National Exams December 2012

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.
- One of two calculators is permitted any Casio or Sharp approved models.
- 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: - Mandatory to respond both Problem # 1 and # 2

Problem 1. Briefly answer the following questions:

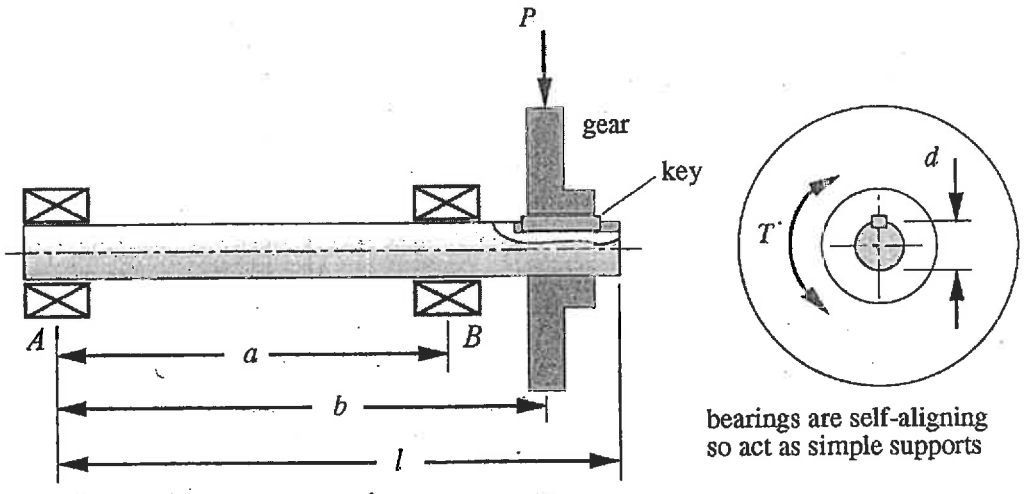
(a) Name at least five green design criteria. **(1 mark)**
(b) Why is a hollow shaft preferred over a solid shaft? What are the disadvantages of a hollow shaft? **(3 marks)**
(c) Describe the relationship between the Ocvirk number and the applied load, and what is the suggested Ocvirk number in bearing design? **(4 marks)**
(d) What happens when the eccentricity ratio equals one in a journal bearing? **(2 marks)**

Problem 2. A shaft is simply supported at A and B as shown. A constant magnitude transverse load P is applied on the gear (with no weight to be considered) as the shaft rotates subjected to a time-varying torque from the minimum of – 200 lb·in to the maximum of 500 lb·in. If l = 17 in, a = 6 in, b = 12 in, and P = 1500 lb, perform the following:

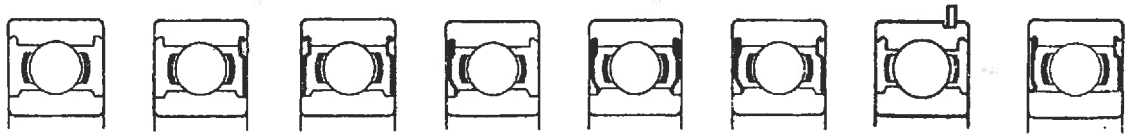
(a) Find the shaft diameter required to obtain a safety factor of 2 in fatigue loading if the shaft is steel with ultimate strength of 108 ksi, and yield strength of 62 ksi. Assume no stress concentration (ignore the key in your calculation). What would be the maximum deflection in bending of the shaft? **(12 marks)**

(b) Determine the size of parallel key necessary to give a safety factor of at least 2 against both shear and bearing failure for the design shown using the shaft diameter found in (a). **(9 marks)**

(c) Choose a suitable 6300 ball bearing from attached Fig. 10.23 for a 5% failure rate. Select the bearing that has the least bore diameter and meets the load-rating requirement. Specify bearing number, bore, OD, width (all in in.) and the basic dynamic load rating of the bearing. Using L_{10} = 60 (millions). **(9 marks)**



Note: not to scale



OPEN	ONE SHIELD	TWO SHIELDS	ONE SEAL	TWO SEALS	SEAL & SHIELD	OPEN, WITH SNAP RING†	RADIAL SEAL & SHIELD
Suffix	.Z	.2Z	.RS	.2RS	.RSZ	.NR	.RSRZR

This configuration only shown to illustrate new standard enclosures. Some bearings are now being converted.

