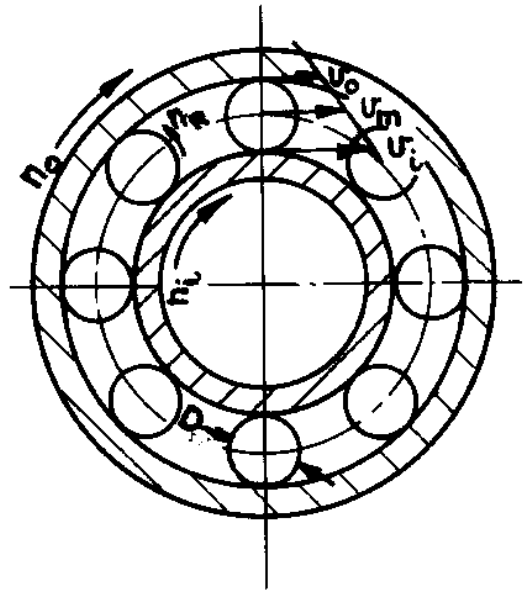
Example 10.1 Ball and Cage Speeds in a Deep-Groove Ball Bearing



Problem Statement

The 209 DGBB of Ex. 7.1 rotates at shaft speed 1800 rpm. Estimate the cage and ball speeds.

Problem Solution

Ex. (2.1) $\alpha^0 = 0$E
$D = 12.7$ mm (0.50 in.)
$d_m = 65$ mm (2.559 in.)

Ex. (2.5) $\gamma = 0.1954$

Eq. (10.13) $$n_m = \frac{n_i}{2}(1-\gamma) = \frac{1800}{2}(1-0.1954) = 724.1 rpm$$

Eq. (10.14) $$n_R = \frac{d_m n_i}{2D}\left(1-\gamma^2\right) = \frac{65 \cdot 1800}{2 \cdot 12.7}\left(1-0.1954^2\right) = 4430 rpm$$

Example 10.2 Friction Torque in a Radial Cylindrical Roller Bearing

Problem Statement

Estimate the total friction torque of a 209 CRB bath-lubricated with a 20 cSt mineral oil supporting a radial load of 4450 N and rotating at shaft speed of 10000 rpm.

Problem Solution

Ex. (2.7)

$\alpha = 0$E
$D = 10$ mm (0.3937 in.)
$d_m = 65$ mm (2.559 in.)
$\gamma = 0.1538$
$Z = 14$ rollers
$l = 9.6$ mm (0.378 in.)

Eq. (10.17) $$M_l = f_1 F_\beta d_m$$

Table 10.3 **assume $f_1 = 0.0003$**

$$M_l = 0.0003 \cdot 4450 \cdot 65 = 86.78 N \cdot mm (0.7677 in. \cdot lb)$$

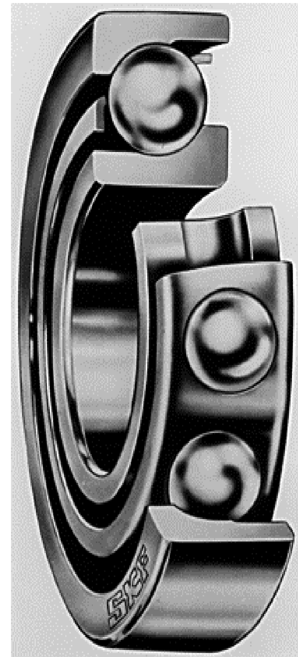
Eq. (10.23) $$M_v = 10^{-7} f_0 (\nu_0 n)^{2/3} d_m^3$$

Table 10.4 **for oil bath lubrication, $f_0 = 3$ for a medium series bearing.**

$$M_v = 10^{-7} \cdot 3 \cdot (20 \cdot 10000)^{2/3} \cdot (65)^3 = 281.8 N \cdot mm (2.493 in. \cdot lb)$$

Eq. (10.26) $$M = M_l + M_v + M_f = 86.8 + 281.8 + 0 = 368.6 N \cdot mm (3.261 in. \cdot lb)$$

Example 10.3 Friction Torque in an Angular-Contact Ball Bearing



Problem Statement

Estimate the rolling friction torque and viscous friction torque of a 218 ACBB jet oil-lubricated with a 5 cSt mineral oil, supporting a thrust load of 22250 N (5000 lb), and rotating at shaft speed of 10000 rpm.

