Curvature sensor for monitoring of dynamic cables

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☐ **Young Researcher** (Proved full-time engineering and science university researchers and Ph.D. students under 35 YO)

ABSTRACT

Dynamic cables undergo repeated bending variations during their lifetime, imposed by platform movement, waves and current. Monitoring of curvature variations would be a means to reduce uncertainty in the global response of the cable during dynamic loading and thereby improve the prediction of accumulated fatigue damage.

A sensor for monitoring curvature variations of dynamic cables during operation has been developed and integrated in the cable cross section. The focus has been to enable high resolution monitoring of the region with highest fatigue loading close to the platform interface. Performance has been verified as part of a full-scale fatigue test of a dynamic cable, by comparing the curvature measurements with data from sensors mounted on the outside of the cable and found to be in good agreement, also for small curvature variations.

KEYWORDS

Dynamic cables, cable monitoring, shape sensing, fatigue monitoring

INTRODUCTION

Dynamic cables (Fig. 1) connected to floating platforms will during their lifetime undergo repeated bending variations imposed by platform movement, waves and current. These bending variations will lead to stress variations in the internal components of the cable, and if the loads over time are too large, this can lead to fatigue failure.

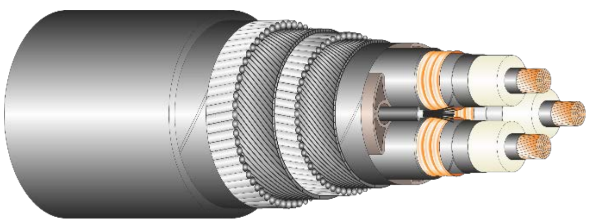

Fig. 1: Example of three-core dynamic HVAC cable

The design of the dynamic cable configuration is performed through global analysis where the environmental conditions, platform motions and cable response are modelled and simulated [1]. The analysis covers extreme environmental events as well as a large number of load cases constituting the fatigue loads. For dynamic cables the main driver of fatigue is the curvature variations induced during operation which result in bending and friction stresses in the cable's internal components. Tension variations typically only give a small contribution to the overall component stress range and the resulting fatigue damage.

The global fatigue analysis is influenced by a large number of input data and parameters such as metocean conditions, platform dynamic response characteristics, marine growth, cable properties, etc. Uncertainty in parameters are normally handled through sensitivity studies in combination with conservative assumptions. Continuous monitoring of the curvature variations of a dynamic cable during operation would therefore be a means to reduce uncertainty in the global response of the cable and thereby improve the prediction of accumulated fatigue damage. This would make it possible to detect if the loading is higher than foreseen, or to identify conservatism in the modelling assumptions that formed basis for the fatigue life assessment.

The cable closest to the floating platform will see the largest curvature variations and normally also the largest fatigue damage. A bend stiffener or bellmouth is installed at the platform interface to protect the cable from overbending. Fig. 2 gives an example of a typical fatigue damage distribution along a dynamic cable in relation to the bend stiffener profile.

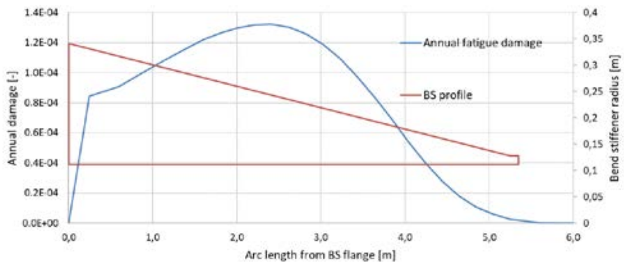

Fig. 2: Example of fatigue damage distribution along cable in relation to bend stiffener

This example features a 5.3 m long bend stiffener and the peak of the fatigue damage is approximately 2.5 m from the bend stiffener flange. The damage is well distributed within the bend stiffener and drops towards the bend stiffener tip. For a bellmouth, the fatigue damage can be even more concentrated over a shorter section of the cable.

Monitoring curvature variations within the bend stiffener or bellmouth region will therefore be most important if fatigue damage accumulation in the cable is of interest. A high spatial resolution within the bend stiffener will be necessary in order to accurately capture the fatigue damage distribution. Fatigue damage will be driven by a combination of a few large cycles and a large number of small curvature cycles, where curvature cycles as low as 0.01 m^{-1} can give a significant contribution to the overall fatigue damage. For fatigue monitoring it is thus also necessary to resolve and track small curvature variations.

Finally, curvature variations occur with a time period governed by the period of the incoming waves which typically will be in the range of 2-20 seconds. To be able to capture the peaks in curvature response the sampling frequency must therefore be sufficiently high.

This paper describes a method for monitoring curvature variations of a dynamic cable based on an integrated sensor rod instrumented with optical fibers inscribed with several Fiber Bragg Gratings (FBG) sensitive to strain