A Synthetic turbulence model for numerical simulation of marine current turbine

Clément Carlier[1,2], Grégory Pinon[1,*], Benoît Gaurier[2], Grégory Germain[2], Elie Rivoalen[3]
[1]*Laboratoire Ondes et Milieux Complexes (LOMC), UMR 6294, CNRS - Université du Havre, France*
[2]*IFREMER, Marine Structures Laboratory, Boulogne-Sur-Mer, France*
[3]*Laboratoire d'Optimisation et Fiabilité en Mécanique des Structures, INSA de Rouen, France*

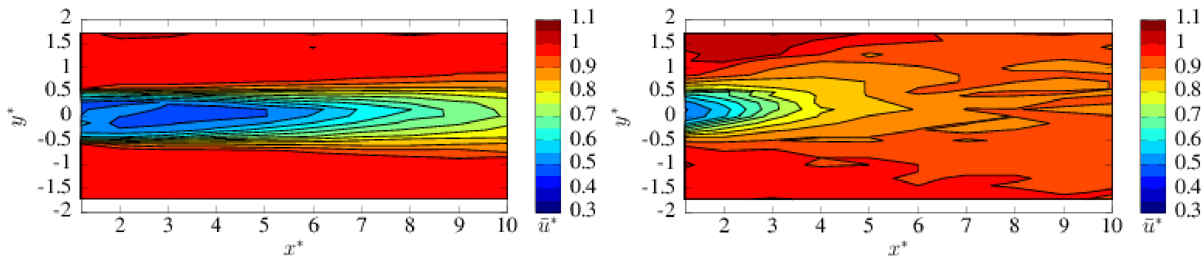
Summary: The ambient turbulence intensity is a key factor in the study of marine current turbines. Indeed recent studies have shown that ambient turbulence intensity highly modifies the behavior of horizontal axis marine current turbines. Consequently numerical simulations have to represent the ambient turbulence or at least its effects on the performance and wake of the turbines. This paper presents the latest numerical developments carried out at LOMC in collaboration with IFREMER in order to take into account the effects of ambient turbulence.

Introduction

The recent experimental trials run at the IFREMER flume tank of Boulogne-Sur-Mer, France, have shown that ambient turbulence intensity I_∞ (eq. (1)) highly modifies the behavior of horizontal axis marine current turbines [1,2].

$$I_\infty = 100\sqrt{\frac{\frac{1}{3}\left[\sigma^2(u_\infty)+\sigma^2(v_\infty)+\sigma^2(w_\infty)\right]}{\bar{u}_\infty^2+\bar{v}_\infty^2+\bar{w}_\infty^2}} \qquad (1)$$

One of the most noticeable influence can be observed in the wake, downstream of the turbine. Indeed as shown in Fig. 1 the higher the turbulence intensity is, the faster the wake effects decrease. Moreover the interactions between turbines are also highly modified by the effect of the turbulence intensity as shown by Mycek et *al.* [2] for interactions between two turbines.



(a) I_∞ = 3% (b) I_∞ = 15%

Fig. 1. Wake behind a turbine with TSR=3.67, U_∞=0.8 m.s^{-1} for different turbulence intensities I_∞.

In order to take into account the effect of the ambient turbulence in our numerical simulations, a new module have been integrated in the three-dimensional software developed at LOMC [3].

Methods

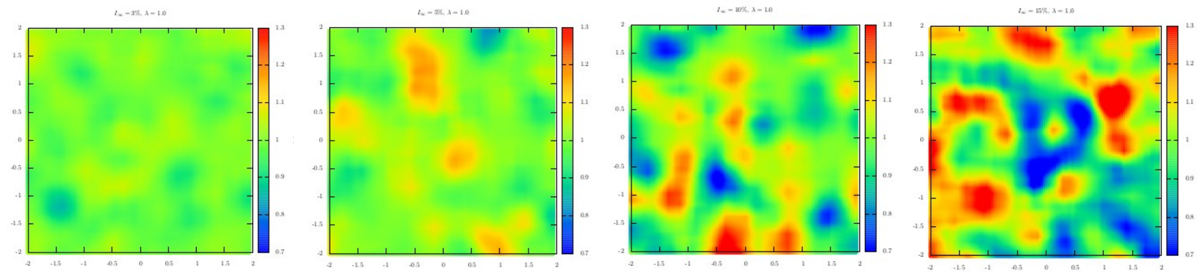
The software developed at LOMC is based on an unsteady Lagrangian method: the Vortex method [4], a velocity-vorticity numerical implementation of the Navier-Stockes equations. In this method the turbines are represented using a panel method and the flow is discretised with vorticity-carrying particles emitted at the trailing edge of the turbines blades.

* Corresponding author. *Email address*: gregory.pinon@univ-lehavre.fr

In order to represent the ambient turbulence effects in our three-dimensional software the Synthetic-Eddy-Method [5] was chosen. Togneri *et al.* [6] already adapted this model to their BEMT code for tidal turbines. The Synthetic-Eddy-Method generates a flow with a given turbulence intensity I_∞ and a given anisotropic ratio $(\sigma_u : \sigma_v : \sigma_w)$ by adding a perturbation term to the upstream velocity of the flow U_∞. This perturbation term is calculated as the influence of N generated "turbulent structures" randomly dispatched in the study space. In our software the "turbulent structures" are advected using the upstream velocity U_∞ and for each structure leaving the study space a new one is generated on the inlet.

Results

Figure 2 display preliminary results obtained with the Synthetic-Eddy-Method. It shows example of perturbed flow-field generated with the model for the same anisotropic ratio ($\sigma_u : \sigma_v : \sigma_w$) and different turbulence intensities I_∞.



(a) $I_\infty = 3\%$ (a) $I_\infty = 5\%$ (a) $I_\infty = 10\%$ (a) $I_\infty = 15\%$

Fig. 2. Example of velocity field provided by the ambient turbulence model for different value of I_∞.

Conclusions and Further Works

A new module was added to our three-dimensional software to represent the ambient turbulence and its effects on the behavior of marine current turbines. The next step in this work is to use this ambient turbulence model with one marine current turbine and confront the numerical results obtained with experimental data [1] for $I_\infty = 3$ and 15%. The final goal of this study is to simulated an entire farm of marine current turbines for any turbulent intensity.

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