Investigation on Simple Numeric Modelling of Anomalous Eddy Current loss in Steel Plate Using Modified Conductivity

Yanhui Gao[1], Yuhei Matsuo [1], Kazuhiro Muramatsu[1]
[1] Dept. of Electrical and Electronic Engineering, Saga Univ., Saga, Saga 840-8502, Japan
gyanhui@cc.saga-u.ac.jp, 07236082@edu.cc.saga-u.ac.jp, muramatu@cc.saga-u.ac.jp

Abstract — To calculate the eddy current loss in laminated steel plates of reactor driven by inverter power supply accurately, the anomalous eddy current loss generated by domain wall motion should be considered. A simple numeric modelling of anomalous eddy current loss by modifying the conductivity of steel plates is sometimes used. However, investigation on this method in detail has not been carried out. This method is applied to the loss calculation of various kinds of oriented and non-oriented materials taking into account skin effect and not and compared with the measured data. The variation of the modified conductivity with flux density and frequency is calculated and an improved method is proposed using the obtained modified conductivity to consider the anomalous eddy current loss accurately.

I. Introduction

We have developed the method of magnetic field analysis which models a laminated core as a solid one taking account of eddy currents in the steel plate by using the finite element method [1]. In this method, the 1D eddy current sub-analysis of steel plate is carried out for each element in main-analysis of the solid core model and the classical eddy current loss can be obtained directly. However, in the iron loss calculation of reactor under inverter power supply, the calculated iron losses are much smaller than the measured one [2] because the anomalous eddy current loss generated by domain wall motion was neglected [3]. In order to take account of the anomalous eddy current loss, the numeric modelling of modifying the conductivity of steel plate is sometimes used [4] but investigation in detail has not been carried out.

In this paper, first, the conductivity modification method to include the anomalous eddy current loss is applied to the loss calculation of various kinds of oriented and non-oriented materials to include the anomalous eddy current loss, taking account of skin effect and not. The calculated iron losses are compared with the measured data from catalogue to figure out the applicability of the proposed method. Then variation of the modified conductivity with the maximum average flux density and frequency is obtained by making the calculated iron losses equal to the measured data. Finally, an improved method will be proposed to consider the anomalous eddy current loss accurately using the modified conductivity.

II. Methods of Modelling

First, the simple numeric modelling method for considering the anomalous eddy current loss by modifying the conductivity of steel plates taking account of skin effect is described. In this modelling, the classical eddy current in the steel plate with the modified conductivity σ^* (= $k_e\sigma$, k_e : the modified factor, σ: the original conductivity of steel plates) is calculated by using the 1D nonlinear eddy current finite element analysis as shown in Fig. 1. The modified factor k_e is determined by fitting the calculated iron losses of one sheet of steel plate with the measured data under chosen flux density and frequency.

Next, the simple calculation method of the iron loss not taking account of skin effect using the empirical equation of the classical eddy current loss [5] is described. The anomalous eddy current loss is considered when the original conductivity is multiplied by the modified factor k_e. The modified factor k_e is also determined by fitting the calculated iron loss with the measured one under chosen flux density and frequency.

III. Analyzed Model

The simple numeric method is applied to the iron loss calculation of one sheet of steel plate of various kinds of materials. Non-oriented and oriented magnetic materials with different thickness of the steel plates are chosen. The steel plate is assumed to be infinity in x and y directions. The applied average flux density B is the sinusoidal waveform with amplitude B_{max}. By fitting the iron loss calculated under chosen B_{max} and f with the measured data in catalogue, a constant value for the modified factor k_e in the applied method with skin effect can be determined.

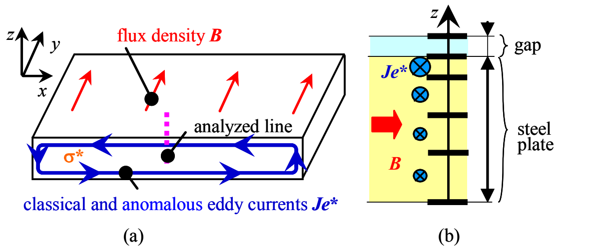

Fig. 1. Modelling method of modifying conductivity taking account of skin effect, (a) modelling, (b) mesh for half region of one steel plate.

IV. Results and Discussion

Fig. 2 shows the iron losses at different maximum average flux densities B_{max}s and frequencies fs obtained from the simple numeric modelling taking account of skin effect and the catalogue data of non-oriented materials JIS C 2552-1986: 35A270 and 35A440, respectively. k_e is determined at fitting point shown in Fig. 2. The iron losses of the non-oriented materials obtained from the simple numeric modelling are in good agreement with the catalogue data in a wide range of frequencies. Fig. 3 shows the iron losses under same conditions not taking account of skin effect and the catalogue data of the same non-oriented materials. The iron losses obtained from the simple calculation method are not in good agreement with the catalogue data in high frequencies.

Therefore, for the non-oriented materials, the method of modifying the conductivity taking account of skin effect is applicable for accurate anomalous eddy current loss calculation.

In the same way, the iron losses under same conditions with and without consideration of skin effect of the oriented materials JIS C 2550-1986:23P90 and 23P110 are shown in Fig. 4 and 5. It is found that the calculated iron losses are not in accordance with the catalogue data for the oriented materials either with or without considering the skin effect.

