EFFECT OF MECHANICAL STRESS ON THE MAGNETIC PROPERTIES OF AMORPHOUS FE-B RIBBONS

J. Kecer, L. Novák

KF FEI TU, Park Komenského 2, 040 01 Košice

E-mail: Jan.Kecer@tuke.sk

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1. Introduction

An important group of materials for electronics purposes is the group of soft magnetic materials, whose main representatives are transformer plates. The first amorphous ferromagnetic materials were made a few decades ago, whose some magnetic properties are significantly better than plate (eg. coercivity is of one order lower). We can determine most of the parameters which characterize ferromagnetic materials (magnetic polarization of saturation J_S, coercivity H_C, permeability, constant of magnetic anisotropy, premagnetic losses) from hysteresis loop. These parameters characterize ferromagnetic material from the perspective of possible technical applications. In order to ensure the stability of magnetic properties in operating conditions it is useful to know the interactions between changes in structural properties of amorphous materials and changes in their magnetic properties [1,2]. From this point of view, we have dealt with the effect of mechanical stress in this work. It is one of the variables, together with an external magnetic field and temperature, in which it can be expected a significant impact on changes in magnetic properties of amorphous ferromagnets prepared by rapid quenching of the melt.

2. Methodology of the measurement

The studied material $Fe_{84}B_{16}$ was prepared by rapid quenching of the melt, in the form of ribbons, in the KFKI MTA in Budapest, where their amorphousness and composition was checked. Magnetic parameters of the samples were determined by magnetometric method. When measuring the dependence of magnetic parameters on mechanical stress, the sample was directly burdened.

3. Results and discussion

In figure 1 is shown a hysteresis loop with the initial magnetization curves at different values of the mechanical tension. We can see that with the increasing value of mechanical stress, these curves curled to the axis *J*. By applying mechanical stresses on amorphous sample $Fe_{84}B_{16}$ is highlighted the impact of internal stresses in the direction of stress, which induces an easy axis magnetising direction and it results in the hysteresis loop curling. It is assumed that the energy of stress anisotropy is reduced due to mechanical stresses.

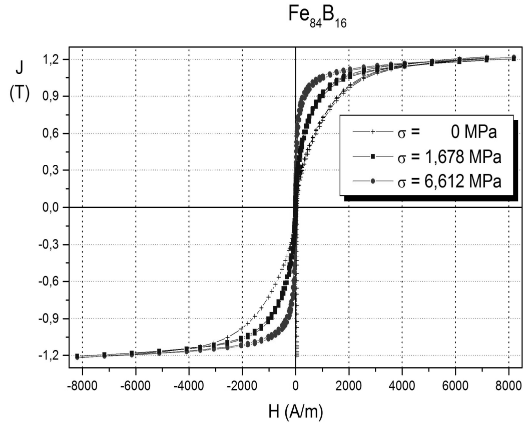
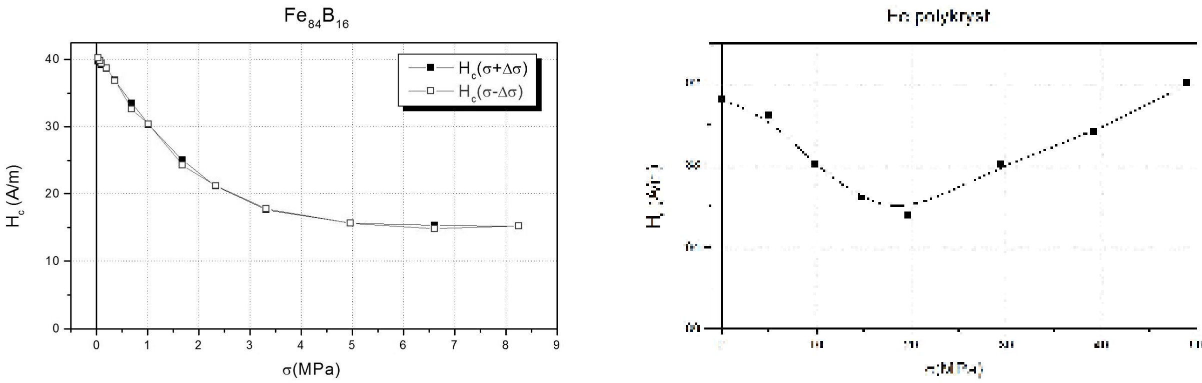


Fig. 1:
Hysteresis loop at different values of the mechanical stress.

