UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: July 2016

Module Number: ME3304 **Module Name: Strength of Materials**

[Three Hours]

[Answer **all questions**, each question carries **twelve** marks]

(State the assumptions where necessary and do the calculations stating the units)

Q1. a) Briefly describe the failure criterions with the base of following two categories.

i) Deformation

ii) Fracture

[2.0 Marks]

b) State Griffith's criterion for fracture of brittle materials and discuss the relationship of the Griffith's criterion with the 1st law of thermodynamics.

[2.0 Marks]

c) Using above mentioned (Q1.b) criterion; show the fracture strength of a material which is given by,

$$\sigma_f = \sqrt{\frac{8E\gamma_s}{\pi a(1+\upsilon)(1+k)}}.$$

Where,

σ_f - Fracture strength of a material,

a - Crack size

υ - Poisson's ratio

k - Stress intensity factor

E - Modulus of elasticity

γ_s - Specific surface energy of a fractured surface

[2.5 Marks]

d) Draw the graphs with respect to energy associated with the crack for the following terms.

i) Strain energy release ($\bar{U}$)

ii) Strain energy (U_s)

iii) Critical crack length

[2.5 Marks]

e) A thin sheet of steel has a tensile strength of 1950 MPa. Calculate the percentage reduction in strength due to the presence of a central crack in the sheet, which is 4 mm long and orientated perpendicular to the stressed direction. For this steel, E can be taken as 200 GPa, the energy of fracture surface as 2 J/m^2 and the work of plastic deformation of each crack tip is 2x10^4 J/m^2.

[3.0 Marks]

Q2. a) Briefly describe the Transgranular and Intergranular Fracture.

[1.5 Marks]

b) Discuss three methods which are used to strengthen the metals.

[1.5 Marks]

c) Explain two methods of reducing stress concentrations.

[2.0 Marks]

d) What is meant by:

i) The stress concentration factor

ii) The stress intensity factor

iii) The critical stress intensity factor

[3.0 Marks]

e) A 3 mm thick, 10 cm wide tension panel containing an edge crack of 1 mm yielded at a load of 150 kN. However, at a load of 120 kN, another panel of same material cracked into two pieces when the crack was 5 mm long. With this information, calculate the yield stress and fracture toughness of the material. SIF for the edge crack is $K_I = 1.12\,\sigma \sqrt{\pi a}$.

[4.0 Marks]

Q3. a) Define the fatigue damage and briefly describe three factors influencing fatigue crack growth.

[2.5 Marks]

b) Explain the following terms

i) Endurance Limit

ii) Endurance Strength

[2.5 Marks]

c) Differentiate Primary creep, Secondary creep and Tertiary creep of materials.

[3.0 Marks]

d) Consider a hypothetical material in which the S-N curve is linear from a value equal to the fracture stress σ_f at one cycle (log N = 0), falling to a value of $\sigma_f/2$ at log N = 7 as shown in **Figure Q3**. This behaviour can be described by the following equation

$$\log N = 14\left(1 - \frac{S}{\sigma_f}\right)$$

The material has been subjected to $n_1 = 10^5$ load cycles at a level $S = 0.6\sigma_f$. Estimate how many cycles n_2 the material can now withstand if raise the load to $S = 0.7\sigma_f$.

[4.0 Marks]

Q4. a) Consider a small rectangular element in a deformed body that has its edges oriented along the principal axes. No shearing strains occur, only normal strains are applied. Hence the shape of the element does not change, however, its volume changes, show that the quantity known as volumetric strain is given by,

$$\frac{\Delta V}{V} = \frac{Change\ in\ volume}{Original\ volume} = \epsilon_1 + \epsilon_2 + \epsilon_3.$$

[4.0 Marks]

b) A cube of steel has an edge length of 25 mm when unstressed. A tensile stress of 50,000 Pa is applied normal to one pair of parallel faces, and a tensile stress of 60,000 Pa applied normal to the second pair of parallel faces. What is the distance between the third pair of parallel faces after the application of the load?

