Numerical Study of Wave Interaction with a Modular Oscillating Wave Surge Converter

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ABSTRACT
Wave Energy Converters (WECs) are a new class of offshore structures, which aim at collecting energy from the waves in highly energetic locations for approximately 25 years. The design of these machines therefore requires improving the knowledge on wave-structure interaction, as well as the wave loads exerted on such devices under extreme sea states. In this study, we focus on a modular Oscillating Wave Surge Converter (OWSC), which is an alternative to Oyster, the OWSC developed by Aquamarine Power Ltd. Oyster consists of a wide buoyant flap, located in 10 to 15 meters water depth, which pierces the free surface and oscillates back and forth under the action of incoming waves. The dynamics of Oyster and wave impacts on this device have been studied over the past few years and a new concept, where several thinner modules replace the unique wide flap, has been introduced recently. 3D numerical simulations based on a finite volume Navier-Stokes flow solver are performed to study the response of the modules depending on the wave excitation. The free surface is captured thanks to a Volume of Fluid method and the motion of the solid bodies is modelled through an Immersed Boundary Method. The oscillation pattern of the modules appear to depend on the wave period, as well as the spacing. The dynamics of the modular flap in comparison with a unique flap and the interactions between the different modules depending on wave characteristics, as well as geometrical parameters are investigated.

KEY WORDS: Oscillating Wave Surge Converter; wave impact; fluid-structure interaction; numerical simulation; Volume of Fluid; Immersed Boundary Method.

INTRODUCTION - MODULAR OSCILLATING WAVE SURGE CONVERTER
Bottom-hinged Wave Energy Converters (WECs) have been introduced over recent years and have been shown to capture efficiently the power contained in the waves (Folley et al. (2007); Whittaker and Folley (2012)). Oscillating Wave Surge Converters (OWSCs) are large buoyant flaps, hinged at the seabed and which oscillate back and forth under the action of incoming waves with taking advantage of the horizontal motion of water particles, which is amplified in intermediate and shallow water. To convert the mechanical energy into electricity, these oscillations are generally used to pump high pressure water on shore in order to drive a hydro-electric plant. OWSCs are a new class of offshore structures and their design therefore requires some fundamental understanding in order to optimize their performance on one hand, but also to ensure these devices will survive both fatigue and extreme loading during their 25 year design life.

One such OWSC has been developed by Aquamarine Power Ltd. and is called Oyster (Folley et al. (2007); Whittaker and Folley (2012); Renzi et al. (2014)). The dynamics of Oyster-like OWSCs have been investigated in previous studies (Henry et al. (2014a,b); Rafiee et al. (2013)) and understanding its behaviour under extreme sea state, during which the device is likely to endure strong loads is gaining more and more attention. Indeed, with highly energetic waves, the flap oscillates back and forth with a high angular velocity and the flap tends to slam into the next incident wave (Henry et al. (2014a,b, 2015)), thereby leading to strong loads on the structure. In addition, the power capture is directly linked to the rotation of the flap, which is induced by the horizontal force of the waves. Reducing the loads acting on the foundation while maintaining a good performance of the device is challenging.

In order to achieve such a target and to operate bottom-hinged WECs more easily, a modular Oscillating Wave Surge Converter has been introduced as an alternative to a single flap (Wilkinson et al. (2014)). It was shown that loading can be reduced, particularly the yaw loads acting on the device, while the rotation was not significantly different from a rigid flap, thereby suggesting that the performance would be of the same order. Sarkar et al. (2016) solved the linearized equations of motion of the modules and different Power Take Off strategies were investigated. It was shown that the performance of the modular OWSC was close to that of a single flap and additional resonance peaks were observed on the angular motion of the modules, thereby enhancing the performance of the WEC under certain wave conditions. However, neither non-linear effects, nor viscous effects were considered.

Direct numerical simulations offer the ability to improve the knowledge acquired with the experimental investigation and various methods have been used to simulate such flows. Early works of Rafiee and Dias (2012); Rafiee et al. (2013); Henry et al. (2014b) investigated the wave interaction with an OWSC with the Smoothed Particle Hydrodynamics method. Such methods appear to be well suited for such flows where a wide variety of spatial scales are involved (from wave lengths of a few meters