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Published in:

The 8th European Wave and Tidal Conference : EWTEC 2009

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

De Backer, G., Vantorre, M., Beels, C., De Rouck, J., & Frigaard, P. (2009). Performance of Closely Spaced Point Absorbers with Constrained Floater Motion. In *The 8th European Wave and Tidal Conference : EWTEC 2009: Book of Abstracts* (pp. 53-54). The 8th European Wave and Tidal Conference.

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Performance of closely spaced point absorbers with constrained floater motion

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Objectives

Point absorbers are intended to be installed in arrays to achieve considerable amounts of power. Some developers have even proposed devices, consisting of several multiple, closely spaced point absorbers. Hence, there is a need to:

- assess the behaviour of closely spaced bodies in unconstrained and constrained conditions.
- optimize the performance of an array, rather than optimizing the performance of an isolated body.

Methodology

Linear model

A linear frequency domain model is employed. The hydrodynamic parameters are obtained from WAMIT. Each point absorber is equipped with its own PTO, exerting a damping force proportional to the buoy velocity. The buoys are tuned with a control force proportional to their acceleration.

Implemented restrictions

- A **slamming** restriction to reduce the probability of rising out of the water. Condition: the significant amplitude of the buoy position relative to the surface elevation should be smaller than the draft of the buoy.
- A **stroke** restriction to limit the absolute position of the buoy. Condition: The significant amplitude of the buoy position must be smaller than 2 m.
- A **force** constraint to reduce the total control forces. This restraint is mainly intended for the case where the PTO delivers the tuning force. Condition: The significant amplitude of the control force is limited to 200 kN.

Optimization strategies

- OPSB**: Optimal control parameters of a single body, applied to the array.
- DO**: Diagonal optimization. All buoys get the same control parameters, but they are optimized with a simplex search method for unconstrained conditions and a sequential quadratic programming (SQP) method in constrained conditions.
- IO**: Individual optimization. Every floater has its own optimal control parameters. (SQP)

Configuration

- An array of 12 buoys in a staggered grid (Fig. 1).
- The interdistance between two successive rows is 6.5 m.
- The incoming waves propagate in the direction of the x -axis, when the angle of incidence is 0° .
- The buoys have a conical shape with a cylindrical upper part and diameter of 5 m.

