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Research on Rotational Accuracy of Cylindrical Roller Bearings

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Abstract

To investigate transferring mechanism of form error of bearing elements and rotational accuracy in cylindrical roller bearings, according to the bearing components motion and geometric relationships, a prediction model for rotational accuracy of cylindrical roller bearings based on roundness error of the inner raceway is presented. The effects of roundness error (i.e., amplitude, order) in the inner raceway, the number of rollers and radial clearance on the radial runout of inner ring are analyzed. Analytic solutions of the radial runout of inner ring are deduced when shapes of bearing elements are an ideal circle, which verifies the correctness of the presented model. The results show that the proposed model has better precision accuracy.

Keywords: Cylindrical roller bearing; Rotational accuracy; Radial runout; Roundness error; Form error

1. Introduction

The main function of rolling bearing is used to support shafting and maintain its rotational accuracy. The rotary accuracy of the bearing often directly affects the precision of mechanical system[1,2]. During the processing of bearing elements, geometrical error is inevitable. Geometrical error of bearing elements is one of the most important factors which cause the motion error of a bearing. Therefore, it is extremely important to research the influence of geometrical error of bearing elements on 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. Okamoto et al.[3] developed a model to predict the orbit of shaft center of a ball bearing based on form errors of outer raceway. The influences of number of balls, dimension error of balls and form error of the raceways on the size and shape of the orbit of shaft center were analyzed. Noguchi et al. [4-6] established a computational model for non-repetitive runout of a ball bearing considering form error of the outer raceway and diameter error of balls, and analyzed the influences of geometrical error of the raceways, ball numbers, diameter difference and geometrical error of the balls on non-repetitive runout of a ball bearing. Jang al.[7] analyzed the mechanism of resulting in non-repetitive runout of a ball bearing which is used in disks, and characterized the transmission path of non-repetitive runout of a ball bearing from the bearing to the disk. Yang et al.[8-10] developed a mathematical model and a five-freedom model to study the effects of geometrical errors on the non-repetitive runout of an angular contact ball bearing, respectively. Liu et al.[11] proposed a computational model about non-repetitive runout of a high-speed angular contact ball bearing based on five-freedom quasi-static model, and studied the influences of the waviness of bearing elements on non-repetitive runout of an angular contact ball bearing. Li et al.[12] established 5-DOF static model of non-repetitive runout of deep groove ball bearings, and investigated the influences of the distribution of diameter errors among rollers and roundness error of the inner or outer raceway on non-repetitive runout of a deep groove ball bearing. Bhateja et al.[13] established a prediction model for rotational accuracy of the cageless hollow roller radial bearing considering dimension difference of rollers, and analyzed the influences of the change of internal and external diameter of rollers, diameter and the position of rollers on rotational accuracy of

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bearing. Wang et al.[14] presented a model to predict geometric accuracy of a roller bearing considering form error in the inner or outer raceway, and studied the effects of the diameter error of roller, the amplitude and order of roundness error in the raceways on geometrical precision of the bearing. Previous research work mainly analyzed the influences of the profile of inner and outer raceways on rotational accuracy of bearing, and established a computational model for rotational accuracy of bearing based on roundness error of inner raceway[15]. A computational model for rotational accuracy of bearing based on form error of outer raceway was developed, and studied the effects of roundness error in the outer raceway on the radial runout of outer ring. Roundness error in the outer raceway is experimentally investigated and the function relation between the radial runout of outer ring and harmonic distribution parameters in the outer raceway was obtained [16,17,18].

In this paper, according to the geometrical model of cylindrical roller bearings, considering roundness error in the inner raceway, a prediction method for the radial runout of inner ring is presented. The influences of the amplitude and order of roundness error in the inner raceway, number of rollers and radial clearance on the radial runout of inner ring are analyzed.

2. Mathemetical model of rotational accuracy

In this paper, some assumptions are made as follows:

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

(2) The rollers are uniformly distributed in the circumferential direction.

