INFLUENCE OF PRESSING TIME ON THE MAGNETIC PROPERTIES OF IRON-PHENOLPHORMALDEHYDE RESIN COMPOSITES

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1. Introduction

The most important properties of soft magnetic composites (SMCs) include high electrical resistivity, very small eddy current losses and low total losses at high frequencies.Soft magnetic composites are materials used in different electromagnetic equipments such as rotors, stators, induction coil cores, actuators, electrical converters and other rotating devices. The soft magnetic composites consist of ferromagnetic powder, which are covered by a very thin electrical insulating layer. The insulating layer in the SMCs plays a key role in lowering total core losses. Compacting of powder allows to produce components of different shapes.

The resulting electric and magnetic properties of soft magnetic composites are affected by properties of ferromagnetic powder and insulating layer, pressure of compaction, temperature of heat treatment, weight percentages of insulating layer, interaction between particles of the composite. In the present work, the produced SMCs consist of ASC 100.29 powder and the insulating layer is the phenol-formaldehyde resin (PFRB) modified by boron. The weight ratio of insulating layer to the ferromagnetic particles was 3 wt.%. Measured samples were pressed for different pressing times.

2. Experimental

The samples of magnetic composite material were prepared from two components: iron powder Höganäs ASC 100.29with the size fraction in the range from 45 μm to 212 μm and phenol-formaldehyde resin(PFRB) modified by boron(3 wt.%). The chemical synthesis of hybrid resin PFRB modified by boron was synthesized by the analogous sol–gel process and were carried out according to the procedure thoroughly described in our previous work [1].The powder was compacted at 700 MPa for 2 or 5 min into the cylindershapeat150°C. This temperature does not degrade the insulation layer[1]. The cylinder samples dimensions were: outer diameter of 10 mm and height of 3 mm and samples were used for measurement of specific electrical resistivity by Van der Pauw method. The densities were evaluated from dimensions measurements and mass of the bodies. The samples were drilled into the form of toroid for measuring of complex permeability and total magnetic losses. The complex permeability was measured by an impedance analyser (HP4194A) in the frequency range from 1 kHz to 40 MHz. The AC hysteresis loops were measured at frequency range from

290 Hz to 1000 Hz, at maximum induction of 0.1 T by Permeameter AMH-1K-S. Total hysteresis losses were determined in J/m^3 as an area of the hysteresis loop.

3. Results

The values of pressing time, specific electrical resistivity, density, porosity and relaxation frequency of prepared samples are in Tab. 1. The specific electrical resistivity of the 5 min pressed sample is higher probably due to better creeping of the resin and thus more appropriate covering of the ferromagnetic particles. The Fig.1 shows the real part of complex permeability for two samples pressed for different time. The sample which was compressed 2 min is characterized by highervalue of real part of complex permeability (71) in the constant region up to 10^5 Hz in comparison with sample compressed for5 min showing real part of complex permeability of 62. The reason is more contact points of ferromagnetic particles.

Tab. 1: *The values of pressing time, specific electrical resistivity, density, porosity and relaxation frequency of prepared samples.*

	Sample1	Sample 2
Pressing time [min]	2	5
Specific electrical resistivity [Ω.m]	$9.84 \cdot 10^{-6}$	$3.9 \cdot 10^{-5}$
Density [g/cm^3]	6.74	6.76
Porosity %	2.57	2.34
Relaxation frequency [kHz]	550	920

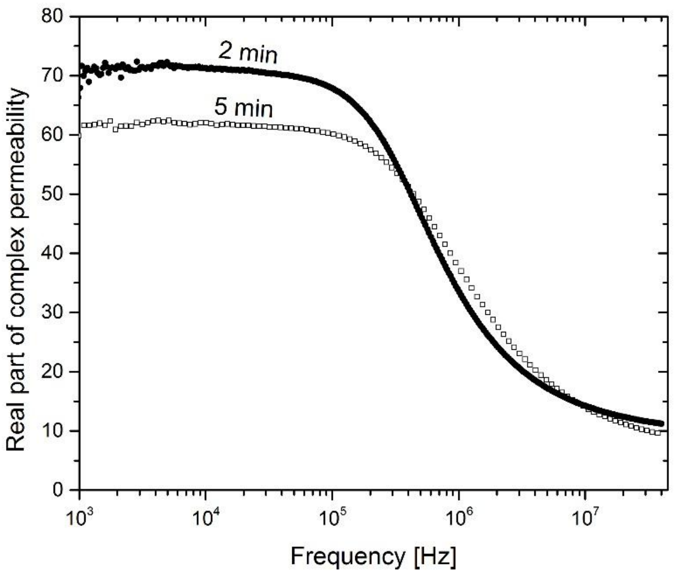

Fig. 1: *The dependence of real part of complex permeability on frequency for samples pressed for 2 min and 5 min, respectively.*

The frequency dependence of the real and the imaginary parts (Fig. 1, Fig. 2) of the complex magnetic permeability shows that maximum of the imaginary part of the complex permeability is observed at a frequency at which is observed maximum decrease of the real part of the complex permeability. This frequency is called the relaxation frequency. The imaginary part of complex permeability corresponds to relaxation frequency of domain walls and the relaxation frequency increases with increasing of specific electrical resistivity (Tab. 1). The higher value (920 kHz) was measured for 5 min pressed sample (Fig.2).

