EFFECT OF ATH FILLERS ON THE SURFACE TRACKING AND EROSION RESISTANCE OF NATURAL RUBBER-LLDPE BLENDS

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Abstract: *Polymeric insulators are increasingly being accepted by the electric utilities worldwide. The tremendous growth in the application of polymeric insulators is due to their substantial advantages compared to porcelain and glass insulators. This paper describes the investigation of electrical surface tracking and erosion behavior on the new formulated thermoplastic elastomer (TPE) with different level of alumina trihydrate (ATH) contents. The natural rubber blends with linear low-density polyethylene (LLDPE) at different weight ratio are used as base polymer of the TPE materials. Experimental results show that the blends filled with different level of ATH are significantly influences the surface tracking properties. ATH content with 50 pph is found to be practically improved the surface tracking and erosion resistance of the compounds. Scanning electron microscope is carried out to relate the surface tracking properties with the morphological analysis.*

Keywords: *surface tracking, leakage current, polymer, insulator.*

1. Introduction

Outdoor insulators made of polymers such as silicone rubber (SR), ethylene propylene rubber (EPR) and ethylene vinyl acetate (EVA) filled with filler such as silica and alumina trihydrate (ATH) are being in practice. Despite the fact that these polymer materials are being proven good for high voltage applications, the research on new formulated material especially on TPE compound is still be implemented in order to make them more competitive in the market.

The used of polymeric insulators (PIs) for replacement the traditional insulators is due to the substantial advantages such as low surface energy, lightweight, higher mechanical strength to weight ratio, resistance to vandalism and better performance in the present of wet and contamination conditions [1].

No one base polymer material alone has all the necessary properties for high voltage insulating material. In service, insulating materials are subjected to environmental stresses, which lead the degradation to be occurred. In order to minimise the degradation process on the materials, the fillers are added to the material compound. In high voltage polymeric materials, ATH fillers impart high electrical tracking and fire retardance as well as reinforced the physical strength [2].

ATH plays an important role in improving surface tracking and erosion resistance. It reduces part of the polymer, which then decreases thermal decomposition products because of endothermic dehydration [3].

The focus of this paper is to investigate the influence of ATH fillers on the tracking performance of the new formulated thermoplastic elastomer (TPE) by the IEC 587 tracking test method.

2. Materials Preparation

Two different weight ratio of base polymer with a loading of different level of ATH are used in this work. The LLDPE, manufactured by Titan (M) Sdn Bhd and natural rubber (NR) of SMR-CV grade, obtained from Rubber Research Institute of Malaysia (RRIM) are used as base polymer. ATH filler supplied by Excelab Technology Sdn Bhd is mixed with the base polymer in order to improve the electrical surface tracking and erosion resistance. Table 1 shows the formulation of the compounds for the tracking test.

Table 1: Formulation of compounds

Sample	Base Polymer Ratio (%)		ATH (pph of base polymer)
	NR	LLDPE	
R3PE2A R3PE2B R3PE2C R3PE2D	60	40	0 50 100 150
R2PE3A R2PE3B R2PE3C R2PE3D	40	60	0 50 100 150

The blends of NR and LLDPE filled with ATH are prepared using a Brabander Plasti-Corder, PL-2000 at 160°C for 13 minutes with rotor speed 40 rpm. Then the samples of blends are compression moulded into a slab-shaped with a dimension of 120x50x6mm in the electrically heated hydraulic press at 160°C. The total moulding time is 15 minutes at pressure 100-120 kg/cm^2.

3. Experimental Set-Up

3.1 Hardware Set-up and Test Procedures

The experiment of tracking resistance is conducted according to IEC 587 test methods. This test is normally known as Inclined-Plane Tracking (IPT) test and its schematic diagram is shown in Figure1.

A 1.0 kVA, 0-20 kV high voltage transformer is used to supply a high voltage stress across the sample. The sample is contaminated and wetted by flowing down the contaminant solution. A 0.1% by mass of ammonium chloride solution with non-ionic wetting agent is used as the electrolyte. The flow-rate of the electrolyte is controlled by the peristaltic pump to the required value. The slab-shaped sample is mounted with the flat test surface on the underside, at an angle of 45° from the horizontal with the stainless steel electrodes 50 mm apart. Eight layers of filter paper are clamped between the top electrode and the sample in order to get the proper flowing of contaminant electrolyte. The procedures how to conduct the test are described details in [4].

