Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	FATIGUE AND FRACTURE MECHANICS
COURSE CODE	:	BDC 40403
PROGRAMME	:	BDD
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTIONS	:	ANSWER **FOUR(4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 (a) Based on the Fracture Mechanics Approaches, please choose either true **(T)** or false **(F)** for statements below.

i. Do recognize that the presence of cracks or crack-like manufacturing and metallurgical discontinuities can significantly reduce the strength of a component or structure.
ii. Do not consider that fracture toughness depends much more on metallurgical discontinuities and impurities than does ultimate or yield strength. Low impurity alloys have better fracture toughness.
iii. Do expect doubling thickness or doubling ultimate strength of a component to double the fracture load. Cracks can exist and fracture toughness may drop appreciably with both thickness and ultimate strength increases.
iv. Do recognize the importance of distinguishing between plane stress and plane strain in fracture mechanics analysis as fracture toughness, crack tip plasticity, and LEFM limitations can be significantly different for the two conditions.
v. Do not neglect the importance of nondestructive flaw or crack inspection for both initial and periodic inspection periods.
vi. Do not note that most fatigue crack growth usually occurs in mode I even under mixed-mode conditions, and hence the opening mode stress intensity factor range ΔK_I is often the predominant controlling factor in fatigue crack growth (FCG).
vii. Do not investigate the possibility of using LEFM principles in fatigue crack growth life predictions even in low strength materials; crack tip plasticity can be small even in low strength materials under fatigue conditions. If plasticity is large, EPFM may be required.
viii. Do consider the possibility of inspection before fracture. High fracture toughness materials may not provide appreciable increases in fatigue crack growth life, but they do permit longer cracks before fracture, which makes inspection and detection of cracks more reliable.

(8 marks)

(b) Describe the failure of the Liberty Ships during the World War II supply vessels. How did the prevailing social and economic factors contribute to the design and manufacturing of these vessels and ultimately compromise theirs mechanical performance. You can choose the write about a different example or case study that has undergone the same or similar failure.

(17 marks)

Q2 (a) Describes the following terms and give the examples in the engineering application.

(i) Linear elastic fracture mechanics (LEPM)
(ii) Elastic-plastic fracture mechanics (EPFM)

(10 marks)

(b) A plate of center-cracked in tension condition as shown in **Figure Q2(b),** accurate values of *F* from numerical results are given in the Tada (2000) handbook as indicated in **Table Q2(b)**

Table Q2(b)

$\alpha = a/b$	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$F = F(\alpha)$	1.000	1.006	1.025	1.058	1.109	1.187	1.303	1.488	1.816	2.578

(i) Compare these values with the expression for F from **Figure Q2 (b)** that is recommended for any α. What it its accuracy for $\alpha \leq 0.9$?

(ii) Two approximations for F that are sometimes employed for center-cracked plates are

$$F = \sqrt{\sec\frac{\pi\alpha}{2}}, \qquad F = \sqrt{\frac{2}{\pi\alpha}\tan\frac{\pi\alpha}{2}}$$

where the arguments of the trigonometric functions are in radians. Compare each of these with the numerical values, and characterize the accuracy of each for $\alpha \leq 0.8$.

(15 marks)

Q3 (a) Distinguishes:

(i) The fracture toughness of K_{IC}

(ii) The fracture toughness of J_{IC}

(6 marks)

(b) A double-edge-cracked plate of 7075-T651 aluminium has dimensions, as defined in **Figure Q3b(i),** of b =15.9 mm, t =6.35 mm, large h, and sharp precracks with a = 5.7 mm. Under tension load, failure by sudden fracture occurred at a force of P_{max} = 55.6 kN. Prior to this, there was a small amount of slow-stable crack growth, with the P-v curve being similar to **Figure Q3b(ii)**., Type I, and crossing the 5% slope deviation at P_Q =50.3kN..

(i) Calculate K_Q corresponding to P_Q.

(ii) At the K_Q point, determine whether or not plane strain applies and whether or not LEFM is applicable.

(iii) What is the significance of the K_Q calculated?

(19 marks)

Q4. (a) Describe the mechanisms of fatigue failure based on the **Figure Q4 (a)** with using S-N curve to show the started of the crack.

(10 marks)

(b) The steel 50CrMo4 can be assumed to have an S-N curve of the form of

$$\sigma_a = AN_f^B$$

Some fatigue test data for unnotched specimens under axial stress with zero mean are given in the **Table Q4 (b)**.

(i) Plot these data on log–log coordinates (refer to **Figure Q4 (b)**), and determine approximate values for
the constants A and B.

