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University of Ruhuna- Faculty of Technology

Bachelor of Engineering Technology Honours Degree
Level 4 (Semester I) Examination, July 2023
Academic year 2021/2022

Course Unit: ENT4142 - Machine Design (Written) **Duration: 2 hours**

Instructions to Candidates:

- This question paper contains **FIVE (5)** questions.
- Answer **only FOUR** questions.
- Marks allocated for each question are indicated.
- You may use calculators if needed.
- All symbols have their usual meaning. Required graphs and tables are included as Annex.

Question 01 **(100 marks)**

Figure Q1 shows a machined alloy steel shaft heat-treated to 320 BHN. The shaft rotates at high speed while being subjected to a static load F, distributed as given in the Figure Q1. Given: D = 30 mm ; L_1 =100 mm ; L_2 = 150 mm.

a) Draw shear force and bending moment diagrams. (40 marks)
b) What is the maximum load that the shaft can bear, while ensuring an infinite fatigue life? (30 marks)
c) What is the maximum load, that the shaft will have $3x10^4$ cycles of fatigue life? (30 marks)

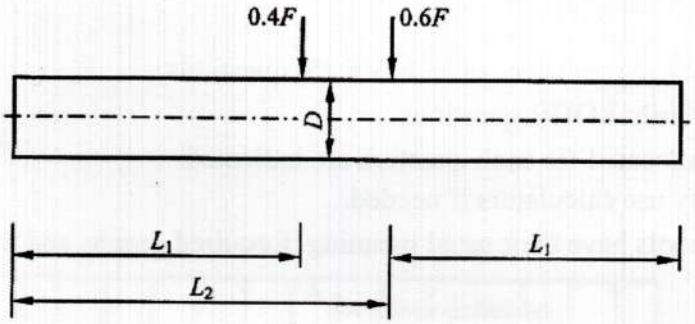


Figure Q1: A machined alloy steel shaft rotating at high speed

Question 02 **(100 marks)**

A hollow shaft is required to transmit 600 kW at 110 r.p.m.. The maximum torque being 20% greater than the mean torque on the shaft. The shear stress (τ) is not to exceed 63 MPa and twist over a length of 3 m on the shaft is not to exceed 1.4°. If the internal diameter to the external diameter ratio (d_i/d_0) is 3/8. Modulus of rigidity (G) of the shaft material is 84 GPa.

a) Find the angular velocity of the shaft (ω) in rad s^{-1}. (10 marks)
b) Find the mean torque transmitted by the shaft (T_{mean}). (10 marks)
c) Find the maximum torque transmitted by the shaft (T_{max}). (10 marks)
d) Find the polar moment of inertia (J) of a hollow circular section of the shaft in terms of the external diameter of the shaft (d_o). (10 marks)
e) Calculate the external diameter of the shaft (d_o) using the maximum torque transmitted by the shaft considering strength of the shaft. (25 marks)
f) Calculate the external diameter of the shaft (d_o) using the polar moment of inertia (J) of a hollow circular section. (25 marks)
g) Suggest the most suitable external diameter of the shaft (d_o) from calcutaed diameter of the Q2(e) and Q2(f). (10 marks)

Question 03 **(100 marks)**

A simple beam AB supports a concentrated load ***P*** at a point C as shown in Figure Q3. The load ***P*** acts at distance *a* from the support A and distance *b* from the support B. Considering the entire beam as a free body, answer the following questions.

a) Find the reactions at A and B. (10 marks)

b) Derive expressions for the shear force (V) and the bending moment (M) at any distance x from A to C ($0<x<a$). (20 marks)

c) Derive expressions for the shear force (V) and bending moment (M) at distance x from C to B ($a<x<L$). (30 marks)

d) Draw shear-force and bending-moment diagrams. (20 marks)

e) If a = 75 mm, b = 25 mm and P = 1000 N Calculate the maximum bending moment (M_{max}) of the beam and the corresponding shear force (V) at that point. (20 marks)

