Multi-axis PAWEC[1] behaviour and their operation in arrays

D Richardson, Dr G A Aggidis

SUPERGEN MARINE III

Introduction

Why incur substantial mooring costs to restrain a wave energy device and then not receive any energy payback from it? A reciprocal force resisted only by the mooring system is a wasted opportunity for capturing energy.

There are of course very good reasons why most current wave energy converters do not exploit all the forces acting on them: namely cost and risk. A multi-axis system is necessarily more sophisticated and therefore more expensive and riskier than an equivalent system of fewer axes. Accurate predictions from modelling are also more difficult to obtain, driving up the risk further. However, as multi-axis point absorbers offer the opportunity for greater energy capture it is prudent to examine their potential and feasibility.

Therefore this research sets out to identify if multi-axis point absorbers offer a way forward to higher kWh/m^{2}seabed and lower wave energy costs. It will mainly focus on the hydrodynamic characteristics of such devices while recognising that the multi-axis PTO system is also hugely important for the success of these devices.

This work, carried out as part of the SuperGen UKCMER project, builds on that of earlier work carried out at Lancaster University as part of SuperGen Marine Phase II [1] and also from earlier investigations into multi-axis point absorbers [2].

Multi-axis Movement

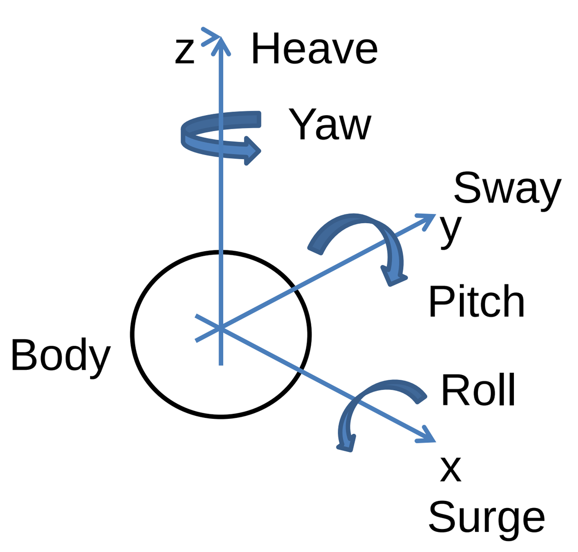


Figure 1: Degrees of freedom

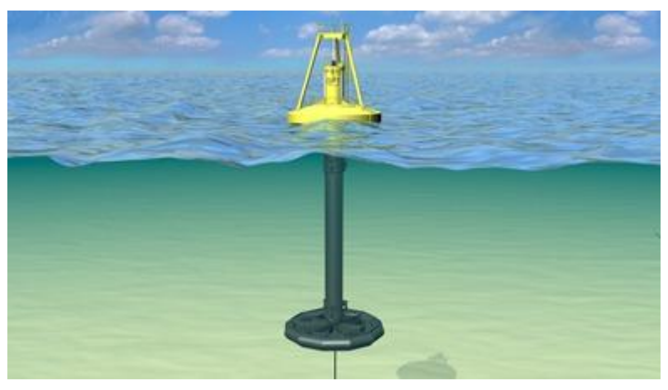


Figure 2: OPT's PowerBouy, an example of a heave only point absorber [3]

Applying a Cartesian coordinate system (Figure 1) to a floating wave energy converter defines 6 degrees of freedom in which the body can move. These are the three translational and three rotational modes, denoted surge, sway, heave, roll, pitch and yaw.

The majority of point absorbers extract energy only with the heave response (Figure 2). A PAWEC can be considered multi-axis (a MA-PAWEC) if it extracts energy from more than one degree of freedom e.g. Heave and surge (note: degrees of freedom are not limited to Cartesian axes, the axes can be defined arbitrarily).

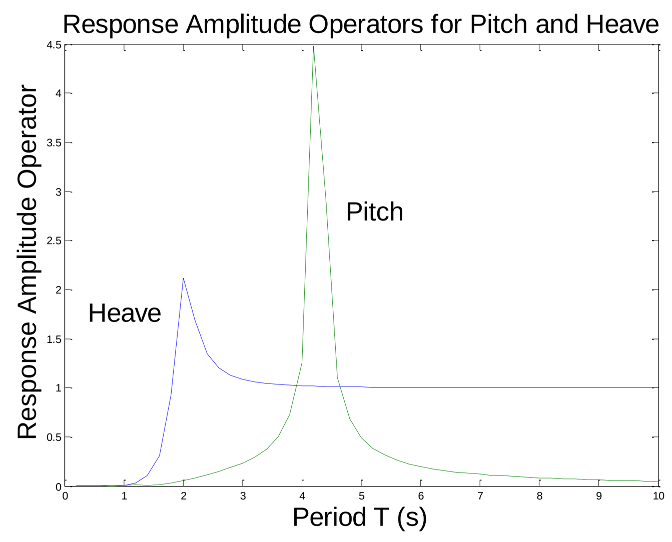
Hydrodynamic Optimisation

For this work the calculations to determine the hydrodynamic response of any given geometry in order to optimise the design is carried out in the software package WAMIT. WAMIT is a BEM (Boundary Element Method) code and uses panel methods to describe the geometry based on either a flat quadrilateral mesh or B-splines.

