Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 62 (2017) 375 – 379

www.elsevier.com/locate/procedia

10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16

Forecast for Radial Runout of Outer Ring in Cylindrical Roller Bearing

LI Jishun[a,b]* , YU Yongjian[c], XUE Yujun[b]

[a]*Henan Key Laboratory for Machinery Design and Transmission System, Luoyang 471003, China*
[b]*School of Mechanical Engineering, Henan University of Science and Technology, Luoyang 471003, China*
[c]*School of Mechanical Engineering, Northwestern Polytechnical University, Xi'an 710072, China*

* Corresponding author. Tel.: +86-379-6427-8961; fax: +86-379-6427-8961. *E-mail address:* li_jishun@163.com

Abstract

The radial runout of outer ringin cylindrical roller bearing is investigated by numerical computation. Considering form error of outer raceway, a forecasting model for the radial runout of outer ring in cylindrical roller bearing is developed to study the influences of roundness error (i.e., amplitude, order) of outer raceway, number of rollers and radial clearance on the radial runout of outer ring. To testify the presented forecasting method, an analysis algorithm for computing the radial runout of outer ring with outer raceway shape of ellipse is derived. The comparison of the prediction results with the analytical results shows that the presented forecasting method has the better forecast precision.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Cylindrical roller bearing; Radial runout of outer ring; Roundness error; Forecast

1. Introduction

The rotational accuracy of a rolling bearing is a main index of the bearing performance, which plays an important role in rotating performance of equipment shafts. Geometric error of bearing components is the key factor which affects the radial runout of the inner and outer rings. Therefore, it is significant to study the relationship between the geometric error of bearing components and the rotational accuracy of the bearing.

At the present, the research on rotational accuracy of rolling bearing is mainly concerned on non-repetitive runout, orbit of shaft center and radial runout. Noguchi et al.[1] established a mathematical model for calculating the non-repetitive radial runout of ball bearing, considering position and diameter error of ball, and theoretically analyzed the non-repetitive radial runout of the rotational frequency of the cage. Okamoto et al.[2] designed a device for measuring radial runout of ball bearing, which was used to analysis the influence of the shape error of outer raceway and dimension error of balls on the rotational accuracy of ball bearing. Tandon et al.[3] presented a new analytical model for calculating vibrational frequency of rolling bearing caused by single defect of rolling elements or rings. Shi et al. and Song et al.[4-5] developed simulation and prediction models of rotary accuracy of cylindrical roller bearing, and analyzed the influence of harmonic amplitude and order of roundness error in inner and outer raceway, roller number, radial clearance on motion accuracy of bearings. Wu and Li et al.[6-7] proposed simulation mathematical models for non-repetitive radial runout of deep groove ball bearing considering the roundness error of rings and diameter error of balls, and obtained the influence of roundness error and diameter error of balls on the non-repetitive runout. Wang et al.[8] investigated the mapping relationship between geometrical error and geometrical accuracy of rolling bearing, and obtained the influence of the diameter error of rollers and geometrical error a on the geometrical precision of bearing. Yuan et al.[9] studied the effects of numbers and diameter error of balls on the non-repetitive runout of the ball bearing. Zhang and Xue et al.[10-11] proposed a method for adjusting radial clearance of bearings to improve the rotational accuracy of machine tool. Li and Lei et al.[12-15] presented new methods for the detection technology, the evaluation algorithm, the error separation and purification method of the cylindricity and roundness error.

In this paper, a prediction model for the radial runout of outer ring of cylindrical roller bearing is established considering roundness error of outer raceway. Also, the

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2016.06.041

influence of amplitude and order of roundness error in outer raceway, the number of rollers and radial clearance raceway on the radial runout of outer ring is analyzed. It can be used to design and develop cylindrical roller bearings with high precision.

2. Mathemetical model of rotational accuracy of bearing

In this paper, some assumptions are made as follows:

(1) The influence of the form error of outer raceway on the rotation accuracy of bearing is taken into account.

(2) The elastic deformation of bearing components is not taken into account.

(3) There is no relative slip between rollers and rings.

(4) The roller is uniformly distributed in the circumferential direction.

(5) Only the rollers below the bearing are considered.

