

EVALUATING POWER TAKE-OFF CONTROL ALGORITHMS FOR WAVE ENERGY CONVERTERS WITH AN OPENFOAM NUMERICAL WAVE TANK

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Wave energy conversion is an active field of research, aiming to harness the vast amounts of energy present in ocean waves. It has been shown that an essential development trajectory towards an economically competitive wave energy converter (WEC) is through early device experimentation and refinement, using numerical tools [1]. The use of OpenFOAM for wave energy experiments has been reported in many publications in recent years, (see review in [2]), and shows promise as useful numerical tool for WEC development.

OpenFOAM's CFD based solvers, allow high fidelity numerical simulations of the fluid structure interaction between the WEC and the ocean to be performed. The CFD simulations include a range of nonlinear effects that are neglected by the potential flow solvers which are traditionally used for WEC simulation. Historically, CFD simulations of WEC operation were computationally infeasible. However nowadays, the ever improving capabilities and reducing cost of high performing computers, allows CFD simulated experiments of WEC operation to be performed with reasonable computation times.

Implementing an OpenFOAM numerical wave tank (NWT) for wave energy experiments was reported in [2] and then used in [3-5], to provide experimental data of WEC behaviour, to identify parameters for hydrodynamic models. The experiments in [3-5] involved driving WEC motions by input waves and by directly applied forces (which replicate the WEC's power take-off (PTO) system). This functionality, in addition to the NWT's ability to instantaneously probe any variable with zero measurement noise and apply perfect actuation forces, makes the NWT a useful testbed for designing and evaluating PTO control algorithms.

Latching control has been investigated using an OpenFOAM NWT by [6]. The present work focuses on controlling the WEC performance via the PTO force. PTO control has the ability to improve the performance of a WEC, by calculating the optimal PTO force profile to apply to the WEC body, in order to capture the maximum amount of energy from an incident wave field. Control algorithms, use a dynamic model of the WEC's performance to calculate the optimal PTO force to apply to the WEC body. The control algorithms, take information measured from probes and sensors as input and then output the calculated best PTO force to apply to the WEC body.

PTO control is implemented in the present work, by first creating a pipe between OpenFOAM and MATLAB, as described in [7]. The OpenFOAM simulation then sends data to the MATLAB program at each time step and waits for the MATLAB program to pass back the optimum PTO force to be applied to the WEC body. The PTO force is implemented in the OpenFOAM simulation by modifying the restraints function in the `sixDoFRigidBodySolver` utility, following a similar procedure reported in [8] who applied mooring forces to the WEC body. Currently, the NWT is being used to evaluate the pseudospectral control algorithms, previously reported in [9-10].

The aim of this presentation/poster is to demonstrate the concept of utilising an OpenFOAM based NWT as an effective testbed for evaluating WEC control design. The presentation/poster will briefly discuss the previous applications of producing experimental data for the identification of hydrodynamic models, and then move onto the new topic of control algorithm evaluation. The implementation of an OpenFOAM NWT for control algorithm evaluation will be discussed and the challenges faced by this application compared to the previous work presented.

Additionally, the presentation/poster hopes to engage discussion and feedback from other attendees on a number of OpenFOAM specific issues related to the implementation of the present application, namely:

- Turbulence modelling for a WEC oscillating on the air/water interface in response to the wave motion of the free surface,

- Meshing strategies and the mesh resolution required for:
 - Capturing the fluid /WEC interface for different turbulence models,
 - Capturing the fluid/air free surface for different wave creation, propagation and absorption techniques,
- Dynamic mesh motion for large amplitudes WEC oscillation in multiple degrees of freedom,
- Wave creation and absorption techniques for the NWT. The presentation/poster will present a comparison between the popularly used waves2Foam toolbox [11] and the recently released OlaFoam toolbox [12], and
- Best approach to sampling the free surface elevation during run-time and passing the measured value to the modified restraint function in the *sixDoFRigidBodySolver*.

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References

- [1] J. Weber, ‘WEC technology readiness and performance matrix – finding the best research technology development trajectory’, in Proceedings of International Conference on Ocean Energy, Dublin, 2012
- [2] J. Davidson, M. Cathelain, L. Guillemet,, T.L. Le Huec and J. V. Ringwood, ‘Implementation of an OpenFOAM numerical wave tank for wave energy experiments’, in Proceedings of European Wave and Tidal Energy Conference (EWTEC), Nantes, 2015
- [3] J.V. Ringwood, J. Davidson and S. Giorgi, “System Identification”, in Numerical Modelling of Wave Energy Converters: State-of-the-art techniques for single WEC and converter arrays, Elsevier, 2016
- [4] J. Davidson, S. Giorgi and J.V. Ringwood, ‘Identification of wave energy device models from numerical wave tank data – Part 1: Numerical wave tank identification tests’, IEEE Transaction on Sustainable Energy, 2016
- [5] J. Davidson, S. Giorgi, and J. V. Ringwood, “Linear parametric models for ocean wave energy converters identified from numerical wave tank experiments,” Ocean Engineering, vol. 103, 2015.
- [6] G. Giorgi and J. V. Ringwood, “Implementation of latching control in a numerical wave tank with regular waves”, Journal of Ocean Engineering and Marine Energy, 2016
- [7] J. Palm, “Connecting OpenFOAM with MATLAB”, Online, Chalmers University of Technology, <http://www.tfd.chalmers.se/hani/kurser/OSCFD2012>
- [8] J. Palm, C. Eskilsson, G. Mourd Paredes, and L. Bergdahl, “CFD simulation of a moored floating wave energy converter”, , in Proceedings of European Wave and Tidal Energy Conference (EWTEC), Aalborg, 2013
- [9] R. Genest and J. V. Ringwood, ‘A critical comparison of model-predictive and pseudospectral control for wave energy devices’, 2016
- [10] R. Genest and J. V. Ringwood, ‘Receding horizon pseudospectral control for energy maximisation with application to wave energy devices’, 2016
- [11] N. G. Jacobsen, D. R. Fuhman and J. Fredsøe, A wave generation toolbox for the open-srouce CFD library: OpenFOAM, International Journal for Numerical Methods in Fluids, vol. 70 pp 1073-1088, 2012
- [12] P. Higuera, J.L Lara, I.J. Losada, Realistic wave generation and active wave absorption for Navier-Stokes models: Application to OpenFOAM, Coastal Engineering, Vol 71, pp. 102-118, 2013