DEVELOPMENT OF A DIAGNOSIS TECHNIQUE FOR ASSESSING THE PROPERTIES OF NUCLEAR AGED CABLES

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ABSTRACT

The ageing of insulating of electrical equipments installed in the French installations is studied by EDF R&D since many years. One of the research goals is to develop an experimental method allowing a better monitoring of in service cables state. The results of first investigations define NMR spectroscopy to be an useful tool for studying aged polymer cables. NMR leads to the estimation of the average number of monomer units between two cross-links. This information will be used in a mechanical approach, currently in development, which should provide the tensile curve of a given material from the description of its macromomolecular network.

KEYWORDS

Nuclear cables, polymer, diagnosis method, NMR.

INTRODUCTION

The ageing of electrical cables installed in the French installations is studied by EDF R&D since many years. One of the research goals is to develop an experimental tool or a method allowing a better monitoring of in service cables state. In particular, we are focussing on ageing of polymer materials constituting the jacket and the insulation of the electrical conductor. The ageing processes of a polymer linked to its exposure to different environmental factors such as irradiation or temperature are very diverse and complex. These days, any diagnosis technique is applied on site in the case of maintenance or lifetime prediction.

Among the ageing assessment methods, elongation at break test enables a link with the mechanical end-of-life criterion commonly used : an absolute value of 50% of elongation at break. But for that empirical purpose, the mechanical tests necessary for expertise are destructive and involve an on site sampling, what is not include in the EDF maintenance politic.

In literature, other type of test as Oxidation Induction Time (OIT) or density measurements [1] are presenting as alternative diagnosis technique because non destructive. Nevertheless until now, those approaches remain restricted because empirical. Indeed, such studies were limited to link the evolution of the elongation at break parameter to the evolution of another property (like OIT, density ...) under ageing conditions. This empirical approach permits the determination of abacus. But those abacuses are formula dependant, meaning the parameters are only valid for a given type of cable. This kind of approach is not industrially perennial because for each new cable generation, in case of obsolescence for example, new tests are needed to determine the new abacuses.

Considering all the listed points, EDF is not in favour of this set of empirical procedures.Moreover, our research approach is scientifically different since it is based on the understanding of molecular ageing mechanisms. The main idea being to demonstrate that it is necessary to develop a link between the molecular and the macromolecular description of polymer materials that enter in the composition of the cables: justification of properties observed at the macromolecular state passes via the understanding of mechanisms at the molecular scale.

For that purpose, in recent years EDF has developed a generic approach based on the understanding and kinetic modelling of polymer ageing by thermo and radio-oxidation [2][3]. From this model, we can have access to the physico-chemical description of the polymer under ageing conditions and obtain some information as the evolution function of time of density, oxidation products concentration, oxidized layer thickness, scission or reticulation chain rate.

The objective is now to link the output data of the kinetic model to the macroscopic end-of-life criterion (an absolute value of 50% of elongation at break of jacket or insulation cable). For that, we propose to use NMR experiment as a diagnosis technique. Indeed this technique permits the access to information at the macromolecular scale which is the intermediate scale between the molecular and macroscopic scales. Moreover, recent study has proven the feasibility of NMR applied to the cables of nuclear power plants. In the case of aged cables, NMR seems to be a good tool for studying the organisation in solid state of charged polymer-matrix systems and the mobility of polymer chains. This technique leads also to the characterization of the considered polymer material from a micro-sampling. Practically, estimation of the average number of monomer units between two cross-links will be obtained from the NMR experiment. This information will be used as input data for the mechanical modelling now under development in EDF R&D. At mid-term, the goal of this approach is to provide the tensile curve of a given material from the geometrical description of its macromolecular network (the more detailed description of this modulus is not the object of this paper but the reader can refer to the references [4] and [5]).

This article will give a summary of the main results derived from studies using NMR technique. In a first part, NMR results from a test model case will be presented. In particular, the accent will be done on the determination of the physical parameter useful as input data for the mechanical approach. Then, the first results of NMR experiment on formulated polymer samples are presented.