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New possibilities of application of composite materials with soft magnetic properties

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Materials

ABSTRACT

Purpose: The purpose of the paper is characteristic of properties and application possibilities of modern soft magnetic materials and to show the influence of them on the developed of modern technology in different branches of techniques. Another aspect involved in the paper is to present the material and technological solution which makes possible obtaining soft magnetic composite materials: nanocrystalline material – polymer type.
Design/methodology/approach: The main base of the paper is to show the properties and possibilities of application of modern soft magnetic materials with taking into consideration the development of manufacturing technology of these materials which by obtaining the maximum possible values of properties allows for simplification of machines and devices construction with use of magnetic elements.
Findings: Modern soft magnetic materials have optimum technology of production with properties that allow for miniaturizing, simplification and lowering the costs of devices.
Practical implications: The usability of modern soft magnetic materials as inductive component in electronic industry depends upon further investigations.
Originality/value: The paper is the review of modern magnetic materials development and shows the material and technological solution which make possible obtaining magnetic composite materials with assumed properties.
Keywords: Composite materials; Manufacturing and processing; Magnetic materials; Application

1. Introduction

The dynamical development of the technical civilisation depends to a greater and greater extent on development of the material engineering which still searches for the non-conventional materials with the unique mechanical and physical properties. It is connected, among others, with the development of the contemporary electrotechnical and electronic industry employing the modern soft magnetic materials [1, 2]. Figure 1 shows evolution of soft magnetic materials.

The search for the new soft magnetic materials has lead, among others, to development of research on the Fe based metallic materials with the nanocrystalline structure, having the great soft magnetic properties [3, 4].

Bonding of powders of Fe based nanocrystalline metallic materials with the polymers and low-melting alloys makes it possible to obtain the composite materials. These soft magnetic composite materials may be made by sintering, injection moulding, hot compacting, upseting, casting and explosive consolidation but they can more affect the nanocrystalline structure of magnetic component [5-10].

The properties of the composite magnets depend mostly on the magnetic powder and binding agent types and on the technology employed. The portion of the polymer matrix affects the mechanical and magnetic properties of the manufactured composite materials. The mechanical properties increase along with the increasing portion of resin in the matrix but this increase has a negative effect on the magnetic properties. Usually the 2.5÷3.0 % mass portion is assumed, i.e., 15÷20 % volume portion, and compacting pressure is 350÷900 MPa [11].

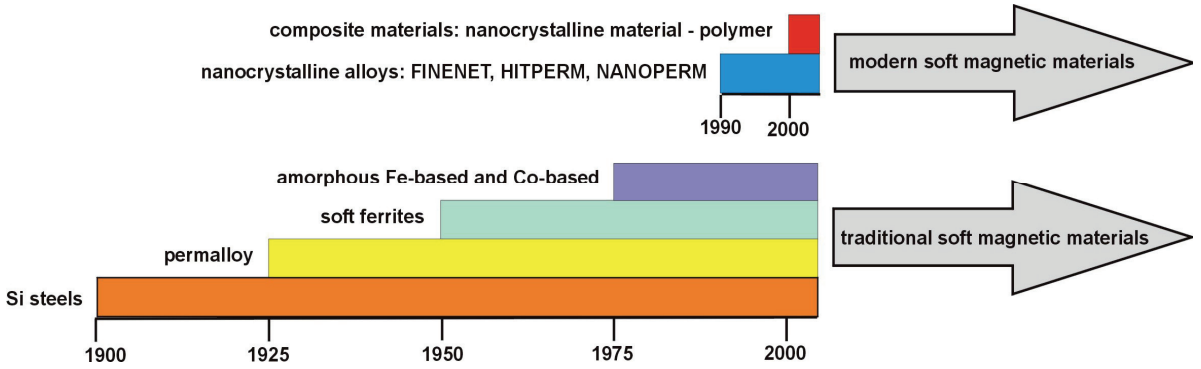


Fig. 1. Development traditional and modern soft magnetic materials [2]

Soft magnetic composite materials are characteristic of various magnetic, mechanical, and physical properties depending on the powder manufacturing and compacting technology. This makes it possible to obtain materials for various applications, according to the particular requirements [7].

The advantage of the bonded composite materials is their simple technology, possibility of forming their properties, lowering manufacturing costs because of no costly finishing and lowering of material losses resulting from the possibility of forming any shape.

The goal of the work is to show sample of soft magnetic composite materials with polymer matrix reinforced with FINEMET particles manufactured by one-sided unaxial pressing and possibilities of application these materials.

2. Experimental

For fabrication of composite materials was used powders of nanocrystalline soft magnetic materials: $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ (FINEMET). Composite materials were bonded by the use of 2.5 % wt. of thermoplastic polyethylene. The technology of composite materials obtaining is presented in Table 1.

