SELECTED ENGINEERING PROBLEMS
NUMBER 8
DEPARTMENT OF ENGINEERING PROCESSES AUTOMATION AND INTEGRATED MANUFACTURING SYSTEMS

Bartosz ŚWIEBODA, Mariusz Piotr HETMAŃCZYK*

Department of Engineering Processes Automation and Integrated Manufacturing Systems,
Faculty of Mechanical Engineering, Silesian University of Technology, Gliwice
*mariusz.hetmanczyk@polsl.pl

IDENTIFICATION OF THE OPERATIONAL STATE OF THE ROTOR MACHINE USING VIBRATION PARAMETERS MONITORING

Abstract: The article presents a method to identify the operational state of a rotating machine based on vibration symptoms. The tests were performed on the balancing and alignment laboratory stand. In the measurements, acceleration sensors and the IFM VSE100 diagnostic module were used. The measurements were made while maintaining the constant rotational speed of the motor shaft. The diagnosis was based on the vibration values measured from the bearing housings of the shaft (on which discs with the initial imbalance were placed).

1. Introduction

Over the last decades, there has been a significant increase in the functionality of technical means, and hence the complexity of their functions. Such state resulted in the emergence of a new research field, which is technical diagnostics supported by the advanced computer technology. Availability, operational safety, reliability, durability of machines and technical devices used in the production processes are of enormous importance in achieving the economic success of the company [1,3].

Large production losses can be resulted by undesirable damage of technical equipment (leading to consequent downtimes or failures). Appropriate assessment of the technical condition [8,9] of the machine allows to make decisions at particular stages of the lifecycle (the construction, manufacturing and operation phases).

A commonly used form of operational states evaluation is vibration diagnostics, which allows an assessment of the machine's condition by examining the generated vibrations parameters.

The vibrations induce cyclically variable stresses and strains in the machine components. Prolonged exposure to stresses results in exceeding the material fatigue limit and consequently in failures or damages. The described phenomena cause various types of damage [6], such as: malfunctions of impellers, bearings, seals, gears, couplings, screw connections, etc.

In the case of vibration diagnostics, the methods of operational state evaluation may take the following form: measurement of basic vibration parameters in the time domain (a displacement, a velocity or an acceleration), analysis in the frequency domain, folding of vibrations characteristics, analysis of orbit, differential spectrum, Cepstrum or envelope methods.

2. Configuration of the balancing and alignment laboratory stand

The laboratory stand has been mounted on a frame made of aluminum profiles, due to increase a stiffness and reduce a weight. The control panel and a frequency inverter have been mounted on the separate frame.

The electric drive system is based on SEW Eurodrive equipment (an AC three-phase asynchronous motor [2,4] controlled by the Movitrac B frequency inverter). The binary inputs and the external control panel have been connected to the frequency inverter via the RS485 communication interface (remote panel used to set main control commands). To parameterization the Movitools MotionStudio software was used. Figure 1 shows the basic configuration of the complete laboratory stand.

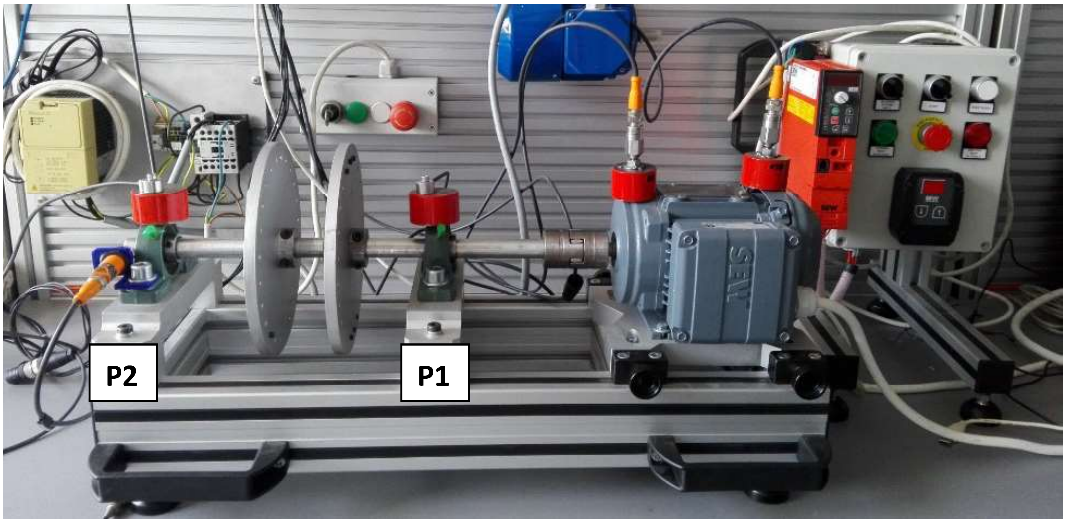


Fig.1. View of the balancing and alignment laboratory stand

The stand was extended with the VSE100 vibration diagnostics module (with VSE001 and VSE004 vibration sensors) and the IFM FR1 speed monitor. The main application of the station is vibration monitoring, resulting from [5]:

- unbalance - simulated by means of discs mounted directly on the shaft, connected with the AC motor by a jaw coupling,
- misalignment of the motor rotor and coupled shaft - regulation of the degree of inaccuracy of angular and radial position of the shafts is possible with the aid of adjustment bolts that allow changing the foundation conditions of the motor (in both horizontal and vertical planes).

