MULTI-CHANNEL MEASURING INSTRUMENT AND DESIGN OF A ROLLING BEARINGS TEST RIG

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Abstract

This paper presents the vibrodiagnostic test rig for analyzing the condition of rolling bearings. The rolling bearings are the most widespread mechanical elements, which are also considered critical elements within the mechanical assembly. Typically functionality, reliability and exploitative properties of the entire machine system depend on the functional capabilities of rolling bearings. The paper presents a design of a rolling bearings vibrodiagnostic test rig, which allows for simulating loads that are close to real loads during the operation of bearings, as well as a measuring instrument VibroLog, which is used for the acquisition and display of measured data. The newly developed measuring instrument VibroLog modular device for measuring and analysis of several diagnostic bearing parameters: vibration, speed, temperature and sound pressure. With this modularity, it enables easier diagnostics and speeds up the process of finding problems and faults in bearings.

Keywords: Rolling bearing fault detection, test rig and equipment, multiparameter analysis, vibration, sound, temperature.

INTRODUCTION

Rolling bearings have a wide range of applications in various mechanical systems. The reliable operation of such mechanical systems depends on the condition of the installed rolling bearings. Bearings develop various defects during their operation, which depend on the environment and mode of operation. Mistakes that can occur in bearings include those in the inner ring, outer ring, and rolling elements, which can result in catastrophic failure of the entire machine or facility [1]. For these reasons, it is necessary to monitor the condition of rolling bearings and employ specific diagnostics to detect defects in order to prevent potential accidents.

In recent decades, various diagnostic methods have been used to monitor the condition of bearings, such as oil sample analysis [2], acoustic emission [3–6], and vibration analysis [7–9]. Vibration testing and other parameter assessments of complex systems help manufacturers ensure the quality, reliability, and durability of systems and their components. These tests can reveal weaknesses in a system that may become apparent over time but can be detected early through regular testing.

Vibration measuring instruments and systems are primarily developed by mechanical component manufacturers and companies specializing in vibrodiagnostics. They often define vibration test specifications and procedures based on extensive experience and expertise in the field of vibrodiagnostics. Vibration testing provides a structured approach to understanding the operation of mechanical systems and identifying faults and damage.

With a well-established diagnostic methodology, it is relatively straightforward to determine the extent of bearing damage and the remaining service life of the bearing. This data is vital for the concept of preventive and proactive maintenance of all systems containing bearings. This is one of the reasons why developed countries pay special attention to preventive bearing maintenance and monitoring their condition.

The paper presents a measurement system for assessing the condition of rolling bearings, which includes a bearing test rig, the VibroLog measuring instrument, which is a data collector and analyzer, a modular device for measuring multiple diagnostic parameters of bearings (vibration, speed, temperature, and sound pressure), and the VibroLogApp application for analysis and display of measured results, developed in the Java programming language.

STRUCTURE OF THE BEARING TESTING SYSTEM

Bearing Testing Equipment

To fully understand the behavior of rolling bearings, comprehensive testing and data assessment for defined loading scenarios are required. There are multiple levels at which the behavior of bearings can be monitored. Testing at the lowest level focuses on general phenomena occurring in bearings and is typically conducted in laboratories. Specialized test devices are usually used to study the tribological issues of rolling or other types of bearings. The next step is component-level testing, where the bearing is tested as an integral component of a system. The most common tests at this level involve bearing life tests under various types of loading, where the time to bearing failure is of utmost interest under the tested conditions. The highest level of testing is operational testing, where the bearing is inserted into a real system, and various parameters are observed. Such tests are typically very valuable as they can show the actual response of the bearing to real operational conditions. The drawback is the high cost of such tests [10].

The fundamental requirement in designing the bearing testing and diagnostic equipment presented in this paper is the ability to simulate loads that are close to real operational loads. This was taken into account during the equipment's design.

