**Research On Single-Phase Motors for Driving Auxiliary Units of Electric Rolling Stock**

Usan Berdiyev, Gulchiroy Kakhkharova а), Elena Iksar

Tashkent State Transport University, Tashkent, Uzbekistan

a) Corresponding author: [kahharovagulchiroy@gmail.com](mailto:kahharovagulchiroy@gmail.com)

**Abstract.** The article presents the results of research on single-phase motors for driving auxiliary units of electric rolling stock. During the operation of single-phase motors, specific features appear in terms of the formation of magnetic components of vibration and noise. Existing methods for calculating magnetic noise and vibration have unsatisfactory convergence and accuracy in calculating individual values, in particular, inductions, interacting harmonics, forces, deformations, etc.

**INTRODUCTION**

Single-phase machines have a number of specific features in terms of the formation of magnetic components of vibration and noise. This is explained by the presence, along with the directly rotating system, of a reverse rotating system of the first and higher harmonics of the magnetic field. The presence of the main reverse rotating harmonic of the field causes the torque to pulsate at twice the frequency of the network, which leads to significant tangential vibration of the stator of a single-phase motor [1, 3]. The interaction of the higher harmonics of the forward and reverse sequence systems can lead to an increase in the radial component of magnetic vibration and magnetic noise in single-phase motors compared to three-phase motors.

Designing motors with optimal sheet spacing primarily reduces the magnetizing current, losses in the machine steel, and the saturation coefficient. In this case, it is advisable to choose the minimum relative magnetizing force as the criterion for optimality, since the percentage of magnetizing current is very high in low-power motors. In [2. 6], for the convenience of mathematical description of the machine dimensions, it is assumed that the stator and rotor teeth have a constant width along their entire length, and the slots have the shape of an isosceles trapezoid. To extend the optimization to a range of machines of different power, the optimization was performed in relative units (relative to the stator diameter), and transition coefficients from ideal slots to real ones were introduced.

The features of power supply AD in auxiliary EP on EPS are phase power asymmetry (at power supply from an electromechanical phase splitter, according to capacitor circuit, in some cases from a direct frequency converter) and non-sinusoidal supply voltage (an important feature when powered by a static frequency converter (FC), including from AIN). Complex power supply conditions for ADs as part of auxiliary EP, coupled with and possible structural asymmetry AD due to defects, arising during manufacture and in the process of operation, require the use of methods for calculating characteristics, abandoning certain simplifying assumptions, methods that allow for more accurate calculation of electromagnetic, mechanical, and thermal characteristics.

The electrical engineering industry is the only sector where issues of standardization and methods of noise and vibration control are addressed at the level of state standards. In this regard, requirements for the vibroacoustic characteristics of electrical machines have been included in all types of regulatory and technical documentation (technical specifications, technical requirements, GOST standards for specific types of motors, etc.) [1, 2]. In some cases, these requirements are very strict, which has led to the need to develop special design methods, improve technology, and create and refine methods for researching and calculating vibration and noise.

The paper considers the sources of high-frequency components of magnetic noise and vibration in electromagnetic asymmetrical single-phase machines, and identifies the degree of increase in magnetic vibration and noise in single-phase machines compared to symmetrical three-phase machines.

Among the variety of AC motors, single-phase capacitor induction motors (OКАД) are the most widespread, which in most cases retain the advantages of AC motors, and in some cases surpass the latter:

-power supply from a single-phase network;

-ability to regulate starting and other rotation moments;

- increased energy efficiency;

-independence of the motor shaft rotation direction from the applied voltage phase;

-variety of OKAD braking methods.

OKAD is widely used in road repair and construction machinery, in autonomous power engineering, the nuclear and radio engineering industries, in transport, in drilling rigs, submersible pumps, irrigation, household appliances, healthcare, trade, public utilities, etc.

To date, the following has been done in this area:

-a calculation method has been developed that allows for a mathematical generalization of the regulated OKAD under various connection schemes and methods of regulating the OKAD rotation speed;

-the main methods of regulating the speed of OCA have been studied, the regulatory, working, and energy properties of OCA have been identified, and the basic laws of engine control parameters for optimizing engine operation according to various criteria have been formulated;

-known methods of OKAD braking have been summarized and new methods have been proposed, ensuring effective reduction of engine speed and reverse rotation.

