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Impact Alumina tri-hydrate and Silica Inorganic Fillers on the Electrical and Ultrasonic Properties of Non-Ceramic Insulators

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Abstract- This paper illustrates the performance of non-ceramic and composites insulating materials for outdoor insulation, namely unsaturated polyester resins with commonly used inorganic filler under different environmental conditions. The effect of type and concentration of filler (Alumina tri hydrate (ATH) and Silica (SiO_2)) on the electrical properties of polyester composite as a high voltage insulating materials, were investigated by means of electrical and ultrasonic techniques. Ultrasonic Wave Velocities (longitudinal and shear) were measured at frequencies of 4MHz at room temperature. Results showed that flashover voltage reaches to 24.22 kV for sample without filler and 34.88 kV for Sample containing 70% of ATH filler in dry condition. A comparison between inorganic fillers under various environmental conditions showed higher flashover voltage values for samples containing ATH filler than those of samples containing Silica (SiO_2) filler at all filler concentrations. Also, results of density, ultrasonic wave velocities, electrical properties showed the improvement of the polymer composite with type of filler.

Keywords – Non-Ceramic Insulators, Environmental Effects, Flashover Voltage, Ultrasonic Measurements, Polyester, ATH , Silica.

I. INTRODUCTION

High voltage outdoor insulation design and monitoring are vital to ensure reliable operation of the power transmission and distribution. Ceramic and glass insulators have been used for a long time and there is considerable experience in manufacturing, installation and their field performance is well-known. However, some problems with this type of insulators in contaminated conditions led to the necessity of finding alternatives. One option is the use of non-ceramic insulators which have shown advantages compared to ceramic and glass insulators, such as low weight construction, good performance in contaminated environments and easy handling [1-3]. These advantages have driven the utility people to prefer polymer insulators over conventional ceramic or glass insulators. The polymeric materials, particularly silicon rubber, epoxy, ethylene propylene diene monomer (EPDM) and polyesters are used as insulators for transmission, distribution, termination of underground cables, bushings and surge arrester housings [4]. The environmental conditions have the greatest effect on the performance of the outdoor insulators. The accumulation of contamination, like salt, dust and sand eventually leads to a complete flashover on the surface of the insulator. Contamination flashover has become a significant aspect in designing outdoor insulators and it has been under extensive research. When the insulator surface gets covered by soluble salts and in the presence of moisture, the insulator surface becomes more conductive. After the formation of conductive layers, dry band regions will appear on the surface leading to the start of partial arcs. These arcs get elongated which finally bridges the whole insulator leading to a flashover [5]. Insulator flashovers result in expensive and undesirable power outages. It is known that in order to minimize contamination related problems and prevent flashover, it is important to reduce leakage current as much as possible [6,7]. Unsaturated polyesters are widely used in the composite industry. They can provide excellent mechanical and chemical properties, good chemical and weather resistance, and a low cost. Further advantages of unsaturated polyester resins over other thermosetting resins are that they are easy to handle, can be pigmented, and can be easily filled and fiber reinforced in a liquid form[8]. 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[9]. Filler materials are used extensively with polyester resin for a variety of reasons, such as cost reduction, and more importantly, to enhance some physical and/or mechanical properties. Through the present work several types of inorganic fillers(Alumina tri hydrate and silica) were incorporated into the polyester resin. ATH and silica are the two fillers that are mainly being used by manufacturers [10]. Composite insulator, which is made of organic polymer materials, has a weaker aging resistance performance than porcelain or glass insulator. Aging of composite insulators under atmospheric environments will lead to internal defects in form of void, delamination and interfacial degumming. It has been shown that the electric field will be distorted at the internal defects and the long-term effect of high field intensity will cause partial discharge, which will weaken the insulating property of composite insulator. In extreme cases, composite insulators could even be punctured or fractured, and the security of electric systems will be severely endangered. A non-destructive testing method for internal defects detection is desperately needed to test and evaluate the state of composite insulators [11]. Nondestructive testing methods ore one of the most dynamically developing branches of science in general. The procedure of ultrasonic tests on objects comprises passing waves into objects, scanning objects by moving head over their surface and detecting signals caused by waves passed through objects. The basic rule in such tests is to know dependencies between the value of an ultrasonic parameters being measured (for example, ultrasonic longitudinal and shear velocities) and the tested property of internal structure of the polymer material under investigation. Dependencies between acoustic parameters and structural properties of polymer materials are usually determined empirically based on measurements of standard samples with precisely defined and known structural parameters [12, 13].

The aim of this study is to find out the effect of surface contamination and fillers on flashover performance of non-ceramic insulators. In this context, the present work looks at the effect of ATH and silica on the performance of polyester. The electrical performance is measured by flashover voltages. The longitudinal and shear ultrasonic velocities were measured in order to calculate the elastic moduli of these samples.

II. EXPERIMENTAL SET-UP AND TECHNIQUES

A. Material specimen

A polyester / styrene mixture with a ratio of (70/30)% by weight has been prepared in the shape of cylindrical rods having 1cm diameter and 2 cm length. Two types of inorganic filler have been added to the above mixture, namely ATH ($AL_2O_3.3H_2O$) and silica (SiO_2) as a powder with various concentration (40, 50, 60 and 70%) to obtain different composites.

B. Electrical test supply and electrodes

The Ac (50Hz) high voltage was obtained from a single phase high voltage auto transformer (100kV-5kVA). The output voltage of the transformer was smoothly controlled by (0-220 V) VARIAC regulating the voltage applied to its primary winding. The electrodes were made of copper with 1cm diameter and 2cm thickness. The electrodes were fixed to the specimens, one at the top and the other at the bottom carefully to ensure a good contact. It is vital to ensure that the electrodes had very smooth without any irregularities to avoid the non-uniform electric filed according to ASTM D-2303-64T. The experiments were carried out in a high voltage laboratory. According to IEC 1109, flashover voltage should be determined by averaging five flashover voltages on each specimen for accuracy.

