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Corrosion resistance of composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ – PE type in acid environment

B. Ziębowicz*, L.A. Dobrzański, M. Drak, A. Wydrzyńska
Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: boguslaw.ziebowicz@polsl.pl

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ABSTRACT

Purpose: The purpose of the paper is to present corrosion resistance of composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ – PEHD type in acid environment.

Design/methodology/approach: Composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ – PEHD type were manufactured by one-sided uniaxal pressing. Composite materials were placed in a corrosive environment and two tests were carried out as specified below: test at the temperature of 25°C, solution of 0.1 M chloride acid HCl, time of 348h, test at the temperature of 25°C, solution of 0.1 M sulfuric (VI) acid H_2SO_4, time of 348h.

Findings: The main purpose of obtaining this kind of composite materials is broadening possibilities of nanocrystalline magnetic materials application that influence on the miniaturization, simplification and lowering the costs of devices.

Practical implications: The manufacturing of composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ – PEHD type greatly expand the applicable possibilities of nanocrystalline powders of magnetically soft materials however further examination to obtain improved properties of magnetic composite materials and investigations of constructions of new machines and devices with these materials elements are still needed.

Originality/value: Results allow to complete data concerning composite materials nanocrystalline powder – polymer type which are an attractive alternative for traditional materials with specific magnetic properties.

Keywords: Composites; Corrosion resistance

MATERIALS

1. Introduction

The development of technique mostly is conditioned by the progress in know-how of new manufacturing technologies of nonconventional materials and improvement of traditional technologies. To these nonconventional materials can be also included composite materials composed from nanocrystalline powders with specific magnetic properties and polymers (FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD) [1-4]. New worked out materials should be investigated to collect to a data base of their physical, chemical and mechanical properties. These data allow to their broad practical application in many techniques fields. Unfortunately in the case of many materials, also composite materials nanocrystalline powder – polymer type, the data base of their properties is incomplete and should be completed as soon as possible. Majority of papers concerning nanocrystalline alloys FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) and composite materials with them refers to their magnetic and mechanical properties [5-11] but there is a lack of literature concerning their corrosion resistance. This paper is an attempt to complete data base and it will bring, in the future, new application possibilities of these composite materials in the construction of new electric and electronic devices.

2. Material and methods

The experiments were made with the polymer matrix composite materials: FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) powder bonded with the high density pressureless polyethylene (PEHD). Powder of the $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ was made by the high-energy grinding in the shaker type 8000SPEX CertiPrep Mixer/Mill for 0.25h, structure of the powders was nanocrystalline [2]. The amount of polymer matrix was 2.5%, 5.0%, 7.5%, wt.. Advanced composite materials were compacted by the one-sided uniaxial pressing. The following compacting process parameters were used: pressure 350 MPa, pressing temperature 170°C, pressing time 0.25h [2,4]. Figure 1 shows examples of manufactured composite materials.

Fig. 1. Composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) - PEHD

Metallographic examinations were made on the LEICA MEF4A light microscope equipped with the computer image analysis system at the magnification of 500x. Figure 2 shows the structure of composite materials observed using light microscope.

Composite materials were placed in a corrosive environment and two tests were carried out as specified below: test No.1 – at the temperature of 25°C, solution of 0.1 M chloride acid HCl, time of 348h, test No.2 – at the temperature of 25°C, solution of 0.1 M sulfuric (VI) acid H_2SO_4, time of 348h. Before placing in the corrosion environment the surface of the samples were polished and cleaned in the ethyl alcohol. Corrosion resistance were evaluated on the base of mass changes during the corrosion tests. The measurements were made on the analytical balance with accuracy of 0.0001g after 24, 48, 96, 192 and 384h of corrosion tests. In order to characterize damages to the composite material surface, microscopic observations were carried out using LEICA MEF4A optical microscope.

3. Results

Figures 3 and 4 show the mass loss of the composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD. On the base of the results of the corrosion test it was found that the mass loss of the composite materials is initially high and then tendency of decreasing is observed. It was found that the mass loss is stabilizing with the time after 96h of the corrosion tests.

