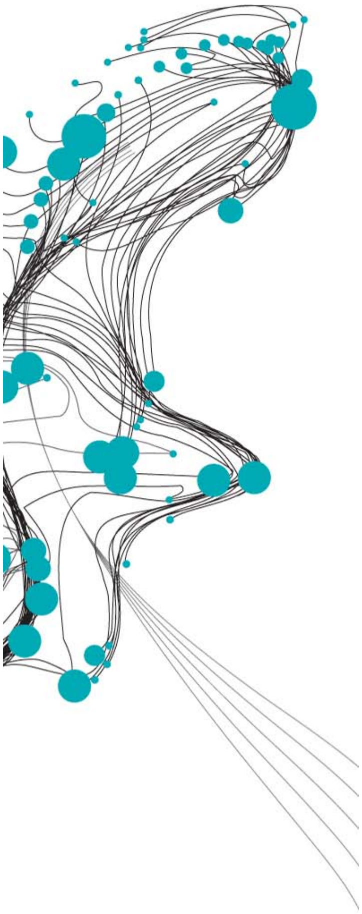
Study for the hull shape of a Wave Energy Converter-Point Absorber



Wave energy can become a sustainable source of energy for the human needs in the future. Wave energy is defined as the energy transferred under wind waves in offshore environment. For capturing wave energy and transforming it to electrical, special devices called Wave Energy Converters (WECs) are used. Numerous types of WECs exist. The device studied in this research is the so-called Point Absorber. The Point Absorber captures the wave induced up and down motion of a floating buoy and transforms it to electrical power with the use of a damper. A mechanical spring is used so as to adjust the natural frequency of the buoy's oscillation (Figure 1). Optimum configuration for the damper and the spring under irregular sea waves have already been derived by previous researchers. This study is about deriving a more efficient in power extraction design in terms of the buoy's shape and dimensions (Design Optimization). Furthermore, the model for deriving power predictions is studied for including viscous effects and the changing position of the buoy in wave force estimation (Physical Modeling Improvement).

The model used for deriving power predictions for the Point Absorber is the widely known as Linear Mass-Spring-Damper System. Solutions are derived either in the Frequency Domain or the Time Domain. Frequency Domain solution is fast and valuable for deriving statistics. The Time Domain solution is valuable for including nonlinear effects such as viscous damping. Hydrodynamic input based on Linear Wave Theory is produced by the 3D-Diffraction Theory code NEMOH. Viscous effects are estimated with the aid of the Computational Fluid Dynamics code ComFLOW3 for deriving drag coefficients for every design.

For design optimization, three different shapes were assessed. A Cylinder, a cylinder with hemispherical bottom called Bullet and a cylinder with a conical bottom called Cone. Optimum dimensions for each shape were derived by the Frequency Domain model. Next, Forced Oscillation Tests in the numerical wave tank of ComFLOW3 were conducted for assessing the capacity of each of the three designs in producing viscous effects. Time Domain simulations including viscous effects approximately supplemented the comparison.

For modeling improvement two models were produced. In the first model, a time-dependent adjustment of the drag coefficients derived by Forced Oscillation Tests was implemented. The implementation was based on the parameterization of the drag coefficient by using the Keulegan-Carpenter and Reynolds numbers. In the second model, a time-dependent estimation of the wave force was implemented. This was achieved by estimating the wave force of the undisturbed wave field and the diffracted wave field at every time step.

By implementing the proposed methodology the following conclusions were deducted about the design optimization and modeling improvement:

- The Bullet was qualified as the most efficient shape (Figure 2)
- The radius of the most efficient Bullet was found equal to 10m and the total vertical length was found equal to 15m.
- Including viscous effects reduced the predicted power extraction for more than 10%.
- The inclusion of viscous damping shifted the position of the optimum damper configuration especially for sea states where the natural frequency of the buoy coincided with the peak frequency of the sea state.
- The inclusion of the buoy's position in the wave force estimation was proved to be rather computationally expensive without adding significant physical accuracy to the model. The assumption of estimating the wave force always at equilibrium position was proved to be valid at least for large buoys.

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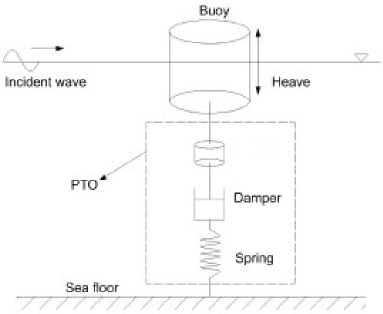

Figure 2 Point Absorber design

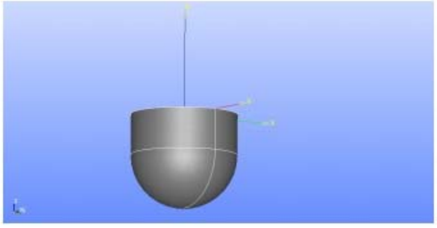

Figure 1 Final Bullet design

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