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Temperature Influence on the Functional Properties of Inductive Components with Mn–Zn Ferrite Cores

D. Jackiewicz[a,*], M. Kachniarz[b] and A. Bieńkowski[a]

[a]Institute of Metrology and Biomedical Engineering, Warsaw University of Technology, A. Boboli 8, 02-525 Warszawa, Poland

[b]Industrial Research Institute for Automation and Measurements, Al. Jerozolimskie 202, 02-486 Warsaw, Poland

The paper presents the results of investigation of the temperature influence on the inductance and power losses in ferrite cores. Such effect can significantly influence the utility parameters of electronic devices, particularly in precision equipment. For example slight parameter change in this type of components in measuring devices can cause significant changes in output parameters. It is also equally important for mobile devices where increase of losses can limit the duration of service. Special measurement system composed of hysteresis graph, cryostat and PC was utilized to perform the experiment. The cores used during the investigation had closed magnetic circuit. In order to perform measurements of magnetic properties of the material, two sets of windings (magnetizing and sensing) were made on each core. The cores were placed in a cryostat, which was used to set the temperature value within the range from –20 to +50 °C. The magnetic properties were measured by the hysteresis graph, to assess the influence of the temperature on the functional parameters.

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1. Introduction

The magnetic cores of inductive electronic components are main elements of these devices. These components are inductors, transformers or electromagnets, usually made as wound ring cores made of ferrite [1, 2]. The quality, precision, and stability of the electronic components depend mostly on the cores parameters. Main functional properties of the ferrite cores are inductance and power loss [3]. Their characteristics may be influenced by many factors, such as temperature, humidity, and mechanical stress. The core temperature may change under the influence of the heat dissipated by the systems and the core itself.

Changes of the value of inductance may affect the parameters of the electrical circuit. The increase of the value of power losses leads to higher energy consumption. The important thing, from the users and constructors point of view, is knowledge about the temperature influence on the properties of the magnetic cores of an inductive electronic components [4].

The research presented in this publication focuses on demonstrating the influence of temperature on the magnetic properties of the cores of electronic components for the purpose of correcting their work and as guidelines for constructors.

2. Experimental

During the experiment, power losses and inductance were measured at different temperatures. Measurements were made for three different manganese-zinc ferrite cores. In order to change the operating temperature, the core was immersed in silicone oil in the cryostat chamber. Measurements were made for a temperature range of –20 °C to 50 °C. Figure 1 shows schematic block diagram of the measurement stand in configuration 1. It consists of PC, hysteresisgraph, cryostat, sensing winding and magnetizing winding [5]. The hysteresis graph is used to measure power losses and magnetic hysteresis loops For the measurement of the inductance, the measurement stand in configuration 2 is used. During measurement the RLC bridge circuit was connected to the sensing winding. For the control of the measuring electrical current value, an amperometer was connected in series with the sample.

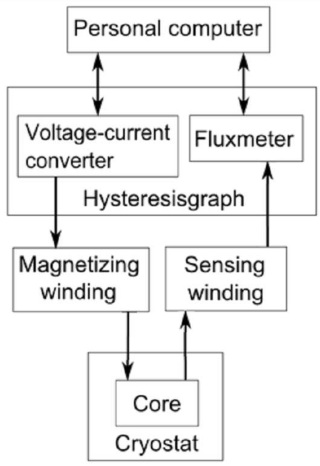

Fig. 1. Schematic block diagram of the measurement stand in configuration 1.

*corresponding author; e-mail: d.jackiewicz@mchtr.pw.edu.pl

Power losses measurements were made for the magnetizing field value calculated from the maximum coercive field value for each core. The current value, during the inductance measurements, was 35 mA. The RLC bridge circuit was set to series equivalent circuit. Table I consists the magnetic parameters of the investigated cores, Table II contains the details of the investigated cores.

TABLE I

The magnetic parameters of the examined cores

Core	F938	F-3001	N41
initial permeability	12700	3000	2000
maximum flux density [mT]	384	325	453
maximum coercive field [A/m]	7	14	22
maximum remanence [mT]	120	77	106

TABLE II

The details of the examined cores

Core	F938	F-3001	N41
magnetic length [mm]	78,5	60	92
cross-section area [mm^2]	85	62	98
magnetizing turns	10	5	10
sensing turns	20	10	20

3. Results and discussion

Figures 2, 3, and 4 show magnetic hysteresis loops for three cores: F938, F-3001, and N41 in different temperatures. The value of the magnetizing field amplitude is about 10 times higher than coercive field. For all cores, the maximum magnetic flux density decreases under the influence of temperature. This is the result of decrease of spontaneous magnetization under the influence of increasing temperature.

