

## DC inline plane test of silicone rubber samples with different filler for high-voltage insulation

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### ABSTRACT

This paper is about preparation of silicone rubber (SiR) samples with different filler for high-voltage insulation purpose. The fillers used were silica from waste glass, calcium carbonate from cockle shell, silica/calcium carbonate and wollastonite. All the fillers were crushed into powder and undergo internal mixer and hot press as a material preparation. It was expected that the combination of filler with silicone rubber would give better result when experiencing ageing process. The direct current (DC) inclined plane test was used to investigate the tracking and erosion on silicone rubber composites. The tracking length was observed between the top and bottom electrode. Comparison would then be made between the silicone rubbers with different fillers based on the result obtained from the experiment.

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## 1. INTRODUCTION

Silicone rubber (SiR) insulators have been the chosen candidates for outdoor high voltage applications, generally due to better performance. However, SiR is liable to long term aging effects. In pollution area where outdoor insulation housing is subject to dry-band arcing (DBA), power supply tends to be interrupted once SiR erodes leading to insulation failure [1]. Before this, composite insulator types used as a choice that is capable as a most advance dielectric insulator in future because of its capability as a good insulator [2].

The properties of composite designs which have lighter weight, more toughness, more seismic performance make it more flexibility compared to ceramic insulator. All those features will reduce installation cost, better endurance and offer better line design. The researchers and common industrial practitioners have various of method to fabricate silicon rubber with filler. As mention in [3-5] to determine the level of material degradation the surface potential decay measurement on the surface in-service aged composite insulator sheds can be used.

Basically, to increase the performance of the polymeric composite properties there are reinforcement's material are regularly used which is also to reduce the material cost. Silica, calcium carbonate and Wollastonite is the fillers that mostly been used for appliants of electrical insulation. Silica from waste glass is a very solid material that possesses an amorphous or non-crystalline [6-8]. High voltage transmission mostly use silica glass as a filler to create best insulator to fulfill high quality electrically insulating materials with excellent optical, thermal, electrical, mechanical, and other properties [9].

## 2. RESEARCH METHODOLOGY

This research focus on the performance of silicone rubber filled silica, calcium carbonate, calcium carbonate and wollastonite as mineral based fillers systems for high voltage insulators application. The fillers are derived from waste resources of silica form waste glass while calcium carbonate from the cockle shell. The formulations of fillers are consisted of several percent of it. The composites will be prepared by using an internal mixer and will undergo hot pressing. Direct current (DC) Inclined Plane (IP) tracking test will be done on the samples to investigate the tracking and erosion behavior [10]. The procedures for this research shown in Figure 1.

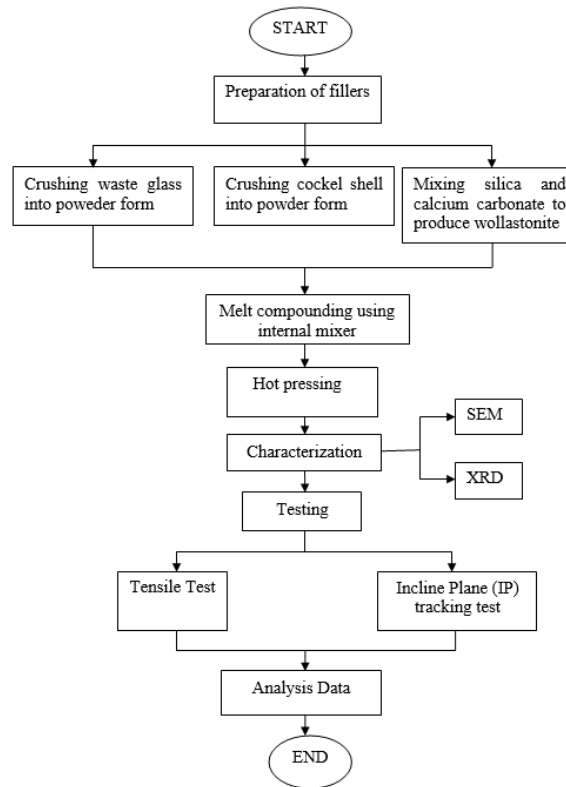


Figure 1. Procedures for this research

## 3. MATERIAL PREPARATION

Waste glass produces silica, cockle shells create calcium carbonate used to act as filler. The first step is naturally cockle shell being washed properly to clean it from dirt and it been dried for 24 hours in an oven operated at 80°C. then, waste glass material will be pulverize using crusher machine and the cockle shell will be blended into granule form. It is to make sure it be in powder form. Waste glass produces silica, cockle shells create calcium carbonate used to act as filler. The first step is naturally cockle shell being washed properly to clean it from dirt and it been dried for 24 hours in an oven operated at 80°C. Then, waste glass material will be crush using crusher machine and the cockle shell will be blended into granule form. Two opposing cycle was used in Horizontal Mill Machine. The machine operates for 30 minutes each cycle at 400 rpm, with 15 minutes resting time in between. This process to make sure cockle shell and waste glass samples can be transformed into powder form.

