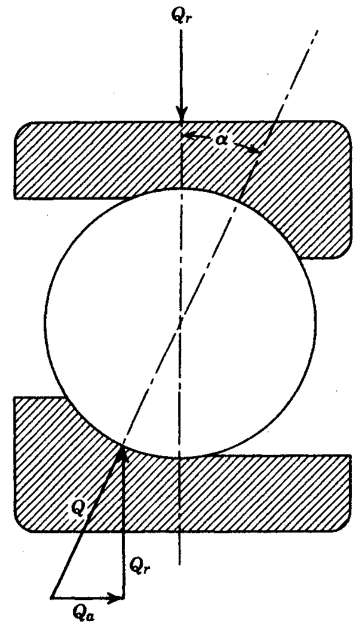
# *Example 6.1* Ball-Raceway Contact Stresses and Deformations

## Problem Statement




**For the 218 ACBB of Example 5.2 determine the maximum normal contact stresses and contact deformations**

## Problem Solution

**Eq. (2.27)** $$\gamma = \frac{D}{d_m}\cos\alpha = \frac{22.23}{125.3}\cos 38.9° = 0.1381$$

**Since this value is only slightly larger than the 0.1359 value of Ex. 2.6 and since we shall use Fig. 6.4 to determine $a_i^*$, $b_i^*$, and $\delta_i^*$, the values of $\Sigma\rho_i$, $\Sigma\rho_o$, $F(\rho)_i$, and $F(\rho)_o$ calculated in Example 2.6 will be used here.**

**Fig. 6.4** $a_i^* = 3.50$, $b_i^* = 0.430$ and $\delta_i^* = 0.630$

**Eq. (6.39)** $$a_i = 0.0236 a_i^* \left(\frac{Q_i}{\Sigma\rho_i}\right)^{1/3} = 0.0236\cdot 3.50\left(\frac{3543}{0.108}\right)^{1/3} = 2.64mm$$

**Eq. (6.41)** $$b_i = 0.0236 b_i^* \left(\frac{Q_i}{\Sigma\rho_i}\right)^{1/3} = 0.0236\cdot 0.430\left(\frac{3543}{0.108}\right)^{1/3} = 0.324mm$$

**Eq. (6.47)** $$\sigma_i = \frac{3Q_i}{2\pi a_i b_i} = \frac{3\cdot 3543}{2\pi\cdot 2.64\cdot 0.324} = 1976MPa$$

**Eq. (6.43)** $$\delta_i = 2.79\cdot 10^{-4}\delta_i^* Q_i^{2/3}\Sigma\rho_i^{1/3} = 2.79\cdot 10^{-4}\cdot 0.630\cdot(3543)^{2/3}\cdot(0.108)^{1/3} = 0.0195mm$$

**Fig. 6.4** $a_o^* = 3.10$, $b_o^* = 0.455$ and $\delta_o^* = 0.672$

**Eq. (6.39)** $$a_o = 0.0236 a_o^* \left(\frac{Q_o}{\Sigma\rho_o}\right)^{1/3} = 0.0236\cdot 3.10\left(\frac{3543}{0.0832}\right)^{1/3} = 2.56mm$$

**Eq. (6.41)** $$b_o = 0.0236 b_o^* \left(\frac{Q_o}{\Sigma\rho_o}\right)^{1/3} = 0.0236\cdot 0.455\left(\frac{3543}{0.0832}\right)^{1/3} = 0.3754mm$$

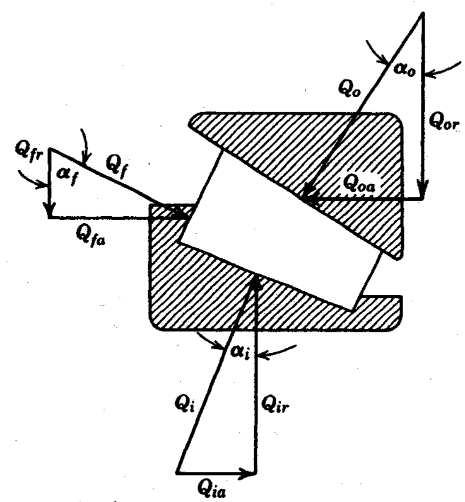
**Eq. (6.47)** $$\sigma_o = \frac{3Q_o}{2\pi a_o b_o} = \frac{3\cdot 3543}{2\pi\cdot 2.56\cdot 0.3754} = 1762MPa$$