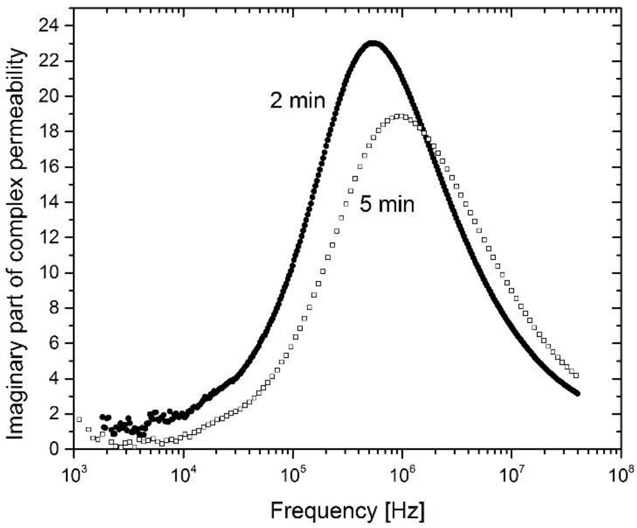

Fig. 2: *The dependence of imaginary part of complex permeability on frequency for samples pressed for 2 min and 5 min, respectively.*

The Fig.3 shows the dependences of total losses on the frequency for two samples pressed for different time measured in the frequency range from 290 Hz to 1000 Hz at maximum induction of 0.1 T. The 2 min pressed sample shows lower total losses. This is caused by the lower value of static hysteresis loss.

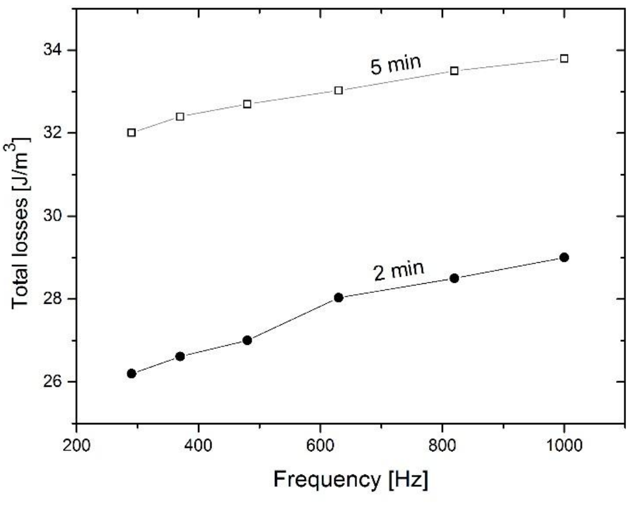

Fig. 3: *The dependence of total losses on frequency for samples pressed 2 min and 5 min, respectively.*

4. Conclusion

In this paper, we were prepared SMCs composed of iron powder and insulation layer - phenol-formaldehyde resin. The samples were investigated in the frame of the specific electrical resistivity, the real and imaginary parts of the complex magnetic permeability and the total losses for the samples with different pressing time. Investigated effect of pressing time showed that longer pressing time causes creep of the insulating layer and therefore more appropriate covering. The relaxation frequency increases with increasing of specific electrical resistivity. The value of total losses in the frequency range has been affected by hysteresis loss. The sample which was pressed 5 min was characterized by higher electrical resistivity, lower initial permeability and higher total losses than 2 min pressed sample.

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References:

[1] M. Strečková, R. Bureš, M. Fáberová, Ľ. Medvecký, J. Füzer, P. Kollár, *Chinese J. Chem. Eng.***23**, 736 (2015).

[2] Z. Birčáková, P. Kollár, J. Füzer, M. Lauda, R. Bureš, M. Fáberová: *IEEE Trans. Magn.***50**, 6301507 (2014).

[3] F. Alves, C. Ramiarinjaona, S. Bérenguer, R. Lebourgeois, T. Waeckerlé, *IEEE Trans. Magn.* **38**,3135(2002).

[4] Y. Zhou, M.Wang, Y. Chi, X. Qu, P. Liu, Z. Zhao, *IEEE Trans. Magn.* **52**,2800104 (2016).

[5] H. Shokrollahi, K. Janghorban, *J. Mater. Process. Technol.***189,** 1 (2007).

[6] C. Kaynak, C. C. Tasan,*Eur. Polym. J.***42**, 1908 (2006).

[7] B. Slusarek, *Prz. Elektrotech.* **86**, 16 (2010).

[8] P. Kollár, V. Vojtek, Z. Birčáková, J. Füzer, M. Fáberová, R. Bureš, *J. Magn. Magn. Mater.***353**, 65 (2014).

[9] A. H. Taghvaei, M. Stoica, F. Mazaleyrat, K. G. Prashanth,M. Samadi Khoshkhoo, K. Janghorban, J. Eckert, *Intermetallics* **43**, 1 (2013).