OTC 19432

Investigation of Riser Seafloor Interaction Using Explicit Finite Element Methods

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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.

Abstract

The seabed response due to riser loading and the trench formation phenomenon are of great significance for safe and economic riser design. This paper summarizes an investigation of seabed response and trenching due to riser loading using explicit finite element methods and Arbitrary/Lagrangian and Eulerian meshing schemes. Results are compared to laboratory tests in order to understand the impact of active and passive failure mechanisms in the soil with vertical travel of the riser. The impact of strength degradation is discussed in the conclusion of the paper.

Introduction

Seabed response in the touch down zone is known to have a significant impact on the fatigue life of steel catenary riser systems. Current industry practice is to characterize the seabed response using either linear/nonlinear soil springs or rigid surfaces. This is primarily due to the requirements of existing software tools for riser design. This approach of representing the integrated response ignores the complex individual mechanisms that comprise the riser-soil interaction problem.

In the global analysis of riser systems, it is also common to represent the seabed as a flat surface. However, ROV observations of existing risers and mooring lines have shown the formation of trenches in touchdown region. In some cases, trenches were formed only a few months after installation. It is known that with the right environmental conditions a riser resting on relatively weak soil may dig a trench in the seabed due to repeated motion. The trench formation will impact fatigue damage accumulation and, depending on the system could result in higher top end loads that impact the host system performance.

This paper discusses the use of explicit finite element methods to simulate riser seafloor interaction, including the interaction with the surrounding water, a key factor in the trench formation process. An Eulerian solution (fixed grid) procedure is used to adequately capture gross deformation in the soil due to riser loading. The Eulerian finite element formulation also facilitates multi-material interaction between the riser cross section, the soil mass and the surrounding water. Simulation results were compared to test data for the interaction of planar pipe sections and kaolinite material. Results under investigation were the global load deflection curves, when the riser cross section was subjected to a single vertical displacement cycle comprising of a downstroke followed by an upstroke and finally ending with a downstroke. The impact of soil strength degradation is discussed in the conclusion section of this paper but was not investigated numerically in this study.

Background

The seabed response due to riser loading and the trench formation phenomenon are of great significance for safe and economic riser design. Bridge et al. (2004) presented a seabed response model due to vertical loading. This model was based on the test data from the STRIDE and CARISIMA JIPs. The model consists of a backbone penetration curve (Figure 1), which characterizes the ultimate resistance provided by the seabed during the initial downward penetration of the riser. Bridge et al. (2004) observed that during the unloading of the riser, the initial seabed response is much stiffer than the initial penetration curve. Bridge et al. (2004) also showed that the riser experiences a downward resistance (suction resistance) during the uplift, limited to the maximum mobilized suction resistance. Once the maximum suction force is reached, there is