The task of using OCA in traction drives and auxiliary mechanisms of electric transport remains to be solved.

It is known that the magnetic component of noise in asynchronous machines is primarily caused by high-frequency oscillations (1000-8000 Hz) of the stator yoke under the action of radial electromagnetic forces caused by the interaction of higher harmonics of the field of various origins [1, 3, 4]. It is natural to assume that in single-phase machines, all possible interactions between harmonics of not only the direct but also the reverse field, as well as between harmonics of both fields, will lead to the emergence of a large number of radial electromagnetic forces that excite magnetic noise and vibration, i.e., to an increase in noise and vibration in single-phase machines compared to symmetrical three-phase machines [2, 3, 6].

Existing methods for calculating magnetic noise and vibration in asynchronous machines have unsatisfactory convergence with experience. There is no direct experimental evidence for the theoretical assumptions underlying these methods, the correctness of the calculation of individual quantities, in particular, inductions, interacting harmonics, forces, deformations, etc.

Electric motors used in electric rolling stock operate under more severe conditions than those used in general industry. Increased vibration also affects their operation, so the requirements for electric motors in electric rolling stock are very high. Various auxiliary electric machines are used in electric rolling stock [3, 5]. Single-phase asynchronous motors can be used in these machines. These motors are also affected by various internal and external forces. To justify the design expressions for the dynamic vibration damper, its dimensions are determined by the value of the required stiffness of its elastic element K(v) ,which is defined by the expression;

(1)

The motor mounting stiffness ks and the dynamic coefficient rlg included in this expression are related to the natural frequency of the motor fg , which characterizes the motor mounting conditions during operation [2, 4, 7].

To identify the relationship between the dimensions of the vibration damper and the engine mounting conditions, we transform expression (1), keeping in mind two main cases that may occur in practice:

- the required reduction factor for tangential vibration using a vibration damper is specified ( =const);

- the maximum permissible value of tangential vibration of the engine with a vibration damper (xml-ph-0000@deepl.internal=const)isspecified.  
of the motor with a vibration damper ( = const).

Considering the first case, we substitute the values of the rigidity of the installation and the dynamic coefficient of the motor into expression (1) [3, 4, 6]. For a network frequency fc = 50 Hz, we obtain

 ( -104) (2)

In this expression, the value

z = ( -104) (3)

characterizes the motor installation conditions, and the rest is a constant value for a given motor. For convenience of analysis, Fig. 1 shows the dependence Z = F(fg) [3, 8, 9]. From this dependence, it follows that in the pre-resonance region of the motor installation (fg <100 Hz - elastic installation), with an increase in fg, the value of Z decreases, which leads to a decrease in , and therefore, and, i.e., the dimensions of the vibration damper. However, with an increase in fg,the value of the tangential vibration of the engine Vтincreases, as well as, since it is specified that

(=const). According to the expression, a decrease in with a simultaneous increase in leads to a sharp increase in abg(m), which means a significant increase in mechanical stress in the elastic element of the vibration damper. The latter circumstance limits the reduction in the size of the vibration damper as it approaches resonance [3, 9, 10, 14].

In the resonance region (the region of rigid engine mounting, fg >100 Hz), as fg increases, the value of Z increases (Fig. 1), which leads to an increase in the required dimensions of the vibration damper to maintain a constant vibration reduction ratio. Since and decrease with increasing f(g), and increases, the stress in the elastic element of the vibration damper is significantly reduced and its dimensions are determined only by the required vibration damping efficiency [3, 11, 13].

It should be noted that as fgincreases in the resonance region, the magnitude of the engine's tangential vibration decreases. Therefore, there is reason to believe that the requirement for the multiplicity of vibration reduction using a vibration damper to remain unchanged when the stiffness of the engine mount increases is relatively rare in practice, namely in the case of particularly strict restrictions on the permissible vibration level [3, 9, 12,18]. In the latter case, as well as when the engine is operating in conditions close to resonance, when the dimensions of the vibration damper can increase significantly, for strength reasons, it may be recommended (to reduce the required dimensions of the vibration damper) to use a vibration damper in combination with vibration isolation.

