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Application of nanostructural materials in manufacturing of soft magnetic composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ - PEHD type

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Materials

ABSTRACT

Purpose: The purpose of the paper is to show the possibility of application in different branches the techniques of nanostructural soft magnetic composite materials: $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powder bounded by polyethylene and the worked out technique of their obtaining.

Design/methodology/approach: The main base of the paper is to show the properties and possibilities of application of modern nanostructural soft magnetic composite materials as a result of finding new nanotechnologies that result the practical application of nanomaterials obtained by these techniques.

Findings: Modern nanostructural soft magnetic composite materials have optimum technology of production with properties that allow for miniaturizing, simplification and lowering the costs of devices.

Practical implications: Showing the possibilities of new technological solutions leading to manufacture materials than can replace the traditional ones.

Originality/value: The paper shows samples of nanostructural magnetic composite materials and shows the material and technological solution which make possible obtaining these materials.

Keywords: Composite materials; Manufacturing and processing; Nanostructural materials; Nanotechnology; Application

1. Introduction

The development of civilization is connected with continuous development of new technological solutions leading to obtain new materials with better properties. These new materials can with satisfaction replace traditional materials. [2, 8-11]

Today not a lot of people are aware of the fact that now is coming new technological revolution connected with practical application of know from twenty years nanotechnology. In the coming few years we will be the witness of changes, by which computer revolution can be see as something not much meaningful.

Nanotechnology leads to obtain nanomaterials, objects or structures which dimensions do not extend 100 nm. As an example can be shown obtaining of soft magnetic nanocomposite materials. To manufacture of these materials can be used nanostructural powders of Fe alloys bounded and pressed by polymers. Investigations of nanomaterials are made in the Institute of Engineering Materials and Biomaterials from decade and there is a great hope connected with these materials for future. [1, 4-7, 12-15]

The purpose of the paper is to show of possibility of application in different branches the techniques of nanostructural soft magnetic composite materials: $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powders bounded with polyethylene and worked out technology of their manufacturing.

2. Experimental

Schematic diagram of the technological operations for manufacturing nanostructural soft magnetic composite materials is presented in Figure 1. Base parameters of composite materials obtaining are shown in Table 1.

Observations of the structure of composite materials were made on the DSM 940 OPTON scanning electron microscope at the maximum magnification of 500 x using the secondary electron detection at the 20 kV accelerating voltage.

Investigations of magnetic properties were made 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.

Structure of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ powders were examined on the DRON-2 X-ray diffractometer with the HZG-3 goniometer and computerized reflected radiation recording system, equipped with the cobalt anode lamp, powered by current with 40 kV voltage and with 20 mA heater current. Recording of the investigated diffraction lines was made by the step method in the angular range of $40 \div 120^o$. Counting time at the measurement point was 5 s. On the base of the X–ray research in order to determine the size of powders crystallites Scherrer's relation [16] was applied based on the survey of the diffraction line width was applied:

$$d = \frac{0,9\lambda}{B \cdot \cos\theta_B} \quad (1)$$

where:
d – crystalline particle diameter [nm],
B – widening of diffraction line measured in the middle its maximum intensity [radian],
λ - length of X-radiation wave [nm],
θ_B – diffraction angle of beam of radiation corresponding with Bragg's maximum [^{o}].

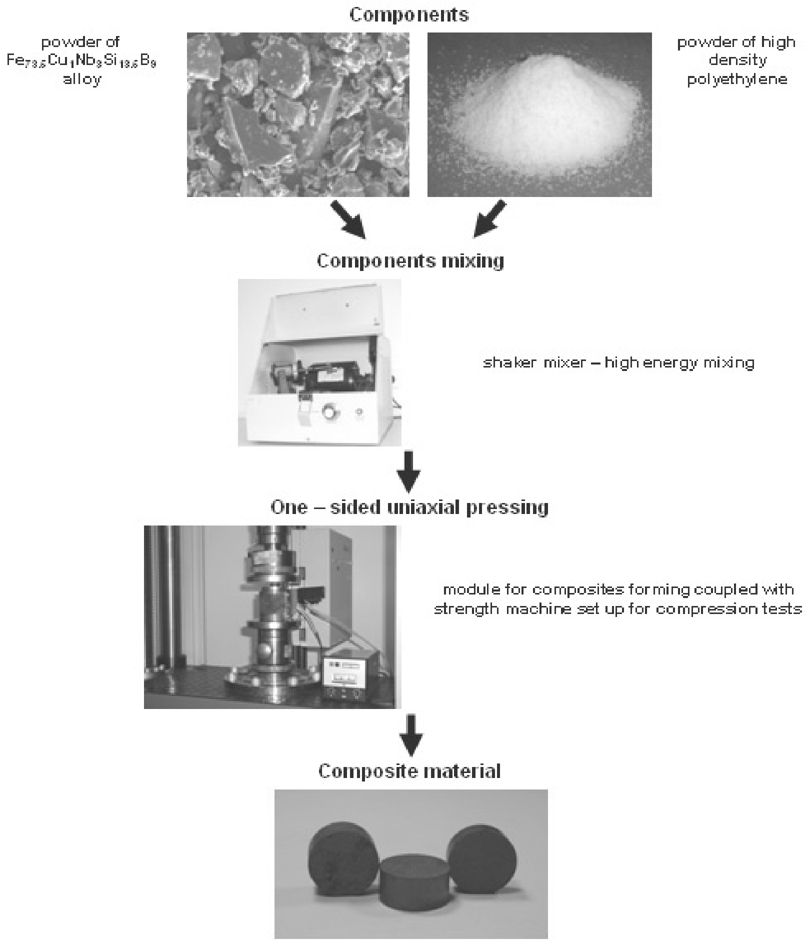

Fig.1. Schematic diagram of the technological operations for manufacturing nanostructural soft magnetic composite materials

