The Characteristics of Wave Impacts on an Oscillating Wave Surge Converter

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ABSTRACT

Wave impacts on an Oscillating Wave Surge Converter are examined using experimental and numerical methods. The mechanics of the impact event are identified experimentally with the use of images recorded with a high speed camera. It is shown that it is the device which impacts the wave rather than a breaking wave impacting the device. Numerical simulations using two different approaches are used to further understand the issue. Good agreement is shown between numerical simulations and experimental measurements at 25th scale.

KEY WORDS: Wave Energy Converter; Oyster; OWSC; Wave Impact; Slam; Computational Fluid Dynamics; Smoothed Particle Hydrodynamics

INTRODUCTION

Oscillating Wave Surge Converters (OWSCs) are a class of Wave energy Converter (WEC) which are designed to absorb energy contained in the horizontal motion of water within ocean waves (Whittaker 2012). They are typically sited in the intermediate water depths of the nearshore region in order to take advantage of the amplification of horizontal water particle motion due to shoaling effects (Folley 2007).

Aquamarine Power Ltd is the developer of one such OWSC called Oyster (Whittaker 2007; Henry 2010). Oyster consists of a buoyant flap which is hinged at the seabed and pierces the water surface. The flap is arranged to have its principle axis normal to the dominant wave direction. Wave action forces the flap to pitch back and forth and this mechanical energy is used to pump water ashore where it drives a Pelton turbine and electrical generator.

Oyster has undergone extensive wave tank testing at Queen’s University Belfast and experimental data is used to predict power output and to define load cases for use in design. The load case can divided into two distinct areas; the fatigue load cases which define the operating loads over the lifetime of the device and the extreme load cases which define the maximum loads expected, generally occurring in severe but infrequent conditions defined by their return period (Doherty 2011). Quasi-static or pulsating wave loads are measured with a 6 axis load cell during experimental testing of Oyster in extreme sea conditions to define the extreme load case. However, in these extreme sea tests it was observed that there was an occasional impulsive component on the load time history. This short duration but high magnitude load was found to coincide with a wave impact event.

It is important to characterize the impact as it affects the design of the local flap skin, which must withstand the impact pressure, and the global structure, which will transmit the impulse load to the foundations. The key variables which must be defined are the pressure magnitude, duration (rise and fall time) and spatial distribution.

The characteristics of wave impacts on various maritime structures have been studied for many years, mainly in response to failures at sea such as the damage to the bow of the Schiehallion FPSO investigated by Voogt and Buchner (2004) and Xu and Barltrop (2005). The wave impact problem is apparent in static coastal structures (Goda 1985) such as vertical walls and rubble mound breakwaters (Cuomo 2011) and in dynamic bodies such as ships which are subject to impact such as bottom, deck and bow slam (Mizoguchi 1996). In more recent times the impacts of waves on the walls of the internal chambers of Liquid Natural Gas (LNG) carriers has received particular attention (Braeunig 2009; Lafeber 2012). While design codes do exist to deal with wave impact in these established industries research is still on going to fully understand the problem.

As there is currently a lack of empirical load data for WECs, knowledge and guidance must be drawn from other industries, but the characteristics of WECs present a greater challenge in determining appropriate loads for their design. A wave energy converter is designed to actively interact with, and therefore disturb, the wave field and its motion responses would generally be considered large. For example, a WEC such as Oyster will be designed so that the pitch motion of its flap is maximised in order to efficiently absorb power, conversely, a ship may be designed so that pitch and roll motions are reduced to...