Formation of micro-cracks at the surface of a high voltage cable screen induced by aluminum corrosion

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ABSTRACT

The main purpose of this study is to investigate the adhesion between corroded aluminium conductor strands and the semi-conductive cable screen. In this paper it is proposed that increased adhesion is one of the pre-requisites for the local degradation of the semi-conductive cable screen causing severe water treeing in the XLPE insulation. A model test set-up was developed and used including samples with a dried corrosion layer between a heat pressed semi-conductive cable screen and an aluminium metallic surface. The results show that the adhesion was strongly increased when the Al surface was corroded.

KEYWORDS

HV subsea cables, water treeing, stress induced electrochemical degradation, corrosion, adhesion.

INTRODUCTION

There is an increasing demand to produce lighter power cables for deep water applications and a major weight element in a cable is the conductor. Today the inter array cables are normally equipped with copper conductors. By replacing the copper with aluminum, the weight at the same electrical cross section is halved. For dynamic cables, a wet design is preferable since a metallic water barrier adds weight and complexity. However, there is a risk of increased water tree growth due to degradation of the inner semi-conductor if liquid water is present at the conductor strand surfaces [1].

SEM investigations have revealed that the interface between the semi-conductive screen and metallic strands (cable conductor) contains small micro-cracks. These structures were found to generally occur at points of corrosion at the surface of the aluminum conductor (strands) [1]. It has previously been proposed that this was a result of an electrochemical reaction between the aluminum conductor and the carbon black of the inner semiconductor in combination with mechanical stress and called “Stress-induced electrochemical degradation" (SIED) [2].

The hypothesis presented in this paper is that the corrosion layer at the aluminum conductor strand surface strongly increases the adhesion between the conductor and the conductor screen. When this corrosion layer cracks [3], the adhered semi-conductive surface will be subjected to axial forces at the surface of the semi-conductive conductor screen material inducing micro-cracks. It is likely that the residual mechanical stresses in the insulation system after extrusion contributes to the inception of the micro cracks [4].

The main purpose of this paper is to examine if corrosion can cause an increased adhesion between the aluminum surface and the semi-conductive cable screen using simple model samples.

EXPERIMENTAL

To test this hypothesis, we have developed a simple model system (Figure 1, left) to test the adhesion between semi-conductive materials and aluminum, and investigate the effects of corrosion.

To measure the adhesion energy between a coating layer (made of the semi-conductive material) and a metal surface (aluminum), we used a blister method where the setup is based on the formation of a blister by injecting nitrogen gas under pressure between the coating and the substrate. The adhesion energy is determined by recording the pressure as a function of the recorded blister radius development.

Blister Experiment

The adhesion between the semi-conductive material and the uncorroded or corroded aluminum surfaces were investigated by using the blister method. A blister is formed by injecting nitrogen gas under pressure between the coating, i.e., the semi-conductive material, and the substrate, i.e., the aluminum disc. A laser is moved over the blister with a speed of x cm/s. Two programmable step engines were used to measure the blister profile and thereby the radius of the blister between successive pressure increases (0.5 bar steps). The adhesion energy is determined by recording the pressure as a function of the recorded blister radius development and calculated using Equation 1.