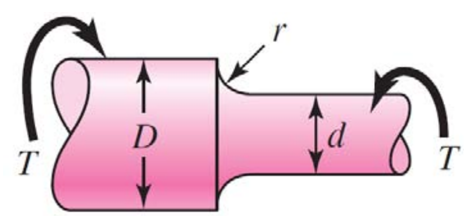
Sheet 1
Variable loading

1. Estimate S'_e for the following materials:
   a. AISI 1020 CD steel.
   b. AISI 1080 HR steel.
   c. 2024 T3 aluminum.
   d. AISI 4340 steel heat-treated to a tensile strength of 1700 MPa.

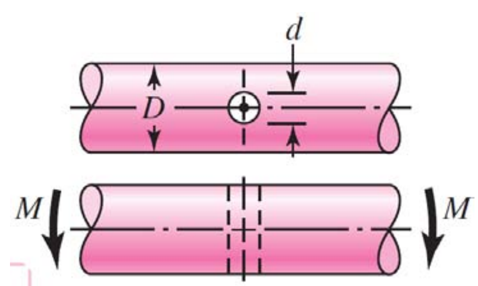
2. A 4130 Normalized steel has a mean ultimate tensile strength of S_{ut} = 670 MPa and a mean yield strength of 436 MPa.
   a. Estimate the endurance limit of the material.
   b. Estimate the endurance strength for a polished rotating-beam specimen corresponding to 104 cycles-to-failure.
   c. Estimate the expected life under a completely reversed stress of 380 MPa

3. The figure shows a grounded shaft (rotates) which is manufactured from 1095 Normalized. The ultimate tensile strength of S_{ut} = 1010 MPa and yield strength of 500 MPa. The shaft rotates at 150°C and suffers from variable torsion load.
   a. Calculate the allowable endurance limit in torsion with reliability of 99.99.
   b. If the midrange component of the stresses is 300 MPa and the amplitude component is 100 MPa, calculate the static factor of safety and the fatigue factor of safety using Modified Goodman method.

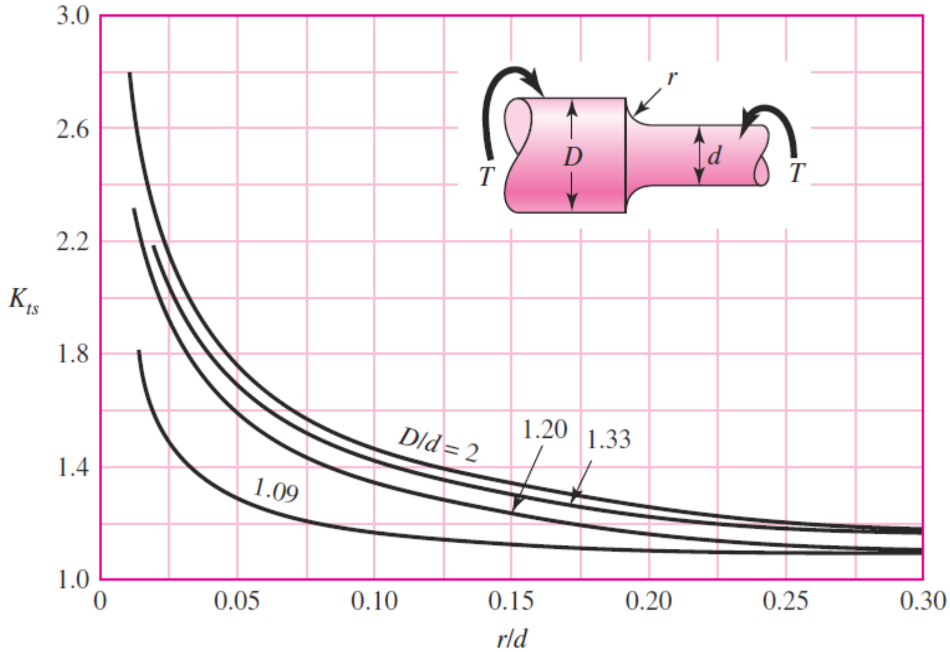


(D=50mm, d=30mm and r=1mm)

