Fatigue- creep in conductors and armouring as constraint for allowable installation depth

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ABSTRACT

Subsea power cables are subjected to a range of mechanical loads during its manufacturing, installation and operational life. Installation and offshore jointing operations represent prolonged high- tension configurations together with cyclic loading. Due to the relative short duration, cyclic loading typically do not cause creep or fatigue failure of any of the cable components. Conventional subsea power cable designs and application typically maintains copper or aluminium elements primarily in displacement control. Emerging cable designs and applications where aluminium and copper increasingly function also as load carrying element is proportionally affected by the cable tension in terms of fatigue and creep. In this sense, fatigue and creep properties of an Al-Mg-Si alloy conductor material is here studied. Fatigue testing is designed to represent the operational conditions and emphasize the effect of elevated mean stress in a stress- controlled setting. The effect of cable tension in terms of resulting fatigue curves is assessed by global dynamic analysis and local fatigue analysis.

KEYWORDS

Subsea power cables; Fatigue; Creep; Mean Stress; Aluminium alloy; Offshore jointing; Dynamic analysis, Installation capasity

INTRODUCTION

Subsea power cables require both its initial installation and following recovery and repair operations. These operations are normally assessed by cross-section and dynamic analysis. The former intends to evaluate if the combinations of curvatures and cables loads causes any of the cable elements to exceed some established mechanical limit criteria. The latter focuses on the integrity of the cable system d during the temporary dynamic suspension under offshore operations. This will assess if the extreme- or cyclic loads exceeds the cable capasity or fatigue life. The fatigue life evaluations require appropriate input data to predict the amount of inflicted fatigue damage. The fatigue properties of critical components such as the conductor are dependent on cable design, manufacturing route and the specific scenario.

It is generally true that for conventional subsea power cable designs and moderate depth- the fatigue properties of its components can be considered generic for a given design. This preposition entails that steel armoring is used and cable design and application do not cause yielding of the steel.

When cable design is changed, or applications moves towards deeper water, significant changes in how the load is distributed can occur. Examples of this include armourless cables, copper- armored cables and use of high strength aluminum alloys as cable conductor. These applications will all move a Cu- or Al component from displacement controlled to stress controlled. Depending on the load, temperature and cyclic frequency, prolonged stress-controlled loading of Cu- or Al will cause combined fatigue and creep damage. The effect of the latter depends on whether the component is subject to load- or displacement control.

This paper assesses some of these constraints and focuses on the effect of installation depth on fatigue life of subsea power cables during offshore operations. The onset of creep will be covered by assessing the effect of a maintained mean stress under stress controlled cyclic loading of a AA6101 aluminium alloy conductor wires. The effect thereof is further assessed in by fatigue analysis of the conductor in cable cross-section undergoing offshore jointing.

FATIGUE OF ALUMINUM CONDUCTORS

Limited literature exits for fatigue of aluminium conductors in subsea power cables. Multiple work is disseminated for overhead cables which generally uses the same materials and similar designs. For instance, Martinez *et al.* [1] investigate the notch effect on the same alloy as investigated in this paper but deviate in sequence of aging and work hardening. Kalombo *et al* [2] compare the different overhead conductor designs and note the greater notch sensitivity of AA6201 compared to AA1370 as normally used in subsea power cables. From this it is clear that fatigue life of conductors will depend on the cable stranding process and final surface condition. This is evident also for copper [3]. The fatigue life of conductors will also degrade due to fretting [4]. Finally, temperature and environmental effects must be taken into account. Laurino et al [5] found that the precipitation hardened AA6101 is potentially sensitive to hydrogen embrittlement where hydrogen is absorbed into the material as result of corrosive reactions. Hydrogen will reduce the fatigue life- in particular for the aged condition. It was also demonstrated that a refined microstructure due to work hardening could negate the degrading action of hydrogen. which could be relevant for wet design cables which would operate under elevated humidity.

CYCLIC LOADING OF CONDUCTORS AND LOADING MODE

Cyclic loading of power cable conductors is highly complex. Inter-wire friction drastically changes the response under a global load whereas the stick- to- slip phenomena changes the loading mode on the individual wires. While the stick-mode phase cause tension- compression in the wires during global bending, the slip phase changes the loading mode to bending. i.e. not only will the two phases be associated with a different peak strain response for a given