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)

Design Loads Uncertainties Study - Thermal Buckling of Subsea Pipelines

Jiong Guan   *Per R. Nystrøm*

IKM Ocean Design AS
Stavanger, Norway

ABSTRACT

Thermal buckling has become an important issue for HPHT (high pressure high temperature) subsea pipelines design. The uncertainty of design loads could result in a large cost impact in terms of the measures required for controlling pipeline buckles and expansion, such as seabed intervention, buckle trigger device and so on. The uncertainty is represented with condition load effect factor, γ_C, in the format of Load and Resistance Factor Design (LRFD) in the design guideline DNV RP-F110. The applied loads are multiplied by condition load effect factor, γ_C, to have design loads. Without addressing the uncertainties involved in the design load properly, it could result over-conservative or under-conservative design. The standard calibration methods of the condition load effect factor, γ_C, are introduced together with a design example in this paper. The uncertainties of soil resistances are discussed specifically and explain how the large variation and non-symmetric upper and lower bound associated with soil resistance affect the condition load effect factor, γ_C, calibration. In addition, the statistics of pipeline penetration on the clay and sandy seabed is given based upon the real pipeline as-laid survey data. The pipeline penetration on the sandy seabed has highly non-symmetric probability distribution compared with that in clay seabed. In order to investigate the uncertainties of resulting bending moment response of pipeline under thermal buckling, a statistical analysis approach stemming from the Markov Chain Monte Carlo (MCMC) Bayesian techniques has developed.

KEY WORDS: Subsea pipelines; Global buckling; Statistical analysis; Condition load effect factor; Markov Chain Monte Carlo.

INTRODUCTION

The uncertainty of design loads significantly affects the analysis results of subsea pipeline under thermal buckling. It could have a large cost impact in terms of the measures required for controlling pipeline buckles and expansion towards spools etc. These include seabed intervention, buckle trigger device and so on. The uncertainty is represented with condition load effect factor, γ_C, in the format of Load and Resistance Factor Design (LRFD) in the design guideline DNV RP-F110, 'global buckling of submarine pipelines'. The applied loads are multiplied by condition load effect factor, γ_C, to have design loads.

The uncertainties of pipe-soil interaction, pipe material properties, trawl pull-over loads are addressed in DNV RP-F110. The model uncertainty is partially accounted by giving the condition load effect factor, γ_C, a lower bound value of 0.8. For each of the aspects considered, the uncertainty is defined as the coefficient of variation for the bending moment response for the upper bound, best estimate and lower bound design value. This approach is based on the assumption that upper bound and lower bound responses have same variation from the best estimate response in the probabilistic point of view. In some situations, the pipeline buckle response becomes highly non-linear with the variation of design parameters. For example, soil friction always gives big variations for the bending moment response, considering the complexity of pipe-soil interaction, installation procedures and so on.

In this paper, the general calibration procedures for the condition load effect factor, γ_C, has been given according to the requirement of DNV RP-F110. The specific discussion has been given for the parameters with large variation and non-symmetric upper and lower bound, as explained by the example of pipeline on-bottom soil resistances. The probability distribution of pipeline penetration for the clay and sandy seabed are given based on the pipeline as-laid survey data.

A statistical analysis approach stemming from the Markov Chain Monte Carlo (MCMC) Bayesian techniques is devised for statistical inference of the uncertainties of bending moment of pipeline during thermal buckling, where Bayesian method can incorporate subjective knowledge with experimental results, or observations and MCMC can deal with sophisticated distribution efficiently. The effectiveness of the MCMC approach is demonstrated by applying the technique to analyze the relationship of pipeline buckle response to the design soil parameters. It is then applied to derive the distributions of the variation of the resulting bending moment. More accurate distributions can be established following the same approach when more survey data become available.

Finally, a design example is given for the condition load effect factor,