Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Efficient Assessment of Subsea Pipelines and Flowlines for Complex Spans

James Wang, Paul Jukes, Steven Wang, Gang Duan
JP Kenny, Inc
Houston, TX, USA

ABSTRACT

Pipeline spans occur when a flowline is laid on a rough seabed and/or when upheaval buckling of the flowline is generated due to thermal expansion. This not only results in static and dynamic loads on the flowline at the span section, but also generates Vortex Induced Vibration (VIV) responses. The phenomenon, if not predicted and controlled properly, will result in significant damage to the pipeline integrity.

The span issues can be very complicated to analyze due to the long span lengths, a rough seabed, the large number of spans, and multi-span interactions. In addition, the complexity can be more onerous and challenging when soil uncertainty, unknown residual lay tension, and variation of spans from year to year is considered in the analysis.

The methodology discussed in this paper will not only highlight the most important areas in the assessment of the complex spans but also provide many technical details. The new methodology presented in this paper includes the following: The initial data assessment for seabed and wave/current is discussed and certain assumptions are made for a conservative design; Understanding of DNV design code and implementing it using advanced numerical FE tools is an evaluation basis for span analysis; In the FEA modeling, many details are discussed such as model length and concrete induced SCF (Stress Concentration Factor) at field joints; Certain sensitivity studies for concrete degradation, survey accuracy, and soil stiffness are also discussed to ensure the most conservative cases are captured. Special cares are mentioned in the ULS check for wave/current data (extreme or significant) and wave load application to interacting spans; In addition, an example of fatigue calculation for an interacting span is provided.

The approach used in the methodology brings a useful guideline to the span analysis, especially in the complex span conditions.

KEYWORDS: Boundary Condition (BC); DNV (Det Norske Veritas); FLS (Fatigue Limit State); FM (Force Model); KP (Kilometer Post); Mode Shape; Natural Frequency; RM (Response Model); VIV (Vortex-Induced Vibration); ULS (Ultimate Limit State); and Unit Stress.

NOMENCLATURE

Boundary Condition Coefficients:	c1 – c3
Concrete Stiffness Enhancement Factor:	CSF
Critical Buckling Load:	P_{cr}
Effective Axial Force:	S_{eff}
Effective Mass:	m_e
Maximum Current Velocity	U
Moment of Inertia for Steel:	I
Pipe OD:	D
Static Deflection:	δ
Strouhal number	S_t
Vortex Shedding Frequency	f_s
Young's Modulus:	E
Natural Frequency	f

INTRODUCTION

When a pipeline experiences potential damage due to a span, it is important to adopt an appropriate methodology to identify any potential damage. The integrity of the pipeline can then be evaluated with confidence in order to make a decision for the future service of the pipeline.

The analysis for a free spanning pipeline can be very complicated due to variations of the current/wave data within different pipeline sections, soil complexity, multimode vibrations and a high number of spans that can either be very long or interacting. Even more complexities will be introduced when both response and force models are considered in the analysis. The response model is an empirical model providing the maximum VIV response in both in-line and cross-flow directions. A force model is based on Morison's equation for direct in-line loading. The response model has been commonly used in many analyses in JPK projects.

The span evaluation of new or existing pipelines is compliant with the design principles in DNV-RP-F105 (DNV, 2006). Based on the DNV code, the study of free spanning pipeline includes both response and force models. The response models are based on a Vortex Induced Vibration (VIV) amplitude response where the VIV is caused by vortex shedding across the pipeline. There are two types of oscillations to consider: in-line and cross-flow oscillations. The in-line oscillation occurs when the pipeline vibrates in a lateral motion. The cross-flow oscillation occurs when the pipeline vibrates in a vertical motion. The influencing factors in VIV design are:

- Pipe size, weight, and geometry;
- Any additional weight such as content, insulation, and fittings;
- Current and wave parameters;
- Residual lay tension within the pipeline;
- Operational conditions such as temperature and internal pressure.

VIV analysis includes natural frequency calculations, which are normally performed using a Finite-Element (FE) method for the following reasons:

- The seabed geometry is complicated;