MEASURENMENT AND ANALYSIS OF THE MAGNETOSTRICTION OF ORIENTED AND NON-ORIENTED ELECTRICAL STEEL SHEETS

Tao Chen, Qingxin Yang, Changgeng Zhang, Yongjian Li

Hebei University of Technology, China
Changgeng,zhang@hebut.edu.cn

Keywords: Magnetostriction, Electrical sheet steel, Power transformer.

Abstract

Magnetostriction is an important cause of vibration and noise in transformer operation. It is of great significance to measure and study the magnetostriction of electrical steel sheet for transformer design, optimization and vibration and noise reduction. In this paper, a single sheet tester is set up to measure the alternating magnetostrictive characteristics of a single sheet sample of electrical steel with laser interferometer. Further, the variation trend of magnetostriction with magnetization frequency is also studied.

1 Introduction

As an indispensable equipment in power network, the vibration and noise of transformer has been paid more and more attention. The main reasons for the vibration and acoustic noise generated by the transformer during operation are as follows: the magnetostrictive effect of the core material, the air gap in the core and the electromagnetic force between the lamination, and the mechanical noise caused by the structural parts.

As the core material of power transformer, the magnetostrictive effect of electrical steel sheet is worth measuring and studying. Hisashi Mogi and Tomoya Nakase have measured the magnetostriction of oriented electrical steel sheets by using laser interferometers [1,2]. Setareh Gorji Ghalamestani designed and built a single sheet tester based on the laser interferometer to measure the magnetostriction [3]. Philip Anderson et al. measured the magnetostriction of oriented electrical steel sheet under temperature and harmonic conditions [4-6]. Yongjian Li et al. measured the magnetostriction of non-oriented electrical steel sheet along different magnetization angle [7]. However, the study on the magnetostriction of oriented and non-oriented electrical steel sheet with the change of magnetization frequency is still not perfect, and the measured results are few.

For oriented and non-oriented electrical steel sheets, the magnetic and magnetostrictive characteristics of two typical materials at magnetization frequency from 50Hz to 200Hz are measured and compared in this paper. The magnetostriction of them with the variation of magnetization frequency is discussed in detail.

2 Measuring devices and systems

The measuring system consists of a single sheet tester and a laser interferometer. Synchronous acquisition of induced voltage and magnetostriction is realized.

2.1 Single sheet tester

The single sheet tester (SST), as shown in fig. 1, consists of an iron core, an exciting winding, an induction winding and other structural parts.

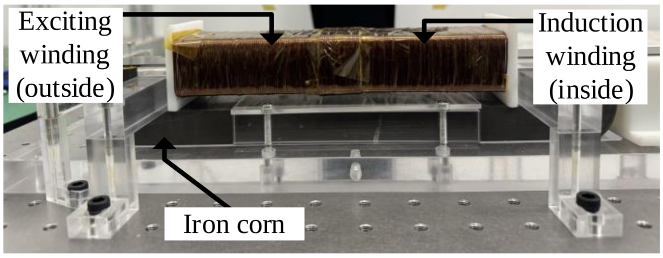


Fig. 1 The single sheet tester

The measurement principle of the SST is based on Ampere circuit law and Faraday's law of electromagnetic induction. The magnetic field intensity and magnetic induction intensity are calculated by (1) and (2), respectively.

$$H = \frac{n_1 I}{l} \tag{1}$$

$$B(t) = -\frac{1}{An_2}\int u(t)dt \tag{2}$$

Where n_1, n_2 represent the number of turns of the excitation winding and the induction winding respectively, I represents the excitation current, l represents the length of the effective magnetic circuit, A represents the cross-sectional area of the effective magnetic circuit, and u represents the induced voltage.

2.2 measuring system

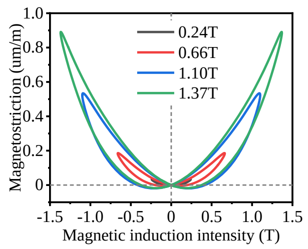
The NI-DAQ is used to generate sinusoidal excitation voltage and collect induced voltage. The laser interferometer is used to collect the vibration velocity signal of the reflector pasted on the surface of the sample, and convert the vibration velocity into the magnetostriction by (3). Ten percent of the induced voltage is set to the trigger level of the vibration velocity to implement the synchronous measurement of the magnetic induction intensity and magnetostriction.

$$\varepsilon(t) = \frac{\int v(t)\,dt}{l} \tag{3}$$

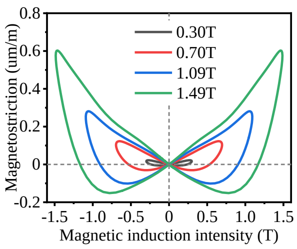
where v is the vibration velocity, l is the distance from reflector to clamp end.

