Magnetostrictive properties and magnetoelastic Villari effect in the high-permeability Mn-Zn ferrites *)

Adam Bieńkowski

Institute of Metrology and Measuring Systems, Warsaw University of Technology, sw. A. Boboli 8, 02-525 Warsaw, Poland

Roman Szewczyk

Industrial Research Institute for Automation and Measurement, Al. Jerozolimskie 202, Warsaw, Poland

Alicja Wiśniewska

Institute of Electronic Materials Technology, Wólczynska 133, 01-919 Warsaw, Poland

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Paper presents the results of investigation carried out on the magnetostrictive and magnetoelastic characteristics of high-permeability $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite. During the investigatation of magnetostrictive characteristics of the ferrite, the semiconductor strain gauges mounted on the frame-shaped samples were utilized. The same frame-shaped samples were used for investigation of magnetoelastic characteristics of $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite. Presented results confirmed that high-permeability $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite has near-zero, negative magnetostriction. Moreover, in spite of its low magnetostriction, this ferrite is highly sensitive on steresses from external forces.

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1 Introduction

Polycrystalline, high-permeability Mn-Zn ferrites are widely used as the cores of inductive components, especially for telecommunication applications and in switching mode power supplies [1]. In spite of the fact that Mn-Zn ferrites are known since early fifties, properties of these materials are still investigated and improved. One of the most important of functional properties of Mn-Zn ferrites are their magnetostrictive and magnetoelastic properties. In a case of high-permeability inductive cores an increase of their magnetostriction may cause significant increase of core losses. For these reason Mn-Zn ferrites are optimized for nearly-zero magnetostriction [1]. On the other hand low-magnetostrictive materials are commonly considered as not being stress sensitive [2]. As a result, the influence of external compressive stress on magnetic properties of Mn-Zn ferrite should be negligible. In a case of other materials it is known that external stresses may change functional properties

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of magnetic material. Such change may be the reason of malfunction or even damage of electronic device with inductive component. In spite of the fact that both magnetostrictive and magnetoelastic properties of ferrites are very important from practical point of view, the results of simultaneous investigation on magnetostriction and influence of stresses on magnetic properties (magnetoelastic Villari effect) of Mn-Zn ferrites seems to be still not satisfactorily explained.

2 Experimental method

In our experiment, frame-shaped sample produced by conventional ceramic process was used. The volume density d_v of the sample was equal to 4940 kg/m^3, initial permeability μ_i of the sample was equal to 7000 and coercive field $H_c = 12$ A/m.

Methods of investigation of magnetostriction of magnetic materials were described by P. T. Squire [3]. Due to the fact that full magnetostrictive loop should be determined, highly sensitive semiconductor strain gauges were used. This method of investigation was described in [4].

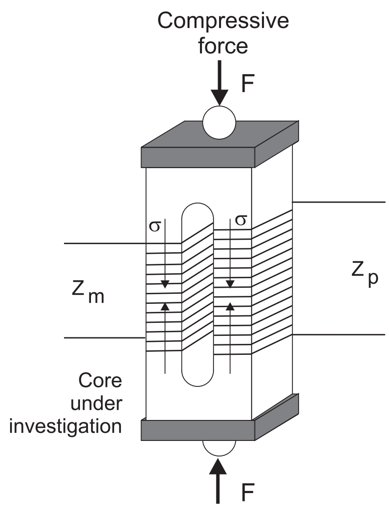

Fig. 1. The method of applying the uniform compressive stress to the frame-shaped sample (z_m, z_p -magnetizing and sensing winding)

The same, frame-shaped sample was used for investigation of magnetostriction and for magnetoelastic Villari-effect measurements. The method of applying uniform compressive stresses to the columns of the frame shaped sample [4] is presented in Fig. 1.

Compressive stresses were applied to the frame-shaped sample by the ball joints to avoid bending of the sample. Changes of magnetic properties of the sample were measured by computer-based measuring facility containing precise current source and fluxmeter.

3 Results and conclusion

Initial magnetostrictive curve and a family of the magnetostrictive hysteresis loops are presented in Fig. 2. Magnetostrictive hysteresis dependence on the function of flux density B in the core is presented in Fig. 3. Maximal value of magnetostriction λ does not exceed -1.2×10^{-6}. This maximal value of magnetostriction can be considered as technical saturation. It should be pointed out that during the magnetization cycle the value of magnetostriction λ does not come back to zero. The minima on magnetostrictive hysteresis loop are reached for magnetizing field equal to the coercive field.

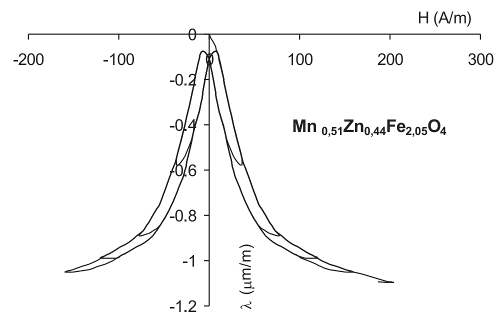

Fig. 2. Initial magnetostrictive curve and family of the magnetostrictive hysteresis loops of $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite

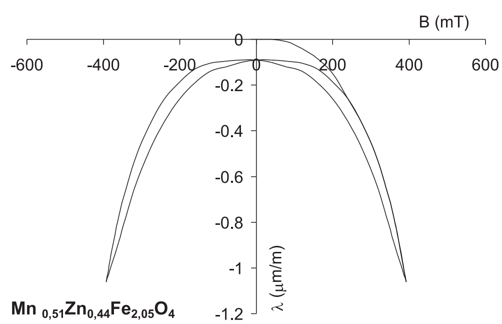

Fig. 3. Magnetostrictive hysteresis loop in dependence on the flux density B in the core made of $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite

The influence of compressive stresses on the shape of magnetic hysteresis loop of the investigated Mn-Zn ferrite is presented in fig. 4. Under compressive stresses up to 60 MPa the value of maximal flux density decreases from 315 mT to 135 mT and coercive field increases from 4.8 A/m to 30 A/m.

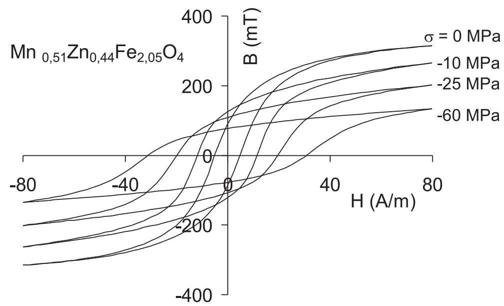

Fig. 4. The influence of compressive stresses on the shape of hysteresis loop of $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite

Presented experimental results indicate that the investigated high-permeability ferrite $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ is sensitive to the external stresses. Significant magnetoelastic Villari effect was observed in spite of low magnetostriction of this ferrite. Probably this phenomenon is connected with the fact that also magnetostriction of this ferrite changes under the influence of the stresses [5]. As a result, material with nearly zero magnetostriction (magnetostriction measured without stresses) may be stress-sensitive. This effect should be taken into consideration by both producers as well as users of the cores made of $Mn_{0.51}Zn_{0.44}Fe_{2.05}O_4$ ferrite.

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