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

(4) There are no axial geometric and form errors in the raceways and rollers.

2.1. Geometric model of the bearing

Only considering roundness error in the inner raceway, the inner ring is a noncircular contour. The geometric model of a cylindrical roller bearing is shown in Fig. 1. A global Cartesian coordinate system *XOY* is set up at the center of the bearing. The plane *XY* coincides with the center plane of outer raceway. Local coordinate system $x_i o_i y_i$ is set up at the center of inner raceway, which only translates, and the plane $x_i y_i$ coincides with the center plane of inner raceway. Outer ring is fixed, and inner ring is rotated in this bearing. Δx is the displacement of inner ring in the horizontal direction, and Δy is the displacement in the vertical direction, which is the radial runout value of inner ring.

In coordinate system $x_i o_i y_i$, when the inner ring turned an angle α , the contour radius $R_i(\theta)$ of inner raceway is expressed by equation (1).

$$R_i(\theta_i) = d_i / 2 + \sum_{m=1}^{\infty} C_{im} \cos(m(\theta_i - \alpha) + \varphi_{im}) \tag{1}$$

Where θ_i is position angle of any point on the inner raceway in coordinate system $x_i o_i y_i$. d_i is the diameter of inner raceway. m is harmonic number. C_{im} is the amplitude of the mth harmonic component in inner raceway. φ_{im} is the phase angle of the mth harmonic component in inner raceway.

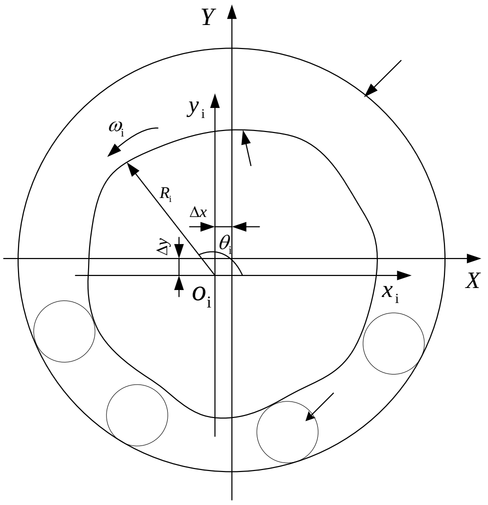

Fig. 1. Geometric model of a cylindrical roller bearing

2.2. Contact state of the inner raceway

It is assumed that every roller below the bearing contacts with the outer raceway. According to geometric model of a cylindrical roller bearing, the center coordinates of the rollers is obtained. The inner ring is moved with a certain step in the plane *XY*. The position relationship (contact, separate, interference) between the rollers and the inner raceway is obtained by the minimum distance between the surface of rollers and the inner raceway. The contact state of the inner raceway is obtained in each location of inner ring.

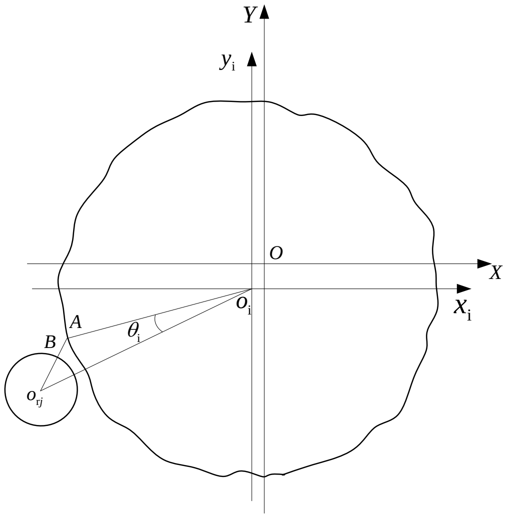

Fig. 2. Geometric relationship between roller and inner raceway

When the inner ring is translated to a certain position, the geometrical relationship between a roller and the inner raceway is shown in Fig. 2. The distance between point *E* on