The study on external influence on the phasechronometric profile of asynchronous electric motors

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Abstract. The article deals with the main points of the research on the electric motors influenced by impact and imbalance. Equipment for securing load determining the imbalance was manufactured to obtain asymmetry on the motor shaft. The results of the study on external influence on the phasechronometric profile of the asynchronous electric motors operation are obtained and processed.

1. Introduction
The application of phasechronometric approach for electric motors is proposed for the development of a technical condition assessment system. The system will reduce the number of accidents and reduce potential economic losses. The asynchronous motor model AIR56B2 was chosen as the study subject. Angular displacement sensor (angular encoder) LIR 158A is used as a measuring transducer in the measuring system implementation process to create measurement marks. The sensor produces measuring pulses corresponding to the shaft angular displacements. The stand block diagram is shown in figure 1. The sensor is mounted on the motor shaft (figure 2) with the help of a coupling and special equipment [1].

![Figure 1. Structural scheme of the stand: 1 – electric motor, 2 – frequency converter, 3 – power source, 4 – angular displacement sensor, 5 – information processing unit, 6 – personal computer, 7 – special software](image)

Figure 1. Structural scheme of the stand: 1 – electric motor, 2 – frequency converter, 3 – power source, 4 – angular displacement sensor, 5 – information processing unit, 6 – personal computer, 7 – special software
Figure 2. Fastening the sensor to the motor shaft: 1 – angle encoder, 2 – equipment for fastening the sensor, 3 – coupling, 4 – transition pin, 5 – studs for fastening the snap-in, 6 – electric motor

The signal from the sensor in the digital signal form enters the information processing unit, and then in the time intervals format is transmitted to a computer, where the data is processed using special software. The mathematical model provides for the interrelation of measurement results and measurement information processing with the subject design (for example, the spectrum of torsional vibrations, natural frequencies, rotation chronogram, etc.). The mathematical model allows the transition from experimental data to individual system characteristics (inertia moments, stiffness, overall-mass, electrical parameters, etc.) [2-4].

Imbalance characterizes the unbalance of the machine rotating parts. Unbalance occurs when the rotation axis does not coincide with the inertia main axis. The combination of these axes is achieved by balancing. The duralumin sleeve was made to create asymmetry on the motor shaft and conduct an imbalance study. The sleeve serves as an additional load on the shaft, as well as a tool for securing the steel weight, which determines the imbalance. Type of installation for the experiment is shown in figure 3.

According to the Huygens-Steiner theorem [5]

\[ J = J_c + md^2 \]  

(1)

\( J \) is the required moment of inertia towards the parallel axis, 
\( J_c \) is the known moment of inertia towards an axis passing through the body mass center, 
\( m \) is the body mass, 
\( d \) is the distance between the specified axes.

According to the formula (1), it is obtained that the steel weight of 28 grams introduces an additional moment of inertia equal to 26.218 kg \( \cdot \) m\(^2\).
2. Results

Rotation chronograms are constructed according to the time intervals increments sets obtained during the measurement process. Chronograms in the phasechronometric method [6]) are graphs of changes in the rotation phase duration depending on the phase number. The numbers of measurements (phases) are indicated on the abscissa axis, the phase duration in seconds is indicated on the ordinate axis. Such chronograms allow estimating the uneven rotor rotation. Three graphs reflecting the electric motor idling (figure 4) and external influences on the shaft: an impact (figure 5) and an imbalance (figure 6) are shown for comparison. 5000 measurements are made for one rotor revolution in this experiment.

![Figure 4. The chronogram of rotation at idle, 15 Hz](image)

Instant speed change occurs upon impact. This is displayed on the chronogram by peaks. The material point makes a fading motion in case of resistance. The applied external effect caused by the impact of three screws fixed symmetrically on the sleeve is reflected in the chronogram in the triple peaks form of superimposed damped oscillations characteristic per rotation (figure 5). The operation of an electric motor with an imbalance introduced into the shaft on the chronogram (figure 6) is reflected as an impact, but the single one, at the point where the superposition of gravity and inertia reaches its maximum.
Figure 5. The chronogram of rotation upon impact

Figure 6. The chronogram of rotation for imbalance

Figure 7. Spectral analysis: (a) – the spectrum of the natural frequencies of the system at idle, 15 Hz; (b) – spectrum of natural frequencies of the system upon impact; (c) – the spectrum of the natural frequencies of the system when the imbalance
3. Discussion of results
Spectral analysis of time series showed the presence of repetitive peaks in the range of 10 Hz and 30 Hz. Only the main harmonic appears at idle. The main harmonic coincides with a given frequency on the frequency converter. For example, we select the frequency of 15 Hz for an experiment; on the spectrogram we see the corresponding peak of 14.56 Hz. The difference is due to the use of insufficiently accurate engine frequency converter as part of the stand. Upon impact, the tripling of peaks occurs, i.e. two additional peaks appear. Subharmonics are absent in the imbalance. Due to the fact that the imbalance manifests itself as an impact with rapidly damped oscillations, and due to smaller impact energy, it slightly distorts the spectrogram general view. Thus, with the help of spectral studies we can only identify impacts. The presence of motor shaft oscillation frequencies, independent of the shaft rotation and load options, indicates the presence of stable signs of the mechanism operation, which can be used as diagnostic ones. Carried-out research provides additional information to verify the electromechanical system mathematical model parameters.

4. Conclusion
The obtained results of phasechronometric analysis of the simplest effects on a rotary machine prove the effectiveness of the described approach. The sensitivity shown by the developed measuring equipment together with the innovative phasechronometric approach allows us to make a conclusion not only about the possibility of transferring developments to the field of diagnostics of industrial facilities based on electric motors (drives, pumps, etc.), but also about the applicability of the method in the field of study transients in rotary machines caused by more complex external influences.

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