Co-ordination Action on Ocean Energy (CA-OE)

WP1: Modelling of Ocean Energy Systems {Conclusion of WorkPackage}

Tedd, James; Frigaard, Peter

Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

Co-ordination Action on Ocean Energy (CA-OE)

WP1: Modelling of Ocean Energy Systems {Conclusion of Work Package}

James Tedd
Peter Frigaard

ISSN 1901-726X
DCE Technical Report No. 38

AALBORG UNIVERSITY
Department of Civil Engineering

Aalborg University
Department of Civil Engineering
Water and Soil

DCE Technical Report No. 38

Co-ordination Action on Ocean Energy (CA-OE)

WP1: Modelling of Ocean Energy Systems {Conclusion of Work Package}

by

James Tedd
Peter Frigaard

Scientific Publications at the Department of Civil Engineering

Technical Reports are published for timely dissemination of research results and scientific work carried out at the Department of Civil Engineering (DCE) at Aalborg University. This medium allows publication of more detailed explanations and results than typically allowed in scientific journals.

Technical Memoranda are produced to enable the preliminary dissemination of scientific work by the personnel of the DCE where such release is deemed to be appropriate. Documents of this kind may be incomplete or temporary versions of papers—or part of continuing work. This should be kept in mind when references are given to publications of this kind.

Contract Reports are produced to report scientific work carried out under contract. Publications of this kind contain confidential matter and are reserved for the sponsors and the DCE. Therefore, Contract Reports are generally not available for public circulation.

Lecture Notes contain material produced by the lecturers at the DCE for educational purposes. This may be scientific notes, lecture books, example problems or manuals for laboratory work, or computer programs developed at the DCE.

Theses are monograms or collections of papers published to report the scientific work carried out at the DCE to obtain a degree as either PhD or Doctor of Technology. The thesis is publicly available after the defence of the degree.

Latest News is published to enable rapid communication of information about scientific work carried out at the DCE. This includes the status of research projects, developments in the laboratories, information about collaborative work and recent research results.

Published 2007 by
Aalborg University
Department of Civil Engineering
Sohngaardsholmsvej 57,
DK-9000 Aalborg, Denmark

Printed in Aalborg at Aalborg University

ISSN 1901-726X
DCE Technical Report No. 38

Introduction

In October 2004, the Co-ordination Action on Ocean Energy (CA-OE) was launched, co-financed by the European Commission, under the Renewable Energy Technologies priority within the 6th Framework programme, contract number 502701, chaired by Kim Nielsen, Rambøll, Denmark. The project involves 41 partners.

In general the public is not aware of the development of ocean energy and its exploitation. There is a need to make a united effort from the developers and research community to present the various principles and results in a coordinated manner with public appeal.
The main objectives of the Co-ordination Action on Ocean Energy are:

- To develop a common knowledge base necessary for coherent research and development policies

- To bring a co-ordinated approach within key areas of ocean energy research and development.

- To provide a forum for the longer term marketing of promising research developments

The partners of this co-ordination action are the leading forces from the academic field of ocean energy and the pioneering SME organisations on the road to commercialisation of ocean energy systems. New academic knowledge, data gathered from sea tests of ocean energy systems, and other experiences can be shared between the partners and disseminated more widely.

From April 4th to 6th 2005 the first workshop of the Co-ordination action was held at Aalborg University, with the title "Modelling of Ocean Energy Systems". Beginning with a reception on the first evening the workshop aimed to foster closer co-operation between the partners in addition to covering the technical topics. This paper provides a summary of the workshop and gives conclusions and recommendations from the work presented.

The plan for the first workshop was to use the first full day for presentations and discussions within the group of partners. This allowed confidentiality. The second full day was scheduled as an open workshop day with access for the developers and researchers from outside the group of partners, allowing dissemination of knowledge to developers from outside the group. Partners in the project were offered the opportunity to give rather short presentations, either the first day or the second day. To facilitate general co-ordination between partners there was plenty of opportunity to speak informally and network during a reception on the first evening, a dinner on the second evening and ample time during breaks in the proceedings.

