate surface detail and a minimum thickness of 20 mm.

(iii) Creep resistant nickel alloy turbine blade.

(iv) Bronze belt buckle in the shape of a designer logo. [40%]

(c) Explain why the initial densification rate of a powder compact during sintering depends on both the particle size and the sintering temperature. Give one advantage and one disadvantage of liquid phase sintering. [20%]

4 As shown in Fig. 3, a wide rectangular billet of thickness h_1 is reduced to a thickness h_2 using a plane strain indirect extrusion process. The moving die is driven at speed v_1 and the material leaves the fixed die at speed v_2. The interface between the fixed die and moving die is frictionless. The die semi-angle is α, and the extrusion force per unit width is F. Note that Fig. 3 only shows the top half of the process, which is symmetric about line *OB*.

(a) Explain why the extrusion force F is lower for indirect extrusion than for direct extrusion. Give two other measures that could be taken to reduce the extrusion force for a given h_1/h_2. [20%]

(b) The indirect extrusion process is to be analysed using the equilibrium method. Coulomb friction is assumed between the material and the die, with a coefficient of friction μ.

(i) Sketch the stresses acting on the small element of material shown in Fig. 3. Hence, show that the *x*-component of stress in the material (σ_x, taken as positive in compression) satisfies the following equation between lines *OO′* and *AA′*:

$$\frac{d\sigma_x}{dh}h + \sigma_x = p\left(1 + \frac{\mu}{\tan\alpha}\right),$$

where h is the thickness of the material and p the pressure exerted by the die on the material, both at a position *x*. [40%]

(ii) Explain why σ_x is constant within the material to the left of line *AA′*, and equal to F/h_1. [10%]

(iii) Assuming the coefficient of friction μ to be negligibly small, and assuming the Tresca yield criterion with uniaxial yield stress *Y*, derive an expression for the extrusion force per unit width, F. [30%]

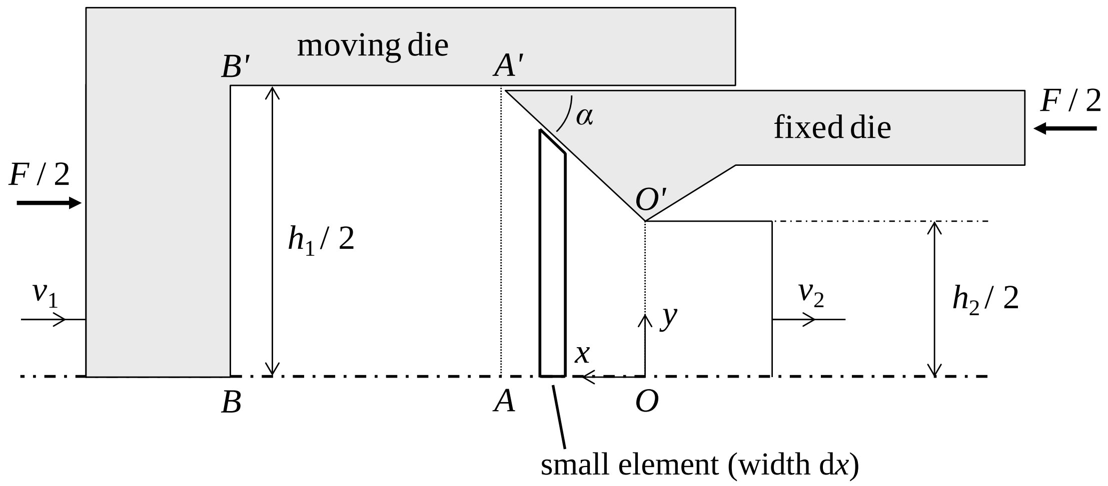

Fig. 3

END OF PAPER

THIS PAGE IS BLANK