# Methods of new technological developments of electric motors based on soft magnetic materials

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**Abstract.** Application conditions of composite materials based on ASC100.29 iron powders with an oxide coating in electrical machine devices as a stator with improved performance are considered in the article. The conditions for increasing the stability of the operation of electric motors are determined based on changes in the thickness of the oxide layer. Three-dimensional models of magnetic circuits were used, which made it possible to achieve a force of up to 4500 N with a torque of 3 to 8 Nm, which made it possible to obtain an engine power of 100-200 W. As a result, experimental characteristics of dependences $\mu=f(h)$, $H=f(h)$) and the power of specific losses on the thickness of the oxide coating $\omega_{уд}=f(h)$ were obtained. Methods for measuring the dynamic characteristics of the stator magnetic circuit are determined.

## 1 Introduction

Composite materials with the necessary set of performance characteristics are widely used in the nodes of various mechanisms. In any technical applications, certain properties of solids are used: electrical, magnetic, optical, thermal, mechanical, corrosion-resistant, etc. [4, 6]. The production of magnetic materials with low energy losses during re-magnetization is one of the urgent problems of the industry today. Despite the fact that research and development of such materials have been conducted since the beginning of the last century, the study of the mechanism of re-magnetization and improving the quality of these materials is still relevant today. This is due to the fact that magnetic materials are widely used in various electrical devices (generators, electric motors, measuring installations, inductors, etc.) [1, 4, 9, 15].

This article focuses on optimizing the torque of auxiliary units of motors, improving the efficiency of dimensions, weight and other performance characteristics and parameters. Typically, this optimization is associated with the need to change the operating modes of the motors: at a constant variable speed or in the start-stop mode. This can be achieved using soft magnetic materials (SMM). These materials have a wide range of elements in composition and properties [1.4]. The method of using soft magnetic materials in the technology of developing electric motors opens up new opportunities for their wide

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application, both in auxiliary units and improving their performance. Soft magnetic materials have the following advantages over other hard magnetic materials.

They have the ability to be easily magnetized and demagnetized without loss; are able to ensure the passage of the maximum flow through a unit cross-section of the magnetic circuit, reducing the size and weight; provide low losses when working in alternating fields, which in turn reduces the heating temperature, increases efficiency and working induction of the electric motor [2, 3, 5]. These materials satisfy the mechanical properties, and the stability of the operation of the electric motor over time at different temperatures. The most promising soft magnetic materials are materials based on metal powders, the particles of which are covered with a thin layer of insulation. The presence of insulation makes it possible to reduce electromagnetic losses and increase the quality factor of the composites.

## 2 Objects and methods of research

Research is based on the method of using soft magnetic materials in the form “metal-dielectric–metal” [M.D.M.] for the development of various electric motors. It is known that with an increase in the power frequency, the speed of rotation of electric motors increases [7, 9].

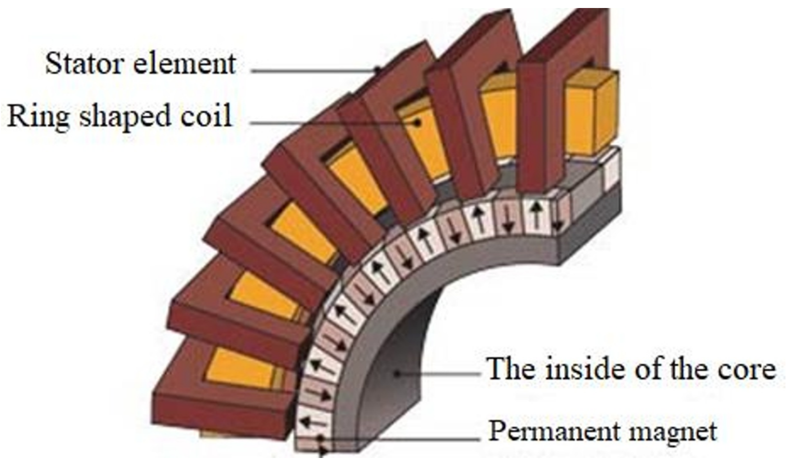


**Fig. 1.** Engine on the base of SMM (soft magnetic materials)

On the basis of soft magnetic materials, a cross-flow engine was developed (Fig. 1). Three-dimensional modeling was used for this electric motor since the magnetic circuits themselves are three-dimensional. This system is capable of reaching a force of 4500 N at a torque of 3 to 8 Nm. The power of this engine reaches 100-200 W, at a rotation speed of up to 280÷300 rpm [8, 9, 13].

