Ref. No.: Ex/ME(M2)/PC/B/T/323/2024

B.E. MECHANICAL ENGINEERING THIRD YEAR SECOND SEMESTER - 2024

Subject: DESIGN OF MACHINE ELEMENTS-III

Time: 3hr **Full Marks: 100**

Instructions: Answer any **five** questions.

1. **(a)** A helical compression spring is required to deflect through approximately 25 mm when the external force acting on it varies from 500 to 1000 N. The spring index is 8. The spring has square and ground ends. There should be a gap of 2 mm between adjacent coils when the spring is subjected to the maximum force of 1000 N. The spring is made of cold-drawn steel wire with ultimate tensile strength of 1000 N/mm^2 and permissible shear stress in the spring wire should be 50% of the ultimate tensile strength (G = 81,370 N/mm^2). Design the spring and calculate: (i) wire diameter; (ii) mean coil diameter; (iii) number of active coils; (iv) total number of coils; (v) solid length; (vi) free length;

   (b) What type of stress is induced in helical extension spring?

   (c) What do you understand by free length, compressed length and solid length? **[15+2+3]**

2. **(a)** A semi-elliptic leaf spring consists of three extra-full - length leaves and 12 graduated-length leaves, including the master leaf. The centre-to-centre distance between two leaves of the spring is 1.1 m. The maximum force that can act on the spring is 80 kN. For each leaf the ratio of width to thickness is 7:1. The modulus of elasticity of the leaf material is above 2,05,000 N/mm^2. The leaves are pre-stressed in such a way that when the force is maximum, the stresses induced in all leaves are same and equal to 400 N/mm^2. Determine i) the width and thickness of the leaves ii) the initial nip: and iii) the initial pre-load required to close the gap C between extra full-length leaves and graduated-length leaves.

   (b) Explain Nipping of Leaf spring? What is the objective of nipping of leaf spring?

   (c) Write the factors for selection of spring wire material? **[12+3+5]**

3. It is required to design a pair of spur gears with 20° full-depth involute teeth. The input shaft rotates at 720 rpm and receives 5 kW power through a flexible coupling. The speed of the output shaft should be 144 rpm. The pinion as well as the gear are made of steel Fe 410 (S_{ut} = 410 N/mm^2). The service factor for the application is 1.25. The gears are machined to meet the specifications of Grade 6.

   (i) Assume suitable number of teeth for the pinion and the gear.

[Turn over

(ii) For preliminary calculations, assume the pitch line velocity as 5 m/s and the factor of safety as 2. Estimate the module and select the first preference value of the module.

(iii) Using this value of the module, calculate the pitch circle diameters of the pinion and gear and the face width

(iv) Determine static load and the dynamic load by Buckingham's equation. Also, calculate the beam strength and the correct value of factor of safety based on beam strength.

(v) Using a factor of safety of 2 for wear strength, specify the surface hardness for gears.

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4. (a) The following data is given for a pair of parallel helical gears made of steel: power transmitted = 20 kW, speed of pinion = 720 rpm, number of teeth on pinion = 35, number of teeth on gear = 70, centre distance = 285 mm, normal module = 5 mm, face width = 50 mm, normal pressure angle = 20°, ultimate tensile strength = 600 N/mm^2, surface hardness = 300 BHN, grade of machining = Gr. 6, service factor = 1.25. Calculate - (i) the helix angle; (ii) the beam strength; (iii) the wear strength; (iv) the static load; (v) the dynamic load by Buckingham's equation; (vi) the effective load; (vii) the effective factor of safety against bending failure; and (viii) the effective factor of safety against pitting failure.

(b) What is the difference between double and herringbone helical gears?

(c) Explain significance of Lewis Form Factor in gear design. **[15+2+3]**

5 (a) A pair of straight bevel gears is mounted on shafts, which are intersecting at right angles. The number of teeth on the pinion and gear are 30 and 45 respectively. The pressure angle is 20°. The pinion shaft is connected to an electric motor developing 16.5 kW rated power at 500 rpm. The service factor can be taken as 1.5. The pinion and the gear are made of steel (Sut = 570 N/mm^2) and heat-treated to a surface hardness of 350 BHN. The gears are manufactured in such a way that the error between two meshing teeth is limited to 20 mm. The module and face width are 6 mm and 50 mm respectively. Determine the factor of safety against bending as well as pitting.

(b) Deduce the expression for wear strength of bevel gears? **[14+6]**

6. (a) The gear box for the worm gears of examples 20.4 and 20.5 has an effective surface area of 0.25 m^2. A fan is mounted on the worm shaft to circulate air over the surface of the fins. The coefficient of heat transfer can be taken as 25 W/m^2 °C. The permissible temperature rise of the lubricating oil above the atmospheric temperature is 45°C. The coefficient of friction is 0.035 and the normal pressure angle is 20°. Calculate the power transmitting capacity based on thermal considerations.

(b) Deduce the expression for force analysis of worm gear? **[8+12]**

7. **(a)** Prove that the thickness of a cylinder wall with closed ends as per Distortion energy theory of failure

$$t = \frac{D_i}{2}\left[\sqrt{\frac{\sigma}{\sigma - P_i\sqrt{3}}} - 1\right]$$

(b) Prove that $\sigma_t = A + B/r^2$ *and* $\sigma_r = A - B/r^2$ for a thick cylindrical pressure vessel subjected to internal pressure, terms have usual meaning Draw the tangential stress distribution in both cases when it is subjected to internal pressure p_i and external pressure p_o respectively. Assume radii ratio = 2.0 **[8+12]**

z	*Y*	*z*	*Y*	*z*	*Y*
15	0.289	27	0.348	55	0.415
16	0.295	28	0.352	60	0.421
17	0.302	29	0.355	65	0.425
18	0.308	30	0.358	70	0.429
19	0.314	32	0.364	75	0.433
20	0.320	33	0.367	80	0.436
21	0.326	35	0.373	90	0.442
22	0.330	37	0.380	100	0.446
23	0.333	39	0.386	150	0.458
24	0.337	40	0.389	200	0.463
25	0.340	45	0.399	300	0.471
26	0.344	50	0.408	Rack	0.484

Module (m) (mm)	*Class - 1*	*Class - 2*	*Class - 3*
Up to 4	0.050	0.025	0.0125
5	0.056	0.025	0.0125
6	0.064	0.030	0.0150
7	0.072	0.035	0.0170
8	0.080	0.038	0.0190
9	0.085	0.041	0.0205
10	0.090	0.044	0.0220

Grade	*e (microns)*
1	0.80 + 0.06 ϕ
2	1.25 + 0.10 ϕ
3	2.00 + 0.16 ϕ
4	3.20 + 0.25 ϕ
5	5.00 + 0.40 ϕ
6	8.00 + 0.63 ϕ
7	11.00 + 0.90 ϕ
8	16.00 + 1.25 ϕ
9	22.00 + 1.80 ϕ
10	32.00 + 2.50 ϕ
11	45.00 + 3.55 ϕ
12	63.00 + 5.00 ϕ