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Numerical investigation of wave-induced forces on a semi-submerged vertical cylinder

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Context and Objectives

This study, part of the DRACCAR project, analyzes the effects of breaking waves on offshore wind turbine tower vibrations using 3D Fluid-Structure Interaction (FSI) modeling at laboratory scale. FSI simulations capture complex wave-structure dynamics, focusing on high-harmonic forces and Secondary Load Cycles (SLC), which are often neglected but may amplify the vibratory response of the structure. The objective is to better understand these complex loading mechanisms to optimize the design and reliability of offshore structures subjected to extreme marine conditions.

Figure 1. Experimental setup of fixed cylinder in the tank [1].

Method

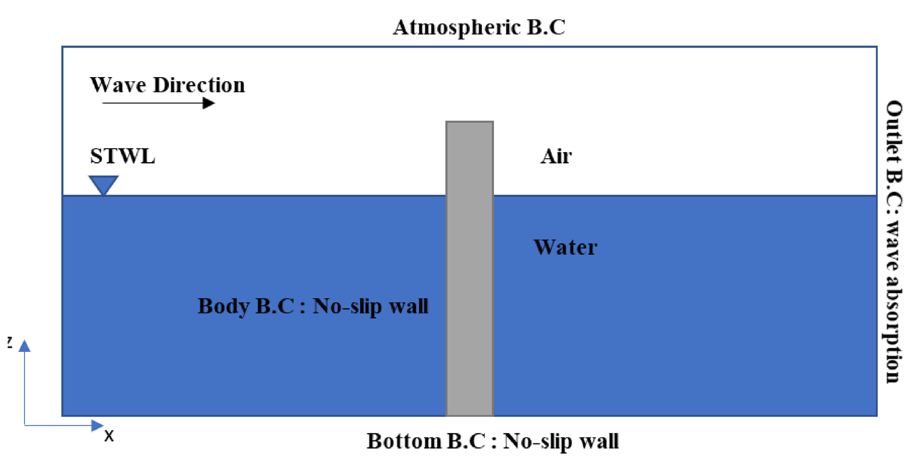

Figure 2. Schematic of the computational domain, geometry and boundary conditions.

A three-dimensional numerical model is developed in the present work to simulate the interaction between regular waves and a vertical cylinder fixed to the seabed. The numerical flume geometry and boundary conditions are illustrated in Figure 2. The cylinder, with a diameter of 0.06 m, is positioned at the center of the flume. Regular waves of height H=0.12 m and period T=0.86s are generated and propagated within the domain. A locally refined mesh is used in the vicinity of the cylinder to ensure higher resolution of the fluid-structure interaction (Figure 3).

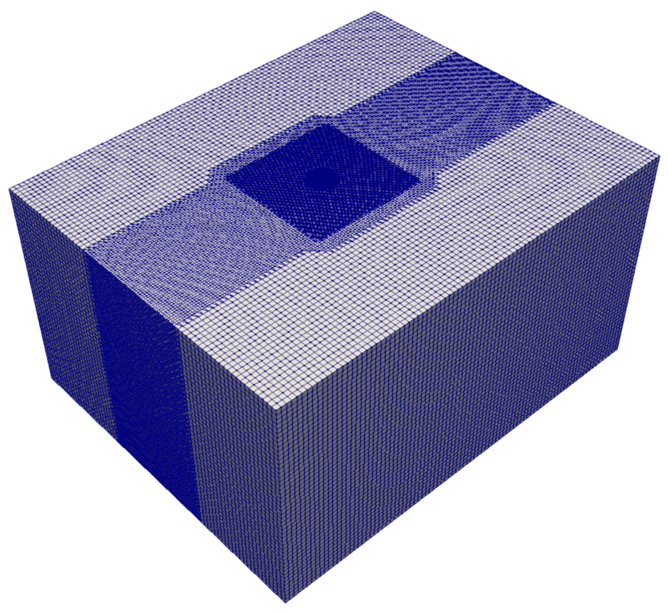

Figure 3. Numerical mesh of the domain.

Results and discussion

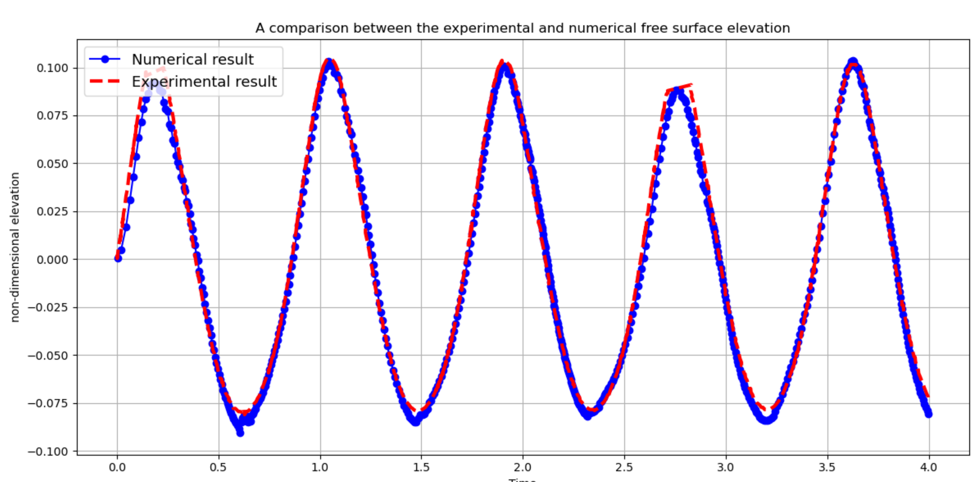

Figure 4. Free surface elevation over time: Validation of OpenFOAM results against experimental data [2].

