Study on Magnetic Properties of Magnetic Materials with Multiple Factors

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Study on Magnetic Properties of Magnetic Materials with Multiple Factors

Jiang Wenyu¹, LI Weiye², Lou Jianyong¹, Wu Shidong³

¹State Key Laboratory of Electrical Insulation and Power Equipment, Xi'an Jiaotong University, Xi'an, China
²CRRC Zhuzhou Locomotive Co., Ltd., Zhuzhou, China
³Wuxi putian core co., LTD, Wuxi, China
jylou@mail.xjtu.edu.cn (Lou Jianyong)

Abstract. With the vigorous development of the power industry, the demand for electromagnetic equipment is also increasing. It is of great significance to accurately simulate the magnetic properties of the magnetic materials under the external conditions of different frequencies and pressures in the electrical equipment for the precise design and improvement of the performance of the equipment. First of all, this paper briefly introduces the research background of electrical magnetic materials. Since this paper is based on the practical application of engineering, the Epstein square method and the ring sample method are used to record and test the magnetic properties of the silicon steel sheet under the influence of frequency and pressure. Finally, based on the processed and analyzed experimental data, this paper summarizes the magnetic properties of magnetic materials, which theoretically analyzes and explains the possible reasons to serve for engineering application.

1. Introduction

With the vigorous development of electric power industry, the demand for electrical energy related equipment is also increasing, and various new electromagnetic equipment are emerging in endlessly. How to produce the equipment required according to the specified parameters, which requires the manufacturer to accurately design and manufacture the equipment according to the accurate magnetic parameters of electromagnetic materials in the actual working conditions of electromagnetic equipment [1-2]. Therefore, it is of great significance to test the magnetic properties of magnetic materials under non-standard conditions.

The measurement of magnetic properties of silicon steel is mainly focused on dynamic magnetization at home and abroad, which includes three aspects: one dimensional, two-dimensional and three dimensional magnetic property measurement. About the research work of two dimensional magnetic properties, Japan, Korea and some European countries started earlier. In our country, the research on the measurement of magnetic properties of silicon steel sheet is relatively late. In 2009, Shenyang University of Technology organized an International Conference on the measurement of two dimensional magnetic properties, and also made some research results. But for now, there are no existing test instruments at home and abroad, which can accurately measure two-dimensional magnetic properties, and the theoretical research is limited to the laboratory stage. The measurement method of three-dimensional magnetic properties is at the beginning stage. At present, Zhu Jianguo of Sydney University of science and technology in Australia has made a preliminary research in this field and made a three dimensional
measurement model [4-5]. However, the magnetic field uniformity and flux density curve of the tested samples are not ideal, and further discussion is needed. Compared with one-dimensional magnetic materials, the testing technology of magnetic properties of magnetic materials is relatively perfect. The Epstein ring method and ring sample test method have good repeatability and accuracy. Today, it is still used as a most mature magnetic testing technology by many manufacturers [7].

Due to the complexity of research methods, there is still much room for development in measuring magnetic materials. In this paper, we have made an experimental sample of various grades of electric silicon steel sheet. Under different frequency and pressure conditions, the main parameters such as loss, permeability and remanence of the sample were measured experimentally. Finally, we analyze the experimental data and summarize the variation rule of magnetic properties of magnetic materials.

2. Magnetic properties measurement under the influence of external frequency

Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

2.1. Experimental instruments and samples
TD8100 Magnetic material testing system,
Epstein frame,
Test samples of silicon steel sheet, No. 30AQ130.

![Image](a)TD8100 (b)Epstein frame (c)30AQ130.

2.2. Experimental test
According to the experimental operating instructions, this paper prepares the experimental samples and carries out the Epstein frame continuous frequency test. In this paper, the frequency range of silicon steel sheets is 50Hz~1000Hz, and 20 parameters are measured at intervals of 50Hz. Finally, the experimental data at different frequencies are arranged.

2.3. Postprocessing of experimental data
Magnetic parameters such as loss, permeability and remanence of electric magnetic materials are especially important. Therefore, two groups of silicon steel sheets were tested in continuous frequency state, and the related magnetic properties were obtained after testing.

2.3.1. Total loss ratio at different frequencies.
It is intuitively shown that the four measurements of the two sets of test samples are basically consistent within the allowable range of error, indicating that the test methods and theories adopted in this paper are repeatable.

From the test data, we can see that the change trend of the total loss ratio of 30AQ130 is: in the 50Hz~400Hz stage, the loss curve is approximately linear. At the frequency of 400Hz~600Hz, the slope of curve decreases and the amplitude increases slowly. When the frequency is 600Hz~1kHz, the total loss ratio of silicon steel sheets will increase in concussion. Generally speaking, the above situation can be understood as, on the microcosmic aspect, the increase in frequency within a certain range increases the particle movement in the magnetic material and the friction between the particles, which leads to the increase of the loss of the particles, and in the macro aspect, the performance is total loss ratio.

