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Effect of High Pressure High Temperature Flowlines and Soil Interaction on Deepwater Subsea Development

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Abstract

In response to the challenge of deep waters and High Pressure High Temperature (HPHT) flowlines, theoretical and experimental work have been recently undertaken to understand and predict the complex behavior of pipe-soil interaction. Since this behavior is not very predictable, project teams must apply a systematic decision approach - taking into account the uncertainties and complexities of the phenomena.

This paper discusses: the pipe-soil interaction approach for deep waters HPHT projects; presents the decision making process in dealing with the uncertainties; and shows the sensitivity of the HPHT product on the flowlines design, subsea layout, and platform host location. The importance of good geotechnical program, quality soil information, proper pipe-soil interaction modeling, lessons learned from other HPHT projects, and systematic decision approach are keys to the successful execution and operation of the subsea development. The work presented in this paper is intended to help raise awareness of the technical challenges of the HPHT flowlines-soil interaction and shows the importance of the decision making process to result in the best balance between economical and technical constraints.

Challenges of HPHT

The HPHT developments have unique challenges and require careful considerations of all design, installation, and operational aspects. Lessons learned from other projects re-emphasize the importance of these aspects. For example, the original Erskine pipeline was installed in the North Sea in 1996, utilizing a snake lay procedure to ensure any axial expansion within the pipe was accommodated for by lateral deflection in the curvature of the pipe. After the pipe went into first operation in December 1997, it was noted that the pipe was deflecting laterally as planned. However, the deflection shape was tighter than the design expansion shape. The pipeline failed due to higher than designed for loads in both the carrier and the pipeline during start-up (heat) and shutdown (cooling). The decision was made not to repair the pipeline, but to replace it.

The challenges for the HPHT flowlines are due to the complex soil-structure interaction, the possibility of driving most materials such as pipe, insulation, and field joints to their limits, and the sensitivity of the soil parameters to the HPHT analyses outcome. From the project execution perspective, the challenge is to optimize between the required analyses/design time and the procurement of the long lead items.

Pipe Soil Interaction

Introduction

The process of systematically evaluating the pipe-soil resistance is becoming increasingly more important to the design of pipelines, especially when they are subjected to high temperature and susceptible to phenomenon such as lateral buckling and axial creeping. In general, two parts are required to solve pipe-soil interaction problems. The first part is analytical and involves well defined pipeline properties. The second part requires the determination of pipe-soil resistance which depends on less-known soil properties. It is the latter that has more uncertainties due to the unpredictable and highly variable nature of soil conditions and the lack of reliable pipe-soil resistance prediction methods.

Methodology

The soil axial and lateral resistances depend on several factors. Most of these factors have a wide range of uncertainties. In general, these resistances strongly relate to the installation methods, pipeline weight history, and pipeline displacement magnitudes.

Figure 1 illustrates the general methodology followed in determining the axial and lateral soil resistances for clayey type materials.