Table 1.
Technology of composite materials

Reinforcement	$Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ (FINEMET) - time of milling 0.25h
Matrix	high density polyethylene (PEHD)
Pressure	350 MPa
Temperature	170 ^oC
Pressing time	0.25 h
Atmosphere	free air

Examples of manufactured composite materials with specific magnetic properties are shown on Figure 2.

Observations of morphology of powder and the structure of composite materials were made on the DSM 940 OPTON scanning electron microscope at the maximum magnification of 400 x using the secondary electron detection at the 20 kV accelerating voltage.

Metallographic examinations were made on the LEICA MEF4A light microscope equipped with the computer image analysis system. The powder grains size measurements were carried out on the light microscope. Test results were analysed statistically using the Leica-Qwin and Microcal Origin 6.0 program.

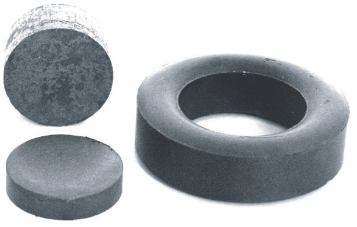


Fig. 2. View of composite materials: FINEMET-PEHD

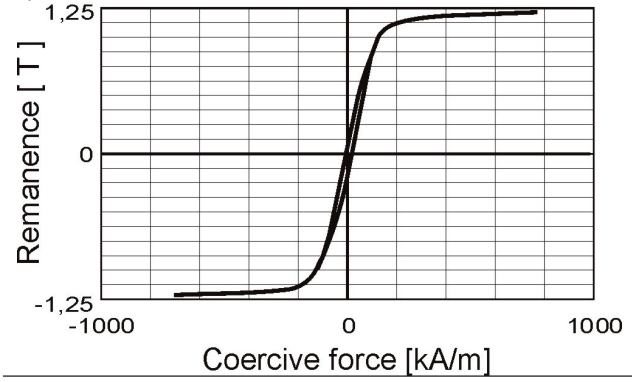
Examination of magnetic properties were examined on the Lake Shore Cryotronics Inc VSM vibratory magnetometer with the working voltage of 30 V, maximum field intensity 1800 kA/m and the time-constant 3 s. The examination results were collected and processed using the IDEASTM VSM Software package which featured the integral part of the VSM system.

Compression tests were made on the INSTRON 1150 all-purpose testing machine.

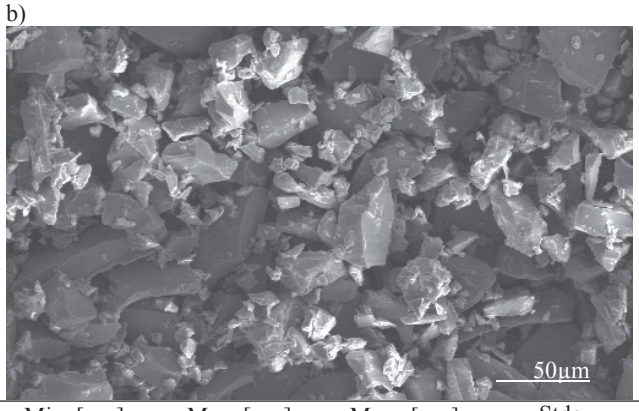
3. Results and discussion

Figure 3 shows hysteresis loop of composite materials, morphology and powder size of magnetic powder, the fracture of composite materials observed in scanning electron and the structure of composite materials observed on light microscope for FINEMET – PEHD composite materials. Powders used for fabrication of the composite materials differ with grain sizes and are characteristic of flaky shape. The biggest influence on magnetic properties of composite materials have the shape and the size of powder particles. Flaky shape with sharp edges powder particles causes the smallest demagnetizing effect. During the compacting process the powder particles get closer to each other what increases their contact area and causes their mechanical meshing. That is the reason why the shape of particles has great influence on mechanical properties of obtained composite materials because the connection of their elements is made by the adhesion forces. This results in obtaining the best magnetic properties because the demagnetizing effect is the smallest. Occurrence of the small portion of pores was observed in the fabricated composite material, which attests to the good compacting of powders.

a)

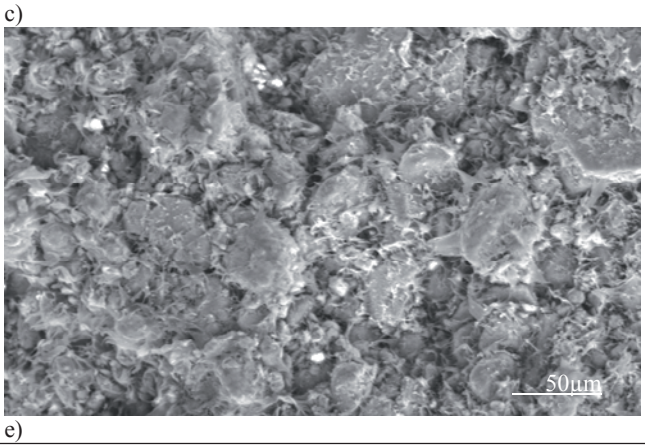


b)



