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# Analysis of vibration in electric motors using contact and contactless methods

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# Analysis of vibration in electric motors using contact and contactless methods

Bobur Narzullayev[1], Bakhodir Ramazonov[1, a)], Javokhir Boboqulov[1], Lola Karabayeva[2]

[1] *Navoi State University of Mining and Technologies, Navoiy, Uzbekistan*
[2]*Tashkent state technical university named after Islam Karimov, Tashkent, Uzbekistan*

*Corresponding author:* bahodirmagistr2021@gmail.com

**Abstract.** Nowadays, electric motors are widely used in industrial enterprises to drive the drives of large-capacity machines and mechanisms. Electric motors are the mainstay of production. Therefore, ensuring the failure-free, reliable and stable operation of electric motors is one of the important tasks for our researchers. This article presents the results of two methods of analyzing the vibration state of motors - contact and non-contact vibration analysis. The results obtained showed that the vibration signals recorded using contact and non-contact sensors differed by 20 percent from each other. It was noted that the use of a non-contact method, which allows for direct and accurate measurement of vibration on a rotating shaft, is the most optimal solution.

## INTRODUCTION

Currently, large industrial enterprises of our country place high demands on the reliable and uninterrupted operation of electromechanical equipment. The main element of electromechanical equipment is its electric motor. Electric motors are the main part of the technological process, and their failure leads to a stoppage of the technological process and significant economic losses [1-4]. Therefore, their stable operation is very important. Vibration analysis in electric motors allows for early detection of defects, prevention of malfunctions from escalating, and planned maintenance. Vibration in an electric motor is the displacement of a point in the motor relative to a certain average (zero) position. By analyzing vibration in an electric motor, it is possible to identify malfunctions in its components and even plan its service life in advance. Vibration analysis can be carried out in two ways, Figure 1 below shows a schematic division of the methods for vibration analysis of the motor [5-9].

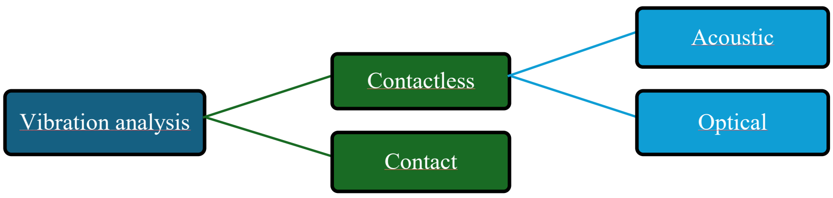


**FIGURE 1.** Vibration analysis methods

The above figure shows the vibration analysis methods. If the measuring sensor is directly connected to the electric motor, it is called the contact method. That is, in the contact method, the measuring sensors are directly fixed to the surface of the motor [10-20]. The measuring sensor accurately records the vibrations of the rotor and housing, and detects bearing failures at an early stage [21-25].

If we carry out the analysis in an optical or acoustic direction, it is called the non-contact method. That is, it is a method of measuring without attaching any sensor to the motor housing and shaft. This method does not require mechanical contact and allows you to diagnose insulation failure without stopping the motor [26-36]. According to the operating principle of the sensors used in the contact method of vibration analysis, it is divided into optical and acoustic types. Since the acoustic analysis of electric motor vibrations is cheaper than the optical method, the acoustic (ultrasonic) method is widely used (Figure 2).

The vibration monitoring system consists of the following elements: a set of ultrasonic sensors (USS); a transmitting unit (TU); a receiving unit (RU); a set of contact vibration sensors (CVS); a laser digital tachometer (LDT); an analog-to-digital converter (ADC); an analyzer unit (UA).