3. Parametrization of the VSE100 diagnostic module

The VSE100 module is a main part of the vibration monitoring system. In addition, the module allows for monitoring the vibrations level in order to detect the unbalance of the shaft or even degree of wear of individual bearing components [1,2,6,7].

In order to configure the diagnostic electronics, the IFM VES004 software was used. Usage of high accuracy sensors allows to preserve satisfactory resolution in wide measuring ranges. It is also possible to select different filters for monitoring and machine protection. Up to 32 individual functions provide reliable and repeatable vibration characteristics, as well as performance and undisturbed flow of data (used to optimize machine functioning).

Performing the monitoring and diagnosis processes required a creation of a new project. The program options have been configured for characteristic parameters of used sensors (Fig. 2).

Sensors have been mounted on the left (P2) and right (P1) bearing housing (Fig. 1). The axes of the sensors have been oriented in the vertical direction. The next step was setting the rotational speed value. In the considered case, a fixed speed value was selected (set to 1500 rpm). Such a choice is dictated by the fact that there was no coupling between the analogue output of the vibration diagnostic module and the speed monitor input (only the function of controlling the current speed value on the front panel of the rotational speed monitor has been used).

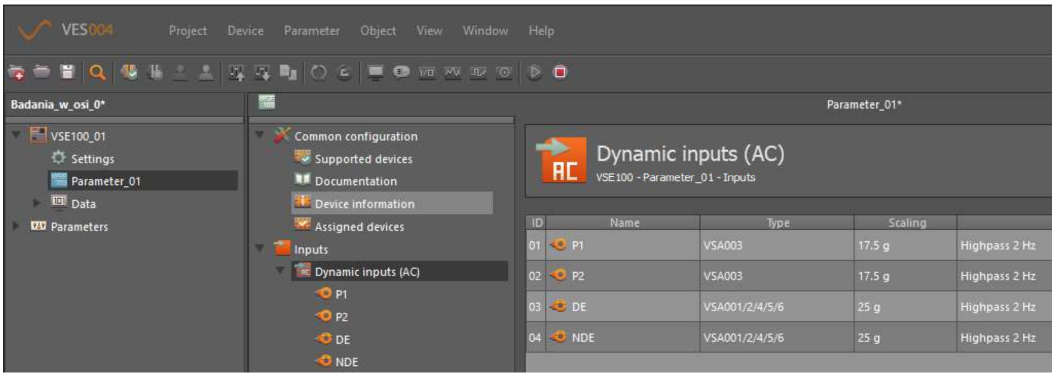
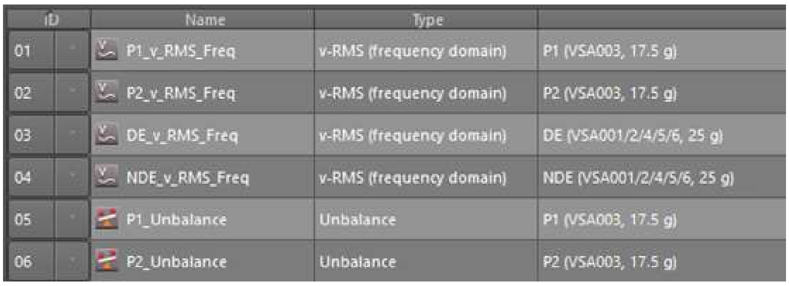


Fig.2. View of the configuration window of sensors connected to the VSE100 module

The last step of the configuration was setting the parameters gathered from the sensors (Fig. 3). In the considered case the RMS (in the frequency domain) and unbalance values (measured from sensors P1 and P2) were chosen.



ID	Name	Type	
01	P1_v_RMS_Freq	v-RMS (frequency domain)	P1 (VSA003, 17.5 g)
02	P2_v_RMS_Freq	v-RMS (frequency domain)	P2 (VSA003, 17.5 g)
03	DE_v_RMS_Freq	v-RMS (frequency domain)	DE (VSA001/2/4/5/6, 25 g)
04	NDE_v_RMS_Freq	v-RMS (frequency domain)	NDE (VSA001/2/4/5/6, 25 g)
05	P1_Unbalance	Unbalance	P1 (VSA003, 17.5 g)
06	P2_Unbalance	Unbalance	P2 (VSA003, 17.5 g)

Fig.3. View of the settings window selected for testing parameters

The tests did not take into account the signals measured from the DE (Drive End) and NDE (Non-Drive End) sensors (mounted on the motor housing).

