ELIZADE UNIVERSITY, ILARA-MOKIN,
ONDO STATE, NIGERIA
DEPARTMENT OF MECHANICAL ENGINEERING

SECOND SEMESTER EXAMINATIONS

2017/2018 ACADEMIC SESSION

HOD'S SIGNATURE

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

CLASS: 500 Level Mechanical Engineering

TIME ALLOWED: 2½ hours

INSTRUCTIONS: Answer any four questions

Date: July/August, 2018

Question 1

a) Write a short note on the concept of fracture mechanics.

b) By area of deformation under load, state the three divisions of fracture mechanics

c) Discuss any three pertinent questions and corresponding corollaries that show the perspective view of fracture mechanics

d) Briefly describe the concept of linear elastic fracture mechanics (LEFM)

Question 2

a) Using appropriate figures depicting intercrystalline or transcrystalline facets, describe ***Microfractography***

b) With the aid of relevant figures, compare *engineering and true stress-strain diagrams of brittle and ductile metal materials*

c) Briefly describe the following stages of fracture process

i. Formation (Initiation) of a Crack
ii. Initiation of an Unstable Crack
iii. Unstable Growth (Propagation) of a Crack
iv. Stopping an Unstable Crack

d) A steel sample with fracture toughness of 55.6 MN $m^{-3/2}$ is subjected to stress of 1265 MPa. Given that the largest surface crack has length of 0.5 mm, will this material rupture? The shape function (the shape factor) has the value of 1.13 for relatively short surface cracks.

Question 3

a) There are certain differences for diverse materials in the definition of brittle failure. Explain the phenomenon of brittle failure in steels of low and medium strength, high-strength steels and aluminum alloys of higher strength.

b) The concept of crack tolerance and residual strength can be understood by considering the fracture behavior of a plate, containing a central crack of length 2a, loaded in remote tension under uniform stress σ as shown in Figure 1.

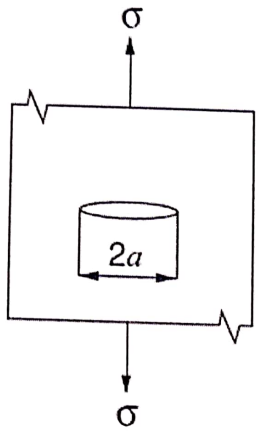


Figure 1: Illustration of the fracture behavior of a centrally cracked plate loaded in uniform remote tension

Using a schematic plot of failure stress versus half-crack length which divides the fracture behavior into three regions, explain this concept of crack tolerance and residual strength further.

c) With the aid of relevant equations, describe the following Classical Theories of Failure:

(i) Maximum Principal Stress (or Tresca) Criterion
(ii) Maximum Shearing Stress Criterion
(iii) Maximum Principal Strain Criterion

d) A slab is made of steel having fracture toughness of 85.6 MPa.m^{½} in the state of plane strain. If the board is exposed to tensile stress of 355 MPa during operation, determine minimum length of a surface crack that leads to a fracture. The shape function (the shape factor) has the value of 1.12 on the surface.

Question 4

a) Using relevant schematics and equations, explain Griffith's Crack Theory of Fracture Strength

b) Explain Orowan (1952) extension of Griffith's brittle fracture concept to metals

c) With the aid of appropriate diagrams, describe the three basic types of stress (modes) of a body with a crack with the option of material separation in its front

d) Calculate local fracture deformation in ductile failure of hardened and tempered carbon steel in whose structure carbidic particles of a spherical shape are released, in area before a blunted and tensile-stressed crack where the stress state $\sigma_m/\sigma_{ef} = 1.65$. Average distance between carbides is 6.4 μm and their average size is 1.3 μm.

Question 5

a) State the four Hume-Rothery rules that favor high solubility of impurity atoms in substitutional solid solutions

b) Use relevant schematics to describe the following imperfections in crystalline solids

(i)Vacancies (ii) Interstitials (iii) Solute (or impurity) atoms

c) Describe fracture toughness as a material characteristic

d) Calculate the deformation necessary for nucleation of a cavity on an inclusion of a spherical shape in steel with ferritic pearlitic structure, if surface energy of decohesion of the inclusion and matrix is 6.2 J/m^2, the modulus of elasticity of the inclusion is 260 GPa and its diameter $2r = 10\ \mu m$.

Question 6

a) Describe fatigue as a type of failure

b) Figure 2 shows a typical setup for fatigue testing. Use the figure to explain the procedure for carrying out such a test. Depict with the appropriate graph the complete stress reversal during each revolution so that the maximum stress varies between $+\sigma_a$ and $-\sigma_a$

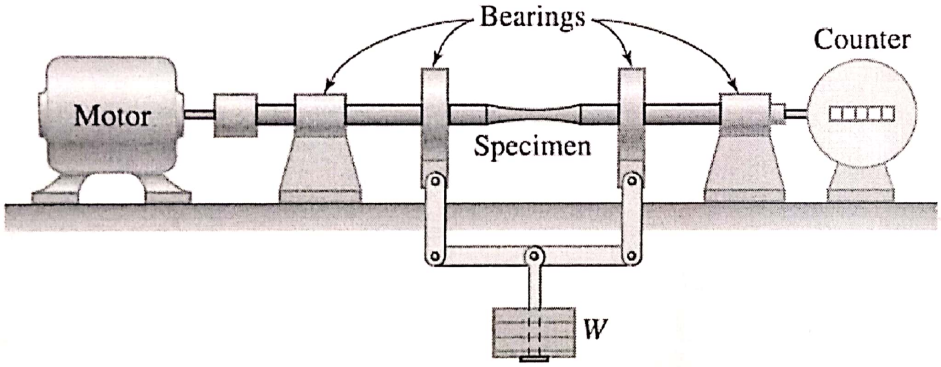
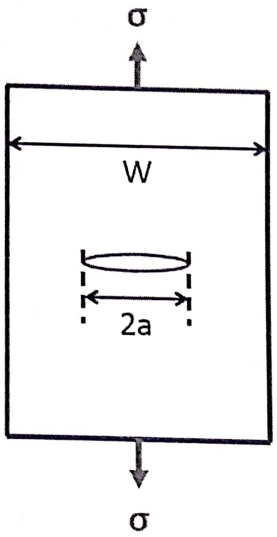


Figure 2: Fatigue testing machine that applies reversed bending to the specimen.

c) Explain the Fractography of Fatigue Failures

d) Figure 3 shows a 65mm wide sample plate of 7074-T8 aluminium alloy containing a central through-crack of length 2a.



Given that $K_{Ic} = 24.6$ MN $m^{-3/2}$; $\sigma_y = 570$MPa

i). Under an applied stress of 180 MPa, determine if the plate will fail by fracture with a crack half-length a of: 1 mm

ii). Determine the limiting crack size a_y below which the plate will fail by yielding (assume Y = 1)

Figure 3: Sample plate of 7074-T8 aluminium alloy