B.E. MECHANICAL ENGINEERING SECOND YEAR SECOND SEMESTER EXAM 2023

DESIGN OF MACHINE ELEMENTS - 1

Time: **Three hours** Full Marks: **100**

Missing data, if any, are to be reasonably chosen.
Different parts of a question must be answered together.
Give sketches wherever applicable.

Section – A

1. Show the stress-strain curves (along with the important points on these curves) for both ductile and brittle materials. Discuss the procedure for determining the yield strength of a material which does not exhibit a well-defined yield point on the stress-strain diagram. Write down the design criteria for the above-mentioned two types of material. What do you understand by true stress and true strain and mention the relation by which these parameters are related to engineering stress and engineering strain, respectively. [04+02+02+04]

2. Explain the interrelation between design, material and processing. Explain what do you understand by DFMA and highlight a few important guidelines under DFMA. Justify the following statement - "Machining of cast components should be minimized". [04+04+02]

3. Schematically show the regions of safety (for bi-axial state of stresses) corresponding to the following failure theories: Maximum Normal Stress Theory, Brittle Coulomb-Mohr theory and Modified Mohr theory. State of stress at a point in a machine component made of brittle material (S_{ut} = 80 MPa and S_{uc} = 200 MPa) is given as follows: σ_x = 0 N/mm^2, σ_y = - 40 N/mm^2, τ_{xy} = 80 N/mm^2. Determine the factor of safety following the Brittle Coulomb-Mohr and Modified Mohr theory. Comment on the conclusion drawn from the calculated values. [03+07]

4. Two circular rods are connected by means of a knuckle joint. The axial force acting on the rods is 25 kN. The rods and the knuckle pin are made of plain C-steel 45C8 with tensile yield strength (S_{yt}) of 380 N/mm^2. Factor of safety can be considered as 2.5. Calculate the following dimensions from design equations: Design the eye end and the knuckle pin. [10]

Section – B

(Answer **Any 3**: 14 × 3 = 42)

5. Figure Q5 shows a rotating shaft (Simply-supported at its two ends by bearings) along with all its associated dimensions. The shaft is subjected to a transverse (non-rotating) force of 5kN at a distance of 400 mm from the left end. The shaft is machined from plain carbon steel 30C8 (S_{ut} = 500 N/mm^2) and the expected reliability is 95%. The equivalent notch radius at the fillet section can be taken as 3 mm, while the notch sensitivity can be considered as 0.80. Comment with proper reasons on which is the critical section of the shaft and consequently determine the life of the shaft. [14]

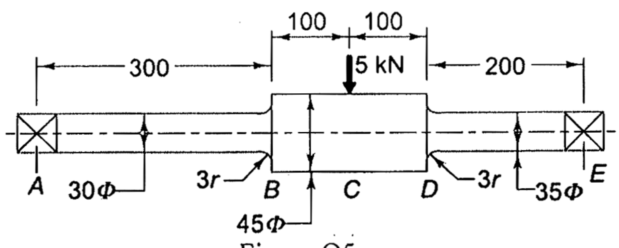

Figure Q5

[Turn over

6. A transmission shaft carries a pulley midway between two bearings. The bending moment at the pulley varies from 200 N-m to 450 N-m, as the torsional moment varies from 100 N-m to 275 N-m. The shaft is made of C-steel having S_{ut} = 540 N/mm^2 and S_{yt} = 400 N/mm^2. The shaft is manufactured through machining and the expected reliability is 90%. The notch sensitivity factor can be taken as 0.80 and the theoretical stress concentration factor is determined as 1.55. The size factor is assumed to be 0.85. Considering a factor of safety of 2.5, determine the diameter of the shaft following (*i*) Soderberg Line (*ii*) Goodman Line and (*iii*) Gerber Line. [14]

7. A solid shaft carries a single pulley (which is part of a vertical belt-pulley drive) of 200 mm diameter fixed at its mid-span with a key. The shaft is supported at its two ends by two bearings 750 mm apart and transmits 7.5 kW power at 360 rpm. The belt tensions act vertically downward and the ratio of belt tensions on the tight side to slack side is 2.5:1. The shaft is made of plain carbon steel 40C8 (S_{ut} = 650 N/mm^2, S_{yt} = 380 N/mm^2 and G = 80 GPa) and the factor of safety is 2.5. For this shaft, the permissible angle of twist is 3^0 per meter length. Design the shaft from the point of view of strength and torsional rigidity and estimate a suitable diameter. [14]

8. Discuss the design principle for columns. A column, with a circular cross-section of diameter 25 mm, is hinged at both ends and it is made out plain carbon steel (S_{yt} = 385 N/mm^2 and E = 210 GPa). The length of the column is 400 mm. It is subjected to an axial compression along its centroidal axis. Determine the slenderness ratio of the column and comment under which regime it should be considered.. Also find out the critical buckling load for the column using the appropriate formula. If the end conditions of the column are changed to fixed-free, what changes would you need to incorporate to obtain the correct value of critical buckling load. [05+09]

Section – C

9. Two circular rods (Material: Plain C-Steel with S_{yt} = 400 N/mm^2, S_{ut} = 650 N/mm^2 and corrected endurance limit (S_e) of 175 N/mm^2) are to be connected using a cotter joint. The rods are subjected to axial fluctuating tensile loads varying between 25 kN to 70 kN. Find out the relevant dimensions for the rod and the spigot end following appropriate design principles. Assume appropriate factor of safety. [16]

Relevant Data, Charts and Tables for Design:

Standard Shaft Diameters: 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85 ...

