Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Study of Relational Equation between Indent and Elongation For Cable Aging Evaluation

Jong-Seog Kim,[a]
Research Institute of Korea Electric Power Corporation
103-16 Munji-dong, Yuseong-gu, Daejon, Korea
HL5JAA@kepri.re.kr

1. Introduction

Attempts to extend the lifetime of NPP have become one of the major concerns in the world nuclear industry. Consequently, life evaluation and lifetime management of cable to survive over 40 years has become major topic of discussion. For the life extension of nuclear power plant, two kinds of actions are required in accordance with regulatory rule of plant life extension. One is TLAA(time limited aging analysis) and the other one is AMP(aging management program). TLAA is an evaluation of residual life to insure the survival during the extended period. AMP is a monitoring of aging degradation to insure that aging degradation does not go beyond the allowable limit during extended period.

For the life evaluation of cable, break-elongation test of ASTM D412 has been widely used. Since dumbbell specimen for break-elongation test has to be supplied from plant cable, it is not easy to apply this method to operating plant. One of alternatives is indent test which nondestructively measures the aging of cable jacket. Because indent test has no approved standard, we have to compare the test result with that of break-elongation test. Since two kinds of tests for one aging evaluation are time consuming, we decided to develop relational equation between elongation and indent which can deliver relative elongation value from indent data. Relational equation between elongation and indent based on the actual test results of CSP and CR cable jacket is described herein.

2. Methods and Results

2.1 Test Method

2.1.1 Accelerated Aging

Electric ovens with air circulating fans were used for accelerated aging of cables. Dumbbell specimens for elongation test and 100mm long cables for indent test were prepared for accelerated aging during 48hours, 72hours, 96hours, 168hours and 164hours at the temperatures of 116℃, 126℃, 136℃ and 146℃. Specimens were air cooled for 24 hours after finishing the accelerated aging

2.1.2 Break-Elongation Test

Break-elongation test is destructive aging evaluation method which measures the elongation length after elongates aged dumbbell specimens until they are broken. Dumbbell specimens were prepared in accordance with ASTM D412 'Die C' dimension as shown on figure 1. We kept the speed of 500±50mm/min during break-elongation test.

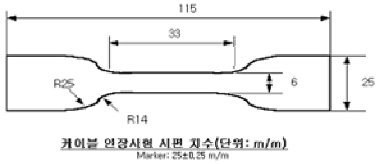

Figure 1. Standard figure of elongation specimen

2.1.3 Indent Test

Indent test is nondestructive aging evaluation method which measures the hardness of cable by pressing a cable surface with steel probe at the vertical direction. Portable cable indenter was used for this test. 2mm round bar and 0.56mm edge of truncated con type probe was used for indenting. Dimension of indent probe is shown on figure 2. Pressing load was limited to $0.5kg_f$ to protect damage of cable jacket. Indent depth didn't go over 0.7mm for all of cable specimens.

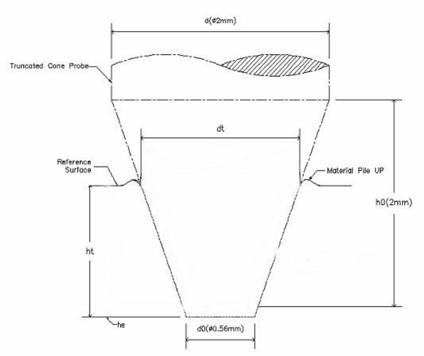

Figure 2. Figure of truncated cone probe

2.2 Test Result

2.2.1 Relation between elongation and indent data

As result of experiment, it was found that elongation and indent data have proportional relation. Figure 3 and figure 4 show relationship between elongation rate and indent modulus for CSP and CR cables aged at 116℃, 126℃, 136℃ and 146℃ during 48, 72, 77, 88, 93, 94, 96, 168, 264, 312 hours. Figure5 and figure6 show relationship between elongation length and indent depth. Relational equations between elongation and indent are described as equation (1) ~ (4)

