Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2009

Development of Cable Indenting Mini-Robot and Aynalzing Method

Kyung-Nam Jang, Jong-Soeg Kim, Sun-Chul Jeong, Kyung-Heum Park
Research Institute of Korea Electric Power Corporation
103-16 Munji-dong, Yuseong-gu, Daejon, Korea
jkn@kepri.re.kr

1. Introduction

There are a lot of cables in the nuclear power plant. The cables, especially inside containment, are exposed in the harsh environment. Those cables may be aged more rapidly due to the high temperature and radiation, and the life time of them may be shorter than other cables in mild environment. If the life time of the cables in the harsh environment is expired due to the rapid aging, those cables should be replaced immediately. On the contrary, the condition inside containment may be less harsh than designed condition. In this case, we can extend the life time of the cable by using Arrhenius equation. For the replacement in the appropriate time before the end of life time or life extension of cable in less harsh environment, we should perform the frequent condition monitoring of the cable. Among the many method of condition monitoring, we used the indenting method which can measure the hardness of the cable jacket because this method is non-destructive, need short test time and small equipment. In 1991, EPRI developed the first cable indenter which can measure the hardness of the cable jacket[1]. In 2001, KEPRI developed computer equipped cable indenter which uses same methodology of EPRI[2]. These devices are very convenient for condition monitoring of nuclear cables, but have large variance of test data. From this reason, the test data from once or twice test cannot represent aging condition of the cable. In order to acquire a lot of test data quickly, we developed indenting robot moving automatically through the cable. And we propose the methodology that can evaluate the representative value from the acquired test data with statistics.

2. Development of Cable Indenting Mini-Robot

We focus on designing small-sized and light-weight robot, because the robot should be on the cable, and move though the cable. So, we separate the main robot and control system. 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. Figure 1 shows the schematic diagram of robot system. PC can control the main robot and get the result data of indenting test with USB-to-Serial communication.

2.1 Shape of the main robot

The main robot is composed of actuation module which move the robot through the test cable and inspection module which perform indenting test.

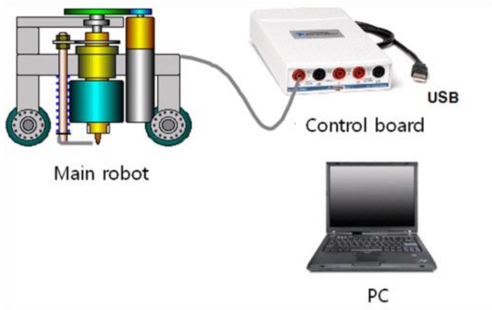

Fig. 1. Schematic Diagram of Robot System

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.

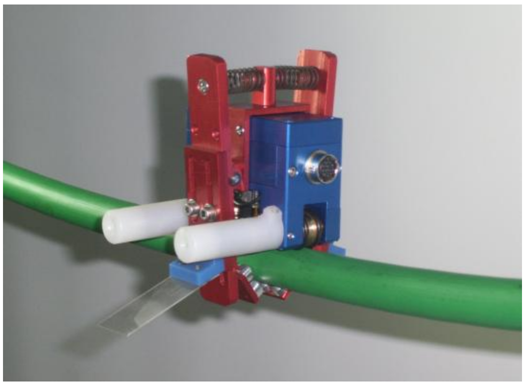

Fig. 2. Shape of the Main Robot Fixed on the Cable

2.2 Control System of the Cable Indenting Mini-Robot

Figure 3 shows the schematic diagram of control system of the cable indenting mini-robot. The control board contains main controller(ATMEGA128/ATMEL), digital and analog I/O port, RTC(Real Time Clock) module, motion controller and two motor drivers.

