MT26 International Conference on Magnet Technology
Vancouver, Canada | 2019

Mon-Af-Po1.15-03 [36]

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

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➤1. INTRODUCTION

- In this paper, a magnetic properties measurement system for ring sample is designed considering the influence of temperature.
- By using the ring specimen method, the magnetic properties of the ferrite, the nanocrystalline and amorphous alloys materials are measured in the range of 25℃ to 120 ℃ from 1kHz to 20kHz.
- 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 MEASURING PRINCIPLEN

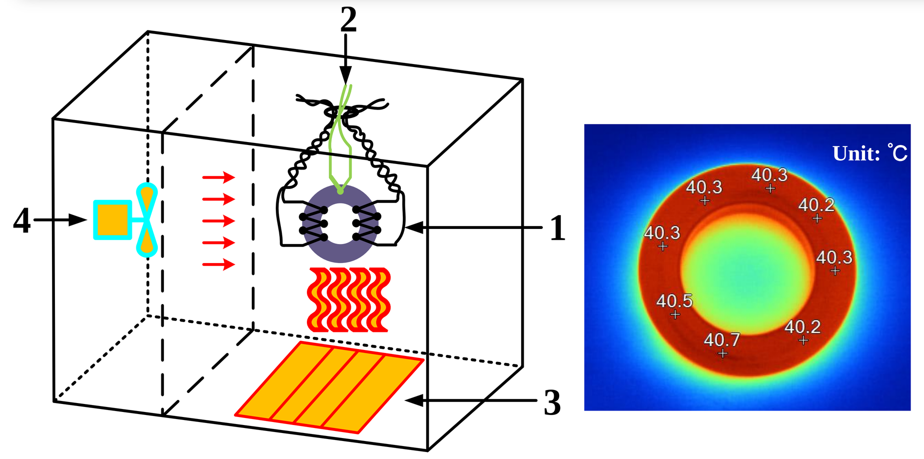


Fig. 1 (a) Simplified heating device diagram.
(b) Temperature distribution of magnetic rings after heating.

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

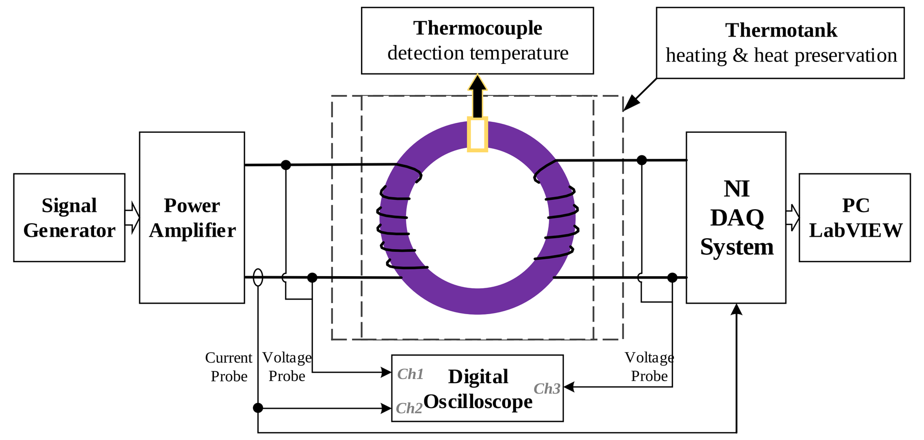


Fig. 2 Schematic diagram of magnetic properties measurement based on ring sample method.

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 to obtain acquisition of primary side current I_1 and induced no-load voltage U_2.

3) The corresponding magnetic field intensity ***H*** and magnetic flux density ***B*** are obtained by Ampere law and Faraday's law of electromagnetic induction, respectively.

