Multiscale modelling of the mechanical non-linear behaviour of submarine power cables used for floating wind turbines

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The design of submarine power cables (or umbilicals) is based on the calculation of their response in service. This involves determining the time history of their response to different sea states. To do this, softwares (such as Deeplines, Orcaflex, etc.) are used, in which the umbilical is described as a beam, and subjected to hydrodynamic forces and to the movements of the floater that supports the wind turbine. It is therefore important, on the one hand to provide the stiffness characteristics of the umbilical to this beam model, but also from the results obtained from this model, to calculate the local stresses. The latter will then be used in a fatigue analysis.

The determination of the overall behaviour of the umbilical can be done through mechanical tests or from analytical or numerical models, see for example [1-4]. In the latter case, the numerical approach is based on a multiscale approach, namely the homogenization theory of periodic structures. It allows to define a problem posed on a 3D helical period of the cable, thus minimizing the size of computational domain. This approach relies on a detailed 3D finite element model of the umbilical period, and was implemented in a previous thesis at GeM [5], see Fig. 1. The results show that the overall behaviour of the umbilical is complex, in particular it is non-linear in bending, see Fig. 2, due to the contact interactions between its components.

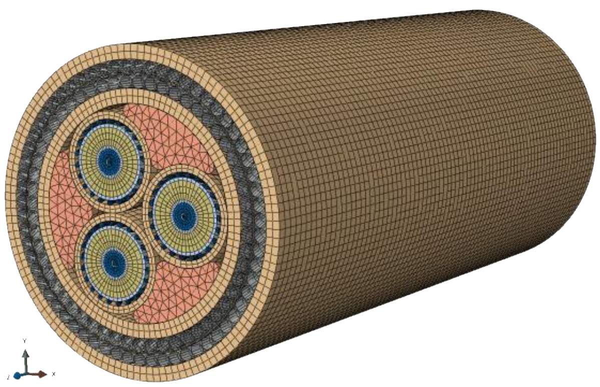
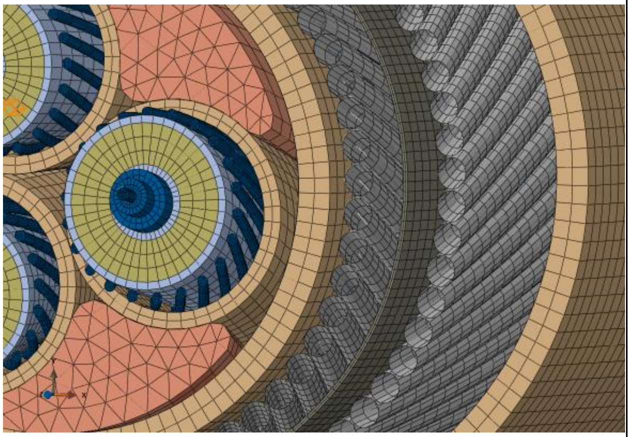

Figure 1. Finite element model of a 3D part of the umbilical. Overall view and details, from [5]

Taking into account this behaviour, obtained from these 3D computations, in the beam model raises several problems. The softwares propose non-linear beam models but according to predefined laws. This leads to approximations with respect to the real behaviour, in particular for taking into account the coupling between bending and tension. On the other hand, a precise approach based on a strong coupling between the beam model of the software and the 3D detailed finite element model, at each step of the calculation and at each integration point of the beam, would lead to prohibitive calculation times.

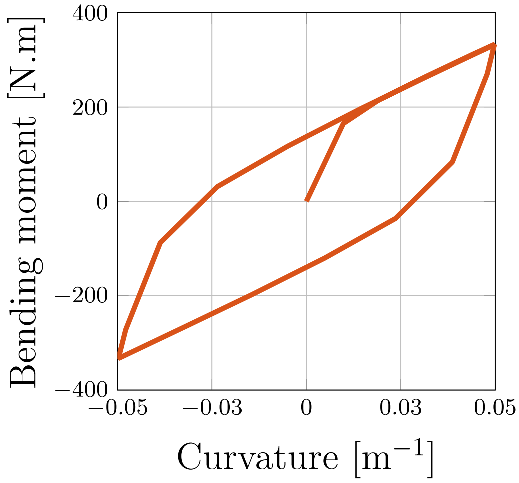

Figure 2 : Non-linear bending behaviour

It is therefore appealing to be able to evaluate the level of approximation of the existing nonlinear models, and to study how to improve them at lower cost, without resorting to the strong coupling mentioned above. In this context, data-driven approaches, which has been proposed recently, can be considered [6]. This consists in a first step to generate a coarse data base in the space of beam strains and stresses, which then will be locally enriched if the previous discretization is too coarse. Another important feature of the problem is the history dependence of data sets, which makes the use of data driven approaches more difficult.
Thus, the development of a non-linear multi-scale method that circumvents the limitations of a strongly coupled approach is the main objective of the thesis.

Beyond this objective, it is also necessary to have an experimental mechanical characterization of the umbilical against which the numerical models can be compared. These experiments will be carried out on the IFREMER bending bench, and measurements at sea will also be carried out.

<u>Candidates with a solid background in mechanics of solids and structures, finite elements, and computational modeling/programming are encouraged to apply.</u>

Main references

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