4. An example of measurement and diagnosis of the laboratory stand

In the first stage, a preliminary analysis of the operational status of the laboratory stand was made. For this purpose, the machine under study was classified into one of the groups defined in the ISO 10816 standard (to define vibration thresholds for initial assessment). The performed measurement of the RMS value (Fig. 4) indicates that the evaluated object was in a condition that enables further work (without the need to implement additional corrective actions).

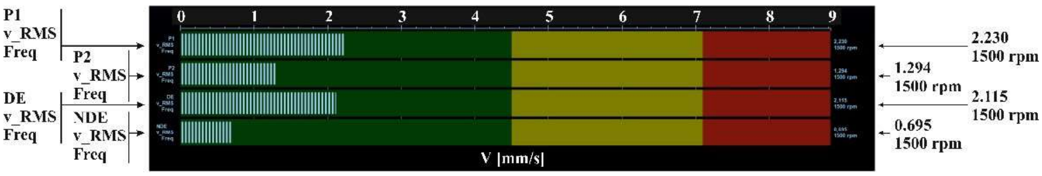


Fig. 4. View of the RMS velocity values (measured on the bearing supports of the tested system)

However, it was decided to improve the parameters determining the quality of the system's operation, which required a diagnosis based on FFT spectra (Fig. 5,6).

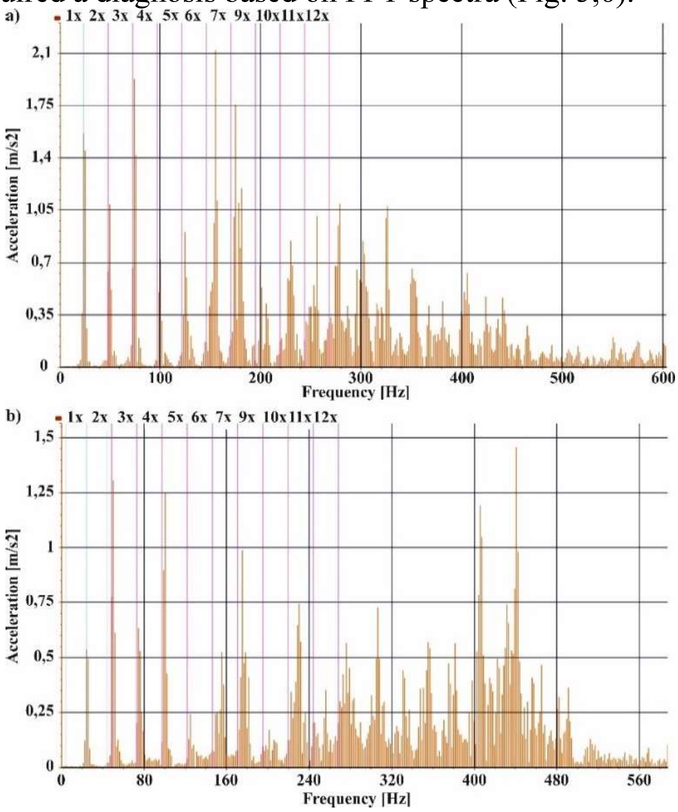


Fig.5. View of the vibration spectrum measured on the bearing support (with visible unbalance symptoms): a) location P1, b) location P2; where: 1x÷12x – harmonics

On the FFT spectra characteristic frequencies of the rotational speed and harmonics of the first frequency component were determined. In the presented case a frequency of the motor rotational speed was equal 25.18 [Hz], which gives directly the value of the rotational speed equals 1510.8 [rpm]. The first diagnosed irregularity was an existing problem with the unbalance of disks mounted on the rotor (Fig. 5).

For the purpose of further analyzes, the amplitudes of vibration accelerations measured in the vertical direction (the sensor axes) were selected. In the analyzed case, the value of acceleration vibration amplitudes were, on the support P1 - 1.558 [m/s^2], and on the support P2 - 0.519 [m/s^2]. The stage of eliminating the unbalance and determining the orientation of fixing the correction mass has been omitted. After corrections improvement (Fig. 6), values of acceleration vibration amplitudes were: on the support P1 - 0.138 [m/s^2], on the support P2 - 0.077 [m/s^2].

