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Electrical and Mechanical Properties of Aromatic Polyamide/Polyester Composites

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Abstract **- Isolation system integrity is perhaps the most important factor in the satisfactory changes in transformer performance and improvements in transformer isolation systems that occur continuously. Thermal and electrical degradation properties in an Insulation paper has been inspected to improve reliability and to enable preventative maintenance technology in transformers. This paper deals with the experimental studies on the electrical and mechanical properties of aramid paper with different concentrations of polyester (0%, 30%, 50%, 60%, and 70%). The dielectric strength (kV/mm) of aramid/polyester was tested in several thermal conditions such as 25, 70, and 100℃, and the dielectric strength of aramid/polyester was tested after being exposed to thermal aging for 24 hours in high temperatures (150℃ and 220℃). The electrical resistivity (ohm. cm) was carried out. Also, a tensile strength test was applied under different aged conditions to check the various properties of aramid/polyester samples. The results showed that the electrical and mechanical properties of the insulation paper modified by adding polyester. Maximum values of AC dielectric strength, electrical resistivity, and tensile strength were obtained from 60% of polyester content.**

Keywords: Dielectric strength, Polyester, Aramid, Electrical resistivity, Tensile strength.

I. INTRODUCTION

In a power system, the transformer is one of the most significant pieces of electrical equipment. Its performance has a direct impact on the safety of such power systems.

The transformer's internal insulation requirements gradually increase as the voltage increases; because of the advantages of polymeric materials and the unique features of nanoparticles, polymer-based Nano composites have been intensively explored and implemented with the rapid growth of materials science.

The use of nanoparticles to modify insulating oil and insulating paper has expanded dramatically in the last 15 years. For many years, transformers have been essential components in electric power distribution and transmission networks. As a result, the insulating quality of a transformer is critical.

Electrical insulation materials serve to insulate electrical appliance components from each other and from the earth while also giving mechanical support to the components: Because electrical appliances are continually in contact with conductors, the material chosen is a critical component in their efficiency, dependability, and life.

Only in transformer locations where voltage stresses are relatively low by design are insulating oils employed alone as electrical insulation.

Solid dielectric materials, on the other hand, are employed in transformer areas where high voltage stresses or a certain physical configuration is required.

Packaging and separators frequently employ this hard insulating material. As insulating support structures, cellulose papers produced from specially selected synthetic and thick wood pulp polymer are commonly utilized.

"When insulating papers, Press boards, and wooden pieces, heat and vacuum should be used to remove moisture and air before being impregnated with an oil to increase their resistance to electrical breakdown"

Many different factors influence the electrical breakdown strength of solid polymers. Temperature, humidity, test duration, applied voltage type, electrode pressure, discharge in the ambient medium, and cavities are all aspects to consider."

Excess moisture or water has always been thought to produce poor performance in solid dielectrics, and can even lead to breakdown under extreme electrical stress. To investigate the electrical properties of polyamide (aramid) paper used as indoor and outdoor insulation, it was chosen and exposed to various temperatures and moisture levels.

In this manuscript polyamide with polyester has been investigated for its electrical and mechanical properties.

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II. EXPERIMENTAL TECHNIQUE-SAMPLES PREPARATION

All materials used are commercial products, which were utilized in the experimental work without further treatment. ARAMID and different percentages of polyester are utilized in the experiment as shown in Table 1. Sheet samples were prepared from ARAMID and polyester with different percentages. Five samples were prepared at different percentages, ARAMID without the polyester, ARAMID with 30% polyester, ARAMID with 50% polyester, and ARAMID with 60% polyester, and ARAMID with 70% polyester.

2.1 Dielectric Strength Test

Figure 1 shows a circuit schematic for the dielectric strength test. The circuit consists of a manually controlled variable transformer coupled to a step-up transformer, allowing for human control of the applied voltage to the sample. The protection resistor protects the supply from overloading upon the breakdown of the sample under test. The disc-shaped samples have a diameter of 25 mm and a thickness of 0.25 mm. The voltage flowed at a rate of 4kV/sec. For all samples, measurements were taken at temperatures of 25, 70, 100, 150, and 220°C. Each test was repeated for a collective of ten samples, with all of the paper being measured with treated mineral oil.

