Journal of Achievements in Materials and Manufacturing Engineering

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

The dependence of the functional properties of the nanocomposite with matrix made of Epidian 100 resin due to size of reinforcement made of $Fe_{67}Co_{10}Ni_{1}W_{2}B_{20}$ alloy

A. Siejka [a,*], M. Szota [a], M. Nabiałek [b], P. Pietrusiewicz [b], A. Łukaszewicz [a], J. Klimas [a], K. Błoch [b]

[a] Institute of Materials Science and Engineering, Czestochowa University of Technology, ul. Armii Krajowej 19, 42-200 Częstochowa, Poland

[b] Institute of Physics, Czestochowa University of Technology, ul. Armii Krajowej 19, 42-200 Częstochowa, Poland

* Corresponding e-mail address: abukowska@wip.pcz.pl

ABSTRACT

Purpose: Objective of the paper was to determine the effect of particle size fraction for the mechanical properties of powders and magnetic fields produced powder consisting of iron-based alloys and an epoxy resin (trade name Epidian 100) which was obtained as a result of press.

Design/methodology/approach: Samples were produced by the method of single-unilateral pressing. To achieve the pursued objective, the following tests were performed: microstructural observations – light microscope, roughness tests, statistical the hysteresis loops.

Findings: On the basis of the research it can be stated that with the increase in the size fraction of the reinforcement of composites increased their roughness and greater was their density. In addition, with the increase in the size fraction of the reinforcement of composites increased the field coercivity, while decreasing saturation magnetisation.

Research limitations/implications: The study not specified time and the influence of baling pressure on the mechanical properties and magnetic properties of composites produced using the single-uniaxial press.

Practical implications: The division into three fractions powder using a sieve analysis did not allow for adequate separation of powders. In each fraction were small particles. In the future, it will be used a long period of time sieving powders.

Originality/value: The paper presents new method producing magnetic composites, where possible was give shape by using epoxy resin.

Keywords: Polymer composites; Pressing; Magnetic powders

Reference to this paper should be given in the following way:

A. Siejka, M. Szota, M. Nabiałek, P. Pietrusiewicz, A. Łukaszewicz, J. Klimas, K. Błoch, The dependence of the functional properties of the nanocomposite with matrix made of Epidian 100 resin due to size of reinforcement made of $Fe_{67}Co_{10}Ni_1W_2B_{20}$ alloy, Journal of Achievements in Materials and Manufacturing Engineering 77/2 (2016) 64-68.

PROPERTIES

1. Introduction

Composite materials are amongst to the most known materials, therefore, newer connections between materials are sought, which will give new opportunities for application in industry. Composite materials are man-made materials and consist of at least two different materials with a clear boundary between them, and. should be characterised by different properties than the component materials [1-5].

The composites consist of two main components [6-9]:

- matrix,
- reinforcement.

The matrix is the phase in which the reinforcing elements are distributed during reinforcement of the composite is materials with high strength properties. The reinforcement can be added in various forms.

The advantages of those materials are easiness of formation, low cost of production, possibility to design application properties. Therefore, newer connections between materials are searched in order to obtain better properties [10].

The aim of the paper is to determine the effect of powder fraction size on mechanical and magnetic properties of the produced composites where the matrix is Epidian 100 epoxy resin and the reinforcement powder is made of iron-based alloy.

2. Materials and experimental methods

Materials produced from the $Fe_{67}Co_{10}Ni_1W_2B_{20}$ alloy and the epoxy resin and subjected to low-energy crushing were used to the study. A very important step in the production of materials is their professional preparation. It is necessary to prepare homogenous ingot which is possible by repeated melting. homogenization, of melted material, relies on melting done a few times. Melting of the particular alloy components can be usually carried out in an electric arc or an induction furnace. The chamber in which alloy components aremelted was an inert gas.

The crystalline ingots (Fig. 1) obtained in this way were crushed and was divided into three fractions of reinforcement were separated: 20-50 μm, 50-100 μm and 100-200 μm. Then each fraction was combined with the Epidian 100 epoxy resin. Each of samples w compressed under a pressure of 5 MPa for 10 sec.

In case to consolidate powders the samples in a furnace for 2 h at a temperature 160°C were placed. The samples contain 95% wt of the alloy powder and 5% wt of the epoxy resin (Fig. 2). Marks of the samples are shown in Table 1.

