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Research of magnetic properties of hybrid composite elements

Streszczenie. *Hybrydowe elementy są jednym z nowych rozwiązań jakie oferuje metalurgia proszków. Elementy hybrydowe składają się przynajmniej z dwóch obszarów wykonanych z materiałów o innych właściwościach magnetycznych, wykonanych w jednym procesie technologicznym. Takie elementy pozwolą na redukcje kosztów i czasu produkcji silników elektrycznych. Zagadnieniem poruszanym w referacie jest badanie właściwości magnetycznych magnesów hybrydowych złożonych z warstwy magnetycznie twardej proszku Nd-Fe-B oraz warstwy kompozytu żelaza.* ***Badania właściwości magnetycznych kompozytowych elementów hybrydowych***

Abstract*. Hybrid elements are one of the new solutions offered by powder metallurgy. Elements consisting of powders with different magnetic properties make the question of how measure the magnetic properties of hybrid elements composed of layers of material magnetically hard and magnetically soft and dielectromagnets made from a mixture of these same powders. Hybrid elements were made of magnetically hard Nd-Fe-B melt-spun ribbon powder and soft magnetic iron powder.*

Słowa kluczowe: metalurgia proszków, dielektromagnetyki, elementy hybrydowe, magnesy wiązane.
Keywords: powder metallurgy, smc, hybrid elements, bonded magnets.

Introduction

Magnetic parameters of hard and soft magnetic materials are measured by separate methods; depending on the type of material different measuring systems are used. Hard magnetic materials can be measured by induction method; the changes in magnetic flux are measured during demagnetization of the sample. This method allows to determine the demagnetization curve and the basic parameters of the magnetic sample. For studies of soft magnetic materials, the magnetization curve and magnetic hysteresis loop are designated for different frequency of magnetizing current. On the basis of these characteristics magnetic permeability and core losses of material are determined. Such studies are carried out on ring samples, on which are placed magnetizing and measuring windings.

Recently, powder metallurgy gives new possibilities of manufacturing complex structures, called hybrid magnetic elements. These elements consist of at least two layers of powder materials with different magnetic properties. One advantage of powder metallurgy is the ability to produce such structures in a single technology process, without gluing. The powder metallurgy method also allows to adjust the physical properties of magnetic circuits in accordance with the requirements of electrical machine design [1].

The most popular materials used to manufacture such components are: Nd-Fe-B hard magnetic powder and soft magnetic powder. Hybrid elements for electric machines are manufacture by bonding the powder material. Bonding agents for both powders must have similar bonding temperature. Bonding material plays a double role; it is a binder and insulator of powder grains. The use of dielectric materials as a means of bonding agent can reduce the losses from eddy currents. The parameters of technology processes affect the physical properties of finished element. Magnetic elements: made of a bonded hard magnetic powder are called dielectromagnets; made of soft magnetic powder are called dielectromagnetic. It is important to know the impact of technological parameters on the physical properties of the hybrid elements during design of electric motors. The most important parameters of hybrid elements for magnetic circuits of machines are their magnetic parameters. However, many difficulties are associated with measuring magnetic properties of heterogeneous structures. Research previously conducted using the measurement method with open magnetic circuit showed that the measured properties change with the method place and direction of the sample in the gap of an electromagnet [2]. In the current study of magnetic properties measurements were made using the induction method.

Experiments

In the experiment two types of hybrid elements were used; one layered hybrid element and second hybrid mixture element. The studies compared the results of magnetic properties: samples made of the magnetically hard and magnetically soft layers and the samples made from a mixture of such materials.

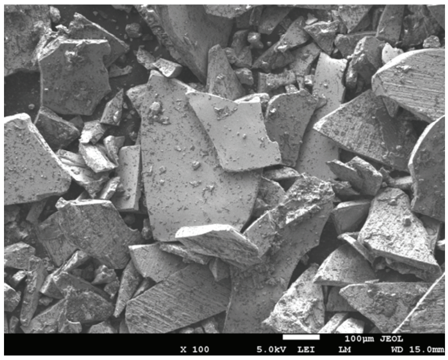


Fig. 1. SEM photos of powders Nd-Fe-B with epoxy resin

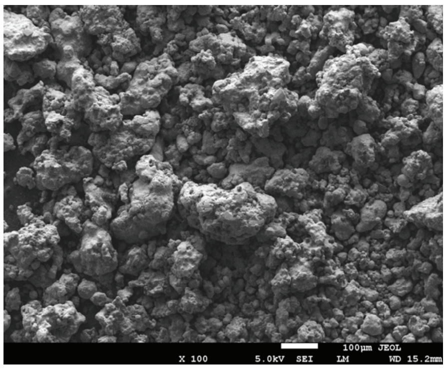
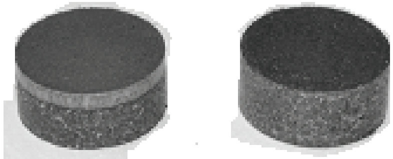


Fig. 2. SEM photos of powders iron

For preparation hybrid elements, compression moulding technology was used. This technology allows to prepare hybrid elements comprise of different types of powder materials. In the experiment, samples were manufactured from hard and soft magnetic powders. As hard magnetic powder Nd-Fe-B powder from melt spun ribbon was used. To Nd-Fe-B powder 2.5 wt % of epoxy resin and 0.2 wt % lubricant was added. For the soft magnetic part of element, iron powder with 0.6 wt % LB1 – lubricating binder was used. Figure 1 and 2 shows SEM images of powders' grains used in experiments.

