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Monitoring and Effective Integrity Management of Laterally Buckled Flowlines in Deep Water

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Abstract

This paper reviews various methods available for surveying and monitoring the condition of laterally buckled flowlines in deepwater, with sufficient accuracy to meet integrity management requirements.

Subsea pipelines are increasingly being required to operate at higher temperatures and pressures. The natural tendency of a pipeline is to relieve the resulting high compressive loads by buckling. In deep water developments, various methods have been adopted to encourage and control lateral buckling as a cost-effective and practical solution. However, to demonstrate that the selected method is effective in practice and, hence, that a flowline is fit for purpose, it is necessary to obtain positional data of high accuracy to feed into the lateral buckle response and fatigue models, post-lay, after start-up, and throughout operational life. Experience from the integrity assessment of a number of pipelines has shown that estimating loads within lateral buckles by matching FE-generated profiles to survey-generated profiles is not easy, even in relatively shallow water. This is primarily due to survey accuracy limitations, which tend to increase with water depth. These challenges are demonstrated with examples from actual projects.

Introduction

The operating condition of HPHT (high-pressure high-temperature) flowlines means that they are susceptible to lateral buckling. A lateral buckle results from instability due to axial compressive loading, otherwise known as Euler buckling. Extreme conditions can develop within a lateral buckle; on first load, the stresses can exceed yield and may involve significant plasticity, whilst in normal operation, regular shutdowns can lead to high stress cycles.

The key limit states in a lateral buckle are:

- local buckling
- fatigue
- weld fracture

These limit states are addressed in design by specifying the formation of lateral buckles at regular intervals along the flowline length. This is an efficient solution to the high axial force problem and allows the load to be shared between the lateral buckle sites. Various methods are used to ensure the reliable initiation of lateral buckles. However, the result is a dynamic system that will respond to variations in the operating temperature and pressure throughout the life of the flowline. As with any dynamic system, conditions may arise that prevent the system behaving as the designers intended, introducing the threat of overloading, or the excessive accumulation of fatigue damage. Management of the integrity of such a system therefore requires monitoring of the operating conditions and system response throughout its life.

In the case of lateral buckling, local curvature in the buckle is the critical parameter, and there are methods for measuring this. However, most monitoring methods involve determining the position of the flowline, and deriving the curvature from this. Clearly, the accuracy of the determination of load and fatigue accumulation therefore depends upon the accuracy with which position, or shape, can be measured; this paper investigates the various methods available, and the relative accuracies that can be achieved. However, integrity management of pipelines also requires the monitoring of other characteristics, such as internal and external corrosion, and external damage, as well as information related to internal operating conditions (pressure, temperature and corrosivity).

This paper addresses the extent to which the various methods for measuring position and condition should fit into an integrated integrity management strategy. This includes external and internal inspection vehicles, with their associated positioning systems and data acquisition methods. Static data acquisition systems are also reviewed.

Integrity Management

Fitness for Purpose and Design Life

Integrity management is the process of maintaining a pipeline system fit for purpose for the design life or, indeed, for as long as it might ultimately be required. In many areas of the world a number of pipeline systems are still operating many years beyond the original design life. This is perfectly