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Ageing Deterioration of High-Density Polyethylene Cable Spacer under Salt Water Dip Wheel Test

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Abstract**—**This paper presents the experimental results of high-density polyethylene cable spacers for 22 kV distribution systems under salt water dip wheel test based on IEC 62217. The strength of anti-tracking and anti-erosion of cable spacer surface was studied in this study. During the test, dry band arc and corona discharge were observed on cable spacer surface. After 30,000 cycles of salt water dip wheel test, obviously surface erosion and tracking were observed especially on the ground end. Chemical analysis results by fourier transforms infrared spectroscopy showed chemical changed from oxidation and carbonization reaction on tested cable spacer. Increasing of C=O and C=C bonds confirmed occurrence of these reactions.

Keywords**—**Cable spacer, HDPE, ageing of cable spacer, salt water dip wheel test.

I. Introduction

RESENTLY, high-density polyethylene (HDPE) cable spacer has been widely used in power transmission and distribution system. HDPE cable spacers have advantages of low cost, light weight and low electric field stress when comparing with the ceramic type. After long time in service, surface of HDPE cable spacer became inferior and dust was accumulated. Cable spacer would be cleaned by rain difficultly. As a result, leakage current was undesirably increased and electrical insulation characteristics of cable spacer were decreased. There were several reasons for cable spacer deteriorations such as manufacturing processes, material selections, and product designs. Another important factor was the service environment such as tropical climate and high UV intensity [1]-[4].

Basically, the problem of high electric-field concentration on the contact points between the covered conductor and spacer or ties cannot be controlled. This problem has been studied by [5]-[7]. Performances of cable space have been evaluated by many researchers [4], [8]-[10]

Numbers of HDPE cable spacer were use in distribution system of Provincial Electricity Authority of Thailand (PEA) and Metropolitan Electricity Authority of Thailand (MEA). Damaged cable spacers during service were reported by these electric utilities [3]. However, no ageing characteristic of HDPE cable spacer were studied in Thailand. By this reason, this paper reports the experimental study on ageing deterioration of high-density polyethylene cable spacer for 22 kV PEA distribution system in Thailand under salt water dip wheel test.

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II. Test Arrangements

A. Specimen

Polymer cable spacers made of high-density polyethylene by injection molding for 22 kV PEA distribution system were used in this study. Configuration and dimension of specimen are illustrated in Fig. 1. As illustrated in Fig. 1, leakage distance between phase A to ground and between phase B to ground is approximately 310mm.

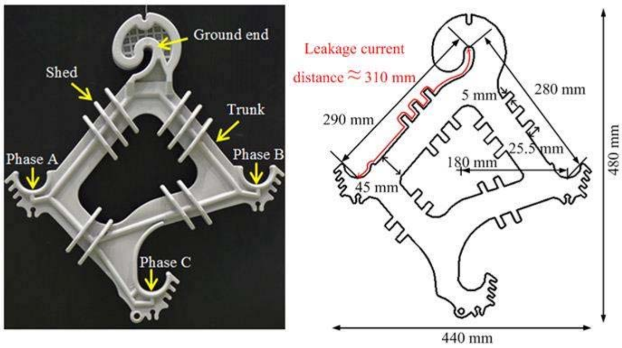

Fig. 1 Configuration and dimensions of specimen

B. Test Arrangement

Four items of cable spacers were installed on the wheel as shown in Fig. 2. Only two phases near ground end were energized. Voltage was energized via stainless rods and stainless sphere as shown in Fig. 3

