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ENERGY-SAVING MATERIALS FOR ELECTRICAL ENGINEERING

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ANNOTATION

This article discusses the issue of widespread introduction with a high specific consumption of magnetic materials in the production of micromachines; a very promising direction is the development of a waste-free technology for the manufacture of magnetic cores and cores using powder metallurgy methods. The use of soft magnetic materials obtained by powder metallurgy methods allows reducing the loss of electrical steel and eliminating many labor-intensive operations, automating the technological process and ensuring the required dimensional accuracy of parts, excluding further finishing machining. Using soft magnetic materials for the construction of electrical machines, it is possible to obtain a sufficiently high value of the efficiency η and reduce the losses due to hysteresis.

Keywords: Soft magnetic, electric drive development, motor elements, power reserves, peak values, magnetic anisotropy, unconventional principles, soft magnetic alloys, composite material induction, hysteresis losses

INTRODUCTION

The appearance of static converters based on fully controlled semiconductor devices has made it possible to significantly expand the scope of electrical machines, primarily asynchronous motors and transformer-reactor equipment in all areas of electromechanics: from traditional electric drives to complex mechatronic systems [1, 3].

However, as practice shows, the presence of only hardware for the implementation of control functions, along with the use of standard typical control algorithms, is insufficient to achieve high technical and economic performance of a drive with asynchronous motors.

If we trace the technological line of the electrical industry, it is easy to see that it consists of three parts - production, transmission and consumption of electrical energy [4, 6].

If the generation and transmission of electrical energy has a single characteristic form, i.e. transmission of one type of energy by the same equipment - synchronous generators and power lines (power lines), then consumption has a diverse form (conversion of electrical energy into mechanical, light, thermal, electromagnetic and other types of energy). Also, it has several modes of operation of electrical machines [1, 2].

Modern directions of development of the electric drive is the organic combination of the machine - the engine and the tool machine and their merging. This allows you to abandon the mechanical transmission, simplifies the kinematics, makes it simpler and more reliable in operation.

The great potential of the electric drive is revealed as modern trends in the production of new magnetically soft materials develop.

The electric drive is widely used in various sectors of the economy: mechanical engineering; semiconductor and converter technology instrument making. In this regard, an opportunity opens up for a clearer understanding of the laws and types of movement, for the movement of work objects connected by organs and means of electric drive. All elements of the electric machine and electric drive operate in difficult conditions (dustiness, various meteorological conditions, etc.).

We list some urgent tasks that need to be solved in the future [1, 7]:

1. Development of special technical means for energy saving in a mass asynchronous electric drive operating with a variable load on the shaft;
2. Development of specialized electric motors for specific working mechanisms with specific working conditions. At the same time, special attention should be paid to the development of electric machines integrated with working mechanisms;
3. To unify as much as possible units and parts of machines based on magnetically soft composite material for use in ground and underground electrified transport.

METHOD

To date, the chain of electrical facilities "Generation and transmission of electrical energy" operates with fairly high values of the efficiency factor η. The same cannot be said about the consumer, because every day there are new entrepreneurs who introduce new production capacities, and from the first day they cannot work at full capacity. This is primarily due to the low loads of the applied electric motors of production mechanisms [2, 3].

Therefore, until it is possible to raise the consumer's η value to the required level (92-97%), it is impossible to increase production efficiency with this.

There are several circumstances here:

firstly, at the design stage, the power consumption of the electric motors of the working mechanisms was incorrectly calculated and selected;

secondly, often the mechanical characteristics of the selected electric motors do not match the mechanical characteristics of the working mechanisms, neither in shape nor in size;

thirdly, the peak values of the efficiency of the drive motor and the working mechanism do not match in terms of load;

fourthly, most industrial, transport machines and machine tools are low-speed and their shaft rotation speeds do not coincide with the standard speeds of asynchronous motors (3000; 1500; 1000; 750, etc. rpm). Hence, different gearboxes are required, which make the equipment heavier, more expensive, reduce energy performance and reliability. Considering that two-thirds of the electricity generated by the Republic of Uzbekistan is consumed by electric machines, it becomes obvious that reducing losses in them will be a high contribution to the implementation of energy-saving policy. This applies equally to both high-power electric machines, where the material benefit from saving electrical energy is clearly felt, and low-power machines. The latter is explained by the presence of a large fleet of low-power electric machines, where the saving of electric energy by only one percent will exceed the average value of consumption in the republic. Therefore, the problems of energy supply are directly related to energy saving in the operation of electrical machines and electric drives. This puts forward new scientific, technical and economic tasks for specialists [4, 5, 6].

RESULTS AND DISCUSSION

Currently, in the production of electrical machines, known soft magnetic alloys are mainly used, 90% of which are electrical steels of various types [1, 3, 4]. Such materials have almost reached the limit of their physical, mechanical and operational properties, and in order to create a new generation of products, it is necessary to use a completely new class of soft magnetic materials with improved characteristics, which can be used as obtained and studied composites.

