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Seafloor Interaction with Steel Catenary Risers

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ABSTRACT

This paper describes the key features of a seafloor-riser interaction model. The soil is represented in terms of non-linear load-deflection (P-y) relationships, which are also able to account for soil stiffness degradation due to cyclic loading. The analytical framework considers the riser-seafloor interaction problem in terms of a pipe resting on a bed of springs, and requires the iterative solution of a fourth-order ordinary differential equation. A series of simulations is used to illustrate the capabilities of the model. Thanks to the non-linear soil springs with stiffness degradation it is possible to simulate the trench formation process and estimate moments in a riser.

KEY WORDS: Steel catenary riser, P-y curve, Finite differences

INTRODUCTION

The fatigue life of a riser pipe loaded by extreme storms, vessel movements, and vortex-induced vibrations, is one of the critical issues when designing the compliant systems comprised of a large floating structure attached to the seafloor by vertical tethers or mooring lines. It is especially difficult to estimate fatigue stresses due to the interaction between the seafloor and the riser because of the high non-linearity of soil response. The touchdown zone (TDZ) where the SCR contacts the seafloor (Fig. 1) has often proved to be the critical location for fatigue analysis, since the maximum bending stresses usually occur in this part of the riser (Bridge et al., 2003, 2004). In addition, these studies have also shown fatigue damage to be sensitive to seafloor stiffness. Although linear elastic seafloor models (e.g., Pesce et al., 1998) provide very useful insights about seafloor-riser interactions, they cannot fully describe the complex interaction problem including trench formation, non-linear soil stiffness, limited soil suction, detachment of the riser from the seabed, and cyclic degradation of soil stiffness, as shown by full-scale experimental testing (Bridge and Willis, 2002; Bridge et al., 2004).

This paper presents an analytical framework for simulating seafloor-riser interaction as a linearly elastic pipe on a series of non-linear soil springs. The soil model follows the P-y model proposed by Aubeny and Biscontin (2006) but includes the effects of the degradation in stiffness due to cyclic loading, as indicated by cyclic load tests of model pipes supported on soil (Dunlap et al., 1990; Clukey et al., 2005). The proposed seafloor-riser interaction model considers only vertical riser motions. Although lateral motions of the riser also affect riser performance (Morris et al., 1988; Hale et al., 1992), observations indicate that typical riser trenches are about 4 pipe diameters wide. Therefore, significant lateral soil resistance will be mobilized only when the pipe is pushed into contact with the walls of the trench. Otherwise, vertical soil resistance will be generated during every load cycle, even if displacements are small in amplitude. In addition, the magnitude of the soil resistance is generally greater in the vertical than in the lateral direction, due to the greater confinement provided at depth. This seafloor-riser interaction model considers only the length of the riser comprising the touchdown zone. Small displacement beam analysis is adapted to treat the interaction problem, since the typical ratio of trench depth to trench length is about one percent. The end moment, generated by large uplift motions at the touchdown point (TDP) and axial tension in the riser are also considered as boundary conditions in the model.

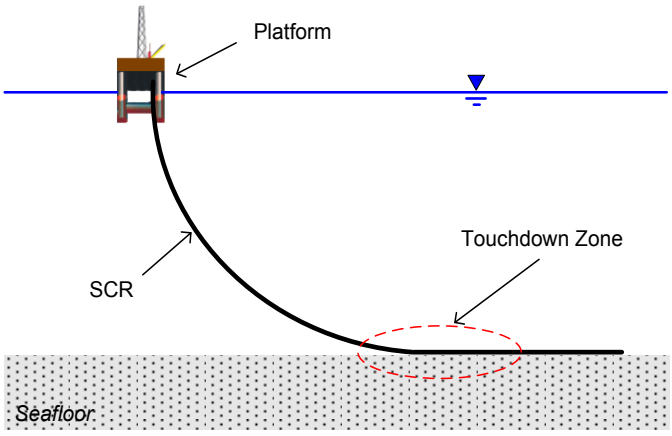

Fig. 1 Seafloor-Riser Interaction Problem.