DIELECTRIC SPECTROSCOPY ANALYSIS OF ELECTRICALLY AGED LOW DENSITY POLYETHYLENE

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1. INTRODUCTION

For decades, insulated polymers have been widely used in power cables. Initially, low density polyethylene (LDPE) and later cross-linked polyethylene (XLPE) have been the most common insulators in medium and high voltage power cables. Electrical ageing of the insulation is inevitable and may in the long run give rise to costly cable failure. Understanding the ageing related phenomena is essential to achieve better quality materials and will provide an extended life time of the cables.

One of the most puzzling phenomena in electrical ageing is water treeing. it is the result of degradation of the polymer under the effect of an alternate electric field and aqueous salts [1.2]. Since the first time was detected nearly three decades ago, much work has been published, showing that many different factors seem to affect water tree inception and growth, such as temperature, mechanical stress, type and concentration of ionic salts, applied electric field (frequency and value), polymer morphology and composition, etc. Revealing the complex nature of water tree mechanisms of inception and growth, conflicting and difficult to reproduce results have been reported either for field aged or laboratory accelerated aged specimens. This shows the importance of god characterization of sample properties prior and after ageing. Many theoretical models have been proposed but none seems to fully explain inception and growth mechanisms.

The experimental results and models point to a complex mechanism involving electro, mechano and chemical processes. In the laboratory special accelerated ageing techniques were developed. In order to obtain better quantitative data, different characterization methods must be used and also it is necessary to gather information from different experimental techniques.

2. EXPERIMENTAL SETUP FOR ELECTRICALY AGEING LDPE IN THE LABORATORY

In this work samples of low density polyethylene (LDPE) were aged in the laboratory under an AC electric field. Disc shaped samples of ≈ 200 μm thickness and diameter of ≈ 30-35 mm were press-molded. Many different configurations and geometries have been used in laboratory experiments for electrical ageing polymers. The basic configuration of a modified Cigré cell developed by Houlgreave et al [11, 12] was chosen (see figure 1).

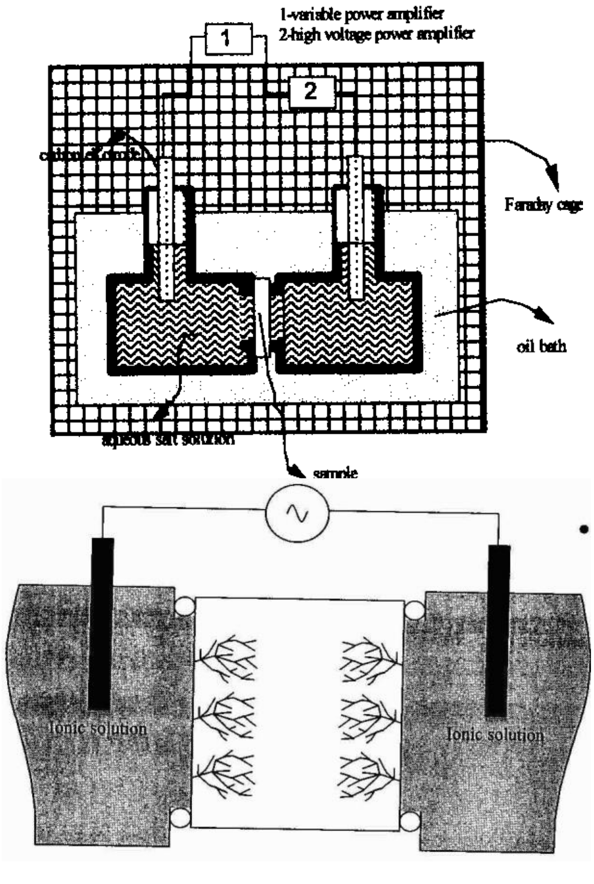


Figure 1. The apparatus for electrical ageing at low frequency of LDPE disks using a modified Cigre cell.