Basically the test is successfully conducted when the effective scintillation is observed, which means the existence of small yellow to white arcs just above the teeth of the lower electrode.

The test is conducted for 5 hours under contaminant and wet conditions. A 2.5 kV test voltage with 0.15 ml/min electrolyte flow-rate as per standard are used throughout the experiment. The resistivity of contaminant solution is maintained between 370-400 Ω-cm. In order to get the good measurement, the experimental set-up is enclosed with Faraday cage to avoid any outside noise or unnecessary signals.

3.2 Morphological Studies

The surface microstructure of the polymer compound surface is carried out with scanning electron microscope (SEM). Before scanning, the samples are sputter-coated with platinum to minimise charging effect. A 20 mA sputtering current with 70 seconds coating time is used to obtain 6 nm deposited platinum film thickness. The electron gun of SEM is energised at 10 kV in order to avoid any possible damaged to the material surface if the higher voltage is used. The micrograph of the compound surface is recorded at 200 magnifications for clearer observation.

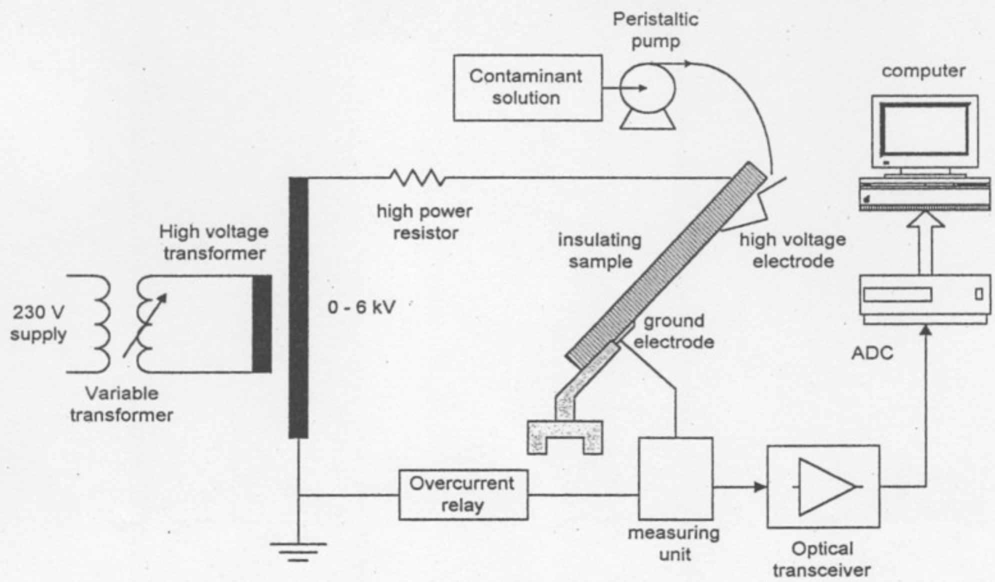
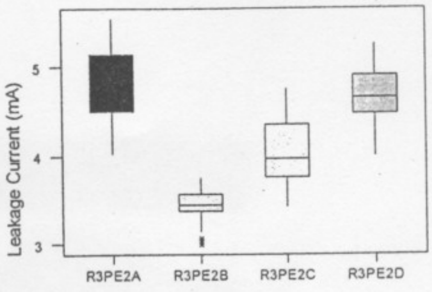


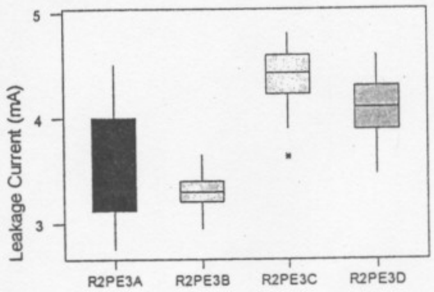
Figure 1: Experimental set-up for surface tracking

