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.
- 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 Ocyrk number and the applied load, and what is the suggested Ocyrk 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 \(-200\text{ lb-in}\) to the maximum of \(500\text{ lb-in}\). If \( l = 17\text{ in} \), \( a = 6\text{ in} \), \( b = 12\text{ in} \), and \( P = 1500\text{ lb} \), 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 \(108\text{ ksi} \) and yield strength of \(62\text{ ksi} \). 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)
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<th>BEARING NUMBER*</th>
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<th>WIDTH inch</th>
<th>SNAP RING DIMENSIONS inches</th>
<th>MAX. F I L E T T R A D I A L R A D I U S &amp; H A U G H 1nch</th>
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* Bearing numbers listed are for open bearings only. For shields, seals and snap rings, add suffix or prefix indicated below bearing number. 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 124-127.

**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)