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NUMERICAL EXPLORATION ON THE EFFECT OF THE HYDRODYNAMIC DRAG COEFFICIENT UPON TOPSIDE LOADING IN STEEL TUBE UMBILICAL RISERS

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ABSTRACT – In this work, the effect of the drag coefficient on the topside effective tension of an umbilical riser system is explored through batches of finite element analysis structural simulations of a typical riser system in Brazilian offshore ultra-deep waters. These simulations were performed in OrcaFlex, considering a steel tube umbilical riser cross-section. The drag coefficient is a determining factor of the system behavior and response to sea currents and it was found that its accuracy in global dynamic analyses of such systems could help streamline cross-section designs and correlate simulations to real-world applications. It was also found that a value of 1.2 for the drag coefficient could be interpreted as conservative for umbilical design and dynamic analysis.

1. INTRODUCTION

Umbilicals are a type of subsea cabling system often employed in offshore energy developments and are usually composed by different components such as hoses with or without carcass, electric power cables, electric signal cables, fiber optic cables, steel tubes, armor wires, plastic sheaths and fillers. Its function may be as a connection between a floating production unit (FPU) and subsea equipment, between FPUs, or between subsea equipment. An illustrative example of an umbilical is presented in Figure 1.

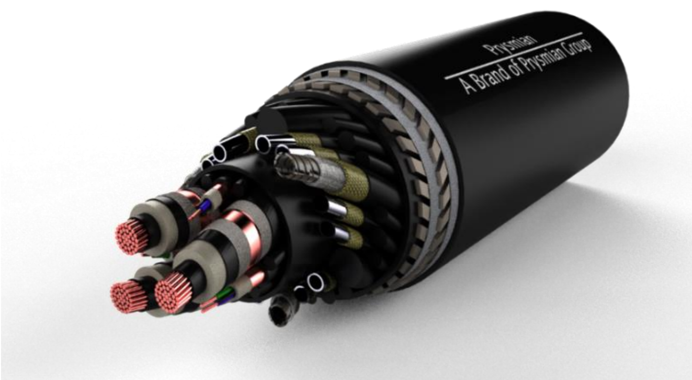

Figure 1 – Hybrid umbilical containing typical components found in umbilical cross-sections

Umbilicals are categorized by loading type, whereas umbilicals mainly subjected to dynamic loading due to waves and currents are called risers, and umbilicals that lay on the seabed, mainly subjected to static loading, are named flowlines.

The heterogeneous composition of an umbilical cross-section presents a challenge in engineering analyses pertaining to the structural limits of the product. One way this is addressed is through a complex group of simulations. These will consider the functional, environmental and accidental loads. These simulations aim to determine the product's structural behavior under its application scenario as well as the resulting loads being applied to the product. Of these loads, the topside effective tension is often found to be a critical point in the proposed umbilical system design (API, 2017).

Among a plethora of input variables used in global dynamic analyses, the drag coefficient is taken into account in the calculations that impose a load and displacement of the riser umbilical due to the effect of sea current profiles.

This work aims to explore the effects of the hydrodynamic drag coefficient on the topside loading of a steel tube umbilical installed in typical conditions for oil and gas exploration in Brazilian offshore ultra-deep waters (typically, water depths over 1500m).

2. METHODOLOGY

2.1. Global Analysis Input Data

Umbilical cross-section: The cross-section chosen for this study was a steel tube umbilical comprised of 13 ½" steel tubes with 1.2mm wall thickness and an outer polymeric sheath, as shown in Figure 2. Some of its relevant technical parameters are also presented in Table 1.

