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

Nondestructive Method Evaluating Aging of Cable in Nuclear Power Plants by Ultrasonic Wave

Hyunsub Kim, Changdae Park, Chisung Song
Energy System Research Center, Korea Institute of Machinery & Materials, 171 jang-dong, Yuseong-gu Daejeon,
samak@kimm.re.kr

1. Introduction

Several cables which are used in nuclear power plants(NPP) have been used for the supply of electric power, control of electric signal, etc. Safety-related cables must be qualified to perform their function under specified service NPP condition and design basis event(DBE) condition. The most common traditional method for determining the condition of cable materials is the measurement of the ultimate tensile elongation. Unfortunately, the elongation measurements are considered to be destructive and they require a complex and expensive operation therefore, it is necessary to develop the nondestructive evaluation method of these cables for the deterioration and lifetime estimation.

The nondestructive testing and evaluation (NDT and NDE) of cable materials commonly involve the use of ultrasonic waves. In this study, we have investigated the correlation between the ultrasonic wave propagation velocity and degradation degree of aged cable materials.

Test cables are aged several hours at isothermal conditions in electric heating chamber and tested destructively by the procedure of ASTM D412 for measuring the Elongation At Breaking point(EAB). In the acoustic experiments using ultrasonic wave, the propagation velocity of ultrasonic wave throughout the specimen cable jacket are measured.

2. Theoretical Background and Experimental Methods

2.1 Theoretical equations of wave propagation velocity

In general, the propagation velocity of ultrasonic wave throughout the solid material is dependant on the density, poisson's ratio, temperature and elastic modulus, etc. Longitudinal(V_L) and shear(V_T) wave velocity equations are as follows, respectively[2].

$$V_L = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}} \quad (1)$$

$$V_T = \sqrt{\frac{E}{2\rho(1+\nu)}} \quad (2)$$

where E is the Young's modulus, ρ is a density and ν is a poisson's ratio.

In this study, the longitudinal wave velocity is used to estimate the degradation degree of aged cables. Since the physical properties such as hardness, modulli, and density of cables are changed according to the aging degree of cable, the ultrasonic wave propagation velocity throughout the aged cable is changed as the equation (1). The correlation of ultrasonic wave propagation velocity with the degradation degree of cables can be obtained.

2.2 Experimental setup for measuring the ultrasonic wave

CSP and CR cable are used for these experiments. It is measured that velocity changes of ultrasonic wave is due to the properties change of aged cable. The experimental configuration for measuring the propagation velocity through the aged cable is shown in Figure 1.

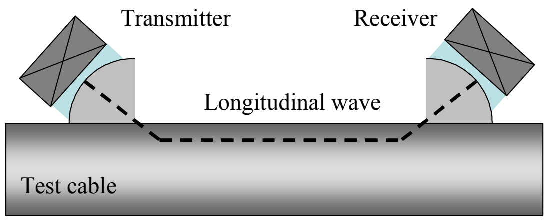

Figure 1. Experimental setup of ultrasonic wave

An ultrasonic wave pulse is transmitted from the left sensor and received at the right sensor by the Panametrics 5073PR pulser/receiver. The ultrasonic waveforms are recorded as digital data into a personal computer via a Tektronix 3032B. Measurements were made by the ultrasonic echo-pulse procedure using calibration marks of time. The frequency of the sounding signal is 1 MHz.

2.3 Tensile tests

For the comparison with the acoustic experiment stated in the previous section, EAB test are performed.

The procedures for tensile testing of the cable followed essentially the procedures of ASTM D412. Tensile testing generally involved the determination of three quantities: modulus, tensile strength, and elongation-at-break(EAB). The tensile experimental device(KSU-05M) was equipped with a data storage to record the load-cell output. For each sample, identically aged cables were tested, with the number of observations adjusted in an attempt to bring the 95% confidence interval for the mean failure elongation to within 10% of the mean [1].

