Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2017/2018

COURSE NAME : FATIGUE AND FRACTURE MECHANICS
COURSE CODE : BDC 40403
PROGRAMME : BDD
EXAMINATION DATE : DECEMBER 2017 / JANUARY 2018
DURATION : 3 HOURS
INSTRUCTIONS : ANSWER **ALL** QUESTIONS

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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. 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)

(b) Distinguish:

(i) Infinite-life design and Safe-life design

(ii) Fail-save design and Damage-tolerant design

(8 marks)

(c) Describes the fracture mechanisms are involved in two materials as shown in **Figure Q1.**

(9 marks)

Q2 (a) Define the following terms:

(i) Linear elastic fracture mechanics (LEPM)

(ii) Elastic-plastic fracture mechanics (EPFM)

(6 marks)

(b) A steel pressure vessel as shown in **Figure Q2** is subjected to a hoop stress of 420 MPa perpendicular to the crack depth acts as a tensile stress. The vessel has an internal semi-elliptical surface crack of dimension $a = 3$ mm, $2c = 10$ mm, $B = 6$ mm. If the $\sigma_{ys} = 900$ MPa and $K_{IC} = 60$ MPa$\sqrt{\text{m}}$.

(i) Evaluate the stress intensity factor, K_I

(ii) Will the pressure vessel leak? and judge

(14 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**. 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) List of **Three (3)** criteria caused of fatigue failure.

(3 marks)

(b) A stressed element in a reciprocating link experiences a maximum stress of + 180 MPa and a minimum of – 20 MPa. Calculate other fatigue loading parameters:

(i) Mean stress
(ii) Stress amplitude
(iii) Stress range
(iv) Load ratio

Sketch the stress cycles and indicate on the diagram the calculated loading parameters.

(8 marks)

(c) A fatigue fracture of the low carbon steel is occurred after 10^5 cycles at $\sigma_a = 300$ MPa and 10^7 cycles at $\sigma_a = 250$ MPa.

(i) Determine the number of cycles to failure, when the $\sigma_a = 280$ MPa is applied.
(ii) The stress amplitude is changed to 300 MPa after 10^6 cycles at $\sigma_a = 250$ MPa. Estimate number of cycles to failure after the stress amplitude is changed.

(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.

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(12 marks)

"END OF QUESTIONS"

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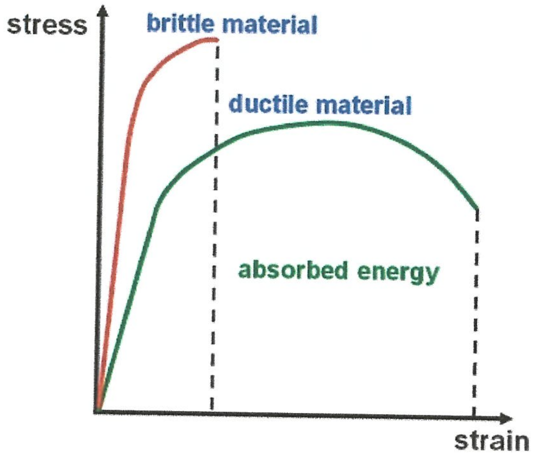
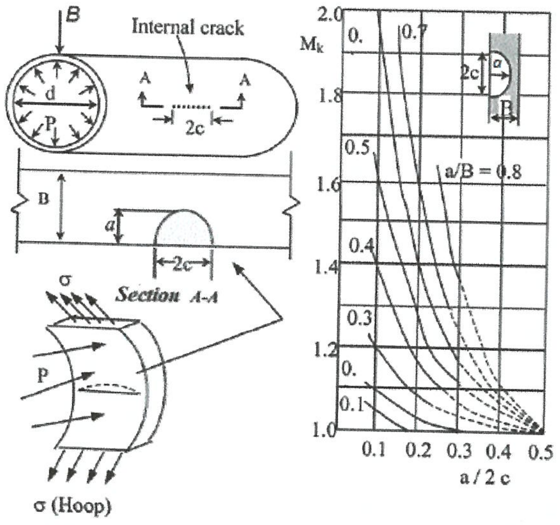