## 4. PREPARATION OF WOLLASTONITE

Two main elements in the production of wollastonite samples there are Calcium Oxide CaO and Silica SiO<sub>2</sub> [10, 11]. Calcium carbonate and silica by weighing both using ratio 48.3%: 51.7% and go through ball milling process at 20 rpm for 45 minutes. Mixture of the calcium carbonate and silica powder is important to this process to make sure it turn into homogeneous form. Then, the mixture will be calcined with setting of 10°C/min heat up, temperature 1000°C in 3.5 hours and 10°C/minutes for cooling process. The chemical

composition of composite of glass and cockle shell after calcination process was affirm using X-ray diffraction (X-RD) technique. Silicon rubber, filler, dicumyl peroxide and color (black) was added for each samples. The step of preparing the wollastonite was shown in Figure 2.

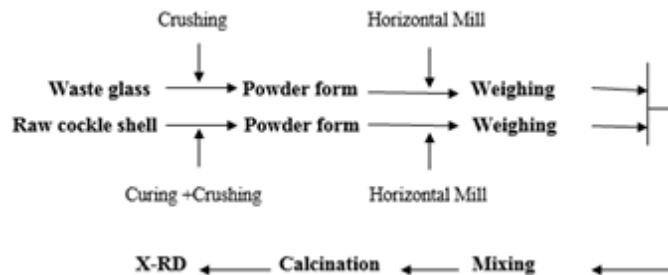


Figure 2. Preparation for wollastonite

**5. PREPARATION OF WOLLASTONITE**

The internal mixer utilized at roller rotor speed of 50 rpm and temperature is set at 180°C to make sure the mixture of composite was scatter uniformly whole the formulation. The amount of composite is approximately 50g per run for each mixture. Internal mixer used at Agensi Nuklear Malaysia (Nuklear Malaysia Agency) to mix mixture of the composite for 7 minutes shown in Figure 3. The dimension of 50mm x 120mm x 6mm of the composites compressed using hot press machine with a pressure 70 kg/cm<sup>3</sup> and temperature of 185° for 15 minutes compression period. Then, the machine with internal water flow for 12 minutes cooled the composite sheet that has been produced. The flat sheet sample with the thickness of 6mm have been produced.



Figure 3. Internal mixer

**6. RESULT**

Each of the filler was add into silicone rubber with different percentage that is 5%, 10%, 20%, 30% and 40%. Figure 4 shows example of silicon rubber samples with 5%, 10% and 20% wollastonite filler.

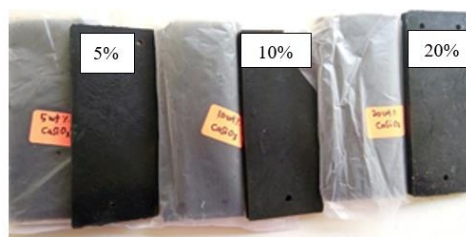


Figure 4. Example of silicon rubber samples with 5%, 10% and 20% wollastonite filler

All the sample will be tested using DC incline plane test (IPT) according to BS EN60587 shown in Figure 5.

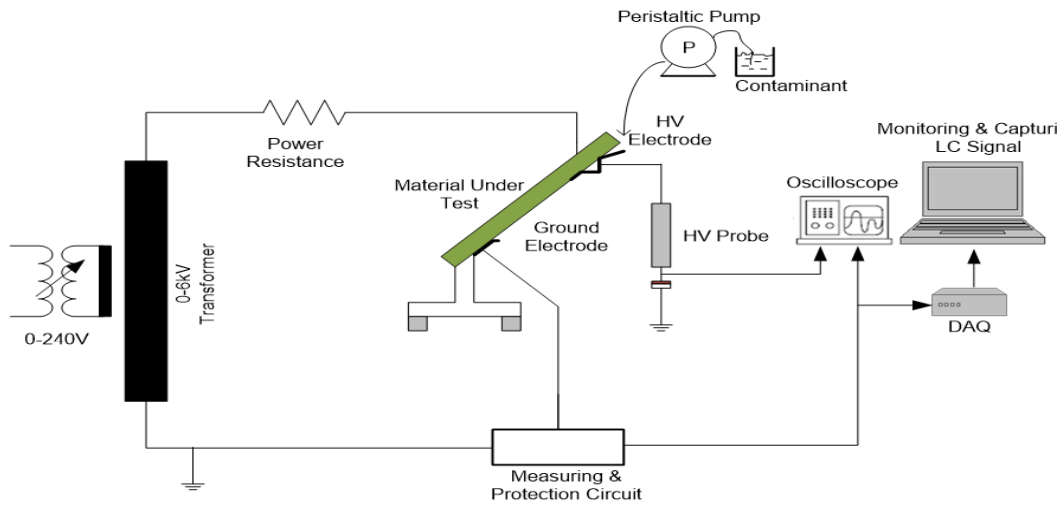


Figure 5. Schematic of inclined plane test 12 [12]

**5.1. Result from DC Incline Plane Test (IPT)**

The sample for 30% were tested using 3.5kV DC incline plane test. Figure 6 shows the spark on the surface of insulator start during 15 minutes test and erosion and tracking start on insulator surface after 50 minutes of test.

