A STUDY ON THE RELIABILITY OF POLYESTER INSULATORS BLENDED WITH BORAX

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ABSTRACT

In this study results from Inclined plane tracking test method obtained on various borax concentrations are reported. In the first part of the study polyester samples blended with different concentration of borax has been tested in laboratory conditions according to ASTM D 2303 surface tracking test method. At the next stage the results were given to Weibull++ 7 programme to investigate the reliability of the lifetime of the samples. By using the basic reliability function we propose a Weibull statics model to predict the life time of polyester samples with different borax concentrations.

I. INTRODUCTION

High voltage applications led to researchers to develop new type of insulator. Polymeric insulation materials have to suffer several degradation mechanisms throughout their service life.

Electrical aging of insulators is associated with a wide variety of phenomena such as breakdown, discharges, treeing, electron interactions with charges, phonons, matters, etc. Several test methods have been developed to examine the performance of polymeric materials, however usually they exhibit too many random factors associated with them, which reduce their reliability.

Polyesters are becoming increasingly popular because of their low cost, ease of use, versatility. They have excellent dielectric properties and superior surface hardness and are highly resistant to most chemicals. They are widely used for making small electrical components to very large structures.

Each polymer is unique in its flammability characteristics. Some polymers, such as polyamide-imide, polyarylate, polyetheretherketone, polyetherimide, polyethersulfone and polyphenylene sulfide are inherently resistant to burning and require no further treatment. Other polymers, such as polyamides, polycarbonate and polysulfone are somewhat less resistant and several polymers burn readily. However, the flammability of these polymers may be significantly reduced by compounding with reactive and nonreactive halogenated compounds, phosphate esters, and antimony oxide[1,2].

In our previous studies we present the use of borax minerals as a filler in an unsaturated polyester resin reduces the flammability and enhances the electrical properties of the composite as compared to the polyester alone[3-5].

In this research, a model based on improved Weibull statistics has been proposed for estimating the breakdown time of polymeric insulation material. By using appropriate parameters this improved model can estimate the remaining lifetime within a reasonable accuracy in varying boron concentration. For determination of model parameters several tests have been performed according to ASTM D2303 accelerated Inclined Plane Tracking Test method. With this study borax concentration seemed to increase the useful lifetime of insulating materials.

II. EXPERIMENTAL

All tests have been performed according to the ASTM D2303 test procedure under 4kV applied voltage and 36ml/h contaminant flow rate[6]. Polyester samples have been prepared with 0.25% MEKP (Methyl Ethyl Ketone Peroxide) and 0.25% cobalt as an accelerator. All powder like borat minerals have diameter less than 35 µm and are added to unsaturated polyester resin at different percentages by mass. Final products are kept in an 45ºC oven for 4 hours and then cut in pieces with the dimensions of 100mm*55mm*9mm.

All specimens were tested in a closed cabinet with an open roof and minimum air circulation. For each set at

least 10 samples were used. ASTM D 2303 recommends to continue the test until the tracking pattern reaches 25 mm from the earth electrode up to the HV electrode, however to enable a complete structural pattern analysis, the experiment was not stopped until the gap between both electrodes has been crossed completely.

III. STATISTICAL ANALYSIS

The tracking (initiation) stage can occupy tens of minutes with typical test values of electrolyte flow rate, voltage and conductivity. The Weibull distribution depends mainly on two parameters, β the 'shape' and α the 'scale' parameters. In order to determine these values a batch of identical samples were stressed at constant voltage and flow rate and the initiation time 't' for each batch has been observed.

Cumulative Weibull distribution F(t) can be shown as,

$$F(t) = 1 - \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right] \quad (1)$$

The Weibull shape parameter, β, is also known as the Weibull slope. This is because the value of β is equal to the slope of the line in a probability plot. Different values of the shape parameter can have marked effects on the behaviour of the distribution.

By taking the derivative of cumulative Weibull distribution(cdf) function we have the probability density function, pdf as,

$$\frac{dF(t)}{dt} = f(t) = \left(\frac{\beta}{\alpha}\right)\left(\frac{t}{\alpha}\right)^{\beta-1} \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right] \quad (2)$$

Reliability function R(t) can be expressed as,

$$R(t) = 1 - F(t) \quad (3)$$

$$R(t) = \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right] \quad (4)$$

IV. RESULTS AND DISCUSSION

In this research the effect of borax concentration on the useful life expectance of composite polyester insulators have been investigated. Test results reveal clearly, that specimens produced by different borax concentrations differ within each other considerably in tracking initiation times and also in the carbonised tracking patterns.

