Investigation of the impact of different ovens and number of air exchanges on the thermooxidative ageing performance according to IEC 60811-401

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ABSTRACT

Thermooxidative ageing is one possible failure mode for power cables and is therefore regulated in the relevant standards. The testing procedure is described in IEC 60811-501 and IEC 60811-401. In this paper the impact of different loadings of a thermooxidative antioxidant and different oven types and test conditions are compared. It is shown that, depending on the type of oven selected and conditions used, different performance can be observed for the same polymer composition. It is concluded that the number of air exchanges in combination with how the air flows through the oven significantly impacts the results.

KEYWORDS

Thermooxidative ageing, thermal ageing, XLPE, testing, oven type, mechanical properties.

INTRODUCTION

The green transition to locally and remotely produced energy, as well as the transformation of the transport sector from fossile to electric vehicles, requires increased production of distribution and transmission cables. Simultaneously, the EU through the REACH regulation aims to evaluate and balance the use of different chemicals present in everyday products, both for industrial and public consumers [1]. An efficient and optimised use of additives in products are key to fulfill these goals and ensure future competitiveness.

The majority of polyolefins currently produced are consumed in products with a modest lifetime, such as different forms of films or injection molded products. However, some polyolefin applications are exceptions to this, as exemplified by pipes and cables. For power cables, rated 6 kV and higher, the expected service lifetime is commonly 40 years. In order to ensure such high level of performance and reliability the cables are stringently evaluated and tested so that the electrical and mechanical characteristics are sufficient. One of the features that is evaluated is the thermooxidative ageing performance of the cable.

Thermal oxidation of a cable insulation layer can lead to poorer dielectric performance and in the worst case cable failure. To avoid this type of failure the insulation composition comprises a thermooxidative antioxidant which purpose is to interfere with the thermooxidative ageing reaction and stabilise the insulation layer. As the thermooxidative ageing reaction is slow at cable operating temperatures an accelerated testing setup is needed to test the performance and predict the cable life length.

Thermal ageing tests are included in all relevant cable standards like HD620, IEC 60502-2, IEC 60840 etc, which refer to IEC 60811-501 and IEC 60811-401 for the test methods. To summarise, sample dumb-bells are prepared from the cable insulation layer and aged in an oven at 135°C for 7 days. If the aged dumb-bells fulfil the tensile criteria the cable core has passed the thermooxidative ageing test.

Here the allowed test conditions described in the standard and how they translate to the reality in the field are important to understand. Test conditions that do not represent actual service conditions could lead to overdesigned systems and a missed opportunity for efficient chemical usage. In this paper the impact of different loadings of a thermooxidative antioxidant and different oven types and test conditions are compared. The results are then discussed in relation to the above-mentioned European challenges.

MATERIALS AND EQUIPMENT

The materials evaluated are conventional XLPE compositions containing a LDPE, an antioxidant, and a peroxide. The LDPE has an $MFR_{2.16}$ of 2 g/10min measured at 190°C and a density of 922 kg/m^3. The selected antioxidant (AO) was the commercialy available Irgastab Cable KV10 (CAS: 110553-27-0). Five different antioxidant concentration levels were evaluated (Table 1) and compositions were crosslinked under conventional conditions.

Name	Amount AO (wt%)
Composition 1 (C1)	0.10
Composition 2 (C2)	0.13
Composition 3 (C3)	0.15
Composition 4 (C4)	0.18
Composition 5 (C5)	0.20

Table 1. Compositions with different AO concentration for thermooxidative evaluation.

The thermooxidative ageing was performed in five different ageing ovens. The cell oven used, Elastocon EB20 (CO), had a volume per cell of 2.4 l and 15 air exchanges per hour (Figure 1). This corresponds to 0.6 l/min air flow where the air is introduced via a small hole in the bottom of the cell.