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Development of insulation deterioration diagnosis of motor coils
モータ巻線の絶縁劣化診断技術の開発

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The relation between the aging conditions and the partial discharge (PD) characteristics in twisted enameled magnet wires has been investigated for early detection of deterioration of electrical insulation of motor windings. In particular, an application of repetitive impulse voltage pulses was used for the PD measurements in order to simulate inverter surge. The aging temperature was varied from 220 to 300 °C, and the exposure time was changed from 1 to 1000 hours. As the results, the small deterioration due to the thermal accelerated aging, which cannot be detected by conventional methods such as a withstand voltage test, was clearly found as a decrease of repetitive PD inception voltage (RPDIV).

1. Introduction

For motor manufactures, it is very important to detect deterioration of insulation capabilities of motor coil windings due to manufacturing defects, mechanical stresses, environmental ones such as temperature and humidity, and electrical discharge activities. In particular, recent inverter-fed random wound motors are suffered from inverter-surge voltage pulses [1]. Failure of motor operations due to insulation breakdown causes a heavy cost of repair and loss of service. Thus, it is necessary to make a method of early detection of deterioration of insulation capabilities of motor windings. Recently, we have started to develop a new diagnostic method to detect insulation failures of random wound motors [2]. In this study, a thermal stress on motor coil windings was considered as one of degradation processes, and measurements of partial discharge of twisted pair samples simulated for random wound motor windings with thermal accelerated stresses were carried out. Especially, repetitive impulse voltage pulses were applied to the twisted pairs in order to simulate inverter-surge voltage.

2. Experimental setup

The twisted pair consists of two enameled magnet wires to simulate random wound motor coils. The total length and the number of the twisted turns are 120 mm and 10, respectively. The diameter of conductor is 1.4 mm. mm. Ester-imide (EI) is used as insulation organic material, and amide-imide (AI) is coated on the EI layer in order to protect the surface from mechanical damage during manufacturing processes of motor windings. The temperature class of the insulation material is class F standardized by the IEC (International Electrotechnical Commission) which withstands a temperature of 155 °C. The twisted pairs were heated in a temperature-controlled oven to simulate thermal aged motor windings. The aging temperature was varied from 220 to 300 °C, and the exposure time was changed from 1 to 1000 hours. The experimental procedure in this study is shown in Fig. 1. Five twisted pairs for each kind of aging conditions were used for PD measurements. Here, the measurement was carried out in atmospheric air, and the ambient temperature and humidity were 25 °C and 30 %, respectively. Repetitive impulse voltage pulses were generated by an impulse winding wire testing machine (ECG-KOKUSAI Co., type: DWX-05). This power supply has been used as a common impulse generator with a fixed impulse sequence pattern specific to round-robin test (RRT) for repetitive PD inception voltage (RPDIV) measurement in Japan [3].

The PD was detected by a photomultiplier tube (PMT, Hamamatsu Co., type: R960, 185-650 nm) and narrowband antenna (patch antenna, center frequency 1.8 GHz) [4]. The repetitive impulse voltage pulses were measured by a high voltage probe (Tektronix Co., type: P6015A, 75 MHz). The measured data was recorded by a digital oscilloscope (Tektronix Co., type: DPO7104). Ten voltage impulses with the same negative voltage amplitude were applied to the twisted pairs with a period of 20 ms. The peak value of the impulses

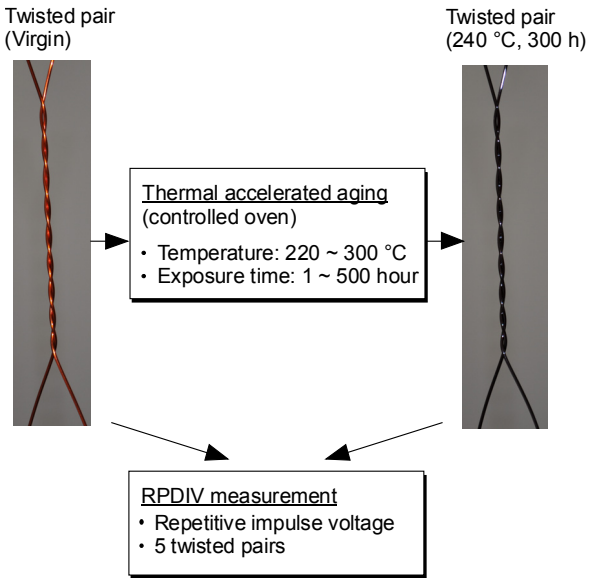

Fig. 1 Experimental setup

was increased from 1 kV to 2 kV.

3. Experimental results

Firstly, the RPDIV of the virgin twisted pair was about 1.9 kV. Figure 2 shows the RPDIV of the thermally degraded twisted pairs as a function of the thermal aging time at each temperature. Each data point was obtained by averaging over the measured RPDIV of 5 twisted pairs. Here, the horizontal axis of Fig. 2 is logarithm of t_a. The breakdown voltage of the twisted pairs degraded thermally at 240 °C (10 h) from the withstand voltage test was same as that of the virgin sample, however, a significant decrease of the measured RPDIV was observed. The RPDIV of the twisted pair at t_a = 10 h decreased into 90 % of PDIV of the virgin sample. This decrease of RPDIV was reproducibly measured in this study. In addition, the PDIV was linearly decreased by plotting (PDIV-log t_a) with the increase in t_a. Therefore, it could be considered that insulation capability of random wound motors could be estimated by the decrease of the RPDIV. The sensitivity of the RPDIV for detection of thermal deterioration of enameled wires is higher than that of the PDIV under a voltage application of ac 60 Hz [2].

4. Summary

The RPDIV measurements of the twisted pairs with thermal stresses have been performed in order to develop a new evaluation method of degradation of insulation capabilities in electrical motors. From the results in this study, it is found that the small degradation of the enamel layer gives rises to the

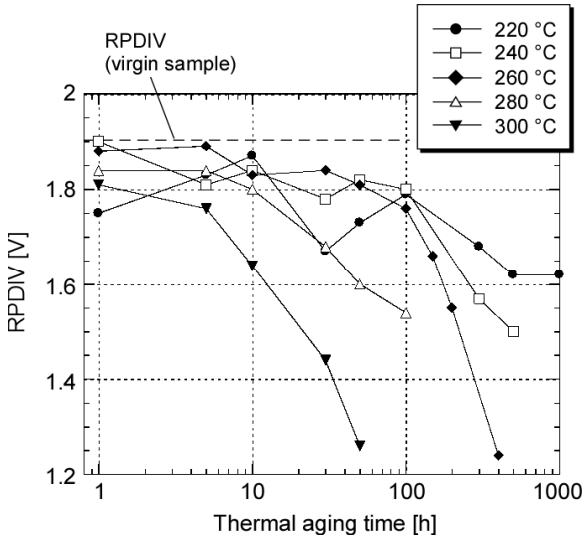

Fig. 2 Effects of thermal stresses on the RPDIV

significant reduction of RPDIV. The other deterioration processes such as salt damage for electrical motors in a ship will be considered in the future. In addition, this method will be applied to not only twisted pair samples but also actual motors.

Acknowledgments

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