Table 1: Relationship between endurance limit (S'_e) and ultimate strength (S_{ut}) for different materials under rotating beam test

Material	Endurance Limit (S'_e)
Steel	$0.5S_{ut}$
Cast iron and cast steel	$0.4S_{ut}$
Wrought Aluminium alloys	$0.4S_{ut}$
Cast Aluminium alloys	$0.3S_{ut}$

Table 2: Surface Finish Modification Factor $(k_a = a(S_{ut})^b)$

Surface Finish	Factor a	Exponent b
Ground	1.58	-0.085
Machined or Cold Drawn	4.51	-0.265
Hot Rolled	57.7	-0.718
Forged	272	-0.995

Table 3: Size Modification Factor (k_b)

Diameter (d)	k_b
$d \leq 7.50$	1.00
$7.5 < d \leq 50$	0.85
$50 < d$	0.75

Table 4: Reliability Factor

Reliability (%)	Reliability Factor
50	1.000
90	0.897
95	0.868
99	0.814
99.9	0.753
99.99	0.702

Load Modification Factor: (k_c)

k_c = 1.00 (Bending)
= 0.85 (Axial)
= 0.59 (Torsion)

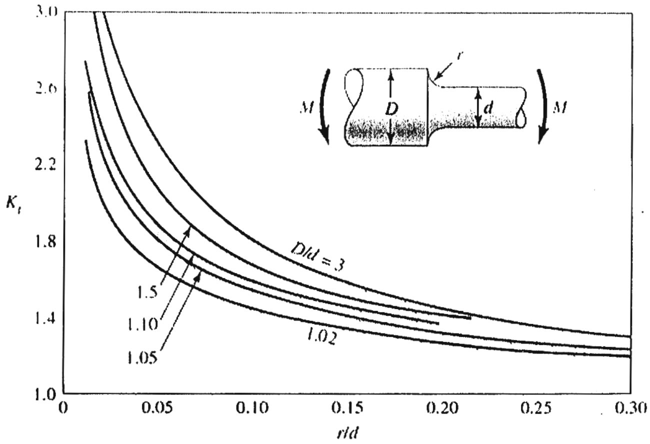

Chart 1: Round shaft with shoulder fillet in bending.

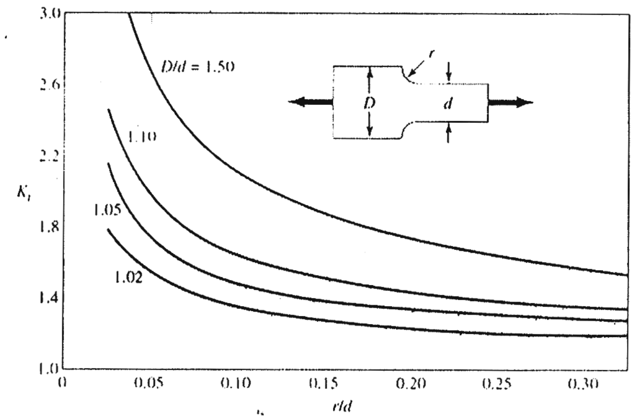

Chart 2: Rectangular filleted bar in tension or simple compression.

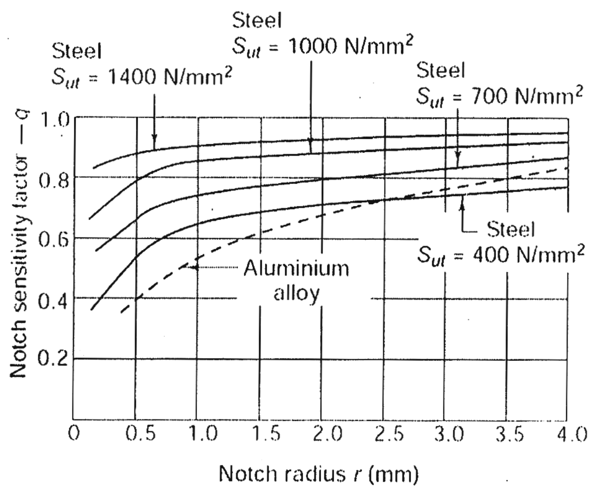

Chart 3: Notch Sensitivity Charts