Appearance of Spotted Design by Magnetic Anisotropy Numerical Calculation

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Abstract — Spotted design appears by magnetic anisotropy numerical calculation. Magnetic flux density distribution parts in the strong part and the weak part like a spotted design. The spotted design appears like magnetic domain structure as cord pattern. They have also fractal characteristics dependent on the number of the analysis mesh. The same spotted design as the one obtained by magnetic anisotropy is also observed by structure analysis in crystal structure level.

I. Introduction

Magnetic anisotropic characteristic is an important phenomenon for electrical steel, because it makes much influence on the design and development of the electrical equipment. Numerical calculation is widely used, and several magnetic anisotropic calculation models are considered. Among them, φ-anisotropic method is considered to have superior merits to the others from a point of view of the convenience of measurement and calculation scheme [1].

When φ-anisotropic method was applied to a simple calculation model at this time, a special phenomenon of a spotted design came out. A repeated pattern of strong part and weak part is observed in magnetic flux density distribution, which quite resembles the magnetic domain structure. It also has the fractal structure when some part of them is enlarged. Then the details are reported as below.

II. Numerical Calculation Method and Model

Static magnetic field based on A-method is used here. To calculate the non-linear magnetic characteristic of the steel (in Fig. 1-(a)), the Newton–Raphson method is applied for a convergence calculation. Finite element method and Galerkin method are used as a numerical calculation method.

Fig. 1-(b) is a two-dimensional calculation model. A specimen with magnetic anisotropic characteristics is excited from left to right in X-axis. It is divided into an A-part and a B-part. The B-part is at the center of 30mm×30mm in the specimen and the other is A-part. The A-part has a magnetization easy axis in the X-axis. The direction which inclines 30 degrees from the X-axis is a magnetization easy axis of the B-part.

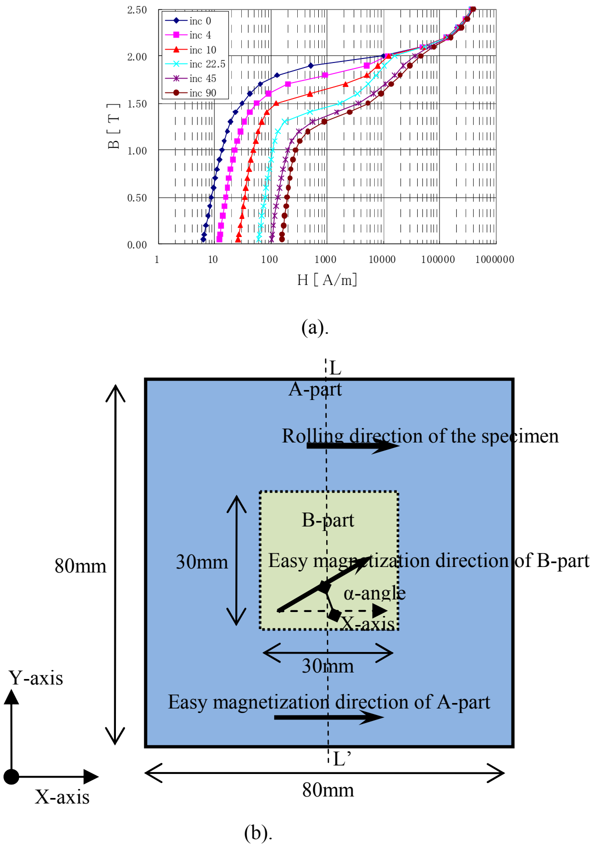

Fig.1. Two-dimensional calculation model of φ-anisotropic model with exiting coil (α=15), (a) non-linear magnetic characteristic of the steel, (b) specimen.

III. Calculation Results and Discussion

Calculated magnetic flux density distribution is shown in Fig.2, when division mesh size changes as 30×30, 64×64, 160×160, 240×240. The spotted design appears for all mesh sizes. As mesh size becomes big, the pitch of the outbreak frequency of the spotted design becomes small.

To obtain the details distribution of the spotted design, the one by fine mesh as 960×960 is shown in Fig. 3. It is partially enlarged in sequence from Fig. 3-(a) to Fig. 3-(c).

