MET2
MANUFACTURING ENGINEERING TRIPOS PART IIA

Tuesday 26 April 2016 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

10 minutes reading time is allowed for this paper.

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

1 An axisymmetric nozzle, shown in cross-section in Fig. 1, is to be manufactured from aluminium alloy.

(a) A casting route is considered, using an Al-Si alloy and either sand casting or pressure die casting. Compare the outcome of these two processes in relation to the following design considerations:

(i) dimensional accuracy and tolerance; [25%]

(ii) mechanical properties; [20%]

(iii) component cost. [15%]

Include in your answers a discussion of the strengths and weaknesses of each process, referring to any key material, process or design parameters, as appropriate.

(b) It is decided instead to manufacture the component from a heat treatable aluminium alloy. First, a solid circular cylindrical bar is extruded. The bar is then heat treated, followed by machining of all geometric features.

(i) Describe three ways in which the quality of the final component will be improved by following this processing route instead of a casting route. [15%]

(ii) Explain why the deformation and thermal histories of the aluminium alloy are coupled during the extrusion process, and why this has to be carefully controlled. [15%]

(iii) A quality control check carried out after the machining process shows that the nozzle has a lower hardness at point A (Fig. 1) compared to point B. Give two possible explanations. [10%]

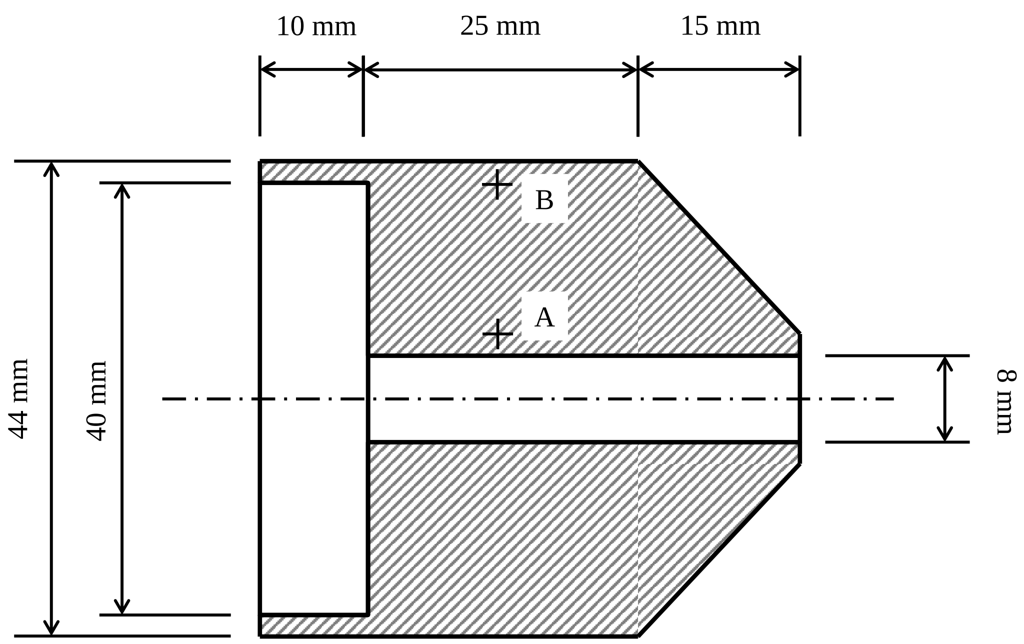

Fig. 1

(TURN OVER

2 The forging of a prismatic bar of BS 220M07 steel is shown in Fig. 2. The lower platen is fixed, while the upper platen moves vertically with speed v. The forging force at this instant is F. The material can be assumed to deform in plane strain. The length of the forged bar out of the plane of deformation is L.

(a) The forging force F is to be calculated using the upper bound method. Plastic deformation is assumed to occur in narrow shear bands indicated by the dashed lines in Fig. 2, dividing the solid into rigid blocks sliding relative to each other, with the shear yield stress k acting at their interfaces.

