DEGRADATION CHARACTERISTICS OF THE POLYPROPYLENE-INSULATED CABLES AND JOINTS AT EMERGENCY OVERLOAD

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ABSTRACT

KEPCO has been developing the polypropylene-insulated cables in order to improve the ampacity since 2013. Operating temperature of the cable is 110 degree that is higher than XLPE-insulated cable's (90 degree). And emergency operating temperature of the cable is also needed to be applied to the distribution system.
Therefore, this study carried out the experiment for compatibility and degradation characteristics between conventional joints and terminations and cables at emergency temperature. After test, the samples were evaluated electrical and thermal characteristics. Based on the results of the tests, we can present the operation conditions of the polypropylene-insulated cable.

INTRODUCTION

Operations at the emergency overload temperature of 130 degree for insulations rated 90 degree continuous shall not exceed 1500 hours cumulative during the lifetime of the XLPE-insulated cable[1][2]. However, in an emergency operating temperature for Polypropylene-insulated cable has not been set. Decision of it's the emergency temperature is one of the most important things in underground distribution system. Lower temperatures for emergency overload conditions may be required because of the type for material used in the cable, joints, terminations and separable connectors or because of cable environmental conditions. The conventional facilities which are used in underground distribution system were designed by taking account of 130 degree according to XLPE. If the higher temperature, the economic efficiency will be reduced because of the change of its materials. For this reason, KEPCO has to decide to the emergency operating temperature of Polypropylene-insulated cable in consideration of various conditions. Therefore, we performed the basic tests to determine the emergency temperature of it.

COMPATIBILITY TEST

Experimental setup

Polypropylene-insulated cables are connected to the conventional joints and terminations (Fig. 1). Joints are two types that one is pre-molded, the other is cold shrink. The first step is a conductor temperature of 130 degrees, a holding time of 72 hours. The second step is a conductor temperature of 140 degrees, a holding time of 72 hours. Finally the third step is a conductor temperature of 150, a holding time of 72 hours. This test simulated the worst conditions..
The sample from each step was carried out for the electrical performance test such as voltage withstand test and impulse voltage test (Fig. 2)[3].

(a) Experiment setup

(b) Joints
Fig. 1 Experiment Setup

(a) Voltage withstand test

(b) Impulse test

Fig. 2 Electrical performance test

Results

The results of electrical performance test are as follows in Table 1. Despite the severe test conditions, all three samples exhibited good characteristics. The breakdown of the joints is made of manufacturing defect.

Table 1. Results of the electrical performance test

No.	Condition	Assessment Method		
		Voltage withstand test (52kV, 1min)	Long duration voltage test (78kV, 60min)	Impulse voltage test (±150kV, 5times)
1	130℃/72hrs	Pass	BD @ joint	Pass
2	130℃/72hrs 140℃/72hrs	Pass	Pass	Pass
3	130℃/72hrs 140℃/72hrs 150℃/72hrs	Pass	BD @ joint	Pass

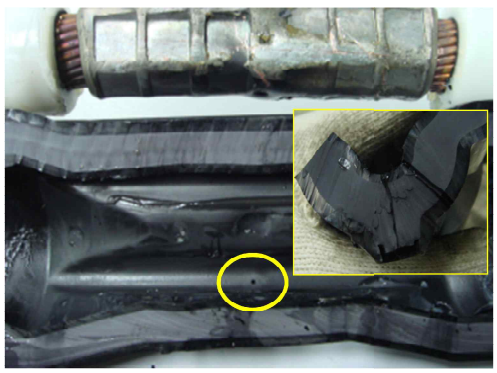
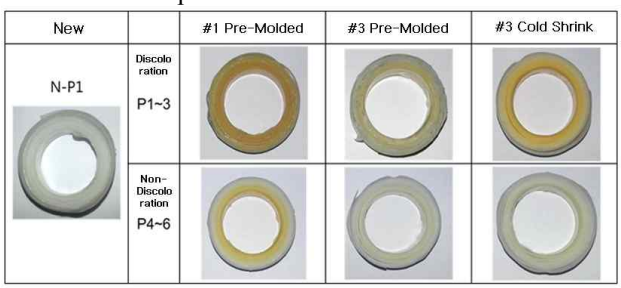


