ENGINEERING TRIPOS PART IIA
MANUFACTURING ENGINEERING TRIPOS PART I

Tuesday 3 May 2011 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

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

Manufacturing Engineering Tripos:
20 page answer booklet, rough work pad

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

Final version

1 Figure 1 shows a plane strain sheet drawing operation through a die of semi-angle α. Equilibrium plastic analysis is to be used to find the drawing stress σ_{draw}, starting from the stresses acting on the shaded volume element which is shown in enlarged view at the bottom of Fig. 1. Friction between the die and the sheet is represented by a friction factor m where the shear stress on the interface is m times the yield stress in pure shear k ($0 < m < 1$).

(a) The application of horizontal and vertical force equilibrium to the shaded element leads to the following relationships between the stresses:

$$h \frac{\mathrm{d}\sigma_1}{\mathrm{d}h} + \sigma_1 - p - mk \cot\alpha = 0$$

$$\sigma_2 + mk \tan\alpha - p = 0$$

where the symbols are defined in Fig. 1 and compressive stresses are taken as positive.

Use these relationships and the von Mises yield criterion to derive the following expression for the draw stress σ_{draw}:

$$\sigma_{\text{draw}} = \frac{Y}{\sqrt{3}} \left(2 + m \tan\alpha + m \cot\alpha\right) \ln\left(\frac{h_i}{h_o}\right)$$

where Y is the uniaxial yield stress.

State any assumptions you make, and comment on their validity. [40%]

(b) Sketch a graph showing the magnitude of the normalised stress σ_{draw} / Y plotted against the drawing ratio h_o / h_i for friction factors $m = 0$ and $m = 1$, with die semi-angle $\alpha = 30°$. Find the limiting draw ratio in each case, and comment on the results. [30%]

(c) Without further calculation, describe with sketches how this sheet drawing operation could be analysed by using the upper bound method. Show how the effect of friction would be included. [30%]

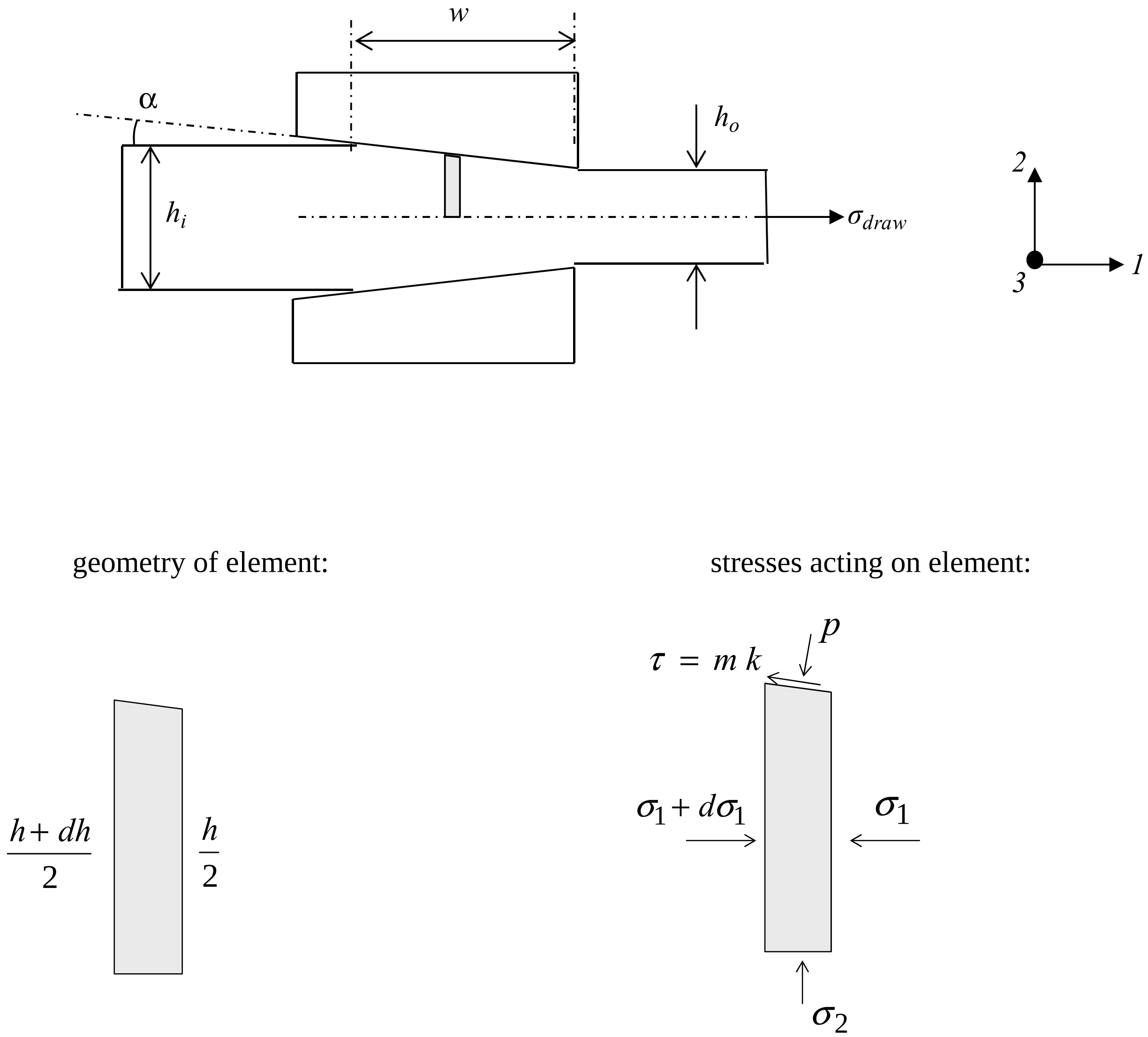
w
α
h_o
h_i
σ_{draw}
2
1
3
geometry of element:
stresses acting on element:
$\tau = m\,k$
p
$\frac{h + dh}{2}$
$\frac{h}{2}$
$\sigma_1 + d\sigma_1$
σ_1
σ_2