The cells were immersed in an insulator oil bath. The aqueous solution acted as electrodes on both sides of the disc shaped samples (planar electrodes). The samples were aged at an applied AC field of 6 kV/mm at 50 Hz, at three different constant temperatures of room temperature (RT), 35º C and 50º C. The aqueous solution was of sodium chloride 1M and the ageing time varied from 250 h up to maximum 1000 h. For each ageing time the field was applied to all of the samples except to a reference one which was kept in solution with no field.

3. SAMPLE CHARACTERIZATION PRIOR AND AFTER AGEING

In order to render the water trees permanently visible after ageing one electrically aged sample for each time an temperature was dyed using methylene blue following the technique described by Shaw & Shaw [13]. The photograph of the dyed trees were obtained using an optical microscope coupled with a photographic camera (enlarged 100x to 400x). Figure 2 shows a typical example. The tree is seen from the top, the field is applied perpendicular to the plane of the image (surface of the disks). For each dyed sample maximum size and numbers of water were registered.

Figure 2. Water trees grown in LDPE (applied field 6kV/mm, 50Hz, 50°C in a 1M (NaCl) solution for 350h).

4. RESULTS AND DISCUSSION

Typical graphs of surface potential contour plots are shown in the next figures. Also the comparison between surface potential contour plot and the picture of the sample.

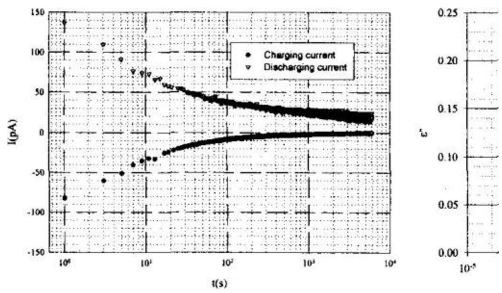


Figure 3. Charging and discharging currents curves (LDPE sample with ageing conditions: 6kV/mm, 50Hz, 1M, NaCl, RT**,** 500h. Poling conditions: 2kV/mm, 16h00).

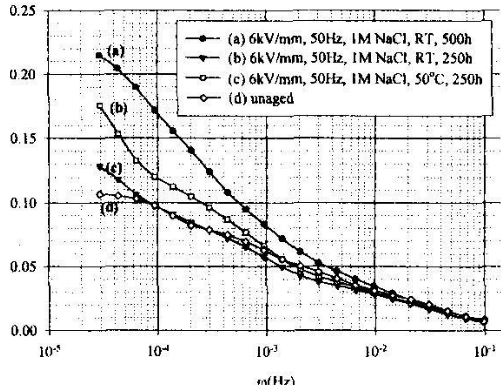


Figure 4. Comparing the change ε'' with frequency for different ageing conditions.