Problem Solution

Ex. (2.3) $\alpha = 40°$
$D = 22.23$ mm (0.875 in.)
$f = 0.52$

Ex. (2.5) $Z = 16$ balls

Ex. (2.6) $d_m = 125.3$ mm (4.932 in.)
$\gamma = 0.1359$

Eq. (9.8)

$$C_s = \phi_s iZD^2 \cos\alpha$$

Table 9.2 **at $\gamma = 0.1359$, $\varphi_s = 15.48$**

$$C_s = 15.48 \cdot 1 \cdot 16 \cdot (22.23)^2 \cos 40° = 93760N(21{,}070lb)$$

Eq. (9.15) $F_s = X_s F_r + Y_s F_a$

Table 9.4 **$X_s = 0.5$, $Y_s = 0.26$**

$$F_s = 0.5 \cdot 0 + 0.26 \cdot 22250 = 5785N(1300lb)$$

Eq. (10.18) $f_1 = z\left(\frac{F_s}{C_s}\right)^y$

Table 10.1 **for $\alpha = 40°$, $z = 0.001$ and $y = 0.33$**

$$f_1 = 0.001\left(\frac{5785}{93769}\right)^{0.33} = 3.988 \cdot 10^{-4}$$

Eq. (10.20) $$F_\beta = 0.9F_a \cot\alpha^0 - 0.1F_r$$

$$F_\beta = 0.9 \cdot 22250 \cot 40° - 0.1 \cdot 0 = 23860N(5363lb)$$

Eq. (10.17) $$M_l = f_1 F_\beta d_m = 3.988 \cdot 10^{-4} \cdot 23860 \cdot 125.3 = 1192N \cdot mm(10.55in. \cdot lb)$$

Eq. (10.23) $$M_v = 10^{-7} f_0 (\nu_0 n)^{2/3} d_m^3$$

Table 10.3 **for jet oil lubrication $f_0 = 6.6$**

$$M_v = 10^{-7} \cdot 6.6 \cdot (5 \cdot 10000)^{2/3} \cdot (125.3)^3 = 1762N \cdot mm(15.59in. \cdot lb)$$

Eq. (10.26)

$$M = M_l + M_v + M_f = 1192 + 1762 + 0 = 2954N \cdot mm(26.13in. \cdot lb)$$

Example 10.4 Friction Torque in a Radial Needle Roller Bearing

Problem Statement

Estimate the friction torque of a drawn cup, radial needle roller bearing operating in a heavy truck manual transmission clutch. The bearing pitch has a pitch diameter of 20 mm (0.787 in.), operates with a radial load of 51 N (11.5 lb), and rotates at a shaft speed of 3500 rpm in SAE 50 weight oil with a viscosity of 94 cSt at operating temperature.

Problem Solution

Eq. (10.28)

$$M = d_m\left(4.5\times10^{-7}\nu_0^{0.3}n^{0.6} + 0.12F_r^{0.41}\right)$$

$$M = 20\left[4.5\times10^{-7}\left(94^{0.3}\right)\left(3500^{0.6}\right) + 0.12\left(51^{0.41}\right)\right]$$

$$M = 12.04 N\cdot mm\left(0.1065 in.\cdot lb\right)$$

Example 10.5 Friction Torque in a Needle Roller Thrust Bearing

Problem Statement

Estimate the friction torque of a needle roller thrust bearing operating in a heavy truck manual transmission clutch. The bearing pitch has a pitch diameter of 46 mm (1.81 in.) and length of 2.6 mm (0.102 in.), operates with a thrust load of 825 N (185.5 lb), and rotates at a shaft speed of 3500 rpm in SAE 50 weight oil with a viscosity of 94 cSt at operating temperature.

Problem Solution

Eq. (10.29)

$$M = 4.5\times10^{-7}\nu_0^{0.3}n^{0.6}d_m + 0.016F_a l$$

$$M = 4.5\times10^{-7}\left(94^{0.3}\right)(3500)^{0.6}(46) + 0.016(825)(2.6)$$

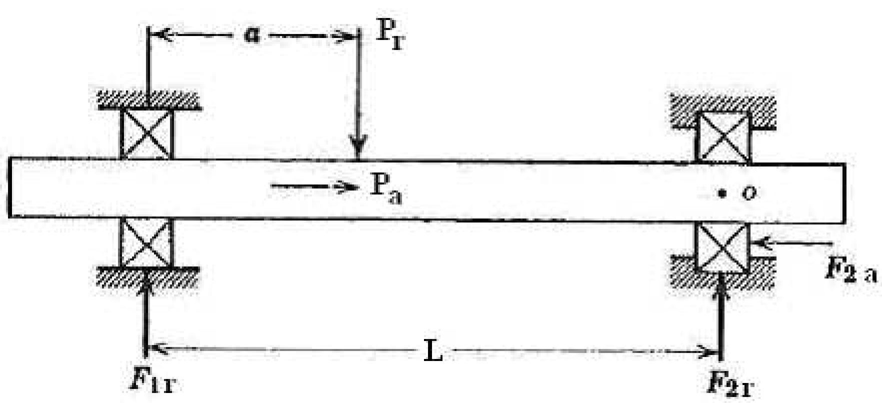
$$M = 34.33N\cdot mm(0.3039in.\cdot lb)$$

Example 10.6 Friction Torque in a Tapered Roller Bearing

Problem Statement

Estimate the friction torque of a tapered roller bearing mounted in the #2 position on a double reduction-parallel shaft industrial gearbox, where the low speed shaft contains a helical gear. The applied separating (radial) and thrust (axial) load associated with the gear set are 144,800 N (32,560 lb) and 37,300 N (8386 lb) respectively. The shaft rotates at 70 rpm with splash oil lubrication. The lubricant is an AGMA 5 with a viscosity of 32 cSt at operating temperature. The distance between bearing effective centers (*L*) is 60 mm (2.36 in.) and the gear center (*a*) is at a distance of 16 mm (0.63 in.) from bearing position #1 effective center. Both bearing positions use a 30228 series tapered roller bearing with the following dimensions:

