Calculation of Activation Energy by OIT Method for aging evaluation of NPP cable

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1. Introduction

Extending the lifetime of nuclear power plant is one of the most important concerns in the world nuclear industry. Cables are one of the long live items which have not been considered to be replaced during the design life of NPP. In order to simulate the natural aging in nuclear power plant, a study on accelerated aging needs to be conducted and to carry out the accelerated aging test, we must calculate the activation energy of the cable if we don't have the activation energy information. The activation energy is the most important element and it can be calculated by indentor modulus and elongation data and so on. But there is often only a limited quantity of material available in the deposit for testing, so it is important the samples for any destructive test are conserved as much as possible. But if there is only a limited quantity of the material, OIT(Oxidation Induction Time) is very useful with calculating activation energy and evaluation of the cable lifetime.

2. Method and Result

2.1 Arrhenuis Model

Arrhenius equation is generally used as a physical model for making predictions on the lifetime in accelerated thermal aging. Heating for accelerated aging has to follow the monitoring result of plant environment to prove that accelerated aging equals natural aging. It is assumed that the rate of the thermal aging decrease in an inverse manner to the temperature, such that the rate constant "k" can be described as follows.

$$(\ln k = \ln A - Ea/RT)$$

where "A" is a constant for the material being tested, "Ea" is the activation energy for the process, "R" is the gas constant, "k" is the boltzman constant and "T(°K)" is the absolute temperature. A graph of the reaction rate on a log scale against "1/T" should show a straight line whose slope is determined by the activation energy "Ea". Activation energy controls the sensitivity of the degradation rate.

2.2 Theory of OIT test

OIT measurements use standard thermal analysis equipment, e.g DSC(Differential Scanning Calorimeter) to measure the onset of oxidation of a microsample exposed to flowing oxygen at a constant temperature. The OIT time shows a good correlation with ageing degradation in some cable materials. It is known that the effectiveness of the antioxidant depends on the temperature. In the condition monitoring of cable aging, OIT testing is particularly useful for materials like XLPE and PE, for which no confident results can be obtained from indenter or elongation measurements. OIT is a technique that can be used to evaluate aging of organic materials. OIT testing can be used as a evaluation of the cable lifetime technique for electric cable used in electric power plants, control, instrumentation, and power cables. Polymers age by means of chemical reactions with oxygen. Antioxidants are chemicals added to polymers in order to inhibit oxidative reactions. As long as antioxidants remain in an insulation polymer, the properties of the cable insulation do not degrade significantly. The OIT is related to the amount of antioxidant remaining in a polymer, and thus to the age, or remaining life, of the polymer. In an OIT test, a small sample of material is placed in a DSC and subjected to a constant temperature of approximately 180℃ to 220℃ in an oxygen atmosphere until a strong exothermic reaction occurs in the material. The strong exothermic reaction begins when the antioxidant is consumed. The period from the start of the test until the strong exothermic reaction begins is the OIT. This time is indicative of the amount of remaining life of the insulation material. The shorter the OIT, the closer is the material to its end of life. Figure 1 and figure 2 shows a picture of DSC(Differential scanning calorimeter) machine and sample cell & reference cell

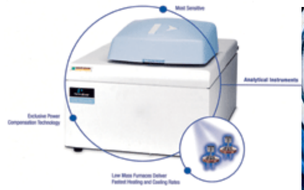

Figure 1. DSC

Figure 2. sample cell & reference cell

2.3 OIT test result of NPP cables

Figure 3 shows a general DSC graph of OIT measurement. Isothermal OIT time in the figure 4 is the data that we want to obtain through this experiment.

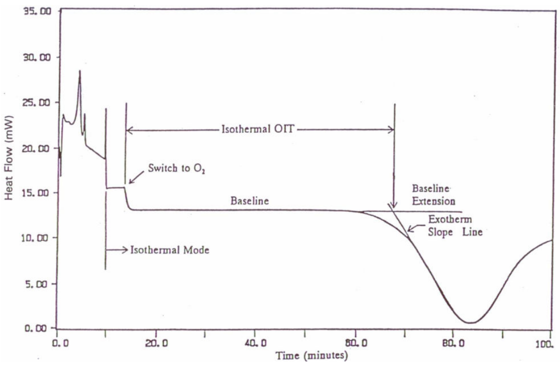

Figure 3. DSC thermogram of OIT measurement

Figure 4 and figure5 shows an OIT test result of XLPE insulation, CSP cable of NPP cable. XLPE insulation cable showed typical OIT graph and 11.3 minutes OIT time. And CSP cable showed typical OIT graph and 16.5 minutes OIT time

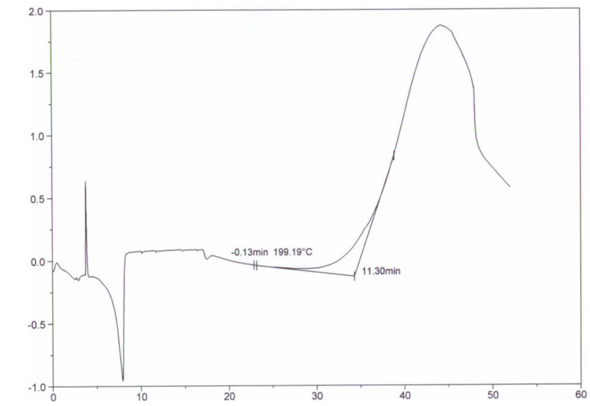

Figure 4. OIT test result of XLPE insulation cable

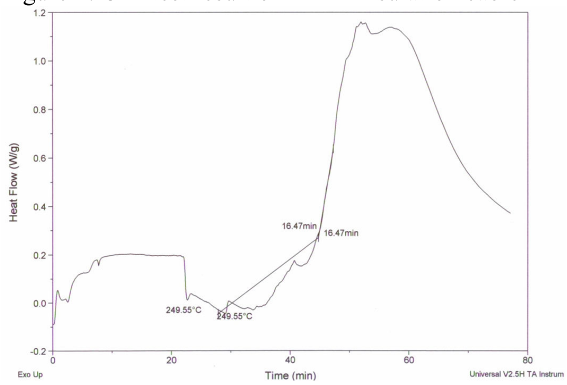

Figure 5. OIT testing of CSP cable in NPP

To calculate the activation enery of CSP cable, if we have 9 OIT test result at least. E.g three various accelerated aging temperature specimen and three various accelerated aging time specimen is needed.
For example, if we had 126℃, 136℃ and 146℃ accelerated aging carried out and 48hr, 196hr and 336hr accelerated aging time for each specimen, we can easily calculate the activation energy only if the material shows typical OIT graph and time.

3. Conclusion

When we use Oxidation Induction Time(OIT) for calculating activation energy and evaluation of the cable lifetime, the material must have typical OIT graph and OIT time. OIT test was implemented for the XLPE and CSP cables and they showed typical OIT graph and time. To calculate the activation energy of the cable, there must be at least 9 specimen for three various accelerated aging temperature and time. It was verified that the evaluation of XLPE and CSP cable life can be evaluated by using OIT Method. OIT testing is particularly useful for materials like XLPE and PE, for which no confident results can be obtained from indenter or elongation measurements.

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