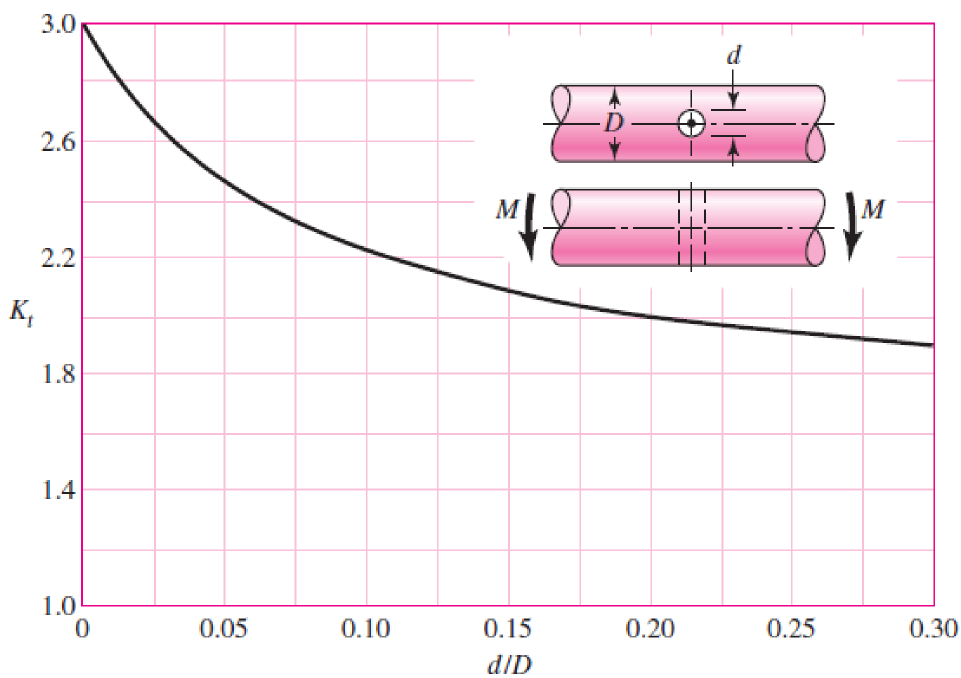
4. The figure shows a forged axel (doesn't rotate) which is manufactured from G10400 CD. The ultimate tensile strength of S_{ut} = 590 MPa and yield strength of 490 MPa. The axel works at 80°C and suffers from variable bending load.
   a. Calculate the allowable endurance limit in bending with reliability of 99.9.
   b. If the midrange component of the stresses is 250 MPa and the amplitude component is 150 MPa, calculate the static factor of safety and the fatigue factor of safety using ASME-Elliptic method.



(D=70mm and d=10mm



3.0
2.6
2.2
1.8
1.4
1.0
K_{ts}
0
0.05
0.10
0.15
0.20
0.25
0.30
r/d
D/d = 2
1.20
1.33
1.09
T
D
r
d
T

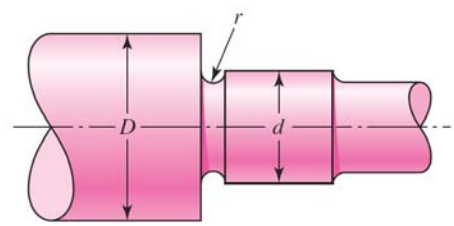


3.0
2.6
2.2
1.8
1.4
1.0
K_t
0
0.05
0.10
0.15
0.20
0.25
0.30
d/D
d
D
M
M

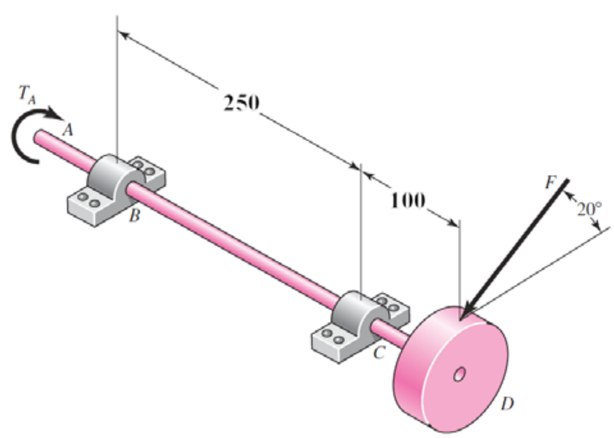
Sheet 2
Shaft Design

1. A shaft is loaded in bending and torsion such that M_a = 60 Nm, T_a = 40 Nm, M_m = 50 Nm, and T_m = 30 Nm. For the shaft, S_{ut} = 700 MPa and S_y = 550 MPa, and a fully corrected endurance limit of S_e = 200 MPa is assumed. Let K_f = 2.2 and K_{fs} = 1.8. With a design factor of safety n = 2. Determine the minimum acceptable diameter of the shaft.

