Reexamination of applicability of H-coil method for single-sheet tester

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As an evaluation method for the magnetic field strength in a single-sheet tester (SST) used for measuring the magnetic properties of electrical steel sheets, the magnetic current (MC) method is standardized, despite requiring an effective magnetic path length [1]. In contrast, the H-coil (HC) method [2, 3] has not yet been standardized due to the lack of a systematic examination of its measurement accuracy and repeatability compared to the MC method. Therefore, various factors affecting the measurement accuracy, such as the winding length and width of the H-coil and its installation position, are reexamined. The repeatability is also investigated by measurements taken over several dozen days. Then, both methods are compared.

Keywords: Single-sheet tester; H-coil method; Magnetic current method; International standardization; Electrical steel sheet

1. Introduction

Electrical steel sheets, widely used as iron core materials, require precise evaluation of their magnetic properties to design low-loss devices. An SST is commonly used for this purpose, employing two methods to evaluate the magnetic field strength: the IEC standardized MC method and the HC method. The HC method does not use an effective magnetic path length, which is required in the MC method. The HC method may be advantageous for getting magnetic properties applicable to magnetic field analysis. This is because the magnetic field strength near the specimen surface can be directly measured with high accuracy. However, it has not been approved as a standard method for half a century due to insufficient examination of its applicability, although the HC method is frequently used when evaluating machine characteristics. To improve the situation, we clarify the measurement repeatability after a comprehensive study focusing on HC dimensions to validate its effectiveness and enhance its reliability

2. Results and discussion

In this study, the measurement repeatability of the HC and MC methods is examined using three types of grain-oriented (GO) electrical steel sheets and a non-oriented (NO) one. A specimen size is 100 mm × 500 mm. A vertical double-yoke SST is used, of which the inner distance between the pole pieces and the width of the wound-core type yoke are 306 mm and 15 mm, respectively. Based on the influence of the HC's area size and the measurement accuracy obtained from the nonlinear 3-D finite element analysis, an HC with dimensions of 85 mm × 200 mm is adopted.

Fig. 1 shows the coefficient of variation $CV\,(n)$ of iron loss P for n measurements, where n indicates the measurement number. The magnetic field strengths are evaluated simultaneously by the HC and MC methods. $CV\,(n)$ is defined as follows. $P_{\mathrm{ave}}\,(n)$ is the average iron loss for n measurements.

$$CV(n)=\sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\{P_k-P_{\mathrm{ave}}(n)\}^2}\,/\,P_{\mathrm{ave}}(n),\ (n=1,2,...,N,N:37). \quad (1)$$

$CV\,(n)$ s for the GO and NO are examined at the maximum flux densities of 1.7 T and 1.5T, respectively. In both methods, $CV(n)$ ranges from a similar variation of 0.2 % to 0.6 %. It cannot be concluded that the HC method is obviously inferior to the MC method.

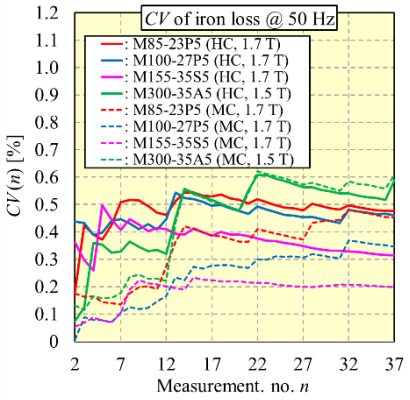

Figure 1: Coefficients of variation of iron losses measured by the H-coil and MC methods.

Fig. 2 shows the effective magnetic path lengths L_{eff}. It is calculated as the iron loss obtained by the MC method matches that obtained by the HC method. L_{eff} changes depending on B_{m} as well as grades of electrical steel sheets. The details will be described in the full paper.

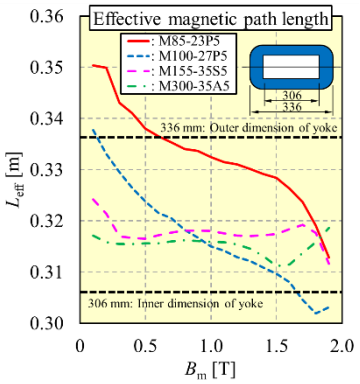

Figure 2: Effective magnetic path length.

References

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