ABSTRACT

Some offshore production fields require transporting of production fluids through very long submarine pipelines without a previous separation process. In the case of gas production, condensate will appear in the pipeline due to the pressure losses and low temperatures. For some production conditions a slug flow pattern may then develop in the pipeline, and because of the irregular sea bottom profile, there may be pipe unsupported spans of even hundreds of meters long. Therefore, slugs traveling in the pipeline will act as moving loads for the unsupported pipe, producing a dynamic response that in some cases might reduce the fatigue life of the pipeline.

In this work, a finite element (FE) model of a pipeline transporting slugs has been developed and used to assess the fatigue life of a horizontal pipeline. Slug hydrodynamic characteristics have been obtained using Taitel & Barnea’s model. The structural FE model is based in Bernoulli beam elements where slugs, once they have been geometrically characterized, are input as moving loads traveling in the pipeline. The system dynamic response was calculated for different spans conditions and slugs characteristics corresponding to different gas-liquid ratios typical from gas field production conditions. Once a steady state condition was obtained in the dynamic response, mean and alternating stress levels were obtained for each analyzed case and introduced in fatigue formulae to obtain the fatigue life of the pipeline. Results show that for some production conditions and free span longitudes, fatigue life of pipeline may experience important reductions due to slug flow. These free spans are obviously most likely to happen in extra long submarines pipelines.

INTRODUCTION

One of the current challenges of the oil and gas industry is the exploration and production of deep water fields (up to 3,000 m deep) avoiding the use of platforms to separate gas and liquid but requiring very long pipelines, which can be in excess of 200 km, from the sub sea facilities to the shore line.

Design and operational modeling of these long tieback pipelines include the analysis of tubular structure under different service load conditions.

Without a previous separation process, it is possible the apparition of a slug flow pattern in the gas-condensate pipelines. The slug flow pattern in the pipeline can be produced either by the slippage of gas and liquid phases (dynamic slug) at certain gas-condensate production rates or by the liquid accumulation in the multiphase flow at any pipeline section (terrain-induced slugging). This last type slug flow condition can cause large transient surges and it is mainly produced by the hilly condition of the seabed. The transient nature of slugs might become critical and can accelerate material’s fatigue with the risk of pipe failure, increasing inspection and maintenance costs if not properly considered.

This paper discusses the modeling of “dynamic slug” effect over fatigue life cycle of pipelines with extra long tiebacks (> 100 km). In order to determine the pipeline fatigue life it is necessary to calculate the dynamic stress level produced by the slugs. The prediction of the flow regime is essential to characterize the flow conditions that can produce pipeline vibration. For horizontal or near horizontal two-phase flow, five different flow regimes could be possible, i.e. stratified (smooth and wavy), annular, dispersed bubble and intermittent (slug flow). Only intermittent flow is able to induce vibration in the pipeline because of the transient variation of local fluid weight at different points in the pipe. In this work, the well