Comparing three calculation methods of load distribution in radial bearings

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An iterative based Newton-Rhapson computational method is presented, which calculates the load distribution in statically radially loaded rolling elements bearings. The method results are compared with Stribeck results, which consider *null* diametral clearance, and with an approximate integration methods described by Hamrock and Anderson, Oswald, Zaretsky and Poplawski, and others. Numerical examples results for 209 and 218 deep groove, angular-contact ball and roller bearings have been compared with those from the literature.

Keywords (from 3 to 5 max): rolling element, bearing, numerical, iterative, static

1. Introduction

The application of a radial load to the shaft of a rolling element bearing causes a displacement between the rings, which causes deformation of the rolling elements (balls or rollers) and elimination of the clearance along an arc of $2\psi_l$. For static balance, the applied load must be equal to the sum of the components of the rolling elements loads parallel to the direction of the applied load [1]. In this work the results of the load distribution obtained by three methods are compared for a range of applied radial load ranging from zero to 10,000 N.

2. Methods

The first method obtains the total radial displacement using the Newton-Raphson method - the author did not find in the literature the procedure adopted here to determine the total displacement. From the knowledge of the displacement the normal loads in the elements are obtained. The second method uses Stribeck results, which consider *null* diametral clearance [2]; and the third method uses an approximation for integral form for static equilibrium equation [3].

2.1. Basic equations

$$\delta_{i+1} = \delta_i + \frac{F_r - K_j \Sigma\left(\delta\cos\psi - \frac{P_d}{2}\right)^{3/2}\cos\psi}{\frac{3}{2}K_j \Sigma\left(\delta\cos\psi - \frac{P_d}{2}\right)^{1/2}\cos^2\psi}, \tag{1}$$

$$Q_{\max} = \frac{4.37F_r}{Z\cos\alpha}, \tag{2}$$

$$\int_0^{\psi_l}\left(\cos\psi - \frac{P_d}{2\delta}\right)^{3/2}\cos\psi\, d\psi = 2.491\left\{\left[1 + \left(\frac{\frac{P_d}{2\delta}-1}{1.23}\right)^2\right]^{1/2} - 1\right\}. \tag{3}$$

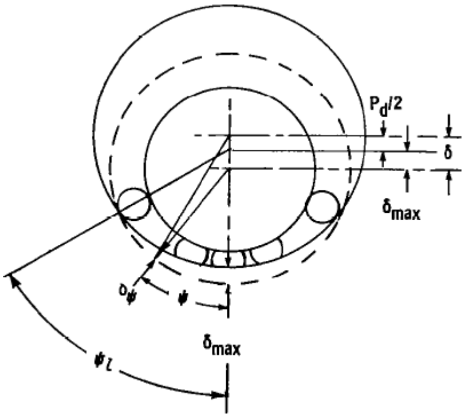

Figure 1: Radially loaded rolling-element bearing.

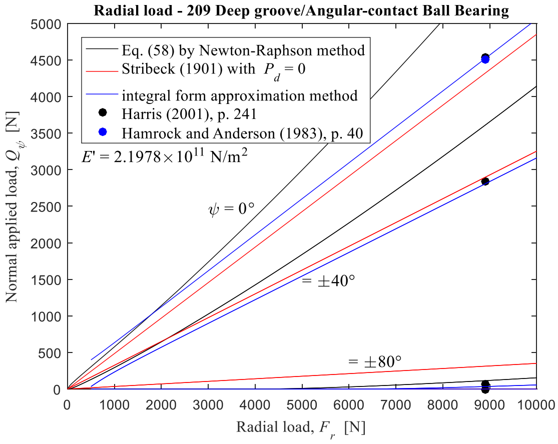

Figure 2: Normal ball loads, as functions of the radial load, for the maximum loaded ball, $Q(\psi = 0^{o})$, and for the loaded balls located at $\psi = \pm40^{o}$ and $\psi = \pm80^{o}$; together with some results published in the literature.

3. Discussion

In the absence of results measured in the laboratory, it cannot be said that the results of this work are better or worse than the results obtained by other researchers, but they seem to be more accurate numerically. Fig. 1 shows the bearing under radial loading, and Fig. 2 shows that the method of this work obtains higher ball loads than the published results, which seem to be more in agreement with results obtained by integral approximation method. It is also observed that the Stribeck method, which considers zero radial clearance for the entire radial load range, estimates a higher load as the circumferential position angle increases. The integral approximation method cannot be used for small radial loads, because the fit curve is not appropriate.

4. References

[1] Harris, T. A., “Rolling Bearing Analysis,” 4th ed., John Willey & Sons Inc., New York, 2001.

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[3] Hamrock, B. J. and Anderson, W. J., “Rolling-Element Bearings,” NASA RP-1105, 1983.

[4] Oswald, F. B., Zaretsky, E. V. and J V Poplawski. Effect of Internal Clearance on Load Distribution and Life of Radially Loaded Ball and Roller Bearings. *Tribology Transactions*, 2012, 55(2): 245–265.