Journal of ELECTRICAL ENGINEERING, VOL 69 (2018), NO6, 407–410

COMMUNICATIONS

Vector B-H tester for simple evaluation of vector magnetic characteristics

Shohei Ueno*, Masato Enokizono, Shinichi Inoue*****

This paper presents Vector B-H tester. Vector magnetic characteristics can express the vector relationship between magnetic flux density vector and magnetic field strength vector. A precise measurement method of vector magnetic characteristics has been imposed. However, this method spends time and requires an effort to prepare the measurement. Vector B-H tester can easily measure and evaluate the vector magnetic characteristics.

Keywords: vector B-H tester, vector magnetic characteristic, magnetizing current method

1 Introduction

In order to development high efficiency electromagnetic appliances such as a motor, it is necessary to measure detail magnetic characteristic of magnetic material used as a core. Vector magnetic characteristic is well known as a detail magnetic characteristic.

In precise measurement of vector magnetic characteristics [1, 2], a method combining search coil method and H-coil method is used generally. However, this precise measurement method spends time, effort and money to prepare samples for the measurement. For example, in the search coil method, it is necessary to drill four holes of $\Phi = 0.4$ mm in a sample of approximately 80×80 square mm, and to wind the coil through the holes. The other method has to use a calibrated double H-coil that is very expensive and difficult to handle. Vector B-H tester does not need winding the search coil and using double H-coil. In this paper we present Vector B-H tester to easily measure vector magnetic characteristics and evaluate its feates.

2 Vector magnetic characteristic

In the practical material, it is well known that the magnetic flux density and the field strength are vector quantities and their relation can be expressed by a tensor. However, the conventional measurement method such as SST and Epstein only provide scalar quantities. On the other hand, vector magnetic characteristics can measure the magnetic characteristics as a vector quantity. In order to evaluate accurately a magnetic material, it is necessary to measure vector magnetic characteristics.

Figure 1 shows the representation of the alternating and rotating flux conditions. In the definition, we used four parameters: the maximum magnetic flux density $B_{\max}$, the inclination angle Θ_B, the axis ratio α, and the excitation frequency F. The inclination angle is defined as the angle between the rolling direction and the direction of the maximum flux density vector. The axis ratio is the ratio of the minimum flux density to the maximum flux density. The precise circular rotating flux condition corresponds to $\alpha = 1$ and the alternating flux condition means $\alpha = 0$.

The magnetic flux density waveforms in x- and y-directions are defined by parameters of $\boldsymbol{B}_{\max}, \Theta_{\mathrm{B}}$, and α and are controlled to be sinusoidal with the feedback control using a personal computer. The iron loss are calculated from the measured flux density vector $\boldsymbol{B}$ and the measured magnetic intensity vector $\boldsymbol{H}$ with the following equation

$$P = \frac{1}{\rho T} \int_0^T \left(H_x \frac{\mathrm{d}B_x}{\mathrm{d}t} + H_y \frac{\mathrm{d}B_y}{\mathrm{d}t} \right) \mathrm{d}t \tag{1}$$

where ρ is material density and T is period of the exciting waveform.

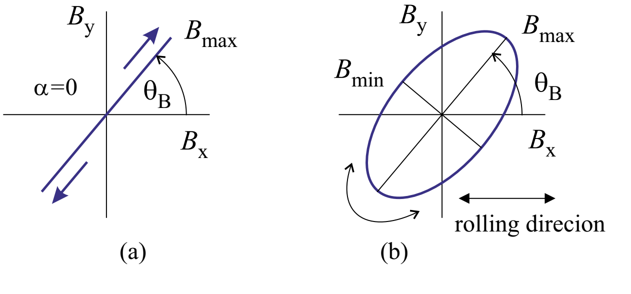

Fig. 1. Definition of magnetic flux conditions: θ_B - inclination angle, $\alpha = B_{\min}/B_{\max}$ - axis ratio