Table 1.
Base parameters of composite materials obtaining

Components	
Reinforcement	powder of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy (FINEMET – trade name) – time of milling: 1.0 hour, grain size 9-42 μm – flaky shape
Matrix	powder of high density polyethylene (PEHD) – 5.0% wt., grain size 50-500 μm
Parameters of one – sided uniaxial pressing	
Components mixing time	0.25 h
Pressure	350 MPa
Temperature	170 °C
Pressing time	0.25 h
Atmosphere	free air

Table 2.
Properties of composite materials

H_c [A/m]	B_r [T]	H_{max} [kA/m]	B_s [T]	μ_{max}	P_{max} [W/kg]	R_c [MPa]	A_c [%]	E_c [MPa]	ρ [g/cm^3]
604.9	0.0058	796	1.14	77	1.39	57.3	8.7	659.8	4.8

3. Results and discussion

X-ray examinations show that structure of the powder $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy used to obtain the composite materials: amorphous matrix, which is testified by peaks coming from the αFe(Si) phase (Figure 2). Basing on the Scherrer's relationship the average size of the αFe(Si) phase crystallites was determined. The average crystallite size is equal d = 13.8 nm.

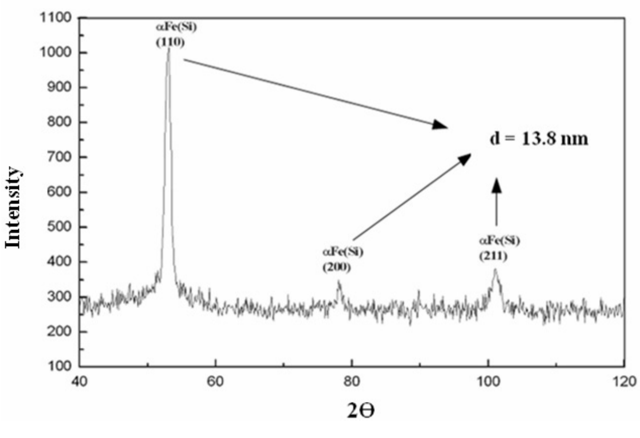

Fig. 2. X-ray diffraction patterns powder of the $Fe_{73,5}Cu_1Nb_3Si_{13,5}B_9$ alloy

Results of the magnetic properties, mechanical properties and density of the composite material are presented in Table 2.

Microscopic images of composite fractures obtained after decohesion in the compression test are presented in Figures 3. It was observed, basing on the microscope examinations, that the $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powder particles get closer as a result of the one – sided uniaxial pressing. This caused increase of their contact area and mechanical meshing of particles during the compaction process, which rendered adhesion forces possible. No polyethylene clusters were observed on fracture structures of composite material, which attests to its uniform distribution in composites (Figure 3). Powders used for fabrication of the composite materials 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. 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 polymer in the matrix but this increase has a negative effect on the magnetic properties as nonmagnetic material.

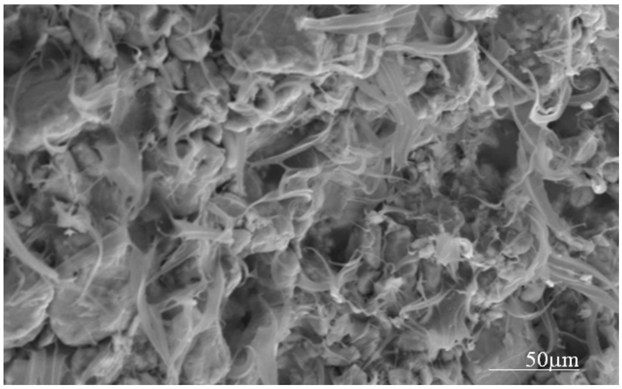

Fig. 3. Microscopic images of composite material fractures obtained after decohesion in the compression test.

4. Conclusions

The dynamical development of the technical civilisation causes greater and greater progress in magnetic materials.

Application for composite materials manufacturing the nanostructural powder with great magnetic properties but limited application because of geometrical shape, allows to develop the technologies connected with devices converting electric current. These nanostructural soft magnetic composite materials can find a use: magnetostriction converters, telecommunication engineering, telephone exchange power pack, magnetostriction transducers, sensors, magnetic cores in high frequency transformers, transformers impedance coils, magnetic screen, computer power packs, read-write head of digital devices, signal transformers, frequency transformers, frequency converters, instruments for power measurements.

In comparison with 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.

Modern magnetic materials, with exellent magnetic properties allow to miniaturize the 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.

Materials – technological solutions shown in the paper is one of many practical application of nanotechnology and nanomaterials.

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