At absolute zero temperature, all the spin moments in each magnetic domain are ordered. As the temperature increases this order will gradually be affected by the heat motions of the atoms. Consequently, the value of spontaneous magnetization will decrease. When the temperature reaches the Curie point the spontaneous magnetization will disappear. The heat energy of the atomic movements will be comparable to the energy of the exchange forces [6].

Figure 5 show temperature dependence on inductance. Due to the fact that the inductance depends on the size of the core and the number of windings turns, the change in inductance better reflected in percentage. For all three

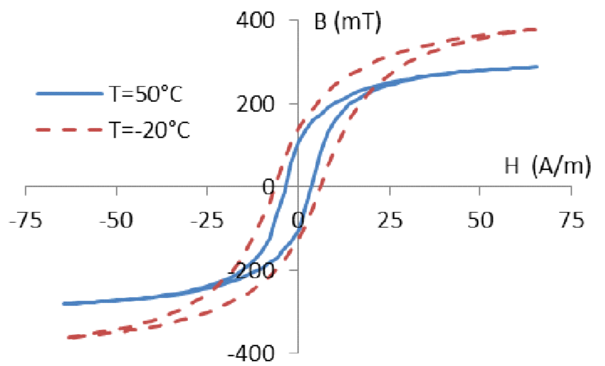

Fig. 2. Magnetic hysteresis loops of the F938 under variable temperature. H — magnetizing field, B — flux density.

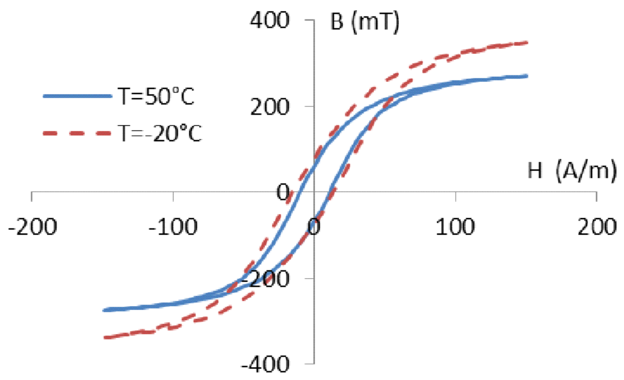

Fig. 3. Magnetic hysteresis loops of the F-3001 under variable temperature. H — magnetizing field, B — flux density.

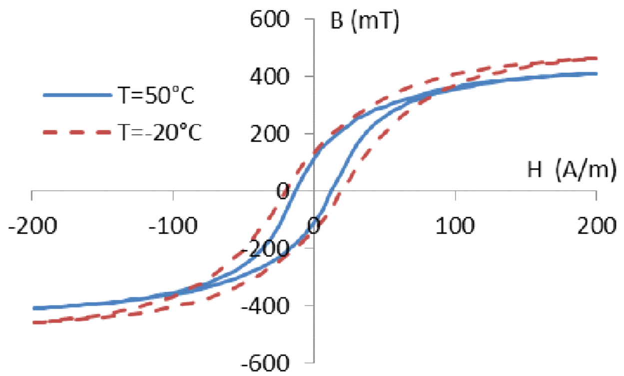

Fig. 4. Magnetic hysteresis loops of the N41 under variable temperature. H — magnetizing field, B — flux density.

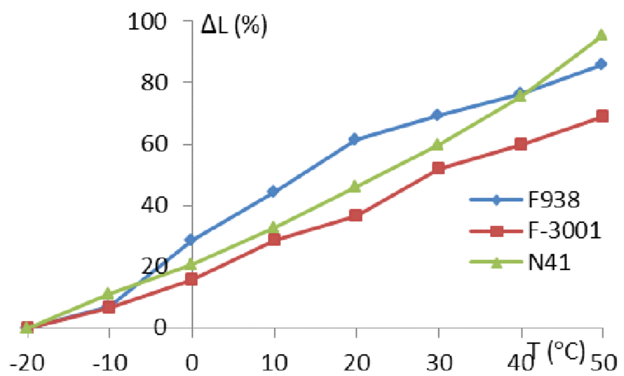

Fig. 5. Percentage change of inductance under the influence of temperature for the investigated cores.

cores the inductance is increasing. Changing the temperature from −20 to 50 °C resulted in nearly double increase in inductance.

