Ex/ME/5/T/412/2019(old)

Bachelor of Engg (Mechanical Engg) Fourth yr, 1st semester Examination, 2019(old)

Machine Design III

Time: Three hours | Full Marks: 100

Missing data, if any, may be assumed.

Answer any five **questions**

1. a) State the conditions for Clavarino's equation to be used for cylinder wall thickness.
   b) State the advantages and disadvantages of hemispherical head for cylindrical pressure vessel.
   c) What is Class III pressure vessel?
   d) State the bore diameter and load range (low/medium/high) of the bearing 6315.
   e) State the assumptions of Petroff's equation.
   f) Define V.I. of a lubricant. State its physical significance.
   g) State the advantages and disadvantages of chain drive.
   h) State and explain load-life relationship for rolling contact bearings.
   i) Explain the meaning of chain number 16A-1.
   j) Compare the relative merits and demerits of silent chain in comparison to roller chains. 2 x 10

2. a) A thick cylinder is made of ductile material with closed ends having inner diameter D_i and subjected to internal pressure P_i. According to the distortion energy theory of failure, $\sigma = S_{yt} / FOS = \sqrt{\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]}$ where σ_1, σ_2 and σ_3 are principal stresses. Apply this theory to prove that the cylinder wall thickness is given by: $t = \frac{D_i}{2}[(\frac{\sigma}{\sigma - \sqrt{3}P_i})^{1/2} - 1]$. Symbols have usual meaning.

   b) A compound cylinder consisting of an inner cylinder having radii 150 mm and 200 mm respectively and a jacket of outer radius 250 mm is subjected to an internal pressure of 50 N/mm^2. Considering shrink-fit amount 0.1 mm and $E = 207$ kN/mm^2, calculate the stress field at inner, outer and mating surface of the compound cylinder.

10+10

3. a) It is required to design a chain drive to connect a 12 kW, 1400 rpm electric motor to a centrifugal pump running at 700 rpm. Assume variable load with moderate shock, drop lubrication and 4 mm reduction in center distance to accommodate initial sag. The relevant design data is furnished in Tables 1 - 4. Design the chain drive and provide a proper roller chain along with its dimensions, determine the pitch circle diameters of driving and driven sprockets, the number of chain links and the correct centre distance between the axes of sprockets.

b) Explain the different types of lubrication of chain drive. 15+5

4. a) For a circular step thrust bearing, write down the appropriate Reynolds equation. Hence deduce the expression for load capacity and total power loss for such a bearing.

b) A 50 mm diameter hardened and ground steel journal rotates at 1440 rpm in a lathe turned bronze bushing which is 50 mm long. From manufacturing considerations, hydrodynamic lubrication is possible with a minimum oil film thickness of 12 μm and the diametral clearance of 0.12 mm. The lubricant used has viscosity 0.03 Pa-s at operating condition, mass density 880 kg/m^3 and specific heat 1880 J/kg-K.. Calculate the maximum radial load that the journal can carry operating under hydrodynamic lubrication. Also find the required volume flow rate and temperature rise. Performance characteristics for full journal bearings are provided in Table 5.

10+10

5. a) Derive Stribeck's equation for static load carrying capacity of rolling element bearings.

b) A single-row deep groove ball bearing is used for a 30 seconds work cycle consisting of two parts as given in Table A. For this application, the static and dynamic load capacities are 50 and 68 kN respectively. Calculate the life of the bearing in hours. The load factors are given in Table B. 10+10

	Part I	Part II
Duration (s)	10	20
Radial load (kN)	45	15
Axial load (kN)	12.5	6.25
Speed (r.p.m.)	720	1440

Table A

F_a/C_0	$F_a/F_r \le e$		$F_a/F_r > e$		e
	X	Y	X	Y	
0.025	1	0	0.56	2.0	0.22
0.040	1	0	0.56	1.8	0.24
0.070	1	0	0.56	1.6	0.27
0.130	1	0	0.56	1.4	0.31
0.250	1	0	0.56	1.2	0.37
0.500	1	0	0.56	1.0	0.44

