Vector Magnetic Characteristic Analysis of a Surface Permanent Magnet Motor by means of Complex E&S Modeling

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Abstract — This paper presents analyzed results of a surface permanent magnet motor by using the developed complex E&S modeling. The calculated results are compared with ones of the conventional E&S modeling for verification. The results demonstrate that the complex E&S modeling is very useful in designing under consideration of the rotational magnetic loss and magnetic anisotropy.

I. INTRODUCTION

In order to develop high-efficiency electrical machines, it is necessary to consider accurate magnetic properties in the structural designing. Recently measuring techniques of vector magnetic properties have been developed and their achievements have been got a lot of attention. The vector magnetic property enables us to know the rotational iron loss distributions and the magnetic anisotropic properties in the relationship between the flux density vector ***B*** and the field strength vector ***H*** [1].

We proposed the E&S modeling to consider the vector magnetic properties in magnetic field analyses. However, the E&S modeling is very time-consuming because of low-convergence property. To solve this problem, we have developed a complex E&S modeling with assumption that both the flux density and field strength waveforms are sinusoidal. The calculated results are compared with ones of the conventional E&S modeling for verification. The computation time of the complex E&S modeling becomes 1/20 in comparison with one of the conventional one [1].

In this paper, we reports results of the magnetic characteristic analysis of a surface permanent magnet motor, by combining the finite element method and the complex E&S modeling. The knowledge obtained in the numerical simulations is reported.

II. COMPLEX TYPE E&S MODELING

Assuming that the magnetic flux density and field strength waveforms are together sinusoidal, the time derivative can be replaced by the complex number, jω. Thus the complex E&S modeling can be expressed as follows,

$$\begin{cases} \dot{H}_x = \left(\bar{\nu}_{xr} + j\omega\bar{\nu}_{xi}\right)\dot{B}_x \\ \dot{H}_y = \left(\bar{\nu}_{yr} + j\omega\bar{\nu}_{yi}\right)\dot{B}_y \end{cases} \quad (1)$$

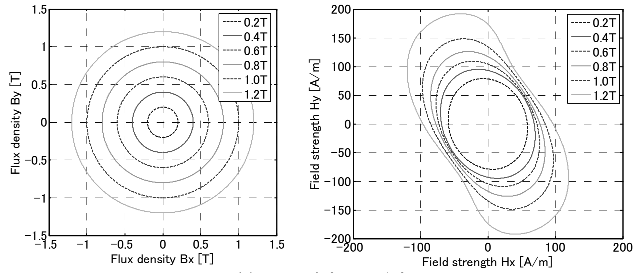
where, $\bar{\nu}_{xr}, \bar{\nu}_{yr}$ are the effective magnetic reluctivity coefficients and $\bar{\nu}_{xi}, \bar{\nu}_{yi}$ are the effective magnetic hysteresis coefficients. The variables with dot mean the complex variables. The governing equation of the magnetic field under consideration of the complex E&S modeling can be expressed by

$$\frac{\partial}{\partial x}\left(\bar{\nu}_{yr}\frac{\partial \dot{A}_z}{\partial x} + j\omega\bar{\nu}_{yi}\frac{\partial \dot{A}_z}{\partial x}\right) + \frac{\partial}{\partial y}\left(\bar{\nu}_{xr}\frac{\partial \dot{A}_z}{\partial y} + j\omega\bar{\nu}_{xi}\frac{\partial \dot{A}_z}{\partial y}\right) = -\dot{J}_{0z} \quad (2)$$

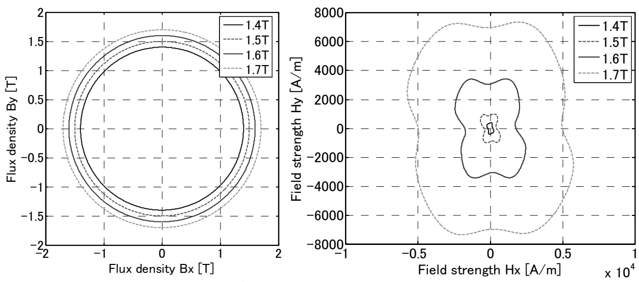
where, $\dot{A}_z$ is the magnetic vector potential and $\dot{J}_{0z}$ is the exciting current density in z-direction.

III. APPLICABLE RANGE

To use the complex approximation, we have to define the applicable range. Fig. 1 shows the vector magnetic property of the non-oriented electrical sheet in rotating flux conditions. The flux density trajectories are precise circular. The explanatory note shows the maximum magnetic flux densities. As shown in this figure, the field strength vector trajectories of the non-oriented electrical sheet are not ellipse. According to this result, the applicable range of complex E&S modeling was decided below 1T.



(a) From 0.2 T to 1.2 T.



(b) From 1.4 T to 1.7 T.

Fig. 1. Vector magnetic property of the non-oriented electrical sheet under rotating flux conditions.

IV. SURFACE PERMANENT MAGNET MOTOR MODEL

Fig. 2 shows the surface permanent magnet motor model. The arrows show the residual magnetization. Fig. 3 shows the finite element mesh arrangement. As shown in Fig. 2, three-phase stator windings were distributed. Table I shows the conditions used in the analysis.

