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Effects of mooring systems on the performance of a wave activated body energy converter

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ABSTRACT

Aim of this paper is to analyse the power and hydraulic performance of a floating Wave Energy Converter with the purpose at optimising its design for installation in arrays. The paper presents new experiments carried out in 1:30 scale on a single device of the Wave Activated Body type in the deep-water wave tank at Aalborg University. Power production and wave transmission were examined by changing the mooring system, the wave attack and the device orientation with respect to the incoming waves.. To assure the best performance the device size may be "tuned" based on the local peak wave length and the mooring system should be selected to allow the device for large movements.

1. Introduction

For optimising power capture, Wave Energy Converters (WECs) must operate at or near resonance. Therefore moorings of WECs should allow for large motions of the structure, in order to serve their primary function, but also comply with many other requirements [1], for example interact with the body dynamic in order to increase the overall efficiency. So far there is very limited research dedicated to verify to which extent the mooring arrangements are influencing the hydrodynamic loading on the structure, as well as the power extraction capabilities [2].

Floating WECs (f-WECs), specifically suited to severe wave conditions, reduce by absorption the incident wave energy and may thus be used not only for energy production but also for coastal protection purposes. Also the research devoted to the changes of the wave field around f-WECs is fairly limited. A detailed experimental study on a single f-WEC, a model of the Wave Dragon (www.wavedragon.net), was performed by Nørgaard and Pulsen, [3]. However, the knowledge gained from floating breakwaters (FB) can provide a substantial contribution to define the wave transmission coefficient K_T for f-WECs. For FBs, K_T is often given as a function of peak wave period T_p and significant wave height H_s, the FB geometrical and dynamic properties (mass, added mass, damping factor, natural period of oscillation) and finally of the characteristics of the mooring system [4,5]. K_T is usually related to l/L_p, being L_p the peak wave length and l the FB length parallel to the incident wave direction. The larger the incident wave length L_p relatively to l, the larger the K_T [6]. It is therefore expected that a sufficiently long f-WEC may be effective in reducing wave transmission.

Aim of this contribution is to examine both the power production and hydraulic performance of a given f-WEC, i.e. DEXA device (www.dexawave.com), depending on the mooring system. DEXA is an f-WEC that belongs to the Wave Activated Body (WAB) type, where the energy production is based on the relative movement of separate parts.

Preliminary tests showed that for high values of the wave steepness DEXA is very effective [7], and therefore may produce energy also when the sea conditions are not extreme, such as in case of strong winds in short fetches.

In order to assess if DEXA is suitable solution for installation in a multi-purpose wave farm, the specific objective of this paper is to analyse how the device efficiency η and the transmission coefficient K_T vary with mooring type, wave height, wave steepness and orientation of the device with respect to incoming waves.

Section 2 describes the tests, including the facility, the device geometry, the mooring system, the tested regular and irregular wave conditions and the performed measurements. Section 3 specifically addresses the process adopted for optimising the

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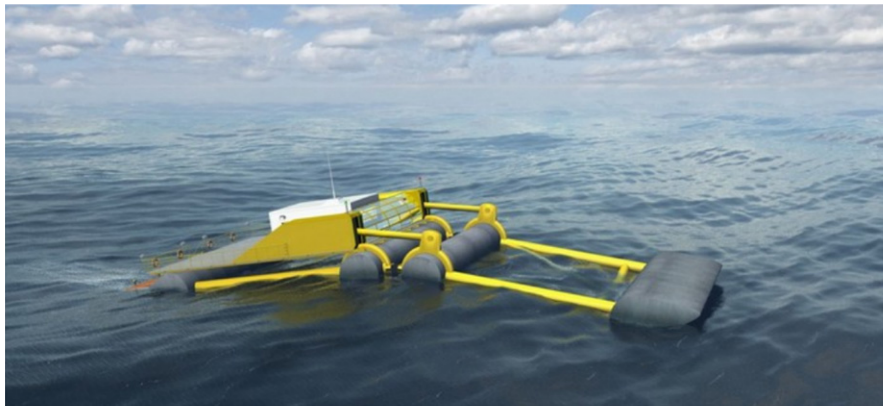

Fig. 1. 3D rendering image showing a single DEXA device full scale (from www.dexawave.com).

rigidity of the Power Take-Off (PTO) system in order to maximise power production and device efficiency. Section 4 describes the wave field around the device in terms of wave transmission, wave reflection, wave radiation and changes of wave direction induced by the device. The design and performance of such installation based on the joint analysis of the dependence of η and K_T on l/L_p are also discussed. Some conclusions are finally drawn in Section 5.

