Evaluation of the Performance Quality of Asynchronous Motors

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October 24, 2023

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Abstract. Since the majority of AC induction machines used around the world are fitted with aluminum cast squirrel cage rotors it might be falsely assumed that the design of these rotors is a trivial matter. Development of the locomotive engineering network and increasing the efficiency of profitable work are important in the railway industry today. Based on this, it is necessary to improve the quality of operation of asynchronous electric motors in locomotives. A lot of scientific research has been conducted on this. In particular, the results presented in this small research paper are the result of all research. In the scientific research work, the calculation values of the efficiency of the magnetic field rods of the short-circuited rotor in the use of asynchronous electric motors were cross-analyzed according to the type of material.

1 Introduction

In the use of locomotives and their exploitation, asynchronous electric machines are especially used nowadays [10-14]. Asynchronous electric machines have several advantages:

1) absence of an electromechanical switch;

2) the absence of a collector ensures that there is no risk of sparking;

3) improvement of traction properties of the electric locomotive due to the power characteristic of the electric machine. This reduces the tendency of the wheel to spin;

4) a sharp reduction in copper consumption in the production of torque engines.

But despite such advantages, there are also disadvantages in asynchronous torque electric machines. In particular, we will consider the rotor of the AE-92-4 type asynchronous motor used in the VL-60, VL-80 electric locomotives in use at "Uzbekistan temir yullari" JSC. The rotor of asynchronous motors is mainly of two types. They are an asynchronous motor with a short-circuited rotor and an asynchronous motor with a phase rotor (Fig. 1 a, b).

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a) b)

Fig.1. a) – short-circuited rotor, b) – phase rotor.

We will consider a number of failures that occur in the rotor of the AE-92-4 type asynchronous motor. The rotor of this asynchronous motor is a short-circuited rotor, and its rods are made of cast aluminum. In this article, we will consider what differences should arise when the rotor of an AE-92-4 type asynchronous motor is made of cast aluminum and cast copper. To do this, first of all, in this article, we will consider the resistance of both materials and the results of scientific research on the effect of these resistances on the magnetic field that occurs in the stator and rotor of an asynchronous motor [1, 6-8, 17].

2 Objects and methods of research

We determine the short-circuited rotor resistance r_2. The short-circuited rotor has a steering wheel with an apple ring. Multiphase windings are wound on the rotor, where the number of phases is equal to m2, and the number of slots of the rotor is equal to Z_2. In this case, one sturgeon is installed in each phase, therefore the expression m_2=Z_2 is appropriate. Fig. 2 shows a schematic view of the coils and ring of the stern. Here, the currents on the masts and the directions of the short-circuited ring currents are set between adjacent masts.

