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Numerical Modelling of OWC-Shoreline Devices Including the Effect of Surrounding Coastline and Non-flat Bottom

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ABSTRACT

The purpose of this paper is to investigate the applicability of a 3D radiation-diffraction boundary element code based in the linear wave theory to shoreline bottom-standing OWC wave power plants, taking into account the bathymetry and topography of the site. The Azores European Pilot plant on the Island of Pico is used as a test case. Results to be presented include the effect of the bathymetry and topography on the performance of the Pico plant, the comparison with laboratory results, and the influence of the accuracy in the evaluation of the radiation impulse function on the overall performance of the Pico plant.

INTRODUCTION

The European Pilot Plant on the Island of Pico, in the Azores, is an OWC device consisting mainly of a bottom-standing concrete structure located in a natural convergent channel between the rocky coastline and a small islet.

The structure forms a pneumatic chamber at its upper part (above water level) whose interior dimensions are 12 x 12 m^2 at mean water level. An opening on the submerged part of the front wall enables the entrance of water into the chamber, and by the effect of incident waves the water free surface inside the chamber is forced to oscillate (oscillating water column), inducing an up-and-down air displacement. The chamber is connected to the atmosphere by an air duct containing a reversible air turbine of the Wells type coupled to an electric generator. The alternating air flow exiting the interior chamber drives the turbine. A detailed description can be found in Falcão et al. (1995).

The design of this power plant, in particular the selection of the geometry of the structure, was based on experimental work with a scale model in an irregular wave tank. The model included the plant's structure in acrylic glass, the surrounding coastal area (in appropriate material) in an extension of about 120 m and the bathymetry of the bottom, up to about 12 m in depth. The description of these experimental tests is in Sarmento (1993), Joyce et al. (1993) and Holmes et al. (1995).

The measurements from the tests were used for developing a wave-to-wire mathematical model for simulating the performance of the plant. The hydrodynamic part of the model is based on the linear theory of surface waves (Sarmento and Brito-Melo, 1993). This model takes into account the effects of the shoreline and bathymetry, but is limited to the tested geometry of the Azores Power Plant. In order to develop a model capable of optimising and simulating the performance of shoreline OWC devices without requiring experimental work, one has to turn to numerical modelling where the effects of coastline or non-flat bottom could be taken into account.

A numerical boundary element code using a panel method has been recently applied for the modelling of wave energy devices of the oscillating water column (OWC) type in the frequency domain (Brito-Melo et al., 1999). This work consisted in an extension of an existing computational code, AQUADYN, developed at the Laboratoire de Mécanique des Fluides, Ecole Centrale de Nantes, for the study of floating bodies' hydrodynamics in a fluid of infinite or constant finite depth (Delhommeau, 1987).

The adaptation to OWC devices required, basically, a modification on the water free surface dynamic boundary condition to account for the effect of an oscillatory pressure over the internal water free surface (Brito-Melo et al., 1999). This modification has been implemented and the extended version—AQUADYN-OWC—has been well validated with internal consistency tests and published results for isolated plants in flat-bottom oceans.

The aim of the present paper is the application of this numerical code to the Azores Power Plant, including the modelling of the natural gully where the device is installed and of the ocean bottom in its vicinity. Numerical results will be presented showing the influence of bathymetry and topography of the surrounding coast in the hydrodynamic coefficients, transfer functions and impulse response functions (time-domain). A comparison with experimental results obtained from transient tests performed with a 1:35 scale model will be presented, as well as an analysis of the impact of inaccuracies in the estimation of the radiation impulse response function on the device's overall performance.

HYDRODYMAMIC FORMULATION

Decomposition of Problem

We consider a 3D OWC bottom-standing device (see Fig. 1 for a 2D scheme). We take a Cartesian coordinate system with x, y horizontal, and z positive upwards, as the origin on the mean free surface.

We consider the fluid domain to be bounded by the following:

- the seabed, at $z = -h(x, y)$
- the body and surrounding coastline surface, S_b
- the water free surface in the interior of the chamber, S_i

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KEY WORDS: Oscillating water column, hydrodynamic coefficients, frequency domain, wave-energy, boundary-element method.