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Nondestructive Aging Evaluation of Hypalon Cable Using Ultrasonic Propagation Time

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1. Introduction

The traditional method for determining the aging condition of cable material is the measurement of the ultimate tensile elongation. The elongation measurement method is destructive. It takes a long time and many efforts. For the assessment of cable aging condition in an operating NPP, it is necessary to develop the nondestructive evaluation method [1].

The density of a cable material varies with polymer curing and the cable aging time. The ultrasonic propagation time is affected by its density [2]. It is known that the evaluation of cable aging can be evaluated by ultrasonic propagation time. In this study, we have investigated the correlation between the ultrasonic propagation time and aging time of cable materials.

2. Theoretical Background and Experimental Methods

2.1 The character of hypalon cable

Polymeric materials combined with a number of additives and fillers are used in electrical cables. The commonly used jacket materials are hypalon, silicone rubber, polyimide and polychloroprene [3]. We identified this polymeric material by Fourier Transform Infrared Spectroscopy (FTIR). FTIR uses an infrared radiation beam to modulate the wave length of light of an IR beam shot through the sample. The beam can also be reflected spectrum to a database of thousands compounds. Figure 1 shows the FTIR graph of hypalon cable jacket.

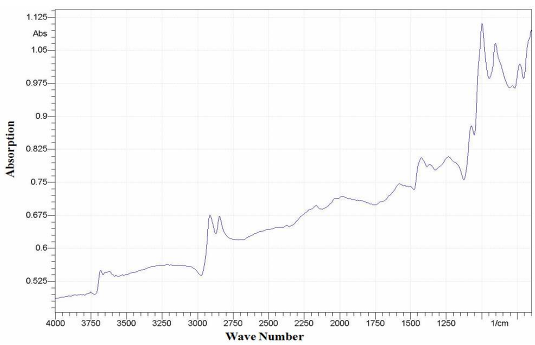

Fig. 1. FT-IR Graph of Hypalon Cable Jacket

Hypalon is widely used in industrial and automotive applications. Its activation energy calculated by TGA is 0.86eV as shown on figure 2.

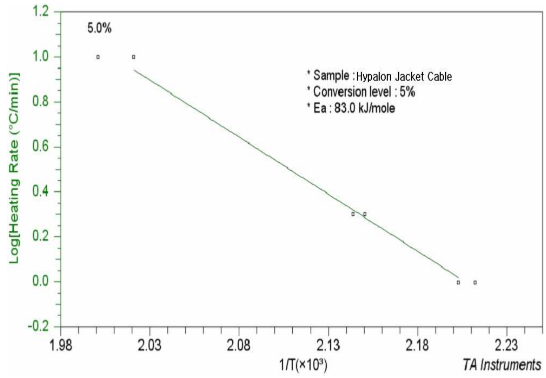

Fig. 2. Activation Energy of Hypalon Cable Jacket

2.2 Theoretical method of ultrasonic cable performance tester

The propagation velocity of ultrasonic wave throughout the solid material is dependent on the density, poisson's ratio, temperature and elastic modulus, etc. Longitudinal (V) wave velocity equation is as follows [4].

$$V = [(E/\rho)\times(1-\nu)/(1+\nu)(1-2\nu)]^{1/2} \quad (1)$$

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

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 propagation time with the degradation degree of cables can be obtained by this equation.

2.3 Experimental setup for measuring the ultrasonic propagation time

Hypalon cables are used for these experiments. It is found that the propagation time changes of ultrasonic wave came from the density changes of aged cable. The experimental configuration for measuring the propagation time through the aged cable is shown in Figure 3.

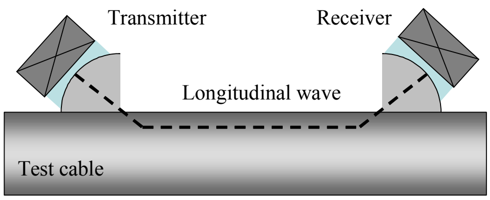

Fig. 3. Experimental setup of ultrasonic wave

The experimental device of Mitsubishi cable industries limited was used. The ultrasonic propagation time measurement was made as shown on figure 4. The frequency of the sounding signal is 1 MHz.

Fig. 4. Ultrasonic Cable Performance Tester.

3. Results and Discussion

It is confirmed that mechanical properties of cable material such as density and ultrasonic propagation time varied according to the aging time. Several studies showed that the activation energy and degradation rate vary with the composition of the cable material and with the temperature. Test cables are aged several hours at isothermal condition in electric heating oven and TID radiation at radiation facility.

The ultrasonic propagation times of ultrasonic wave based on the cable aging time are measured. Test results of ultrasonic cable performance tester are shown on table 1 and figure 5. The ultrasonic propagation time is plotted based on aging time. Figure 5 shows the ultrasonic propagation time of ultrasonic cable performance tester through the jacket material of the cables with respect to aging life from 0 year to 100 years. As cable materials degrade with aging time, their ultrasonic propagation time tends to decrease.

Table 1. Ultrasonic Propagation Time of sequence measurement

Aging	Order of Measurement (㎲)				
Life(yrs)	1st	2nd	3rd	4th	5th
0	15.49	15.54	15.54	15.47	15.55
20	15.53	15.52	15.41	15.46	15.44
40	15.36	15.41	15.36	15.37	15.39
60	15.26	15.26	15.29	15.31	15.27
80	15.13	15.18	15.18	15.15	15.12
100	15.04	15.08	15.08	15.07	15.09

It is found that ultrasonic propagation time has relation of linear equation with aging time as this equation (2).

$$y = -0.0047x + 15.547 \qquad (2)$$

where y is ultrasonic propagation time and x is aging life of hypalon cable jacket.

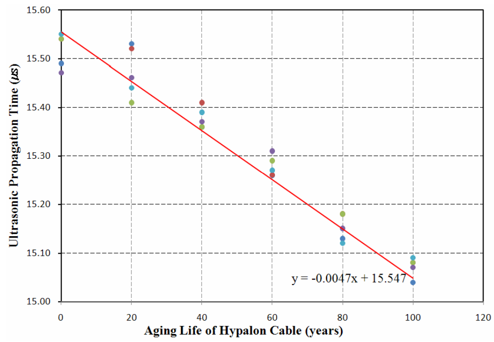

Fig. 5. Ultrasonic Propagation Time of ultrasonic cable performance tester.

4. Conclusions

The cable aging evaluation of hypalon cable jacket by using ultrasonic cable performance tester was implemented in the laboratory. It was noted that propagation time decreased according to the aging life increased. Since the decreasing rate had a linear character, a mathematical law of linear equation could be developed based on the result of this experiment.

It is confirmed that the method of ultrasonic propagation time can be useful to evaluate the aging condition of hypalon cable jacket.

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