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UNDERSTANDING AND OPTIMIZATION OF LONG TERM AGEING IN CABLE INDUSTRY

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ABSTRACT

In this paper we present an approach to new and improved methods to understand the ageing of polymer materials used in cables in order to be able to better predict their lifetime. EPDM compounds (filled and unfilled) were aged by exposure to gamma radiation. The evolution of the mechanical properties was investigated, the principal reactions in the polymer matrix due to the irradiation elucidated and the influence of the filler on the ageing process was followed. The results are: At low dose of irradiation the EPDM material is cross-linked. At higher doses the material degrades (chain scission).The presence of a filler can strongly influence the evolution of the mechanical behavior after ageing.

KEYWORDS

Ageing, EPDM, cable, irradiation, degradation.

INTRODUCTION

Polymer materials in cables and accessories are exposed to severe environmental conditions. An example would be cables in nuclear power plants where the cables might be exposed to elevated temperatures and gamma irradiation. These conditions are known to cause their ageing and consequently their degradation over the time. Once this degradation has progressed long enough the cable loses the mechanical and/or electrical properties that are required from the customer.

Figure 1: Cables in nuclear power plants may be exposed to irradiation.

The correct choice of polymer materials and additives used for cable insulation and sheath can improve the resistance of the cable against this ageing process. Since many years semi-empirical methods are used in order to predict the lifetime of polymer materials under certain conditions, most often for the ageing at elevated temperatures. In general these methods are based on the well known equation of van't Hoff and Arrhenius:

$$\ln(k) = \frac{-E_a}{R}\frac{1}{T} + \ln(A) \qquad [1]$$

This equation dates back to 1884 and tells us that when a chemical reaction has a rate constant k which obeys the Arrhenius equation, a plot of ln(k) versus T^{-1} gives a straight line (T = temperature). The slope of this line allows to calculate the activation energy E_a of the reaction.

Considering the fact that this equation was developed to describe a simple and well defined chemical reaction it works astonishingly well for complex systems such as polymer compounds where neither the exact chemical degradation reactions are known nor the reaction rate constant k, which in general is approached by the evolution of a mechanical property such as the loss of 50% of elongation at break or something like that.

However in many cases, the Arrhenius equation does not allow to predict the evolution of the degradation of polymer materials as precisely as we want it. Examples are nuclear cables where the ageing of the polymers in the cables is due to elevated temperature and gamma irradiation, and to make things even more complicated where the irradiation dose can vary over a wide range, from the "usual' low level of irradiation to high doses which can occur in case of an incident. In such a complex situation where different degradation mechanisms interfere we need to understand the different chemical reactions, their interaction and in which way different materials used in polymer compounds will accelerate or not these chemical reactions.

Several industrial and academic partners have therefore started a research program for the better understanding of the long term ageing of polymers: the mechanisms of degradation under the influence of irradiation and elevated temperatures, the influence of different materials used in polymer compounds on the ageing process, mathematical models which would allow to calculate the influence of the ageing of polymer materials on their mechanical properties and hence to predict their lifetime.

In this paper we present the first results of this study: the influence of gamma irradiation on the mechanical properties of filled and unfilled EPDM.