

# Mica Filler Effect on Electrical Characteristics of Polymer Insulators

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**Abstract** – This paper presents an experimental measurements of ac 50 Hz flashover voltage (kV) of hydrophobic polyester and composite insulators under dry and some environmental conditions. Cylindrical rod polyester composite samples with varying concentrations (20 to 40 weight %) of mica have been prepared to improve the electrical and mechanical properties in addition to maximize the surface flashover voltage and decrease the erosion and tracking phenomena. By using five lengths for each concentration (0.5, 1, 1.5, 2, and 2.5) cm each test was repeated five times on each sample under the same conditions to check the accuracy of the results. Results showed that electrical properties of composite were found to increase with mica concentration at 2.5cm sample length flashover voltage reaches to 25.5kV for samples without filler and 50.41 kV for samples containing 40% of mica filler in dry condition. A comparison between five different conditions showed higher flashover voltage for samples in dry condition than that of samples in (wet, 5wt.% sodium chloride, 10wt.% sodium chloride, and 10wt.% nitric acid) conditions at all filler concentrations. Mechanical properties such as compressive and tensile strength were found to decrease with mica concentration.

**Keywords** – Environmental Effects, Flashover Voltage, High Voltage Composite Insulators, Mica Filler.

## I. INTRODUCTION

The application of non ceramic insulators in recent years has increased to the extent that more utilities are considering the use of these insulators on major transmission lines. The quality of non ceramic insulators has improved significantly and simultaneously these insulators have become more economically competitive with ceramic types[1]. Polymeric insulating materials with excellent weather resistance and mechanical performance have been developed[2]. Hydrophobic polymeric surfaces are characterized by a low surface conductivity which in turn gives a low discharge activity and a higher flashover voltage. This holds also for polluted environments. Reduced hydrophobicity implies a higher risk for flashover of the insulator. Hydrophilic materials, on the other hand, are very sensitive to polluted environments, and are characterized by a low significant activity of local discharges[3]. Wind together with rain can cause localized discharges and flashover the surface of the insulator[4].

When these polymeric insulators are installed in coastal areas the salt and airborne particles are deposited on their surfaces and the pollution builds up gradually. Under dry conditions these deposits do not decrease the surface insulation strength, whereas in wet weather condition a conductive layer is formed which results in flow of leakage

current which lead to occurring flashover voltage [5]. In the present work we measured the flashover voltage under dry, wet, 5wt.% sodium chloride, 10wt.% sodium chloride, and 10wt.% nitric acid conditions.

Cylindrical rod specimens chemically were prepared from polyester and mica had been tested to examine the flashover voltage performance of composites. The ac(50Hz) flashover voltage of composite specimens had been investigated in this study. Mica filler is in use for increasing the electrical and mechanical performance of composite specimens. The performance of filled polymers was generally determined on the basis of the interface attraction of filler and polymers. Incorporating inorganic mineral filler into plastic resin improves various properties of the materials [6]. Many kinds of inorganic fillers such as silica, alumina, mica, and aluminum nitride have been used for conventional polymer composite in order to apply them to insulation materials. In particular, mica has been used widely in polyester composites for high voltage (HV) applications [7]. Polyester resin mixed with other materials is becoming to be used throughout the electrical industry. However as with other polymeric insulating materials under abnormal long term stress conditions It suffers from several breakdown mechanisms such as treeing, surface tracking or erosion. Polyester is used as electric insulation in indoor and outdoor applications [8]. Mica is one such type of filler and is a particularly abundant mineral. Mica had been widely studied filler due to its unique set of properties. Mica has an outstanding mechanical, thermal, electrical and chemical properties rarely found in any other products. Mica provides cost effective improvements [9]. Insulation materials should have good mechanical characteristics as any serious degradation in the mechanical properties of an insulating materials leads to dielectric failure[10]. In the present work the effect of mica of varying concentrations on electrical and mechanical properties of polyester thermoplastic resin were studied.