Fig. 3 part of break down

We performed additional test about polypropylene insulation of #1pre-molded, #3 pre-molded, #3 cold shrink. Test methods are FTIR, DSC-OIT. The results are shown as Fig. 5 and Fig. 6. Sample of #1 should be excluded from analysis because the part is carbonized when break down. The sample except the #1 pre-molded can be seen the fact that degradation proceeds as compared to the new one. In accordance with the progress of degradation, carbonyl peak (1742cm^{-1}) is decreased as the antioxidant is consumed and terminal vinyl peak (898cm^{-1}) is increased. OIT of discoloration part (P1~P3) is decreased as compared to the new one.

Table 2. test samples



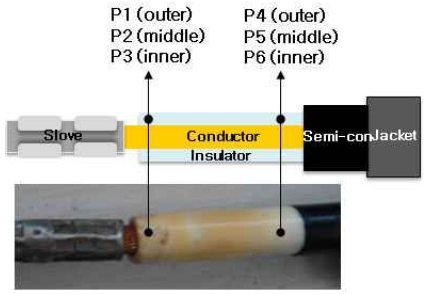
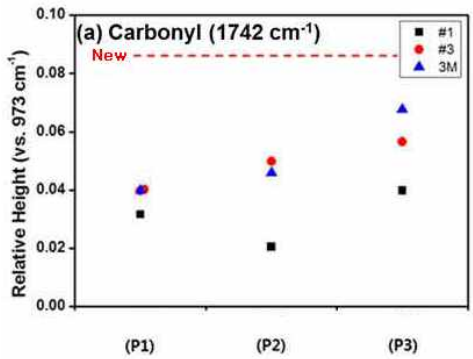
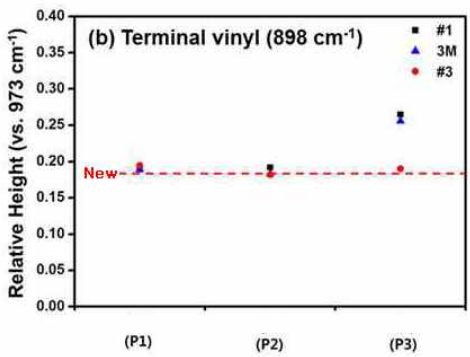
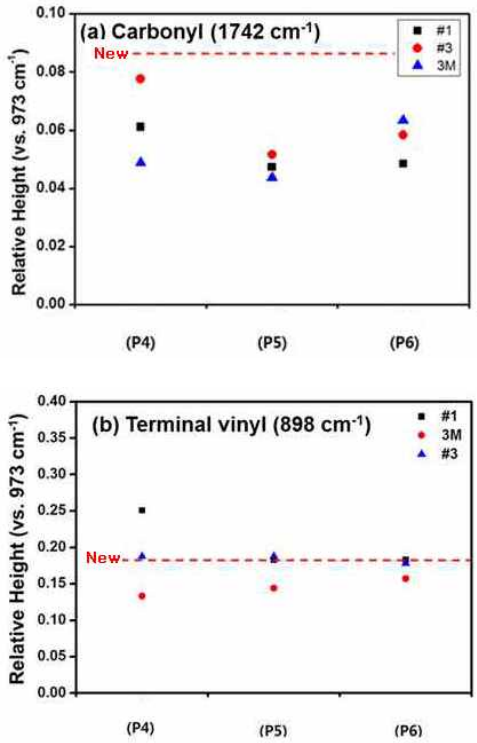