* Department of Innovative Engineering, Faculty of Science and Technology, Oita University ,Oita, Japan, ueno-shohei@oita-u.ac.jp, ** Vector Magnetic Characteristic Technical Laboratory, Usa, Japan, enoki@oita-u.ac.jp, *** Metron Technology Research Co., Ltd., Osaka, Japan, shinichi.inoue@metron.co.jp

DOI: 10.2478/jee-2018–0061, Print (till 2015) ISSN 1335-3632, On-line ISSN 1339-309X

Table 1. Comparison between precise measurement system and Vector B-H tester

	Precise measurement system for vector magnetic characteristic	Vector B-H tester
Converge of Measurement	$B_{\max} = 0.1 - 1.8$ T $\theta_{\mathrm{B}} = 0 - 180^\circ$, $\alpha = 0 - 1.0$	$B_{\max} = 0.1 - 1.8$ T $\theta_{\mathrm{B}} = 0 - 90^\circ$, $\alpha = 0 - 1.0$
Measurement time	10 minute /one data	1 minute / one data
Handling	Sensitive and technical	Nice
Utilization & Application	Useful for magnetic & characteristic analysis	Useful for fundamental design complex vector analysis

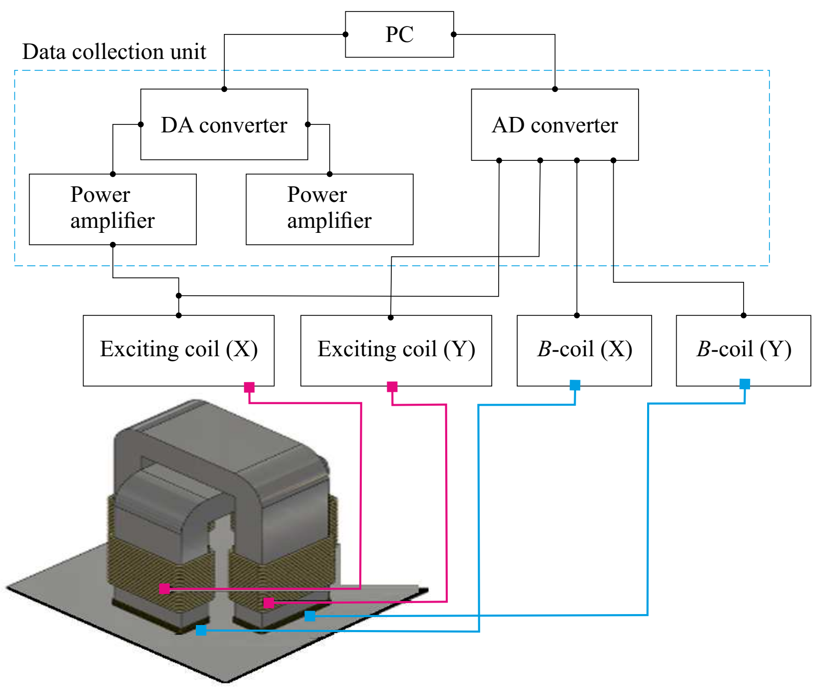

Fig. 2. Measurement system

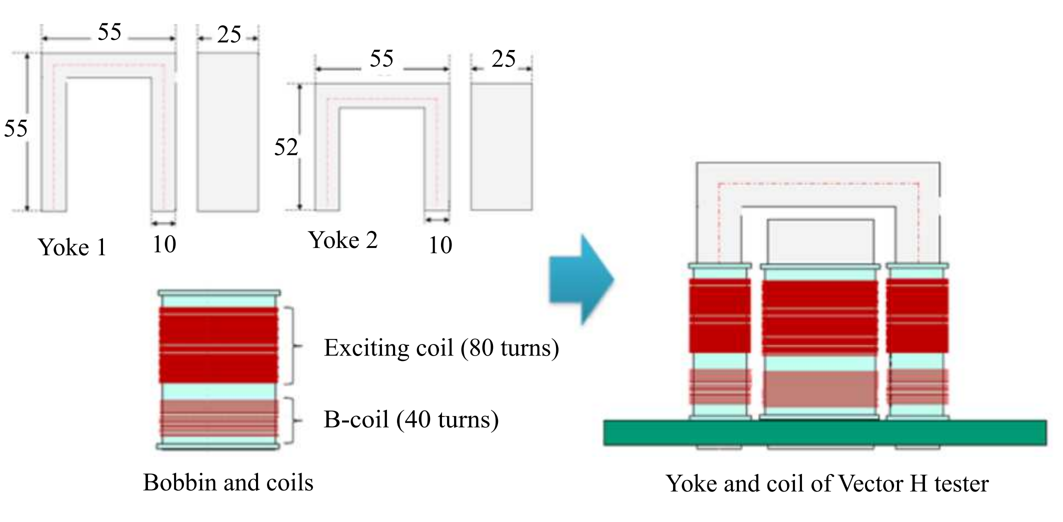

Fig. 3. Details of each yoke and coil

3 Vector B-H tester

Figure 2 shows the measurement system of the Vector B-H tester. The data collection unit of vector tester consists of D/A converters, A/D converters and a set of two power amplifiers, for x - and y - direction. A sample used in the measurement is 80 mm $\times$ 80 mm sheet and placed

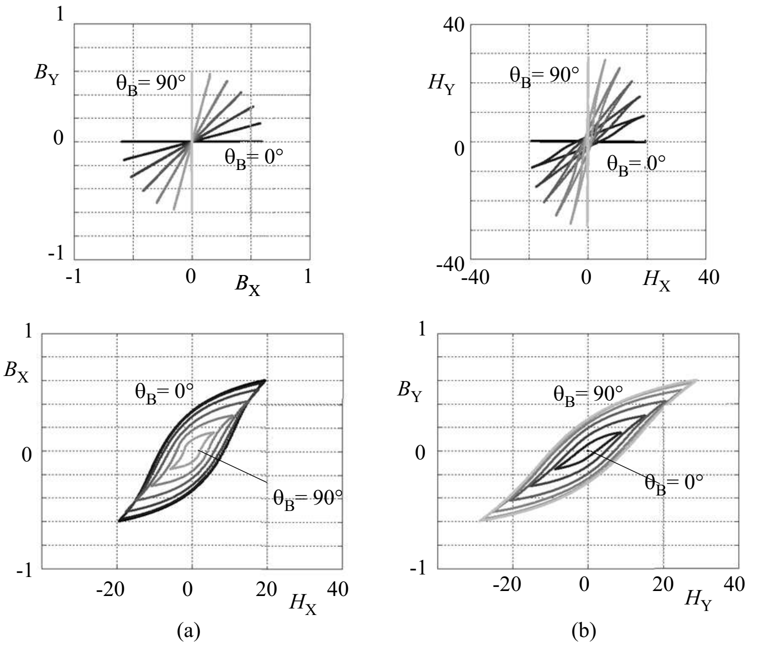

Fig. 4. Measurement result of $|\boldsymbol{B}|$ and $|\boldsymbol{H}|$ loci (up), and hysteresis loops of each direction; with sequence of inclination angles: 0,15,30, 45,60,75,90 degres