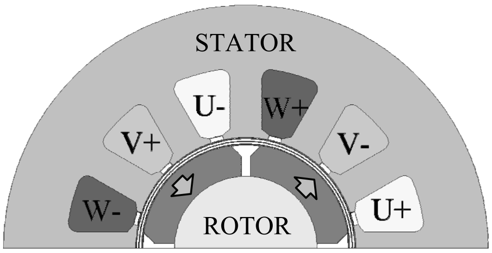


Fig. 2. Surface permanent magnet motor model

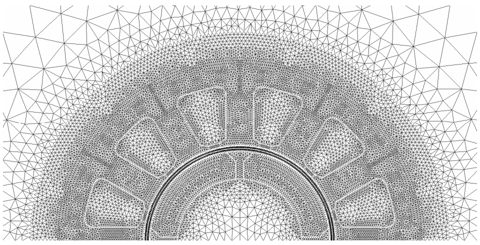


Fig. 3. Finite element mesh arrangement

TABLE I
CONDTIONS USED IN THE ANALYSIS

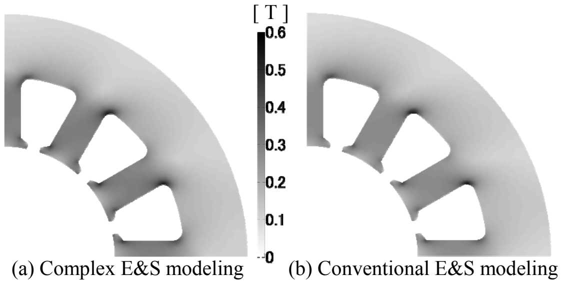
Outer diameter of the stator core	53.4 mm
Outer diameter of the rotor core	39.6 mm
Number of turns of the exciting coils	100
Electrical steel sheet	50A470
Exciting current	0 A
Residual magnetization	0.2 T
Revolution speed	1500 min^{-1}
Rolling direction	0 or 180 deg

V. CALCULATED RESULTS AND DISCUSSIONS

Figs. 4, 5, and 6 show the distributions of the maximum magnetic flux density, the maximum magnetic field strength, and the iron loss, respectively. The distributions obtained with the complex E&S modeling accorded well with ones of the conventional E&S modeling. Fig. 7 shows the hysteresis loops in X- and Y-direction. The shapes of hysteresis loops calculated by using the complex E&S modeling also accorded well with ones of the conventional E&S modeling.

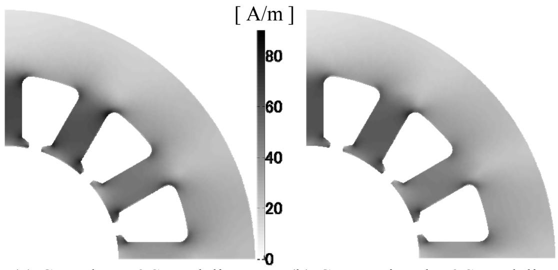
VI. CONCLUSION

This paper presents analyzed magnetic characteristics of the surface permanent magnet motor by using the complex E&S modeling. The results were compared with ones of the conventional E&S modeling in verification and a good agreement was demonstrated. The non-load and load characteristics of the surface permanent magnet motor were neglected in this digest because of the limitation of pages. The detailed results and a simplified optimization techniques based on the complex E&S modeling will be shown at the presentation and in the full version of paper.



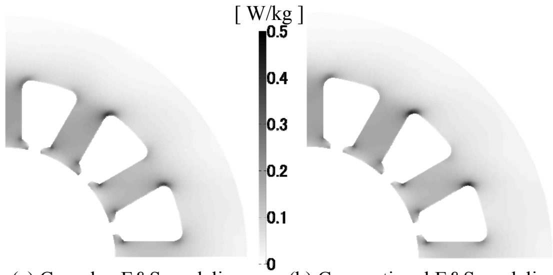
(a) Complex E&S modeling (b) Conventional E&S modeling

Fig. 4. Distributions of the maximum magnetic flux density.



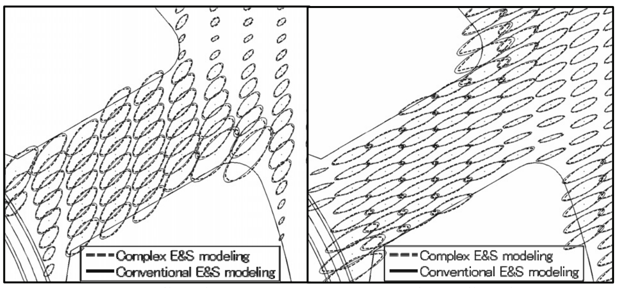
(a) Complex E&S modeling (b) Conventional E&S modeling

Fig. 5. Distributions of the maximum magnetic field strength.



(a) Complex E&S modeling (b) Conventional E&S modeling

Fig. 6. Iron loss distributions.



(a) X-direction (b) Y-direction

Fig. 7. Distributions of hysteresis loops in X- and Y-direction.

VII. REFERENCES

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