China Corner

Development on Insulating Materials for Inverter-fed Motors in China

1. Overall

The carrier frequency of inverter-fed motor has been developed from a few kHz to more than 10 kHz currently since pulse width modulation (PWM) control mode is widely adopted in inverter-fed motor. Consequently, the stator winding of electric motor is able to withstand a higher change rate of voltage (dU/dt) and the turn-to-turn insulation of electric motor could also withstand a greater electric stress. Under variable-frequency voltage, the turn-to-turn insulation is subjected to a voltage dozens of times higher than that under sinusoidal voltage waveform. In this case, the partial discharge would generate in the interior of materials, which is the main reason for premature failure of insulation material in inverter-fed motor [1-2]. In addition, although the low-order harmonic components are greatly reduced due to PMW, there are very high harmonic components caused by PWM in the output voltage waveform of inverter-fed motor. These high harmonic components become particularly critical in the condition of low-voltage output. Their amplitudes can even be approximate to fundamental waveform. Their existence causes an increase in the resistance of the conductors of stator and rotor, resulting in a temperature rise of about 10%-20% [3-5]. Therefore, thermal loss is one of reasons for accelerating the aging of insulating materials. The effect of space charge, the electromagnetic excitation, vibration, etc can also accelerate the aging process of insulation materials. These factors greatly affect the performance of insulation materials in the inverter-fed motor. This article focuses on the research and application progress in corona-resistance wire enamel, corona-resistant film and silicone impregnating varnish in China.

2. Corona-resistance wire enamel

Before 1990’s, Chinese researchers who were major in insulation material used the method of adding inorganic fillers into the polymer to improve the corona-resistance performance of the corona-resistance wire enamel. However, the production technology of the inorganic fillers in the early stage only reached micron size or submicron size. As a result, the surface of the enameled wire using the enamel which was filled by this kind of fillers was too rough to meet the technology requirements. After 1990’s, as the production technology of the nano-particles was becoming more and more mature, people began to have the nano-particles filled into the wire enamel to form higher heat-resistances wire enamel. In recent years, China has been launching great number of research works in the field of the application of the corona-resistance wire enamel for variable frequency motor. Researchers from Harbin University of Science and Technology, Xi’an Jiaotong University, Shanghai Electric Research Institute and Shanghai Electric Cable Research Institute, etc have done related research works in different aspects [6, 7] and have achieved great progress. The results of the researches prove that the compound corona-resistance wire enamel that consists of nano-particles can result in the improvement of the corona-resistance performance up to 5~100 times [8, 9]. Furthermore, some achievements have been transferring into industrial applications. For example, the research conducted by Shanghai Electric Research Institute and Shanghai Electric Cable Research Institute is now being transferred into a small-scale production in Chang Shu Weifu Company [10].

3. Polyimide film

Polyimide (PI) film is widely used as insulation material in motor due to its excellent thermal, mechanical and electrical properties. Thus, it plays a significant role in extending the service life of motor through improving the corona resistance performance of PI film. According to the Twelfth Five-Year Plan, there will be a leapfrog development on high-speed rail in China during this period, for which the traction motor with high power is the key equipment. Therefore, how to improve the breakdown performance and the corona resistance property of PI film is now one of the key issues Chinese researchers have to deal with.

On one hand, China chose to introduce foreign high performance PI film. Chinese engineers have worked on the manufacturing technology of motor insulation using these PI films. For example, CSR Zhuzhou Electric Co., Ltd and Chang Shu Weifu Company have achieved what Kaption CR PI film has successfully applied to JD150S high-speed hybrid (power 1020kW, voltage 1950kV, rotating speed 4000r/min) as turn-to-turn insulation through winding and sintering on copper wires. After a few year exploration practices, the manufacturing technology of PI film insulation in China has been gradually put into use in industry.

On the other hand, researchers have been developing new PI film through incorporating nanoparticle into PI matrix. Researchers in Xi’an Jiaotong University, Harbin University of Science and Technology, Shanghai Jiaotong University and Tongji University, etc, have done some works on the corona resistance, breakdown performance, space charge and thermal property of PI nanocomposite [11-14]. Some advantageous results have been obtained. For example, the corona resistance property of PI nanocomposite film has a great improvement [14-15].

4. Impregnation paint of organic silicon

Impregnation paint of organic silicon has wide application in special motor such as traction electric machine. This kind of paint can meet the requirement of high heat resistance and high reliability of the insulation system of the variable-frequency traction motor. At present, China is in the process of gradually digesting and absorbing "C-
level system of insulation structure” from foreign countries, and, at the same time, designing and applying the impregnation resin of organic silicon that has better performance in corona resistance. For example, CSR Zhuzhou Electric Co., Ltd has employed 3551 solvent-free organic resin and H62A/B organic resin produced by Wacker Chemie AG on KZ4A and DJ4 traction electrical machine. Moreover, after several years of technological advancement, Zhuzhou Times New Materials Technology Co., Ltd has achieved great breakthrough on the technology of production and application of the impregnation paint of organic silicon. Machinery Industry Electric Material Product Quality Supervision and Inspection Center of China has verified that its products have the same performance as similar products from overseas.

5. Others

Researchers and engineers in Xi’an Jiaotong University, Harbin University of Science and Technology, Shanghai Jiaotong University, CSR Zhuzhou Electric Co., Ltd and some others have investigated the aging and breakdown mechanism of insulation materials under nonsinusoidal applied field. In the early researches, Chinese researchers mainly focused on the origin of aging and breakdown of insulation materials, such as the effect of thermal, space charge, vibration, etc., on the aging and breakdown. Based on these researches, Chinese researchers and engineers proposed that adding micro inorganic filler into polymer was likely to improve the aging property of turn-to-turn insulation material. With the development of nanotechnology, Chinese researchers gradually pay more and more attention on the effect of nanoparticles on the aging and breakdown of insulation material in recent years [11, 12, 16, 17]. For example, Liu had proposed that nano TiO2 can optimize the distribution of bulk electric field in TiO2/PI composite [11]. After corona discharge, nmTiO2 deposited on the surface of composite and formed an electron shielding layer. This layer can capture charge carriers. The captured charge carriers transport around the surface of composite due to the higher conductivity of nmTiO2, which is advantageous to reduce the accumulation of charges. In addition, nmTiO2 can absorb the ultraviolet rays caused by corona discharge, reducing the degradation of polymeric matrix [11].

These investigations are beneficial for the understanding on the ageing mechanism of PI film in inverter-fed motors, so that the design of the structure of turn-to-turn insulation [18] and inverter-fed motor has been improved. The traditional inverter-fed motor has been changed to baseband system inverter-fed motor. For example, the VFG series products of variable frequency motors manufactured by Shanghai Fukuda Motor Co., Ltd are the baseband system inverter-fed motors. They have been widely used as infinitely variable speed electric drive, such as in pump station and mechanical engineering.

Reference


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