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Program: B. Sc. Engg. (IPE)
Semester: 6th

Date: 24 May 2024
Time: 10.00 pm to 01:00 pm

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination
Course Number: IPE 4609
Course Title: Product Design I

Summer Semester: 2022-2023
Full Marks: 150
Time: 3 hours

Answer all the 6 (six) questions below. The distribution of marks and the CO-PO mapping are given in brackets. Necessary equations, tables and charts are attached with this question.

Q1. A furniture company is focusing on a creative product design. **[5+20]** (CO2, PO2)

i) Briefly explain the three phases of the creative design.
ii) Describe the morphological design phases for the product development.

Q2. Human Factors involves the study of the interplay between humans, machines, and their surrounding environment. **[4+10+5+6]** (CO2, PO2)

i) Determine the importance of human factor in the design of a product.
ii) Describe different forms of human factors.
iii) State the characteristics of environmentally responsible designs.
iv) Analyze different types of mental blocks that restricts the thinking capability of a designer.

Q3. ISO standards are internationally agreed by experts. Think of them as a formula that describes the best way of doing something. **[8+10+7]** (CO2, PO2)

i) Discuss several reasons of widely adaptation of ISO standards.
ii) Describe the fundamental quality management principles of ISO 9001 standard.
iii) Define PDCA cycle based on the quality system clauses of ISO 9001.

Q4. (a) Draw a schematic representation of engineering vs true stress-strain curves and identify different points/regions of those curves. **[5]** (CO1, PO1)

(b) Given that the plane stresses $\sigma_x = 90$ MPa, $\sigma_y = 190$ MPa, and $\tau_{xy} = 80$ MPa. **[5]** (CO1, PO1)

i) Calculate the centre and radius of the Mohr's circle.
ii) Draw a schematic representation of the Mohr's circle and identify the points of the principal normal and shear stresses in the x-y plane. Do not need to draw the circle accurately and find the values of principal stresses.

(c) An electric motor transmits100 kW to a gear box through a 50-mm-diameter and 2.5-m-long solid steel shaft that transmits shock energy of 100 Nm. Find the maximum instantaneous stress and the elongation. Also, find the torque **[15]** (CO1, PO1) transmitted through the shaft that rotates at 1000 rpm and the angular torsion of the shaft. Take bulk modulus, $K = 175$ GPa and Poisson's ratio, $\mu = 0.3$.

Q5. (a) Determine the shear force diagram and bending moment diagram for the following simply supported beam as shown in ***Figure 1***. **[10]** (CO1, PO1)

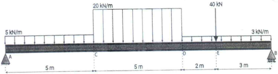


Figure 1

(b) A hollow shaft, as shown in ***Figure 2***, is subjected to a bending load of 3 kN, pure torque of 1000 N-m and an axial pulling force of 15 k N. Calculate the stresses at A and B. **[15]** (CO1, PO1)

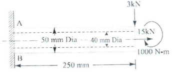


Figure 2

Q6. The cantilever rod shown in ***Figure 3*** carries a downward load F that varies from 2000 to 4000 N. The rod has a machined surface finish everywhere except the shoulder area, where a grinding operation has been performed to improve the fatigue resistance of the rod. Using a 98.5% probability of survival and the Goodman line, the Soderberg line and the Gerber line, determine the safety factor for infinite life if the rod is made from annealed AISI 1040 steel. Take a size factor of 0.85 and no thermal or miscellaneous effects. **[25]** (CO1, PO1)

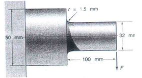


Figure 3

Maximum and minimum principal stresses

$$\sigma_{t1} = \frac{\sigma_1}{2} + \frac{1}{2}\left[\sqrt{(\sigma_1)^2 + 4\tau^2}\right]$$

$$\sigma_{t2} = \frac{\sigma_1}{2} - \frac{1}{2}\left[\sqrt{(\sigma_1)^2 + 4\tau^2}\right]$$

