AE-10

Magnetic Properties of Fe-Based Ribbons and Toroidal Cores Prepared by Continuous Stress-Annealing by Joule Heating.

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Introduction

Recently, size reduction and improvement in efficiency of magnetic cores with controlled permeability such as choke coils are strongly required for high-density packaging and energy saving of electric devices. For these requirements, we have proposed an Fe-based toroidal core with controlled permeability and showed their excellent magnetic properties [1].

From the viewpoint of increasing the controllability of the permeability, we have reported several methods of stress-annealing, and found that a continuous stress-annealing with a furnace (CSA-F) and Joule-heating under tensile stress (JH) are hopeful methods of obtaining a long ribbon [2, 3]. In this report, we propose a new fabrication method, which is called the continuous stress-annealing by Joule-heating (CSA-JH), and show CSA-JH method enables us to reduce an effective annealing time compared with the CSA-F method. Moreover, a magnitude of tensile stress during annealing for obtaining a suitable anisotropy energy value could be reduced compared with the JH method.

Experimental Procedure

Amorphous $Fe_{73.5}Cu_1Nb_3Si_{15.5}B_7$ ribbons (Hitachi Metals Ltd.), 2 mm wide and 20 μm thick, were annealed under tensile stress, σ, from 50 to 175 MPa by the CSA-JH method in air. The apparatus used for annealing is shown in Fig.1. Rotatable Cu tubes connected with a dc-current source were used as electrodes, and the moving ribbon was kept contact with the electrodes. The supplied current density, j, and the moving velocity, v_m, of the ribbons were varied from 32.5 to 42.5 A/mm^2 and from 1 to 200 cm/min, respectively.

Results and Discussion

In order to investigate suitable annealing conditions for CSA-JH, amorphous ribbons were annealed at various conditions, and then relationship among the development of anisotropy, j and v_m was evaluated. Figure 2 shows the results for the development of anisotropy. The completely developed anisotropy indicated by the symbol of "○" could be obtained stably in the range of v_m = 1-200 cm/min at j = 37.5 A/mm^2. The highest velocity, 200 cm/min, enables us to reduce effective annealing time by 75 % compared with that for the CSA-F method. Figure 3 shows dependence of anisotropy energy, K_u, on σ, together with results for CSA-F [2] and JH [3]. The slope of the K_u, vs σ curve for the ribbons prepared by CSA-JH was 2 times as large as that for JH, indicating that we can reduce a required σ value.

Finally, we confirmed magnetic properties of a toroidal core prepared by the CSA-JH method. A toroidal core with, D = 20 mm was prepared from a 50 cm-long annealed ribbon (j = 40 A/mm^2, v_m = 9 cm/min and σ = 50 MPa), and its ac-magnetic properties were evaluated at B_m = 0.1 T in the frequency range from 0.1 to 1 MHz. The core showed ultimate low magnetic loss values and the constant permeability of 300 up to 1 MHz. These properties were almost the same as those for the previously reported one [1]. From these results, it was clarified that the CSA-JH method, which combined some productive advantages of the CSA-F and the JH methods, is one of effective techniques for production of high performance toroidal core with controlled permeability.

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[2] T. Yanai *et al., J. Magn. Magn. Mater.*, **290-291** (2005) 1502.
[3] T.Yana *et al., Conf. Proc. of SMM 16*, **2** (2004) 737.

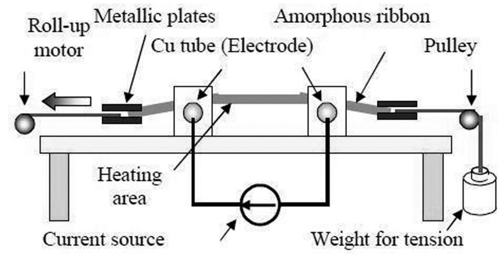

Fig.1 Schematic representation of continuous stress-annealing with Joule-heating.

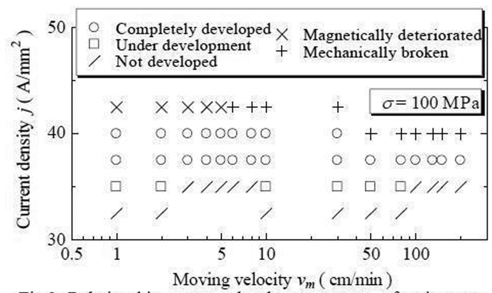

Fig.2 Relationship among development state of anisotropy, current density, j, and moving velocity, v_m. "○", "□", "/", "×", and "+" indicate "completely developed", "under development", "not developed", "occurence of large corecivity", and "mechanically-broken during annealing", respectively.

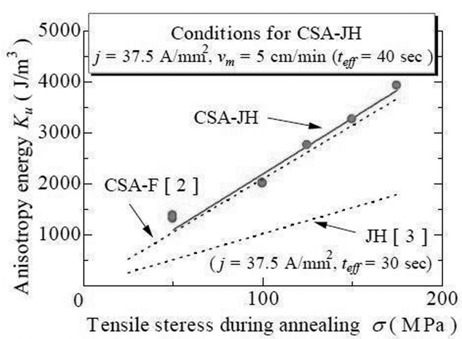

Fig. 3 Anisotropy energy of ribbons prepared by CSA-JH as a function of tensile stress during annealing. The results obtaind by CSA-F and JH were also shown in the figure [2, 3].