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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	FATIGUE AND FRACTURE MECHANICS
COURSE CODE	:	BDC 40403
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2018/JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTIONS	:	ANSWER **FIVE (5)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

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Q1 (a) Define the terms below:

(i) Infinite-life design
(ii) Safe-life design
(iii) Safety factor of design

(6 marks)

(b) 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. Don't 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. Don't neglect the importance of nondestructive flaw or crack inspection for both initial and periodic inspection periods.

vi. Don't 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 FCG.

vii. Don't 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)

(c) Name and describe the fracture mechanisms involved in two materials as shown in **Figure Q1(c).**

(6 marks)

Q2 (a) Distinguish the strength and fracture toughness. Explain, why need to improve the Alloy 2 as shown in **Figure Q2(a).**

(8 marks)

(b) A plate of width 1.4 m and length 2.8 m is required to support a tensile load of 4 MN (in the long direction). Inspection procedures are capable of detecting through-thickness edge cracks larger than 2.7 mm. The two titanium alloys in the table (see **Table Q2(b)** on page are being considered for this application. For a factor of safety of N = 1.3 against yielding and fracture, which one of the two alloys will give the lightest weight solution?

(12 marks)

Q3. (a) Explain:

(i) The fracture toughness for K_{IC}

(ii) The fracture toughness for J_{IC}

(6 marks)

(b) Explain details of the procedure to conduct the fracture toughness testing for J_{IC} of Magnesium alloy AZ31. The graph of the load versus load line displacement and fractography of crack growth Δa are shown in **Figure Q3(b)**. Obtain the value of the fracture toughness for J_{IC}. The procedure of testing should be included the J value interrupted displacement and the graph of R- curve.

(14 marks)

Q4. (a) Based on the failure of component as shown in **Figure Q4(a)**, why the component is failure and list of **Three (3)** criteria caused of this failure. Judge why you say it.

(6 marks)

(b) A stressed element in a reciprocating link experiences a maximum stress of + 180 MPa and a minimum of – 20 MPa. Calculate the fatigue loading parameter by the load ratio. Sketch the stress cycles and indicate on the diagram the calculated loading parameters.

(4 marks)

(c) A fatigue fracture of the low carbon steel is occurred after 222 cycles at σ_a = 948 MPa and 132150 cycles at σ_a = 524 MPa. The tests are conducted on unnotched, axial loading under zero mean stress. Determine the number of cycles to failure, when the σ_a = 700 MPa is applied. Discuss the fatigue limit of this material.

(9 marks)

Q5 (a) Describes the three stages of fatigue crack propagation as show in **Figure Q5(a).**

(8 marks)

(b) The influence of *R*-Ratio on fatigue crack growth rate, da/dN and stress intensity factor range (ΔK) is given in **Table Q5** and plotted *da/dn* versus *ΔK* as shown in **Figure Q5 (b)** for Centre Crack Tension (CCT) RQC-100 steel.

i. Determine the coefficient, *C* and exponent, *m* of the Paris equation for stage II fatigue crack growth rate region

ii. Calculate the critical length of a through-thickness edge crack for fast fracture of the plate under fatigue loading with stress amplitude of 110 Mpa. Assume the geometry factor, *Y* = 1.12

iii. Use the fracture mechanics concept, appraise the relationship between effect *R*-ratio and crack length.

(12 marks)

Q6 (a) Sketch and Describes the classification of basic bulk forming processes:-

(i) Rolling

(ii) Forging

(iii) Extrusion

(9 marks)

(b) Explain the effect of microstructure of forming processes on the fatigue behaviour of materials.