BEARING NUMBER*	BOUNDARY DIMENSIONS						SNAP RING DIMENSIONS inches			MAX. FILLET RADIUS Shaft & Hsg. inch	APPROX. WEIGHT lb.	S_L LIMITING SPEED ‡ rpm	C DYNAMIC LOAD RATING lb.	C_o STATIC LOAD RATING lb.
	BORE mm	BORE inch	O. DIAM. mm	O. DIAM. inch	WIDTH mm	WIDTH inch	H	S	t					
6300	10	.3937	35	1.3780	11	.4331	.125	1.562	.044	.025	.13	22000	1400	850
6301	12	.4724	37	1.4567	12	.4724	.125	1.625	.044	.040	.15	20000	1700	1040
6302	15	.5906	42	1.6535	13	.5118	.125	1.821	.044	.040	.20	18000	1930	1200
6303	17	.6693	47	1.8504	14	.5512	.141	2.074	.044	.040	.25	16000	2320	1460
6304	20	.7874	52	2.0472	15	.5906	.141	2.276	.044	.040	.34	14000	3000	1930
6305	25	.9843	62	2.4409	17	.6693	.195	2.665	.067	.040	.58	11000	3800	2550
6306	30	1.1811	72	2.8346	19	.7480	.195	3.091	.067	.040	.83	9500	5000	3400
6307	35	1.3780	80	3.1496	21	.8268	.195	3.406	.067	.060	1.07	8500	5700	4000
6308	40	1.5748	90	3.5433	23	.9055	.226	3.799	.097	.060	1.41	7500	7350	5300
6309	45	1.7717	100	3.9370	25	.9843	.226	4.193	.097	.060	1.95	6700	9150	6700
6310	50	1.9685	110	4.3307	27	1.0630	.226	4.587	.097	.080	2.50	6000	10600	8150
6311	55	2.1654	120	4.7244	29	1.1417	.271	5.104	.111	.080	3.30	5300	12900	10000
6312	60	2.3622	130	5.1181	31	1.2205	.271	5.498	.111	.080	3.81	5000	14000	10800
6313	65	2.5591	140	5.5118	33	1.2992	.304	5.892	.111	.080	4.64	4500	16000	12500
6314	70	2.7559	150	5.9055	35	1.3780	.304	6.286	.111	.080	5.68	4300	18000	14000
6315	75	2.9528	160	6.2992	37	1.4567	.304	6.679	.111	.080	6.60	4000	19300	16300
6316	80	3.1496	170	6.6929	39	1.5354	.346	7.198	.122	.080	9.53	3800	21200	18000
6317	85	3.3465	180	7.0866	41	1.6142	.346	7.593	.122	.100	11.00	3400	21600	18600
6318	90	3.5433	190	7.4803	43	1.6929	.346	7.986	.122	.100	11.60	3400	23200	20000
6319	95	3.7402	200	7.8740	45	1.7717	.346	8.380	.122	.100	13.38	3200	24500	22400
6320	100	3.9370	215	8.4646	47	1.8504	—	—	—	.100	16.34	3000	28500	27000
6321	105	4.1338	225	8.8582	49	1.9291	—	—	—	.100	17.8	2800	30500	30000
6322	110	4.3307	240	9.4488	50	1.9685	—	—	—	.100	21.0	2600	32500	32500
6324	120	4.7244	260	10.2362	55	2.1654	—	—	—	.100	32.3	2400	36000	38000
6326	130	5.1181	280	11.0236	58	2.2835	—	—	—	.12	40.1	2200	39000	43000
6328	140	5.5118	300	11.8110	62	2.4409	—	—	—	.12	48.1	2000	44000	50000
6330	150	5.9055	320	12.5984	65	2.5590	—	—	—	.12	57.8	1900	49000	60000

*Bearing numbers listed are for open bearings only. For shields, seals and snap rings, add suffix or prefix indicated below bearing diagram. Eg. 6300.Z, 6300.RS, 6300.NR, etc. Check availability of closures for larger sizes.

†Snap ring bearings available with shields or seals. Add both suffixes. Eg. 6300.ZNR, etc.