2. Description of the tests

2.1. The facility

The hydrodynamic tests were performed in the deep-water directional wave basin of the Hydraulics and Coastal Engineering Laboratory at Aalborg University, DK. The basin is 15.7 m long (waves direction), 8.5 m wide and 1.5 m deep. The wave generator is a snake-front piston type composed of 10 actuators with maximum stroke length of 0.5 m, enabling generation of short-crested waves. The software used for controlling the paddle system is AwaSys developed by the same laboratory [8]. Regular and irregular long and short crested waves with peak periods up to approximately 2.5 s, oblique 2D and 3D waves can be generated with good results.

Passive wave absorption is carried out. A 1:4 dissipative beach made of concrete and gravel with average diameter $D_{50} = 5$ cm is placed opposite to the wave maker. The sidewalls are made of crates (1.21 × 1.21 m, 0.70 m deep).

2.2. The device

The DEXA device consists of two rigid pontoons with a hinge in between, which allows each pontoon to pivot in relation to the other (Fig. 1). The draft is such that at rest the free water surface passes in correspondence of the axis of the four buoyant cylinders. The Power Take-Off (PTO) system consists of a low pressure power transmission technology based on water ("Aquagear") and is placed close to the centre of the system, in order to maximise the stabilisation force [7].

In the laboratory, one DEXA model (Fig. 2) was adopted in scale 1:30. The model is 2.10 m long cross-shore and 0.81 m wide long-shore, and totally weighs 33 kg, the weight of the PTO system being about 10 kg.

The device brings on board a PTO system (Fig. 3) that consists of a metal bar with an elongate-shaped hole, a wire welded at the two ends of the hole and a small electric engine with a wheel. The bar is connected to one half of the device and the wheel to the other, via a load cell (strain gauge equipped "bone"). The wire is rolled up around the wheel that is forced to rotate while translating along the bar hole. The rigidity of the PTO was modified by varying the resistance of the wheel to rotation and therefore the current in the engine. It was possible to set up to 17 rigidities.

Two mooring systems were tested (Fig. 4). One is the up-scaled reproduction of the "spread type" [1]. It consists of four steel chains which are fixed to the bottom with heavy anchors and are linked to the device at the fairlead point in the middle of the legs by

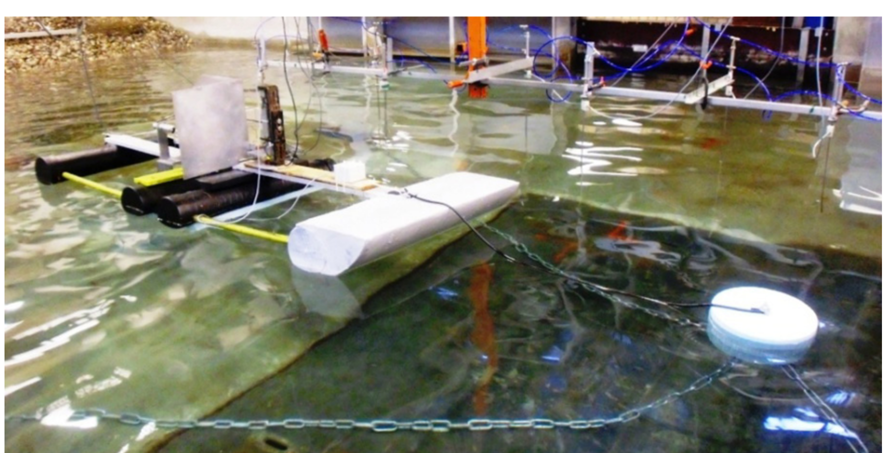

Fig. 2. Picture of the DEXA model, 1:30 scale, in the deep water wave basin, Aalborg, DK. CALM mooring system.