ABSTRACT

In this paper, the results of a study on the effects of geometry control on the performance of overtopping wave energy converters with a simple geometry built in coastal structures (simple OWECs) are presented. Empirical formulae, derived based on experimental tests on simple OWECs with varying geometry, are applied to a number of test cases. It appears that adapting the slope angle and crest freeboard of a simple OWEC to the sea states at a specific nearshore location, can result in significant increases in obtained hydraulic power.

KEY WORDS: overtopping; wave energy converter; optimal geometry; slope angle; crest freeboard; geometry control.

INTRODUCTION

The energy contained by ocean waves is a highly potential source of renewable energy. A wide variety of devices which are able to extract energy from ocean waves exists, Waveplam (2009), with development stages ranging from idea to prototype at sea. One of the device categories is the type of overtopping wave energy converters (abbreviated OWECs). Its working principle is based on waves running up a slope and overtopping into a reservoir, which is emptied into the ocean through a set of low-head turbines, Kofoed (2002).

OWECs built in coastal structures tend to be more economically viable than offshore floating OWECs, Graw (1996). Although offshore floating OWECs are located in more energetic waves, the installation and maintenance costs are comparatively high. In consequence of the rising global water level, the crest level of many coastal structures needs to be increased. This intervention brings along the opportunity to install OWECs into coastal structures with shared costs. Maintenance costs are also lower for OWECs built in coastal structures due to increased accessibility.

The geometric characteristics of the slope profile of an OWEC require very particular attention as these characteristics affect the performance of the OWEC to a large extent. Over the past five years, extensive research has been carried out with regard to a specific OWEC: the Seawave Slot-Cone Generator (abbreviated SSG), Margheritini et al. (2009), which is primarily designed to be deployed in breakwaters. The SSG consists of three reservoirs – one on top of the other – allowing the overtopped water to be collected on different levels for a broad range of waves: larger waves fill up all three reservoirs, while smaller waves overtop into the lowest reservoir. Empirical formulae are available, Kofoed (2002) and Margheritini et al. (2009), to determine the fixed “optimal” slope angles of the fronts of the reservoirs and the fixed “optimal” vertical and horizontal distances between the three reservoirs, based on the maximization of the overall hydraulic efficiency. The overall hydraulic efficiency \( \eta_{\text{hydr,overall}} \) is defined as the sum of the hydraulic efficiencies \( \eta_{\text{hydr,j}} \) for all sea states at the deployment site multiplied with their probability of occurrence \( FO_j \), Eq. 1.

\[
\eta_{\text{hydr}} = \sum_{j=1}^{n} \frac{P_{\text{hydr,j}}}{P_{\text{wave,j}}} = \sum_{j=1}^{n} \frac{\rho g q R FO_j}{64 \pi \frac{H_{\text{w,j}}^2}{T_{\text{w,j}}}}
\]

The hydraulic efficiency of an OWEC for a specific sea state, characterized by a significant wave height \( H_{\text{w,j}} \) and energy wave period \( T_{\text{w,j}} \), is defined as the proportion of the hydraulic power (proportional to the potential energy of the water overtopping the crest of the OWEC) to the wave power for that sea state, Eq. 1 ( \( \rho \) stands for the water density, \( g \) is the acceleration of gravity, \( R \) is the crest freeboard and \( q \) is the average overtopping rate). The deep water definition is applied for the wave power.

An “optimal” geometry determined by maximum overall hydraulic efficiency does not ensure a maximum hydraulic efficiency for each individual characteristic sea state. A maximum individual (for each sea state) hydraulic efficiency requires an optimization of the geometry for each sea state, involving the application of geometry control during operation of the OWEC. An optimal geometry is obtained for a specific sea state when the corresponding product \( q_i R_{w,i} \) is maximal, Eq. 1. An index \( i \) is added to the crest freeboard to emphasize that when applying geometry control, also the crest freeboard can be adapted to each sea state.

The question rises if introducing geometry control significantly increases the overall hydraulic efficiency of an OWEC at a specific location compared to the fixed “optimal” geometry. It is clear that when a location is dominated by one sea state, geometry control will not be effective. 

Optimization of Overtopping Wave Energy Converters by Geometry Control

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