MAGNETOELASTIC PROPERTIES OF SELECTED AMORPHOUS SYSTEMS TAILORED BY THERMOMAGNETIC TREATMENT

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1. Introduction

Magnetoelastic properties are observed as the changes of flux density B, achieved for given value of magnetizing field H, under the influence of mechanical stresses [1], both compressive [2] and tensile [3]. This effect is very important from both theoretical and application point of view.

Theoretical analyses of magnetoelastic effect are connected with quantitative modelling of interaction of magnetic and mechanical processes. This interaction is especially visible in amorphous systems due to the lack of magnetocrystalline anisotropy [4]. Moreover, in amorphous magnetic alloys, the uniaxial anisotropy may be induced, during the magnetic field annealing [5]. As a result, the amorphous alloys are especially interesting magnetic materials for fundamental research on magnetoelasticity.

Magnetoelastic effect in amorphous alloys was widely investigated also due to its possible application in development extremely robust stress sensors, also for large diesel engines of locomotives [6]. However, until now, investigation on magnetoelastic properties of amorphous alloys tailored by thermomagnetic treatment was carried out in very limited way. To fill this gap, magnetoelastic properties of $Fe_{61}Co_{19}Si_5B_{15}$ alloy after thermomagnetic treatment were tested for both compressive and tensile stresses, what is significant novelty. Moreover, results of presented investigation opens new ways of modelling the magnetoelastic effects in amorphous systems tailored by thermomagnetic treatment.

2. Samples preparation and the method of investigation

Research was carried out on three ribbon ring cores made of $Fe_{61}Co_{19}Si_5B_{15}$ amorphous alloy. Inside diameter was 25 mm, outside diameter was 32mm, whereas height was 8mm. Samples were subjected to thermomagnetic treatment with use of specialized furnace presented in figure 1a. All cores were annealed in temperature 380 ^{o}C for one hour. First core was annealed without magnetic field. Second and third core were annealed in magnetic field equal 200 kA/m and 260 kA/m respectively.

Idea of the method for generation of uniform compressive and tensile stresses in the ring shaped samples is presented in figures 2b and 2c. In this method stresses occurs perpendicularly to the base of the ring core. The technical solution of mechanical systems for generation of compressive stresses uses set of specialized, nonmagnetic backings. Details of these systems were presented previously [7, 8].

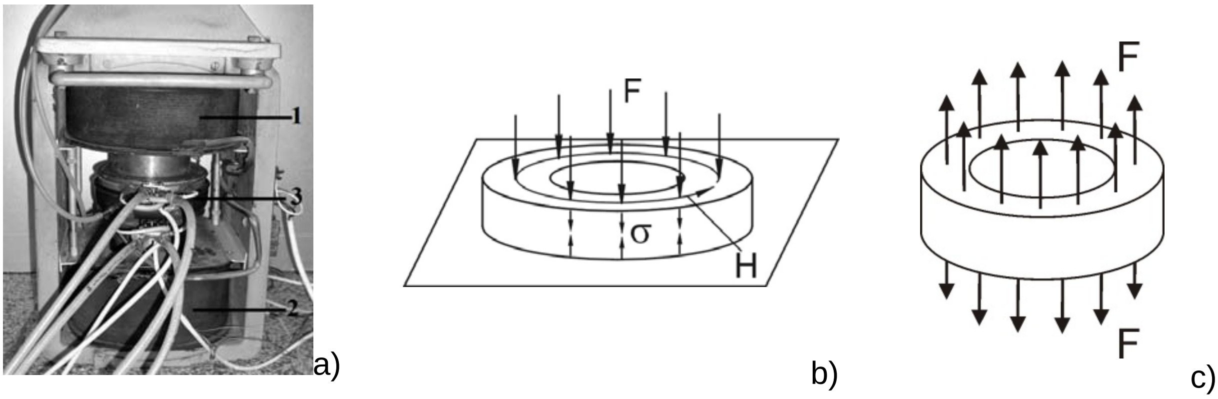

Fig.1: *Key elements of methodology: a) specialized furnace for thermomagnetic treatment: 1, 2 – magnet polepieces, 3 – furnace with ring-shaped core , b) idea of generation of compressive stresses, c) idea of generation of tensile stresses*