C. Ultrasonic technique

The ultrasonic wave velocities (longitudinal V_L and shear V_S) at room temperature were measured by pulse-echo single contact probe technique described in detail in ASTM E494-95 [14]. In this method, x-cut and y-cut transducers (KARL DEUTSCH) operated at frequency 4 MHz and a digital ultrasonic flaw detector (Kraut Kramer USIP20) was used. The two velocities with the density measurements with accuracy 1 kgm^{-3}, were used in determining two independent second-order elastic constants (SOECs), namely, the longitudinal (L) and shear (G) moduli. For pure longitudinal waves $L = \rho\ V_L{}^2$ and for pure transverse waves $G = \rho\ Vs^2$. The elastic bulk modulus (B), Young's modulus (E), micro-hardness(H) and Poisson's ratio (σ) can be determined from L and G using the standard relations $E = (1+\sigma)\ 2G$, $\sigma = [(L-2G)/2(L-G)]$, $H = (1-2\sigma)E/(6(1+\sigma))$.

III. RESULTS AND DISCUSSION

Flashover voltages have been recorded for composite samples under dry, sodium chloride, sodium hydroxide and hydrochloric acid contaminated conditions.

A. Flashover voltage for dry specimens.

Effect of flashover voltage of polyester specimens with different concentrations (40, 50, 60 and 70wt.%) of fillers (ATH and silica) under dry condition is shown in figure.1.

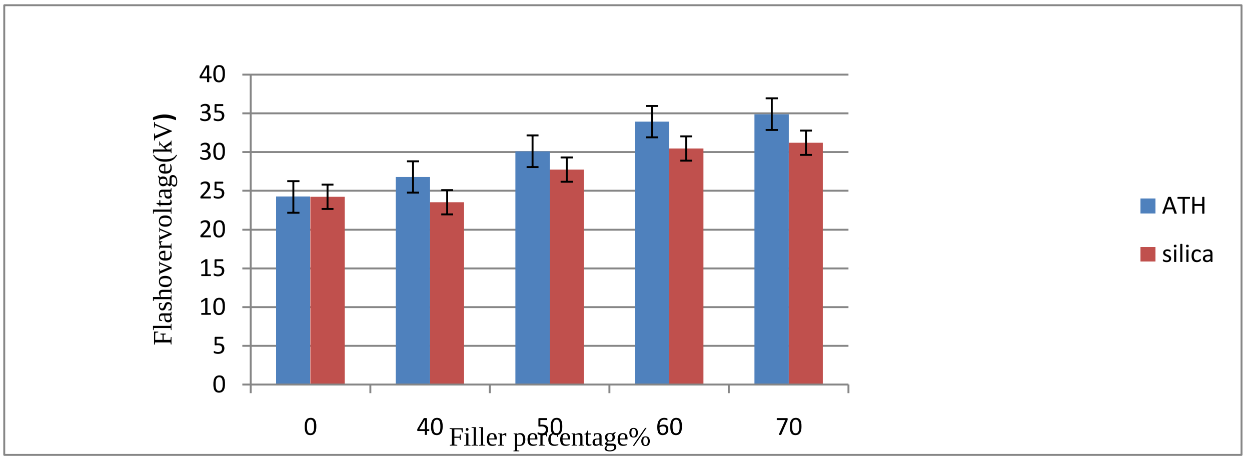

Figure 1. Flashover voltage via the percentage of ATH and silica fillers in composite samples under dry condition

From this figure it can be noticed that, the unfilled polyester specimen has lower flashover voltage value than its value of samples containing ATH filler at all filler concentrations. Flashover voltage of unfilled polyester sample is 24.22kV, and The value of flashover voltage increases with the increase in percentage of ATH in the samples. It was 26.78kV for 40% ATH and 34.88kV for 70% ATH filler percentage. Adding 40, 50, 60 and 70 wt% of ATH filler leads to increasing flashover voltage values 26.78kV, 30.11kV , 33.92kV and 34.88kV respectively to be higher than unfilled polyester composite. ATH filler increases the electrical performance of polyester by 10.56%, 24.31%, 44.01% and 44.04% respectively.

For polyester composite samples filled by silica, it can be seen that the flashover voltage of samples decreases from 24.22kV for (0% silica) sample to 23.54kV for (40% silica) with a decrement percentage 2.8% and the flashover voltage of samples increases from 24.22kV for (0% silica) to 31.21kV for (70%silica) with an increment percentage 28.86%. If the amount of silica filler increases gradually from 50% to 60% and 70% in samples, the flashover voltage will be 27.73kV, 30.46kV and 31.21kV respectively. The increment percentage of flashover voltage from a sample to another is 14.49%, 25.76% and 28.86% respectively.

From these results we can notice that , the surface of samples is improved by increasing the filler percentage, this may be due to ATH and silica fillers fill in the blanks while in the case of unfilled specimen, there are some blanks so, the surface of the sample becomes smooth and this improves the flashover voltage because the leakage current egged path for passage while in unfilled condition the surface of the sample is rough which makes leakage current pass easily.

B. Flashover voltage of specimens under sodium chloride contaminated condition.

Effect of flashover voltage of polyester specimens with different concentrations (40, 50, 60 and 70wt.%) of fillers (ATH and silica) under sodium chloride condition is shown in figure.2.

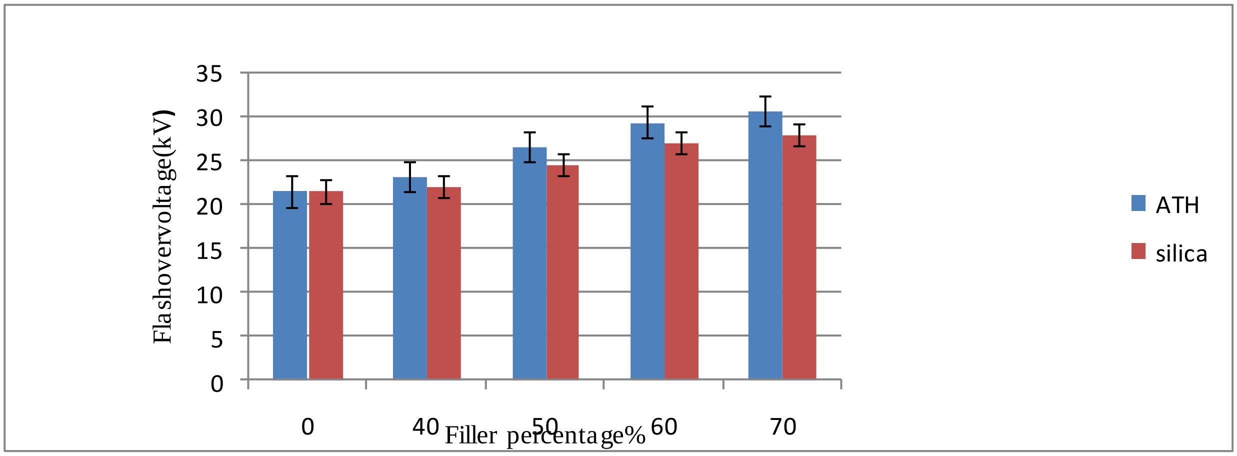

Figure 2. Flashover voltage via the percentage of ATH and silica fillers in composite samples under sodium chloride condition

