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Pipe-Soil Interaction uring Lateral Buckling and Pipeline Walking — The SAFEBUCK JIP

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Abstract

This paper addresses the influence of pipe-soil interaction on the design of pipelines susceptible to lateral buckling and pipeline-walking. The pipe-soil response is the largest uncertainty in the design of such systems, and has a significant influence on the structural limit states. Generic guidance has been developed to guide the design process, but project-specific physical model testing is often necessary, and new advancements in the understanding of pipe-soil interaction are rapidly being made.

Force-displacement response models were developed during Phase I of the Safebuck joint-industry project (JIP) based on large- and small-scale tests carried out by the Safebuck JIP and project-specific test data donated by JIP participants. These models are currently being applied by JIP participants on a number of projects, to quantify the susceptibility to lateral buckling and pipeline walking, and design safe and effective means to control these phenomena. However, of all the design parameters, the soil response causes the greatest uncertainty in design because of the extreme sensitivity of design solutions to the axial and lateral resistance imposed by the soil. Improving the understanding of pipe-soil response provides the greatest scope for refining the design of such systems.

The purpose of this paper is to outline the significant influence that pipe-soil interaction has on the pipeline design process and highlight the ways in which the uncertainty in pipe-soil resistance severely complicates pipeline design. The paper then reviews and updates previous force-displacement-response models (published at OTC 2006) incorporating more recent experience from large and small-scale tests. Significant new data is included to illustrate the behaviour of 'heavy' pipes, which display a lateral response that differs significantly from most previously-published data, mostly related to 'light' pipes. The response of soil berms during cyclic lateral loading is also highlighted, demonstrating the cumulative rise in lateral pipe restraint.

1 Introduction

Subsea pipelines are increasingly being required to operate at higher temperatures and pressures. The natural tendency of a hot pipeline is to relieve the resulting high axial stress in the pipe wall by buckling. Such uncontrolled buckling can have serious consequences for the integrity of a pipeline. The need to control lateral-buckling has led to a radical advance in pipeline engineering with a greater need for robust lateral-buckling design solutions. The Safebuck JIP was initiated to address this challenge and aims to raise confidence in the lateral-buckling-design approach and to improve understanding of the related phenomenon of pipeline walking.

The pipe-soil force-displacement response is the largest uncertainty in the design of such systems. With lateral buckling it is necessary to understand the soil behaviour at large displacements, and through many cycles of loading, well beyond the point of failure. Such behaviour is outside the bounds of conventional geotechnics or extensive earlier research on pipeline stability. Most previous research into pipe-soil interaction has been related to stability under hydrodynamic loading, with the aim being to ensure the pipe remains in place. A lateral buckling design requires the pipe to break out from the as-laid position and move across the seabed, typically by several diameters.

The purpose of this paper is to outline the significant influence that pipe-soil interaction has on the pipeline design process and highlight the way in which the inherent uncertainty in pipe-soil resistance severely complicates pipeline design. The paper then reviews and updates previous force-displacement-response models (published at OTC 2006) to incorporate