B.E. CHEMICAL ENGINEERING SECOND YEAR SECOND SEMESTER EXAM 2022
MACHINE DESIGN

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.
Answer any **Four (4)** questions

1. It is required to design a joint, for two circular rods, that transmits only axial forces. From a comprehensive force analysis of the entire machine, it is determined that the maximum tensile load on the joint is 35 kN. Any plastic deformation of the rods/joint result in loss of component functionality and hence to be avoided. There should not be any relative rotation between the rods about an axis perpendicular to the rod axes.

(*i*). What type of joint would you recommend for the above-mentioned situation? Write down the names of different parts of the joint. [01+02]

(*ii*). Yield strength in tension (S_{yt}) of the material is 380 N/mm^2. Consider appropriate factor of safety for each part with justification. Design the joint. Draw a schematic representation of the joint and tabulate all the evaluated dimensions at the end of the problem. [03+12+05+02]

2. (*a*). Define: Strength and Efficiency of riveted joint. A bracket is fixed to the wall by means of 5 identical rivets as shown in Figure Q2(*a*). Find out the standard rivet diameter (from Table) considering permissible shear stress as 70 MPa. [02+02+10]

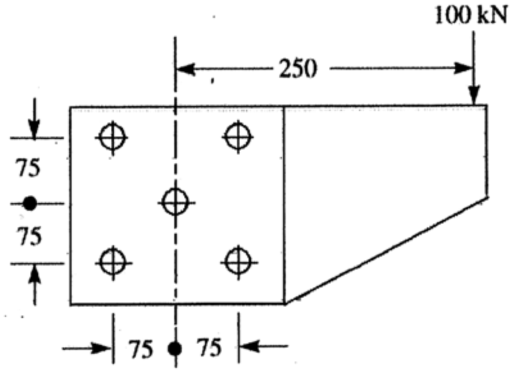

Figure Q2(*a*)

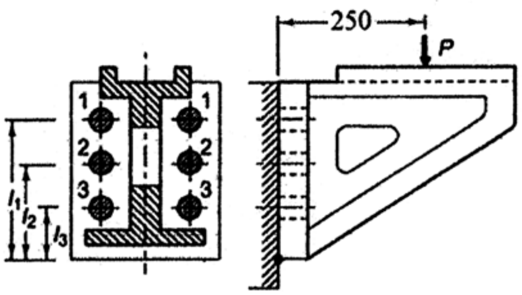

Figure Q2(*b*)

(*b*). Write down the designation of fine series threads. A metal bracket is connected to vertical wall by a group of identical bolts, as shown in Figure Q2(*b*). The joint is under eccentric loading, where, the magnitude of the vertical force (P) is 50 kN. Material of the threaded fasteners is C-steel having S_{yt} = 400 N/mm^2 (Consider a Factor of safety of 2.5). Determine the standard dimension of the bolts. [01+10]

3. (*a*). Define: S-N diagram. Draw a typical S-N diagram for a ferrous and non-ferrous specimen in a standard rotating beam test and explain the term endurance limit. Also mark the different zones on the curve clearly. [02+03+03+02]

(*b*). Write short notes (any 3): [05 × 3]

- (*i*). Resilience and Toughness
- (*ii*). Stress-strain diagram
- (*iii*). Fullering and Caulking
- (*iv*). Autofrettage
- (*v*). Factors influencing factor of safety

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Machine Design **Ex/Che/ES/B/Mech/T/226/2022**

4. (*a*). Design and draw a rigid (protected type) shaft coupling to transmit a rated load of 22.5 kW at 720 rpm. The service factor may be assumed as 1.35. Allowable shear and crushing stresses in the shaft and bolt are 40 N/mm^2 and 80 N/mm^2 respectively. Allowable shear and crushing stresses of the key are 56 N/mm^2 and 112 N/mm^2, respectively. Allowable shear stress of CI flange is 35 N/mm^2. [20]

(*b*). Discuss the function of spigot and recess as used in rigid shaft coupling. Write down the purposes of using rubber bush and brass lining in bushed-pin type flexible coupling. Explain the reason behind using a stepped pin in flexible bush pin type coupling. [01+02+02]

5. (*a*). 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 0.8 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. [18]

(*b*). A flat plate subjected to a tensile force of 5 kN is shown in Figure Q5(*b*). The plate material is grey cast iron with S_{ut} = 225 N/mm^2 and the factor of safety is 3.0. Determine the thickness of the plate. [07]

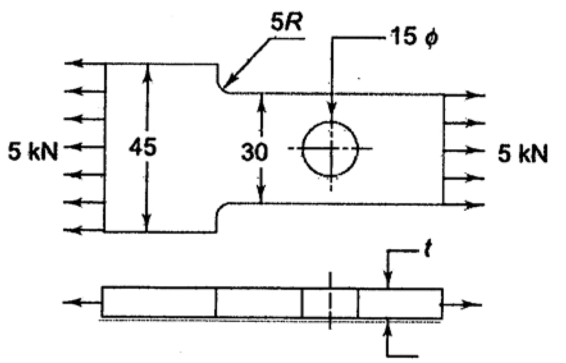

Figure Q5(*b*)

