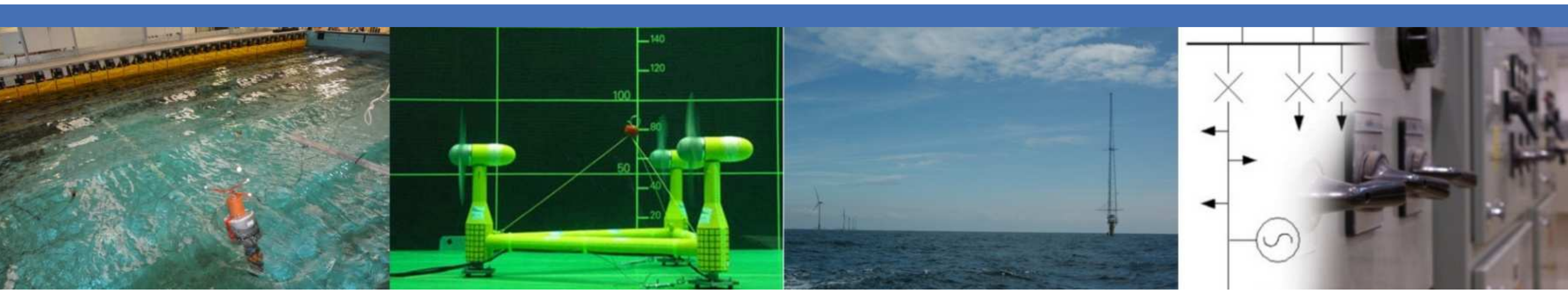
Marine Renewables Infrastructure Network



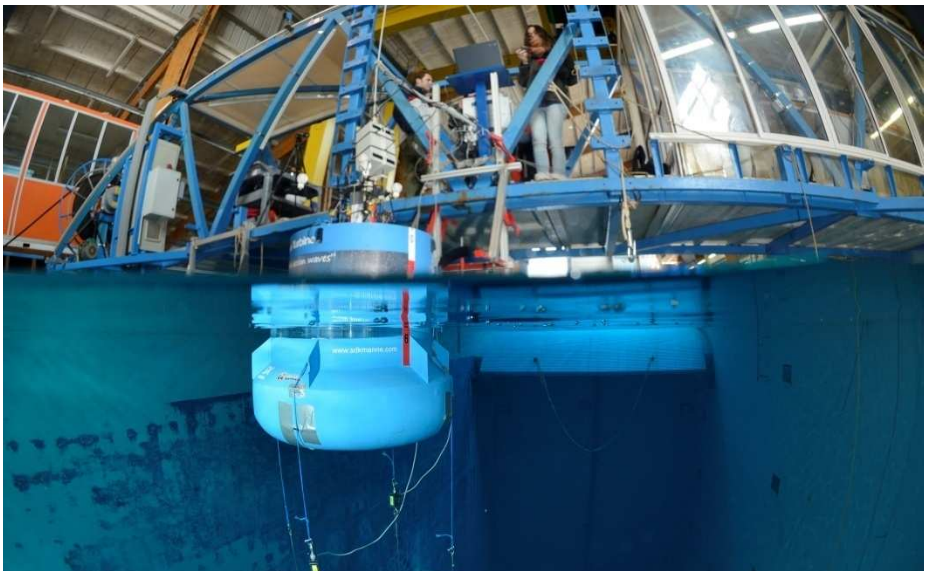
Infrastructure Access Report

Infrastructure: IFREMER Deep Seawater Wave Tank

User-Project: SDK Wave Turbine

SDK Wave Turbine

SENDEKIA MARINE



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EC FP7 "Capacities" Specific Programme
Research Infrastructure Action

ABOUT MARINET

MARINET (Marine Renewables Infrastructure Network for emerging Energy Technologies) is an EC-funded network of research centres and organisations that are working together to accelerate the development of marine renewable energy - wave, tidal & offshore-wind. The initiative is funded through the EC's Seventh Framework Programme (FP7) and runs for four years until 2015. The network of 29 partners with 42 specialist marine research facilities is spread across 11 EU countries and 1 International Cooperation Partner Country (Brazil).

MARINET offers periods of free-of-charge access to test facilities at a range of world-class research centres. Companies and research groups can avail of this Transnational Access (TA) to test devices at any scale in areas such as wave energy, tidal energy, offshore-wind energy and environmental data or to conduct tests on cross-cutting areas such as power take-off systems, grid integration, materials or moorings. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users, with at least four calls for access applications over the 4-year initiative.

