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Study of HTV Silicone Rubber with Different Concentrations of Filler ATH

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ABSTRACT: It is desirable to develop High Temperature Vulcanizing (HTV) Silicone rubber with optimal amount of filler Alumina Tri Hydrate (ATH). HTV silicone rubber is used as housing material in composite insulators for high voltage applications. In the present work, HTV silicone rubber with different concentrations of filler ATH (0, 40, 50, 60phr (parts per hundred rubber)) was prepared. Physical, mechanical, electrical and processing properties of these Silicone rubbers were studied and results were compared. 50phr ATH filler content is optimal and gave the best results. HTV silicone rubber from different sources and with varying content of ATH filler were kept under natural weather for 300 days for weathering studies and change in properties were recorded. There was not much variation observed in the properties of silicone rubber after exposing to natural weather. Physical and mechanical properties increased at the beginning and remained constant. There was no erosion observed on the silicone rubber samples and all the samples withstood the applied voltage of 4.5kV during tracking and erosion test.

Key words: HTV silicone rubber, ATH, Hydrophobicity

I. INTRODUCTION

Earlier porcelain and glass insulators were used for high voltage outdoor applications such as sub-stations and distribution and transmission lines. Composite insulators have gained great importance in recent years in the field of insulation technology for medium and high-voltage transmission lines and substations. Composite insulators consist of mainly three components i.e., core material, housing material and end fittings. Core material is load-bearing Fiber Glass Reinforced Plastic (FRP) rod covered by housing material such as polymeric weather sheds made of silicone rubber and fit with metal end fittings. Composite insulators have many advantages in comparison to porcelain or glass insulators such as light weight, easy handling, better resistance to break and very good performance in highly polluted environment and low cost. Because of these important properties, the composite insulators have gained worldwide importance and are considered the primary replacement for porcelain and glass insulators.

II. MATERIALS AND METHODS

A. Materials

Silicone rubber compound without ATH-IS 0A, silicone rubber compound with 40 phr ATH- IS 40A, silicone rubber compound with 50 phr ATH- IS 50A, silicone rubber compound with 60 phr ATH- IS 60A. HTV silicone rubber and ATH were got from company i-Silicone.

All the rubber samples were prepared by compression molding with a pressure of 160 mmHg, curing temperature of 160ºC and curing time of 10 minutes.

B. Methods

Specific Gravity. Specific gravity of samples was determined by using Electronic Densimeter (EW-300SG by Alfa Mirage). Known amount of cured rubber sample was placed on the container of the densimeter and the weight of the sample was stored then the sample was placed on the water container of the densimeter. This test was carried out as per reference standard DIN 52479.

Hardness. Hardness of the samples was determined by using Durometer of type shore-A (Model number Shore-A / RR-ISI5181 by Hiroshima). Rubber samples of thickness 6mm were used to measure the hardness. The Durometer was pressed against the flat sample and hardness was measured. This test was carried out according to the reference standard ASTM D 2240.

Tensile strength and ultimate elongation. Tensile strength and ultimate elongation were determined by using dumbbell shaped specimen. The specimen was cut from 2 mm rubber sample. Specimen was tested using universal testing machine (Hiroshima). The test specimen was fixed between the grips in the testing machine and the specimen was pulled steadily at specified rate until it breaks. The force exerted on the specimen at the time of rupture is the tensile strength of the specimen. The percentage increase in the original length of rubber during tensile strength test was noted as ultimate elongation. Five specimens were tested and average value was calculated. This test was carried out as per standard ASTM D 412.

Tear strength. Test specimens were prepared according standard ASTM D 624 Die-C. The test specimens were cut from 2 mm thick rubber sample. Specimen was tested using universal testing machine. Specimen was placed in the grips in the testing machine, then uniform pulling force was applied on the specimen until it broke down. Tear resistance is calculated by dividing the force at the point of rupture by thickness of the specimen. Three specimens were tested and average value was calculated.

