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Performance Study of Silicone Rubber Polymer was Filled Fly Ash as Insulator Material on High Voltage Transmission Tower

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Abstract— Silicone rubber has emerged as an alternative material for porcelain insulators and glass insulators on a high voltage transmission because it is lightweight, so it helps in planning the structure of the transmission tower. However, due to the cost of production of silicone rubber insulators are expensive and it is less resistant to climate change, it has not been used extensively as in Indonesia. One method to get silicone rubber insulator that is cheap is to mix it with other materials in the form filler that is inexpensive and easy to obtain as fly ash of coal because this material has a particle size that is very fine and its contents are materials that have been and are being investigated as filler of silicone rubber. This paper describe about the research that has proven the feasibility of fly ash as filler for silicone rubber. The results of this study is the tensile strength of silicone rubber increased proportional to the increase of fly ash content on silicone rubber, but lowers elongation-to-break of the silicone rubber. Furthermore, the electrical properties, namely the dielectric strength of silicone rubber will increase with the addition of filler (fly ash), where the greatest dielectric strength on the composition of the filler (fly ash) 40%. As for the relative permittivity is increased with the addition of filler (fly ash) to silicone rubber by 50%. And the silicone rubber surface resistance will increase with the addition of filler (fly ash).

Keywords—silicone rubber, fly ash, filler, high voltage insulator, transmission tower

I. INTRODUCTION

Electrical energy is channeled through a network of transmission and distribution of electricity. For the transmission of electrical energy by a considerable distance required high working voltages so that power losses can be reduced. Currently applied voltage on the transmission in Indonesia is 70 kV up to 500 kV, while the distribution voltage is 20 kV. High voltage transmission require particular insulating material that have high reliability as equipment separating between parts voltage with no voltage as well as retaining and supporting line transmission [1] [2].

Until now, porcelain insulators and glass insulators are still widely used in the Indonesia power system. Use of type the insulators this in high voltage transmission that the higher is less profitable because required more mass of the insulator so require transmission tower construction more robust and higher, thus requiring greater investment costs. Porcelain insulators and glass insulators require special handling because it is easily broken, especially in the transport and installation process [3].

Since the last few years polymer material has emerged gradually and was developed as an alternative to porcelain materials and glass materials. Advantages of polymer material in this case silicone rubber is dielectric properties, volume resistivity, thermal properties, and mechanical strength [4] [5] [6] [7]. The weight ratio of the various types of insulators made of polymer is 36.7% up to 93% lighter than porcelain insulators [3]. Although various advantages, to date the use of silicone rubber in several countries are still limited as in Indonesia due to the high production cost of silicone rubber insulators, so many researchers who conducted the optimization of material that can be mixed with silicone rubber, especially in terms of the material filler concentrated on silica (SiO_2) [8] [10], alumina (Al_2O_3) [11], titanium dioxide (TiO_2) [9], and magnesium oxide (MgO) [10].

One source of filler material is coal fly ash that contains chemical elements, among others, silica (SiO_2), alumina (Al_2O_3), ferrous oxide (Fe_2O_3) and calcium oxide (CaO), also contains elements of other enhancements that magnesium oxide (MgO), titanium oxide (TiO_2), alkaline (Na_2O and K_2O), sulfur trioxide (SO_3), phosphorus oxide (P_2O_5) and carbon [12]. Thus allowing the coal fly ash can be used as an alternative filler of silicone rubber polymers. Therefore, to determine whether the coal fly ash can be used as filler material to high voltage insulators, will be done testing on the material of silicone rubber that filled with coal fly ash to be used as a high voltage insulator material in an effort to reduce the burden of transmission tower.

II. EXPERIMENTAL PROCEDURE

This test follows the procedure as shown in flowchart in Fig. 1.