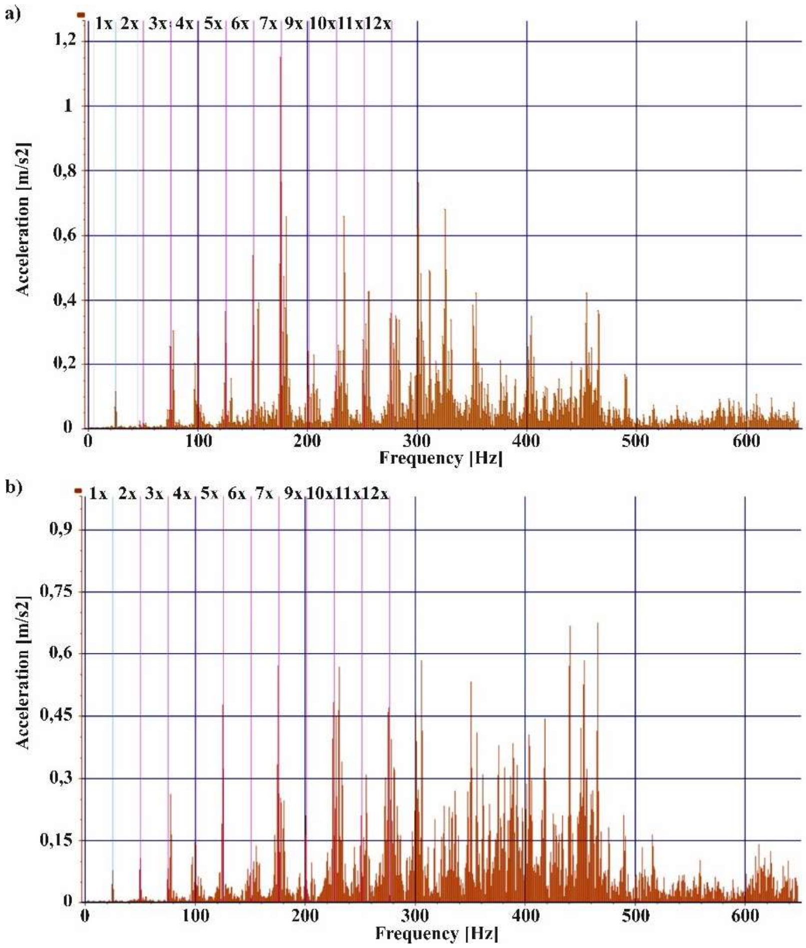


Fig.6. View of the vibration spectrum measured on the bearing support (with removed unbalance state): a) location P1, b) location P2; where: 1x÷12x - harmonics

Such prepared laboratory stand will be used for further research including the impact of mechanical vibrations on the condition of rotating machines. The laboratory stand has been stripped of the discs burden, which resulted in elimination of large values of dynamic forces.

5. Conclusions

The FFT spectrum analysis allows to the identification of a deterioration rate of the machine's condition (with simultaneous detection based on the identification of the source of harmonic frequencies and amplitudes of vibration in the specified frequency range). The advantages of vibration parameters evaluation are achievement of the full failures selectivity and a large number of technical standards. Due to the structure of considered technical devices each analysis can be performed on different level of complexity.

Overall the vibration monitoring is performed on the basis of separate configurations of measuring systems: continuous on-line monitoring systems (large, small and medium-size machines), systems of periodic monitoring or ad-hoc methods (diagnosis in the offline mode) and diagnostic centres.

The advantages of evaluating vibration parameters are [5]: obtaining full selectivity of identifiable damages, large number of technical standards (identifying criteria for the assessment of the technical condition of machinery and measurement procedures), measurements in a wide range of rotational speeds, defined and well-described measuring procedures [1,2].

References

1. Adams M.L.: Rotating Machinery Vibration: From Analysis to Troubleshooting (2nd Edition). New York: CRC Press, 2009.
2. Dutta N.K., De S.K.: Electric Machines and Electric Drives: Problems with Solutions. New Delhi: PHI Learning Pvt. Ltd., 2012.
3. Ehrich F.F. (ed.): Handbook of rotordynamics. Malabar: Kreiger, 2004.
4. Giri F. (ed.): AC Electric Motors Control: Advanced Design Techniques and Applications (1st Edition). Oxford: John Wiley & Sons, 2013.
5. Hetmańczyk M.: Applicability Analysis of Directed Graphs to Diagnosis and Prediction of States of Mechatronic Drives Using Minimal Set of Process Data. Gliwice: The Silesian University Publishing House, 2016.
6. Ibrahim M.A.: Disturbance Analysis for Power Systems. USA: John Wiley & Sons, 2011.
7. Krause P., Wasynczuk O., Sudhoff S., Pekarek S.: Analysis of Electric Machinery and Drive Systems (3rd Edition). New York: John Wiley & Sons, 2013.
8. Lees A.W.: Vibration Problems in Machines: Diagnosis and Resolution. New York: CRC Press, 2015.
9. Mohanty A.R.: Machinery Condition Monitoring: Principles and Practices. New York: CRC Press, 2014.