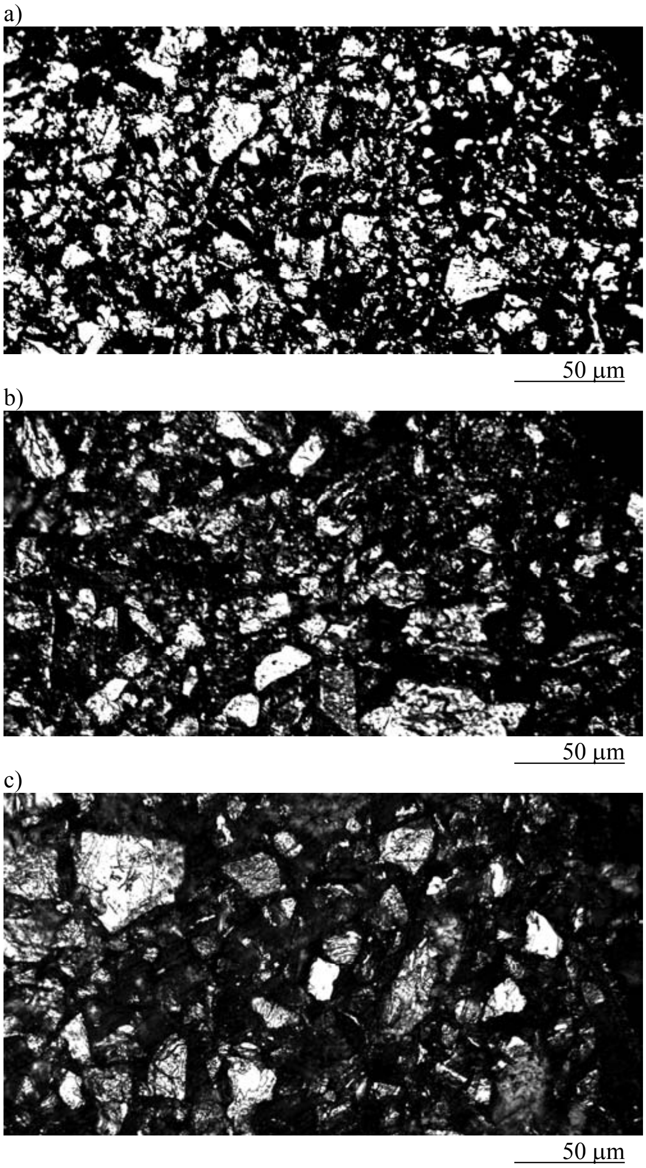

Fig. 2. Structure of composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD: a) 2.5% wt. PEHD, b) 5.0% wt. PEHD, c) 7.5% wt. PEHD

The reason of corrosion rate decreasing (mass loss) versus the time can be the fact that on the surface of composite materials a coating of corroded material in the form of iron oxides and hydroxides is deposited that makes difficult the access of corrosive environment to composite material. The best corrosion resistance shows samples with 7.5% wt. HDPE portion. It can be caused by the fact that polyethylene is resistant to the acids in which corrosion test were made and its higher portion in composite material increases isolation of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ (Fig. 2). $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy bonded by polyethylene into composite materials shows higher corrosion resistance in comparison with not bonded alloy [12-15]. The import factor influencing unfavourable on the corrosion resistance is the flaky shape of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powder particles (Fig. 2). Near–spherical shape seems to be more optimal taking into account corrosion resistance of composite materials. Unfortunately near–spherical shape influences unfavourable other properties (mechanical and magnetic) of this material [2-4].

