Study on wave energy convertor net with coupled CFD-MBD tool

Xiang Li[1], Qing Xiao[1,*] , Atilla Incecik[1] and Anthony McDonald[2]

[1] Naval Architecture, Ocean and Marine Engineering, University of Strathclyde, Glasgow
(qing.xiao@strath.ac.uk)
[2] Industrial Doctoral Centre for Offshore Renewable Energy, Edinburgh

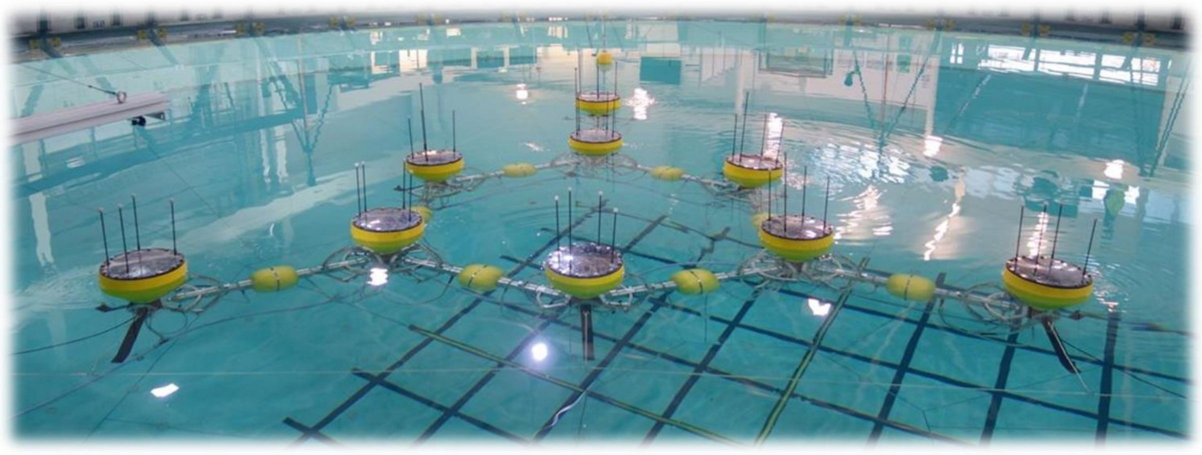
Present work is mainly based on numerical simulation of WEC net motion problem with Computational Fluid Dynamic method coupled with Multibody dynamic algorithm. The fluid solver is developed based on OpenFOAM[1]. Basic theory used in OpenFOAM is by discretising Naiver-Stokes equation:

$$\frac{\partial \rho U}{\partial t}+\nabla\cdot\left(\rho\left(U-U_g\right)U\right)=-\nabla P_d-g\cdot x\nabla\rho+\nabla\left(\mu_{eff}\nabla U\right)+\left(\nabla U\right)\cdot\mu_{eff}+f_\sigma$$