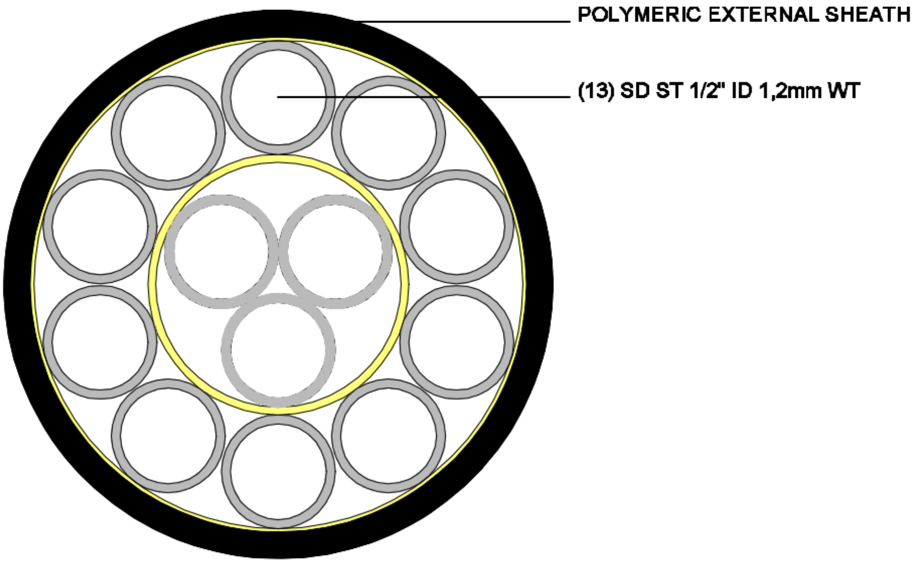

Figure 2 – Steel tube umbilical cross-section

Table 1 – Steel tube umbilical technical parameters

Umbilical Technical Parameters	Data
Outside Diameter (mm)	72.8
Nominal Mass – Weight in Air and Tubes Filled (kg/m)	9.17
Operational Minimum Bending Radius (m)	5.6

2.2. Enviromental and Configuration Data

Global configuration: The umbilical was simulated in OrcaFlex in typical enviromental conditions for Brazilian offshore ultra-deep waters with a catenary configuration at a water depth of 2150m, as shown in Figure 3.