From this figure it can be noticed that, flashover voltage increases with increasing the percentage of both ATH and silica fillers for all samples. Flashover voltage of unfilled polyester sample is 21.51kV, and The value of flashover voltage increases with the increase in percentage of ATH in the samples. It was 23.26 kV for 40% ATH and 30.63kV for 70% ATH filler percentage. Adding 40, 50, 60 and 70 wt% of ATH filler leads to increasing flashover voltage values 23.26kV, 26.62kV, 29.41kV and 30.63kV respectively to be higher than unfilled polyester composite. ATH filler increases the electrical performance of polyester by 8.13%, 23.75%, 36.72% and 42.39% respectively.
Same trend for flashover voltage values for polyester composite samples filled by silica with the same percentages. It was 22.02kV for 40% silica and 27.94kV for 70% silica filler percentage. Adding 40, 50, 60 and 70wt% of silica filler leads to increasing flashover voltage values 22.02kV, 24.53kV, 27.05kV and 27.94kV respectively to be higher than unfilled polyester composite. Silica filler increases the electrical performance of polyester by 2.37%, 14.03%, 25.75% and 29.89% respectively.
The results show that flashover increases with increasing ATH and silica fillers, but the values of flashover voltage in sodium chloride condition is less than dry condition , this because water along with pollutant accumulated on the surface form a conducting layer which allows the flow of leakage current affecting on its flashover performance. The conductive contamination dissolved within the water. This condition results in leakage current flow and arc formation , which in turn causes flashover.

C. Flashover voltage of specimens under hydrochloric acid contaminated condition.
Effect of flashover voltage of polyester specimens with different concentrations (40, 50, 60 and 70wt.%) of fillers (ATH and silica) under hydrochloric acid condition is shown in figure.3.

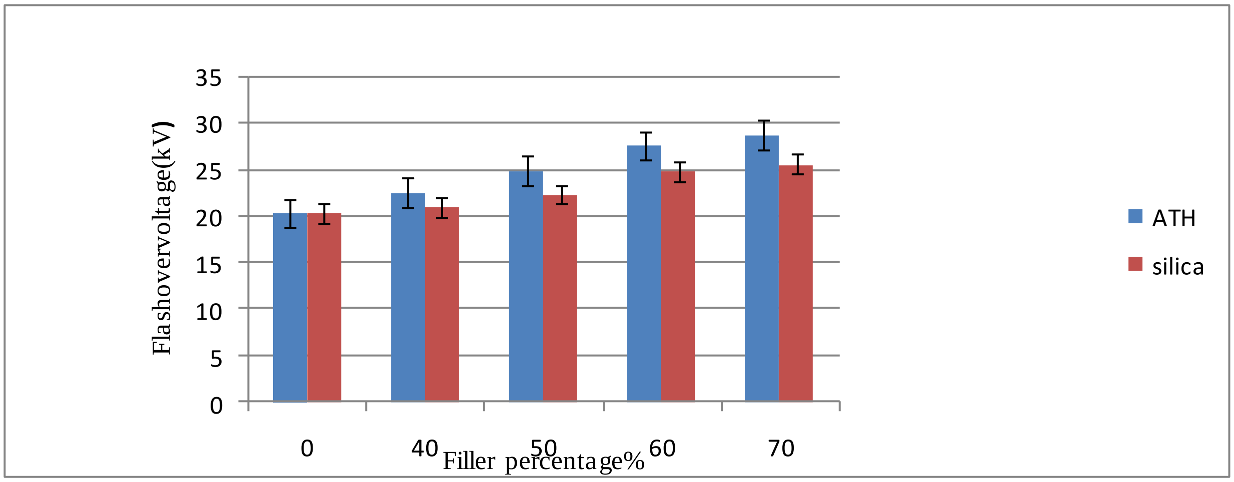

Figure 3. Flashover voltage via the percentage of ATH and silica fillers in composite samples under hydrochloric acid condition

It can be observed from this figure that, for all samples of ATH and silica fillers , the values of flashover voltage increased as the filler percentage (%) increases. Flashover voltage of unfilled polyester sample is 20.32kV, and The value of flashover voltage increases with the increase of percentage of ATH in the samples. It was 22.53 kV for 40% ATH and 28.87kV for 70% ATH filler percentage. Adding 40, 50, 60 and 70 wt% of ATH filler leads to increasing flashover voltage 22.53kV, 24.88 kV, 27.63kV and 28.87kV respectively to be higher than unfilled polyester composite. ATH filler increases the electrical performance of polyester by 10.87%, 22.44%, 35.97% and 42.07% respectively.
The flashover voltage values behave the same way in the polyester composite samples filled by silica with the same percentages. It was 20.96 kV for 40% silica and 25.62 kV for 70% silica filler percentage. Adding 40, 50, 60 and 70wt% of silica filler leads to increasing flashover voltage 20.96kV, 22.37kV, 24.81 kV and 25.62kV respectively to be higher than unfilled polyester composite. Silica filler increases the electrical performance of polyester by 3.14%, 10.08%, 22.09% and 26.08% respectively.
The results show that flashover increases with increasing ATH and silica fillers, but the values of flashover voltage in hydrochloric acid condition is less than dry condition , because surface leakage current consists between two electrodes. This leakage current results from hydrochloric acid as this acid is very strong leads to faster flashover at small values if it is compared to condition without contamination.

D. Flashover voltage of specimens under sodium hydroxide contaminated condition.

Effect of flashover voltage of polyester specimens with different concentrations (40, 50, 60 and 70wt.%) of fillers (ATH and silica) under sodium hydroxide condition is shown in figure.4.

