Study on the Influence of Temperature on Transformer Core Vibration

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I. INTRODUCTION

•Vibration-based transformer condition monitoring and diagnosis technique has been widely used recently, and core vibration occupies a large proportion in the total vibration of operating power transformer.

•Besides the fluctuant operating voltage, temperature of silicon steel is considered as the major influential factor on core vibration characteristics. However, the relationship between core vibration characteristics and temperature has not been studied yet.

•The objective of this work was to study the influence of temperature on transformer core vibration. Temperature-vibration correction curve was also proposed to correct the vibration response of transformer core under different temperature.

II. METHODOLOGY

A. Experimental System

➢The tested core model was a three-phase three-limb transformer core (without high-voltage windings) with rated voltage of 400V/10kV, rated magnetic flux density of 1.68T, frequency of 50Hz and capacity of 100kVA.

➢A temperature chamber was used to control the core temperature.

➢Core vibration signals were measured by vibration acceleration sensor(PCB 601C01 and 352C65) and NI 9234 data acquisition module.

➢Power quality analyzer was used to get the exciting voltage and current. Moreover, thermocouple thermometer was used to monitor the core temperature.

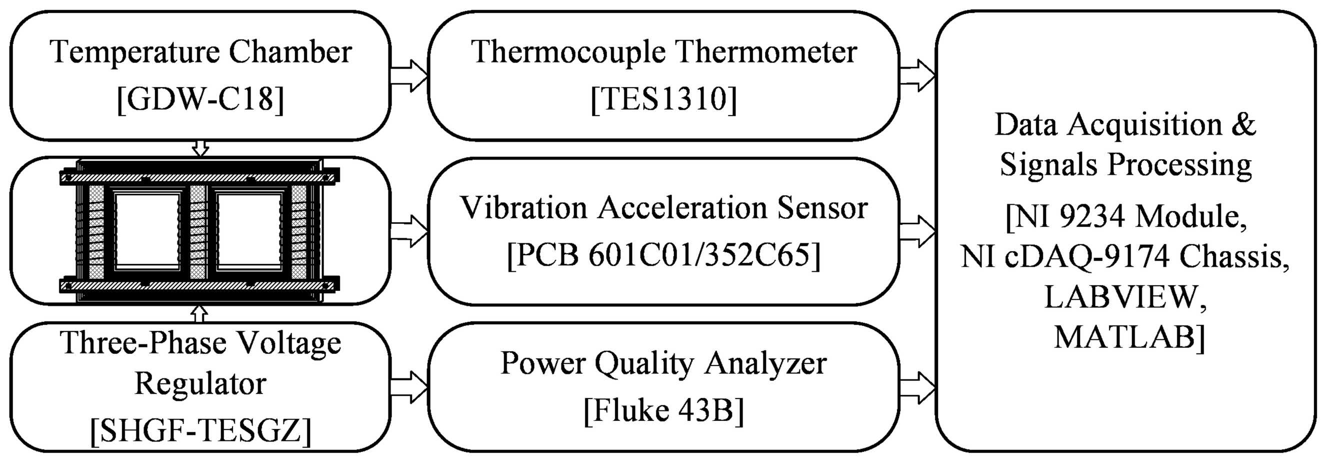


Fig.1 Overview of experimental system

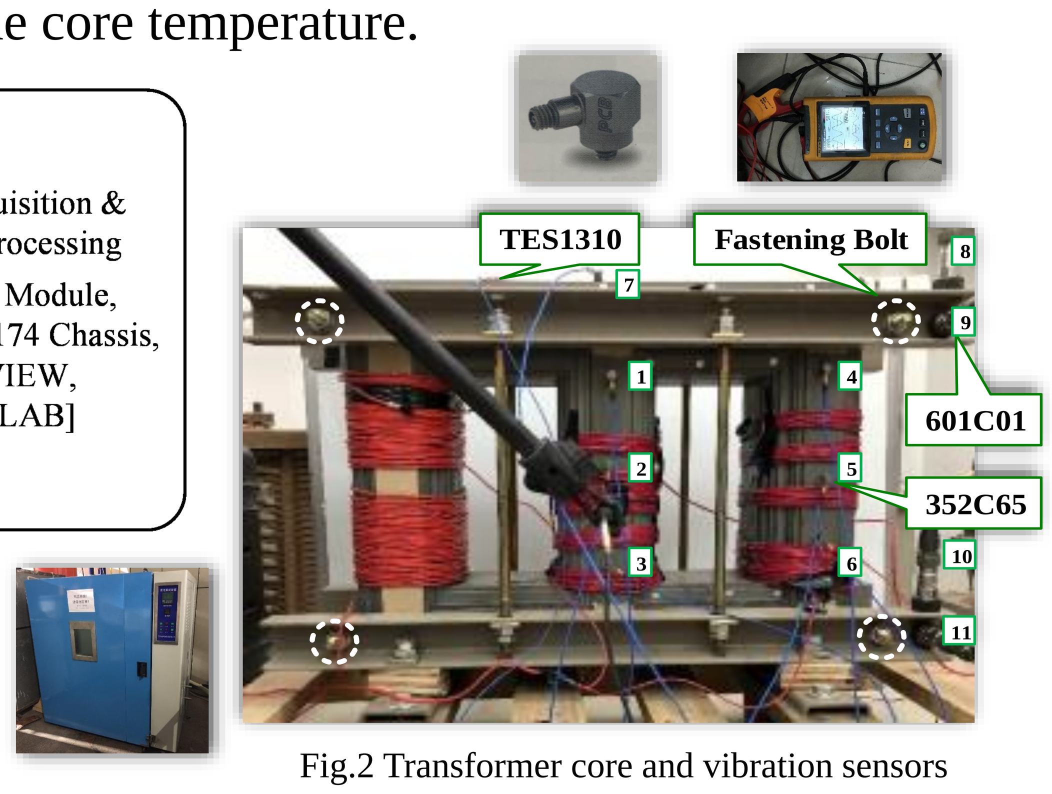


Fig.2 Transformer core and vibration sensors

B. Experimental Procedure

➢The rated low-voltage windings were wrapped around three core limbs separately. Rated clamping force were regulated by the four fastening bolts.

➢The transformer core was heated to 100 ℃ by temperature chamber first, and then was cooled naturally to room temperature(25 ℃) outside the chamber. Thermocouple thermometer was used to get the surface temperature.

➢Transformer core was excited and vibration signals were measured at temperature step of 1(or 2) ℃.

➢Fast Fourier transform was applied to extract the spectrum and the relationship between core vibration characteristics and temperature was investigated.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Vibration Features of Transformer Core

A three-phase three-limb transformer core model was excited by rated excitation voltage of 400V(line voltage) at frequency of 50Hz. The excitation voltage waveform was standard sine wave and the winding current was shown in Fig.3

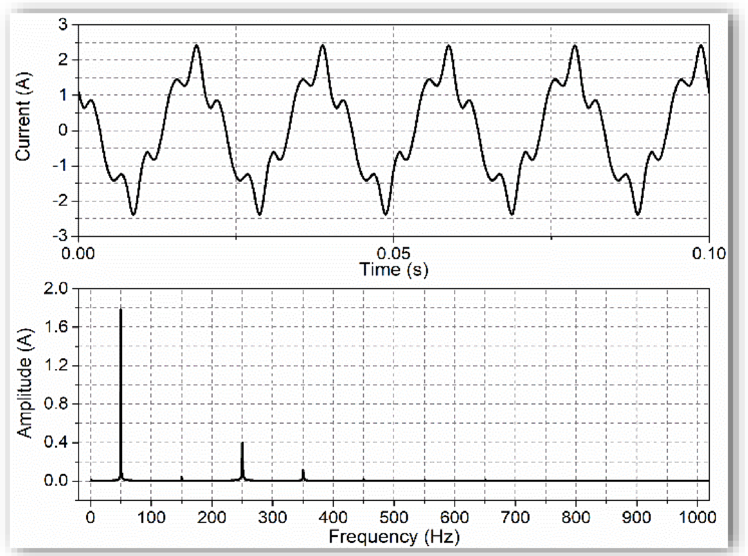


Fig.3 Excitation current waveform and spectrum

Transformer core vibration in different directions and different positions were measured. The vibration spectra of partial measuring points at room temperature(25℃) were shown in Fig.4. (Unit g is gravitational acceleration)