MARINET partners are also working to implement common standards for testing in order to streamline the development process, conducting research to improve testing capabilities across the network, providing training at various facilities in the network in order to enhance personnel expertise and organising industry networking events in order to facilitate partnerships and knowledge exchange.

The aim of the initiative is to streamline the capabilities of test infrastructures in order to enhance their impact and accelerate the commercialisation of marine renewable energy. See www.fp7-marinet.eu for more details.

Partners

Ireland
University College Cork, HMRC (UCC_HMRC)
Coordinator
Sustainable Energy Authority of Ireland (SEAI_OEDU)

Denmark
Aalborg Universitet (AAU)
Danmarks Tekniske Universitet (RISOE)

France
Ecole Centrale de Nantes (ECN)
Institut Français de Recherche Pour l'Exploitation de la Mer (IFREMER)

United Kingdom
National Renewable Energy Centre Ltd. (NAREC)
The University of Exeter (UNEXE)
European Marine Energy Centre Ltd. (EMEC)
University of Strathclyde (UNI_STRATH)
The University of Edinburgh (UEDIN)
Queen's University Belfast (QUB)
Plymouth University(PU)

Spain
Ente Vasco de la Energía (EVE)
Tecnalia Research & Innovation Foundation (TECNALIA)

Belgium
1-Tech (1_TECH)

Netherlands
Stichting Tidal Testing Centre (TTC)
Stichting Energieonderzoek Centrum Nederland (ECNeth)

Germany
Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V (Fh_IWES)
Gottfried Wilhelm Leibniz Universität Hannover (LUH)
Universitaet Stuttgart (USTUTT)

Portugal
Wave Energy Centre – Centro de Energia das Ondas (WavEC)

Italy
Università degli Studi di Firenze (UNIFI-CRIACIV)
Università degli Studi di Firenze (UNIFI-PIN)
Università degli Studi della Tuscia (UNI_TUS)
Consiglio Nazionale delle Ricerche (CNR-INSEAN)

Brazil
Instituto de Pesquisas Tecnológicas do Estado de São Paulo S.A. (IPT)

Norway
Sintef Energi AS (SINTEF)
Norges Teknisk-Naturvitenskapelige Universitet (NTNU)

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Rev.	Date	Description	Prepared by (Name)	Approved By Infrastructure Manager	Status (Draft/Final)
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About This Report

One of the requirements of the EC in enabling a user group to benefit from free-of-charge access to an infrastructure is that the user group must be entitled to disseminate the foreground (information and results) that they have generated under the project in order to progress the state-of-the-art of the sector. Notwithstanding this, the EC also state that dissemination activities shall be compatible with the protection of intellectual property rights, confidentiality obligations and the legitimate interests of the owner(s) of the foreground.

The aim of this report is therefore to meet the first requirement of publicly disseminating the knowledge generated through this MARINET infrastructure access project in an accessible format in order to:

- progress the state-of-the-art
- publicise resulting progress made for the technology/industry
- provide evidence of progress made along the Structured Development Plan
- provide due diligence material for potential future investment and financing
- share lessons learned
- avoid potential future replication by others
- provide opportunities for future collaboration
- etc.

In some cases, the user group may wish to protect some of this information which they deem commercially sensitive, and so may choose to present results in a normalised (non-dimensional) format or withhold certain design data – this is acceptable and allowed for in the second requirement outlined above.

Acknowledgement

The work described in this publication has received support from MARINET, a European Community - Research Infrastructure Action under the FP7 "Capacities" Specific Programme.

