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Extension of the super-elements method to the analysis of a jacket impacted by a ship

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ABSTRACT

The aim of this paper is to present a simplified analytical method for estimating the crushing resistance of an oblique cylinder impacted by the stem of a striking ship. The collision angle of the vessel is arbitrary, i.e. oblique collisions are also considered in this article. The two extremities of the tube are assumed to be clamped. These developments are intended to be used for evaluating the crashworthiness of an offshore wind turbines jacket. To achieve this goal, closed-form expressions are first derived for the particular situations of a horizontal and a vertical cylinder by applying the upper-bound method. An interpolation formula is then proposed to get the resistance opposed by the tube for any inclination angle. In order to validate these theoretical developments, some comparisons are made with the results of numerical simulations. These latter are performed using the finite elements software LS-DYNA. In almost all cases, the analytical prediction of the resistance is found to be in quite good agreement with the numerical ones. Finally, another comparison is made by simulating an OSV collision with a full jacket. In this case, the theoretical model is found to be insufficient for large impact energies and points out the need of further research.

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1. Introduction

Nowadays, it is more and more important for the humanity to produce energy in a sustainable manner. This is particularly true for electricity generation, which may no longer be provided by classical nuclear or coal power plants, which are considered to be too dangerous for the environment. Amongst all the existing ways of producing electricity, offshore wind turbines appear to be a promising one and many governments are supporting their development all over the world.

Amongst all the loads to be considered when dimensioning an offshore wind turbine supporting system, the case of a ship collision has to be treated carefully as it may have very severe consequences for the structure and the vessel. This is precisely the subject of this paper, in which an impact occurring between a given ship and the jacket of a non-floating offshore wind turbine (Fig. 1) is considered.

To assess the impact resistance of the jacket, it is of course possible to resort to finite elements simulations, as this has been done by Amdahl and Holmas [1], Vredeveldt and Schipperen [2], Biehl [3] or Amdahl and Johansen [4] for example. As both the ship and the collided structure have to be finely meshed, the modeling effort can be important. Such approaches are also time-expensive and consequently not convenient at the beginning of the design process, when the final properties of the structure are not completely fixed. Moreover, in the framework of a full collision risk analysis where different striking vessels and collision scenarios have to be considered, a simplified analytical approach allowing for a rapid approximation of the jacket crashworthiness becomes more relevant.

A basic idea consists in idealizing the jacket as a set of individual tubes (Fig. 1) with particular connections at their extremities. In this paper, it is assumed that the deformations only take place on the cylinders in contact with the bow, all the adjacent being unaffected. This hypothesis is the single restriction postulated in this paper.

The problem of an impact occurring on a cylinder has already been treated in the literature by Hoo Fatt and Wierzbicki [5], Wierzbicki and Suh [6] or Zeinoddini, Harding and Parke [7], amongst others. All these authors have considered the case of a concentrated load acting at the mid-length of a cylinder having a length L and a radius R (Fig. 2(a)). Nevertheless, this work is insufficient, as the analysis of a jacket component impacted by a ship (Fig. 2(b)) is similar to the one of an eccentric oblique impact, initially located at a distance L_1 from the left support, occurring on a cylinder having an inclination ζ and where the striking direction is characterized by an angle α. Moreover, the bow shape may also have an influence on the deformation pattern, which is not necessarily the same as for a concentrated force. The work detailed in this paper goes one step further by accounting for all these particularities and aims to be a generalization of what has already been done by many authors.

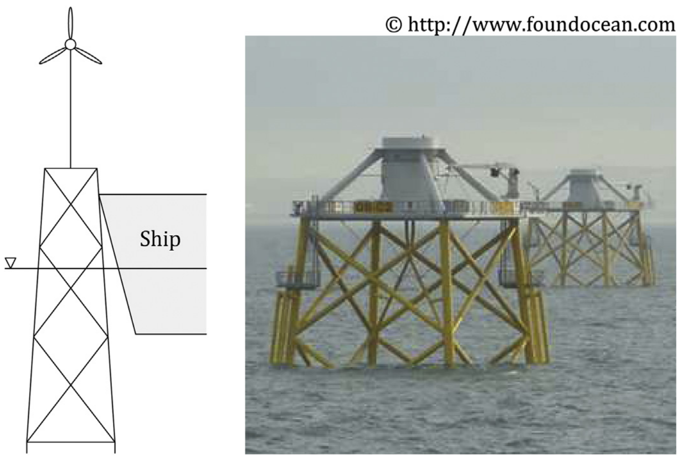

Fig. 1. Collision on an offshore wind turbine.