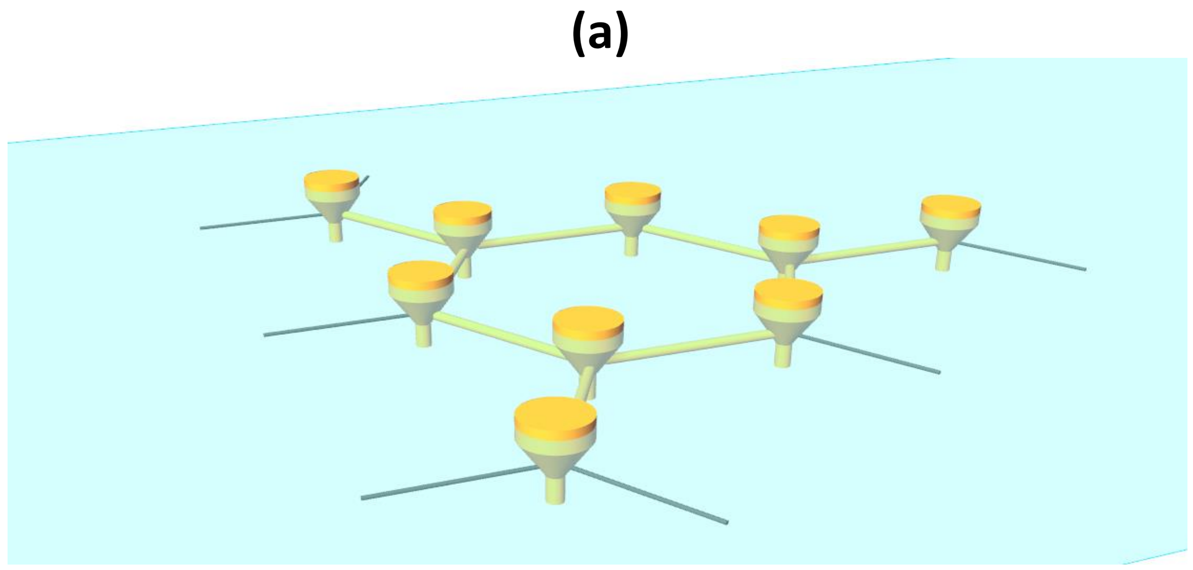
A second-order Crank-Nicolson scheme is used for temporal discretization. A second-order upwind scheme is adopted for convective terms. Gradient terms are handled via a second-order cell-limited Gauss linear scheme. The multibody dynamic problem is to solve following Differential-Algebraic Equations (DAE) equations which contain several constraints :

$$M\dot{x}=p$$
$$\dot{p}+\phi_x^T\lambda=f\left(\mathbf{x},\dot{\mathbf{x}},t\right)$$
$$\phi\left(\mathbf{x},t\right)=0$$

In our simulation, strong coupling is adopted to get better accuracy.

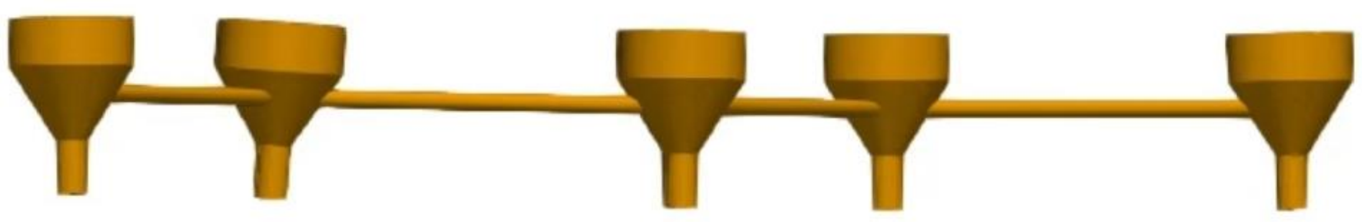


(a)



(b)

