계면조건에 따른 에폭시와 고무 거시계면의 절연내력

論 文
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Dielectric Strength of Macro Interface between Epoxy and Rubber According to the Interface Condition

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Abstract - Macro interfaces between two different bulk materials which affect the stability of insulation system exist inevitably in the complex insulation system using in extra high voltage (EHV) electric devices. In this paper, interface between epoxy and ethylene propylene diene terpolymer (EPDM) was selected as an interface in electrical insulation system and the AC dielectric strength of the interface was investigated. Air compress system was used to give pressure to the interface. Specimens were prepared in various ways to generate different surface conditions for each type of interface. Increasing interfacial pressure, decreasing surface roughness and spreading oil over surfaces improve the AC interfacial dielectric strength. Especially, the dielectric strength was saturated at certain interfacial pressure

Key Words : Macro interface, Dielectric strength, Epoxy, EPDM, Oil

1. INTRODUCTION

As modern industrialized society progresses, the demand for electric power is increasing rapidly. The electric power system is getting amazingly bigger and complicated, which can easily induce serious troubles from the potential of large fault problems and/or system failure. The interface is not always a weak point, but many defects such as voids, metallic or other contaminants, dusts are easy to be introduced at the interface. These defects make the interface to be a weak point in the electrical insulation. Cable jointing devices and accessories are weak-link in the practical underground power delivery systems.

In Korea, about 40% of underground power transmission line failure is related with cable joint devices and accessories. Because most high voltage insulation systems consist of different materials forming composite insulation, the macroscopic interfaces are existed in the systems.

Complex insulation method is used in extra high voltage (EHV) and ultra high voltage (UHV) electrical insulation systems. The interfacial breakdown between two internal dielectric surfaces is a main cause of failure in multiple insulation systems [1].

The interfacial dielectric breakdown is a complex phenomenon, and interfacial discharges leading to a dielectric failure and space charge formation due to different permittivity of the contacting dielectrics are main causes of breakdown [2].

In this paper, the interface between epoxy and ethylene propylene diene terpolymer (EPDM) was selected as a interface in EHV insulation systems and tested AC interfacial breakdown properties with variation of many conditions to influence on electrical properties, such as interfacial pressure, roughness and oil.

Many factors can affect the dielectric performance of an interface [3]. Among these factors interfacial pressure plays a major role in interfacial dielectric strength. In order to better understand this phenomenon, breakdown experiments were performed on the interface between epoxy and EPDM pressed one against the other. To achieve this, interfacial dielectric strength tester with air compress system was prepared.

2. EXPERIMENT

2.1 Design of specimen

It is necessary for the specimen, which is used to investigate the properties of macro interface, to have below conditions:

1) Electrodes do not contact interface.
2) Pressure can be applied to interface.

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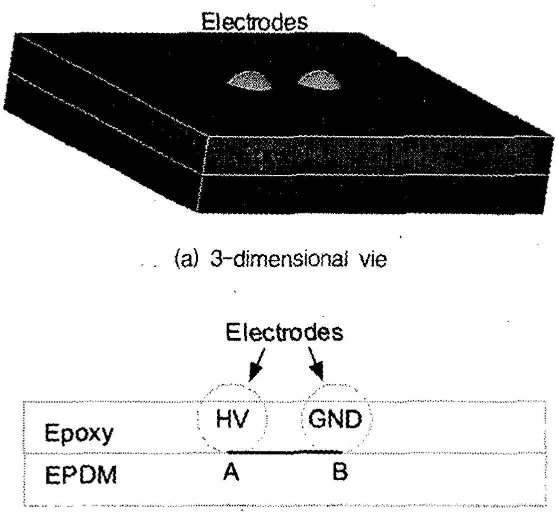
3) Between two electrodes, the direction of electric field is parallel to the surface of interface.

Fig 1 shows the structure of the specimen. The specimen consists of epoxy, EPDM, and two electrodes. The structure of electrodes was designed to have electric potential longitudinally along the interface, and to have uniform electric field.



(a) 3-dimensional vie

(b) Side view

Fig. 1 Structure of specimen

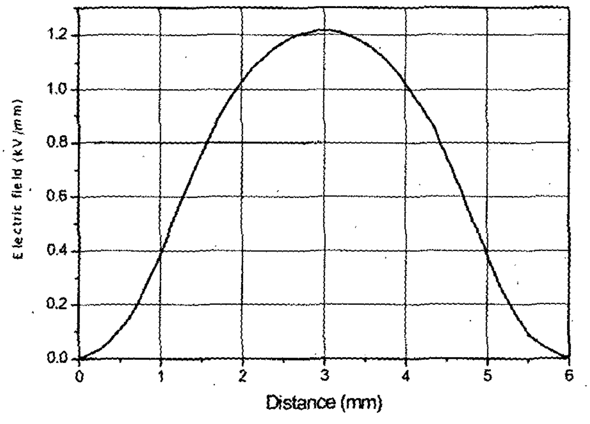


Fig. 2 Distribution of electric field at the interface between electrodes (40kV, tangential to interface)

