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Co ADDED FINEMET AND NANOPERM ALLOYS WITH FLAT HYSTERESIS LOOPS

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Abstract. The Co-modified Finemet and Nanoperm type alloys were subjected to thermo-magnetic treatment and an effect of temperature and magnetising field frequency on their soft magnetic properties was investigated. It was found that Finemet type alloys containing 40 at.% Co and the FeCoNbP Nanoperm type alloy exhibit good stability of their magnetic properties at elevated temperatures, whereas properties of Finemet modified with 58.8 at.% Co are the least stable. Magnetic permeability of the investigated alloys was ranging from 1000 to 5000, making them particularly suitable for application as magnetic components in power electronics.

1. INTRODUCTION

Considerable advances have been made recently in developing new types of soft magnetic alloys for high temperature and high frequency applications [1-5]. Improved high frequency properties are required from soft magnetic materials because the electronic equipment operates at increasingly higher frequency. Partial substitution of Fe with Co in nanocrystalline Finemet type alloys makes that they exhibit good soft magnetic properties also at elevated temperatures. Co addition not only increases the Curie temperature of an amorphous matrix, increasing the decoupling temperature, but also makes the material suitable for magnetic field annealing by Fe-Co pair ordering effect. The effect of Co was studied for a normal Finemet [3,5] composition and for a new $Fe_{85-x}Co_xNb_5B_8P_2$ alloy [2]. Large induced magnetic anisotropy, flat hysteresis loop and good properties in the high frequency range make these alloys very attractive and suitable for application in modern power electronics.

The aim of this work was to study an effect of the elevated temperature and high frequency on soft magnetic properties of Finemet modified with Co and the FeCoNbBP alloys.

2. EXPERIMENTAL

The $Fe_{73.5-x}Co_xCu_1Nb_3Si_{13.5}B_9$ (x = 0, 40, 58.8) and FeCoNbBP amorphous ribbons, 10 mm wide and about 20 mm in thickness, were fabricated by melt-spinning technique. Before casting, chemical composition of the master alloys was examined using X-ray microanalyser. Amorphousness of the ribbons was checked by means of X-ray diffractometry. All the samples in a form of toroidal cores, with an external and internal diameters of 21.5 and 15.5 mm, respectively, were annealed for 1 hour at the optimal temperature for each composition in the protective atmosphere of argon, in an external magnetic field H_T of 160 kA/m applied in parallel to the toroid axis. After thermo-magnetic treatment, the AC (alternating current) magnetic

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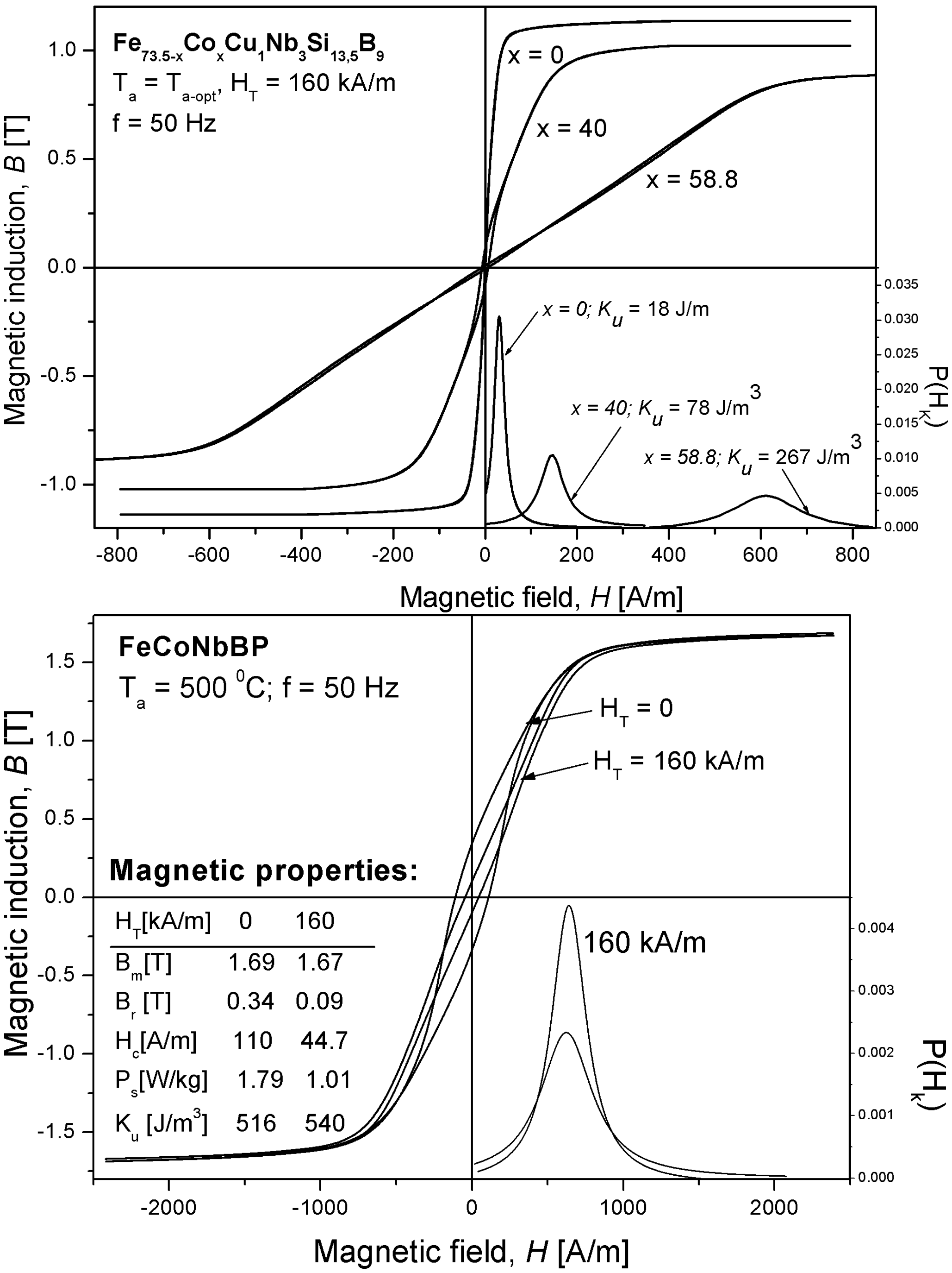

