MAGNETOELASTIC, RING-SHAPED TORQUE SENSORS WITH THE UNIFORM STRESS DISTRIBUTION

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Abstract:

Paper presents the new methodology of application of uniform torque to the ring-shaped magnetoelastic sensing elements. The results of investigation on the influence of a torsion on the magnetic properties of different amorphous Fe-based ring cores are also presented. The results of tests on $Fe_{78}Si_{13}B_9$ amorphous alloy in as-cast and annealed state as well as $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ nanocrystalline alloy indicate, that torque sensitivity is connected with both alloy composition and state on the alloy. Moreover the most sensitive is $Fe_{78}Si_{13}B_9$ amorphous alloy in annealed state. As a result this alloy is the most suitable as a core of magnetoelastic torque sensors.

Keywords: *magnetoelastic effect, sep torque sensors, sep amorphous alloys*

1. Introduction

High magnetoelastic sensitivity of amorphous alloys creates new possibility of technological break-throu in the area of magneto mechanical sensors application [1]. Possibilities of application of ring shaped sensing cores for force measurements was widely presented in previous publications [2], but was mainly focus on sensors utilizing magnetic amorphous strips and wires [9, 10]. On the other hand possibility of application of amorphous ring cores for torque measurements seem to be still not practical rectified. This paper presents the new methodology of application of the torque to the ring-shaped magnetoelastic elements. With this methodology the uniform distribution of stress in core may be achieved. As a result influence of the torque on magnetic ring core can be tested from fundamental research point of view as well as from the point of view of sensor's applications [8].

2. Method of investigation

The lack of methodology which enable application of the uniform, torsional axial shearing stress to the core subjected to external torsion was the main problem connected with development of magnetoelastic torque sensors with ring-shaped sensing elements [3]. To overcome this problem a new methodology of applying torsional axial shearing stress to the ring-shaped magnetoelastic sensing element was developed [6].

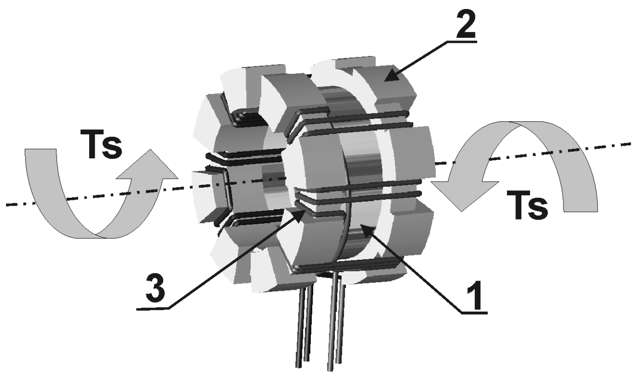


Fig. 1. Device for application of uniform torque to ring-shaped sensing elements (1-ring-shaped core under investigation, 2-magnetizing and measuring windings, 3-non magnetic backing with grooves, 4-shaft for torque transfer)

The specialized mechanical system utilizing this method is presented in figure 1. In this method the ring core under investigation (1) is mounted to the base planes and special nonmagnetic backing with radial grooves (3) are attached to the base planes of the ring shaped core. The torque is applied in direction of axis of the ring core. Due to these grooves the core can be winded (2) and changes of its parameters under influence of torsion can be measured. Described special backing system is necessary to obtain uniform torsional shearing stress in the ring-shape core.

This method of applying torsion to the ribbon ring cores can be utilized in development of the new type of magnetoelastic torque moment sensors. To predict properties of such sensors influence of torque on the hysteresis loop $B(H)_{Ts}$ - characteristics, influence of torque on flux density ($(B(Ts)_H$ - characteristics) as well as influence of torque on permeability ($(\mu(T_s)_H$ - characteristics) were tested .