In total 18 presentations were given during the workshop. Developers of the Ocean Energy devices were asked to speak about their experience from using physical or numerical modelling of their device. Partners working within the area of developing physical or numerical model were offered to speak about their models. Partners dealing with the development of common standards were giving status of their work. All sessions were closed with an open broad discussion in order to spot common problems.

Proceedings from the workshop are available on www.wave-energy.net and CA-OE.ramboll.dk. The first mentioned webpage is for public access whereas the last mentioned webpage is a restricted page for members of the coordinated network, and contains the full text of the papers presented.

Scope and Objective

The basis for predicting real sea production of power is typically based upon results obtained from model testing and numerical models. This is the main focus of the modelling conducted for Ocean Energy. These must be compared to each other to correlate results and improve the accuracy and usability of both physical and numerical models. Where available it is desirable to compare these to experimental data from pilot plant systems.

There are other common uses for modelling within Ocean Energy, these include:

- Resource prediction and mapping – within both Wave and Tidal energy there are many numerical methods used for predicting the resource. For Wave energy these aim to transform the offshore wave climate, which is well understood, to the near shore wave climate, where the seabed topography is more complex and devices may be situated. For Tidal energy a focus is made on the exact sites where higher tidal currents exist.

- Structural and or Force Modelling – Both numerical and physical models are made of the forces within the structures and mooring of Ocean Energy devices.

- Hydrodynamic Modelling – Numerical models are in development to accurately predict and show the detailed behaviour of the Water particles. These are too computationally intensive to be applied at the current state, but are a focus of development.

The objectives of the Workshop are to work towards the objectives in Work Package 1 which are:

1. State of the Art – Each Ocean and Tidal developer partner in the project shall prepare a paper covering their use of modelling. These were presented at the Workshop.

2. Numerical Modelling (Task 1.1) – The task leader shall produce an expert summary assisted by three other academic partners. Within modelling of ocean energy systems there are no standard numerical models and the results derived for the same physical model using different assumptions can be very different. The objective of the first work package is therefore to invite developers of numerical models to develop common standards for boundary conditions being imposed, calibration of numerical models developed, verification techniques for the validation of model outputs and apply these to the comparable results on the systems included in the proposal.

3. Model test data (Task 1.2) – The task leader shall produce an expert summary assisted by two other academic partners. Data from model testing in different scale on the different systems will be collected, analysed against common standards and presented in a comparable format.

In addition to these specific objectives the Workshop aims to further the objectives of the whole coordination action. That is to bring together all players within Ocean energy Science and Technology activities in order to:

- Keep them informed/increase awareness of the latest technological, fiscal and financial developments;
- Share knowledge and research outcomes from the global research activities being pursued;
- Develop best practice and implement common standards in the research and development programmes being pursued; and
- Promote commercialisation of the technology in the medium to long term.

These are harder to measure of course, but are shown in the project by measureables such as the exchange of research personnel between partners.

Conclusions

This report has summarised the findings of the 1st work package of the Co-ordination Action on Ocean Energy, which is considering the modelling of Ocean Energy Systems.
Further work should investigate Modelling Best Practice guidelines, advances in numerical modelling, particularly combining modelling, methods to improve the utilisation of real sea prototype data by numerical modellers and modelling the wave and tidal resource.

Choice of Methods

Modelling of ocean energy systems has a long history. Systems have been modelled since the start of the wave energy development. The modelling has been based on:

- Hydraulic laboratories
- Numerical models
- (Electrical laboratories)
- Open sea / Lake tests in scale 1:10 to 1:4

Many different topics have been modelled. Hydrodynamic forces on structure, movements of the device, mooring systems, fouling, corrosion, stresses in the structure, power take off, influence on grid, etc. Most effort has been put into modelling of hydraulic performance.