Existing work has already proven that under optimum conditions MA-PAWECs can absorb more energy than those operating under a single mode. In reality, PTO systems cannot maintain optimal conditions over a wide range of frequencies. This leads to a more irregular power output with the associated costs.

One of the most significant advantages of multi-axis PTO is its ability to exploit multiple resonant frequencies to reduce this irregularity. Figure 3 (above-right) shows the response amplitude operators (RAOs) for a simple geometry (cylinder). The RAOs show the resonant peaks clearly.

Figure 3



The two modes displayed are pitch and heave, and so are uncoupled. What is clearly visible is the difference in resonant frequency for each mode. Thus the system as a whole has a wider bandwidth and is better able to deal with wide spectrum seas.

Whether this is sufficient to justify the additional cost is not clear as the cost functions for the additional PTO system are not yet defined. This will be the subject of further work to put multi-axis in a commercial context.

Extending to Variable Geometry

The same numerical approach has been applied to more complex geometry. Figures 5 and 6 show examples of what it is possible to model using the B-spline representation. The B-splines are defined by their 'control points' (knots). Each control point then becomes a geometric parameter that can be altered to try and adjust a hydrodynamic characteristic. For any arbitrarily complex device there is such a large number of control points needed to describe the surface that it becomes unfeasible to linearly optimise for each parameter. Instead, a solution space is defined in which a genetic algorithm searches to optimise the desired conditions.

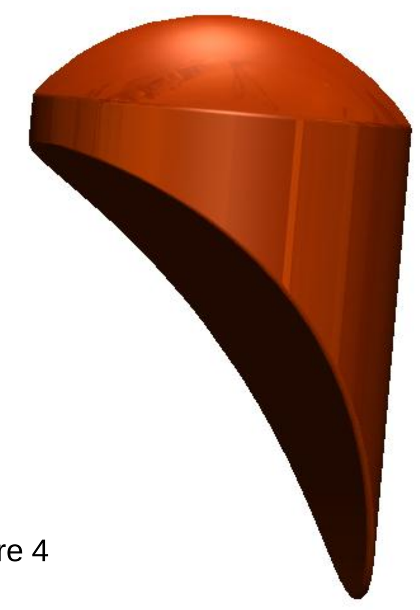


Figure 4

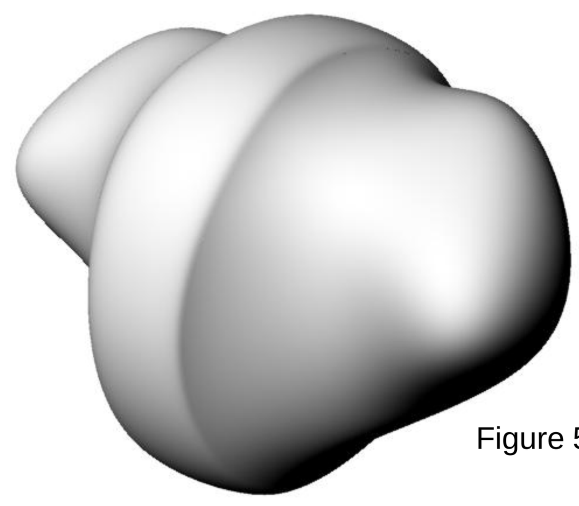


Figure 5

MA-PAWECS will rarely operate in isolation and the design process should account for this. The same optimisation technique can be applied to an array to optimise the geometry for the behaviour of an array. This may lead to different designs depending on the location within the array.

Figure 6

Conclusion

Based on the limited modelling so far and previous work carried out in this area, multi-axis devices do offer significant advantages over single mode operation when considering the hydrodynamic energy absorption characteristics. This research should provide more certainty on this in the future for both single devices and crucially, for arrays.

References

1.A.P. McCabe, G.A. Aggidis, M.B. Widden, Optimizing the shape of a surge-and-pitch wave energy collector using a genetic algorithm, Renewable Energy, Volume 35, Issue 12, December 2010, Pages 2767-2775

2.Pizer DJ (1993) Maximum wave-power absorption of point absorbers under motion constraints. Appl Oean Res 15:227-234

3.http://www.forbes.com/forbes/2012/0227/technology-ocean-energy-searay-columbia-power-next-wave_2.html

Notes:

1.PAWEC=Point Absorber Wave Energy Converter