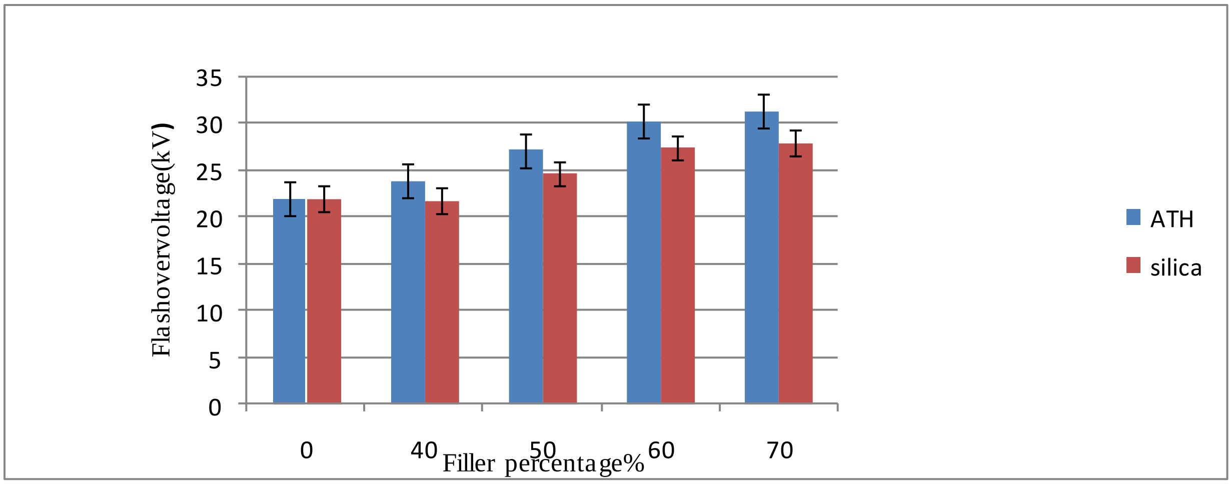

Figure 4. Flashover voltage via the percentage of ATH and silica fillers in composite samples under sodium hydroxide condition

From this figure it can be noticed that, the unfilled polyester specimen has lower flashover voltage value than its value of samples containing ATH filler at all filler concentrations. Flashover voltage of unfilled polyester sample is 22.01kV, and The value of flashover voltage increases with the increase of percentage of ATH in the samples. It was 23.94kV for 40% ATH and 31.45kV for 70% ATH filler percentage. Adding 40, 50, 60 and 70 wt% of ATH filler leads to increasing flashover voltage 23.94kV, 27.23 kV, 30.27 kV and 31.45kV respectively to be higher than unfilled polyester composite. ATH filler increases the electrical performance of polyester by 8.76%, 23.71%, 37.52% and 42.88% respectively.

For polyester composite samples filled by silica, it can be seen that the flashover voltage of samples decreases from 22.01kV for (0% silica) sample to 21.83kV for (40% silica) with a decrement percentage 0.81% and the flashover voltage of samples increases from 22.01kV for (0% silica) to 28.03kV for (70%silica) with an increment percentage 27.35%. If the amount of silica filler increases gradually from 50% to 60% and 70% in samples, the flashover voltage will be 24.76kV, 27.52kV and 28.03kV respectively. The increment percentage of flashover voltage from a sample to another is12.49%, 25.03% and 27.35% respectively.

The results show that flashover increases with increasing ATH and silica fillers, but the values of flashover voltage in sodium hydroxide condition is less than dry condition , this because surface leakage current consists between two electrodes. This leakage current leads to faster flashover at small values if it is compared to condition without contamination.

From the obtained results it has been observed that in all conditions; dry, sodium chloride, sodium hydroxide and hydrochloric acid, ATH filler in polyester improves the flashover voltage values better than silica filler this is due to ATH is mainly a composite of alumina, whereas silica is mainly silicate. ATH alone is an insulating material but silica is a poor conductor of electricity. With increased filler concentration, fewer organic molecules are exposed to the heat of the arcing. Increasing the filler concentration improves the thermal conductivity of the material, thereby improving the heat dissipation.

IV. SOFT PROGRAM (MATLAB) RESULTS IN FLASHOVER VOLTAGE TEST

Curve fitting methods allow to create, access, and modify curve fitting objects. That allowed to like plot and integrate, to perform operations that uniformly process the entirety of information encapsulated in a curve fitting object.

A. Curve fitting results in flashover voltage for dry specimens.

Figure 5 shows flashover voltage of polyester samples with different ATH filler percentages under dry condition by using curve fitting.

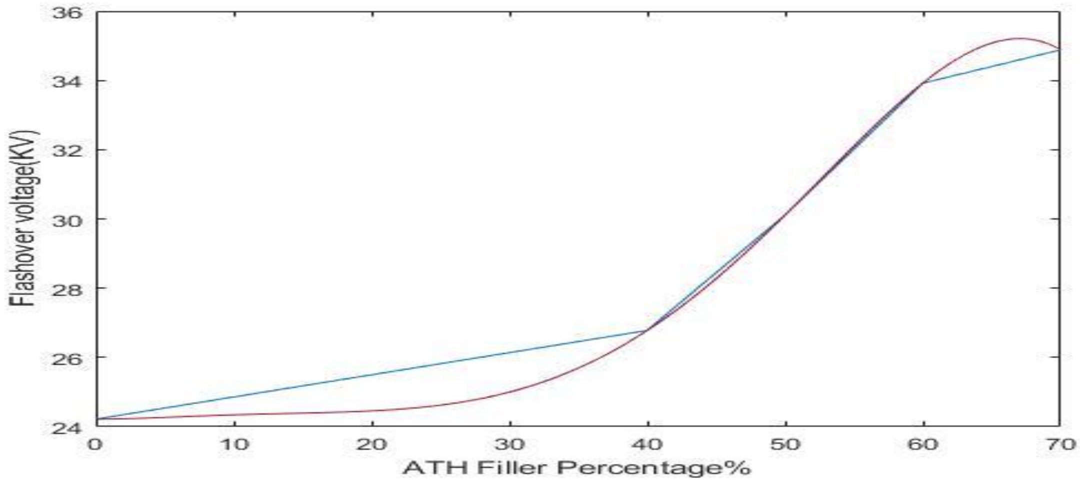

Figure 5. Curve fitting results for flashover voltage (kV) of polyester with different ATH filler percentages under dry condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 5th degree polynomial equation as follow:

Y = P1*X^5 + P2*X^4+ P3*X^3 + P4*X^2+ P5

Where y is the flashover voltage (KV) under dry condition , x is the percentage of ATH filler.