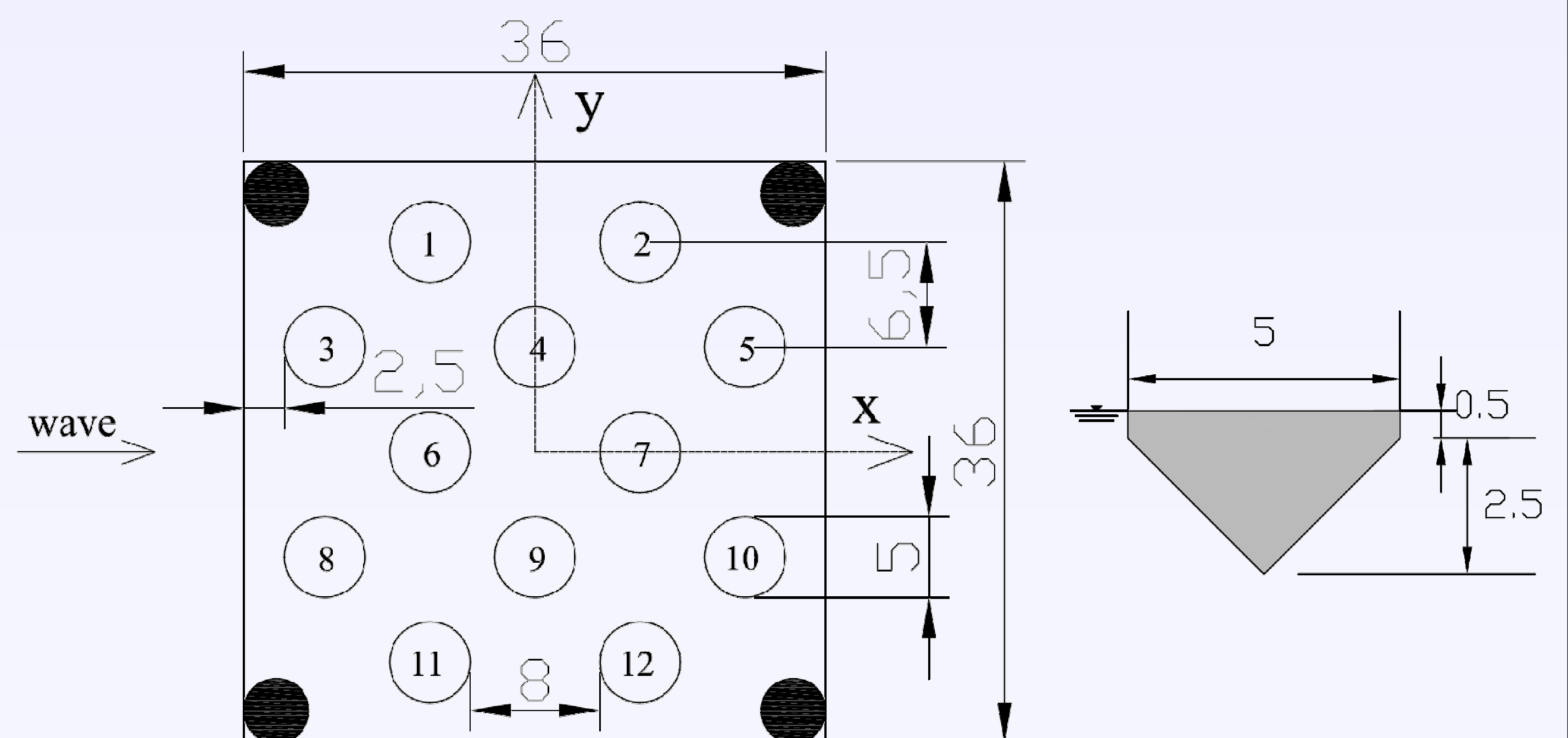


Fig. 1 Array configuration and buoy layout (dimensions in [m]).

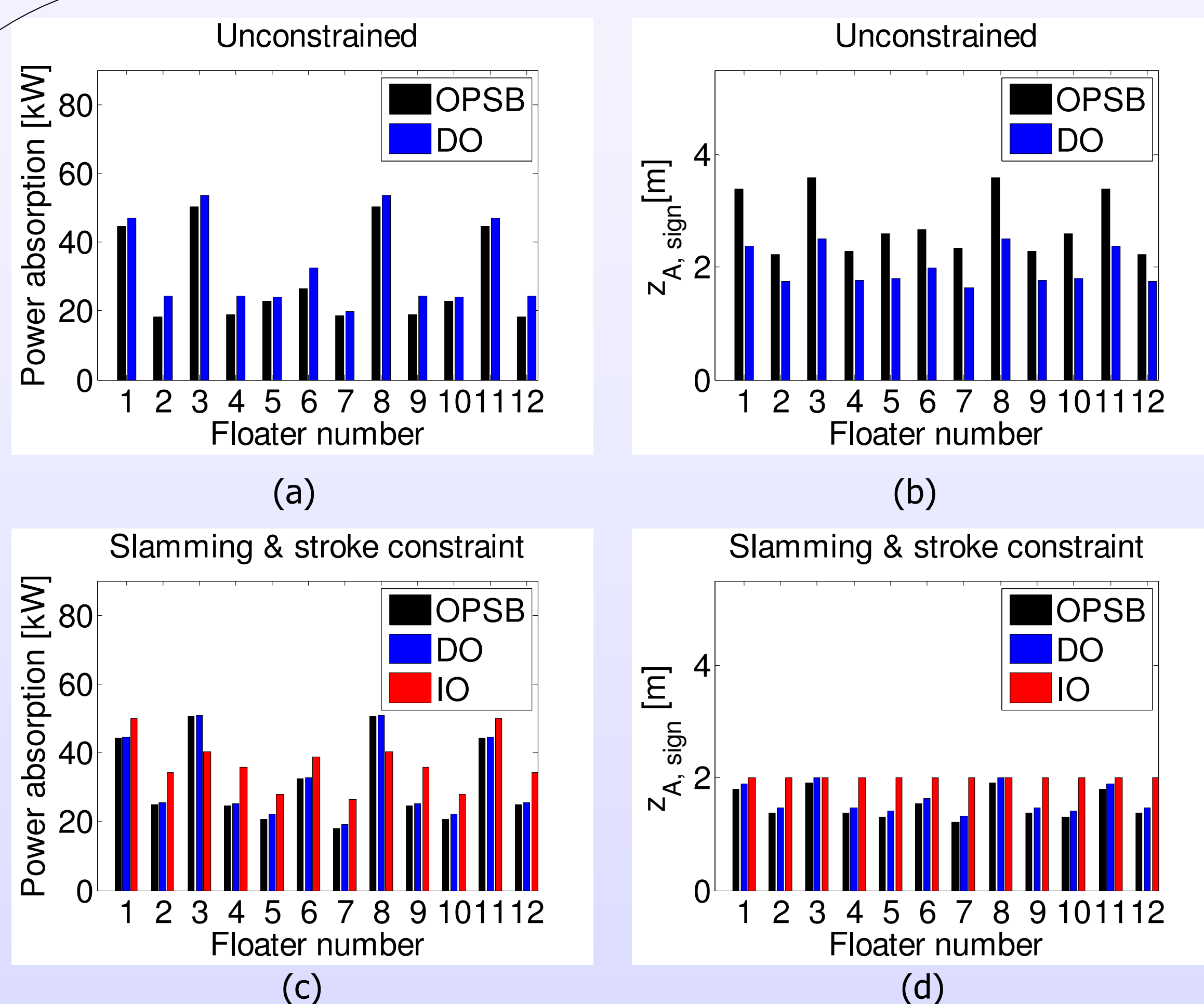


Fig. 2 Power absorption and significant amplitude of the buoy position for unidirectional wave: $H_s = 2.25$ m, $T_p = 7.22$ s, in unconstrained and constrained conditions.