Fig 1. Sketch of the (a) Experimental model (b) Numerical Model of the WEC net



(a)) *t*=74s

(b) *t*=78s

Fig 2. Side view of the WEC net in wave tank for *T*=9.5s

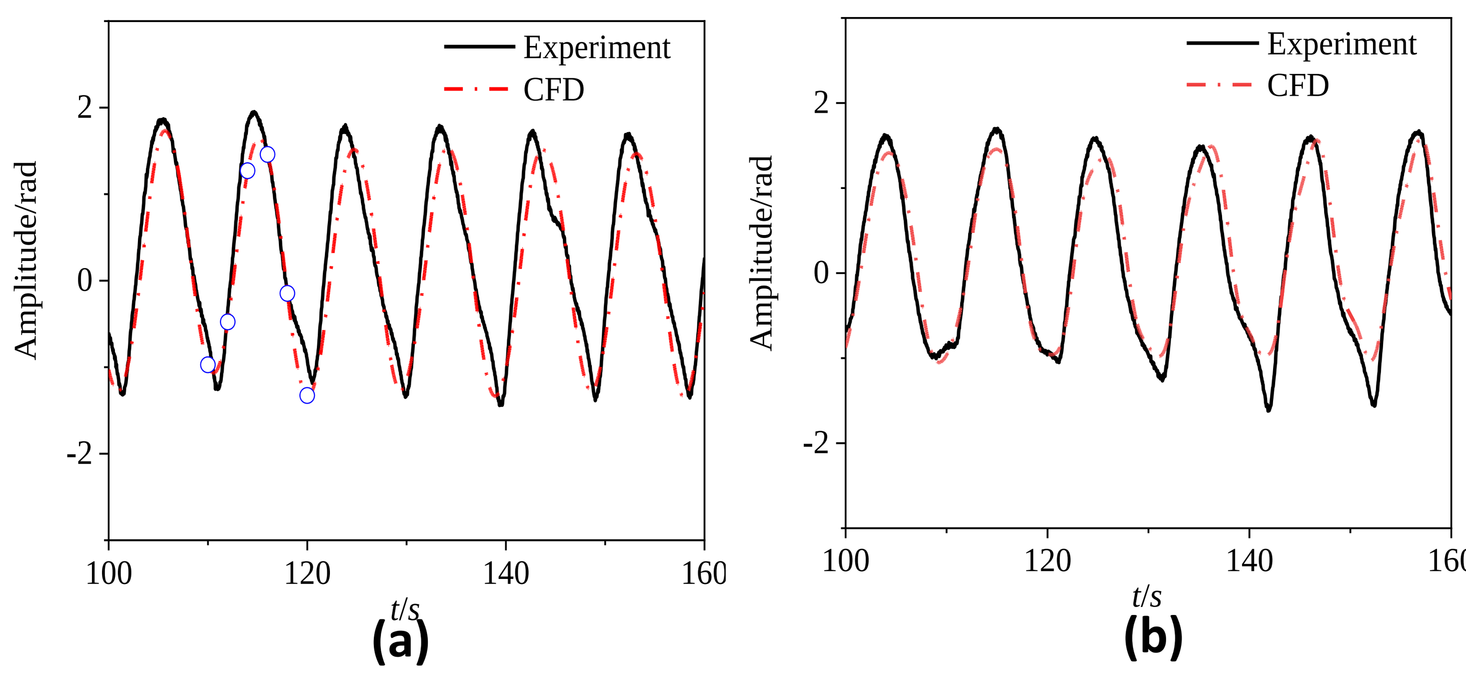
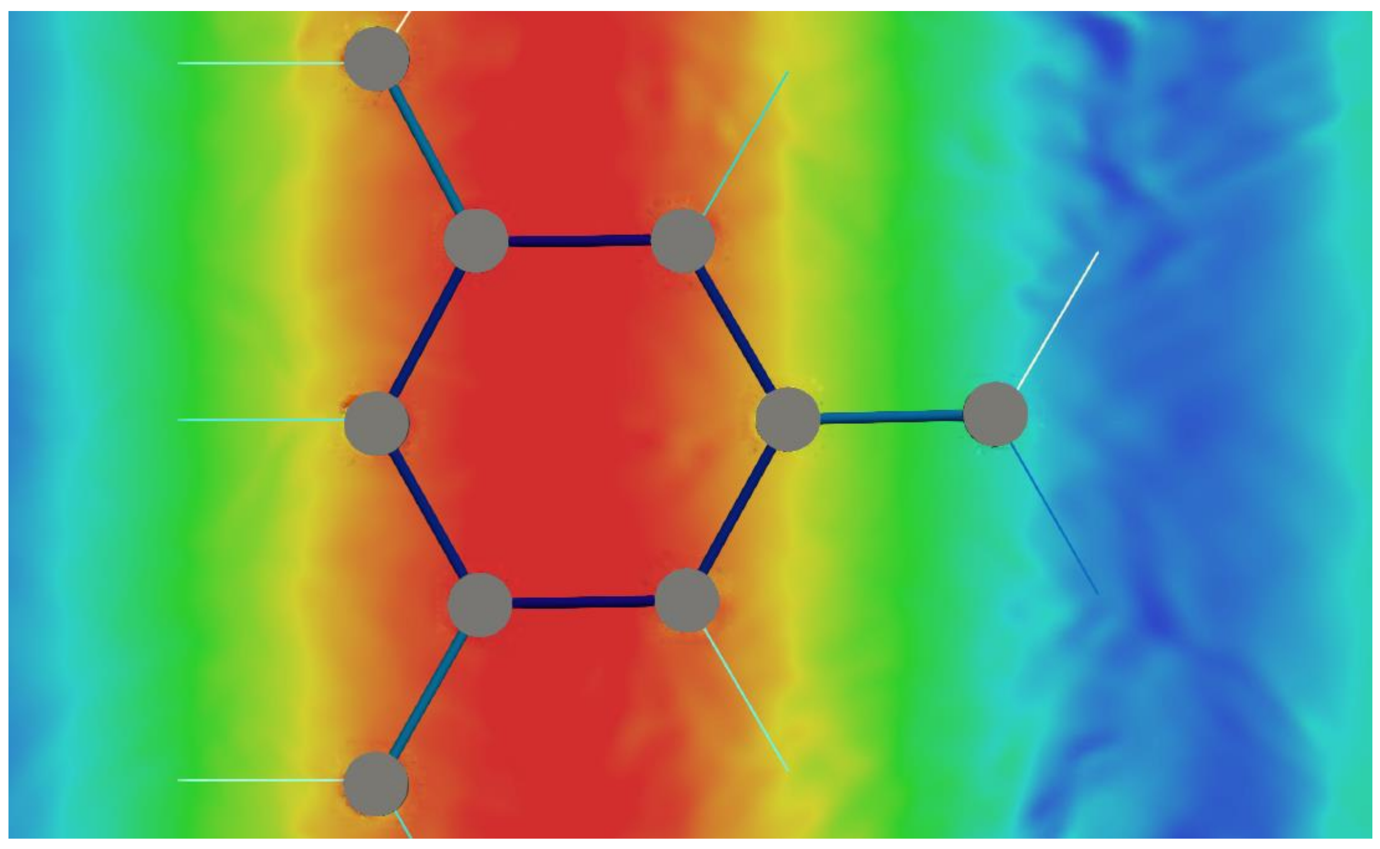