After 1 hour and a half the test was stopped and the tracking length on the insulator surface was measured. The tracking length was around 4.5cm. The condition for insulator with 30% of wollastonite and the tracking length shown in Figure 7(a) and 7(b). Scanning Electron Microscopy (SEM) was conducted after DC incline plane test was done. The SEM conducted to make analysis of surface morphology of the insulator housing can be effectively used as a tool for the measurement of extent of degradation during aging [13, 14].

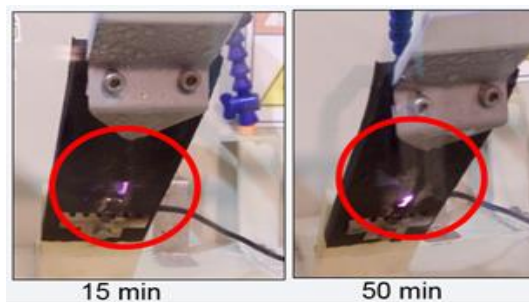


Figure 6. Spark on insulator surface during DC incline plane test (IPT)

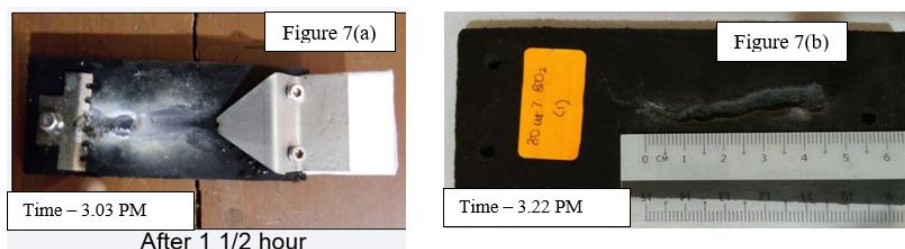


Figure 7(a). Condition insulator with 30% wollastonite filler after DC IPT test and (b). Tracking length on the insulator

Beside the condition of the surface on insulator were tested. The waveform during DC incline test were also obtained and saved using LabVIEW. Table 1 shows the condition for the insulator tested using different voltages.

Table 1. Surface and Condition Observation of Insulator using Different Voltages

Type of Wave	Voltage used (kV)	Surface and Condition Observation
Capacitive	0 - 1	Nothing happen
Resistive	1 - 3	Smoke with slow arching sound
Symmetrical	3.5 - 4	Spark of leakage current with smoke and arching sound
Unsymmetrical	4 - 5	Spark of leakage current separated between low and high part of the insulator surface

Leakage current data during different times which start during 3.03 PM and with voltage of 2.5kV that captured using LabVIEW then been evaluated using MATLAB shown in Figure 8. The result of waveform shows the difference between AC and DC waveform to the leakage current [15].

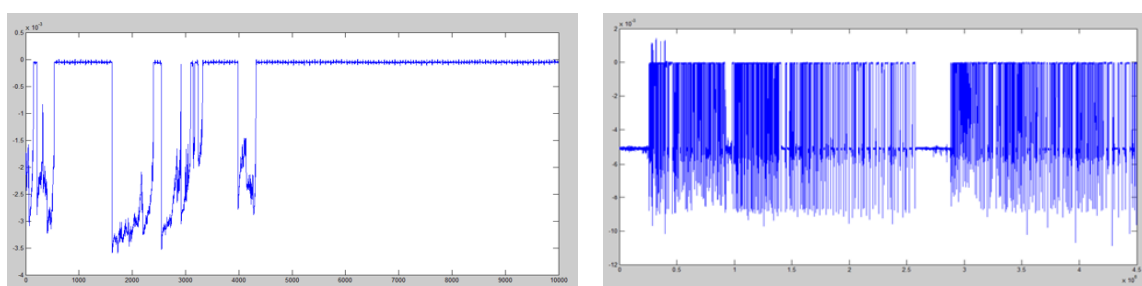


Figure 8. Leakage current data during different time

The samples of different filler into silicone rubber is prepared. There are several investigations that will be done to check combination of filler and SiR as matrix could improve the tracking and erosion behavior. DC incline plane test also could successfully indicate an enhanced interaction between fillers and SiR [16-19]. Leakage current of DC incline plane test can be evaluated and can show the surface condition for the insulator [20]. There are also several other methods that can be shown by using the leakage current waveform obtain such as using total harmonic distortion as mention in [21-24].

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