H_c [kA/m]	B_r [T]	B_s [T]	μ_{max}	Min. [µm]	Max. [µm]	Mean [µm]	Stdev.
0.537	0.006	1.3	81	10.3	69.2	34.7	6.5

c)



d)

e)

mechanical properties	R_c [MPa]	A_c [%]	E_c [MPa]
	27.4	8.6	330.8

Fig. 3. FINEMET - PEHD composite material: a) hysteresis loop, b) powder $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$, c) fracture of composite material (SEM), d) structure of composite material (LM), e) mechanical properties

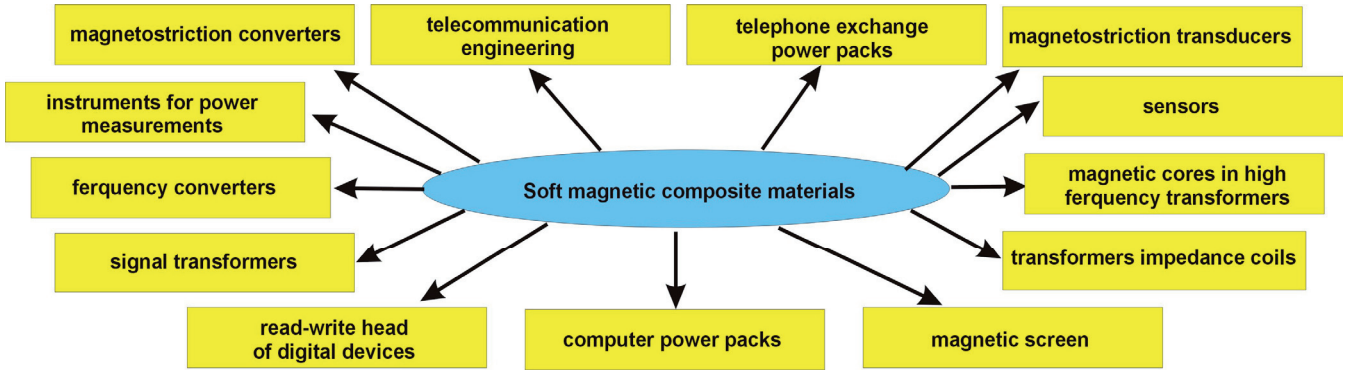


Fig. 4. Application of soft magnetic composite materials [3, 4, 9, 12-15]

Small amount of pores in composite materials causes the small portion of air gaps. The increase of air gaps is responsible for linearization of B=f(H). The linearization causes the decrease of magnetic properties of materials. Thus very important is to optimizate the technological process of materials obtaining.

The mass portion of polymer matrix in composite materials and the internal structure decide also about the magnetic properties but the influence is smaller than in the case of the powder particles. Nanostructure of the powder decides about the magnetic properties of composite materials. Technological

process of composite materials manufacturing takes into account the leaving of the structure of magnetic component of composite materials. The portion of the polymer matrix affects the mechanical and magnetic properties of the composite materials. The portion of polymer matrix must be sufficient to bind composite components powders to composite material. The mechanical properties increase along with the increasing portion of resin in the matrix but this increase has a negative effect on the magnetic properties as nonmagnetic material.

4. Possibilities of application

The range of magnetic materials application growths with improvement of their magnetic, mechanical, electrical and thermal properties. Figure 4 shows possibilities of soft magnetic composite materials applications. The application of magnetic composite materials allows to miniaturise magnetic elements, construction simplification and lower both manufacturing and material costs.

5. Conclusions

The research carried out make possible to develop the general technological process that allow to fabricate composite materials consisting of the nanocrystalline powders of the soft magnetic materials bounded by thermoplastic polymers with the required properties.

The advantage of the bonded composite materials is their simple technology, possibility of forming their properties, lowering manufacturing costs because of no costly finishing and lowering of material losses resulting from the possibility of forming any shape.

The manufacturing of composite materials greatly expand the applicable possibilities of nanocrystalline powders of soft magnetic materials.

The dynamical development of the technical civilisation causes greater and greater progress in magnetic materials. It is the result of the fact that modern civilisation is based on converting electric current devices and there is the need to extent the possibilities of their application. Contemporary civilization needs also materials with better properties. In comparison to classical soft magnetic materials modern soft magnetic materials have optimum technology of elements manufacturing by obtaining the assumed properties which allows to miniaturize, simplificate and lower the costs of devices. Composite materials nanocrystalline material – polymer type are the examples of these materials. Their dynamical development is observed from the nineties of XX century.

Modern magnetic materials, with exellent magnetic properties allow to miniaturizing of machines and devices. That influence also on our common life because most of devices till now consider to be stationary ones can be now replaced in any places.

The development in magnetic materials is still in progress. Now there are taken into consideration not only magnetic properties but also other like mechanical, physicalproperties or corrosion resistance are coming to be important.

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