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Managing Fatigue in Deepwater Flexible Risers

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Abstract

Dynamic flexible risers are unique in the sense that they can accommodate substantial curvature variations combined with high tensile loads without compromising their fatigue capacity. However, as the fatigue endurance assessment becomes increasingly challenging with increasing water depth it is of utmost importance to know the fatigue driving mechanisms in flexible risers used for deepwater applications. Thus, key fatigue drivers are discussed in this paper including high inter-layer contact pressure due to severe tension and ambient hydrostatic pressure loads, corrosion fatigue in connection with high strength steel armour, riser structural properties (e.g. stiffness and damping), impact from riser VIV and second order springing effects of the floating unit. Furthermore, helpful fatigue analyses procedures are presented including a methodology based upon transfer functions that can determine the fatigue damage along the length of a riser thus facilitating an efficient irregular wave fatigue assessment.

At present, dynamic flexible risers are used in connection with oil and gas floating production facilities in water depth down to approximately 2000m. However, research is ongoing to further expand the flexible riser capabilities thus meeting the requirements of the future offshore field developments at even more demanding water depth between 2000m and 3000m. Thus, it is demonstrated in the paper how a new flexible pipe concept, Flextreme®, having excellent fatigue performance can be used for deep- and ultra-deepwater applications, and how failure modes normally associated with the conventional flexible pipe structure have been eliminated.

Finally, ways to manage the risk of fatigue failure during operation of a deepwater flexible riser are addressed, including presentation of a condition monitoring technique using optical fiber technology. Also, a concept based upon active flushing of the riser annulus is described which can be used to extend the service life of in particular sour service risers.

Introduction

Fatigue assessment of flexible riser systems in general is a challenging design task, involving dynamic system configurtion analyses combined with static pipe cross-sectional stress calculations. Despite the fact that flexible riser systems have been analyzed for a couple of decades substantial resources are still being spent to develop theoretical analysis models that can better describe their fatigue behaviour. As a result, many of the governing fatigue input parameters can now be established with a high degree of accuracy (e.g. design S-N curves, stress distribution of pipe cross-section), thus increasing the confidence in the results. Furthermore, the recent advances in condition monitoring (including optical fiber technology) make it possible to verify the riser integrity during service. However, the originally established safety factor of 10 is often still used as acceptance criterion when assessing the accumulated fatigue damage. This circumstance becomes increasingly challenging with increasing water depth as deepwater riser systems may have difficulties in meeting similar safety factor, in particular when analyzing risers subjected to corrosion fatigue. Thus, it is important to understand the key fatigue driving mechanisms for deepwater riser systems to establish a sound basis for assessing the fatigue endurance with confidence. Thereby, it becomes viable to establish an updated safety factor without compromising the intended reliability of the riser system. Recent work on establishing reliability-based fatigue safety factors can be found in [1] and [2].

So far, conventional flexible pipe structures similar to the one shown in Figure 1 have been used as basis when designing deepwater risers with pipe sizes of up to 8-inch internal diameter targeted at 2,000m water depth. This has been possible by using combinations of high strength material grades for the steel armour layers, high-inertia pressure armour wires, low-friction anti-wear tapes, and optimization of pipe cross-section and riser system configuration. The fatigue challenges for deepwater risers are mainly concentrated at the riser top due to bending combined with high tension, and at the seabed touch down area due to pipe bending combined with high ambient hydrostatic pressure loads. This is also driven by the fact that almost all deepwater risers are in a simple catenary configuration. Thus, the use of high strength material grades is required to