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Fatigue Analysis of Unbonded Flexible Risers With Irregular Seas and Hysteresis

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Abstract

Unbonded flexible-pipe risers provide a structurally compliant solution in offshore production systems for the recovery of oil & gas. Fatigue analysis of unbonded flexible-pipe risers has seen new advances in recent years and these are beginning to make an impact on new designs and life extensions of riser systems. This paper reviews some of these new advances for the steel amour wires in flexible pipes and describes an application on extending the life of a riser system that is nearing the end of its original design fatigue life or indeed a green field riser system.

The application presented in the paper gives a comparison of the fatigue lives predicted by the state of current practice and the new advanced methods. The new methods are equally applicable to the new design of fatigue critical riser systems.

The results in the paper show that the advanced methods produce longer fatigue lives than the current state-of-practice methods. The life extension is obtained from the following advanced analysis methods:

1. A comprehensive global dynamics analysis of the riser
2. Three-dimensional pipe bending in the local stress analysis
3. Hysteresis damping of the riser bending response

The first two advances bring the fatigue analysis of flexible risers to a standard that is comparable with steel risers. Note however, the local stress analysis for a flexible riser is more complex than for a steel riser and this conventionally results in much less global analysis performed for a flexible riser. The third advance applies only to unbonded flexible risers and there have been few attempts to-date that account for the reduction in bending as attributed to the hysteresis damping effect.

Introduction

Unbonded flexible pipes have a composite wall construction where the key components are polymer sheaths for fluid containment and helically wound steel amour wires for strength. The construction is highly compliant in bending in comparison to a steel pipe. Unbonded flexible pipes are widely installed as compliant risers in offshore floating production systems and as subsea flowlines due to their ease of installation.

The complex composite construction of these pipes has largely resulted in conservative methods of fatigue design. These conservatisms are presently subject to reappraisal in both existing and new riser systems.

The fatigue design of existing flexible riser systems is more frequently being reassessed as the actual operating conditions become documented and these prove to be harsher than planned in the original design. Design fatigue lives are being significantly reduced as operational data show increased levels of wave-induced loading or conditions for corrosion-fatigue of the steel amour become established. It is generally preferable to prove the riser is fatigue tolerant to these new harsher conditions as opposed to replacing the riser. Extending the service life of the riser beyond the original design is also a key objective of these fatigue reassessments.

New flexible riser systems designed for deeper water applications are also pushing back accepted conservatisms of design. The high level of extreme and fatigue bending motion in the touchdown zone of a deepwater flexible catenary riser is one example that is forcing back conservatisms of the design.

Applying advanced methods of analysis in predicting the global motions of the riser and the local stress in the steel amour is highly effective in reducing the conservatism of fatigue life assessments when required. The methods include extensive application of irregular or stochastic seas with a computationally efficient discretization of the riser, including hysteresis damping of the riser bending motion, increased account of the directionality in the wave loading and following this through to the stress analysis. Each of these methods improves the design fatigue life of a flexible riser.

The application presented in this paper is based on a fatigue reassessment of an existing riser system where the motion of the floating production vessel was under-predicted and the onset of corrosion-fatigue was not considered until after the riser system was installed. The fatigue design is proven to be safe with the new harsher conditions by performing a reassessment that accounts for irregular seas in several directions and hysteresis damping on the pipe bending response.

Unbonded Flexible Riser Structure

Figure 1 shows a cut away section of a standard unbonded flexible pipe. The pipe cross section fundamentally relies on