UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

Module Number: ME6206 **Module Name: Solid Mechanics**

[Three Hours]

[Answer **all questions**, each question carries **12** marks]

Q1. Consider a thin disc of uniform thickness, with inner diameter and outer diameter d_i and d_o, respectively, is rotating about its axis at a angular velocity. Take the density of disc material as b and poisons ratio as c.

a) Show that the radial stress (σ_r) and circumferential stress (σ_c) of the rotating disc at a diameter d are given by,

$$\sigma_r = \frac{ba^2(3+c)}{32}[d_i^2 + d_o^2 - \frac{d_i^2 d_o^2}{d^2} - d^2]$$

$$\sigma_c = \frac{ba^2(3+c)}{32}[d_i^2 + d_o^2 + \frac{d_i^2 d_o^2}{d^2} - \frac{(1+3c)d^2}{(3+c)}]$$

[7.0 Marks]

b) Show that the yielding stress of the disc is given by,

$$\sigma_{yield} = \frac{ba^2(3+c)}{16}[d_o^2 + d_i^2(\frac{1-c}{3+c})]$$

[5.0 Marks]

Q2. a) A solid shaft of 120 mm diameter is required to transmit 200 kW at 100 r.p.m. If the angle of twist of the shaft not to exceed 2°, find the length of the shaft. Take the modulus of rigidity for the shaft material as 90 GPa.

[4.0 Marks]

b) A solid steel shaft of 120 mm diameter is to be replaced by a hollow steel shaft of the same material with external diameter equal to the 1.5 times of its internal diameter. The torque transmitted by both shafts are same.

i) Calculate the inner diameter and outer diameter of the hollow shaft, if the maximum allowable shear stress of solid shaft is equal to 90% of the maximum allowable shear stress of hollow shaft.

[4.0 Marks]

ii) Discuss the advantages/disadvantages of solid shaft replacement by the hollow shaft.

[4.0 Marks]

Q3. a) Consider a thick wall cylinder of internal radius r_i and external radius r_o contains fluid at an internal pressure of P. Determine the longitudinal stress acting on the wall of the cylinder if,

i) Cylinder with end caps
ii) Cylinder with piston
ii) Cylinder build in between rigid end supports

[3.0 Marks]

b) A cylinder of a hydraulic jack has a bore of 150 mm and is required to operate up to 13.8 MN/m^2 of pressure. Determine the required wall thickness of the hydraulic jack for a limiting tensile stress of the material of 41.4 MN/m^2.

[6.0 Marks]

c) Briefly explain three industrial applications of thick wall cylinders.

[3.0 Marks]

Q4. To better understand the strain state for an old oil tanker, strain gages where attached to the surface of the tanker at the location shown (Figure Q4). With the help of the strain gage results, it was determined that the strains at that location were ε_x = -800 μ, ε_y = 400 μ, and γ_{xy} = 400 μ.

a) Using transformation equations, what is

i) the principal direction and principal normal strains,

[2.5 Marks]

ii) the maximum strain direction and the maximum shearing strain, and

[2.5 Marks]

iii) the strains at an angle of 30°?

[2.5 Marks]

b) By considering strain in the Z direction as 0 μ,

i) Draw the strain Mohr's circle corresponding to the Z-X plane.

[1.5 Marks]

ii) Draw the strain Mohr's circle corresponding to the Z-Y plane.

[1.5 Marks]

iii) Draw the 3D Mohr's circle of strain in this system.

[1.5 Marks]

Q5. To better understand the stress state for a new tractor, a structural analysis computer program was used to determine stresses in the tractor's front-end bucket. For the location shown (Figure Q5). It was determined that the stresses are σ_x = 30 psi, σ_y = 10 psi, and τ_{xy} = 20 psi.

a) Using transformation equations, what is

i) the principal direction and principal normal stresses,

[2.5 Marks]

ii) the maximum shear direction and the maximum shearing stress, and

[2.5 Marks]

iii) the stresses at an angle of 15°?

[2.5 Marks]

b) By considering stress in the Z direction as 0 psi
(use a separate graph sheet for this part),

i) Draw the stress Mohr's circle corresponding to the Z-X plane.

[1.5 Marks]

ii) Draw the stress Mohr's circle corresponding to the Z-Y plane.

[1.5 Marks]

iii) Draw the 3D Mohr's circle of stress in this system.

[1.5 Marks]

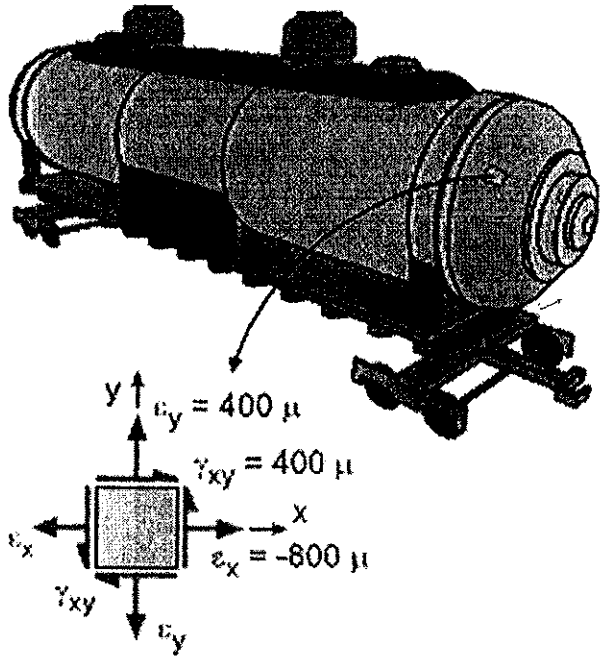

Figure Q4

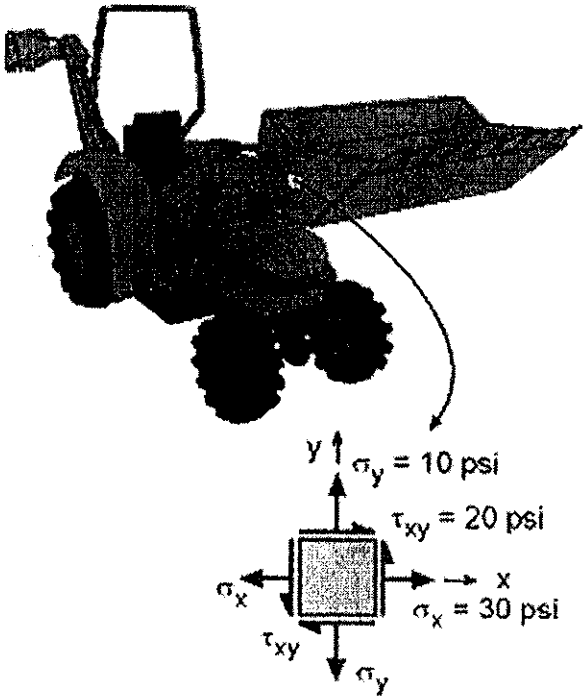

Figure Q5