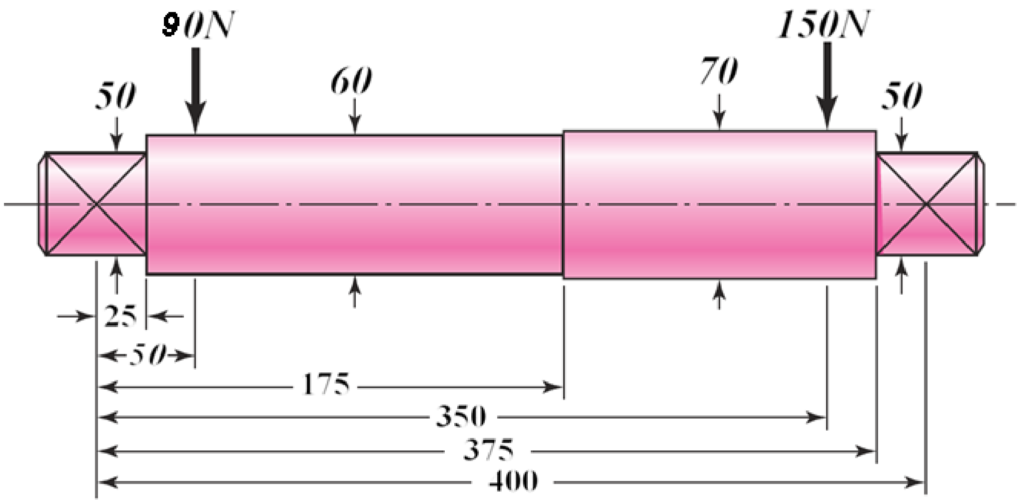
2. The section of shaft shown in the figure is to be designed to approximate relative sizes of d = 0.75D and r = D/20 with diameter d conforming to that of standard metric rolling-bearing bore sizes. The fillet radius range is from 1 to 3 mm. The shaft is to be made of SAE 2340 steel, heat-treated to obtain minimum strengths in the shoulder area of 1226 MPa ultimate tensile strength and 1130 MPa yield strength. At the shoulder the shaft is subjected to a completely reversed bending moment of 70 Nm, accompanied by a steady torsion of 45 Nm. Use a design factor of safety 2.5 and size the shaft for an infinite life.



3. 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 150mm pitch diameter. The force F from the drive gear acts at a pressure angle of 20º. The shaft transmits a torque to point A of T_A = 300 Nm. The shaft is machined from steel with S_y = 400 MPa and S_{ut} = 550 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. Static yield analysis.
   b. Fatigue-failure analysis. Assume 0.1mm fillet radii at the bearing shoulders for estimating stress concentration factors.



4. The shaft shown in the figure carries a 90 N gear on the left and a 150 N gear on the right. Estimate the first critical speed due to the loads, the shaft's critical speed without the loads, and the critical speed of the combination.



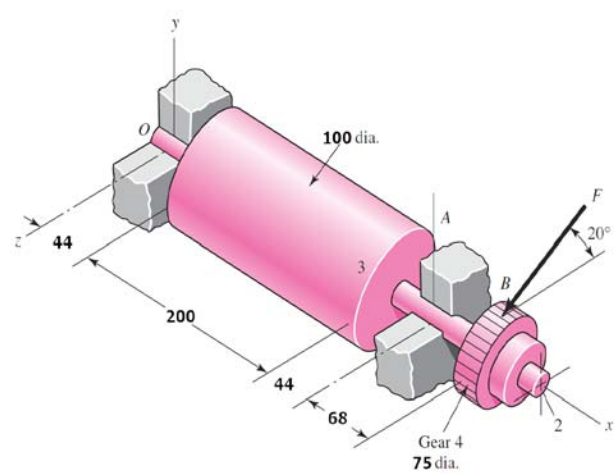
Sheet 3
Rolling bearing

1. A certain application requires a deep groove ball bearing with the inner ring rotating, with a design life of 30000 hour at a speed of 300 rpm. The radial load is 1.898 kN and an application factor of 1.2 is appropriate. The reliability goal is 0.90. Find the catalog basic load rating C with which to enter a bearing table.