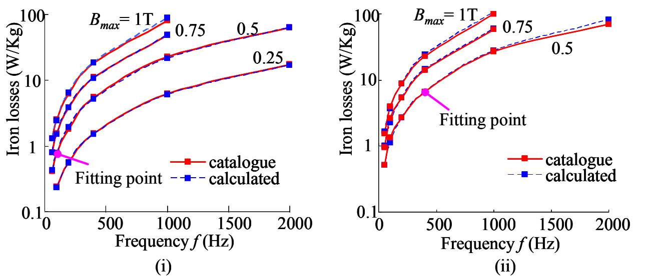

Fig. 2. Comparison of calculated iron losses with catalogue data taking account of skin effect of non-oriented materials (i) 35A270, k_e = 1.62, (ii) 35A440, k_e = 1.45.

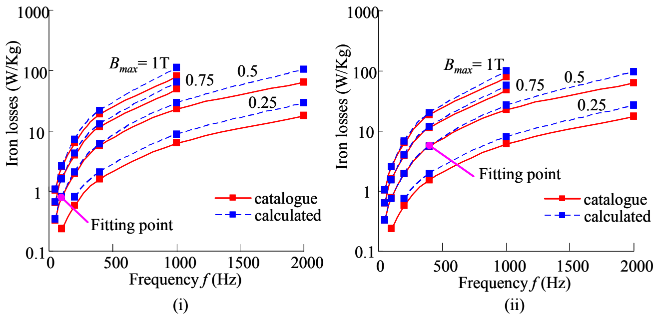

Fig. 3. Comparison of calculated iron losses with catalogue data not taking account of skin effect of non-oriented materials (i) 35A270, k_e = 1.94, (ii) 35A440, k_e = 1.75.

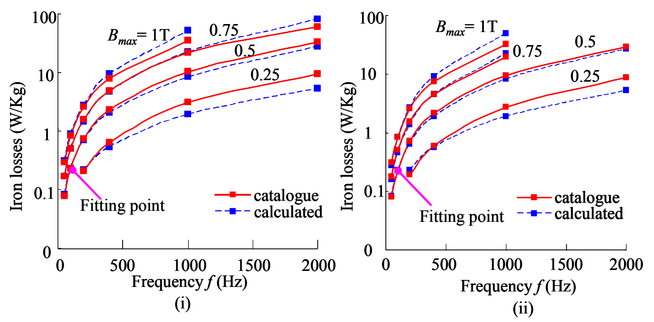

Fig. 4. Comparison of calculated iron losses with catalogue data taking account of skin effect of oriented materials (i) 23P90, k_e = 2.92, (ii) 23P110, k_e = 2.38.

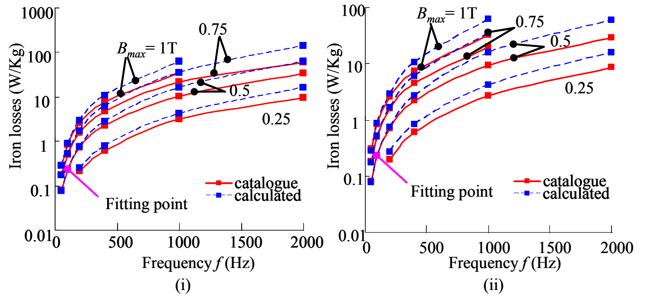

Fig. 5. Comparison of calculated iron losses with catalogue data not taking account of skin effect of oriented materials (i) 23P90, k_e = 2.66, (ii) 23P110, k_e = 2.57.

Furthermore, the variation of the modified factor k_e with the maximum average flux density B_{max} and frequency f of oriented materials are obtained by fitting the calculated iron losses with the measured ones and the obtained variation of k_e of material 23P90 without skin effect is shown in Fig. 6 as an example. We found that the variation of k_e with frequency f is much larger than that with B_{max} normally and the variation of k_e with B_{max} can be almost neglected. Next, the variation of k_e is approximately a regular nonlinear function of the frequency f such as shown in Fig. 6. A quadratic fitting curve shown in Fig. 6 is obtained using the nonlinear quadratic regression method. It can be seen that the fitting curve can coincide with the variation of the modified factors well enough. An improved method for the oriented materials to consider the anomalous eddy current loss accurately using the obtained modified factor variation will be proposed and reported in the full paper.

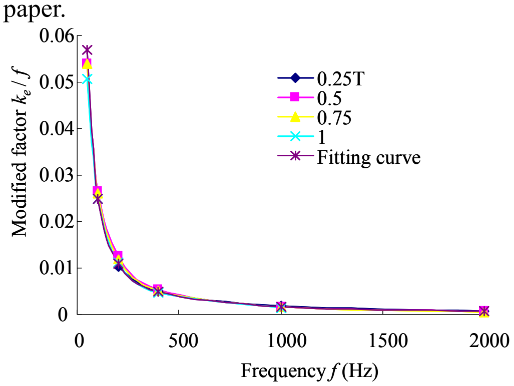

Fig. 6. Variation of modified factor k_e with maximum average flux density B_{max} and frequency f. (oriented material: 23P90).

V. References

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