Jicable 95

D.2.15. Modèle cinétique permettant d'évaluer la durée de vie des matériaux de câbles K1 en EPR-CSPE et K2 en PVC utilisés dans les centrales nucléaires.

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D.2.15. A practical model for the lifetime prediction of LOCA (EPDM-CSPE) and (PVC) cables in nuclear power stations

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Résumé

Les matériaux polymères entrant dans la composition des câbles électriques sont très utilisés dans le bâtiment réacteur des centrales nucléaires. En fonctionnement normal, ils subissent des contraintes thermiques (40°C) et radiatives (0,01 Gy/h) sur des périodes supérieures à 30 ans. A partir des résultats expérimentaux obtenus, un modèle cinétique basé sur la loi de DAKIN a été développé à EDF. Il s'exprime sous la forme d'une fonction de vieillissement décrivant la variation de l'allongement à la rupture en fonction du temps, de la température et du débit de dose, et permet par extrapolation, la prédiction de la durée de vie. L'objectif de cet article est de présenter une nouvelle expression du modèle cinétique construite sur le principe de superposition temps-température-débit de dose.
Nous avons appliqué ces deux modèles avec succès sur différents matériaux de câbles : deux élastomères, l'"éthylène propylène diène monomère (EPDM) et le polyéthylène chlorosulfoné (CSPE) et un thermoplastique : le polychlorure de vinyle (PVC).

Abstract

Polymeric materials are widely used as electrical cables inside building reactor of nuclear power plants. In their operating conditions, they are subjected to thermal (40°C) and radiation (0,01Gy/h) stresses for period up to 30 years. From experimental results, a kinetic model based on the Dakin's law have been developed at EDF. It yields an ageing function describing the changes in elongation at break versus time, temperature and dose rate and allowed extrapolated lifetime prediction. The aim of this paper is to present a new expression of the kinetic model based on the time-temperature-dose rate principle, and developed from the ageing function.
We have successfully applied this two models on three different cables materials, two elastomers, Etylene-Propylene Diene Monomer (EPDM) and Chlorosulfonated Polyethylene (CSPE) and a thermoplastic : Polyvinyl chloride (PVC).

INTRODUCTION

Cable in nuclear power stations must provide reliable service after decades of operation in hostile environment, involving stresses such as temperature and irradiation. In order to simulate long term behaviour, accelerated ageing in thermal and radiation conditions has been carried out. Material degradation is monitored by measuring the variation of a sensitive criterion of ageing.
In a previous paper **[1]**, a kinetic model relating the dependance of a sensitve property on temperature, dose rate and time was presented.
This present paper outlines the development of a new model based on the time-temperature-dose rate superposition deduced from the kinetic model **[1]**.
Examples of the application of the two models to three pratical materials used in electrical cables on the property of elongation at break are given.

1 - KINETIC MODEL EXPRESSIONS

1.1- Ageing function

In previous papers **[1] [2] [3]**, a method for predicting the long term behaviour of polymer materials in combined radiation plus thermal environment has been presented. The kinetic model developed expresses the dependancy of a property (P) with temperature (T), dose rate(I) and time (t). The « ageing function » of the property P can be described by the following equation :

$$\frac{P(t)}{P_0} = \left[1 + (\beta - 1) K_t(T,I).t\right]^{\frac{1}{1-\beta}} \qquad (1)$$

P(t) is the property value at t time, P_0 its initial value,
β is the overall order of the degradation process.

The rate constant $K_t(T,I)$ is expressed as the sum of a thermal and radiative contribution, that is :

$$K_t(T,I) = K_{th}(T) + K_{tr}(T,I) \qquad (2)$$

The thermal rate constant expression $K_{th}(T)$ follows an Arrhenius Law :

$$K_{th}(T) = k_{ot}.\exp\left[\frac{-E_a}{RT}\right] \qquad (3)$$

where k_{ot} and E_a are respectively the pre-exponential factor and the activation energy for the thermal ageing.

The radiative rate constant $K_{tr}(T,I)$ is given by the relationship :

$$K_{tr}(T,I) = k_{or}.I^{\alpha}.\exp\left[\frac{-E_a'}{RT}\right] \qquad (4)$$