EGT2
ENGINEERING TRIPOS PART IIA

Tuesday 2 May 2017 9.30 to 11

Module 3C1

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.*

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

STATIONERY REQUIREMENTS
Single-sided script 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 The plane strain forging of a rectangular block is shown in Fig.1a. The block has height w and width $3w$. The block is supported on its lower face by a rigid, flat platen. The upper face is indented by a rigid block of width w. The forging force is F per unit depth into the diagram. Sticking friction can be assumed between surfaces in contact, and the material has a shear yield stress k.

(a) Analyse the forging problem by using the *upper bound method*. Fig. 1b shows half of the forging, with the dotted lines showing the assumed pattern of shear planes. The distance z represents the unknown depth of yielding. The indenting block moves at velocity v relative to the supporting face.

(i) Show that the forging force F per unit depth is given by

$$F = 2kz\,[\,(w/z)^2 + 2\,]$$ [35%]

(ii) Hence, find the values of z and F that give the best upper bound for this assumed pattern of plastic deformation. [15%]

(b) The forging problem can also be analysed by the *equilibrium method*. Using the Tresca yield criterion, it can be shown that the pressure p acting at the surface of the block varies with the distance x from the centre-line as shown in Fig.1c as follows:

$$p = k\,[\,3 - 2(x/w)\,] \qquad \text{for } x > 0$$

The pressure variation is symmetric about the centre-line.

(i) List, in qualitative terms, the steps that would be involved in this method of analysis [15%]

(ii) Use the given pressure variation to calculate the forging force, F. [15%]

(c) Compare the values of F obtained in parts (a) and (b), and comment on any differences. Suggest how the upper bound analysis in part (a) might be improved. [20%]

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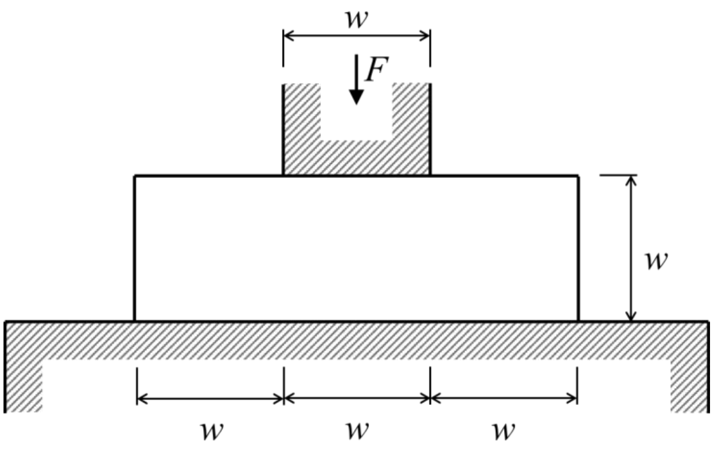

Fig. 1a

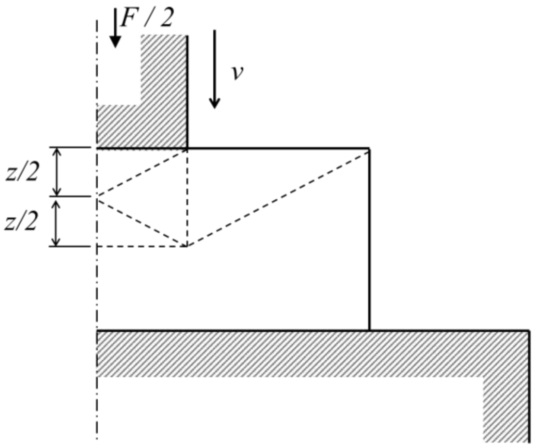

Fig. 1b

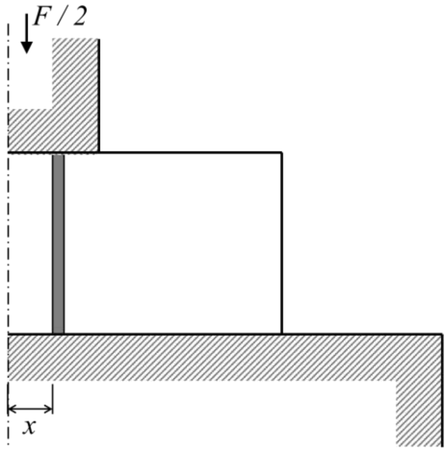

Fig. 1c

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2 Fig. 2 shows a thin-walled cooking pot, made from cast iron by sand casting.