On the basis of soft magnetic materials, an electric machine with an internal rotor and axial magnetic flux, and with a toroidal flux (Fig. 2) was developed [4, 7, 9, 12]. The use of electric machines based on powder technology (Fig. 2) made it possible to increase the electromagnetic force by 3 times, the power density by 30%, and reach a power of 100 W to 100 kW. At the same time, a greater torque of up to 15 Nm was provided at a rotation speed of 1500 rpm [3, 8, 11, 14].

Since the speed of electrical machines depends on the frequency, using powder technology with increasing frequency, it is possible to increase the rotation speed by 3 times.

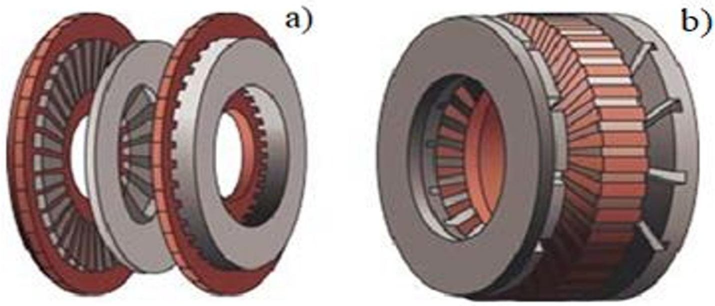


**Fig. 2.** Electric machines based on soft magnetic materials: a) with an internal rotor; b) with toroidal axial flow

## 3 Results and their discussion

The dependence of the magnetic permeability μ and magnetic induction *B* on the magnetic field strength *H* for the stator was obtained (Fig. 3) [7, 12, 14].

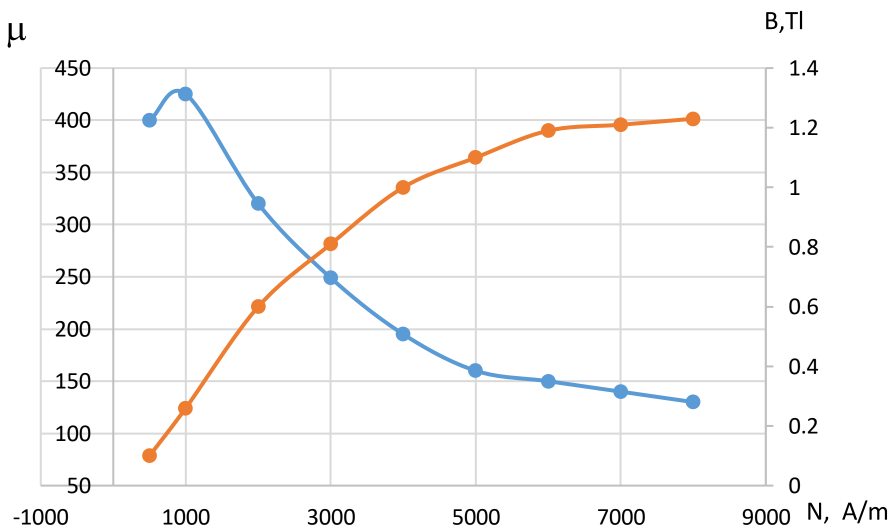


**Fig. 3.** Dependence of magnetic permeability and magnetic induction on the strength of the magnetic field: 1 - dependence of magnetic permeability; 2 - dependence of magnetic induction.

The dependence of magnetic specific losses $\omega_{sp}$ on the magnetic field strength was also determined (Fig. 4).

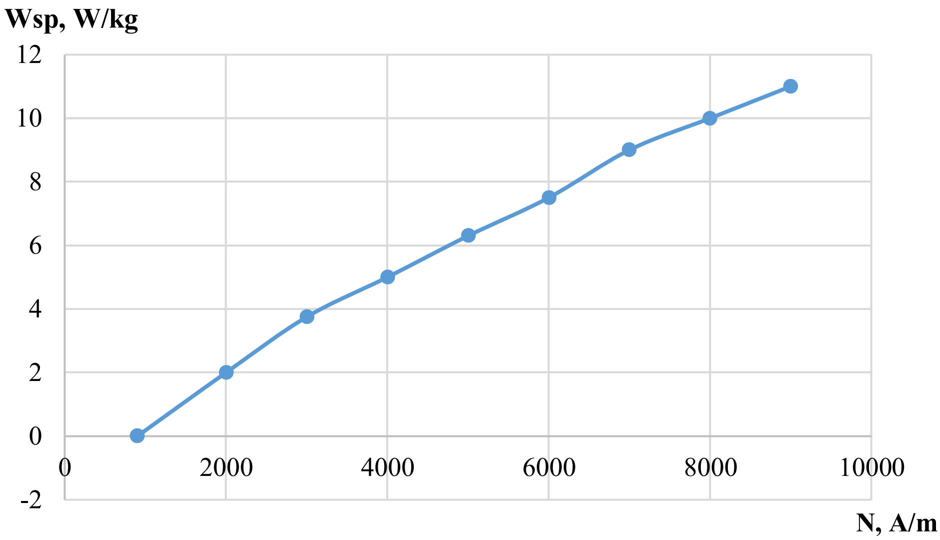


**Fig. 4.** Dependence of specific magnetic losses on the magnetic field strength

An experimental setup was used (Fig. 5) to determine the dynamic characteristics of the developed stator magnetic circuit.

