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Amorphous Soft Magnetic $Fe_{80}B_{11}Si_9$ Alloy in Tensile Stress Sensors Application

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Paper presents the results of investigations of the influence of the tensile stresses on magnetic characteristics of $Fe_{80}B_{11}Si_9$ amorphous alloy in as quenched and annealed state. For the tests, a special methodology of application of uniform tensile stresses to the ring shaped sample was developed. Due to special non-magnetic pads, the magnetizing and sensing coils can be wound around the core. Experimental results indicate high stress sensitivity of $Fe_{80}B_{11}Si_9$ alloy in both as-quenched and annealed state. Permeability of the core decreases over 64% and 58% for as-quenched and annealed core respectively, especially for lower values of the amplitude of magnetizing field.

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1. Introduction

Iron-rich amorphous alloys [1], such as $Fe_{80}B_{11}Si_9$ alloy, exhibit high permeability and limited value of coercive force. As a result, such alloys are used as the cores of inductive components of switching mode power supplies [2], as well as the cores of power and current transformers [3]. Moreover, the magnetic characteristics of iron-rich amorphous alloys change significantly under the influence of mechanical stresses [4]. These changes may be so considerable due to the fact, that amorphous alloys do not have a crystalline structure. As a result, in the total balance of free energy of amorphous alloy sample, the energy of magnetocrystalline anisotropy is absent. This leads to a high stress sensitivity, connected with the fact that significant changes of magnetic properties are caused by even quite small stress-induced changes of the energy of magnetoelastic anisotropy.

Influence of compressive stresses on magnetic properties of amorphous alloy similar to $Fe_{80}B_{11}Si_9$ was elaborated previously [5]. This paper presents the experimental results focused on the influence of tensile stresses on properties of the $Fe_{80}B_{11}Si_9$ amorphous alloy in as-quenched and annealed state.

2. Methodology of investigation

Investigation was carried out on two ring-shaped cores made of $Fe_{80}B_{11}Si_9$ amorphous alloy. Both cores had outside diameter of 32 mm, inside diameter of 25 mm and height of 10 mm. First core was in as-quenched state, whereas the second was annealed in 350 °C for one hour.

In the magnetoelastic investigation the tensile stresses σ were applied to the ring core perpendicularly to the magnetizing field direction. Due to the fact, that cores with closed magnetic circuits were used, the demagnetization energy in the core was negligible. Device for application of uniform tensile stresses σ to the ring-shaped core, magnetized by field H is presented in Fig. 1.

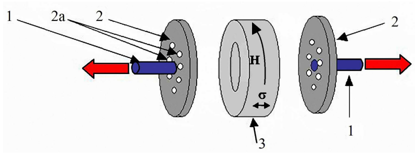

Fig. 1. Schematic diagram of device for application of uniform tensile stresses σ to the ring-shaped core: 1 – rod, 2 – nonmagnetic backings, 2a – holes for magnetizing and measuring windings, 3 – amorphous ring shaped core.

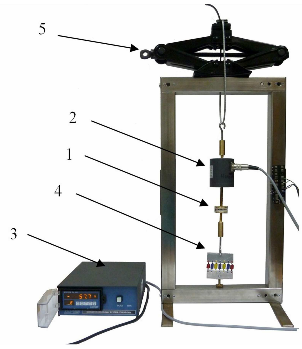

Fig. 2. Mechanical setup for controlling the tensile stresses σ in the ring-shaped core: 1 – amorphous ring shaped core, 2 – verification sensor, 3 – sensor control, 4 – set of springs, 5 – force generator.

The mechanical setup used to control the tensile force and generate the uniform stresses in ring-shaped core is presented in Fig. 2.

The influence of stresses on the shape of hysteresis was measured by digitally controlled hysteresis-graph HB-PL2.0. On the basis of the results of the measurements of hysteresis loops, the values of maximal flux density B for a given amplitude of magnetizing field H_m, as well as magnetic permeability amplitude μ_a were calculated.

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3. Results

The influence of tensile stresses σ on the shape of $B(H)$ hysteresis loop of $Fe_{80}B_{11}Si_9$ amorphous alloy is presented in Fig. 3. The stress dependence of the maximal flux density B generated in the core for a given value of magnetizing field H_m, as well as the stress dependence of permeability amplitude μ_a are presented in Figures 4 and 5 respectively.

