TECHNICAL SCIENCES

МАГНИТНЫЕ СВОЙСТВА МАГНИТОМЯГКИХ КОМПОЗИТОВ, ИСПОЛЬЗУЕМЫХ В ЭЛЕКТРОМАШИНОСТРОЕНИИ

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MAGNETIC PROPERTIES OF SOFT MAGNETIC COMPOSITES USED IN ELECTROMECHANICAL ENGINEERING

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Аннотация

В статье рассматриваются способы использования композиционных магнитных сплавов для элементов электротехники. Изучены основные методы получения магнитомягких композиционных материалов с целью получения высокоэффективных частиц ММК, так как для получения деталей высокой плотности их необходимо подвергнуть электроизолированию порошком. Высокие плотности обычно улучшают магнитные свойства как для поддержания низких потерь на гистерезис, так и для получения высокой плотности потока. Они дают эффект при использовании для сердечников электродвигателей на основе магнитомягких композиционных материалов.

Abstract

The article discusses the methods of using composite magnetic alloys for elements of electrical engineering. The main methods of obtaining soft magnetic composite materials have been studied in order to obtain high-performance MMC particles, as it should be subjected to electrically insulated powder to obtain high-density parts. High densities generally improve magnetic properties, both to keep hysteresis losses low and to obtain high flux density. These give an effect when used for the cores of electric motors based on magnetically soft composite materials.

Ключевые слова: композиционные материалы, магнитомягкие материалы, сердечники, роторы и статоры, гистерезисная кривая, магнитные сплавы, механическая и магнитная плотность сплавов, движущая сила полдера.

Keywords: composite, soft magnetic, materials, cores, rotors and stators, hysteresis curve, magnetic alloys, mechanical and magnetic density of alloys, ponder motive force.

Introduction. It is known that of all metals, only three metals, for example, iron, nickel, cobalt, have ferromagnetism, i.e. the ability to significantly thicken magnetic field lines, which is characterized by magnetic permeability. The relative magnetic permeability of ferromagnetic metals reaches tens and hundreds of thousands of units; for the rest, it is close to unity, if the relative permeability is somewhat greater than unity, then it is paramagnetic, and if it is less than unity, it is diamagnetic [1,3].

The purpose of this work is to develop the main elements of electrical machines using composite magnetically soft materials.

Soft magnetic materials are used for applications such as core materials in inductors, stators and rotors for electrical machines, drives, sensors and transformer cores. Traditionally, soft magnetic cores, such as rotors and stators in electrical machines, are made from stacked steel lamellar magnetic cores. Soft magnetic composite (SMC) materials are based on soft magnetic particles, usually based on iron, with an electrically insulating coating on each particle [2 - 4]. By pressing the isolated particles, optionally together with lubricants and/or binders, using a conventional powder metallurgy process, MMC parts are obtained. By using this powder metallurgical technology, it is possible to obtain MMC components with a higher degree of freedom in design than using steel lamellar magnetic cores, since the MMC material can carry three-dimensional magnetic flux, and also because three-dimensional shapes can be obtained as a result of the pressing process. In order to make MMC parts highly efficient and reduce their size, it is necessary to improve the operational characteristics of soft magnetic powders [4, 5].

Methods. One important parameter for improving the performance of MMC parts is to reduce their core loss characteristics. When a magnetic material is subjected to an alternating field, energy losses occur due to both hysteresis losses and eddy current losses. The hysteresis loss is proportional to the frequency of the alternating magnetic fields, while the eddy current loss is proportional to the square of the frequency. Thus, at high frequencies, it is predominantly eddy current losses that matter, and there is a particular need to reduce eddy current losses and at the same time keep hysteresis losses low. This means that it is desirable to increase the electrical resistivity of magnetic cores [6].

