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Techniques for the Assessment of Pipe-Soil Interaction Forces for Future Deepwater Developments

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Abstract

A large subsea development will comprise a floating production system connected to subsea wells by a large network of infield flowlines. These flowlines are all susceptible to lateral buckling and pipe-walking under operating conditions, with the challenge of meeting design limits states associated with local buckling, fracture and low-frequency fatigue damage during the operational cycles. The pipe-soil interaction response is the largest uncertainty in the design of such systems, and has a significant influence on the pipe response and structural limit states.

The Project therefore commissioned a series of project-specific test programmes, at large-scale and small-scale, to improve understanding of axial and lateral pipe-soil interaction under monotonic and cyclic loading. The project has also carried out novel *in-situ* pipe-soil interaction tests in the field. The test programme was focused on relatively heavy pipe behaviour associated with pipe-in-pipe systems in very soft deepwater clay. The findings from these tests have led to a radical reappraisal of the interaction mechanisms and provided much greater confidence in optimised design solutions for the project.

The test methods are described and the results and interpretation are summarised. These illustrate the significant advance in geotechnical knowledge and understanding achieved during this project, which is expected to benefit many future projects.

Background

Field Description

This typical deepwater subsea development will comprise a floating production system connected to subsea wells by a large network of infield flowline systems, including:

- Production flowlines with high performance pipe-in-pipe insulation, and uninsulated service flowlines;
- Water injection networks comprising plastic-lined rigid steel pipe;
- Gas injection flowlines comprising uninsulated pipe for a future gas export system.

Susceptibility and Control

Any pipeline which is subjected to above ambient temperatures and pressures has a tendency to relieve the resulting high axial stress in the pipe wall by expanding longitudinally. This expansion is resisted by the axial soil resistance between the pipe and the seabed. This restraint causes an axial compressive force to develop in the pipeline, which can cause buckling. Because these pipelines are laid in deep water there is no requirement for pipeline trenching and therefore no lateral or uplift restraint acting on the pipeline to prevent buckling, apart from the lateral resistance between the pipe and the soil.

A key challenge for this subsea flowline design is the control of lateral buckling, pipe walking, or route curve instability of the flowlines between the riser base and the drill centres. Conceptual engineering and FEED (front end engineering design) confirmed that all flowlines are susceptible to lateral buckling and several are susceptible to pipe-walking. If left uncontrolled, this behaviour can have serious consequences for the integrity of a pipeline.

Uncontrolled lateral buckling can lead to high strains and cyclic loads at the buckle crown, which can compromise the integrity of a pipeline, due to local buckling of the pipe section, weld fracture or fatigue failure. In addition, these flowlines have in-line tee assembly structures (ITAs) and pipeline crossings which require careful consideration to prevent unplanned ‘rogue’ buckles forming close to the ITAs that might compromise their integrity. Lateral buckling is therefore controlled using