(i) Draw a velocity diagram for the process, showing the velocities of regions A - E that are labelled in Fig. 2. [25%]

(ii) Hence, derive an expression for the forging force F in terms of the geometric parameters and the shear yield stress k. Sticking friction should be assumed between the deforming bar and the platens. [40%]

(iii) Comment on the contribution of friction to the power required to forge the bar. [10%]

(b) After forging, the bar (which has dimensions as shown in Fig. 2) is normalised and then quenched in water. The equivalent diameter D_e for the bar is estimated to be $D_e \approx 3W$.

(i) Explain why this estimate for D_e is reasonable. [10%]

(ii) If $W = 20$ mm, use the CCT diagram in Fig. 3 to identify the phases present in the centre of the bar, their approximate proportions and the hardness at the surface of the bar. [15%]

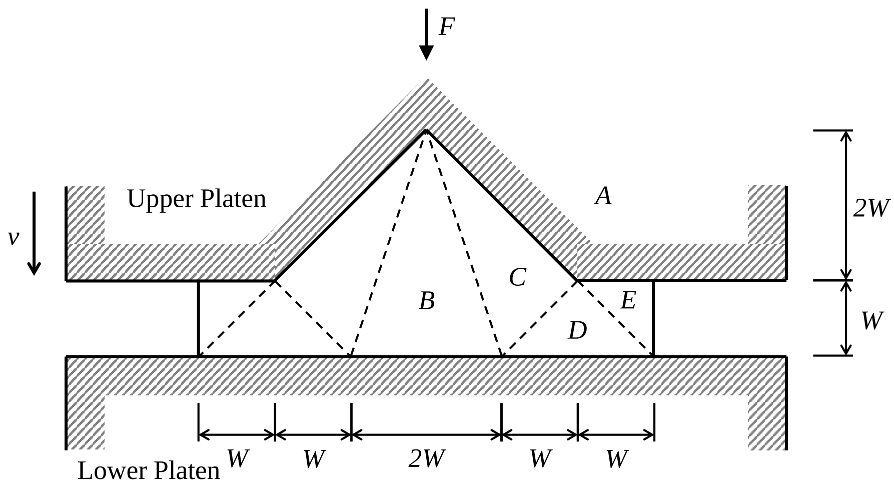
F
Upper Platen
v
A
2W
B
C
E
D
W
Lower Platen
W
W
2W
W
W