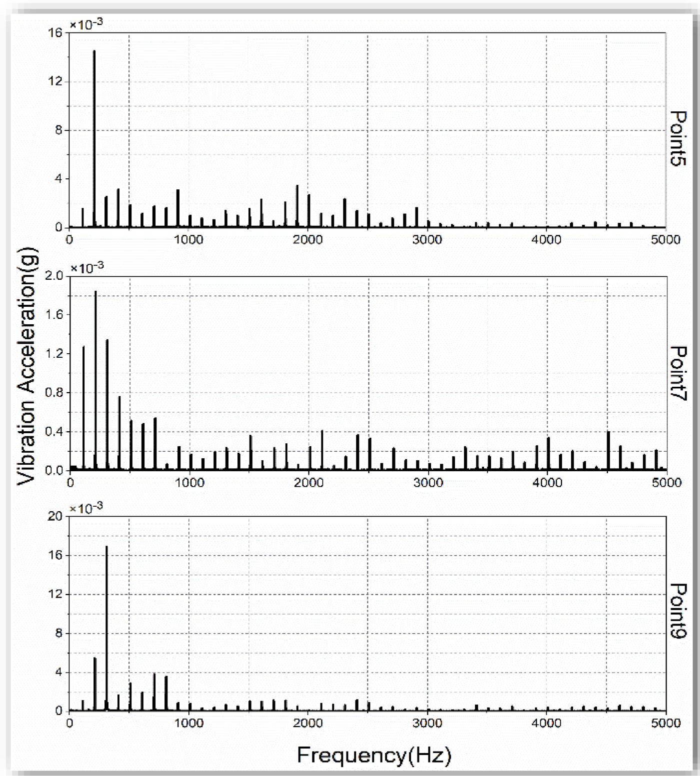


Fig.4 Core vibration spectrum

B. Influence of Core Temperature

Under rated voltage excitation, core vibration was measured during the whole natural cooling process. For each selected measuring point, harmonic spectrum was analyzed and the variation relationship of vibration spectrums and three typical temperatures were shown in Fig 5.

The total power of core vibration is also extracted and changing trend with temperature is shown in Fig.6

