Advanced soft magnetic measurements system under multi-physical fields coupling

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Soft Magnetic Materials (SMMs) are widely used as key media for magnetic field conduction in electrical motor cores due to their low coercivity, easy magnetisation and high saturation magnetic flux density. However, electric motors typically operate under complex and dynamically coupled physical fields (including electromagnetic, thermal, and mechanical stress fields), which can lead to unpredictable changes in the properties of SMMs. To address these challenges, this paper investigates the combined effects of multi-physical fields on the magnetic properties of SMMs by constructing a multi-physical fields measurement platform for these materials, which provides more real and reliable data for their application in electric machines.

Keywords: SMMs; multi-physical fields; measurement platform

1. Introduction

Magnetic properties testing of soft magnetic materials is the basis for motor design and optimisation [1], of which Epstein, the ring sample method and the monolithic measurement method are the three most common single-field measurement methods in soft magnetic materials [2] [3]. These methods, which are of great significance in the magnetic evaluation of soft magnetic materials. However, these methods are unable to simulate the complex physical fields of electric machines, so there is a need to develop a measurement system under the multi-physical fields coupling of stress, temperature and magnetic field to reflect the macroscopic magnetic property changes of soft magnetic materials under the action of physical fields of electric machines.

In this paper, the simulation of complex operating conditions of electric machines is achieved by developing a novel measurement method for soft magnetic materials under multi-physical fields coupling, which has the effect of simultaneously loading stress, temperature and magnetic field. And the performance of a non-oriented silicon steel is tested and discussed.

2. Results and discussion

This paper investigates the performance regularity of non-oriented silicon steel under the combined influence of stress, temperature and magnetic field by building a multi-physical fields measurement system for soft magnetic materials, the measurement system is shown in Figure 1(a) and the measurement principle is shown in Figure 1(b).

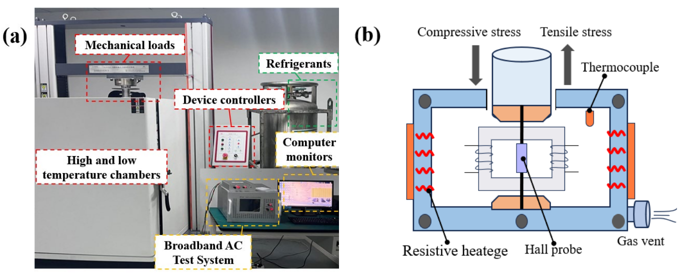

Figure 1: (a) hysteresis loops of samples with different magnetic flux density. (b) Loss curves considering multi-physical fields.

The upper side of the sample is the area receiving stress, and the lower side is the fixed area, the size of the stress is controlled by computer and the stress test range is -100~500MPa. The temperature module is controlled by heating and cooling devices, and the temperature test range is: -70~200°C. The temperature is measured by the temperature module. The magnetic field module completes the input of excitation and the output of signal through the coils on both sides of the sample, the magnetic field strength: 0~30000A/m, the frequency is 0~3000Hz.

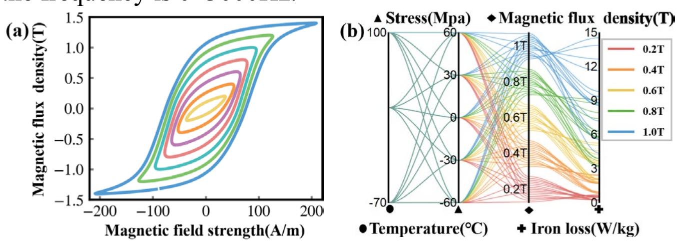

Figure 2: (a) hysteresis loops of samples with different magnetic flux density. (b) Loss curves considering multi-physical fields.

Figure 2 (a) demonstrates the hysteresis loop of non-oriented silicon steel under a magnetic field, where the magnetic flux density increases with increasing magnetic field strength. Figure 2 (b) demonstrates the sensitivity of the magnetic properties of non-oriented silicon steel to stress and temperature under multi-physical fields coupling. The results show that although high temperatures weaken the effect of stress on losses, the tendency of increasing losses is more pronounced at higher frequencies. Overall, the total loss increases with the strength of the multi-physical fields.

References

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