Version CYB/4

EGT2
ENGINEERING TRIPOS PART IIA

Thursday 29 April 2021 9.00 to 10.40

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 and at the top of each answer sheet.*

STATIONERY REQUIREMENTS
Write on single-sided paper.

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed.
You are allowed access to the electronic version of the Engineering Data Books.

10 minutes reading time is allowed for this paper at the start of the exam.

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 A small gear wheel is to be manufactured from carbon steel.

(a) A candidate production route is to machine the part from bar stock. As a first step, a layer of thickness d (which is small compared to the bar diameter) is machined from the surface of the bar. The machining process is shown in Fig. 1. Plane strain deformation can be assumed, with out-of-plane depth D. In Fig. 1, the workpiece (i.e. the surface of the bar) is moving from left to right. The bar has shear yield strength k, and the tool can be assumed rigid.

(i) Assuming plastic deformation is confined to a single primary shear zone at 45° to the surface of the workpiece, and neglecting friction between the chip and the tool, use the upper bound method to calculate the cutting force F in terms of k, d and D. [25%]

(ii) Explain how this upper bound calculation can be used to inform the tooling design and processing conditions. [25%]

(b) An alternative production route is powder processing.

(i) Considering mechanical properties and process economics, describe the advantages and disadvantages of a powder route compared to machining from bar stock. [20%]

(ii) Two possible powder routes are cold compaction followed by sintering, and Metal Injection Moulding (MIM). Outline the similarities and differences between these two routes. In each case, explain how the different stages influence product quality. [30%]

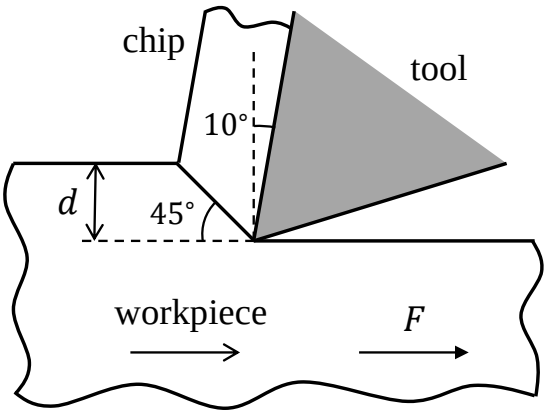

Fig. 1

2 (a) Figure 2 shows the proposed cross-section of a part to be manufactured from a crystallisable thermoplastic. The part is prismatic, with out-of-plane depth 30 mm.

(i) Explain how the molecular structure of a thermoplastic influences crystallisation, and how the degree of crystallinity affects its properties. [20%]

(ii) An injection moulding process is tried, but produces a part with poor dimensional accuracy. Suggest how the processing conditions and the design of the part might be altered to address this. [20%]

(iii) The injection moulded part is also found to contain residual stresses. Explain the origin and consequences of these residual stresses, and how they might be reduced. [15%]

(iv) An extrusion process is considered instead. Discuss the impact of melt swell on dimensional accuracy and explain how this could be reduced. [15%]

(b) An aircraft fuselage panel is to be manufactured from unidirectional long-fibre pre-preg sheets of Carbon Fibre Reinforced Polymer (CFRP).

(i) Explain why a balanced layup is necessary for this application and suggest a suitable layup sequence. [10%]

(ii) Explain why the fibre-matrix interface strength has to be carefully controlled. [20%]

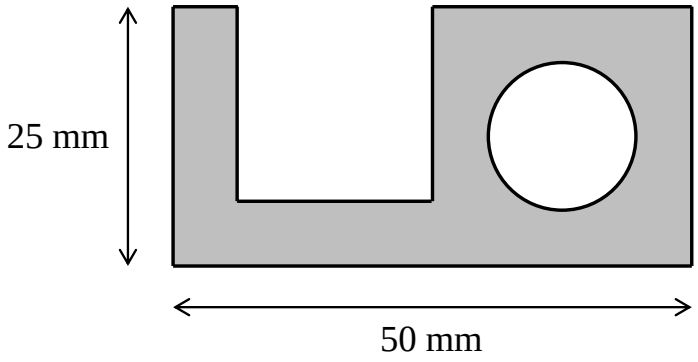

Fig. 2

3 Figure 3 shows the cross-section through a bracket designed to hold a shop sign to an external wall. It consists of a mild steel plate that has been electroplated with copper, joined by fastener 1 to an uncoated mild steel section, which is joined by fastener 2 to the external wall. Fasteners 1 and 2 are high carbon steel bolts.

(a) Rapid corrosion of the uncoated mild steel section is observed around fastener 1. Explain this observation, and suggest how the joint could be redesigned to reduce this. Use sketches to support your answer. [30%]

(b) It is decided to electroplate fasteners 1 and 2 with copper. Brittle failure of fastener 2 now occurs. Explain this observation, and discuss how the failure of fastener 2 could be avoided. [20%]

(c) Fastener 1 is replaced by an arc welded joint. A continuous seam weld is formed between the two steel components.

(i) Describe the distribution of residual stress across the arc welded joint, and explain its origins. [15%]

(ii) Explain why any discontinuities in the seam weld would reduce the lifetime of the joint. [15%]

(iii) Cracking is observed in the heat affected zone on the side of the electroplated steel. Explain why this is unlikely to be a consequence of hardenability, and suggest an alternative explanation. [20%]

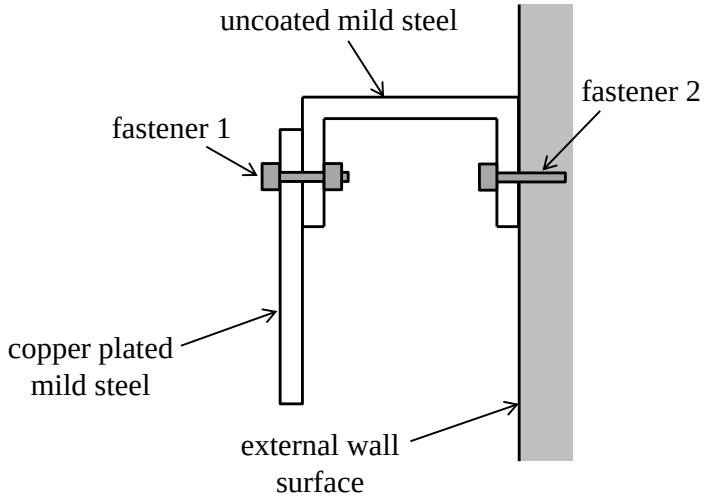

Fig. 3

4 Alloying additions in metals may influence (i) form freedom and achievable component size, (ii) mechanical properties and (iii) process economics. For each of the following alloying additions, consider in turn attributes (i), (ii) and (iii). State whether the alloying addition has any influence. If it does, state whether the influence is positive or negative, and explain why.

(a) Si in Al casting alloy. [20%]

(b) S in free machining steel. [20%]

(c) W in high alloy steel. [20%]

(d) Ni in austenitic stainless steel. [20%]

(e) Ti in microalloyed steel. [20%]

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ANSWERS

Q1(a)(i) $F = 1.70kDd$