## II. EXPERIMENTAL SET-UP AND TECHNIQUES

### A. Material Specimen

Specimens have been prepared from unsaturated polyester resin, having the transparent white color. Specimens were fabricated as cylindrical rods having 1cm diameter and 10mm thickness. Brown powder mica filler has been added to polyester. Mica filler has been used with different concentrations, the composition of the specimens is given in table 1.

### B. Test Apparatus

The ac(50Hz) high voltage was obtained from a single-phase high voltage auto transformer (100kV-15kVA). The

electrodes were made of copper with 1cm diameter. The electrodes were fixed to the specimens, one at the top and the other at the bottom carefully to ensure a good contact. The experiments were carried out in a high voltage laboratory. The high voltage (HV) supply was provided by a single-phase high voltage auto transformer (100kV-15 kVA). The flashover voltage was measured for dry, wet, 5wt.% sodium chloride, 10wt.% sodium chloride and 10wt.% nitric acid conditions of composites with different five lengths of samples for each concentration of mica (20, 30 and 40wt.%). The contamination slurry was prepared by mixing an appropriate amount of sodium chloride in water. By immersing the sample in the slurry until contamination was applied on the sample. After pollution is achieved on the sample they were tested. The high voltage between two electrodes increased gradually from zero by constant rate 2kV/sec until the flashover voltage (kV) occurs. By using five lengths for each concentration (0.5, 1, 1.5, 2, and 2.5) cm each test has been done five times on each sample under the same conditions to check the accuracy of the results.

Table 1. Composition of specimens with different concentrations of Mica filler.

Polyester by weight (%)	Concentration of mica filler by weight (%)
80%	20%
70%	30%
60%	40%

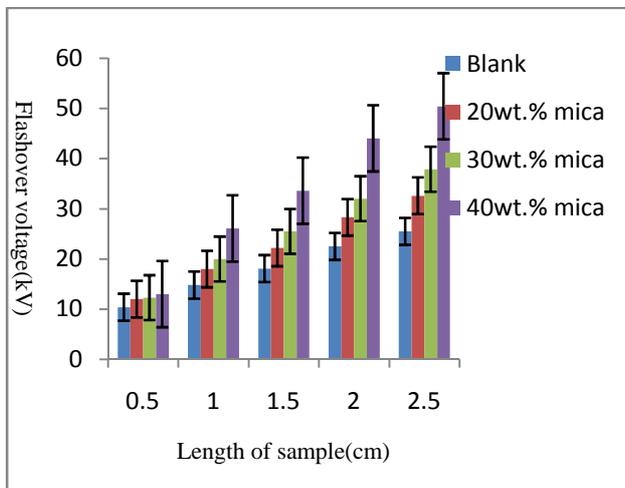


Fig. 1. Flashover voltage via the percentage of mica in composite samples in dry condition

### C. Mechanical Test

Mechanical tests such as compressive and tensile strengths have been done to evaluate the mechanical performance of composite insulators according to ASTM D695 and ASTM D638 for compressive and tensile strengths respectively, three identical specimens have been tested.

## III. RESULTS AND DISCUSSION

Flashover voltages have been recorded for composite samples under dry, wet, 5wt.% sodium chloride, 10wt.%

sodium chloride, and 10wt.% nitric acid contaminated conditions.

### A. Flashover voltage of dry specimens

Effect of different concentrations of mica filler (20, 30, and 40wt.%) on the electrical performance of composite insulators under dry condition is shown in Fig.1. From this figure it can be seen that:

The unfilled polyester specimens have lower flashover voltage value than its value of samples containing mica filler at all filler concentrations under different sample lengths this may be due to mica fills in the blanks while in the case of unfilled specimens, there are some blanks.