Results and Discussion. The experimental density was determined by the hydrostatic weighing method [3, 4], which is as follows. First, the sample is weighed in air at room temperature, and then the sample is immersed in distilled water [6, 7]. Samples in the form of compressed cores were taken for weighing. The experimental density dexp is determined from the expression:

$$d_{exp} = \frac{P_1 \cdot d_T - P_1 \cdot d_{air}}{P_1 - P_2} \quad (1)$$

where:

P_1 -is the weight of the sample in air;

P_2 is the weight of the sample immersed in distilled water;

d_T is the density of distilled water at a given temperature;

d_{air} is the air density.

The accuracy of this method is determined by the accuracy of determining its weight and the density of the liquid used.

In addition, in order to further reduce the hysteresis loss, stress relief heat treatment of the pressed part is required. In order to achieve effective stress relief, the heat treatment should preferably be carried out at a temperature above 300°C and below the temperature at which the insulating coating would be damaged, i.e. about 600°C, in a non-reducing atmosphere [7].

When studying the magnetic properties of the samples, a setup was used, which is based on the method of measuring the ponder motive force. The method makes it possible to study the temperature dependences of the magnetization and magnetic susceptibility at small amounts of matter [2, 6]. This makes it possible to relatively quickly achieve temperature equilibrium over the entire volume of the sample. It is obvious that the absence of a temperature gradient on the sample at the moment of measuring the specific magnetization or susceptibility provides the most accurate determination of their values.

As is known [3], the ponder motive force is determined by the expression:

$$F = m\sigma_x \frac{\partial B}{\partial x} = \frac{m\chi_g}{\mu_0} B \frac{\partial B}{\partial x} \quad (2)$$

where m-is the mass of the sample, σx, χg -are the magnetization and magnetic susceptibility of the unit mass of the sample, respectively, μ_0 is the magnetic constant, B is the magnetic induction, $\partial B/\partial x$ - is the magnetic induction gradient B along the x axis.

Measurements of the values of magnetic characteristics carried out by this method can be carried out with an accuracy of 1% if a calibration sample of the same shape and size is available (for example, from nickel) [5, 6].

The choice of electromagnet parameters is determined by the maximum values of the sample dimensions. The electromagnet must create a magnetic field that has a constant value of the product of the strength H and its gradient $\partial H/\partial x$ in a space of such dimensions between the pole pieces that it overlaps the dimensions of the ampoule in which the sample is located with a margin.

Figure 1 shows a schematic diagram of the installation. The electromagnet contains an annular magnetic circuit and cores with pole pieces made of E12 steel [3,4]. The electromagnet's design allows to add the 2Z space between them. The diameter of the pole pieces d = 145 mm. The electromagnet coils are wound with a 2 mm × 5 mm copper bar with the number of turns increasing towards the outer ends of the core. A similar method of variable winding is typically used in solenoids to increase field uniformity and eliminate the edge scattering effect. The annular magnetic circuit of the electromagnet, on the one hand, ensures the minimum scattering of the magnetic field in space. On the other hand, with a vertical arrangement, such a design is convenient for turning the electromagnet at any angle relative to a stationary sample [7, 8]. When used In order to prevent the sample from sticking to the pole pieces and at the same time ensure sufficient measurement accuracy, the mass of the sample, for example, of a ferromagnetic substance, should not exceed a few milligrams, and of an antiferromagnetic substance, of the order of one gram. To study the main magnetic characteristics of composite magnetic materials using ASC100.29 iron powders, 24 × 13 × 10 mm cores were made from materials with a density of $\rho = 7.6$ g/cm^3 [9].

Samples of composite magnetic material were annealed in vacuum at a temperature of 350ºC for 3 hours. The electromagnetic characteristics were studied using an F5050 microwebermeter. Measurement of the frequency characteristics of composite materials in a wide range of magnetic fields, magnetization reversal frequencies and temperatures was carried out on an express magnetometer in the frequency range up to 10 kHz and magnetic fields up to 30 kA/m [6, 7].

