ME 423
Instructor: Ramesh Singh
Questionnaire #3 (Shafts, Bolts, Welded Joints, Bearings and Gears)
For practice not to be submitted (Quiz 2 will cover until bearings Q12)

1. A shaft is loaded in bending and torsion such that M_a =70N·m, T_a =45N·m, M_m = 55 N · m, and T_m = 35 N · m. For the shaft, S_u = 700 MPa and S_y = 560 MPa, and a fully corrected endurance limit of S_e = 210 MPa is assumed. Let K_f = 2.2 and K_{fs} = 1.8. With a design factor of 2.0 determine the minimum acceptable diameter of the shaft using the
   (a) DE-Gerber criterion.
   (b) DE-elliptic criterion.
   (c) DE-Soderberg criterion.
   (d) DE-Goodman criterion. Discuss and compare the results.

2. The rotating solid steel shaft is simply supported by bearings at points *B* and *C* and is driven by a gear (not shown) which meshes with the spur gear at *D*, which has a 150-mm pitch diameter (See Figure 3). The force *F* from the drive gear acts at a pressure angle of 20°. The shaft transmits a torque to point *A* of T_A =340 N · m. The shaft is machined from steel with Sy =420 MPa and Sut = 560 MPa. Using a factor of safety of 2.5, determine the minimum allowable diameter of the 250-mm section of the shaft based on (*a*) a static yield analysis using the distortion energy theory and (*b*) a fatigue-failure analysis. Assume sharp fillet radii at the bearing shoulders for estimating stress-concentration factors.

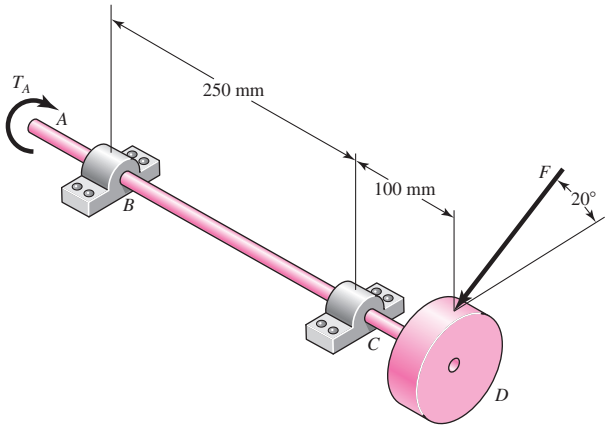

Fig. 3. Steel shaft with bearings

3. A 25 mm-diameter uniform steel shaft is 600 mm long between bearings.
   (a) Find the lowest critical speed of the shaft.
   (b) If the goal is to double the critical speed, find the new diameter.
   (c) A half-size model of the original shaft has what critical speed?

4. A 30-mm thick AISI 1020 steel plate is sandwiched between two 10-mm thick 2024-T3 aluminum plates and compressed with a bolt and nut with no washers. The bolt is M10 × 1.5, property class 5.8.

   (*a*) Determine a suitable length for the bolt, rounded up to the nearest 5 mm.
   (*b*) Determine the bolt stiffness.
   (*c*) Determine the stiffness of the members.

5. An M14 × 2 hex-head bolt with a nut is used to clamp together two 15-mm steel plates.

   (*a*) Determine a suitable length for the bolt, rounded up to the nearest 5 mm.
   (*b*) Determine the bolt stiffness.
   (*c*) Determine the stiffness of the members.

6. A 50-kN load is transferred from a welded fitting into a 200-mm steel channel as illustrated in Fig. 1. Estimate the maximum stress in the weld.