4. Results and Discussion

The test is conducted by measuring the leakage current (LC) flows along the material surface under high voltage stress. An on-line LC monitoring system is developed to monitor the progress of the test. For data analysis using computer, a LabVIEW program is written to communicate with analog to digital converter (ADC) to sort out the LC signals and displays it on the computer screen.
Figure 2 shows the box-plots which indicates the average magnitude as well as variation of LC signals.



a) 60%NR, 40%LLDPE



b) 40%NR, 60%LLDPE

Figure 2: LC magnitude with different level ATH

Generally, the range of LC is between 2 to 6 mA. The same results are also observed for silicone rubber and EVA from the previous works [5]. From both composition of base polymer, it is found that the compound with ATH 50 pph shows a good surface tracking due to the lowest LC. The less or over 50 pph ATH will both decrease the surface tracking and erosion capability. It is believe that the ATH fillers play an important role in improving surface tracking by allows endothermic reaction that results in a release of water vapor when heated by arc discharges. This released water vapor then cools the surface, thus limiting the thermal degradation.

However at very large levels of ATH, the fillers are difficult to compound and thus resulting rougher surface (as shown in Figure 3) because of the difficulty of dispersing it uniformly in the compound and leads to increase the surface LC. Meanwhile for the low-level ATH (less than 50 pph), the filler does not give sufficient protection against the damage during surface discharge and tracking activity.

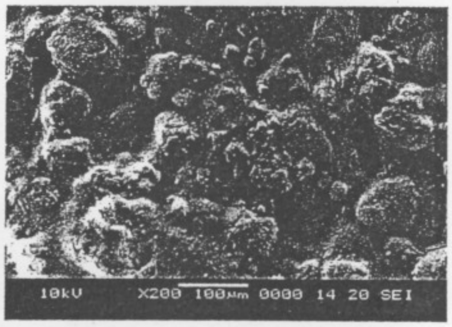
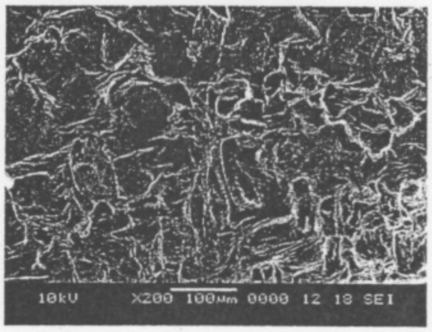
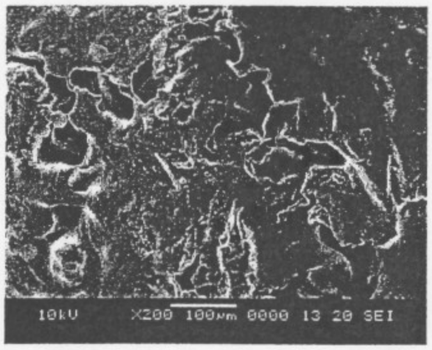


Figure 3: SEM micrograph for compound with higher ATH fillers

Figure 4 shows the surface microstructure of compound with 60% NR, 40% LLDPE loading with 50 pph ATH filler before and after tracking test. The inspection of the micrographs of virgin compound indicates the base polymer and ATH components are miscible. Small amount of ATH has a good adhesion with the base polymer matrix.



a) Virgin compound



b) After surface tracking test

Figure 4: SEM micrograph of sample R3PE2B

Figure 4(b) shows the changes of surface microstructure after the compound is subjected to high voltage stress under wet and contaminant conditions. It is observed that the surface structure is porous and some cracks appear due to the dry-band arcing. The melting phase of polymer matrix is observed due to the high temperature generated from the discharges. It is reported in [6] that the temperature generated at the point of discharges is above 200°C, and this temperature is enough to melt the base polymer in the compound.

SEM micrographs for the other compositions (not shown in this paper) have indicated that the LC levels as well as surface discharge conditions influence the condition of surface damaging.

Conclusion

The surface tracking and erosion resistance of the new formulated TPE material with different loading of ATH fillers is investigated by the IEC 587 test method. It is found that the different level of ATH gives the significant effect on LC magnitude as well as surface microstructure conditions. The capability of tracking and erosion resistance of the new formulated materials is optimization with approximately 50 pph ATH filler contents. The blends of the material can be improved without changing the surface tracking properties by adding suitable additives or compatibilizers in the future.

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