Legal Disclaimer

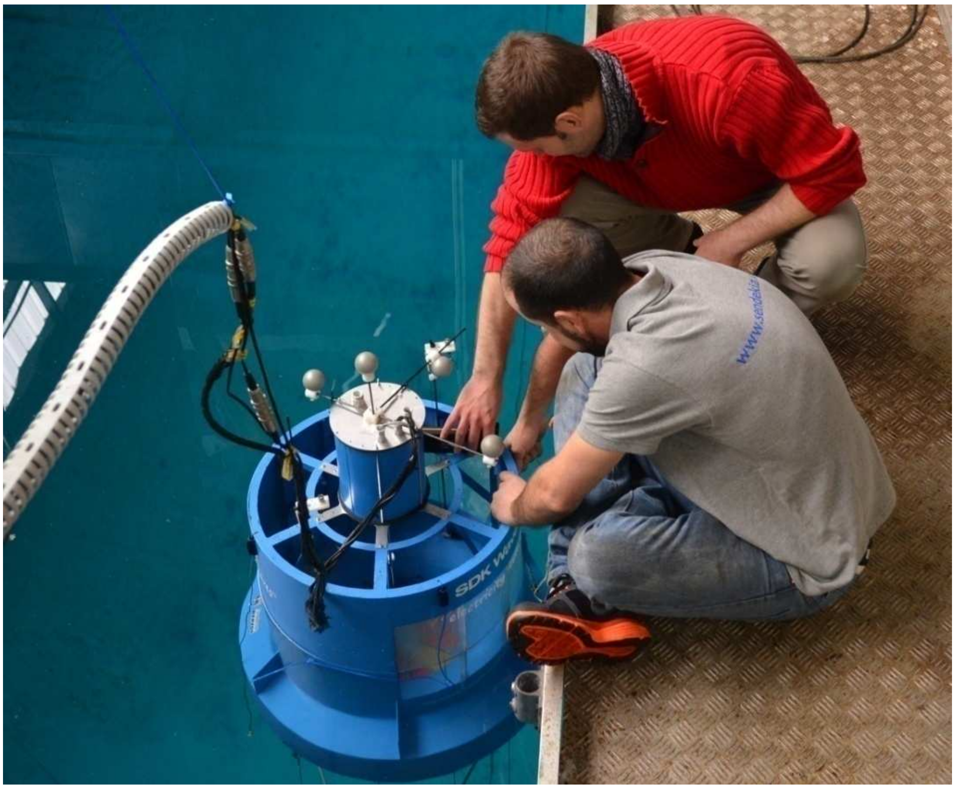
EXECUTIVE SUMMARY

SENDEKIA has invented and patented a unique conversion system consisting on a water turbine working with an oscillating water column. SDK Wave Turbine, Sendekia's patented technology is able to take off power from hydraulic bidirectional oscillating movement. This means that we are capable of taking off power both on inflow and outflow. That's because the pitch of the blades changes as flow changes, from positive to negative, always propelling in the same direction, like a whale's tail.

SDK Wave Turbine can be install floating or fixed in a breakwater. The buoy is deployed with a simple four-wire mooring attached to an anchoring weight on the seabed. At the bottom of the buoy there is an opening that allows flow between the oscillating water column chamber and the sea. The turbine is located there.

In the north of Spain exists a similar Infrastructure but with less wave generation capabilities. The buoy can take advantage from waves between 1 and 7 meters, and periods range from 6 to 20 seconds. SENDEKIA is looking for internationalize the technology by university collaboration and partnerships with other companies.

With the results achieved with MARINET support Sendekia will be able to perform the detailed engineering to build the first prototype for testing in the sea.



CONTENTS

1 INTRODUCTION & BACKGROUND

1.1 INTRODUCTION

Sendekia began research and development using a 1 to 50 scale model of the turbine, which worked immediately. The pitch changes with the water flow and the fly wheel control the speed fluctuation of the turbine. In order to optimize the shape of the chamber, we measured the speed rate of the turbine using different chamber designs.

After the concept was validated we proceed to measure the power take off of the device. While 1:50 scale was too small for this we built a 1:10 model with better fabrication accuracy and the knowledge gained from previous tests. By measuring the torque and speed of the shaft, was calculated the instant power take off. The first performance measurements were around 8%, but then we had more than the 30 %.

1.2 DEVELOPMENT SO FAR

We implemented CFD simulation that allowed us to study the hydrodynamics of the device, estimated power and to compare results with scale test and performed shape modifications.

Thanks to CFD's information, we made changes in our device. We built a new 1:20 scale model; this new model was previously proved in the tank from CEHINAV (Centro de Esnsayos Hidrodinámicos) E.T.S.I. Navales, in Madrid, Spain, where we saw the perfect dynamic behaviour of the device. We want to prove the PTO system in IFREMER Deep Seawater Wave Tank, where we expect to have better results that reflect our improvements.

