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WAKE SIMULATION OF A MARINE PROPELLER

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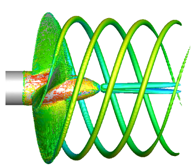
The prediction of fluid dynamic interaction between propellers and the hull is very important for the improvement of ship performance. It is being directly related to vibrations, noise and propulsion performances. In this context, the demand for the improvement of performances implies a rising interest in the development and application of detailed numerical and experimental tools. The physical mechanisms that characterize the interaction between the propeller and the hull are very complex. But, even if one limits ourselves to the study of the simpler case of an isolated propeller in a uniform flow, called open water conditions, one is confronted with severe numerical and physical challenges. A comprehensive description of the state of the art can be found in Felli et al. [1], who experimentally investigated the flow around a propeller in a water channel.

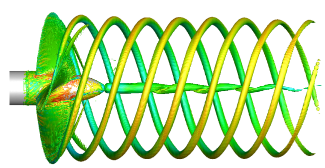
The flow past a propeller model is analyzed with the aim of establishing limits and capabilities of different turbulence modeling approaches. First, two classical RANSE turbulence closures, namely Menter k-ω SST and EARSM models, are used. Then, a DES approach based on the k-ω model is employed to complete the analysis. These models are used with the ISIS-CFD unstructured finite-volume solver.

The propeller geometry is the INSEAN E779A model, i.e. a four blade, fixed-pitch, right-handed propeller characterized by a nominally constant pitch distribution and a very low skew. In this paper, the rotational speed of the propeller is kept fixed to a value of $n = 25$ rps and the different advance coefficients $J = U_\infty/nD$ are obtained by changing the inflow velocity U_∞. The Reynolds number Re $= 1.78\times10^6$ is based on radius of the propeller ($L_{ref} = 0.1135$ m) and the velocity of the tips of the blades ($U_{ref} = n\pi D \simeq 17.829$ m/s).

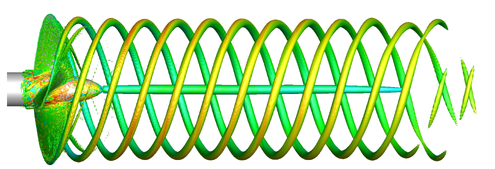
One starts the study by assessing the global open water characteristics of the model. Several numerical results for different values of the advance coefficient J are compared to the experimental data. Concerning the thrust and the torque, the predictions obtained with the different approaches differ by less than 5% for the low values of the advance coefficient and by less than 3% for the high value of J. It can be concluded that, from the point of view of global quantities estimation, there seems be no justification in using a more accurate turbulence model. However, it is crucial to evaluate the ability of the computational model to create and convect far enough the vortical structures which are associated with a propeller flow. A general overview of the wake of the propeller is given in figure 1 which presents the surface of the non-dimensional value λ_2 = -2 of the second largest invariant of $\mathbf{S}^2 + \mathbf{\Omega}^2$ ($\mathbf{S}$ and $\mathbf{\Omega}$ being the symmetric and antisymmetric component of $\nabla\mathbf{u}$). This figure shows steady results obtained with two RANSE models (k-ω SST and EARSM) and a flow field obtained by averaging instantaneous fields coming from unsteady DES computations, all computed on the same grid. RANSE models yield tip vortices but they vanish more or less rapidly in the wake according to the turbulence model used and the level of anisotropy associated. With DES approach, the tip vortices are maintained much further in the wake. These differences are caused by too high a level of turbulent kinetic energy associated with RANSE turbulence models, even in the wake of the hub.



(a) k-ω SST



(b) EARSM



(c) DES SST

Figure 1: Vortical structures visualizations for J = 0.71 (λ_2 = -2)

In the final paper, several advance coefficients will be investigated.

REFERENCES

[1] M. Felli, R. Camussi and F. Di Felice. Mechanismes of evolution of the propeller wake in the transition and far fields. *J. Fluid Mech.*, Vol. **682**, 5–53, 2011.