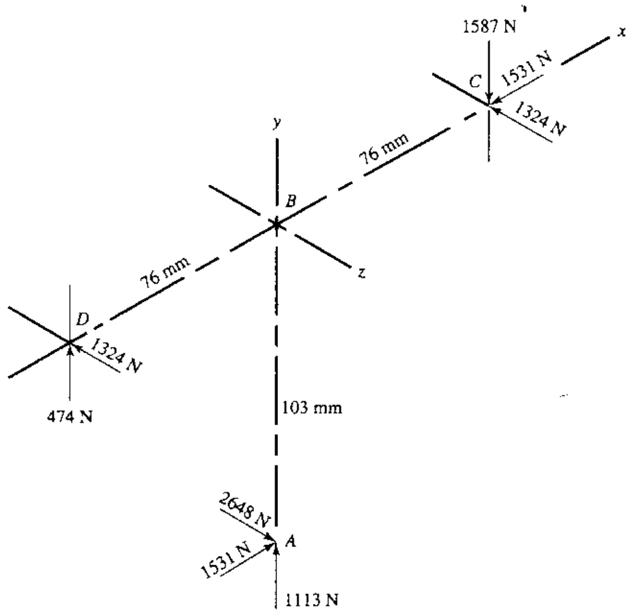
**EXAMPLE 11-7** The second shaft on a parallel-shaft 18.7 kW foundry crane speed reducer contains a helical gear with a pitch diameter of 205 mm. Helical gears transmit components of force in the tangential, radial, and axial directions (see Chap. 13). The components of the gear force transmitted to the second shaft are shown in Fig. 11–12, at point *A*. The bearing reactions at *C* and *D*, assuming simple-supports, are also shown. A ball bearing is to be selected for location *C* to accept the thrust, and a cylindrical roller bearing is to be utilized at location *D*. The life goal of the speed reducer is 10 kh, with a reliability factor for the ensemble of all four bearings (both shafts) to equal or exceed 0.96 for the Weibull parameters of Ex. 11–3. The application factor is to be 1.2.

**Figure 11-12**

Forces in pounds applied to the second shaft of the helical gear speed reducer of Ex. 11–7.




(*a*) Select the roller bearing for location *D*.

(*b*) Select the ball bearing (angular contact) for location *C*, assuming the inner ring rotates.

Solution The torque transmitted is $T = 2.648(0.103) = 0.2727$ kN·m. The speed at the rated horsepower, given by Eq. (3–41), p. 138, is

$$n_D = \frac{9.55H}{T} = \frac{9.55(18.7)}{0.2727} = 655 \text{ rev/min}$$

The radial load at $D$ is $(1324^2 + 474^2)^{0.5} = 1406$ N, and the radial load at $C$ is $(1587^2 + 1324^2)^{0.5} = 2067$ N. The individual bearing reliabilities, if equal, must be at least $\sqrt[4]{0.96} = 0.98985 \doteq 0.99$. The dimensionless design life for both bearings is

$$x_D = \frac{L}{L_{10}} = \frac{60L_D n_D}{60L_R n_R} = \frac{60(10\,000)655}{10^6} = 393$$

(*a*) From Eq. (11–7), the Weibull parameters of Ex. 11–3, an application factor of 1.2, and $a = 10/3$ for the roller bearing at $D$, the catalog rating should be equal to or greater than

$$C_{10} = a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}}\right]^{1/a}$$

$$= 1.2(1406)\left[\frac{393}{0.02 + 4.439(1 - 0.99)^{1/1.483}}\right]^{3/10} = 16.0 \text{ kN}$$

Answer The absence of a thrust component makes the selection procedure simple. Choose a 02-25 mm series, or a 03-25 mm series cylindrical roller bearing from Table 11–3.

($b$) The ball bearing at $C$ involves a thrust component. This selection procedure requires an iterative procedure. Assuming $F_a/(VF_r) > e$,

1. Choose $Y_2$ from Table 11–1.
2. Find $C_{10}$.
3. Tentatively identify a suitable bearing from Table 11–2, note $C_0$.
4. Using $F_a/C_0$ enter Table 11–1 to obtain a new value of $Y_2$.
5. Find $C_{10}$.
6. If the same bearing is obtained, stop.
7. If not, take next bearing and go to step 4.

As a first approximation, take the middle entry from Table 11–1:

$$X_2 = 0.56 \qquad Y_2 = 1.63.$$

From Eq. (11–8$b$), with $V = 1$,

$$\frac{F_e}{VF_r} = X + \frac{Y}{V}\frac{F_a}{F_r} = 0.56 + 1.63\frac{1531}{(1)2067} = 1.77$$

$$F_e = 1.77VF_r = 1.77(1)2067 = 3.66 \text{ kN}$$

From Eq. (11–7), with $a = 3$,

$$C_{10} = 1.2(3.66)\left[\frac{393}{0.02 + 4.439(1 - 0.99)^{1/1.483}}\right]^{1/3} = 53.4 \text{ kN}$$

From Table 11–2, angular-contact bearing 02-60 mm has $C_{10} = 55.9$ kN. $C_0$ is 35.5 kN. Step 4 becomes, with $F_a$ in kN,

$$\frac{F_a}{C_0} = \frac{1.531}{35.5} = 0.0431$$

which makes $e$ from Table 11–1 approximately 0.24. Now $F_a/[V\,F_r] = 1531/[(1)\,2067] = 0.74$, which is greater than 0.24, so we find $Y_2$ by interpolation:

| $F_a/C_0$ | $Y_2$ | |
|---|---|---|
| 0.042 | 1.85 | |
| 0.043 | $Y_2$ | from which $Y_2 = 1.84$ |
| 0.056 | 1.71 | |

From Eq. (11–8$b$),

$$\frac{F_e}{VF_r} = 0.56 + 1.84\frac{1531}{2067} = 1.9$$

$$F_e = 1.92VF_r = 1.9(1)2067 = 3.93$$

The prior calculation for $C_{10}$ changes only in $F_e$, so

$$C_{10} = \frac{3.93}{3.66}53.4 = 57.3 \text{ kN}$$

From Table 11–2 an angular contact bearing 02-65 mm has $C_{10} = 63.7$ kN and $C_0$ of 41.5 kN. Again,

$$\frac{F_a}{C_0} = \frac{1.531}{41.5} = 0.0369$$

making $e$ approximately 0.23. Now from before, $F_a/VF_r = 0.74$, which is greater than 0.23. We find $Y_2$ again by interpolation:

| $F_a/C_0$ | $Y_2$ | |
|---|---|---|
| 0.028 | 1.99 | |
| 0.0369 | $Y_2$ | from which $Y_2 = 1.90$ |
| 0.042 | 1.85 | |

From Eq. (11–8$b$),

$$\frac{F_e}{VF_r} = 0.56 + 1.90\frac{1531}{2067} = 1.967$$

$$F_e = 1.967VF_r = 1.967(1)2067 = 4.065\text{kN}$$



The prior calculation for $C_{10}$ changes only in $F_e$, so

$$C_{10} = \frac{4.07}{3.66}53.4 = 59.4 \text{ kN}$$

Answer From Table 11–2 an angular-contact 02-65 mm is still selected, so the iteration is complete.