Cage Dynamic Analysis of High-Speed Angular Contact Ball Bearings

CATEGORY OR KEYWORDS
Angular contact ball bearings; Dynamics; Cage whirl; Centrifugal force; Cage wear; Test

AUTHORS AND INSTITUTIONS
Tao ZHANG [1, 2], Xiaoyang CHEN [1]*, Shijin CHEN [1], Jiaming GU [2]
[1]Research Institute of Bearings, Shanghai University
[2]Bearing R&D Center of Shanghai Prime Machinery Co. Ltd.

INTRODUCTION
During the operation of high-speed angular contact ball bearings, frequent collision between the cage and the balls and guide ring often results in cage unstable motion. One of the common failure modes of high speed rolling bearings is the friction torque fluctuation or cage breakage caused by cage instability. The influences of operation conditions, geometry, and friction on the cage stability have been studied a lot[1-3]. However, the influences of these factors on the cage motion are indirect and coupled with each other, and there are few studies on the mechanism of cage whirl.

ABSTRACT
Based on the dynamic model and the working conditions of parched elastohydrodynamic lubrication (EHL) of high-speed instrument rotor ball bearings, the cage forces and motions are investigated under the two conditions; one is the outer ring fixed and inner ring rotation, the other is the inner and outer rings rotation in reverse. By the force decomposition, the influences of the forces on the cage mass center motion are obtained, and the mechanism of cage stable whirl is explained. It is found that the centrifugal force generated by cage mass center whirl is the main driving force for maintaining the whirl radius, and the friction forces of ball/cage pocket and cage/guide ring maintain the whirl speed. The collision forces of ball/cage pocket and cage/guide ring contacts bear the cage centrifugal force and the proportion they bear affects the wear rate of cage pocket and guide surface. When the inner and outer rings rotation in reverse and the rotational speed of the cage is close to zero, the interactions of the ball/cage pocket are weakened, so that the cage is difficult to form a stable whirl for lacking of the centrifugal effect. When the cage forms a circular whirl orbit under the centrifugal force, the interactions of the ball/cage and the cage/guide ring are increased, resulting in an increase in the cage wear rate. It is helpful to improve the wear life of high-speed ball bearings by decreasing the centrifugal force of the cage whirl. Finally, the simulation results of the cage whirl were verified by the cage dynamic performance test of high-speed angular contact ball bearing.

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REFERENCES
[1] Kingsbury, E.P., Walker, R., (1994), “Motions of an Unstable Retainer in an Instrument Ball Bearing,” Journal of Tribology, **116**(4), pp. 202-208.
[2] Gupta, P.K., (1991), “Modeling of Instabilities Induced by Cage Clearances in Ball Bearings,” Tribology Transactions, **34**(1), pp. 93-99.
[3] Niu, L.K., Cao, H.R., He, Z.J., et al., (2016), “An Investigation on the Occurrence of Stable Cage Whirl Motions in Ball Bearings Based on Dynamic Simulations,” Tribology International, **103**, pp. 12-24.