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Stability and post-buckling response of sandwich pipes under hydrostatic external pressure

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ABSTRACT

Sandwich pipe systems can be considered as potentially optimum design configurations for overcoming the shortfalls of single-walled pipes for deep-water applications. This potential design alternative has gained considerable attention in recent years. In this paper the stability of these systems is investigated. The possible equilibrium paths are evaluated and the effect of the various significant parameters on the characteristic behavior of the system is discussed. The Finite Element (FE) software package ABAQUS is used to construct more than 3000 FE models of the sandwich pipes with practical configurations. Four design configurations are considered for the sandwich pipes with respect to the adhesion among the interfaces. The post-buckling behavior of each of these configurations is determined, with emphasis on a wide practical range of parameters. The behavior of these configurations is examined and the efficiency of each system is discussed. Finally, a simplified and fairly accurate equation is developed and recommended for calculating the pressure capacity of sandwich pipes. The parameters of the proposed equation are also fully defined.

1. Introduction

The demand for various sources of energy has been steadily increasing. Although new sources of energy are being continuously explored, nevertheless oil and gas are still considered as the main sources of energy. On the other hand, because the reserves in shallow-waters are fast depleting, the extraction of deep-water oil reserves is currently being actively persuaded. Such an endeavor cannot be deemed feasible, unless effective and efficient oil transportation systems are developed. As a result, the integrity of current pipelines must be significantly improved.

A single-walled steel pipe is a typical pipeline used to extract oil from typically shallow waters. This design configuration has limitation when used in deep-water applications. Restrictions such as the limited external pressure capacity, high thermal conductivity and pipeline buoyancy related issues (during their installation) limit the water depth in which a single-wall pipe configuration can be used. A sandwich pipe (SP), on the other hand, can be considered as a clever design alternative that can overcome these restrictions. In general, a sandwich pipe consists of two stiffer pipes (usually steel) sandwiching a lighter weight core layer (usually a polymeric material). With such a configuration, an SP can enjoy the structural and thermal insulation benefits provided by the two stiffer pipes sandwiching a core material that offers efficient thermal and structural properties. Moreover, the secondary containment provided by the external pipe improves the reliability of the system in case of product leakage.

SP systems can be categorized as Pipe in Pipe (PIP) systems. In PIPs, the core layer offers both structural functionality as well as thermal insulations. Employing the three constituent layers in PIP systems allows the designers to design each part of the system for a specific purpose, and also considering the whole system as an integrated structure. For example, the internal pipe (also referred to as the product pipe), can be designed based on the corrosion considerations and/or for facilitating the safe transport of the product. The core layer can have various functions; it can provide thermal insulation between the product and its surrounding environment (which is the main function of most PIP systems), and/or serve as a support for the internal or external pipe to resist against internal and external pressures. The core layer can also serve as a host for a structural health monitoring system, as well as facilitating heating or cathodic protection systems. Based on the main function of the core layer, a wide range of materials such as plastics, gels, ceramics and composite materials can be selected as the core. The external pipe, also called the sleeve pipe, which would be in contact with the surrounding environment, must be able to resist corrosion and other structural requirements. Moreover, the secondary containment provided by the external pipe improves the

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