Ref. No.: Ex/ME(M2)/PC/B/T/323/2023

B.E. MECHANICAL ENGINEERING 3rd yr, 2nd sem - 2023

Subject: DESIGN OF MACHINE ELEMENTS-III

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

Instructions: Answer any five questions.

1. **(a)** A railway wagon moving at a velocity of 1.5 m/s is brought to rest by a bumper consisting of two helical springs arranged in parallel. The mass of the wagon is 1500 kg. The springs are compressed by 150 mm in bringing the wagon to rest. The spring index can be taken as 6. The springs are made of oil-hardened and tempered steel wire with ultimate tensile strength of 1250 N/mm^2 and modulus of rigidity of 81370 N/mm^2. The permissible shear stress for the spring wire can be taken as 50% of the ultimate tensile strength. 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; (vii) pitch of the coil; (viii) required spring rate; and (ix) actual spring rate
(b) What is the Wahl factor? Why is it used?
(c) Distinguish between closely coiled and open coiled helical springs? **[15+2+3]**

2. **(a)** A semi-elliptic leaf spring used for automobile suspension consists of three extra full-length leaves and 15 graduated-length leaves, including the master leaf. The centre-to-centre distance between two eyes of the spring is 1 m. The maximum force that can act on the spring is 75 kN. For each leaf, the ratio of width to thickness is 9:1. The modulus of elasticity of the leaf material is 2,07,000 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 450 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?
(c) Write the factors for selection of spring wire material? **[10+5+5]**

3. **(a)** Deduce the expression for wear strength of gear tooth of spur gear?
(b) It is required to design a pair of spur gears with 20° full-depth involute teeth consisting of a 20-teeth pinion meshing with a 50 teeth gear. The pinion shaft is connected to a 22.5 kW, 1450 rpm electric motor. The starting torque of the motor can be taken as 150% of the rated torque. The material for the pinion is plain carbon steel Fe 410 (S_{ut} = 410 N/mm^2), while the gear is made of grey cast iron FG 200 (S_{ut} =200 N/mm^2). The factor of safety is 1.5. Design the gears based on the Lewis equation and using velocity factor to account for the dynamic load (m = 7 mm) **[10+10]**

4. **(a)** A pair of parallel helical gears consists of 24 teeth pinion rotating at 5000 rpm and supplying 2.5 kW power to a gear. The speed reduction is 4:1. The normal pressure angle and helix angle are 20° and 23° respectively. Both gears are made of hardened

steel (S_{ut} = 750 N/mm^2). The service factor and the factor of safety are 1.5 and 2 respectively. The gears are finished to meet the accuracy of Grade 4.

(i) In the initial stages of gear design, assume that the velocity factor accounts for the dynamic load and that the face width is ten times the normal module. Assuming the pitch line velocity to be 10 m/s, estimate the normal module.

(ii) Select the first preference value of the normal module and calculate the main dimensions of the gears.

(iii) Determine the dynamic load using Buckingham's equation and find out the effective load for the above dimensions. What is the correct factor of safety for bending? (iv) Specify surface hardness for the gears, assuming a factor of safety of 2 for wear consideration

(b) Define Herringbone Gear? What is the difference between double and herringbone helical gears? **[15+5]**

5 (a) A pair of bevel gears, with 20° pressure angle, consists of a 20 teeth pinion meshing with a 30 teeth gear. The module is 4 mm, while the face width is 20 mm. The material for the pinion and gear is steel 50C4 (S_{ut} = 750 N/mm^2). The gear teeth are lapped and ground (Class-3) and the surface hardness is 400 BHN. The pinion rotates at 500 rpm and receives 2.5 kW power from the electric motor. The starting torque of the motor is 150% of the rated torque. Determine the factor of safety against bending failure and against pitting failure.

(b) What are the advantages and disadvantages of straight bevel gears over spiral bevel gears **[14+6]**

6. (a) A pair of worm and worm wheel is designated as, 1/30/10/10
The input speed of the worm is 1200 rpm. The worm wheel is made of centrifugally cast, phosphor bronze and the worm is made of case-hardened carbon steel 14C6 (S_b = 28.20). Determine the power transmitting capacity based on the beam strength.

(b) Deduce the expression for force analysis of worm gear?

(c) What are the advantages of worm gear drives? **[8+12]**

7. (a) Deduce the Lame's equation for pressure vessels?

(b) A high-pressure cylinder consists of a steel tube with inner and outer diameters of 20 and 40 mm respectively. It is jacketed by an outer steel tube, having an outer diameter of 60 mm. The tubes are assembled by a shrinking process in such a way that maximum principal stress induced in any tube is limited to 100 N/mm^2. Calculate the shrinkage pressure and original dimensions of the tubes (E = 207 kN/mm^2).

(c) Define Autofrettage? Explain the ways of reducing Autofrettage? **[6+8+6]**

8. Write Short Notes: **[4 x 5 = 20]**

(i) Spring Index
(ii) Surge in spring
(iii) Module in gear
(iv) Contact ratio of gear
(v) Undercutting of gear

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	$0.80 + 0.06\,\phi$
2	$1.25 + 0.10\,\phi$
3	$2.00 + 0.16\,\phi$
4	$3.20 + 0.25\,\phi$
5	$5.00 + 0.40\,\phi$
6	$8.00 + 0.63\,\phi$
7	$11.00 + 0.90\,\phi$
8	$16.00 + 1.25\,\phi$
9	$22.00 + 1.80\,\phi$
10	$32.00 + 2.50\,\phi$
11	$45.00 + 3.55\,\phi$
12	$63.00 + 5.00\,\phi$