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EFFECT OF ATH FILLER CONTENT ON THE PERFORMANCE OF SILICONE RUBBER BY INCLINED PLANE TRACKING AND EROSION TEST METHOD

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Abstract: Contamination flashover is a major concern affecting the reliability of power systems. Many utilities have switched over from porcelain and glass insulators to Silicon Rubber (SIR) based polymeric insulators to combat contamination problem. By and large, Aluminum Tri-hydrate (ATH) is used as filler material to improve the tracking and erosion property. The evaluation as per IEC 60587 does not simulate the UV radiation, any particular type of pollutant deposited on the insulator surface and the conductivity of the contaminant more likely to damage the polymeric insulator surface. In the present work, tracking and erosion of silicon rubber material with different proportions of ATH filler content included in its nano form is evaluated. In addition to experimental variables in the IEC 60587 test method site specific variables like UV radiations, hydro carbon pollution (present on the insulator surface due to presence of brick kilns in India) and low severity fog conditions are introduced to the standard test method. The surface resistance and hard ness measurements as well as X –ray diffraction analysis are also made to determine the extent of degradation of the insulator material surface resulted during tracking and erosion test. The study revealed that, the tracking and erosion performance of SIR depends on the proportion of ATH filler and it is found that ATH and silicon in equal parts by weight is the best combination. It is also noticed that incorporating nano ATH filler further improves the performance.

Keywords: Silicone rubber (SIR), Nano dielectrics, Aluminium Tri-Hydrate (ATH) Tracking and erosion, UV radiations, Hydro carbon(HC), X-ray diffraction (XRD)
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INTRODUCTION

Silicone Rubber (SIR) or Poly-Di-Methyl-Siloxane (PDMS) is attaining popularity among all other polymeric housing materials due to its major advantage of hydrophobicity recovery property. But lack of field experience in India and standardization of material composition have made its use for limited applications. It is also well known that tracking has been one of the causes of insulation failure. Tracking is developed from continuous dry band arcing due to the flow of leakage current on the insulator surface under wet contaminated conditions. Nevertheless, various laboratories all over the world are contributing in standardizing the polymeric material composition so that its tracking and erosion performance under various environmental conditions is satisfactory.

Polymeric insulators suffer from environmental and electrical ageing stresses in service that may cause the performance to deteriorate. The environmental conditions include Ultra-Violet (UV) radiations mainly from sun, corona and dry-band arcing, pollution, thermal shock etc. The absence of environmental stresses in the testing of material has made poor correlation between the results obtained from the laboratory and that of the field data. Some factors may accelerate the tracking and erosion and some may decelerate. Hence there is a need to simulate the combined effect of various factors during the stage of material evaluation.

Aluminium Tri-Hydrate (ATH), a flame retardant is being extensively used as a filler material in order to improve the tracking and erosion resistance of polymeric materials. High level of ATH prolongs the time to track and endothermic dehydration of ATH cools the surface, thereby prevents rapid rise in temperature [1]. Addition of ATH filler beyond a threshold value offers a deteriorating effect on the SIR sample [2]. With continuous ageing in field, flexibility of the material reduces and tends to become brittle. Hence the problem of optimization of ATH filler in the base polymer is a subject for the present investigation.

EXPERIMENTAL DETAILS

In order to assess the performance on the basis of resistance to tracking and erosion, a detailed study is made on the SIR formulations by varying ATH filler content from 80% to 120% in steps of 10%, in base polymer, employing Inclined Plane Tracking and Erosion Test (IPTET) in accordance with IEC 60587. Each test samples of dimensions 50 mm 120 mm having thickness of 6 mm is used for the test. In addition, four different formulation of SIR with ATH nano filler percentage indicated in the bracket Viz. N1(50%), N2(60%), N3(60%) and N4(60%) are also evaluated. Out of the four different AC voltages mentioned in the present standard i.e. 2.5, 3.5, 4.5 and 6 kV, 4.5kV voltage level appeared to be the most critical as the arcing tend to concentrate in some points to cause excessive erosion [4]. Hence during IPTET, a constant voltage of 4.5kV is applied with 0.6ml/min rate of flow of contaminant electrolyte (ammonium chloride solution with non ionic wetting agent) maintained throughout the test duration of 6

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hours. The end point of experiment is considered as either flow of 60mA leakage current over 2 seconds or formation of tracking over 25mm or the depth of erosion exceeding 3mm (50% of standard thickness 6mm). .