(11 marks)

"END OF QUESTION"

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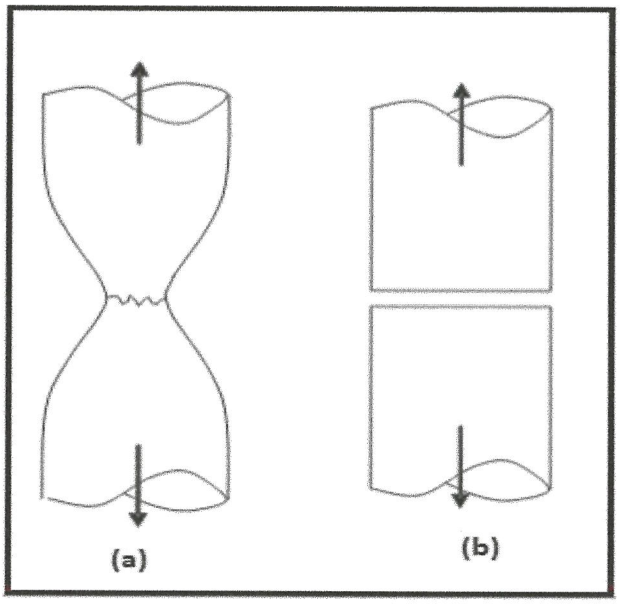

Figure Q1(c)

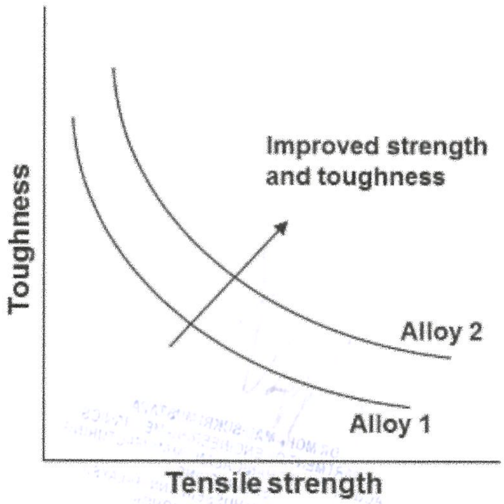

Figure Q2(a)

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Table Q2

Values of K_C for Some Metals

Material	$K_C, MPa\sqrt{m}$	S_y, MPa
Aluminum		
2024	26	455
7075	24	495
7176	33	490
Titanium		
Ti-6AL-4V	115	910
Ti-6AL-4V	55	1035
Steel		
4340	99	860
4340	60	1515
52100	14	2070

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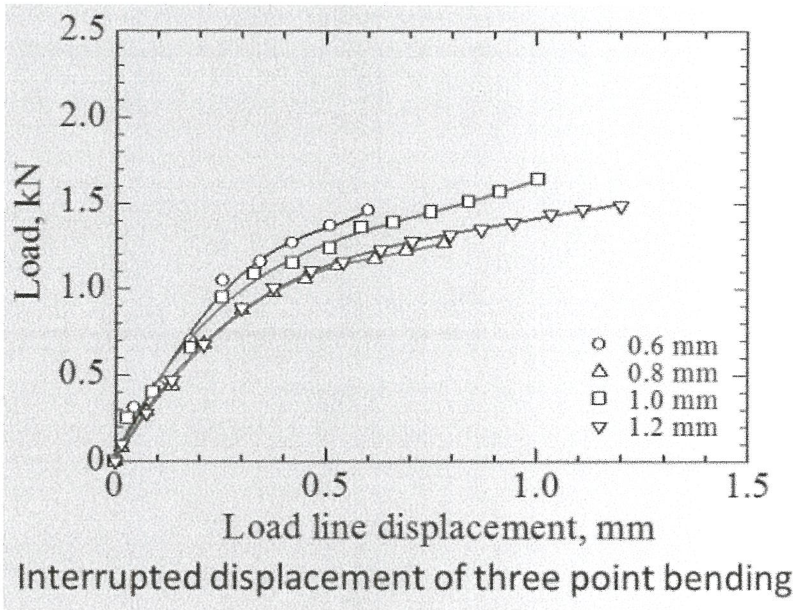
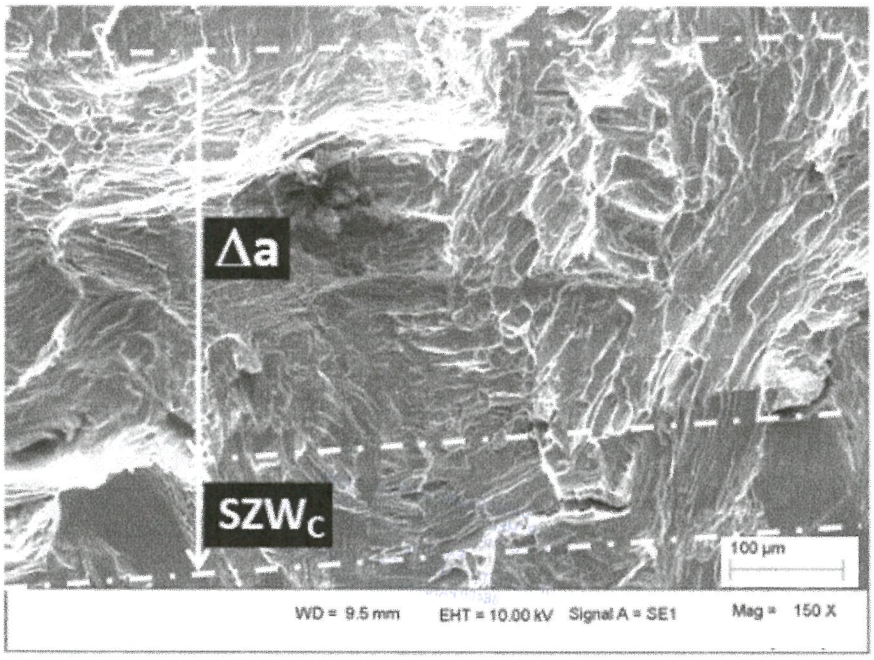