In the pre-resonance zone, as fgincreases, the value of Z decreases (Fig. 1), which in this case leads, in accordance with (3), to an increase in the dimensions of the vibration damper. It is obvious that the stress in the elastic element, in accordance with (1), decreases in this case, and the dimensions of the vibration damper are determined only by the required permissible vibration value of the engine with the vibration damper [3, 12, 16,18].

In the resonance zone, with an increase in the rigidity of the engine installation, the value of Z increases, which leads to a decrease in kv and the size of the vibration damper. At the same time, there is an increase in stress in the elastic element, which limits the reduction in the size of the vibration damper.

**RESULTS AND DISCUSSION**

Thus, the dimensions of the vibration damper depend on the conditions of the engine installation during operation and can be determined by formulas, taking into account specific requirements.



**FIGURE 1.** Dependence characterizing the installation conditions of a single-phase motor

The design of the vibration damper must ensure ease of adjustment and tuning of its natural frequency. The vibration damper is tuned by moving the load along the elastic element [3, 9, 14]. It is necessary to emphasize the requirement for high reliability of the vibration damper attachment to the motor, since the stability and, to a certain extent, the efficiency of operation depend on this.

When installed on the housing of a single-phase motor, the vibration damper must be located:

- in a plane perpendicular to the motor rotation axis, with the vibration damper's axis of symmetry passing through the axis coinciding with the motor rotation axis;

- the axis of symmetry of the vibration damper load must be 900 with the axis parallel to the motor rotation axis.

The latter condition is not necessary only in the case of a spherical load and a circular cross-section of the elastic connection [11, 15, 17,18].

**CONCLUSIONS**

Magnetic noise is a consequence of vibration of the motor stator package under the action of vibration-exciting forces caused by the interaction of magnetic field harmonics of various origins in the air gap of the machine. The so-called sound level (dBA) is used as the standard value for noise assessment, which is the frequency-corrected (correction A) total sound pressure level measured with the machine mounted elastically without additional mass. Correction A is established as international and consists in reducing the measured noise levels at frequencies below 1000 Hz, i.e., in reducing the sensitivity of the measuring device at low frequencies, which is consistent with the peculiarities of human noise perception [2, 3, 7]. Therefore, when studying magnetic vibrations in terms of their influence on the magnetic noise of the motor, it is advisable to consider only high-frequency components, since low-frequency components do not affect the practically important acoustic characteristic of the machine - the sound level.

The effective value of the vibration velocity is accepted as the normalized parameter of the vibration generated by an electric machine. Unlike the sound level, the overall vibration velocity level is determined equally by both high-frequency and low-frequency vibration components [6, 15, 17,19].

Thus, despite the relatively low level of high-frequency magnetic vibration, due to its decisive influence on the magnetic noise of single-phase motors, this component is of independent interest for research.

