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Flow Induced Pulsations due to Flexible Risers

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Abstract

Flexible rough bore pipes are widely used in the oil and gas industry. One application is their use as risers and jumpers for gas production, transport and injection. In the past, some flexible pipes have been experiencing high amplitude tonal pressure fluctuations above critical velocities. These pulsations can cause mechanical vibrations at topside and subsea platforms, resulting eventually in topside/subsea piping failures [Swindell 2007].

A Joint Industry Project, sponsored by BP, Bureau Veritas, ExxonMobil, Shell, StatoilHydro, TNO and the UK Health & Safety Executive, has addressed the technical issues associated with this singing phenomenon. A good understanding of the phenomenon has been achieved, by combining actual offshore measurement data, laboratory test results at low, medium and high pressures and numerical acoustic and flow simulations. The JIP has recently been completed and the final results are now available.

The singing behaviour is strongly influenced by the corrugation geometry, the operating process conditions and the characteristics of the upstream and downstream connecting piping. Another critical parameter is the liquid content of the gas. Small amounts of liquid already increase the critical velocity significantly. Guidelines have been developed on practical assessment and mitigation measures for existing assets and precautionary design measures for planned assets.

This paper describes the influence of the topside and subsea piping and of the liquid content of the gas on the critical velocity to trigger the singing phenomenon. Furthermore, it describes the operational and design guidelines that have been developed.

Introduction

In recent years a number of floating production platforms that use flexible risers for exporting or injecting gas have experienced high levels of piping noise and vibration. The problem can be attributed to flow induced pressure pulsations (FIP) from the flexible riser's shackle-type carcass, which has a corrugated (Agraff) profile. When gas passes through the flexible riser vortex shedding occurs at each of the internal corrugations, generating pressure pulsations. As the gas flow is increased, high levels of distinctive tonal noise (frequency increasing with flow rate) and vibration occur on the associated piping. The pulsation induced vibration forces acting on the piping can excite mechanical natural frequencies if the piping is not properly supported. The resulting piping vibrations then lead to fatigue failure, particularly in welded connections to the main piping. The pulsation induced vibrations have resulted in at least two piping failures on small bore side branches on topside piping. With the problem evident for gas flow velocities as low as 1.5 m/s, production capacity may be severely limited. To date at least seven assets worldwide have all experienced this problem and it is considered likely that this number will increase as the demand for gas export from deepwater fields increases.

A Joint Industry Project (JIP), involving BP, Bureau Veritas, ExxonMobil, Shell, StatoilHydro, Shell, TNO and the UK Health & Safety Executive, has addressed the technical issues associated with the high amplitude, pressure pulsations and the associated short term pipe work vibration-induced fatigue issues. The pulsations are generated due to vortex shedding and shear layer instabilities at the corrugations. At each corrugation a boundary layer grows which separates at the upstream edge of the corrugation. This forms an unstable shear layer which can dampen or magnify acoustic flow disturbances. If a coupling occurs with an acoustic field, for instance in the case of an acoustical resonance in the tube, a feedback mechanism occurs where the acoustical field is amplified by the shear layer instabilities and the acoustical field itself magnifies the layer instabilities [Bruggeman 1997, Kooijman 2007, Kopiev 2005, Kristiansen 2006, Popescus 2008, Petrie 1979, Ziada 1991].

In the JIP by combining actual offshore measurement data; part and full scale test results at low, medium and high pressures; and both theoretical acoustic and flow simulations, the whistling behavior is examined. In the project specifically