IRON LOSS EVALUATION FOR A SMALL HIGH-EFFICIENCY MOTOR STATOR CORE MADE OF AN ULTRATHIN ELECTRICAL STEEL SHEET UNDER PWM INVERTER EXCITATION USING THE STATOR WINDING EXCITATION METHOD

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Abstract. To develop a small high-efficiency motor for an aerospace machine, we developed a new stator core made of a 0.08-mm-thick ultrathin electrical steel sheet. The *B-H* curves and iron loss of the stator core were measured using the stator windings excitation method that we proposed. Experiments shows that when the excitation frequency was 2000Hz, the iron loss of the stator core was very low, and the eddy-current loss was especially low. Additionally, we measured the iron loss under pulse width modulation (PWM) excitation in the stator core. The stator core made of a 0.08mm-thick ultrathin electrical steel sheet for a small high-efficiency motor was deemed suitable for an aerospace machine.

1. Introduction

Motors used in space should be light and should generate little of heat. Small high-efficiency motors are being developed all over the world. In order to obtain a small high-efficiency motor, it is necessary to develop a high speed rotation motor. It is well established that the rotational speed of the motor is proportionate to driving frequency. However, when the rotational speed of the motor increases, it is understood that the iron loss in the stator core increases. Moreover, the drive by a PWM inverter increases the iron loss in the stator core of the motor [1, 2]. When the PWM inverter is used or a motor rotates at high-speed, the ensuing increase of iron loss in the stator core manifests as an eddy current. In order to decrease the eddy-current loss in the stator core of a small, high-efficiency motor, we developed a new stator core made of an ultrathin electrical steel sheet. Moreover, we compared the iron loss of the stator core that used this ultrathin electrical steel sheet and the iron loss of the stator core that used a conventional electrical steel sheet. In this paper, we report usefulness of the stator core made of an ultrathin electrical steel sheet.

2. Measurement Method

We prepared two small motor stator cores that were made of two kinds of electrical steel sheets including the 0.08-mm-thick ultrathin electrical steel sheet and a 0.35-mm-thick electrical steel sheet. The two stator cores were called the 0.08mm_Core and the 0.35mm_Core. Figure 1 shows the dimension and arrangement of a stator core, a dummy rotor, excitation coils and a search coil. The effective magnetic pass length shown in Fig. 1 occurred when the iron loss as measured. The dummy rotor was also made of the 0.08-mm-thick ultrathin electrical steel sheet. The stator cores and the dummy rotor were cut off of the laminated electrical steel sheet with a wire-electrical discharge machine and both laminated thicknesses were 12.5 mm. Figure 2 shows the schematic drawing of the magnetic property evaluation system under PWM wave excitation. When the iron loss was measured under PWM wave excitation, the excitation magnetic flux density controlled the maximum value (B_{ex1st}) of the fundamental wave of the measured magnetic flux density in the stator core.

3. Results

The iron loss W_i [W/kg] was evaluated using Eq. (1), where, ρ [kg/m^3] is the material density of stator cores and T [s] is the period of the excitation current (see below).

Figure 3 shows the measured the *B-H* curve of the 0.08mm_Core using the stator windings excitation method when the modulating signal frequency (f_m), the carrier frequency (f_c), B_{ex1st}, and modulation index (m) were 200 Hz, 5 kHz, 1.2 T, and 0.6, respectively. From this figure, the *B-H* curve was long and slender because there was a gap of 0.1 mm between the stator core and the dummy rotor. Moreover, the minor loop was observed through the influence of the PWM excitation wave form.

The comparison between the measured iron loss (W_{isin}) under the sinusoidal wave excitation and the measured the iron loss (W_{ipwm}) under PWM wave excitation when f_m, f_c , and m were 200Hz, 5 kHz and 0.6, respectively, is shown in Fig.4. As seen in Fig. 4, W_{isin} and W_{ipwm} of the 0.08mm_Core were smaller than those of the 0.35mm_Core. Moreover, the ratio of W_{ipwm} and W_{isin} (W_{ipwm}/W_{isin}) was 1.32 in the 0.08mm_Core, and