During the assessment of bearing condition using the developed diagnostic system, a comparative analysis of three crucial parameters indicating the level of bearing damage is performed. This modularity was important during the design of the testing instruments, as it provides a better overview of the bearing's condition. The parameters under examination are vibration (Vrms), sound pressure (P), and temperature (T), measured by vibration sensors, a microphone, and a temperature sensor, respectively [11]. Figures 1 and 2 show the drawings and appearance of the bearing test rig [11,12].

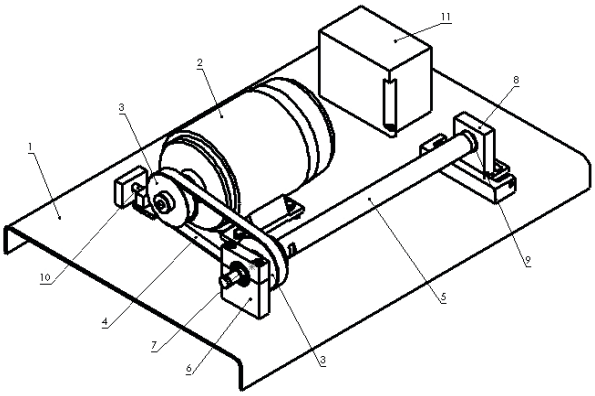

Fig. 1. *Drawing of the bearing test rig (1 - Base plate, 2 - Drive electric motor, 3 - Belt pulley, 4 - Timing belt, 5 - Shaft,6 - Bearing housing, 7 - Bearing 1 (the bearing under test), 8 - Plain bearing housing, 9 - Plain bearing, 10 - Tensioner, 11 - Frequency regulator)*

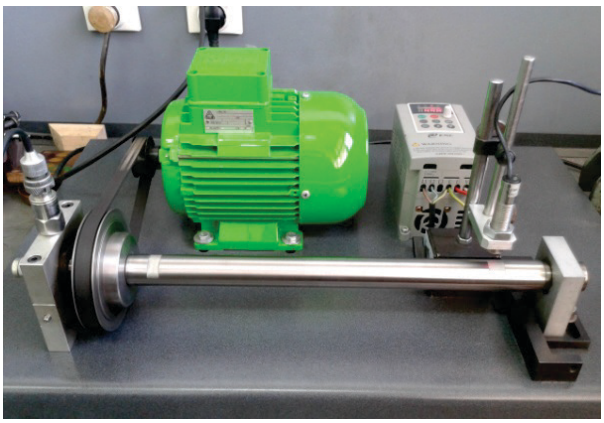

Fig. 2*. Appearance of the bearing test rig*

The assembly and disassembly of the tested bearing specimens are quick and straightforward due to the design of the housing. This requirement is achieved by creating a two-part housing, as shown in Figure 3.

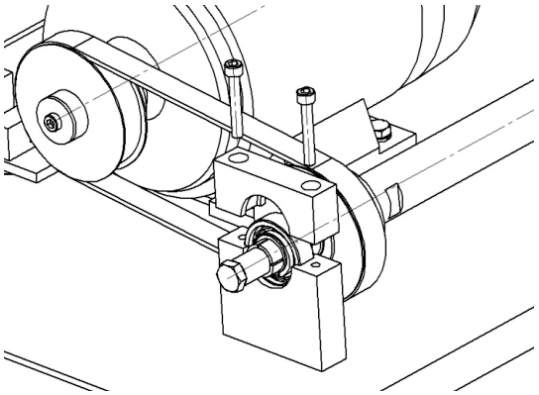

Fig. 3. *Design of the housing for the tested bearing*

The device is constructed in such a way that it can simulate:

- Radial load
- Bearing misalignment
- Preloading of the inner ring (reduction of internal clearance)

Radial loading of the bearing is achieved using a special tensioner and sliding guide located at the base of the electric motor. These components allow for linear movement of the electric motor during tensioning, ensuring that the axes of the electric motor and the bearing shaft remain parallel.

