NUMERICAL AND EXPERIMENTAL INVESTIGATION ON SALT-FOG AGING OF SILICONE INSULATORS

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Abstract: This paper describes the change in polymer materials of insulators under aging conditions. In order to examine the factors that are related with deterioration, the salt fog aging test was conducted on 24 KV insulators for 500 hours. The applied voltage and salt fog were generated according to recommendations of IEC 61109. After the test, the virgin and aged samples were analyzed by Fourier Transform Infrared Spectroscopy (FT-IR) and contact angle measurements. FTIR results showed that after an initial decrease of the number of methyl groups, a restoration occurs on the surface of aged sample. It can be due to the movement of LMW polymer chains (polymer liquid or polymer oil) in the bulk to the surface due to the difference of densities. Moreover, STRI hydrophobicity test and contact angle measurements showed that the hydrophobic character of the virgin sample decreased slightly under stress factors of salt fog chamber.

1 INTRODUCTION

Composite insulators have now been used on distribution lines for several years[1]. However, damages such as losing its hydrophobic character which affects the insulator performance are produced by aging of insulator weathershed[2,3]. one of the natural pollutants which strongly affects the electric performance of polymeric composite insulators is salt contamination[4]. Therefore, it is of interest to study the chemical and morphological influence of salt deposits on the surface of insulators.

Otsubo et. Al. investigated on aging of three types of polymers under salt fog stress[5]. They used a saline conductivity of 0.1 mS/cm for the experiment. They based their hypothesis on the fact that evaluating the polymer performance in actual applications is more appropriate when a lower conductivity saline solution is applied. They claimed that the designation of their system makes them able to control the humidity rather than the conventional saline flow. The results of their investigations showed that the environmental humidity and wettable condition of the sample strongly influence the rate of increase of leakage current and the aging time. Also, the ability of silicone rubber sample to hydrophibicity recovery is more than that of two other polymer materials. Stanislaw et. Al. investigated on hydrophobic characteristics of EPDM and Silicon rubber insulator materials after exposure to saline pollution[6]. They found out that the aging of EPDM insulator housing increases the surface energy and makes it hydrophilic. However, the polymer of the silicone rubber insulator housing may recover the chemical degradation. It is due to the fact that the polymer reorientation and oil and low molecular immigration may be stimulated by external energizing factors. Sebo et. Al. conducted fog chamber aging tests to analyze the cumulative charge test data, for both low and high salinity fog conditions [7]. This test was conducted on silicone rubber and EPDM insulators for 500 hours in both of the chamber. It was found out that silicone rubber insulator housing materials show lower magnitude of cumulative charges in both of the low and high salinity chambers. Tourreil et. Al. exposed 72KV and 230 KV composite long rod insulators to salt fog procedure according to IEC 507[8,9]. The insulators were monitored during the laboratory aging by measurements of peak currents and by recording flashovers when they occurred. It was found out that the position of the insulators remarkably influence the electrical performance. Moreover, it was concluded that in order to determine the long term electrical behaviour of composite insulators in service in the laboratory, the salt fog aging procedure, in conjunction with the rapid flashover clean fog is a diagnostic test method.

In the present work, chemical and morphological changes of an energized insulator in the salt fog chamber were examined. Fourier Transform Infrared Spectroscopy (FT-IR) was used to evaluate chemical structure of the insulator before and after the aging test. Contact angle measurements and STRI hydrophobicity classification were used to examine the hydrophobic property of the insulator before and after the test.

2 EXPERIMENTAL

2.1 Test Specimens and Procedures

The polymeric 24KV insulator material was purchased from Taban Niroo Company of Iran. After the duration of the test, a piece of 2mm thickness was taken from the upper side of the insulator sheds. It is due to the fact that the environmental stresses of the chamber strongly affect these parts.