Hybrid sample consisted of two layers, a layer made of iron powder was 30 wt % of weight of sample, the rest was Nd-Fe-B powder. Both types of powder was compressed in one technological process(fig. 2a). The second set of samples were made from a mixture of iron powder and Nd-Fe-B powder. For this samples the iron powder constitute of 30 wt %, the same as in the case layered hybrid elements(fig. 2b). All samples were compression moulded with 900 MPa pressure, then cured at 180°C for 2 hours [4]. Figure 2 shows both types of samples.



a) b)

Fig. 3. Hybrids elements used in research;

Results of experiments

Magnetic properties of hybrid elements were measured on cylindrical samples (diameter=10 mm; height=4 mm) by induction method using an AMH-20K-HS hysteresisgraph produced by Laboratorio Elettrofisico Walker LDJ Scientific. Hysteresisgraph measures hard magnetic materials in agreement with International Standard IEC 60404-5 [3]. The standard determines the methods of measurements of magnetic properties such as remanence B_r, coercivity of magnetic polarization H_{cJ}, coercivity of magnetic induction H_{cB}, maximum density of magnetic energy $(BH)_{max}$. The method of measurement of magnetic properties involves on insertion the magnet between magnetic poles of electromagnet, and measured the magnetic polarization and magnetic field in the sample with a change in the external magnetic field. Magnetic induction in the sample is determined from the relation (1).

(1) $$B = \mu_0 H + J$$

where: B – magnetic flux density, μ_0 –magnetic permeability of air, J – magnetic polarization.

Characteristics B=f(H) or J=f(H) are plotted as results of measurements. Hysteresisgraph used for measurements is equipped with a measuring system consisting of two measuring fluxmeters. One fluxmeter measures polarization J, second measures field strength H. Figure 4 shows the measuring equipment.

Fig. 4. AMH-20K-HS hysteresisgraph

Magnetic properties of prepared samples were determined. Layered hybrid elements were measure two times. In the first case hard magnetic layer was on the top of sample and in the second case was on the button of sample. In both cases the polarization of samples was suitable. In firs measurement pole N was on iron layer in the second measurement pole N was on Nd-Fe-B layer. In both cases result of measurements were the same. It means that the position of hybrid magnets between poles does not have influence on results of magnetic properties. Table I shows magnetic properties of hybrid elements proper by two methods, layered hybrid element and mixture. Figure 5 shows the demagnetization curves of both type of samples.

Table 1. Result of measurements of magnetic properties of hybrid elements

	Type of hybrid elements	B_r [T]	H_{cJ} [kA/m]	H_{cB} [kA/m]	$(BH)_{max}$ [kJ/m^3]
1	Layered	0.633±0.006	409±6	265±4	42.2±0.9
2	Mixture	0.592±0.006	311±5	176±3	23.3±0.5

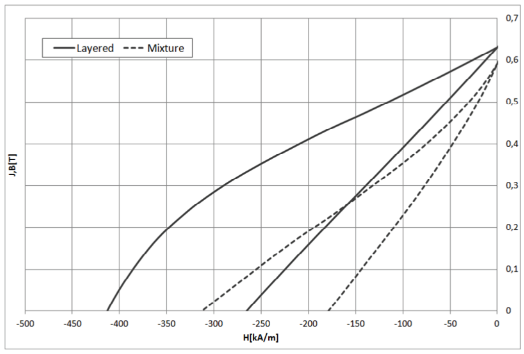


Fig. 5. Demagnetization curves of layered and mixture hybrid samples

Result of measurements of magnetic properties show that layer hybrid element indicate higher magnetic properties. Contents of hard and soft magnetic powders in layered and mixture samples were the same.

Summary

Results of experiments show that induction method of measuring magnetic properties of hybrid elements is better than measuring this samples in open magnetic circuit. Position of the samples between electromagnetic pools did not change the results. According to standard IEC 60404-5 in the case that samples of permanent magnets must by homogenous nature. Layered magnets are not homogeneous it can cause measurement error. In layered magnets B_r is higher because magnetic flux leakage is smaller then flux leakage in mixture magnets. In mixture magnets part of magnetic flux is circulating inside permanent magnets consisting iron particles. The investigation on methods of measurement magnetic properties of layered hybrid elements are still conducted.

REFERENCES

[1] Slusarek B., Gawrys P., Przybylski M., Dlugewicz L. Dielektromagnesy Nd-Fe-B z nabiegunnikami w silnikach prądu stałego typu PRMO-30-5D, *Elektronika,* 2 (2005), 66-70
[2] Slusarek B., Przybylski M., Karbowiak M., Hybrid magnetic elements*, International Conference on Advances in Powder Metallurgy & Particulate Materials*, Hollywood, 27-30 June 2010
[3] Standard IEC 60404-5 *Magnetic materials - Part 5: Permanent magnet (magnetically hard) materials - Methods of measurement of magnetic properties*, (2007)
[4] Kapelski D., Slusarek B., Jankowski B., Karbowiak M., Przybylski M., Powder magnetic circuits in electric machines, *14th International Conference on Advances in Materials and Processing Technologies*, Istanbul, 13-16 July 2011

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