HydroComp

WES Structural Materials and Manufacturing Processes Stage 1 Public Report

CorPower Ocean

This project has been supported by Wave Energy Scotland

1. Project Introduction

The HydroComp project partners worked together toward the study of innovative materials for wave energy devices structure using Balmoral's long experience in structural design, polymer materials and manufacturing methods for offshore environments, CorPower Ocean and Wave Venture expertise in numerical modelling, design load cases, system design and Levelized-Cost-of-Energy (LCOE) analysis.

CorPower Ocean, Balmoral and Wave Venture combined their efforts to assess the viability of hybrid Fibre Reinforced Polymer (FRP) applied to the specific case of a prime mover of point absorber Wave Energy Converters (WEC). This was done using an approach assessing affordability, availability, survivability, performance and its impact on overall project LCOE. Specific efforts were made to calculate the structural loads together with structural and stress analysis. The material performance, manufacturing & logistics results and the risk assessment were used to feed the LCOE analysis, where key performance and cost metrics were used to assess the viability of the proposed solution, including CAPEX, OPEX, structural efficiency, performance to load ratio and finally LCOE.

2. Description of Project Technology

CPO calculations and scale testing have shown that the wave energy structures made possible by the filament winding and other FRP based manufacture process are lightweight and strong and thanks to being inherently detuned in storm waves show good survivability and low ratio of Max/Avg loading. Such lightweight structures together with PTO having advanced control are very promising in terms of energy absorption with much higher energy production per cubic displacement and weight than other devices. This combination of survivability and high energetic performance leads to significant improvements in LCOE. We estimate that the CPO device using hybrid composite prime mover can give more than 50% reduction in prime mover CAPEX, 10% reduction in OPEX and up to 10% reduction in overall LCOE compared to the same device with steel buoy. Note that the CPO buoy structure used for this estimate is relatively small with respect to the power output (thanks to advanced control giving high efficiency in the primary power absorption), where other WEC having a larger prime mover representing a larger portion of the total cost may see a larger proportional reduction in LCOE.

3. Scope of Work

The proposed work programme was designed to address the outstanding technical challenges through the combination of application of wave energy and structural analysis tools, application of material and manufacturing partner know-how and experience. The work plan and work package were designed to deliver a coherent and successful overall project:

- General project management was included in the WP01;
- the loads calculations work package (WP02) provided detailed understanding of the relevant Design Load Cases (DLC), and prioritize the critical DLCs;
- WP03 was a material performance assessment work package, composites and foams were assessed for suitability on a range of criteria;
- WP04 was a manufacturing feasibility study and outputted the related mandatory WES deliverables;
- WP05 was a structural design and stress analysis making use of CAD and FEA tools to produce a design that is suitable for the DLC's;

- WP06 undertook a tightly coupled hydrodynamic-structural analysis that allowed a very computationally efficient assessment of fatigue and stress cumulative frequency analysis;
- WP07 was a planning and risk assessment for future work, and;
- WP08 was the LCOE calculation work package.

4. Project Achievements

The Material, Manufacturing, Logistic and performance assessments have allowed the following conclusions to be drawn:

- Polyester/E-Glass material is the first choice moving forward, this is due to the performance of the material for the several different load cases and the relatively low cost of the material;
- the deconstruction of the Hull in its currently proposed configuration is influenced by practical aspects from all stages of the manufacturing, handling and transportation, and assembly process. This current definition divides the Hull into 47 principle elements;
- the 46 upper Hull panels are proposed to be manufactured by Resin Injection Moulding. This process lends itself well to the style of panels' topography and scale defined for each of the panel types. Economically, this allows for production manually and using semi-automation;
- the Stem (or Shroud), because of its essentially cylindrical form, lends itself most effectively to filament winding as a manufacturing process;
- for the connection between the panels the configuration of choice was an overlap bonded joint, with every panel being held together with an adhesive component to create a structurally strong and watertight bond;
- varying the hull mass between 35 tonnes and 80 tonnes, which is representative of the range going from a composite hull to a steel hull, gives a reduction of annual energy output in the range 10 to 20%;
- Overall the results show that, in the specimen wave farms investigated, the innovations of the HydroComp project allow the CorPower WEC to approach its LCOE targets. The HydroComp LOCE is slightly better than the CorPower Baseline target.