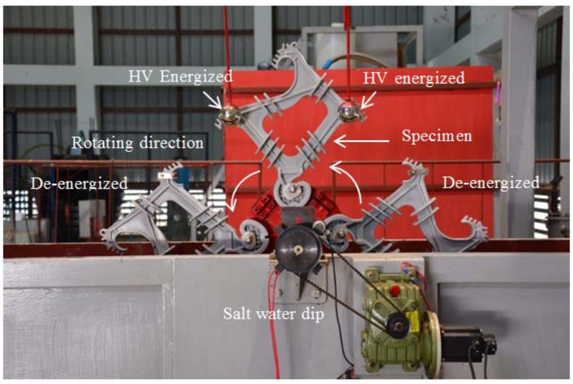

Fig. 2 Specimen installation

Fig. 3 Voltage Energized via Stainless Rod and Stainless Sphere

C. Test Method

Test methods for salt water dip wheel test were based on IEC 62217 [11]. Test was conducted continuously for 30,000 cycles. As illustrated in Fig. 2, one test cycle takes time 192 second and includes 4 test positions, energized, de-energized, salt water dip and de-energized, respectively. For each position, test specimen remains stationary for about 40 second and takes 8 second for rotate to the next position. Salt water was re-newed every week and re-newing time must less than 1 hour.

D. Test Conditions

Test was conducted based on test conditions in IEC 62217, as illustrated in Table I. Test voltage was generated from 22 kV, 30 kVA single phase transformer.

TABLE I
TEST CONDITIONS

Test Voltage	AC 15 kV continuously applied
Voltage stress	48.4 V/mm
NaCl content of de-ionized water	1.4 kg/m± 0.06 kg/m3
Test duration(1 cycle = 192 second)	30,000 cycles

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Visual Observation

During test, many discharge activities were observed. Dry band arc and corona discharge were often observed on the ground end, trunk and energized end. Especially on the ground end was observed severe arcing. Yellow light paths indicate dry band arcing and purple light indicate corona discharges [12] as show in Fig. 4. This phenomenon caused ageing deterioration on surface of HDPE cable spacer.

After 30,000 tests cycles, damaged surface of tested cable spacers was observed. Tracking and erosion occurred on tested specimen surface. Severe surface erosion was observed on the ground end portion, near ground end and trunk between sheds near ground end, as illustrated in Fig. 5.

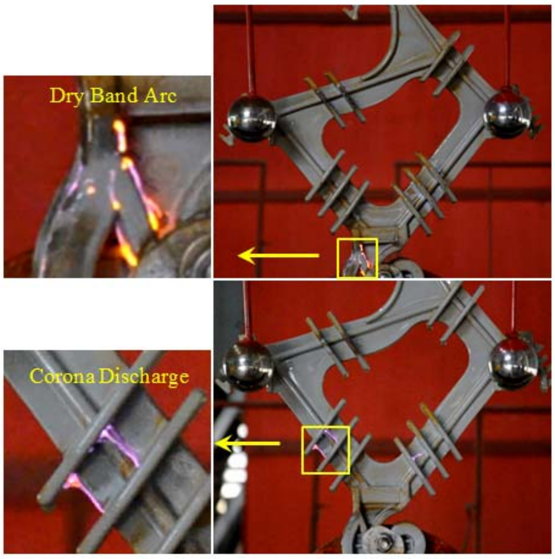

Fig. 4 Discharge Activities

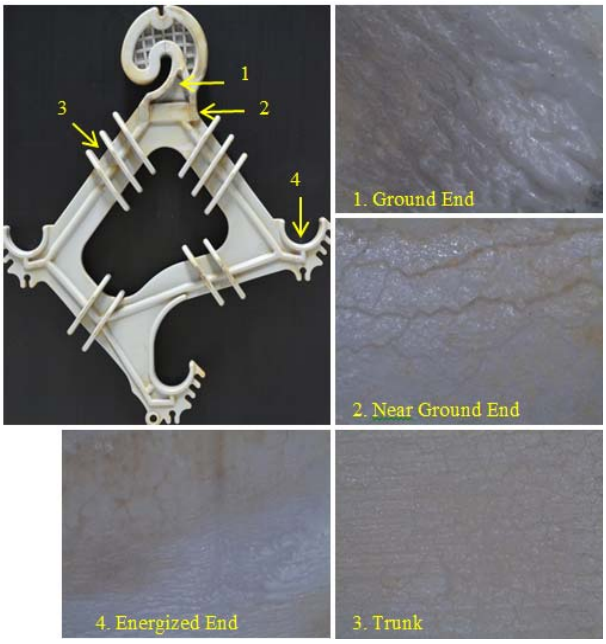

Fig. 5 Tracking and Erosion After Tested [Specimen 4]