(a) Graph Load Versus Load Line Displacement



(b) Strecth zone, SZW_C and ductile crack growth Δa

Figure Q3

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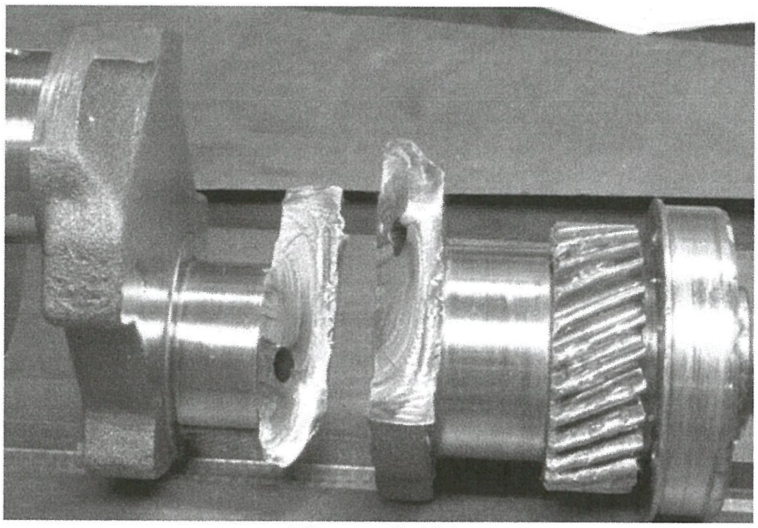

Figure Q4(a)