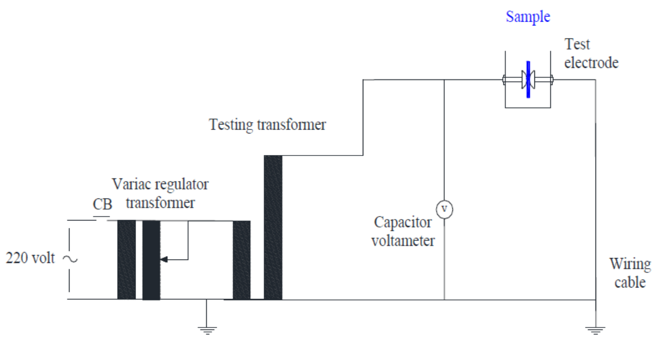

Figure 1: Schematic diagram of the puncture test arrangement

2.2 Electrical Resistivity Test

The resistance readings are recorded in meters as shown in Fig. 2. The resistance depends on the resistance value and the dimensions of the sample. The electrical resistance (ρ) of a solid is determined by passing an electric current through a sample and then measuring the resulting voltage drop over a specified length. The formula for electrical resistance can be written as follows:

$$\rho = (R * A) / L$$

Where R: is the electrical resistance of a uniform sample (Ohm: Ω), A is the cross-sectional area of the sample (cm^2) and L is the length of the sample (cm).

Figure 2: Electrical resistivity tester

2.3 Mechanical Test

The mechanical properties of the sample were determined according to ASTM D412a-98. The tensile strength (MPa) was measured by using a 50mm/min crosshead speed; tensile testing machine (model Z010) at temperatures 21 and 25 degrees which were made in Zwickau (Germany). Five specimens are measured for each composition. The tensile strength (MPa) test is used to measure the ability of the sample to withstand the tension force. The dimension of the sample is 70 mm in length and 25 mm in width has a duple shape as shown in Fig. 3. The sample is clamped from two ends and the machine is rotating with a crossed speed of 30mm/min until the mechanical breakdown occurs.

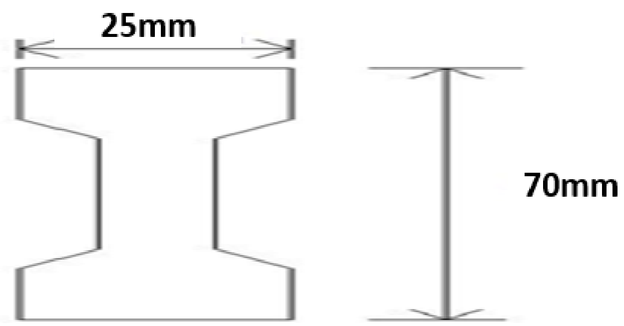

Figure 3: Aramid sample for tensile strength test

III. RESULTS AND DISCUSSION

3.1 Dielectric Strength Measurement at Different Temperatures

The dielectric strength from the insulation samples at different temperatures is discussed. All the practical results were plotted and gathered to be easy for analysis and discussion"

3.1.1 At 25 ℃

The dielectric strength experimental measurements have been recorded in the laboratory for the aramid/polyester insulator at 25°C. Fig. 4 shows a relationship between the dielectric strength of aramid and different concentrations of polyester.

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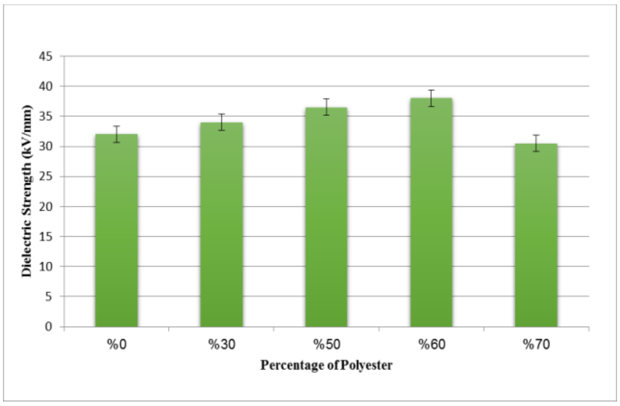

Figure 4: Dielectric strength (kV/mm) of the aramid/polyester at 25℃

It can be seen from Fig.4 that the dielectric strength of (0% polyester) is 32kV/mm. While the value of dielectric strength of (30% polyester) is 34 kV/mm with an increasing percentage of 6.25%, but the dielectric strength of (50% polyester) is 36.5kV/mm with an increasing percentage of 14.063%, while the value of dielectric strength of (60% polyester) is 38kV/mm in the sample with an increasing percentage of 18.75%, the dielectric strength of the percentage of the last sample of (70% polyester) is 30.5 kV/mm with reduction percentage of 4.7%. So the dielectric strength improves when the percentage of polyester in aramid increases up to (60%), but when the percentage of polyester in aramid becomes (70%) or more, the dielectric strength decrease. It can be interpreted from Fig. 4 that the dielectric strength of aramid was improved by adding polyester.