Fig. 1. Flat hysteresis loops (a) for the Finemet type alloys and (b) for the FeCoNbBP alloy annealed with and without a transverse magnetic field.

properties of the cores were measured (coercivity H_c, magnetic induction B_m, magnetic permeability μ_{max} and power losses P_s) at different magnetising field frequencies (50 Hz - 100 kHz) and at the temperatures up to 400 °C using a computerized hysteresis loop tracer.

3. RESULTS AND DISCUSSION

Figs. 1a and 1b show dynamic (50 Hz) flat hysteresis loops for soft magnetic cores from Finemet type alloys modified with Co and from the $Fe_{85-x}Co_xNb_5B_8P_2$ alloy. Flat hysteresis loops of the

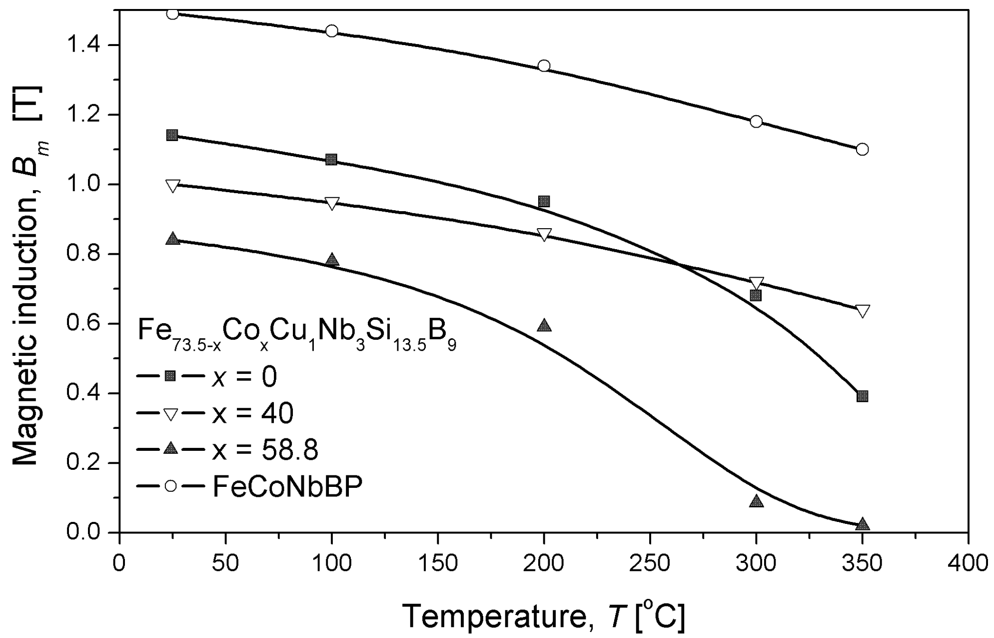

Fig. 2. Temperature dependence of magnetic induction for the Finemet type alloys and the FeCoNbBP alloy.

