Estimation method for punched magnetic properties of electrical steel sheet

Takahiro Mizuta[a], Akito Ito[a], Yu Hirotani[a], Koji Fujiwara[b]

[a] *Mitsubishi Electric Corporation, Amagasaki, Japan.* [b]*Doshisha University, Kyoto, Japan*

It is well-known that the magnetic properties of electrical steel sheets used in motors deteriorate during manufacturing processes. To identify the magnetic properties of the punched edges, it is necessary to measure several punched test specimens. In this paper, we estimate the punched magnetic properties of unmeasured materials based on multiple punched measurement results and apply them to the magnetic field analysis of an induction motor. We confirm that the no-load loss of measured magnetic properties is in good agreement with that of the estimated magnetic properties.

Keywords: Magnetic properties, Punching, Estimation, BH curve, Iron loss.

1. Introduction

In recent years, there has been a significant push towards the energy and resource efficiency of equipments, including motors. It is well-known that the magnetic properties of electrical steel sheets used in motors deteriorate during manufacturing processes. Previous research has identified the magnetic properties at the punched edges by measuring several punched electrical steel strips and applied these properties to magnetic field analysis [1]. However, this application requires the actual measurement results of punched test specimens, making it impossible to apply to materials without such measurement results. Therefore, this report attempts to estimate the punched magnetic properties of unmeasured materials based on multiple punched measurement results. Additionally, the impact of estimation accuracy on motor performance is examined through magnetic field analysis.

2. Measurements results and estimation method

The properties of the electrical steel sheets investigated are shown in Table 1. In this report, we used the measurement results from Nos.1 to 7 to estimate the measurement results of No.8. The test specimen size is 30mm × 180mm. Multiple punched test specimens with widths of 6 mm and 2 mm were prepared and put together to form a 30-mm width. For comparison, we used the same method to measure a 30mm × 180mm-sized wire-cut test specimen. The measured BH curve of No.1 is shown in Figure 1 (a). The following equations are used to represent the degradation of the BH curves.

$$B_p(H) = \mu_0(1-p)\,H + p\,B(H) \quad (1)$$

$$p = p_0 \quad (B \le B_{midp}) \quad (2)$$

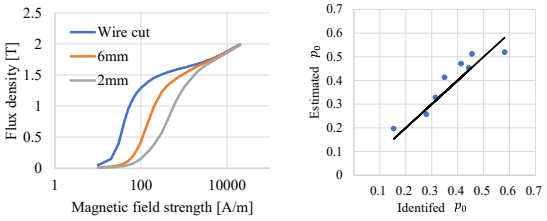
$$p = p_0 + (1-p_0)\frac{B - B_{midp}}{B_{maxp} - B_{midp}} \quad (B_{midp} < B \le B_{midp}) \quad (3)$$

$$p = 1 \quad (B_{maxp} \le B) \quad (4)$$

$B(H)$ is the BH curve of the wire-cut specimen, and the p_0 and B_{midp} values were identified so that the BH curve of the punched specimen matches $B_p(H)$. The correlation between the identified p_0, B_{midp}, grain size and hardness was analyzed and estimation equations were developed. The estimated result of p_0 is shown in Figure 1 (b). As can be seen, the estimated p_0 can be well fitted to the identified p_0. The details are omitted here, but iron loss can be estimated in the same way.

No	Thickness [mm]	Grain Size [μm]	Hardness [HV]
1	0.50	84	153
2	0.35	45	163
3	0.35	93	204
4	0.50	38	135
5	0.25	85	227
6	0.35	64	200
7	0.35	83	166
8	0.35	75	192

Table1: Properties of the investigated electrical steel sheets



(a) (b)

Figure 1: (a) Measured BH curve of No.1 (b) Comparison between identified p_0 and estimated p_0 in 6mm width.

3. FEM comparison in induction motor

To verify the estimation accuracy, magnetic field analysis was conducted on an induction motor, with a 160-mm stator outer diameter. The no-load loss was calculated based on the measured punched magnetic properties of No. 7 and estimated punched magnetic properties. The Comparison results are shown in Figure 2. Both results show good agreement, confirming the usefulness of the estimation method.

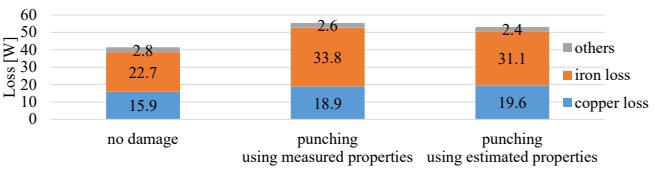


Figure 2: Calculated iron loss of induction motor by magnetic field analysis

References

[1] H. A. Weiss *et al.*, " Impact of Punching Parameter Variations on Magnetic Properties of Nongrain-Oriented Electrical Steel," in *IEEE Trans Ind Appl*, vol. 54, no. 6, pp. 5869-5878, Nov.-Dec. 2018