Coefficients

P1 = -7.33e-08
P2 = 8.908e-06
P3 = -0.0002789
P4 = 0.003197
P5 = 24.22

Figure 6 shows flashover voltage of polyester samples with different silica filler percentages under dry condition by using curve fitting.

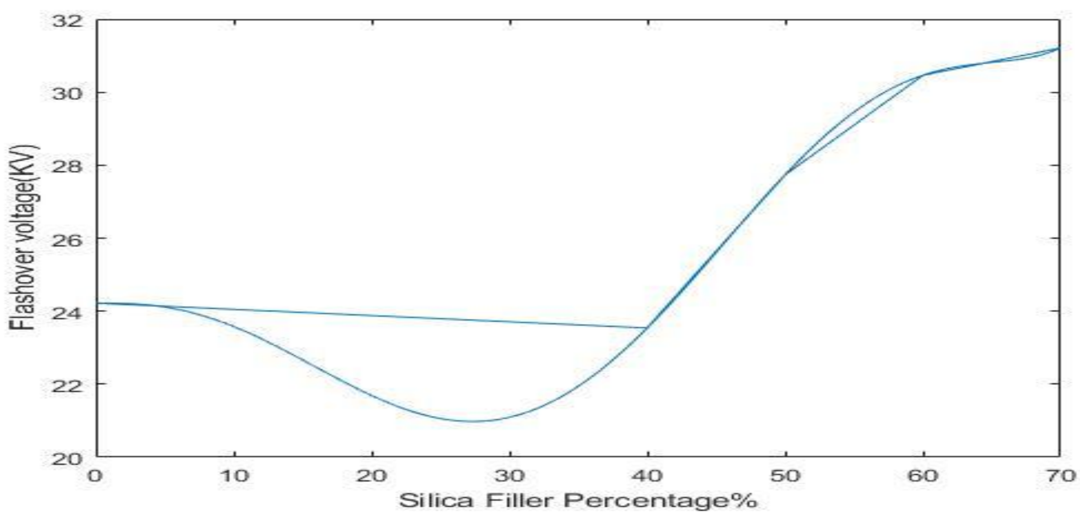

Figure 6. Curve fitting results for flashover voltage (kV) of polyester with different silica filler percentages under dry condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 6th degree polynomial equation as follow:

Y = P1*X^6 + P2*X^5+ P3*X^4 + P4*X^3+ P5

Where y is the flashover voltage (KV) under dry condition , x is the percentage of silica filler.

Coefficients

P1 = 4.763e-09
P2 = -9.039e-07
P3 = 5.617e-05
P4 = -0.001116
P5 = 24.22

B. Curve fitting results in flashover voltage of specimens under sodium chloride contaminated condition.

Figure 7 shows flashover voltage of polyester samples with different ATH filler percentages under sodium chloride contaminated condition by using curve fitting.

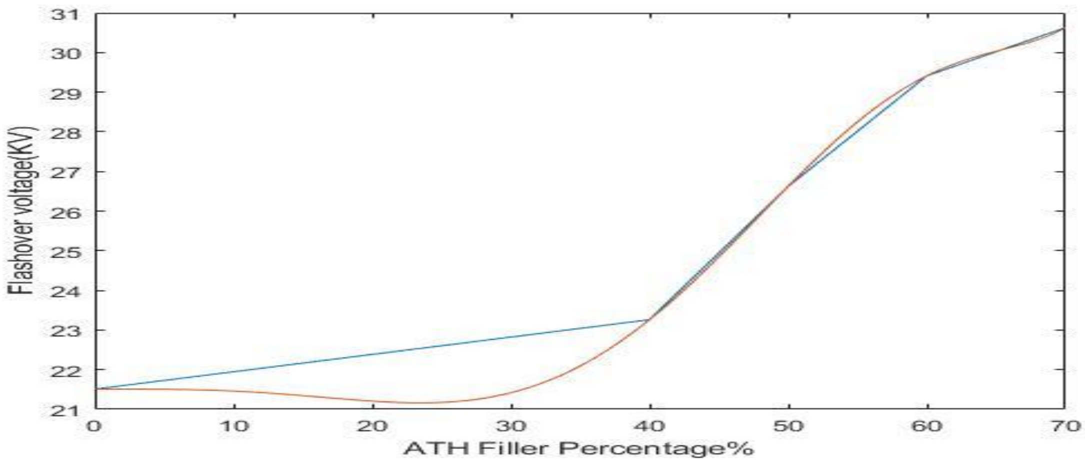

Figure 7.Curve fitting results for flashover voltage (kV) of polyester with different ATH filler percentages under sodium chloride condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 7th degree polynomial equation as follow:

Y = P1*X^7 + P2*X^6+ P3*X^5 + P4*X^4+ P5

Where y is the flashover voltage (KV) under sodium chloride condition , x is the percentage of ATH filler.

Coefficients

P1 = 5.339e-011
P2 = -9.719e-09
P3 = 5.624e-07
P4 = - 9.68 e-06
P5 = 21.51

Figure 8 shows flashover voltage of polyester samples with different silica filler percentages under sodium chloride contaminated condition condition by using curve fitting.

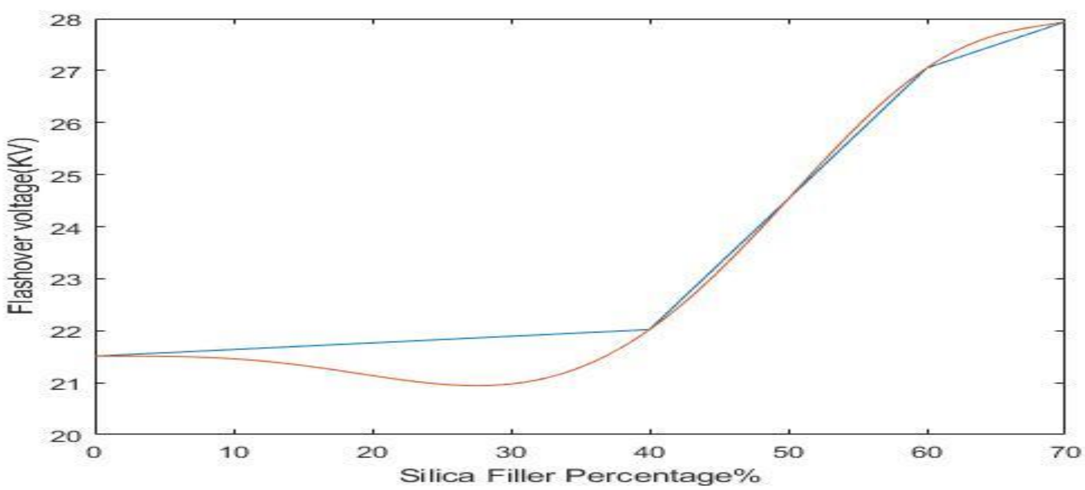

Figure 8. Curve fitting results for flashover voltage (kV) of polyester with different silica filler percentages under sodium chloride condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 7th degree polynomial equation as follow:

Y = P1*X^7 + P2*X^6+ P3*X^5 + P4*X^4+ P5

Where y is the flashover voltage (KV) under sodium chloride condition , x is the percentage of silica filler.