Fig. 1

2 (a) Grey cast iron is sometimes described as having high castability. What is meant by the term *castability*? [20%]

(b) Samples taken from different parts of a casting with variable cross-section made from grey cast iron showed tensile strengths ranging from 180 to 350 MPa. The strain to failure of all the samples was <1%. The tensile strengths of samples from a casting with the same dimensions, made from the same alloy to which 0.5 wt% magnesium had been added, were all >380 MPa, and their strain to failure was between 8% and 14%. Provide detailed qualitative explanations for these observations. [30%]

(c) Explain the steps you would take to obtain minimum chemical inhomogeneity in a net-shape casting made from bronze (88 wt% Cu, 12 wt% Sn), at the lowest process cost. [25%]

(d) Describe and explain the process steps needed to produce polyethylene fibre with a very high elastic modulus. What influence would the polymer molecule chain length have on the elastic modulus? [25%]

3 (a) A solid cylindrical component of low alloy steel is to be heat-treated to achieve a certain hardness (on its axis) by quenching and tempering. Describe the microstructural changes that take place at each step in the process. Explain how the key parameters of the material, process conditions and component dimensions influence the thermal and microstructural changes during the process. [25%]

(b) Why is a maximum value of hardness often prescribed for the heat-affected zone (HAZ) in the arc welding of medium-carbon steel plate? Explain how the steel composition and welding conditions will affect the maximum hardness in the HAZ. [25%]

(c) Why do welded structures often exhibit residual stresses? What problems can these cause? How can these stresses be reduced? [25%]

(d) In a failure investigation, samples of a high-strength stainless steel were loaded in tension at different strain rates in a bath of hot salt solution. At low and at high strain rates the steel exhibited ductile failure, but at an intermediate strain rate it showed brittle fracture at a lower stress. Explain these observations. [25%]

4 (a) Describe the process steps involved in manufacturing a ceramic component by powder routes involving (i) uniaxial pressing, and (ii) cold isostatic pressing. [25%]

(b) Fig. 2(a) shows a sectional view of a stepped cylindrical bush with an external groove, to be made from alumina ceramic. Discuss the advantages and disadvantages of using methods involving uniaxial pressing or cold isostatic pressing to make this component. What further information would you need to enable you to choose between these two process routes? [25%]

(c) The alumina component shown in Fig. 2(a) will be subjected in use to high tensile stress along its axis. Discuss how the manufacturing process, material and component design might be modified to ensure that it does not fail under this stress. [25%]

(d) The bottom face of the component is required to be joined to a flat stainless steel plate to form the assembly shown in Fig. 2(b). Describe two methods which could be used to make this joint and discuss the limitations which these joining methods might impose on the service conditions of the assembly. [25%]

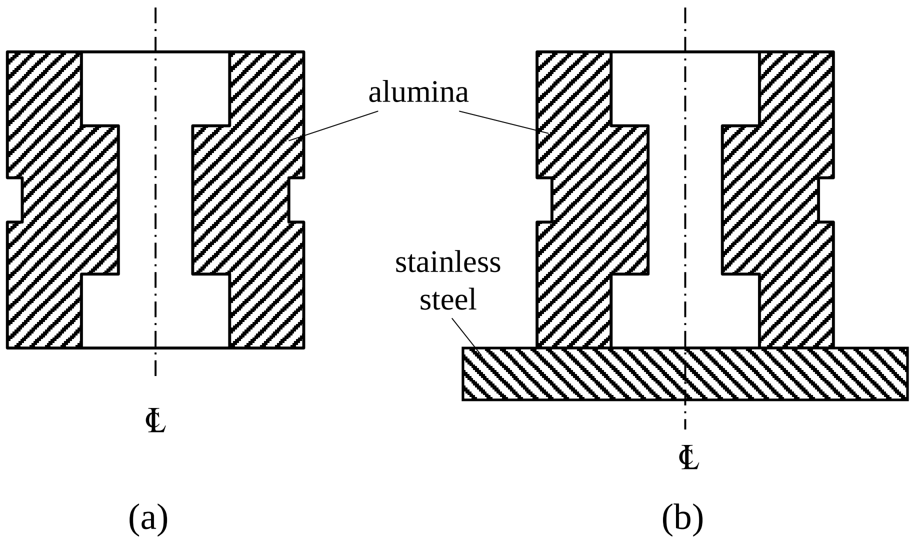

Fig. 2.

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