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A STUDY ON THE INSULATION CAPACITY OF POLYMERIC COMPOSITE MATERIALS BLENDED WITH BORON MINERALS

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ABSTRACT

Boron minerals which are widely found in Turkey and U.S.A. has become quite popular during recent years due to their superior flame reatardance capabilities in electric systems. In this study four different types of boron minareals such as tincal, ulexite, colemanite and boric acid has been used. In the first part of the study polyester samples blended with different type and concentration of boron minerals has been tested in laboratory conditions according to ASTM D 2303 surface tracking test method. At the next stage before the test rocess similar sampleshave been aged artificially by using DC vibration motor according to results the mean breakdown time increase with boron concentration. However lateral vibration has reduced the service life of composite samples up to 50 %

Keywords: *Bor minerals, surface tracking, composite insulators, mechanical vibration.*

1. INTRODUCTION

Although insulators with polymeric housings have been used around the world in outdoor high voltage applications for over 30 years, an adequate life time testing procedure that would allow evaluation and comparison of the electrical properties is still absent. This is mainly caused by the fact that the majority of composite insulators, due to their chemical properties of their external surfaces, represent dynamic (time variable) properties. The present knowlege about this phenomenon is insufficient and this is the main reason why different flashover voltage values can easily be obtained for an insulator [1]. It is necessary to study the dynamic properties of the insulator surfaces in order to elaborate a reliable test methodology, and also to increase our understanding on the degradation mechanisms of polymeric insulators.

For many years boric acid and borats have been widely used for various purposes. Nowadays bor compounds are also quite popular in several applications such as music CD's, car accessorries, transformers, magnets, etc. Since 19th century the excellent flame reterdant properties of borat has been well known for many researchers, however until recent years phospor, halogen and several other materials are investigated in detail. Several studies based on the flame reterdant properties of borat minerals clearly indicate that below flame onset temperature, borat minerals form a kind of glass sheet on the surface of the composite insulator,

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which eventually prevents the flame leading into the material [2-7].

Several environmental factors such as temperature variations, mechanical stress, UV radiation, etc. accelerate the ageing process of polymeric insulators. Also vibration has an undesirable effect on the mechanical and electrical properties of these polymeric insulators. In most cases ageing leads to space charge, channed formation and material heating which consequently decrease the useful lifetime of polymeric material. Previous studies were based on determining the performance of composite insulators (polyester resin blended with tincal mineral) subjected to mechanical vibration. [7].

In this study several minerals such as tincal, ulexite, colemanite and boric acid were added to unsaturated polyester resin with different percentages. These composite insulators were artificially subjected to mechanical vibration, which might have an undesirable effect on the electrical and mechanical properties of the tested samples.

In order to increase the accuracy of the results, several factors such as humidity, temperature, applied voltage, contaminant flow rate, etc. were kept stable at certain values during the test period. All tests have been performed accordingly to the ASTM D2303 test standard [8].

Table 1: *Boron minerals used in this study*

Mineral	Composition	Formula	B_2O_3 %	H_2O %
Tincal (Raw Boraks)	$Na_2O.2B_2O_3.10H_2O$	$Na_2B_4O_7.10H_2O$	36,5	47,2
Ulexite	$Na_2O.2CaO.5B_2O_3.16H_2O$	$Na_2Ca_2B_{10}O_{18}.16H_2O$	43,0	35,6
Colemanite	$2CaO.3B_2O_3.5H_2O$	$Ca_2B_6O_{11}.5H_2O$	50,9	21,9
Sassolit (Borik acid)	$B_2O_3.3H_2O$	H_3BO_3	56,4	43,6

2. EXPERIMENTAL PROCEDURE

2.1. Materials

Chemical formulas and also the water level (by mass) of various boron minerals used as flame reterdant additives are given in Table 1.
All tests have been performed according to the ASTM D2303 test procedure under 4kV applied voltage and 36ml/h contaminant flow rate. 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.

2.2. Test Procedure

Throughout their service life outdoor HV insulators may be subjected to lateral mechanical vibration usually caused by wind. In this study several polymeric composite insulators enriched with 4 different types of boron minerals are artificially subjected to mechanical vibration. Previous researches on this subject revealed that boron concentration more than 0.6% percent do not have any significant contribution to the heat absorbtion capacity of polyester, hence the maximum boron concentration has been selected as 0.5% for all bor minerals [2].