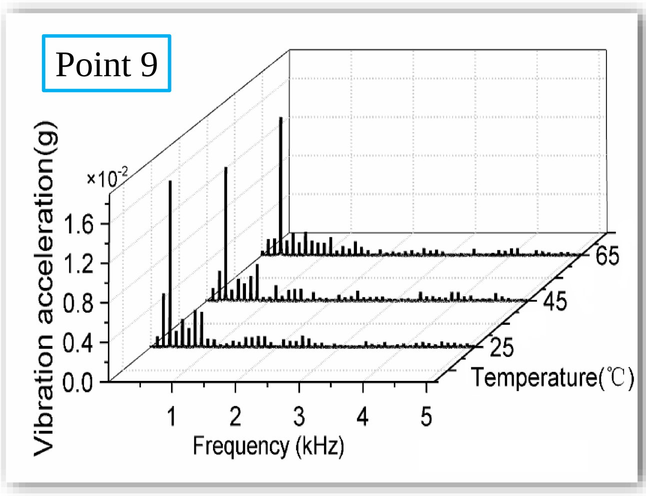


Fig.5 Temperature influence on vibration spectrum

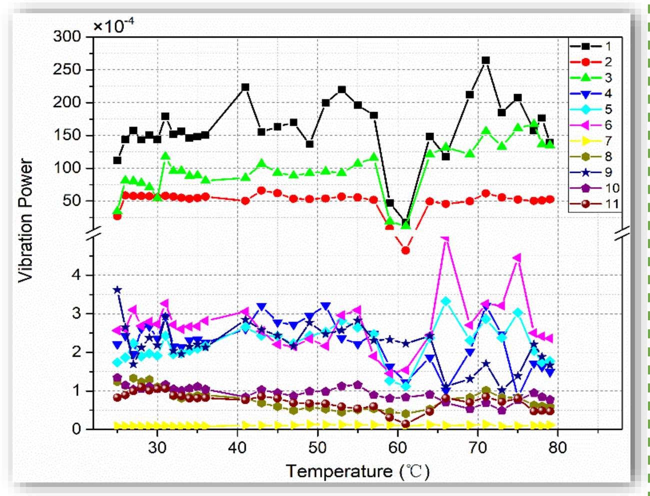
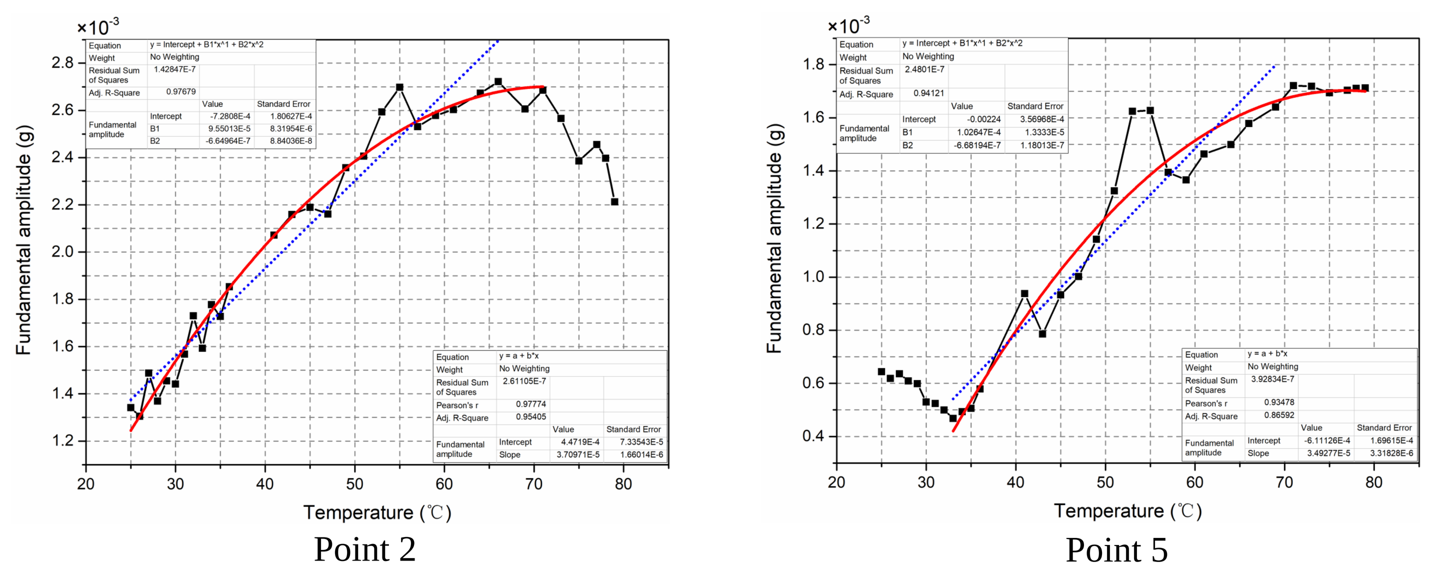


Fig.6 Temperature influence on vibration power

Table 1 GROWTH RATE OF FUNDAMENTAL AMPLITUDE

Measuring point		1	2	3	4	5	6	7	8	9	10	11
Fundamental Amplitude(g)	45℃	0. 004003	0. 002189	0. 004043	0. 000573	0. 000933	0. 001709	0. 001288	0. 000817	0. 001292	0. 002132	0. 001232
	65℃	0. 004487	0. 002673	0. 004666	0. 000922	0. 001499	0. 002078	0. 00132	0. 001296	0. 001676	0. 002143	0. 001396
Growth rate(%)		12. 08	22. 09	15. 40	60. 83	60. 73	21. 61	2. 54	58. 69	29. 7	0. 50	13. 26

Fundamental vibration component shows obvious increasing trend as temperature rises. Fundamental amplitude growth rate of each measuring point when temperature rises from 45 ℃ to 65 ℃ is shown in table I. Polynomial fitting method is applied and fitting results of some points are shown in Fig.7.



