Modelling of Viscoelastic Dynamic Bending Stiffness for VIV Analysis of Submarine Cables

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ABSTRACT

During cable installation, free spans can occur in areas with uneven seabed. In combination with current and waves there is a risk that Vortex Induced Vibrations (VIV) are introduced in the cable span. VIV can cause wear and fatigue on the cable's weak components such as the lead sheath.

KEYWORDS

Free span, Bending Stiffness, Vortex Induced Vibrations, Structural Damping.

INTRODUCTION

Free spans is a phenomena that can occur for power cables, umbilicals and pipelines. It can happen along the cable route if the seabed is so uneven that the cable cannot adapt to it, as shown in Pic. 1. Free spans can also occur if the cable exits a J-tube bell mouth above the seafloor. The reason for the uneven seabed can be a pockmark, boulder, anchor scar, cliff, scour, and etcetera. The normal approach to avoid free spans is to change the route to circumvent the location with too uneven seabed, but sometimes that is not possible or the free span may occur after the cable has been laid and even trenched.

The hazards that comes with a cable free span is mainly impact with fishing equipment or vibrations that occur due to the flowing fluid around the cable which creates vortices which in turn can induce vibrations. The vibrations may lead to fatigue and wear on cable components. The flowing fluid around the cable can be induced by both ocean current and waves, this phenomena is called Vortex Induced Vibrations, VIV.

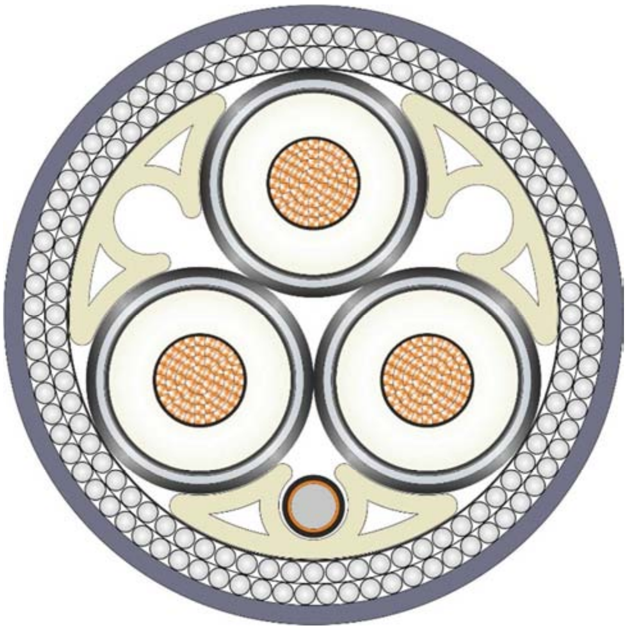
Pic. 1: Model over free span due to cliff.

Predicting VIV

There is no standard or recommendation for predicting VIV in power cables. There are industry accepted standards to assess VIV in pipelines such as DNV RP F105 [1]. Methodologies to assess the resulting fatigue damage in umbilicals and flexible pipes have been described in references [2] and [3] with the verifying testing described in reference [4]. There is also a range of purpose built software for VIV assessment which reduce the level of conservatism such as, VIVANA, Shear7 and OrcaFlex for example. These software can account for the stick-slip behaviour of the helical layers of armour wires.

Critical parameters to evaluate the risk for onset of VIV are the bending stiffness and the structural damping of the object. The Eigen frequency is proportional to the square root of the bending stiffness and a higher Eigen frequency results in longer allowed free spans and higher water velocities. These parameters are easily determined for a steel pipe with a linear bend stiffness. For a power cable this becomes even more complex due to the bitumen covering the helically laid armour wires. The bitumen layer will have a large impact on the bending stiffness, the Eigen frequency and the allowed free span length of a submarine cables.

A typical three core double armoured cable with copper conductor, XLPE insulation, lead sheath, filler profiles and two steel wire armour layers with bedding is shown in the picture below:



Pic. 2: Typical cross-section for double armoured submarine cable.

Bitumen, which is used as part of the corrosion protection system of the armour wires, is a viscoelastic material where the mechanical properties vary with temperature and strain velocity. The bending stiffness and structural damping of a submarine cable with bitumen covered armour wires will therefore depend on temperature, bending amplitude and bending speed.

This paper studies the effects of bitumen on the bending stiffness of submarine cables and how the stiffness varies with bending speed and temperature. A numerical model is developed to calculate the build-up of stress in the