Aging of the sample was conducted in a salt fog chamber of dimensions 2m×3m.×5m constructed in the Niroo Research Institute of Iran. The applied voltage and salt fog were generated according to the recommendations of IEC 61109. The duration of the test was 500 hours.

2.2 Analysis Techniques

Fourier transform infrared(FT-IR) and attenuated total reflectance spectroscopy (ATR-IR) techniques were used for surface characterization. Infrared spectra were recorded on a Bruker IFS 484 microscope, between 400 and 4000cm^{-1}.

The contact angles of water were measured by the extension method with horizontal protractor eyepiece at room temperature(type: contact angle measuring system G10 KRUSS). at five different positions of one sample, water droplets were placed and the averaged value was adopted as the contact angle. In order to ensure repeatability, the size of attached water droplets was kept constant about 5µl while the contact angle was measured after 1 min of droplet placing. The values of the polar and dispersive components were obtained by the Owens and Wu equations [10, 11].

STRI hydrophobicity test was also conducted according to STRI classification guide [12].

3 RESULTS AND DISCUSSION

In order to do chemical analysis, FT-IR result was used to monitor the chemical changes of the insulator sample under the stress factors of the salt fog chamber.

Figure 1a and 1b show the FT-IR spectrum of the virgin and aged samples. In this figure, the absorption peak in 1005 cm$_{-1}$ is attributed to Si-O bond. Also, the absorption peak at 1259 cm$_{-1}$ refers to Si-CH_3 bond and 2962 cm$_{-1}$ to stretching C-H bond. The Comparison of the FT-IR result of the virgin and aged sample in figure 1 shows that the intensity of Si-CH_3 bond increased in the aged sample. In order to have further information about the chemical changes of the samples, the absorption peak ratio of Si-CH_3 to that by Si-O was calculated. Table 1 shows the ratio calculated for these two samples. It can be seen that this ratio in the aged sample have an increase in comparison with that of virgin sample.

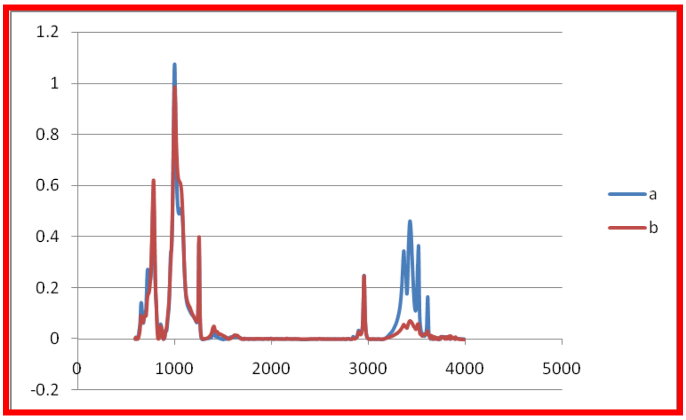

Figure 1: FT-IR spectrum of the (a) virgin and (b) aged sample

sample	Si-CH3/Si_O
virgin	0.354038
aged	0.406046

Table 1: The adsorption peak ratio of the virgin and aged sample

An explanation for this occurrence may be related to a fact about SIR insulators. It is believed that the CH_3 groups are one of the main factors for surface hydrophobicity of SIR insulators. Therefore, a reduction in the absorption peak ratio of Si-CH_3 to that by Si-O is an indicator of chemical degradation of the insulator under the aging conditions. However, in the present work, an increase of this ratio is seen after 500 hours aging in the salt fog chamber. It can be due to the fact that LMW polymer chains or polymer oil can immigrate to the surface of the insulator due to the density difference.

In order to measure the hydrophobicity, contact angle measurements were performed. Figures 2a and 2b show the contact angles of the virgin and aged samples respectively. It can be seen that the virgin sample showed a more hydrophobic character than that of the aged one. This is due to the reduction of groups of the Si-CH_3 of the surface under the stresses of the salt fog environment of the chamber. However, this difference is almost negligible. It can be attributed to the fact that CH_3 groups of the Si-CH_3 of the surface of along with those immigrate to the surface let the surface retain its hydrophobic property.