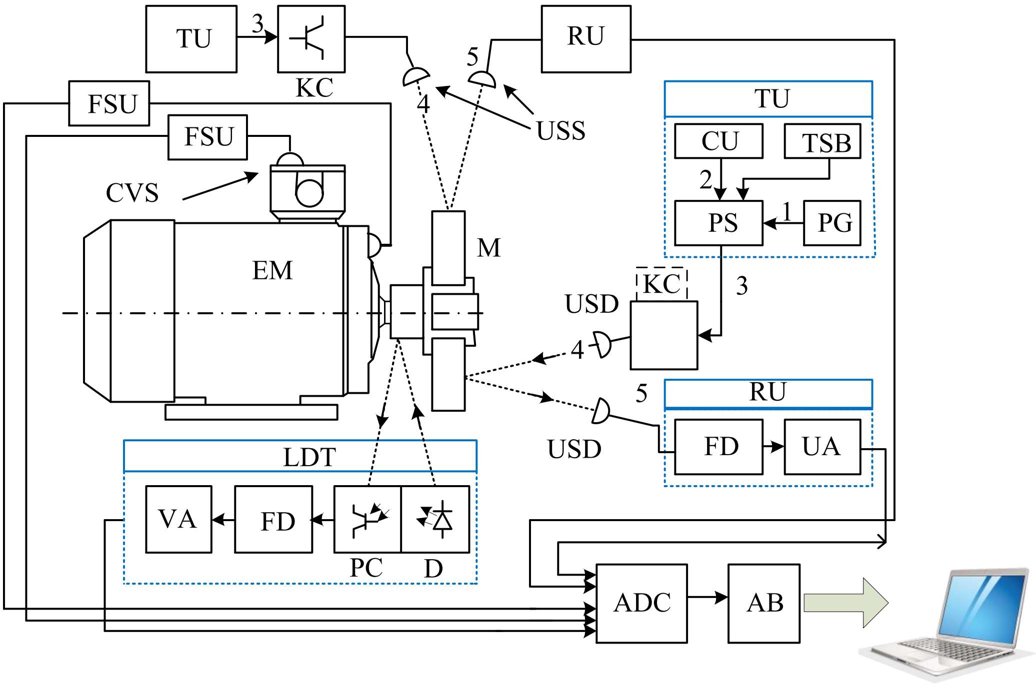


**FIGURE 2.** Schematic diagram of the non-contact (ultrasonic) vibration analysis of an electric motor.

The ultrasonic signal transmitter is built on the basis of a pulse generator (PG) and a task sequence block (TSB). Using the TSB settings, it is possible to set the phase manipulation sequence - Barker code and other sequences with a minimum width of the autocorrelation function. At the output, the signal is transmitted to the transmitter USD through a key circuit (EK) using a pulse shaping device (FIP). The control unit has the ability to set the duration and level of discreteness of the generated signal. The receiving path consists of a noise filtering device (FD) and a voltage amplifier (VA) based on an inverting amplifier. The tachometer unit consists of a light-emitting diode (D) based on a light-emitting diode and a receiving photocell (FE). Using the filter (FD), unnecessary excess waves are filtered, and the signal is amplified by an amplifier (UA). All signals are transmitted to an analog-to-digital converter (ADC) and then sent to the analyzer unit (AB). Signals from contact sensors (CVS) are cleaned of noise using a filter (FD) and transmitted to the ADC.

The system is implemented on the basis of the FPGA XC3S500E microcircuit, which is part of the Xilinx Spartan-3E series of modules. In the process of analysis, an electric drive equipped with an asynchronous electric motor (EM) of the AIR63A4U31 series was selected as the control object. The motor power is 250 W, and the rotation frequency is 1370 rpm. A flywheel (F) is installed on the engine shaft as a load. In the process of general analysis of the state of the control object, ultrasonic (US) transducers were placed in different directions (x, y or z) like contact sensors. In this case, the radiation of the ultrasonic transducer was directed to the rotating working mechanism, which is impossible when using contact sensors. The speed of rotation of the electric motor was additionally controlled using a tachometer.

Comprehensive analysis of vibration signals. Experiments were conducted in laboratory conditions to record vibration signals during start-up and loaded operating modes of an electric motor. Figures 3 and 4 show the time variation of the vibration frequency of the motor and the amplitude values (vibration amplitude at the fundamental frequency) during the start-up of the electric motor. Graphs of changes in vibration frequencies obtained in different directions and with different measurement methods (Figure 3) show that transient processes manifest themselves differently in all cases: the duration of the transient process is not the same, the shape of the frequency change graphs is different. The increase in the vibration frequency measured using contact sensors from the initial value after start-up to the steady-state value is approximately 400 ms (Figure 3, curves 1 and 2 in a). In measurements using ultrasonic transducers (UWT), this time is more than 500 ms (Fig. 3, curves 3 and 4 in b). Significant frequency fluctuations are observed in the graphs in the Z-axis direction (curve 3). This indicates that the data obtained by different methods differ significantly from each other and can complement each other. In addition, comparing the vibration signals with the tachometer signal (curve 5) shows that the dynamics of the shaft rotation speed, vibration frequency and amplitude changes in the Z-axis and perpendicular to it (y) direction of the electric motor in the acceleration mode differ sharply.

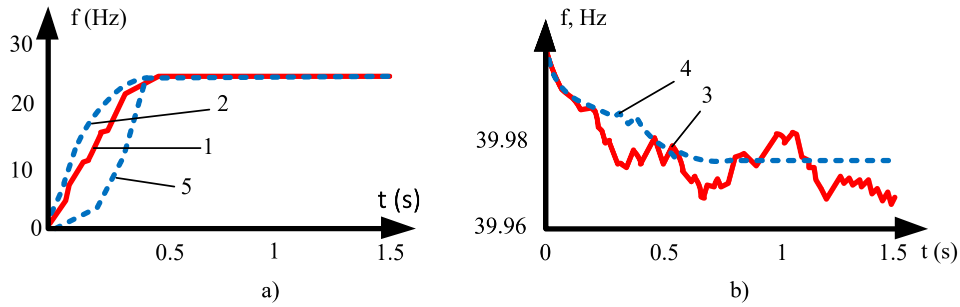


**FIGURE 3.** Frequency dependence graph of vibration analysis of an electric motor. a) readings from a contact vibration sensor and a laser digital tachometer, b) readings from an ultrasonic device.

