16th IMEKO TC4 Symposium
Exploring New Frontiers of Instrumentation and Methods for Electrical and Electronic Measurements
Sept. 22-24, 2008, Florence, Italy

Laser measurements in the motor bearing diagnostics

Ariel Dzwonkowski[1], Leon Swędrowski[2]

[1] *Faculty of Electrical and Control Engineering, Gdansk University of Technology, Narutowicza 11/12 Str., Gdansk, 80-952 POLAND, Phone: (+48 58) 347 1778, Fax: (+48 58) 347 1726, e-mail: a.dzwonkowski@ely.pg.gda.pl*
[2] *Faculty of Electrical and Control Engineering, Gdansk University of Technology, Narutowicza 11/12 Str., Gdansk, 80-952 POLAND, Phone: (+48 58) 347 1284, Fax: (+48 58) 347 1726, e-mail: l.swedrowski@ely.pg.gda.pl*

Abstract- Statistics say that bearings are this part of induction motors which is most susceptible to damage. That is why the issues connected with diagnostics of bearings are so important. The equipment employed for bearing diagnostics usually makes use of vibrations as the criterion for technical condition of the bearings.
This paper presents exemplary results of the research conducted on bearings with artificially introduced damages. A scanning laser vibrometer PSV-400 Polytec has been used for vibration measurements. The research of technical condition of the same bearings was simultaneously carried out with the usage of DREAM – a vibration diagnostics system.

I. Introduction

Some damages of mechanical parts such as bearings, rotor, shaft or the damages in the elements of electromagnetic system, for example in the wiring of stator, rotor or of the magnetic circuit can appear in induction motors. The methods used to diagnose the damages in induction motors are based on various physical phenomena. These methods mostly involve measurements of vibrations, temperature, acoustic phenomena and current [1, 2, 3, 4].
This paper shows diagnostic methods which employ the acceleration of vibration measurements. The appearance of a specific kind of damage in the motor is a source of additional forces whose character is oscillatory and which can be noticed in the damaged area. These forces result in vibrations which form the basis for diagnostic research [5]. When the course of these vibrations is subjected to spectral analysis, we obtain a number of components related to specific types of damages. A scanning laser vibrometer PSV-400 Polytec has been employed for vibration measurements. This device is not yet commonly used for bearing diagnostics, due to high costs of research equipment. The research has been conducted on a number of artificially damaged bearings. When damage is artificially introduced into a bearing, it can observed, in the spectrum of the vibrations, the appearance of not only those components which result from the introduced damage, but also components characteristic for other bearing damages. It is to be assumed that the introduction of one type of damage into the bearing results in quick development of secondary damages. Therefore, in diagnostic research it does not suffice to introduce a certain kind of damage into a bearing. It is also necessary, in the course of research, to control the development of secondary damages with the usage of another verified diagnostic system, such as the DREAM [6]. This paper presents exemplary results of testing damaged bearings with the usage of laser vibrometer PSV-400.

II. The measurement system

A. Scanning laser vibrometer PSV-400 Polytec

The scanning laser vibrometer PSV-400-M4 allows to measure, simultaneously at numerous points, vibrations of machines or appliances as well as those of their structural parts. It is possible to determine up to 512 testing points. The scanning laser vibrometer guarantees a contact-less measurement. Thanks to it, the vibration picture of the tested construction is not disturbed by the mass of measuring sensors. What is more, the measurement can be conducted from a considerable distance (about 50 m), which allows us to protect the appliance from the influence of harmful factors. At the beginning of the measurement process we determine a grid of points covering the tested area and turn the scanner on.

The measurement data is then sent to the acquisition card of measurement signals and later to the computer. In further stages of the research the vibration data is subjected to analysis with the usage of special-purpose software which allows conducting spectral analysis, drawing diagrams or maps and exporting the data in a variety of formats [7].

