



OTC 19386

Fatigue Design of Flexible Risers with a Non-Dry Annulus

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This paper was prepared for presentation at the 2008 Offshore Technology Conference held in Houston, Texas, U.S.A., 5–8 May 2008.

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ABSTRACT

The fatigue performance of unbonded flexible risers is severely reduced if a non-dry corrosion-fatigue environment becomes established in the annulus space that houses the steel armour layers. This is in contrast to the exemplary fatigue performance achieved when the annulus space stays dry throughout the service life. Flexible riser operations have shown that there are several mechanisms for the annulus to lose its dry-state. A flexible riser that is not tolerant to a non-dry annulus often needs to be replaced at short notice or shut-down due to the rapid onset of corrosion fatigue induced by CO₂ and H₂S. Field operators are demanding flexible riser systems that can survive with non-dry annulus conditions for the full service life of the field. The loss of production endured from replacing a riser or simply shut-down without replacement has severe implications on the profitability of a field, especially in marginal and deepwater developments.

This paper demonstrates how recent advances in analysis are influencing the design of new flexible riser systems that can sustain life of field operation with a non-dry annulus. These advances are accomplished by various methods that include optimising bending stiffeners so that concentrated fatigue hotspots are eliminated and modelling bending hysteresis of flexible risers. Frequency domain techniques are also shown to be an efficient and accurate method for flexible pipe fatigue analysis, thus enabling considerable modelling detail of the seastate loading environment in an efficient manner.

The application of new design methods and results are shown at various fatigue critical locations on deepwater flexible risers. The key conclusion of the paper is that life of field design of flexible risers can be achieved with onerous corrosion-fatigue conditions if proper rigour is applied in the fatigue design.

INTRODUCTION

Flexible pipe risers are composite structures which are employed in the retrieval of offshore oil and gas reserves. Flexible pipe cross sections are normally constructed from concentric layers of steel, polymer and insulation. Both bonded and unbonded constructions are common place. Unbonded pipes have a larger range of operating pressure and temperatures. This is mainly due to a strength capacity of the steel armouring and availability of high temperature polymers.

Given the complexity of the flexible pipe cross-section, it has taken the industry much longer to fully understand how to compute the fatigue life of flexible risers compared to steel risers, for example. For a simple steel pipe, it is easy to convert global moments and tensions into pipe wall stresses; for flexible pipe this global-to-local interface is much more complex. For these reasons, traditional fatigue design of flexible risers has been based on simplified, conservative assumptions which were easy to satisfy for dry annulus conditions. However, with operating experience demonstrating that the actual annulus conditions in a flexible condition to be far from dry, this puts the onus on the industry to significantly improve its fatigue annulus methodology and reduce unnecessary conservatism while maintaining a safe design. This paper highlights some of the key issues and provides some solutions.

FATIGUE DESIGN METHODOLOGY OVERVIEW

A comprehensive fatigue methodology for flexible risers has been developed as part of the Real Life Joint Industry Project [1]. The Real Life Methodology provides guidance on wave selection, riser configuration analysis for fatigue load states and methods to interface global riser loads with the nonlinear, hysteretic response of the local pipe cross-section. The methodology derived in [1] has mainly focused on the use of time-domain irregular seastate analysis of the Hs-Tp seastates selected from the wave scatter diagram. Specific irregular-wave time-domain analysis are performed for the highest occurring