Previous tests in E.T.S.I.Navales, Spain

1.2.1 Stage Gate Progress

Previously completed: ✓
Planned for this project: ➲

STAGE GATE CRITERIA	Status
Stage 1 – Concept Validation	
• Linear monochromatic waves to validate or calibrate numerical models of the system (25 – 100 waves)	✓
• Finite monochromatic waves to include higher order effects (25 –100 waves)	✓
• Hull(s) sea worthiness in real seas (scaled duration at 3 hours)	✓
• Restricted degrees of freedom (DofF) if required by the early mathematical models	✓
• Provide the empirical hydrodynamic co-efficient associated with the device (for mathematical modelling tuning)	✓
• Investigate physical process governing device response. May not be well defined theoretically or numerically solvable	✓
• Real seaway productivity (scaled duration at 20-30 minutes)	➲
• Initially 2-D (flume) test programme	➲
• Short crested seas need only be run at this early stage if the devices anticipated performance would be significantly affected by them	✓
• Evidence of the device seaworthiness	✓
• Initial indication of the full system load regimes	✓
Stage 2 – Design Validation	
• Accurately simulated PTO characteristics	➲
• Performance in real seaways (long and short crested)	➲
• Survival loading and extreme motion behaviour.	➲
• Active damping control (may be deferred to Stage 3)	
• Device design changes and modifications	➲
• Mooring arrangements and effects on motion	➲
• Data for proposed PTO design and bench testing (Stage 3)	➲
• Engineering Design (Prototype), feasibility and costing	➲
• Site Review for Stage 3 and Stage 4 deployments	
• Over topping rates	
Stage 3 – Sub-Systems Validation	
• To investigate physical properties not well scaled & validate performance figures	
• To employ a realistic/actual PTO and generating system & develop control strategies	
• To qualify environmental factors (i.e. the device on the environment and vice versa) e.g. marine growth, corrosion, windage and current drag	
• To validate electrical supply quality and power electronic requirements.	
• To quantify survival conditions, mooring behaviour and hull seaworthiness	
• Manufacturing, deployment, recovery and O&M (component reliability)	
• Project planning and management, including licensing, certification, insurance etc.	
Stage 4 – Solo Device Validation	
• Hull seaworthiness and survival strategies	
• Mooring and cable connection issues, including failure modes	
• PTO performance and reliability	
• Component and assembly longevity	

STAGE GATE CRITERIA	Status
• Electricity supply quality (absorbed/pneumatic power-converted/electrical power)	
• Application in local wave climate conditions	
• Project management, manufacturing, deployment, recovery, etc	
• Service, maintenance and operational experience [O&M]	
• Accepted EIA	
Stage 5 – Multi-Device Demonstration	
• Economic Feasibility/Profitability	
• Multiple units performance	
• Device array interactions	
• Power supply interaction & quality	
• Environmental impact issues	
• Full technical and economic due diligence	
• Compliance of all operations with existing legal requirements	

1.2.2 Plan for This Access

Thanks to CFD models, we know the dynamic behaviour and energy that Sendekia's device can produce. We need relevant experimental results, which show that the CFD results and improvements introduced in previous models are working as we expect.

The improvements introduced were:

CFD analysis: calculate PTO, load on mooring, hydraulic performance, design, etc.

Design:

- Mechanical design.
- Naval architecture (Structural Design).
- Electrical design.
- Control.

We introduced these improvements in a new 1:20 model. The first goal that we have is to measure power and energy of the device in diverse sea states. The rest of the data that we will obtain, are related with this main objective. This information allows us to optimize the device behavior in real sea conditions and the energy captured by the device. The energy captured is the main focus, taking in mind that the dynamic behavior was previously checked.

Variables to study:

- Wave elevation, internal buoy water level.
- Potential available energy.
- Process resonance and phase response of the chamber + turbine.
- Internal flow.
- Internal pressure.
- Shaft power (torque and rpm).
- Optimizing of variable pitch angle.
- Buoy Motion (Heave, Pitch, Roll, etc)
- Structural loads, mooring line loads.

2 OUTLINE OF WORK CARRIED OUT

2.1 SETUP

SDK Wave Turbine was tested fixed and free floating. CFD studies simulate the behavior of the fixed deployment, so we could compare the CFD results with the experimental results. The fixed system simulates a stable platform or breakwater location in other hand the moving system simulates the deployment of one device anchored to the seabed with 100 m depth; therefore we will obtain the buoy's movements and the effects on power take off.

