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Study on the DesignTechniques of Ultrasonic Cleaning Device of Motor Winding

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***Abstract*—The insulation level of the motor Winding would be degraded with time and the motor Winding would resumed tide soon after processing, the mechanism of this problem yielding was analyzed, the ultrasonic cleaning method was studies and one ultrasonic cleaning device was designed. Its safety was verified by the destructive experiment. The test show that this device can clear away the depositional dirt in the winding thoroughly, which provides a new idea and method to ensure its insulation level and realize its safe and reliable operation.**

Keywords-Motor Winding; Ultrasonic; Cleaning; Resume tide; Destructive experiment

I. INTRODUCTION

To ensure implementing functions safely and reliably to prevent accidents occurring, the insulation level must reach the appropriate and scientific requirements[1-3]. In many important situations such as aviation, aerospace and national defense, the insulation level will be far lower than the national standard regulation after working a period[4-5]. In this case, it is required to execute cleaning, baking, vacuum pressure impregnation for motor Winding to recover its insulation level. However, with a complex shape and precise structure, it is hard to clear the dirt invading into its narrow gap thoroughly with the traditional cleaning methods, which caused the insulation resistance decreased rapidly and sharply after the cleaned machine operates a period.

This paper studied the application method of ultrasonic techniques in motor Winding cleaning, analyzed the ultrasonic cleaning method according to the structural characteristics of motor Winding and cleaning properties of its dirt and designed one ultrasonic cleaning device, which realized a thorough cleaning to the motor Winding. Also it provides a new idea and method to ensure the reliable performances and safe working state of the machine.

II. THE ANALYSIS TO THE INSULATING PROPERTY OF THE MOTOR WINDING

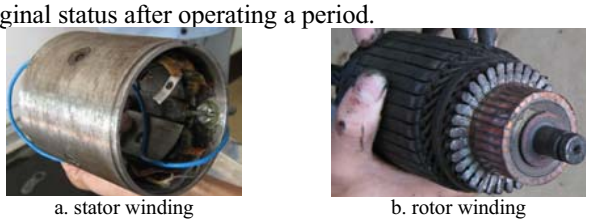
A. The mechanism analysis of the insulation level degrading with time

For AC asynchronous machine, taking Y2 series motors with insulation of level B as an example, the national standards specify compulsorily that the hot insulation resistance of this kind of machine shouldn't be less than 2 MΩ. In other words its insulation resistance should be 64 MΩ when the ambient temperature is 25℃[6]. However after investigation and study it is found that the practical insulation situation is far less than this value with the insulation resistance in the range of several to ten or more MΩ. By analysis that the main reason causing the insulation resistance dropping is owing to the salt mist in watercraft and oil pollution entering the inside of the machine. In many situations, they are used under the standard.

For DC machine, the situation is even worse. Since that the operation of DC machine closely depends on carbon brush, through investigation and study it is found that in most cases the cold insulation resistance of this kind of machine is generally below 0.5 MΩ, similarly the resistance of the main Generator exciter and the main transformer exciter is both about 0.1 MΩ. Through a deep analysis, it is considered that the main reason causing this situation is that the powered carbon of carbon brush enters the inside of the motor Winding accompanied by oil pollution appendiculate on the surface of the winding.

B. The mechanism analysis of the rapid compound tide of the motor Winding after its cleaning.

In the scheduled maintenance, the motor Winding is often cleaned, baked and go through vacuum pressure impregnation. The insulation resistance of machine after these processing maybe all reach several hundreds MΩ. However, when the machine went into work again, the insulation resistance will drop sharply and soon drops to its original status after operating a period.



a. stator winding　　b. rotor winding

Figure 1. The structure of the motor Winding

After study and analysis, it is found that the main reason causing this result is that the machine is cleaned not thoroughly. Nowadays one of the most advanced cleaning methods is to spray washing by adding electric cleaning liquid into the spray gun. However since the geometric shape of the motor Winding is as complicate as shown in Fig 1, it is hard for the spray washed liquid to enter the complex gap so that it can't completely operate on the dirt. Moreover, the structure of the motor Winding is assembled precisely hard to detach. Therefore even if by spray washing only the mixture of powered carbon and oil pollution on the surface

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of motor Winding can be washed out, the oil pollution in the capillary inside the winding can't be reached which will be still appendiculate on the winding surface. In this situation if vacuum pressure impregnation is taken, the insulating varnish can't associate with winding very well. However in scheduled maintenance, a high insulation resistance can be acquired mainly because its inside humidity is forced out after baking the machine. However once back into the bad working environment again, owing to the powered carbon and oil pollution still present in the inside of the winding, the machine will soon be in resume tide.