Ferro and ferrimagnets with low coercive force, high values of initial and maximum magnetic permeability, and low magnetization reversal losses in dc and ac fields are classified as soft magnetic materials [1, 3, 8]. Depending on the characteristics of devices, electrical machines and other devices, the following requirements are imposed on soft magnetic materials:должны иметь однофазную и однородную структуру с минимальной концентрацией одно- и двумерных дефектов;

have low energy, magnetic anisotropy, which affect the area of the hysteresis loop and the magnetic permeability of the material;

have high values of saturation induction, which allow to increase the magnetic flux density in the magnetic core;

have a relatively high electrical resistivity, which affects the specific losses during magnetization reversal associated with energy losses due to eddy currents;

minimum porosity and minimum content of non-metallic or foreign materials.

Powders made from soft magnetic materials or iron-based alloys are one of the components of electrical products. Currently, they are replacing electrical steel in some areas of production. The most widespread use of iron-based magnetic alloys for the manufacture of cores in power and distribution transformers [5, 7, 8].

For materials operating in alternating magnetic fields, the most important properties are the initial magnetic permeability and specific magnetic losses [7]. The value of electrical resistivity determines the cutoff frequency with which it is advisable to use this material.

The use of materials is possible with small dimensions of the product, when the shielding effect of eddy currents is excluded and magnetization reversal is achieved over the entire thickness of the part. This is possible if the relation is fulfilled:

$$d \leq 10^5 \sqrt{\frac{2\rho}{\mu_{max}}},$$

where d is the thickness of the magnetic core, mm; ρ is the specific electrical resistance of the magnetic core material, Ohm·m; μmax is the maximum relative magnetic permeability [2, 5].

It follows from the formula that magnetic cores made of materials with high magnetic permeability can be used in alternating magnetic fields, provided that their electrical resistance is significantly increased or a layered structure is formed, and the layer thickness should not exceed the calculated value. Since alloying can increase the electrical resistivity by no more than an order of magnitude, the thickness of the magnetic circuit operating at a frequency of 50 Hz should not exceed three times the thickness of a sheet (0.35) of electrical steel, that is, 0.35·3≈1 mm. An increase in porosity also makes it possible to increase the electrical resistivity, but at the same time, the effective induction decreases, resulting in an increase in total losses. It is known that the losses due to remagnetization of the magnetic material P are the sum of the hysteresis losses and eddy current losses [3, 5]:

$$P = P_e + P_g,$$

where Pe - are eddy current losses, Pg - are hysteresis losses.

Because each particle of material is covered with an insulating layer, eddy current losses are minimal. This means that the total losses are mainly composed of hysteresis losses. Hysteresis losses are created during the displacement of the domain walls at the initial stage of magnetization. Due to the inhomogeneity of the structure of the magnetic material, energy is expended on the movement of the domain walls.

Hysteresis losses are usually reduced by annealing the material [7, 8]. Such a process relieves the stresses of the internal structure of the material, reduces the number of dislocations and other defects, and also somewhat enlarges the grain. Figure 1 shows the dependence of loss on induction for the ASC100.29 core material at a frequency of 1 kHz during full loop magnetization reversal before annealing and after annealing in vacuum at 350°C for 3 hours. It has been established that annealing of finished cores from a composite material makes it possible to reduce losses and increase the induction of the material by 5–8%, which is in fact consistent with [5, 7, 8].

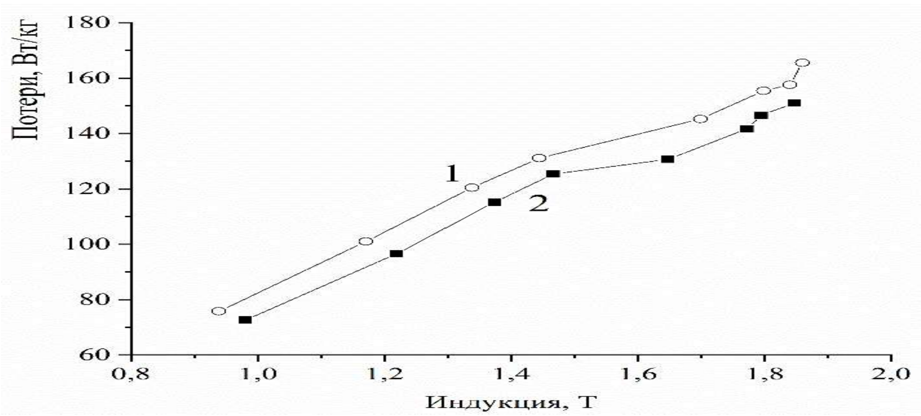

Figure 1. Losses for a low-frequency composite material based on ASC100.29 before annealing (1) and after annealing in vacuum at 350°C for 3 hours (2) with full loop magnetization reversal

CONCLUSION

The advantages of composite magnetic material over electrical steel and other soft magnetic alloys allow for their wider use in electrical machines in order to increase power density at high speed with less loss.

The results obtained in the course of the work indicate the possibility of developing new magnetically soft composite materials and the prospects for their practical application for the creation of various electrical devices of a new type [3, 7, 8]. Elucidation of the dependence of the loss for a low-frequency composite material based on ASC100.29 before annealing (1) and after annealing in vacuum at 350°C for 3 hours (2) during magnetization reversal along the full hysteresis loop of materials on the conditions for their preparation makes it possible to synthesize composite materials with given magnetic properties. On the basis of such materials, it is possible to create highly efficient electric motors and generators, magnetic components of wide application for electrical engineering.

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