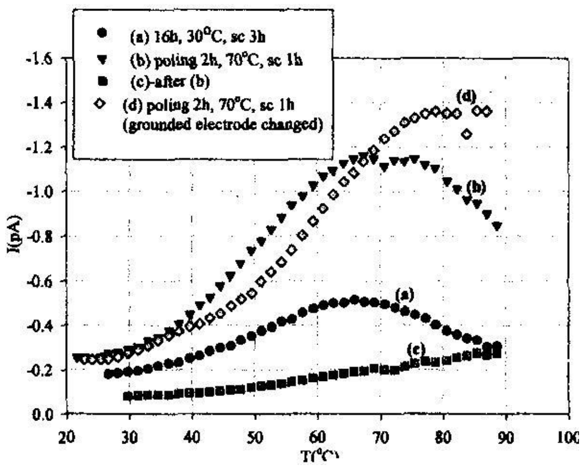
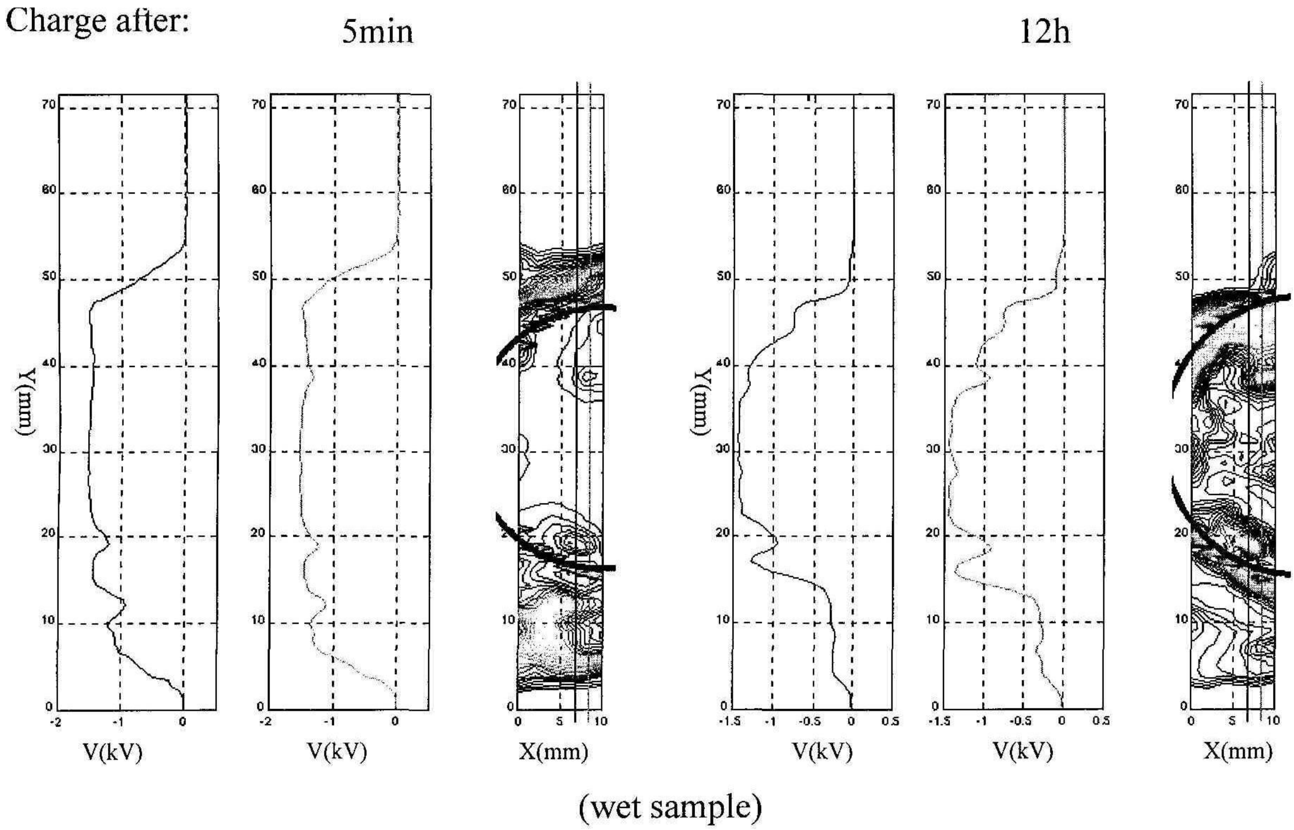


Figure 5. Several results from TSDC measurements performed on the same aged LDPE sample (ageing conditions: same as fig. 3).



5. CONCLUSIONS

The analysis of the low frequency dielectric loss of electrically aged LDPE shows an increase with electrical ageing. This could be further verified by extending the frequency range down to 10^{-5} Hz in order to measure the changes at the expected peak maximum.

TSDC results are however inconclusive whether the measured current is due to dipoles or space charge. The observed difference between charge release from the two samples surfaces indicates that there is an asymmetrical distribution of space charge or polarization. This agrees with the optical microscope observations showing that one of the sides has a greater water tree density than the other. A difference on the initial TSDC current level (near 20º C) appears to be more dependent on the short-circuit time than on the poling time (compare (b) and (d) runs in fig. 5). If a TSDC is performed without poling (see figure 5-(c)) the measured current is near zero, revealing that space charges have been removed or that the dipoles have been disoriented.

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