2.2 Calculation of electric field

Fig. 2 shows the distribution of tangential electric field at the interface between two electrodes (path A-B in Fig. 1 (b)). High voltage was applied on the left electrode. Applied voltage was 40 kV. At the middle point between two electrodes, the electric field was 1.217 kV/mm. As shown in Fig 1, the electric field was highest at the middle point between two electrodes. At the middle point

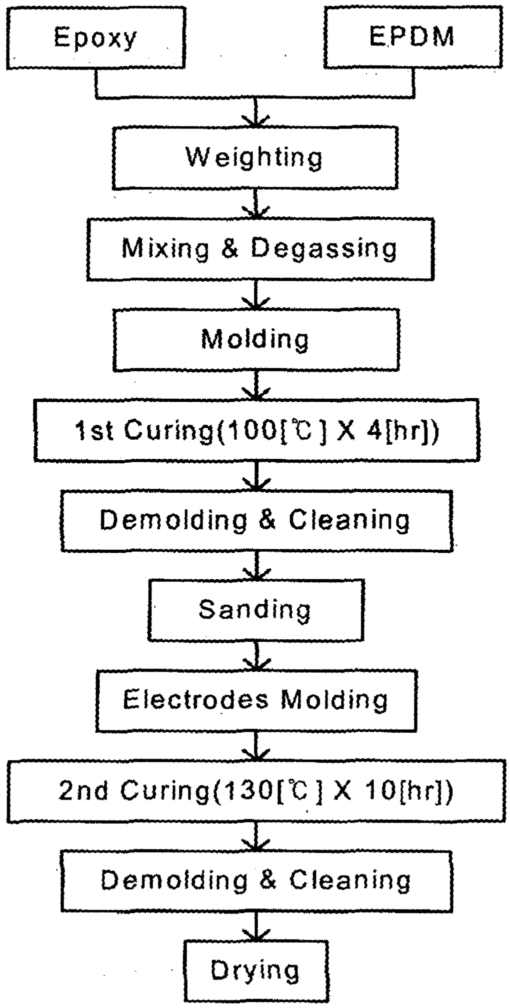


Fig. 3 Manufacturing process of epoxy specimen

electric field vector direction was same longitudinally along the interface direction. So, it was predicted that electric field will be concentrated on this point.

2.3 Preparation of specimen

The specimen consists of epoxy and EPDM. Epoxy was Bisphenol-A liquid type resin [100phr] + Methyl tetra Hydro Phthalic Anhydride (MeTHPA) [100phr]. EPDM was an industrial manufacture.

The glass transition temperature of epoxy and EPDM is 90~100 ℃ and -60 ℃, respectively. In other words, EPDM is a material with elasticity at operation temperature, but epoxy is not. Cavities of elastic materials are easily reduced by pressure. So the surface condition of epoxy was likely to affect electric properties of interface more.

The manufacturing process and configuration of specimen was shown in Fig 3. After 1st curing, specimens were sanded with sandpaper, and electrodes were molded. And then 2nd curing was carried out.

