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EXPERIMENTS AND SIMULATIONS ON THE VIBRATION OF SHUNT REACTOR AND THE NOISE CONTROL

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ABSTRACT

The vibration signals in the running dry type shunt reactor are measured by the vibration measurement system; the operating noise of the dry type shunt reactor is also tested by the noise measurement system. The modal analysis of the magnetic core is analyzed in different running temperature of the dry type shunt reactor. By adjusting the air gap materials of the magnetic core, a method of reducing vibration and noise of large dry type shunt reactor is presented.

Keywords: *Dry-Type Shunt Reactor; Vibration; Noise Control.*

1. INTRODUCTION

Foreign scholars launched the analysis of vibration signals of shunt reactors earlier. In recent years, Chinese scholars also began to study this subject. But researchers at home and abroad pay more attention to the vibration model and inherent characteristics of reactors. On the vibration and noise of reactors, most researches mainly focus on the oil-immersed reactors. The research on the large dry-type shunt reactors is rarely involved. Z.G. Dong [1, 2] presented by experimental research that the noise spectrum of reactor mainly consists of low frequency components. The reactor with air-gap in the core should not be resonance structure, in order to prevent the generation of resonance. J. J. Guan [3] pointed out that the vibration and noise of shunt reactor are mainly generated by the vibration of discus, which is caused by the stretching of gap materials in magnetic circuit under Maxwell Forces. Q.W. Li. [4] analyzed the measures and the effects for reducing vibration of the 750KV shunt reactors.

In this paper, the vibration signals in the running dry type shunt reactor are measured by the vibration measurement system; the operating noise of the dry type shunt reactor is also tested by the noise measurement system. The vibration characteristics of reactor core at different operating temperatures were studied. The source of vibration and noise of the large 10,000-volt dry-type shunt reactors were explored in-depth. The effective measures to control the vibration and noise of reactors are introduced and practiced. The research can offer effective guidance on the practical application of shunt reactors.

2. EXPERIMENTS ON VIBRATION AND NOISE OF DRY TYPE SHUNT REACTOR

Experiment Setting and Specimen. Dry type shunt reactor is mainly composed by the discus, the air-gap, iron yoke and coils, seeing Figure1. The resin-casted dry type three-phase shunt reactor was tested here, with the rated capacity of 8000kvar, rated voltage of 10000V, maximum operating voltage of 12000V. The signals of vibration and noise were collected by DH5923 dynamic signal measurement and analysis system and Dasp2003 signal collection and processing system under the rated work voltage.

The following contents were concerned in tests: The effect of the strongly-compacted core with dish-spring structure on the vibration and noise of the reactor; the vibration and noise of the reactor and its core under continuous working state and at various temperatures.

Experiment Results. Table 1 shows the experiment results of the reactor with dish-spring structure or not. It is shown that the dish-spring structure cannot obviously reduce the level of vibration and noise of the reactor, but it can improve the stability of the whole structure clearly.

Table 2 shows the experiment results of the reactor under various temperatures. We can see

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that, as the temperature in the reactor core rises, the vibration of the core increases and the noise of overall structure also rises. At the same time, the vibration and noise of the core are shown in Table 3. It shows that the vibration and noise of the reactor mainly come from the vibration and noise of the core. The vibration and noise of the core will increase with increase in its temperature.

The noise spectrum analysis chart of measuring points at different temperatures is shown in Figure2. We can see that each frequency of 100 Hz, 200 Hz, 300 Hz and 400 Hz has an almost same proportion at low temperature, while the higher temperature causes greater change of the spectrum. At higher temperature, the frequency of 100 Hz has a larger proportion than other frequencies. The potential reason maybe comes from the change of the structure of the core, which is caused by the raise of the inner temperature of the core. This maybe is the main reason for the rapid raise of noise of the reactor.

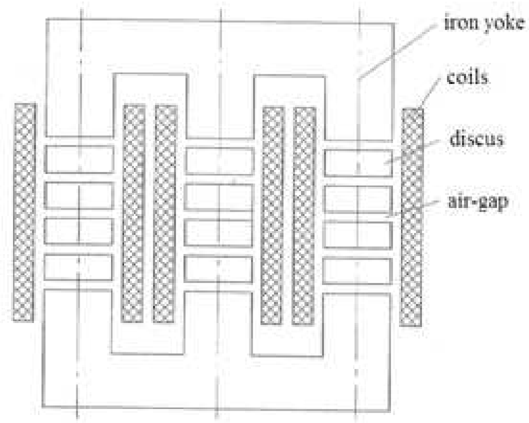

Figure 1 Diagram of dry type shunt reactor

Table 1 The experiment results of the reactor with dish-spring structure or not

Test results		Reactor with dish-spring	Reactor without dish-spring
Right side of reactor	Vibration intensity (m/s2)	0.52	0.45
	Noise (dB)	81.5	80.7
Left side of reactor	Vibration intensity (m/s2)	0.21	0.20
	Noise (dB)	63.3	62.4