In order to simulate bearing misalignment, the second support for the shaft, which carries the plain bearing, is adjustable. The direction of movement is perpendicular to the axis, enabling the tilting of the shaft relative to the bearing.

The connection between the inner ring of the bearing and the shaft is established through a specially designed split shaft with a taper. This solution allows for controlled tightening of the front screw, generating a force that is transmitted through the taper to the inner ring of the bearing. This method enables preloading of the inner ring and reduction of the bearing clearance [11,12].

Measurement Instruments

The VibroLog measurement instrument is a tool for data collection and analysis. It is a multi-channel modular device designed for measuring diagnostic parameters of bearings, including vibration, rotational speed, temperature, and sound [11].

Fig. 4. *VibroLog device with sensors*

The fundamental components of the measurement equipment shown in Figure 4 are as follows:

1. Microphone
2. Vibration sensor (SKF Model CMSS2100)
3. Temperature sensor (PT1000, 0 – 200°C)
4. VibroLog measurement electronics (RoTech Belgrade, Serbia)
5. Photoelectric sensors with a reflective strip (photocell and proximity switch)

The VibroLog analyzer utilizes the following vibrodiagnostic methods:

- Measurement of vibration parameters (velocity, acceleration)
- Spectral analysis. Spectrum characteristics: 2048 spectral lines in the measurement range of 0.5 Hz - 10 kHz.

An application called VibroLogApp has been developed in Java to connect the VibroLog device to a personal computer. This application allows for data acquisition from the sensors, visualization in the form of charts and vector values, and saving data in specific formats. The application connects to the acquisition device via a 100 Mb/s Ethernet interface. The ModbusRTU Protocol is used for message exchange and hardware control, transmitted over the UDP communication protocol.

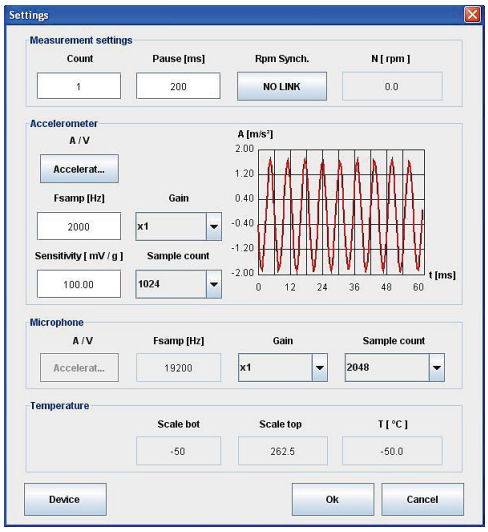

Fig. 5. *Display of the window for adjusting measurement and sensor settings*

The following pictures show the spectra and measured values when the shaft is in the axis, Figure 10 shows the spectra of a damaged rolling bearing whose condition is not acceptable, measured values Vrms=34.11[mm/s], prms=13.65 [Pa], and Figure 11 shows the spectra of undamaged rolling bearing whose condition is acceptable, measured values Vrms=1.53 [mm/s], prms=1.33 [Pa].

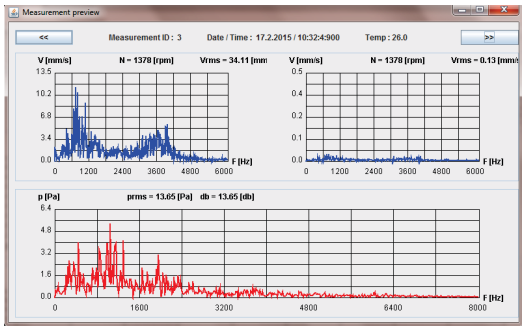

Fig. 10*. Spectra and measured values on badly damaged bearing when the shaft is aligned at 1378 rpm- unacceptable condition*