Resistance to tracking and erosion. Test specimen of size 150mm x 50mm was cut from 6 mm thick rubber sample. Equipment Liquid Contaminant Inclined Plane Tracking and Erosion of Insulating Materials as per ASTM D-2303 was used for this test. Contaminant solution was prepared by using ammonium chloride and wetting agent isooctilphenoxypolietoxi ethanol at a concentration of 0.1% and 0.02% respectively. Resistivity of the contaminant solution was 3.95Ωm ±0.05Ωm. Test method-1: Constant voltage tracking voltage of 4.5kV of standard IEC-60587 was used. Specimen was fixed in the equipment and constant voltage of 4.5kV was applied for 6 h with the contaminant flow rate of 0.6 ml/min.

Standard values for different properties of silicone rubber. For a silicone rubber to be used as housing material for high voltage applications in composite insulators, it should meet the specified requirements as shown in Table 1.

Table 1: Standard values for different properties of silicone rubber.

Sl No	Property	Reference Standard	Standard Value
1	Hardness(Shore-A)	ASTM D-2240	61 – 75
2	Specific gravity	DIN 52479	1.52 – 1.58
3	Tensile strength (N/cm^2)	ASTM D-412	Minimum 400
4	Ultimate elongation (%)	ASTM D-412	Minimum 150
5	Tear strength (N/mm)	ASTM D-624, Die-C	Minimum 13
6	Resistance to tracking and erosion	IEC 60587, Method-1	Should withstand the voltage of 4.5kV and there should not be Erosion on the surface
7	Surface resistivity(TΩ/cm^2)	IEC 60093	Minimum 100
8	Volume resistivity (TΩ/cm)	IEC 60093	Minimum 100
9	Arc resistance (seconds)	ASTM D 495	More than 200
10	Dielectric constant	ASTM D 150	Minimum 3.5

Surface and volume resistivity. Surface and volume resistivity of the specimen were measured using Mega-ohmmeter. Test specimen of size 100mm x 100mm were cut from 2 mm thick rubber sample. Electrodes according standard ASTM D-257 were used for the test.

Arc resistance. Arc resistance of the specimen was measured using Arc Resistance Tester. Specimen of size 12.5mm x 12.5 mm was cut from 2 mm thick rubber sample. Test specimen was placed below the electrodes and arc was produced between the two electrodes. The distance between the electrodes was 5mm. Time required for the specimen to burn was noted as arc resistance.

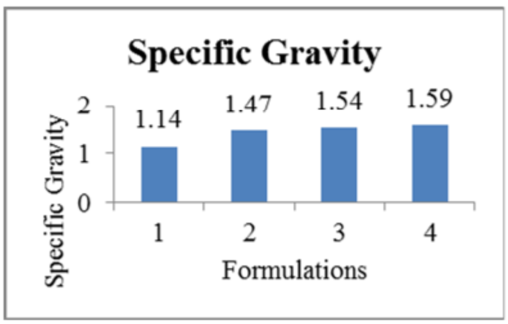
Dielectric constant. Dielectric constant of specimen was measured using the Automatic Dielectric Constant test setup. Test specimen of size 100mm x 100mm were cut from 2 mm thick rubber sample. Electrodes according to standard ASTM D-257 were used for the test.

Loss and recovery of hydrophobicity. Hydrophobicity of silicone rubber is the property which allows the silicone rubber surface to form the water droplets on the surface instead of allowing water to flow continuously. Silicone rubber may lose this property during service due to the exposure to electrical discharges and constant wetting of the surface. Corona was generated on the surface of silicone rubber samples using the High frequency resonant variable voltage corona generator. Water was sprayed on the sample to check the surface hydrophobicity before and after corona generation.