(ii) Obtain refined values for A and B, using a linear least-squares fit to log N_f versus log σ_a. Then calculate σ'_f and b for Equation

$$\sigma_a = \sigma'_f(2N_f)^b$$

Table Q4(b)

σ_a MPa	N_f cycles
448	30 000
448	85 000
414	144 000
469	252 000
372	351 000
459	520 000
345	701 000

(15 marks)

Q5 (a) A large component is subjected to a cyclic loading under $\Delta\sigma$ = 300 MPa and R = 0. The component need to endure 37,627 cycles, with an initial single-edge crack length, a_i – 2 mm. The material behaves according to Paris Law,

$$\frac{da}{dN} = 2 \times 10^{-8}(\Delta K_I)^{2.45},$$

where da/dN is in m/cycles and ΔK_I is in MPa$\sqrt{m}$. Assume the geometry factor, Y = 1.12.

i. Determine the final crack length, a_f, for the component.

ii. Predict the plane strain fracture toughness for the component at the end of the loading cycles.

(15 marks)

(b) Describe the effect of microstructure of rolling direction on the fatigue behaviors in stages of fatigue crack growth of Aluminium Alloy.

(10 marks)

- END OF QUESTIONS –

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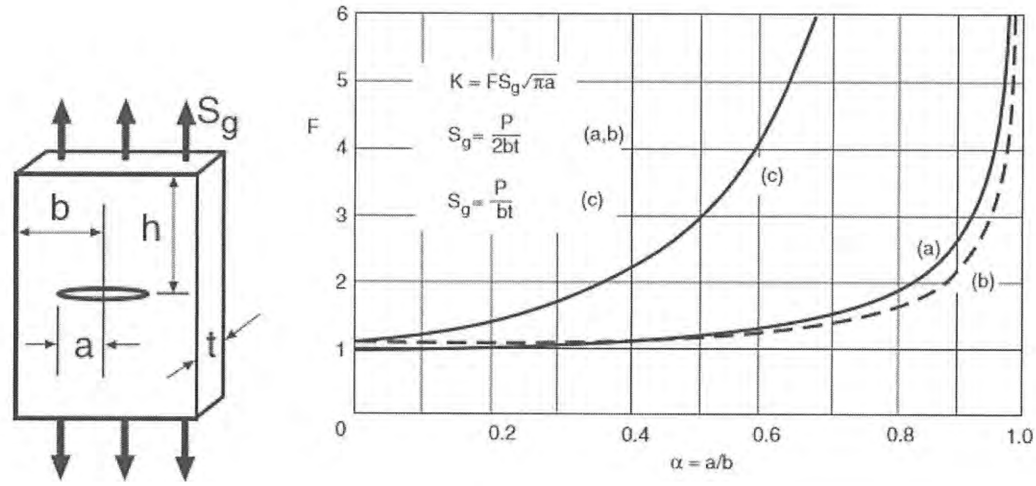

Figure Q2(b)

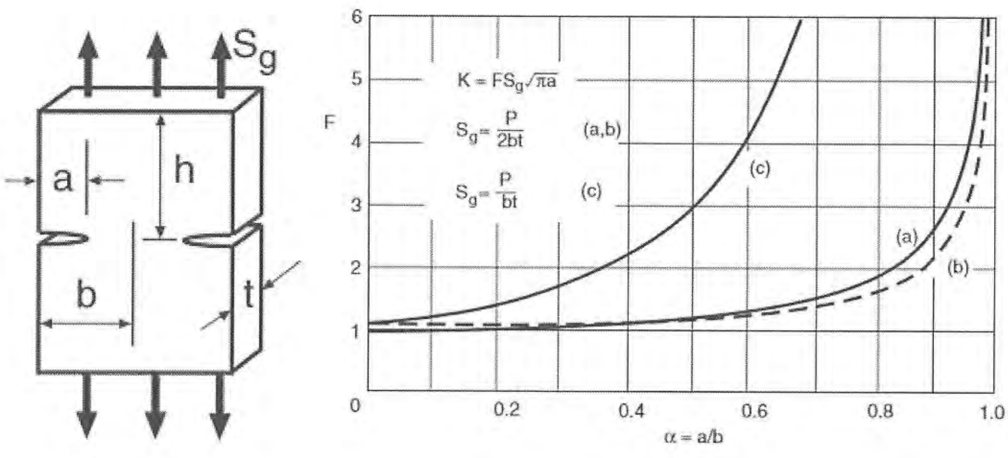

Figure Q3b(i)

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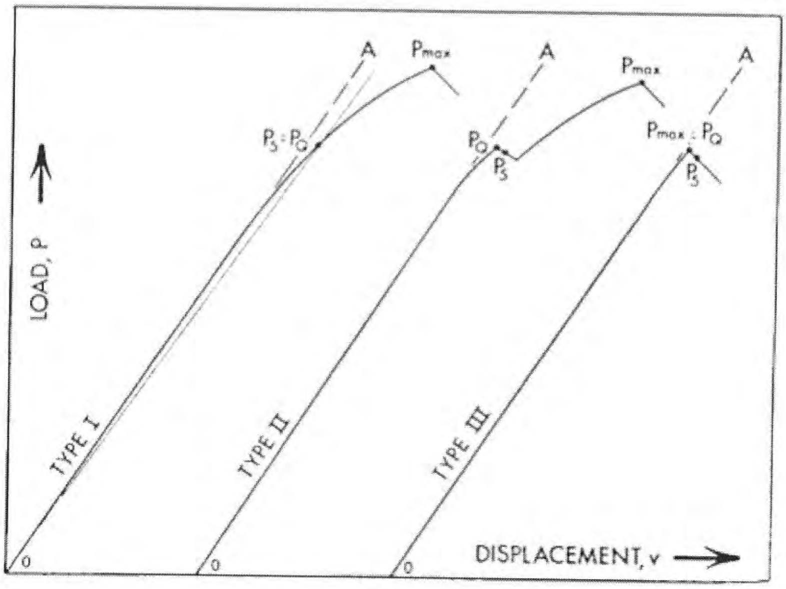