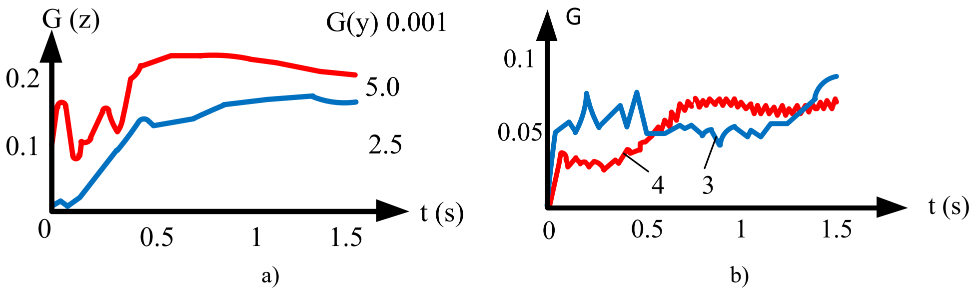


**FIGURE 4.** Time-amplitude graph of vibration analysis. a) readings from a contact vibration sensor, b) readings from an ultrasonic device.

Part A of Figure 4 above (curves 1 and 2) shows a bi-directional variation of the amplitude of the spectrum of vibrational signals derived from contact sensors. Significantly different vibrational amplitudes in different directions from graphs create a clear possibility art A of Figure 4 above (curves 1 and 2) shows a bi-directional variation of the amplitude of the spectrum of vibrational signals derived from contact sensors. Significantly different vibrational amplitudes in different directions from graphs create a clear possibility. Thus, the deviation of the mechanical load of the Working Mechanism from the plane of rotation leads to the fact that the body vibrations are much larger in the direction along the shaft axis (z) than in the direction perpendicular to it (y).

For ultrasonic (non-contact) vibrational signals, the vibrational amplitude is mainly manifested in the phase modulation depth of the signal and has very little effect on its amplitude [37-66]. Therefore, the level of ultrasonic signals recorded in any measurement direction, regardless of the amplitude of the vibration, will be almost the same. Or ultrasonic (non-contact) vibrational signals, the vibrational amplitude is mainly manifested in the phase modulation depth of the signal and has very little effect on its amplitude. Therefore, the level of ultrasonic signals recorded in any measurement direction, regardless of the amplitude of the vibration, will be almost the same. This does not require additional schematic solutions to account for the different measurement ranges of the amplitude of object surface fluctuations. Analysis of ultrasonic vibrational signals Spectra shows that the amplitude of the body vibrations varies several times (even at the order level) if the vibrational amplitudes along the shaft axis of the rotating working mechanism (z) and in the direction perpendicular to it (y) are comparable. Analysis of ultrasonic vibrational signals Spectra shows that the amplitude of the body vibrations varies several times (even at the order level) if the vibrational amplitudes along the shaft axis of the rotating working mechanism (z) and in the direction perpendicular to it (y) are comparable. That is, the shaft vibrations are transmitted to the housing with significant attenuation, so it is possible to obtain the values of the measurements carried out directly remotely on the rotating elements of the electric motor [21-25].

The increase in vibration frequency during vibration varies by more than 20% in contact and ultrasonic measurements during transient process time (1, 2, 4 curves in Figure 3). The electric motor vibrates significantly on the Z axis even when operating in normal mode (Figure 3, curve 3 in Part B), which is not observed in contact measurements of body vibrations. He increases in vibration frequency during vibration varies by more than 20% in contact and ultrasonic measurements during transient process time (1, 2, 4 curves in Figure 3). The electric motor vibrates significantly on the Z axis even when operating in normal mode (Figure 3, curve 3 in Part B), which is not observed in contact measurements of body vibrations. The shaft under load achieves normal rotational speed much more slowly at this time the vibration frequency in the shaft is significantly behind the body vibration frequency. Thus, it becomes possible to detect slow changes in shaft amplitudes using non-contact ultrasonic vibration analysis.

## CONCLUSIONS

In conclusion, it can be said that there is an opportunity for complex vibrational analysis of an electric motor using non-contact ultrasonic measurements. It has been found that there are significant differences in the values of recorded vibrational signals using contact and non-contact sensors. Signals obtained by different methods contain information of a different naturalizing, it can be said that there is an opportunity for complex vibrational analysis of an electric motor using non-contact ultrasonic measurements. It has been found that there are significant differences in the values of recorded vibrational signals using contact and non-contact sensors. Signals obtained by different methods contain information of a different nature. It is possible to simultaneously compare the vibration parameters of the moving and stationary elements of the electric motor from the complex data obtained from all sensors. This makes it possible to determine the electromechanical indicators that arise in the vibrational state of the electric motor.

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