Modelling races waviness for high precision ball bearings

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Ball bearings waviness can have an important impact on the bearing behavior. Using current manufacturing processes, it's possible to reduce waviness magnitude but not avoid it. That's the reason why it's necessary to take them into account as early as the modelling stage. The aim of this paper is to present a semi-analytical model considering rings sinusoidal shape defects. To accurately model the ball/race contact, it's necessary to consider contact forces reorientation which is often neglected in other models in the literature. For this, the races are modeled using an analytical expression of torus with waviness on its radius.

Keywords: ball bearings, waviness, 3D contact model, static equilibrium

1. Introduction

Waviness is one of the most common races defect that appear on the bearing's races during the manufacturing processes. Although it has an important impact on the dynamic system behavior, it can also significantly affect the performance of high precision ball bearings. We will focus on this type of bearings which are used to do accurate pointing and thus rotated slowly.
Previous studies have already been done on the impact of waviness on the bearings behavior by considering variations of races diameter and sometimes, a change in the contact stiffness depending on the position [1]. Nevertheless, the contact deflections are always supposed to be normal to the contact surface, in the direction of the ball (and bearing) center. The contact loads can then be calculated using Hertz theory [2]. However, in reality, the presence of waviness changes the position of the contact points and also the normal direction at these points (Figure 1).

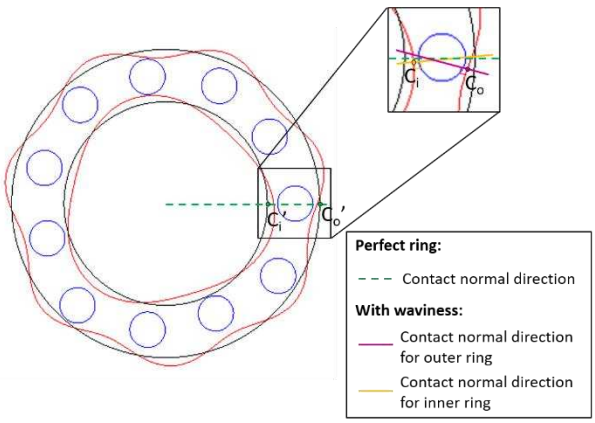

Figure 1: Geometric modifications due to waviness

2. Methods

2.1. Hypotheses
The proposed model was developed under some hypotheses:

- Rings are considered as rigid bodies
- No lubrification is taken into account

2.2. Races waviness
To be able to define the exact position of each contact point, the race surface is defined in 3D using the analytical expression of a torus with waviness.

2.3. Contact model
The contact between balls and races is modelled using nonlinear springs. Each contact is decomposed into normal and tangential loads which are respectively defined by Hertz and Dahl models.

2.4. Static equilibrium
An energetic approach is used to solve the static equilibrium with geometrical constraints. This method has the advantage to have a formalism that allows a progressive increase in complexity to consider for example: rings flexibility or quasi-static and dynamic aspects.

3. Results and discussion

By introducing races waviness on a static ball bearings equilibrium model, we can calculate the variations of many local parameters such as the contact stiffness, the position of the contact point, the load and deflection direction… These modifications have a significant impact on the bearing's mechanical parameters. For example, the load on each ball changes over time, reducing the bearing's life. Another phenomenon called wobble can also appear. It consists of a change in the bearing rotation axis due to the variation of the angular deflection and can affect the stability of the whole system on which the bearing is mounted.
This model can be used for single or coupled ball bearings to help design them and predict their behavior depending on the application. To get a more accurate model, we can also model the rings flexibility [3] by considering a modification of the rings geometry and introducing it in the same way as waviness.

4. References

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