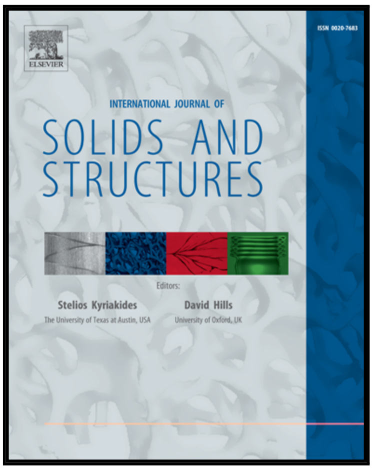

COUPLED LATERAL AND AXIAL SOIL-PIPE INTERACTION AND LATERAL BUCKLING Part I: Formulation

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COUPLED LATERAL AND AXIAL SOIL-PIPE INTERACTION AND LATERAL BUCKLING

Part I: Formulation

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Abstract

A general formulation for the two dimensional lateral buckling problem is developed employing classical rod theory. A nonlinear differential system with seven unknowns is derived. Governing equations include a number of previously unaccounted nonlinear terms expressing interaction of various variables representing pipeline geometry and external loads. A rigorous derivation of the transformation of surface loads due to internal and external pressures to line loads revealed some previously unknown limitations on its applicability. Several boundary value problems are formulated corresponding to common pipeline engineering problems. Nonlinear dynamics methods are employed to draw some preliminary results on the behavior of the solutions. It is shown that the trivial solution corresponding to a perfectly straight pipeline experiencing no initial deformation and initial force is unstable.

1.1 Introduction

Deepwater subsea pipelines are commonly laid partially buried on seabed consisting of clay or fine sediments. They usually transmit products at elevated temperatures and high pressures. Typically, sufficient time passes before a pipeline is operated allowing it to reach an equilibrium state at sea water temperature not much higher than the freezing point of sea water. The pipeline which may have started at a laybarge at a temperature ranging from near freezing point of water in arctic regions to above 40 deg C in tropical climates may experience some contraction or expansion while attaining this equilibrium state. Pipelines are normally welded on a laybarge in a rectilinear configuration. However, due to limitations of the position control or the environmental loads and sometimes even intentionally, the installed pipeline ends up with a geometry somewhat offset from its intended straight line (or the curved) route (Preston 1999)[1](Rathbone 2008)[2]. This offset combined with the seabed bathymetry can result with a complex as-laid pipeline geometry.

After the pipeline is put in operation, although influenced by the reservoir fluid characteristics such as the product temperature and pressure and other pipeline characteristics such as insulation thickness, pipe diameter, and product flow rate, the temperature distribution along the pipeline usually takes hours or days to reach a steady state after the product starts running through the pipeline (Alves 2012)[3]. At that point, the pipe steel can reach to temperatures close to or even above the boiling point of water. When the pipeline seeks to move to dissipate the strain energy generated by the