To ensure a safe and reliable motor performance, its insulation treatment must reach an ideal and satisfying result, to solve which the key is to solve the problem how to clean the motor Winding thoroughly.

III. THE ANALYSIS OF THE ULTRASONIC CLEANING CHARACTERISTICS OF THE MOTOR WINDING

A. The ultrasonic cleaning principle of the motor Winding

The ultrasonic cleaning method to the motor Winding consists of two steps as follows. Firstly, the ultrasonic operated on the liquid medium to generate "cavitations". And then, the motor Winding was suspended in the liquid medium to receive the effect of "cavitations".

The ultrasonic will make the pressure in the medium change alternately centered at the static pressure. If the ultrasonic strength is increased, the pressure amplitude will also increase accordingly. When the ultrasonic strength increases to some extent, tension yields and negative pressure region forms. In the negative pressure region cavitation bubbles form and grow rapidly. When they leave the negative pressure region, the pressure behind makes the cavitation bubbles close suddenly, which produces a strong shock wave and local high temperature and high pressure. This is "cavitations"[7-8], whose model is shown as Fig 2.

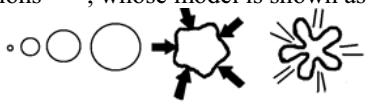

Figure 2. The model diagram of "cavitations"

The impact pressure yielded by vacuole collapsing in "cavitations" can shatter the filth in the gap of the motor Winding and spray them into the cleaning liquid. Since the ultrasonic frequency is high, the "cavitations" yielded can reach 20 to 40 thousand times per second. Therefore as long as the motor Winding can contact to the liquid adequately, it can be cleaned thoroughly.

B. The comparison and analysis of the cleaning effects between ultrasonic cleaning and other methods

The ultrasonic cleaning displays huge superiority compared to other many cleaning methods, especially in specialized situations it has replaced the traditional techniques such as immersion cleaning, brushing, pressure washing, vibration cleaning and steam cleaning[9-11]. The high efficiency and high cleanliness of the ultrasonic cleaning machine benefit from the penetrability and cavitations shock wave generating from its sound wave propagation in the medium, so it is easy to wash out the parts with complex shape, intracavity and pore and its cleaning speed can increase tens of times than the traditional methods. It has unique cleaning effect that other cleaning means can't reach especially for blind hole and various geometric objects. Its advantages are summarized as follows:

(1) Good cleaning effects, high cleanliness and the cleanliness is the consistent to all work pieces.
(2) Rapid cleaning speed which can increase production efficiency.
(3) Safe and reliable since there is no need to contact cleaning liquid manually.
(4) Deep hole, fine draw and work piece shelter can also be washed out.
(5) Solvent, heat energy, working place and labor can be saved.

Therefore, the ultrasonic cleaning can clear all various impurities adhered on the inside of the motor Winding thoroughly to keep the winding surface smooth and clean. Then through baking and vacuum pressure impregnation, the insulating varnish can be coated on the conductor surface uniformly and firmly so that the motor insulation level can keep in the rational range for a long time, which can largely decrease motor failure rate. Thus the ultrasonic cleaning is an excellent cleaning method for motor Winding.

IV. THE RESEARCH ON THE DESIGN METHOD OF THE ULTRASONIC CLEANING INSTRUMENT

A. The analysis on the composition structure and operation mode of the ultrasonic cleaning device

The ultrasonic machine mainly consists of ultrasonic generator, ultrasonic transducer and cleaning tank. Its general layout is shown as Fig 3. When the work piece are cleaned, put the cleaning liquid into the tank and also operate ultrasonic. When the ultrasonic generator transfers the AC in 50Hz into ultrasonic frequency (for example 44 thousand Hz)electrical oscillation signal, and then delivers it to the ultrasonic transducer at the bottom of the liquid tank through output cable, the transducer transfers the ultrasonic frequency electrical oscillation signal into ultrasonic frequency mechanical vibration and sends it into the cleaning liquid[9-10]. The cleaning tank is a container for accommodating the cleaning liquid and to be cleaned objects.