**Eq. (6.43)** $$\delta_o = 2.79\cdot 10^{-4}\delta_o^* Q_o^{2/3}\Sigma\rho_o^{1/3} = 2.79\cdot 10^{-4}\cdot 0.672\cdot (3543)^{2/3}\cdot (0.0832)^{1/3} = 0.01902mm$$

**Note that** $\sigma_{i,max} > \sigma_{o,max}$

This is true for most ball and roller bearings; i.e., contact normal stress is greater at the inner raceway contact than at the outer raceway contact.

# *Example 6.2* Roller-Raceway Contact Stresses and Deformations




## Problem Statement

**Estimate the maximum normal contact stress and deformation at the inner raceway of the 90000 series TRB of Ex. 5.3**

## Problem Solution

**Eq. (2.27)** $$\gamma = \frac{D}{d_m}\cos\alpha = \frac{22.86}{142.2}\cos 22° = 0.1490$$

**Eq. (2.37)** $$\Sigma\rho_i = \frac{1}{D}\left(\frac{2}{1-\gamma_i}\right) = \frac{1}{22.86}\left(\frac{2}{1-0.1490}\right) = 0.1028mm^{-1}$$

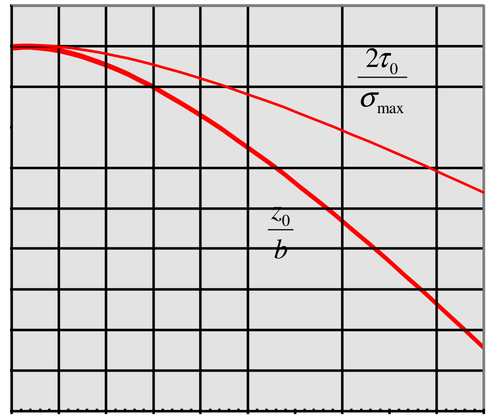
**Eq. (6.52)** $$b_i = 3.35\cdot10^{-3}\left(\frac{Q_i}{l\Sigma\rho_i}\right)^{1/2} = 3.35\cdot10^{-3}\left(\frac{59410}{30.48\cdot0.1028}\right)^{1/2} = 0.461mm$$

**Eq. (6.49)** $$\sigma_{i,\max} = \frac{2Q_i}{\pi l b_i} = \frac{2\cdot59410}{\pi\cdot30.38\cdot0.461} = 2692MPa$$

**Because this roller has a straight profile and is heavily loaded, very high edge stresses will occur that will cause rapid fatigue failure. The roller needs to be properly crowned to avoid the edge stresses!**

**Eq. (6.54)** $$\delta_i = 3.85\cdot10^{-5}\frac{Q_i^{0.9}}{l^{0.8}} = 3.85\cdot10^{-5}\frac{(59410)^{0.9}}{(30.48)^{0.8}} = 0.0491mm$$

## *Example 6.3* Ball-Raceway Contact Subsurface Stresses




### Problem Statement

**For the 218 ACBB of Ex. 6.1 determine the maximum orthogonal shear stress and depth below the surface where it occurs for the inner and outer raceways**

### Problem Solution

Ex. 6.1 $a_i$ = 2.64 mm (0.1040 in.)

Ex. 6.1 $b_i$ = 0.324 mm (0.0.01277 in.)

$$\frac{b_i}{a_i} = \frac{0.324}{2.64} = 0.1227$$

**Fig. 6.14** $\frac{2\tau_{0i}}{\sigma_{i,\max}} = 0.498$ **and** $\frac{z_{0i}}{b_i} = 0.493$

$$\tau_{0i} = 0.249\sigma_{i,\max} = 0.249 \cdot 1976 = 492MPa$$

$$z_{0i} = 0.493b_i = 0.493 \cdot 0.324 = 0.160mm$$

Ex. 6.1 $a_o$ = 2.558 mm (0.1007 in.)

