Simulation of the wave evolution and power capture of an oscillating wave surge converter

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ABSTRACT

For oscillating wave surge converters (OWSC) the incident wave field is changed due to the movement of the flap structure. A key component influencing this motion response is the Power Take-Off (PTO) system used. This paper examines the relationship between incident waves and the perturbed fluid field near the flap using the Computational Fluid Dynamics method by using Reynolds Averaged Navier-Stokes (RANS) equations. Further, it investigates the influence of a PTO system in the energy extracted from regular waves. Whilst this wave evolution is not significant in the effective power captured by a unit device, it is of great importance when performing in arrays as neighbouring devices may influence each other.

KEY WORDS: wave energy; power take-off; oscillating wave surge converters; power capture; wave pattern; Computational Fluid Dynamics; OpenFOAM.

INTRODUCTION

The Oscillating Wave Surge Converter (OWSC) is one of the most promising operating devices that use Wave Energy Conversion (WEC) technology in terms of its energy absorption capabilities and hydrodynamic performance (Babarit 2015). This device consists of a surface-piercing buoyant flap rotating around a hinge fixed to the sea bottom. The pitching motion of the WEC device combined with a hydraulic Power Take-Off (PTO), which connects the flap to its base, captures the energy from nearshore ocean surface waves (Cameron et al. 2010).

The OWSC operates usually at intermediate water depth where the energy is extracted from the surge motion of the waves (Dhanak and Xiros 2016). Under the action of these incident waves the flap oscillates back and forth (see Fig. 1). This oscillatory motion is dominated by the diffraction and the radiation effects of the incident wave acting on the device. Whilst the first is related to the solid body as an obstacle encountered by the fluid flow, the latter is identified with the oscillatory motion of the flap and consequent generation of secondary wave fields. Both effects will depend on the size of the flap and its oscillation (Henry et al. 2010).

In conjunction with the Queen’s University Belfast (QUB), Aquamarine Power (AP) developed and deployed the full-scale prototype of an OWSC called Oyster at the EMEC (European Marine Energy Centre) site in Orkney. During and after the designing stage of the Oyster, QUB in cooperation with AP, undertook extensive experimental and numerical studies. These studies focused mainly on understanding the hydrodynamic response of the OWSC in different wave environments as well as in increasing its performance.

Initial experimental studies regarding the response of a flap-type surface-piercing WEC to waves are reported in (Folley, Whittaker, and Henry 2007; Schmitt and Elsaesser 2015). These were early estimations of the power output and performance of the energy device under the action of small amplitude regular waves. Further two-dimensional experimental studies for OWSC were undertaken in order to understand the wave slamming phenomenon when the device operates in extreme sea conditions (Henry et al. 2014, 2015).

Using experimental models to understand the hydrodynamic performance of OWSC is generally demanding in terms of cost and time. To complement these experimental tests, numerical models are a viable alternative to estimate the performance of wave energy converters in the early stages of design. Various approaches of numerical modelling have been implemented to understand the hydrodynamic performance of OWSC with incident wave fields. These approaches include using the method based on potential flow theory (Renzi and Dias 2013; Renzi et al. 2014), smoothed particle hydrodynamics (SPH) method (Rafiee, Elsaesser, and Dias 2013; Brito et al. 2020), and the Computational Fluid Dynamics (CFD) method based on Reynolds averaged Navier-Stokes (RANS).

Among these methods, the CFD approach has been widely used, as it can account for more non-linear effects than the potential flow approach, whilst is much cheaper than experiments (Huang et al. 2019). Studies of the hydrodynamic response of OWSC to ocean waves have been carried...