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Effect of Lateral Pipelay Imperfections on Global Buckling Design

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ABSTRACT

Global buckling for exposed HPHT (High Pressure / High Temperature) subsea pipelines is an important feature that needs to be assessed during detailed design. Lateral imperfections (or horizontal out-of-straightness) due to pipelay can either be intended, i.e. due to lay route or due to unintended as-laid variations to the idealised lay route. The unintended variations to the idealised lay route can have a significant impact on the design for lateral buckling.

This paper draws upon the results presented by Rundsag et al (2008) to demonstrate that there is an interaction between horizontal out-of-straightness radius and arc length that should be considered when assessing lateral pipelay imperfections. This paper presents the proposed methodology to define and assess potential as-laid variations of the idealised lay route during detailed design.

KEY WORDS: Lateral buckling, subsea pipelines, out-of-straightness, snaked-lay, finite element, high pressure / high temperature.

INTRODUCTION

Thermal buckling of subsea pipelines has traditionally been controlled by trenching and burying the pipeline, i.e. to constrain the pipeline configuration and prevent pipeline movement. Subsea pipelines are increasingly being designed to operate at high pressure / high temperature (HPHT) which may require an uneconomical amount of overburden to prevent upheaval buckling. Pipelines are increasingly being left exposed on the seabed and allowed to buckle laterally, providing that the resulting loads within the buckle are acceptable.

A popular option is to lay the pipeline in a snaked configuration so as to predispose the pipeline to buckle at route bends which are suitably spaced to ensure a limited thermal feed-in to the buckle site and hence acceptable loads in the buckle. This method has been successfully implemented in recent years on a number of projects such as the Penguins project (Matheson et al (2004)) and the Echo Yodel project (Wagstaff (2003)). Further development of the snaked-lay concept is presented by Rundsag et al (2008).

An alternative method is to lay the pipeline over vertical imperfections which are suitably spaced to result in acceptable loads in a buckle. The imperfection acts to both reduce the lateral restraint at the site and to create an initial out of straightness in the pipeline which increases the likelihood of the pipeline to buckle laterally. This method has been successfully employed via the use of natural terrain irregularities on the Åsgard project (Slettebø et al (2001) and Nystrøm et al (2001)) and by the use of vertical triggers on the King project (Harrison et al (2003)).

Independent of buckle control strategy, the effect of unintended pipelay induced horizontal out of straightness needs to be considered in the design of a HPHT pipeline system susceptible to lateral buckling (i.e. horizontal out of straightness may induce buckling in preference to planned sites). Two JIP projects, HOTPIPE and SAFEBUCK, were recently performed in order to further develop industry knowledge of the design of pipelines susceptible to lateral buckling.

The results of the HOTPIPE JIP form the basis for DNV's recently published recommended practice DNV-RP-F110 (2007). The following guidance is provided within the recommended practice in relation to pipelay out of straightness: "A larger imperfection than anticipated may be required in order to allow this to buckle for all sensitivity studies in line with the design procedure." The recommended practice offers no specific details as to what size of pipelay out of straightness imperfection to assume.

The results of the SAFEBUCK JIP have been developed into the SAFEBUCK Design Guideline (2004) which proposes a methodology based on in-place survey data of four operational pipelines donated by JIP members. The guideline proposes that pipelay out of straightness be assessed in terms of lay radii / curvature based on a distribution extracted from the donated survey data.

This paper proposes an alternative methodology to define and assess potential as-laid variations (horizontal out of straightness) to the nominally straight lay route during design. It is proposed that the horizontal out of straightness may be expressed in terms of changes in pipe heading as the significant variable when considering the out of straightness provided the associated arc length is sufficiently small.