In order to account for the effect of environmental factors, a set of five samples each is tested with and without UV radiations thereby accounting for UV radiations that is normally present in the atmosphere. Further hydrocarbon (HC) polluted samples are tested with and without UV radiations. These tests are carried out with a electrolyte conductivity of 2.5 mS/cm. In order to account for the performance of SIR formulations under low current arcs, further set of samples are tested with a solution of lower conductivity of 1.67 mS/cm. During the IPTET leakage current measurements are recorded. The present study is categorized into seven cases depending on the stresses imposed on the sample and the type of formulation, viz. Case-A: IPTET, Case-B: IPTET+UV, Case-C: IPTET+HC, Case-D: IPTET+HC+UV, Case-E: IPTET with low conductivity contaminants, Case-F: IPTET on samples with nano filler, Case-G: IPTET+UV on samples with nano filler.

UV radiation stress is imposed by a UV source which is located at a distance of 0.14metre from the centre of the sample mounted for IPTET so that, it results in an irradiance of $72 W/m^2$ on the sample. UV meter of Lutron make-340 is used to arrive at the placement of the UV source. An UV lamp of OSRAM make, 300W is used as UV source in the present study.

The simulation of hydro-carbon (HC) pollution on SIR is done by burning Acetylene gas with little amount of Oxygen. Such type of pollution is generally seen near Brick Kilns where in burning of tyres and rubber serve as a fuel. In addition, burning of agricultural wastes also produces HC pollution.

RESULTS AND DISCUSSION

This section presents results of the tests with different percentage of ATH filler and without nano filler subjected to IPTET (as per IEC-60587) with and without UV radiations. The effect of hydrocarbon pollution is also discussed. Typical results of different material formulations enumerated as A1 to A5 for Case-A with different percentage of ATH content is shown in Fig. 1.

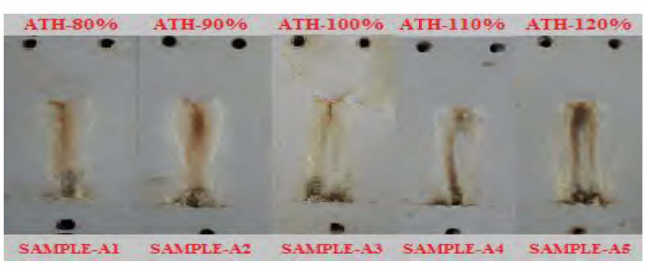


Fig. 1. Photograph of A1 to A5 subjected to IPTET

For the formulation A1 with 80% of ATH, maximum depth of erosion is found to be 3mm and hence considered to have failed. But for other formulations, A2 to A5 the maximum depth of erosion is noticed to be less than 1mm. The sample A1 also showed discoloration which could be due to the chemical reaction on the surface of the sample during dryband arcing. Fig. 2 shows the results of Case-B.

Fig. 2. Photograph of B1 to B5 subjected to IPTET+UV

Also in Case-B, pronounced discoloration is noticed except for the sample B3 (ATH-100%) which had less discoloration. The depth of erosion is less than 0.5mm in sample B1 with ATH-80%. The erosion resistance of all the samples with UV radiations is found to satisfactory. This is due to the transfer of heat energy from the UV radiation to the sample, resulting in enhancement of the temperature in the sample. This appears to have accelerated diffusion of LMW molecules from the bulk to the surface which made the material less wettable. Some literatures also have reported similar behaviour with increase in temperature [5, 6]. As a result, the intensity of erosion due to dry band arcing is reduced. Typical results of case-C and Case-D are shown in the Figs. 3 and 4 respectively.