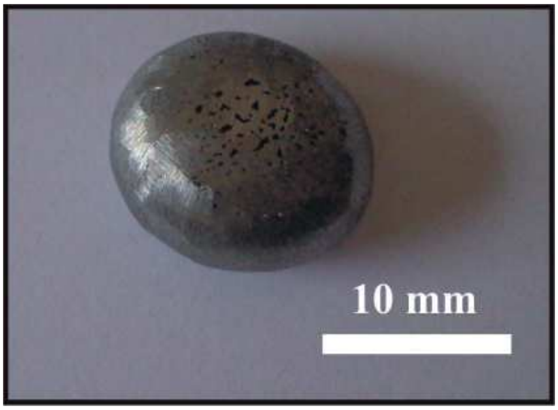

Fig. 1. The crystalline ingot of $Fe_{67}Co_{10}Ni_1W_2B_{20}$ alloy

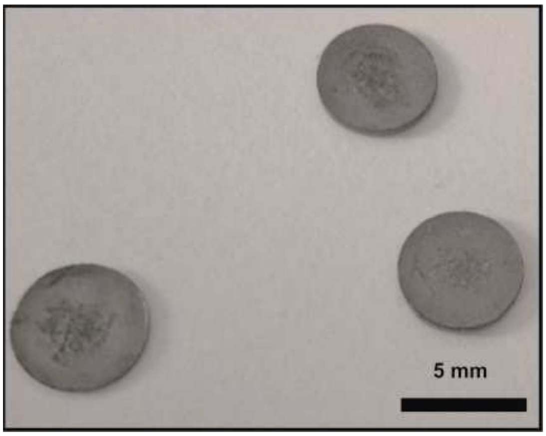

Fig. 2. The macroscopic image of the obtained samples

Table 1.
Summary of participation % wt. (alloy, epoxy resin) of the produced samples

Powder fraction	$Fe_{66}Co_{10}Ni_2W_2B_{20}$, % wt.	Epoxy resin, % wt.
20-50 μm	95	5
50-100 μm	95	5
100-200 μm	95	5

The surfaces of the obtained composites with different reinforcement fraction size by using Axiovert 25 light microscope were observed. In order to examine the roughness profiles of the obtained composites, the studies of profile roughness using Hommel Tester T1000 profilometer were carried out. In order to study roughness, profile the measuring distance of 1.5 mm was chosen. Magnetic properties of the tested samples on the basis of analysis of static hysteresis loops were appointed which were measured by the use of LakeShore vibrating magnetometer working in the magnetic field with 2T intensity.

The measurements of the density of the samples were also conducted., on the basis of which the volume percentage of pores V_{por} in the produced samples were pointed out. For this purpose, the following equation was used [6]:

$$V_{por} = 1 - w_{epid}\frac{\rho_{komp}}{\rho_{epid}} - w_{stop}\frac{\rho_{komp}}{\rho_{stop}} \quad (1)$$

where:
ρ_{komp} – density of the composite, ρ_{epid}, ρ_{stop} – density of the epoxy resin and density of the alloy, w_{epid}, w_{stop} – wt % of the epoxy resin and the alloy.

All studies were performed at the room temperature for samples hardened with a 95% wt. of alloy powder and 5% wt. of epoxy resin.

3. Results

Surfaces of produced composites were observed at a magnification of x100; the images are shown in Figures 3-5.

Surface roughness profiles of the obtained samples are shown in Figures 6-8. On the basis of the studies of surface roughness of analysed composites, the most important parameters are shown in Table 2.

Fig. 3. The surface of the obtained samples with the reinforcement fraction of 20-50 μm

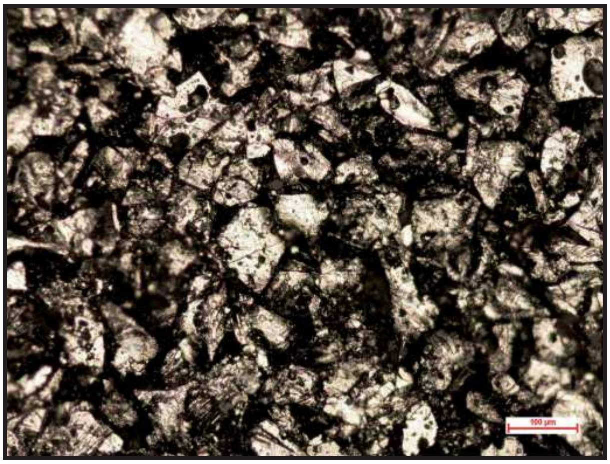

Fig. 4. The surface of the obtained samples with the reinforcement fraction of 50-100 μm