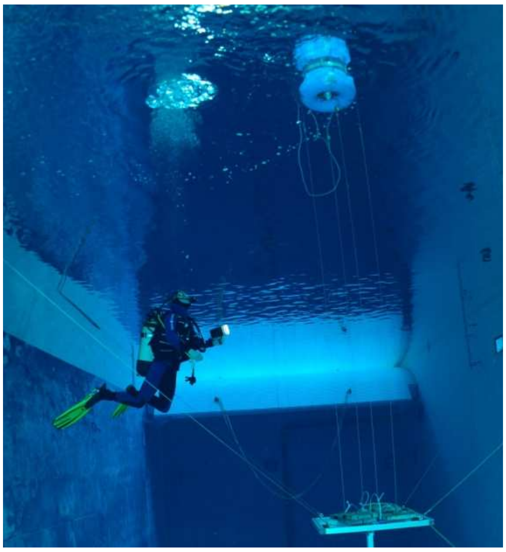
General specifications:

The scale model was 1:20.

PTO: Complete PTO with gear box, electric generator and power control.

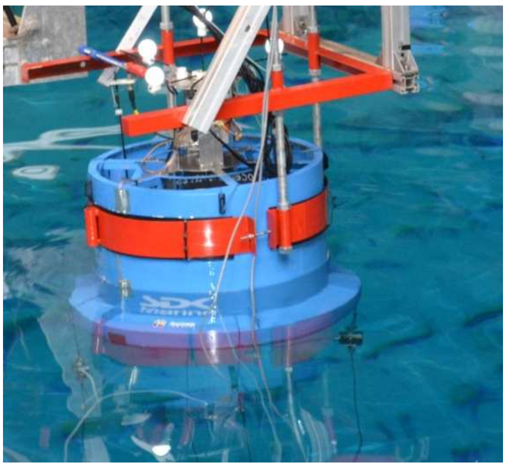
Mooring: 4 wire TLP anchoring system.

The buoy was moored with 4 tensioned wires. The wires connect the buoy with a plate. So the plate acts as a dead weight. The plate was placed in the wave tank bead, as we can see in the picture.



SDK WAVE TURBINE deployment.

As well the buoy was fixed with a substructure to IFREMER's wave tank carriage.



Fixed setup

2.2 TESTS

We tested our device in regular and irregular waves. Regular waves enable mathematical modelling and simple understanding of main parameters affecting the system, irregular waves represent a real sea allowing the study of buoy and power take off behavior sea conditions.

2.2.1 Test Plan

We carried out 208 tests different fixed and buoying configurations in regular and irregular waves:

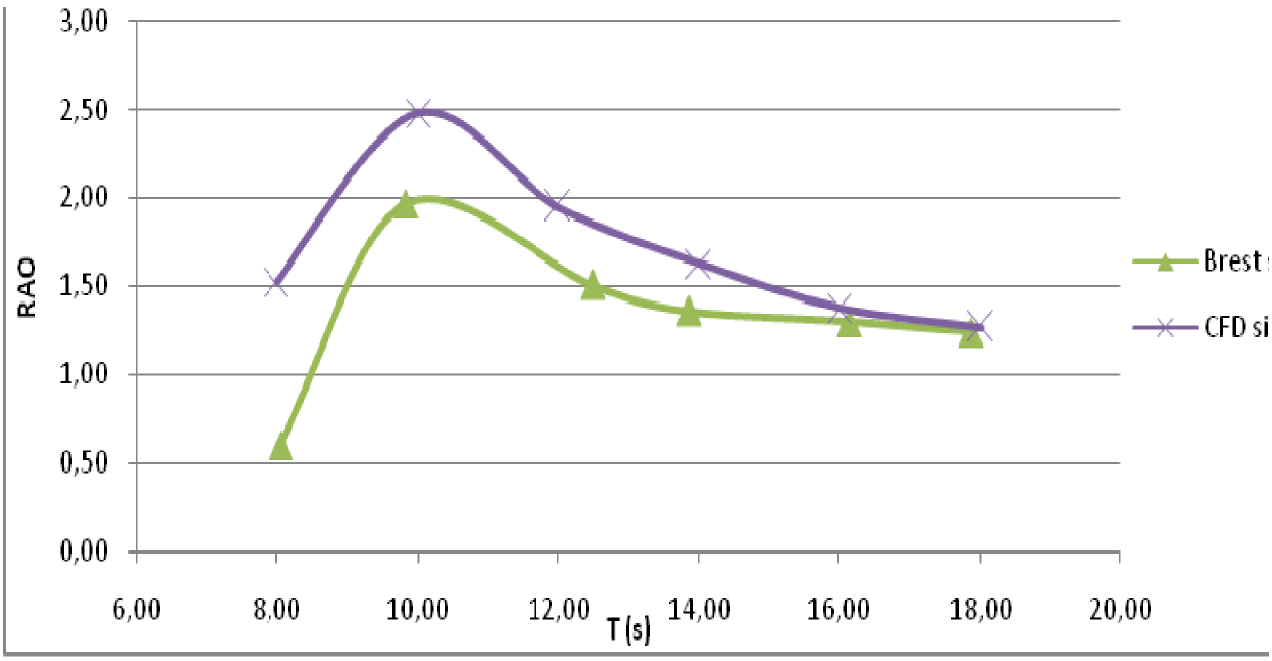
H (m)	T (s)	H (m)	T (s)	H (m)	T (s)
1	8	2	8	4	8
	10		10		10
	12		12		12
	14		14		14
	16		16		16
	18		18		18