Coefficients

P1 = 3.93e-011
P2 = -7.593e-09
P3 = 4.721e-07
P4 = -9.049e-06
P5 = 21.51

C. Curve fitting results in flashover voltage of specimens under hydrochloric acid contaminated condition.

Figure 9 shows flashover voltage of polyester samples with different ATH filler percentages under hydrochloric acid contaminated condition by using curve fitting.

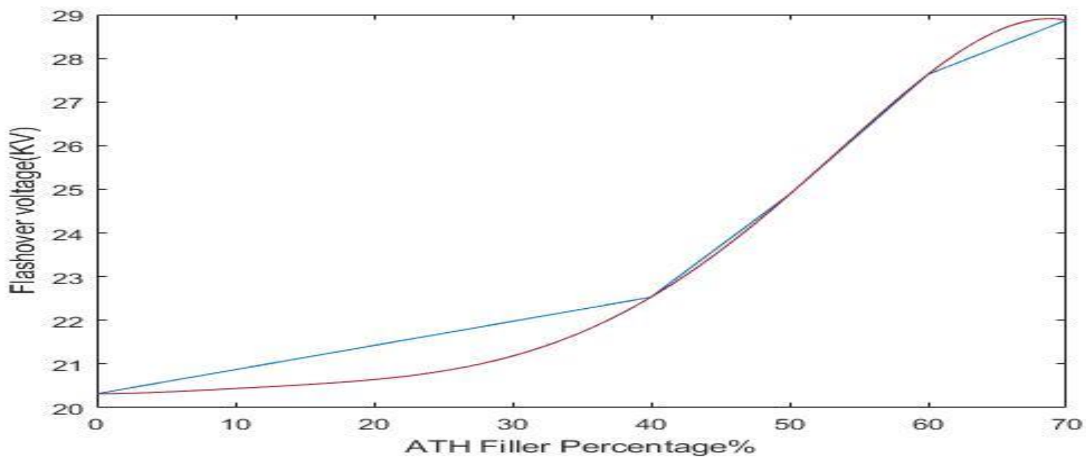

Figure 9.Curve fitting results for flashover voltage (kV) of polyester with different ATH filler percentages under hydrochloric acid condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 5th degree polynomial equation as follow:

Y = P1*X^5 + P2*X^4+ P3*X^3 + P4*X^2+ P5

Where y is the flashover voltage (KV) under hydrochloric acid condition , x is the percentage of ATH filler.

Coefficients

P1 = -4.267e-08
P2 = 5.219 e-06
P3 = -0.0001652
P4 = 0.002369
P5 = 20.32

Figure 10 shows flashover voltage of polyester samples with different silica filler percentages under hydrochloric acid contaminated condition by using curve fitting.

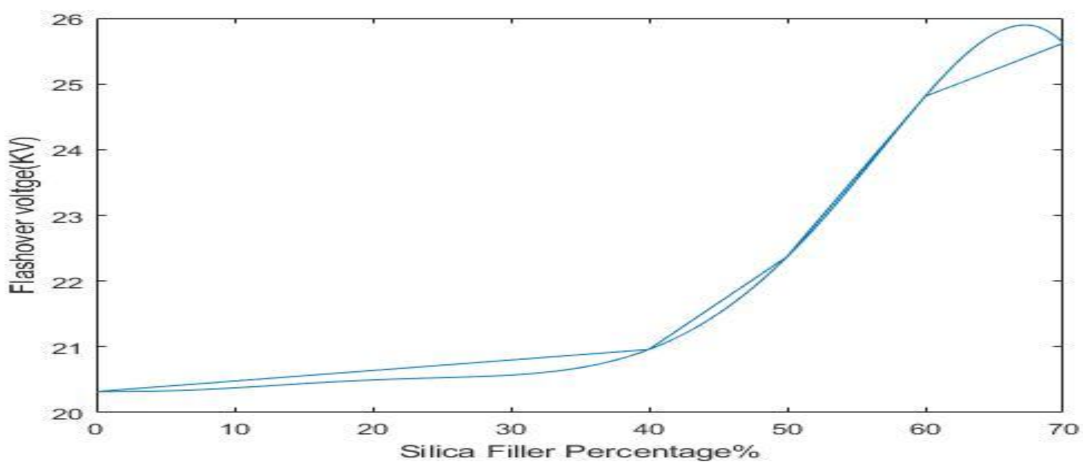

Figure 10. Curve fitting results for flashover voltage (kV) of polyester with different silica filler percentages under hydrochloric acid condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 6th degree polynomial equation as follow:

Y = P1*X^6 + P2*X^5+ P3*X^4 + P4*X^3+ P5

Where y is the flashover voltage (KV) under hydrochloric acid condition , x is the percentage of silica filler.

Coefficients

P1 = -1.285e-09
P2 = 1.827e-07
P3 = -7.962e-06
P4 = 0.0001185
P5 = 20.32

D. Curve fitting results in flashover voltage of specimens under sodium hydroxide contaminated condition.

Figure 11 shows flashover voltage of polyester samples with different ATH filler percentages under sodium hydroxide contaminated condition by using curve fitting.