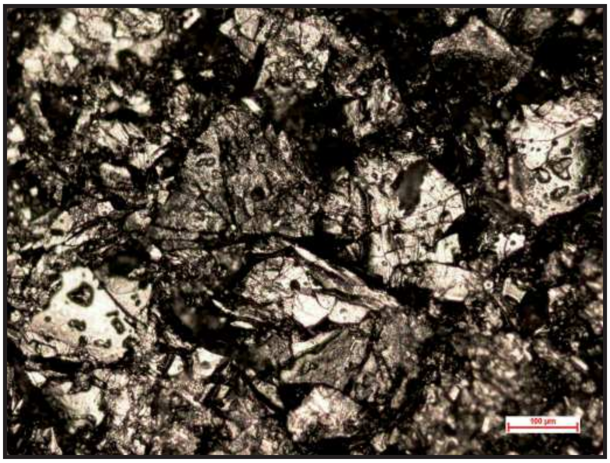

Fig. 5. The surface of the obtained samples with the reinforcement fraction of 100-200 μm

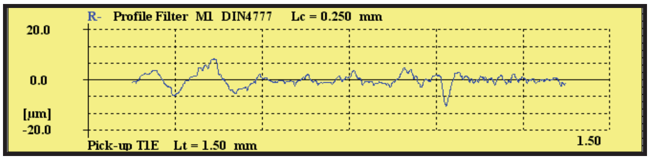

Fig. 6. Graph of roughness level of the obtained sample with reinforcement fraction of 20-50 µm

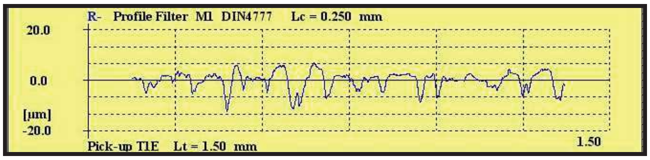

Fig. 7. Graph of roughness level of the obtained sample with reinforcement fraction of 50-100 µm

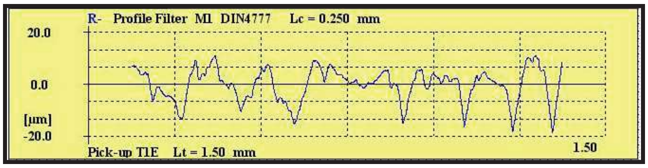

Fig. 8. Graph of roughness level of the obtained sample with reinforcement fraction of 100-200 µm

Table 2.
Summary of roughness tests of the produced samples

Powder fraction	Ra, µm	Rz, µm	Rmax, µm
20-50 µm	1.41	9.15	14.69
50-100 µm	1.79	11.18	14.37
100-200 µm	3.73	19.02	23.24

Legend:
R_a – the arithmetic mean deviation of the roughness profile,
R_z – average height of roughness,
R_{max} – the maximum height of roughness.

In the data presented in Table 2 sample with reinforcement fraction of 100-200 µm had the most developed surface (Rmax). Moreover the sample with the highest parameter Rmax had highest values of most important roughness parameters such as Ra=3.37 µm and Rz=19.02 µm compared to the other samples with the smaller fraction of reinforcement.

The measured measurements of the density of the samples allowed to determine the percentage of pores V_{por} inside the produced samples. Results of those measurements are shown in Table 3.

Table 3.
Summary of density and percentage volume of the pores of the obtained samples

N^o	Powder fraction	ρ_{komp}, g/cm^3	V_{por}, %
1	20-50 µm	3.70	37.6
2	50-100 µm	3.93	34.1
3	100-200 µm	4.25	28.4

In data presented in Table 4, it can be seen that the lowest density had the composite with the reinforcement fraction of 20-50 µm (3.70 g/cm^3) and highest with the reinforcement fraction of 100-200 µm (4.25 g/cm^3). The highest percentage volume of the pores had the composite with the reinforcement fraction of 20-50 µm (37.6%), while the lowest had the sample with the reinforcement fraction of 100-200 µm (28.4%).

Table 4.
Summary of the magnetic parameters appointed from static hysteresis loops

N^o	Reinforcement fraction	$\mu_0 M_s$, T	H_c, kA/m
1	20-50 µm	0.57	7.02
2	50-100 µm	0.97	5.98
3	100-200 µm	1.18	5.22

Static hysteresis loops for the composites with the powder made of the $Fe_{67}Co_{10}Ni_1W_2B_{20}$ alloy and the epoxy resin are shown in Figures 9-11, parameters read from hypothesis loop are shown in Table 4.