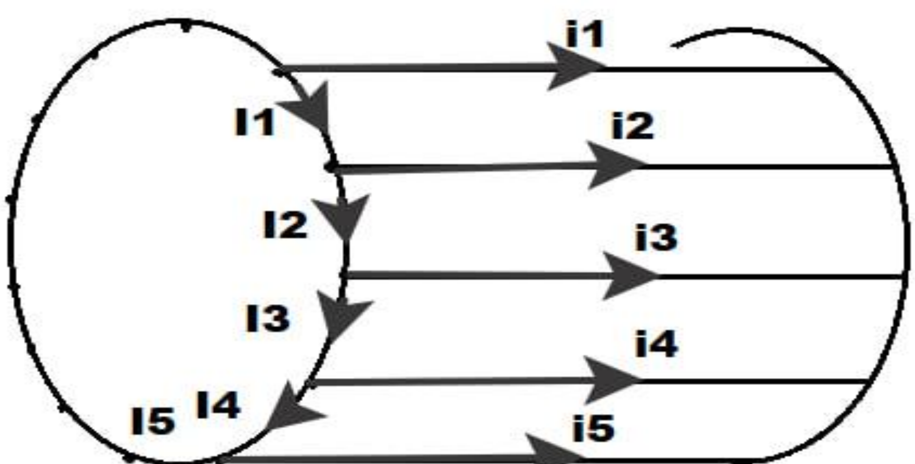


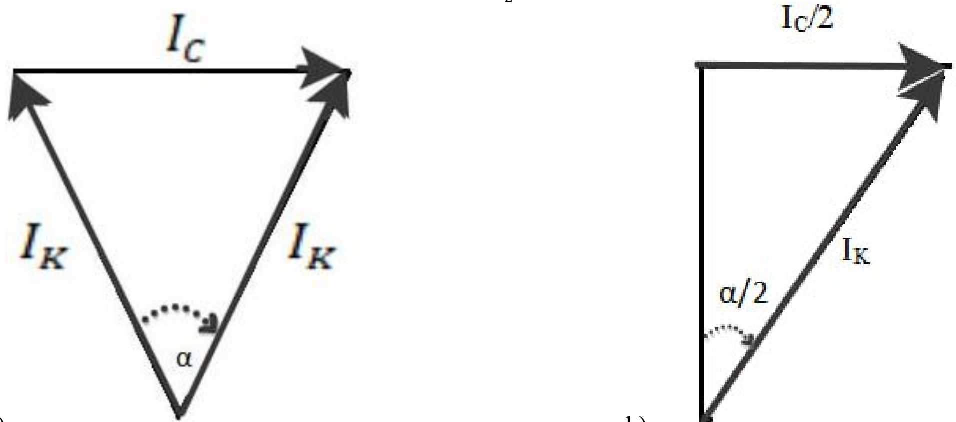
Fig.2. Schematic representation of current directions in a short-circuited rotor.

3 Results and their Discussion

These parts are the part that receives resistances. In this case, the current directions in the rods are defined as i1, i2, i3, ... and the current directions in the short-circuited ring part are defined as I1, I2, I3, ... Here we denote the current in a part of the rings as IK and the current in a part of the rods as IC. To determine the total resistance of a short-circuited rotor made of aluminum, we need to determine the resistance of a part of it. For this, we will create its vector diagram and perform the necessary work on it. A schematic view of a vector diagram of a part of a short-circuited rotor is presented in Fig. 3.

The angle between the phase currents of the short-circuited ring and the adjacent wires is determined by the following formula:

$$\alpha = \frac{2\pi p}{Z_2} \qquad (1)$$



a) b)

Fig.3. Vector diagram of a short-circuited rotor: a) Vector diagram for part of a short-circuited rotor; b) Vector diagram for one half of the rotor.

Figure 3- b) shows the interdependence of I_K and I_C from the vector diagram. In this case, we have the following from the theorem of sines:

$$\sin\left(\frac{\alpha}{2}\right) = \frac{I_C/2}{I_K} = \frac{I_C}{2\,I_K} \qquad \rightarrow \qquad I_K = I_C \cdot \frac{1}{2\,\sin\left(\frac{\alpha}{2}\right)} \qquad (2)$$

We create expression (3) by putting expression (1) instead of a in expression (2);

$$I_K = I_C \cdot \frac{1}{2\,sin\left(\frac{\alpha}{2}\right)} \qquad \rightarrow \qquad I_K = I_C \cdot \frac{1}{2\,sin\frac{\pi p}{Z_2}} \qquad (3)$$

From the vector diagram of the amount of heat generated in the sterns we have;

$$Z_2 I^2{}_C r_2 = Z_2 I^2{}_C r'_C + 2\,Z_2 I^2{}_K r'_K \qquad (4)$$

Here r'_C is the resistance of the stern; r'_K is the resistance in the ring part with the neighboring sterns;

Resistances r_C and r_K are formed based on the geometric dimensions of the ring and the rod. Depending on the type of material used, its relative resistance is taken from Table 1. [9]

Table 1. Specific resistance of metals and alloys (r) (20 ̊C) and temperature coefficient of resistance (a)

Substance	$\rho, 10^{-8}\ Om \cdot m$	α, K^{-1}	**Substance**	$\rho, 10^{-8}\ Om \cdot m$	α, K^{-1}
Aluminum	2,8	0,0042	Nichrom	110	0,0001
Tungsten	5,5	0,0048	Lead	21	0,0037
Jez	7,1	0,001	Silver	1,6	0,004
Copper	1,7	0,0043	Steel	12	0,006
Nickel	42	0,0001	Nichrom		

from expression (4), we arrive at the following expression:

$$r_2 = r_C' + \frac{2r_K'}{\left(2\sin\frac{\pi p}{Z_2}\right)^2} \tag{5}$$

Here r_2 is the total resistance of the short-circuited rotor;
From the last derived expression (4), we calculate for aluminum and copper metals.

