Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Application of Indenting Method for Calculation of Activation Energy

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

1. Introduction

For the calculation of activation energy of cable materials, we used to apply the break-elongation test in accordance with ASTM D412(Stand Test Methods for Rubber Properties in Tension)[1]. For the cable jacket and insulation which have regular thickness, break-elongation test had been preferred since it showed linear character in the activation energy curve. But, for the cable which has irregular thickness or rugged surface of cable inside, break-elongation test show scattered data which can not be used for the calculation of activation energy. It is not easy to prepare break-elongation specimen for the cable smaller than 13mm diameter in accordance with ASTM D412. In the cases of above, we sometime use TGA method which heat the specimen from 50℃ to 700℃ at heating rates of 10, 15, 20℃/min. But, TGA is suspected for the representative of natural aging in the plant since it measure the weight decreasing rate during burning which may have different aging mechanism with that of natural aging. To solve above problems, we investigated alternatives such as indenter test. Indenter test is very convenient since it does not ask for a special test specimen as the break-elongation test does. Regular surface of cable outside is the only requirement of indenter test. Experience of activation energy calculation by using the indenter test is described herein.

2. Methods and Results

2.1 Principle of Cable Indenting

Cables exposed to a harsh environment in a nuclear power plant tend to show signs of aging degradation. One of these symptoms is the hardening of the cable jacket and insulation[2]. KEPRI developed PDA equipped cable indenter. This device is very convenient tool for condition monitoring of cables since it use a non-destructive method for diagnosing the extent of cable aging. Modulus value, the aging level of cable jacket, is calculated by dividing the indenting force with the indent depth[3]. Figure 1 shows a picture of a portable cable indenter developed by KEPRI. Figure 2 shows indenting figure of the cable indenter[4].

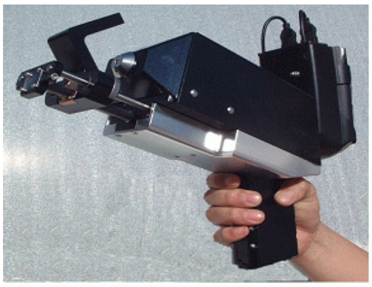

Figure 1. Portable Cable Indenter

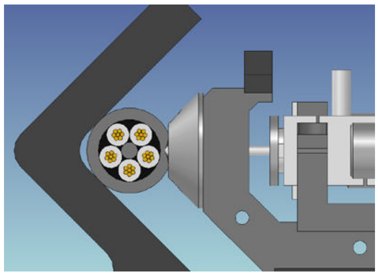

Figure 2. Indenting Figure of Cable Indenter

2.2 Indenter Test result for Cable Jacket

2.2.1 Cable information

Two cable jackets were selected for indenter test. CSP cable jacket is soft and CR cable jacket is relatively hard compared with CSP cable jacket. Manufacture information of test specimens are shown on the table 1.

Table 1. Manufacture information of test specimens

Name	Figure	Manufacturer information
CSP	Green, 5cores	051QLBN8 600V EPR/CSP 5CX10AWG TAIHAN 1995 Class 1E
CR	Black, 9corea	0914LRN8 600V EPR/CR 9CX14AWG TAIHAN 1997

2.2.2 Comparison of activation energy between break-elongation and indenter test

We calculated the activation energy of CSP and CR cable jacket by using break-elongation and indenter test. To investigate the variation of activation energy according to the selected data point, every 5% elongation decrement points in the break-elongation and every 5% modulus increment in the indenter were selected instead of selecting data at 50% break-elongation rate. Figure 1 and figure2 show the activation energies of CSP and CR cables calculated by break-elongation and indenter.

For the CSP cable, we found that activation energy at 50% break-elongation decreasing rate showed 0.885ev and 0.962 ~ 0.945ev were showed at indenter modulus increasing rate of 15% ~ 25%. The value of indenter modulus showed 1.08 times of break-elongation. For the CR cable, activation energy at 50% break-elongation rate showed 0.973ev while 0.8 ~ 0.809ev were showed at indenter modulus increasing rate of 30% ~ 40%. The value of indenter modulus showed 1.01 times of break-elongation.

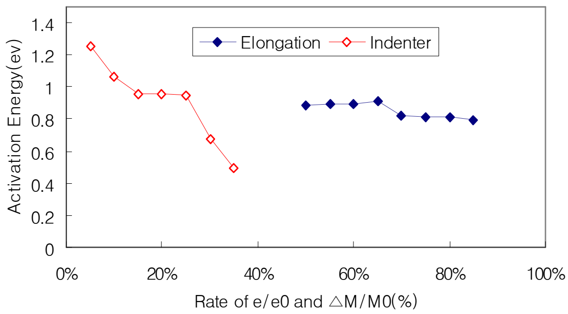

Figure 1. Activation energy of elongation and indenter for CSP cable

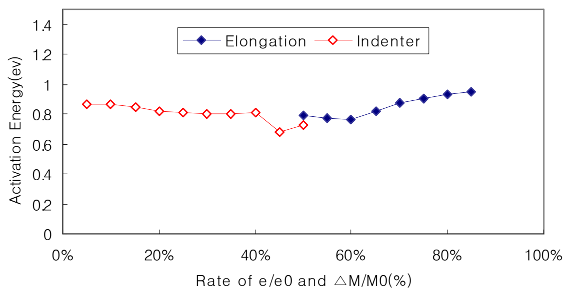

Figure 2. Activation energy of elongation and indenter for CSP cable

Table 1. Activation energy of break-elongation and indenter(ev)

Rate(%)	CSP Cable		CR Cable	
	Elongation	Indenter	Elongation	Indenter
5		1.257		0.871
10		1.068		0.871
15		0.962		0.848
20		0.959		0.822
25		0.945		0.810
30		0.676		0.804
35		0.496		0.800
40				0.809
45				0.681
50	0.885		0.793	0.728
55	0.897		0.777	
60	0.896		0.761	
65	0.912		0.824	
70	0.820		0.876	
75	0.812		0.908	
80	0.808		0.936	
85	0.793		0.946	

3. Conclusion

We have calculated activation energy of CSP and CR cables by using indenter test data. Activation energies of indenter were compared with that of break-elongation test. For the CSP cable, activation energies of indenter had a relatively large deviation compared with that of break-elongation. For the CR cable, activation energies of indenter showed similar character with that of break-elongation. For the indenter modulus data, CR cable showed relatively steady activation energy according to increasing rate of 30% ~ 40% while CSP cable showed irregular character in every region. We concluded that indenter method is applicable for the calculation of activation energy of CR cable or similar hard cable.

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