Mitigation of Flow-Induced Pulsations in Flexibles at Field Conditions with Liquid Injection

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ABSTRACT

Flexible corrugated pipes as used for the transport of gas in offshore deepwater applications can generate undesired flow-induced pulsations (FLIP). This phenomenon has been also traditionally called “singing risers”. The pulsations generated may result in high-amplitude cyclic stresses in the pipe systems attached to the flexible. Moreover, an HSE risk for the operators around the riser arises due to the tonal noise radiated from the system. The root cause for this phenomenon is nowadays well understood. Namely, vortex shedding at each internal corrugation of the carcass induce pressure pulsations which are eventually synchronized and amplified by an acoustical resonance along the length of the flexible. Despite this established knowledge, mitigation or suppression of the phenomenon once it occurs is hard to achieve.

The purpose of this paper is describing field tests executed for a live natural gas export corrugated riser in the North Sea. The tested mitigation measure was liquid injection upstream of the g

INTRODUCTION

Flow-Induced Pulsations in Flexibles (FLIP) has become an important issue for offshore production systems exporting dry gas. FLIP occurs when a feedback loop mechanism is established between the flow shear layer formed at each corrugation of the flexible and longitudinal acoustic resonances of the flexible. Pressure pulsations travel into the systems attached to the flexible. For a typical riser configuration, that means the topside piping and the subsea riser base or manifold. Pressure waves can easily find acoustic resonances in these piping systems, as the frequency of FLIP is normally in excess of 100 Hz for the ground tone (higher for its harmonics). The main risk associated to FLIP is the integrity of small side branch connectors (SBCs), which can fail very quickly as a result of high-cycle fatigue. High levels of noise can also be radiated, which is a health issue to operators present on the platform.

There are several ways to evaluate whether a flexible is going to experience the undesired FLIP phenomenon. The first model developed is based on a joint industry project (Belfroid, 2009) that resulted in an empirical model. This model returns as end result the onset velocity, the flow speed above which FLIP is to be expected. It is based on a large number of lab experiments to determine the dimensions and parameters that play a role and calibrated against the Åsgard platform operating in the Norwegian Continental shelf. This model has been recently implemented in (Energy Institute, 2018), for cases in which dry gas flows through the flexible pipe. Dry gas is defined at a threshold value for the liquid volume fraction of $1 \times 10^{-3}$ (0.1%). Since then, other physics-based models have been developed, such as the Power Balance Method (Nakiboğlu, 2011). In this model, FLIP is estimated as the balance of three different acoustic terms: the source, i.e. the amount of energy that is transferred from the hydrodynamic field to the acoustic field of the flow; the attenuation, which is the amount of energy in the acoustic field that is dissipated by viscous and thermal losses; and finally the radiation losses, which quantify the amount of acoustic energy lost through the ends of the flexible. A review of the aeroacoustics of corrugated pipes can also be found in (Rajavel and Prasad, 2013). Based on the previous research, model and test results are described in e.g. (Legeay, 2017).

FLIP was identified in an Equinor-operated platform producing both natural gas and oil. A flexible riser used for (dry) gas export was