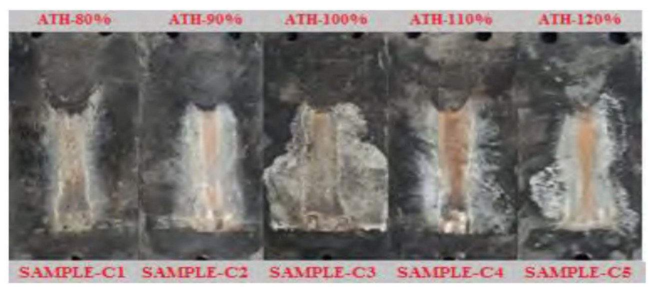


Fig. 3. Photograph of C1 to C5 subjected to IPTET+HC

Fig. 4. Photograph of D1 to D5 subjected to IPTET+HC+UV

The surface degradation on the samples after IPTET, seen between Case-C and Case-D is not appreciable. The pollution layer might have acted as a screen guard or barrier which could have lowered the effect of dryband arcing on the surface of the material and hence the erosion. Also, the inherent property of SIR which is to transfer its hydrophobicity property even to the pollution layer could have contributed in resisting erosion.

The leakage currents are recorded intermittently, once in every 60min. The maximum leakage current recorded during test, is in the range of 35±10mA and is same for the samples without nano filler under IPTET, IPTET+HC, IPTET+UV and IPTET+HC+UV also. There was no significant change in the leakage current due to the presence of hydrocarbon pollutant or UV.

Fig. 5. Photograph of E1to E5 subjected to low current dryband arcing

The photograph of samples E1 to E5 with different ATH percentage subjected to IPTET under low current dry band arcing is presented in Fig. 5. Formulation depicted as E5 with ATH-120% had maximum depth of erosion, more than 4mm. Sample with ATH-80% and ATH-90% had erosion depth of around 2mm and 0.5mm respectively. The remaining samples had negligible erosion. It is observed that for samples with ATH 120% tested with the low conductive contaminant solution experienced extensive erosion which is in contradiction to that in case A (ATH 120%). This may be due to the fact that when the conductivity of the contaminant solution is more, length of the intermediate drybands formed is more and hence the length of the intermediate arcing is more. As the length increases the arcing tend to move away from the surface. Hence only limited amount of erosion is seen. But as the conductivity of the solution reduces, the length of the intermediate dry band arcs reduces, which makes it to come closer to the surface so that the arcs get sufficient time to erode the material on the surface. Thus, it could be inferred that low current dry band arcing is more intense on the SIR formulation than the high current dry band arcing. The maximum leakage current recorded during IPTET for samples E1 to E5 is in the range of 10mA to 22mA.

The photographs of Case-F and Case-G of different nano fillers designated N1, N2, N3, N4 are presented in Figs. 6 and 7 respectively.

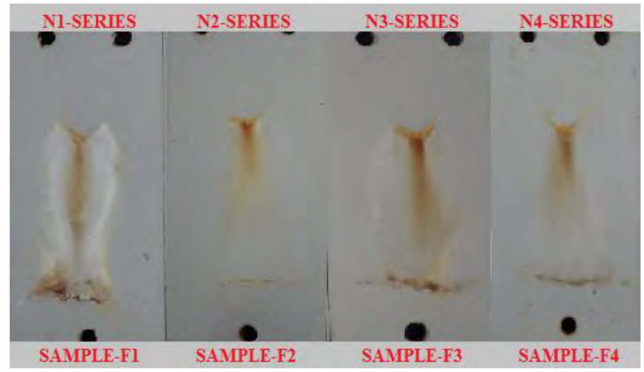


Fig. 6. Photograph of F1 to F4 with nano filler subjected to IPTET

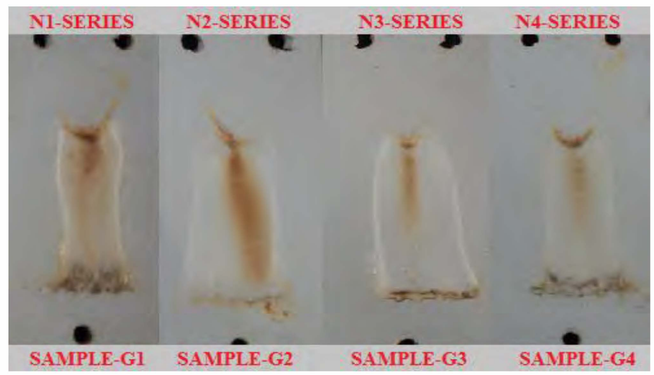


Fig. 7. Photograph of G1 to G4 with nano filler subjected to IPTET+UV

It is observed from Figs. 6 and 7 that there is no tracking and erosion of the samples. However, marginal reduction in the peak leakage current is observed to be within 25±10mA. The samples of N1 series having lower ATH nano filler of 50% had more discoloration and abrasion on the surface compared to others. The leakage current is found to have spread across the entire width of the sample and between the electrodes also i.e. the presence of nano fillers appears to have prevented the concentration of the leakage currents at specific points and therefore no erosion is found. Hence for a comparatively lower ATH content the SIR formulation could perform satisfactorily under the additional stresses imposed on it during the IPTET test.

