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University of Choice

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE
OF
BACHELOR OF SCIENCE IN MECHANICAL AND INDUSTRIAL ENGINEERING

COURSE CODE: **MIE 421**

COURSE TITLE: FRACTURE OF MATERIALS

DATE : 26/4/2022 **TIME:12.00-2.00 PM**

INSTRUCTIONS

Answer question **ONE** and any other **TWO** questions
All symbols carry their usual meaning unless stated otherwise

TIME: **2 Hours**

MMUST observes ZERO tolerance to examination cheating.

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Question 1 (30 Marks)

a) State factors that favor the following fractures

i) Brittle

ii) Ductile

iii) Quasi-cleavage (6marks)

b) Show that the maximum theoretical strength of a material is a function of the material properties given by (6 marks)

$$\sigma_{max} = \sqrt{\frac{E\gamma_s}{a_0}}$$

$$where\ E = Youngs\ Modulus$$
$$\gamma_s = Elastic\ surface\ energy$$
$$a_0 = Lattice\ spacing$$

c) Sketch the micrograph of a specimen whose failure was mainly due to fatigue. (4 marks)

d) On the same graph, show the variation of the following stresses, cleavage, applied and uniaxial yield stress from a temperature of -300°C to +300°C for a given steel material. Define all terms used indicating regions where nucleation controlled and where propagation controlled fractures will dominate. (6 marks)

e) A fracture analysis is required on a 40mm steel plate member of a machine. Check the validity of plane strain under Linear Elastic Fracture Mechanics (LEFM). Given that the yield strength of the steel is 965MPa and Fracture toughness is $65MPa\sqrt{m}$ (8 marks)

Question 2 (20 Marks)

a) Derive the Griffiths equation for a Linear Elastic material (6 marks)

b) A steel plate with a through thickness crack of length 2a=25mm is subjected to a stress of 600MPa normal to the crack. What is the plastic zone size and the modified stress intensity factor for the crack, Take the plate to be infinitely wide and that plane stress conditions prevail. Take the yield strength as 2000MPa, and geometrical correction factor as 1.2

(6 marks)

c) For a plate carrying a central crack of length 2a , Show that plane stress conditions are governed by $\sigma = 2/3\ \sigma_y$ and $2a = W/3$ where σ is the applied

stress, σ_y the uniaxial yield stress, and W=width of the plate. (8 marks)

Question 3 (20 Marks)

a) On a log scale, draw the graph of the variation of the rate of crack growth $\frac{da}{dN}$ with stress intensity range (ΔK). Define the laws application to each zone giving the expression of relevant equations where applicable. (Note da=crack growth and dN change in number of cycles)

(6 marks)

b) Determine the minimum allowable edge crack for mild steel whose endurance limit is 200MPa and threshold fracture toughness range $\Delta K_{th}=8MPa\sqrt{m}$ .Take geometric correction factor as 1.3

(5 marks)

c) A cylindrical bar is subjected to a fluctuating axial load varying from a maximum of 440KN tension to a minimum of 110KN compression. The mechanical properties of the steel are the ultimate stress (σ_u) =1100Mpa, Uniaxial yield stress (σ_y)=1000MPa and endurance limit stress (σ_e)=510MPa. By applying the Goodman's equation and a factor of safety= 3, determine the diameter of the bar.

(9 marks)

Question 4 (20 Marks)

a) During the Second World War, several structural, ships, boilers and equipment failed and this became a major concern to the authorities and several arguments and deductions made: State any FOUR general conclusions from these failures.

(4 marks)

b) With suitable diagrams, show the variation of

i) Constant applied stress with rapture for varying values of temperature where $T_1 > T_2 > T_3 > T_4$

ii) Strain developed against Logarithmic values of time for varying values of constant stress. $\sigma_1 > \sigma_2 > \sigma_3 > \sigma_4$

iii) creep rate against total strain (9 marks)

c

i) Estimate the theoretical strength of a material of a steel alloy whose Young's modulus is 205GPa.

ii) Given that the friction stress of the steel specimen is 165MPa. If the grain size is 50μm and Hall Petch's constant is $5.5MPa\sqrt{m}$. Calculate the Materials yield strength . How does the theoretical strength compare to the yield strength calculated from the Hall-Petch Method ? Explain the disparity

(7 marks)

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