

## Summary Report of CA-OE Training Exchange

**Participant:** John Fitzgerald, Chalmers University of Technology, Gothenburg Sweden

**Host Institution:** Hydraulics and Maritime Research Centre, Cork, Ireland

**Period:** June 27<sup>th</sup> – August 4<sup>th</sup>, 2006  
and continued from:  
August 21<sup>st</sup> – September 1<sup>st</sup>, 2006-09-11

Total exchange of 8 weeks.

### **The Participant:**

The participant is enrolled as a PhD student at Chalmers University of Technology. The subject of his research is to address mooring concerns as applied to ocean wave energy, in terms of their influence on the performance of wave energy converters as well as overall survivability.

The training under this exchange can be summarised under 2 headings:

Part I: Mooring design Case Study, using data for the Galway Bay Test Site

Part II: Free surface hydrodynamics and a frequency domain model of a wave energy device with internally reacting masses.

### **Part I: Mooring design Case Study, using data for the Galway Bay Test Site**

Chalmers has a considerable knowledge base on the analysis of mooring systems, including access to software capable of analysing mooring cables, both statically and dynamically. Combining this knowledge with the amount of experimental data available at the HMRC, as well as contacts with commercial wave energy developers, provided a basis for a useful training activity in the practical design of wave energy mooring systems.

The work concluded in the successful specification of a mooring cable, for a given wave energy converter, suitable for a research deployment at the Galway bay test site.

The analysis followed DNV OS E301 (POSMOOR) guidelines where applicable and the analysis considered the following aspects, among others:

- Environmental Conditions (at the Galway Bay Site):
  - Wind
  - Current
  - Tidal (depth) variationsAnd adverse extreme combinations of the above

Useful data was available for the Galway bay test site, including modelled and measured results for wave heights and directionality.

- Environmental Loads:
  - Steady Loads
    - Wind
    - Current

- Wave drift loads
- Slowly Varying Loads
  - Wind Gust Response
  - Slowly varying drift loads
- Wave Frequency Loads
  - Extreme Waves possible at the site and the motion response amplitude to waves at the mooring attachment points
- Resonant Conditions
- Redundancy
  - Loads on remaining equipment following the accidental failure of a single line.
  - Device excursion following the failure of a single line (collision avoidance).

Experimental data from scaled tank tests were available from the HMRC for a wave energy device and were used to predict the device's motion response to the environmental loads. Mooring loads can then be predicted from motions, either quasi-statically or using fully dynamic line models, as appropriate.

- Mooring Configuration:
  - Individual Line configuration
    - Chain / Cable / Synthetic combinations
    - Addition of Clump-weights and Floats
    - Line weight
    - Line stiffness
  - Anchor Pattern
    - Number of Lines
    - Symmetry of pattern
    - Orientation of moored device relative to predominant environmental loads
- Mooring Costs
  - Procurement
    - Commercial availability and cost of mooring equipment
  - In service costs
    - Deployment: Overall line weight and the cost of the required handling equipment
    - Maintenance: Lifing and required service intervals.
- Performance
  - Resistive loads induced by wave induced motions can result in energy losses to the ocean and so should be minimised.
  - Reactive loads induced by wave induced motions can alter resonant behaviour of the device and therefore influence performance in this way.

#### Summary of Findings:

A variety of mooring configurations can be envisaged for wave energy applications, with combinations of floats and weights that induce minimum loads when subject to wave induced motions. However, when analysed statically, most of these require very large components in order to resist the large steadily (not wave) applied loads associated with storm events, rendering such equipment both expensive to procure and difficult to deploy in the ocean. Overall, the most satisfactory arrangements for this case study came from more conventional catenary chain cables, combined with some additional synthetic rope and floaters to improve performance and compliance considerations.

The survivability problem then became the design of a mooring that is as light and cheap as possible, capable of reacting the maximum possible steady environmental loads, while having a compliance such that additional wave induced motions do not induce prohibitive loads. Dynamic considerations are also important, both in determining that the mooring does not introduce load inducing resonances in horizontal modes, or in influencing the predicted performance of motion dependent devices.

A number of novel design approaches were identified and it proved to be a valuable co-ordination exercise. Overall, the task of optimising mooring designs is complex and there are considerable economic compromises to be made. While on one hand, non-conventional designs might be seen to improve the performance output (and therefore financial turnover) of a device, they can also add to the uncertainty in survivability, the cost of procuring equipment and to the deployment costs of the mooring system.

## **Part II: Free surface hydrodynamics and a frequency domain model of a wave energy device with internally reacting masses.**

Here, use was made of numerical hydrodynamic modelling expertise and software at the HMRC, combined with analytical frequency domain modelling knowledge at Chalmers.

A 3D geometry was selected and parameterised. 9 versions of the external geometry were analysed in the numerical code WAMIT, where the added mass and damping, as well as wave excitation forces were calculated within the frequency range of interest. Inertial properties and hydrostatics were also calculated. The equation of motion of the device was derived analytically and solved in the frequency domain to assess the device's performance.

Parameters other than the external geometry were introduced to the analytical mode, for example to assess the effect of mass distribution between structural mass and the active internally reacting mass. Also, the properties of the (assumed linear) spring-dampers of the internally reacting mass power take-off were varied.

This study is on-going since the initial co-ordination period and it is hoped to demonstrate that the configuration is theoretically capable of producing power effectively, either with rigid internal reacting mass or with an internal fluid reservoir providing the reacting mass.