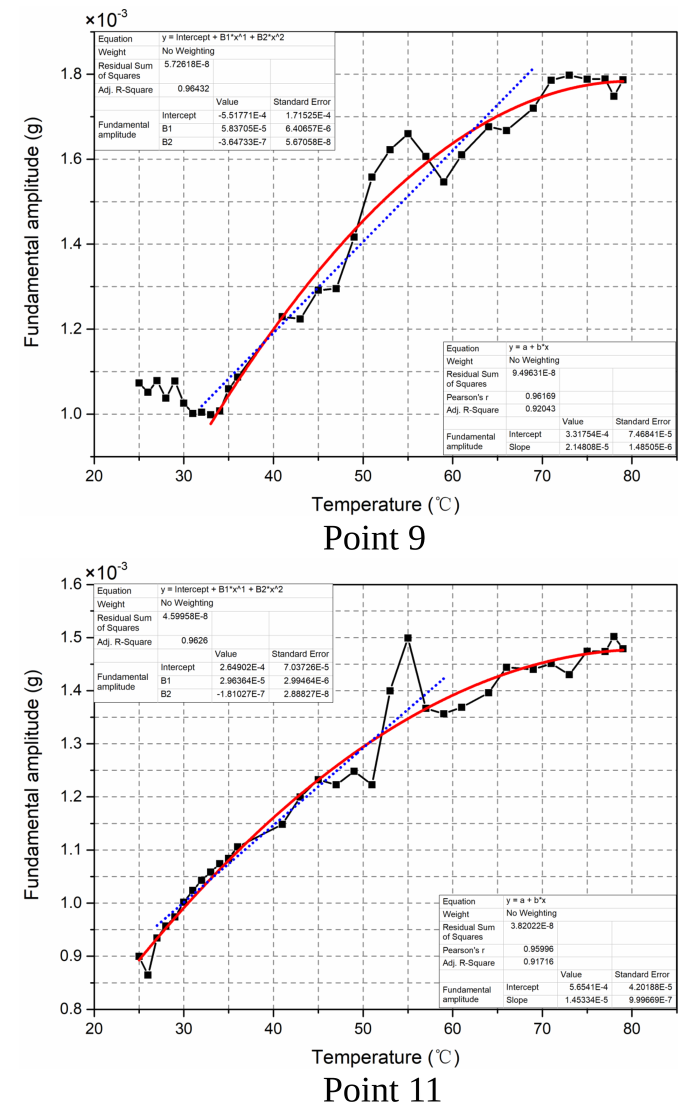


Fig.7 Vibraiton correction curve of some points using polynomial fitting method

IV. CONCLUSION

- Transformer core vibration spectrum is mainly composed of fundamental frequency(twice of excitation voltage) and higher harmonics components.
- Vibration spectrum different from point to point. And vibration amplitudes in normal direction are usually larger than those in parallel direction.
- Within the operating temperature of transformer core, fundamental vibrations of selected measuring points were greatly influenced by temperature while high harmonics were not.
- Vibration amplitude of fundamental frequency increases with the increase of temperature, and it shows a approximate linear relationship below 70 ℃ with growth rates of 0.11-0.37mm·s^(-2)/ ℃, which is different from the measuring points on the core surface. The growth rate decreases and shows a saturation tendency of vibration amplitude occurs over 70℃.
- Temperature-vibration correction curve was proposed to correct the vibration response of transformer core under different temperature and improve the accuracy of vibration-based winding and core condition monitoring and fault diagnosis.

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