Hydrodynamic forces acting on cylindrical piles subjected to wind forced nonlinear water waves

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Abstract. The hydrodynamic forces of nonlinear water waves acting on a cylindrical pile are investigated. Thereby, specific solutions of the nonlinear Schrödinger equation, which can be seen as prototypes of extreme or freak waves, are considered in the presence of gusty wind. Using a spectral scheme for the numerical computation of these solutions, the corresponding velocity potential can be obtained. Depending on the corresponding wave envelope, the wave kinematics, particle trajectories and forces acting on a submerged cylindrical pile are computed. Thereby, the Morison equation is used for the computation of the hydrodynamic forces. The effects of random wind on particle trajectories and forces are studied in detail. With the presented new theory it is possible to determine very efficiently the loads on structures which are exhibited to complicated nonlinear ocean waves, which can also be random.

Introduction

The present analysis deals with the forces acting on a cylindrical pile, which result from wind forced nonlinear water waves. In order to compute the corresponding water waves, the method of multiple scales [1] is used. Thereby, weakly nonlinear solutions of the Euler equations of fluid dynamics are reduced to solutions of the nonlinear Schrödinger equation (NLS), which describe complex wave envelope. Although solutions of the Euler equations are just approximated by solutions of the NLS, it is much more efficient to compute them. Therefore, an analysis of the effects of random wind is much easier to do by studying the NLS than the Euler equations. By this means, Dostal et. al. [2] have studied the behavior of such solutions in the presence of random wind forcing. A result of this analysis is that these solutions can exist in deep water even in the presence of random wind. In the present study, the effect of random wind on the dynamics of the corresponding water particles is analyzed in detail. In order to do this, trajectories of water particles of different waves are considered and the corresponding forces on a cylindrical pile are computed. Thereby, the new theory of Carter et al. [3] is used for the case of complicated nonlinear ocean waves.

Computation of the hydrodynamic forces

Following Dostal et. al. [2], the corresponding numerical solution of the NLS is computed using a relaxation pseudo spectral scheme. These solutions are used to calculate the corresponding velocity potential following an analytical approach of Carter et al. [3]. After getting the velocities and accelerations of the water particles by taking the derivative of the velocity potential in space and time, it is possible to compute the hydrodynamic forces acting on a cylindrical pile by using the Morison equation [4]. A sketch of the considered case of a mono-pod platform in waves is shown in Fig. 1 (a). Applying the described approach on a soliton solution of the NLS with wave frequency $\omega = 1$ rad/s leads to the results summarized in Fig. 1 (b). There it is shown how the wave height η and the horizontal hydrodynamic force F_x acting on a cylindrical pile with diameter $D = 6$ m in a water depth of $H = 30$ m evolve for cases with and without the presence of wind. Thereby, τ describes the scaled time, T the wave period and a_0 the amplitude of the carrier wave. In order to see the influence of the wind clearly, the pile is placed in such a way that it is reached by a solitary wave after a long computation time. It can be seen that wind leads to a higher force and wave height. Therefore, it can be concluded that wind can have a considerable influence on the hydrodynamic forces acting on mechanical structures.

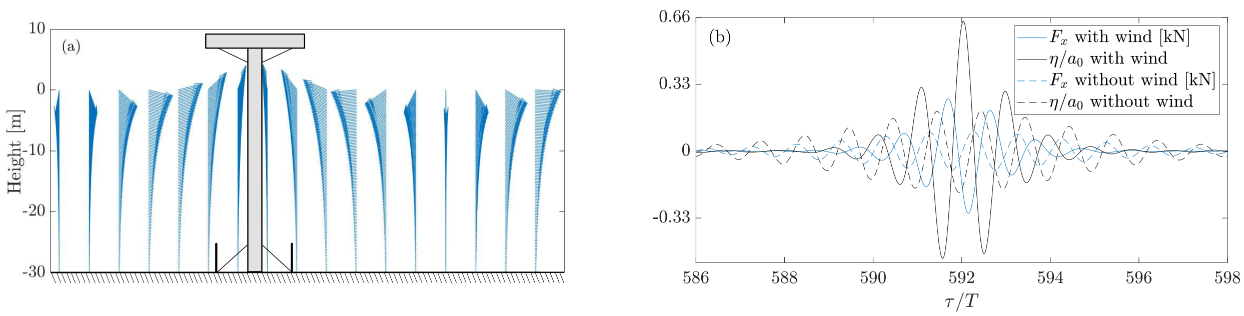

Figure 1: (a) A sketch of the considered case of a mono-pod platform in waves. (b) Temporal evolution of the wave height and the corresponding horizontal hydrodynamic force acting on a cylindrical pile with (solid) and without (dashed) wind.

References

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