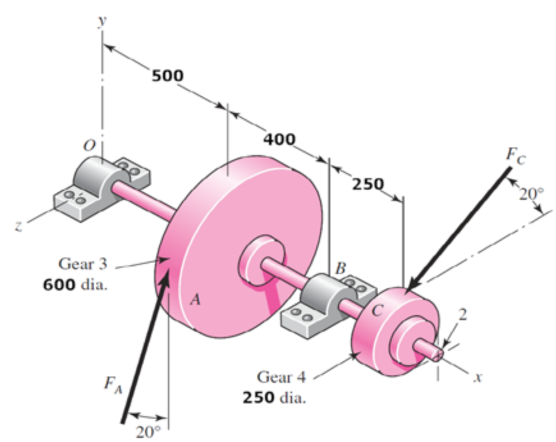
2. An angular-contact, inner ring rotating, ball bearing is required for an application in which the life requirement is 50000 h at 480 rpm. The design radial load is 2.7 kN. The application factor is 1.4. The reliability goal is 0.95. Find the catalog basic load rating C with which to enter a bearing table.

3. A deep groove – single raw ball bearing is to be selected to carry a radial load of 8 kN and a thrust load of 4 kN. The desired life L_D is to be 5000 h with an inner-ring rotation rate of 900 rpm. What is the basic load rating that should be used in selecting a bearing for a reliability goal of 0.90? If the reliability goal is 0.90, what will be the basic load rating?

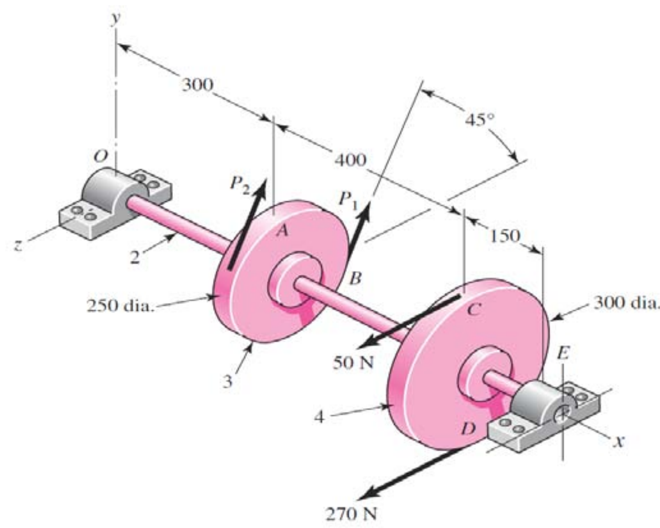
4. Shown in the figure is a gear-driven squeeze roll which mates with an idler roll, below. The roll is designed to exert a normal force of 5.25 N/mm of roll length and a pull of 4.2 N/mm on the material being processed. The roll speed is 300 rpm, and a design life of 30000 h is desired. Use an application factor of 1.2, and select a pair of angular-contact ball bearings to be mounted at 0 and A. Use the same size bearings at both locations and a combined reliability of at least 0.92.



