Modeling of Excess Loss Due to Variation of Grain Orientation in Non-Oriented Electrical Steel Sheet

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Abstract

To clarify the mechanism of the excess loss in a Non-Oriented (NO) electrical steel sheet, a modeling of excess loss taking account of the variation of grain orientation is proposed in this paper. In the proposed method, the NO steel sheet is modeled by grains with random orientations, then an uniaxial anisotropic magnetic characteristic is considered in each grain. The nonlinear eddy current analysis of a simple model composed of cubic grains with different easy axes is carried out by using the initial anisotropic *BH* curves of a Grain-Oriented steel sheet. Then, the calculated eddy current loss is compared with the measured values of an actual NO steel sheet. It is shown that the proposed model can represent the excess loss in low flux density region, but not in high flux density region.

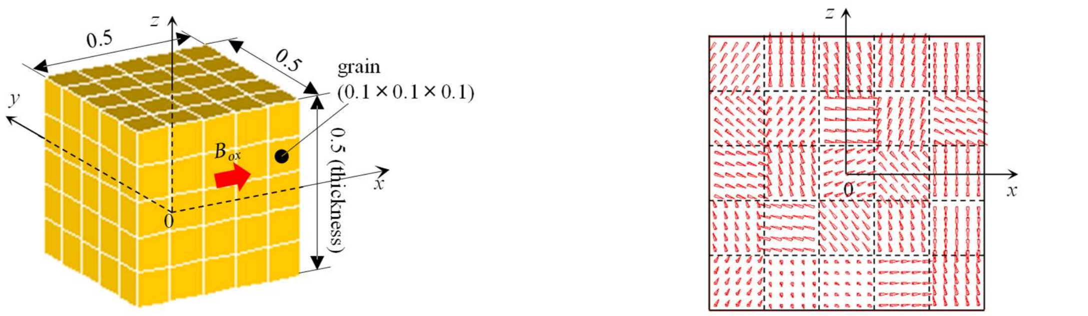
1 Introduction

To investigate the iron loss reduction of electric machines with non-oriented (NO) electrical steel sheets, the mechanism of excess loss in NO steel sheet should be clarified [1]. To explain the excess loss, the Pry and Bean magnetic domain model [2], in which the excess loss is generated by the eddy currents around domain walls due to domain wall movements, is proposed. However, the excess loss of NO steel sheet cannot be explained because the domain width of NO steel sheet is not large enough to increase the eddy current loss in this model [3]. Then, a model to explain the excess loss by the non-uniformity of flux distribution due to the domain wall bowing is also proposed [4]. However, the mechanism of the excess loss of NO steel sheet seems to be not clarified at this moment.

In this paper, a steel sheet model composed of grains with random orientations is proposed to investigate the other possible cause of the excess loss generated in NO steel sheet. The nonlinear eddy current analysis of the proposed model is carried out, then the calculated eddy current loss is compared with the measured values of an actual NO steel sheet.

2 Analysis Model

Fig. 1 (a) shows a simple analysis model of the NO steel sheet (JIS: 50A350) composed of cubic grains with side length of 0.1 mm in a lattice pattern. The thickness of the sheet is 0.5 mm in z direction and the width in x and y directions are assumed to be infinite by using the symmetric boundary conditions. The conductivity σ is 1.923×10^6 S/m. Each grain has the uniaxial anisotropic magnetic characteristic and its easy axis is set to be random as shown in Fig. 1 (b). The initial *BH* curves [5] of the GO steel sheet (JIS: 30P100) is used for the uniaxial anisotropic magnetic characteristic of each grain. The nonlinear eddy current analysis with the $\boldsymbol{A}$-ϕ method ($\boldsymbol{A}$: magnetic vector potential, ϕ: electric scalar potential) is carried out with the flux densities B_{ox} applied in the x direction through boundary conditions.



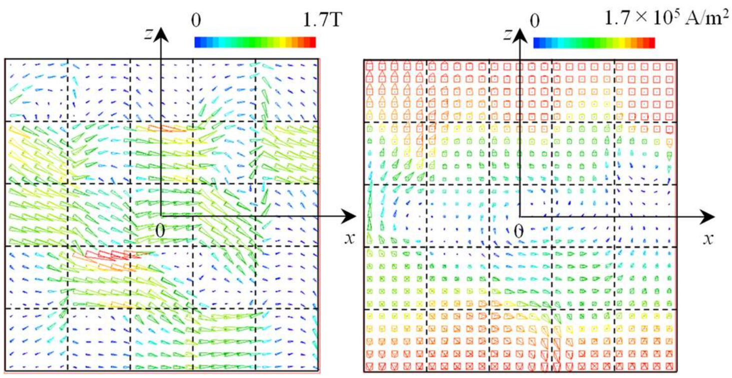
(a) model configuration (b) distribution of easy axes of grains (y = 0)

Figure 1: Analysis model of one sheet of NO steel plate

3 Results and Discussion

In the case the maximum value $B_{ox,\ max}$ of B_{ox} and the frequency f are 0.5T and 100 Hz, respectively, the flux and eddy current distributions of y = 0 obtained from the proposed model are shown in Fig. 2. The flux distribution becomes non-uniform due to the random orientation and the flux concentrates in the inner part as shown in Fig. 2 (a) because the flux in the inner part comes from both upper and lower sides but the flux near the surface comes from only inner part. Then, the area near the surface where the eddy currents are higher becomes larger as shown in Fig. 2 (b) and it causes the excess loss.

Fig. 3 shows the comparison of the average eddy current losses W_e's of $B_{ox,\ max}$ = 0.5 , 1.5 T and f =100 Hz obtained from the proposed model with the measurement ones of 50A350. In the proposed model, in addition to W_e's obtained using the random orientation (No. 1) shown in Fig. 1 (b), those obtained using two other random orientations (Nos. 2 and 3) are also shown. At $B_{ox,\ max}$ = 0.5 T, W_e's obtained from the proposed model are about 20% increased compared with the classical one and in good agreement with the measured one. However, at $B_{ox,\ max}$ = 1.5 T, W_e's obtained from the proposed method are not increased from the classical one and it is still smaller than the measured one because the flux distribution becomes uniform due to the saturation of flux density. So, it can be concluded that the proposed model can explain the excess loss in low flux density region, but not in high flux density region.



(a) flux distribution (b) eddy current distribution

Figure 2: Distributions ($B_{ox,\ max}$=0.5T, f=100Hz, y=0)

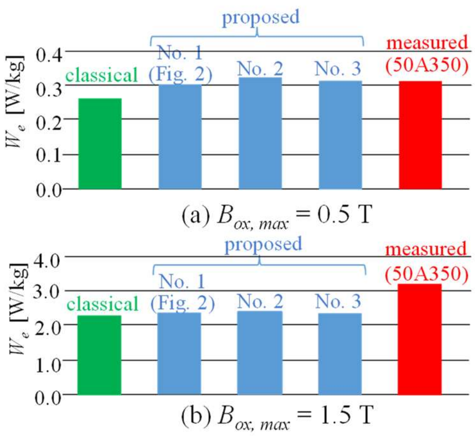


Figure 3: Eddy current losses (f=100Hz)

4 References

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