FACULTY OF ENGINEERING AND ARCHITECTURE

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COMPARATIVE STUDY OF THE HYDRODYNAMICS OF A HEAVING WAVE ENERGY CONVERTER USING LINEAR AND NON-LINEAR WAVE THEORY

Problem statement

How can a heaving wave energy converter (WEC) accurately be modelled in operational and extreme sea states?

Scientific background

Linear models

Using the numerical model, NEMOH

- Frequency domain
- Applies linear potential flow theory – small wave and body amplitudes assumed
- Allows fast calculations

Fig. 1: WEC in operational conditions.

Using the numerical model, WEC-Sim

- Availability to accurately model PTO system
- Time domain
- Enables calculation of average absorbed power and hydrodynamic forces

Smoothed Particle Hydrodynamics

Using the numerical model, DualSPHysics

- DualSPHysics applies the Smoothed Particle Hydrodynamics method (SPH), a Lagrangian meshless method.
- DualSPHysics discretizes the fluid in particles – physical quantities are computed as an interpolation of the values of neighbour-particles [1].
- Allows calculations of WECs in extreme sea states.

Fig. 2: WEC in operational conditions.

PTO system modelling

- DualSPHysics – Chrono-Engine coupling allows accurate modelling of real PTO systems [2]. Chrono-Engine is an open-source multi-physics simulation platform, suited for the numerical modelling of mechanical systems such as joints, springs, hinges... [3].

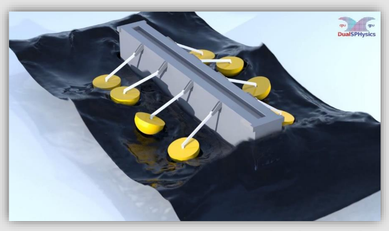

Fig. 3: DualSPHysics coupled to Chrono-Engine. (Brito et al., 2016)

Numerical research

- DualSPHysics has successfully been coupled to Chrono-Engine for the numerical modelling of a linear PTO system [2].
- Previous research shows that linear models lead to overestimations of the absorbed wave power up to 150 % [4].

Research objectives

- Develop an accurate numerical model of a heaving WEC with DualSPHysics, coupled to Chrono-Engine used for the PTO system modelling.
- Compare the hydrodynamic forces and absorbed power calculated using WEC-Sim with the results obtained with DualSPHysics and evaluate in which conditions non-linearities become significant.
- Calculate the wave field modified due to the presence of the heaving WEC (near-field effects).

Methodology

Development

• A WEC-Sim model for the heaving WEC with a linear and a hydraulic PTO system has been developed – see Fig. 4. Besides the forces and the absorbed power, the modified wave field was calculated (Fig. 5) and a comparison between the linear and hydraulic PTO system was made.
• It was concluded that for a heaving WEC the type of PTO system has a significant influence on the average absorbed power, but less on the modified wave field [7].

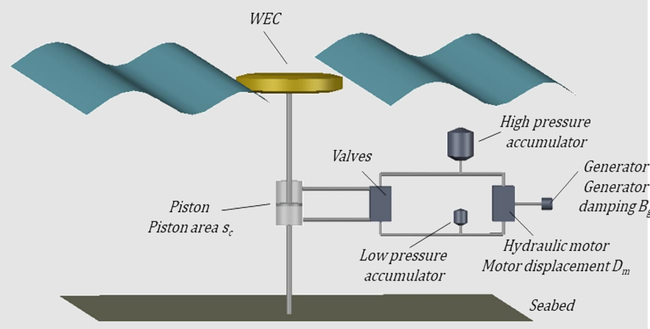

Fig. 4: Schematic representation of the hydraulic PTO system for a heaving cylindrical WEC [7].

Future work

• Develop numerical wave basin in DualSPHysics able to generate the required wave conditions. The heaving WEC will be coupled to Chrono-Engine, enabling the PTO system modelling.
• After modelling a heaving WEC with a linear PTO system, a model of a more accurate PTO system, such as a hydraulic PTO, will be modelled with the Chrono-Engine.

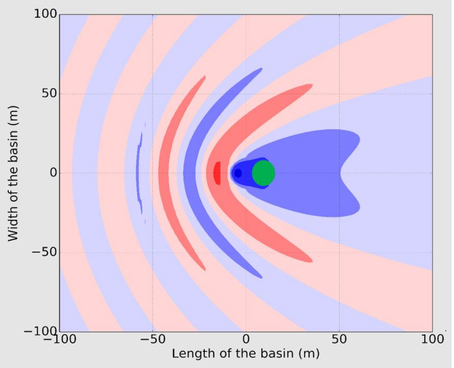

Fig. 5: Amplitude of total wave field surrounding a single heaving WEC .

• The modified wave field surrounding the WEC will be determined using the established DualSPHysics – OceanWave3D coupling , Fig. 6 [5]. OceanWave3D is a non-linear potential flow wave propagation model.
• In the future , the influence of the mooring lines will be investigated as well, using the recently developed coupling between DualSPHysics and MoorDyn [6].

Validation

- A first numerical validation will be done in small waves by checking the results of DualSPHysics with those of WEC-Sim.
- Experiments with heaving WEC arrays will be conducted in 2020 in the Coastal and Ocean Basin (COB) in Ostend, Belgium. This 'WECfarm' project will allow validation of the developed numerical models.

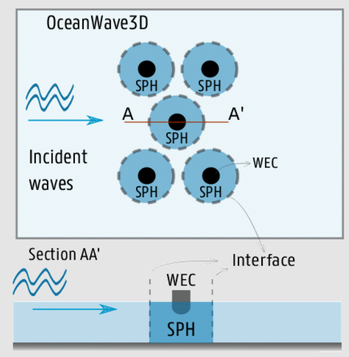

Fig. 6: Coupling between DualSPHysics and OceanWave3D.

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