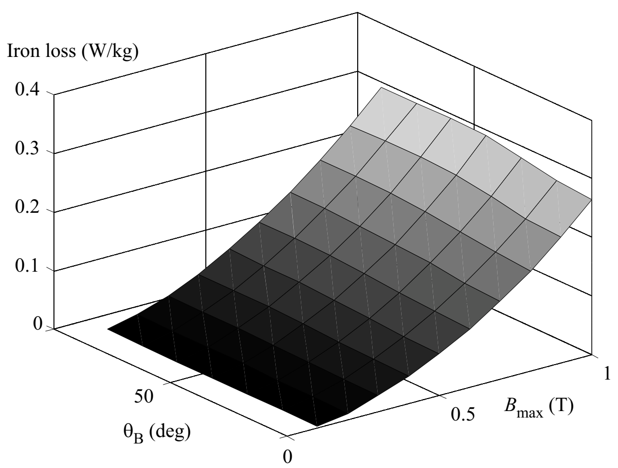

Fig. 5. Iron loss of each direction

at the center of the excitation yokes. The x -direction is to be along the rolling direction. We can arbitrary generate magnetic flux conditions with the two-directional excitation of a sample sheet. The components of the magnetic flux density vector in the x - and y -directions are measured using the B-coil (search coil) directly wound at the excitation yokes. The components of the magnetic field strength vector in the x - and y directions are measured by magnetizing current method [3]. Excitation currents in x- and y- direction are measured using a shunt resistance $(0.5\ \Omega)$ connected to exciting coil. Figure 3 shows details of yokes and coil for Vector B-H tester. Magnetic flux density and magnetic field intensity in both directions are calculated by following equation

$$B = \frac{1}{N_1} S_{\text{eff}} \int V_{\text{Bcoil}} \mathrm{d}t, \tag{2}$$

$$H = \frac{N_2 I}{l_{\text{eff}}}, \tag{3}$$

where S_{eff} is effective cross area, l_{eff} is effective magnetic pass length, I is excitation current, V_{Bcoil} is induction voltage of B-coil, N_1 is winding turn number of B-coil and N_2 is winding turn number of exciting coil. We calibrated l_{eff} and S_{eff} using correction value for measuring the magnetic flux density and the magnetic field strength of specimen. Table 1 shows the comparison between precise measurement system and Vector B-H tester.

4 Measurement result

Figure 4 shows the measured flux density and the field intensity vector loci, and hysteresis loops in each direction, respectively. The grade of measured sample is non-oriented electrical steel sheet. As shown in this figure, the direction of the flux density vector $\boldsymbol{B}$ and field intensity vector $\boldsymbol{H}$ were completely different.

Figure 5 shows the iron loss at each direction. As shown in those figure, the iron loss was the smallest when $\theta_B = 0^\circ$, and the iron loss increased as θ_B approaching to 90° because the magnetic anisotropy is affected. Vector B-H tester can evaluate the magnetic characteristic such as the magnetic anisotropy of one sheet sample easily.

5 Conclusion

As described above, we suceeded in

- developing Vector B-H tester for measuring the magnetic characteristic of soft magnetic material such as non-oriented electrical material.

- showing results the Vector magnetic characteristics can be measured easily, giving appropriate values of quantities including such as the magnetic anisotropy of one sheet sample.

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Received 13 February 2018

Shohei Ueno was born in Oita, Japan, 1988. He graduated from department of engineering, Oita University and obtained master degree in 2014. He was engaged in development of amorphous transformer at Hitachi Industrial Equipment Systems Co., Ltd. during 2014-march 2016. Since April 2016, he is engaged in Oita University as a researcher.

Masato Enokizono was born in Oita, Japan, 1949. He graduated from Kyushu University, School of Engineering and obtained Dr degree in 1978. He became a Professor in 1995. He had research scholarship of the Alexander von Humboldt Fundation in Physikalisch-Technische Bundesanstalt (PTB) lab in Braunschweig in 1986 and 2004. He founded the Vector Magnetic Characteristic Technical Laboratory in 2014. He is an Emeritus Professor of Oita University and a Research Professor of Nippon Bunri University.

Shinichi Inoue was born in Japan, 1962. He graduated from School of Education, Bukkyo University in 1987. He was engaged in system development of magnetic measurement equipment at Mechatron Co., Ltd during 1988-January 1994. Since February 1994, he is engaged in magnetic measurement equipment/system development manufacturing at Metron Technology Research Co., Ltd. Currently he is a President and Representative Director of Metron Technology Research Co., Ltd.