- **d_m = 200 mm (7.87 in.)**
- **D = 23.5 mm (0.93 in.)**
- **l = 27 mm (1.06 in.)**
- **Z = 24**
- **α = 16.2°**
- **K = 1.34**

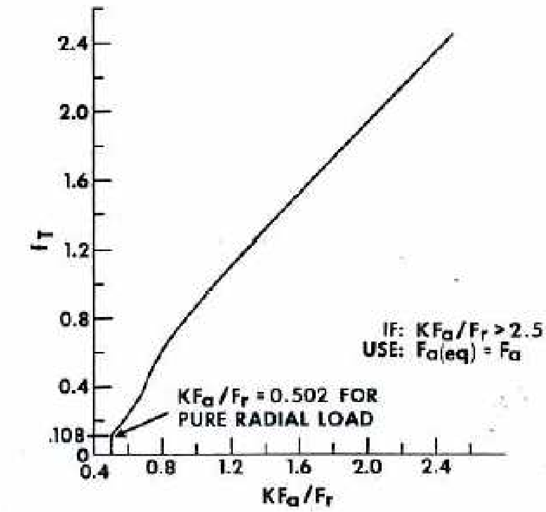


Problem Solution

Eq. (4.6)

$$F_{2r} = P\frac{a}{L} = 144800\frac{16}{60} = 38{,}613N(8681lb)$$

$$F_{2a} = P_a = 37{,}300N(8386lb)$$



$$K\frac{F_{2a}}{F_{2r}} = 1.34\frac{37{,}300}{38{,}613} = 1.29$$

Fig. (10.2) $f_T = 1.2$

Eq. (10.32)

$$G = d_m^{3/2} D^{1/6} (Z \cdot l)^{2/3} (\sin\alpha)^{-1/3}$$

$$G = \left(200^{3/2}\right)\left(23.5^{1/6}\right)(24 \cdot 27)^{2/3} (\sin(16.2))^{-1/3}$$

$$G = 548{,}584\,(288.8)$$

Eq. (10.30)

$$M = 3.76\times10^{-6} \cdot G(n\nu_0)^{1/2}\left(f_t \frac{F_r}{K}\right)^{1/3}$$

$$M = 3.76\times10^{-6} \cdot 548{,}584 \cdot (70 \cdot 32)^{1/2}\left(1.2 \cdot \frac{38{,}613}{1.34}\right)^{1/3}$$

$$M = 3180 N \cdot mm (28.1 in \cdot lb)$$

Example 10.7 Friction Torque in a Tapered Roller Bearing

Problem Statement

Estimate the friction torque of the tapered roller bearing mounted in the #1 position on a double reduction-parallel shaft industrial gearbox of Example 10.6.

Problem Solution

Ex. (10.6)

$$P_r = 144{,}800N(32{,}560lb)$$
$$P_a = 37{,}300N(8386lb)$$
$$L = 60mm(2.36in.)$$
$$a = 16mm(0.63in.)$$
$$n = 70rpm$$
$$\nu_0 = 32cSt$$
$$G = 548{,}584\,(288.8)$$
$$K = 1.34$$

Eq. (4.5)

$$F_{1r} = P\left(1-\frac{a}{L}\right) = 144800\left(1-\frac{16}{60}\right) = 106{,}187N(23{,}872lb)$$
$$F_{1a} = 0N(0lb)$$

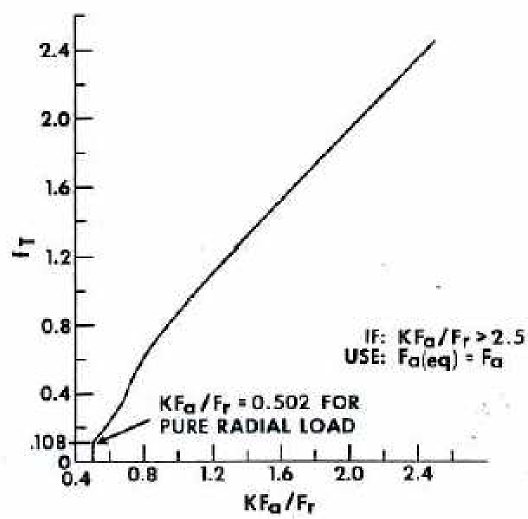


Fig. (10.2)

$$f_T = 1.08$$

Eq. (10.30)

$$M = 3.76\times10^{-6}\cdot G(n\nu_0)^{1/2}\left(f_t\frac{F_r}{K}\right)^{1/3}$$

$$M = 3.76\times10^{-6}\cdot 548{,}584\cdot(70\cdot 32)^{1/2}\left(1.08\cdot\frac{106{,}187}{1.34}\right)^{1/3}$$

$$M = 4301N\cdot mm(38.0in\cdot lb)$$