EGT2
ENGINEERING TRIPOS PART IIA

Monday 6 May 2019 2 to 3.40

Module 3C9

FRACTURE MECHANICS OF MATERIALS AND STRUCTURES

*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
Attachment: 3C9 Fracture mechanics of materials and structures data sheet (8 pages)
Engineering Data Book

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

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

1 (a) Give the physical basis for the use of the energy release rate G as a loading parameter for crack initiation in linear elastic fracture mechanics. [30%]

(b) A double cantilever beam of geometry shown in Fig. 1 behaves in a linear elastic manner with Young's modulus E.

(i) Determine the compliance of each beam when subjected to a transverse end load P, as shown in Fig. 1. [20%]

(ii) Instead of applying end loads to the beams, the ends are now pushed apart by a wedge. Calculate the energy release rate G for an end separation δ. [30%]

(iii) Assume that the toughness of the material is independent of crack advance. Explain whether crack advance will accelerate if the wedge-loading is sufficient to initiate crack growth. [20%]

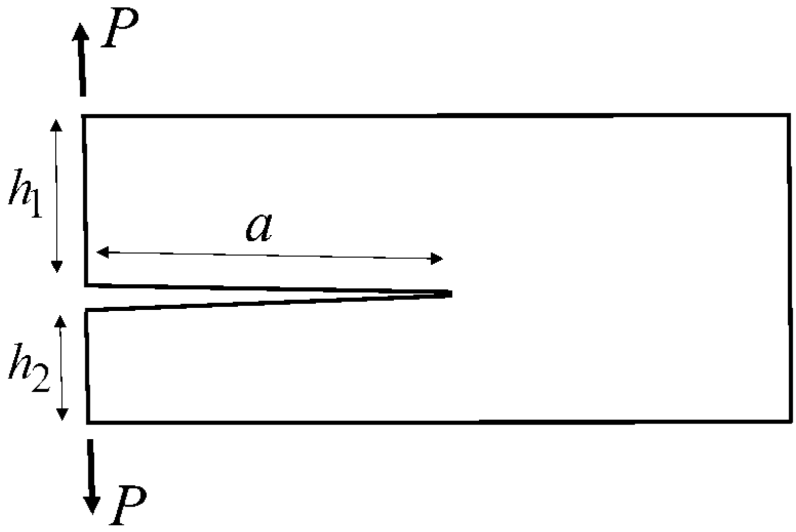

Fig. 1

2 (a) Consider a fatigue crack in a structural steel part. Explain why its growth rate near the fatigue threshold is more sensitive to mean stress than its growth rate in the mid-regime of the Paris plot. [25%]

(b) Why are metallic alloys more flaw sensitive to cyclic loading than to monotonic loading? [25%]

(c) A fatigue crack is grown in an aluminium alloy plate under constant amplitude loading at a load ratio $R = K_{min}/K_{max} = 0.5$, where K_{min} and K_{max} are the minimum and maximum stress intensity factors of the fatigue cycle, respectively.

(i) Describe and account for the crack growth rate transient that follows a single peak overload of magnitude $2K_{max}$. [25%]

(ii) Alternatively, a single peak underload is applied, such that K_{min} drops to zero for a single cycle. Explain whether a crack growth transient results from this underload or not. [25%]

3 (a) Distinguish between small scale yielding and large scale yielding in fracture mechanics. [20%]

(b) Contrast the physical basis of the R-curve in a metallic alloy and in a long fibre composite. [30%]

(c) A thin metallic sheet contains a central crack of length $2a_0$ and is loaded remotely by a uniform in-plane stress σ normal to the crack plane. The R-curve for the sheet is of the form

$$
\begin{aligned}
K_R &= K_0 \sin\left(\frac{\pi \Delta a}{2\lambda}\right) \quad \text{for} \quad 0 \le \Delta a \le \lambda \\
&= K_0 \qquad\qquad\qquad \text{for} \quad \Delta a > \lambda
\end{aligned}
$$

where K_R is the crack growth resistance, Δa is the crack extension, and K_0 and λ are material constants.

(i) Determine the failure strength of the sheet assuming that $a_0 = 0.2\lambda$. [25%]

(ii) Explain with the aid of a sketch why the amount of stable crack extension increases with increasing initial crack length. [25%]

4 (a) Explain how the effect of mean stress upon fatigue crack initiation may be accounted for in component life assessment. [25%]

(b) Account for the dependence of the mode I fracture toughness upon the thickness of a cracked metallic sheet. [25%]

(c) A panel of height H, width $2W$ and thickness B contains a centre-crack of length $2a$. The panel is made from steel of yield strength σ_Y, and, upon subjecting the ends of the panel to an axial load P, the end displacement u satisfies

$$P = \sigma_Y B(W-a)\left(\frac{u}{H}\right)^{1/3}$$

(i) Obtain an expression for the potential energy of the panel for a prescribed load P_0. [25%]

(ii) Calculate the value of the J-integral, again for a given load P_0. [25%]

END OF PAPER