ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Tuesday 27 April 2010 9 to 10.30

ENGINEERING TRIPOS PART IIA
Module 3C1: MATERIALS PROCESSING AND DESIGN

MANUFACTURING ENGINEERING TRIPOS PART I: 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.*

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

Version: 3

1 (a) Define the term *equivalent diameter* in the context of the heat-treatment of metallic components. [10%]

(b) Fig. 1 shows the variation in f (defined by $D_e = fy$) for oil- and water-quenched tubes with varying values of internal diameter x, wall thickness y and length z. D_e is the equivalent diameter. Explain the reasons for the following trends:

(i) the variation in f with x/y;

(ii) the asymptotic limits to f as y/z tends to zero. [25%]

(c) Cylindrical steel components with an outer diameter of 20 mm are to be oil-quenched. Use Fig. 1 to estimate the percentage error in the prediction of equivalent diameter if f is simply assumed to be equal to 1.5, for the following components:

(i) a tube with an internal diameter of 10 mm, and a length of 10 mm;

(ii) a solid cylinder of length 15 mm.

In the context of the quenching of steel, explain whether it is preferable to over-estimate or under-estimate the equivalent diameter. [25%]

(d) Write brief notes to explain, in each case, one beneficial and one detrimental aspect of the following alloying elements in the alloys indicated:

(i) either Mn or Fe in heat-treatable aluminium alloys;

(ii) Pb in carbon steels;

(iii) Ni in low alloy steels. [40%]

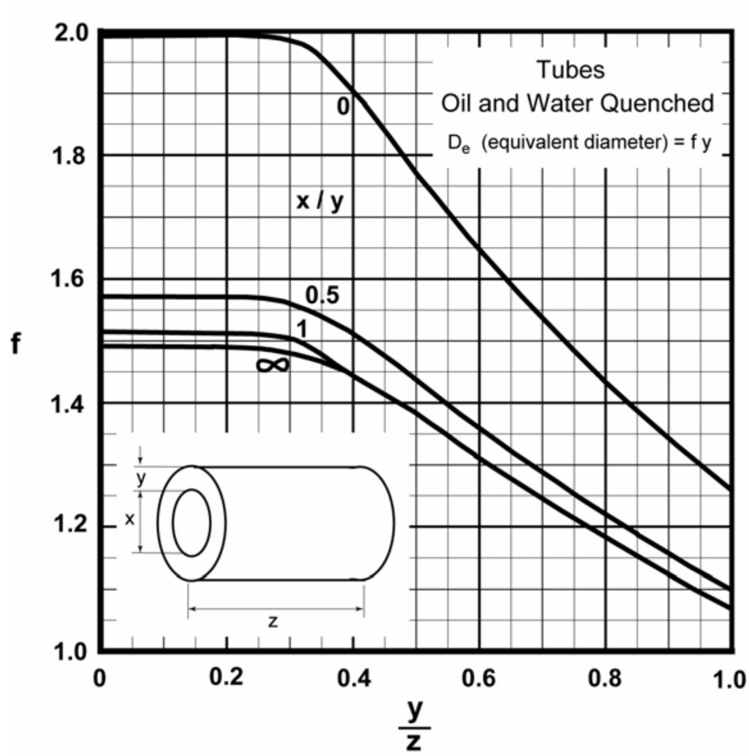

Fig. 1

2 (a) Castings often contain small-scale porosity or larger-scale cavities. Use specific examples to explain how and where such defects may arise, and describe in each case how their formation may be minimised. How successfully can post-casting processes be used to remove porosity? [35%]

(b) Why is it important to be able to control the size and shape of grains in cast components? Describe three ways in which grain size can be reduced during casting. Explain how a single-crystal gas turbine blade can be made from a nickel-base superalloy. [35%]

(c) A square-section polythene rod, to be manufactured by extrusion, must fit snugly into a square hole in a sheet of metal. What problems might be encountered in manufacturing the rod to the required tolerances? Describe measures which could be taken to optimise the extrusion process, explaining how they affect the molecular alignment. [30%]

3 (a) State the assumptions made in the upper bound method for predicting forces in metalworking processes.

Sketch a possible deformation pattern and the associated velocity diagram (hodograph) for each of the following processes:

(i) direct extrusion through a tapering die;

(ii) indirect extrusion through a square die. [25%]

(b) Fig. 2 shows a possible deformation pattern for orthogonal machining by a tool with a rake angle of 22.5°, moving towards the left with a depth of cut d. The workpiece material is assumed to shear at a shear yield stress of k on the plane AB at an angle of 45° to the workpiece surface.

(i) Assume no friction between the chip and the tool. Use the upper bound method to show that the force F on the tool in its direction of motion, per unit depth into the diagram, is given by

$$F = \sqrt{2}\, d\, k$$ [20%]

(ii) Show that if sticking friction is assumed to act between the chip and the tool over a distance of $2d$ along the rake face, then the tool force becomes more than twice the value estimated in part (i). [15%]

(iii) For the model shown in Fig. 2, estimate the maximum temperature rise in the chip for the machining of steel, if frictional heating is ignored. State your other assumptions.
[For the steel: shear yield stress = 500 MPa; density = 7900 kg m^{-3}; specific heat = 450 J kg^{-1} K^{-1}] [20%]

(iv) Explain why in practice in the machining of metals the temperature rise in the tool is typically greater than that in the chip. What are the consequences of a high tool temperature, and how can this temperature rise be reduced? [20%]

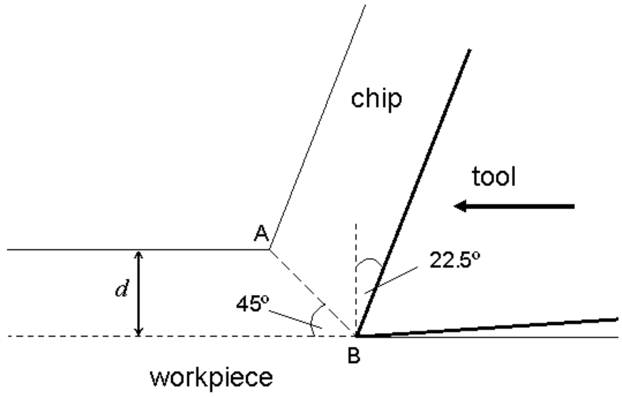

Fig. 2.

4 (a) Mild steel can be protected against corrosion under damp conditions by using coatings made from a range of different materials. Explain why galvanised mild steel does not corrode even if the coating is incomplete, whilst painted steel may start to corrode as soon as the paint layer is scratched. Where will corrosion then take place? [25%]

(b) A small rowing boat is to be manufactured from long-fibre glass-reinforced plastic.

(i) Briefly describe two manufacturing methods which could be used, and outline the advantages and disadvantages of each method. [20%]

(ii) Holes are drilled in the boat hull so that a seat can be fixed. After a few years in service, the hull starts to show environmental degradation in the vicinity of the holes. Suggest possible causes of this phenomenon. [15%]

(c) Welding of steels is associated with a number of possible defects. For each of the following, explain briefly the nature of the phenomenon and how it arises, and suggest ways in which it can be reduced or eliminated:

(i) residual stresses;

(ii) stress concentrations;

(iii) weld decay. [40%]

END OF PAPER