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Indenting Test Result according to the Accelerated Aging Time Variation using Cable Indenting Mini-Robot

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1. Introduction

In the nuclear power plant, a lot of safety-related equipments including cables exist. All the safety-related equipment under the harsh environment should perform the equipment qualification (EQ) and condition monitoring until the end of the qualification life according to the IEEE std 323 [1]. Especially, condition monitoring of installed cables is very important job in order to extend qualified life of those cables. The monitoring program requires that the characteristics subject to aging deterioration be monitored at specific intervals and compared with specified acceptance criteria. The acceptance criteria shall be based on post-age-conditioning characteristics for the qualified cable [2]. According to the Regulatory Guide 1.211 published in NRC, condition monitoring programs may include any appropriate technique, supplemented with walkdowns to look for visible signs of anomalies attributable to aging with particular emphasis on the identification of localized adverse environments or “hot spots” [3]. This paper introduces indenting test method using cable indenting mini-robot, one of the cable condition monitoring methods, and shows the test result according to the accelerated aging time variation.

2. Test Method

Recent few years, KEPRI has developed several types of indenting equipment which is a PDA equipped portable cable indenter [4], multiple cable indenting equipment and cable indenting mini-robot [5]. In this section, test equipment and method using cable indenting mini-robot will be described.

2.1 Cable Indenting Mini-Robot

This cable indenting mini-robot was developed for indenting test while moving automatically through the cable in the cable tray. As that reason, we focus on designing small-sized and light-weight robot. The robot system consists of main robot, control board and data acquisition PC. Battery which supplies electricity to the robot is located in the control board. The main robot is composed of actuation module which move the robot through the test cable and inspection module which perform indenting test.

Actuation module can move and stop through the test cable by DC motor and photo interrupt sensor. Inspection module is composed of force sensor, anvil, servo motor and gear. As a force sensor which is most important part in this robot, we used FSS1500NSB model made in Honeywell. Due to lowness of force sensor signal, we amplified the signal and calibrated zero-point and span.

In order to fix on the test cable, we designed tweezers-shaped fixing module which contain the coil spring, torsion spring and ball caster. The ball caster located in clamping surface presses the cable surface when indenting test, and helps the main robot to move on the test cable. Figure 2 show the shape of the main robot fixed on the cable in the cable tray.

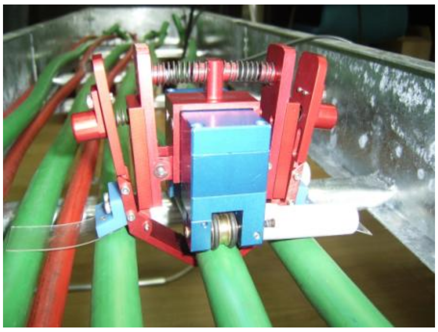

Fig. 1. Shape of the Main Robot Fixed on the Cable

2.2 Test Method using Cable Indenting Mini-Robot

Generally, when several times indenting tests are performed, the results of indenting test have a variance of test data. So we determine the representative value of test data with statistics after performing more than 20 times indenting test according to the procedure showed in Fig. 2. Once fixing the robot on the installed cable, the robot performs indenting test automatically moving through the installed cable. If the test result is abnormal, the test data will be deleted by abnormal data detection algorithm. After acquiring 20 test data, the robot determine representative value and evaluate degradation level of the tested cable comparing with unique database of that cable.

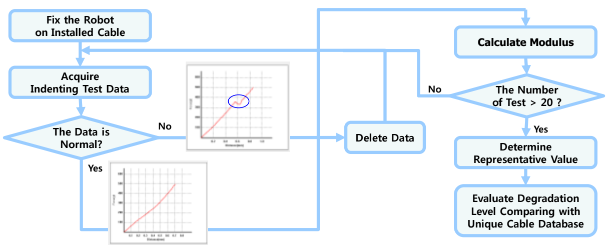

Fig. 2. Procedure for Indenting Test

If evaluated degradation level of tested cable is better than the degradation level after qualified lifetime, the test cable will be able to be used. Otherwise, the tested cable shall be replaced with new cable.

3. Test Result

3.1 Test Specimen Preparation

We prepared 5 test specimens which were accelerated aged or not aged. The material of cable jacket is CSPE (Chlorosulfonated Polyethylene) and the material of cable insulation is EPR (Ethylene Propylene Rubber). Each specimen divided with a 30 cm interval. One specimen was not aged, and four specimens were accelerated aged. The temperature of accelerated aging was 145 ℃, and the durations of accelerated aging were 336, 504, 672, 840 hours respectively. The 5 Test specimens are shown in Fig. 3.

Fig. 3. Test Specimens

3.2 Indenting Test using Cable Indenting Mini-Robot

The robot was fixed in test specimen cable. Because the specimens were in laboratory, not in nuclear power plant, and length of the specimen was 30 cm, we performed the indenting test respectively, not in cable tray. The robot performed indenting test more than 20 times per each specimen, moving through the cable automatically. It took 20 seconds that one indenting test was performed. Fig. 4. shows how to perform indenting test.

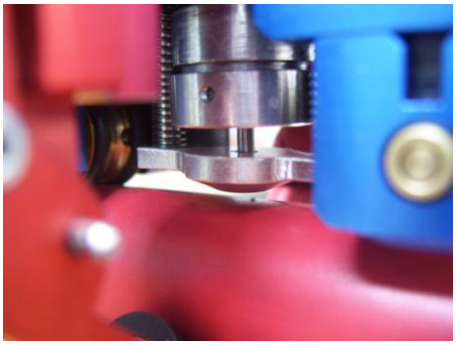

Fig. 4. Performing indenting test fixed in cable

3.3 Test Result of Indenting Test

We acquired 100 data, 20 data per each specimen. The graph that draws all test data is in Fig. 5. The graph shows that the modulus values increase linearly accordint to the accelerated aging time. It means that the hardness of cable jacket increases as time goes by. The reason for large variance in 840 hours accelerated aging specimen is that the stiffer cable jacket, the shorter indenting depth.

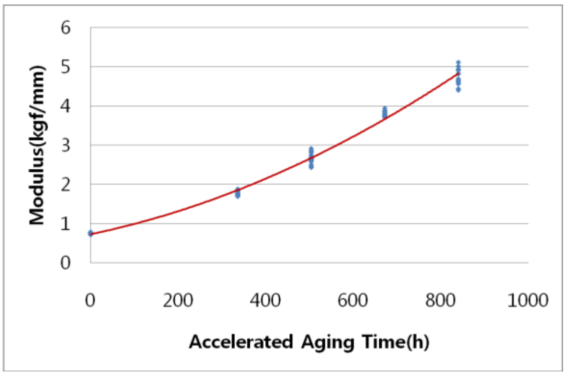

Fig. 5. Modulus according to the accelerated Aging Time Variation

4. Conclusions

For condition monitoring of cables installed in cable tray, we used indenting test method using cable indenting mini-robot which is already developed in KEPRI. To confirm the performance of the cable indenting mini-robot, we prepared 5 test specimens which were 1 un-aged specimen and 4 accelerated aged specimens. The test result shows that the modulus of cable jacket increases linearly as the accelerated aging time increases. It means that if indenting test data, after qualified lifetime goes by, is better than the indenting test data acquired before DBE test in EQ type test, the tested cables can extend their life.

REFERENCES

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