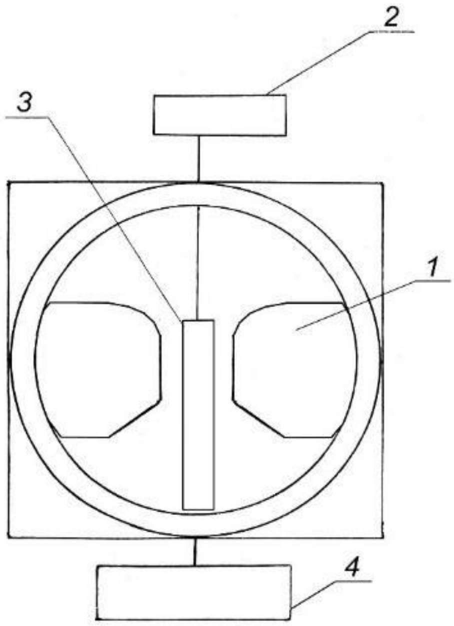


Figure 1. - Block diagram of the installation for magnetic 1 - electromagnet;
2 - device for reading the force of drawing the sample into the magnetic field:
3 – sample unit a thermostat; 4 - device for vacuuming the measurement thermostat

Before normalizing the magnetometer, the magnetic properties are measured on a fluxmeter.

In this case, an F5050 microwebermeter was used to normalize the magnetometer. Figure 2 shows the appearance of the magnetometer, and figure 3 shows the results of express magnetometer data processing and the main characteristics of its operation.

The magnetometer is designed for express control of the magnetic properties of materials - measurement in a wide frequency range of curves of magnetization reversal of samples, magnetic permeability and total losses, both during magnetization reversal and with one-sided magnetization. The set of express flux meter-magnetometer also includes software for processing measurement results [7,9].