Physical Modelling

Within the area of physical modelling two major types of test facilities are available:

- Hydraulic Laboratories
- Real Sea Test Locations.

At the Hydraulic Laboratories testing of the Ocean Energy devices will normally be tested in a length scale 1:50 to 1:20. The main purpose of the testing is normally to quantify the conversion of Ocean Energy (Waves/Current) to Mechanical Energy. Further, the overall performance (Movements/Force etc) is often considered.

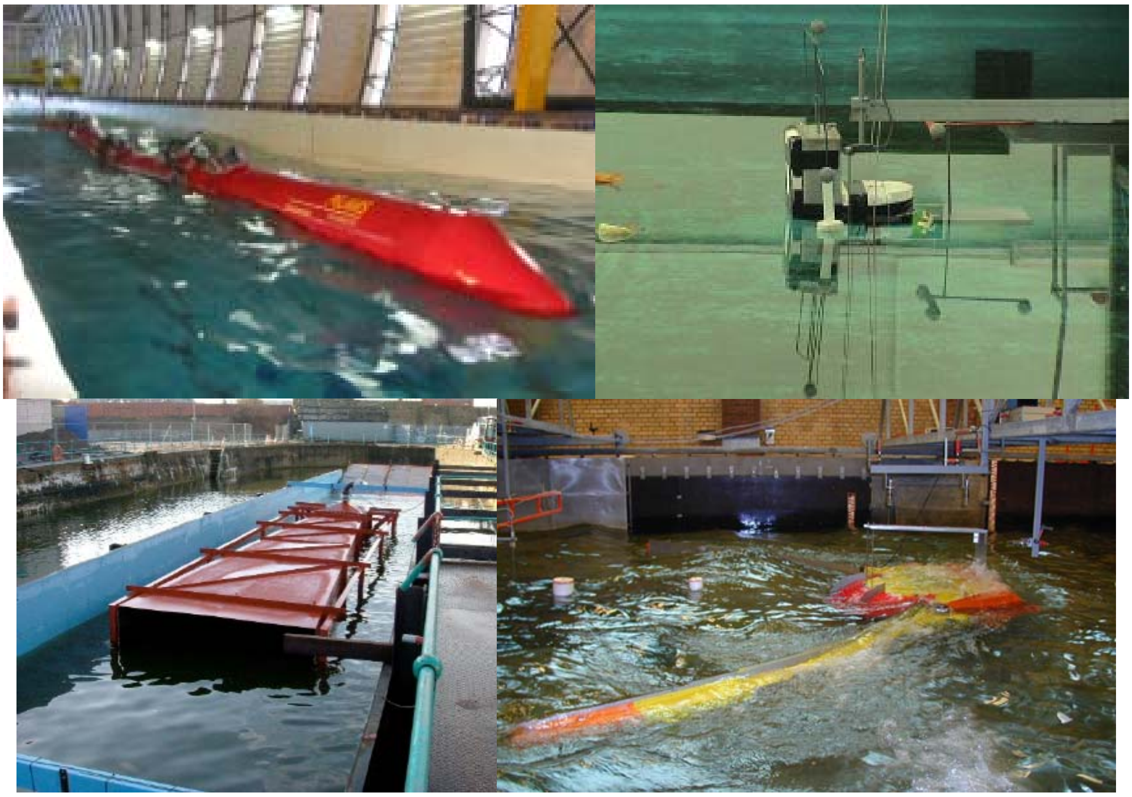

Figure 1, Physical testing, OPD's Pelamis at scale 1:7 at ECN; The OE buoy at scale 1:50 in HMRC Cork; IT Power's OWEL at scale 1:10 in NaREC; The Wave Dragon testing at scale 1:50 in Aalborg University.

Around the world approx. 100 such hydraulics laboratories exist at governmental test institutions, private institutions and universities. Most of these laboratories have a strong background in at least one of: offshore structure, ships or coastal engineering. However, only a few of these have much experience in testing of Ocean Energy systems.