A special design called cord pattern is observed at T-part of Fig. 3-(a). When the T-part is enlarged, another cord pattern is also observed at U-part of Fig. 3-(b). Furthermore, when the U-part is enlarged again, another cord pattern is also observed at V-part of Fig. 3-(c). Since the V-part is an enlargement of the U-part, it is said that the fractal structure

[2] of the cord pattern is clearly observed in the φ-anisotropic calculation results.

The calculated cord pattern quite resembles the measured data of the magnetic domain structure of Si-Fe [3]. Such a plotted design is also observed at the numerical structure analysis in the crystal structure level [4]. The spotted design seems to be a fundamental characteristic of anisotropic property in numerical calculation.

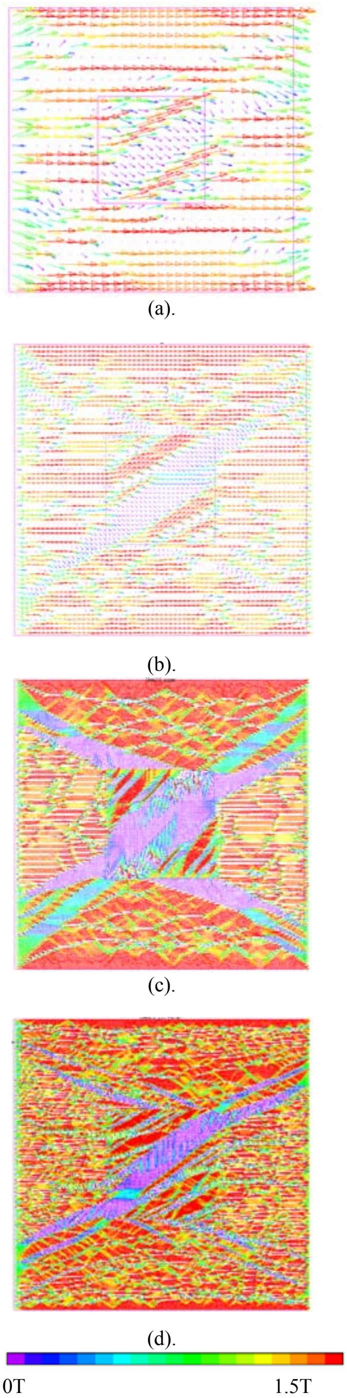

Fig.2. Calculated magnetic flux density distribution in changing division mesh size, (a) 30×30, (b) 64×64, (c) 160×160, (d) 240×240.

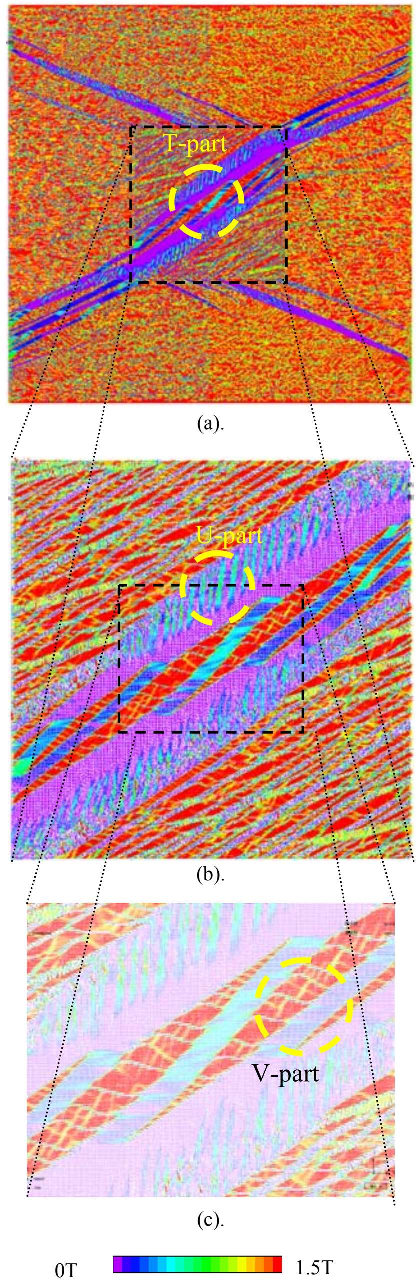

Fig.3. Partially enlarged distribution of magnetic flux density. (a) specimen size, (b) enlargement of the specimen, (c) enlargement of (b).

IV. References

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