Rev.Adv.Mater.Sci. 18(2008) 561-564

# THE MAGNETOELASTIC VILLARI EFFECT IN $Fe_{25}Ni_{55}Si_{10}B_{10}$ AMORPHOUS ALLOY SUBJECTED TO THERMAL TREATMENT

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*Received: March 29, 2008*

**Abstract.** This paper presents experimental results of the magnetic and magnetoelastic investigation on the properties of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy subjected to thermal treatment. During the magnetoelastic tests the uniform compressive stress was applied to the ring-shaped core perpendicularly to magnetizing field direction. Significant changes of magnetoelastic characteristics due to thermal treatment as well as Villari point for the core annealed at 350 °C were observed.

## 1. INTRODUCTION

Iron-nickel based amorphous alloys (such as $Fe_{25}Ni_{55}Si_{10}B_{10}$) are very promising for different technical applications, mainly in power conversion devices, cores of inductive components or magnetic and magnetoelastic sensors. For this reason, magnetic properties of such amorphous alloys were intensively investigated during last years [1]. On the other hand, Fe-Ni based amorphous alloy are also sensitive to the mechanical stresses [2].

Changes of the magnetic properties of the amorphous alloys, due to appearance of the stresses from external forces are very important from technical point of view. It should be noted that external forces might be applied to the material during the assembly process of inductive component with amorphous alloy core or by thermal expansion of the material during the operation of the component. Stresses applied to the material could be especially large in the case of the miniature components, where even small forces may cause significant stresses. Consequently, the magnetoelastic effect may lead to disoperation of the component or even to its failure due to the power losses.

On the other hand magnetoelastic effect may be utilized in development of new class of stress and force sensors. These sensors may be much more robust and cheaper than strain-gauge sensors. Moreover high sensitivity in magnetoelastic sensors based on the amorphous alloys may be achieved [3].

## 2. METHOD OF INVESTIGATION

During the investigation two ring-shaped samples made of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy were tested. Samples were annealed for 1 hour at temperatures 300 and 350 °C respectively. Both samples had outside dimension 32mm, inside dimension 25 mm and height 10 mm. Magnetoelastic tests were performed at the room temperature.

During the magnetoelastic investigation the compressive force F was applied to the ring-shaped sample perpendicularly to the magnetizing field *H* [4]. Special system of nonmagnetic, cylindrical

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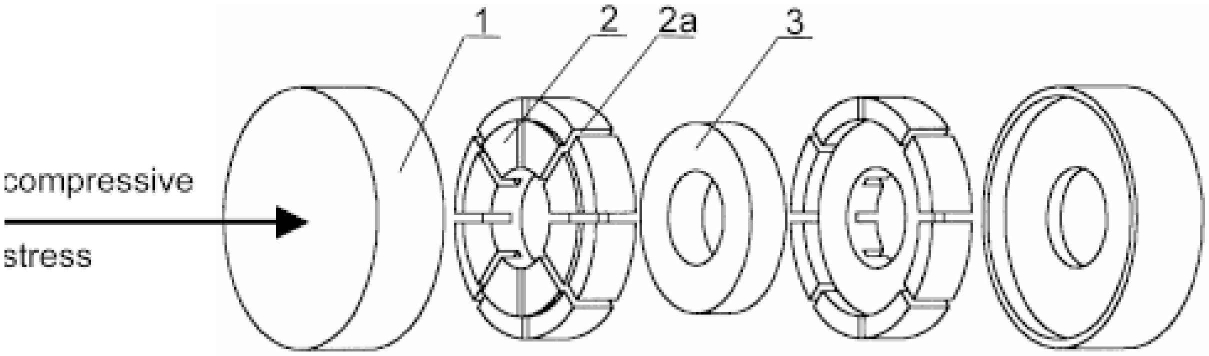


**Fig. 1.** Device for application of the uniform compressive stress to the ring-shaped sensing element (Patent pending P-345758) 1 – base backings, 2 – nonmagnetic cylindrical backings, 2a – grooves or the winding, 3 – core under investigation.

backings were used in order to obtain uniform compressive stresses in the tested ring-shaped core and enable it to be wound. The schematic view of used device is presented in Fig. 1. Base backings (1) allow tested ring-shaped core (3) to be subjected to the compressive force *F*. Due to the special, nonmagnetic cylindrical backing (2) the distribution of stresses in the core is uniform. Measuring and magnetizing windings are placed in grooves (2a) at the cylindrical backings (2) [5]. It should be indicated that due to the uniform distribution of stresses in the sample, the local accumulation of stresses doesn't appear. As a result also brittle materials (such as annealed amorphous or nanocrystalline alloys) can be tested.

