

METHODOLOGY OF TESTING THE MAGNETOELASTIC CHARACTERISTICS OF RING-SHAPED CORES UNDER UNIFORM COMPRESSIVE AND TENSILE STRESSES

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The paper presents unified methodology for testing tensile and compressive stress dependences of ring-shaped magnetoelastic cores. This methodology enables testing of magnetoelastic properties of soft magnetic materials in full range of axial stresses, which is especially important from the point of view of development of physical models of magnetization process under stresses. The paper presents also results of testing the magnetoelastic properties of $\text{Fe}_{25}\text{Ni}_{55}\text{Si}_{10}\text{B}_{10}$ amorphous alloys. These tests confirmed the usability of the developed methodology.

Keywords: magnetoelastic properties, soft magnetic materials.

1 INTRODUCTION

The influence of compressive stresses on magnetic characteristics of amorphous alloys has been intensively investigated. On the base of results of these investigations both models of magnetization process [1, 2] and magnetoelastic sensors has been developed [3].

From the point of view of modelling the magnetoelastic characteristics, the lack of results of measurements on the influence of tensile stresses on the characteristics of magnetic cores with closed magnetic circuit is a significant barrier. This barrier limits further development of the models of magneto-mechanical properties of magnetic materials.

For this reason a novel methodology of applying the tensile stress to the ring-shaped samples was developed. This methodology creates possibility of filling the gap, which was especially important during experimental verification of the models of the magnetic characteristics of materials subjected to axial stresses (both tensile and compressive).

2 EXPERIMENTAL METHOD

For proper testing of the magnetoelastic properties of magnetic materials two conditions should be obtained: (a) samples with closed magnetic circuit should be used and (b) uniform distribution of stresses in the tested sample should be obtained. As a result in case of strip-shaped samples, due to the appearance of demagnetization energy in total free energy of the sample, results of investigation were connected with dimensions of the sample. On the other hand, when ring-shaped samples are loaded in the direction of diameter [4], the distribution of stresses in the sample is highly non-uniform.

Investigation on the magnetoelastic characteristics requires a methodology enabling achievement of the uni-

form compressive and tensile stresses σ in the ring shaped core. Moreover, the investigated core has to be wounded by a magnetizing and sensing winding, to measure the magnetic hysteresis loop. A method enabling magnetoelastic tests of the ring-shaped amorphous alloy core was developed previously [3]. The device for practical realization of magnetoelastic investigation is presented in Fig. 1. This method allows measurement of magnetoelastic characteristics of both bulk material rings and ribbon ring cores. It should be stressed, that device based on the idea presented in Fig. 1 enables also measurements of the influence of torque on magnetic characteristics of the ring-shaped cores [5].

The principle of the novel method of applying the tensile stresses to the ring-shaped sample is presented in Fig. 2a. The tensile force F is applied to the ring-shaped sample perpendicularly to its bases. In such case uniform, tensile stress σ can be reached on the whole length of the magnetic circuit of the sample. It should be indicated, that this methodology allows testing all commercially available, ring shaped cores made of soft ferrites, amorphous and nanocrystalline alloys.

Device for practical realization of developed methodology is presented in Fig. 2b. Tested core (3) is fixed to core backings (2). These core backing are fixed to upper backing and lower backing (2). In backing (2) special holes (2a) were drilled, to enable core to be wound by magnetizing and sensing windings. Compressive force F generated by oil press is transferred by shaft and ball (1) to the lower backing (2). As a result, compressive force F generates uniform tensile stresses in the core (3).

The magnetic properties of the samples, as well as the changes of these properties as a function of compressive and tensile stresses, were measured by digitally controlled measuring system HBPL-1.0. HBPL-1.0 system consist digitally controlled current source and precise flux meter moreover this system works together with hydraulic press

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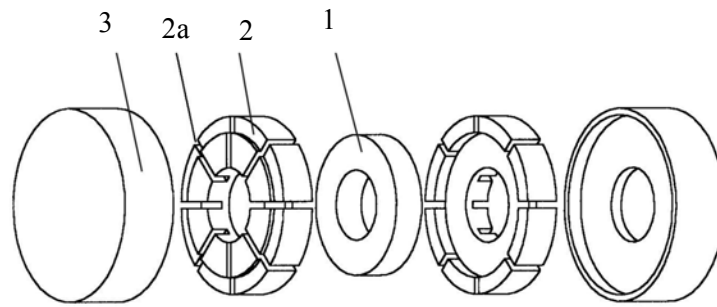


Fig. 1. Method of application of compress stresses to the ring-shaped sample [6]

which enable application of axial stresses to the magnetic sample.

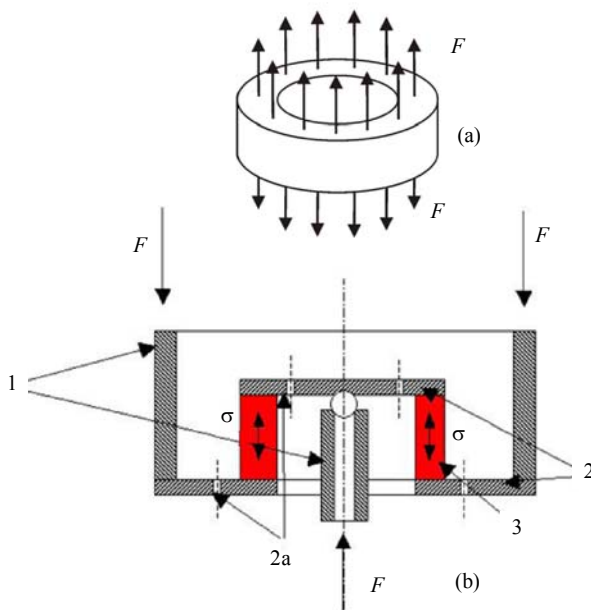


Fig. 2. Method of application of tensile stresses to the ring-shaped sample [7]: a) idea of the method, b) device for practical realization of this idea: 1 – tube and main shaft, 2- upper and lower backings, 2a – hole for winding coil, 3 – ring-shaped core under investigation

3 EXPERIMENTAL RESULTS FOR COMPRESSIVE AND TENSILE STRESSES

The influence of uniform tensile stresses σ on the shape of the hysteresis loop $B(H)_\sigma$ for the core made of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy is presented in Fig. 3a, whereas influence of compressive stresses on the same core is presented in Fig. 3b. Investigated $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy exhibit positive magnetostriction with saturation about $8 \mu m/m$.