In general, the inventors like to use hydraulics laboratories because in these laboratories their device becomes very visual. Also a physical model has some value in convincing others about the value of the device.

Real test sites have been set-up for Ocean Energy.

- Orkney Test Site,
- Nissum Bredning
- Galway bay

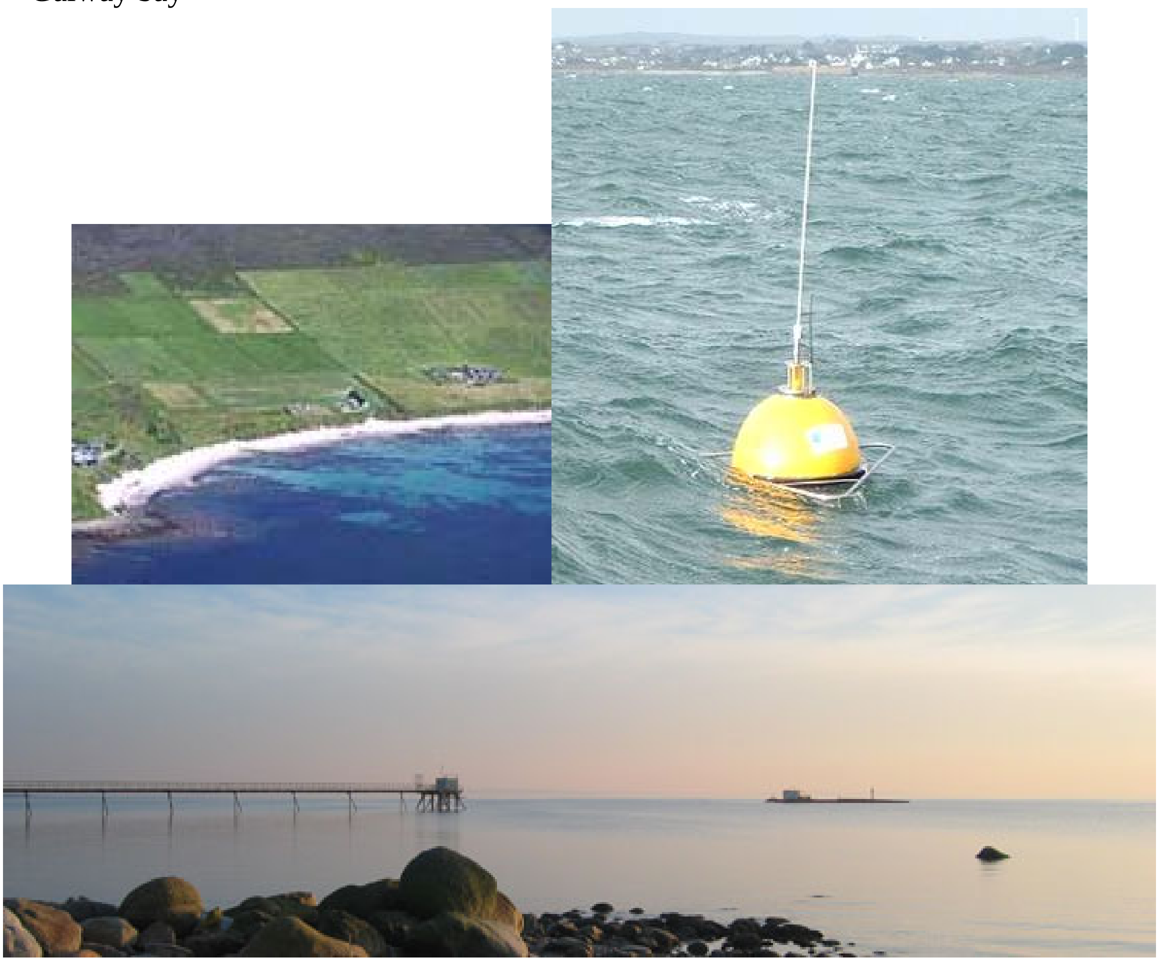

Figure 2, Ocean Energy Test Sites; EMEC tidal site at Orkney, Wave Rider buoy at Galway Bay site; Wave Dragon in Nissum Bredning site;

Some electrical test laboratories exist. Most of these electrical laboratories are connected to universities.