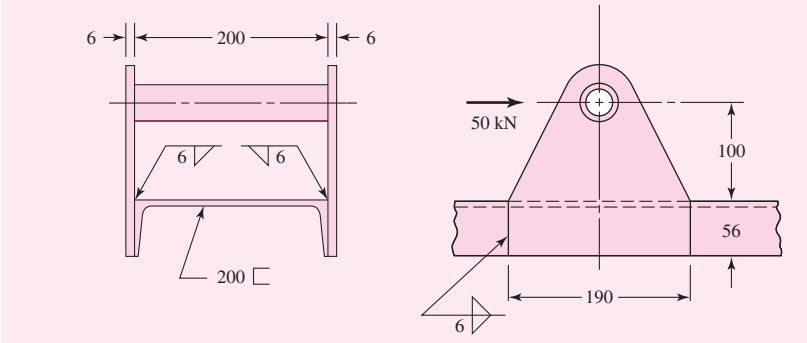

Fig. 1. Weld Geometry for problem 3

7. Perform an adequacy assessment of the statically loaded welded cantilever carrying 2.2 kN depicted in Fig. 2. The cantilever is made of AISI 1018 HR steel and welded with a 10 mm fillet weld as shown in the figure. An E6010 electrode was used, and the design factor was 3.0.
   a. Use the conventional method for the weld metal.
   b. Use the conventional method for the attachment (cantilever) metal.
   c. Use a welding code for the weld metal.

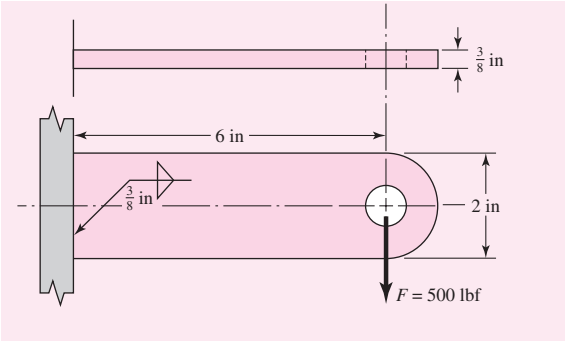

Fig. 2. Weld geometry for problem 4 (convert inches to mm for solving the problem)

8. A certain application requires a ball bearing with the inner ring rotating, with a design life of 25 kh at a speed of 350 rev/min. The radial load is 2.5 kN and an application factor of 1.2 is appropriate. The reliability goal is 0.90. Find the multiple of rating life required, x_D, and the catalog rating C10 with which to enter a bearing table. Choose a 02-series deep-groove ball bearing from Table 11–2, and estimate the reliability in use.

9. A straight (cylindrical) roller bearing is subjected to a radial load of 20 kN. The life is to be 8000 h at a speed of 950 rev/min and exhibit a reliability of 0.95. What basic load rating should be used in selecting the bearing from a catalog of manufacturer 2?

10. A journal bearing has a shaft diameter of 75.00 mm with a unilateral tolerance of -0.02 mm. The bushing bore has a diameter of 75.10 mm with a unilateral tolerance of 0.06 mm. The bushing is 36 mm long and supports a load of 2 kN. The journal speed is 720 rev/min. For the minimum clearance assembly find the minimum film thickness, the heat loss rate, and the maximum lubricant pressure for SAE 20 and SAE 40 lubricants operating at an average film temperature of 60 deg C.

11. Consider a pillow-block bearing with a keyway sump, whose journal rotates at 900 rev/min in shaft-stirred air at 70◦F with $\alpha = 1$. The lateral area of the bearing is 40 in^2. The lubricant is SAE grade 20 oil. The gravity radial load is 100 lbf and the l/d ratio is unity. The bearing has a journal diameter of 2.000 + 0.000/−0.002 in, a bushing bore of 2.002 + 0.004/−0.000 in. For a minimum clearance assembly estimate the steady-state temperatures as well as the minimum film thickness and coefficient of friction.

12. Determine h0 and e using the following given parameters: $\mu = 4$ μreyn, N = 30 rev/s, W = 500 lbf (bearing load), r = 0.75 in, c = 0.0015 in, and l = 1.5 in. Determine the coefficient of friction, the torque to overcome friction, and the power loss to friction.

13. A 21-tooth spur pinion mates with a 28-tooth gear. The diametral pitch is 3 teeth/in and the pressure angle is 20 deg. Make a drawing of the gears showing one tooth on each gear. Find and tabulate the following results: the addendum, dedendum, clearance, circular pitch, tooth thickness, and base-circle diameters; the lengths of the arc of approach, recess, and action; and the base pitch and contact ratio

14. For a spur gearset with $\varphi = 20^\circ$, while avoiding interference, find:
    (*a*) The smallest pinion tooth count that will run with itself
    (*b*) The smallest pinion tooth count at a ratio $m_G = 2.5$, and the largest gear tooth count possible with this pinion
    (*c*) The smallest pinion that will run with a rack