3. Results and Discussion

Typical results of EAB test are shown in Figure 2 and 3 where the elongation and breaking strength are, respectively, plotted with aging time.

Figure 2 and 3 show that the elongation and breaking strength at the cables are in inverse proportion to the aging time. As cable materials degrade with time, their tensile elongation and breaking strength tend to drop clearly, resulting from being harder and more inflexible with aging time. Therefore, the wave propagation velocity throughout the cable jacket is expected to be changed by these tendencies.

Figure 4 shows the wave velocity propagating through the jacket material of the cables with respect to aging time from 0 year(intact specimen) to 60 years. This result shows that the wave propagation velocity monotonously increases with increasing of aging time of cables.

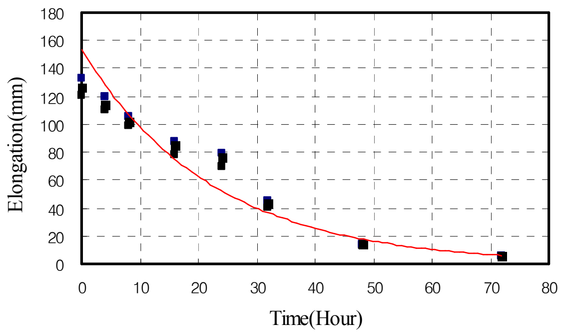

Figure 2. Variation of elongation with the aging time.

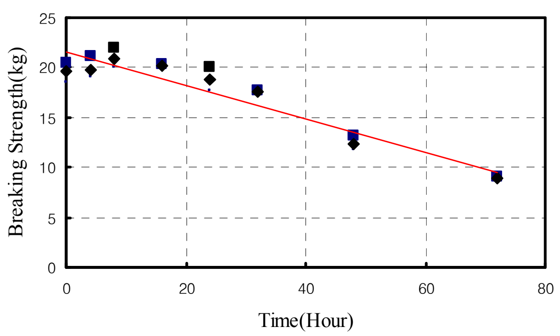

Figure 3. Variation of breaking strength with the aging time.

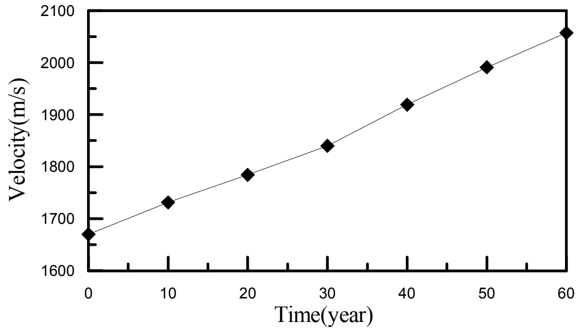

Figure 4. Propagation velocity of ultrasonic wave versus the aging time of test cables

4. Conclusion

This study considered the nondestructive evaluation method of cable materials used in NPP by ultrasonic wave and examined the correlation between the wave propagation velocity and the degradation degree of the cable.

As cable materials degrade with aging time, their elongation and breaking strength decrease increasingly, resulting from the physical properties changes.

It is found that the propagation velocity of ultrasonic wave increase according to the increase of the aging time of cables.

REFERENCES

[1] EPRI NP-4997, Natural versus artificial aging of nuclear power plant components, Interim report, 1986.
[2] J. L. Rose, Ultrasonic waves in solid media, Cambridge : Combridge University Press, 1999.
[3] J. V. Gasa, Z. Liu, M. T. Shaw, Relationship density and elongation-at-break of naturally and artificially aged cable materials used in nuclear power plants, Polymer Degradation and Stability 87, pp.77-85, 2005.
[4] Kenneth T. Gillen, Roger Assink, R. Bernstein, M. Celina, Condition monitoring methods applied to degradation of chlorosulfonated polyethylene cable jacketing materials, Polymer Degradation and Stability 91, pp.1273-1288, 2006.
[5] American Society for Testing and Materials, Standard Test Methods for Rubber Properties in Tension, ASTM D412, 1983.