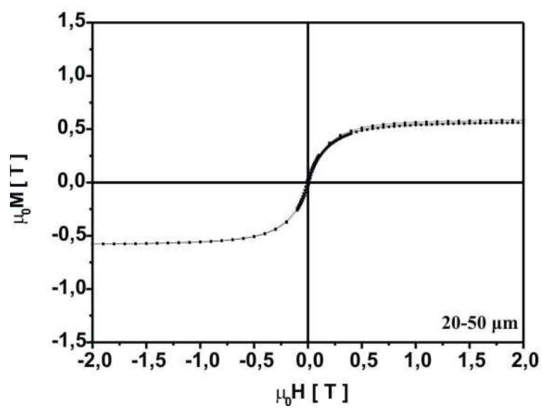

Fig. 9. Static hysteresis loops for the samples with reinforcement fraction 20-50 µm

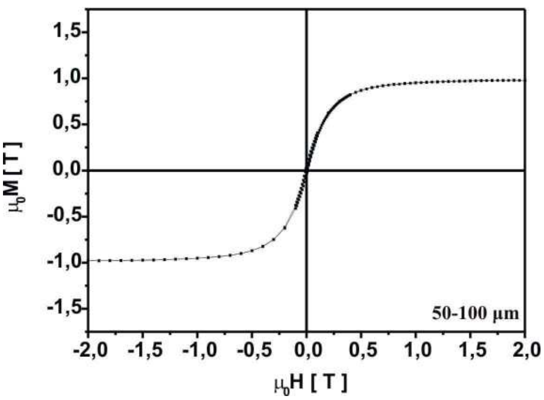

Fig. 10. Static hysteresis loops for the samples with reinforcement fraction 50-100 μm

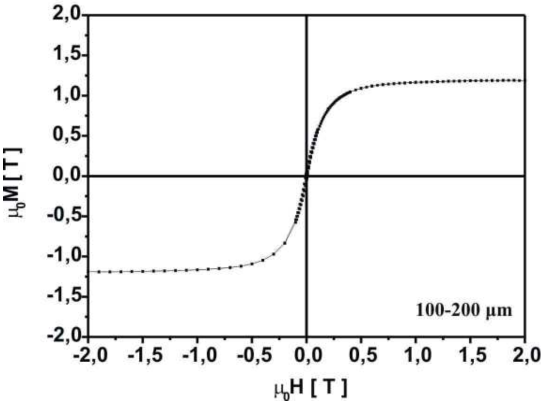

Fig. 11. Static hysteresis loops for the samples with reinforcement fraction 100-200 μm

On the basis of results in Table 4, it can be stated that with increased size of reinforcement fraction decreases coercivity field (H_c). The highest coercivity field (7.02 kA/m) had the composite with the reinforcement fraction of 20-50 μm and the lowest coercivity field had the sample with the reinforcement fraction of 100-200 μm (5.25 kA/m).

4. Conclusions

Based on the studies it can be concluded:

- the highest reinforcement size causes the higher values of surface roughness,
- the higher reinforcement, a fraction of composites, the biggest density,
- the size of the reinforcement had an influence on percentage volume of the pores; the highest reinforcement had a smaller number of the pores,
- coercivity field increases with the size of the reinforcement while saturation magnetisation is decreased.

References

[1] B. Ziębowicz, D. Szewieczek, L.A. Dobrzański, Influence of manufactuing technology on the structure and properties of the composite materials and polymers, Materials Engineering 27/3 (2006) 676-679 (in Polish).

[2] L.A. Dobrzański, Fundamentals of materials science and metallurgy, WNT, Gliwice-Warsaw, 2002 (in Polish).

[3] W Kubiński, Materials science, Vol. I: The primary materials used in technology, AGH Publishing House, Cracow, 2010 (in Polish).

[4] J. Sobczak, S. Wojciechowski, The current trends in the practical application of metal matrix composites, Composites 2/3 (2002) 24-37 (in Polish).

[5] B. Ziębowicz, D. Szewieczek, LA. Dobrzański, J. Wysłocki, A. Przybył, Structure and properties of the composite material consisting of the nano-crystalline Fe73.5Cu1Nb3Si13.5B9 alloy powders and polyethylene, Journal of Materials Processing Technology 162-163 (2005) 145-155.

[6] LA. Dobrzański, M. Drak, J. Trzaska, Corrosion resistance of the polymer matrix hard magnetic composite materials Nd-Fe-B, Journal of Materials Processing Technology 164-165 (2005) 795-804.

[7] M. Soiński, Magnetic materials in technology, NOSiW SEP, Warsaw, 2001 (in Polish).

[8] T. Kulik, Nanocrystalline soft magnetic materials obtained by the crystallisation of metallic glasses, Publishing House of Warsaw University of Technology, Warsaw, 1998 (in Polish).

[9] M. Leonowicz, Nanocrystalline magnetic materials, WNT, Warsaw, 1998 (in Polish).

[10] F. Mazaleyrat, L.K. Varga, Ferromagnetic nano-composites, Journal of Magnetism and Magnetic Materials 4 (2000) 215-216.