A Small-Size Stand for Vibroacoustic and Durability Testing of Rolling Bearings

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Abstract

A small-size stand for vibroacoustic and durability testing of rolling bearings is presented in this paper. Main purposes and motivations for building this stand were not only to assist research and development works but also to familiarize students with techniques and methods of rolling bearings diagnosing as well as to improve their skills of assessment of rolling bearings technical condition. The project assumptions of the stand, mechanical construction and architecture of data acquisition and analysis system (hardware and software) are described in this paper. Finally there are conclusions about stand's capabilities included.

Keywords: vibroacoustics, rolling bearings, durability tests, testing stand

1. Introduction

In the research and development works in the field of rolling bearings technical diagnostics there is a need of disposing of signals and measurement data. The data should preferably comply the entire cycle of rolling bearings life – from a brand-new state to the moment of its full technical degradation. This data may be obtained from machines during their regular work in industrial conditions. It is common that such data are not complete enough to form full symptom life curves of rolling bearings'. The full informative data may be obtained from dedicated for long-term durability testing stands. This devices are usually equipped with a hydraulic load control system. Such a solution provides a possibility to load the testing bearing with forces far above its dynamic load capacity. Stands of this type are usually big and they are very expensive [1].

Considering above, it was justified to design and build a small-size, low-cost stand for vibroacoustic and durability testing of rolling bearings. The elaboration of the stand was also important because many methods of rolling bearings diagnosing use vibroacoustic signals to assess technical condition of rolling bearings. These methods include: wideband root-mean-square (RMS) vibration measurement [2], shock pulse method (SPM) [3], kurtosis determination, crest factor measurement [4], analysis of vibration signal envelope [5], spectral analysis [6] and the use of Teager-Kaiser energy operator [7]. The stand is mainly dedicated to didactical purposes but it also should enable R&D works targeting development of new methods and techniques of the rolling bearings diagnosing. The stand's hardware (including mechanical part) and software should support laboratory classes where students improve their skills in assessment of the rolling bearings technical condition [8].

The long-term testing of rolling bearings on this stand includes all phases of rolling bearings technical degradation. The testing shall also guarantee simultaneous registration of vibroacoustic signals, thermal and work parameters. In this way it is possible to create data libraries which may be used to perform different multi-thread analyses on workstations which are not directly connected with the stand. The collected data may be used for determination of rolling bearings symptom life curves and then for estimation of alert thresholds for specific bearings types [9].

2. Research object and design assumptions

The stand was designed for self-aligning UC205 rolling bearings or other bearings with similar dimensions. Basic parameters of UC205 rolling bearing are shown in Table 1. This specific type of rolling bearings has been chosen as the research object because of possibility of using a typical tension housing. Therefore the bearing can set its position in the housing relative to shaft and housing.

Table 1. Basic parameters of rolling bearing UC205

Inner diameter	25 mm
Outer diameter	52 mm
Static load capacity	7880 N
Dynamic load capacity	14000 N
Maximum operating temperature	110˚C

The following parameters has been taken into account at the design stage:

- compact construction – small size compared to professional stands offered on the market,
- low power consumption; power supply 230 V (single-phase),
- automatic emergency stop in case of:
  - exceeding the vibration threshold,
  - exceeding the temperature threshold,
  - unexpected decrease of motor RPM as an effect of drive unit overload,
- possibility of fluent radial loading of tested bearing in the range 0 – 2000 N.

3. Mechanical part of stand

Mechanical part of the stand is shown in Figure 1. The drive unit of the stand is a single-phase asynchronous 0.75 kW electric motor. The tested bearing is mounted on a separate shaft. This shaft is supported by two rolling bearings with significantly higher dynamic load capacity compared to the tested bearing. The electric motor drives the shaft with the tested rolling bearing by a belt transmission with 2:1 gear ratio. Therefore degradation of the tested bearing is much more intensive and frequent replacement of support bearings can be avoided. The loading system consists of a set of parallel springs. It loads the tested bearing with maximum force of 2400 N. The load value is calculated on the base of springs' deflection which optionally can be measured manually using e.g. a calliper or by an optical sensor. The mechanical part of the stand is mounted in a steel frame with dimensions of 0.4 × 0.5 × 0.4 m. It should be mentioned that the drive unit is vibroisolated using rubber elements between the steel frame and heavy concrete base of the electric motor.