3 Results and discussion

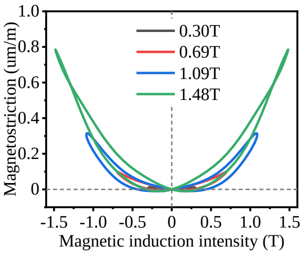
The alternating magnetic and magnetostrictive characteristics of oriented and non-oriented silicon steel sheets at frequencies from 50Hz to 2500Hz were measured, and the measurement results were shown in fig. 3 and fig. 4.



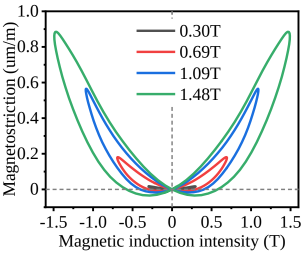
(a) 50Hz



(b) 200Hz

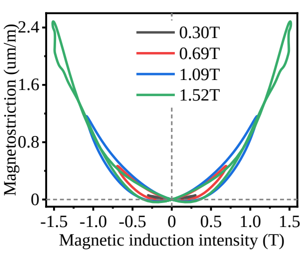


(c) 1000Hz

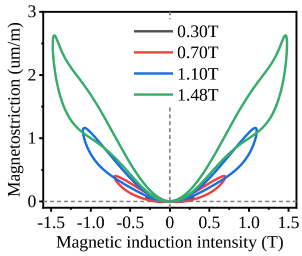


(d) 2000Hz

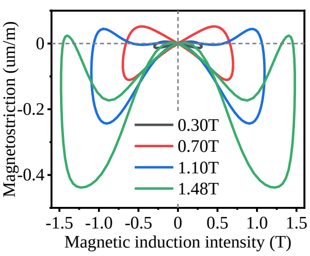
Fig. 3 The Magnetostriction of the oriented electrical steel sheet (B30P100)



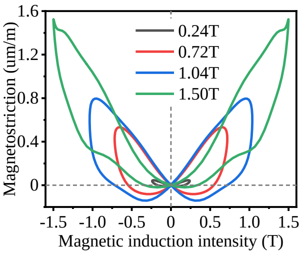
(a) 50Hz



(b) 200Hz



(c) 1000Hz



(d) 2000Hz

Fig. 4 The Magnetostriction of the non-oriented electrical steel sheet (B30AV1500)

4 Conclusion

According to the measurement results, the magnetostriction of the non-oriented electrical steel sheet is larger than that of the oriented electrical steel sheet. At the same time, the magnetostrictive shape of the non-oriented electrical steel sheet is disordered, which is related to the motion of the internal magnetic domains. Magnetostriction at high frequencies is affected by the harmonics in the magnetization of the sample and the intrinsic modes of the sample.

Acknowledgements

This work was supported in part by the National Natural Science Foundation of China, (No. 52277008, No. 92066206, and No. 52130710), the Funds for Creative Research Groups of Hebei Province, (No. E2024202298).

References

[1] H. Mogi, M. Yabumoto, M. Mizokami and Y. Okazaki, "Harmonic analysis of AC magnetostriction measurements under non-sinusoidal excitation," IEEE Transactions on Magnetics, vol. 32, no. 5, pp. 4911-4913, Sept. 1996.

[2] T. Nakase, M. Nakano, K. Fujiwara and N. Takahashi, "Measuring system for magnetostriction of silicon steel sheet under AC excitation using optical methods," in IEEE Transactions on Magnetics, vol. 34, no. 4, pp. 2072-2074, July 1998.

[3] S. G. Ghalamestani, T. G. D. Hilgert, L. Vandevelde, J. J. J. Dirckx and J. A. A. Melkebeek, "Magnetostriction Measurement by Using Dual Heterodyne Laser Interferometers," in IEEE Transactions on Magnetics, vol. 46, no. 2, pp. 505-508, Feb. 2010.

[4] Anderson P. Measurement of the stress sensitivity of magnetostriction in electrical steels under distorted waveform conditions[J]. Journal of Magnetism and Magnetic Materials, 2008, 320(20): e583-e588.

[5] P. K. Klimczyk, P. Anderson, A. Moses and M. Davies, "Influence of Cutting Techniques on Magnetostriction Under Stress of Grain Oriented Electrical Steel," in IEEE Transactions on Magnetics, vol. 48, no. 4, pp. 1417-1420, April 2012.

[6] Somkun S, Moses A J, Anderson P I. Magnetostriction in grain‐oriented electrical steels under AC magnetisation at angles to the rolling direction[J]. IET Electric Power Applications, 2016, 10(9): 932-938.

[7] Dou Y, Li Y, Yue S, et al. Measurement of alternating and rotational magnetostrictions of non-oriented silicon steel sheets[J]. Journal of Magnetism and Magnetic Materials, 2023, 571: 170566.