Method of diagnostics of the rotor eccentricity of an induction motor

A Yu Prudnikov, V V Bonnet and A Yu Loginov

Irkutsk State Agricultural University named after A.A. Ezhevsky, Molodezhny settlement, Irkutsk distrikt, Irkutsk region, 664038, Russia

E-mail: a.prudnicov@mail.ru

Abstract. The main type of electric motors used in the electric drive of technological processes are induction motors with a squirrel-cage rotor. With proper operation, they have a higher MTBF (Mean Time Between Failures). It was found that one of the common causes of engine failure is bearing wear and, as a result, increased rotor eccentricity. We used the oscillating amplitude of the rotor speed in the transient state as a diagnostic parameter. The paper presents a method for this troubleshooting, a block scheme and appearance of the experimental installation, and a single-line diagram of the transmitter for measuring rpm. The experience has established the optimal ADC sampling frequency for experimentation to be carried out. The results of studies of changes in the rotor speed oscillating from time to time under load at rotor eccentricity have been given.

1. Introduction
Induction motors with a short-circuited rotor have been widely used both in agriculture and in industry as a whole. This is due to their relatively low cost and satisfactory performance. The aggressive environment and their inefficient exploitation prevent their rational use in agriculture, as evidenced by the results of studies given in the authors’ works [1-3].

A common mechanical troubleshooting of induction motors is the rotor eccentricity ratio, which in operating conditions is usually caused by abrasive wear of the bearings. The eccentricity of the rotor negatively affects the operation of the motor, which leads to local heating, a power loss and, as a result, premature burnout of the inter-turn insulation [1-4]. This failure of the induction motor entails the process shutdown for the time of motor replacement and costly repair. Diagnostics of rotor eccentricity by known methods [5-7] in operating conditions is complicated by technological factors, such as: voltage unbalance in circuit, vibrations of coupled mechanisms, noise, complexity of installation of diagnostic equipment, etc.

2. Materials and methods
We have developed a new method for diagnosing the rotor eccentricity of an induction motor, which makes it possible to perform diagnostics in operation conditions based on the analysis of the dependence of the rotor speed during motor start [8-9]. The principle of the method is to compare the amplitude of the rotor speed change immediately after its start with a similar amplitude of a technically sound motor.
To implement this method, we have developed an experimental installation, the block scheme and appearance of which are shown in figure 1, 2.

![Figure 1](image1.png)

**Figure 1.** Block diagram of the experimental installation.

where: 1-test induction electric motor, 2-disc with calibrated holes, 3-load feel actuator, 4-transmitter power supply, 5-photo former, 6-analog-to-digital converter, 7-personal computer. As an analog-to-digital converter, a ZET 210 data acquisition card was used to measure signal parameters over a wide frequency range from various primary transducers. The connection to the PC is made via the High Spied USB 2.0 bus.

![Figure 2](image2.png)

**Figure 2.** External experimental setup.

To read the motor speed, we used a calibrated disk with holes that have the same size of transparent and opaque sectors. The disk rotates between a pair of LED-photodiode VD3, VD2 figure3 of optical speed sensor. The photodiode operates without a power source and when light hits it through the disk hole, a voltage appears on its terminals, which is measured by an analog-to-digital converter. As a result, at the output we get a signal in the form of a pulsating voltage, which is converted into a dependence of the rotor speed on time by the method of least squares.
The Zet 210 analog-to-digital converter allows an operation with a sampling rate of up to 500 kHz (50, 100, 200, 320, 500 kHz). We have performed a number of search experiments at different ADC sampling rates. At a frequency of 200 kHz or lower, the starting curved line is smoothed and important diagnostic information is lost during the processing of experimental data figure 4, a. At a sampling rate of 320 kHz or higher, characteristic oscillating motion in the rotor speed appears on the starting curved line, which play a crucial role in determining the presence and magnitude of the eccentricity figure 4, b.

Choosing a higher ADC sampling rate is impractical, since it does not increase the accuracy of diagnostics, but significantly increases the amount of experimental data that becomes difficult to process even when using modern applications.

