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Nonlinear hydroelastic responses of monopile and spar wind turbines in regular waves

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Objective

Floating wind turbines can experience very large hydrodynamic loads in rough seas. As offshore wind turbines grow in size, elasticity in the hull could be an important parameter, as for other (very) large floating structures. However, today's design methods decouple the hydrodynamics from the structural models: the environmental loads are computed on a rigid platform model and applied as external loads to the hull during structural analysis.

Few models have been developed to analyse internal responses in the hull of floating wind turbines considering flexibility [1]. They use either the linear potential flow theory [2], or the generalised Morison formula. Several methods have been tested and show relatively good agreements with experimental measurements on rigid hulls [3], except in extreme conditions where nonlinear effects can be important. The objective of this study is to propose a new approach including nonlinear hydrodynamics and strong hydro-elastic coupling, which can be applied to fixed or floating wind turbines.

Methodology

A new nonlinear and strongly coupled simulation tool has been developed by coupling the weakly nonlinear hydrodynamic solver *WSCN*, based on nonlinear potential theory and developed at the LHEEA laboratory, and a modal analysis solver. The fluid states and the equation of motion of the flexible platform are solved jointly in a single system of equations, integrated in the time domain using a Runge-Kutta 4th order scheme. The strong coupling between the two theories accounts for large platform motions and strong hydro-elastic interaction including, for example, hydrodynamic loads induced by platform deflections.

Results (preliminary and expected)

A first study examines a bottom-fixed offshore wind turbine based on a monopile foundation. The results of *WSCN* are compared with simulations from *Sima* [4] using the Morison formula. A second study considers a floating spar foundation submitted to a variety of sea states.

At this stage, the response of a monopile-like structure (a cantilevered beam 100 m in length and 6 m in diameter) in 30 m water depth has been studied and compared with *Sima* for a set of regular wave conditions. The solvers show a very good agreement in benign waves but differences appear for increasing wave steepness. For example, the power spectral densities of the tip deflection obtained with regular Airy waves of 5 s period and respectively 0.2 and 0.5 m amplitude are shown in Figure 1. Nonlinear effects appear stronger in the *WSCN* response (in blue) in the steeper sea-state with second and third order harmonics (at respectively 2.5 and 3.7 $rad.s^{-1}$).

These results are promising and more severe regular waves shall be simulated, including nonlinear wave kinematics, for both the monopile and the floating spar platform.

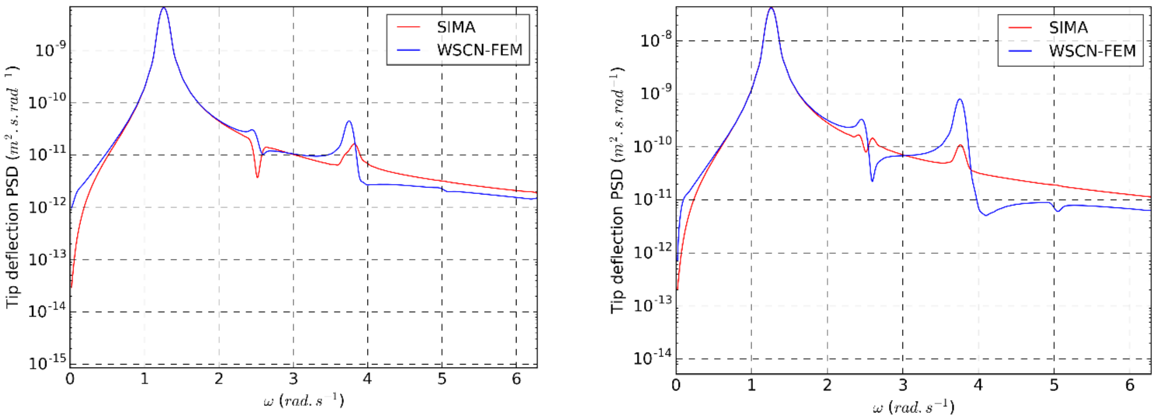

Figure 1: Tip deflection PSD of the monopile obtained with regular waves (A=0.2m, T=5s) on the left and (A=0.5m, T=5s) on the right.

[1] A. Alexandre, R. B. Urbano, J. Roadnight et R. Harries, «Methodology for Calculating Floating Offshore Wind Foundation Internal Loads Using Bladed and a Finite Element Analysis Software (OMAE2018-78035),» *Proceedings of the ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering OMAE2018 June 17-22, 2018, Madrid, Spain,* 2018.

[2] M. Borg, A. M. Hansen et H. Bredmose, «Floating substructure flexibility of large volume 10MW offshore wind turbine platforms in dynamic calculations,» *Journal of Physics: Conference Series,* vol. 753, 2016.

[3] C. Luan, Z. Gao et T. Moan, «Comparative analysis of numerically simulated and experimentally measured motions and sectional forces and moments in a floating wind turbine hull structure subjected to combined wind and wave loads,» *Engineering Structures,* vol. 177, pp. 210-233, 2018.

[4] SINTEF, «Sima,» [En ligne]. Available: https://www.sintef.no/en/software/sima/.