$$e/e_0 = 3.9E^6(P/d_t)^{-2.5} \text{ for CSP cable} \quad (1)$$

$$e/e_0 = 2.2E^6(P/d_t)^{-2.14} \text{ for CR Cable} \quad (2)$$

$$e = 310\ (h_t)^{2.57} \text{ for CSP cable} \quad (3)$$

$$e = 520\ (h_t)^{1.96} \text{ for CR cable} \quad (4)$$

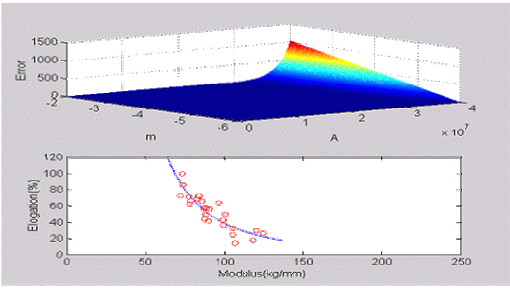

Figure 3. Relation between elongation rate and indent modulus for CSP cable

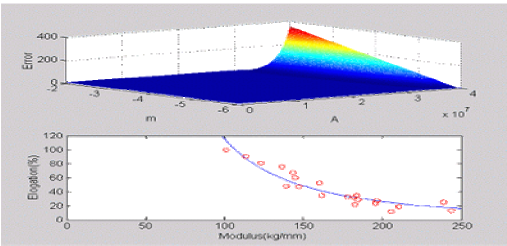

Figure 4. Relation between elongation rate and indent modulus for CR cable

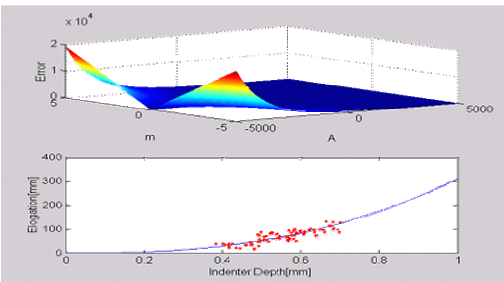

Figure 5. Relation between elongation and indent depth for CSP cable

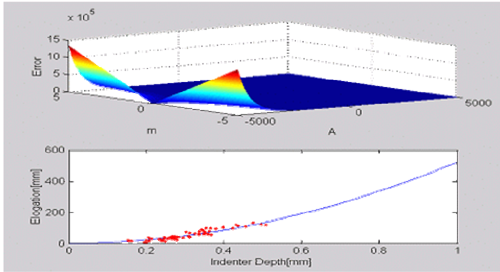

Figure 6. Relation between elongation and indent depth for CR cable

2.2.2 Review of test result

After making the general equation between elongation and indent, we analyze the deviation between actual data and equation data. 14.6% average deviation for CSP cable and 10% average deviation for CR cable at the equation of elongation rate and indent modulus is observed. 9.2% average deviation for CSP cable and 7.9% average deviation for CR cable at the equation of elongation length and indent depth are observed. Equation for indent depth and elongation length had better accuracy than that for indent modulus and elongation rate.

3. Conclusion

Repeated calculations were performed to deliver equations between the elongation and the indent based on actual cable aging data of elongation and indent. Some relational equations between elongation and indent were obtained but coefficients in the equation were different according to the material type. Good convergence was observed when indent depth was used as equation factor instead of indenting modulus. It was verified that elongation data can be delivered by indent data if we had enough amount of experiment result for various material type.

REFERENCES

[1] IAEA, 'Assessment and management of ageing of major nuclear power plant components important to safety', IAEA-TEDOC-1188, 2000

[2] EPRI, 'Cable Indenter Aging Monitor', EPRI NP-7348, 1991

[3] Jong-Seog Kim, 'Evaluation of cable life based on condition monitoring', 01 fall meeting of Korean nuclear society, 2001

[4] Jong-Seog Kim, 'Evaluation of Nuclear Plant Cable Aging through Condition Monitoring', Journal of Korean Nuclear Society, Volume 36, Number 5, pp 475-484, 2004