A HYDROKINETIC TURBINE FOR THE OPERATION OF THE COZUMEL CHANNEL FLOW CONDITIONS

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Introduction

The outcomes presented in this extended abstract are result of the outcomes from a MSc Group Project undertaken at the Department of Mechanical and Aerospace, University of Strathclyde UK.

The aim of this project was to design a marine turbine based on the characteristics of a "slow" moving ocean current that flows between mainland Mexico and the Cozumel Island – the Cozumel Channel. The project focused in four areas: i) turbine location, ii) rotor design, iii) powertrain setup and iv) support structure.

Turbine location

Cozumel Channel has been a site of interest for the deployment of marine energy, given its location within an important Mexican economic region (Alcerreca-Huerta, et. al., 2019). Available information from in situ flow characterisation and numerical modelling was done for the channel, as it can be seen in Figure 1.

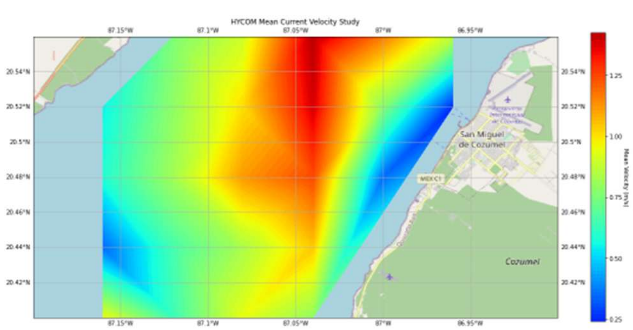

Figura 1. Current Velocity Magnitude Contour Map (taken from Cleland, et al., 2021).

The flow velocity in this area was found to be 1.035m/s, and the additional parameters considered in this study are shown in Table 1.

Table 1. Cozumel Channel Site Properties.

Property	Value
Water Depth of Turbine Site	20m
Mean Ocean Current Velocity	1.035m/s
Estimated Velocity Variation*	≈ 35%
Location	Cozumel western insular shelf
Seabed Type	Carbonate sedimentary rock

* based on the assumptions derived from numerical modelling

Rotor design and powertrain set-up

The hydrodynamic efficiency was the main parameter used to optimised the blade design for the turbine. The design was based on a typical horizontal axis turbine. Permutations including blade profile, chord, twist and number of blades were considered in the design tool. The methodology was based on blade element momentum theory. Figure 2 presents the performance curve obtained from the methodology. This rotor consisted of a 3-bladed rotor design and the optimum blade was composed of 30% of the NACA 63(4)-421 at the root and 70% of the NACA 63(3)-618 at the tip.

The proposed blade was then assessed structurally. Based on the flow characterisation undertaken by using numerical modelling and real site ADCP data, it was concluded that the maximum operating condition for the turbine will include: a flow speed of 2 m/s, a thrust distribution of 4 kN/m per blade and a torque distribution of 31.62 kNm per blade.

Blade deflection, blade root connection and bending moments were considered when evaluating the structural components of the blade, root connection and hub design, as captured in Figure 3.

The main considerations made when determining the powertrain design for the turbine where capital cost, weight, reliability, and efficiency. It was thus decided that a 22kW 4 pole induction generator, accompanied by a 1:182 planetary and bevel-helical gearbox was the optimum design for this device. The power output at optimum conditions was determined to be 17.767kW with a powertrain efficiency of nearly 90%.

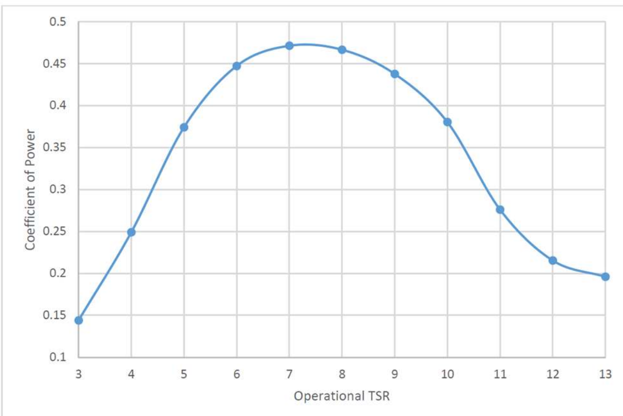

Figure 2. Power coefficient of a 3-bladed turbine of 10m in diameter (taken from Cleland, et al., 2021).

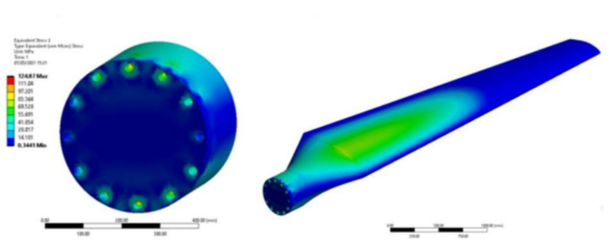

Figure 3. Stress distribution along the blade and root connection for extreme loading conditions (taken from Cleland, et al., 2021).

Support Structure

A structure to mount the turbine was designed, analysed, and optimised to meet the specific requirements of the Cozumel Site. Gravity based foundations were investigated and analysed based on their structural integrity and fatigue life and then optimised to balance performance and cost. A ranking method was utilised to select the final design which is shown in Figure 4.

A turbine design life of 20 years was considered for the economic analysis. It was calculated that the full capital, maintenance and decommissioning cost for the turbine and components was $810,128 USD. This costs in combination with the energy computed from the flow characterisation and the hydrodynamic efficiency of the turbine, were used to evaluate the cost of energy which was determined to be $325 USD/MWh. This cost of energy is in the region of high-energetic tidal stream turbines (Noonan, 2018).

Figure 4. Final rendered model of the turbine (taken from Cleland, et al., 2021).

Future work will include a more in detailed cost analysis including information from an established in-situ supply chain.

References

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