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An Analysis of Insulating Reliability in Epoxy Composites for Molding Materials of PT

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Abstract

The DC dielectric breakdown of epoxy composites used for transformer was experimented and then its data were simulated by Weibull distribution equation in this study. The more hardener increased the stronger breakdown strength at low temperature because of cross-linked density by the virtue of ester radical, and the breakdown strength of specimens with filler was lower than it of non-filler specimens because it was believed that the adding filler formed interface, charges were accumulated in it, the molecular mobility was raised, the electric field was concentrated, electrons were accelerated and then electron avalanche was early accomplished. From the analysis of Weibull distribution equation, it was confirmed that as the allowed breakdown probability was given by 0.1[%], the value of applied field was needed to be under 17.20[kV/㎜].

Key Words: Epoxy Composites, Weibull Distribution Equation, Allowed Breakdown Probability

1. INTRODUCTION

As the scale of a power delivery system is increased, the insulating design techniques such as a materialization of high electric field and a security of reliability in insulating composition are required and so organic polymer materials having a good electrical insulation are gradually expanded as a insulation materials[1],[2]. As a electric field or the data of life are very important, and as the phenomena of electrical degradation are investigated, the data that show the relation between breakdown and non-breakdown are also essential. Therefore it is needed that breakdown properties are accurately estimated by treating a statistics because these data of life time and breakdown are generally scattered.

In order to estimate the values of the allowed electric field under a allowed breakdown probability, dielectric breakdown experiments were performed and then the insulating reliability was analyzed with Weibull distribution equation.

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2. EXPERIMENTAL

2-1. Specimen Preparation

The specimens used in this study were designed to have a constant mixing rate in the epoxy resin of Bisphenol-A type and the MeTHPA(Methyl Tetra Hydro Phthalic Anhydride).

Bisphenol-A type is in liquid phase at room temperature, and the MeTHPA is a hardener of acid hydro-anhydride system. Also, the DY-040 and the SiO_2 with amount of 5[wt%] are added to improve both the impact strength and the machinery strength. and the silane coupling agents, which belong to an amino silane system (chemical name; N-(N-(β-Aminoethyl)-Aminopropyl -trimetoxy- Silane)), have been used for surface treatment of fillers[3],[4].

2-2. Design of Mixing Ratio

Since the electrical and physical properties of epoxy composites depend greatly on the mixing ratio among resin, hardener, and filler, as well as the hardening conditions[5]~[7], these aspects are need to be considered in manufacturing specimens. The design parameters and their condition used for this study are summarized in Table 1.

Table 1. Mixing Ratio [wt%]

Samples	Epoxy	Hardener	DY -040	Filler	Curing Condition
H 80FN	100	80	5	0	▶1st Curing; 100[℃] ×2[hr]
H 90FN	100	90	5	0	
H100FN	100	100	5	0	
H100F60	100	100	5	60	▶2nd Curing; 140[℃] ×6[hr]
SH100F60	100	100	5	60	

2-3. Experimental Method

The formation of DC breakdown experimental devices is shown in Fig. 1. All specimens were experimented to measure DC breakdown strength in silicon oil in the temperature range from 20[℃] to 150[℃]. And the step-up of DC voltage was also 1[kV/sec] and its voltage was stepped up until breakdown was happened. And the experiments were performed by 10 times a each specimen under same condition using experimental devices of Fig. 1 and their average value was chosen as DC breakdown strength.

