Wave energy conversion with a novel point-absorber array: experimental proof-of-concept

Herman Martens Meyer [a], Leif Arne Tønnesen [b], Olav Gundersen [a], Atle Jensen [a]
[a] Department of Mathematics, University of Oslo, Oslo, Norway
[b] Concrest Energy
hermam@math.uio.no

HIGHLIGHTS

We present experimental results from a proof-of-concept model test of a novel wave energy converter that combines the principles of a point absorber array with a shared closed-loop hydraulic power-take-off system, tested in the new wave tank at the University of Oslo.

1 INTRODUCTION

The oceans provide a vast resource of energy in the form of surface waves [1]. With a growing demand for green alternatives in the global energy mix, wave energy is a promising yet largely underdeveloped field. In contrast to fields such as solar and wind energy, where the market has converged towards a few design-preferences, the design of wave energy converters (WECs) diverges substantially between different operating principles and power take-off methods [2], suggesting that the field remains immature. Although waves offer high energy density and availability [3], major challenges remain for this field to become profitable.

We present experiments on a novel WEC concept: the patent-pending point-absorber array from Concrest Energy with a shared closed loop hydraulic power-take-off system that combines the principles of point absorbers and wave attenuators. A 1:40-scale model was built and tested in the new wave tank at the University of Oslo under regular and irregular long-crested waves with different wave headings.

Experimental model testing provides an effective means to evaluate concepts in realistic conditions and inform further development [4]. The present work was intended as both a proof-of-concept test and an initial validation of the new wave tank facility, providing practical insight into its capabilities, limitations, and operational use.

2 WEC CONCEPT AND EXPERIMENTAL MODEL

The operating principle of the Concrest WEC is schematically shown in Fig. 1. Each buoy drives a piston pump that discharges water into the hydraulic circuit, allowing the buoys to operate cooperatively rather than as isolated point absorbers. The differential force and velocities between buoys in an opposite wave phase generate a flow that drives a turbine. The flow discharged from pumps in an upward stroke assists the return stroke of the other pumps, replacing the need for actively controlled reposition mechanisms. Optimum cooperation is achieved with an equal number of buoys in wave crests and wave troughs, which requires a high number of buoys arranged along the direction of wave propagation.

For the scaled model, the buoy geometry was scaled except for the height, allowing testing at different drafts. The hydraulic components, however, could not be scaled accordingly, resulting in both pistons and water supply hoses being oversized, and pipe diameters being

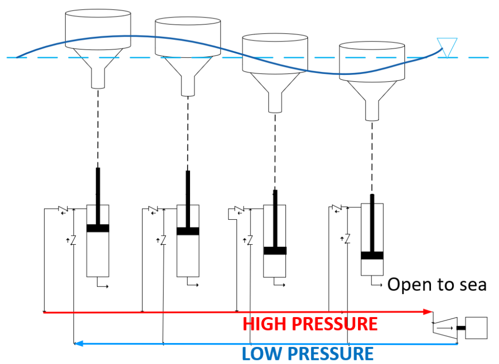

Figure 1: Illustration of the Concrest Energy WEC working principle.

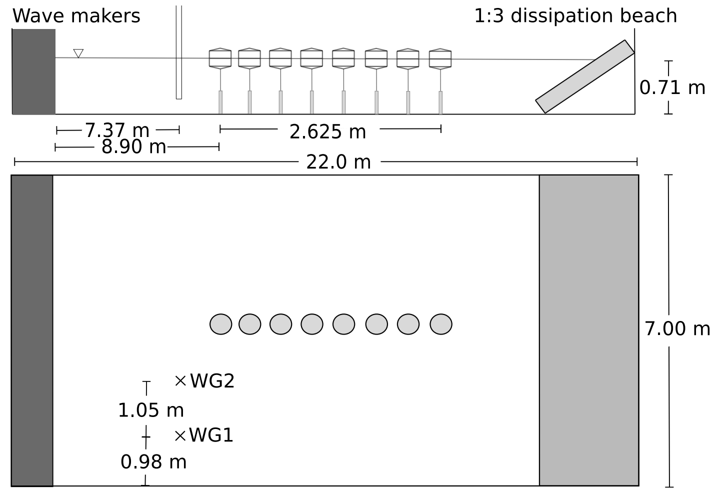

Figure 2: A schematic of the University of Oslo wave tank and the experimental setup used in the present study. Not to scale.

larger than optimal. This likely results in a greater hydraulic mass than that of a uniformly scaled device, which reduces the system responsiveness and alters the WEC model's natural frequency. The model included a choke valve, which acted as a turbine analogue, flow and pressure instrumentation, and a water supply to account for piston head leakage. This provided a functional experimental setup for testing the array under both regular and irregular wave conditions.

