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Validation of Umbilical Fatigue Analysis by Full-Scale Testing

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A highly efficient umbilical analysis scheme for consistent fatigue life calculation of metallic helix elements such as steel tubes, armor wires in umbilicals, and flexible risers is briefly discussed in this paper. This scheme was developed by DNV GL and is used in the commercially available umbilical analysis tool Helica. The calculation efficiency is due to an analytical calculation of helix bending stresses assuming so-called loxodromic helix geometry (i.e., slip is assumed to take place in the axial helix direction only). DNV GL, along with Ultra Deep, launched a joint industry project (JIP) to validate the loxodromic assumption, which is used in local analysis stress calculations of umbilicals and flexible pipes, by comparing calculations with high-quality bending test measurements. Validation against high-tension/low-tension bending tests is considered to cover umbilicals installed at normal to deep water depths. Details of the validation methodology and sample results are presented in this paper.

INTRODUCTION

In recent years, significant advancements have been made in umbilical technology. Subsea umbilicals are designed with multipurpose functionality including subsea control and monitoring, chemical injection, gas lift, and electric power transmission, etc. Deepwater dynamic umbilicals pose additional challenges due to high-end termination loads and potential fatigue concerns. As a result, umbilical designs have become increasingly complex and require advanced tools and methods for design, analysis, and testing.

To achieve flexibility during bending, elements of umbilical or flexible pipe are arranged in a helical geometry. When the umbilical or pipe cross section is bent, initially the helical elements stick with the pipe. Once the frictional resistance is overcome, these elements slip and therefore release stored frictional stresses, as shown in Fig. 1. Thus the helical geometry and relative slip between components makes the umbilical compliant. However, assessment of fatigue stresses in helical elements becomes complex because of such stick/slip behavior.

The accuracy of the bending stress calculation is very critical in fatigue life estimation. The stick/slip behavior due to the unbonded helical arrangement of components in umbilicals and flexible pipes makes calculation of bending stresses complicated and challenging. DNV GL has developed a highly efficient umbilical analysis tool Helica (hereafter referred to as "the Program") for consistent fatigue life calculation of helix elements in umbilicals and flexible risers.

Several papers have been published regarding the Program over the years. Sødahl et al. (2010) and Skeie et al. (2012) go into details of mathematics of the implemented methodology. Sødahl et al. (2011) talk about a methodology for using the Program in vortex-induced vibration (VIV)-induced fatigue assessment. Wang and Ekeberg (2014) discuss and compare several methodologies of which the Program is one. Dhaigude and Sharma (2014) outline the Program methodology and describe details of the joint industry project (JIP) effort of which this paper is a result. Dhaigude et al. (2016), Ekeberg and Dhaigude (2016), and Dhaigude and Ekeberg (2016) document the results of the validation of the Program methodology. This paper focuses on the methodology and efforts necessary to get in a position to be able to compare high-quality stress measurements with calculations.

UMBILICAL ANALYSIS TOOL/PROGRAM

The Program is commercially available and is being used by several umbilical manufacturers. The Program allows cross-sectional modeling of components with helix elements in an unbonded structure. An average description is applied in the longitudinal direction of the pipe. It is assumed that the helix elements are arranged in concentric layers. Each helix layer is treated by means of an equivalent tube model with stiffness properties assembled from individual elements. Distance from the centerline of the cross section can be specified for individual elements in the same layer. For modeling umbilicals, different types of helix elements can be applied in the same layer. It is assumed that all the elements have a linear elastic material property that is consistent with material utilizations in the normal operating regime. Details of the Program formulation are available in related publications

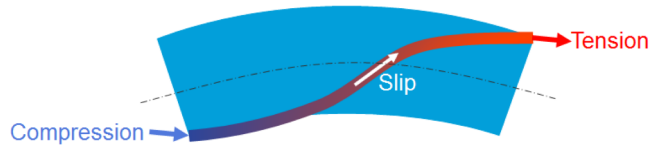

Fig. 1 Slip of helical elements due to bending

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