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CONSTITUTIVE MODELING OF UNBONDED FLEXIBLE RISERS UNDER TENSION

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ABSTRACT

Marine risers are classified into two categories: drilling and production risers. A drilling riser is used for exploratory drilling and is made of steel which contains a drill string. A production riser consists of a cluster of flow lines, which transfer the crude oil from the seabed to the sea-surface. Traditional production marine risers are vertical rigid steel structures, which are prevented from buckling by the application of a tensile force at the top end of the riser. Flexible pipes represent an alternative but widely used design concept, and can be of two generic types: unbonded, without adhesive agents between the layers, and bonded, when layers are adhesively bonded together [1]. The pipe cross-section of a flexible riser is a composite construction of spirally wound steel layers and thermoplastic materials. Flexible risers withstand much greater vessel motions than rigid steel risers and do not require external tensile force at their extremes [2].

Flexible risers consist of multiple layers. The classical approach to model flexible risers is to use only one beam model to represent all layers by suitably summing up the contributions of all the layers together to the area, moment of inertia, mass and weight. This is called "Composite" riser modeling scheme and its advantage is the computational efficiency. However, this method fails to capture the nonlinear load path and the interaction between layers. Hence, the multi-layer modeling scheme approach was provoked by the inadequacy of composite model results.

In this latter approach, although the loads (tension, shear and moment) in each layer are fully captured and the interaction between layers is considered, the disadvantages are the considerable modeling effort involved and the computational inefficiency. One of the applications of the multi-layer approach is the bending curvature analysis. This is because the internal layer does not have the same bending-curvature characteristics as the outer layer, and only the multi-layer modeling approach which incorporates simulation of the inter-layer contact can simulate this effect. Another important application of multi-layer models is the possibility of computing the amount of pressure preload required

for the inner layer. This is because layers of a typical unbonded flexible pipe are held together by friction, and the amount of friction in turns depends on the interaction between its individual component layers. In particular, energy dissipation due to friction is particularly important in the important case of cyclic loading, which may be induced by Vortex Induced Vibrations for instance, as it results in hysteretic response and structural damping.

In this paper we discuss the derivation of a constitutive model for unbonded flexible risers under axial tension. The model is based on the definition of a slip-onset function, depending on the stress resultants as well as on the current values of internal and external pressure, and of an associated slip-onset surface, which in turn delimits a no-slip domain. Values of the resultant stresses inside the no-slip domain represent a no-slip state between layers of the riser, while values on the slip-onset surface or outside the no-slip domain represent a full-slip state. This type of transitional hysteretic constitutive model will be suitable for implementation into finite element codes to analyze the highly non-linear behavior of long unbonded flexible riser structures. The advantages of this method are its computational efficiency and its capability of fully capturing the nonlinear load path and the interaction between layers. The input parameters of the developed model are identified using the results of detailed three-dimensional, non-linear finite-element simulations of a small length of riser [3]. Additional results of the three-dimensional simulations are used for validation.

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