III. RESULTS AND DISCUSSION

In the following discussion formulation 1, 2, 3, 4 means; Formulation: 1 - IS 0A, 2 - IS 40A, 3 – IS 50A, 4 – IS 60A

Specific gravity



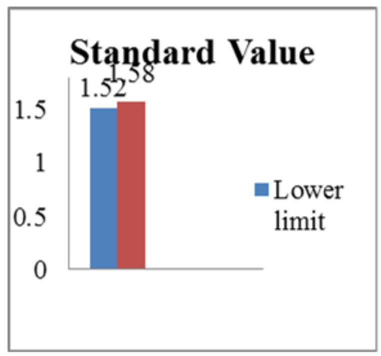
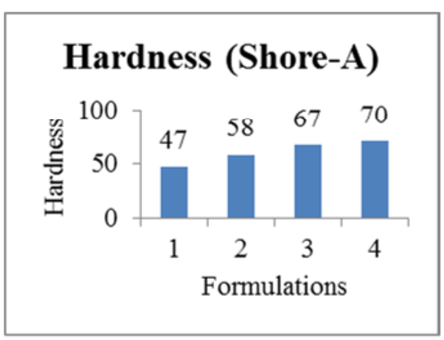


Fig. 1: Specific gravity values for different formulations

Figure 1 shows the specific gravity values for different formulations and standard value range of specific gravity. The specified value for specific gravity of HTV silicone rubber for outdoor application is between 1.52 and 1.58. Specific gravity of HTV silicone rubber increased with increased ATH content. Specific gravity of formulation 1 without filler ATH had lower specific gravity and it increased with the filler ATH concentration.

Hardness



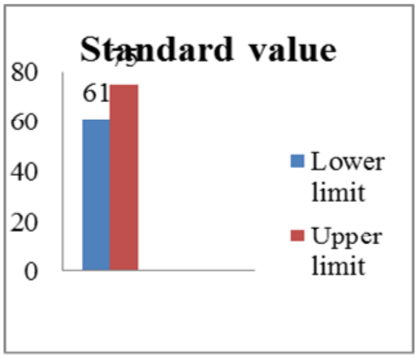


Fig. 2. Hardness values for different formulations.

Figure 2 shows the hardness (shore-A) values for different formulations and standard value range for hardness. The specified value for hardness of HTV silicone rubber for outdoor application is between 61 and 75. Formulation 3 with 50phr (parts per hundred rubber) ATH is considered as standard formulation-with which the properties of other formulation were compared. Rubber with hardness below 61 would be too soft and hardness above 75 would be too hard for high-voltage outdoor application. Rubber without filler ATH had lower hardness and hardness increased with an increase in the filler ATH concentration.

Tensile strength and ultimate elongation. Figure 3 shows the tensile strength values for different formulations and standard minimum value of the HTV silicone rubber for high-voltage outdoor application. Standard minimum value of tensile strength of HTV silicone rubber used in high-voltage outdoor application is 400 N/cm^2. Formulation 1 has the highest tensile strength and tensile strength decreased with an increase in the filler ATH concentration.

Figure 4 shows the ultimate elongation values for different formulations and standard minimum value of the HTV silicone rubber for high-voltage outdoor application. Standard minimum value of tear strength of HTV silicone rubber used in high-voltage outdoor application is 150%. Formulation 1 has the highest elongation and elongation decreased with an increase in the filler ATH concentration.

Tear Strength. Figure 5 shows the tear strength values for different formulations and standard minimum value of the HTV silicone rubber for high-voltage outdoor application.

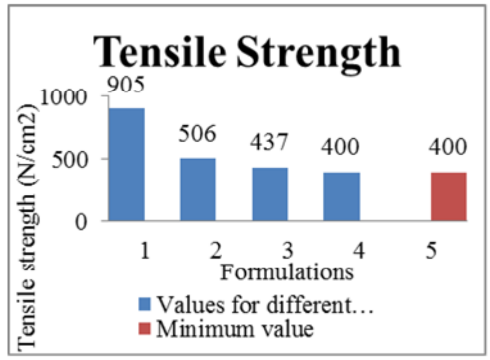


Fig. 3. Tensile strength values for different formulations.