For a short-circuited rotor made of aluminum, it is required to determine the values of r_C and r_K. For this, we take the specific resistance of aluminum from Table 1 as r=2.8*10^{-8} Ohm*m and determine it using the following expression:

$$r = \rho \cdot \frac{l}{s}, \text{ om} \tag{6}$$

Here, the values of λ and S for the rotor of the AE-92-4 asynchronous motor are taken from its standard drawing (Fig. 4).

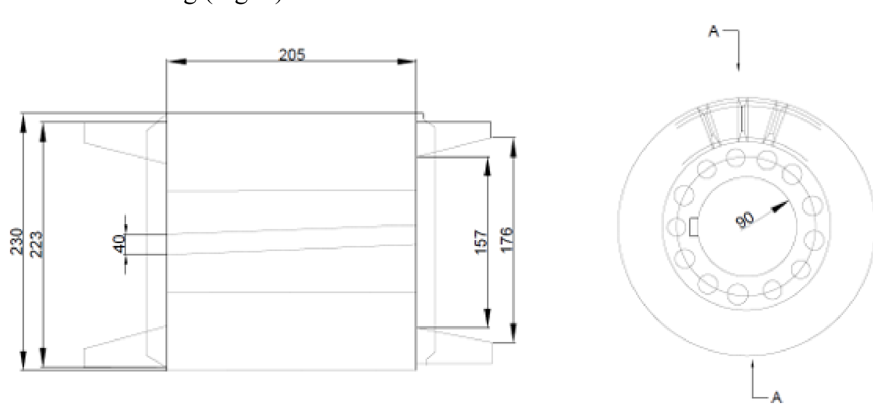


Fig.4. Its standard drawing for the rotor of the AE-92-4 asynchronous motor.

3.1. So, we calculate for aluminum metal:

The total resistance of adjacent bars made of aluminum metal is found by the following formula.

$$r'_C = 13 \cdot r_C \tag{7}$$

$$r_C = 2{,}8 \cdot 10^{-8} \cdot \frac{205 \cdot 10^{-3}}{40 \cdot 10^{-6}} = 14{,}35 \cdot 10^{-11} Om$$

$$r'_C = 13 \cdot r_C = 13 \cdot 14{,}35 \cdot 10^{-11} = 186{,}55 \cdot 10^{-11} Om$$

Total resistance in the ring section

$$r'_K = 2 \cdot r_K \tag{8}$$

$$r_K = 2{,}8 \cdot 10^{-8} \cdot \frac{33{,}5 \cdot \pi \cdot 4 \cdot 10^{-3}}{\pi \cdot 33{,}5^2 \cdot 10^{-6}} = 0{,}334 \cdot 10^{-11} Om$$

$$r'_K = 2 \cdot r_K = 2 \cdot 0{,}334 \cdot 10^{-11} = 0{,}668 \cdot 10^{-11} Om$$

$$r_{2Al} = 186{,}55 \cdot 10^{-11} + \frac{2 \cdot 0{,}668 \cdot 10^{-11}}{\left(2 \cdot \sin\left(\frac{\pi}{13}\right)\right)^2} = 192.4 \cdot 10^{-11}\ Om$$

3.2. We calculate for copper metal:

The total resistance of adjacent rods made of copper metal is found by the following formula.

$$r_C = 1{,}7 \cdot 10^{-8} \cdot \frac{205 \cdot 10^{-3}}{40 \cdot 10^{-6}} = 8{,}7125 \cdot 10^{-11} Om$$

$$r'_C = 13 \cdot r_C = 13 \cdot 8{,}7125 \cdot 10^{-11} = 113{,}2625 \cdot 10^{-11}\ Om$$