**REFERENCES**

1. Berdiyev, U.T., Berdiyorov, U.N., Sulaymonov, U.B., Khalikova, L.U., Ways to Improve the Energy Performance of Asynchronous Electric Motors of Rolling Stock. Aip Conference ProceedingsOpen source preview, 2023, 2612, 050017
2. A. Vetcher, A. Iron powders with insulating layers: structure and magnetic properties /A. Vetcher, K. Yanushkevich // Material science "Nonequilibrium phase transformations": Proceedings of V International scientific conference, Varna, Bulgaria, 09-12 September 2019. – Varna, 2019. – P.27– 29.
3. Gapparov, A., Berdiyev, U. [Descrease in noise and vibration of single-phase asynxronous motors in rolling stock](https://www.scopus.com/pages/publications/85092172573)., [Iop Conference Series Materials Science and EngineeringOpen source preview](https://www.scopus.com/authid/detail.uri?authorId=57219315612), 2020, 883(1), 012177 .
4. Berdiyev, U., Berdiyorov, U., Toshpulatova, M. "[Problems and Tasks of Creating Energy-Saving Electric Machines](https://www.scopus.com/pages/publications/85132979260)." [Aip Conference ProceedingsOpen source preview](https://www.scopus.com/authid/detail.uri?authorId=57219315612), 2022, 2432, 020002 .
5. Berdiev, U.T., Kolesnikov, I.K., Tuychieva, M.N., Khasanov, F.F., Sulaymonov, U.B., Methods of new technological developments of electric motors based on soft magnetic materials. E3s Web of ConferencesOpen source preview, 2023, 401, 03038
6. Alymkulov K. Single-phase asynchronous motors for low-power electric drives. Bishkek-1995.
7. Sulaymonov U., Jelutkevich A., Nabiyevna M., Sayfullayev O., Berdiyorov U. Research of energy-saving composite materials for electric motors. (2023) E3S Web of Conferences, 461, art. no. 01054. DOI: 10.1051/e3sconf/ 202346101054.
8. S. F. Amirov, Sh.A. Sharapov, A.Kh. Sulliev, O.T. Boltaev. Biparametric resonant transformer sensor of large linear movements. AIP Conf. Proc. 26 December 2023; 2624 (1): 030007. DOI: 10.1063/5.0132847
9. Pirmatov N.B., Berdiyev U.T., Usmonov K.K., Nazirkhanov T.M., Berdiyorov U.N. Device for measuring the magnetic scattering field of the frontal part of the stator winding of a traction asynchronous electric motor of an electric rolling stock. (2023) E3S Web of Conferences, 401, art. no. 03021, DOI: 10.1051/e3sconf/202340103021
10. Yusupov D.T., Ismoilov I.K., Berdiev U.T., Kutbidinov O.M. Development of a simulation model for assessing the technical condition of the cooling system of oil power transformers by measuring the temperature of the tank and the external environment 15th International Conference on Thermal Engineering: Theory and Applications, ICTEA 2024. No. 1, vol. 12024.
11. Sauchuk HK, Yurkevich NP, Akhmedov AP, Kolesnikov IK, Berdiyev UT, Khudoyberganov SB, Khakimov SH Physical and thermal properties of binary (Bi-Ti-O)-TiO2 UHF-ceramics (2024) https://www.scopus.com/ inward/record. uri?eid=2-s2.0-85199155227&partnerID=40&md5=ccbd0010d5 ffcfaa5e 077619c15e6149
12. 12.Yusupov D.T., Avazov B.K., Kutbidinov O.M., Bazarov M. Cleaning of transformer oils using the electric field. IOP Conference Series: Earth and Environmental Science, 1231 (1), art. no. 012024, Cited 7 times. DOI: 10.1088/1755-1315/1231/1/012024
13. Structure and magnetic characteristics of composites based on encapsulated iron powders ASC100.29/G.A. Govor, M. Pshybilski, A.K. Vecher, K.I. Yanushkevich, J. Zukrowski, T.M. Tkachenko // Bulletin of the Foundation for Fundamental Research. –2020. –No. 1. –Pp. 105–111.
14. Analysis of a PM machine with concentrated fractional pitch windings / F. Magnussen [et al.] // Proceedings of Nordic Workshop on Power and Industrial Electronics (NORPIE), Trondheim, Norway, June 14–16. – 2004. – Mode of access: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.539.6560&rep =rep1&type=pdf. – Date of access: 15.03.2020.
15. Ritsuo A. Anchors of DC microelectric motors pressed from iron powder / A. Ritsuo, A. Laansoo // In: Electrical Engineering Industry. Series: Electrical Materials, Issue 6, 1971. - P. 10-12.
16. Panasyuk O.A. Powder soft magnetic materials for operation in constant and alternating fields / O.A. Panasyuk // In: Powder magnetic materials. - Kiev: Published by IPM AN USSR, 1987. - P. 108-121.
17. U.T. Berdiev, G.Sh. Abidova, G.R. Kakhharova Analysis of the associated parameters in the use of composite magnets in electric motor elements. Central Asian Academic Journal of Scientific Research, ISSN\*-2181-2489, Volume 2., SSUE 4|2022, pp. 291-295.
18. G.Sh. Abidova, G.R. Kakhharova, S.B.Nuriddinov Calculation and development of a device for automatic gain selection of a measuring amplifier. Scientific Online Journal Integral. Integral 01.05.2022. Moscow www.hiscience.ru. P.4-14.
19. U.T. Berdiev, G.R. Kakhharova “Energy-Efficient Brushless Electric Drive”. Respublican scientific-practical online conference “Application of modern methods in the development of science. 27. December 2022. <HTTPS://Academics> research.com/index.PHP/Conference. P.154-159.