Table B

6. Write short notes on (any four)

(a) Polygonal effect in a chain drive system

(b) Failure of chain drive

(c) Tower experiment

(d) Autofrettage

(e) Mechanism of pressure development in hydrodynamic bearings

(f) Stribeck diagram for hydrodynamic bearings 5 x 4

Table 1 Dimensions and breaking loads of roller chains

ISO chain number	Pitch p (mm)	Roller diameter d_1 (mm)	Width b_1 (mm)	Transverse pitch p_t (mm)	Breaking load for single strand chain (kN)
06 B	9.525	6.35	5.72	10.24	10.7
08 B	12.70	8.51	7.75	13.92	18.2
10 B	15.875	10.16	9.65	16.59	22.7
12 B	19.05	12.07	11.68	19.46	29.5
16 B	25.40	15.88	17.02	31.88	65.0
20 B	31.75	19.05	19.56	36.45	98.1
24 B	38.10	25.40	25.40	48.36	108.9
28 B	44.45	27.94	30.99	59.56	131.5
32 B	50.80	29.21	30.99	58.55	172.4
40 B	63.50	39.37	38.10	72.29	272.2

Table 2 Power rating for simple roller chain

Pinion speed (r.p.m.)	Power (kW)				
	06 B	08 B	10 B	12 B	16 B
50	0.14	0.34	0.64	1.07	2.59
100	0.25	0.64	1.18	2.01	4.83
200	0.47	1.18	2.19	3.75	8.94
300	0.61	1.70	3.15	5.43	13.06
500	1.09	2.72	5.01	8.53	20.57
700	1.48	3.66	6.71	11.63	27.73
1000	2.03	5.09	8.97	15.65	34.89
1400	2.73	6.81	11.67	18.15	38.47
1800	3.44	8.10	13.03	19.85	—
2000	3.80	8.67	13.49	20.57	—

Table 3 Service factor (K_s)

Type of input power	Type of driven load: Smooth	Moderate shock	Heavy shock
(i) I.C. Engine with hydraulic drive	1.0	1.2	1.4
(ii) Electric motor	1.0	1.3	1.5
(iii) I.C. Engine with mechanical drive	1.2	1.4	1.7

Table 4. Tooth correction factor (K_2)

Number of teeth on the driving sprocket	K_2
15	0.85
16	0.92
17	1.00
18	1.05
19	1.11
20	1.18
21	1.26
22	1.29
23	1.35
24	1.41
25	1.46
30	1.73

Table 5: Performance Characteristics for full journal bearings

L/D	ε	S	$(r/c)\mu$	ϕ^{o}	$\bar{Q} = \frac{Q \cdot 2\pi}{\omega r L c}$
$\frac{1}{4}$	0.1	15.9	-	83	3.45
	0.2	7.58	153	75	3.76
	0.3	4.69	98.5	68	4.07
	0.4	2.85	61.4	61	4.37
	0.5	1.78	40.0	54	4.68
	0.6	1.07	26.7	47	4.99
	0.7	0.591	16.6	39	5.30
	0.8	0.266	8.93	31	5.60
	0.9	0.0738	3.49	8	5.91
$\frac{1}{2}$	0.1	4.30	-	81	3.43
	0.2	2.01	40.9	75	3.72
	0.3	1.235	25.7	68	4.00
	0.4	0.785	17.11	62	4.29
	0.5	0.497	11.95	55	4.57
	0.6	0.320	8.08	48	4.85
	0.7	0.185	5.48	41	5.13
	0.8	0.092	3.25	33	5.41
	0.9	0.032	1.59	23	5.69
1	0.1	1.35	-	79	3.37
	0.2	0.632	12.9	74	3.59
	0.3	0.382	8.04	68	3.79
	0.4	0.261	5.80	62	3.99
	0.5	0.179	4.31	56	4.16
	0.6	0.120	3.21	50	4.33
	0.7	0.0765	2.36	43	4.48
	0.8	0.0448	1.71	36	4.62
	0.9	0.0191	1.06	25	4.76
$\propto$	0.1	0.247	-	69	3.03
	0.2	0.123	2.57	67	2.83
	0.3	0.0823	1.90	64	2.52
	0.4	0.0628	1.53	62	2.26
	0.5	0.0483	1.32	58	1.91
	0.6	0.0389	1.20	54	1.56
	0.7	0.0297	1.10	49	1.16
	0.8	0.0211	0.962	42	0.76
	0.9	0.00114	0.721	32	0.41