Total resistance in the ring section

$$r_K = 1{,}7 \cdot 10^{-8} \cdot \frac{33{,}5 \cdot \pi \cdot 4 \cdot 10^{-3}}{\pi \cdot 33{,}5^2 \cdot 10^{-6}} = 0{,}202 \cdot 10^{-11} Om$$

$$r'_K = 2 \cdot r_K = 2 \cdot 0{,}202 \cdot 10^{-11} = 0{,}404 \cdot 10^{-11} Om$$

$$r_{2Cu} = 113{,}2625 \cdot 10^{-11} + \frac{2 \cdot 0{,}404 \cdot 10^{-11}}{\left(2 \cdot \sin\left(\frac{\pi}{13}\right)\right)^2} = 116{,}793 \cdot 10^{-11}\ Om$$

4 Conclusions

Use of fabricated caged rotors of aluminum or copper Tear dropped bars are extruded, cast or machined Parallel sided bars are lower in cost to make which results in tapered rotor teeth. Bars must be restrained in solts to prevent movement. Based on the method of scientific research, we considered the analysis of which metal it is preferable to make in the development of the short-circuited rotor of the AE-92-4 type asynchronous motor.

$$\eta = \frac{r_{2Cu}}{r_{2Al}} \cdot 100\% = \frac{116{,}793 \cdot 10^{-11}}{192.4 \cdot 10^{-11}} \cdot 100\% = 60{,}7\%$$

The results of these analyzes show that the short-circuited rotor made of aluminum differs by 60.7% compared to the short-circuited rotor made of copper. This difference shows that the copper rotor has a higher efficiency. The results obtained from our scientific research show that the use of copper metal is effective in the development of the short-circuited rotor of the AE-92-4 type asynchronous motor, which will be used in the future. The minimum resistance reduction does not allow the parts of the asynchronous motor to overheat quickly. This, of course, increases the efficiency and life of the engine. The short-circuited rotor of an asynchronous motor is widely used in the locomotive industry. For this reason, it is necessary to constantly provide an effective solution to the above-mentioned problems encountered by them. Because in order to ensure uninterrupted movement of the electric rolling stock in use at “Uzbekistan temir yullari” JSC, it is necessary to pay great attention to the efficiency of all its electrical equipment. From this point of view, the correct operation of auxiliary asynchronous motors in electric locomotives is a solution to possible problems that may arise in the structure of the movement. In the above article, the solution to this problem is scientifically analyzed. That is, in the development of the short-circuited rotor of the AE-92-4 type asynchronous motor, the material of the rotor is made of aluminum and the difficulties in its repair, as well as the working characteristics of the asynchronous motor, are discussed in this article copper is offered.

References

1. Mamayev, S., Fayzibayev, S., Djanikulov, A., & Kasimov, O. (2022, June). Method of selection of mainline locomotives in the unloaded state according to the speed characteristics affecting the electromechanical vibrations of the WMB. In *AIP Conference Proceedings* (Vol. 2432, No. 1). AIP Publishing.
2. Khamidov, O. R., Kamalov, I. S., & Kasimov, O. T. (2023, March). Diagnosis of traction electric motors of modern rolling staff using artificial intelligence. In *AIP Conference Proceedings* (Vol. 2612, No. 1). AIP Publishing.
3. Khamidov, O. R., Kamalov, I. S., & Kasimov, O. T. (2023, March). Heat calculation of pads during locomotive braking. In *AIP Conference Proceedings* (Vol. 2612, No. 1). AIP Publishing.
4. Kasimov, O., Fayzibayev, S., Djanikulov, A., & Mamayev, S. (2022, June). Numerical studies for estimation of temperature fields in bandage material during locomotive braking. In *AIP Conference Proceedings* (Vol. 2432, No. 1, p. 030025). AIP Publishing LLC.

