Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Magnetism and Magnetic Materials 272–276 (2004) 728–730
journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Application of the energy-based model for the magnetoelastic properties of amorphous alloys

Roman Szewczyk[a,*], Adam Bieñkowski[b]

[a] Industrial Reasearch Institute for Automation and Measurements, Al. Jerozolimskie 202, 02-486 Warsaw, Poland
[b] Institute of Metrology and Measuring Systems, Warsaw University of Technology, sw. A. Boboli 8, 02-525 Warsaw, Poland

Abstract

The paper presents results of calculation according to the idea of Jiles–Atherton–Sablik (J–A–S) model, of the stress dependence of the hysteresis loop of the $Fe_{78}Si_{13}B_9$ amorphous alloys in as-quenched state. Mathematical simulation was made on the basis of experimental results. In the experiment uniform, compressive stresses were achieved in the ring-shaped sample due to special nonmagnetic backings. Based on the experimental data, corresponding to the J–A–S model, the quantitative interpretation of changes of the model's parameters is presented and discussed.

PACS: 75.50.Kj; 7.05.Tp; 75.60.−d; 75.80.+q

Keywords: Magnetic hysteresis model; Amorphous alloys; Magnetoelastic effects

1. Introduction

Energy-based Jiles–Atherton–Sablik (J–A–S) [1] model gives a partial description of the magnetizing process $B(H)$ in magnetic materials in the presence of the external mechanical stresses σ. This model allows calculating major and minor hysteresis loops [2,3]. For such calculation, the model's parameters, which describe magnetic properties of the material [4], are necessary.

2. Experimental method

Paper presents results of calculation, accordingly to the idea of J–A–S model, of the stress dependence of the hysteresis loop of the $Fe_{78}Si_{13}B_9$ amorphous alloy in as-quenched state. Mathematical simulation was made on the basis of the experimental results. In the experiment the uniform, compressive stresses (perpendicular to the magnetizing field) were achieved in the ring-shape sample due to special, nonmagnetic backings [4].

*Corresponding author. Tel.: +48-22-8740280; fax: +48-22-8740209.
E-mail address: szewczyk@mchtr.pw.edu.pl (R. Szewczyk).

3. Results and discussion

The influence of the compressive stress σ on the hysteresis loop of the $Fe_{78}Si_{13}B_9$ amorphous alloys in as-quenched state is presented in Fig. 1.

Due to the magnetoelastic Villari effect, the flux density B, increases for the initial values of stresses and next decreases for the stresses σ larger than 20 MPa.

Parameters of J–A–S model were calculated for each experimental hysteresis loop (at a constant value of compressive stress $-\sigma$). The genetic strategies together with Hook–Jeevis optimization method were used [5].

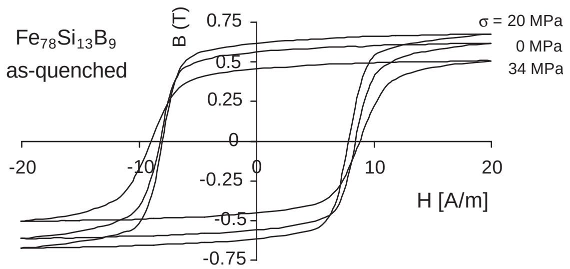

Fig. 1. The influence of the compressive stress σ on the shape of the hysteresis loop of the $Fe_{78}Si_{13}B_9$ amorphous alloy.