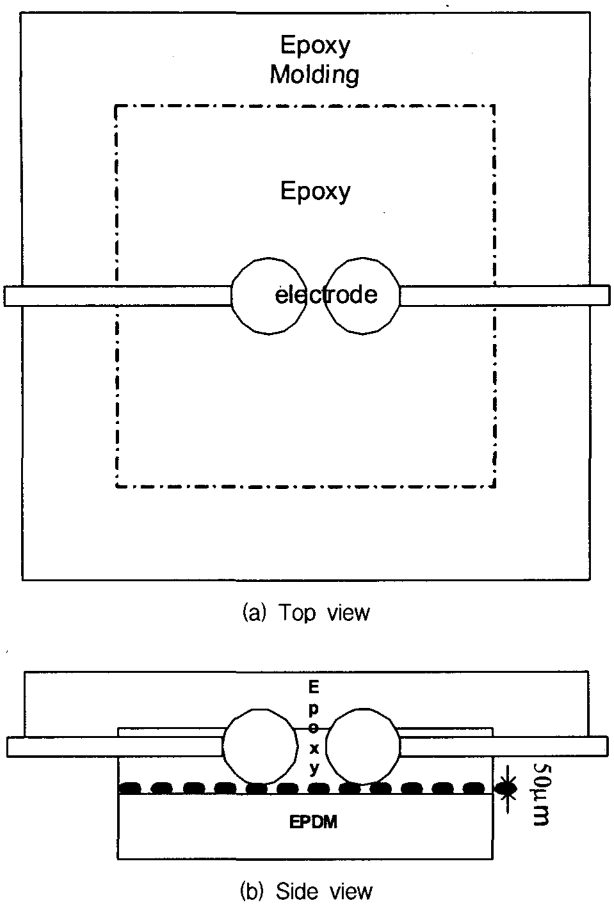


Fig. 4 Schematic drawing of specimen

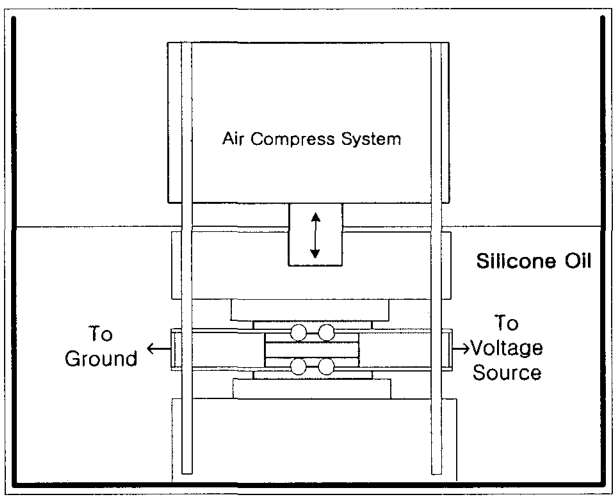


Fig. 5 Interfacial dielectric strength tester

Fig. 4 shows schematic drawing of specimen. Each electrode consists of spherical stainless steel and cylindrical copper wire. In the process of specimen preparation, electrodes were inserted into epoxy to reduce the effect of charge transport from electrode in breakdown progress. The gap between electrode lower side and interface was 50 mm.

2.3 Experimental setup

Test method was selected according to short-time test(current setting: 10 mA, rate-of-rise: 500 V/s) of ASTM D 149-95a(Dielectric breakdown voltage and dielectric strength of solid electrical insulating materials at commercial power frequencies). Fig 5 shows the interfacial dielectric strength tester. Interfacial dielectric strength tester was made of Teflon and Acetal. Air compress system was used to press the specimens.

3. RESULTS AND DISCUSSION

3.1 Variation of the interfacial AC dielectric strength due to interfacial surface condition

Fig. 6 presents variation of the interfacial AC dielectric strength due to interfacial surface condition at room temperature. Specimens were sanded with various sandpapers (#200, #400, #600, #1200). Applied interfacial pressure was 5 kg_f/cm^2.

There are many results concerned with this factor. According to the decreasing of surface roughness, dielectric strength is increased or decreased [5], [6]. It is due to the difference of electrode's structure and materials. When surface roughness was decreased, AC dielectric strength of interface between epoxy/EPDM increased in this investigation.

In the interface between epoxy/EPDM, many defects exist such as void, unevenness, conductive contaminant, water and so on. According to the decreasing of surface roughness, quantity of voids and unevenness is reduced and the concentration of electric field to the unevenness is relieved, and then pre-breakdown discharge may be suppressed.

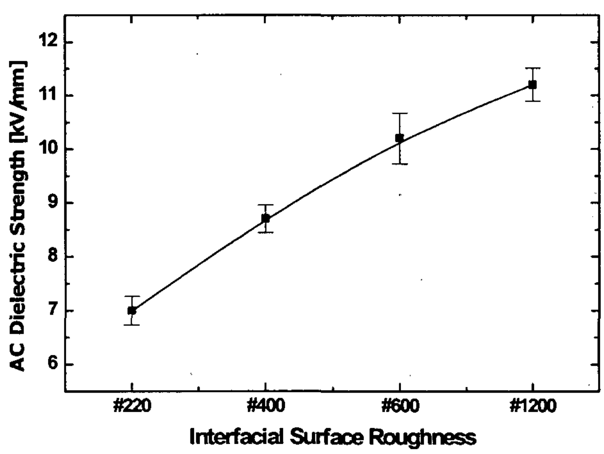


Fig. 6. AC dielectric strength versus interfacial surface roughness

3.2 Variation of the interfacial AC dielectric strength due to interfacial pressure

The measured AC dielectric strength at room temperature is plotted against the interfacial pressure in Fig. 7. Each data point represents the average of total 6 measurements. Specimens were sanded with sandpaper (#1200). Interfacial pressure was from 1 kg_f/cm^2 to 7 kg_f/cm^2.