Surface tracking pattern of polyester sample obtained ASTM D 2303 Inclined Planed Tracking Test is shown in Figure 1.

We study the plain polyester samples to 1.5% borax added polyester samples lifetime with Weibull++7 programme.

Figure 1: Surface tracking patterns of some polyester samples obtained ASTM D 2303 Inclined Planed Tracking Test

The reliability functions for 0.1, 0.2, 0.3, 0.4, 0.6, 0.7, 0.8, 1.0 and 1.5% borax added polyester samples were obtained using 118 experimental results. The reliability functions and average lifetimes were derived for all of the borax concentrations. Reliability of plain polyester samples are illustrated in Figure 2.

Plain polyester samples average lifetime was found as 17:23 and its reliability function as,

$$R(t) = \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right] = \exp\left[-\left(\frac{t}{18.55}\right)^{12.92}\right] \quad (5)$$

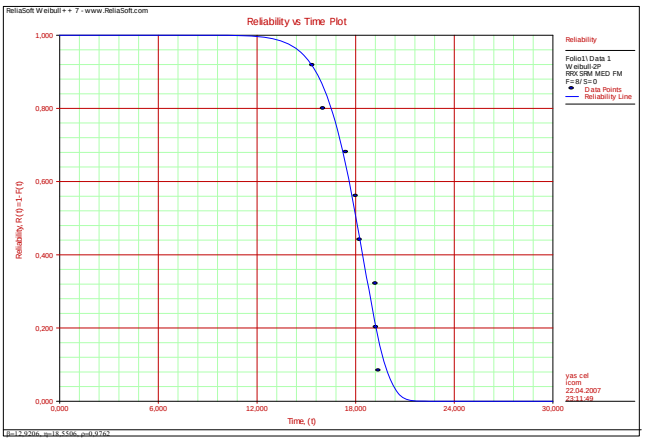

Figure 2: Reliability of plain polyester samples.

Table 1 shows The effect of borax concentration to tracking initiation time and to Weibull parameters α and β.

Weibull distributions with $\beta < 1$ have a failure rate that decreases with time, also known as infantile or early-life failures. Weibull distributions with β close to or equal to 1 have a fairly constant failure rate, indicative of useful life or random failures. Weibull distributions with $\beta > 1$ have a failure rate that increases with time, also known as wear-out failures.

Table 1 : The effect of borax concentration to tracking initiation time and to Weibull parameters α and β.

Boron concentration (%weight)	Tracking initiation time, t (min)	α	β
0	18:24	18,55	12,92
0,1	52:27	58,35	2,49
0,2	54:34	61,01	1,97
0,3	59:41	61,01	1,97
0,4	59:29	67,24	2,57
0,6	45:12	50,89	2,07
0,7	48:01	54,16	2,24
0,8	46:51	53,05	2,36
1,0	62:17	67,17	3,79
1,5	52:43	59,6	1,23

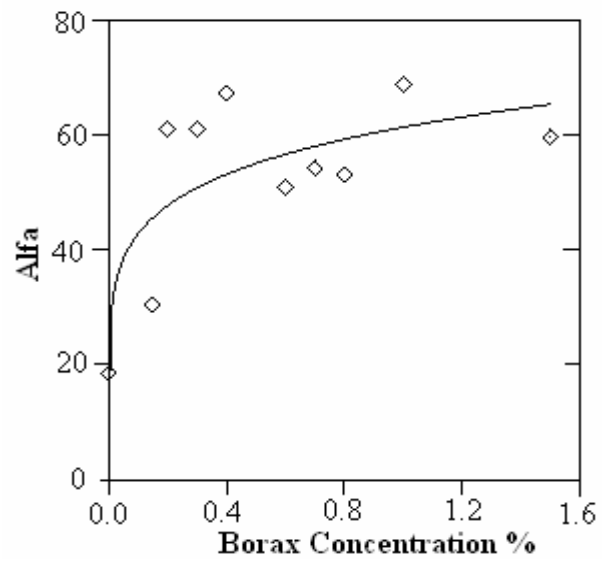

Figure 3 : The effect of borax concentration on the Weibull parameter α.