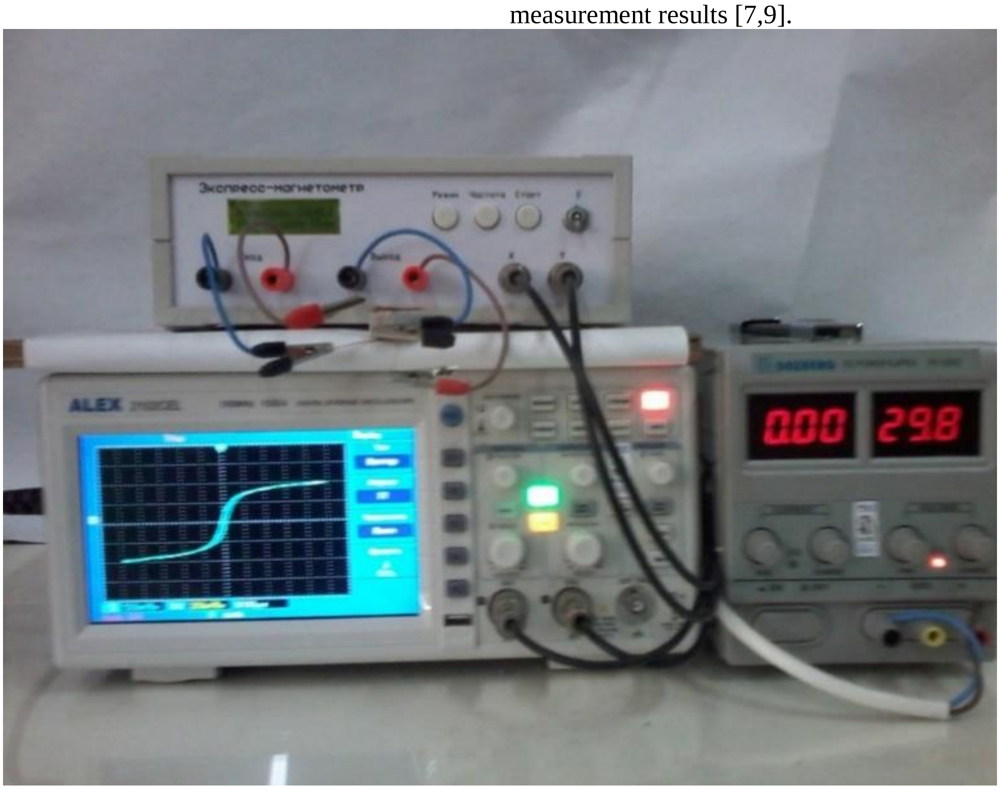
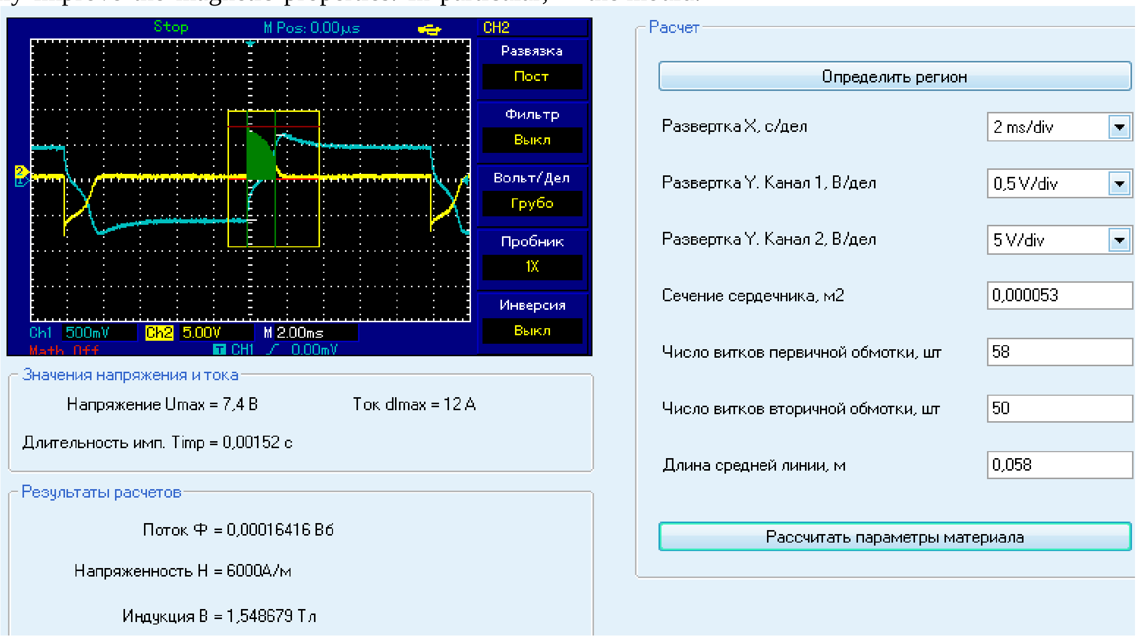