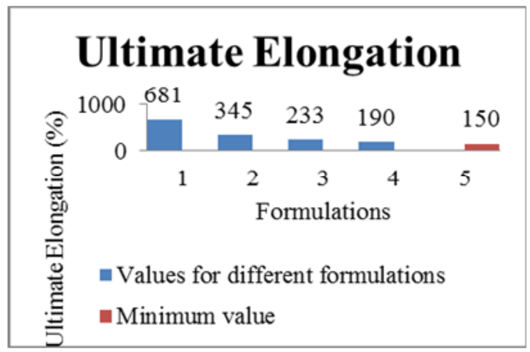


Fig. 4. Ultimate elongation values for different formulations.

Standard minimum value of tear strength of HTV silicone rubber used in high-voltage outdoor application is 13 N/mm. Formulation 1 has the highest tear strength and tear strength decreased with an increase in the filler ATH concentration

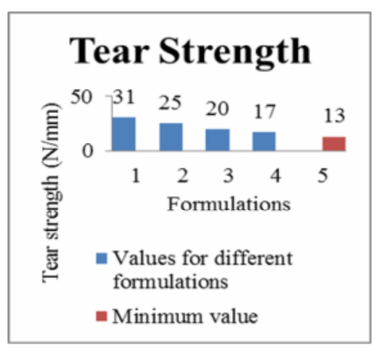


Fig. 5. Tear strength values for different formulations.

a. Surface and volume resistivity

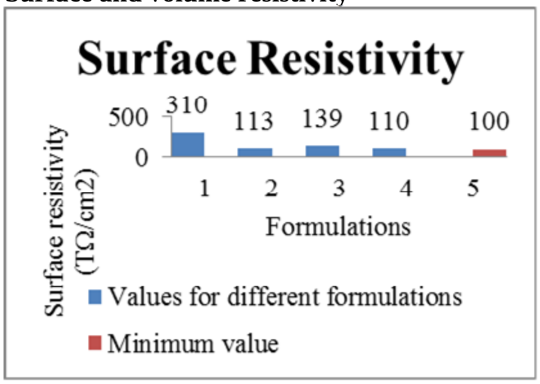


Fig. 6. Surface resistivity values for different formulations.

Figure 6 shows the surface resistivity values for different formulations and standard minimum value of HTV silicone rubber for high-voltage outdoor application. Standard minimum value of tear strength of HTV silicone rubber used in high-voltage outdoor application is 100TΩcm^2.

Figure 7 shows the volume resistivity values for different formulations and standard minimum value of HTV silicone rubber for high-voltage outdoor application. Standard minimum value of tear strength of HTV silicone rubber used in high-voltage outdoor application is 100 TΩ/cm.

Resistance to tracking and erosion

- Formulation 1 rubber compound without ATH failed to withstand the applied voltage of 4.5kV for six hours. The specimen eroded completely within 3 hours.
- Formulation-2 rubber compound with 40phr ATH withstood the applied voltage of 4.5kV for six hours. Erosion was observed in the five test specimen.
- Formulation-3 rubber compound with 50phr ATH withstood the applied voltage of 4.5kV for six hours. There was no erosion observed in the five test specimen.
- Formulation-4 rubber compound with 60phr ATH withstood the applied voltage of 4.5kV for six hours. There was no erosion observed in the five test specimen.

Arc resistance

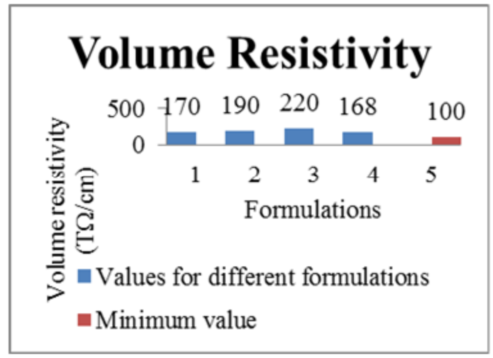


Fig. 7. Volume resistivity values for different formulations.