3 FACILITIES AND EXPERIMENTAL SETUP

The experiments were conducted in the new wave tank at the University of Oslo. The facility includes a 22.0 m long and 7.0 m wide tank equipped with 14 piston-type wave paddles and a 1:3 sloped metallic dissipation beach. A schematic of the experimental setup is presented in Fig. 2. The wave height was recorded using resistance-type wave gauges (Edinburgh Design, WG8USB), which were placed slightly off the centreline to minimize exposure to diffracted waves from the WEC. The WEC response to incoming waves was quantified using the system flow rate, Q, and the pressure difference across the choke valve, Δp. For experiments in irregular waves, we used a 5-minute JONSWAP spectrum with $\gamma = 3.3$, $f_p = 0.70$ Hz, $f_{\mathrm{min}} = 0.2$ Hz, and $f_{\mathrm{max}} = 1.5$ Hz. For the tests, we ran the regular and irregular waves on the original 8-buoy array with $1.5D$ buoy spacing and a more widely spaced array of 4 buoys with $3D$ spacing, where D is the buoy diameter. Both configurations were tested at $\theta = 0°$ and $\theta = 20°$, but only the results from the 8-buoy configuration are presented here.

4 RESULTS AND DISCUSSION

In regular waves, the original 8-buoy array exhibits an optimal frequency response around $f = 0.55$-0.70 Hz, as shown in Fig 3. Beyond this optimal frequency, we observe a rapid drop-off and, especially at higher amplitudes, strong buoy-buoy interactions, including slamming and collisions, which likely reduce performance. There is clearly a lower produced

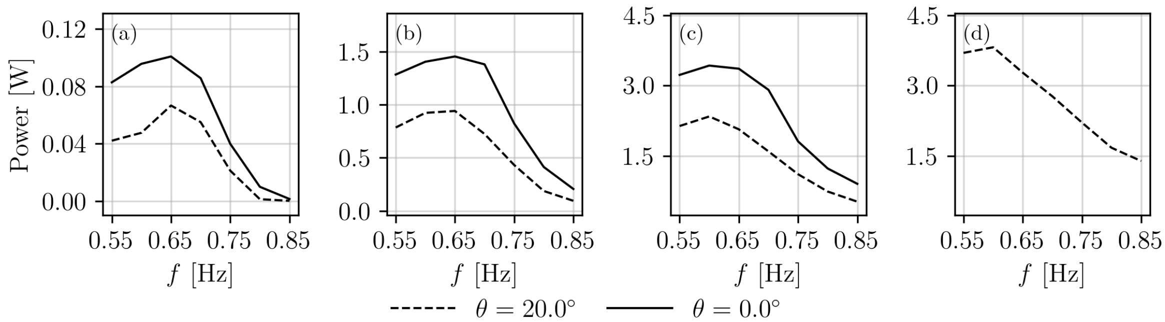

Figure 3: Power as a function of regular wave frequency for amplitudes $a = 1.5$ cm (a), 3.3 cm (b), 5.2 cm (c), and 7.2 cm (d), for the 8-buoy configuration.

power output for cross waves, and visually we observed increased sway, roll, and inter-buoy interactions at $\theta = 20°$.

We observe somewhat similar results for the more widely spaced 4-buoy configuration, but interestingly, a slightly different response to wave heading. More results will be presented at the workshop.

5 CONCLUSION

These proof-of-concept experimental results demonstrate that this WEC concept is able to generate power. Hydrodynamically, interactions between closely spaced buoys seem to reduce optimal wave capture. These interactions also seem to contribute to the reduction of generated power at $\theta = 20°$.

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