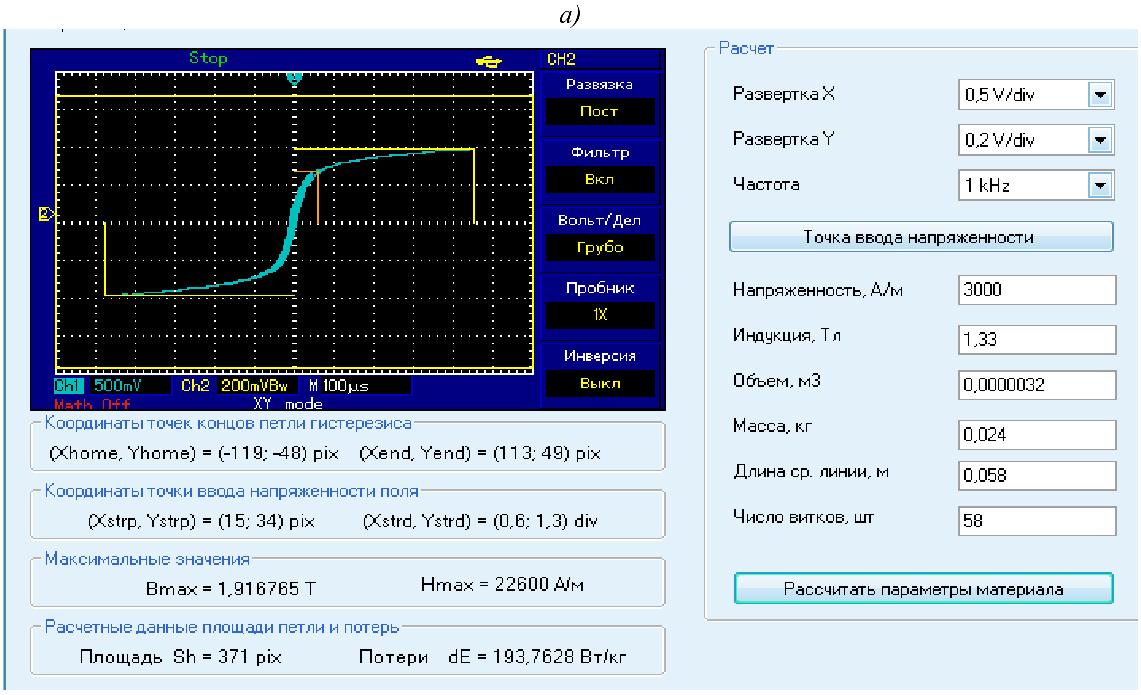
Figure 2 - Appearance of the magnetometer

Conclusion. In order to obtain highly efficient MMC particles, it must also be possible to subject the electrically insulated powder to compression molding at high pressures, since this is very often desirable in order to obtain high density parts. High densities generally improve the magnetic properties. In particular, high densities are needed to keep hysteresis losses low and to obtain high saturation flux density.

Additionally, the electrical insulation must withstand the required high compression pressures without being damaged when the pressed part is ejected from the mould.



a)



б)

Figure 3. Results of data processing in the express flux meter (a) and express magnetometer (b) modes

The results obtained during the study indicate the possibility of developing new magnetically soft composite materials and the prospects for their practical application for the creation of various electrical devices, the main element for the core elements of the rotors and stators of the electric motor.

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РЕАКЦИИ ГЕТЕРОЦИКЛИЗАЦИИ АМИНОВ И АМИДОВ С МОНО- И БИФУНКЦИОНАЛЬНЫМИ СОЕДИНЕНИЯМИ

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REACTIONS OF HETEROCYCLIZATION OF AMINES AND AMIDES WITH MONO- AND BIFUNCTIONAL COMPOUNDS

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Аннотация

Исследованы реакции гетероциклизации аминов и амидов с моно- и бифункциональными соединениями. Проведены реакции циклоконденсации мочевины и тиомочевины с гидрохиноном проводили в стационарных условиях. Синтезированы 5-гидрокси-1,3-бензоксо-2-тион с выходом 92% от теории, и 5-гидрокси-1,3-бензоксо-2-он с выходом 94% от теории. Синтезированы индол и его производные реакцией анилина и его производных с гликолями и триолами при температуре 250-600°C и давлении $1{,}1.10^5$-1.10^7 Па в присутствии катализаторов (CdO, ZnO, PbO_2, Al_2O_3, BO_3) . Найдены оптимальные условия процесса и предложена вероятная схема стадии образования индола.

Abstract

The reactions of heterocyclization of amines and amides with mono- and bifunctional compounds have been investigated. Cyclocondensation reactions of urea and thiourea with hydroquinone were carried out under stationary conditions. Synthesized 5-hydroxy-1,3-benzoxo-2-thione with a yield of 92% of theory, and 5-hydroxy-1,3-benzoxo-2-one with a yield of 94% of theory.

Indole and its derivatives have been synthesized by the reaction of aniline and its derivatives with glycols and triols at a temperature of 250-600°C and a pressure of 1.1.105-1.107 Pa in the presence of catalysts (CdO, ZnO, PbO_2, Al_2O_3, BO_3). The optimal conditions of the process are found and a probable scheme of the stage of indole formation is proposed.