$$\ln(\alpha) = 0.156195 * \ln(N) + 4.11597 \quad (6)$$

$$\alpha = 61.31N^{0.16} \quad (7)$$

It was observed that the shape parameter decreases with increasing boron concentrations. The condition $\beta > 1$ denotes the degradation caused by aging. The decrease in β caused by increased borax concentration shows that the reliability also increases. Increasing the concentration of borax improves the dissipation of surface energy and also tracking resistance,

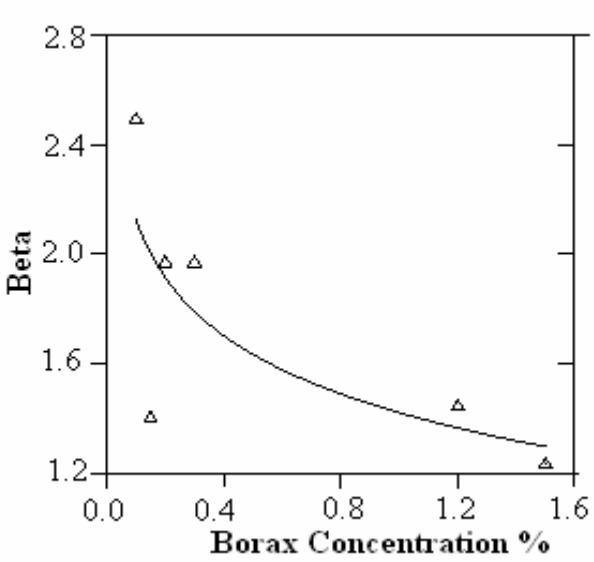

Figure 4 : The effect of borax concentration on the Weibull parameter β.

The dependence of Weibull shape and scale parameters on borax concentration are illustrated in Figures 3 and 4.
Using the plots given in Figures 3 and 4, empirical relations for shape and scale parameters are derived and given in Eqns. 6, 7, 8 and 9.

$$\ln(\beta) = -0.174525 * \ln(N) + 0.342462 \quad (8)$$

$$\beta = 1.4N^{-0.17} \quad (9)$$

Substituting the shape and scale parameter relations of Eqns. 7 and 9 into Eq.4, the following empirical relation is obtained for the dependence of the reliability function on borax concentration:

$$R(t) = \exp\left[-\left(\frac{t}{61.31N^{0.16}}\right)^{1.4N^{-0.17}}\right] \quad (10)$$

The lifetime estimation dependency on borax concentration is illustrated in Figure 5.

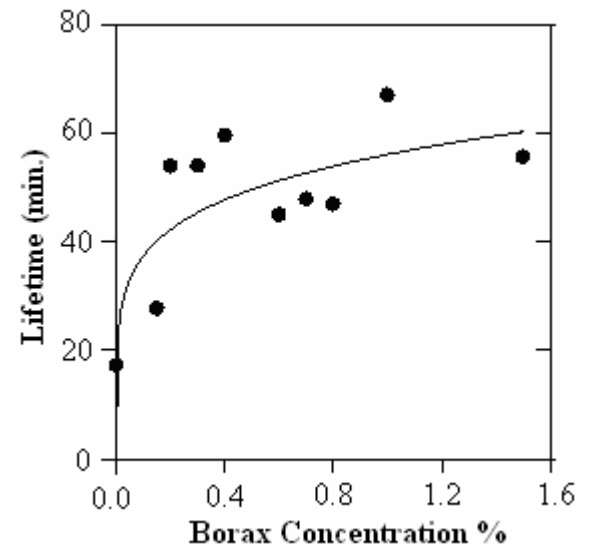

Figure 5 : The effect of borax concentration on the tracking initiation time.

According to the experimental results, we propose an equation for polyester samples lifetime vs borax concentration in equation 11.

$$\ln(t) = 0.175996 * \ln(N) + 4.02897 \quad (11)$$

V. CONCLUSION

Based on the experimental and statistical studies carried out on polyester resin with different borax concentration, the following conclusions are drawn with respect to the tracking and erosion resistance of composite:

- When tested in the inclined plane test, the tracking and erosion resistance of polyester samples increased with increased concentration of borax.
- According to the two parameter Weibull distribution, the β shape parameter is found as $\beta > 1$ for all types of polyester samples. β shape parameter decreases with the borax concentration. So we can say that polyester samples realiability is increased with borax concentration.
- An empirical equation for the dependency of the reliability on borax concentration is derived in this work.
- It can be said that borax can also be used in polymeric insulators as flame retardant

VI. REFERENCES

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