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The results of the production tests of the method for diagnosing the eccentricity of the rotor of an asynchronous electric motor

Artem Prudnikov[1*], *Vyacheslav* Bonnet[1], *Alexandr* Loginov[1], and *Yakov* Bonnet[2]

[1]Irkutsk State Agricultural University named after A.A. Ezhevsky, Molodezhny settlement, Irkutsk distrikt, Irkutsk region, 664038, Russia
[2]Moscow State Technical University named after N. E. Bauman, 5/1, 2nd Baumanovskaya str., Moscow, 105005, Russia

Abstract. Ensuring the reliability of electrical equipment in agriculture remains an urgent problem, since rugged operating conditions and aggressive environment hinder its rational use. The high accident incidence rate of asynchronous motors in most cases is invariably caused by the failure of the inter-turn insulation and interphase short circuit or short circuits to the housing. The probability of an emergency situation increases with an increase in the radial clearance in the bearings and, consequently, the occurrence of static eccentricity of the rotor. The developed method for diagnosing the static eccentricity of the rotor of an asynchronous motor is based on the analysis of the rotor speed; the amplitude of the rotor speed change was used as a diagnostic parameter. The paper presents the change in the rotation frequency depending on the difference in the amplitudes, resulted from the study conducted for different values of static eccentricity. The test results have shown that with an increase in the eccentricity of the rotor, the amplitude of the speed fluctuations increases.

1 Introduction

The use of asynchronous motors with a short-circuited rotor in various branches of agriculture is due to their high reliability and low cost. The effective use is hindered by an aggressive environment and a low level of operation, which is confirmed by the research results [1-4].

A promising research area is the diagnosis of motors in transient modes of operation, since this process takes place within a short time, but has a high informative value. A lot of work has been devoted to transients in asynchronous electric motors, but the start-up mode is still a little-studied process [12-15]. The most common mechanical malfunction of the engine is the eccentricity of the rotor caused by bearing wear [5-11], [20]. The eccentricity significantly deteriorates operational characteristics of the machine and causes its non-serviceable condition. The unevenness of the air gap, to an asymmetry of the magnetic system and a change in the inductive resistances of the phases of the stator and rotor windings. The

* Corresponding author: a.prudnicov@mail.ru

eccentricity significantly reduces the technical and economic performance of the motor, since the current consumed by the motor increases. Therefore, timely diagnosis of the eccentricity is an urgent task. Eccentricity reduces the technical and economic performance of the motor, leads to increased local heating and, as a result, its premature failure. Therefore, it is necessary to identify and eliminate this malfunction as early as possible.

2 Materials and methods

To calculate the diagnostic parameters and the nature of their dependence on the magnitude of the eccentricity, we have obtained a system of equations describing the electromechanical equilibrium of an asynchronous machine in case of malfunctions [17, 24]:

$$U_{1n.ph.} \cdot \frac{\varepsilon}{2\delta_0 \cdot k_{c1} \cdot k_{c2}} = R_s \cdot i_s \cdot \frac{U_{1n.ph.}}{I_{1n.ph.}} + \frac{2U_{1n.ph.}}{I_{1n.ph.}(\omega_1+\omega_e)} \cdot \left(L_s \cdot \frac{di_s}{dt} + 2M \cdot \frac{di_r}{dt}\right), \quad (1)$$

$$0 = R_r \cdot i_r \cdot \frac{U_{1n.ph.}}{I_{1n.ph.}} + \frac{2U_{1n.ph.}}{I_{1n.ph.}(\omega_1+\omega_e)} \cdot \left(L_r \cdot \frac{di_r}{dt} + 2M \cdot \frac{di_s}{dt}\right), \quad (2)$$

$$J \cdot \frac{d\omega}{dt} = 2M \cdot i_s \cdot i_r \cdot \sin[(\omega_1 + \omega_e) - \omega] \cdot t - M_c, \quad (3)$$

where $U_{1\,n.ph.}$ is the nominal phase to neutral voltage; ε is the relative eccentricity of the rotor; δ_0 is the average value of the air gap at eccentricity; k_c is the Carter's gap coefficient, taking into account the slotting of the stator k_{c1} and the rotor k_{c2}; ω_1 - is the angular frequency of the main wave of the supply voltage; $I_{1\,n.ph.}$ is the nominal phase current; R_s,R_r are electrical resistance of the stator and rotor, respectively; i_s, i_r are currents in the stator and rotor winding, respectively; M is the rated electromagnetic moment; M_c is the active moment; J·ω is the angular impulse; L_s, L_r are the intrinsic inductance of the stator and rotor windings, respectively.