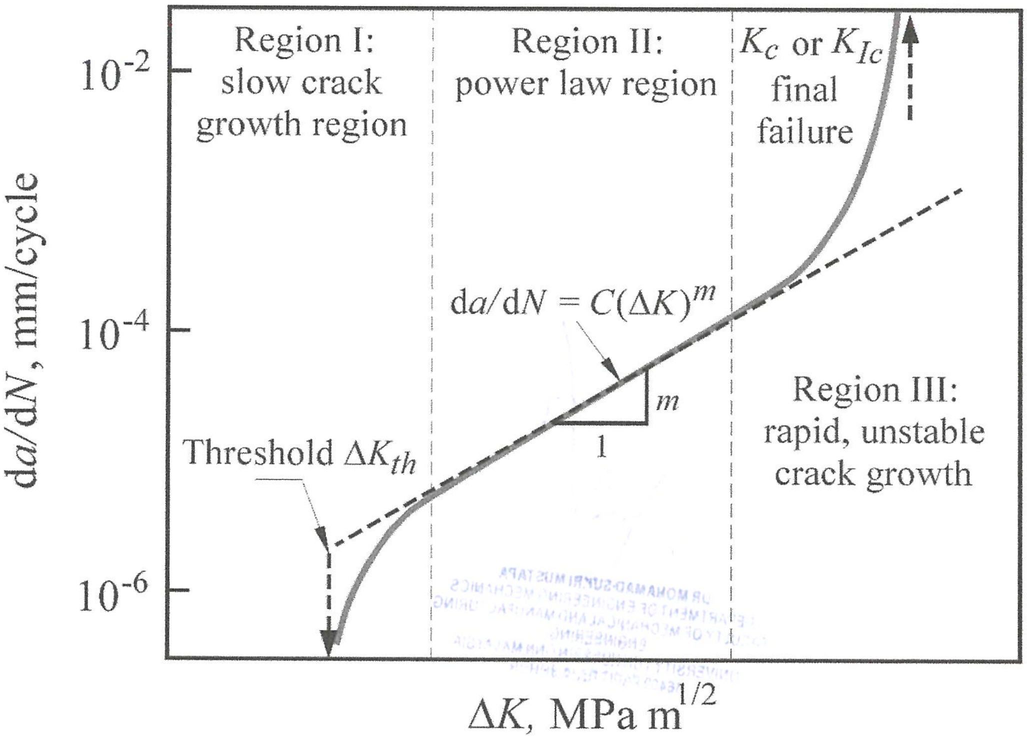

Figure Q5(a)

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Table Q5

da/dN mm/cyc	ΔK $MPa\sqrt{m}$	R	$\overline{\Delta K}$ $MPa\sqrt{m}$
3.10E-05	20.1	0.1	20.66
7.54E-05	25.2	0.1	25.90
1.68E-04	30.2	0.1	31.04
5.02E-04	40.5	0.1	41.63
1.56E-03	49.8	0.1	51.19
5.08E-03	65.7	0.1	67.54
1.27E-02	81.4	0.1	83.68
2.34E-02	99.0	0.1	101.77
4.87E-02	114	0.1	117.19
8.72E-06	11.2	0.5	13.43
2.78E-05	15.2	0.5	18.22
4.94E-05	19.5	0.5	23.38
1.51E-04	25.4	0.5	30.45
2.65E-04	30.3	0.5	36.32
8.33E-04	40.7	0.5	48.79
2.90E-03	51.5	0.5	61.74
6.86E-03	64.9	0.5	77.80
1.70E-05	11.6	0.8	17.67
3.28E-05	13.5	0.8	20.57
8.91E-05	16.5	0.8	25.14
1.64E-04	20.0	0.8	30.47
4.13E-04	24.0	0.8	36.57
5.58E-04	27.1	0.8	41.29

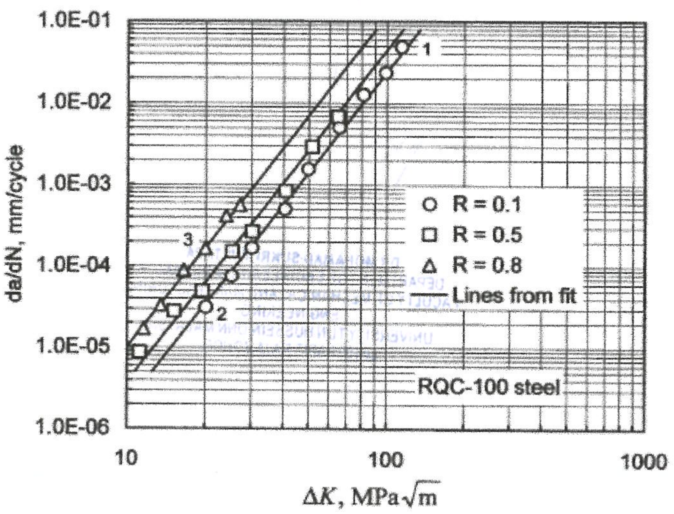

Figure Q5(b)