‡For grease lubricated bearings without seals. For other conditions, see Page 114.

For mounting data, shaft and housing fits and shoulder diameters, see Pages 124-132.

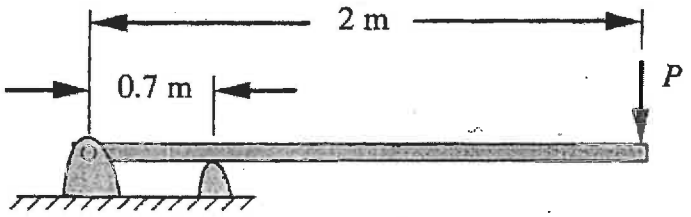
FIGURE 10-23

Dimensions and Load Ratings for 6300 Series, Medium, Metric, Deep-Groove (Conrad-type) Ball Bearings *Courtesy of FAG Bearings Corporation, Stamford, Conn.*

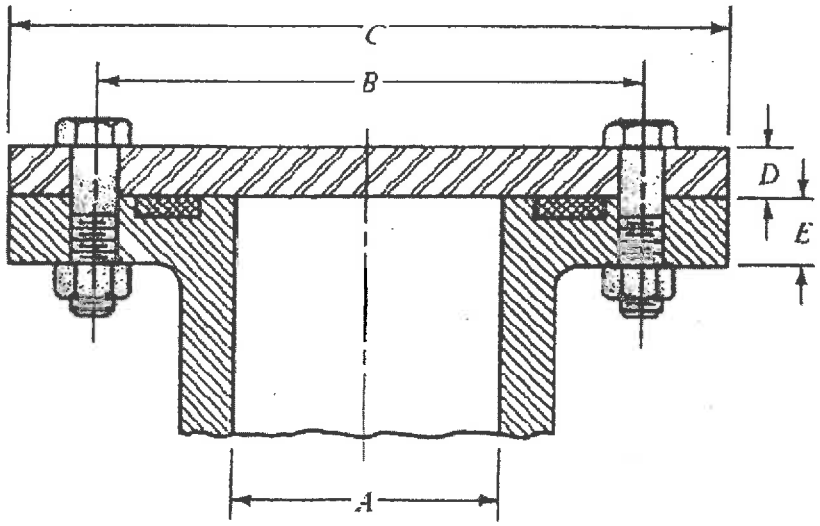
Part II Must Answer 3 questions of your choice

Problem 3. Design a single-surface disk clutch to transmit 100 N.m of torque at 750 rpm using a molded lining with a maximum pressure of 1.2 MPa and friction coefficient of 0.25. Assume uniform wear. Find the outside and inside diameters required using an inside to outside diametral ratio of 0.577. What is the power transmitted? **(20 marks)**

Problem 4. An overhung diving board is shown in the following figure with a cross-section of 305 mm x 32 mm. Find the largest principal stress that will result when a 70-kg person jumps up 25 cm at the free end and lands back on the board. Assume that the board weighs 25 kg and deflects 10 mm statically when the person stands on it. What is the static safety factor if the material has an ultimate stress of 130 MPa in the longitudinal direction? **(20 marks)**



Problem 5. The figure below illustrates the connection of a steel cylinder head to a steel pressure vessel using 10 bolts and a confined-gasket seal. The effective sealing diameter is 150 mm. The other dimensions are: $A = 100$ mm, $B = 200$ mm, $C = 300$ mm, $D = 20$ mm and $E = 25$ mm. The pressure vessel is used to store gas at a static pressure of 6 MPa. Metric 12 mm diameter bolts are to be used as they give a reasonable bolt spacing. The factor of safety for separation is to be at least 1.5 and the factor of safety for yielding is to be at least 2. Determine the required bolt preload and select a suitable grade of bolt. **(20 marks)**



Problem 6. For a single short-shoe drum brake with a drum width of 40 mm as shown in the following figure, find the torque capacity and required actuating force F_a for $a = 110$ mm, $b = 70$ mm, $e = 25$ mm, $r = 35$ mm, and $\theta = 40^\circ$. What value of c will make it self-locking? Assume the maximum allowable lining pressure is 1.3 MPa and the friction coefficient for the brake lining material is $\mu = 0$. **(20 marks)**