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CROSSLINKING AND WATER TREEING IN POLYETHYLENE INSULATION

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ABSTRACT

The target for the present study is to analyze whether the presence of crosslinks in polyethylene influence the water tree initiation and propagation in polymer insulation materials. Combining the results of two studies – the first with crosslinks introduced via irradiation, and the second where crosslinks are introduced via peroxides, it can be concluded that crosslinking of the polyethylene chains does not affect the water tree growth but it affects the number of the initiated trees which is lower after crosslinking. This conclusion applies to both the base material and the materials containing additives.

KEYWORDS

Cable insulation, Polyethylene crosslinking, Water treeing.

INTRODUCTION

Crosslinked polyethylene (XLPE) has been extensively used in the last decades in underground transmission and distribution cables, replacing the thermoplastic low density polyethylene (LDPE) which was previously used for extruded cable insulation. The main reason was that the presence of crosslinks improved the thermal and dimensional stability. Besides its mechanical resistance and intrinsic electrical performance, another property that needs to be considered when choosing the insulating material for medium voltage (MV) power cables is its water tree resistance. Indeed ageing due to water treeing had been earlier identified as one of the main causes of MV cable insulation breakdown [1,2,3] .

In some cable constructions, the insulation material is exposed to water and this, in combination with the electrical stress, will cause water filled tree-like structures to grow. These structures, called water trees [4], degrade the dielectric properties of the insulation (e.g. reducing breakdown strength and increasing dielectric loss) and consequently limit the service life length of the cable. A question that is not fully resolved is whether the crosslinks themselves in XLPE play a role in the water treeing process. This is what we are trying to answer in this paper by using the main results of two studies that were carried out on crosslinked and non-crosslinked plaque samples.

In the first study, polyethylene crosslinking was obtained by irradiating the samples with high energy electron beams [5]. The properties of the samples, non-irradiated and irradiated, were analyzed by determining the crosslinking degree by gel fraction measurement and their oxidation profile using FTIR spectroscopy. In the second study three types of crosslinked polyethylene systems were evaluated: one containing only peroxide and the other two having, beside the peroxide, also a tree retarding additive system. The results were compared with those obtained on their thermoplastic correspondents.

EXPERIMENTAL

The samples used in both studies were circular plaques (disks) prepared from LDPE pellets. On one side of each disk small needle-like defects were introduced as initiation sites for water trees.

In the first study the material tested was LDPE without additives, referred to as material A. Two sets of samples were analyzed: *irradiated samples* – in air or in vacuum, using different doses -, and *unirradiated samples* – as reference. The samples used for water treeing were characterized by the crosslinking degree and by the oxidation level. Water trees were produced in all samples, whether irradiated or not, using the same conditions. The degradation caused by water trees was assessed by tree length measurements.

As the most common technique used for cable manufacturing is not irradiation but chemical crosslinking via peroxides [6], the second study focused on the behaviour, with respect to water treeing, of three *model material systems* A, B and C, crosslinked with peroxide. These polymer systems can be characterised as:

- a base resin of LDPE, usually used to prepare compounds for power cable insulation, which was labelled A in thermoplastic form and XLA after crosslinking with dicumyl peroxide;
- two compounds, made of the base resin A with two different chemical tree retardant additive systems, labelled B and C in thermoplastic form and XLB and XLC after crosslinking with dicumyl peroxide.

These three samples A, B and C contained antioxidant as well.

Samples

Disks of 0.5 mm thickness and 50 mm diameter were made by compression moulding from pellets of polyethylene. For the first irradiation study, pellets of LDPE without additives were pressed at 185°C and 40 bars. Afterwards, the samples were cooled in air at room temperature. For the second chemical crosslinking study, the preparation of the thermoplastic (TP) samples A, B and C was carried out as presented above. The crosslinked (XL) samples were prepared by melt pressing 20 min at 200 ^{o}C and 200 bars. The samples were cooled to room temperature, still under pressure, by a cooling rate of 15 ^{o}C/min. After crosslinking all plaques were degassed at 70 ^{o}C for 72 h to remove the crosslinking by-products. The thermoplastic samples were also heat treated using the same conditions to give a similar thermal, and hence morphological, history.

The general methods to introduce water tree initiation sites