

National Exams May 2016

07-Mec-B1, Advanced Machine Design

Notes

- Time: 3 hours.
- This is an open book exam.
- **Answer all questions of Part I (i.e. Questions 1, 2), and only THREE questions from Part II of the examination.**
- Make sure your answers are neat and clear.
- State all assumptions clearly. If doubt arises as to the interpretation of any question, write down a clear statement of any assumptions made.
- All answers must be clearly annotated with a summary of the approach, method, and results written in clear and correct English.
- Document your sources of information whenever you use a tabulated value or an equation.
- Any non-communicating calculator is permitted.
- Assume any missing data and make sure to properly state in your answer.
- The examination marks 100 in total.
- Failure to follow the above directions will result in grade penalties.

PART I

Problem 1. Briefly answer the following questions:

- (a) Name at least five green design criteria. (1 mark)
- (b) Why is a hollow shaft preferred over a solid shaft? What are the disadvantages of a hollow shaft? (3 marks)
- (c) In hydrodynamic lubrication of a journal bearing, how is the minimum oil film thickness related to the viscosity of the lubricant? (2 marks)
- (d) In general, is von Mises' criterion more conservative in predicting yielding than Tresca's criterion? (1 mark)
- (e) Explain why in plane strain tension, the material exhibits a higher load carrying capacity before yielding compared with uniaxial tension? (3 marks)

Problem 2. Two identical 3 in. power screws (single threaded) with Acme threads are used to raise and lower a 50 ton sluice gate of a dam. The quality of construction and maintenance (including lubrication) are good, resulting in an estimated friction coefficient of 0.1 for both screws. The collar bearings have an effective diameter of 5 in. and a coefficient of friction of 0.03, as roller thrust bearings are used. Friction of the sluice gate in its tracks adds 2 tons to its weight when raising and reduces its apparent weight by 2 tons when lowering. The gate is designed to move at a speed of 2 ft/min. Find: (a) the torque required to drive each screw to either raise or lower the sluice gate; (b) the rotation speed of the screws; and (c) the horse-power needed by each screw's motor to raise the gate (raising torque \times angular velocity). Use the following tables for the sizes of the Acme threads. (30 marks)

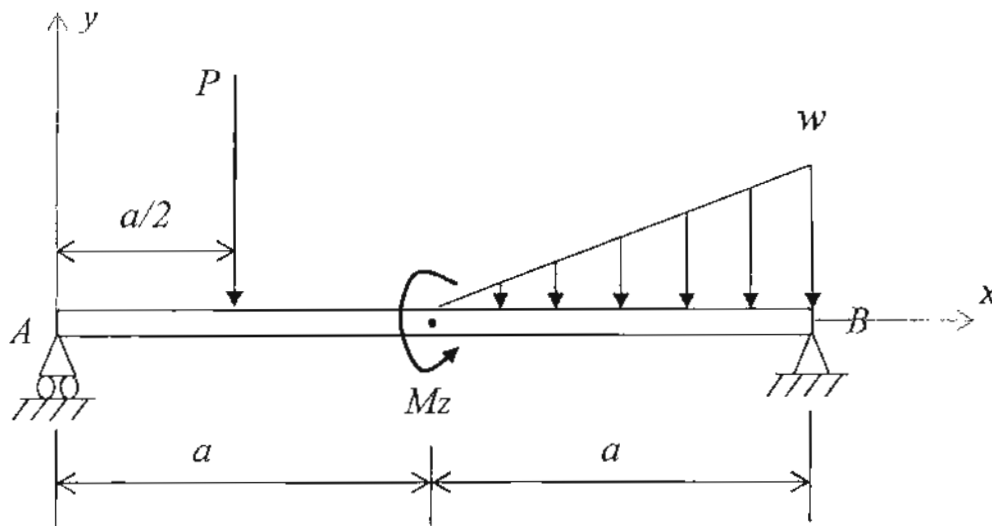
Major Diameter (in)	Threads per inch	Thread Pitch (in)	Pitch Diameter (in)	Minor Diameter (in)	Tensile Stress Area (in ²)
0.250	16	0.063	0.219	0.188	0.032
0.313	14	0.071	0.277	0.241	0.053
0.375	12	0.083	0.333	0.292	0.077
0.438	12	0.083	0.396	0.354	0.110
0.500	10	0.100	0.450	0.400	0.142
0.625	8	0.125	0.563	0.500	0.222
0.750	6	0.167	0.667	0.583	0.307
0.875	6	0.167	0.792	0.708	0.442
1.000	5	0.200	0.900	0.800	0.568
1.125	5	0.200	1.025	0.925	0.747
1.250	5	0.200	1.150	1.050	0.950
1.375	4	0.250	1.250	1.125	1.108
1.500	4	0.250	1.375	1.250	1.353
1.750	4	0.250	1.625	1.500	1.918
2.000	4	0.250	1.875	1.750	2.580
2.250	3	0.333	2.083	1.917	3.142
2.500	3	0.333	2.333	2.167	3.976
2.750	3	0.333	2.583	2.417	4.909
3.000	2	0.500	2.750	2.500	5.412
3.500	2	0.500	3.250	3.000	7.670
4.000	2	0.500	3.750	3.500	10.321
4.500	2	0.500	4.250	4.000	13.364
5.000	2	0.500	4.750	4.500	16.800