Changes in the design parameters of an asynchronous machine, including the geometry of the air gap, can be evaluated using specially developed algorithms that allow analyzing signals that can be measured without interfering with the technological process. Such signals are the mains voltage and the rated current of the stator, as well as the frequency of rotation of the motor rotor [16, 18, 19, 21, 22]. We have proposed an eccentricity diagnosing method based on comparing the amplitude of the change in the rotational speed of the rotor of a technically serviceable A_1 motor with a similar amplitude of a motor with an eccentricity A_2. Having obtained the difference of these amplitudes, ΔA, it is possible to estimate the magnitude of the eccentricity from empirical dependencies resulted from simulations and experiments [17], [23-26].

3 Results and discussion

To approbate the proposed method of diagnosing the eccentricity of the rotor of an asynchronous motor in operational conditions, we conducted post-repair tests of 0.37 kW AIRP80A6 motors in idle mode. As an example, Figure 1 shows the rotor speed of an asynchronous motor as a function of time in idle mode at eccentricity of 0 and 30%. The black line shows the starting curve of a serviceable motor, and the red line corresponds to motor with an eccentricity.

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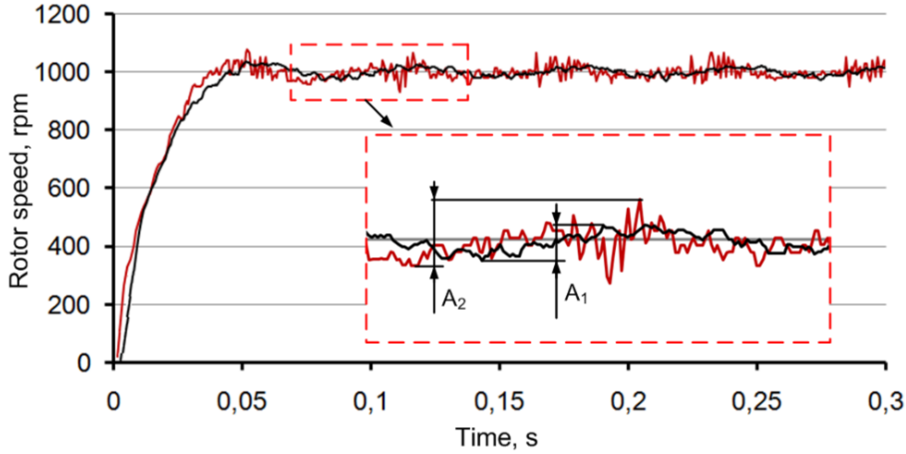

Fig. 1. The dependences of the rotational speed of the rotor of the asynchronous motor on the time in idle mode at an eccentricity of 0 and 30%.

Also, as part of the technical inspection of 0.37 kW motors, installed at the VO-5,6 (Climate-45) window exhaust fans, we have obtained the rotor speeds of the asynchronous motor depending on the time under load mode Figure 2.