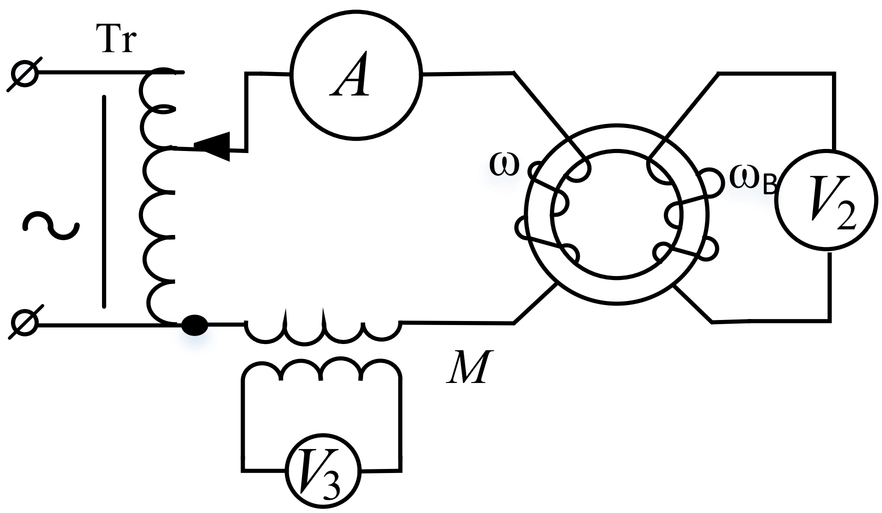


**Fig. 5.** Experimental setup for determining the dynamic characteristics of the developed stator

To determine the magnetization reversal losses, the circuit shown in Fig. 6 was used.

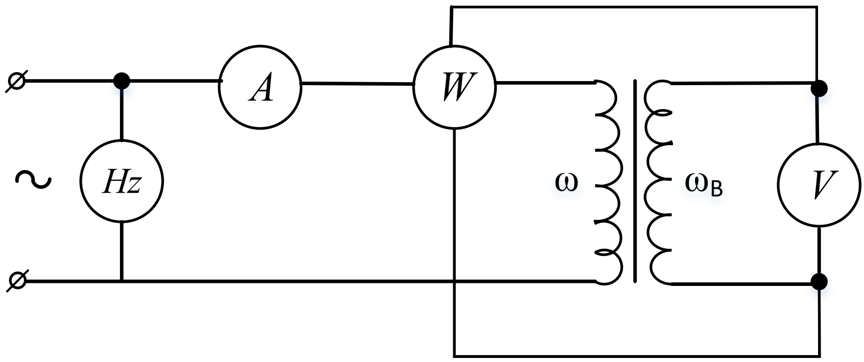


**Fig. 6.** Experimental circuit for determining magnetization reversal losses

Based on the ASC100.29 powder with an oxide coating from 1 to 20 Nm, the electromagnetic characteristics increase, while with a further increase in the coating thickness they begin to decrease [4, 8, 15, 17]. Figure 7 shows the dependence of the magnetic permeability on the thickness of the oxide coating [12, 15].

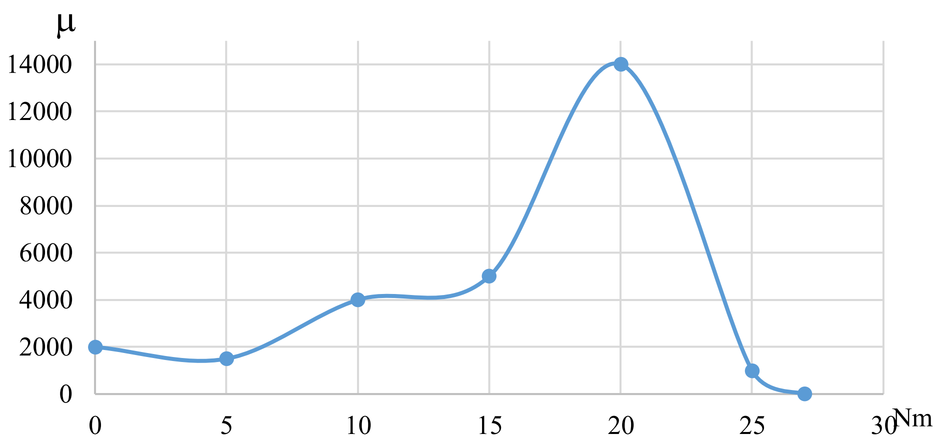


**Fig. 7.** Dependence of the magnetic permeability of ASC100.29 powder on the thickness of the coating with the oxide material

The dependences of the strength (Fig. 8) and the density of specific magnetic losses (Fig. 9) for the ASC100.29 powder material with an oxide coating, depending on its thickness are shown in Figs. 8 and 9 [16, 17, 18].

