Guidance for the avoidance of vibration-induced fatigue failure in subsea systems

GUIDELINES FOR THE AVOIDANCE OF VIBRATION-INDUCED FATIGUE FAILURE IN SUBSEA SYSTEMS

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1 INTRODUCTION

The risks from flow-induced vibration excitation of pipework are widely acknowledged in onshore process plants and offshore topsides facilities. The EI guidelines for avoiding associated fatigue failure, EI *Guidelines for avoiding vibration-induced fatigue failure in process pipework*, have become an industry standard, particularly for the design of new plant. Conversely, the vibration assessment of subsea pipework has historically been limited to external vortex-induced vibration of riser systems and unsupported pipeline spans due to tidal currents and wave action. Consequently, comprehensive integrity management guidelines for subsea systems, such as EI *Guidelines for the management of integrity of subsea facilities*, do not adequately address flow-induced vibration. However, recent failures of subsea equipment, in part due to increased flow rates, have raised the risk profile of internal flow-induced vibration excitation.

Many parts of the existing EI *Guidelines for avoiding vibration-induced fatigue failure in process pipework* are also applicable to subsea pipework. The methodologies from these guidelines have therefore been adapted, along with more recent understandings of flow through flexible risers, to develop the current document for the avoidance of vibration-induced fatigue failure in subsea systems.

1.1 SCOPE

This guidance document provides an understanding of, and various methodologies for, minimising the risks from internal flow-induced vibration excitation of subsea pipework systems. The scope covers all subsea systems from the mud line to the topsides interface, including well trees, flowline termination assembly (FTA), PLETs, manifolds, jumpers, instruments and flexible risers. Services will include production, oil/gas export, gas lift and gas/water injection. Procedures are provided to cover both the design of new subsea facilities, and the assessment and upgrade of existing systems.

This document covers the most common piping excitation mechanisms, with the exception of slugging flow and environmental loading.

1.2 OVERVIEW OF PIPING VIBRATION ON SUBSEA FACILITIES

Potential vibration-induced fatigue failures of subsea pipework are a major concern to the industry due to issues associated with:

– The hidden nature of any threat – there is usually no direct evidence to the operator of a vibration problem occurring.
– Safety and environmental impacts due to loss of explosive gases and/or hydrocarbon pollutants.
– Production downtime.
– High costs associated with remedial actions.
– Difficulties in obtaining subsea measurements on existing equipment.

The most common causes of flow-induced vibration excitation are expanded in this section.

1.2.1 Flow-induced turbulence

Broadband low frequency energy is generated by turbulent flow through valves, expansions, tees and bends. This energy, combined with fluid momentum changes associated with changes of flow direction, interacts with the pipe wall and can excite both the pipework and its supporting structure. Methodologies are available to estimate the levels of excitation based on fluid flow data for single-phase flow and multi-phase flow for different flow regimes.

1.2.2 Flow-induced pressure pulsations

In gas systems, flow instability/vortex shedding associated with flow past a discontinuity can generate small pressure perturbations with a discrete frequency. If the excitation frequency is close to an acoustic frequency of the gas in the pipework system, lock-on can occur, leading to the generation of relatively high flow-induced pressure pulsations. In subsea pipework systems the two situations where this phenomenon can occur are:

- Closed branches – flow past closed branches (dead legs) generates vortices in the mouth of the branch; the pressure perturbations can then excite an acoustic resonance of the gas in the closed branch.
- Flexible risers/jumpers – rough bore flexible risers/jumpers are extensively used to connect components of subsea systems. Flow over the internal corrugations also generates vortices with discrete frequencies, which can then excite acoustic modes of the connected pipework systems (both subsea and topsides in the case of flexible risers).

Although both mechanisms lead to the excitation of pressure pulsations, the acronym FLIP is usually reserved for flow-induced pulsations (FLIP) associated with rough bore flexible risers. Methodologies are available to estimate the likelihood of issues due to both pulsations in dead legs and FLIP.

1.2.3 High-frequency acoustic excitation

In gas systems, high levels of high-frequency acoustic energy can be excited downstream of a pressure-reducing device, especially if choked flow occurs. Whilst relief and blowdown systems are not usually found on subsea systems, such conditions can occur downstream of choke valves.

1.2.4 Surge/momentum changes

Surge is a pressure wave caused by the rapid change of momentum in liquid systems when a valve is closed. The pressure wave is propagated back upstream at the speed of sound in the liquid and can give rise to high levels of transient force on the pipe wall.

High transient forces can also be generated by the rapid change of fluid momentum caused by the sudden opening of a valve, in both gas and liquid services.