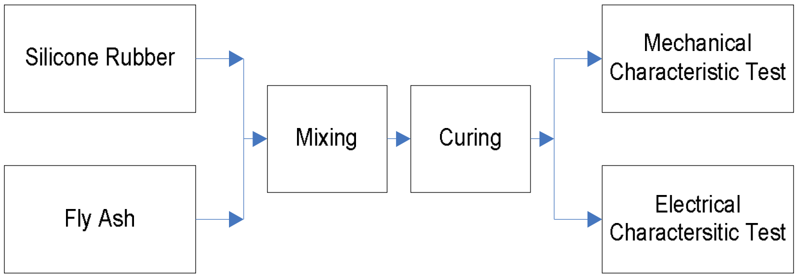

Fig. 1 . Experimental Procedure Flowchart

A. Preparation Material

Type of RTV silicone rubber used is 683 [13]. Fly ash material taken from Coal fire Power Plant in South Sulawesi province (Indonesia). Fly ash compounds have been examined using XRF is SiO_2 = 40,16%; Al_2O_3 = 19,48%; CaO = 8,35%; Na_2O = 2,4%; MgO = 3,8%; P_2O_5 = 0,15%; SO_3 = 1,33%; K_2O = 1,75%; TiO_2 = 1,3%; Cr_2O_3 = 0,05%; MnO = 0,29%; Fe_2O_3 = 20,22%; CoO = 0,06%; SrO = 0,12%; ZrO_2 = 0,06%; BaO = 0,19%; Pr_6O_{11} = 0,05%; Nd_2O_3 = 0,08%.

Beginning of the experiment is silicone rubber and fly ash mixed with manual mixing technique, then the mixture is inserted into a vacuum chamber to remove trapped air bubbles. The mixture is poured into a mold of 2 mm to obtain a test material with a uniform thickness and to facilitate the testing of dielectric breakdown strength without reducing the ease of measuring other parameters. In the process of curing, the material was placed in a room with a humidity of 80% which runs for 24 hours. The test material was made in the number of different contents of fly ash coal. The composition of the fly ash and the silicone rubber is 0% Fly Ash, 5% fly ash, 10% fly ash, 15% fly ash, 20% fly ash, 25% fly ash, 30% fly ash, 35% fly ash, 40% fly ash, 45% fly ash and 50% Fly ash.

B. Laboratory Test Conducted

Tensile Strength test was conducted to determine the mechanical properties of silicon rubber before and after is filled with fly ash. The tensile tests using ASTM 638. The next test is the test of elongation-to-break is one type of deformation which is the size of the change that occurred when the test material was given style.

The other is testing the dielectric strength test conducted in accordance with ASTM D149. Electrodes used in the measurement is a needle electrode on the top plate and the electrode at the bottom. Voltage frequency of 60 Hz is used in this test. Tests were carried out under room temperature 27 °C and a humidity of 80%.

Relative permittivity is obtained by measuring the capacitance of the capacitance meter test materials. Material placed between the parallel circular plate and measurements were performed with a frequency of 800 Hz. Capacitance measurements performed below room temperature 26 °C and humidity around 85%. Capacitance value obtained is then converted into relative permittivity. The testing procedure is based on ASTM standard D257. Furthermore test voltage of 5670 V DC instrument for the measurement of the volume resistivity and the test voltage is 2730 V DC is used for measurement of surface resistivity.

III.RESULT AND DISCUSSION

Here in Table 1 show the results of testing of the test material.

TABLE I
RESULTS OF TESTING THE TEST MATERIALS

Fly ash content	**0%**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**	**40%**	**45%**	**50%**
Tensile Strength (kgf/mm^2)	0.13	0.13	0.14	0.15	0.20	0.20	0.21	0.18	0.16	0.16	0.15
Elongation at break (mm)	345.0	227.4	158.9	147.4	140.4	132.7	114.7	101.9	94.2	94.0	93.6
Breakdown Voltage (kV/mm)	9.80	10.10	10.21	12.20	14.91	15.50	16.15	16.30	16.77	16.05	14.15
Relative Permitivity	2.70	2.83	2.99	3.56	3.79	3.73	3.68	3.69	3.71	3.77	3.84
Surface resistivity (GOhm/sq)	5.37	5.53	5.74	6.12	6.71	7.90	8.37	8.67	9.12	9.89	11.38

Explanation of the tables of test results in Table 1 will be shown in the next section.

A. Tensile strength

Fig. 2 shows about mechanical properties such as tensile strength of silicone rubber increased when filled with coal fly ash.

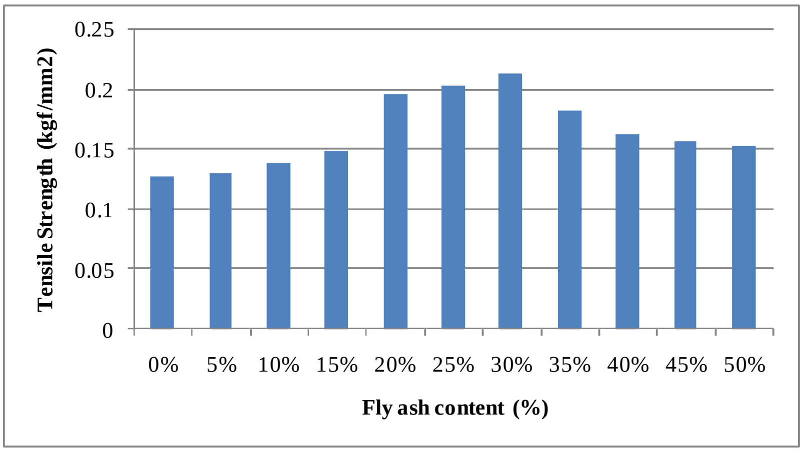

Fig. 2 Effect of fly ash content on tensile strength of fly ash filled silicone rubber