B. Vibrations diagnosis system DREAM

The vibration diagnosis system DREAM allows diagnosing various rotating machines, including rolling bearings, slide bearings, ventilators, pumps, toothed gears and electromechanical systems of electric machines.
This system is composed of an analyzer – collector of data DC 11 with a vibration sensor and the DREAM software for PC computer. The measurement process begins with the installation of the vibration sensor on the tested object. The output of the sensor is connected to the input of the data collector and the vibration spectrum is analyzed and registered in the collector. In the further stages of the research, the registered spectrum is transferred, using RS232 interface, to the PC computer and analyzed with the DREAM programme [6].

III. Experimental research

The research has been made on induction motors of the type STg80X-4C, with the following parameters: P_n = 1,1 kW, U_n = 380 V, n_n = 1400 RPM, I_n = 2,9 A.
The bearings installed in these motors were 6204 type. The motors were supplied directly from three-phase supply network, with the voltage of 400 V.
The research has been conducted both on undamaged and purposely damaged bearings.
The damages were introduced separately into three elements of the bearing, namely the outer ring, the inner ring and the rolling element. A several bearings of 6204 type has been damaged and tested. Undamaged units have also been tested for comparison. The diagnostic research with the usage of the DREAM system has been conducted in order to check the kind of damage and the stage of its development. The system differentiates between damaged and undamaged bearings, identifies the kind of possible damage and the stage of its development.
The laser vibrometer was programmed to conduct measurements of acceleration signals on both the front and one side of the motor. The range of spectral analysis was assumed up to 400 Hz, with the resolution of 0,001 Hz.
To present the results of measurement from laser vibrometer the program in LabVIEW was elaborated.
The results of the research conducted on an undamaged bearing and on a bearing with artificially introduced damage of the inner ring are presented on the figures 1, 2 and 3.

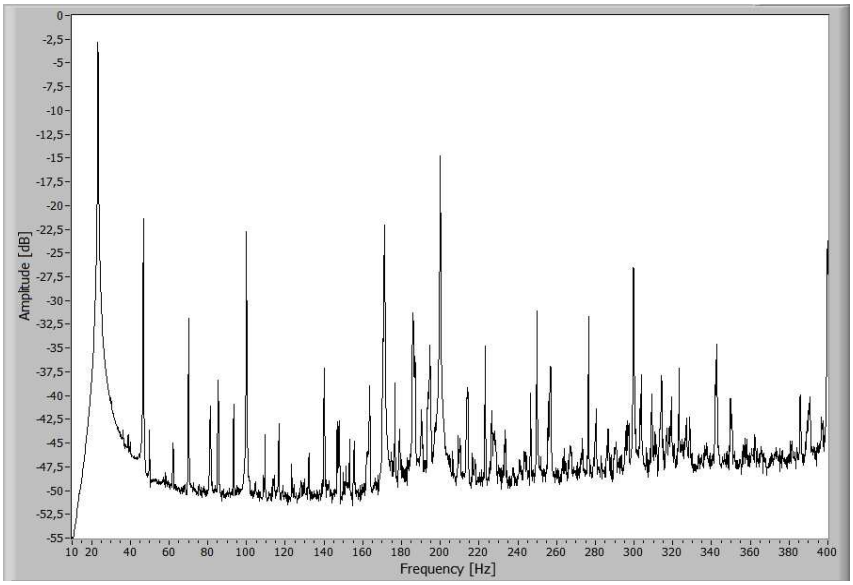

Figure 1. The vibration spectrum of the undamaged bearing, obtained with the usage of scanning laser vibrometer.