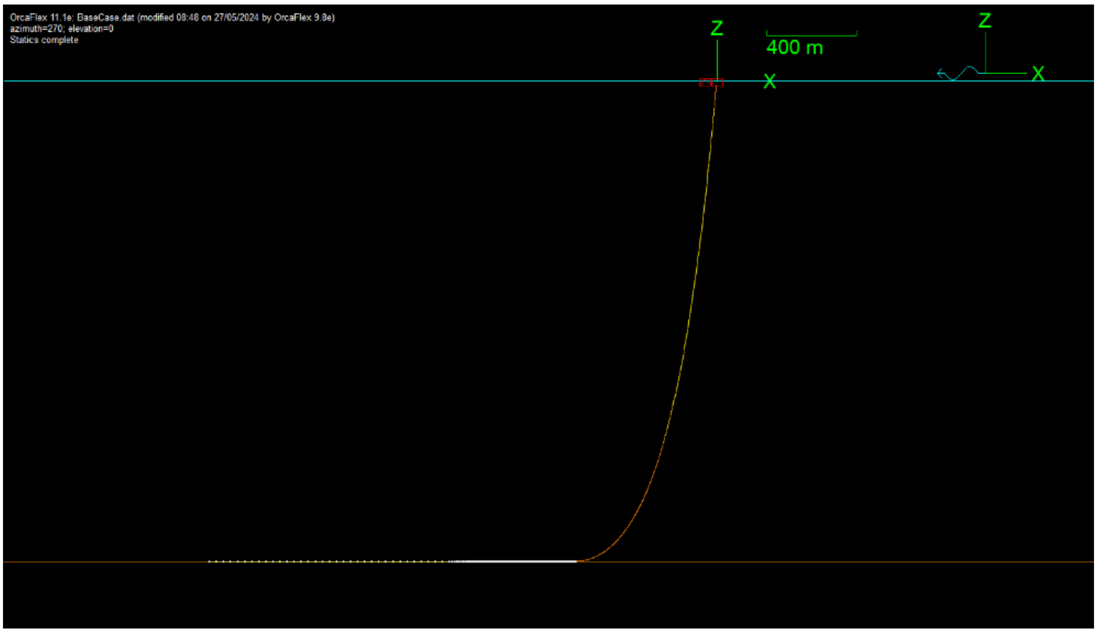

Figure 3 – Umbilical system configuration

Its static effective tension at the top was calculated to be 112.14 kN. A wave scatter table was used in order to generate loadcases that include all possible permutations of typical wave and current profiles for each batch of simulations, and a batch of simulations was prepared for each drag coefficient studied.

Umbilical Drag Coefficient: The drag coefficent (*CD*) of an umbilical riser is akin to that of a circular cylinder under normal flow. Thus, it depends on Reynolds number (*Re*) and surface finish, that are the main parameters that influence pressure and friction drag. It is also known to be, under typical environmental conditions, between 0.28 and 1.2 (Orcina, 2024)

In this study, 7 batches of simulations were prepared, with respective *CD* values ranging from 0.28 to 1.5.

3. RESULTS AND DISCUSSION

The results of the simulations performed are found in Figure 4, normalized by the tension found under a baseline case (*CD* = 1.2).

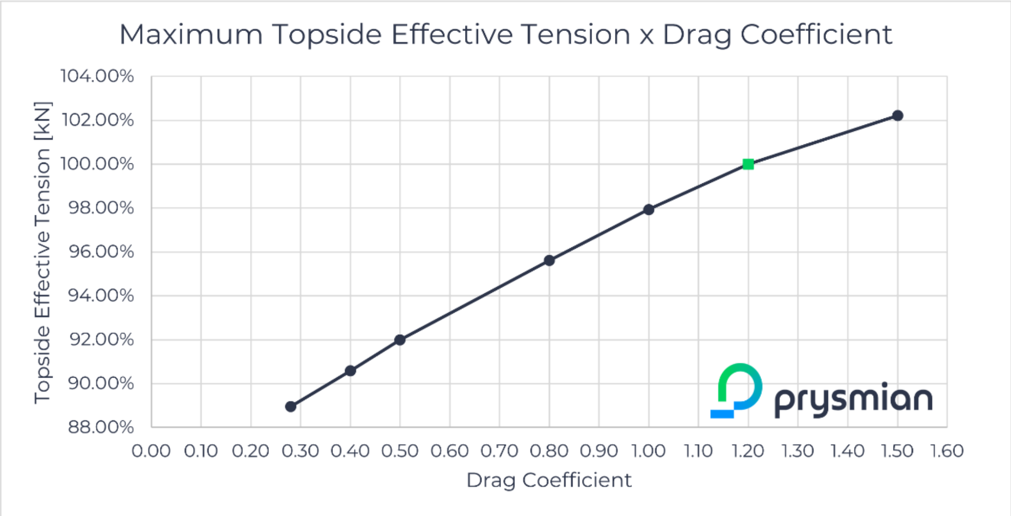

Figure 4 – Results of topside effective tension over drag coefficient plot

As it can be observed that the effect of the drag coefficient follows roughly a linear growth curve, it may be inferred that a refinement of drag input values could offer a good avenue for simulation correlation to real-world applications and experiments in cases where there would be a mismatch between the predicted and measured topside effective tension. Not only that, but also, in the engineering and design phase of a project, more accurate values could be used in order to check for structural capability while streamlining the cross-section design.

Finally, given that industry standards determine maximum values near CD=1.1 for rough unshielded circular cylinders (API, 2007) or between 1.0 and 1.2 for spiral wire with sheathing over a cylinder (DNV, 2017), these results also show that a value of 1.2 for the drag coefficient could be construed as a conservative approach to umbilical design and dynamic analysis.

6. REFERENCES

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