## 3. RESULTS OF THE INVESTIGATION

The influence of the compressive stress s on the shape of hysteresis loop of the $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy annealed at 350 °C is presented in Fig. 2. An increase of the compressive stress $\sigma$ causes first an increasing of the flux density *B*. But for higher values of compressive stresses the flux density *B* decreases.

Magnetoelastic characteristics describing changes of the flux density *B* of both investigated samples, as a function of compressive stress $\sigma$ (for constant values of the magnetizing field $H_m$), are presented in Fig. 3. It was observed that magnetoelastic $B(\sigma)_H$ characteristics of the core annealed at 300 °C are monotonous (Fig. 3a), whereas for the sample annealed at 350 °C, maximum on $B(\sigma)_H$ characteristics (Fig. 3b) was detected for $\sigma$ = 1 MPa. Such maximum is known as the Villari reversal point. The appearance of the Villari point on the $B(\sigma)_H$ characteristics (Villari point) is probably connected with the changes of the sign of saturation magnetostriction constant $\lambda_s$ under stresses $\sigma$ [6]. However, changes of the magnetostriction of amorphous alloys subjected to stresses requires further investigation.

## 4. CONCLUSION

Presented results indicate that even relatively small changes of annealing temperature of the samples made of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy might significantly change its magnetoelastic characteristics. Producers and users of the inductive components based on Fe-Ni rich alloys should consider this effect.

For the sample annealed at 350 °C Villari reversal point at the $\sigma$ = 1MPa was observed, whereas magnetoelastic characteristics of sample annealed in 300 °C were monotonous. The appearance of the Villari point on the $B(s)_H$ characteristics is probably connected with the changes of the sign of saturation magnetostriction constant $\lambda_s$ under stresses $\sigma$ .

## ACKNOWLEDGEMENTS

This work was supported by Ministry of Science and Higher Education under the grant realized in the years 2005/2008.

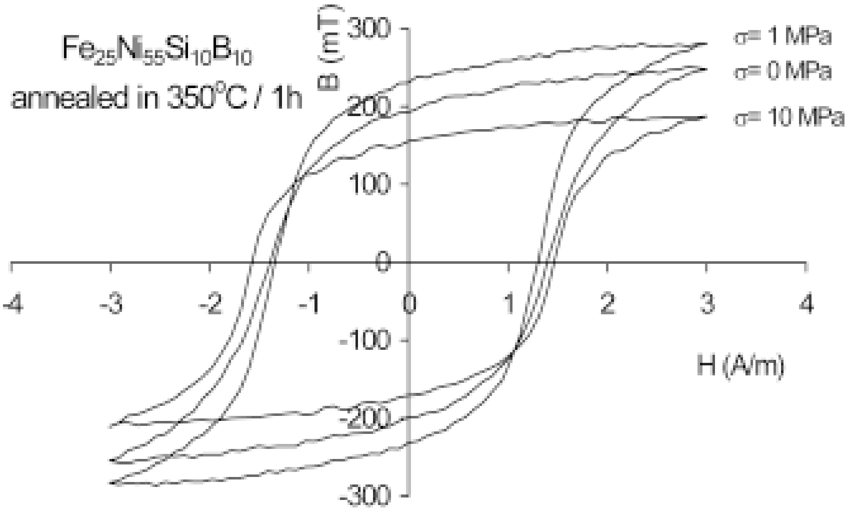


**Fig. 2.** The influence of compressive stresses σ on the magnetic hysteresis loop $B(H)_\sigma$ of $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy core annealed at 350 °C for 1 hour.