3. Investigated material

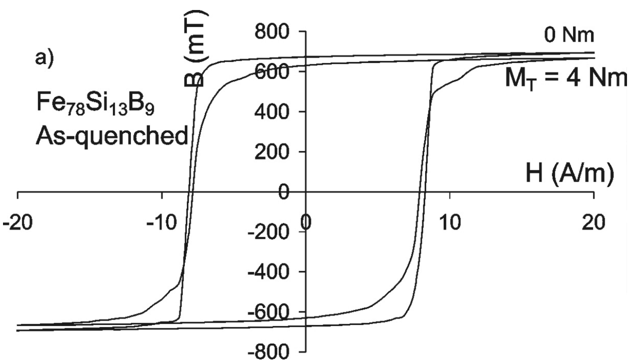
Investigation on the torque sensitivity of ring-shaped magnetic cores was carried out on amorphous alloys with different chemical composition and in different state connected with production process. The core no. 1 was made of $Fe_{78}Si_{13}B_9$ amorphous alloy in as-cast state. The core no. 2 was made of the same $Fe_{78}Si_{13}B_9$ amorphous alloy, but subjected to thermal treatment at the temperature 365oC for 1 hour. The core no. 3 was made of $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ alloy subjected to thermal annealing in the temperature 550 °C for 1 hour. As a result nanocrystalline structure was achieved in this core [4, 7].

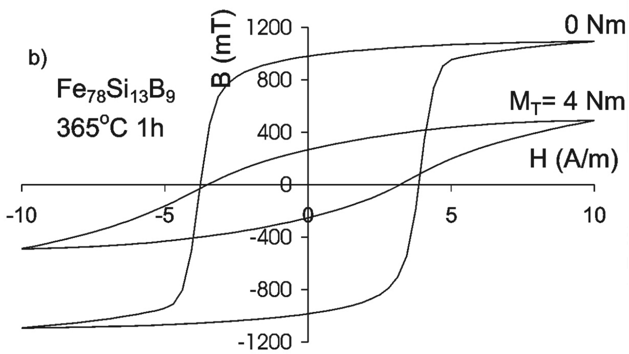
Due to significant differences in core's composition as well as state connected with thermal treatment different values of magnetostriction λ_S in cores can be expected. As a result significant differences in torque sensitivity among the cores is also anticipated [5].

4. Results

The results of investigation of the influences of a torque on the hysteresis loop of investigated cores ($B(H)_{Ts}$ - characteristics) are presented in figure 2. It should be indicated that investigated cores exhibit different value of coercive field Hc. Moreover the most significant changes of value of flux density B was observed in the case of annealed $Fe_{78}Si_{13}B_9$ amorphous alloy. In the case of this alloy value of flux density decrease from 1090 to 490 mT.

Figure 3 presents the influence of torsion on the magnetic permeability μ_a in the ring-shaped cores. The core is subjected to influence of torque T_s and than magnetized at constant value of magnetizing field H_m. Also in this case the highest observed changes of amplitude magnetic permeability m_a was observed in annealed $Fe_{78}Si_{13}B_9$ amorphous alloy magnetized by low value of magnetizing field H_m. For this core amplitude magnetic permeability μ_a decreases from 145800 to 26680 (for torque up to 5 Nm). It should be highlighted, that such big changes (over 80 percent) of the amplitude magnetic permeability μ_a can be easily converted to output signal from torque measuring transducer. As it was indicated in previous publications for conversion of permeability to useful signal both resonant circuit and transformer configuration can be utilized.





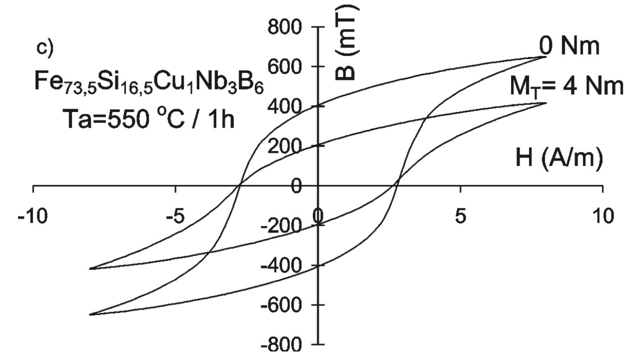


Fig. 2. The influence the torque on the hysteresis loop ($B(H)_{MT}$ - characteristics) of a) $Fe_{78}Si_{13}B_9$ amorphous alloys in as-quenched state, b) $Fe_{78}Si_{13}B_9$ amorphous alloy subjected to thermal treatment at the temperature 365 °C for 1 hour, c) $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ alloy subjected to thermal annealing in the temperature 550 °C for 1 hour