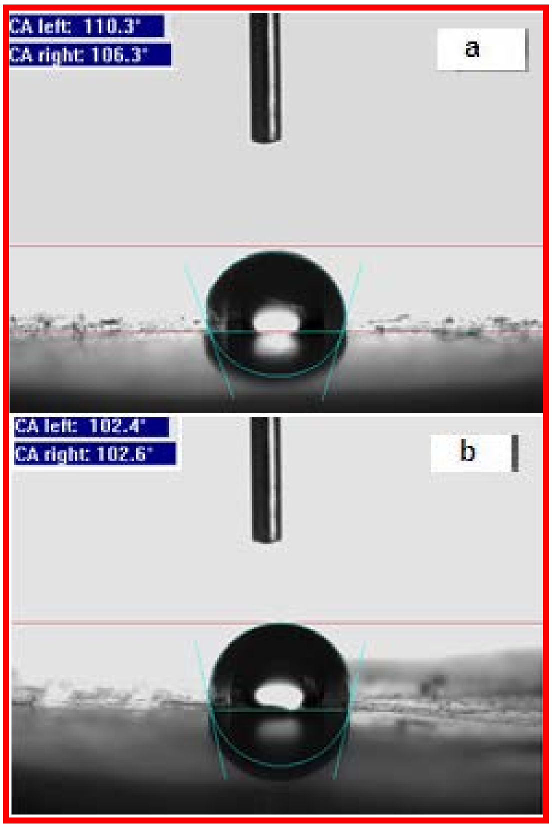

Figure 2: Contact angles of the (a) virgin and (b) aged samples

STRI hydrophobicity test results are displayed in figures 3a and 3b. It is clear from these figures and STRI hydrophobicity classification that the sample did not lose its major hydrophobicity and is categorized in HC2 classification. Therefore, the results of STRI test match with that of contact angle measurements.

It should be noted that the numerical investigation of salt fog aging is in progress in our future work.

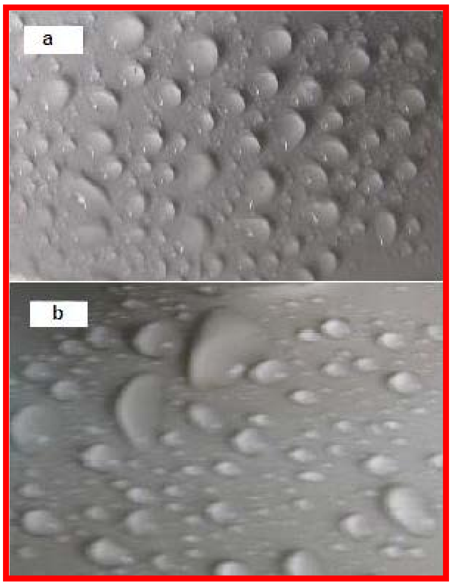

Figure3: STRI hydrophobicity of (a) virgin and (b) aged samples

4 CONCLUSION

An energized silicone rubber insulator was placed under aging conditions of salt fog chamber. The duration of the test was 500 hours. After the test, the virgin and aged samples were assessed with different analytical techniques. FT-IR results showed that the aged sample retains almost the same amount of CH_3 groups as that of the virgin one. This can be related to the immigration of LMW polymer chains and polymer oils to the surface. Therefore, although some of the Si-CH_3 bonds may be lost, the movement of LMW polymer chains and polymer oils to the surface may help the sample to cope with it. Contact angle measurements showed that the hydrophobicity of the aged sample decreased in comparison with that of the virgin one. This is attributed to the reduction of Si-CH_3 bonds under the stressful environment of the chamber. However, the immigration of LMW polymer chains and polymer oils to the surface causes the sample to reduce the severity of the aging effect. The STRI results matched with those of the contact angle measurements.

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