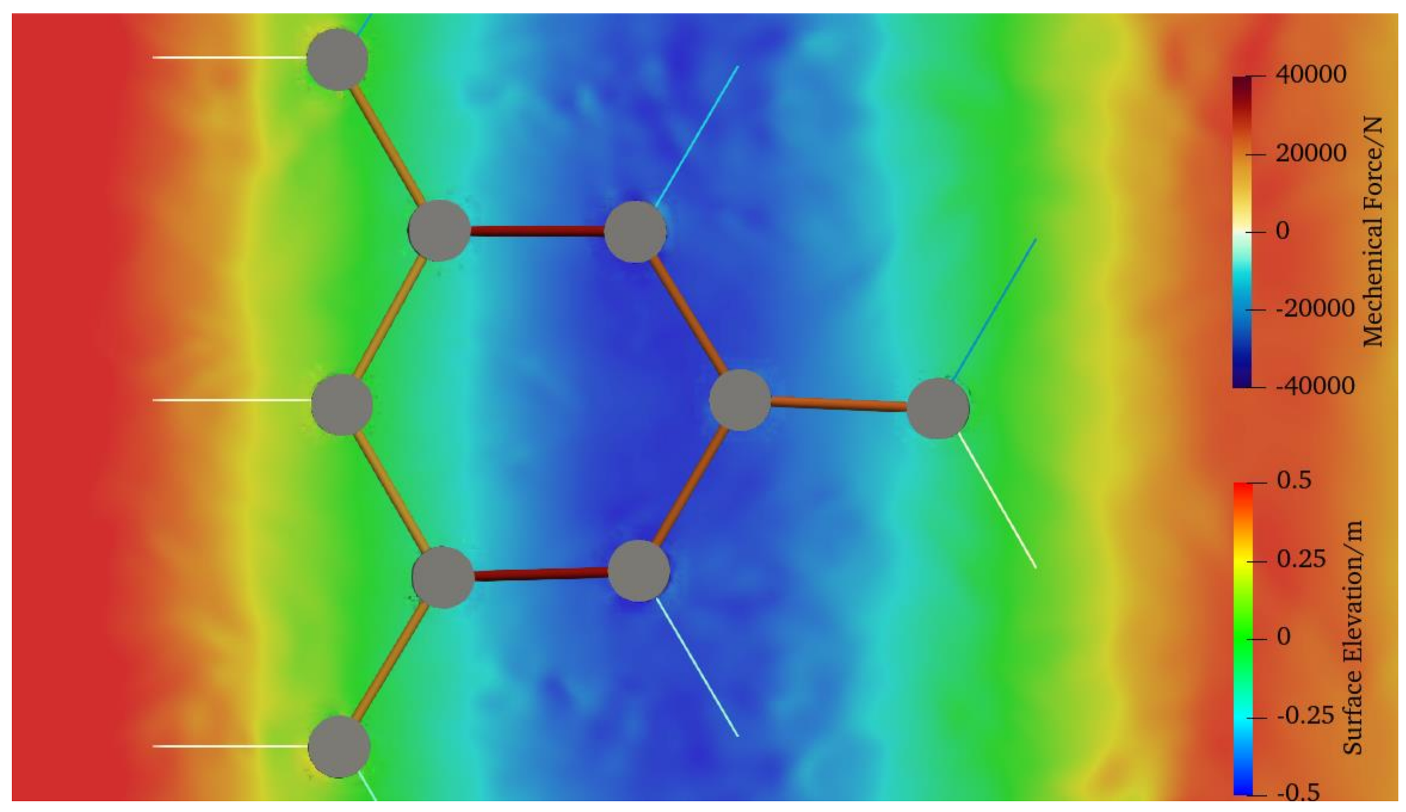
Fig 3. Pitch mode of the central WEC node for (a) T=9.5s and (b) 10.5s