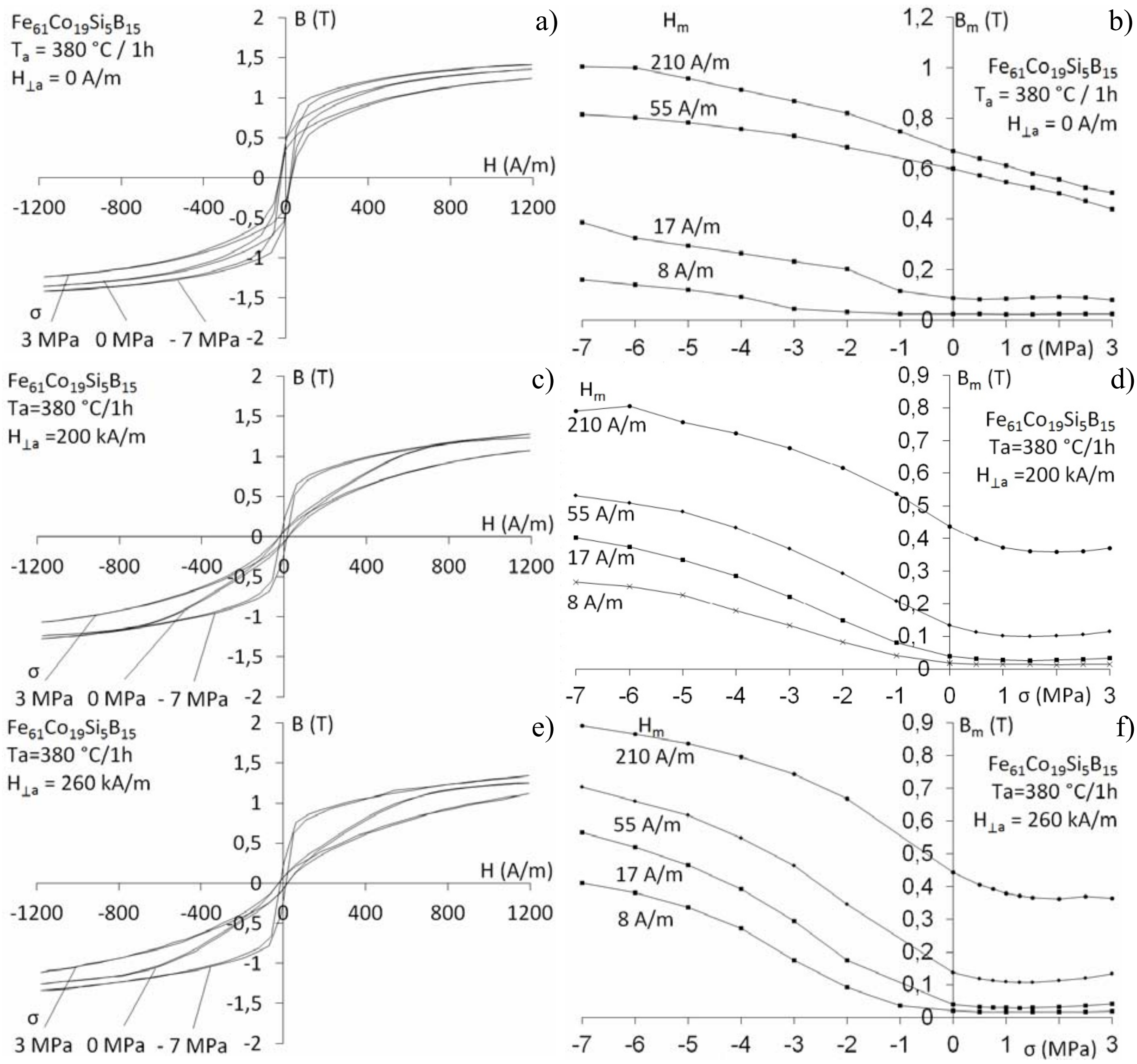

Fig.2: *Results of magnetoelastic tests of cores made of $Fe_{61}Co_{19}Si_5B_{15}$ amorphous alloy annealed in 380 ^oC /1 hour: a), c), e) influence of compressive and tensile stresses σ on B(H) hysteresis loops of tested cores, b), d), f) magnetoelastic $B(\sigma)_H$ characteristics of cores*

3. Results

The influence of both compressive and tensile stresses in the shape of hysteresis loops of $Fe_{61}Co_{19}Si_5B_{15}$ amorphous alloy is presented in figure 2a, 2c and 2e, whereas magnetoelastic $B(\sigma)_H$ characteristics are presented in figures 2b, 2d and 2f. For analyses of the results Lechatelier principle [9] should be considered. Moreover it should be taken into the account, that both compressive and tensile stresses σ are perpendicular to magnetizing field direction. Accordingly to these physical principles and due to the fact, that $Fe_{61}Co_{19}Si_5B_{15}$ amorphous alloy has positive value of saturation magnetostriction, under tensile stresses, the value of flux density B should decrease, whereas under compressive stresses, flux density B should increase. Results of experiments presented in figure 2 are in good agreement with this theoretical analyse.

On the other hand, analyse presented above has only qualitative character. For quantitative magnetoelastic effect analyses, detailed physical principles modelling should be performed, considering also the value of uniaxial, thermomagnetic induced anisotropy. The model, which creates possibility of such quantitative analyse is expended Jiles-Atherton model [10]. Presented experimental results enable such novel, quantitative analyses based on theoretical models of magnetization process.

4. Conclusion

Presented results confirm usability of presented methodology of magnetoelastic testing of ribbon ring-shaped cores for both compressive and tensile stresses. In presented methodology, the uniform stress distribution in the core is achieved, what creates possibility of theoretical analyses of magnetoelastic effect.

From qualitative point of view, presented results confirm Lechatelier principle. Moreover, on the base of presented results, extended Jiles-Atherton model may be verified and developed considering uniaxial, thermomagneticaly induced anisotropy in $Fe_{61}Co_{19}Si_5B_{15}$ amorphous alloy.

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