1.85 in the 0.35mm_Core. It is thought that the cause of the decreased iron loss of the 0.08mm_Core under the PWM inverter excitation condition was caused by a decrease in the eddy-current loss by a decrease in the electrical steel sheet thickness.

$$W_i = \frac{1}{\rho T} \int H_{ex} \cdot \frac{dB_{ex}}{dt} dt \quad (1)$$

Conclusions

We developed a new stator core made of a 0.08-mm-thick ultrathin electrical steel sheet. The magnetic properties of the new stator core were measured using the stator windings excitation method. The iron loss of the ultrathin electrical steel sheet clearly decreased at a excitation frequency (200Hz). The iron loss of the stator core was limited under PWM wave excitation as well. The stator core made of 0.08mm-thick ultrathin electrical steel sheet was suitable for the small high-efficiency motor well. The full paper shows the usefulness of the stator core made of an ultrathin electrical steel sheet..

Acknowledgments

We would like to thank the Japan Society for the Promotion of Science (grant no.17K06480) for partially funding our study.

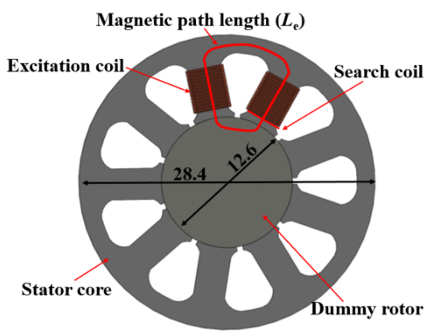

Fig.1. Arrangement of a stator core, a dummy rotor, excitation coils, and a search coil.

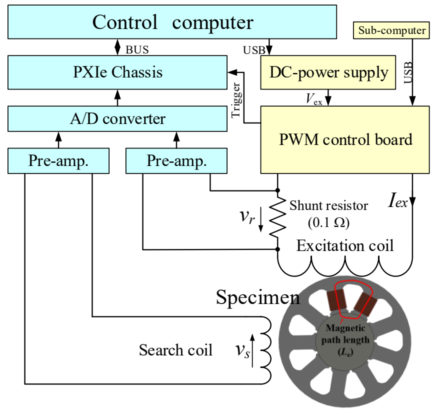

Fig.2. Schematic drawing of the magnetic property evaluation system under the PWM inverter excitation.

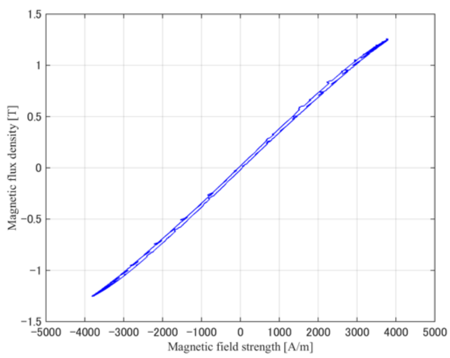

Fig.3. *B-H* curves (0.08mm_Core, f_m=200Hz, f_c=5kHz, m=0.6, B_{ex1st}=1.2T).

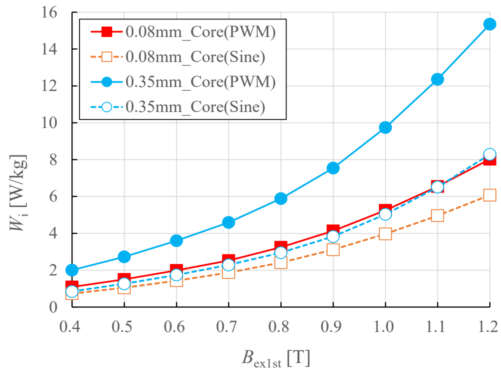

Fig.4. W_{isin} vs. W_{ipwm} (f_m=200Hz, f_c=5kHz, m=0.6).

References

[1] Kogi R., Odawara S., and Fujisaki K. Iron Loss Increase due to Increase of Carrier Frequency on Inverter, IEE Japan, MAG-13-150, 2013, pp. 7-12.

[2] Oka M., Enokizono M., Mori Y., Yamazaki M. Building Factor Evaluation of the Stator Core made of Ultrathin Electrical Steel Sheet for the High-speed Motor, Material Science Forum, Vol. 915, 2018, pp. 9-15.