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Preliminary Numerical Study on the Influence of a Wind Field on Wave-induced Load on a Circular Cylinder

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ABSTRACT
The design load for offshore structures can be established from experimental and numerical investigations. When these are conducted, only the indirect effect of wind is taken into account. I.e. the wave spectrum is defined from fetch and wind speed. Nevertheless, the wind can have a direct effect on steep waves if airflow separation and vortexes develop above the waves. This could potentially cause increased wave-induced loads or change the breaking probability for waves and thereby the load statistics. This paper presents preliminary results from numerical simulations on how a local wind field affects wave kinematics and wave-induced loads on a cylinder. The waves are generated as spatio-temporal focused wave train. The wave field, including surface elevation and kinematics, is computed with the fully nonlinear potential solver program, OceanWave3D. The wave-induced load on the cylinder is computed from the output of the kinematics and the FNV force model. The wind forcing term is modelled by means of Jeffrey's sheltering mechanism. Wave field and wave-induced loads are compared for different wind velocities and configurations of a focused wave. The presence of wind above a steep non-breaking wave increases the surface elevation until breaking is initiated for high wind velocity. The maximal wave-induced load for an initial non-breaking wave is obtained for the highest wind velocities due to the sudden initiation of breaking. The capability of the wind to increase surface elevation and load for wind above initially breaking waves is more questionable. The numerical model simply exchanges the energy transfer between breaking dissipation and wind energy differently depending on wind velocity and wave field; nevertheless, no significant increase in surface elevation or load is discovered in this case. The highest wind velocity can, on the contrary, lead to a second breaking wave, which increases the line force. Finally, the numerical simulations are validated successfully against experimental investigations without wind.

KEY WORDS: Offshore structure; Wave-induced load; Wind effect on wave; Airflow Separation;

INTRODUCTION
An increasing number of detections of rogue waves has occurred recently; hence, much attention is paid to these lately. The studies are justly performed, since the increased wave height of rogue waves can result in breaking waves and increased load on offshore structures if being hit. Tychsen, Fabricius, Ottesen and Stevanato (2016) report of photo and video recordings revealing an incidence of two consecutive waves exceeding the 10,000 years wave height hitting one of the offshore structures in the North Sea. Moreover, there was an accident in 2015, where an extreme wave hit the COSL Innovator platform (Midttun, 2016), resulting in one fatality and severe damage to the platform. Naturally, this has created an increased need for more knowledge on generation and occurrence of rogue waves, breaking waves, and the loads they inevitably will expose to the offshore structures. The features and statistics regarding extreme and breaking waves have been studied extensively. The increase in load due to a breaking wave was investigated in (Kjeldsen, Tørum and Dean, 1987). An amplification factor on the connection force for two-dimensional plunging waves was measured up to three times the forces from regular non-breaking waves. Moreover, the dynamic amplification on the force has variations depending on the duration of the impulse from the breaking wave and the natural frequency of the platform. Nielsen, Schlütter, Sørensen and Bredmose (2012) report an amplification factor of 1.5 on the force response. In (Tychsen, Fabricius, Ottesen and Stevanato, 2016) a dynamic amplification factor of 1.5 was inferred, and this factor was calculated to range from 1.5-1.9, for natural frequencies relevant for offshore structures considering a single degree of freedom system. All these experimental studies were however performed under typical laboratory conditions, meaning that there was no wind present, when the waves were travelling. That the direct effect of wind is not taken into account can potentially be of importance to the kinematics and load obtained during the tests.

Some studies on the effect of wind on steep waves have been conducted, but the wave-induced load was not examined. Touboul, Giovanangeli, Kharif and Pelinovsky (2006) examined the local effect from wind over high and steep waves experimentally and numerically. The experimental study was conducted at the Large Air-Sea-Interaction Facility (LASIF) in Marseille. The waves were generated as spatio-temporal focused waves, and tests were conducted with and without wind. Introducing wind extends the duration of the period, in which the waves are focused, and increases the amplitude slightly for strong wind. Moreover, the focusing point is moved further downstream, which in (Giovanangeli, Kharif and Pelinovsky, 2006) is explained with a current introduced in the tank, when wind is blowing over the surface. In the numerical simulation a nonlinear Boundary Integral Equation Method (BIEM) and a Mixed Euler-Lagrange (MEL) time marching scheme