The risk assessment has allowed a detailed identification of risks of proposed solutions. Based on the outcomes of the risk assessment a test plan with recommendations for future testing has been created. This plan makes recommendations of practical investigation, evaluation, design and development activities, with the intention of qualifying the project direction within the scope of the Hull requirement. It includes a direction for progressing knowledge and confidence with the selection and application of identified materials and material combinations, methods of assembly and of manufacturing processes.

A new software has been implemented for coupled hydrodynamic and structural analysis, written in Python 3.4 and the copyright in this represents Arising IP generated in this project.

5. Applicability to WEC Device Types

During the HydroComp project the investigations have been focus on the CPO WEC full-scale concept, allowing the consortium to benefit from valuable experience in structure specification, load cases definition and calculation, manufacturing methods, performance, cost and reliability assessment of structural materials. Although initially focused on CPO concept, the challenges faced by WEC developers are somehow similar when it comes to the main structure of the prime mover and especially when looking at FRP structure, where the main challenges are:

- Complexity and cost related to handling and shipping WEC buoys as a single piece assembled structure. The cost of shipping an assembled buoy between manufacturing site and the deployment site can be as high as 30% of the total production cost of the structure;

- Time, effort and cost related to the manufacturing of local reinforcement in hybrid FRP buoy designs. Where large shell structures can be quickly manufactured at low cost using existing methods, the time and cost for adding local FRP and metal reinforcement is significantly higher for conventional labour-intense methods.

Solution for these generic challenges using innovative materials and effective manufacture and assembly of the structural shell thanks to composite polymer materials investigated and identified during the HydroComp project may be applicable for a range of other point absorbers, benefiting a large portion of the wave energy sector.

6. Communications and Publicity Activity

The SMMP Stage 1 HydroComp project was presented during WES annual conference on the 28th of November 2017.

7. Recommendations for Further Work

Based on the investigations and results of the Stage 1, the following recommendations for further work has been drawn:

- Based on the design & Stress analysis work, extensive testing will need to be carried out to validate the conclusions that have been drawn up. This involves full scale testing of the panel structures, using the adhesive bonding material to combine several panels together. This testing will further emphasise the feasibility of using a composite material for the Hull structure as opposed to steel;
- Practical testing is required to qualify the calculations made to-date, as well as identify if refinement of the design can achieve further weight savings;
- Based on the insights gained in the LCOE study the following suggestions are made for the priorities in future research and design work on the HydroComp hull:
    - More detailed logistics should be modelled: The logistics of manufacture, land transport, assembly, water transport, installation should be studied in more detail to better understand the cost centres, resource requirements and throughput bottle necks.
    - More detailed operational simulation: The FMECA and the recovery sequences used in the operational simulation should be further developed to better reflect the possible improvements in lifetime costs due to the HydroComp hull.
    - Cost assumptions should be reviewed: Because it is necessary to represent the whole system, whole lifecycle in the LCOE analysis it is necessary to check cost assumptions in areas other than the specific innovations of HydroComp so that we can be confident in the results.
    - Explore low sensitivity to tooling costs: The results of the analysis indicate that the LCOE value is particularly insensitive to tooling costs so practical scenarios that involve increased tooling investment for lower unit costs or shorter production runs should be investigated.
    - Improve LCOE uncertainty estimate: In this analysis uncertainty was only assigned to cost data, uncertainty in other categories of data should be considered in future. In particular uncertainty in learning rates will lead to significantly increased uncertainty in the 'learned costs'.

8. Useful References and Additional Data

Confidential

D02 – Confidential technical report, HydroComp Stage 1

Public

CorPower Ocean AB – http://www.corpowerocean.com/

Balmoral Offshore engineering – http://www.wave-venture.com/

Wave Venture Ltd - http://www.balmoral-group.com/balmoral-offshore/