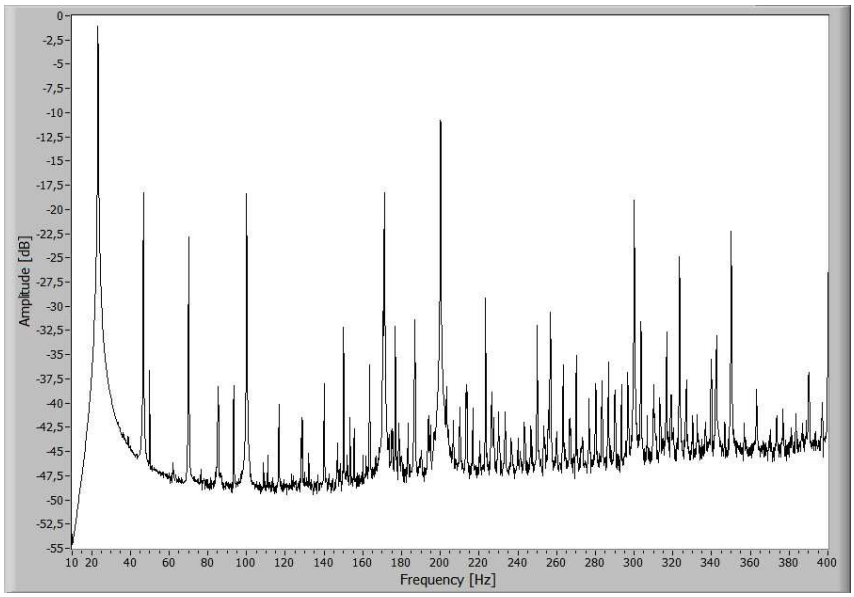

Figure 2. The vibration spectrum of the bearing with the damage of its inner ring, obtained with the usage of scanning laser vibrometer.

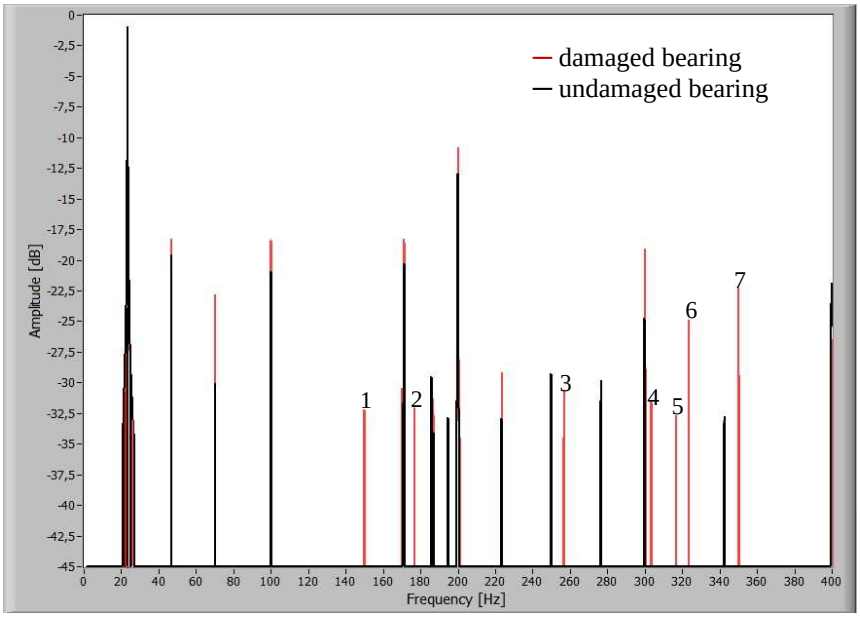

Figure 3. The compilation of vibration spectrum of the undamaged bearing and of the bearing with the damage of inner ring.

The analysis of the above figures shows that the number of components in the spectrum of acceleration signals for the undamaged bearing is smaller than in the case of the bearing with artificially introduced damage of its inner ring. The new frequencies, showed on figure 3, are: 1 - 150 Hz, 2 - 176,7 Hz, 3 - 256,9 Hz, 4 - 303,4 Hz, 5 - 316,9 Hz, 6 - 323,3 Hz, 7 - 350,3 Hz. It can be notice that amplitudes of some harmonics which appear in the vibration spectrum of the motors with damaged and undamaged bearings are higher in spectrum, measured on machine with damaged bearings. The researches results of bearings with damages of inner ring, made with usage of vibration system, obtained different frequencies in vibration spectrum. The diagnostic system DREAM reported the damage of the inner ring and showed the frequency of 113,08 Hz, which is characteristic for this type of damage. However, a component of this particular frequency does not appear in the vibration spectrum obtained during the research with the usage of the laser vibrometer.
The research has been conducted for other kinds of bearing damages.