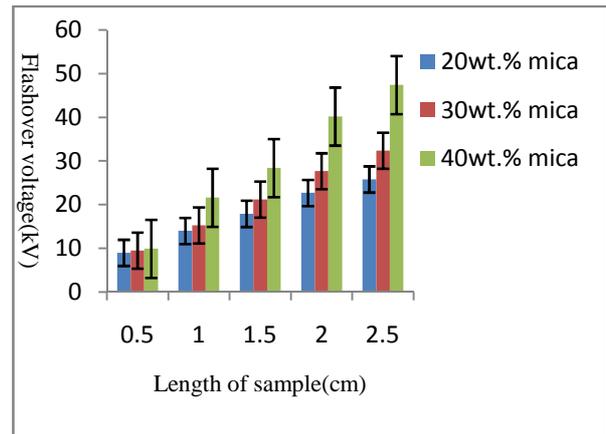


Fig. 2. Flashover voltage via the percentage of mica in composite samples in wet condition

It is interesting to note that composite samples mica<sub>20</sub> (polyester+20wt.%mica), mica<sub>30</sub>(polyester +30wt.% mica), and mica<sub>40</sub> (polyester + 40wt.% mica) increase flashover voltage compared with unfilled polyester sample from (10.4, 14.8, 18.1, 22.5, and 25.5 ) kV to (12, 18, 22.2, 28.3, and 32.6 ), (12.30, 20, 25.5, 32, and 37.88 ) and (13, 26.09, 33.62, 44.03, and 50.41)kV at sample lengths (0.5, 1, 1.5, 2, and 2.5) cm, respectively.

The increment percentage of flashover voltage from unfilled polyester to filled polyester with (20, 30, and 40wt.%) is (15.38, 18.26, and 25%), (21.62, 35.13, and 76.28 ), (22.65, 40.88, and 85.74 ), ( 25.77, 42.22, and 95.68) and ( 27.84, 48.54, and 97.68 ) % with (0.5, 1, 1.5, 2, and 2.5 ) cm, respectively.

Among the three concentrations taken in this study, the inclusion of 20wt.% mica samples causes a maximum reduction in flashover voltage for all sample lengths (0.5, 1, 1.5, 2, and 2.5)cm.

Improvement in the flashover voltage value for polyester sample loaded with 40 wt.% has been achieved compared with polyester sample loaded with 20wt.% and 30wt.% of mica filler.

Flashover voltage of all specimens with different concentration of mica increases by the increase of mica percentage until 40wt.%. If mica percentage exceeds 40wt.%, leaching of filler is observed and samples become brittle.

### B. Effect of Mica Concentrations on Flashover Voltage of Composite Specimens Under Wet Condition

Simulates the effect of wet condition on composite insulators ; the composite specimens were immersed to water. A comparison between three different concentrations of mica filler (20, 30, and 40wt.%) has been done to measure the ability of each concentration to withstand wet condition and increase the value of flashover voltage.

Effect of mica filler with different concentrations (20, 30, and 40wt.%) on the electrical performance of composite insulators under wet condition is shown in Fig.2.

The above figure shows the relationship between mica concentration (20, 30, and 40wt.%) and flashover voltage (kV) under wet condition. From this figure it can be seen that:

At mica<sub>20</sub> composite specimens, the flashover voltage are (9, 14, 17.93, 22.71, and 25.81) kV for sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm respectively, under wet condition .

At mica<sub>30</sub> composite specimens, the flashover voltage are (9.51, 15.3, 21.2, 27.7, and 32.4)kV for sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm respectively under wet condition.

At mica<sub>40</sub> composite specimens, the flashover voltage are (9.92, 21.6, , 28.41, 40.21, and 47.42)kV for sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm respectively, under wet condition .

The increment percentage in the flashover voltage value for polyester sample loaded with 20wt.% compared with polyester samples loaded with 30wt.% and 40wt.% of mica filler is (5.66% and 10.22%), (9.28% and 54.28%), (18.23% and 58.44%), (21.97% and 77.05%), and (25.53% and 83.72% )for (0.5, 1, 1.5, 2, and 2.5) cm, respectively.

In wet condition, the values of flashover voltage decrease compared to dry condition. This is because the hydrophobic nature of polymer materials, makes water tend to beads rather than to form filaments along the surface . These beads under electric stress consist water film results in leakage current flow, which in turn causes flashover .