(a) List the parameters that determine the mould filling rate in sand casting, and explain qualitatively why they are relevant. [20%]

(b) Chvorinov's formula for the solidification time t in casting is:

$$t = C\,(V/A)^2$$

(i) Define the parameters in this equation, and explain the physical basis for the dependence of time on the square of (V/A).

(ii) Use this formula to estimate the solidification time for the cooking pot. Assume that the pot has a wall thickness of 4 mm, and that $C = 0.65$ s mm^{-2}. [20%]

(c) Suggest locations for (i) the parting plane of the mould; and (ii) one of the in-gates for filling the mould. For each case, give a reason for your suggestion. [15%]

(d) Describe one type of defect that could arise during each of: (i) mould filling; and (ii) solidification. For each case, suggest a means for avoiding this defect. [15%]

(e) The alloy used contains 3.5 wt% C and 0.5 wt% Mg. Briefly outline three reasons for this choice of composition. [15%]

(f) The pot is surface coated by enamelling. Identify two benefits and one disadvantage of applying this surface treatment. [15%]

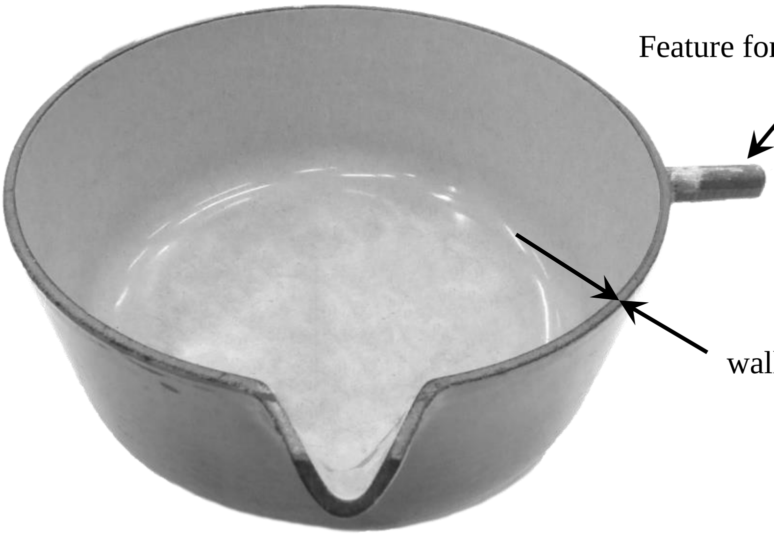

Fig. 2

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3 The body of a prototype cycle trailer is to be fabricated from rolled aluminium alloy sheet. Three options are being considered for the choice of alloy, each having the same tensile strength:

A: non-heat-treatable, low alloy content, cold-rolled;

B: non-heat-treatable, high alloy content, hot-rolled and annealed;

C: heat-treatable, medium alloy content, hot-rolled and naturally aged.

(a) Describe the hardening mechanisms in these three alloys, and explain how they can all have similar strengths after processing. [20%]

(b) What microstructural changes occur in alloy B during the annealing treatment? Describe how the final microstructure depends on:

(i) the strain applied during rolling;

(ii) the number per unit volume of intermetallic second phase particles and dispersoids. [25%]

(c) The trailer body is assembled by TIG welding.

(i) Describe the essential features of the process of TIG welding.

(ii) Sketch the variation of hardness across the weld region that would be expected for each of the alloys A, B and C immediately after welding.

(iii) Explain the microstructural changes responsible for any hardness variation across the weld region noted in part (ii).

(iv) Samples containing trial welds were machined from each alloy, and tested in tension one week after welding. How would the strengths measured for the three alloys differ, and why? [30%]

(d) Discuss the factors other than strength that would need to be taken into account in finalising the choice of alloy and joining process for the trailer body. [25%]

4 Two small, variable-section components are to be made from different materials: one from alumina (a ceramic) and the other from polyethylene (PE, a polymer). Both are disc-shaped, 50 mm in diameter, with thickness varying between 5 mm and 10 mm. The alumina component is to be made by cold pressing followed by sintering. The PE component is to be made by injection moulding.

(a) Describe briefly how each component would be manufactured by the relevant process. [30%]

(b) For each component, explain why its microstructure would be likely to be inhomogeneous. What problems would this cause? How could these problems be reduced by making changes to the manufacturing process (but without using a completely different process)? Discuss any disadvantages of making these changes. [40%]

(c) For each component, suggest an alternative processing route that could be used to achieve the same shape and size from the same material. In each case discuss the advantages and disadvantages of the alternative process. [30%]

END OF PAPER

Numerical answers

q.1 (a) (ii) $z = 0.71\ w$; $F = 5.66\ kw$

q.2 (b) (ii) $t = 2.6$ s

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