$$B(t)=\frac{1}{N_2 S}\int_0^t u(t)dt$$

$$H(t)=\frac{N_1 i(t)}{l}$$

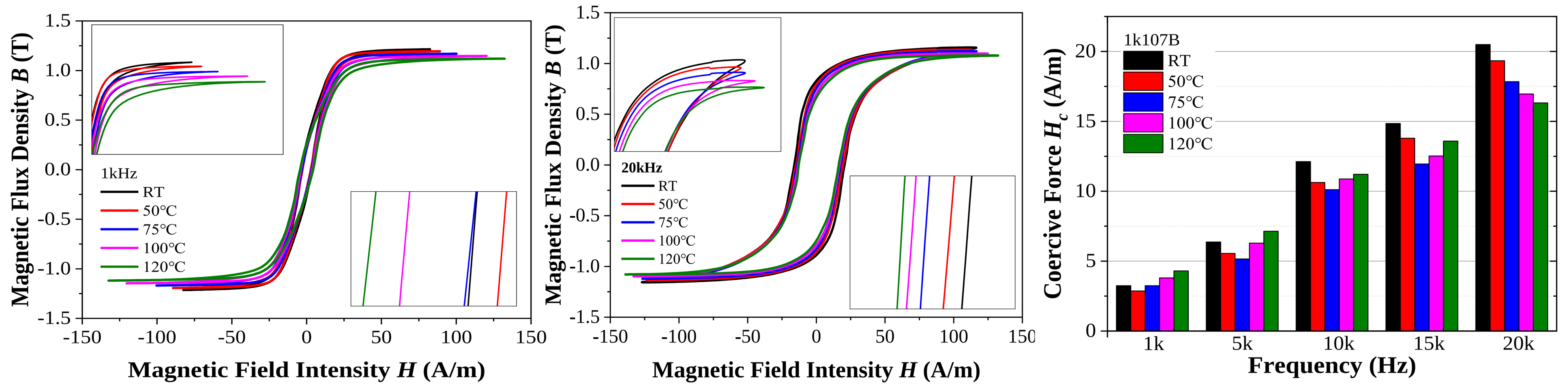
$$P_{core}=\frac{1}{T}\int_0^T pdt = fV\oint HdB$$

➤3. STUDY ON MAGNETIC PROPERTIES OF MATERIALS

TABLE I PARAMETERS OF THREE MAGNETIC MATERIALS

Material	A_e (mm²)	l_e (mm)	T_c (°C)
Nanocrystalline alloys (1k107B)	93.8	141.4	570
Amorphous alloys (1k101)	75	141.4	400
Mn-Zn Ferrite (N87)	95.75	103.0	210

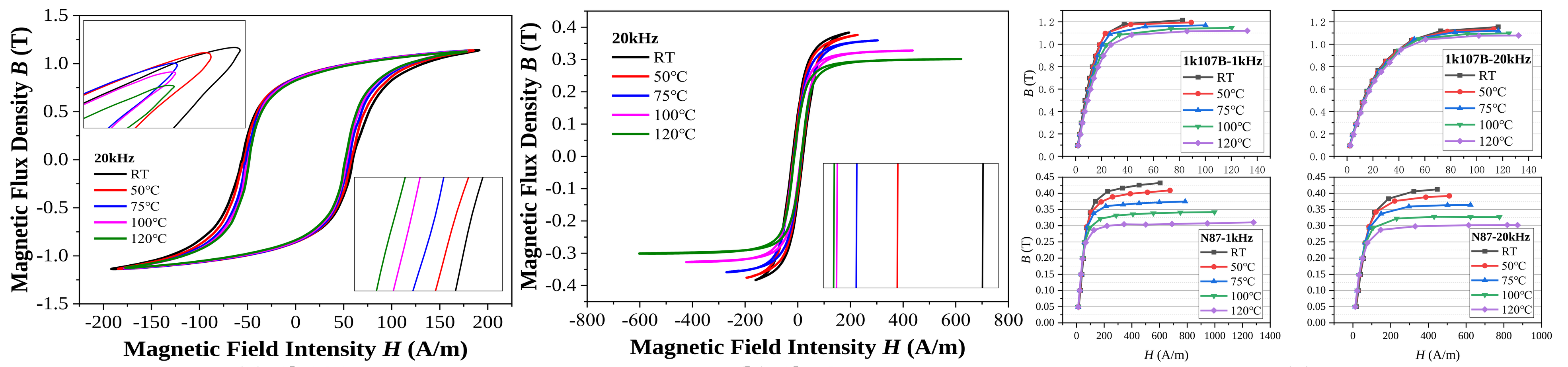
Above three materials are measured at room temperature (RT, approximately 25 ° C), 50, 75, 100, 120 ° C, and 1, 5, 10, 15, 20 kHz, respectively.