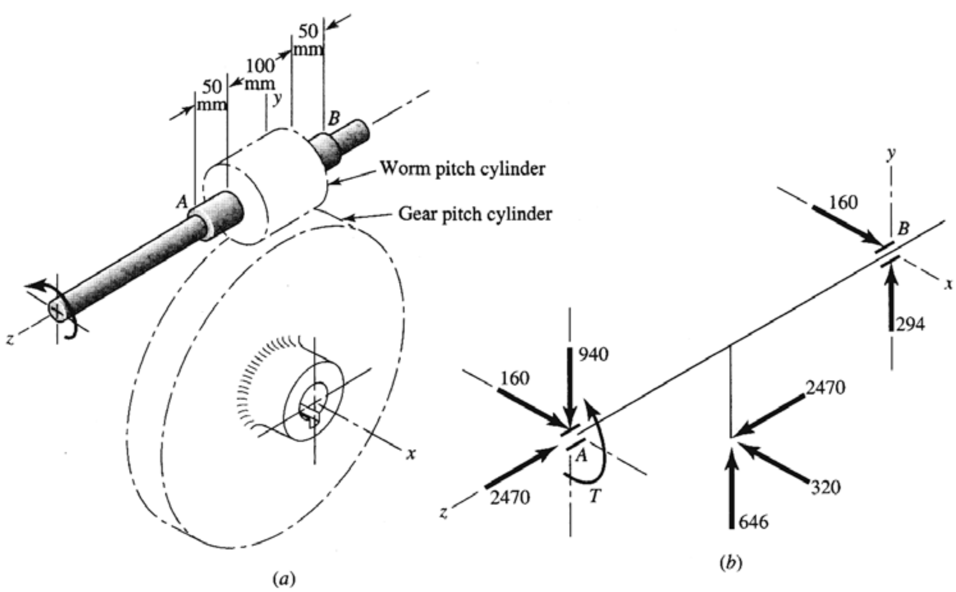
5. The figure shown is a geared countershaft with an overhanging pinion at C. Select an angular contact ball bearing from Table 11–2 for mounting at O and a straight roller bearing for mounting at B. The force on gear A is F_A = 2.65 kN and at gear C is F_C = 6.36 kN. The shaft runs at a speed of 480 rpm. Calculate the reactions at bearing O and B. Specify the bearings required, using an application factor of 1.4, a desired life of 50000 h, and a reliability of 0.90.



6. The figure is a schematic drawing of a countershaft that supports two V-belt pulleys. The countershaft runs at 1200 rev/min and the bearings are to have a life of 60 kh at a combined reliability of 0.999. The belt tension on the loose side of pulley A is 15 percent of the tension on the tight side. Select equal diameter deep-groove bearings for use at O and E. the bearing bore range is from 20 to 30 mm. use application factor equal unity.



7. The worm shaft shown in part *a* of the figure transmits 1 kW at 600 rpm. A static force analysis gave the results shown in part *b* of the figure. Bearing A is to be an angular-contact ball bearing mounted to take the 2470 N thrust load. The bearing at B is to take only the radial load, so a straight roller bearing will be employed. Use an application factor of 1.3, a desired life of 25 kh, and a reliability of 0.99. Specify each bearing.



Sheet 4
Spur and Helical gears

1. A 17-tooth spur pinion has a module of 3 mm, runs at 1200 rpm, and drives a gear at a speed of 600 rpm. Find the number of teeth on the gear and the theoretical center-to-center distance.

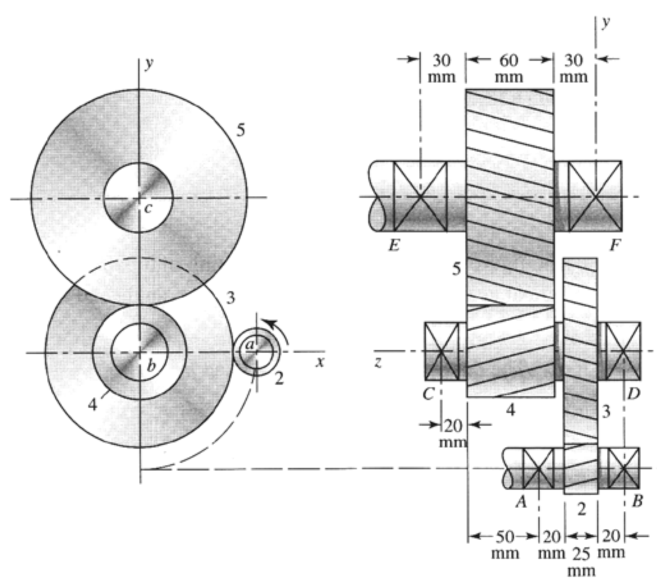
2. A 15-tooth spur pinion has a module of 3 mm and pressure angle of 20º. It runs at a speed of 1500 rpm. The driven gear has 60 teeth. Find the speed of the driven gear, the circular pitch, and the theoretical center-to-center distance. Calculate the contact ratio.

3. A parallel helical gearset uses a 17-tooth pinion driving a 34-tooth gear. The pinion has a right-helix angle of 30°, a normal pressure angle of 20°, and a normal module is 5.0 mm. the pinion width is 35 mm and gear width is 30 mm. Find the following:

    a. The normal and transverse circular pitches
    b. The normal base circular pitch
    c. The transverse diametral pitch and the transverse pressure angle
    d. The addendum, dedendum, and pitch diameter of each gear
    e. The contact ratio.

