Mathematical Modelling of a Coefficient of Nonlinearity in Dynamics of Deep Groove Ball Bearing with Damage

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Abstract. The presented research is a part of widely research of the nonlinear dynamic behaviour of rolling bearings, which are the parts of all rotating assemblies and machinery. In accordance with the state-of-the-art requirements for the advanced mechanical design and industrial digitalization, the large experiments and research are performed and the new mathematical model of the dynamic behaviour of rolling bearings with damages is developed. The results obtained for a particular type of deep groove ball bearings are presented, and the possible further research and implementation of the obtained model in digitalized self-monitoring systems is discussed.

Introduction

The existing demands for light weight design of mechanical elements in correlations with the demands for increasing reliability and machinery digitalization, lead to the requirements for developing new methods and mathematical models for permanent monitoring and maintenance of the crucial machinery parts. The rolling bearings monitoring is mandatory in all rotating assemblies and machinery in the framework of digitized production, and required precise predefined mathematical relations and models for programming the self-monitoring digitalized systems.

The main postulates of the theory of nonlinear dynamics [1, 2] are used in the presented research in order to develop the mathematical model for efficient prediction of behaviour of deep groove ball bearings with defects. The particular type of single-row deep groove ball bearing 6206 is chosen, and large set of experimental testing of samples with pre-manufactured damages on the inner and outer raceway is performed [3].

Results and discussion

For developing a mathematical model of a damaged single-row rolling bearings, the differential equation of motion is derived as a special case of a general nonlinear oscillator [2] with strong cubic nonlinearity [1]. For radial rolling bearings, this matrix form of the equation of nonlinear dynamics could be reduced to a one-degree-of-freedom system [4] given as:

$$m_{red}\ddot{y} + C_r\dot{y} + K_r y + qy^3 = F$$

The nonlinear part of this equation, represented by the coefficient of nonlinearity q, depicts how existing damage influences the rolling bearing vibrations. For a particular radial rolling bearing type, an expression for the coefficient q is obtained by an iterative procedure based on the experimental measurements of the bearing vibration response [3], and defined to be dimensionally consistent with the presented equation of motion. The coefficient of nonlinearity depends on the damage dimension, local contact deformation and external load distribution among rolling elements. Based on an empirical iterative procedure, the following formula is proposed for the conical-shaped damages on the inner raceway of the 6206 ball bearings:

$q = \left(\frac{d_d}{d_0}\right)^3 \frac{F_\delta}{\delta^3}$, Fig.1, where: d_d – is the diameter of the damage on a contact surface; d_0 – is the average diameter of the damage for a particular rolling bearing type obtained by the producer; F_δ – is a load distributed on the most loaded rolling element, obtained by Finite Element Analysis and δ – is a local deformation on the most loaded rolling element in contact with the damaged raceway surface, obtained by Finite Element Analysis performed for a particular case of the rolling bearing type, as well as for a particular type and dimensions of the modelled damage.

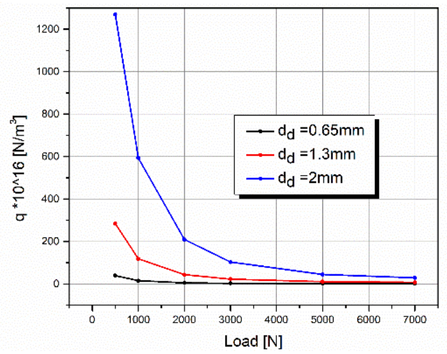

Figure 1: Nonlinearity coefficient variation

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