Fig. 2

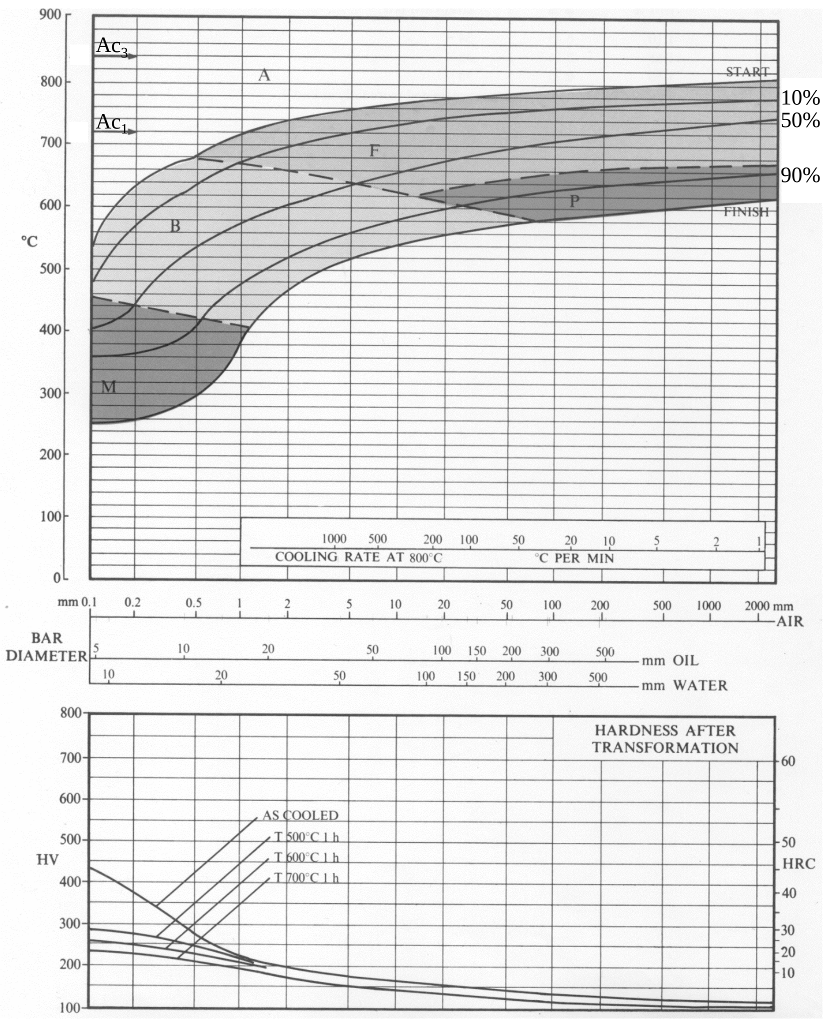
Ac3
Ac1
A
F
B
P
M
START
FINISH
10%
50%
90%
°C
COOLING RATE AT 800°C
°C PER MIN
BAR DIAMETER
AIR
mm OIL
mm WATER
HARDNESS AFTER TRANSFORMATION
AS COOLED
T 500°C 1 h
T 600°C 1 h
T 700°C 1 h
HV
HRC

Fig. 3

3 A component is designed to support a temperature probe within a hot gas flow containing abrasive dust. The component is a thin-walled tube, fixed at one end and subjected to a rapidly oscillating force at the other, which induces bending stresses with amplitude less than the yield stress. The component can be exposed to water, and occasionally it can reach high temperatures (up to 450 °C).

(a) Prototype components are manufactured from carbon steel. The following surface treatments are considered in order to increase the life-span of the component: paint; shot peening; laser hardening; galvanisation.

(i) For each surface treatment, explain the mechanisms by which they can protect the component from degradation in service. [40%]

(ii) Explain any possible problems that might limit the effectiveness of these surface treatments when in service. [20%]

(b) Instead of surface treatment, the following replacement materials are considered: stainless steel; nylon; silicon nitride.

(i) For each material, suggest how the component might be manufactured. [15%]

(ii) Assess the suitability of each material for this application, commenting on both mechanical properties and resistance to degradation in service. [25%]

4 A handrail for a train carriage consists of an aluminium alloy tube with its ends fitted into aluminium alloy brackets for mounting to the carriage wall.

(a) The handrail is to be re-designed so that both the tubular rail and mounting brackets can be moulded in one piece from a semi-crystalline thermoplastic polymer using injection moulding. For ergonomic reasons, the outer diameter of the tubular section cannot be changed. Discuss how the following considerations might influence the success of the re-design:

(i) component shape and geometric detail;

(ii) injection moulding process variables;

(iii) polymer molecular structure. [45%]

(b) Describe two ways in which additives might be used to improve the properties of the injection moulded polymer handrail. What are the disadvantages of using additives? [25%]

(c) To save weight, an alternative concept is to replace the aluminium alloy tube with a carbon fibre reinforced polymer tube (CFRP, with an epoxy matrix) with its ends fitted into aluminium alloy brackets for mounting to the carriage wall.

(i) Explain why this design may be preferable to manufacturing the complete assembly (handrail and mounting brackets) out of CFRP. [10%]

(ii) Comment on the suitability of the following techniques for joining the CFRP tube to the aluminium alloy brackets: hot plate welding; rivetting; adhesive bonding. Include in your answer any technical and quality considerations. [20%]

END OF PAPER

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