The results of the research on a bearing with artificially introduced damage of the outer ring are presented on the figure 4, and figure 5.

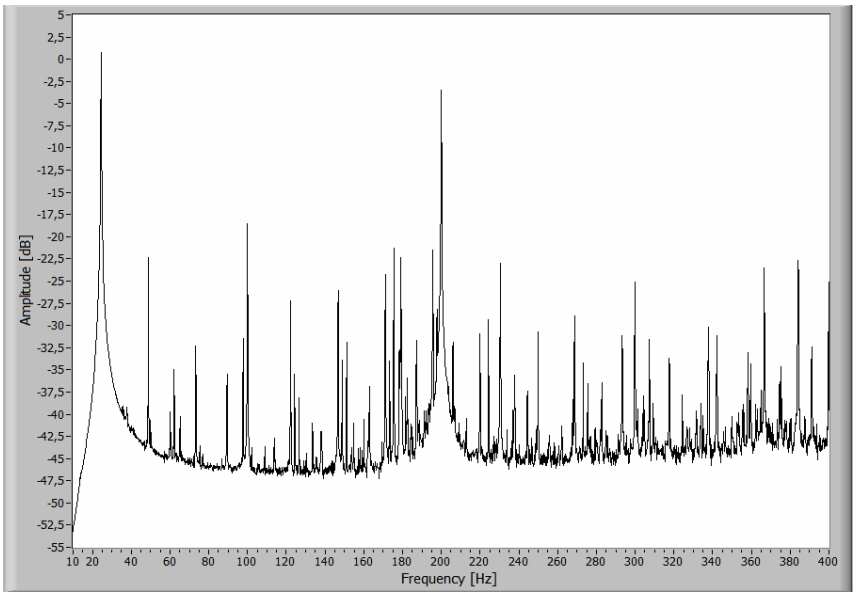

Figure 4. The vibration spectrum of the bearing with the damage of its outer ring, obtained with the usage of scanning laser vibrometer.

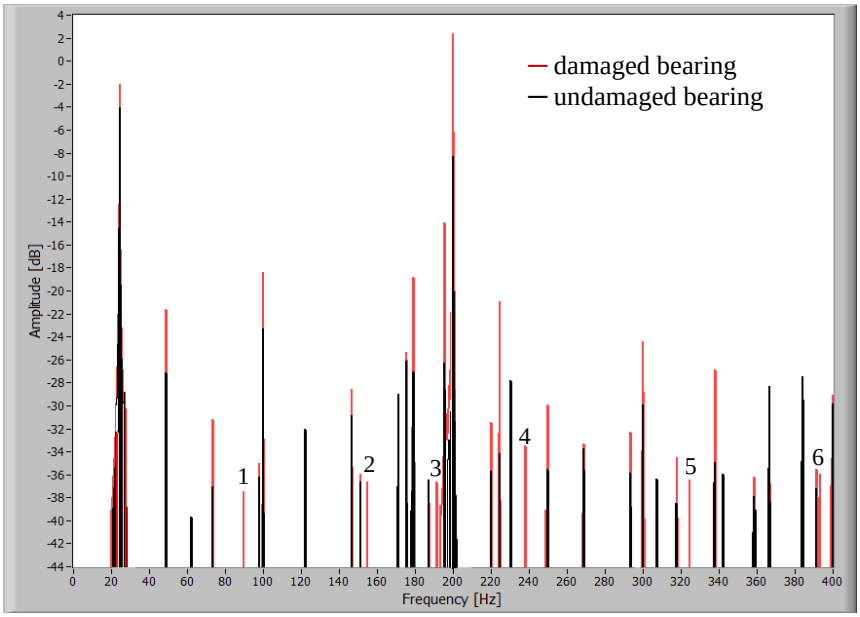

Figure 5. The compilation of vibration spectrum of the undamaged bearing and of the bearing with the damage of outer ring.