Investigated core was annealed at $350^\circ C$ for 1 hour in presence of magnetic field $3kA/m$ applied in the direction of the ribbon. Such thermomagnetic annealing generates anisotropy in the amorphous alloy, which increases magnetic permeability of the core.

Under the tensile stresses σ up to 5 MPa, value of flux density B decreases from 550 mT to 205 mT, whereas coercive field H_c doesn't change significantly. On the other hand under the compressive stresses σ up to -10 MPa, value of flux density B increases from 480 mT to 650 mT.

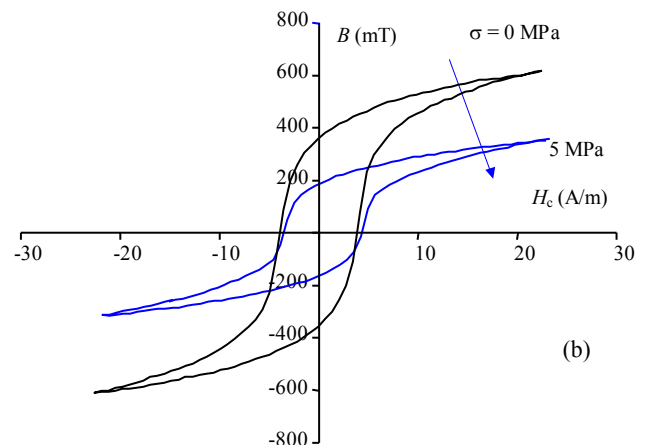
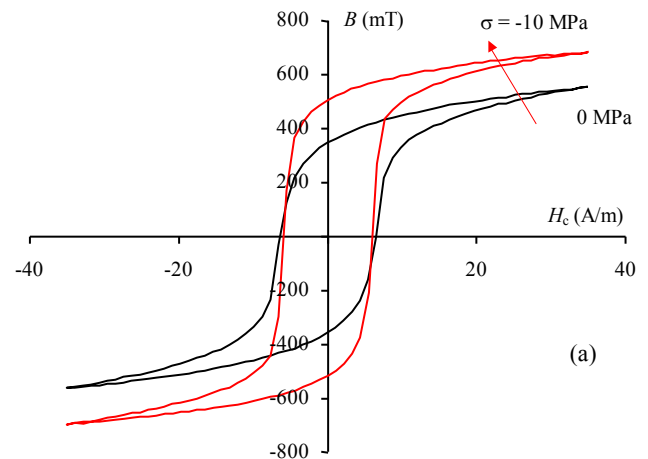


Fig.3. Magnetic $B(H)_\sigma$ dependences for the core made of $Fe_{25}Ni_{55}Si_{10}B_{10}$ annealed in perpendicular field, in $T_a=350^\circ C$ for 1 hour: a) compressive stresses dependence, b) tensile stresses dependence

The influence of compressive stress $-\sigma$ and tensile stress $+\sigma$ on the relative changes of maximal flux density B in $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy is presented in Fig. 4. The measurements were performed for magnetizing

field H_m equal 25 A/m. It should be indicated, that $B(H)_\sigma$ characteristics are monotonous, what is especially important from the point of view of sensors development.

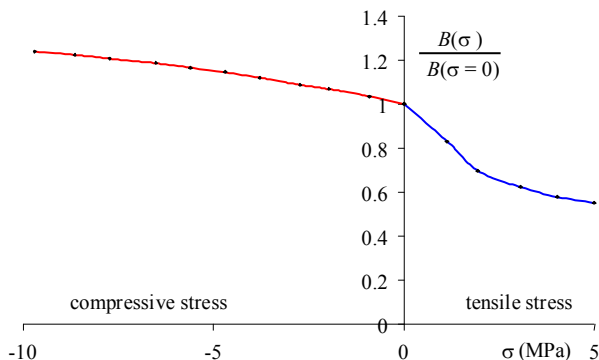


Fig. 4. Relative changes of flux density B in the core made of $\text{Fe}_{25}\text{Ni}_{55}\text{Si}_{10}\text{B}_{10}$ alloy, subjected to both tensile and compressive stresses

4 CONCLUSION

The presented methodology of applying the compressive and tensile stress to the ring cores enables achieving the uniform distribution of stresses along the whole length of the magnetic circuit of the sample. This method enabled fundamental research on influence of tensile stresses on magnetic characteristic of amorphous alloys; also it may be useful for construction of magnetoelastic compressive and tensile stress sensors.

Presented results of the investigation on the influence of the compressive and tensile stress on the magnetic properties of amorphous alloys, confirm their high stress sensitivity. Moreover relative changes maximal value of flux density B for both tensile and compressive stresses are monotonous. This confirms the previously presented

models of magnetoelastic phenomenon. It should be stressed that such a confirmation was not presented before due to the lack of possibility of testing the influence of tensile stresses on magnetic characteristics of ring-shaped cores.

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