Testing Submarine Cables for Combined Axial Compression and Bending Loads

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ABSTRACT

To verify that a dynamic power cable can sustain combined compression and cyclic bending loads, a test program has been performed in a new built full-scale rig specially designed for testing combined compression and bending loads. The loads used in the test program where established based on the extreme loads from the dynamic analysis.

This paper describes the new rig and the test program performed. The paper also gives background to the loads used in the test program and discusses the potential failure modes associated with axial compression.

KEYWORDS

Compression, Bending, Full-scale testing, Dynamic cables

INTRODUCTION

Background

Dynamic analyses are performed to verify that the structural integrity of a submarine power cable is maintained during an installation campaign. The analysis can be performed for different weather conditions with the purpose to establish the weather restriction of an installation operation.

For dynamic cables, a global analysis is performed to establish the extreme and fatigue loads that will be applied to the cable during its service life. Since the dynamic cable is a permanent installation it is important to verify that the integrity of the cable is maintained even during the worst storm conditions. In the analysis, the curvature, torsion and tension of the cable is evaluated and the results are compared to the cable integrity criteria.

In the case of large vertical movements of the vessel or host platform, the cable can be subjected to axial compression, i.e. negative tension. There are currently no standards or recommendations which give guidance with regards to acceptable levels of axial compression in power cables, nor how to verify that the cable can sustain axial compression. Due to lacking knowledge, common industry practice is therefore to not allow axial compression. For cable laying “zero compression” will often be the limiting criteria, thereby restricting the weather window of the installation operation. For a dynamic installation a zero compression integrity criteria can have a large impact on the feasibility of the configuration.

To verify that a dynamic power cable can sustain combined compression and cyclic bending loads, a test program has been performed in a new built full-scale rig specially designed for testing combined compression and bending loads. The dynamic cable will be used to energize a Floating Storage and Offloading (FSO) vessel, where the cable will be suspended from the floating vessel in a tethered wave configuration and enter the vessel through a turret together with several flexible flow lines.

This paper describes the new rig and the test program performed on the power cable. The paper also discusses the potential failure modes associated with axial compression.

Failure modes from axial compression

Very little data has been published on axial compression of submarine power cables. In [1] an axial compression test on the power cores of a deep water umbilical is reported. The axial compression was the result of temperature differences inside the umbilical and the test was performed without bending. For flexible pipes, which are used in the offshore production of oil and gas, experimental studies regarding axial compression have been reported in [2] and [3], where two different failure modes of the helical armour wires were studied.

Numerical and analytical studies of armour wire buckling and birdcaging in flexible pipes has also been reported in [4], [5] and [6].

Based on these studies it can be concluded that excessive axial compression can result in birdcaging or buckling of the helical armour wires. For a power cable the same failure modes of the armour wires can be expected.

When a cable is exposed to axial compression a negative tension is created in the load bearing components, primarily the armour wires and conductor(s). The compressive force onto the cable will be distributed between the different components based on their relative axial stiffness in compression. A second effect of negative tension in the helical elements is that a radial force outwards will be created. Radial deflection of the armour wires is prevented by the outer covering. Since the radial stiffness of the inner central core(s) is larger compared to the radial stiffness of the outer covering the axial stiffness of the cable in compression will be significantly lower compared to the axial stiffness in tension.

The process of buckling/birdcaging of armour wires can be divided into three main failure modes [6]:

- Birdcaging – Due to negative tension the armour wires move radially, lifting from the supporting inner layers. If the radial force becomes too large this can result in failure of the outer covering and a sudden radial expansion of the armour wires occurs – a birdcage is created, as showed in Fig. 1. This failure mode is related to the strength of the outer covering and is not