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Global Buckling and Axial Stability for HP/HT Flowlines

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Abstract

During the last 10 years, the offshore oil and gas industry has identified that short, high pressure, high temperature flowlines can translate axially ("Walk") during their operational life due to start-up and shut-downs cycles. More recently, flowline systems that utilize wet insulation, and have a comparatively low specific gravity also have a high propensity to respond in this manner, even for systems that are in the order of 15 to 20 miles long. The objective of this paper is to identify key design aspects of wet-insulated flowline axial stability and the associated analysis approaches and mitigation options.

This paper also highlights a new associated design issue for flowline/pipeline systems on a steeply sloping seabed. Through finite element analysis of wet-insulated systems on steep slopes, cyclic thermal loading is observed to cause the hot and cold flowline ends to expand independently (resulting in significant cumulative end expansions >20 ft) until a point of stability is reached. The response of the system is unique due to interaction between the seabed slope, flowline expansion, lateral displacement and effect of the thermal gradient and thermal cycling.

Selecting a non-direct or "meandering" flowline route and performing associated full scale 3-Dimensional finite element modeling can mitigate these significant end expansions and resolve several other technical issues to achieve a feasible flowline configuration.

Introduction

To help meet the continued global energy demand, oil and gas fields are being developed in deeper water (3,000 to 10,000-ft range). Among several design/installation/cost challenges that these deepwater developments face, is ensuring a favorable routing for the flowline system design. However, some seabed features may not be easily avoided without adding significant cost to the project. These features may include fault crossings, areas of steep slopes, escarpments, canyons, valleys, etc. Other local conditions like high bottom currents, seabed instability areas, shallow/deep-seated slope failures and potential locations for other geo-hazard events (debris flows, mass gravity flows, turbidity currents, etc.) may further complicate the overall design of the flowline system. In addition, flow assurance performance requires that many flowline systems have good thermal properties (low U-value) which are often achieved by applying thermal insulation on the outside of the flowline. A common system configuration utilizes "Wet" insulation. This is a single or multilayer coating system applied on the outside of the flowline and exposed to the "wet" marine environment. These systems typically have low specific gravities that result in a low flowline submerged weight and consequentially low axial frictional resistance. Combining the project terrain with the low system specific gravity and typical production temperature and pressure conditions leads the flowline system to being susceptible to Global Lateral Buckling as well as Axial Translation (Walking).

This paper addresses design issues related to global buckling and axial stability of wet-insulated high-pressure high-temperature (HP/HT) flowline systems. A case study, defined as a wet-insulated production flowline system (D/t~17, inlet temperature = 200^{o}F) that is routed across an area of steep slope, has a product-filled SG of 1.5 and is ~20-miles in length, helps to demonstrate these challenges.

Problem Overview/Description

There are currently several deepwater flowline systems that are routed across challenging seabed features with seabed slopes ranging between 5^{o} to ~40^{o} (see Figure 1). Some project examples that have negotiated such features include the Atlantis project over the Sigsbee Escarpment in the Gulf of Mexico, Ormen Lange over the Outer Continental Shelf in the North Sea, Medgaz across the Mediterranean and Blue Stream across the Black Sea. For low pressure and temperature flowlines or export pipelines, it is comparatively easy to manage the axial stability design because the cyclic response of the flowline/pipeline is not aggravated (or worsened) by high axial force distribution along the length of the flowline/pipeline.