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Full-Scale Testing of Flexible Riser System Subjected to Internal Flow-Induced Vibration

M.J. Every, Sound Research Laboratories; H.G.D. Goyder, Cranfield U.; T. Jee, Trevor Jee Assocs.; R. Swindell, Bureau Veritas; and L. Billingham, BP Exploration and Operating Co.

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Abstract

Noise and vibration in flexible riser production systems exporting dry gas can cause failure of small bore connections due to fatigue-induced vibration. The fundamental cause is vortex shedding within the corrugated, flexible riser. Small scale testing and Finite Element modeling have been used to demonstrate the extent of the problem and the conditions under which it might occur. These model results agreed with measurements which were made on the Schiehallion FPSO operating West of Shetland. A means has been developed and proved experimentally to test full scale equipment at operational dynamic and static pressures with a gas flow of natural gas. This methodology was used to test a replica of the Flow Termination Assembly currently deployed sub-sea on Schiehallion. The work showed that a fatigue failure was indeed possible, but the necessarily unfavourable condition had not occurred to date. We were able to show under what conditions it might occur and to explain why it had not occurred to date. Finally a means to mitigate the potential problem was developed, proved and deployed. The work allowed the continued operation of the export line without risk of fatigue failure and for the production flow rate to be safely, further increased.

Introduction

Flexible risers are increasingly being used offshore and most recently for the export of dry gas. This has led to the phenomenon of the singing riser whereby large pressure fluctuations within the riser can be heard as acoustic tones. If the frequency of the tones is coincident with the structural natural frequency of the equipment associated with the riser, large amplitude vibrations may be excited. This might lead to fatigue failure.

This phenomenon is widespread on many systems. It affected the export riser system of the BP Schiehallion FPSO. Modifications were made to the affected topside equipment to avoid fatigue damage. However, it was not known if there was likely to be a problem with the sub-sea 'Flow Termination Assembly', FTA. Some limited sub-sea measurements did indicate high vibration levels although there was not sufficient instrumentation to determine the associated stresses. As a consequence of these measurements flow restrictions were imposed to maintain the topsides and sub-sea vibration within limits. The operator sought assurance that the sub-sea system could safely be operated up to design capacity significantly in excess of the operational limit.

A consortium was formed by the authors to investigate the problem. Our work involved Finite Element modeling and small scale, atmospheric, acoustic testing which demonstrated the likelihood of high stress levels and the condition under which they would occur. However, the scaling laws were not understood and it was not possible to model several of the parameters, either numerically or at small scale. Full scale testing was therefore done and a description of this work forms the major part of this paper. A replica of the FTA deployed on Schiehallion was tested in a flow loop using methane at the full scale export pressure of 170 bar. The dynamic pressure fluctuations, mimicking those within the riser, were provided by a siren.

The tests showed a theoretically possible set of circumstances and flow regime, that would excite a structural response which could lead to fatigue failure. Structural modifications were proposed and tested. These have subsequently been implemented offshore. The work has given considerable insight and enabled existing installations and future designs to be best configured to avoid similar problems. The economic ramification was that gas production export rate could be significantly increased

Theory and Definitions

As the dry gas flows over the internal corrugations in the riser there are oscillations in the fluid shear layers and vortices are shed. The shedding is not necessarily correlated along the length of the riser.