Figure Q3b(ii)

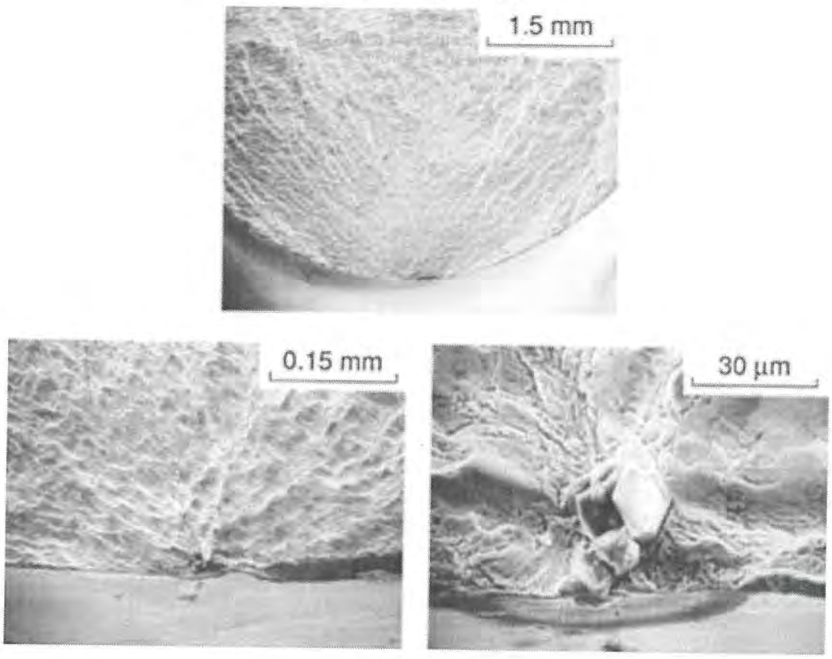

Figure Q4(a)

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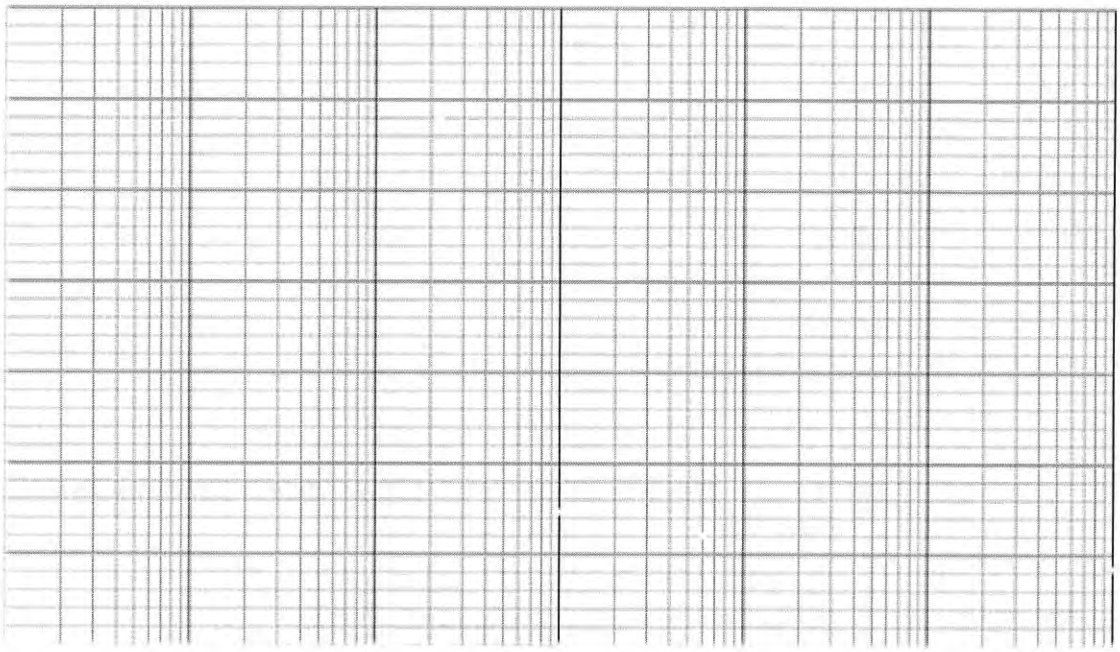

Figure Q4 (b)