Table 14-3

Principal Dimensions of American Standard Acme Threads.
See Reference 2 for More Complete Dimensional and Tolerance Information.

Part II

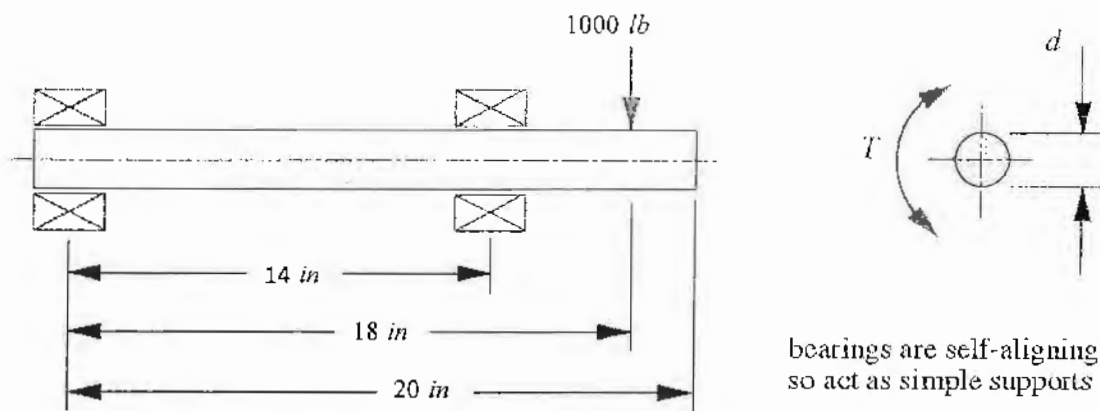
Problem 3. A simply supported, round, steel beam AB is loaded by a transverse load, $P = 5$ kN, a concentrated moment, $M_z = 9$ kN.m, and a linearly distributed load with a peak intensity, $w = 9$ kN/m, all in the x - y plane as shown in the following figure. Find out the reaction forces at support A and B . Draw the shear force and bending moment diagrams of the beam. If the diameter of the beam is 55 mm, calculate the maximum bending stress of the beam? Use $a = 1$ m in your calculation. **(20 marks)**



Problem 4. Design a single-surface disk clutch to transmit 120 N.m of torque at 750 rpm using a molded lining with a maximum pressure of 1.2 MPa and friction coefficient of 0.3. Assume uniform wear. Find the outside and inside diameters required using an inside to outside diametral ratio of 0.625. What is the power transmitted? **(20 marks)**

Problem 5. A simply supported shaft is shown in the following figure. A constant magnitude transverse load of 1000 lb is applied as the shaft rotates subjected to a time varying torque that varies from 0 to 2000 lb.in. Find (1) the diameter of the shaft required to obtain a safety factor of 2 in fatigue loading if the shaft is steel with $S_{ut} = 108 \text{ ksi}$, and $S_y = 62 \text{ ksi}$, and (2) the corresponding maximum deflection in torsion and in bending. Assume no stress concentration.

(20 marks)



Problem 6. A steel bar, $22 \text{ mm} \times 30 \text{ mm}$ in cross-section, is loaded axially in tension with $F_{min} = 8 \text{ kN}$, $F_{max} = 24 \text{ kN}$. A 10-mm hole passes through the centre of the 30-mm side. Find:

- (1) The fatigue stress concentration factor;
 - (2) Worst case mean and alternating stresses;
 - (3) Fatigue strength for a finite life of 500000 cycles.
- Assume $S_{ut} = 500 \text{ MPa}$ and reliability of 99.999% .

(20 marks)