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Statistical Analysis of Nonlinear Time Series Based on Bearing Dynamic Response

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Summary:
In the paper, the statistical analysis of nonlinear time series obtained from measurements of bearing vibrations is conducted. Data are collected from two different type and independent sensors, registering bearing vibrations in two axes. The measurements are mainly used to study bearing dynamic response with different radial internal clearance (RIC). In this paper time series of two different sensors are compared aiming to find correlations between mentioned design parameter and system's behavior.

Keywords: Ball Bearings, Bearing Clearance, Nonlinear Dynamics, Statistical Analysis, Statistical Measures

Introduction

One of the most important parameters in bearing design and exploitation is its radial internal clearance (RIC), which means the distance through which one ring can move to the other in the radial direction. From the bearing performance point of view, the radial clearance is one of the most influential parameters on the tribological phenomena and its proper setting ensures long-time, the maintenance free machine operation [1-2]. The bearing type used to the research is double row self-aligning ball bearing NTN 2309SK with tapered bore. In the bearing with such bore it's possible to change its radial clearance by fastening or loosing dedicated adapter sleeve. Such mounted bearing is taken under precise measurement of the distance between balls and raceways by automated system for measuring the radial clearance of rolling bearings [3-4]. Different value of clearance in the same type of ball bearing means the change in the dynamic response. In order to research bearing's behavior with different clearance, it is mounted in the bearing node. Two different kind of sensors, piezoelectric and MEMS are attached to the bearing's housing in two axes to measure bearing's vibrations. The experiment is performed for 6 different values of clearance and for 1 rotational velocity, in total we obtain 6 cases. In order to find correlation between considered parameter and dynamic response, statistical analysis of time series is performed using mean, standard deviation and kurtosis.

Experimental setup

Measurement procedure starts with setting radial clearance by fastening or loosening adapter sleeve dedicated to the bearing. Such axially loaded bearing is mounted on shaft's journal of automated system for measuring the radial clearance of bearing (see Fig. 1). On the setup, the clearance is measured 3 times and the final value is averaged. Bearing after measurements is mounted in the gearbox (see Fig.2 and Fig.3). The data are collected for only one fixed bearing. In the gearbox, 2 sensors are mounted to the housing (see Fig. 4) and acceleration's results are collected in plane perpendicular to the bearing's axis. Third component along bearing axis can be neglected in case its fixed, longitudinal displacement is very low in its amplitude.

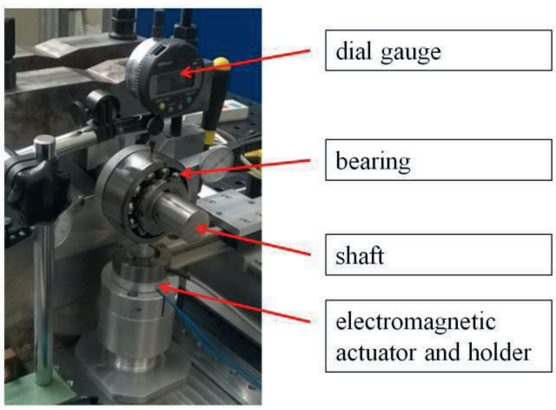

Fig. 1. Clearance measurement setup with a double row self-aligning ball bearing with tapered bore and adapter sleeve.

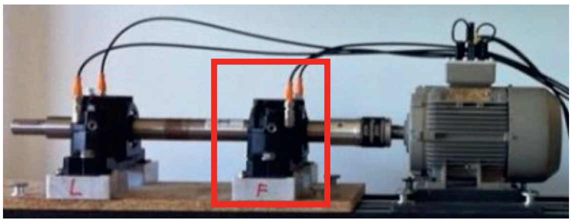

Fig. 2. Experimental gearbox. Red rectangle indicates tested bearing. Two accelerometers are mounted on the housing.

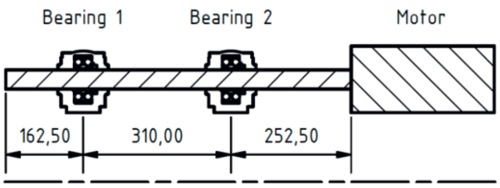

Fig. 3. Cross-section view of gearbox. In bearing node, bearing 1 is floating and bearing 2 is fixed.

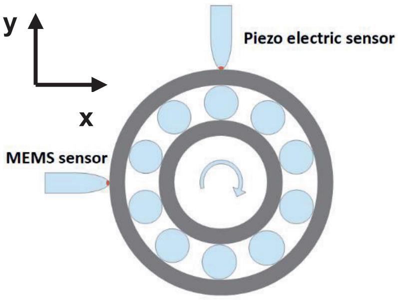

Fig. 4. Illustration of bearing with attached sensors. Data are collected from two axes.

Results

In this paper we consider only measurements by one rotational velocity n = 10Hz and several values of radial internal clearance from different classes: RIC = {7; 20; 22; 34; 41; 46} [µm]. For the analysis of raw signal 15000 data points are taken into account (see Fig. 5) collected with sampling frequency f_s=392Hz. Whole signal is analyzed both from x-axis and y-axis and they are evaluated separately. For the statistical analysis are used mean, standard deviation and kurtosis (see Fig. 6, Fig. 7 and Fig. 8).

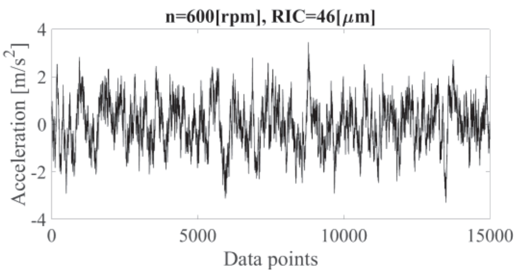

Fig. 5. Exemplary raw signal from x-axis.

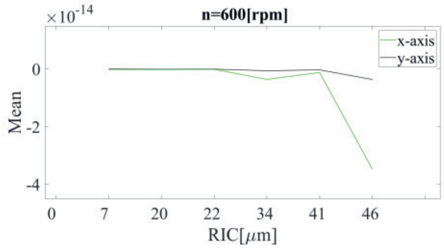

Fig. 6. Mean of the signal in RIC domain.

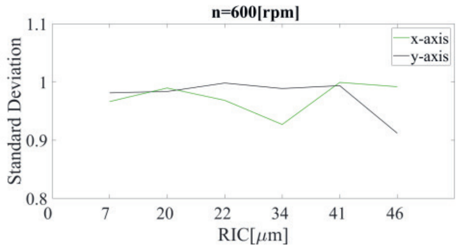

Fig. 7. Standard deviation of the signal in RIC domain.

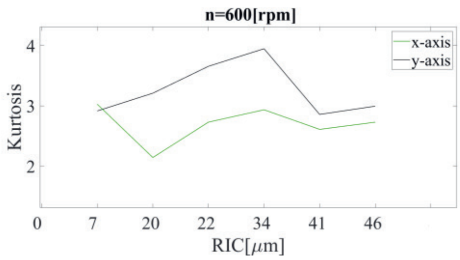

Fig. 8. Kurtosis of the signal in RIC domain.

Conclusions

The first results show that using this simple analysis the optimal value of RIC can be detected. The x-axis signal clearly shows the optimum clearance as given by the specification of the bearing (16 µm – 22 µm). Also the standard deviation detects this optimum. Accordingly, these methods could be used to monitor changes of RIC during application.

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