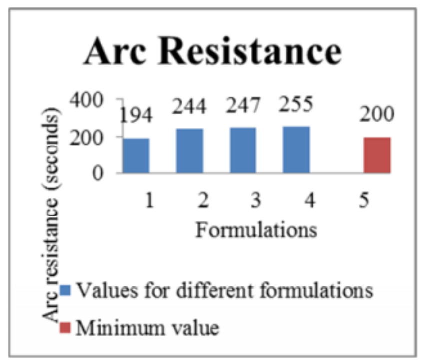


Fig. 8. Arc resistance values for different formulations.

Figure 8 shows arc resistance of rubber compound with different concentrations of filler ATH. Arc resistance of the cured rubber compound increased with increasing concentration of filler ATH.

Dielectric constant

Figure 9 shows dielectric constant of rubber compound with different concentrations of filler ATH. Dielectric constant of the cured rubber compound increased with increasing concentration of filler ATH.

Loss and recovery of hydrophobicity

All the samples followed the criteria as shown the figure 10. Hydrophobicity is classified into 7 classes HC1 to HC6. HC1 is a completely hydrophobic surface and HC6 is a completely hydrophilic surface. After corona generation on the sample, the surface became hydrophilic (Classified as HC6) and the surface regained hydrophobicity (Classified as HC2) within 48 hours.

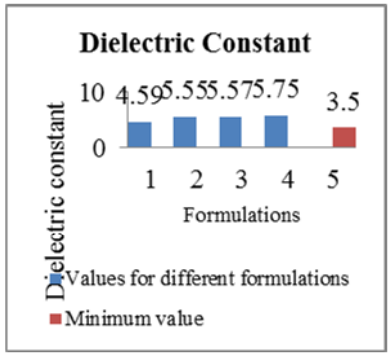


Fig. 9. Dielectric constant values for different formulations.

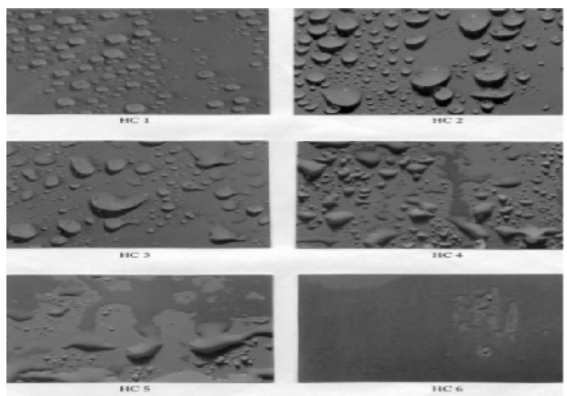


Fig. 10: Criteria for hydrophobicity classification.

CONCLUSIONS

From the results obtained for HTV silicone rubber with different concentration of filler ATH it is concluded that formulation-3, silicone rubber with 50phr ATH was considered the optimal housing material for high voltage applications in composite insulators. 50phr ATH was considered as the optimum concentration for the HTV silicone rubber compound. Physical properties hardness (Shore-A) and specific gravity increased with increasing concentration of filler ATH. Mechanical properties tensile strength, tear strength and ultimate elongation decreased with increasing concentration of filler ATH. Electrical properties such as arc resistance and dielectric constant increased with increasing concentration of filler ATH. Surface and volume resistivity does not have a linear relationship with concentration of filler ATH.

Silicone rubber without filler ATH failed to withstand the applied voltage for 6 h and mass erosion was observed on the specimen. Silicone rubber with 40phr ATH could withstand the applied voltage for 6 h and erosion was observed on the specimen. Silicone rubber with 50phr ATH and 60phr ATH could withstand the applied voltage for 6 h and no erosion. Therefore addition of filler ATH to the silicone rubber improves the resistance to tracking and erosion.

HTV Silicone rubber IS40A and IS60A are not used as housing material for the high voltage applications in composite insulators. Since IS40A has low values for physical properties and high values for mechanical properties as compared to standard values and also there is no resistance for tracking and erosion. Although IS60A can withstand applied voltage and no erosion and good electrical properties it cannot be used for high voltage applications since it has high values for physical properties and low values for mechanical properties as compared to standard values. IS50A meets all the specified requirements as mentioned in the table 1, therefore it can be considered as good housing material for high voltage applications.

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