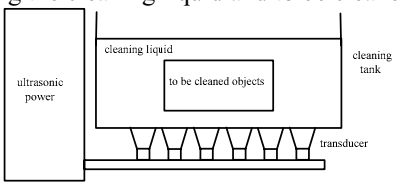

Figure 3. The general layout of the ultrasonic cleaning machine

B. *The general structural design and realization of the ultrasonic cleaning instrument of the motor Winding*

The designed ultrasonic cleaning device of the motor Winding is shown as Fig 4, which consists of two parts, that is ultrasonic generating power and transducer adopting frequency-sweep technique with working frequency of about 28 thousand Hz.

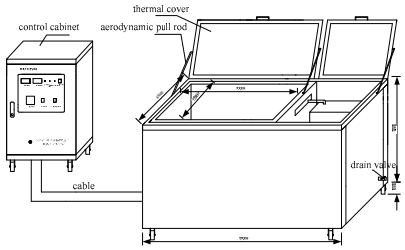

Figure 4. The overall structure design of the ultrasonic cleaning device

The transducer is installed on three sides that are the bottom and also two opposite sides of the cleaning tank just as shown in Fig 5.

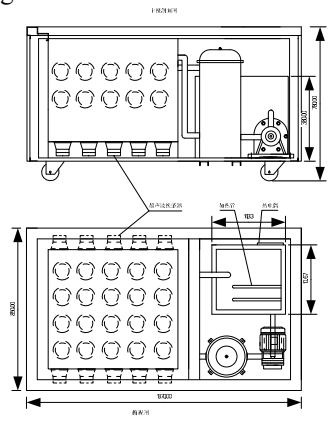

Figure 5. The cutaway view of the cleaning tank

C. *The design of cleaning liquid filtering and recycling*

The system for the cleaning liquid filtering and circulating shown in Fig 6 is designed on the ultrasonic cleaning device. The cleaning liquid is recycled through filtering with circulating pump. Moreover it can strengthen the fluidity of the cleaning liquid to ensure the ultrasonic cleaning effect. The fluid liquid can adequately accomplish its growth and closure movement of the vacuole which is benefit for the cleaning effect. Besides, the flow of the cleaning liquid is also benefit for the exchange of the cleaning liquid temperature to keep it in the range needed by ultrasonic cleaning.

D. *The design principle and analysis of the ultrasonic generator*

The ultrasonic generator system is generally made up of rectifier unit, power inverter, matching network, feedback network, signal processing circuit, driving circuit and transducer, whose principle block diagram is shown as Fig 6.

During work, the three-phase industrial frequency AC is turned into smooth DC after rectifying and filtering by rectifier and then is sent to inverter; The inverter adopts electric semiconductor device (IGBT) as switching device and turns DC into AC of needed frequency; It is operated on the transducer load by matching network to make the circuit stay in resonant condition. Sample the current and voltage signal in resonance circuit and obtain the feedback signal suitable for DSP processing by feedback network; The signal processing circuit realizes the functions of frequency tracking and power regulation; The output signal from DSP is input into the high-frequency driving circuit as the driving and control signal of the power tube IGBT.

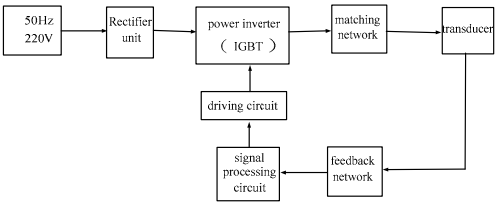

Figure 6. The principle block diagram of the ultrasonic generator

V. 4 THE DESTRUCTIVE EXPERIMENT STUDY ON THE ULTRASONIC CLEANING OF THE MOTOR WINDING

A. *4.1 The objective analysis of the destructive experiment*

As is known from the ultrasonic cleaning mechanism, the destructive capability of the ultrasonic "cavitations" is very strong. Therefore, for the ultrasonic cleaning of the motor Winding, it is very important and essential to control the destructive capability of "cavitations" in a certain range.

By analysis, the key to solve the destructive effect is to control the power and time for cleaning. This paper designs a destructive experiment to test and guide designing scientific power and time for the ultrasonic cleaning device.