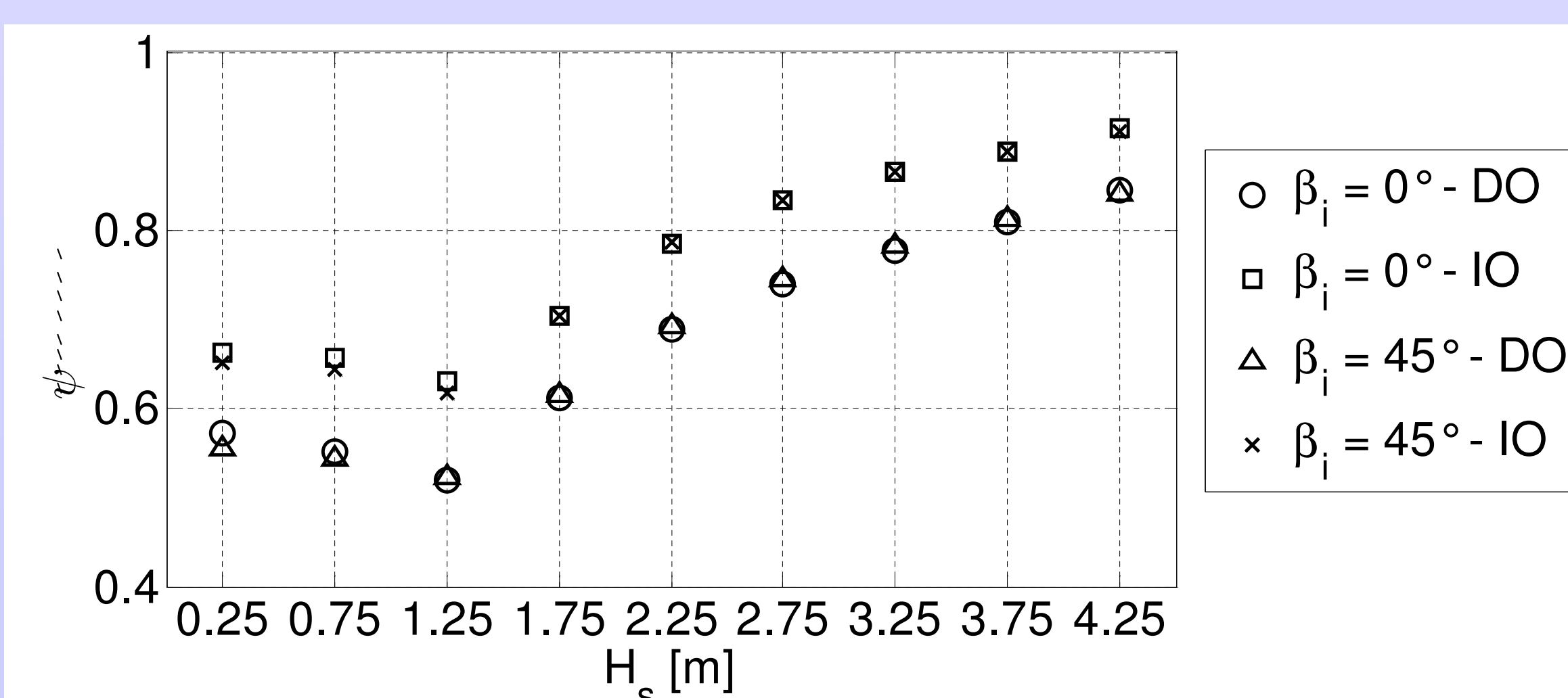


Fig. 3 \tilde{q} -factors as a function of H_s (T_p varying between 5.3 s to 9.1 s) for the slamming, stroke and force constraints.

Results and conclusions

Unconstrained conditions: Fig. 2(a) en (b)

- The power absorption is unequally distributed among the floaters.
- The total power absorption is increased when diagonal optimization is used compared to the optimal parameters of a single body.
- The buoy motions are quite large.

Constrained conditions: Fig. 2(c) en (d)

- The power absorption is considerably increased with individual optimization (increase of 14 – 16 % compared to DO).
- The absorbed power is better distributed: the front buoys absorb generally less, whereas the rear buoys absorb more power compared to unconstrained conditions.
- The characteristic displacement of the buoys is limited to 2 m. With DO, all buoys reach this maximum level. The stroke restriction is dominant on the slamming restriction.

Gain factor \tilde{q} : Fig. 3

- Definition of \tilde{q} : ratio of the total power absorbed by the array to the power absorbed by the same number of point absorbers in isolation, subjected to the same constraints.
- For all sea states: individual optimization outperforms diagonal optimization.
- Variation of the angle of wave incidence ($\beta = 0^\circ$ versus 45°) gives very small differences in the total power absorption in this test case.
- The gain factor rises from $H_s = 1.75$ m onwards. This is probably caused by the constraints which become important in more energetic wave classes. Since, a single body is relatively more affected by the constraints, the gain factor rises in larger waves.

Future work

It is recommended to extend the application for random waves, since real waves are multidirectional. The influence of the angle of incidence and the spreading parameter should be further assessed in this context.