2.3 RESULTS

This chapter resume general results of main sensor data acquired.

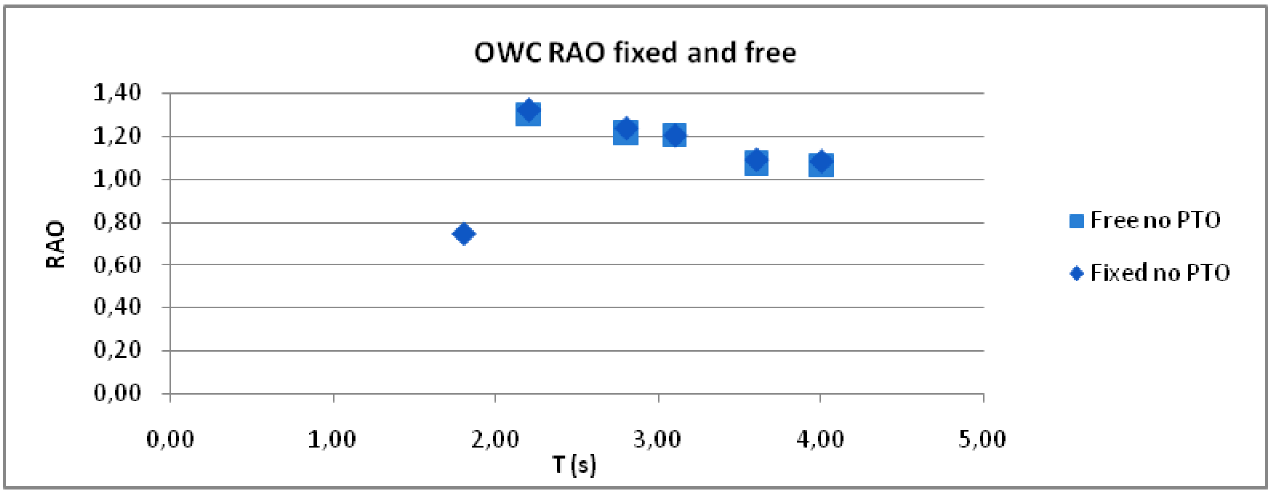
- OWC water level.

  Test results are bit different from CFD analysis mainly caused by viscosity effects that modify the hydraulic behaviour, at this moment we are developing a more accurate model to quantify this effects.



