Advanced Rotational Moulding for Wave Energy Technologies (ARMWET)

WES Structural Materials and Manufacturing Processes Stage 1 Public Report

PolyGen Ltd

This project has been supported by Wave Energy Scotland

1. Project Introduction

The ARMWET project targets the application of new technologies which overcome existing challenges with the implementation of the rotational moulding of polyethylene structures for wave energy converters (WECs).

The leaders of the project, PolyGen Ltd, focus on a selection of advanced engineering methods which have applications for WECs, including the spreading loads throughout the polymer structures, and the implementation of hybrid concrete elements.

Wave Venture Ltd utilise their *Wave Venture TE*™ software to analyse the hydrodynamic performance of the PolyGen WEC, to output relevant load cases that the structures must endure and to estimate energy productivity. The LCOE was also investigated using the *Wave Venture TE*™ software, this included a sensitivity and an uncertainty analysis.

Utilising Rototek Ltd's unique experience and design capabilities for large rotational moulded products, the team together propose a number of designs suitable for use, backed up by advanced FEA simulations using systems validated by formal material testing.

These proposals show a realistic means of reducing the CAPEX and the long term OPEX of the WEC. The LCOE was assessed to be 710£/MWh for farm composed of 25kW capacity WEC units at 1MW maturity. This estimate places the PolyGen WEC device on track to reach the WES target of 150£/MWh at 1GW maturity with a learning rate close to learning rates already achieved in comparable industries.

2. Description of Project Technology

Polymers offer a range of exceptional benefits in marine applications over metals. These properties are particularly apparent in polyethylene, with its excellent fatigue and toughness, affordability, prevalence and recyclability. Numerous marine industries now rely on polyethylene as the primary structural element, including aquaculture fish pens and floating pontoons.

Polyethylene is also by far the most commonly used polymer in rotational moulding, a manufacturing process which also has distinct advantages for WECs. Very large products can be cheaply moulded often with few secondary operations using affordable and globally widespread equipment. They are however typically very thin products, with therefore a limited natural structural integrity.

This and other engineering challenges associated with both the material and the manufacturing have so far prevented even early adoption within the wave energy sector. The application of various engineering techniques may ensure the product is strong enough to withstand the extreme forces imposed by the environment, and the ARMWET project explores these for application on the Volta and other WECs.

3. Scope of Work

Polyethylene is a cheap and readily available polymer with hundreds of modern variants to target specific applications and uses. The nonlinear structural properties are typically not available from suppliers, making it difficult to utilise correctly. Therefore this project started with a detailed material analysis on two material alternatives to enable detailed finite element analysis for use in this and later stages.

A full review of the rotational moulding manufacturing processes was compiled, including machine types, tool types, and implications on material selection. An in-depth research into existing possible design technologies, with attention to relevant WEC applications such as point loading, tension elements, surface compressibility and yield stressing. Research was also done on how concrete could be utilised as a hybrid element, adding both weight and strength.

The forces on a WEC in a relevant environment were then output from a hydrodynamic model for two different WECs, allowing investigations into the application of many rotationally moulded designs in a structural application. The innovations of this project led to a doubling of the power per flap in the Volta device.

These designs were then built into an LCOE model, utilising the performance figures from the hydrodynamic modelling, enabling a detailed assessment of the impact that the rotationally moulded product has on the system. The comparison of the PolyGen WEC pre and post the innovations of this project shows a significant improvement in the LCOE. The sensitivity analysis shows that the LCOE is most sensitive to non-device costs related to the number of WEC devices (e.g. cost of connection) so further increases of device rating are one of the most promising ways of reducing LCOE.

4. Project Achievements

- A register of advanced technologies for use with polyethylene rotational moulding design
- Conception of a valid flap design for the Volta WEC, utilising key advantages of the polymer and rotational moulding techniques.
- Doubling of the power rating per flap
- Clarification of LCOE sensitivities, these will be used to define future research direction.

5. Applicability to WEC Device Types

Predominantly polymer structures are generally more appropriate for smaller scale WECs, particularly for designs where forces can be kept to a minimum.

The results of the ARMWET program show that for the Volta WEC, by keeping the flaps to a reasonably small size (when compared with some other larger, single flap WECs) and by choosing a suitable design for the power take off, a single rotationally moulded product has the potential to withstand the majority of the forces and loads imposed without any specialist designs or additional strengthening elements, such as concrete.

Therefore with the adoption of additional design features or strengthening materials, the potential for a device to be designed and manufactured to withstand greater forces, and therefore operate with a lower risk, presents a valid application for WEC designs.

Furthermore, polyethylene's material properties of zero corrosion, excellent fatigue resistance, affordability and good environmental credentials (such as recyclability and zero toxicity) make it an excellent choice, especially compared to many other materials currently being applied to the marine environment.

Additionally the large and very affordable manufacturing techniques of rotational moulding suggest this is a very applicable technology for the right sized WEC structural products.

6. Communications and Publicity Activity

No formal publicity activities were undertaken as part of this project.

7. Recommendations for Further Work

1. Determine limits of scaling up of rotationally moulded hull forms
2. Validation of material structural behaviour on complex geometry samples
3. More detailed design of the Volta flap, further utilising the advanced technologies proposed within this project
4. Additional analysis of the proposed Volta WEC, including fatigue and buckling analyses, hydrostatic pressures and long term creep
5. More detailed costing study to improve accuracy the LCoE, especially further uncertainty analysis
6. A greater range of inputs and output from the hydrodynamic modelling, including more aggressive environments
7. Verification of the hydrodynamic modelling and power estimation results via scaled physical testing
8. A wider structural analysis of the WEC, based on the improved performance of the rotationally moulded flaps, as part of an examination of manufacturing more elements of the Volta WEC using rotationally moulding

8. Useful References and Additional Data

None