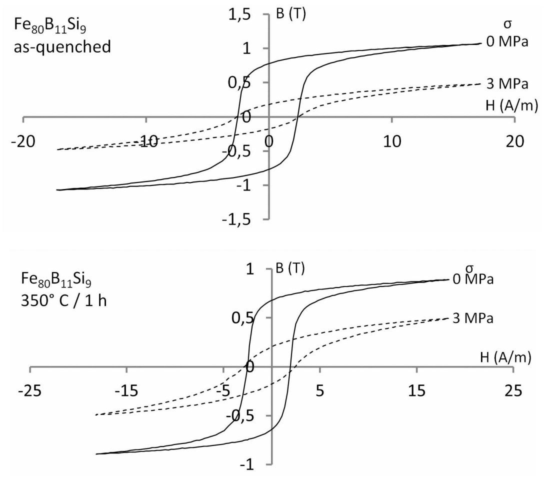

Fig. 3. Tensile stress dependence of $B(H)$ hysteresis loop of $Fe_{80}B_{11}Si_9$ amorphous alloy: a) in as-quenched state, b) annealed at 350 °C for 1 hour.

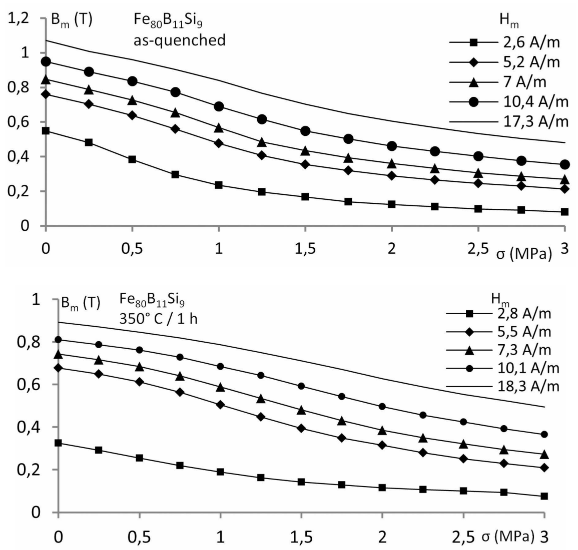

Fig. 4. Tensile stress dependence of maximal flux density B generated in the core for a given value of magnetizing field H_m, for $Fe_{80}B_{11}Si_9$ amorphous alloy: a) in as-quenched state, b) annealed at 350 °C for 1 hour.

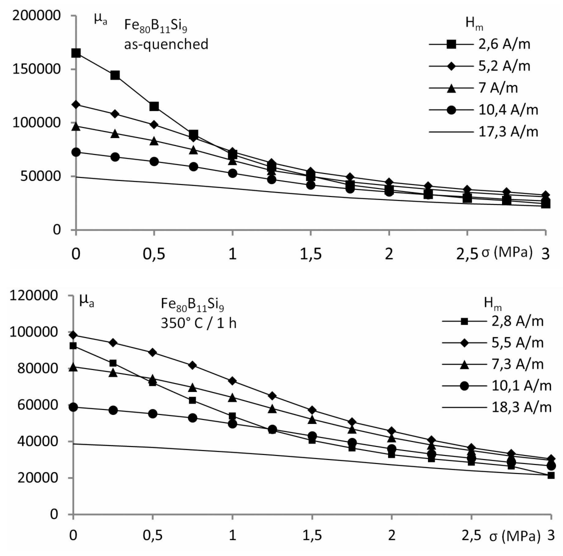

Fig. 5. Tensile stress dependence of permeability amplitude μ_a of the core, for a given value of magnetizing field H_m, for $Fe_{80}B_{11}Si_9$ amorphous alloy: a) in as-quenched state, b) annealed at 350 °C for 1 hour.

4. Conclusions

Results of the investigation indicate a significant stress sensitivity of $Fe_{80}B_{11}Si_9$ amorphous alloy in both as-quenched and annealed state. Moreover, for lower values of the amplitude of magnetizing field H_m, the permeability μ_a of the core decreases by over 64% and 58% for the as-quenched and annealed core respectively. This is especially important from the point of view of further practical application of $Fe_{80}B_{11}Si_9$ amorphous alloy in development of magnetoelastic stress sensor. In such sensors the stress-sensitive magnetoelastic element can also be the element of construction. As a result, there is no need to glue the strain gauge to the tested element. For this reason the magnetoelastic sensors are much more robust and resistive for environmental conditions than the strain gauge based sensors.

Acknowledgments

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