Verification and Validation study of OpenFOAM on the Generic Prismatic Planing Hull

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ABSTRACT

Recent advances in modeling complex hydrodynamic phenomena using Computational Fluid Dynamic (CFD) are leading to a radical transformation in the naval hydrodynamic field. and are considered a mature tool for design and optimization purposes. In case of planning crafts, the free surface flow regime changes completely with respect to displacement hulls. The free waves patterns loose importance while the accurate estimation of the dynamic pressure distribution on the hull due to a water entry like flow becomes essential. In fact, the dynamic equilibrium of the vessel is primarily influenced by the dynamic forces acting on the hull (mostly dynamic lift and not buoyancy) which in turn depends on the (dynamic) wetted area of the planning craft. The running attitude of planning craft strongly depends on the flow field resolution in regions interested by jet spray formations (spray root line) and at the chine and transom where flow separation occurs. Validation and Verification (V&V) studies for high speed planing crafts are very less in comparison with larger displacement hull forms and often lack of high quality experimental reference data. This paper summarizes numerical results obtained using OpenFOAM for performing CFD simulations on a new set of high quality experimental tests performed on a large model, high deadrise prismatic planing hull, tested in a wide range of Froude numbers (see [1]). One of the most relevant intricacies in the fluid dynamic predictions around planning hulls is the correct modeling of the non-linear free surface dynamics [2]. We approach this problem using the Volume of Fluid technique implemented in OpenFOAM which need no boundary condition at the free surface and it has shown the ability to simulate complex free surface flow patterns, such as overturning waves, as well as jet spray detaching from the chine of the planning craft. The solution of the transport equation for the VoF in case of violent surface flows is very dependent on the mesh quality. Typical problems noted by different researchers[3] are numerical (non-physical) diffusion of air under the hull. Techniques to obtain high-quality unstructured meshes, specifically conceived to increase the mesh resolution close to the spray region are discussed in the paper. Practical indication of the level of uncertainty of CFD models for the prediction of the calm water hydrodynamics of the GPPH is given in the conclusion and overall accuracy well compares with the state of the art for displacement hull forms.

References

[1] Weil C.R. Lee E. and Fullerton A. Experimental results for the calm water resistance of the generic prismatic planing hull (gpph). Technical report.

[2] R. Broglia and D. Durante. Accurate prediction of complex free surface flow around a high speed craft using a single-phase level set method. *Computational Mechanics*, 62:421–437, September 2018.

[3] Gaggero S. Ferrando M. and Villa D. Open source computations of planing hull resistance. *Transactions of the Royal Institution of Naval Architects Part B: International Journal of Small Craft Technology*, 157:83–98, 2015.