ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE, NIGERIA

DEPARTMENT OF MECHANICAL ENGINEERING

SECOND SEMESTER EXAMINATIONS

2018/2019 ACADEMIC SESSION

COURSE: MEE 504 – Fracture of Structural Materials (4Units)

CLASS: 500-Level Mechanical Engineering

TIME ALLOWED: 3 Hours

HOD'S SIGNATURE

INSTRUCTION: Answer **Question 1** and any **Four from Qus. 2 –7. Qu. 1 is Compulsory and only short answers are required for each item there.**

Date: July, 2019

Question 1

1) Define the two most common types of fracture in structural materials
2) Distinguish between the two approaches to fracture mechanics study, i.e. Griffith's and Irwin's
3) Compare ***Strength*** with ***Fracture Toughness***
4) Derive an expression relating fracture toughness to stress intensity factor
5) Explain the difference between fracture under plane stress and under plane strain
6) Use sketches to compare the plastic zone at a crack tip for cases of plane stress and plane strain
7) What is the condition for crack growth in fracture mechanics?
8) What is plane strain facture toughness?
9) Sketch two opposite edge cracks of length a in a rectangular plate of width $2W = 4a$, height $h >> W$ under remote stress σ in height direction
10) Sketch with full label a cylindrical vessel of radius r, wall thickness t, with an internal edge crack length a, forming an axial groove and under internal pressure, p
11) Define Fatigue of materials
12) Explain the connection between Fatigue and Fracture
13) State the basic concepts used in the study of Fatigue
14) Sketch the typical graph of crack growth rate vs. range of stress intensity factor. Show the distinct regions of crack growth
15) State the Palmgren-Miner's rule for fatigue failure

16) State the steps for calculating fatigue life under variable amplitude loading

17) Explain the use of the graph in ***Figure 1*** below

18) What is crack instability according to Griffith's criterion?

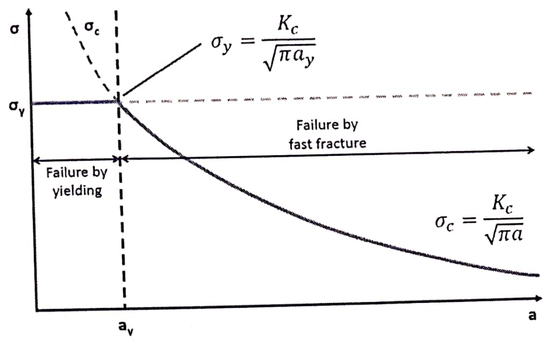


Figure 1

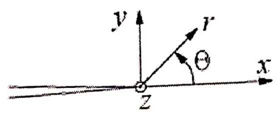
Question 2

A (1 mm)x(15 mm)x100 mm steel strap has a 3-mm long central crack. The strap is loaded in tension to failure in Mode I. Assume the steel is brittle having the following properties (in standard notations): E = 207 MPa, σ_{ys} = 1,500 MPa and K_{IC} = 70 MPa m ½. Do the following:

a) Sketch the object with full label,
b) Determine the critical stress
c) Determine the critical strain energy release rate

Question 3

In ***Figure 2*** below, the stress components in front of a crack tip loaded in Mode III are:



$$\tau_{xz} = \frac{-K_{III}}{\sqrt{2\pi r}} \sin\frac{\Theta}{2}$$

$$\tau_{yz} = \frac{K_{III}}{\sqrt{2\pi r}} \cos\frac{\Theta}{2}$$

$$\sigma_{xx} = \sigma_{yy} = \sigma_{zz} = \tau_{xy} = 0$$

Figure 2

Do the following:

i. Sketch the stress components as in Theory of Elasticity
ii. Sketch the Mode III crack configuration
iii. Calculate the maximum shear stress
iv. Determine the direction of this maximum stress.

Question 4

A thick plate of Aluminum alloy, 175 mm wide, contains a centrally-located crack 75 mm in length. The plate experiences brittle fracture at an applied stress (uniaxial, transverse to the crack) of 110 MPa. Do the following:

i. Draw a sketch of the problem with full label
ii. Determine the fracture toughness of the material
iii. Calculate what the fracture stress would be if the plate were wide enough to permit an assumption of infinite width

Question 5

A 50 mm wide sample plate of 7074-T8 Aluminium alloy contains a central through-crack of length *2a,* see ***Figure 3*** below. For 7074-T8: $K_c = 22.2$ MN $m^{-3/2}$; $\sigma_y = 520$MPa. Under an applied stress of 200 MPa, do the following:

i. Determine if the plate will fail by fracture with a crack half-length a of 5 mm
ii. Determine the critical crack size a_c below which the plate will not fracture under the applied stress, *using an appropriate value of Y; set* $Y = \left[\cos(\frac{\pi a}{W})\right]^{-0.5}$
iii. Determine the limiting crack size, a_y below which the plate will fail by yielding (assume Y = 1)

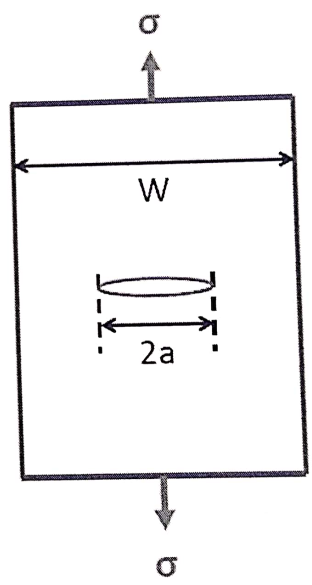


Figure 3

Question 6

A large steel crankshaft ($K_c = 45$ MN $m^{-3/2}$) undergoes cyclic tensile stress 225 MPa and compressive stress 60 MPa during use. Prior to use, it was inspected using ultrasonic techniques, from which the largest surface crack found was 2.5 mm in length.

For the steel in question, the Paris Law constants are: $A = 1.5 \times 10^{-12}$ m/(MN $m^{-3/2})^n$ per cycle, and n = 2.5. Do the following:

i. Sketch the crankshaft with the appropriate cyclic load (Note that it is a crankshaft)
ii. State the Paris Law using the constants A and n given above
iii. Calculate the critical crack length, a_c
iv. State the steps you would use to determine the number of cycles to failure

Question 7

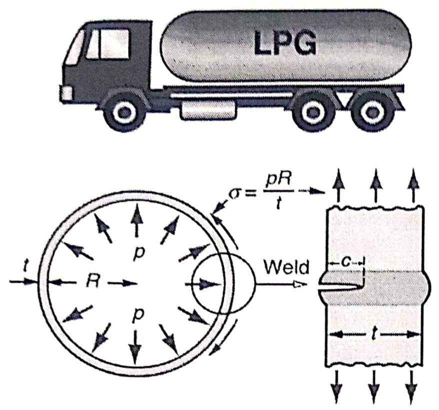


Figure 4

Figure 4 shows an LPG tank with pressure loading and internal circumferential crack. The crack is 10 mm long and located in a longitudinal weld. K_{Ic} of the tank material measured to be 45 MPa$\sqrt{m}$. Calculate

i. Stress based on maximum design pressure p

ii. Stress at which a plate with the given K_{Ic} will fail with a 10 mm crack

iii. Interpret the results for Engineering application

Max design pressure, p = 1.5 MPa, Wall thickness, t = 14 mm, Outer diameter 2R = 1680 mm, Length, L = 3710 mm