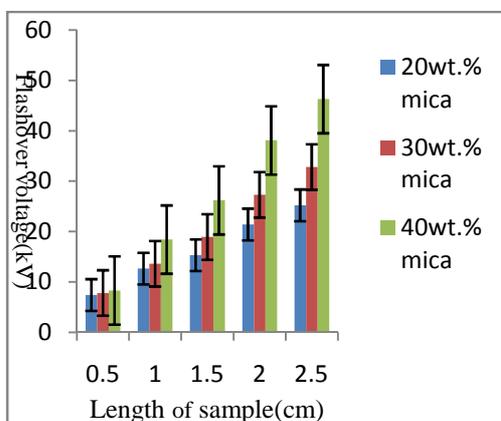


Fig. 3. Flashover voltage via the percentage of mica in composite in 5wt.% sodium chloride condition

### C. Flashover Voltage of Specimens Under 5wt.% Sodium Chloride

In 5wt.% sodium chloride The conductive contamination dissolved within the water. This condition results in surface leakage current flow between two electrodes, which in turn causes flashover.

Effect of mica filler with different concentrations (20, 30, and 40wt.%) on the electrical performance of composite insulators under 5wt.% sodium chloride is shown in fig.3. The above figure shows the relationship between mica concentration and flashover voltage (kV) under 5wt.% sodium chloride condition .

From this figure it can be seen that:

The composite containing 20wt.% mica has a flashover voltage of (7.42, 12.65, 15.31, 21.41, and 25.21)kV at sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm, the flashover voltage increases to (7.81, 13.62, 18.93, 27.3, and 32.81)kV and (8.3, 18.41, 26.2, 38.11, and 46.3) kV at sample lengths (0.5, 1, 1.5, 2, and 2.5)cm with mica percentage of 30 and 40wt.%, respectively when exposed to 5wt.% sodium chloride .

- The increment percentage in the flashover voltage value for polyester sample loaded with 20wt.% compared with polyester sample loaded with 30wt.% and 40wt.% of mica filler is (5.25% and 11.85%), (7.66% and 45.53%) (23.44% and 71.12%), (27.51% and 78%), and (30.14% and 83.65%) for (0.5, 1, 1.5, 2, and 2.5) cm, respectively.

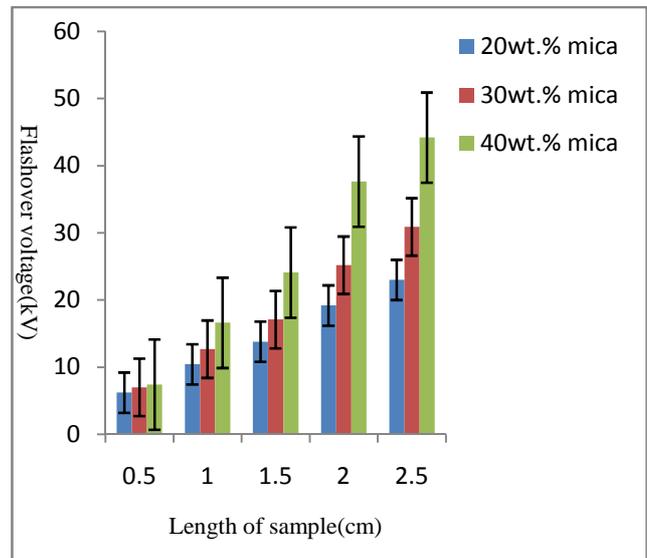


Fig. 4. Flashover voltage via the percentage of mica in composite samples in 10wt.% sodium chloride condition

### D. Flashover Voltage of Specimens Contaminated with 10wt.% Sodium Chloride

In 10wt.% sodium chloride condition concentration of sodium chloride is higher than 5wt.% sodium chloride so, contamination leads to consisting higher surface leakage current between two electrodes which leads to occurring flashover at lower values than 5wt.% sodium chloride.

Effect of mica filler with different concentrations (20, 30, and 40wt.%) on the electrical performance of composite specimens under 10wt.% sodium chloride condition is shown in fig.4. The above figure shows the

relationship between mica concentration and flashover voltage (kV) under 10wt.% sodium chloride condition .