The analysis of the figures 4 and 5 shows that the number of components in the spectrum of acceleration signals for the undamaged bearing is smaller than in the case of the bearing with artificially introduced damage of its outer ring. The new frequencies, showed on figure 5, are: 1 - 89,7 Hz, 2 – 154,8 Hz, 3 – 191,2 Hz, 4 – 237,9 Hz, 5 – 324,4 Hz, 6 – 393,1 Hz. It can be notice that amplitudes of some harmonics which appear in the vibration spectrum of the motors with damaged and undamaged bearings are higher in spectrum, measured on machine with damaged bearings. The researches results of bearings with damages of outer ring, made with usage of vibration system, obtained different frequencies in vibration spectrum. The diagnostic system DREAM reported the damage of the inner ring and showed the frequency of 69,8 Hz, which is characteristic for this type of

damage. This particular frequency does not appear in the vibration spectrum obtained during the research with the usage of the laser vibrometer.
The results of the research on a bearing with artificially introduced damage of the rolling element are presented on the figure 6, and figure 7.

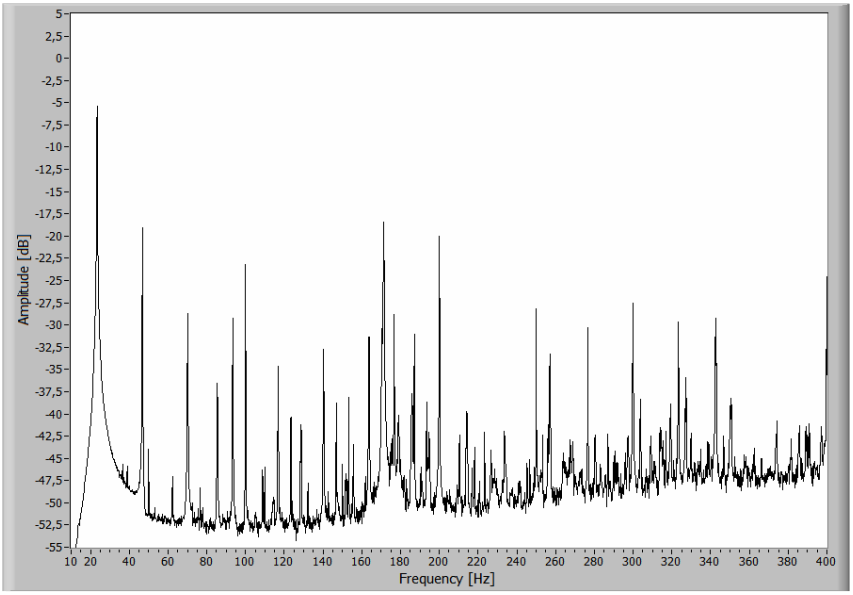

Figure 6. The vibration spectrum of the bearing with the damage of its rolling element, obtained with the usage of scanning laser vibrometer.

