Evaluation method of dc-biased magnetic properties by using ac measurement

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At an annual meeting held in Torino in September 2024, a Chinese national committee responsible for IEC TC68 activities proposed a project that includes an international round-robin test to evaluate dc-biased magnetic properties. This issue is relevant to the ultra-high-voltage dc (UHVDC) power transmission lines installed in China [1]. The proposal specifies excitation by using a dc winding in addition to an ac one. It would be very effective if the ordinary ac measurement system could be applicable to the measurement of dc-biased magnetic properties. To address this problem, the ac measurement system is improved, and features of results obtained by using a distorted flux density waveform are examined.

Keywords: DC-biased magnetic properties, UHVDC power transmission, AC measurement, Distorted waveform

1. Introduction

We have been developing measurement systems under sinusoidal flux conditions [2] for many decades, primarily to investigate the ac magnetic properties of mainly electrical steel sheets used as iron core materials in electric machines such as transformers, inductors, and motors. The system is improved to evaluate the dc-biased magnetic properties by utilizing a distorted flux density waveform [3, 4].

2. Results and discussion

Eq. 1 shows the time variation of average flux density in the specimen to be controlled. Before the measurements are performed, the amplitudes B_{m1} and B_{m3} of the fundamental and 3rd harmonic components in Eq. 1 are calculated under the condition that the maximum flux density B_{max} of $b(t)$ and the amplitude B_m of the ac component of the non-symmetric minor loop are specified. The non-symmetric loop occurs at the tip of the hysteresis loop because the fundamental and 3rd components are in phase. f in Eq. 1 is the excitation frequency.

$$b(t) = B_{m1}\sin(2\pi f t) + B_{m3}\sin(6\pi f t). \qquad (1)$$

Fig. 1 shows the non-symmetric minor loops for $B_m = 0.2$ T. They are extracted from the hysteresis loops. A loop of thick black solid line is measured under the sinusoidal flux condition that only the 3rd harmonic component is used, namely $B_{m1} = 0$ and $B_{m3} = B_m$ in Eq. 1. It seems that reasonable dc-biased non-symmetric minor loops have been obtained.

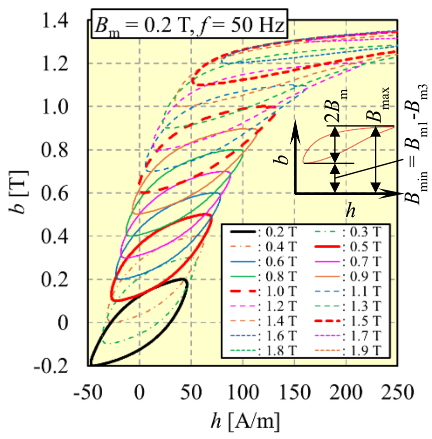

Figure 1: Non-symmetric minor loops for $B_m = 0.2$ T at $f = 50$ Hz.

Fig. 2 shows their area S_{minor} and frequency f_{minor} for $B_m = 0.2$ T. f_{minor} increases as B_{max} increases. The symbols filled in represent the results measured under the sinusoidal flux condition of $b(t) = B_m \sin(6\pi f t)$. Assuming that S_{minor} changes linearly concerning f_{minor} as expressed in Eq. 2, the iron loss P_{minor} at f can be estimated by Eq. 3 [3]. When f is changed from 50 Hz to 100 Hz, f_{minor} at $f = 100$ Hz becomes twice that at 50 Hz because the flux density waveform is identical regardless of f. Therefore, f_{minor} can be controlled by f. When a frequency f_{minor_target} of the target non-symmetric loop is specified, a corresponding excitation frequency f_{target} can be determined as $f_{target} = f_{minor\_target} \times (50 / f_{minor})$ by using f_{minor} at $f = 50$ Hz shown in Fig. 2. The details will be described in the full paper.

$$S_{minor} = S_0 + S_1 f_{minor}. \quad (2) \qquad P_{minor} = S_0 f + S_1 f_{minor} f. \quad (3)$$

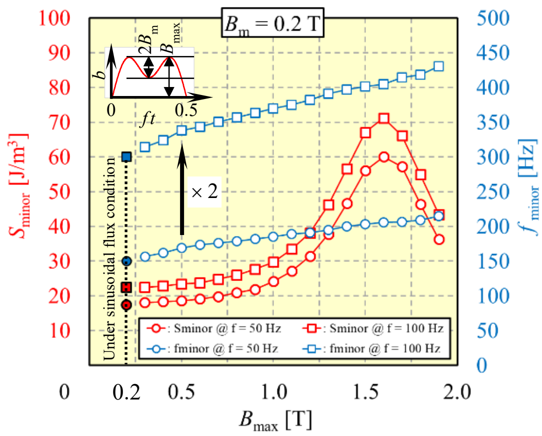

Figure 2: Area and frequency of non-symmetric minor loops (Specimen: non-oriented laminated ring, $W_{15/50} \leq 2.50$ W/kg).

References

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