The test material with the amount of 5% fly ash up to 50% fly ash has a value greater tensile strength than the test material which has no fly ash (0%). The tensile strength of the test material has a maximum value on 30% fly ash content that is equal to 0.21 kgf/mm^2, which increased by more than 62% of silicone rubber with no fillers. The tensile strength of the test material is influenced by the strength of the bond between the particles of coal fly ash and silicone rubber. Another factor that can influence the tensile strength is a cure rate of the test material.

B. Elongation-to-break Test

Likewise for testing elongation-to-break has been tested and magnitude of the value illustrated in Fig. 3 which shows the length of the elongation-to-break of the test material which describes the test material to different sizes of fly ash is added to the silicone rubber has a value elongation- to-break declining rather than silicone rubber with no fillers. This shows that the composition of fly ash affecting the nature of elongation-to-break silicone rubber. The decline of the value of elongation-to-break also affected by the size of the fly ash, where the test materials are particles that have a larger size than the particles of silicon rubber, thereby reducing the extension properties of the test material [14].

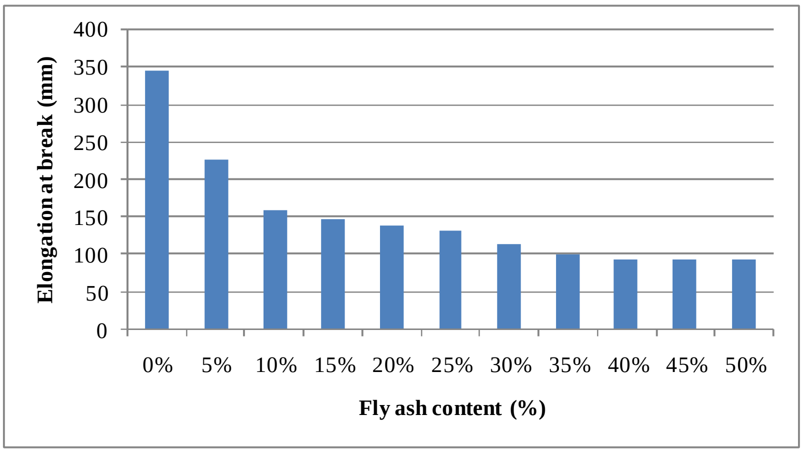

Fig. 3 Effect of fly ash content on elongation at break of fly ash filled silicone rubber

C. Dielectric Strength

Dielectric strength measurements carried out by the breakdown voltage test and the results can be seen in Fig. 4 which shows the dielectric strength of silicone rubber filled with fly ash increased with the addition of fly ash in the test material. Maximum of breakdown voltage is achieved in 40% fly ash in a silicone rubber or an increase of 71% compared with silicone rubber without fly ash.

Breakdown voltage of the test material can be influenced by the intrinsic and extrinsic properties of the test material such as the type of the applied voltage. The presence of air bubbles in the material being tested can be one of the intrinsic factors that lead to a decrease in the dielectric strength of the material. Another factor that can affect the dielectric strength of the test material is resistance volume. If the resistance volume is low, electrical currents in the test material will increase, which will trigger material damage [15].

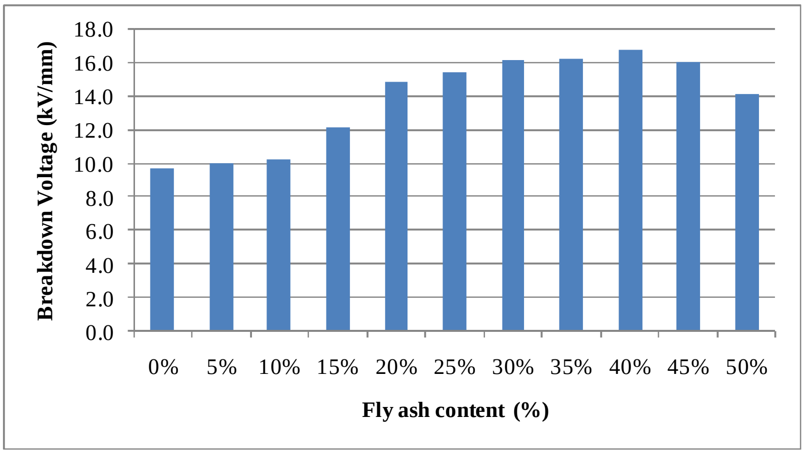

Fig. 4 Effect of fly ash content on dielectric strength of fly ash filled silicone rubber

D. Relative Permittivity

The relative permittivity of the material with a variety of fly ash content has been researched and shown in Fig. 5, where the figures show a relative permittivity of the test material were increased until the filler content of 50% fly ash. Increasing the value of the permittivity of the filler content of 50% fly ash is 44% compared with silicone rubber without filler (0% fly ash). Fly ash make silicone rubber composite has a value of permittivity increased, causing the dielectric loss or dissipation material will increase as well.