B. Contamination Degree

Contamination degree was determined by measuring salt deposit density (SDD). The measurement procedures were based on IEC 60507 [13]. After 30,000 tests cycles, SDD measurement results on the whole surface of each specimen as shown in Table II. No difference contamination degree was measured.

TABLE II
SDD AFTER 30,000 TEST CYCLES

SDD, mg/cm^2			
Specimen 1	Specimen 2	Specimen 3	Specimen 4
0.0130	0.0139	0.0143	0.0130

C. ATR-FTIR Analysis Result

In order to confirmed surface ageing, chemical analysis by ATR-FTIR (attenuated total reflection fourier transform infrared spectroscopy) was conducted to evaluate any chemical change on tested specimen. For HDPE, C-H bonds at wave number 2916, 2847 and 1462 cm-1 indicate side chain and C-C bonds at wave number 720 cm-1 indicates back bone of polyethylene molecule [14]-[15]. Position on tested specimen surface for chemical analysis is shown in Fig. 6.

Appearance of C=O bond at wave number 1,745cm^{-1} and C=C bond at wave number 1,630cm^{-1} indicates the occurrence of Oxidation and Carbonization, respectively. As illustrated in Fig. 7, reduction in C-H bond and C-C bond were observed on all tested specimens when comparing with new specimen. In contrast, increasing in C=O bond and C=C bond were observed on all tested specimens. Ratio of C=O bond and C-C bond is illustrated in Fig. 8. And ratio of C=C bond and C-C bond is illustrated in Fig. 9