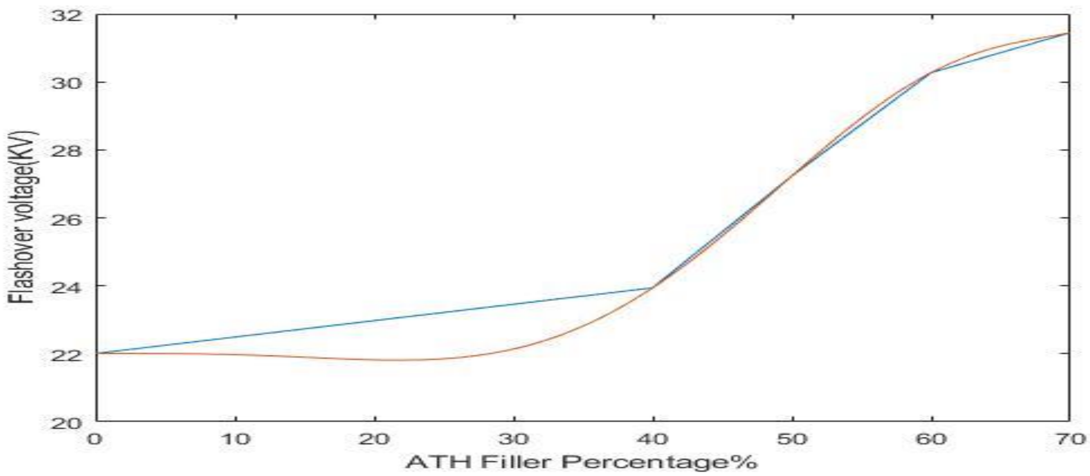

Figure 11. Curve fitting results for flashover voltage (kV) of polyester with different ATH filler percentages under sodium hydroxide condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 4th degree polynomial equation as follow:

Y = P1*X^7 + P2*X^6+ P3*X^5 + P4*X^4+ P5

Where y is the flashover voltage (KV) under sodium hydroxide condition , x is the percentage of ATH filler.

Coefficients

P1 = 3.88e-011

P2 = -7.216e-09

P3 = 4.209e-07

P4 = -7.019e-06

P5 = 22.01

Figure 12 shows flashover voltage of polyester samples with different silica filler percentages under sodium hydroxide contaminated condition by using curve fitting.

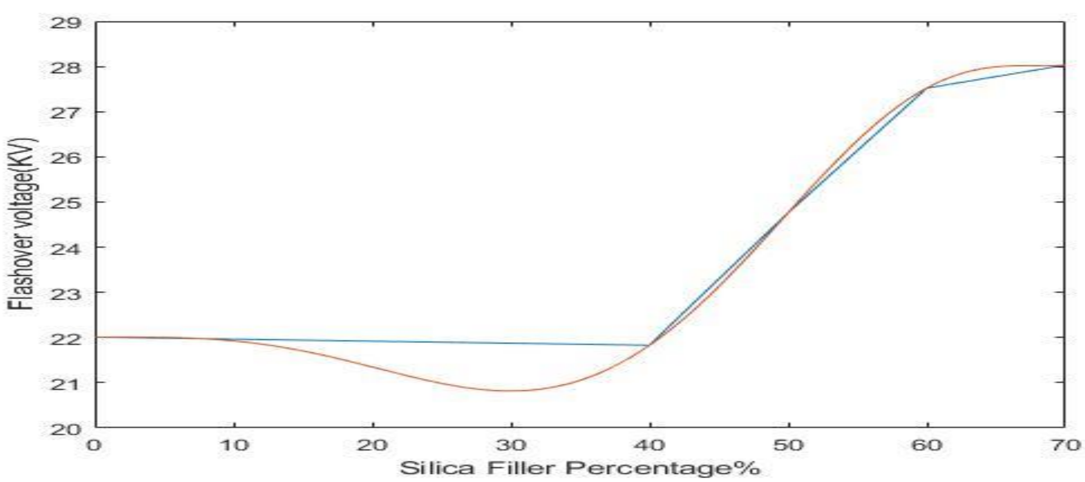

Figure 12. Curve fitting results for flashover voltage (kV) of polyester with different silica filler percentages under sodium hydroxide condition.

From the calculation of the program the best curve fitting for the data obtained can be represented by 7th degree polynomial equation as follow:

Y = P1*X^7 + P2*X^6+ P3*X^5 + P4*X^4+ P5

Where y is the flashover voltage (KV) under sodium hydroxide condition , x is the percentage of silica filler.

Coefficients

P1 = 6.093e-011

P2 = -1.177e-08

P3 = 7.382e-07

P4 = -1.467e-05

P5 = 22.01

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V. ULTRASONIC WAVE VELOCITIES MEASURMENTS AND ELASTIC MODULI CALCULATIONS

A. Density measurements

Experimental values of density of polyester composite samples are plotted in figure.13.

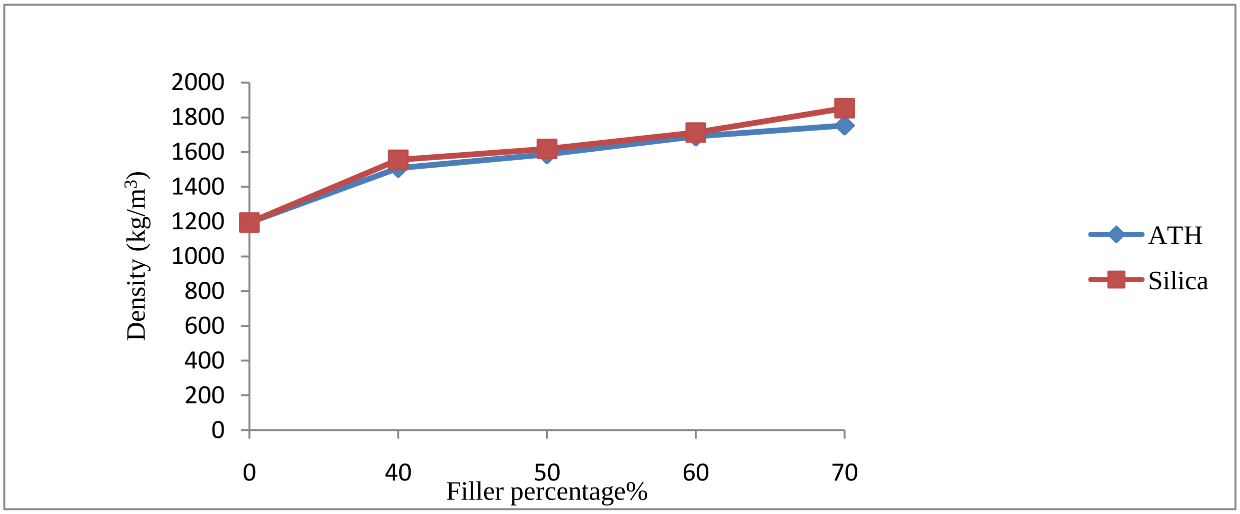

Figure 13.Variation of Density(kg/m^3) of the polyester composite filled with ATH and silica fillers and the filler percentage.

