CFD modelling of an unidirectional impulse turbine for a twin OWC

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One of the most common systems for capturing wave energy is the OWC system., which is equipped with a turbine under different arrangements. This work is dealing with an unidirectional turbine design for a twin turbines system. A numerical CFD model for this turbine has been created and validated, as the first part of a PhD, to be later used to optimize the performance.

INTRODUCTION

Wave energy has been gathering strength in the last years worldwide. Many device deployments are being made or planned for the next future [1]. Among the technologies for harnessing wave energy, one of the most common is the Oscillating Water Colum. This system uses a turbine as Power-Take off, but there is no consensus about the most suitable turbine for these devices[2]. One of the possibilities is called “twin turbines” [3] which is using two unidirectional turbines working alternatively as turbine and flow preventer. Thus, the design of these turbines shows special features.

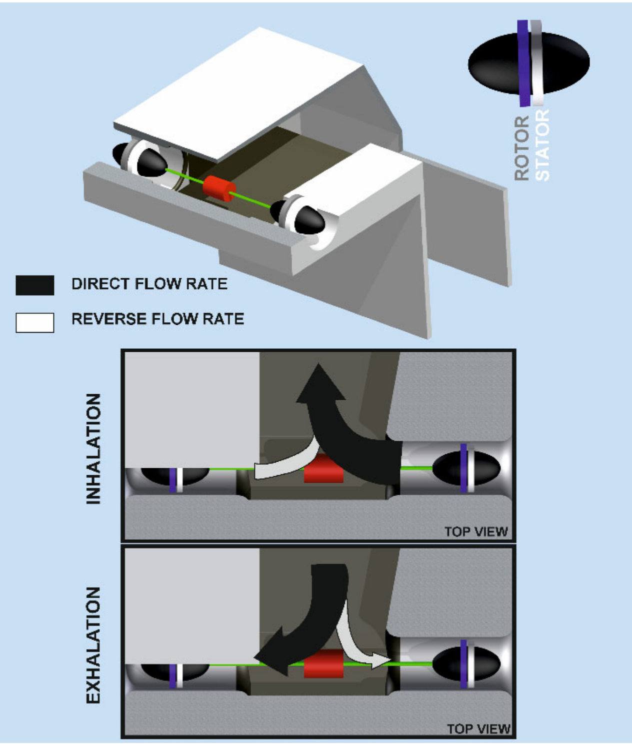

FIG 1. Performance of an OWC twin system [4].

Unidirectional axial turbines for twin systems, working without support from an external rectifying system, have been analysed by several researchers since its proposal in 2009. Experimental work was driven related to the optimum blade for OWC unidirectional turbine [5], even connected to a real-scale system [6]. Apart from those, several works have been published related to the performance of these turbines, both CFD and experimental [4], [7].

However, it is clear from previous experiences of the authors [4] that some improvement remains to be done since a real optimization of the blade has been never done. First task to start the process is to build a reliable numerical model to be used in subsequent step. This work explains the process of creating the model and its first results.

NUMERICAL MODEL

The turbine geometry was extracted from [7], with a setting angle of the guide vanes of 20°. The flow simulation is done with FLUENT v16.2 on a periodic domain (FIG 2). The mesh, composed of hexahedrical cells, consists of 10^6 cells and was built using turboGrid.

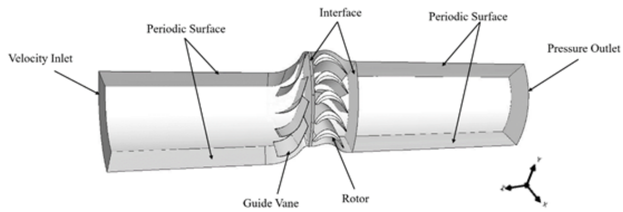

FIG 2. CFD domain and Boundary conditions.

Since the computational volume includes rotating components (ω = 375 rpm), the sliding moving mesh technique (SMM) was used in order to manage the relative movement between the rotor and the stator of the turbine. Therefore, two interfaces are placed upstream and downstream of the rotor (FIG 2).