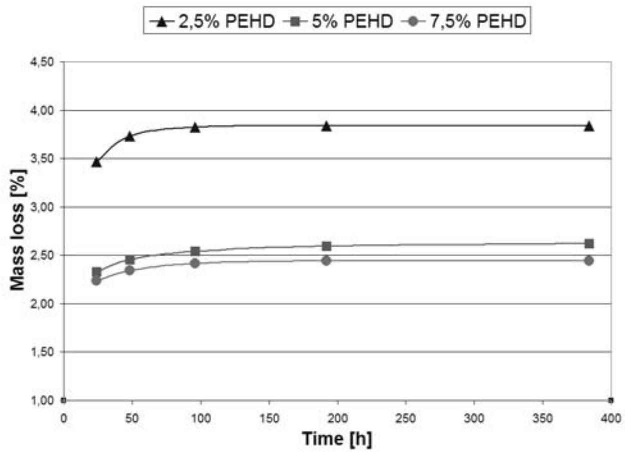

Fig. 3. Mass loss of composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD during corrosion tests in solution 0.1M HCl

Flaky shape of $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powder particles in composite materials allows to better optimization of physical and mechanical properties with corrosion resistance of worked out composite materials.

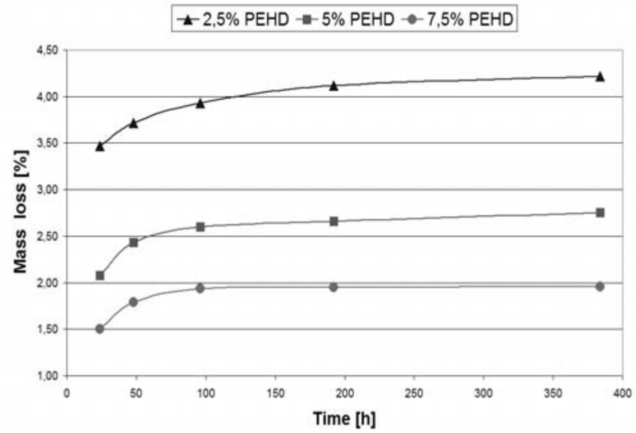

Fig. 4. Mass loss of composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD during corrosion tests in solution 0.1M H_2SO_4

The analysis of composite materials surface topography allows to determine damages occurring as a result of corrosion environment acting. Figures 5 and 6 show corrosion wear of composite materials surface with 5.0% wt. polyethylene portion. After corrosion tests in 0.1M HCl and 0.1M H_2SO_4 solutions on the composite materials surface it was found that small corrosion centre are occurring, which at the beginning do not show tendency to expansion dates, after 96h of corrosion tests, their growth and connecting is observed. Corrosion progress is the higher the lower portion of polyethylene in composite material.

24h | 96h | 384h

Fig. 5. Corrosion of the surface of composite material FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD (5.0% wt.) during corrosion test in solution 0.1M HCl