Fig. 4 test points



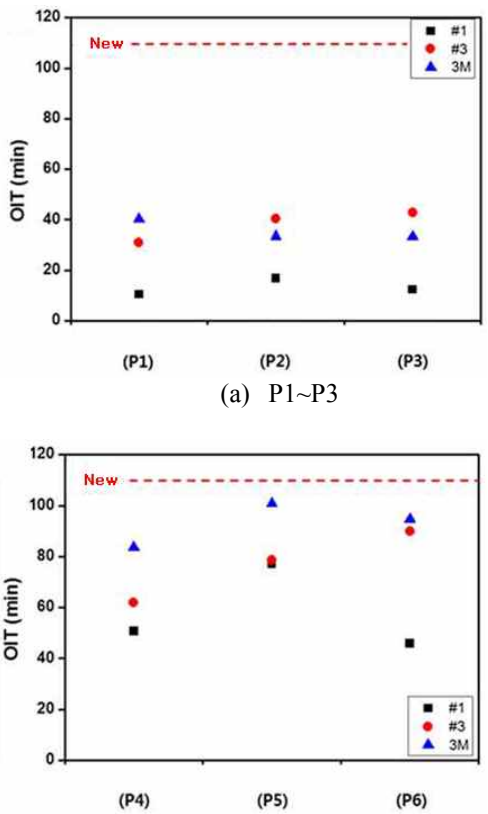


(a) P1~P3



(b) P4~P6

Fig. 5 Results of FTIR



(a) P1~P3

(b) P4~P6

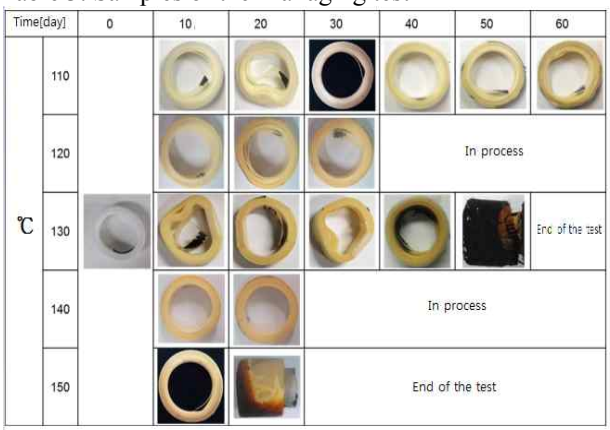
Fig. 6 Results of DSC-OIT

THERMAL AGING TEST

Test procedure

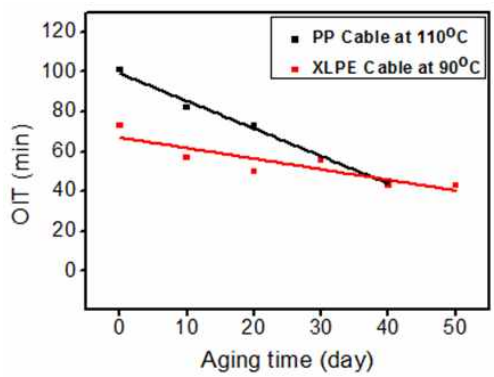
Thermal aging test was carried out test in order to determine the material characteristics according to the time-temperature degradation of Polypropylene [Table 3]. Samples were extracted at 10-day intervals in an oven at a constant temperature. The sample from each step was carried out for the physical performance test such as DSC-OIT, FTIR, tensile strength and elongation. Note that it should be kept in mind that the Polypropylene-insulated cable is the first prototype. The performance improvement is still in progress.

Table 3. Samples of thermal aging test



Results

The results of thermal aging test are interesting. DSC-OIT results with aging time, the initial oxidation induction time is excellent, but the slope is greater decrease due to degradation after 30 day (Fig. 7). FTIR results show that the degradation has progressed. That is, the decrease of carbonyl peak and the increase of terminal vinyl mean the degradation of insulation (Fig. 8). The results of mechanical performance test, the tensile strength of PP, XLPE was no change, but elongation of Polypropylene was a little lower than XLPE's (Fig. 9).