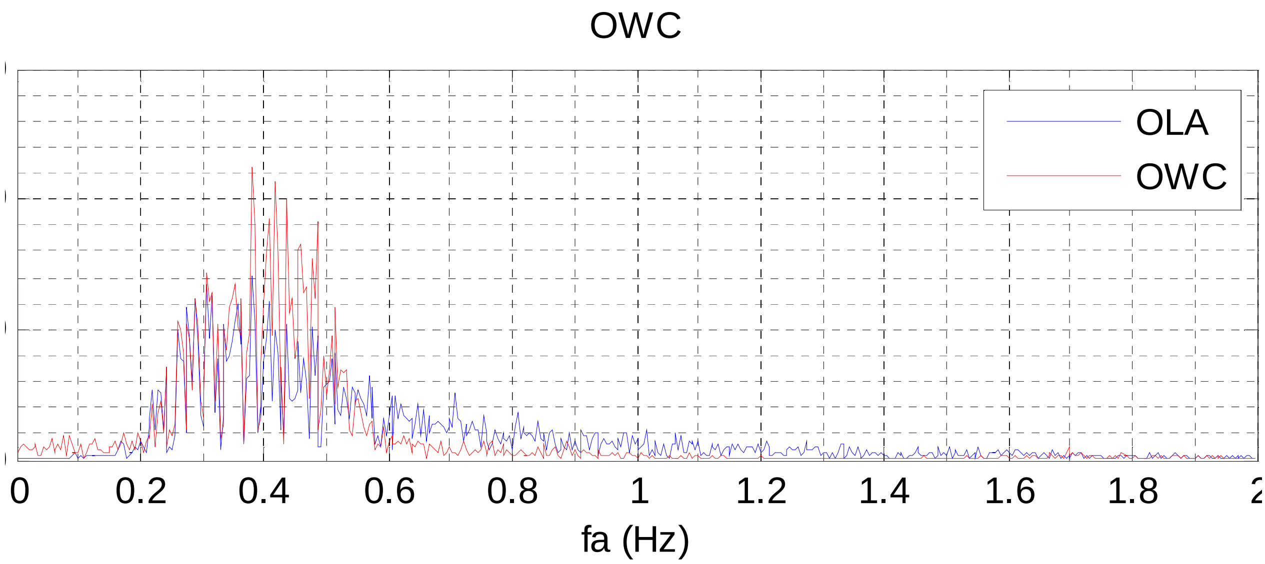
RAO OWC WATER LEVEL CFD vs BREST

OWC behaviour on fixed and free setup is identical.



RAO OWC WATER LEVEL FIXED vs FREE SETUP

On irregular waves OWC amplify energy spectrum in a wide range of frequencies.



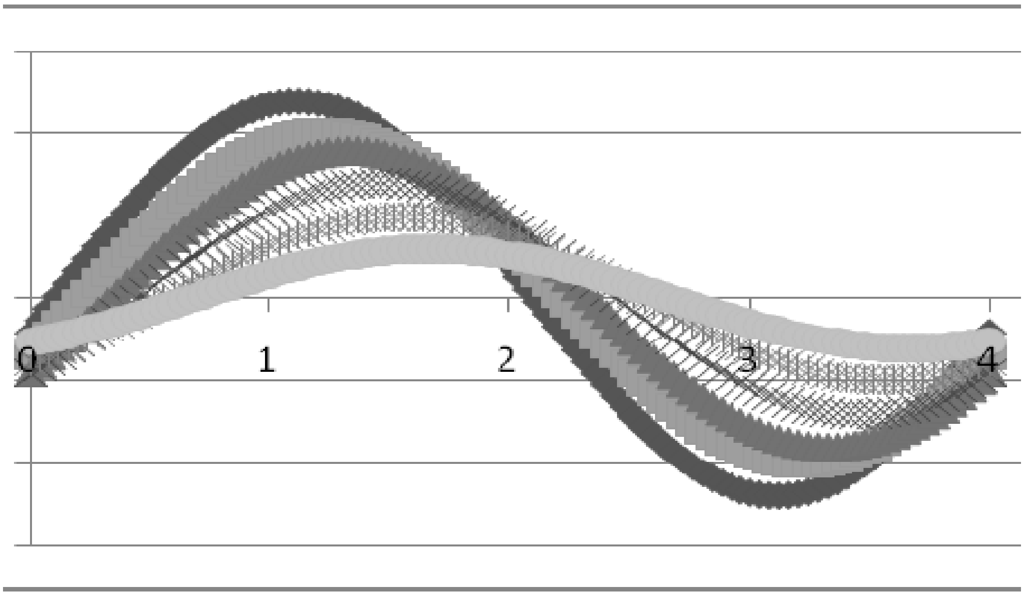
RAO OWC WATER LEVEL AND WAVE SPECTRUM

- Mooring system

Surge: Main movement of the device, up to 5% of mooring length.
Drift: This displacement was not affected by the incoming waves.
Heave: Vertical movement was small do to TLP rigidity. Up to 0,2% of mooring length.
Pitch: Small do to TLP rigidity. Up to 0,5º.
Jaw: This displacement was not affected by the incoming waves.
Roll: This displacement was not affected by the incoming waves.

