The Sequential Reeling and Lateral Buckling Simulation of Pipe-in-Pipe Flowlines Using Finite Element Analysis for Deepwater Applications

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ABSTRACT

This paper presents a sequential integrated reeling and lateral buckling PIP Finite Element Analysis (FEA), using ABAQUS, which captures the full reeling history, and is then included in the operational analysis for lateral buckling. The FEA model is sufficiently long that both the reeling and lateral buckling analysis can be carried out using the same model. This is particularly complex to undertake, due to convergence issues, but these issues have been addressed. Using this reeling module, results show that the effects of reeling should be taken into account for high temperature pipelines.

KEY WORDS: ABAQUS; Finite Element Analysis (FEA); High Pressure High Temperature (HPHT); Flowlines; Non-linear; Pipe-in-Pipe (PIP); Reeling.

INTRODUCTION

The reeling installation process produces residual loading in the pipe-in-pipe system, which has to be taken into account in any subsequent lateral, or upheaval buckling analysis. The effect of residual loads may have a significant effect at higher operational temperatures and, as a result, may reduce the ultimate loading capacity of the flowline. Presently, it is not uncommon for PIP designs to be considered now in water depths up to 3,050 meters (10,000 ft.) and flowline temperatures up to 177°C (350°F), and residual reeling strains should be taken into account in the design. Also, the residual loads may have an effect on the lateral buckling response if a thermal buckle management strategy is to be deployed in the design, such as using pre-lay sleepers or buoyancy, in order to alleviate high axial loads.

In order to capture the strain history during installation, a detailed Finite Element Analysis (FEA) model has been developed that can replicate the reeling process, lay the pipeline down on the seabed, apply temperature and pressure, and then undertake lateral buckling. The analysis is performed using the commercial finite element program, ABAQUS. The significance of the FEA program described within this paper is that it undertakes an integrated reeling and lateral buckling analysis. What makes this FEA model different from previous analysis work is that the FEA model is sufficiently long and capable of undertaking the lateral buckling analysis, so that the results are not affected by any adverse end effects. The ability to have a long model is numerically complex, and convergence is generally extremely difficult. These challenges have been successfully overcome, and this model now allows the combined effect of reeling and lateral buckling to be investigated.

The presented study is part of massive analysis works related to extra high pressure and high temperature PIP sponsored by a major operator. The study targets the Gulf of Mexico (GoM), where subsea production wells are drilled at water depths (WD) between 1,500 to 3,050 meters (5,000 - 10,000 ft.), with flowing product temperatures up to 177 ºC (350ºF), and system shut-in pressure at 64.8MPA (65ksi).

This FE model is a good starting point for any flowline PIP design that will be installed by the reeling method, and to investigate the effect of reeling on the in place operational limit states.

Pipe-in-Pipe (PIP) Systems

Pipe-in-pipe (PIP) flowline systems are frequently used for subsea tie-backs where there is a requirement for high thermal performance. Fig. 1 shows a typical pipe-in-pipe system configuration.
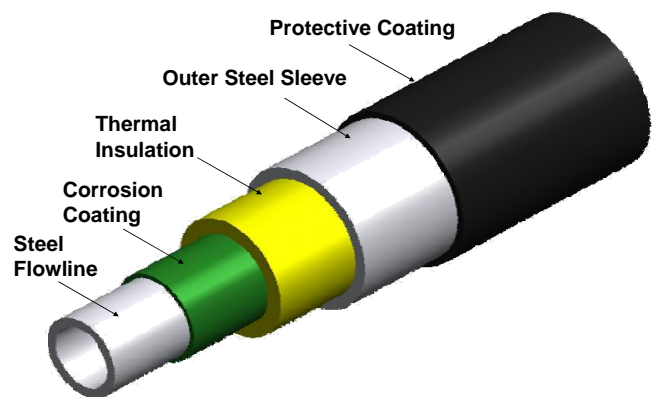

Fig. 1: A Typical Pipe-In-Pipe Configuration

A PIP flowline has the advantage over traditional wet insulated pipelines of allowing a lower 'Overall Heat Transfer Coefficient' (OHTC) for the system. For longer subsea tie-backs, a lower OHTC allows the production temperatures of the internal contents to remain above the wax allowable temperature (WAT), this facilitates longer 'cool-down' times during a 'shut-down' scenario, to prevent hydrate conditions. A shut-down time of at least 8 to 10 hours is considered to be the minimum requirement, which can be a large challenge for long tie-back distances.