Numerical Modelling

An enormous amount of numerical models being able to predict specific items like movements, overtopping, pressures etc on specific devices exist. The problem is that all these models are not generalised. They will only work for the specific device which they have been developed for.

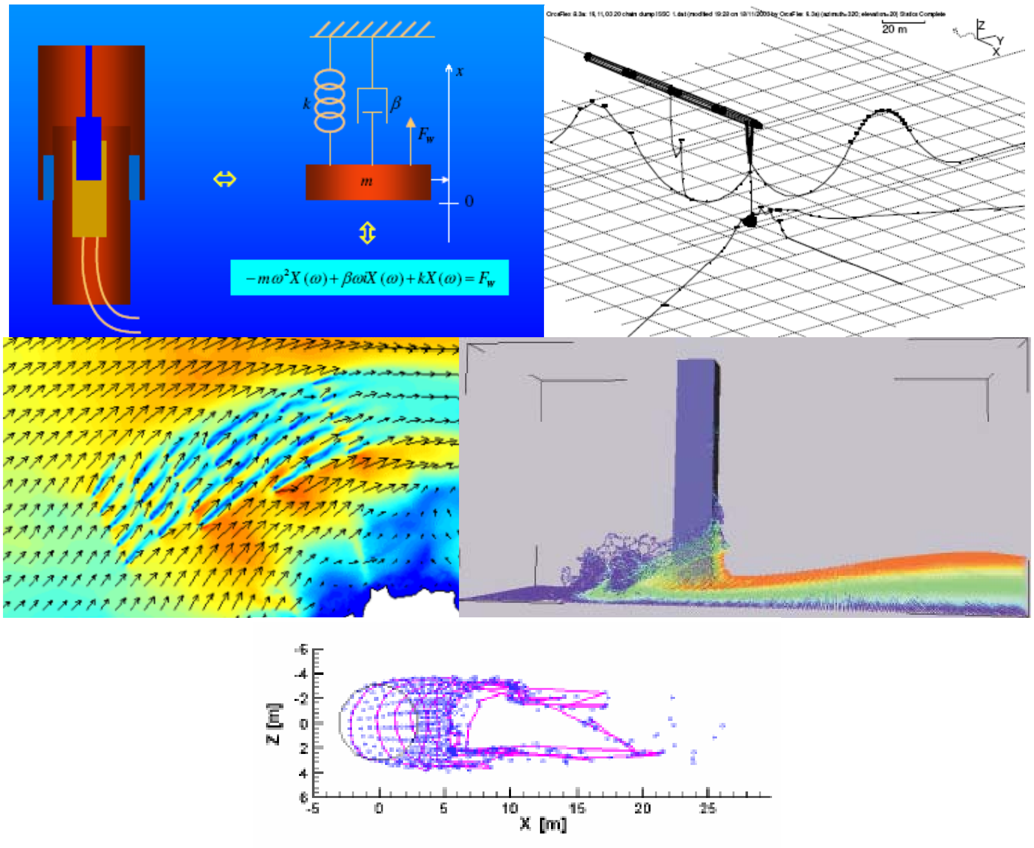

Figure X, Examples of Numerical Modelling, Linearisation used on the AWS; Orcaflex modelling of the mooring of OPD’s Pelamis, Resource modelling by EDF, using Telemac for tidal flows; SPH simulation by ECN of breaking wave; Numerical modelling of Wake of Ponte di Archimide;

During the workshop models within hydrodynamic loading and structural response were presented. BEM, FEM, depth integrated models (Mild slope, Boussinesq), time domain, frequency domain, VOF, CFD etc were buzzwords presented.