B. *4.2 The study on the destructive experiment method*

Choose five different specifications of enameled wires with different diameters and simulate the winding properties of motors with different specifications. The enameled wires are winded and installed on the carrier, shown as Fig 7.

Figure 7. The enameled wires winded and installed on the carrier

Figure 8. The enameled wire cleaning test

In test they are placed in the ultrasonic cleaning liquid shown as Fig 8.

C. 4.3 The destructive experiment results and its analysis

The enameled wire-based ultrasonic destructive experiment results are shown as Table 1.

Table 1 The ultrasonic destructive experiment results of the enameled wire

wire Dimeter (mm)	1.65	1.2	1.0	0.8	0.4
Before cleaning (MΩ)	500	500	200	200	60
Cleaning 20min (MΩ)	500	500	200	200	60
Cleaning 40min (MΩ)	500	500	200	200	60
Cleaning 1h (MΩ)	500	500	200	200	60
Cleaning 2h (MΩ)	500	500	200	160	40
Cleaning 3h (MΩ)	400	400	30	0.5	0
Cleaning 5h (MΩ)	45	10	1	0	0

An experimental conclusion for the ultrasonic experiment simulated by enameled wire can be drawn as follows from the above results:

(1) The thickness of the insulating layer has a great deal with the "destructive effect"of the ultrasonic to the varnished wire.

(2) The cleaning time has a great deal with the "destructive effect"of the insulating layer.

(3) It is considered that ultrasonic cleaning within one hour is safe to the winding insulating layer since the wire winding of the motor Winding is generally above 0.8 mm.

VI. 5 EXPERIMENTAL RESEARCH ON THE ULTRASONIC CLEANING APPLICATION IN THE MOTOR WINDING

A. 5.1 The using methods of the ultrasonic cleaning device for the motor Winding

First check power, power cabinet, cleaning tank and filter equipment to ensure the ultrasonic cleaning device in normal working state. Then add proper cleaning agent according to technological requirements, place the power regulation knob to the minimum position, insert the cable plug of the power onto the power socket, turn on the power switch, place the power regulation knob to the required power value, after all that the ultrasonic cleaning machine starts working. Open the filtering and circulating device, turn on the temperature control switch, and heat to keep the cleaning liquid in the ultrasonic cleaning tank in proper temperature conditions. Finally after the temperature is stable, suspend the motor Winding in the cleaning liquid for ultrasonic cleaning, 15 minutes later, take the motor Winding out, wash it out with clean cleaning liquid, place the knob of the capacity control back to the minimum position when out of work, turn off the power switch.

B. 5.2 The application of the experimental results and its analysis

Each individual part of the machine is contaminated with oil pollution, among which the contamination of the motor Winding is very severe shown as Fig 9, from which it is seen by naked eye that plentiful oil pollution adheres to the motor Winding, and the contamination has degraded its insulation capability largely.

Figure 9. Motor winding before cleaning

The motor Winding after cleaning is very clean shown as Fig 10, contrarily no oil pollution can be seen by naked eye.

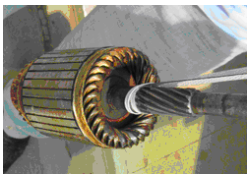

Figure 10. Motor winding after cleaning

By an analysis of the experimental results, it is known that both the surface and intracavity of the work piece through ultrasonic cleaning are washed out in microscopic conditions. The ultrasonic cleaning speed is high, 5 to 10 times of the high pressure washing, and 20 to 50 times of the immersion cleaning. With no dead angle, the ultrasonic cleaning is more suitable for the work piece which has complex structure internal and external, microscopic roughness, slit, small hole, corner and dense components, especially for these work piece with complex shape like motor Winding the ultrasonic cleaning techniques yet should be the first choice.

VII. 6 CONCLUSIONS

This paper analyzed the insulation level fall mechanism of the motor Winding, studied its ultrasonic cleaning method, designed one ultrasonic cleaning device, and devised a destructive experiment to provide a reference for the design of the power and time of the ultrasonic cleaning device for cleaning to avoid the damage of the "cavitations" to the motor Winding. Application experiments indicate for work piece with complicate shape like motor Winding, ultrasonic cleaning is an effective cleaning method.

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