Figure Q1



Front face correction factor M_K for a semi-elliptical surface flaw

Expressions for any $\alpha = a/b$:

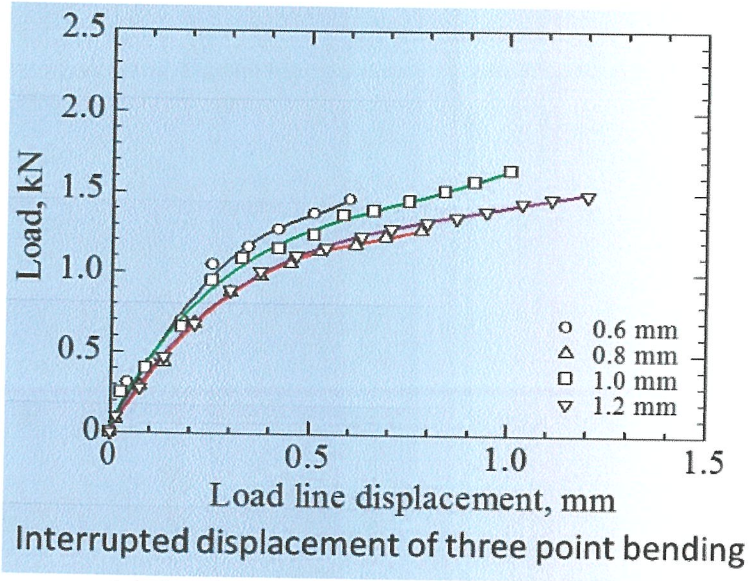
(a) $F = \dfrac{1 - 0.5\alpha + 0.326\alpha^2}{\sqrt{1-\alpha}}$ $\quad (h/b \geq 1.5)$

(b) $F = \left(1 + 0.122\cos^4 \dfrac{\pi\alpha}{2}\right)\sqrt{\dfrac{2}{\pi\alpha}\tan\dfrac{\pi\alpha}{2}}$ $\quad (h/b \geq 2)$

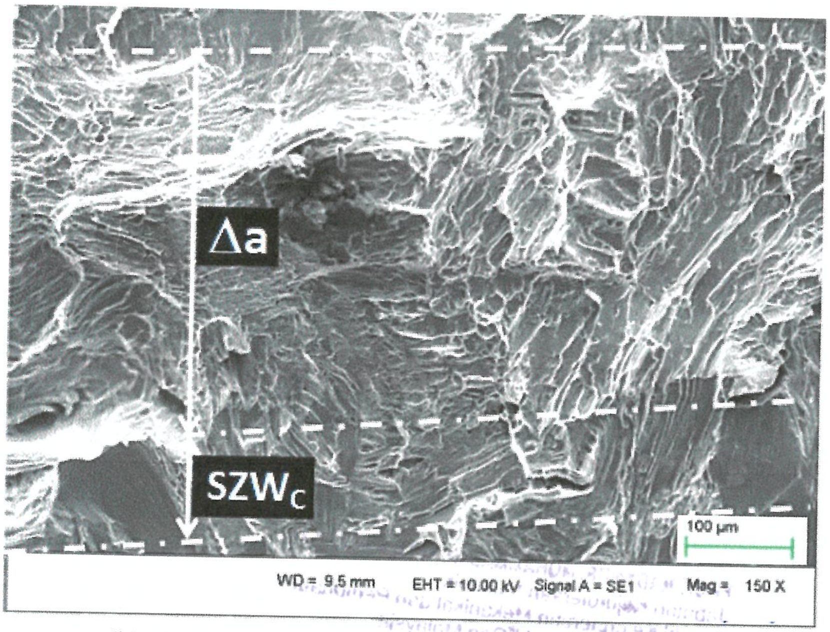
(c) $F = 0.265\,(1-\alpha)^4 + \dfrac{0.857 + 0.265\alpha}{(1-\alpha)^{3/2}}$ $\quad (h/b \geq 1)$

Stress intensity factors for three cases of cracked plates under tension. Geometries, curves, and equations labeled a) all correspond to the same case, and similarly for (b) and (c).