4. The double-reduction helical gearset shown in the figure is driven through shaft *a* at a speed of 900 rpm by 3 kW electric motor. Gears 2 and 3 have a normal module of 2.5 mm, a 30° helix angle, and a normal pressure angle of 20°. The second pair of gears in the train, gears 4 and 5, has a normal module of 4.0 mm, a 25° helix angle, and a normal pressure angle of 20°. The tooth numbers are: N_2 = 14, N_3 = 54, A_4 = 16, N_5 = 36. If the contact ratio is 1, Find:

    a. The directions of the thrust force exerted by each gear upon its shaft
    b. The speed and direction of shaft c
    c. The center distance between shafts
    d. Calculate the forces on each gear
    e. Calculate the reaction at each bearing
    f. Draw the Normal, bending, torsion and shear diagram for each shaft



5. A steel spur pinion has a module of 4.0 mm, 17 full-depth milled teeth, and a pressure angle of 20°. The gear width is 40 mm. The pinion has an ultimate tensile strength at the involute surface of 800 MPa, a Brinell hardness of 232, and yield strength of 620 MPa. Its shaft speed is 1120 rpm, its face width is 50 mm, and its mating gear has 51 teeth. The design safety factor is 2 and the service factor is 1.2 and the lubrication is normal.

    a. Calculate the contact ratio
    b. Calculate the transmitted power based on static bending stress.
    c. Calculate the safety margin for dynamic stress.
    d. Check the wear criteria.

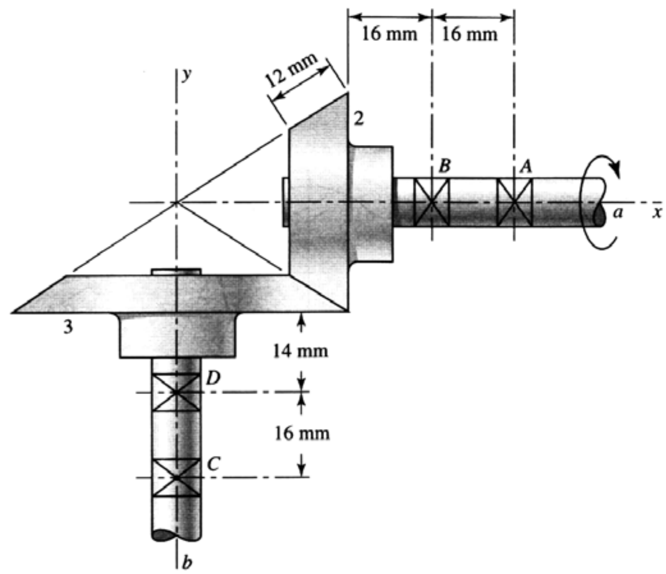
6. A steel spur pinion and gear have a module of 2.0 mm, milled teeth, 17 and 30 teeth, respectively, a 20° pressure angle, and a pinion speed of 525 rpm. The tooth material properties are S_u = 525 MPa, S_y = 290 MPa and the Brinell hardness is 149. For a design safety factor of 2.25, a face width of 22 mm, what is the power rating of the gearset?

7. A steel helical pinion has a module of 4.0 mm, 17 full-depth milled teeth. The pressure angle is 20° and the helix angle is 15°. The gear width is 40 mm. The pinion has an ultimate tensile strength at the involute surface of 800 MPa, a Brinell hardness of 232, and yield strength of 620 MPa. Its shaft speed is 1120 rpm, its face width is 50 mm, and its mating gear has 51 teeth. The design safety factor is 2 and the service factor is 1.2 and the lubrication is normal.

    a. Calculate the contact ratio
    b. Calculate the transmitted power based on static bending stress.
    c. Calculate the safety margin for dynamic stress.
    d. Check the wear criteria.