The observed increase in inductance occurs because that the measurement was conducted within the initial permeability range (measurement current 35 mA).

The main conditions for achieving high value of magnetic initial permeability are high saturation magnetization and low magnetocrystalline anisotropy. Magnetocrystalline anisotropy combines the magnetization vector with specific crystallographic direction. In manganese-zinc ferrites, the direction of easy magnetization is consistent with the direction of the diagonal of elementary cube. In such materials, it is possible to lower the magnetocrystalline energy by increasing the temperature. Decrease of magnetocrystalline anisotropy predominates over the simultaneous decrease of saturation magnetization [6].

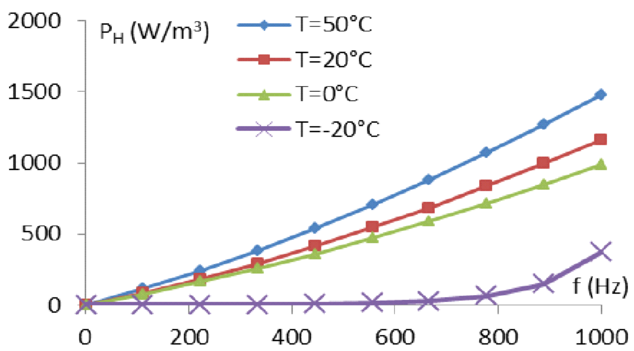

Fig. 6. Frequency dependence of power losses in four temperatures for F938 core.

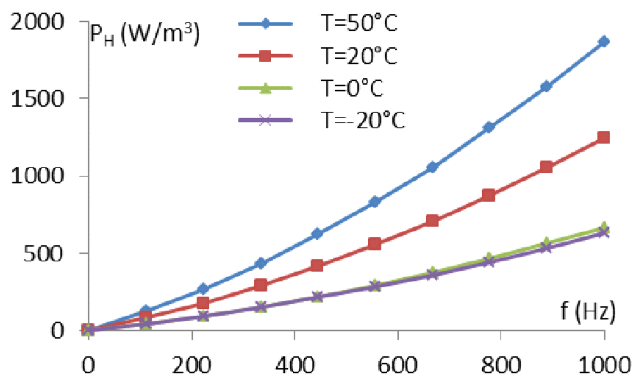

Fig. 7. Frequency dependence of power losses in four temperatures for F-3001 core.

Figures 6, 7, and 8 show frequency dependence of power losses in four temperatures for all investigated cores. It can be observed that there is a strong effect of frequency on the value of power loss. The influence of temperature is different for each investigated core. The highest power loss is observed for core N41, which has the highest coercive field.

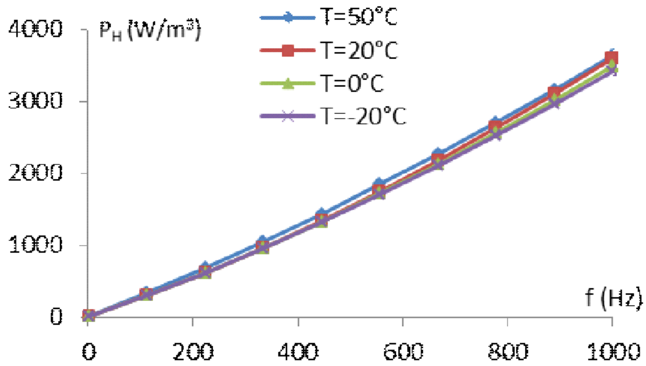

Fig. 8. Frequency dependence of power losses in four temperatures for N41 core.

4. Conclusions

The presented results confirm the influence of temperature on inductance of the manganese-zinc ferrites. In the region of initial permeability, the increase of temperature causes increase of inductance. For three cores the percentage change is similar.

The operating frequency has strong effect on the power loss in manganese–zinc ferrites. The effect of temperature is high for the cores F938 and F-3001 and negligibly small for the N41 core.

The obtained results indicate that the effect of temperature has to be taken into account during the design and operation of inductive electronic components with ferrite cores.

Acknowledgments

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