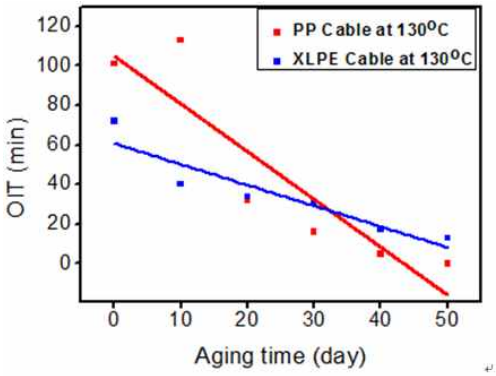


Fig. 7 Results of DSC-OIT

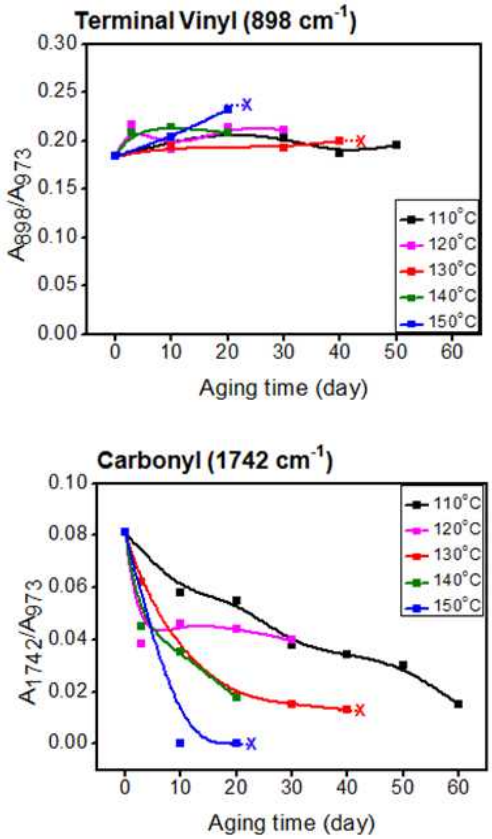
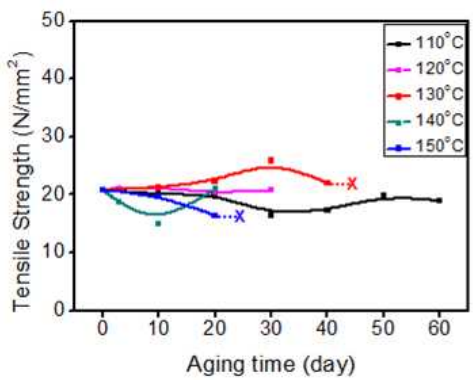


Fig. 8 Results of FTIR



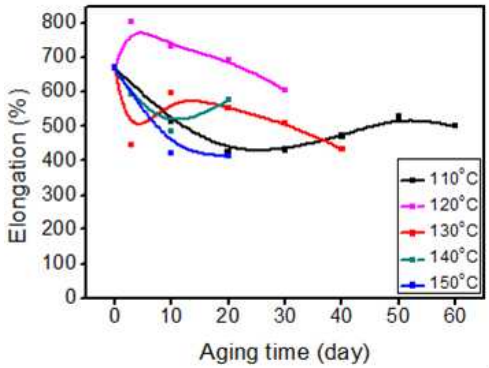


Fig. 9 Results of mechanical test

CONCLUSION

The first compatibility test with joints, despite the severe condition (150 degrees), the electrical performance was good. However the sample can be seen the fact that degradation proceeds as compared to the new one. In thermal aging test, the temperature increases and the longer the time, the physical performance of it was reduced dramatically. In particular, it is necessary to review that decrease of the physical properties of polypropylene at 130 degree. There is in progress for the electrical performance test using Mckeown electrode after thermal aging test. KEPCO should take into account all the electrical and physical characteristics to determine the emergency operating temperature.

REFERENCES

[1] "Impact of Emergency Operating Temperatures on the Integrity of XLPE Transmission Cable Systems", EPRI, Palo Alto, CA: 2003.

[2] ANSI/ICEA S-94-649-2013, "Standard for Concentric Neutral Cables rated 5 through 46"

[3] IEEE Std. 404-2006, "Extruded and laminated Dielectric Shielded cable Joints Rated 2500V to 500000V"