Table 2. The vibration and noise of the overall reactor under various temperatures

Test results		Temperatures			
		84.8oC	92.4 oC	107 oC	113.5 oC
Right side of reactor	Vibration intensity (m/s2)	0.4	0.33	0.5	0.71
	Noise (dB)	53.6	64.1	77.3	85.6
Left side of reactor	Vibration intensity (m/s2)	0.3	0.26	0.23	0.32
	Noise (dB)	53.8	54.4	60.9	68.2

Table 3 The vibration and noise of the core under various temperatures

Test results		Temperatures					
		39.8 oC	70 oC	93 oC	126.7 oC	134.2 oC	141.9 oC
Upper right side	Vibration intensity (m/s2)	0.209	0.245	0.231	0.334	0.523	0.7346
	Noise (dB)	56.9	56	53.5	58.3	76.3	77.9
Lower right side	Vibration intensity (m/s2)	0.109	0.263	0.402	0.42	0.678	0.8395
	Noise (dB)	55.2	56.9	56.1	62	77.1	84.3
Upper left side	Vibration intensity (m/s2)	0.180	0.272	0.229	0.278	0.23	0.3807
	Noise (dB)	53.7	54.5	55	58.5	62.8	70.1
Lower left side	Vibration intensity (m/s2)	0.166	0.233	0.235	0.327	0.258	0.6806
	Noise (dB)	53.1	54.7	54.6	54.9	65.7	70.7

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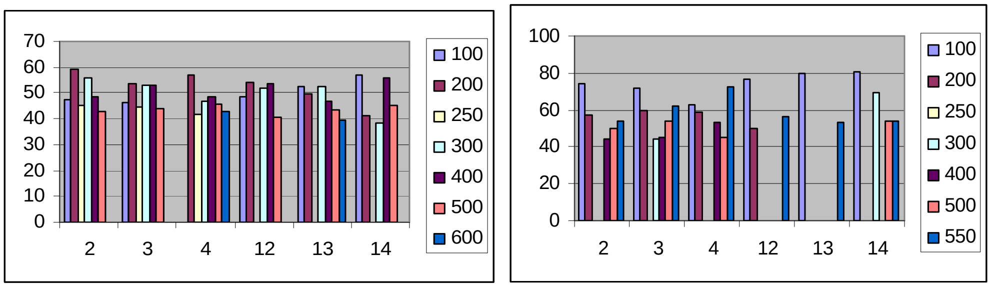