[4.0 Marks]

c) Rework the problem in **Q4.b**, except this time the stresses applied are compressive.

[4.0 Marks]

Q5. a) Consider a mechanical component under direct load F_1 and F_2 giving rise to stresses σ_y, and σ_x, vertically, and horizontally as shown in Figure Q5.a.

i) Derive equations to find τ_θ (shear stress along BC plane) and σ_θ (normal stress to BC plane).

[3.0 Marks]

ii) By examining the equations, conclude the followings,

- Maximum normal stress.
- Maximum shear stress.

[1.0 Mark]

b) The state of plane stress at a point is represented by the stress element shown in Figure Q5.b.

i) Draw the corresponding Mohr's stress circle for the above stress system.

[3.0 Marks]

ii) Find the stresses on an element inclined at 30° clockwise and draw the corresponding stress elements.

[2.0 Marks]

iii) Calculate (or find using corresponding Mohr's stress circle) the principal stresses and the planes on which they act.

[1.0 Mark]

iv) What would be the effect on these results if owing to a change of both tensile loadings to compressive while shear stresses remain unchanged?

[2.0 Marks]

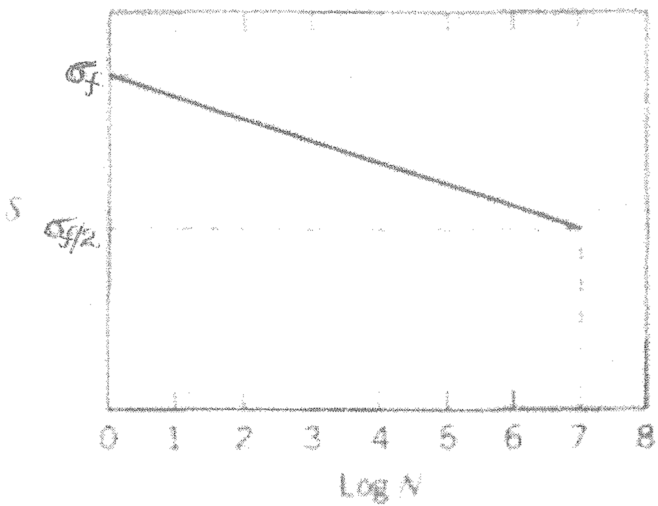

Figure Q3

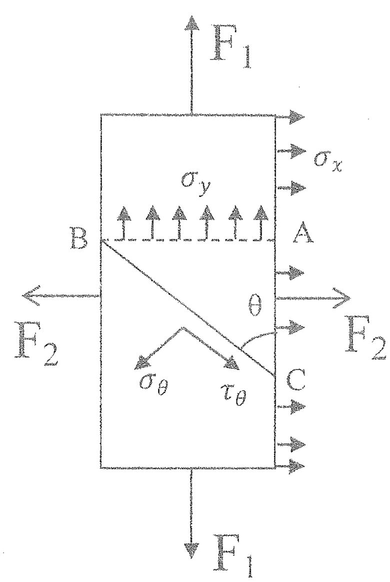

Figure Q5.a

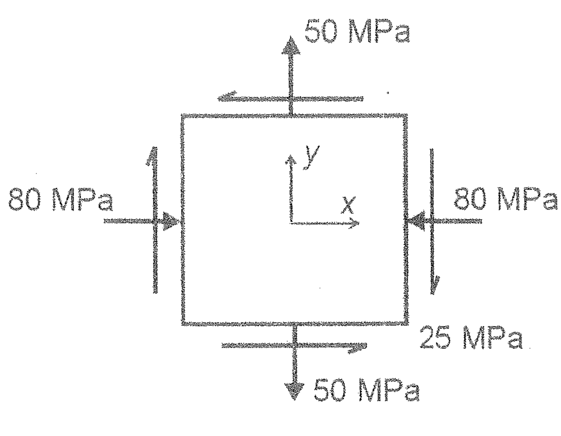

Figure Q5.b