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Catenary riser sliding and rolling on seabed during induced lateral movement

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A B S T R A C T

Catenary risers have an interaction zone with the seabed, usually referenced as flowline. Movements in this region can be induced by sea currents and large offsets in floating unit, leading to touchdown position changes and affecting internal loads along riser length. In this work the contact flowline-seabed is modeled including sliding and rolling friction. Case studies involving large offsets in floating unit and lateral sea currents are solved to better understand the consequences of possible rolling and large sliding. The riser is modeled using a geometrically-exact finite element beam model. The contact is addressed with a new technique to include rotation movements from underlying beam models. This leads to global riser models including complex kinematics, being able to represent scenarios with alternating sliding/rolling and its consequences on internal loads of riser structure. A parametric study is performed to measure the influence of the friction coefficient in tension and torsion along typical flexible pipe and steel pipe catenary risers.

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1. Introduction

The global analysis of risers is important during design of an offshore production plant. Riser nonlinear static analyses are commonly performed, considering hydrodynamic loadings from currents. The floating unit offsets can also be included, by imposing displacements to riser top. The output of static analysis includes riser deformed structure in space and internal loads along its length. This output can be used as a start solution of a dynamic analysis, in which the floating unit movements are set-up and dynamic effects are considered. The dynamic analysis outputs are the varying along time internal loads in riser structure, which may affect fatigue life.

Usually, sea current and floating unit offsets do not affect riser dynamics, once their typical observed time-scale is larger than the riser's largest natural period.[1] A usual approach is to consider a set of static scenarios encompassing combinations of different floating unit offsets and sea currents. These different conditions lead to distinct riser static configurations, which are the start point for a transient dynamic analysis (time domain) or the linearization point of a dynamic frequency domain analysis (see e.g.: Martins (2000) [1] and Takafuji (2007) [2]). Thus, as a start point of dynamics, statics is very important and has to be properly calculated and interpreted.

When performing riser analysis, one can use commercial software developed for that purpose. Alternatively, one can make use of multipurpose finite element packages. Both approaches share the beam or cable assumptions for riser modeling. To use beam elements, for example, cross section data information must be provided. When dealing with steel pipes, cross section data is straightforward to be evaluated. However, when considering a flexible pipe or an umbilical cable, the input is the equivalent stiffness data, since the actual cross section is very complex. These sections are composed by many layers with different materials, and present local interaction effects which may affect the whole cross section equivalent properties. In any of these cases, the global riser configuration is geometrically represented as a 3D curve in space representing the *locus* of successive centroids of cross sections. Some typical riser configurations, such as catenary or lazy wave, present unilateral contact with seabed (see Fig. 1). This condition can be mathematically modeled using inequality constraints, as explored by Gay Neto et al. (2014) [3] for specific risers applications. The basis of that work is found in Wriggers (2002) [4], which develops general computational contact formulation.

The main issue for the modeling of contacting beam structures (e.g.: risers) is the difficulty to consider the actual beam cross section external dimensions for contact detection and kinematics. Wriggers and Zavarise (1997) [5] addressed that in a beam to beam contact formulation. They considered radii offsets for both beam elements at the contact detection and at the evaluation of involved forces. However, this work presented only frictionless interactions. Zavarise and Wriggers (2000) [6] extended the model to represent frictional contact. However the moments induced by friction were not considered. When addressing the contact between risers and seabed, Gay Neto et al. (2014) [3] considered a node to surface approach, which did not consider properly the riser cross section dimensions, neither the moments induced by friction force. For a better understanding of these limitations and how to include such effects in a frictional contact model, the reader is invited to observe Fig. 2. Two possible contact interactions between a circular body and a flat surface are shown: frictionless contact (a) and frictional contact (b). The circular body represents a beam circular cross section, to be used to model a riser.

Looking at centroid C as a pole (to calculate moment of forces), when the contact is frictionless, the moment is null (see Fig. 2a). This occurs because the action line of the contact force c contains the pole. In this case, the normal direction of contact interface n is the same direction of the contact force c. When friction is present, a non-null moment appears (see Fig. 2b), once there is non-null tangential component of contact force and the action line of c does not contain the pole C. If the circular body radius is small, this effect could be, in a first moment, simply disregarded. However, for some problems, such as rolling of a beam on a rigid surface, even if the radius of cross section is small, the

[1] In this context vortex-induced-vibration (VIV) can play a role in dynamics and in riser fatigue life prediction. This effect is not considered in present work.