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Effect of lubricant viscosity grade on mechanical vibration of roller bearings

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Abstract

This work aims to characterize vibration behavior of roller bearings as a function of lubricant viscosity. Experimental tests were performed in NU205 roller bearings, lubricated with mineral oil of three different viscosity grades (ISO 10, 32 and 68). The mechanical vibration was determined through the processing and analysis of bearing radial vibration data, obtained from each of the lubrication conditions, during 2 h of test run for temperature stabilization and under several bearing shaft speeds. The applied radial load was 10% of the bearing nominal load. Through root mean square (RMS) analysis of the vibration signals, it was possible to identify specific frequency bands modulated by the change in lubricant viscosity, which was related to change in oil film thickness.

Keywords: Lubrication; Roller bearing; Vibration; Viscosity

1. Introduction

Depending on some aspects, lubrication in mechanical systems can occur in different regimes: full film, mixed or boundary lubrication. Full film lubrication can be further divided into elastic-hydrodynamic lubrication (EHL), which occurs in non-conformal contacts under high pressure, and hydrodynamic lubrication (HD), occurring under low pressure and usually in conformal contacts [1–3].

Among the group of mechanical components operating under EHL condition, there are the rolling bearings. This machine element type is one of those more sensitive for development of faults related to lubrication deficiency. According to technical publications of rolling bearing manufacturers [5,6], from the total of faults found in this type of component, 50–80% are related to deficient lubrication, resulting from inadequate lubricant use, lack or excess of lubricant, lubricant aging, and presence of solid or liquid contaminant. In the face of high percentage of rolling bearing failures, the development of techniques for detection and diagnosis of faults in rolling bearings, due to lubrication deficiency, is a fundamental contribution to the preservation of machine precision.

In terms of monitoring of rolling bearing performance, vibration measurements are among the most used techniques. Nowadays, a lot of works on detection of localized defects in rolling bearing elements through vibration analysis can be found in the literature [7–9]; conversely, references on the detection of lubrication-induced faults are still found to be less. Among these, there is one [10] pointing out that when a rolling bearing is inadequately lubricated, its vibration response is similar to that of a system submitted to a random excitation. In the case of systems with low damping, the predominant components of such response would correspond to the natural frequencies of the rolling bearing. On the other hand, according to Berry [11], frequency spectra of vibration signals for inadequate lubrication condition are characterized by three or four peaks in the frequency bands from 900 to 1600 Hz, corresponding to natural frequency bands of the rolling bearing. In addition, he affirms that these frequency bands are also seen under adequate lubrication condition; although the vibration magnitudes are much smaller in this case.

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In the same context, another study [12] concludes that vibration energy of a bearing depends on surface irregularities, external loadings, running speed and lubricant viscosity. For instance, it was observed in experimental tests that the influences of lubricant viscosity on vibration response depended on speed: for a bearing under large load and low running speeds, increase in lubricant viscosity causes reduction in vibration energy. In contrast, at high running speeds, vibration energy is high when lubricant viscosity is high.

Furthermore, Massouros [13] cites that, in plain bearings under boundary lubrication condition, the journal rotation results in impacts among the micro asperities of the sliding surfaces at contact, producing vibrations, both normal and tangential, to the sliding direction.

All the mentioned works reinforce the already known complexity concerning the analysis of vibration phenomena occurring in mechanical contacts. The present work intends to contribute for improving knowledge on the relationship between vibration phenomena and lubrication in bearings. This is done by studying how a change in lubricant viscosity can affect the mechanical vibration of a rolling bearing by means of basic procedures of vibration analysis.

2. Methodology

The tested rolling bearings were of NU205 type, presenting the geometry shown in Fig. 1.

Mineral oil without additive was used as lubricant. Three different viscosity grades were tested, ISO 10 (V1), ISO 32 (V2) and ISO 68 (V3), with the purpose of obtaining the vibration response related to different lubrication regimes in the bearing element contacts. The two higher viscosity grades are recommended for bearings operating in the selected test conditions, according to the manufacturers catalogue. The ISO 10 grade was included in the study so as to force a critical condition of lubrication in the contact, toward boundary lubrication.

Fig. 2 shows the equipment used for the tests. The tested rolling bearing is vertically loaded and oil bath lubricated. Known values of radial load can be applied in the tested bearing through a lever and a load cell with a screw system

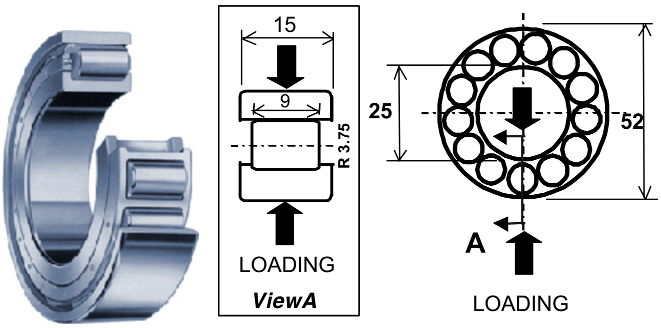

Fig. 1. Geometry of the rolling bearing used in the tests. (a) Three-dimensional overview and (b) details of dimensions.

(see Fig. 2, right side). During the test run, oil heating occurred and a mixer system was used to keep temperature homogeneous within the oil bath. A K-type thermocouple immersed in the oil bath was used to monitor the oil temperature during the test.

A system with pulleys transmits the power from an electric motor to the bearing shaft. Two ball bearings are used to support the shaft. A frequency inverter controls the shaft speed. Actually, machines have an inherent vibration that characterizes the baseline of their dynamical behavior. The baseline dynamics certainly affects the vibration of any monitored component. In fact, in the performed tests, the vibration measured by the accelerometer was affected by the overall dynamical response of the equipment, including all the component parts (shaft, structure, etc.). Then, the results presented in the paper are related to the changes in the vibration of the equipment with respect to its baseline vibration, as a function of the lubricant viscosity of the tested roller bearing.

A piezoelectric accelerometer (PCB 601A31, 0–10 kHz useful range, 16 kHz resonance frequency) attached in the bearing housing measures the bearing radial vibration. The measured signal is amplified and filtered with low band pass filter at a 10 kHz cutoff frequency. The signal is then acquired through an acquisition board at sampling rate of 20 kHz. In the tests, each acquired signal had a number of 100,000 data, corresponding to 5 s acquisition time. All stored data were analyzed with respect to the root mean square (RMS) value.

In order to verify the effect on the bearing vibration of oil viscosity change caused by the increase in oil bath temperature, vibration signals were acquired at every 15 min, during 2 h of testing (time for oil bath temperature stabilization). The applied load was set to 1770 N (corresponding to approximately 10% of the bearing dynamic capacity) and the shaft speed to 40 Hz. This procedure was applied in the tests with the three oil viscosities.

After temperature stabilization, vibration signals were acquired for three shaft speeds (20, 40 and 60 Hz), in order to verify if the trends in vibration behavior with the tested viscosity grades would be kept constant when the speed changed. Experiments with every lubrication condition were repeated several times to check repeatability.

3. Results and discussion

3.1. Oil temperature

Fig. 3 shows oil bath temperature as a function of test time, for the three tested viscosities. A gradual increase in temperature can be observed during the first hour of test and a trend of stabilization in the second hour. This behavior is repetitive for the three tested viscosity grades. According to technical publications of rolling bearings manufacturers [5], both increase and stabilization of temperature occur with any type of rolling bearing, and