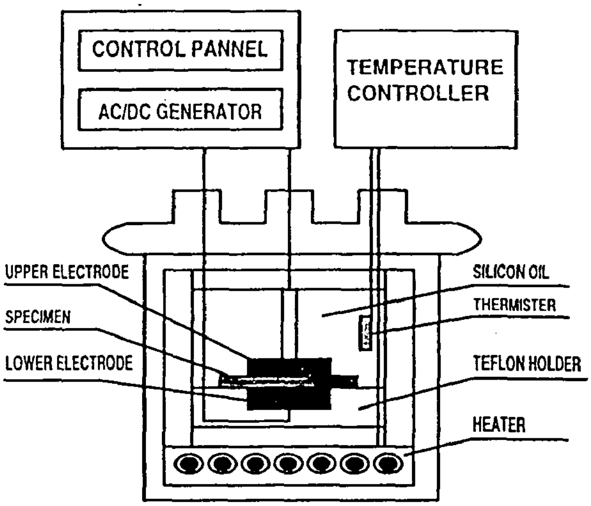

Fig. 1. Experimental Apparatus

3. ANALYSIS OF WEIBULL DISTRIBUTION

The algorithm of Weibull distribution equation is shown in Fig. 2. This procedure was executed to estimate breakdown probability against the appling electric field using breakdown strength of specimens.

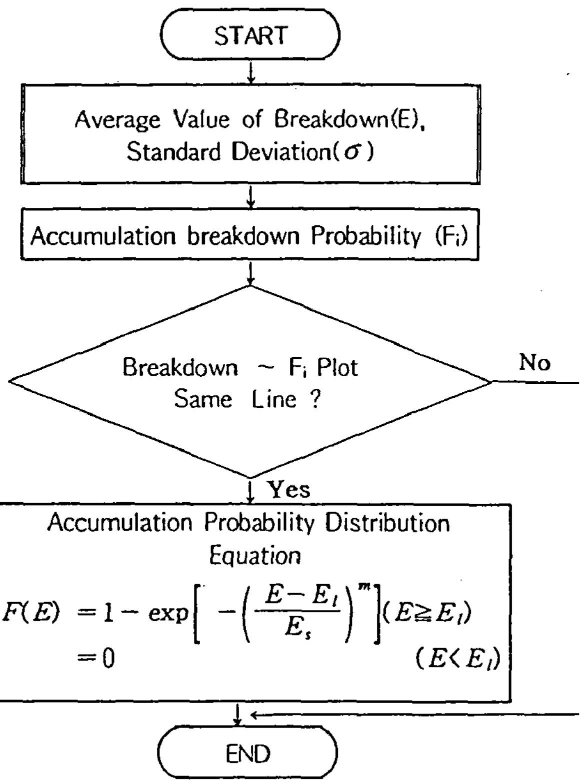

Fig. 2. The Algorithm of Weibull Distribution

Accumulation breakdown probability is given by

$$F_i = \frac{i}{n+1} \qquad (i=1,\ 2,\ \cdot\cdot\cdot,\ n)$$

where, n is the number of the data and i is the specimen number. Using Weibull distribution equation, the equation of accumulation probability distribution is given as follows:

$$F(x) = 1 - \exp\left[-\left(\frac{E-E_l}{E_s}\right)^m\right] \qquad (E \geq E_l)$$
$$= 0 \qquad (E < E_l)$$

where, E is a appling electric field, E_l is a position parameter, E_s is a measuring parameter, and m is a shape parameter, respectively.

4. RESULTS AND DISCUSSION

4-1. The Properties of DC Breakdown

Fig. 3 shows DC Breakdown strength according to ratio of adding hardener and Fig. 4 shows DC Breakdown strength according to adding filler and treating silane coupling agent. It was conformed that DC breakdown strength was raised in proportion to the ratio of hardener and was abruptly lowered near 110[℃] since this vicinity reflects the glass transition