From this figure it can be seen that :

The composite containing 20wt.% mica has a flashover voltage of (6.22, 10.44, 13.81, 19.2, and 23.01)kV at sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm, the flashover voltage increases to (7.01, 12.7, 17.1, 25.2, and 30.91)kV and (7.41, 16.62, 24.1, 37.65, and 45.54) kV at sample lengths (0.5, 1, 1.5, 2, and 2.5)cm with mica percentage of 30 and 40wt.%, respectively when exposed to contamination by 10wt.% sodium chloride condition.

- The increment percentage in the flashover voltage value for polyester sample loaded with 20wt.% compared with polyester sample loaded with 30wt.% and 40wt.% of mica filler is (12.7 and 19.13)%, (21.64 and 59.19)%, (23.83 and 74.51)%, (31.25 and 96.09)%, and (34.34 and 97.91)% for (0.5, 1, 1.5, 2, and 2.5)cm, respectively.

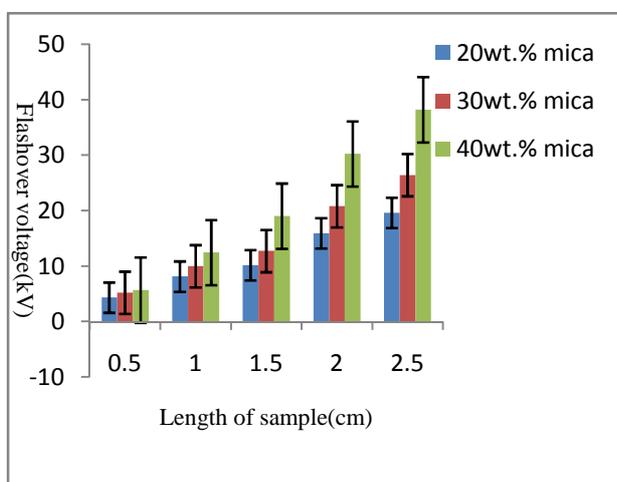


Fig. 5. Flashover voltage via the percentage of mica in composite samples in 10wt.% nitric acid condition

#### E. Flashover Voltage of Specimens Contaminated with 10wt.% Nitric Acid

In 10wt.% nitric acid condition, surface leakage current consists between two electrodes .This leakage current results from nitric acid as this acid is very strong, this leakage current leads to faster flashover at small values if it is compared to condition without contamination.

Effect of mica filler with different concentrations (20, 30, and 40wt.%) on the electrical performance of composite insulators under 10wt.% nitric acid condition is shown in fig.5.

The above figure shows the relationship between mica concentration and flashover voltage (kV) under 10wt.% nitric acid condition .

From this figure it can be seen that :

- The composite containing 20wt.% mica has a flashover voltage of (4.32, 8.11, 10.16, 15.93, and 19.62)kV at sample lengths of (0.5, 1, 1.5, 2, and 2.5)cm, the flashover voltage increases to (5.21, 9.98, 12.72, 20.81, and 26.42)kV and (5.69, 12.44, 19.03, 30.23, and 38.21) at sample lengths (0.5, 1, 1.5, 2, and 2.5)cm with mica percentage of 30 and 40wt.%, respectively when exposed to contamination by 10wt.% nitric acid condition.

- The increment percentage in the flashover voltage value for polyester sample loaded with 20wt.% compared with polyester sample loaded with 30wt.% and 40wt.% of mica filler is (20.60 and 31.71)%, (23.05 and 53.39)%, (25.19 and 87.30)%, (30.63 and 89.76)%, and (34.65 and 94.75)% for (0.5, 1, 1.5, 2, and 2.5 )cm, respectively.

## IV. MECHANICAL RESULTS

### Compressive and Tensile Strength Test Results

From figures 6 and 7 it can be seen that:

- The compressive and tensile strength ( $\text{Kg/cm}^2$ ) values of blank samples are higher than filled samples with different concentrations of mica filler (20, 30, and 40)wt.%.
- The unfilled polyester composite has a compressive strength value of  $1781 \text{Kg/cm}^2$ , the value slightly decreases to (1639.34, 1554.67, and 1439.34)  $\text{Kg/cm}^2$  with the addition of (20, 30, and 40) wt.% of mica filler, respectively.
- The tensile strength value ( $382.67 \text{Kg/cm}^2$ ) of polyester without filler is higher than that of polyester composite with mica filler, where this value decreases to (351.67, 288.67, and 261.34)  $\text{Kg/cm}^2$  with the addition of (20, 30, and 40)wt.% of mica filler, respectively.
- Rate of decrease in the results of compressive strength for mica filler gives  $1639.34 \text{Kg/cm}^2$  at the lowest filler concentration and  $1439.34 \text{Kg/cm}^2$  at the highest concentration, which means that the rate of decrease is almost 12.20 % .
- Rate of decrease in the results of tensile strength for mica filler gives  $351.67 \text{Kg/cm}^2$  at the lowest filler concentration and  $261.34 \text{Kg/cm}^2$  at the highest concentration, which means that the rate of decrease is almost 25.68 % .
- The reduction percentage of compressive and tensile strengths for mica<sub>20</sub>, mica<sub>30</sub> and mica<sub>40</sub> is almost 7.95, 12.70, and 19.18 for compressive strength and 8.10, 24.56, and 31.70 for tensile strength respectively, with compared to unfilled polyester specimens.

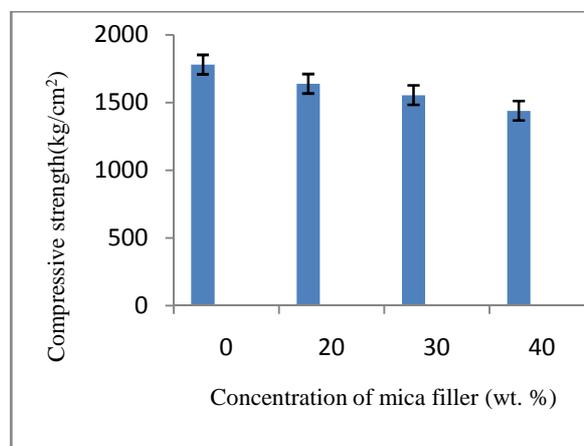


Fig. 6. Compressive strength ( $\text{Kg/cm}^2$ ) of dry specimens against different concentrations of mica filler.

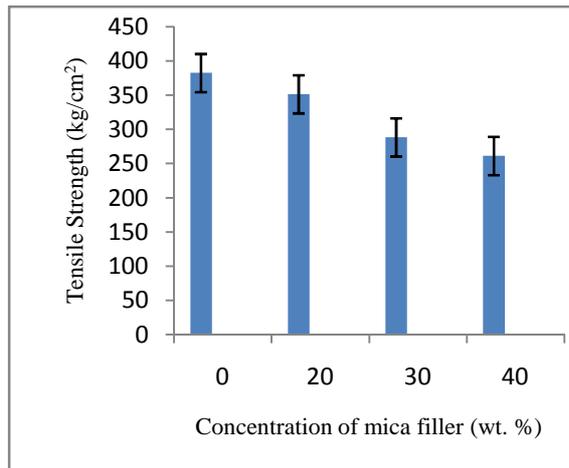


Fig. 7. Tensile strength (Kg/cm<sup>2</sup>) of dry specimens against different concentrations of mica filler.

## V. CONCLUSION

This paper has focused on the environmental effect on the Electrical performance of composite polymer insulators. The findings can be summarized as follows:

1. The percentage of filler have pronounced effects on the electrical and mechanical performance of polyester composite insulators.
2. There is a optimum percentage of filler, which can be added with respect to the quantity of polyester, and the suitable percentage is 30% mica filler.
3. Among the three concentrations taken in this study, the inclusion of 40wt.% mica concentration causes a maximum value of flashover voltage (50.41kV) at 2.5 cm.
4. The unfilled polyester composite has a lower flashover voltage value than of samples containing mica filler at all filler concentrations in dry condition(25.5kV) at 2.5cm.
5. The unfilled polyester has mechanical properties better than other samples loaded with (20, 30, and 40wt.%).
6. Among the five conditions taken in this study (dry, wet, 5wt.% sodium chloride, 10wt.% sodium chloride, and 10wt.% nitric acid), the inclusion of nitric acid is the worst case where it causes faster flashover voltage.

## VI. ACKNOWLEDGMENT

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