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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 Fe73.5Cu1Nb3Si15.5B7 ribbons (Hitachi Metals Ltd.), 2 mm wide and 20 µm thick, were annealed under tensile stress, , 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, , and the moving velocity, , of the ribbons were varied from 32.5 to 42.5 A/mm² 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, , and , 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 , 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.