2.1. Profile radius of outer raceway

Bearing is simplified as a two-dimensional model. A fixed global Cartesian coordinate system *XOY* is set up at the center of the bearing, the center *O* coincides with the center of inner raceway. A local coordinate system xeoeye is fixed in the center of outer ring, which is only translated with outer ring moving. The profile radius of outer raceway can be expressed with addition of roundness error in the outer raceway and outer raceway radius. Roundness error of outer raceway is expressed by the Fourier series. In local coordinate system xeoeye, outer raceway roundness error equation is expressed by equation (1).

$$S(\theta) = d_e/2 + \Delta S(\theta) = d_e/2 + \sum_{m=2}^{\infty}[A_m \sin(m\theta - m\alpha + \varphi_m)] \quad (1)$$

Where ΔS is roundness error in the outer raceway. θ is the position angle of any point on outer raceway. *m* is the harmonic component order. A_m is the amplitude of roundness error. α is the rotation angle of outer ring. φ_m is the phase angle of the *m*th harmonic component in outer raceway. d_e is an ideal diameter of outer raceway.

2.2. Calculation of the central coordinates of rollers

The location of rollers changes with outer ring turning. In order to calculate the central coordinates of rollers when rollers contact with outer raceway, the roller turns to a new location, then the roller is moved radially until it contacts with outer raceway. Therefore, the central coordinates of rollers are calculated through the distance between center of rollers and center of outer ring.

The geometric relationship between the *j*th roller and the rings is shown in Fig. 1. According to the geometric relationship, the distance between point *A* on the surface of the roller and the center *O* of inner ring is calculated by equation (2).

$$AO = Oo_j\cos(\theta_A - \beta_j) + \sqrt{(D_w/2)^2 - Oo_j^2\sin(\theta_A - \beta_j)^2} \quad (2)$$

Where β_j is the position angle of the *j*th roller. D_w is the roller diameter. θ_A is a position angle of point *A*, $\beta_j - \arcsin(D_w/(d_e)) \le \theta_A \le \beta_j + \arcsin(D_w/(d_e))$.

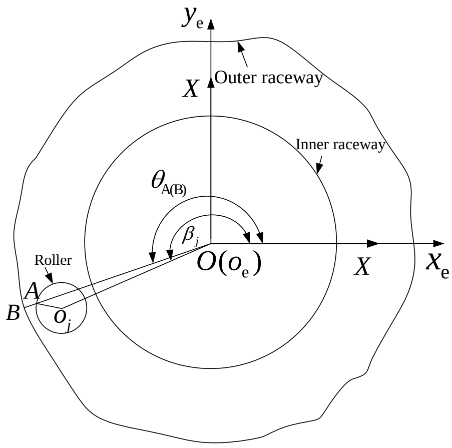

Fig. 1. Geometric relationship of bearing components

When the roller is moved to a location, the distance between any point *A* on surface of the *j*th roller and point *B* on the outer raceway is calculated by equation (3).

$$D = OB - AO = S(\theta_B) - AO \quad (3)$$

When θ_B is changed in its range, the shortest distance between the surface of the *j*th roller and the outer raceway could be obtained. When the shortest distance is more than the convergence error, the *j*th roller is moved until the absolute value of the shortest distance is less than the convergence error. At this time, the *j*th roller contacts with the outer raceway. The distance between the center of the *j*th roller and center of outer ring is obtained, then the central coordinates of the *j*th (j = 1, 2, ..., *N*) roller is calculated by equation (4).

$$\begin{cases} X_j' = Oo_j\cos(\beta_j) \\ Y_j' = Oo_j\sin(\beta_j) \end{cases} \quad (4)$$

2.3. Calculation of the central coordinates of outer ring

The rollers below bearing are divided into two groups. The first group of rollers are on the left side of the *Y* axis. The second group of rollers are on the right side of the *Y* axis. A roller is selected from the first group, and another roller is selected from the second group. It is assumed that two rollers contact with the inner raceway. Based on this assumption, the outer ring and rollers below bearing should be moved up until the rollers contact with inner raceway. At this point, the distance between the centers of two rollers and the inner ring meets the following relationship, as shown equation (5).

$$\sqrt{X_1^2 + Y_1^2} = (d_i + D_w)/2$$
$$\sqrt{X_2^2 + Y_2^2} = (d_i + D_w)/2 \quad (5)$$