Interfacial dielectric failure is a complex phenomenon. Space charge formation, due to the different permittivity of the contacting dielectrics, occurs on the boundaries, which results in a change of physical properties (loss tangent, permittivity) of the composite compared to the single component. Consequently, the dielectric losses may be increased due to interfacial polarization effect, and then it takes a higher heat generation in the dielectrics.

Cavities existing in the interface between epoxy/EPDM may be filled with air or gas whose permittivity and dielectric strength are considerably less than solid.

Partial discharge will occur across the cavities when its' peak stress is equal with the breakdown strength of air, and the voltage at which this occurs is known as the discharge inception voltage. Partial discharges occurred at cavities develop the tracking degradation propagation and lead to the dielectric failure. Discharge inception voltage of air in cavities is proportional to it's pressure level. Interfacial pressure would reduce the volume and number of cavities and raise the air compress in cavities.

AC dielectric strength should be improved by increasing interfacial pressure. Especially, AC dielectric strength is saturated above certain interfacial pressure level(in this investigation pressure level is 5 kgf/cm^2).

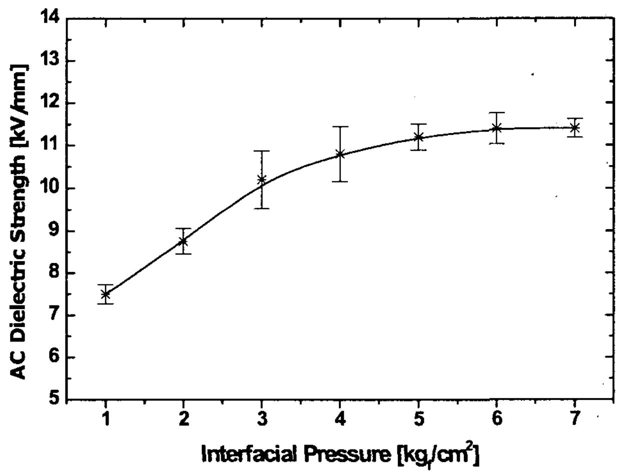


Fig. 7 AC dielectric strength versus interfacial pressur

3.3 Variation of the interfacial AC dielectric strength due to pressure and spreading silicone oil over surfaces

AC dielectric strength due to variation of pressure and silicone oil spreading over surfaces at room temperature is similar to 2, as shown in Fig 8.

Low viscosity silicone oil (350 cSt) and high viscosity silicone oil (12500 cSt) were spread over sanded surfaces with #1200 sandpaper. When oil is spread on the surfaces of the interface, the cavities are filled with the oil. Then oiling plays an important role in eliminating cavities at interfacial surface. Compared with Fig 7, oiled and sanded interface has a better AC dielectric strength.

However, high viscosity silicone oil spreading may make voids at interface because of its poor flowage. So low viscosity oil spread specimens have higher dielectric strength than high viscosity oil spread specimens.

Interfacial AC dielectric strength at 5 $kg_{f/cm}^2$ is 12.1 kV/mm (350 cSt) and 11.95 kV/mm (12500 cSt).

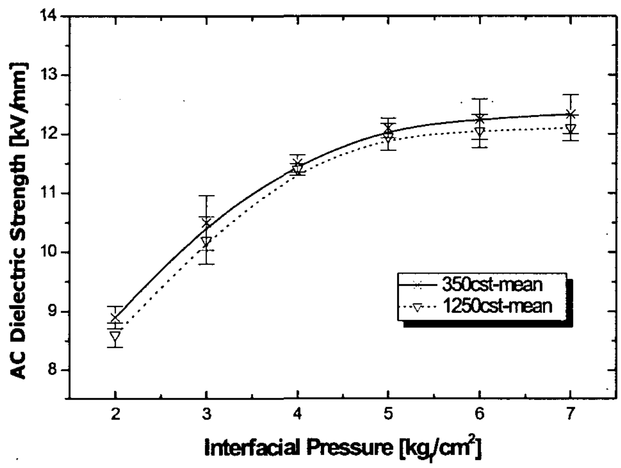


Fig. 8 AC dielectric strength versus interfacial pressure and spreading silicone oil over surface

4. SUMMARY

In this study, the interfacial AC dielectric strength depended on interfacial pressure, surface roughness and spreading oil greatly.

1. Pressure increasing and Roughness decreasing reduce volume and number of cavities, moreover, pressure increasing improves the discharge inception voltage of air or gas in cavities.
2. Spreading oil over surfaces provides a good cavity-filling function.

AC dielectric strength is improved by increasing of interfacial pressure, decreasing of surface roughness and spreading oil over surfaces. Especially, It is saturated at certain interfacial pressure level.

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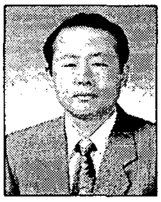

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