Initially composite insulators containing different types and percentages of boron minerals are tested according to ASTM D2303 test standard. At later stages an electrical motor energized by a 24V DC power supply is employed to produce lateral vibration effect artificially. By using 'Mini Seis Vibration and Air Shock Monitoring Device' the magnitude and frequency of vibration on the test rig and test sample have been measured respecively. Before commencing the test procedure, composite samples fixed to the test rig, have been aged for 8 hours by using the vibration motor (Fig.1). The frequeny of the vibration has been measured as 27mm/s (±5%) on the test rig and as 34.6mm/s (±5%) on the test sample respectively. A batch of 3 samples has been used to study each different type and percentage of bor minerals. The basic test setup has been shown in Figure 1.

3. RESULTS

Mean breakdown time for unsaturated polyester resin is meausured as 18.24 minutes for unaged and 11.02 minutes for mechanically aged

samples. Table 2 indicates the means breakdown times for composite insulators containing tincal, ulexite, boric acid and colemanite respectively. In Table 3 mean breakdown times for mechanical vibration is given. Test results revealed clearly that the bor minerals dramatically improve the breakdown time of polyester insulators. Continuous discharges increase the temperature of the surface of the insulator which eventually accelerates the breakdown process. When subjected to high temperatures, boron minerals produce a thin glass like sheet on the surface of the insulator, which prevent thermal degradation and hence improve the life time of insulator. Also due to local heating aqua molecules which form a part of the chemical composition of boron minerals, cause an endotermic reaction which also decelarates the breakdown process. However it is not well understood yet, which of these mechanisms are more efficient in improving the electrical performance of composite insulators.

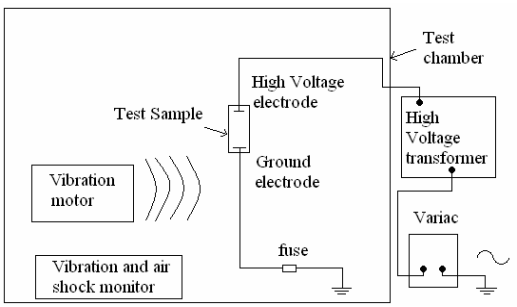

Figure 1: *Test setup according to ASTM D2303 standart (including vibration motor)*

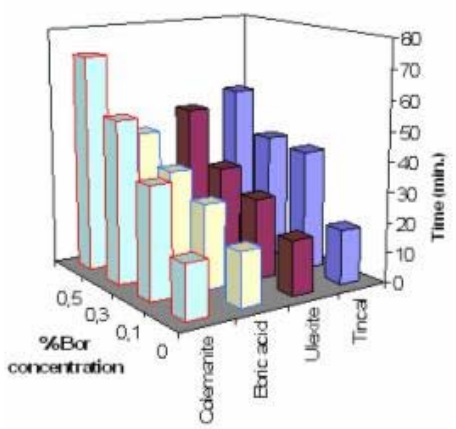

Figure 2 : *Effect of boron concentration on breakdown time.*

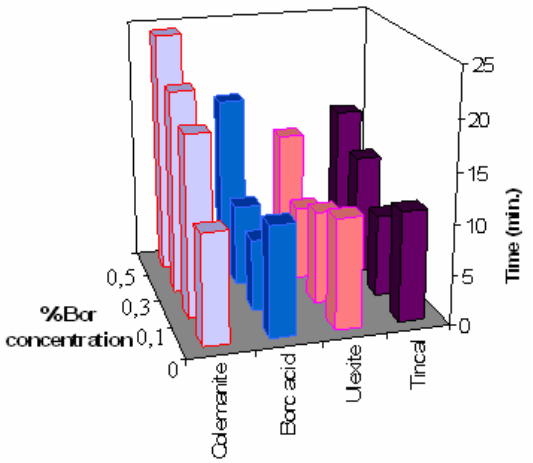

Figure 3 : *Mean breakdown times for mechanically aged polyester samples containing boron minerals*

Previous studies reveals that the heat absorbtion capacity of PVC insulators containing 0.2%-0.4% percent colemanite minerals is 2-3 times higher than the PVC insulators without any additives. According to chemical analyses, at high temperatures colemanite forms a type of glass sheet on the surface of composite material.