3.1.2 at 70℃

The dielectric strength test was carried out to evaluate the polyester addition effect on properties of aramid. The relation of dielectric strength and several percentages of polyester added to aramid when tested at 70°Care shown in Fig. 5.

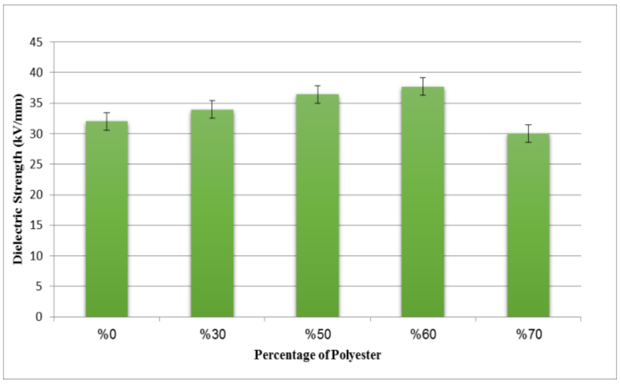

Figure 5: Dielectric strength (kV/mm) of the Aramid/Polyester at 70℃

It can be observed from Fig. 5 that the concentration of polyester (%) in aramid plays an important role in the dielectric strength (kV/mm) values. The dielectric strength values are 32, 33.96, 36.4, 37.70 and 30.5kV/mm at 0, 30, 50, 60 and 70 % wt. polyester content in aramid respectively.

3.1.3 at 100℃

The dielectric strength, results have been analyzed as shown in Fig. 6.

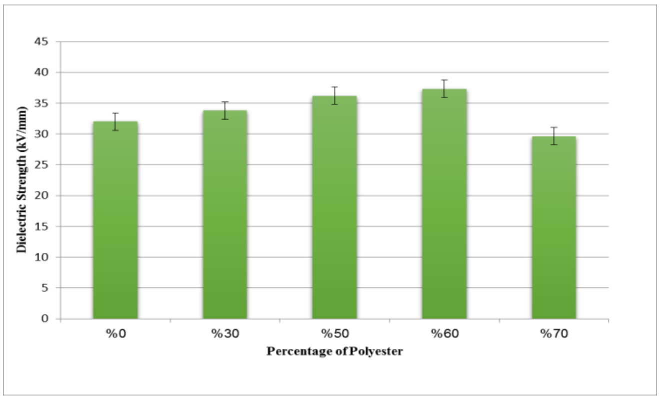

Figure 6: Dielectric strength (kV/mm) of the aramid/polyester at 100℃

It can be noticed from Fig. 6 that at higher content of polyester (70 %), the dielectric strength decreases by increasing the temperature (100°C). The electrical performance improves with increasing the content of polyester. Fig. 6 shows that the aramid sample containing 60% polyester records the maximum dielectric strength compared to the other polyester concentration, the higher the percentage of polyester can lead to the improvement in the dielectric strength performance compared to the pure aramid sample.

3.2 Thermal Aging Effect

Furthermore, the dielectric strength test was carried out after the aramid/polyester samples were exposed to thermal aging for 24hrs in different high temperatures 150℃ and 220℃.

3.2.1 Dielectric Strength at 150℃

Experimental readings for the dielectric breakdown strength of the Aramid/Polyester samples when tested at 150 °c under AC voltage are shown in Table 1. Table1 shows that; the aramid breakdown strength was improved by adding polyester with different concentrations despite the decrease of dielectric strength of aramid due to high thermal stress.

Table 1: Dielectric strength (kV/mm) of the Aramid/Polyester at 150 ℃

The percentage of polyester (%) in Aramid	70%	60%	50%	30%	0%
The average dielectric strength (kV/mm)	28.8	36.45	35.54	33.2	32

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Table1 shows that the dielectric strength of aramid increases with an increase in polyester concentrations up to 60% by weight, but it decreases when the percentage exceeds 60% by weight. It has also been observed that the decrease in the insulation strength occurs with an increase in temperature (150 ° C).

3.2.2 Dielectric strength at 220° C

Aramid paper is heated up to 220 ° C for 24 hours to remove absorbed moisture. The experimental readings of the dielectric breakdown strength of the aramid/polyester samples when tested at 220 ° C under AC voltage are noted in Table 2.

