

Performance of Wells Turbines for Use in Small-Scale Oscillating Water Columns

David G. Dorrell¹ and Min-Fu Hsieh²

¹Dept. Electronics and Electrical Engineering, University of Glasgow
 Glasgow, UK

²Department of Systems and Naval Mechatronic Engineering, National Cheng Kung University
 Tainan, TAIWAN, China

ABSTRACT

This paper will assess the viability of small Wells turbines for oscillating water columns. The paper reports on a complete assessment of the integration of the system. It begins with a study using computational fluid dynamic analysis of a small double stage turbine. The analysis is carried though to assess performance under reciprocating airflow conditions. Experimental data will be put forward from the mounting of a turbine on a small-scale oscillating water column. The turbine will be connected to a DC machine to act as the generator for the system. While the system is simply a demonstrator, information about the column dynamics and turbine sizing is obtained.

KEY WORDS: Oscillating Water Column, Wells Turbine, Computational Fluid Dynamics, Wave Energy

INTRODUCTION

Background

There is now a proliferation of different wave energy devices that are under investigation. These were briefly reviewed by Halliday and Dorrell, 2004 and further explored by Dorrell and Hsieh, 2007. They can be broken down into five basic technology groups (Clement *et al*, 2002): oscillating water columns (OWC); overtopping devices; point absorbers (floating or mounted on the sea bed); surging devices; and mechanical extraction.

This paper is concerned with the oscillating water column (OWC) in conjunction with a Wells turbine. This is a very straightforward device and one that has been tried by several research groups and countries (including the UK, Japan, Portugal, Norway, and several others). An example is illustrated in Fig. 1 and it consists of two basic components: the chamber and the turbine. Waves flow on to the front of the chamber so that the water level inside oscillates with a height and phase difference with respect to the wave fronts. This pressurises and depressurises the column so that air moves in and out of the chamber via a bidirectional turbine. Dorrell and Hsieh, 2007 tested a Savonius rotor turbine whereas here we will test a Wells turbine. Both of these turbines are illustrated in Fig. 1.

In most OWCs the turbine is a Wells type; these have pear-shaped

blades that have the same rotation whatever the airflow direction is. They can have reasonable conversion rates provided the flow coefficient (inlet air velocity/turbine blade tip-speed) is low – about 0.1 (Watterson and Raghunathan, 1996). This gives a high Reynolds number and means that they must be of a reasonably large radius. Torque from the turbine pulsates at twice wave frequency due to the oscillating nature of the device; the power delivery can be smoothed by allowing the turbine speed to vary over a cycle so that kinetic energy is stored in the turbine/generator inertia as the speed increases and then converted to electrical energy as it slows. The Limpet OWC on The Isle of Islay, UK (see Wavegen Ltd. website in references) uses a cage induction generator via a controlled rectifier (to magnetize the generator), DC link and inverter, and this is a common arrangement for this device.

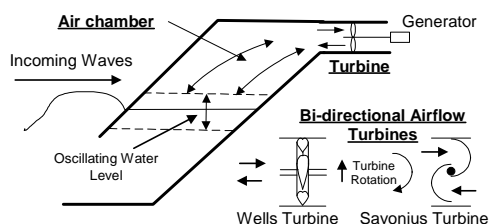


Fig. 1. Oscillating water column arrangement with oncoming waves

OWCs are suitable for use on shoreline locations as well as near-shore locations. The wave resource is often low or of poor quality when the sea shallows (Tucker and Pitt, 2001). Indeed, some locations will have very poor quality waves and the wave fronts will be of limited length and also may not be oncoming on to the front of the column. One way round this is to use a segmented OWC as shown in Fig. 2 (Dorrell and Hsieh, 2007). This could represent a system designed for a harbour wall where the wave fronts travel across the front of the column rather than oncoming into the column front face. For effective operation the width of each section needs to be somewhat less than the wave length. This requires either separate turbines for each section or a cascaded turbine structure (the figure shows three sections and three series-connected Savonius rotors). This decouples the internal oscillating water height in each other and to some extent will aid the smoothing of the power delivery to the turbine generator if sections are oscillating in different phases. The effect of oncoming waves which are not parallel with the