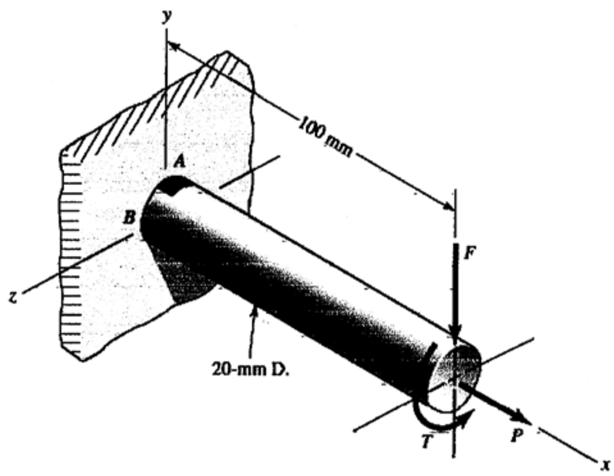

Figure Q6(*b*)

6. (*a*). Deduce the expressions for radial, tangential and longitudinal stresses for a thick cylinder subjected to internal pressure only. Show the distribution of radial and tangential stresses across the thickness of the cylinder. [10+03]

(*b*). A circular beam (diameter 20 mm and length 100 mm) is made of cold-drawn steel with S_{yt} = 460 N/mm^2. It is loaded simultaneously by axial tensile load (*P*), transverse bending load (*F*) at the free end and twisting moment (*T*) as shown in Figure Q6(*b*). The magnitudes of the forces are as follows: *F* = 0.75 kN, *F* = 5.0 kN, and *T* = 40 N-m. Write down the different type of stresses present at point A and B on the post. Determine the factor of safety at the critical point following Maximum normal stress theory, Maximum shear stress theory and Distortion energy theory. Are all the results equally acceptable corresponding to the material of the beam? Explain. [02+09+01]

Table 1: Rivet and Rivet hole Diameter as per Indian Standard

Rivet diameter (mm)	12	14	16	18	20	22	24	27	30	33	36
Rivet hole diameter (mm) **[For general purpose]**	13.5	15.5	17.5	19.5	21.5	23.5	25.5	29	32	35	38

Table 2: Basic dimensions for ISO Metric thread (Coarse Series)

Designation	*Nominal or major dia d/D (mm)*	*Pitch (p) (mm)*	*Pitch diameter d_p/D_P (mm)*	*Minor diameter (mm)*		*Tensile stress area (mm^2)*
				d_c	D_c	
M 4	4	0.70	3.545	3.141	3.242	8.78
M 5	5	0.80	4.480	4.019	4.134	14.20
M 6	6	1.00	5.350	4.773	4.917	20.10
M 8	8	1.25	7.188	6.466	6.647	36.60
M 10	10	1.50	9.026	8.160	8.376	58.00
M 12	12	1.75	10.863	9.853	10.106	84.30
M 16	16	2.00	14.701	13.546	13.835	157
M 20	20	2.50	18.376	16.933	17.294	245
M 24	24	3.00	22.051	20.319	20.752	353
M 30	30	3.50	27.727	25.706	26.211	561
M 36	36	4.00	33.402	31.093	31.670	817
M 42	42	4.50	39.077	36.479	37.129	1120
M 48	48	5.00	44.752	41.866	42.587	1470
M 56	56	5.50	52.428	49.252	50.046	2030
M 64	64	6.00	60.103	56.639	57.505	2680
M 72	72	6.00	68.103	64.639	65.505	3460
M 80	80	6.00	76.103	72.639	73.505	4340
M 90	90	6.00	86.103	82.639	83.505	5590
M 100	100	6.00	96.103	92.639	93.505	7000

Table 3: 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 4: 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 5: 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

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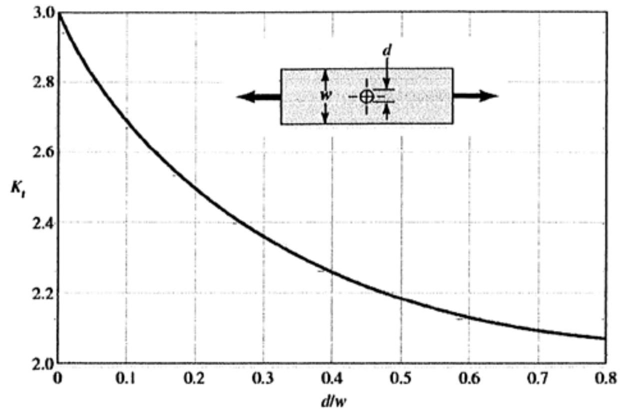

Chart 1: Bar in tension or compression with a transverse hole. $\sigma_0 = F/A$, where $A = (w - d).t$ and t is the thickness.

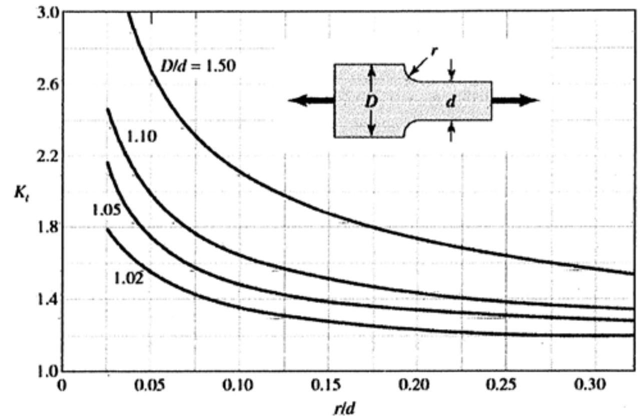

Chart 2: Rectangular filleted bar in tension or simple compression $\sigma_0 = F/A$, where $A = dt$ and t is the thickness.