ABSTRACT

The analysis of floating oscillating water column (OWC) wave energy conversion (WEC) devices involves the coupled dynamics of the water column and the floating structure. In the present study, a mechanical oscillator model was used to examine this relationship for the heave motion of a floating wave energy conversion device. Optimal power take-off damping of the system was determined and the effects on maximum power capture examined. The influence of relative OWC and floating structure natural frequencies on OWC WEC device optimisation was also investigated.

KEY WORDS: Oscillating water column; wave energy converter; power take-off; floating structure; power capture.

INTRODUCTION

Oscillating water column (OWC) wave energy conversion devices consist of a partially submerged chamber open to wave forces at the base (see Fig. 1). The wave forces cause the water column within the chamber to rise and fall, driving the air in and out (inhalation and exhalation) of the chamber typically through a Wells or variable pitch type air turbine. An electrical generator is then utilised to convert the oscillatory airflow established into electrical energy. The pneumatic gearing provided by the air coupling allows the conversion of low frequency wave power into high frequency electrical power.

Oscillating water column type wave energy conversion devices can be located near-shore as a fixed structure or offshore in a floating moored-structure configuration. Much analytical, numerical and experimental work has been undertaken on fixed (e.g. Morris-Thomas & Irvin, 2007) and floating (e.g. Chudley, Mrina, Ming & Johnson (2002)) oscillating water column wave energy conversion. A number of concepts have been demonstrated at scale prototype including the Limpet (Boake, Whittaker, Folley & Ellen 2002), Oceanlinx’s near-shore OWC (Gray, 2007) and the Pico plant (Brito-Melo, Neuman & Sarmento, 2008).

The analysis of floating oscillating water column wave energy conversion devices involves the coupled dynamics of the water column and the floating structure. Mechanical oscillator models have seen considerable use in the study of wave energy converters including oscillating water column wave energy devices (Falnes & McIver, 1985; Thiruvenkatasamy, Neelamani & Sato, 1998). This simplified approach, which does not analyse the full hydrodynamic complexity of the situation, provides clear indication of device performance trends and is particularly useful in the preliminary design and model testing development phases. It can provide a more general description of the system behaviour compared to complex numerical approaches, allowing for greater ease in determining optimal performance.

Adoption of mechanical oscillator modelling to fixed OWC WEC devices for example has provided valuable information regarding optimal power capture and power take-off damping conditions (Mei, 1976). The optimum operating state for a fixed OWC is, predictably, the condition where the oscillating water column natural frequency (dependent primarily on the effective length of the water column) is set at the incident wave frequency. Under this resonant condition, the optimum power take-off damping is theoretically equal to the OWC radiation damping (i.e. $\dot{x} = b$). In practice, when resonant conditions cannot be attained (or the wave energy is spread across a range of frequencies), a larger power take-off damping is optimal to broaden the region over which significant power capture is achieved.

The aim of the present study was to analytically investigate the maximum power capture of a floating oscillating water column wave energy conversion device in heave through a mechanical oscillator