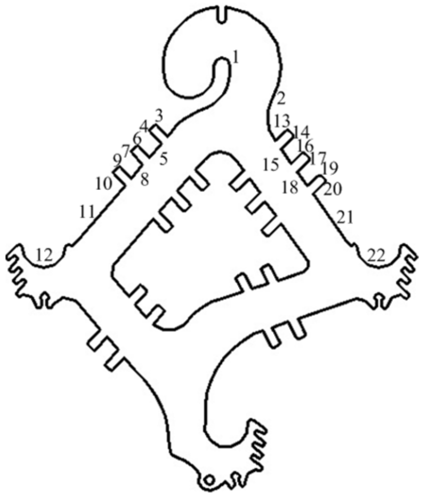

Fig. 6 Position for ATR-FTIR analysis

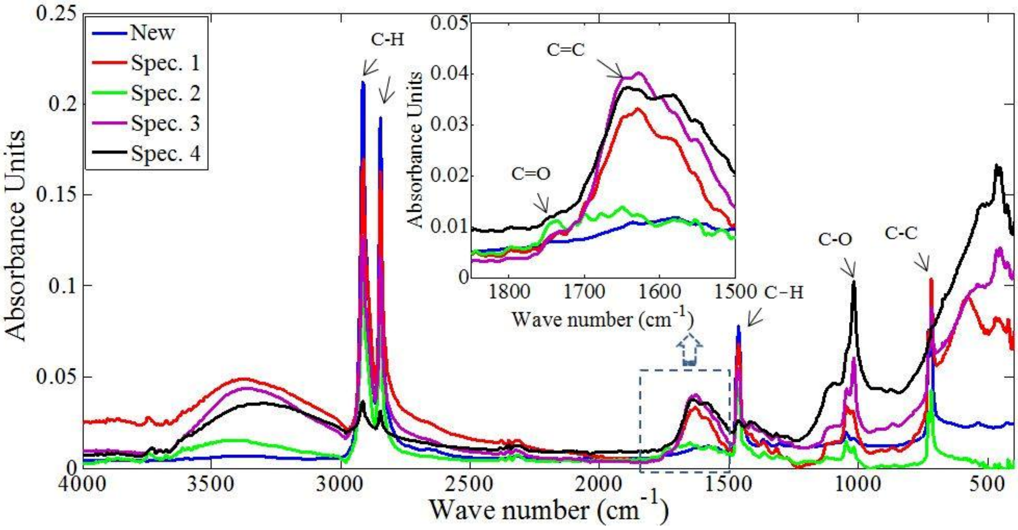

Fig. 7 ATR-FTIR analysis result [Position 1]

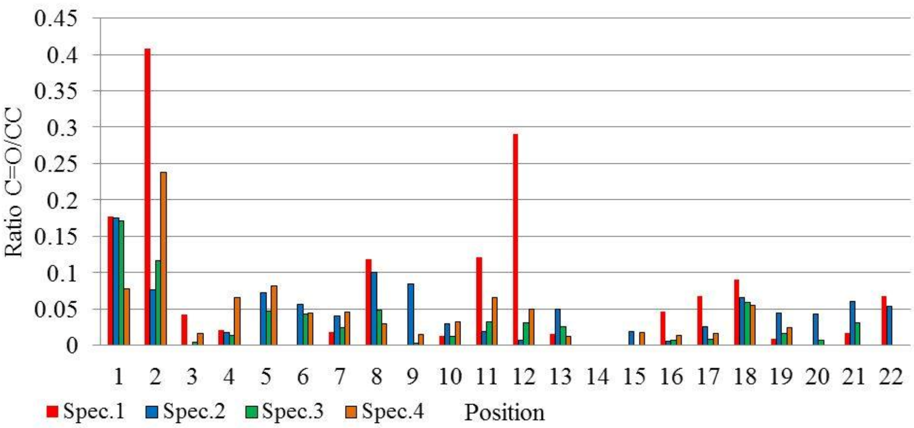

Fig. 8 Ratio of C=O/C-C

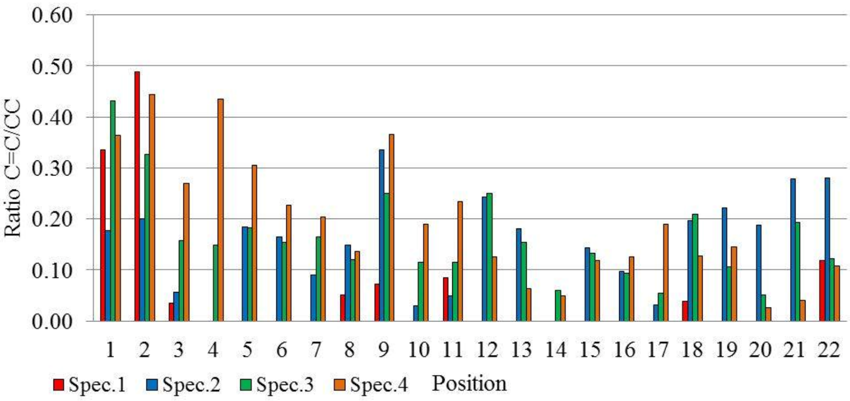

Fig. 9 Ratio of C=C/C-C

IV. Conclusion

Ageing deterioration of high-density polyethylene cable spacer under salt water dip wheel test based on IEC 62217 have been studied. After 30,000 test cycles, surface tracking and ground end erosion were observed on the specimen surface. Dry band arc discharge and corona discharge caused surface damaging of the tested specimen surface. Salt deposit density of tested specimen surface less than 0.02 mg/cm^2 was measured. ATR-FTIR analysis results confirm the difference in degree of surface deterioration of HDPE cable spacer under the salt water dip wheel test.

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