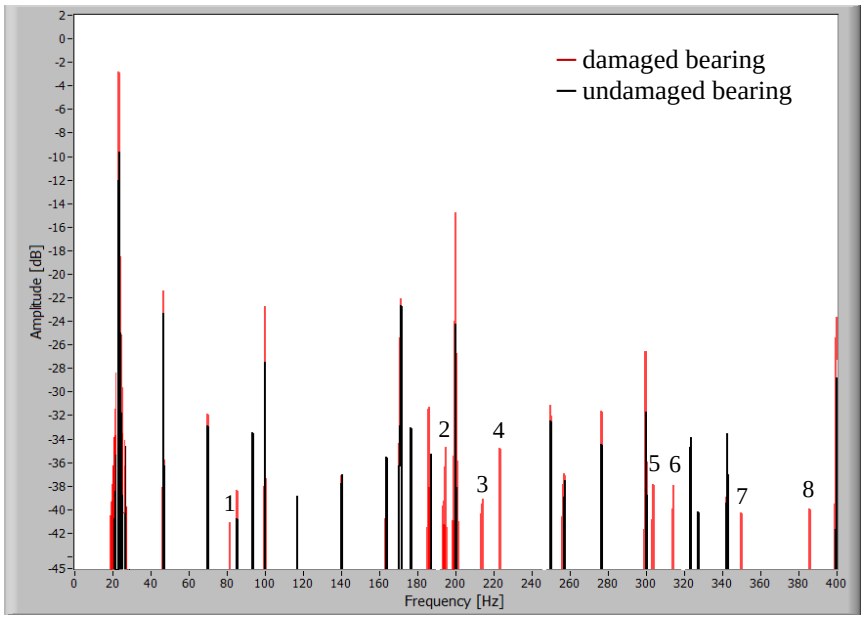

Figure 7. The compilation of vibration spectrum of the undamaged bearing and of the bearing with the damage of rolling element.

The analysis of the figures 6 and 7 shows that the number of components in the spectrum of acceleration signals for the undamaged bearing is smaller than in the case of the bearing with artificially introduced damage of its rolling element. The new frequencies, showed on figure 7, are: 1 - 81,4 Hz, 2 – 194,2 Hz, 3 – 214,2 Hz, 4 – 223,1 Hz, 5 – 303,6 Hz, 6 – 313,9 Hz, 7 – 349,7 Hz, 8 - 385,6 Hz. It can be notice that amplitudes of some harmonics which appear in the vibration spectrum of the motors with damaged and undamaged bearings are higher in spectrum, measured on machine with damaged bearings. The researches results of bearings with damages of rolling element,

made with usage of vibration system, obtained different frequencies in vibration spectrum. The diagnostic system DREAM reported the damage of the inner ring and showed the frequency of 91,2 Hz, which is characteristic for this type of damage. This particular frequency does not appear in the vibration spectrum obtained during the research with the usage of the laser vibrometer.

IV. Conclusions

The research conducted on a number of bearings with the usage of laser vibrometer allows drawing general conclusion. Additional harmonic components, which are not visible in undamaged motors, appear in the vibration spectrum of the motor with damaged bearings, obtained while conducting measurements with the usage of a laser vibrometer. These harmonics may carry information on the type of damage and the stage of its development. Frequencies characteristic for certain types of damages, presented by the vibration diagnostics system DREAM, do not appear openly in the vibration spectrum, which was measured by laser vibrometer. It is to be assumed that, in case of laser research, the components characteristic for certain kinds of damages have different frequencies than those calculated on the basis of dependences known from literature [5]. Therefore, it becomes necessary to elaborate a set of components to be used in bearing diagnostics made by laser vibrometer. Since the introduction of one damage into bearing results in rapid development of secondary damages, it is necessary to conduct comparative research with the usage of advanced vibration diagnostics system in order to determine correctly the harmonics characteristic for certain kinds of damages.
The results which have been obtained so far will be the object of further research, with the aim of elaborating a set of components to be used in diagnostics.

References

[1] Barkow A., Barkowa N., Referowski L., Swędrowski L., Świsulski D., “Progress in machine condition monitoring basing on analysis of generalized vibration spectra”, *International AMSE Conference “System, analysis, control & design”*, Lyon, France, 1994.
[2] Kiral Z., Karagülle H., “Simulation and analysis of vibration signals generated by rolling element bearing with defects”, Tribology International 36, 2003.
[3] Sing G. K., Sa’ad Ahmed Saleh Al Kazzaz, “Induction machine drive condition monitoring and diagnostic research – a survey, *Electric Power System Research* 64, 2003.
[4] Jack L.B., Nandi A.K., Genetic algorithms for feature selection in machine condition monitoring with vibration signals, *IEE Proc. - Vision, Image and Signal Processing*, vol.147, June 2000.
[5] Paone N. Cristalli C., Rodriguez R. M., Comparative study between laser vibrometer and accelerometer measurements for mechanical fault detection of electric motors, *Proc. SPIE*, Vol. 4827, p. 521-529.
[6] Swędrowski L., Dzwonkowski A., Application of vibration methods for calibration of diagnostic system based on motor current analysis, Elektrotechnika i Elektronika, Vol. 25, Issue 2, 2006, p. 202-206.
[7] Polytec GmbH Technical specifications, 2007.