Table 2: Dielectric strength (kV/mm) of the Aramid/Polyesterat **220℃**

The percentage of polyester (%) in Aramid	70%	60%	50%	30%	0%	70%
The average dielectric strength (kV/mm)	25.50	35.00	34.35	32.23	31.80	25.50

Table 2 showed that the dielectric strength values decreased significantly when the temperature was higher. This behavior indicates that materials with a low boiling point are found during thermal aging.

3.3 Electrical Resistivity

The electrical resistivity (ohm. cm) for aramid has been investigated with different concentrations of polyester at the un-aged condition as shown in Fig. 7.

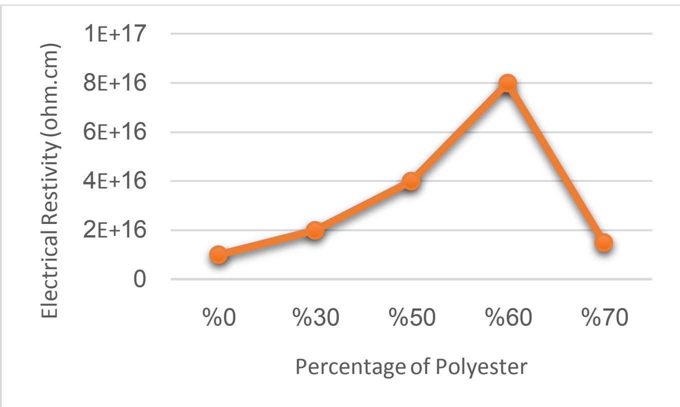

Figure 7: Electrical resistivity of aramid/polyester samples at the un-aged condition

The electrical resistivity (ohm.cm) is measured for aramid/polyester samples Fig.7. The results showed that after adding different concentrations of polyester, the electrical resistivity (ohm. cm) of aramid has been improved significantly. It is shown in Fig. 7 that with the increase of polyester content (from 0% to 70%); the electrical resistivity (ohm. cm) of aramid is increased. Fig. 7 shows that the aramid sample with 60 % polyester records maximum electrical resistivity at 8*1016 (ohm. cm).

3.4 Tensile Strength of Aramid Samples with Different Conditions

The tensile strength test was carried out to investigate the mechanical properties of aramid after adding polyester in different concentrations. Table 3 shows the values of the tensile strength (MPa) for different samples. The effect of acetic acid (CH3COOH) doses with different duration (30, 60, 90, and 120 days) has been investigated through Table 3.

Table 3: Comparisons between samples with different polyester percentages and tensile strength (MPa) under un-aged and aged conditions

Percentages of polyester in aramid	Tensile strength (MPa)				
	120 days	90 days	60 days	30 days	Un-aged
51.49	68.24	89.05	94.68	105.82	0%
95.52	98.53	99.63	102.75	113.7	30%
97.69	103.97	111.33	113.73	116.32	50%
110.75	113.80	116.43	119.53	121.72	60%
90.26	94.33	97.06	100.03	108.14	70%

It can be observed from Table 3 that (0% polyester) sample has the lowest value of tensile strength in all conditions, at un-aged condition, the value of tensile strength 105.82 MPa, after the exposure to CH_3COOH for 30 days the value of tensile strength became 94.68 MPa with percentage loss in tensile strength almost 11%. After exposure to CH_3COOH for 60, 90, and 120 days the values of tensile strength became 89.05, 68.24, and 51.49 MPa with percentage loss in tensile strength almost 16%, 36%, and 51% respectively.

However, (60% polyester) sample has the maximum value of tensile strength in all conditions, at un-aged condition, the value of tensile strength 121.72 MPa, after the exposure to CH_3COOH for 30 days the value of tensile strength became 119.53 MPa with a percentage loss in tensile strength almost 2%.

After exposure to CH_3COOH for 60, 90, and 120 days the values of tensile strength became 116.43, 113.80, and 110.75 MPa with percentage loss in tensile strength almost 4%, 7%, and 9% respectively.

Table 3 shows that the tensile strength (MPa) of all aramid samples with different concentrations of polyester increase with the increase of polyester.

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IV. CONCLUSION

The dielectric strength, electrical resistivity, and tensile strength tests were carried out to evaluate the effect of adding polyester on aramid polyester. This paper has shown the effect of adding polyester to aramid from the experimental results, it can be concluded that:

1. At high temperatures, polyester in different concentrations improved the dielectric strength of aramid.
2. The aramid dielectric strength was decreased by the effect of high temperatures.
3. The addition of polyester to aramid improves electrical resistivity.
4. The electrical and mechanical properties have been improved significantly with polyester loading.
5. Aramid with 60% polyester gave maximum dielectric strength, electrical resistivity, and tensile strength."

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