OTC 18063

Potential Failure Scenario for High-Temperature, Deepwater Pipe-in-Pipe

G. Harrison, BP, and B. McCarron, ASGM Engineering

Abstract

Pipe-in-Pipe has become a common design arrangement to realize a highly insulated, deep water flowline for oil and gas production. For S-lay and J-lay installation methods, the inner pipe may be free-standing inside the outer jacket pipe through the water column during pipelay with the outer pipe carrying the entire pipelay tension loading. This installation method results in permanent capture of a significant compression load for the entire inner pipe of the flowline. Upon startup of the flowline to transport high temperature gas and oil, the inner pipe warms to temperatures ranging from 150-350ºF (66-177ºC), or higher. Elevated temperature and internal operating pressure result in the inner pipe expanding while constrained axially by the outer pipe. The constrained expansion results in further compressive load in the inner pipe. This paper explores the potential failure envelope of the inner pipe for axial compression loading. Finite Element Analysis is used to explore the impact of high compression loads on the inner pipe. Evaluation of mitigation techniques, primarily pre-tensioning of the inner pipe is performed.

Introduction

Pipe-in-Pipe, hereafter PIP, is a common design arrangement to achieve a highly insulated production flowline delivering raw well production from a well or manifold to a remote process location. PIP is popular because it enables substantially lower heat loss per unit length than any available external insulation coating for a single pipe flowline.

For the GoM, the water depth of subsea production wells, and flowing temperatures and pressures are expected to increase in the near future. Water depths between 5000-10,000 ft (1500-3000 meters), wellhead temperatures up to 350ºF (177ºC), and Shut-In Pressures (SIP's) to 20 ksi (138 MPa) are possible. Exploration has begun of the potential problems related to these factors to reduce the problems and execution schedule for projects. The subject paper arose from execution of studies related to this front end work.

Problem Recognition

One of the studies undertaken was to explore thermal expansion of a PIP flowline carrying oil/gas production at temperatures up to 350ºF (177ºC). Goals of the study were to determine PIP flowline thermal expansion loads, and how effective existing solutions of sleeper-induced lateral buckling and buoyancy-induced lateral buckling (Figure 1) were in managing the expected thermal expansion buckling.

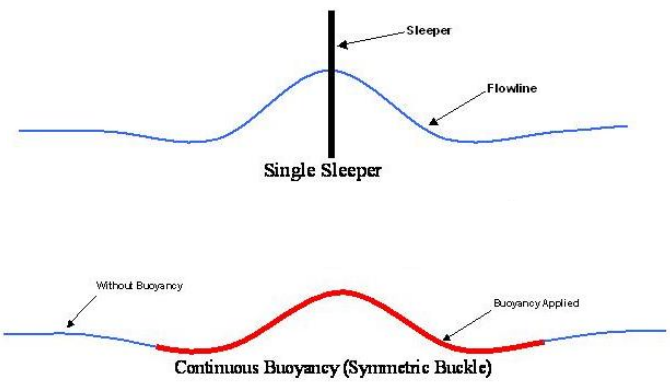

Figure 1 Sleeper & Buoyancy Induced Lateral Buckling

FEA modeling used a static approach to sequentially apply, using a pseudo-time scale, various installation, weight, pressure, and temperature loadings. The inner and outer pipes in PIP flowlines were modelled individually using beam-column elements to capture the global response.

Installation loading was known to impact in-situ axial loads in the inner pipe. Consequently, FE analyses of the PIP included residual 'locked-in' installation loads. In particular, for PIP installed by S-lay or J-lay with the inner pipe free-standing inside the outer pipe, it was recognized that a substantial residual axial compression load would be captured as the lay vessel progressed.

Subsequently, during thermal expansion analyses with sleepers or buoyancy-induced lateral buckles, it was observed that buckle amplitude increased to a level, but remained constant despite rising internal operating temperature. Investigation indicated the inner pipe was reaching yield stress and with a perfectly-plastic material model, no further stress increase occurred, only additional compressive strain on the inner pipe. This was confirmed by modeling the inner pipe