Thus, when diagnosing the rotor eccentricity of an induction motor using a dynamic method with an optical speed sensor with a breaker, the optimal ADC sampling rate is 320 kHz.
3. Results of the study, their discussion
As a result of production tests of AIR90L4U2 induction motors with a power of 2.2 kW, used for driving the air supply fans of poultry houses, the dependence of the rotor speed of the induction motor on the time under load at different values of the rotor eccentricity was obtained.

The appearance of such dependence at value of eccentricity of 0 and 57 % is shown in Figure 5, where A1 and A2 are the amplitude of the change in the rotor speed of a technically sound motor and a motor with a rotor eccentricity, respectively. More detailed results of laboratory and production tests are given in the papers [8-9].

![Figure 5. The dependence of the rotor speed of an asynchronous motor on the time under load with an eccentricity of 0 and 57 %.](image)

To simplify the process of experimental data processing and diagnosis, we have developed the program "Automated system for diagnosing the rotor eccentricity of induction motor", which allows to calculate the value of the relative eccentricity of induction motor both in the idle mode and under load, i.e. the motor can be tested at the workplace without the process shutdown [10]. In addition to diagnosing the rotor eccentricity of an induction motor, this diagnostic system allows to implement a method for determining the power of an induction motor with a short-circuited rotor, observed in the paper [11].

4. Conclusion
The developed diagnostic system, designed to diagnose the rotor eccentricity of an induction motor, makes it possible to perform the measurements to a precision of no more than 3%. The displayed method allows us to determine the presence and magnitude of eccentricity in idle mode and under load, that is, during operation. Standard and specially developed programs were used to process data obtained experimentally, permitting us the obtaining reliable results.

References
[1] Kozhukhov V A and Strizhnev S A 2006 Review of technological failures of induction motors in agricultural production Vestnik of Krasnoyarsk State Agrarian University 11 199–202
[2] Vorobyev A E and Fatyanov S O 2017 Analysis of the causes of failures in the operation of induction motors in agriculture and industrial production Vestnik of the Council of Young Scientists of Ryazan State Agrotechnological University named after P A Kostychev 2(5) 169–74
[3] Khomutov S O 2015 System for maintaining the reliability of electric motors based on comprehensive diagnostics and efficient insulation restoration technology (Barnaul: Interregional Center for Electronic Educational Resources LLC)

[4] Volnikov M I 2018 On the issue of timely non-stop diagnosis of electric motors The role of university science in solving problems of the agro-industrial complex All-Russian (national) scientific and practical conference dedicated to the 90th anniversary of G V Galdin (Penza: Publishing House Penzensky GAU) vol 2 pp 14-7

[5] Safin N P, Prakht V A and Dmitrievsky V A 2017 Investigation of the effect of bearing failures on the efficiency of an induction motor Electrical Engineering 10 87–91

[6] Magdanova K P 2017 Influence of rotor eccentricity on the energy characteristics of an asynchronous motor Nauka-Rastudent.ru 6 007

[7] Polishchuk V I, Novozhilov A N, Isupova N A 2011 Review of methods for diagnosing the rotor eccentricity of AC machines proceedings of higher educational institutions Electromechanics 6 29-33

[8] Prudnikov A Yu, Bonnet V B and Loginov A Yu 2015 Mathematical model of an asynchronous motor with an eccentricity of a rotor Vestnik of KrasGAU 6(105) 94-7

[9] Prudnikov A Yu, Bonnet V V, Gerasimova M N, Loginov A Yu and Rakotsa A 2016 The amplitude of oscillations of the rotor speed as a parameter for estimating the eccentricity of the rotor of an induction motor Angar State Technical University Bulletin 10 70-3

[10] Prudnikov A Yu, Bonnet V V and Loginov A Yu 2019 Automated system for processing diagnostic parameters of asynchronous motors for poultry house ventilation systems IOP Conf. Ser.: Earth Environ. Sci. 315 032019

[11] Bonnet V V, Loginov A Yu, Prudnikov A Yu, Bonnet Y V and Bonnet M V 2020 Method for determining the power of squirrel-cage induction motors IOP Conf. Ser.: Earth Environ. Sci. 421 052009