Effect of temperature and stress on the properties of high-silicon steel under wide frequency magnetic field excitation

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In motor operation, frequency, temperature, and stress changes on the performance of silicon steel will directly affect the modeling accuracy of the motor. The changes of high silicon steel affected by the three are different from those of conventional silicon steel. At low and high frequencies, the effects of temperature and stress on the magnetic properties of silicon steel will also show different patterns. Therefore, in this paper, the magnetic property change law of high silicon steel (10JNEX900) under the two coupled alternation of frequency-temperature and frequency-stress is tested by using a ring specimen. Further quantitatively analyzed the effect of temperature and stress on the magnetic properties of silicon steel at different frequencies. Finally, the reason is explained from the magnetization mechanism of high silicon steel material.

Keywords: high-silicon steel; wide frequency; temperature; stress

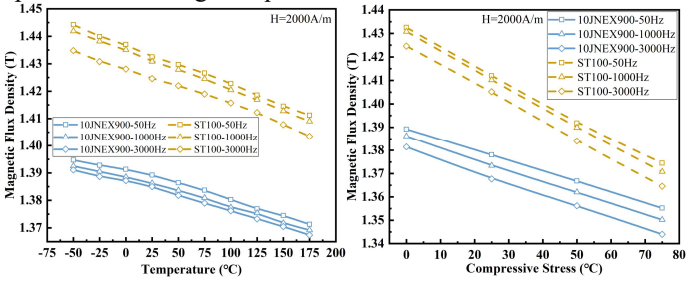
1. Introduction

In recent years, high speed is becoming the main trend of permanent magnet motors, and the consequent problems of high temperature, high stress distribution and high frequency are becoming more and more significant. High-silicon steel is widely used in high-speed motor cores because of its low-loss characteristics. Studies have shown that an increase in frequency has a deteriorating effect on both the flux density and losses of silicon steel sheets. Contrary to conventional silicon steel, the iron loss of 10JNEX900 increases with increasing temperature [1]. Compared to conventional silicon steel, 10JNEX900 shows a smaller increase in iron loss under compressive stress [2]. However, there are fewer studies on the effect of temperature and stress on the magnetic properties of high silica steel at different frequencies. In this paper, the magnetic properties of high silica steel are tested after temperature and stress are loaded separately under a wide frequency range (50Hz-3000Hz) and the results are comparatively analyzed.

2. Results and discussion

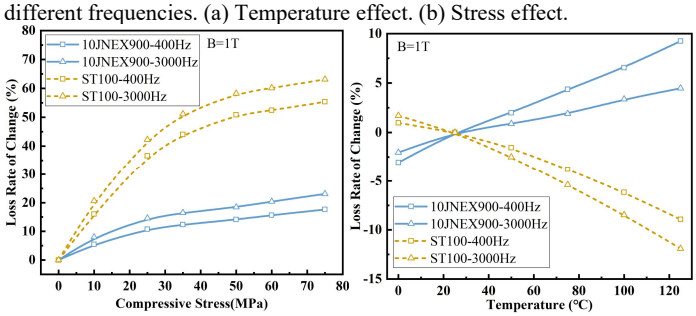
From Figure. 1(a), it can be seen that the magnetic flux density of the 2 materials decreases with increasing temperature. However, the decreasing trend of 10JNEX900 increases significantly between 0°C and 25°C. From Figure. 1(b), the decreasing trend of 10JNEX900 is more gentle compared to ST100. The deterioration of temperature and stress on the magnetic flux density of the 2 materials is not significantly affected by frequency. At low frequencies, the magnetization process is relatively slow and the flux density is more gently affected by temperature and stress. After high-frequency magnetization, the deep skinning effect exacerbates the effect of temperature and stress on the magnetic flux density. However, the thickness of both 10JNEX900 and ST100 is 0.1 mm, and the skinning effect is not obvious.

From Figure. 2(a), it can be seen that the rate of change of iron loss of 10JNEX900 gradually flattens out as the frequency increases, while ST100 decreases more significantly. From Figure. 2(b), it can be seen that the iron loss of 10JNEX900 is less affected by compressive stress. As the frequency increases, the effect of compressive stress on the loss of both materials becomes larger. At low frequency, the increase in hysteresis loss of 10JNEX900 is greater than the decrease in eddy current loss, resulting in greater iron loss with increasing temperature. At high frequency, the eddy current loss of silicon steel accounts for a larger proportion, and the hysteresis loss of 10JNEX900 increases more and more gently. Meanwhile, the effect of stress on total iron loss at low frequency is mainly dominated by hysteresis loss changes. At high frequencies, the application of external compressive stresses substantially increases the resistance to magnetic domain rotation. Therefore, the effect of compressive stress on losses will be more pronounced at high frequencies.



(a) (b)

Figure 1: Variation of magnetic flux density of 2 silicon steel materials at different frequencies. (a) Temperature effect. (b) Stress effect.



(a) (b)

Figure 2: Variation of iron loss of 2 silicon steel materials at different frequencies. (a) Temperature effect. (b) Stress effect.

References

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