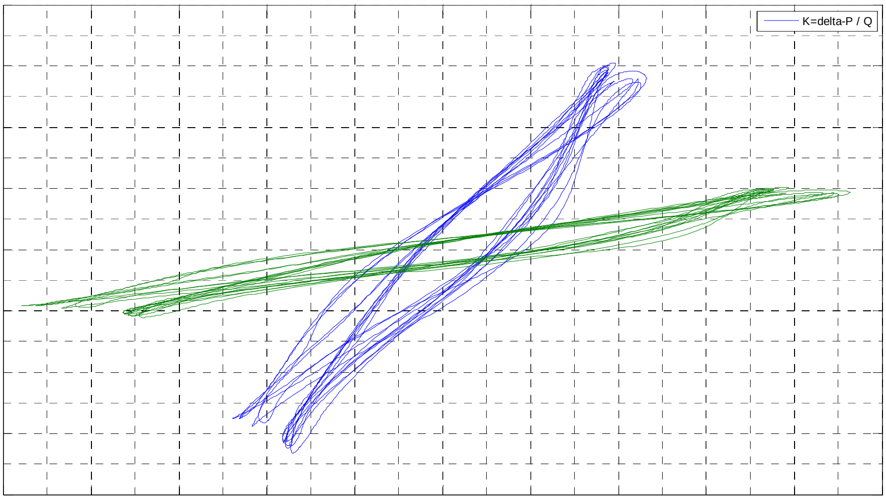
Anchoring forces: Force variation on operational sea condition: up 10 % of pre-tension force.

- Turbine Pressure.
  It was measured how much hydraulic turbine attenuate and change the phase of OWC level in different conditions. As the hydraulic turbine increase differential pressure attenuates OWC flow. (Strong colour line represents OWC level with low differential pressure)



WATER LEVEL WITH DIFFERENT TURBINES

Turbine pressure and flow relationship (K=pressure/flow) depends on PTO setup and adapt to different waves optimizing power conversion. Blew and green lines represent to different (K=pressure/flow)



TURBINE PRESSURE vs FLOW

2.4 Analysis & Conclusions

- Capturing energy with a hydraulic turbine inside the OWC is simple, efficient and simplifies the OWC design.
- The buoys stability with TLP mooring system in operating conditions is excellent. It makes possible install the device with other uses.
- The loads on the wires were lower than expected.

3 MAIN LEARNING OUTCOMES

3.1 Progress Made

For the first time, we could verify the operation of the device, including the mooring system (TLP) and the power take off. We had achieved the power matrix of the device deployed flouting and fixed. As well we obtain information about the dynamic movement of floating deployment and tension forces of the mooring cables.

It has been proved that the working principle of the device match with the results expected. The buoy, mooring system, OWC, hydraulic turbine and mechanical system, demonstrated the potential of the technology. Furthermore, advances in the device design have improved its behavior compared to the previous tests.

3.1.1 Progress Made: For This User-Group or Technology

3.1.1.1 Next Steps for Research or Staged Development Plan – Exit/Change & Retest/Proceed?

Once the data processing obtained in the tests has finished; we will start design a new 1:5 device. This new design will include the knowledge gained from these last tests. The 1:5 prototype will be deployed in real sea condition, focus on the hydraulic turbine performance, the most important and difficult part of the power take off. Moreover this will prove material behaviour in real sea environment.

Also, we expect making in-depth studies about extreme waves behaviour and several devices interaction. This will involve new tests in 1:20 scale model centre on the improvement of the structure design and device performance interaction.

3.1.2 Progress Made: For Marine Renewable Energy Industry

There are no previous experiences involving a hydraulic turbine within an oscillating water column, therefore the tests done in this novel way to capture energy through the hydraulic turbine represent a step forward itself. Getting a better understanding of the phenomenon, thanks to the hydraulic pressures on the turbine and OWC behavior.

3.2 Key Lessons Learned

- The 1:20 hydraulic turbine model could induce worst energy efficiency by introducing greater drag. Lift-drag relationship became worst when the scale is lower. It must be done more tests to extrapolate this behavior into a real scale.
- We can control easily the device. The device is able to adapt to different waves achieving good performance.
- The overall efficiency is not affected by having a fixed or free floating device.
- It will be necessary to build a bigger model (1:5 scale) to analyze in detail the hydraulic turbine efficiency.

4 FURTHER INFORMATION

Website: **www.sdkmarine.com**