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Lateral Buckling Reliability Calculation Methodology Accounting for Buckle Interaction

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Abstract

High pressure/high temperature (HP/HT) flowlines can significantly expand and contract during heating/cooling cycles. For flowlines laid directly onto the seabed this may result in lateral buckling at naturally occurring locations of high out-of-straightness (OOS). When this expansion and contraction is not managed the buckling behaviour may be unacceptable. To manage the buckling behaviour, artificial buckle initiation locations can be designed into the system to ensure the buckling behaviour is acceptable.

Explicit reliability calculation methods must often be combined with analytical and finite element (FE) analyses to demonstrate the safety and effectiveness of a particular lateral buckling design. For EPCI contractors, this presents issues at the tender stage as it is often very difficult to determine the optimum lateral buckling strategy at this stage in a project. The potential for significant design changes to be made relatively late in the design process is a significant motivation to further develop industry expertise in the field of lateral buckling design. Expertise in the use of explicit reliability calculations must also include expertise in the interpretation and use of the results. There are significant difficulties in defining the statistical variations in key design variables such as soil friction coefficients. The reliability answer obtained can be highly dependent upon judgements made in developing input distributions. These difficulties make reliability assessments a key tool in decision making; they allow the effects of uncertainties in the input and response to be assessed in a rational way.

Two examples are presented that demonstrate how reliability techniques can be used to study lateral buckle initiation. They are; an example of the initiation of a single buckle on a sleeper and an example of the potential for buckling between planned initiation sites. An introduction to reliability calculation methods is provided. The examples are

then worked through in depth highlighting the use of the techniques in understanding the initiation problem. Emphasis is placed upon understanding the problem not just producing a numerical answer. When there are difficulties in determining the input distributions, the understanding of what affects any reliability answer is a key input to decision making.

Introduction

The management of the thermal expansion of high pressure/high temperature (HP/HT) flowlines laid directly onto the seabed can be achieved by allowing the flowline to buckle laterally in a controlled manner. The objective is to produce a design solution where the lateral buckling occurs at predetermined locations, and for the thermal expansion feed in at those locations to result in acceptable bending loads in the pipeline.

However, this is a far from simple design task and the industry has undertaken extensive study on the topic of lateral buckling in recent years. Two JIP projects, SAFEBUCK [1] and HOTPIPE [2], were instigated to further the industry's knowledge of the management of the thermal expansion in pipelines. There have also been a significant number of papers published describing the experiences and lessons learnt on projects where the management of lateral buckling was a significant part of the design process [3].

A lot of the work has been directed towards studying pipeline lateral buckling behaviour and the factors that influence it. It has become clear that explicit reliability calculation methods must often be combined with analytical and finite element (FE) analyses to demonstrate the safety and effectiveness of a particular lateral buckling design. This differs from normal pipeline design practice and greatly increases the complexity and uncertainty involved in determining an acceptable lateral buckling design solution.

A key issue is that the industry knowledge of lateral buckling management is still maturing; this can make it very difficult to choose a design solution at the EPCI tendering stage due to the complex design issues. This can prove to be extremely problematic, particularly for deep water projects, due to the significant costs that may be incurred to implement changes to the chosen design solution. This can introduce complex commercial issues that are not readily resolved. As the industry becomes more proficient at designing lateral buckling solutions the difficulties in selecting an appropriate