Cooling control by secondary current heating and magnetic properties for actual laminated stator cores

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In this paper, we evaluated the magnetic properties of actual laminated stator cores were evaluated by the secondary current heating method. The secondary current heating method directly heats the heated object, thus achieving high thermal efficiency and short heat treatment time. In addition, since the secondary current can be controlled by adjusting the excitation voltage, the temperature of the object to be heated can be easily controlled. Based on these advantages, we attempted to further reduce iron loss by heat treatment, including cooling time control. As a result, further reduction of iron loss was obtained by the heat treatment including the newly investigated cooling control.

Keywords: secondary current heating, actual laminated stator core, iron loss

1. Introduction

In recent years, energy conservation has been required in the electrical energy field to achieve carbon neutrality. Therefore, we thought that energy conservation could be achieved by improving the efficiency of motors, which account for about 46% of the world's electric power consumption. One of the factors that deteriorate the magnetic properties of motors is the residual stress generated in the motor manufacturing process. Since this residual stress can be reduced by heat treatment, we proposed the Secondary Current Heating method, which is a direct heating using secondary current [1]. Figure 1 shows the B-H loops of the actual stator cores before and after heat treatment by the Secondary Current Heating method. The area surrounding the B-H loop has been significantly reduced by heat treatment. This is due to the significant reduction of residual stress by Secondary Current Heating. In addition, it is generally known that heat treatment can relieve residual stress by cooling slowly. In order to further reduce iron loss in actual stator cores using the Secondary Current Heating, this paper examines the effect of cooling control on magnetic properties was investigated.

2. Secondary Current Heating method

Figure 2 shows the Secondary Current Heating device. It consists of an excitation coil, yoke, and stator core. When an excitation voltage is applied to the excitation coil, an alternating magnetic flux is generated in the yoke. This alternating flux chainages with the stator core, an induction voltage is generated and a secondary current flows in the stator core. Since the stator core itself generates heat, it can be directly heated, resulting in high thermal efficiency and short heat treatment time. Furthermore, the secondary current can be controlled by adjusting the excitation voltage, enabling cooling control.

3. Results and discussion

Figure 3 Temperature characteristics during heat treatment by the secondary current heating. The heat treatment with air cooling is shown as “Air cooling” and the heat treatment with extended cooling time by changing the excitation voltage is shown as “Slow cooling”. Figure 4 shows the iron loss improvement ratio for Air cooling and Slow cooling. The iron loss improvement ratio is obtained from Equation (1).

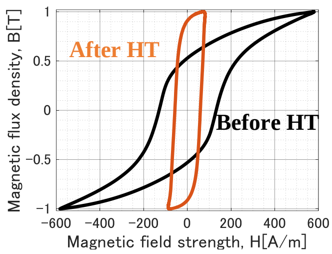

Figure 1: B-H loop

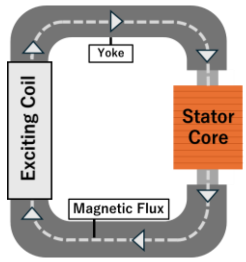

Figure 2: Secondary current heating device.

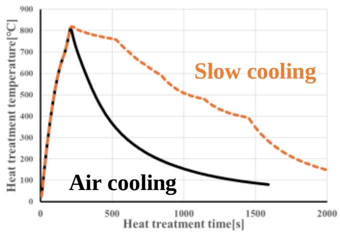

Figure 3: Temperature characteristics.

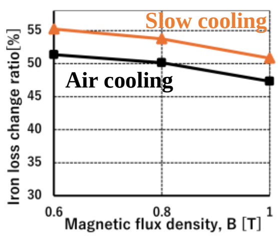

Figure 4: Iron loss improvement ratio.

$$\text{iron loss improvement ratio } [\%] = \frac{(before\ HT) - (after\ HT)}{before\ HT} \times 100 \tag{1}$$

The air-cooling and slow-cooling methods improved iron loss by a maximum of 51% and 55%, respectively. The reason for the higher improvement ratio of slow cooling compared to air cooling is thought to be that the cooling time allowed for a greater reduction in residual stress. As a result, it was shown that cooling control is effective in reducing iron loss. Our full paper will present the effects of cooling controls on other heat treatment conditions and iron loss separations.

References

[1] Yuji Tsuchida, Tomohiro Yano, Journal of The Japan Society of Applied Electromagnetics and Mechanics, Vol. 31, No. 2, pp. 291-296, 2023.6.