(a) 1 kHz (b) 20 kHz (c)

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 variation of the two parameters is consistent with that of 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

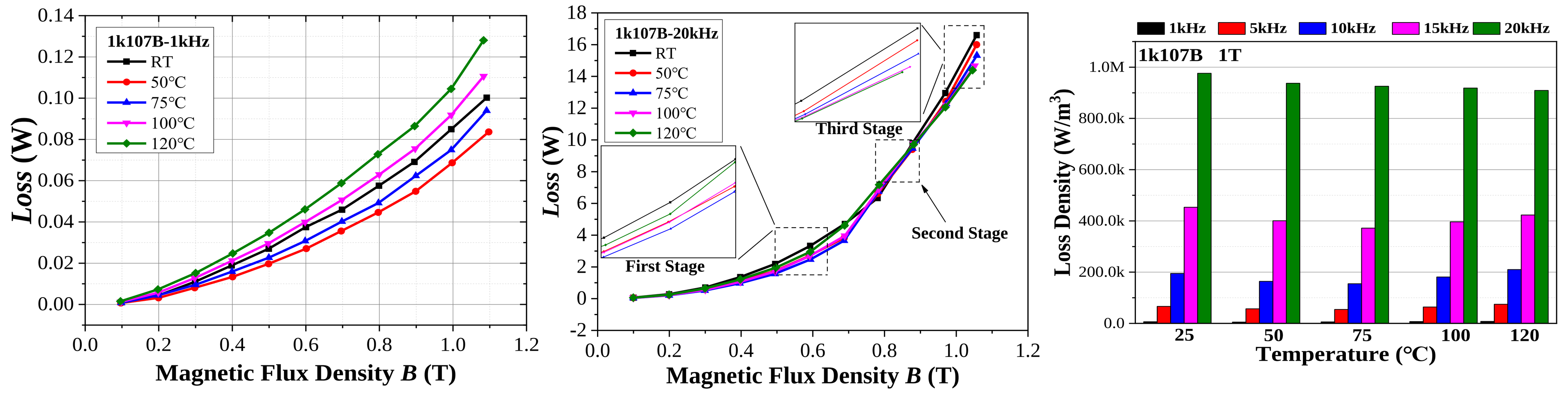


(a) 1k101 (b) 1k107B (c)

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 1k107B 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 1k107B under different conditions, it can be seen that the permeability of the two materials decreases with the increase of frequency and temperature.

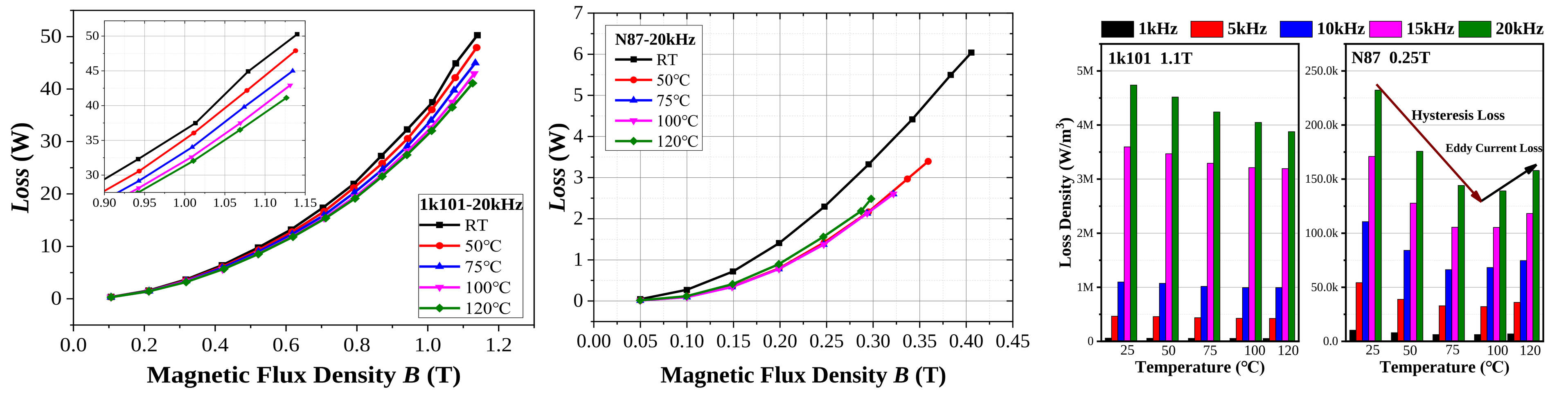
➤4. STUDY ON LOSS CHARACTERISTICS OF MATERIALS



(a) 1 kHz (b) 20 kHz (c)

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

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.



(a) 1 kHz (b) 20 kHz (c)

Fig. 6 The loss curve of 1k101 and N87 at different temperatures.

In terms of 1k101, its loss of 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 ° C to 75 ° C, its loss tends to decrease, but the loss has a tendency to rise from 100 to 120 ° C.

➤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.