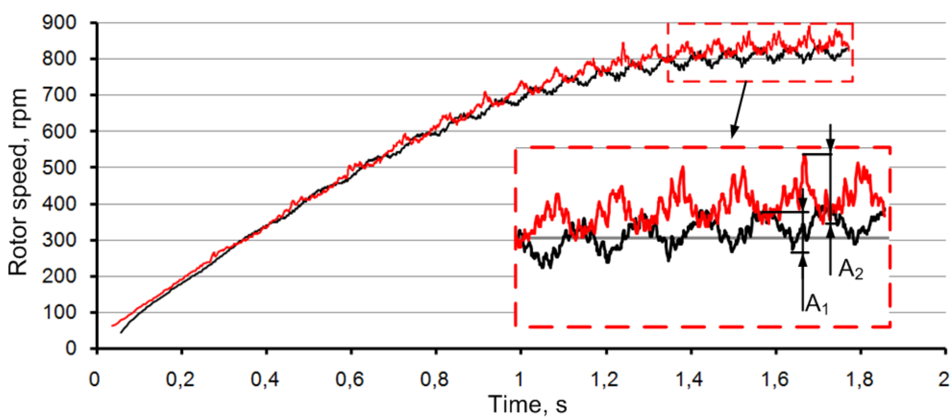

Fig. 2. The dependences of the rotational speed of the rotor of the asynchronous motor on the time in load mode at an eccentricity of 0 and 30%.

It can be seen from Figures 1 and 2 that the amplitude of the change in the rotational speed of the rotor of a technically serviceable A_1 motor is significantly less than that of the motor with the eccentricity A_2. These differences manifest themselves when testing engines both under load and at idle.

To identify the presence and magnitude of the eccentricity, we have obtained the dependence of the relative eccentricity ε on the discrepancy in the amplitudes of the rotation frequency of the rotor ΔA in idle mode and under load for the 0.37 kW AIRP80A6 motor Figure 3.

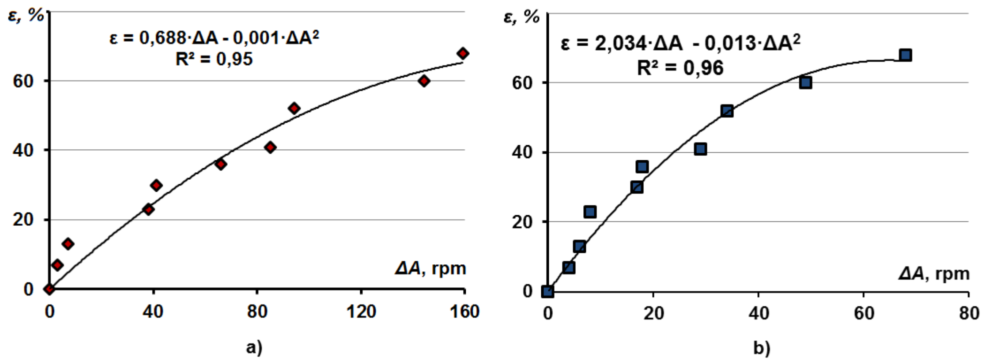

Fig. 3. The dependence of the relative eccentricity ε on the difference in the amplitudes of the rotation frequency of the rotor ΔA in idle mode (a) and under load (b) for the AIRP80A6 motor.

The significance of the obtained equations, shown in Fig. 3 was determined by Fischer's F-criterion for and amounted to $F_{fact} = 152 > F_{tabl} = 5.32$ for the dependence in idle mode, and $F_{fact} = 192 > F_{tabl} = 5.32$ for the dependence under load. Therefore, the obtained regression equations are recognized as significant. The dependencies shown in Fig. 3 can be used for diagnostics during post-repair tests at idle. Diagnostics under load is recommended to be carried out during technical inspection in the course of operation, in particular, for motors operating as the drives of window exhaust fans.

4 Conclusion

Experimental and operational studies of AIRP80A6 motors have shown that when the eccentricity of the rotor of an asynchronous motor occurs, the amplitude of the rotor speed fluctuations changes depending on the magnitude of the eccentricity. The amplitude increases with an increase in the eccentricity of all the motors studied. At the same time, at idle, the discrepancy in the amplitudes of the rotation frequency of the rotor of a technically serviceable engine and with an eccentricity is greater than under load mode. These dependencies are confirmed both for the 0.37 kW motor and for the 1.1 kW and 2.2 kW motors operating in various modes. The obtained dependencies can be used at enterprises operating asynchronous motors, during inspections, as well as for post-repair tests.

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