0304-8853/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2003.11.270

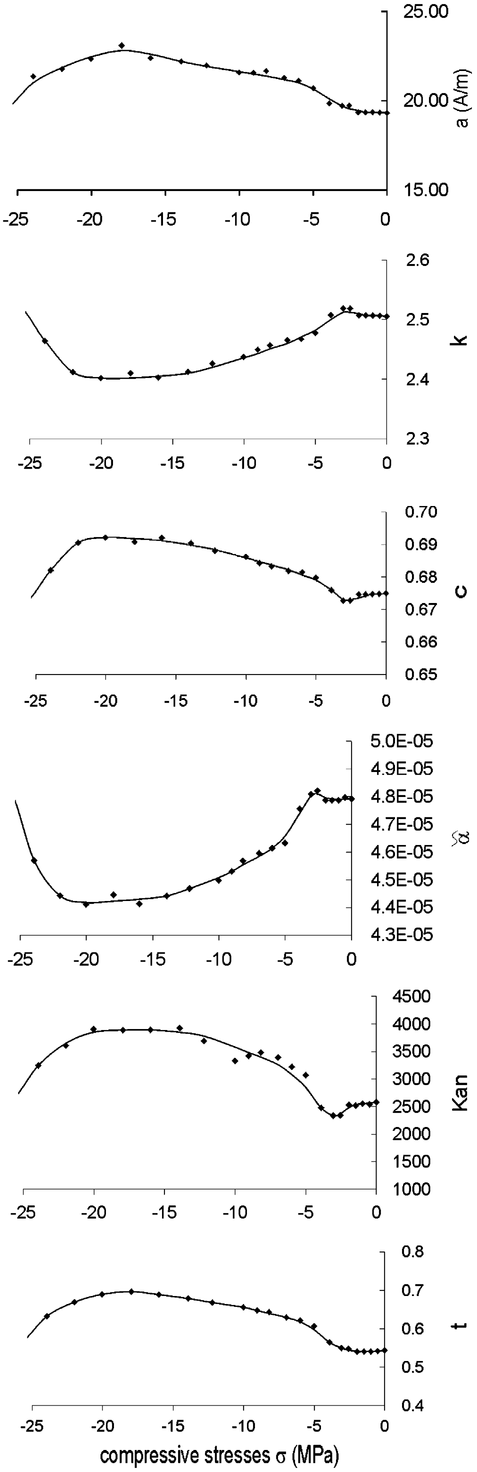

Fig. 2. Dependence of the J–A–S model parameters on applied stress σ.

The calculations were made for the compressive stresses σ up to 25 MPa. As a result of these calculations the stress dependence of the model parameters $a, k, c, \tilde{\alpha}, K_{an}, t$ are presented in Fig. 2. The saturation magnetization ($M_s = 6.23 \times 10^5$ A/m) is assumed to be constant because it does not change under external stresses [6].

The model parameters a and c describe as follow the slope of the hysteresis loops and its reversibility. The character of the changes of these parameters is similar. For value of stresses σ up to 20 MPa, these parameters increase, next maximum occurs (Villari reversal) and then decrease.

The changes of the model parameters k (average energy required to break pinning site) and $\tilde{\alpha}$ (quantifies domain interactions) have opposite character to the changes of a and c. These parameters reach also extreme (minimal) values in the Villari reversal.

The parameter K_{an} describes a value of the anisotropy in the material and parameter t is to quantify a value of the anisotropic phase in the amorphous material [8]. The changes of these parameters confirm that the external stresses have influence on the anisotropy of the amorphous material. Moreover for the stresses lower than a value of the Villari reversal the anisotropy increases and for stresses higher than the Villari reversal it decreases.

It is interesting that for the initial value of the stresses σ, the significant changes of all model parameters were not observed. This is an important difference in the character of the influence of the external stresses on the amorphous alloy and Mn–Zn ferrite [5].

The influence of the compressive stress applied perpendicularly to the direction of magnetizing field is similar to the influence of the tensile stress applied parallel to the magnetizing field [7]. For this reason, presented results create the new possibility of application of J–A–S model for the interpretation of the physical origin of the magnetization process under external stresses σ. Note that this paper describes the physical origin of the Villari effect to the stress dependence of the hysteresis parameters rather than the stress dependence of $d\lambda/dM$.

Acknowledgements

This work was supported by Polish State Committee for Scientific Research under grant in the years 2002/2005.

References

[1] M. Sablik, et al., IEEE Trans. Magn. 29 (1993) 2113.
[2] F. Calkins, et al., IEEE Trans. Magn. 36 (2000) 429.
[3] M. Pasquale, et al., J. Appl. Phys. 85 (1999) 4373.

[4] A. Bieñkowski, et al., Physica Status Solidi A 189 (2002) 787.
[5] R. Szewczyk, et al., J. Magn. Magn. Mater. 254–255 (2003) 284.
[6] D.C. Jiles, J. Appl. Phys. 28 (1995) 1537.
[7] M. Sablik, et al., J. Appl. Phys. 74 (1993) 480.
[8] A. Ramesh, et al., IEEE Trans. Magn. 32 (1996) 4234.