An explicit procedure to evaluate the configuration and stress of Pipelines during Lifting and Laying operations by multi-hooking points

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ABSTRACT

Pipelines are essential equipment used for the transportation and distribution of oil and gas. Their installation is a crucial operation; during the lifting and lowering for onshore installation or the laying for subsea offshore ones, pipelines experience the most considerable induced stress during their lifetime. For this reason, a reliable preventive structural analysis of the installation sequences should be performed to ensure structural safety and to avoid any damage, such as cracking, yielding, and distortions.

A pipeline is a slender structure if compared with its length; therefore, a faithful simulation must consider that its structural behaviour is nonlinear due to shape-dependent (geometric) effects. The load conditions to be analysed involve modelling the pipeline as a slender beam, where the deformed configuration is far from the undeformed, and the main stress is owing to bending, while extension and shear effects turn out to be irrelevant. The significant difficulties in studying the lifting or laying of a slender pipe are the nonlinearity due to large displacements and the not known (a priori) lifted length.

It is possible to examine the behaviour of a pipeline in two ways; the first, analytical, imply to solve a set of nonlinear differential equations where the boundary conditions are of BVP type, and the lifted length is another unknown of the problem. The second, pure numerical, is to perform a Finite Element simulation. In this case, may arise some problems related to the structure instability (e.g. the problem of the lifting of a non-constrained pipe by multi-hooking points) or once again related with the not-known (a priori) lifted-length; the latter implies simulating a much greater length of pipe than the one to be analyzed (e.g. the problem of *J* or *S* laying subsea pipe with an indeterminate contact point with the marine soil).

In this work, we propose a new fast procedure to evaluate the configuration and stress of pipeline lifting by multi-hooking points. The idea comes from the fact that the catenary model is fully determined only by static equilibrium, from which emerge two (first-order) differential equation which may be integrated explicitly and where the solution depends only on one parameter. If the bending stiffness is introduced (as in the case of the pipeline), the analytical formulation introduces a third two-order ODE, which presents the complications previously mentioned.

The question we asked ourselves is the following: "Is it possible to integrate explicitly (i.e. simply as the catenary case!) the nonlinear bending problem of the pipeline?".

The answer is that it can be done, and the focus of this work is to explain the simple and fast procedure to follow based only on the equilibrium equations. This alternative strategy is applied in the paper to examine the stress and configuration occurred during the multi-points lifting of long pipe and during the laying installation of subsea pipeline.

Keywords:

Pipeline; Lifting and Laying; Nonlinear Bending