(a) T=37.50C (b) T=138.80C

Figure 2 The noise spectrum chart of measuring points at different temperature

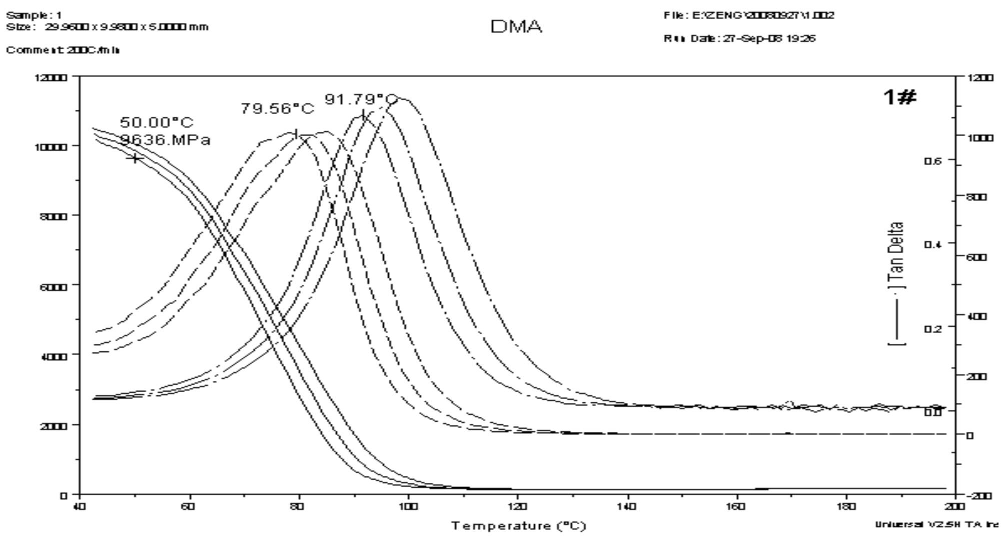

Figure 3 The relationship between elastic modulus of epoxy resin and temperature

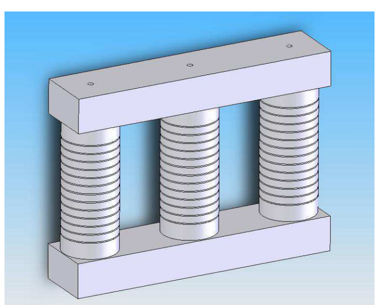

Figure 4 The geometric model of reactor core

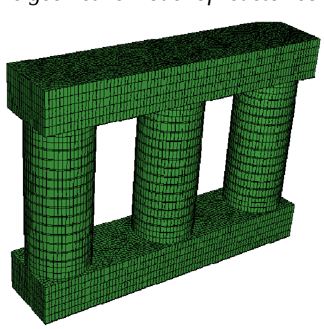

Figure 5 The finite element model of reactor core

To further determine the effect of temperature on the noise of the reactor. We noted that, the air-gap in the core is made by epoxy polymer materials, and mechanical properties of epoxy polymer are very sensitive to temperature. There exists a Glass Transition Temperature, above which the elastic modulus of epoxy resin will decrease sharply, even has a change of magnitude. Figure 3 shows the change of elastic modulus of epoxy resin with temperature rises, which is measured by DMA tests. The Glass Transition Temperature of specimen is around 85oC. Before and after the glass transition temperature, the elastic modulus has a difference of almost two orders of magnitude. Since the internal work temperature of core is far more than the glass transition temperature of epoxy resin, the elastic modulus will change obviously, which have significant impact on the vibration and noise of the reactor.

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3. NUMERICAL SIMULATION ON VIBRATION CHARACTERISTICS OF REACTOR CORE AT DIFFERENT TEMPERATURES

In order to further verify the above analysis on the main reason for the noise of the reactor, the vibration characteristics of reactor core at different temperatures were studied in detail by numerical simulation.

The geometric model of reactor core is shown in Figure 4. The reactors core consists of two parts, steel sheet and epoxy resin material, which finite element model is shown in Figure5. The selected material parameters at different temperatures are shown in Table 4.

The natural frequencies of the overall structure of core at different temperatures are given in Table 5. We can see that, with the change in material properties of epoxy resin, the natural frequencies of core reveal significant changes. Especially, the decrease in the elastic modulus of epoxy resin leads to the migration of the frequency of overall structure of the core, causing a denseness of low-frequency of the core structure. It is verified that the changes in material properties lead to changes in the structure of the system.

Table 4 The selected material parameters in finite element model of the core

Materials	Density (kg/mm3)	Elastic modulus (GPa)	Poisson's ratio
Silicon Steel	7.0×103	120	0.3
Epoxy resin 1	2.49×103	10	0.4
Epoxy resin 2	2.49×103	1	0.4
Epoxy resin 3	2.49×103	0.1	0.4

Table 5 The natural frequencies of the core (Hz)

frequencies	Elastic modulus of epoxy resin		
	0.1GPa	1GPa	10GPa
Frequency of 1st mode	80.116	71.191	111.58
Frequency of 2nd mode	82.949	103.89	189.33
Frequency of 3rd mode	84.352	121.33	204.88
Frequency of 4th mode	89.834	174.79	266.19
Frequency of 5th mode	92.512	186.9	282.41
Frequency of 6th mode	94.64	203.4	316.35
Frequency of 7th mode	95.02	203.57	317.92
Frequency of 8th mode	95.102	208.92	324.59
Frequency of 9th mode	98.474	259.03	341.73
Frequency of 10 th mode	100.66	266.17	434.55

Figure6 illustrates the comparison of the typical vibration modes of the core. The vivid mode and deformation more fully illustrates that the temperature changes lead to the change of structure, causing the different vibration of the core.

4. NOISE CONTROL MEASURES OF REACTOR

According to the above analysis, the main reason for the rapid raise of noise of the reactor is the change of the structure of the core, which is caused by the elastic modulus of epoxy resin at different temperatures. Reminded by this idea, we use marble as air-gap material in the core, instead of epoxy resin. The experiment results show that the vibration and noise of the structure have been controlled effectively. The recorded noises of three reactors at different temperatures are obtained, as shown in Table 6. These results show that, the introduction of new air-gap materials can significantly reduce the noise of reactor at rising temperatures. Before the temperature reaches a stable higher level, the noise of reactor is less than 60dB. Even in the long-running case, the noise level can be maintained at 65dB less.