It can be seen from Fig 1. that the net consists of 9 single WEC nodes which are connected with mechanical linking-arms. Moorings are applied at the outer loop to constrain the deformation of the net. The experiment is conducted in FloWave Ocean Energy Research Facility[2]. When waves pass the net, each node rotates around the arms. The degrees of rotation lead to torque at each joint connected to power take-off devices, which are utilized for power conversion. The coupled CFD-MBD tool can simulate dynamic response of each component, as well as the fluid field around them simultaneously.

The water depth is 63m for all cases. The wave height is 1.5m for Fig 2. and Fig.3 and 1.0m for Fig.4. Fig 2 shows that the motion of each component has influence on other parts in this system. The pitch motion of the central node can be seen in Fig. 3, which shows good agreement with the experimental results. The pitch mode has the same period as the incident waves. When decreasing the wave period from 10.5s to 9.5s, the pitch amplitude increased, because the wave frequency gets closer to the natural frequency of the node structure.



(a)) *t*=86s



(b)) *t*=92s

Fig 4. Free surface-elevation (blue for wave trough, red for wave crest) and mechanical force on each linking-arms (blue for tension, red for compression) when T=9.5s

Seen form Fig 4., the arms are under tension when wave crest is passing, and compression for wave trough, meaning that the mechanical force is significantly affected by wave elevation. They are coupled with each other. It can also noticed that with linking arms and moorings, the net is constrained well without collision between them, although slightly deformation of the net can be noticed. The maximum power take-off for the case in Fig.2 is approximately 7.1kW in our simulation.

It can be concluded that the coupled tool can fully analyze the complex mechanical interaction in a system in hydrodynamic environment.

[1] McDonald, A., Xiao, Q., Forehand, D. and Findlay, D., 2017. Experimental Investigation of Array Effects for a Mechanically Coupled WEC Array. In Proceedings of the Twelfth European Wave and Tidal Energy Conference (pp. 929-1).

[2] Jasak, H., Jemcov, A. and Tukovic, Z., 2007, September. OpenFOAM: A C++ library for complex physics simulations. In International workshop on coupled methods in numerical dynamics (Vol. 1000, pp. 1-20). IUC Dubrovnik Croatia.

Results were obtained using Cirrus High Performance Computer (https://www.cirrus.ac.uk/).