Results of X-Ray Diffraction Test

A polymeric material is partly crystalline and partly amorphous. Crystallinity component gives sharp and narrow peaks and amorphous component gives very broad peak. As the crystallinity increases, material becomes brittle. The crystallinity of the material is assessed from the hump between 10^o and 17^o in the wide angle scan. A typical wide angle scan of the samples with ATH-100% Virgin, Case-A and Case-B is shown in Fig. 8. The hump between

10° and 17° in the wide angle scan for Case-A and Case-B showed similar hump as that of the virgin implying that the material has not become crystalline. The peak observed at 18° is due to the ATH filler in the polymer.

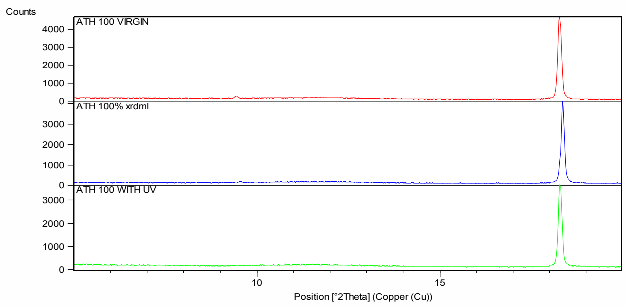
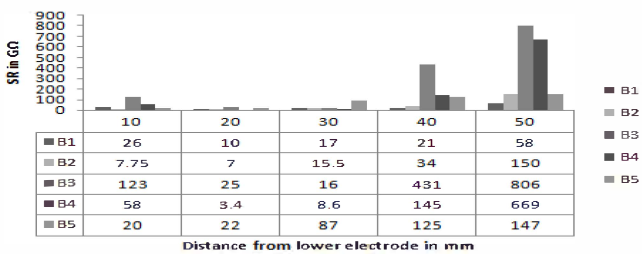


Fig. 8. Wide angle scan of samples with ATH-100% Virgin, Case-A and Case-B

Results of surface resistance and Hardness

Surface resistance (SR) and hardness measurement of the samples are carried out before and after the test. SR. measurements are done in steps of 10mm between the electrodes applying a voltage of 5.6kV for duration of 10 seconds. Virgin samples had SR of order of terra ohms before the test. Typical results of the SR recorded after the test for Case B is shown in the Fig 9.



	10	20	30	40	50
B1	26	10	17	21	58
B2	7.75	7	15.5	34	150
B3	123	25	16	431	806
B4	58	3.4	8.6	145	669
B5	20	22	87	125	147

Fig. 9 SR values of samples B1-B5

The change in the surface resistance values are attributed to accumulation of contaminant on the surface after the tests. Surface hardness of the samples is measured before and after the test by Durometer in shore A method. Surface hardness of virgin and tested samples was in the range of 63-74, which was well within the range of 68±7 as mentioned in the ASTM D2240 standard. This indicates there is no significant change in the surface hardness after the test. The surface resistance, hardness and also X-ray diffraction diagnostic tests for other samples are in progress.

CONCLUSION

The amount of ATH filler material in SIR plays a significant role in the performance of the insulator material. Formulations of SIR with equal ATH filler and silicon rubber showed better tracking and erosion performance even under low current dry band arcing.

Inclusion of lower amount ATH nano filler (50-60%) in the base polymer effectively improved the performance thereby bringing feasibility in reduction on the overall weight of the insulator.

UV radiations at 72 W/m^2 appear to improve the erosion performance of the SIR considered with different percentages of ATH.

Impact of UV radiation and low current dry band arcing on the material is to be considered while standardizing polymeric formulations.

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