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Investigation into the Limit State Design of XHPHT PIP Flowlines using Local and Global Finite Element Analysis Methods

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Abstract

Development of deep water oil reservoirs is presently being considered in the Gulf of Mexico (GoM) where the flowline product temperatures approach 177°C (350°F), and water depths to 3,000 meters (10,000ft). The design of these flowlines requires the use of advanced 'local' and 'global' Finite Element (FE) analysis models, integrated with limit state design methods. This paper presents the 'local' and 'global' FE models developed to investigate the limit state design of Extra High Pressure High Temperature (XHPHT) flowlines.

The 'global' PIP FE model is used to conduct design sensitivity analyses and provide the input loads for limit state design checks. Using the global FE model, investigations are undertaken to examine design issues such as effectiveness of thermal expansion buckle management, application of inner pipe pre-tension and load sharing device, and the effect of operating temperature. The 'local' full size PIP FE model is used to verify the global PIP FE model at a local level. Global and local FE models present comparable results in term of pipeline stress response. A 3D helical arrangement of the inner pipe subjected to high temperature is observed. This helical shape is sensitive to temperature and material thermal expansion coefficient.

The investigation's goal is bridging technology gaps by pushing the boundaries of PIP designs for XHPHT applications in the GoM. These innovative, cutting edge finite element models could be used by the pipeline for future deep water PIP XHPHT projects.

Introduction

The pressure and temperature of the oil and gas contents coming out of the ground and well head may be high, and this can be a key design challenge for pipelines. High Pressure / High Temperature (HP / HT), with pressures in the order of 700bar (10,000PSI), and temperatures being considered up to 160°C (320°F) are not uncommon. High Pressure and High Temperature (HPHT) reservoirs are typically, but not exclusively, gas condensate fields. They are technically more complex to develop because of the inherently higher energy in the well fluid. Although initially developed exclusively by dry tree systems, subsea HP / HT developments are now common place.

To keep the heat in a pipeline, and especially over long tie-back lengths, is a real engineering challenge. One way that this is overcome is to use a PIP design. This is where the pipe carrying the contents is inside an outer pipe separated by an annulus filled with thermal insulation. PIP technology is a design challenge, and is normally used when a low Overall Heat Transfer Coefficient (OHTC) value is required (<1 W/m^2K).

High Pressure (HP) has a major impact on the design of wellhead and other equipment, such as manifold valves, in terms of strength, materials and reliability. For piping, flowlines and risers, HP can also lead to very high wall thicknesses. Equipment manufacture and linepipe fabrication and installation become more complex. High Temperature (HT) has a wider impact, as the whole system has to operate over a greater temperature range between non-producing situations, such as: installation and shut down, and the operational case. Also, due to the uncertainty of material response at elevated temperatures, the industry Codes of Practice is approaching their limits of applicability. Additionally, corrosion and corrosion protection throughout the system becomes a challenge for hotter systems.

Stress based design codes are no longer applicable at these high temperatures, and rather strain based or limit state based designs have to be adopted. Solution is the design of such pipelines using limit state methodology to define confidently the safety margins for very high pressure and temperature pipelines. Also High Integrity Pipeline Protection Systems (HIPPS) systems offer a solution to allow thinner wall thicknesses to be possible, as the pipeline does not have to be designed for the