Methodology

It is a clear statement from most developers that they have used some kind of modelling of their device during the development phase. Actually, most developers have used all types of modelling. To quote:

> *"Numerical and experimental modelling has been the core of the Pelamis development program since its inception." Ocean Power Delivery*

Most devices have a history which can be schematised into the following phases:

- Tests in a hydraulic laboratory to demonstrate performance
- Numerical modelling of system in order to optimize structure
- Tests in a hydraulic laboratory to verify numerical calculations
- Tests in open sea. Still scale tests
- More calculations for further optimisation

The methodology of the developers and the research conducted by the academic institutions is contained in detail in their papers. This is a summary of the methodology.

Wave Energy Developers

Ocean Energy presented their concept the OE buoy. This showed the testing in 1:50 scale performed at UCC in Ireland. The developer also showed the laboratory testing in 1:15 scale in ECN in France. These tested in regular and irregular Brett-schneider sea states. Scaling is not so easy as it is impossible to scale both Froude and Reynolds at the same time.

Ocean Power Delivery presented their Pelamis device. This showed the extensive numerical modelling which has been conducted, working in 2D and 3D, linear and non-linear, and in the time and frequency domains. In model tests scale models have been used in scale 1:80, 35, 20 and 7. The most instrumented has been the scale 1:20.

Aquaenergy Ltd presented their AquaBUOY device. The presentation focused on the technology and a potential deployment site in the Pacific Northwest. Frequency domain numerical modelling has been conducted on the device. This predicted the upper theoretical power that can be achieved.

Teamwork Technology presented the AWS project. This showed the Quasi-nonlinear frequency domain numerical modelling which has been conducted. This was compared to results gained in October 2004 from the demonstrator project in Portuguese waters.

Inginoer Firm Erik Rossen presented the testing of the Wave Rotor. This showed initial tests in the wave flume at DTU in Denmark. Using this a plan for further testing and modelling was presented.

Wave Dragon has presented the testing which has been conducted on their device in the laboratories at Aalborg University. The Effect of the arms has been compared to that expected from numerical simulations. The Overall forces and power capture measured at the prototype is compared to that expected from the 1:50 scale laboratory model.

Tidal Energy Developers

IT Power described the modelling of the SeaFlow turbine. This has consisted of several stages, Using a BEM method for modelling the power capture; extending this to include the effect of waves; extending again to include the control system and turbulence. This has been confirmed by testing a device in a Scottish loch, and then after a larger unit in the Severn Estuary.

EDF run the La Rance tidal project in France. They produced data from the TeleMac system for the resource off the French coast. They also described some testing of vertical axis turbines.

Chris Day presented his SeaHorse tidal project. This however concentrated mainly on the incentives available in the various EU countries, without describing in too much detail the testing and modelling which has been conducted on the device.
Ponte di Archimedes presented their project in the Messina Strait in Italy. The process of testing and modelling which led to the prototype project was clearly presented. The numerical and mathematical modelling has been compared to the measurements from the prototype.

University Research

The University of Ghent presented a paper evaluating linear theory for analysis of a point absorber buoy. Comparisons were made between numerical tests and a simple laboratory set-up. This showed that non-linearities must be considered early in the process.
ECN showed some of the latest work which is being conducted in numerical modelling. This showed how a breaking wave can be modelled numerically, and how developers can use the technology. They concluded with a series of recommendations.
IST presented the frequency time domain and stochastic modelling which they have been working on. These generic mathematical models can be used for devices as disparate as the tapchan or an OWC.
The University of Edinburgh presented a series of shorter talks on a wide variety of subjects. These varied from a tidal island concept, vertical axis tidal turbines with pitch control, a 360 degree laboratory flow tank, new concepts in digital hydraulics and a desalinisation plant.

Results and Conclusions

Several common threads followed through the discussions which are detailed here:

Who are the drivers: Ocean Energy developers or Numerical Model developers?