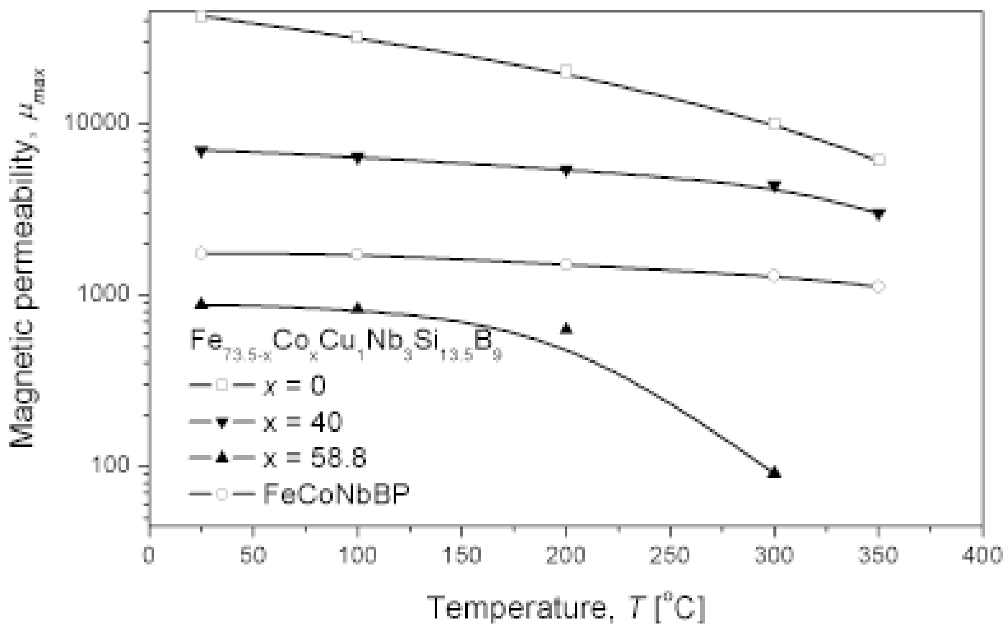

Fig. 3. Dependence of the maximum permeability on temperature for the Finemet type alloys and the FeCoNbBP alloy.

Finemet type alloys are characterised by very low magnetic remanence B_r and low coercive field H_c ($B_r \leq 0.01$ T; $H_c \leq 5$ A/m). Moreover, the Finemet alloys without cobalt and those containing 40 at.% Co exhibit relatively low induced magnetic anisotropy K_u, which at the Co content of 58.8 at.% increases rapidly to 267 J/m^3. The flat hysteresis loops measured for cores from the FeCoNbBP alloy subjected to heat treatment at 500 °C without transverse magnetic field and in the presence of a field of H_T = 160 kA/m have been presented in Fig. 1b. In comparison to the Finemet type alloys [2], the FeCoNbBP alloy after heat treatment without the field H_T exhibits low magnetic remanence B_r

(see Fig.1b), which after heat treatment in a transverse field H_T = 160 kA/m decreases almost four times. The treatment results also in coercivity reduction by more than twice, and of power losses in a core P_s by about 44 %.

Fig. 2 shows dependence of the magnetic induction on temperature measured at the magnetic field strength of 700 A/m for Finemet type alloys and 2000 A/m for the FeCoNbBP alloy. The strongest effect was observed for Finemet with 58.8 at.% Co. Other alloys exhibited similar stability of the magnetic induction, but for Finemet without Co, stronger decrease of induction was observed at the temperatures over 200 °C. Fig. 3 illustrates dependence of maximum permeability μ_{max} on temperature for the studied alloys with different compositions. As we can see, for the Finemet type alloys without Co the permeability decreases very rapidly with the temperature increase. However, permeability of Finemet with x = 40 and of the FeCoNbBP alloy was practically stable within the whole examined temperature range.

Similar relationships were obtained at the frequencies of 50 kHz and 100 kHz. Also in the case of the dependence of coercivity on temperature, the best temperature stability exhibit Finemet alloys at x = 40 and the FeCoNbBP alloy.

The dependence of power losses P_s on temperature for the Finemet type alloys and for the FeCoNbBP alloy, measured at 100 kHz at the induction B = 0.4 T, has also been examined. It is seen that the temperature increase results in strong increase of power losses in the Finemet type alloy containing 58.8 at.% Co.

In the case of other alloys, an effect of temperature increase on power losses P_s is relatively small, which makes them suitable for application at elevated temperatures.

4. CONCLUSION

An effect of temperature and magnetising field frequency on soft magnetic properties (B_r, H_c, μ_{max}, P_s) was investigated for selected Finemet type alloys modified with cobalt and for the $Fe_{85-x}Co_xNb_5B_8P_2$ alloy. The alloys were subjected to thermo-magnetic treatment in a transverse magnetic field in order to induce a transverse magnetic anisotropy K_u in them so as to ensure low power losses during operation in high frequency fields. It was found that from among the alloys examined the least stable magnetic properties at elevated temperatures exhibits the Finemet alloy containing 58.8 at.% Co (Figs. 2 and 3), and its power losses P_s at the frequency increase are the highest. Good stability of the magnetic properties at elevated temperature and frequency have the Finemet type alloys containing 40 at.% Co and the FeCoNbBP alloy. Moreover, they are characterized by relatively low values of maximum permeability μ_{max}, ranging from 1000 to 5000, which makes them suitable for wide application for the magnetic components in modern power electronics.

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