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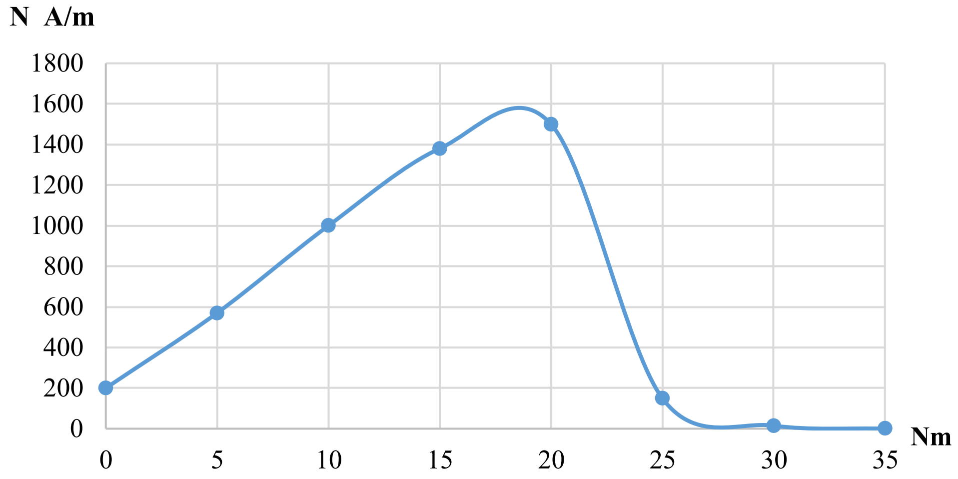


**Fig. 8.** Dependence of the magnetic field strength of ASC100.29 powder on the thickness of the oxide layer

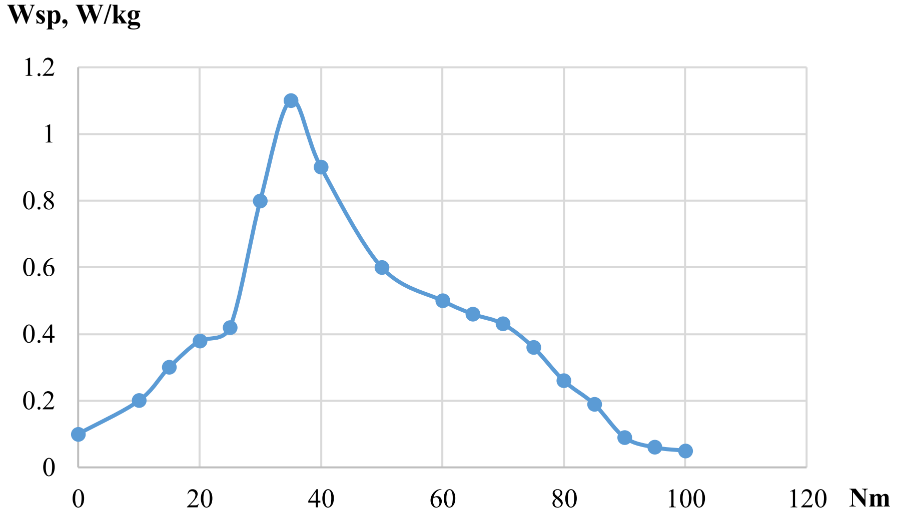


**Fig. 9.** Dependence of power of specific loss of the ASC100.29 powder on the thickness of the oxide layer

## 4 Conclusions

To reduce hysteresis losses, annealing of the material is usually used. This process relieves the stresses of the internal structure of the material, reduces the number of dislocations and other defects, and also enlarges the grain somewhat.

The developed soft magnetic material based on ASC100.29 powder with an oxide layer has good electromagnetic properties and is not inferior to foreign analogs. A magnetic circuit based on soft magnetic materials has sufficient strength, improved efficiency of dimensions, weight, and other performance characteristics.

Methods for measuring dynamic characteristics and stator magnetization losses based on powder technology were developed. The number of turns of the coil depends on the sintering temperature; the higher the temperature the less magnetic field strength, the magnetizing force, and the number of turns.

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