Figure Q2



(a) Graph Load Versus Load Line Displacement



(b) Strecth zone, SZW$_C$ and ductile crack growth Δa

Figure Q3

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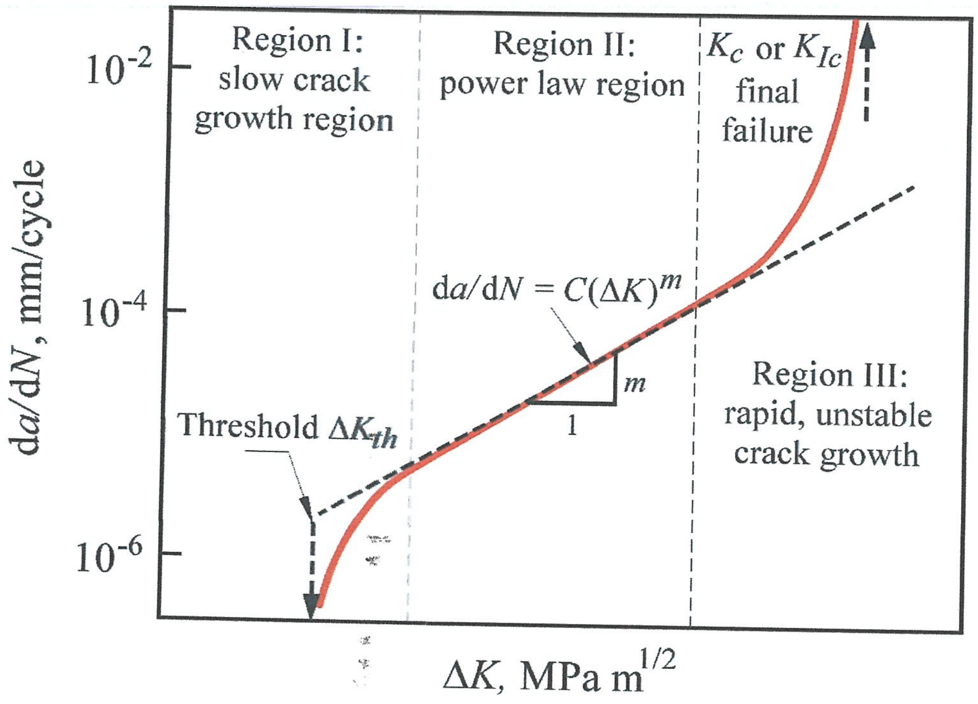
Region I: slow crack growth region
Region II: power law region
K_c or K_{Ic} final failure
10^{-2}
10^{-4}
10^{-6}
da/dN, mm/cycle
$da/dN = C(\Delta K)^m$
m
1
Region III: rapid, unstable crack growth
Threshold ΔK_{th}
ΔK, MPa $m^{1/2}$

Figure Q5 (a)

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Table Q5

da/dN mm/cyc	ΔK MPa$\sqrt{\text{m}}$	R	$\overline{\Delta K}$ MPa$\sqrt{\text{m}}$
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

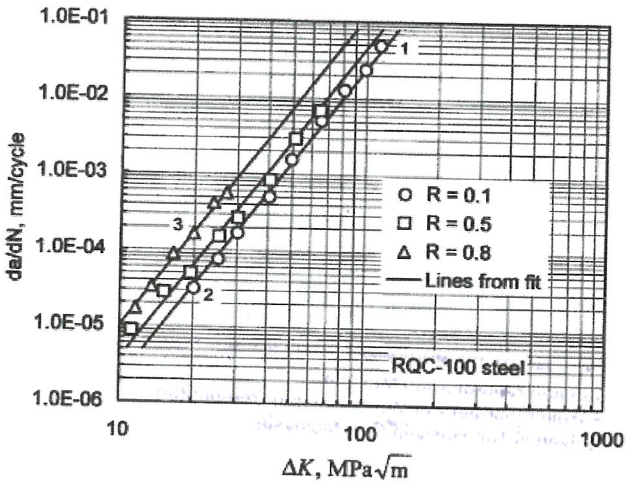

Figure Q5 (b)