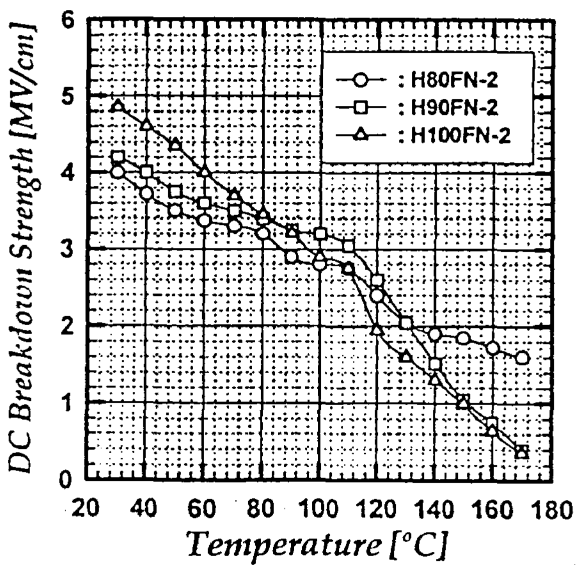

Fig. 3. DC Breakdown strength according to ratio of adding hardener

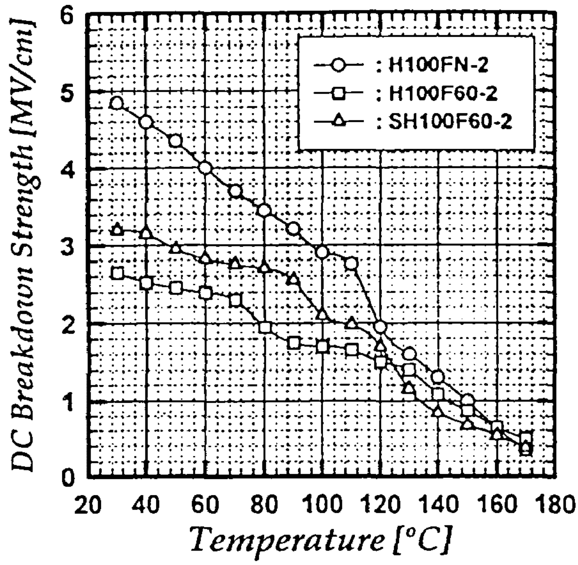

Fig. 4. DC Breakdown strength according to adding filler and treating silane coupling agents

On the other hand, high temperature region assumed an opposite aspect of low temperature region because it is considered that hardener occupies the free volume inside specimen[8],[9]. And DC Breakdown strength of specimens with filler was lowered than it of non-filler specimens since it is believed that as filler is added, interface is formed and so real charge is accumulated in it, the mobility is raised, the electric field is concentrated, and acceleration of electrons and growth of electron avalanche is early accomplished. The specimens with treating silane coupling agents became much higher in the breakdown strength because this suggests that silane coupling agents improve interfacial deformation and relax electric field concentration[10],[11].

4-2. The Distribution of Weibull Probability

Each of parameters obtained from DC breakdown experiments is shown in Table 2.

As the allowed breakdown probability was 0.1[%], the values of the allowed electric field that were obtained from various parameters were increased in proportion to the amount of hardener, and in case of specimen with filler, the values of the allowed electric field were lower than them of specimen treating with silane

Table 2. The values of each parameter obtained form DC breakdown data

Samples	Shape Parameter (m)	Measuring Parameter (E_s)	The Value of Applied Field (at 0.1[%])
H 80FN	3.86	112	18.71 [kV/㎜]
H 90FN	3.64	125	18.74 [kV/㎜]
H100FN	3.57	151	21.81 [kV/㎜]
H100F60	4.31	83	16.71 [kV/㎜]
SH100F60	3.97	98	17.20 [kV/㎜]

coupling agent. This was concurred with DC breakdown properties, and finally it was confirmed that as the allowed breakdown probability was given by 0.1[%], the value of the allowed electric field was needed to be under 17.20[kV/㎜][12].

5. CONCLUSION

From a series of DC breakdown experiments, the properties of DC breakdown were investigated, and in order to analyze insulating reliability in epoxy composites which are widely used for molding materials of transformer, the values of the allowed electric field were calculated with Weibull distribution equation in this article. As a results,

(1) It was conformed that DC breakdown strength was raised in proportion to the ratio of hardener and was abruptly lowered near 110[℃].

(2) High temperature region assumed an opposite aspect of low temperature region.

(3) DC Breakdown strength of specimens with filler was lowered than it of non-filler specimens.

(4) The specimens with treating silane coupling agents became much higher in the DC breakdown strength.

(5) It was calculated that as the allowed breakdown probability was given by 0.1[%], the value of the allowed electric field was needed to be under 17.20[kV/㎜].

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