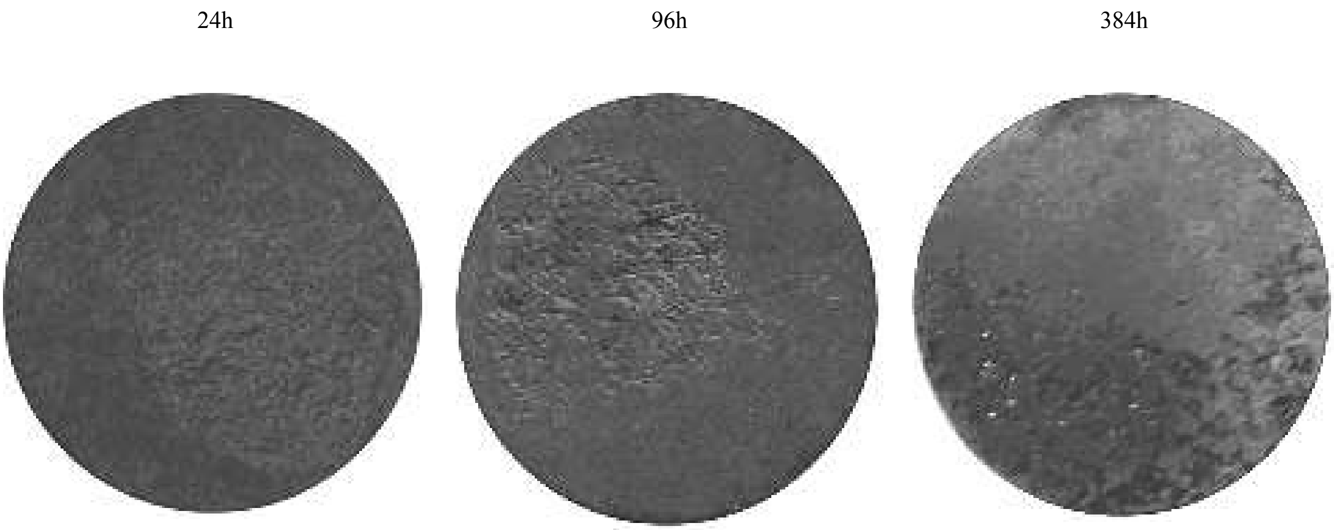

Fig. 6. Corrosion of the surface of composite material FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD (5.0% wt.) during corrosion test in solution 0.1M H_2SO_4

4. Conclusions

Obtained results of corrosion resistance allows to evaluated corrosion wear of composite materials FINEMET ($Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$) – PEHD in acidic solutions of 0.1M HCl and 0.1M H_2SO_4. It was found that the composite materials with 7.5% wt. of polyethylene portion show best corrosion resistance. Results allow to complete data concerning composite materials nanocrystalline powder – polymer type which are an attractive alternative for traditional materials with specific magnetic properties.

References

[1] L.A. Dobrzański, M. Drak, B. Ziębowicz, Materials with specific magnetic properties, Journal of Achievements in Materials and Manufacturing Engineering 17 (2006) 37- 40.

[2] B. Ziębowicz, D. Szewieczek, L.A. Dobrzański, J.J. Wysłocki, A. Przybył, Structure and properties of the composite materials consisting of the nanocrystalline $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ alloy powders and polyethylene, Journal of Materials Processing Technology 162-163 (2005) 149-155.

[3] L.A. Dobrzański, M. Drak, B. Ziębowicz, J. Konieczny, Influence of the structure on the properties of new magnetic composite materials, Fortchritle in der Metallographie 38 (2006) 519-524.

[4] B. Ziębowicz, L.A. Dobrzanski Application of nanostructural materials in manufacturing of soft magnetic composite materials $Fe_{73.5}Cu_1Nb_3Si_{13.5}B_9$ – PEHD type**,** Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 91-94.

[5] P. Gramatyka, R. Nowosielski, P. Sakiewicz, Magnetic properties of polimer bounded nanocrystalline powder, Journal of Achievements in Materials and Manufacturing Engineering 20 (2007) 115-118.

[6] P. Gramatyka, R. Nowosielski, P. Sakiewicz, T. Raszka, Soft magnetic composite based on nanocrystalline FeSiBCuNb and Fe powders, Journal of Achievements in Materials and Manufacturing Engineering 15 (2006) 27-31.

[7] J.M.D. Coey, Magnetic materials, Journal of Alloys and Compounds 326 (2001) 2-6.

[8] R.C. O'Handley, Modern magnetic materials: Principles and applications, Wiley, New York, 2000.

[9] D.C. Jiles, C.C.H. Lo, The role of new materials in the development of magnetic sensors and actuators, Sensors and Actuators A 106 (2003) 3-7.

[10] D.C. Jiles, Recent advances and future direction in magnetic materials, Acta Materialia 51 (2003) 5907-5939.

[11] A. Baron, D. Szewieczek, R. Nowosielski, Selected manufacturing techniques of nanomaterials, Journal of Achievements in Materials and Manufacturing Engineering 20 (2007) 83-90.

[12] C. Koch, I. Ovid'ko, S. Seal, Structural nanocrystalline materials, fundamentals and application, Cambridge University Press, Cambridge, 2007.

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

[14] M.E. McHenry, M.A. Willard, D.E. Lauglin, Amorphous and nanocrystaliine materials for applications as soft magnets, Progress in Materials Science 44 (1999) 291-433.

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