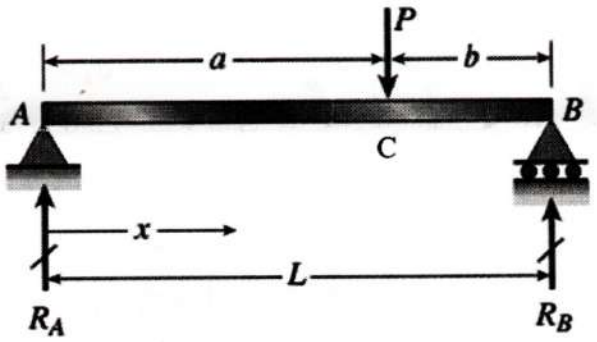
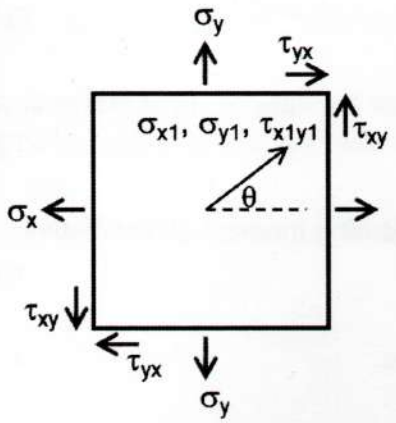


Figure Q3: A simple beam AB supporting a concentrated load *P*.

Question 04 **(100 marks)**

The following equations are known as the transformation equations for plane stress as they allow the stress components to be transformed from one set of axes to another as given in Figure Q4. All the parameters have usual meaning.



$$\sigma_{x1} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\sigma_{y1} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2}\cos 2\theta - \tau_{xy}\sin 2\theta$$

$$\tau_{x1y1} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$$

Figure Q4: Stresses acting on the elements .

a) Drive and obtain following expressions for maximum and minimum principal stresses (σ_1 and σ_2) using the below given equations. (20 marks)

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \qquad \sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

b) Drive and obtain following expressions for the maximum shear stress (τ_{max}) using the above given equations. (10 marks)

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

c) If σ_x = 110 MPa, σ_y= 40 MPa and $\tau_{xy} = \tau_{yx}$ = 28 MPa, determine the stresses (σ_{x1}, σ_{y1} and τ_{x1y1}) acting at an angle θ = 45^o using the transformation equations. (24 marks)

d) Construct a Mohr's circle and label the important stress points for an element in plane stress subjected to stress conditions given in part (c) and answer the following questions.
(i) Find the centre coordinate. (5 marks)
(ii) Calculate the radius of the circle. (5 marks)
(iii) Mark σ_x, σ_y, τ_{xy}, τ_{yx}, σ_1, σ_2, τ_{max} and τ_{min} as a coordinate on the circle. (20 marks)
(iv) Calculate the angle of principle plane (θ_p). (10 marks)

e) If σ_x = 110 MPa, σ_y= 40 MPa and $\tau_{xy} = \tau_{yx}$ = 28 MPa, show the new stress plane on the mohr's cicle (σ_{x1}, σ_{y1} and τ_{x1y1}), when initial plane rotating counter clockwise direction θ = 10^o. (Note: no need to calculate new stresses). (6 marks)

Question 05 **(100 marks)**

a) Briefly explain how the following concepts can be used in the conceptual design phase of product development, providing appropriate examples.

i) Quality Functional Deployment. (10 marks)

ii) Morphological Analysis. (10 marks)

i) Weighted Decision Matrix. (10 marks)

b) Briefly explain the concept: "Factor of safety" using a stress and strain graph of a ductile material. (20 marks)

c) Consider a shaft subjected to a constant direct tensile load and briefly explain how you could make necessary design choices for the case by deriving necessary equations. (20 marks)

d) Define the following terms by deriving or stating appropriate equations.

i) Bearing stress. (15 marks)

ii) Impact stress. (15 marks)

- End of the paper -

Annex

All symbols have their usual meaning.

10^6 cycle strength:

$S_n = C_L C_D C_S S_n'$

* A lower value may be used to account for known or suspected undetermined bending due to load eccentricity.

Factor	Load type		
	Bending	Torsion	Axial
C_L	1.0	0.58	0.9*
C_D	1.0 for $D \le 10$ mm 0.9 for $10 \le D \le 50$ mm		1.0
C_S	From figure shown below		

10^3 cycle strength:

Bending loads: 0.9 S_u
Torsional loads: 0.9 S_{us}
Axial loads: 0.75 S_u