Modelling and Design of an Oscillating Wave Energy Converter

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Introduction

• The SWEC born in 1980’s
• Estimate of 25 kW/m along South Africa’s West coast 700 km long
• Other WEC’s and claimed conversion efficiencies:
  ➢ Archemides Wave Swing - 50% (Fiaz and Salari, 2011)
  ➢ Oscillating surge converter – 60% (Folley, 2004)
  ➢ OWC, Limpet – 60% (Wittaker et al., 2004)
  ➢ Over-topping device – 18% (Tedd, 2007)
  ➢ Pelamis – 70% (Yemm et al., 2011)
The SWEC

Submerged SWEC ‘V’ (adapted from Retief et al., 1982)
The SWEC

SWEC during crest of the wave  (Bavesh, 2006)
The SWEC

SWEC during trough of the wave (Bavesh, 2006)
Problem Statement

Past studies have not been able to accurately model the SWEC:

- Not able to produce accurate results for high frequency wave inputs
- An unaccounted-for loss variable has often been added
Objectives

• Extensive experimental testing:
  ➢ Use results to verify simulation models
  ➢ Make conclusions on the viability of the SWEC as a WEC and the affect of orientation angle

• Produce two verified simulation models:
  ➢ Surface SWEC
  ➢ Submerged SWEC
  ➢ Use models to optimise chamber design
Methodology

• Scale model of a single SWEC chamber
• Measurement apparatus:
  ➢ Orifice flow meter – 5 different plate sizes
  ➢ Wave probes
• Test two configurations in Civil engineering wave flume
• Develop simulation models for two configurations
• Verify simulation models
• Optimise chamber
• Draw conclusions
Experimental testing

CAD drawing of model.

Photo of experimental setup
Surface SWEC configuration

Schematic of Surface SWEC configuration
Submerged SWEC configuration

Schematic of Submerged SWEC configuration
Experimental testing

\[ P_{\text{converted}}(t) = \dot{V}(t) \times \Delta p(t) \]  

(Zhang et al., 2012)

\[ P_{\text{wave}} = \frac{\rho g H^2}{8} C_g \]  

(McCormick, 1981)

\[ \eta = \frac{P_{\text{converted}}}{P_{\text{wave}}} \]
Mathematical modelling

**Mathematical model**
- Linear wave theory
- Trapped air cavity theory
- Newton’s second law
- Ideal gas law
- Isentropic relationship
- Head loss equation
- Energy equation for pipe flow

**Inputs**
- Wave height
- Wave period
- Temperature
- Loss factors
- Model dimensions
- Water height
- Atmospheric pressure

**Outputs**
- Chamber pressure
- Auxiliary pressure
- Chamber surface level
- Power
- Mass flow rate
Results – Surface SWEC

Inner chamber surface level: $z$

H: 0.06m
T: 2.5s
Results – Surface SWEC

Pressure difference between chambers

- Measured
- Simulated

Delta P (pa)

Time (s)

H: 0.06m
T: 2.5s
Results – Surface SWEC

Efficiency - 0.25% Plate

$n$ (%) vs $T$ (s)

- Measured - $H:0.06$
- Simulated - $H:0.06$
Results – Surface SWEC

Efficiency - 0.5% Plate

- Measured - H:0.06
- Simulated - H:0.06
Results – Submerged SWEC

Efficiency - 0.5% Plate

- Measured - H:0.09
- Simulated - H:0.09
Results – Submerged SWEC

Efficiencies - 1% Plate

- Measured - H:0.09
- Simulated - H:0.09
Results – Submerged SWEC

Various orientations - H: 0.09 - 0.5% Plate

- Orientation 1
- Orientation 2
- Orientation 3
- Orientation 4
- Orientation 5
Conclusions

• Experimental results show maximum conversion efficiency of 15% and 13% at operating conditions

• Reaching up to 17% orientation 2 not at operating conditions

• Both models predict conversion efficiency with +- 2% average error

• Optimisation still to be carried out
Thanks