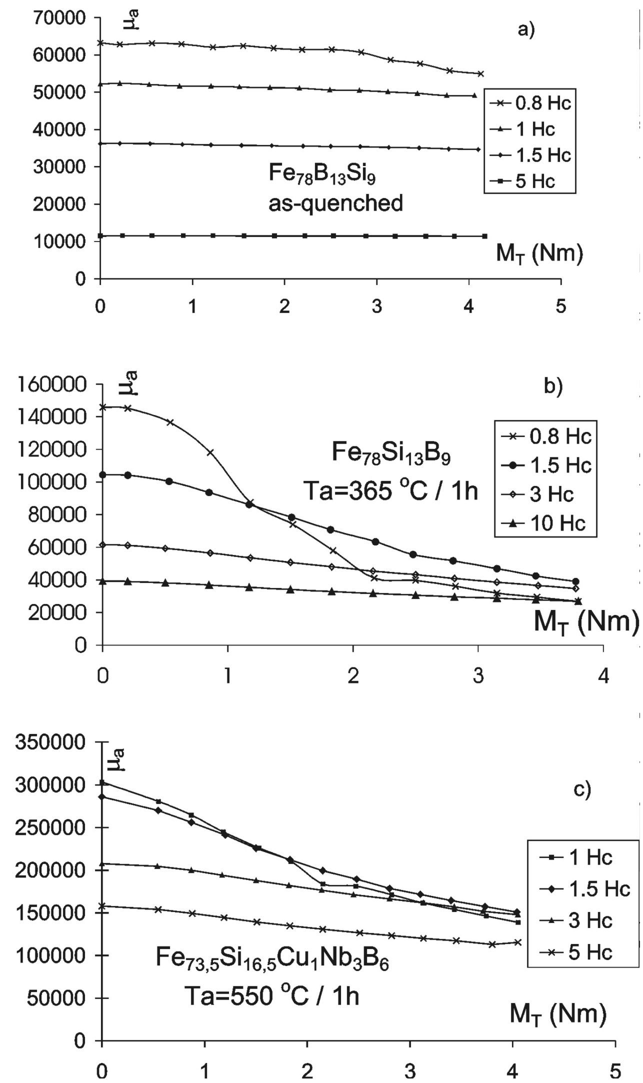


Fig.3. The influence the torque on the amplitude permeability ($\mu_a(M_T)_H$ - characteristics) of a) Fe78Si13B9 amorphous alloys in as-quenched state, b) Fe78Si13B9 amorphous alloy subjected to thermal treatment at the temperature 365 °C for 1 hour, c) $Fe_{73.5}Nb_3Cu_1Si_{13.5}B_9$ alloy subjected to thermal annealing in the temperature 550 °C for 1 hour

5. Conclusion

Newly developed method of applying the torque to the ring shaped sensor creates new possibilities of the construction the torque transducers. In such transducers a uniform distribution of torsional axial shearing stress can be achieved. Moreover presented method creates the new possibilities in the field of both basic researches of the process of magnetization of magnetic materials subjected to shearing stress.

Experimental results presented in the paper proved that magnetoelasting sensing element made of the annealed $Fe_{78}Si_{13}B_9$ amorphous alloy has high stress sensitivity. For torque up to 5 Nm amplitude permeability of the core decrease over 80 percent. This results indicate the possibility of construction a very attractive sensor for a torque measurements.

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