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Exploring the Challenges of Pipe-in-Pipe (PIP) Flowline Installation in Deepwater

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ABSTRACT

This paper intends to unveil the challenges of deep-water PIP installation and provide a trustworthy simulation of PIP installation processes by using advanced analysis tool – “Simulator”, an ABAQUS based JP Kenny in-house Finite Element Analysis (FEA) engine. “Simulator” allows the PIP pipes being modeled individually with realistic interaction between the pipes as PIP being at the normal lay process of S-Lay, J-Lay or Reel-Lay installation. With successful FEA, the load and stress responses of PIP at all installation processes can be calculated in a high level of accuracy. The studies evaluated the effectiveness of Loadshare or intermediate bulkhead, the industry-pursuing solutions that can reduce or eliminate the inner pipe lowering and locked-in compression during J-Lay or S-Lay while increasing the PIP load capacity for the high pressure and high temperature operation.

KEY WORDS: Deepwater; finite element analysis (FEA); global buckling; high pressure and high temperature; J-Lay; Loadshare; locked-in compression; pipe-in-pipe (PIP); S-Lay; thermal expansion.

INTRODUCTION

Developments of deepwater oil/gas reservoirs are presently being considered around the world as the petroleum reserves being declined in mild water depth. The pressure and temperature of the oil and gas contents coming out of the deeper ground onshore or subsea are normally higher, and this can be a key challenge for pipeline design. HP/HT (High Pressure and High Temperature), with pressures in the order of 700bar (10,000psi), and temperatures being considered up to 177°C (350°F) are not uncommon in Golf of Mexico (GoM). High pressure and high temperature reservoirs are typically, but not exclusively, black oil and gas condensate fields. They are technically more complex to develop because of the inherently higher energy in the well fluid. 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, flowline, and riser, HP can also lead to greater wall thicknesses. Equipment manufacturing, linepipe fabrication, and pipeline installation become more complex. High Temperature (HT) has much wider impact, as the whole system has to operate over a greater temperature range between non-producing situations, such as: installation, shut down, and maximum operational case.

Due to exceptional thermal insulation/material capability, the Pipe-in-Pipe (PIP) systems are well suited to the transportation of products at high pressure and high temperature, preventing hydrate formation and ensuring the high arrival temperatures at the production facility. The conventional wet thermal insulation materials currently available in the market have the limits of the maximum service temperature up to 120ºC (250ºF) (Sriskandarajah, 1999), since its thermal conductivity increases at high temperature and its Young’s modulus and compressive strength reduces rapidly. As well known, ensuring the product flow and extending the cool-down time will favor the productivity and enhance the economics of a field development. The applicable water depth is also a constraint for wet insulation single pipe. There were some incidents in GOM in which multiple directions of cracks were observed on the wet thermal insulation steel catenary riser. These are the reasons why PIP being widely used today and planned in the future. As the PIP annulus is normally pressure free, much larger pressure differential has to be adopted during the mechanical design that results in a thicker inner pipe wall when compares with the wet insulated single pipeline.

The installation of Pipe-in-Pipe (PIP) flowlines in deepwater, disregarding to the laying method, can present real challenges due to the PIP string weight and the effect of lowering then locked-in compression of the inner pipe when a PIP is un-bonded. Such inner pipe compression will be enhanced after start-up of a high temperature and high pressure production. It can lead to a greatly increased probability of material compressive yielding, global buckling, and local plastic collapse at the larger bending curvature sections or strain localization areas. A concern is that industry fails to realize the seriousness of such failure potentials and often allows such inner pipe lowering and compression without performing the detailed analysis to assess the impact of such load condition. One reason is that the PIP is commonly treated as a composited single pipe which can not accurately evaluate the PIP load response from installation to operation correctly.

There are two types of PIP system used in the offshore industry, (1) Fully bounded PIP in which entire annulus is filled with insulation material such as the PUF (Polyurethane Foam); (2) Un-bonded PIP (as shown in Fig. 1) in which the insulation is achieved by wrapping the standard sized insulation pads onto the inner pipe. Centralizers might be needed and placed in a designated spacing to protect the insulation and to concentrate the pipes. The insulation materials used in the un-bonded PIP generally have exceptionally low U-Value (Overall Heat Transfer Coefficient). Such design can also reduce the production lead time for the fabrication PIP joint or the PIP stalk.