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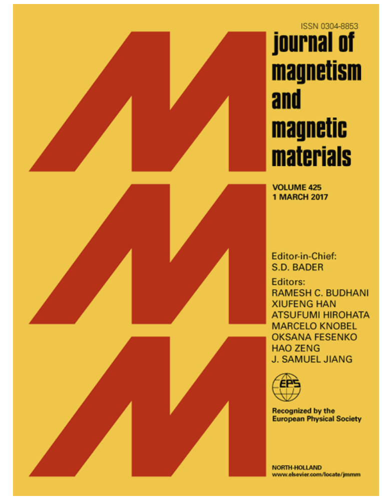

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Experimental investigation into the coupling effects of magnetic field, temperature and pressure on electrical resistivity of non-oriented silicon steel sheet

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Abstract—In order to analyze the performance of magnetic device which operate at high temperature and high pressure, such as submersible motor, oil well transformer, the electrical resistivity of non-oriented silicon steel sheets is necessary for precise analysis. But the reports of the examination of the measuring method suitable for high temperature up to 180 ℃and high pressure up to 140 MPa are few. In this paper, a measurement system based on four-probe method and Archimedes spiral shape measurement specimens is proposed. The measurement system is suitable for measuring the electrical resistivity of unconventional specimens under high temperature and high pressure and can simultaneously consider the influence of the magnetic field on the electrical resistivity. It can be seen that the electrical resistivity of the non-oriented silicon steel sheets will fluctuate instantaneously when the magnetic field perpendicular to the conductive path of the specimens is loaded or removed. The amplitude and direction of the fluctuation are not constant. Without considering the effects of fluctuations, the electrical resistivity of the non-oriented silicon steel sheets is the same when the magnetic field is loaded or removed. And the influence of temperature on the electrical resistivity of the non-oriented silicon steel sheet is still the greatest even though the temperature and the pressure are coupled together. The measurement results also show that the electrical resistivity varies linearly with temperature, so the temperature coefficient of resistivity is given in the paper.

Keywords—non-oriented silicon steel sheet; magnetic field; electrical resistivity; instantaneous fluctutation; temperature and pressure

1. Introduction

Motors made of non-oriented silicon steel sheets need to work in a magnetic environment, the performance will be affected by the magnetic field, such as iron core. The core loss, which is mainly composed of hysteresis loss and eddy current loss, needs to be considered in the design process. In order to calculate the eddy current loss, the electrical resistivity of the non-oriented silicon steel sheet must be known. In general, the electrical resistivity of non-oriented silicon steel sheet is measured in the absence of a magnetic field [1-19]. Obviously, this situation does not correspond with the actual situation.

For designers, in addition to the above factors, the environmental factors are still key factors in the design process. In many extreme working conditions, temperature and pressure should be considered simultaneously. In order to design a motor that is suitable for operating in high temperature and high pressure environment, the properties of the relevant materials should be determined, including the electrical resistivity of the non-oriented silicon steel sheet. Although the existing literatures have analyzed the influence of temperature [3, 15, 19] or temperature and limited direction pressure [18] on the electrical resistivity of the materials, it is difficult to infer the influence of temperature and omnidirectional pressure on the electrical resistivity by using these data. The materials measured in the literatures do not match the materials to be measured in this study.

According to the measurement environment, the shape and characteristics of the test sample, the electrical resistivity measurement methods are different. In all measurement methods, voltammetry is the most simple and convenient measurement method [18]. However, voltammetric measurement accuracy is not high, which makes it more suitable for the measurement of relatively large resistance materials. Therefore, this method is not suitable for situations where higher measurement accuracy is required. In this case, a four-probe method that does not include probe resistance and contact resistance can be used. The method can not only measure the conductivity characteristics of metals and semiconductor materials [1-5, 9, 11, 19], but also determine relative permeability of ferromagnetic materials [1]. Regardless of the probe resistance, contact potential on the measurement results, the number of probes can be appropriately reduced, which are the so-called three-probe measurement method [20] or two-probe measurement method [19]. And these two methods of measurement devices compared to the four-probe measurement method is also simpler, less restrictive conditions. Some of the test samples are not suitable for processing or hope that the samples can be reused, you need to use eddy current method to determine the electrical resistivity, the measurement principle is based on changes in the detection coil impedance [8, 9, 12, 14] or by measuring the Lorentz force size [10] to determine the electrical resistivity. The non-destructive measurement features that make it possible to diagnose conductive materials, that is, to test the quality of the product [14]. Moreover, the eddy current method can be also applied to measure the electrical resistivity of conductive liquid [10]. For measuring the electrical resistivity of anisotropic materials, the well-known Montgomery method [13] is a good choice, but the method requires an iterative calculation to determine the third component of the anisotropy, and this iterative method does not converge in a self-consistent manner. To overcome