The realizable k–εturbulence model, well tested in other works [4], [8], [9], was used with the Enhanced Wall Function. The y^+ values are in the correct range. The time-dependent term is approximated with a second-order implicit scheme. The pressure–velocity coupling was recreated through the SIMPLE algorithm. The highest order MUSCL was used for convection term discretization and the classical central difference approximation for diffusion terms. The time step was set to 10^{-4} s.

FIG 3 Shows the validation of the numerical model in terms of C_A, input coefficients, C_T, toque coefficient against ϕ, flow coefficient. According to the data, the model is considered reliable to continue the analysis.

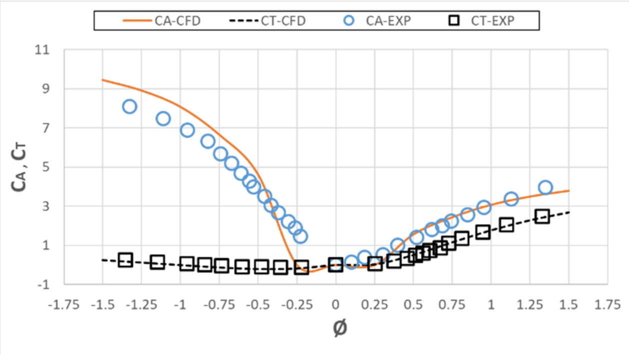

FIG 3. Validation of the CFD model. Exp data from [7].

RESULTS AND DISCUSSION

In this type of machines is of the foremost importance to have a clear unbalanced situation in terms of C_A between direct mode (ϕ>0) and reverse mode (ϕ<0). Since this is the key for the performance as a flow preventer. It can be seen in FIG 3 that this requirement is fulfilled.

Nevertheless, the more unbalanced the situation, the better. Thus, analyzing the flow pattern within the machine in order to know the loss generation mechanisms is critical. Next figures, FIGs 4 and 5, show the loss distribution along the machine. Dividing the domain in four parts following the flow in each direction, including also the kinetic energy loss at the outlet.

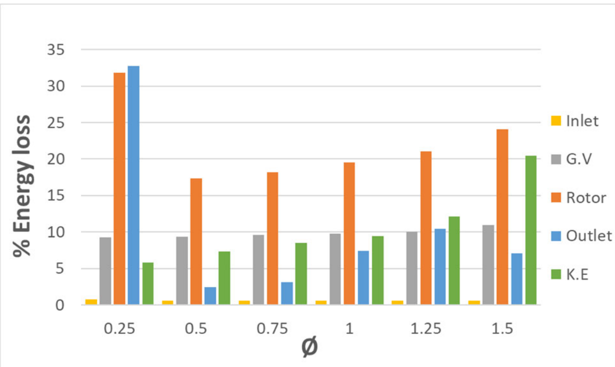

FIG 4. Loss distribution in Direct Mode.

In FIG 4, for direct mode, it can be identified that the rotor is the main source of loss, generated mainly as incidence losses for low flow coefficients and friction for larger ones. It is very important to underline the kinetic energy loss which can be avoided by using a diffuser.

In reverse mode, where large losses are desired, it is seen that the rotor and the GV concentrated most of the loss. Nevertheless, some changes should be done to maximize the loss in the GV.

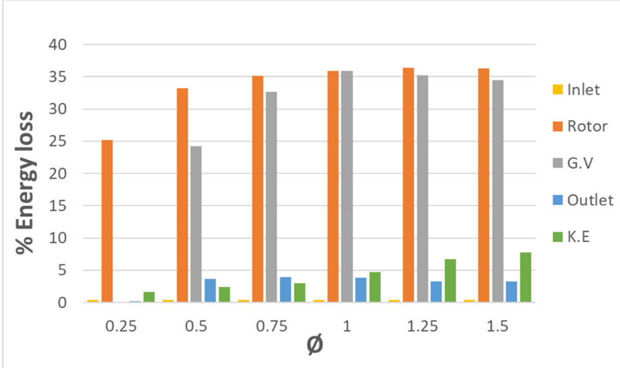

FIG 5. Loss distribution in Reverse Mode.

CONCLUSIONS

A numerical model for an axial impulse turbine has been validated. This has been used to analyze the loss distribution inside the machine, giving information about what improvements could be done. This numerical model will be used in the future to carry out and optimization process.

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