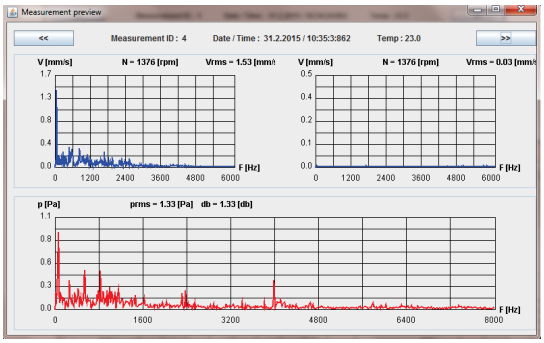

Fig. 11. *Spectra and measured values on undamaged bearing when the shaft is aligned at 1376 rpm - acceptable condition*

CONCLUSION

This paper has presented experimental equipment for testing the condition of rolling bearings. It can be concluded that, for the purposes of monitoring and controlling the condition of bearings, it is useful to perform periodic measurements and analyses of a wide range of relevant bearing condition indicators.

The developed vibrodiagnostic system and the created method enable an assessment of the condition of rolling bearings and their prediction for a wide spectrum of rolling bearings. As they are the most common mechanical components, monitoring their condition increases the reliability and operational characteristics of the entire machinery system.

The advantage of the newly developed bearing testing system (the test rig and the VibroLog measurement instrument), as well as the overall defect method, lies in significantly improving the understanding of the operation of the bearings themselves, thereby facilitating the faster detection of irregularities in their operation.

REFERENCE

[1] Savić B., Urošević V., Šiniković G., Milićević I.: *Multi-parameter measurement system for rolling bearing fault diagnosis*, Symposium on Computer Sciences and Information Technologies YU INFO 2019, Kopaonik, Serbia, 2019.

[2] Cao H., Fan F., Zhou K., He Z.: *Wheel-bearing fault diagnosis of trains using empirical wavelet transform*, Measurement 2016, 82, 439–449.

[3] Glowacz A., Glowacz W., Glowacz Z., Kozik J.: *Early fault diagnosis of bearing and stator faults of the single-phase induction motor using acoustic signals*, Measurement 2018, 113, 1–9.

[4] Glowacz A.: *Fault diagnostics of acoustic signals of loaded synchronous motor using SMOFS-25-EXPANDED and selected classifiers*, Tehnicki Vjesnik 2016, 23, 1365–1372.

[5] Glowacz A.: *Acoustic based fault diagnosis of three-phase induction motor*, Appl. Acoust. 2018, 137, 82–89.

[6] Glowacz A., Glowacz Z.: *Diagnosis of stator faults of the single-phase induction motor using acoustic signals*, Appl. Acoust. 2017, 117, 20–27.
[7] Praveenkumar T., Sabhrish B., Saimurugan M., Ramachandran K.I.: *Pattern recognition based on-line vibration monitoring system for fault diagnosis of automobile gearbox*, Measurement 2018, 114, 233–242.
[8] Sawczuk W.: *The application of vibration accelerations in the assessment of average friction coefficient of a railway brake disc*, Meas. Sci. Rev. 2017, 17, 125–134.
[9] Li Z., Jiang Y., Hu C., Peng Z.: *Recent progress on decoupling diagnosis of hybrid failures in gear transmission systems using vibration sensor signal: A review*, Measurement 2016, 90, 4–19.
[10] Chmelař J., Mossóczy P., Dynybyl V.: *Rolling element bearing test rig development*, 58th ICMD 2017, 6 - 8 September 2017, Prague, Czech Republic, 114-117.
[11] Savić B.: *Mehatronički aspekt istraživanja dinamičkog odziva kotrljajnih ležajeva sa promenom radnih parametara*, Doktorska disertacija, Fakultet tehničkih nauka u Čačku.
[12] Šiniković G.: *Detekcija oštećenja ležaja u ultrazvučnom domenu*, Doktorska disertacija, Mašinski fakultet Univerziteta u Beogradu, 2012.