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A FREE SURFACE MODEL FOR THE NUMERICAL SIMULATION OF OSCILLATING WATER COLUMN SYSTEMS

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The aim of this work is to propose and validate a numerical model that represents the hydrodynamic behavior of an Oscillating Water Column (OWC) device, that has been shown to be one of the most promising ways to extract energy from ocean waves [1]. A conservative level-set scheme (CLS) (introduced by Ollson and Kreiss [2]) was employed to track the free moving interface in an incompressible, transient two-phase flow, globally governed by the Navier-Stokes equation and the mass conservation equation. The CLS method avoid the loss of mass that happens in Standard Level Set (SLS) methods, but complicates the calculation of geometric properties at the interface. The interface is tracked by means of an advection equation, and the CLS function is reinitialized at every time step in order to maintain constant the thickness of the interface. The governing equations are discretized over a Cartesian grid, according to a staggered scheme that helps to avoid spurious pressure modes and it's generally stabler for multiphase flows: pressure is stored at cell centers, while velocities are defined at the cell faces.

Figure 1: Snapshot of the domain used for the simulations: the waves are generated in the left part; the confined space on the right part represents the air chamber, while the small orifice mimics the turbine inlet nozzle. No-slip condition were applied to the boundaries that had to be considered solid, while Neumann and Convective BC were tested on the free boundaries.

The model was firstly validated by simulating the behavior of solitary waves in shallow waters and comparing the results with the analytical data proposed by Mei [3]. Good agreement was found between analytical and numerical data, as showed in Figure 2.

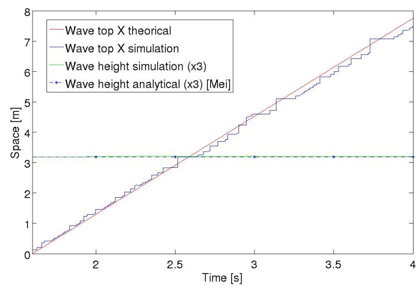
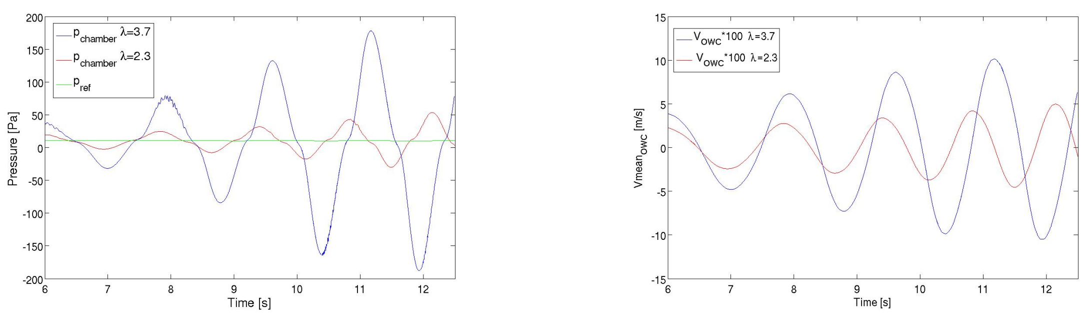


Figure 2: Wave peak position versus time for h_w=0.92 m and a=0.0164 m. The wave was generated according to the following equation: $\eta(x,t) = a\ sech(\kappa/h_w(x-ct))^2$**.**

The same model was then applied to another geometry (showed in Figure 1) and used to investigate the interaction of linear waves with a submerged air chamber; this set-up can constitute an effective way of representing the physical behavior of the OWC device, as demonstrated by Evans [4]. In the final paper, several set-up will be analyzed (varying mesh size, orifice position and diameter) by monitoring local velocities, pressures (examples in Figure 3) and wave elevation in order to optimize the hydrodynamic efficiency of the system.



(a) (b)

Figure 3: Illustrative results for pressure and mean surface velocity in the OWC for different wavelength of the waves. The wave elevation is generated as: $\eta(x,t) = a\ sin(\kappa x - \omega t)$**.**

REFERENCES

[1] SI Ocean, *Ocean energy: state of the art*. Online report, December 2012.

[2] Olsson, E., Kreiss, G., *A conservative level set method for two phase flow*, J. of Comput. Phys., Vol. 210, pp 225-246, 2005.

[3] Mei, C.C., *The applied dynamics of ocean surface waves*. Wiley, New York, 1983.

[4] Evans, D.V., Porter, R., *Hydrodynamic characteristics of an oscillating waters column device*, Appl. Ocean. Res., Vol. 17, pp 155-164, 1995.