The time required to develop even a simple numerical model is generally so long that most developers cannot wait. Therefore the tendency is that the development within numerical modelling is not driven by the existing device developers. The situation is more like the following. A scientist develops a numerical model. He presents the model. The device developer hears about the model. The scientist changes his model to be able to work on the device. There is often some gap at this stage between the numerical modellers and the device developers.

The need for Numerical Modelling

There are short term and longer term needs for development in Numerical modelling.

The tendency has been to model the hydraulics of the devices much more detailed than other topics. This comes from a desire to see the performance of the device in the very early stages. Some other topics such as corrosion, biological, environmental, weather prediction, life time analysis are considered to be more general topics to the wider community than Ocean energy, so expertise from outside can and will be used. There is a lack of modelling of the forces and power take-off systems, which should be addressed in the short term. Although these models may be coarse, they are of great use in the development, to highlight important areas where performance can be increased or cost reduced.

In the long term, numerical models integrating wave forces and power take off system is required. Such a model will necessarily have simpler assumptions in each individual subsystem, but by integrating them the knock-on effects of various parameters may be investigated in better detail. Furthermore models predicting life time of different parts of the devices are missing. These detailed models will be needed when devices come to be certified, giving greater confidence in the performance, and the survivability of the device.

In spite of the broad backing from developers towards numerical modelling, witnessed as most use some form during their development stages, there is some resistance to backing longer term university projects. There is a feeling amongst some developers is that the time required for constructing such a model is too long to wait.

Recommendations for Future Research

Some key areas for further research were identified at the Workshop. These were confirmed at a Modelling group session at the fifth workshop. They are:

Modelling Best Practice

The gradual progression of most device developers as shown in Section 5: starting with small scale physical model testing together with simple numerical simulation, and gradually increasing scale and complexity is very important. Documenting this Best Practice, and encouraging developers to abide by this is should be done. This will prevent device developers from claiming unreasonable, untested results, while allowing them to develop systematically. A first attempt at this is being made by the IEA-OES.

Advances in Numerical Modelling

The short term and long term aspirations for advance in Numerical modelling, shown in Section 6.2 should be furthered. This is as in the short term to develop detailed modelling of forces and power take off systems. In the longer term to develop both integrated models of all the acting subsystems.

Utilising real sea prototype data

As identified in Section 6.1 amongst some of the more advanced device developers and numerical modellers there is a gap. Without useable data from the device prototypes taken during sea testing the numerical models become abstracted from reality. For the device developers, commercial pressures discourage openness with their results. This must be remedied by showing the device developers the applicability of the numerical models.

Resource Modelling

At the moment there are many models which aim to predict wave and tidal flows in the nearshore regions. These are often based on SWAN, boussinesq or finite slope algorithms. Currently the computation times can be very large for even relatively simple bathymetries. Advances in the design of these systems will bring down computation times and improve accuracies. There is also a desire here for increased comparison and calibration from measured data in the real seas.

Benchmarks

In other fields of marine engineering there is considerable use of benchmarks to assess the quality of modelling facilities, or numerical models. For instance in ship design and towing tanks, a simple hull is often set as a benchmark, and tests against this can confirm the quality of measurements on real systems. As the variety of Ocean devices can be quite great, benchmarks could only be made within each family (e.g overtopping wave devices, simple tidal flow rotors, oscillating water columns). A good dataset of these would allow tests to be compared much better across different numerical and physical models.

References

Nielsen, Kim (2005): Coordination Action on Ocean Energy, CA-OE. IEA-OES Newsletter, February 2005. http://www.iea-oceans.org.

Ocean Power Delivery Ltd, Edinburgh, Scotland (2005): The role of numerical and experimental modelling in the development of the Pelamis WEC.

Proceedings of the WS1, available to partners at http://ca-oe.ramboll.dk.

.

ISSN 1901-726X
DCE Technical Report No. 38