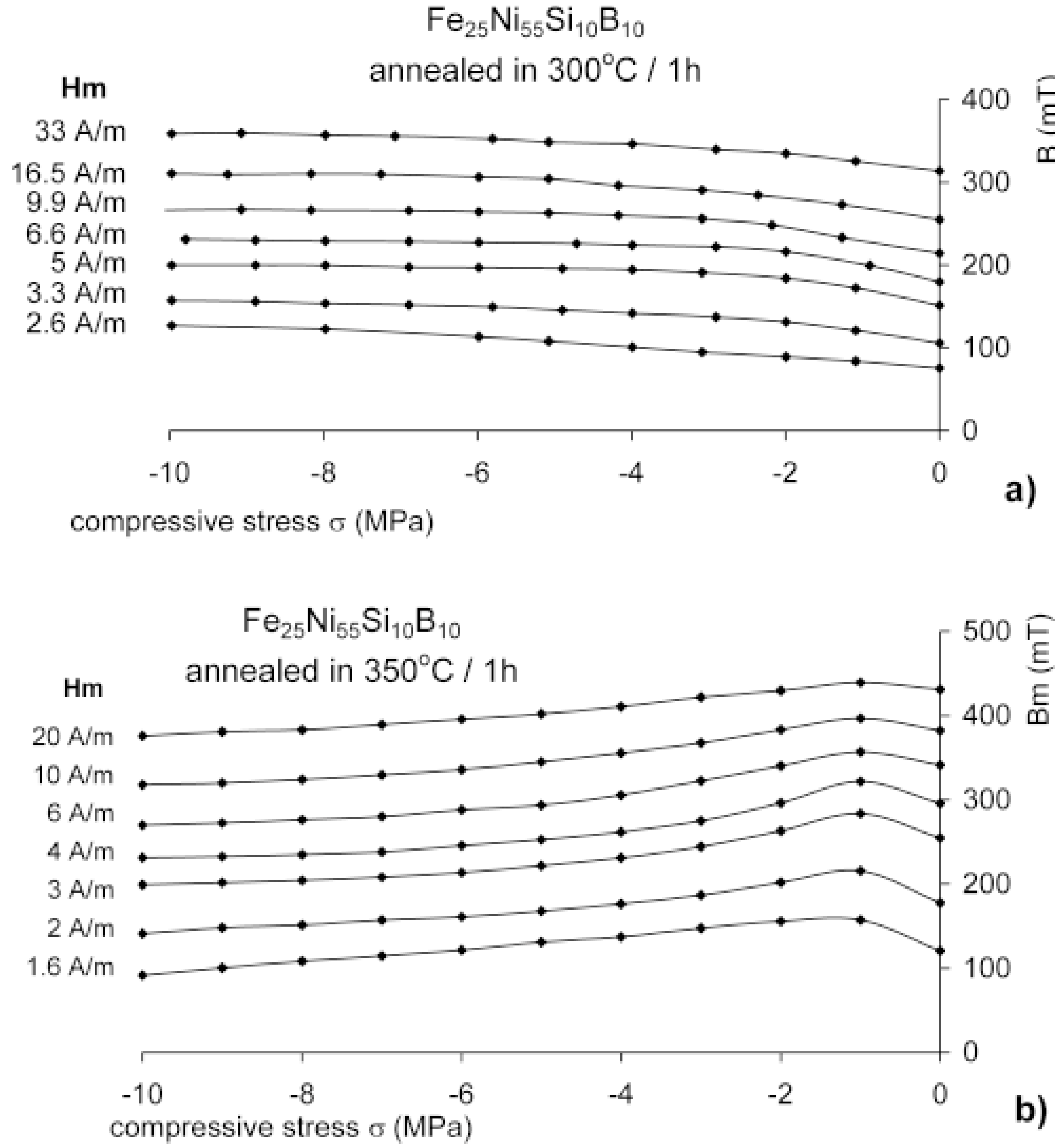


**Fig. 3.** The influence of compressive stresses s on the flux density *B* in the $Fe_{25}Ni_{55}Si_{10}B_{10}$ amorphous alloy core annealed for 1 hour at (a) 300 °C, (b) 350 °C.

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