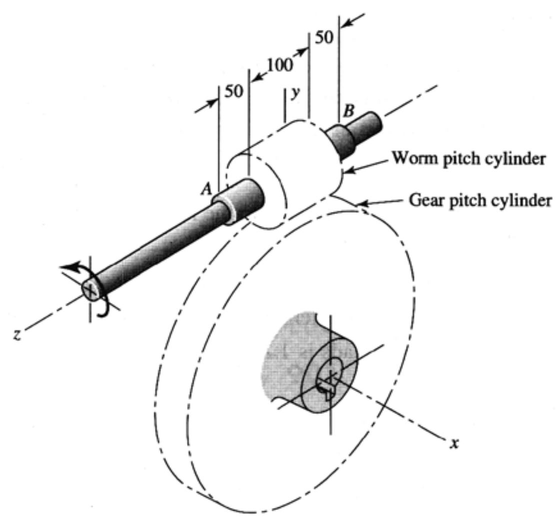
Sheet 5
Bevel and Worm gears

1. The figure shows a 2.5 mm module 15-tooth 20° straight bevel pinion driving a 25-tooth gear. The input speed is 100 rpm. The transmitted power is 2.5 kW. The gears material is Hardened steel grade 8630 with S_u=550 MPa, S_y=345 MPa and BHN=185.



   a. If the bearings at B and D take thrust and radial loads and the bearings A and C take radial load only. Find the bearing reactions at A, B, C and D on both shafts.
   b. Calculate the static bending factor of safety
   c. Calculate the dynamic load factor of safety
   d. Calculate the limiting load of wear factor of safety
   e. If the gear is unsafe what are your suggestions. Check their validity.

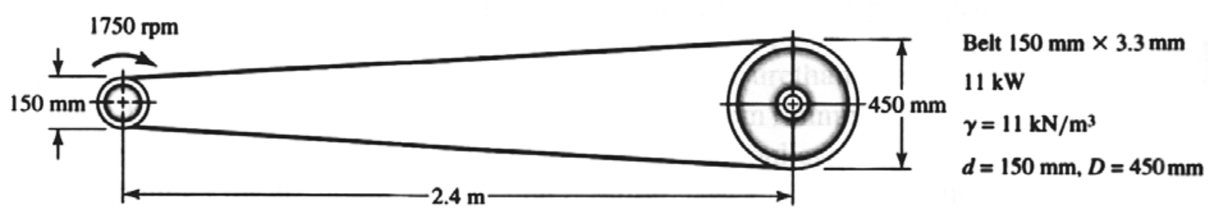
2. A right-hand single-tooth hardened-steel worm has a catalog rating of 2000 W at 10 rev/s when meshed with a 48-tooth cast-iron gear. The module of the worm is 4 mm, the normal pressure angle is 20°, the pitch diameter of the worm is 80 mm, and the face widths of the worm and gear are, respectively, 100 mm and 50 mm. The worm material is hardened Steel grade 4142 with S_u=655 MPa, S_y=415 MPa and BHN=205. The gear material is Bronze alloy grade C95300 with S_u=450 MPa, S_y=170 MPa and BHN=120.



   a. The figure shows bearing A and B on the worm shaft symmetrically located with respect to the worm and 200 mm apart. Determine which should be the thrust bearing, and find the magnitudes and directions of the forces exerted by both bearings.
   b. Check the gear set safety
   c. If it is not safe, give your suggestion and prove it

Sheet 6
Belts

1. A polyamide A-3 flat belt 150 mm wide is used to transmit 11 kW under light shock conditions where Ks = 1.25, and a factor of safety equal to or greater than 1.1 is appropriate. The pulley rotational axes are parallel and in the horizontal plane. The shafts are 2.4 m apart. The 150-mm driving pulley rotates at 1750 rev/min in such a way that the loose side is on top. The driven pulley is 450 mm in diameter.
   a. Estimate the centrifugal tension F_c and the torque T.
   b. Estimate the allowable F_1, F_2, F_i, and allowable power H_a.
   c. Estimate the factor of safety. Is it satisfactory?



2. Design a flat belt-drive to connect horizontal shafts on 4.8 m centers. The velocity ratio is to be 2.25:1. The rotation speed of the small driving pulley is 860 rpm and nominal power transmission is to be 44760 W under very light shock.

3. A 7.46 kW split-phase motor, running at 1750 rpm, is used to drive a rotor pump, which operates 24 hours per day. An engineer has specified a 188 mm small sheave, a 280 mm large sheave, and three B2800 belts. The service factor of 1.3 is used. Analyze the drive and estimate the belt life in hours.

4. Two shaft 6 m apart, with axis in the same horizontal plan, are to be connected with a V belt. The driving pulley is powered by an electric motor with a 75 kW rating power at 1140 rpm. The driven shaft has half of the rotation speed at light-shock machinery load. Select the suitable V belt with safety factor of 1.4.