5. Kasimov, O. T., Djanikulov, A. T., & Mamayev, S. I. (2021, November). Modeling the bending of the tire surface by pads during braking. In *AIP Conference Proceedings* (Vol. 2402, No. 1). AIP Publishing.
6. Djanikulov, A. T., Mamayev, S. I., & Kasimov, O. T. (2021, April). Modeling of rotational oscillations in a diesel locomotive wheel-motor block. In *Journal of Physics: Conference Series* (Vol. 1889, No. 2, p. 022017). IOP Publishing.
7. Djanikulov, A. T., & Safarov, U. I. (2023). Correction of ted field weakening switching diagram for mainline diesel locomotives of te type. In *E3S Web of Conferences* (Vol. 401, p. 01071). EDP Sciences.
8. Djanikulov, A. T., & Abdulatipov, U. I. (2023). Torsional oscillations of armature shaft of generator of main diesel locomotive in diesel start-up mode. In E3S Web of Conferences (Vol. 401, p. 01072). EDP Sciences.
9. Jamilov, S., Ergashev, O., Abduvaxobov, M., Azimov, S., & Abdurasulov, S. (2023). Improving the temperature resistance of traction electric motors using a microprocessor control system for modern locomotives. In *E3S Web of Conferences* (Vol. 401, p. 03030). EDP Sciences.
10. Abdurasulov, S., Zayniddinov, N., Yusufov, A., & Jamilov, S. (2023). Analysis of stress-strain state of bogie frame of PE2U and PE2M industrial traction unit. In *E3S Web of Conferences* (Vol. 401, p. 04022). EDP Sciences.
11. Khamidov, O., Yusufov, A., Jamilov, S., & Kudratov, S. (2023). Remaining life of main frame and extension of service life of shunting Locomotives on railways of Republic of Uzbekistan. In *E3S Web of Conferences* (Vol. 365, p. 05008). EDP Sciences.
12. Yusufov, A., Khamidov, O., Zayniddinov, N., & Abdurasulov, S. (2023). Prediction of the stress-strain state of the bogie frames of shunting locomotives using the finite element method. In *E3S Web of Conferences* (Vol. 401, p. 03041). EDP Sciences.
13. Khamidov, O., & Udalova, D. (2021, May). Technical and Economic Efficiency of Intelligent Data Analysis on the Railways of the Uzbekistan Republic. In *International Scientific Siberian Transport Forum* (pp. 230-239). Cham: Springer International Publishing.
14. Abdurasulov, S., Zayniddinov, N., Yusufov, A., & Jamilov, S. (2023). Analysis of stress-strain state of bogie frame of PE2U and PE2M industrial traction unit. In *E3S Web of Conferences* (Vol. 401, p. 04022). EDP Sciences.
15. Ergashev, O. E., Abduvakhabov, M. E., Khamidov, O. R., Tursunov, N. K., & Toirov, O. T. (2022). INCREASING THE DURABILITY OF GEAR TRANSMISSIONS OF ASYNCHRONOUS TORSION ELECTRIC MOTORS. *Web of Scientist: International Scientific Research Journal*, *3*(10), 1030-1036.
16. Xamidov O., Ergashev O., Abduvahobov M., & Nematova S. (2022). "O'ZBEKISTON" ELEKTROVOZI VA TE10M TEPLOVOZINING TORTUV REDUKTORI TEXNIK HOLATINI BAHOLASH. Current approaches and new research in modern sciences, 1(4), 37-42.
17. Safarov, U., Ergashev, O., & Saidivaliev, S. (2023). The Essence of Explaining the Emergence of Briefly Braking Modes of Diesel Locomotives with Direct Current Electric Transmission (No. 10038). EasyChair.
18. Ablyalimov, O., & Julenev, N. (2023). Logistic indicators of locomotives of diesel traction on high-speed section of the railway. In *E3S Web of Conferences* (Vol. 401, p. 05023). EDP Sciences.

19. Ablyalimov, O. (2023). Indicators of transport logistics of locomotives of diesel traction on Kattakurgan-Navoi section in operation. In *E3S Web of Conferences* (Vol. 401, p. 05022). EDP Sciences.
20. Ablyalimov, O., & Avdeyeva, A. (2023). Operation of locomotives of diesel traction on hilly section of railway. In *E3S Web of Conferences* (Vol. 401, p. 01058). EDP Sciences.