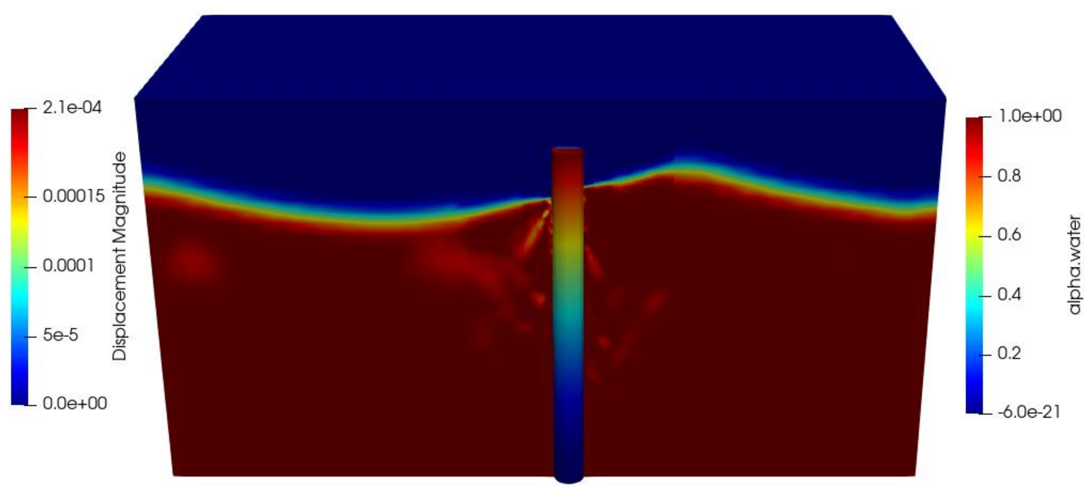

Figure 5. Wave–Cylinder interaction at the final time step : Wave elevation and structural displacement.

This investigation presents the project setup and the general description of the computational domain, Highlighting the potential effects of Secondary Load Cycles (SLC) in fluid-structure interaction. Our model proved reliable, as confirmed by the validation of the free surface elevation (Figure 4). The final interaction frame effectively demonstrated the hydrodynamic impact on the structure (Figure 5) and sequential snapshots of free surface elevation and cylinder displacements under hydrodynamic loads (Figure 6).

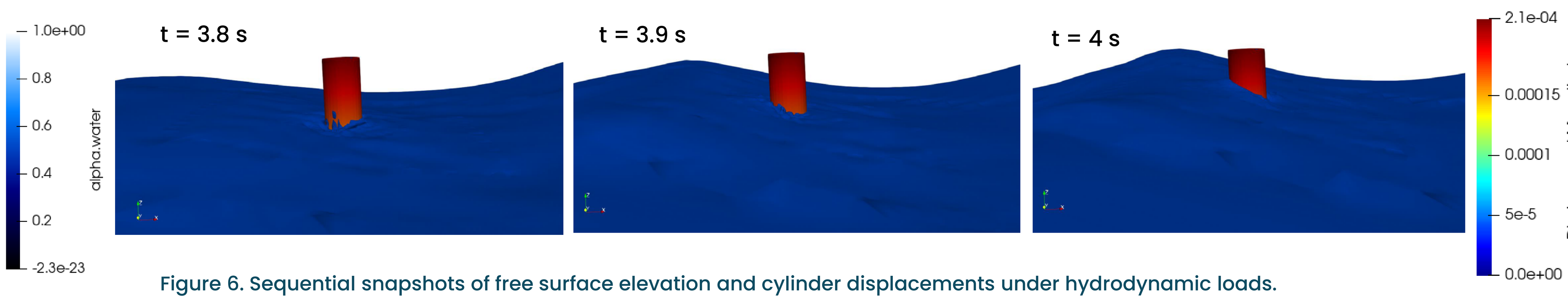

Figure 6. Sequential snapshots of free surface elevation and cylinder displacements under hydrodynamic loads.

Perspectives

This work represents an intermediate step in a broader study; the computational model will be extended and adapted to other geometries in subsequent phases of the research.

References

[1] Grue, J., Huseby, M., 2002. Higher-harmonic wave forces and ringing of vertical cylinders. Appl. Ocean Res. 24, 203–214. https://doi.org/10.1016/S0141-1187(02)00048-2

[2] Chen, L.F., Zang, J., Taylor, P.H., Sun, L., Morgan, G.C.J., Grice, J., Orszaghova, J., Tello Ruiz, M., 2018. An experimental decomposition of nonlinear forces on a surface piercing column: Stokes-type expansions of the force harmonics. J. Fluid Mech. 848, 42–77. https://doi.org/10.1017/jfm.2018.339

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