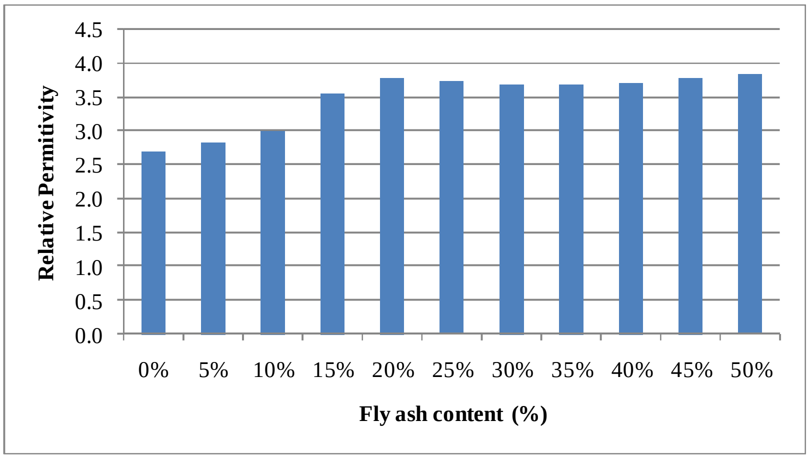

Fig. 5 Effect of fly ash content on relative permittivity of silicone rubber composite

E. Surface Resistivity

Fig. 6 shows that increased levels of fly ash in the silicone rubber will make the surface resistivity of the test material becomes higher. Value of the surface resistance on the composition of the content of fly ash 50% is of 11.38 GOhm/sq increased 42% compared with silicone rubber without filler (0% fly ash). Measurement value determined by thickness of test materials. Surface resistivity also affected by surface recovery.

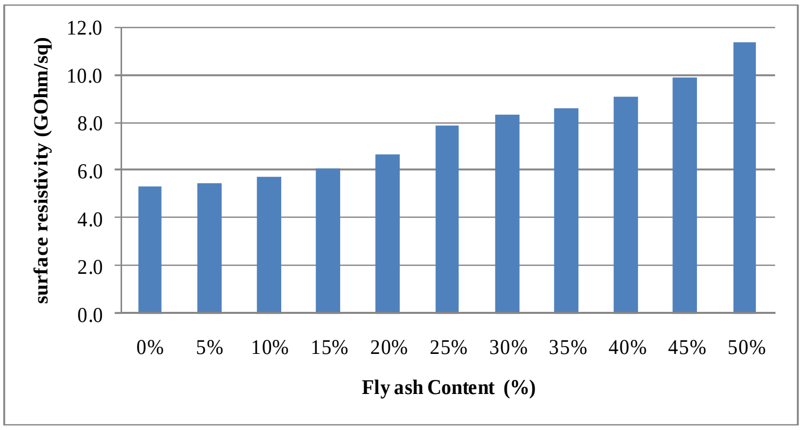

Fig. 6 Effect of fly ash content on surface resistivity of fly ash filled silicone rubber

IV. CONCLUSION

Silicone rubber containing coal fly ash is possible use as insulator material of high voltage, which it is proved in research that has been done. The results showed that the fly ash feasible for use as a filler to silicone rubber for its ability to increase the tensile strength, dielectric strength, relative permittivity, and the surface resistivity. The content of fly ash as filler for silicone rubber most excellent is 30% fly ash because it provides better improvement for electrical and mechanical properties of silicone rubber. The tensile strength of the test material is increased by the increase in fly ash on silicone rubber, where the largest increase of the filler content of 30%. But the increasing impact of fly ash composition on the silicone rubber decrease elongation-to-break of silicon rubber. Furthermore, the dielectric strength test materials that will increase with the addition of filler (fly ash), where the greatest dielectric strength is at 40% filler composition. As for the relative permittivity is increased with the addition of filler (fly ash) in the silicone rubber by 50%. And the surface resistance of test materials increased with the addition of filler (fly ash) to 50%.

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