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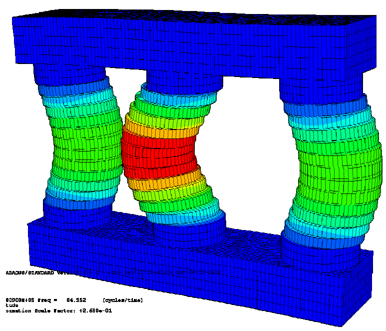
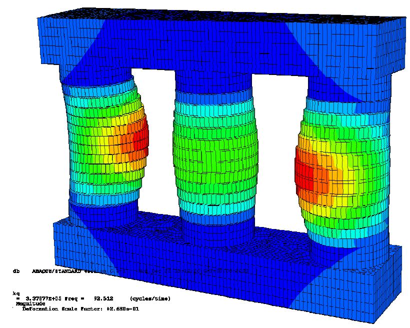
Table 6 The noises of three reactors with marble as air-gap material (dB)

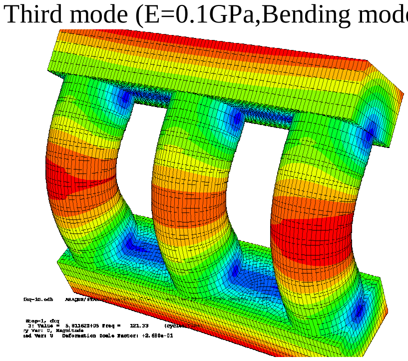
Type of reactor	97.4	123	142
BKSC80000	56.6	55.7	59.3
TK 666241	54.7	55.8	61.1
TK688175	56.1	56.2	59.6



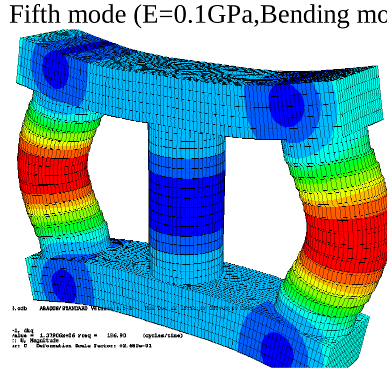
Third mode (E=0.1GPa,Bending mode)



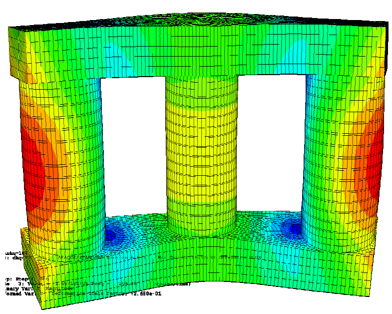
Fifth mode (E=0.1GPa,Bending mode)



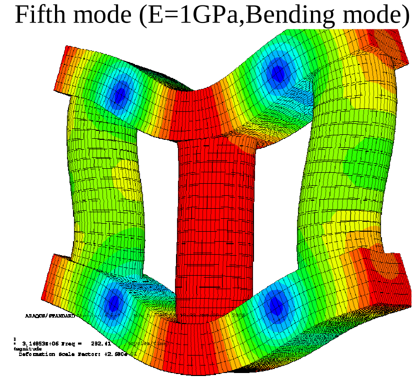
Third mode (E=1GPa,Bending mode)



Fifth mode (E=1GPa,Bending mode)



Third mode (E=10GPa,Bending mode)



Fifth mode (E=10GPa,Bending mode)

Figure 6 The illustration of the typical vibration modes of the reactor core

5. SUMMARY

This paper studies the vibration characteristics of core and coil of dry shunt reactors in power-up work state for the first time. The source of vibration noise of the large 10,000-volt dry-type shunt reactors was explored in-depth. It is found that the decrease in the elastic modulus of epoxy resin with rising temperature leads to the migration of the frequency of overall structure of the core, causing a denseness of low-frequency of the core structure. It is verified that the changes in material properties

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lead to changes in the structure of the system, finally increasing the vibration and noise of reactors. Based on the above conclusions, the practical measures to control the vibration and noise of reactors are presented. The vibration and noise of the structure have been controlled effectively, with a decrease in noise of about 15dB. With noise reduction, the reactors can meet the requirements of national environmental standards.

6. ACKNOWLEDGEMENTS

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