DEVELOPMENT OF A POINT ABSORBER WAVE ENERGY CONVERTER FOR INVESTIGATION OF WAKE EFFECTS IN LARGE SCALE EXPERIMENTS

VASILIKI STRATIGAKI [(1)], PETER TROCH [(2)], MARC VANTORRE [(3)] & MATT FOLLEY [(4)]

[(1)] *PhD Researcher, Ghent University,*
Technologiepark 904, Zwijnaarde, B-9052, Belgium. E-mail: Vasiliki.Stratigaki@UGent.be

[(2)] *Professor, Ghent University,*
Technologiepark 904, Zwijnaarde, B-9052, Belgium. E-mail: Peter.Troch@UGent.be

[(3)] *Professor, Ghent University,*
Technologiepark 904, Zwijnaarde, B-9052, Belgium. E-mail: Marc.Vantorre@UGent.be

[(4)] *Senior Research Fellow, Queen's University Belfast,*
School of Planning, Architecture & Civil Engineering, Belfast BT9 5AG, Northern Ireland, UK. E-mail: M.Folley@qub.ac.uk

1. Introduction

The shrinking reserves of fossil fuels in combination with the increasing energy demand have enhanced the interest in sustainable and renewable energy sources, including wave energy. In order to extract a considerable amount of wave power, large numbers of Wave Energy Converters (abbreviated as WECs) will have to be arranged in arrays or farms using a particular geometrical layout. The operational behaviour of a single device may have a positive or negative effect on the power absorption of the neighbouring WECs in the farm (so-called near-field effects). As a result of the interaction between the WECs within a farm, the overall power absorption is affected. Finally, the wave height behind a large farm of WECs is modified which may influence neighbouring farms, other users in the sea or even the coastline (so-called far-field effects).

Several numerical studies on large WEC arrays have already been performed (e.g. Troch et al., 2010; Child, 2011; Borgarino et al., 2012), but large scale experimental studies on near-field and far-field wake effects of large WEC arrays are not available in literature. Within the HYDRALAB IV European programme, the research project WECwakes (Stratigaki et al., 2011; 2012) has been introduced to perform experiments on large arrays of point absorbers for different layout configurations and inter-WEC spacings. The aim is to validate and further develop the applied numerical methods (Folley et al., 2012), as well as to optimize the geometrical layout of WEC arrays for real applications. A scale model of such a point absorber WEC has been developed and optimized experimentally (Fig. 1). The model has been constructed in the workshop of Ghent University. Its geometry, construction and operational behaviour is simple, allowing the production of the model in large numbers for experiments on large scale in the Shallow Water Wave Basin of DHI, in Denmark.

Figure 1. The developed generic point absorber WEC during experiments in: the wave flume of Ghent University, Belgium (left); the wave basin of Queen's University Belfast, Northern Ireland, UK (right).

2. Characteristics of the scale model

A generic point absorber (buoy) has been developed with a total height of 61 cm, a hemispherical bottom and a cylindrical PVC prefabricated upper part (Fig. 1). The buoy's draft is 31.5 cm, equal to its diameter, with a total mass of 20.545 kg. The WEC has only one degree of freedom: it is restricted to heave motion along a vertical, square, hollow stainless steel axis that is anchored in a concrete square cement base. The axis passes through a slightly larger shaft bearing inside the device, which continues over the total height of the buoy to avoid water infiltration. The square form of the axis hinders rotation. The movement of the buoy in the horizontal plane, due to the margin between axis and shaft bearing, is prevented by two PTFE bearings at the top and bottom of the buoy, chosen for the low friction coefficient on steel. The power take-off (abbreviated as PTO) is simulated by a mechanical brake, through which the extracted energy is lost by friction. The PTO consists of 4 springs, exerting a normal force on two PTFE-blocks on top of the buoy, which are pressed against the axis.

3. Developing the point absorber WEC model

For the preparation of the large scale experiments in the wave basin at DHI, tests have been performed in the wave flume of Ghent University (Fig. 1, left) and the wave basin of Queen's University Belfast (Fig. 1, right). The model is being tested under the action of regular and irregular long- and short-crested waves, for four different test cases: without the presence of the buoy; with the buoy as fixed obstacle; with the buoy but no damping applied through the PTO; and with the buoy and damping applied through the PTO.

The model is being tested for representative wave conditions of several European Countries (e.g. Belgium, France, Germany, Portugal, Denmark, The Netherlands).

3.1 Experiments in the 2-D wave flume of Ghent University, Belgium

The first series of experiments has been carried out in the large wave flume of the laboratory at Ghent University, which has a width of 1.0 m and a water depth of 0.7 m. Those experiments aim at the structural testing of the model (rigidity of vertical axis, base stability for different installation techniques, internal friction issues, etc.) and the optimization of the measuring techniques for the vertical motion of buoy (using camera, potentiometer or LVDT), as well as for the horizontal motion of the vertical axis of the WEC (using a camera).

The horizontal movement of the vertical axis of the WEC is limited, indicating a sufficient bending stiffness, with the best results achieved when the base is moored, while the influence of the measuring techniques used for the buoy motion has been determined. In this experimental setup, the reflection from the sidewalls does not allow investigation of the buoy motion and the water surface elevations, as the buoy diameter is large compared to the width of the wave flume.

3.2 Experiments in the 3-D wave basin of Queen's University Belfast, Northern Ireland, UK

The same series of tests has been performed in the wave basin of Queen's University Belfast, which is 15 m wide and 17 m long, with a water depth of 0.61 m. The experiments in the wave basin aim at the tuning of the PTO-system for the wave conditions of the large scale experiments in DHI, concentrating on optimum power absorption. Moreover, the influence of the WEC model on the wave field and its vertical motion have been investigated, which were not possible in the wave flume. Measurements of the vertical motion of the buoy using a potentiometer and of the water surface elevation using a network of resistive wave gauges have been taken.

During the tests in the wave basin, the repeatability of the (un)damped buoy motion has been confirmed, indicating the effectiveness of the developed PTO-system. Optimum power absorption has been achieved.

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