Magnetic Properties Measurement and Analysis of High Frequency Core Material Considering Temperature Effect

Ming Yang1, Yongjian Li1, Qingxin Yang1,2, Shuaichao Yue1, Changpeng Zhang1, Hutzau Hein1, and Chengcheng Liu1
1 State Key Laboratory of Reliability and Intelligence of Electrical Equipment, Hebei University of Technology, Tianjin, 300130, China
2 Tianjin University of Technology, Tianjin, 300384, China
E-mail: liyongjian@hebut.edu.cn

1 INTRODUCTION

In this paper, a magnetic properties measurement system for ring sample is designed considering the influence of temperature.

(a) 1 kHz
(b) 20 kHz

The saturated magnetic density, coercivity, remanence and loss characteristics of the above three materials at different temperatures are analyzed.

The stability of different materials at different frequencies is compared by using the coefficient of variation. Meanwhile, the conductivity of material was measured and analyzed by using van der Pauw method.

2 MEASURING DEVICE AND MEASUREMENT METHODS

A thermistor with real-time temperature regulation is used to heat the magnetic ring sample, as shown in Fig. 1a. The magnetic ring is placed at the center of the heating region in the thermistor and the bottom is the heat source, which is used to heat up the whole region. Meanwhile, the circulation system of the thermistor can accelerate the internal air flow, makes the heating on the magnetic ring more uniform. The thermistor has the functions of real-time temperature monitoring and PID control. The thermocouple with refractory fiberglas is used to take the temperature of the magnetic ring coil in real time to ensure that the temperature of the magnetic ring can reach the pre-temperature.

In Fig. 2, the main steps to measure the magnetic properties of core materials are as follows:

1) The sinusoidal voltage signal generated by the signal generator is amplified by the power amplifier to excite the primary side winding of the magnetic ring, and the secondary side is equivalent to no load.
2) The NI data acquisition system is used for data acquisition of primary side current and induced no-load voltage.
3) The corresponding magnetic field intensity H and magnetic flux density B are obtained by Ampere's law and Faraday's law of electromagnetic induction, respectively.

3.3 STUDY ON MAGNETIC PARAMETERS OF MATERIALS

Table 1: Parameters of three magnetic materials

<table>
<thead>
<tr>
<th>Material</th>
<th>A (T)</th>
<th>Jc (A/m)</th>
<th>Zr (℃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanocrystalline</td>
<td>9.8</td>
<td>4.4</td>
<td>51.0</td>
</tr>
<tr>
<td>Ferrites (N87)</td>
<td>75</td>
<td>14.1</td>
<td>-400</td>
</tr>
<tr>
<td>Mn-Zn Ferrites</td>
<td>98.7</td>
<td>103.0</td>
<td>210</td>
</tr>
</tbody>
</table>

Above three materials are measured at room temperature (RT, approximately 25℃), 50℃, 75℃, 100℃, 120℃ and 1.5, 10, 15, 20 kHz, respectively.

In Fig. 3, the hysteresis loop and coercive force of 1k107B at different temperatures.

The saturation flux density of 1k107B decreases at 1 kHz and 20 kHz as the temperature rises, but the coercive force and remanence decrease firstly and then increase at 1 kHz.

With the frequency increasing, the saturation flux density and the coercive force becomes large. The temperature at the lowest point of coercive force will be higher than that at the lower frequency.

Fig. 4 The hysteresis loop of 1k101 and N87 at different temperatures.

In Fig. 4, the coercive force of 1k101 decreases as temperature rises, but the regularity of remanence and saturation flux density may fluctuate slightly at lower frequencies. The overall variation is weaker than that of 1k101 and N87. The coercive force and remanence of N87 decrease as temperature rises, and the trend is consistent at different frequencies. From the magnetization curves of N87 and 1k101 under different conditions, it can be seen that the permeability of the two materials decreases with the increase of frequency and temperature.

4.4 STUDY ON LOSS CHARACTERISTICS OF MATERIALS

In terms of 1k107B, as shown in Fig. 5(a), its loss decreases firstly and then increases with temperature rising at 1, 5, 10 and 15 kHz. Meanwhile, the fluctuation of loss becomes small, i.e. the difference of loss curves decreases at different temperatures. At 20 kHz, the loss changes through three stages with the magnetic flux density increases.

Fig. 5 The loss curve of 1k107B at different temperatures.

In terms of 1k101, its loss decreases with temperature rising at constant frequency, but with the increase of magnetic flux density, the loss is more seriously affected by temperature.

In terms of N87, as shown in Fig. 6(b), when the temperature is from 25℃ to 75℃, its loss tends to decrease, but the loss has a tendency to rise from 100 to 120℃.

5 CONCLUSION

(1) Based on the experimental data, the influence of temperature on magnetic properties and loss characteristics of three core materials, namely nanocrystalline (1k107B), amorphous (1k101) and ferrites (N87), are systematically investigated and discussed at a broad frequency range.

(2) It can also provide data support for the magneto-thermal coupling of transformer core materials and provide theoretical support for the microscopic research of magnetic materials.