From this figure it can be noticed that, the density of pure sample is 1195.3 kg/m^3 and the values of densities of samples are increased with increasing the ATH filler percentage. It was 1508.63 kg/m^3 for 40% ATH and1752.89 kg/m^3 for 70% ATH filler percentage .

The density values behave the same way in the polyester composite samples filled by silica with the same percentages. It increased from 1554.9 kg/m^3 with 40% silica filler to 1851.27 kg/m^3 with70% percentage.

The increase of densities for polyester composite samples with both types of fillers is due to the direct addition of the ATH.

B. Ultrasonic longitudinal and shear wave velocities measurement

Results obtained for the examined samples are plotted in figure.14.

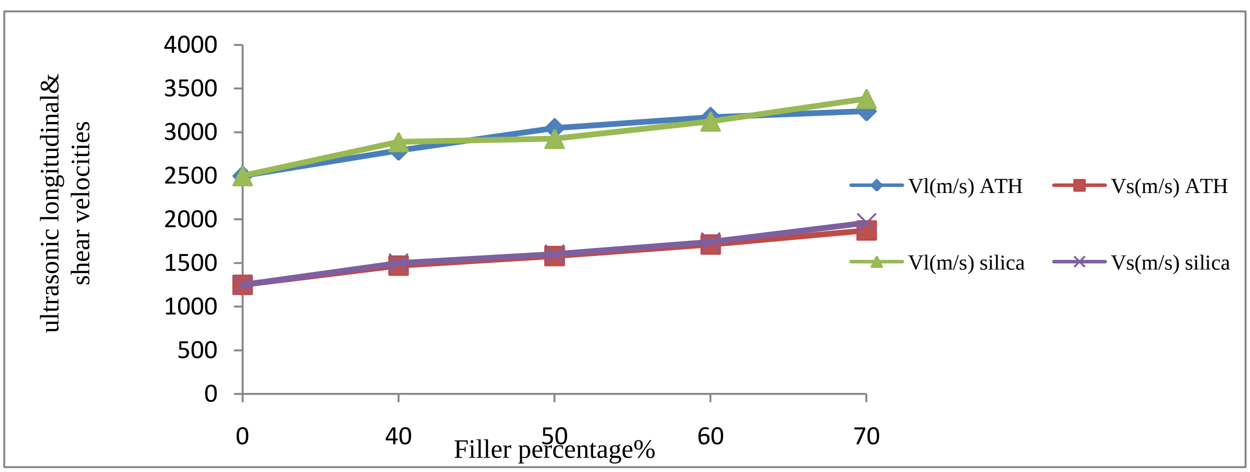

Figure 14. Ultrasonic Longitudinal and shear wave Velocities for polyester composite filled with ATH and silica fillers and the filler percentage.

From this figure it can be observed that, the values of longitudinal and shear ultrasonic wave velocities increased as the ATH and Silica fillers percentage increases respectively.

For longitudinal ultrasonic wave velocities, the values increased from 2500 m/s for pure polyester samples and 2790.9 m/s for 40% ATH filler to3240.64 m/s for 70% ATH filler. In silica filled polyester samples, the ultrasonic velocity increased by increasing the concentration of the silica filler. It was 2890.47 m/s for the 40% silica and 3385.48 m/s for 70% filler.

For shear ultrasonic wave velocities, the values increased from 1250 m/s for pure polyester samples and 1470.59 m/s for 40% ATH filler to1875m/s for 70% ATH filler. In silica filled polyester samples, the ultrasonic velocity increased by increasing the concentration of the silica filler. It was 1500 m/s for the 40% silica and 1960.78 m/s for 70% filler.
The increase of ultrasonic wave velocities is related to the decrease in the inter atomic spacing of the material (increase in density or decrease in molar volume). This means that the structure of polyester samples improved with increasing the filler ATH or SiO_2 percentage. Also, the increase in longitudinal and shear ultrasonic wave velocities may be attributed to the increase of connectivity of the polyester network [15].

C. Elastic moduli calculations

The elastic moduli, Longitudinal elastic modulus (L), Shear elastic modulus (G), Bulk elastic modulus (B), Poisson's ratio (σ),Young's elastic modulus (E) and the micro-hardness (H) are calculated for samples of polymer composite materials and the results are shown in table (1).

Table -1 Elastic moduli and Poisson's ratio of the investigated samples

Filler		L(Gpa)	G (GPa)	B (Gpa)	Σ	E (Gpa)	H (Gpa)
Type	PE%						
Blank	0	7.471	1.868	4.980	0.3333	4.980	0.2075
ATH	40	11.749	3.263	7.399	0.3078	8.534	0.4181
	50	14.726	3.964	9.441	0.3159	10.431	0.4866
	60	17.008	4.965	10.387	0.2938	12.848	0.6824
	70	18.408	6.163	10.192	0.2484	15.386	1.0337
SiO2	40	12.991	3.499	8.326	0.3157	9.206	0.4298
	50	13.870	4.143	8.346	0.2870	10.664	0.5882
	60	16.728	5.179	9.823	0.2758	13.214	0.7741
	70	21.218	7.118	11.728	0.2476	17.760	1.1975

As seen from the table, the elastic moduli values of L, G, B, E increases as the filler percentage increases and this may be due to the increase in the average number of bonds per unit volume and cross link density which is related to increasing of hardness and rigidity of the sample material.

VI. CONCLUSION

The following conclusions may drawn from the present investigation:

- The performance of polymeric insulating materials exhibits a marked dependence on the environmental conditions.
- Adding inorganic fillers such as ATH and silica increases the flashover voltage under different environmental conditions .
- There is a optimum percentage of filler, which can be added with respect to the quantity of polyester, and the suitable percentage is 70% of ATH filler.
- Among the four concentrations taken in this study, the inclusion of 70% ATH concentration causes a maximum value of flashover voltage (34.88KV) under dry condition.
- Among the four conditions taken in this study (dry, sodium chloride, sodium hydroxide and hydrochloric acid), the inclusion of hydrochloric acid is the worst case where it causes faster flashover voltage.
- The type and filler concentration have pronounced effects on the longitudinal and shear ultrasonic velocities of composite materials. This means that the rigidity and compactness of the specimens depend on the type and concentration of the filler.

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