Ex. 6.1 $b_o$ = 0.375 mm (0.0.01478 in.)

$$\frac{b_o}{a_o} = \frac{0.375}{2.558} = 0.1468$$

**Fig. 6.14** $\frac{2\tau_{0o}}{\sigma_{o,\max}} = 0.497$ **and** $\frac{z_{0o}}{b_o} = 0.491$

$$\tau_{0o} = 0.2485\sigma_{i,\max} = 0.2485 \cdot 1762 = 438MPa$$

$$z_{0o} = 0.491b_o = 0.491 \cdot 0.375 = 0.184mm$$

**For case-hardening steel bearings, the values of $z_{0i}$ and $z_{0o}$ can be used to estimate the required case depth. Note that the maximum shear stresses at the centers of contact occur at $z_{1i} = 0.76b_i$ and $z_{1o} = 0.755b_o$ for the inner and outer raceways respectively (see Fig. 6.12). Hence $z_{1i} = 0.246$ mm (0.00867 in.) and $z_{1o} = 0.281$ mm (0.01108 in.). It is more conservative to base case depth on these values. Case depth should exceed $z_0$ or $z_1$ by at least a factor of three.**

# *Example 6.4* Spherical Roller-Raceway Contact

## Problem Statement

**The 22317 SRB of Ex. 2.9 experiences a peak roller load of 2225 N (500 lb). Estimate the type of contact at each raceway.**

**Ex 2.7** $l = 20.71$ mm (0.8154 in.)

**Ex 2.9** $\Sigma\rho_i = 0.0979$ mm$^{-1}$ (2.487 in.$^{-1}$)

**Ex 2.9** $F(\rho)_i = 0.9951$

**Ex 2.9** $\Sigma\rho_o = 0.068$ mm$^{-1}$ (1.726 in.$^{-1}$)

**Ex 2.9** $F(\rho)_o = 0.9929$

## Problem Solution

**Fig. 6.5** $a_i^* = 10.2$

**Eq. (6.38)** $$a_i = 0.0236 a_i^* \left(\frac{Q_i}{\Sigma\rho_i}\right)^{1/3} = 0.0236 \cdot 10.2 \left(\frac{2225}{0.0979}\right)^{1/3} = 6.828 mm$$

$$2a_i = 2 \cdot 6.828 = 13.64 < 20.71 mm = l$$

**Therefore, point contact occurs at the inner raceway-roller contacts!**

**Fig. 6.5** $a_o^* = 8.8$

**Eq. (6.39)** $$a_o = 0.0236 a_o^* \left(\frac{Q_o}{\Sigma\rho_o}\right)^{1/3} = 0.0236 \cdot 8.8 \left(\frac{2225}{0.068}\right)^{1/3} = 6.65 mm$$

$$2a_o = 2 \cdot 6.65 = 13.3 mm < 20.71 mm = l$$

**Therefore, point contact occurs at the outer raceway-roller contacts also!**

## *Example 6.5* Spherical Roller-Raceway Contact

### Problem Statement

**If the 22317 SRB of Ex. 2.9 experiences a peak roller load of 22,250 N (5000 lb). Estimate the type of contact at each raceway.**

### Problem Solution

**Ex 2.7** $l = 20.71$ mm (0.8154 in.)

**Fig. 6.5** $a_i^* = 10.2$

**Eq. (6.38)** $$a_i = 0.0236 a_i^* \left(\frac{Q_i}{\Sigma\rho_i}\right)^{1/3} = 0.0236 \cdot 10.2 \left(\frac{22250}{0.0979}\right)^{1/3} = 14.69 mm$$

$$2a_i = 2 \cdot 14.69 = 29.38 > 20.71 mm = l$$

$$1.5l = 1.5 \cdot 20.71 = 31.06 > 2a_i = 29.38$$

**Therefore, modified line contact occurs at the inner raceway-roller contacts!**

**Fig. 6.5** $a_o^* = 8.8$

**Eq. (6.39)** $$a_o = 0.0236 a_o^* \left(\frac{Q_o}{\Sigma\rho_o}\right)^{1/3} = 0.0236 \cdot 8.8 \left(\frac{22250}{0.068}\right)^{1/3} = 14.31 mm$$

$$2a_o = 2 \cdot 14.31 = 28.62 mm > 20.71 mm = l$$

$$1.5l = 1.5 \cdot 20.71 = 31.06 > 2a_o = 28.62$$

**Therefore, modified line contact occurs at the outer raceway-roller contacts also!**