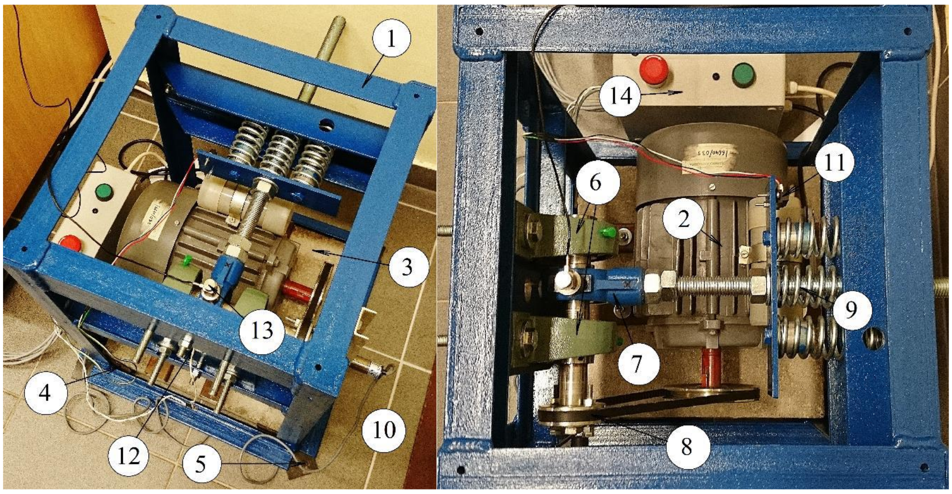

Figure 1. Mechanical part of the rolling bearings testing stand (1 – steel frame, 2 – electric motor, 3 – motor base, 4 – vibroisolation, 5 – rubber separation elements, 6 – support bearings, 7 – tested bearing in tension housing, 8 – belt transmission, 9 – springs loading system, 10 – tachometer (RPM measurement), 11 – optical sensor (springs deflection measurement), 12 – temperature sensor (temperature measurement), 13 – vibration transducer (piezoelectric accelerometer), 14 – signal acquisition and motor control device (the SAMC device))

4. Instrumentation and IT structure of the stand

Figure 2 presents a simplified diagram of: signal acquisition, signal analysis and data transfer. The stand is equipped with devices which measure diagnostic signals: vibration acceleration (RMS value) and temperature of the tested bearing. In addition operating parameters like: instantaneous rotation speed of the shaft, instantaneous frequency of power supply and the load force of the tested bearing are measured.

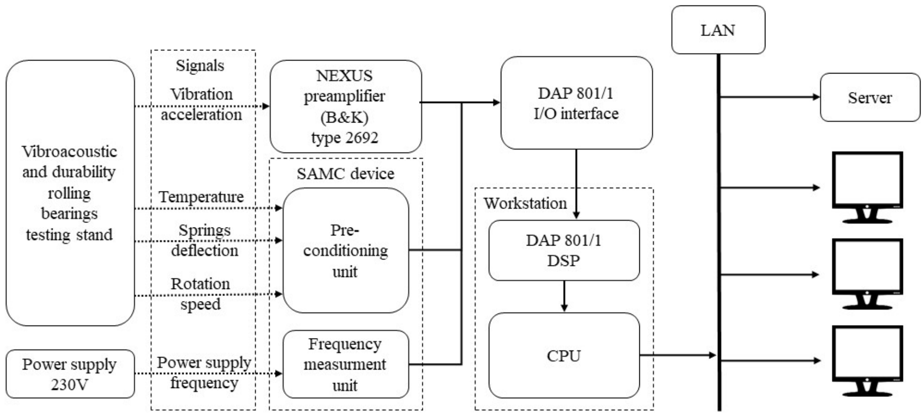

Figure 2. Signal acquisition, signal analysis and data transfer diagram

Signals from tachometer, temperature and optical sensors (springs deflection measurement) are pre-conditioned by a signal acquisition and motor control device (the SAMC device) which is shown in Figure 3. The signal of vibration acceleration is amplified and filtered using anti-aliasing filters in NEXUS preamplifier (B&K) type 2692. The signal acquisition module included in the SAMC device is responsible for tachometer, optical sensor and temperature signals' adjustment to analog-to-digital converter's (ADC) input range 5V and low-pass filtering of these signals (noise reduction). The SAMC device is necessary for input protection of digital signal processor (DSP). It also enables manual or external electric motor control using digital signal from DSP. All signals are transferred to a DSP I/O interface of DAP 801/1.

