

## **Darrieus turbine modellings Comparisons with performance measurements and PIV fields**

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Darrieus marine turbines are subjected to large variations of relative velocity on the blades both in amplitude and direction during rotation. As a result, the incidence of the relative speed of the incoming flow on the blade can exceed by far the static stall angle, in which case a major unsteady phenomenon, known as "dynamic stall", may occur. It is characterized by the shedding of large vortical structures impacting the mean and dynamic load as well as the turbine efficiency.

In this paper, the ability of a RANS modelling to address the complex flow field of a Darrieus turbine is examined. The considered turbine is the A-12 small scale marine turbine model developed at LEGI. It is a three bladed model inspired by the Darrieus turbine (Fig. 1). The specificity of the turbine is a special design of the arms linking the blades to the rotor which limits the induced drag and the hydrodynamic interactions with the blade. The turbine diameter and height are 175 mm. The chord of the blades defined as the length of the curved midline is  $c = 32.08$  mm, leading to a solidity  $\sigma = 1.1$  which corresponds to the best efficiency according to Shiono et al. [1]. The blade profile is a NACA0018 foil section projected on the rotation circle. The corresponding blade camber is 4.6%. The incident flow velocity  $U_\infty$  is 2.8 m.s<sup>-1</sup> resulting in a Reynolds number based on the diameter of the turbine  $Re_D = 4.9 \times 10^5$ . The blade Reynolds number  $Re_c$ , based on the chord length, depends on the operating condition investigated in this paper and is on the order of  $2 \times 10^5$ .

The LEGI water tunnel [2] used for testing the turbine model. It is a closed loop with a water capacity of 36 m<sup>3</sup>. A motor pump of 165 kW with variable speed allows a flow rate up to 500 L.s<sup>-1</sup>. The flow rate is measured by a turbine flow meter with an accuracy of  $\pm 0.5\%$ . The test section used for marine turbine experiments is shown in Fig. 2. It has a cross section of 0.70 x 0.25 m with a length of 1 m. Maximum speed in the test section is 2.8 m.s<sup>-1</sup>. A force balance mounted on the top of the test section allows measuring the instantaneous torque and the forces exerting on the turbine. Three transparent PMMA (Polymethyl Methacrylate) windows on the bottom and on the two sides allow ample optical access for visualization and PIV measurements [3]. The turbulence level has been measured in the water tunnel equipped with another test section by Franc and Michel [4] and is very low (typically smaller than 2‰) thanks to honeycombs and elbows equipped with guiding blades.

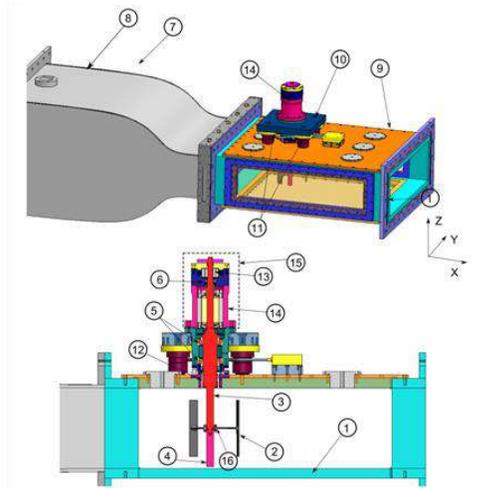
A fully turbulent model and a transitioning model are used to study the possible occurrence of a partially laminar boundary layer developing along the blades at moderate Reynolds number aforementioned. The wall grid refinement sensitivity ( $y^+$ ) has been precisely studied in a previous study [5]. The performances obtained with the 2 models are compared to those obtained experimentally with the balance. In addition the ability of computations to capture the dynamic stall is investigated using two dimensions - two components (2D-2C) and two dimensions - three components (2D-3C) Particle Image Velocimetry (PIV) (fig.3). The vortex shedding mechanism is described in detail on the basis of measured velocity and vorticity fields for different values of the tip speed ratio which strongly influences dynamic stall.

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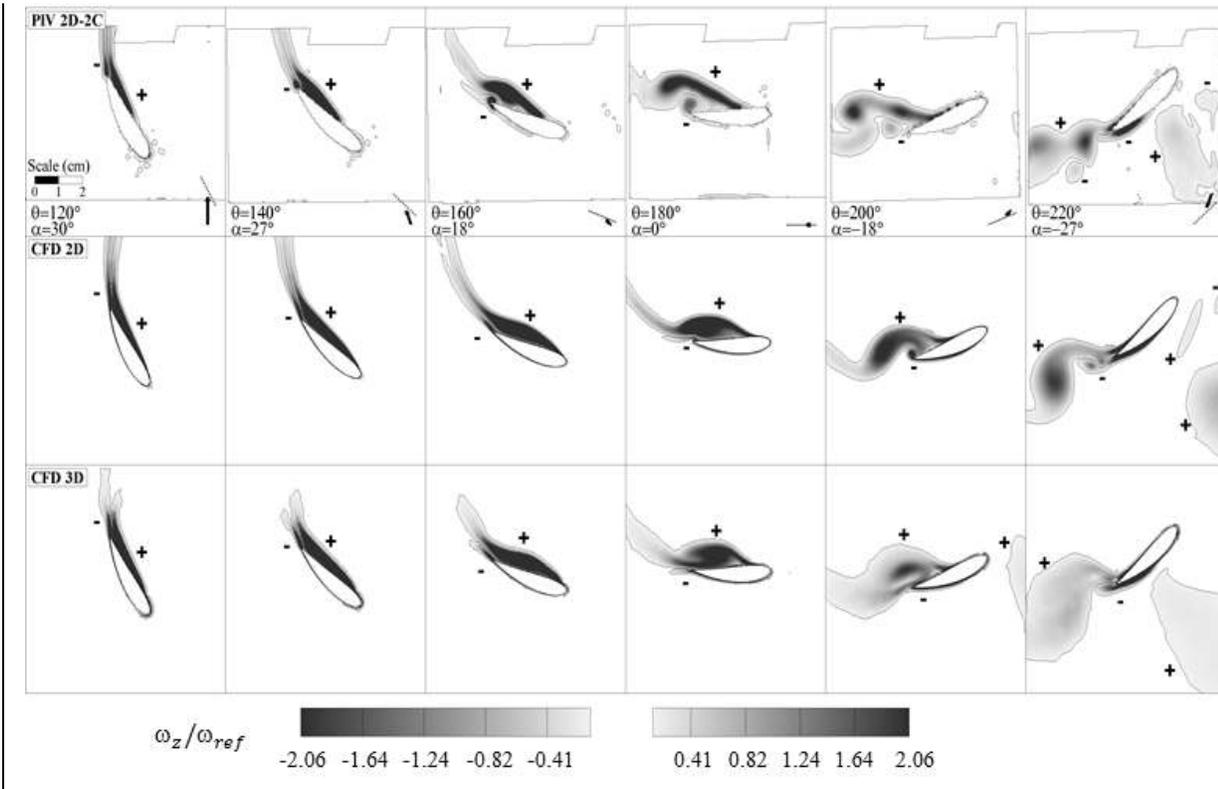
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**Fig. 1** Achard<sup>®</sup> marine turbine



**Fig. 2.** Views of the experimental setup.



**Fig. 3.** Comparison of the normalized vorticity fields between 2D-2C PIV measurements, 2D and 3D computations, for  $\lambda = 2$ , at  $\theta=120^\circ$  to  $220^\circ$

*References:*

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