$$\tau_{max} = \frac{1}{2}\left[\sqrt{(\sigma_1)^2 + 4\tau^2}\right]$$

Resilience

$$U = \frac{\sigma^2 \times V}{2E}$$

Table 1: Mechanical Properties of Selected Carbon Steels

AISI Number	Condition[a]	Yield Strength, MPa	Ultimate Tensile Strength, MPa	Elongation in 50 mm, %	Reduction in Area, %	Brinell Hardness, HB
1006	Hot Rolled	170	300	30	55	85
	Cold Drawn	280	330	20	45	95
1010	Cold Drawn	305	365	20	40	105
	Hot Rolled	180	325	28	50	95
1015	Cold Drawn	325	385	18	40	111
	Hot Rolled	190	340	28	50	100
1018	Cold Drawn	370	440	15	40	126
	Hot Rolled	220	400	25	50	116
1020	Q&T 870° C	295	395	37	60	100
	Cold Drawn	350	420	15	40	121
	Hot Rolled	205	380	25	50	110
1030	Annealed	317	430	30	60	130
	N 925° C	345	520	32	61	150
	Q&T 205° C	648	848	17	47	495
	Q&T 315° C	621	800	19	53	400
	Q&T 425° C	579	731	23	60	300
	Q&T 540° C	517	669	28	65	250
	Q&T 650° C	441	586	32	70	210
	Cold Drawn	440	525	12	35	149
	Hot Rolled	260	70	20	40	130
1040	Annealed	350	520	30	57	150
	N 900° C	374	590	28	55	170
	Q&T 205° C	593	779	19	48	262
	Q&T 425° C	552	758	21	54	240
	Q&T 650° C	434	634	29	65	192
	Cold Drawn	490	585	12	35	170
	Hot Rolled	290	525	18	40	149
1050	Annealed	365	636	24	40	190
	N 900° C	427	748	20	39	220
	Q&T 205° C	807	1120	9	27	514
	Q&T 425° C	793	1090	13	36	444
	Q&T 650° C	538	717	28	65	235
	Cold Drawn	580	690	10	30	197
	Hot Rolled	340	620	15	35	179

Note[a]: N, normalized; Q&T, quenched and tempered

Endurance limit for steels,

Upper limit: for bending, $S'_e = 0.5S_u$;
for axial loads, $S'_e = 0.45S_u$;
for torsion, $S'_e = 0.29S_u$.

Fatigue Stress Concentrations: $K_f = 1 + (K_c - 1)q_n$

Modified Endurance Limit: $S_e = k_f k_s k_r k_m S'_e$

Surface finish factor: $k_f = eS_{ut}^f$

Size factor:

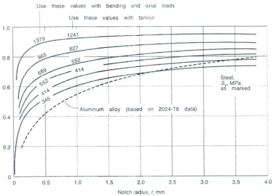
$$k_s = \begin{cases} 1 & d \leq 8 \text{ mm} \\ 1.189d^{-0.112} & 8 \text{ mm} < d \leq 250 \text{ mm} \end{cases}$$

Temperature factor: $k_t = \dfrac{S_{ut}}{S_{ut,ref}}$

Reliability factor: $k_r = 0.512\left[\ln\left(\dfrac{1}{R}\right)\right]^{0.11} + 0.508,$

Table 2: Surface finish factor

Manufacturing process	Factor e	Exponent f
Grinding	1.58	-0.085
Machining or cold drawing	4.51	-0.265
Hot rolling	57.7	-0.718
As forged	272.0	-0.995



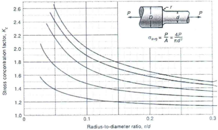
Effect of Nonzero Mean Stress:

Gerber parabola: $\frac{K_f n_s \sigma_a}{S_e} + \left(\frac{n_s \sigma_m}{S_{ut}}\right)^2 = 1$

Goodman line: $\frac{K_f \sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{1}{n_s}$

Soderberg line: $\frac{K_f \sigma_a}{S_e} + \frac{\sigma_m}{S_{yt}} = \frac{1}{n_s}$

Yield line: $\frac{\sigma_a}{S_{yt}} + \frac{\sigma_m}{S_{yt}} = \frac{1}{n_s}$



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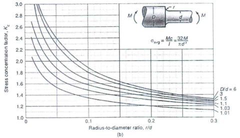

(b)