The next parameter is coerivity H_c. The main reason for the existence of coercivity are irreversible displacements of domain walls, which are generally the result of defects in the structure of real materials, such as dislocations, inclusions (non-ferromagnetic, or with different magnetic anisotropy), grain boundaries and also stress centers. The amorphous ferromagnets prepared by rapid quenching of the melt cannot talk about defects of structure, therefore the value of coercivity is considerably lower compared to the crystalline magnetic materials. Figure 2a depicts the dependence



a) *b)*

Fig. 2: *The dependence of coercivity on mechanical stress.*

of coercivity in continuous exposure and release of amorphous ribbons by mechanical tensions. We observe that by increasing the load on the sample coercivity decreases significantly (by more than 50%), as confirmed by the actual conduct of the hysteresis loop. Gradual release of tension coercivity increases to its original value. For comparison, figure 2b shows the dependence of coercivity in continuous exposure of annealed iron wire by mechanical tension. The impact on the amorphous ribbon is significant. The coercivity is closely related to anisotropy. Given that in amorphous ferromagnets crystallographic anisotropy is absent, the priority becomes the magnetoelastic anisotropy. We can write

$$H_C \approx \frac{K_\sigma}{J_S}, \quad (1)$$

where K_σ is the constant of magnetoelastic anisotropy. Magnetoelastic anisotropy in amorphous ferromagnets with nonzero magnetostriction is associated primarily with the internal stresses introduced into the material in a process of rapid quenching of the melt. For the constant of magnetoelastic anisotropy, if the direction of an external magnetic field and mechanical stress is parallel, we can write

$$K_\sigma = -\frac{3}{2}\lambda_S \sigma, \quad (2)$$

where λ_S is coefficient of magnetostriction of saturation, σ is the mechanical stress. If we assume, at the prevailing magnetoelastic anisotropy, an uniform distribution of internal stresses in the volume of samples and isotopic magnetostriction, then we can modify the equation (2) to the form

$$K_\sigma = \frac{1}{2}F_{rm}, \quad (3)$$

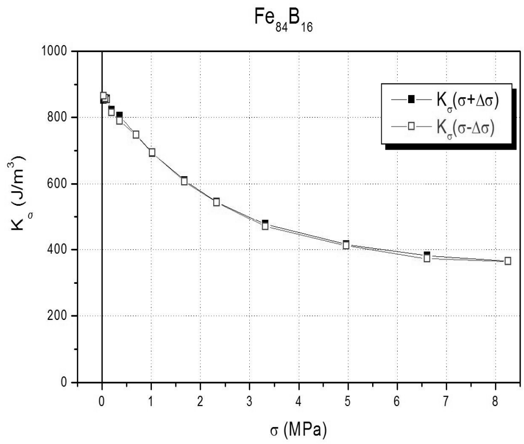


Fig. 3: *The dependence of the constant of magnetoelastic anisotropy on mechanical stress.*

where F_{rm} is a reversible energy of magnetization, it is determined by the area bounded by the decreasing branch of hysteresis loop (J_S - J_R) (Fig. 1), a line parallel to the axis *H*, a passing value J_S and the axis *J* [3,4,5], for which we can write

$$F_{rm} = \int_{J_R}^{J_S} H \mathrm{d}J = F_S - F_R, \quad (4)$$

where F_S is the energy density in a saturated state and F_R is the energy density in the remanent state. This means that the area above the downward branch of the hysteresis loop (F_{rm}) is proportional to the constant of magnetoelastic anisotropy.

Figure 3 depicts the dependence of the constant of magnetoelastic anisotropy on mechanical stress in continuous exposure of the sample and release tension. From this picture is clear, that by increasing tension constant K_σ drops by about half. We can write, using equation (2), for two different measurements

$$K_{\sigma 1} = -\frac{3}{2}\lambda_S(\sigma_0 + \sigma_1),\; K_{\sigma 2} = -\frac{3}{2}\lambda_S(\sigma_0 + \sigma_2), \quad (5)$$

where σ_0 is a part of internal stresses parallel to the applied magnetic field. By partitioning equations (5) and subsequent modification we obtain an equation for calculating the stress dependence of magnetostriction

$$\lambda_S = \frac{2(K_{\sigma 1} - K_{\sigma 2})}{3(\sigma_2 - \sigma_1)}. \quad (7)$$

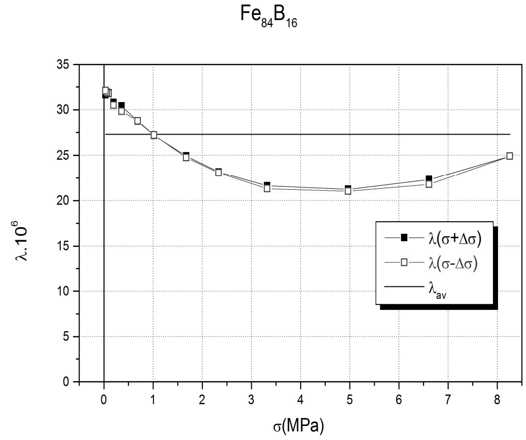


Fig. 4: *The dependence of magnetostriction on mechanical stress.*

The calculated dependence of magnetostriction in continuous exposure and release of amorphous ribbons by mechanical tensions is plotted in Fig.4. Due to the change of stress we can see the change of magnetostriction.

4. Results

Internal tensions, significantly affecting the magnetic parameters, are introduced into the material already under preparation. Although the rate of internal stresses in amorphous tape is high, we can see significant changes in the measured magnetic parameters induced by mechanical stresses. By applying mechanical stress on amorphous sample $Fe_{84}B_{16}$, is highlighted the impact of internal stresses in the direction of stress, which induces the direction of axis of easy magnetising and it results in filling the hysteresis loop to the *J* axis, coercivity values decreasing by half, constant of magnetoelastic anisotropy decreasing by half and change in the value of magnetostriction.

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