This sheet usually prevents the flame entering into the deeper layers of insulating material. However colemanite, more than 0.4% percent, do not have any considerable effect on the insulation capability of PVC insulators [5]. According to the test results, (Fig.2 and Fig.3) 0.1% percent ulexite improves the lifetime 2 times, 0.3% percent 2.5 times and finally 0.5% percent 4 times. Similar results have been obtained for samples having boric acid and tincal as additives.

Table 2: Mean breakdown times for composite insulators prepared with bor minerals

Borax mineral	0.1 %	0.3 %	0.5 %
Tincal	40:32	41:55	55:01
Ulexite	27:16	33:22	50:34
Boric acid	28:37	35:02	44:27
Colemanit	37:38	54:26	72:08

Table 3: Mean breakdown times for mechanically aged composite insulators prepared with bor minerals

Borax mineral	0.1 %	0.3 %	0.5 %
Tincal	8:19	12:02	15:04
Ulexite	9:24	7:42	13:04
Boric acid	7:15	8:17	17:18
Colemanit	18:17	20:41	24:42

4. CONCLUSION

In this research the electrical insulation capacity of composite insulators containing different types of boron minerals have been measured by using ASTM D2303 test method. According to test results lateral vibration effect has decreased the mean breakdown time of polyester samples without any additives up to 40% percent. Tincal ore improves the breakdown time significantly, however regardless of the tincal concentration, lateral vibration reduces the lifetime of composite insulator by 70%-80% percent. Ulexite and boric acid revals similar results and hence they also do not improve the lifetime of an insulator subjected to vibration.

Among all these bor minerals, colemanite seems to be the most effective additive and hence improves the lifetime of polyester based composite insulators up to 3-4 times, however even colematine can not decelerate the mechanical aging process caused by the lateral vibration.

REFERENCES

[1] T.G.Gustavsson., S.M.Gubanski, H.Hillborg, S.Karlsson and U.W.Gedde, "Aging of Silicone Rubber under AC or DC Voltages in a Coastal Enviroment", *IEEE Transactions on Dielectrics and Electrical Insulation*, Vol.8, No.6, pp.1029-1039, 2001.

[2] Aysel ERSOY, Ayten KUNTMAN, Mukden UĞUR, "Improvement of flame reterdant properties in polyester insulators", *8th International Conference on Solid Dielectrics (ICSD 2004*), pp.336-338, 5-9 Temmuz 2004, Tolouse, Fransa.

[3] C.Martin, J.C.Ronda, V.Cnoliz, "Boron-containing novolac resins as flame retardant materials", *Polymer Degradation and Stability*, 2005.

[4] V. I. Kodolov, S. G. Shuklin, A. P. Kuznetsov, L. G. Makarova, S. G. Bystrov, O. V. Demicheva, T. A. Rudakova, "Formation and investigation of epoxy ıntumescent compositions modified by active additives", *Journal of Applied Polymer Science*, Vol.85, pp.1477-1483, 2002.

[5] C. Tian, H. Wang, X. Liu, Z. Ma, H. Guo, J. Xu, "Flame retardant flexible poly (vinyl chloride) compound for cable application", *Journal of Apllied Polymer Science*, Vol.89, pp.3137-3142, 2003.

[6] B.Garba, "Effect of zinc borate as flame retardant formulation on some tropical woods", *Polymer Degradation and Stability*, Vol.64, pp.517-522, 1999.

[7] Aysel ERSOY, Ayten KUNTMAN, Mukden UĞUR, İbrahim GÜNEŞ, "Bor Katkısının Yorulmaya Maruz Bırakılmış Polyester Yalıtkanların Servis Ömrü Üzerine Etkileri", *III. Ege Enerji Sempozyumu Ve Sergisi*, 24-26 Mayıs 2006, Muğla.

[8] "Standard test methods for liquid contaminant, inclined plane tracking and erosion of insulating materials", *ASTM D (2303),* pp.258-270, 1983.

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