2.3.2. Total loss ratio at different frequencies.

The main magnetic circuit of a new type of electromagnetic equipment, such as large capacity transformer and high power motor, must be used for electrical magnetic materials, and the magnetic properties of the magnetic materials determine the loss of the work of the electromagnetic equipment. If manufacturers want to meet the design requirements, they must understand the specific values of magnetic materials in their working environment. In this way, not only can they save the cost of loss, but also we can design product performance parameters more accurately. Therefore, it is necessary to test the permeability of electric magnetic materials under different conditions. Two groups of samples will be tested for permeability at different frequencies.
As can be seen from the above figure 3, the permeability curves of the two kinds of silicon steel test samples coincide with the frequency variation, and the permeability of the two tested samples is basically the same in the range of error. Therefore, in the range of 50Hz~1000Hz, the relationship between frequency variation and permeability change is that, with the increase of frequency, the permeability of samples decreases correspondingly. However, no matter what frequency the sample was tested, it did not reach the magnetic permeability of the material itself. This is mainly due to the large gap in the test sample connection, resulting in larger leakage and larger permeability.

2.3.3. Remanence at different frequencies.
The magnitude of remanence of electric magnetic materials can determine some characteristic functions of magnetic devices. Based on the measured data, the following relation curves can be obtained by analogy with the above analysis methods.

![Figure 4. The relation curve of $f$ and $Br$.](image)

It can be seen from figure 4. In the frequency range of 50Hz~300Hz, remanence increases exponentially with the increase of frequency. When the frequency is 300Hz~400Hz, the remanence is basically stable. The main reason for this phenomenon is that at the beginning of the test, the test sample does not reach the saturation point, so the demagnetization curve of the hysteresis loop and the magnetic sense will change with the saturation degree, and the remanence base of the test sample will not change when the test sample reaches saturation. When the frequency is greater than 400Hz, the remanence is stable in the form of oscillation.

3. Measurement of magnetic properties under the influence of external pressure

3.1. Experimental instruments and samples
Pressure applicator,
Test samples of silicon steel sheet, No. 23JGH.
3.2. Experimental measurement
According to the experimental operation rules, the magnetic characteristic parameters of ring test sample under different pressure were tested. In this section, the measurement experiments are carried out according to the pressure of the core clamp of the transformer. The pressure range is 0.01Mpa~0.15Mpa, the interval 0.01Mpa, 15 parameter points are measured, and the experimental data under different pressure is arranged.

3.3. Experimental measurement

3.3.1. Data analysis under normal condition.

The experimental measurements under normal conditions are carried out first in order to compare the latter ones. From the graph, we can see that the total loss ratio of 23JGH increases with the increase of the B value of the test point, and the magnitude of the increase also increases.

3.3.2. Total loss ratio under different pressures.
Figure 7. The relation curve of $B$ and total loss ratio.

It can be seen from the loss curve shown in the upper left diagram. When the applied pressure is 0.01Mpa, the 0.02Mpa curve basically coincides, and the pressure becomes 0.03Mpa, the loss increases. While the loss curves of curves 0.03Mpa, 0.04Mpa, 0.05Mpa, 0.06Mpa, 0.07Mpa and 0.08Mpa basically coincide, and the loss values are basically the same. When the applied pressure is 0.09Mpa and 0.10Mpa, the loss is the largest. It can be seen from the top right-hand diagram that when the pressure of test sample increases from 0.10Mpa to 0.11Mpa, the loss decreases. When it is 0.11Mpa~0.15Mpa, the loss is basically the same.

3.3.3. Magnetic permeability under different pressures.

Figure 8. The relation curve of $B$ and $u$.

As shown by the left figure 8, when the pressure is applied to the test sample at 0.01Mpa~0.02Mpa and 0.11Mpa~0.15Mpa, the permeability parameter curve of the test sample basically coincides. When the applied pressure rises from 0.02Mpa to 0.03Mpa, the permeability increases. When the pressure is at 0.03Mpa~0.10Mpa, the permeability parameter curve of the test sample is reclosing, and the test parameters are consistent within the range of error, that is, the permeability of the sample is constant in the range of pressure.

3.3.4. Remanence under different pressures.
As shown above, when the pressure is applied to the test sample at 0.01Mpa~0.08Mpa and 0.11Mpa~0.15Mpa, the remanence parameter curve of the test sample is in a changing interval, and the whole is increased in the form of concussion. When pressure is applied to 0.09Mpa and 0.10Mpa, remanence increases significantly. On the other hand, it is also seen from the graph that the remanence parameter increases with the increase of the B value of the test point.

In the analysis of experimental data, data can be synthesized by polynomials, which provides convenience for engineering calculation.

4. Conclusion
Firstly, this paper puts forward the test method of ring test and Epstein frame. According to adopted the experimental scheme, we selected different brands of silicon steel sheet samples, and made many kinds of test products. By testing the test samples of silicon steel under continuous frequencies and different pressures, we recorded 20 magnetic properties under different frequencies and 15 different pressures. For the most concerned magnetic properties, we also have done graphic processing compared with the total loss ratio $P$, permeability $u$ and remanence $Br$. The paper obtains the variation rules of magnetic properties and analyzes the changing rules of experimental data. Finally, we get the conclusion of magnetic properties of electric silicon steel under the influence of frequency and pressure.

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