NUMERICAL SIMULATION OF WAVE-INDUCED VEGETATION DYNAMICS USING A PARTITIONED COUPLING BETWEEN THE SPH METHOD AND AN FEA STRUCTURAL SOLVER

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INTRODUCTION

Sustainable coastal defense is promoted by wave-vegetation interaction that occurs in coastal zones and is able to dissipate wave energy and baffle currents. To study the complex fluid-structure interactions involved, numerical models present themselves as a suitable tool able to offer an in-depth view over the near field kinematics and dynamics. Taking into account the effect of vegetation dynamics is necessary, and often modelled through coupled fluid and structural solvers. This implies increased complexity, adaptive re-meshing tools, and numerically expensive simulations given the disparity between dimensions of the fluid domain and the very thin structural elements. The aim of this work is to present a novel numerical coupling tool based on the meshless Smoothed Particle Hydrodynamics (SPH) method, which can handle ultra-thin vegetation and resolve the vegetation kinematics without the use of any fitted parameters.

NUMERICAL MODELS

In this work, the coupling presented in Martinez-Estevez et al., (2021) is employed. DualSPHysics (Domínguez et al., 2021) software is used to solve the fluid flow, and the finite-element analysis (FEA) solver of Project Chrono (projectchrono.org/) is used to model the vegetation dynamics. DualSPHysics is a GPU accelerated open-source software based on the SPH formulation. The model is characterized by a mesh-free Lagrangian approach in which the domain is discretized using particles, and the velocity and pressure fields are solved using the Navier-Stokes equations. The structural solver is based on the Euler-Bernoulli beam element capable of undergoing large deformations and rotations. The coupling combines the effectiveness of meshless methods in resolving free surface and violent hydrodynamic flows with the robustness of mesh-based structural solvers. The communication interface between both solvers is built using a dummy envelope that transfers forces and displacements between the two solvers. The main novelties in this implementation are the decoupling of the geometric properties of the embedded structure (ultra-thin vegetation) from the resolution of the fluid domain, the smooth handling of the fluid-structure interface using a meshless approach, and the exact numerical modelling of ultra-thin vegetation without scaling or fitted parameters.

MODEL VALIDATION AND RESULTS

The coupling is validated against the experimental setup of Luhar & Nepf, (2016) in which the wave-induced dynamics of a thin flexible plate ("blade") under oscillatory flow are investigated. The experiment is reconstructed using a numerical wave flume in DualSPHysics, where the particle resolution (initial interparticle distance) is 0.005 m. The thin plate, with a thickness (T=0.0004 m) 10 times smaller than the fluid resolution, is embedded using the SPH-FEA coupling.

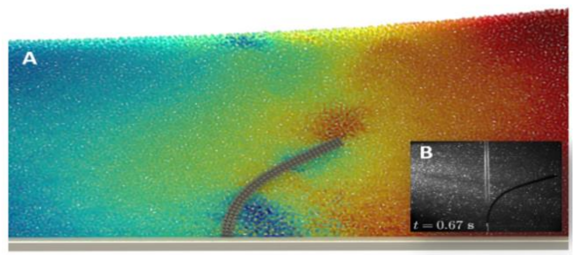

Figure 1 – Comparison of blade posture between (A) presented coupling and (B) experiments, at *t* = 0.67 s.

As shown in Figures 1 and 2, the model accurately captures the blade kinematics and tip displacements observed in the experiments. This excellent agreement is achieved over multiple wave cycles and without the use of any fitting parameters for the fluid and structural solvers. More details and additional validation cases will be presented in the conference paper.

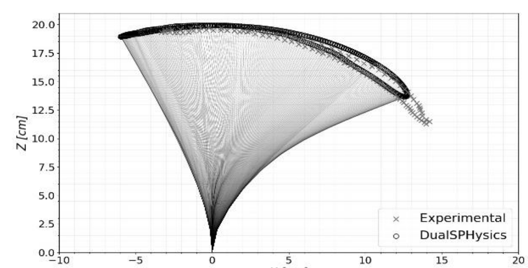

Figure 2 – Comparison of the horizontal (X) and vertical (Z) tip excursions of the blade over a wave period between the presented numerical coupling and experiments.

REFERENCES

Domínguez, J. M. et al. (2021). DualSPHysics: from fluid dynamics to multiphysics problems. *Computational Particle Mechanics*.

Luhar, M., & Nepf, H. M. (2016). Wave-induced dynamics of flexible blades. *Journal of Fluids and Structures*, *61*, 20-41. ttps://doi.org/10.1016/j.jfluidstructs.2015.11.007.

Martínez-Estévez, I., et al (2021). Simulating complex fluid-elastic structure interactions within DualSPHysics: An extended coupling with FEA structural solver, in SPHERIC Int Workshop, pp. 220-225.