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Dynamic Analysis of Pipe-in-Pipe Steel Catenary Risers With Direct Modeling of Structure Interaction

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Abstract

During conceptual engineering for a deepwater Gulf of Mexico field development project, the option of a long distance dual flowline tie-back to a semi-submersible platform was assessed. Pipe-in-pipe (PIP) steel cantenary risers (SCRs) were considered for connecting the PIP flowlines to the platform, to satisfy stringent thermal insulation requirements.

Preliminary analysis results for the PIP SCRs based on an equivalent single pipe finite element (FE) model and use of generic correction factors to account for PIP behavior indicated marginal performance for both fatigue and extreme hurricane loading conditions. Therefore, to improve response prediction accuracy, application-specific correction factors were established by comparing results from the single pipe model and a detailed PIP model, for selected static and dynamic load cases. This paper describes the analysis models and methodology, the load cases assessed, and summarizes the results and conclusions.

Introduction

Hydrodynamically loaded PIP structures have been in use since the first offshore platforms were installed more than fifty years ago. In the case of such platform conductors, Stahl and Baur[1] reported that when an inner pipe (casing or tubing) is not ideally centralized, it provides additional contribution to the global bending moment by an amount equal to the product of its tension and the offset (or eccentricity) of its centerline from the centerline of the outer conductor pipe. This contribution can be significant for platform conductors when assessing their global stability, particularly for deep reservoirs when the tension in the casings and tubing is large.

Top-tensioned risers also often consist of two or more concentric pipes. For computational efficiency, such risers are conventionally analyzed using an equivalent single pipe model.

SCRs, on the other hand, have historically tended to be single pipe structures and therefore have not required such considerations. However, recently, PIP flowline SCRs have been used for deepwater developments in order to satisfy stringent flow assurance requirements. As with vertical risers, it is evidently advantageous to use a single pipe model for the majority of design analyses. However, in order to safely use this approach, it is first necessary to establish appropriate and reliable means to correct for PIP effects that are not captured in the single pipe model.

Case Study Data

The water depth at the host platform location considered was approximately 6000 feet. The PIP riser consisted of an 11 3/4” outside diameter steel outer pipe, and a 7 5/8” outside diameter steel inner pipe. Figure 1 presents a sketch of the PIP arrangement, with discrete centralizers.

It was proposed that the inner and outer pipes be connected by bulkheads at the top of the riser (immediately below the flexible joint) and at a location on the seabed beyond the extreme touchdown point.

The centralizers were spaced at six-foot intervals over the full length of the riser between the two bulkheads. The outer diameter of the centralizers was taken to be equal to the drift diameter of the outer pipe, to facilitate installation.

Analysis Methodology

Static and dynamic global analyses were performed for selected load cases using a detailed PIP model and a single pipe model. The results from the two models were compared to investigate the significance of the interaction between the inner and outer pipes, which is not captured in the single pipe model.

All of the analyses discussed in this paper were performed using the ABAQUS/Standard® time-domain finite element analysis software and the ABAQUS/Aqua® module for calculation of hydrodynamic loads and buoyancy forces[2].

PIP Global SCR Model

A model of the SCR, extending from the static seabed region to the riser hang-off was established using first-order beam-column elements.

The outer and inner pipes were modeled explicitly, with the same unstrained lengths, and were rigidly connected at both ends of the model to simulate bulkheads. For select load cases, thermal expansion was applied to the inner pipe to