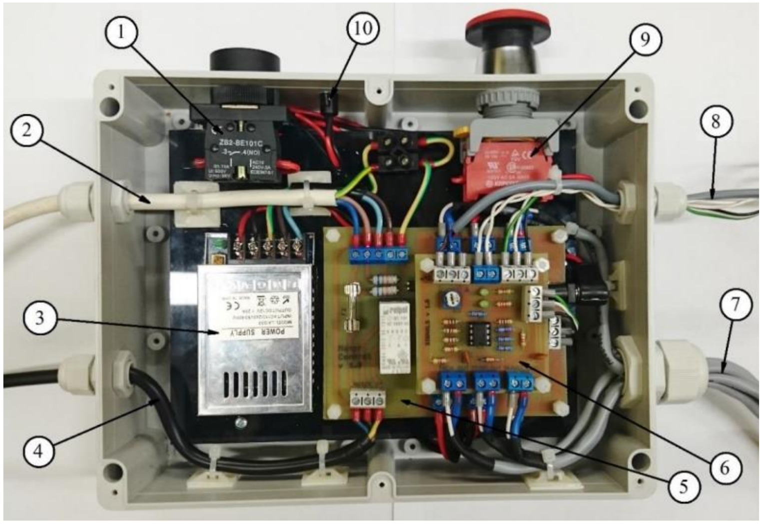

Figure 3. Signal acquisition and motor control device (1 – power switch, 2 – 230 V power supply, 3 – 12 V power supply, 4 – motor supply, 5 – motor control unit with power supply frequency measurement unit, 6 – signal conditioning unit, 7 – signal outputs, 8 – signal inputs, 9 – emergency stop, 10 – LED indicator)

While choosing digital signal processor the following features and parameters of DSP have been taken under consideration: ADC resolution, maximum sampling frequency, number of digital and analog input and output channels, price and device availability. Due to this parameters the DAP 801/1 (Microstar Laboratories) signal processor has been chosen. This DSP is a board which can be mounted in a workstation. Its basic parameters are presented in Table 2 [10].

Table 2. Basic parameters of DAP 801/1 signal processor

ADC resolution	12 bits
ADC sampling frequency	105 kHz
Analog input voltage ranges	-2,5 to +2,5V 0 to 5V -5 to +5V -10 to +10V
Number of analog input channels	8
Number of digital input/output channels	8/8

The sampling frequency (105 kHz) is high enough to observe bearings degradation in higher frequencies about 50 kHz. Due to that the assessment of rolling bearings condition using the SPM method is also possible.

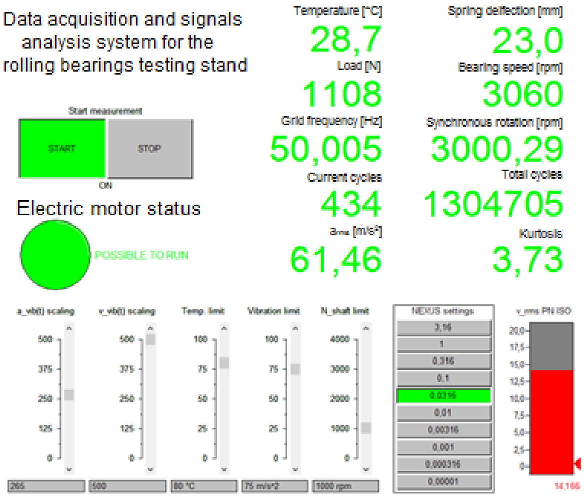

Figure 4. Measurement and control panel of data acquisition and analysis application for the rolling bearings testing stand

The stand is equipped with data acquisition and analysis application. The software was made in DASYLab (Data Acquisition System Laboratory) programming environment and it controls DAP 801/1 signal processor [11][12]. A screenshot of the measurement and control panel is presented in Figure 4. The elaborated application can visualize results of measurements as numerical data or in diagrams. The slip of asynchronous motor can be calculated using precisely measured instantaneous rotation speed of the shaft and the power supply frequency. The slip is indirect measure of load moments of the tested rolling bearing. Optionally vibration acceleration and velocity signals and their spectra can be presented as diagrams. The measuring system displays current RMS value of vibration velocity according to PN ISO 10816-1 standard [13]. There is also a possibility to set an alarm thresholds for RMS vibration acceleration, temperature and rotation speed. After one of the thresholds is exceeded system can automatically finish measurements and turn off the drive unit using digital control signal which is sent to the SAMC device. The rolling bearings testing stand may work without human direct supervision and it gives a possibility to carry out long-term researches.

The workstation with DAP 801/1 signal processor is connected to LAN and to data server. Results of measurements and analyses transferred to the server create data libraries. This data can be read by other workstations connected to LAN.

5. Conclusions and remarks

The carried out tests confirm that: the stand is fully functional and fulfils the project assumptions. Necessary corrections and adjustments were introduced during the first test. The experiment was carried out from the brand-new state of the bearing to the vibration phase of its technical degradation. With radial load equal to 1000 N and shaft rotation speed of 3000 RPM the bearing shall be completely degraded in about 3 months. The length of this experiment allows tracking the development of damages in vibroacoustic signals and forming symptom life curves of rolling bearings.

The stand for vibroacoustic and durability rolling bearings testing may be an alternative for professional industrial devices for bearings' long-term durability tests and it can be applied in e.g. didactical process performed in vibroacoustics and technical diagnostics laboratory. This stand provides precise measurements and autonomic work which is necessary in long-term researches. Compact construction of the stand containing overload protection system and automatic turn off system, activated after exceeding limit values of operating parameters or diagnostic signals, allows autonomic work without frequent human supervision. The data obtained from the stand will be used in future researches.

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