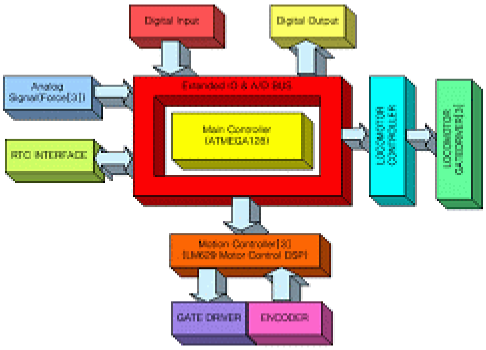

Fig. 3. Schematic Diagram of Control System

3. Analyzing Method of Test Data

3.1 Indenting Test Results Measured by Cable Indenting Mini-Robot

We performed 60 times indenting test using cable indenting mini-robot. The Histogram of test result is shown in figure 4. The average value of measured modulus is 867.8 gf/mm, and standard variation is 34.96. In the graph, there is an outlier data which is away from the average or median value. We wanted to exempt the outlier data by analyzing in order to evaluate representative value.

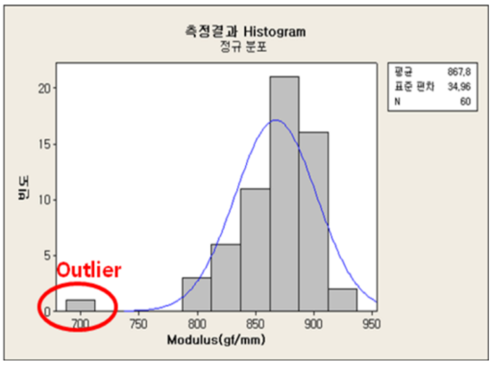

Fig. 4. Histogram of Test Result

3.2 Analyzing Method of Test Data

We used the quartile value as statistics method. In descriptive statistics, a quartile is any of the three values which divide the sorted data set into four equal parts, so that each part represents one fourth of the sampled population. Interquartile range(IQR) is equal to the difference between the third and first quartiles. We decided the outlier which is over 1.5 times IRQ plus third quartile and below 1.5 times IRQ minus first quartile. In the test result data, we extracted only one data as an outlier. The box plot shows quartiles and outlier easily.

After exemption of outlier, we should decide representative value among the test data. We selected the average value among the test result data except outlier. So, the representative value of measured modulus is 870.4 gf/mm.

If we should evaluate the degradation level of the cable installed in NPP, we should perform the aging evaluation process which is shown in figure 5. If we have indenting test database of test cable, we can evaluate the degradation level in 10 minute.

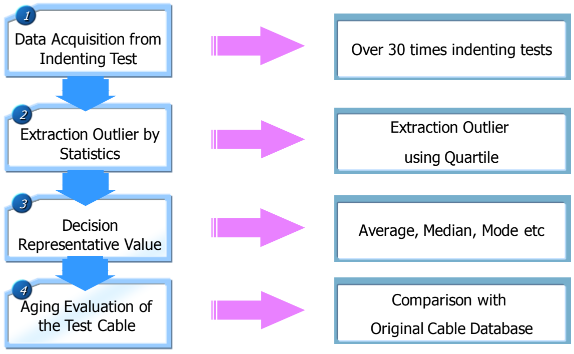

Fig. 5. Aging Evaluation Process of Cable

4. Conclusions

Indenting test data which is acquired from an existing cable indenter have large variance. In order to reduce the variance of test data, we developed the cable indenting mini-robot which can move automatically through the cable. The robot was designed as a small-size and light-weight robot. The test result shows that the variance of test result data was reduced. In order to exempt outlier among the test data, we proposed the methodology using quartile value. After that we could evaluate the representative value except outlier data. If we use cable indenting mini-robot which we developed and indenting test database of test cable, we can evaluate the degradation level of the cable installed in NPP within 10 minute.

REFERENCES

[1] EPRI, 'Cable Indenter Aging Monitor', EPRI NP-7348, 1991
[2] Jong-Seog Kim, 'Evaluation of cable life based on condition monitoring', 01 fall meeting of Korean nuclear society, 2001