Ventilation Inception and Growth of Surface-Piercing Super-Cavitating Hydrofoils.

A fundamental study by CFD simulations

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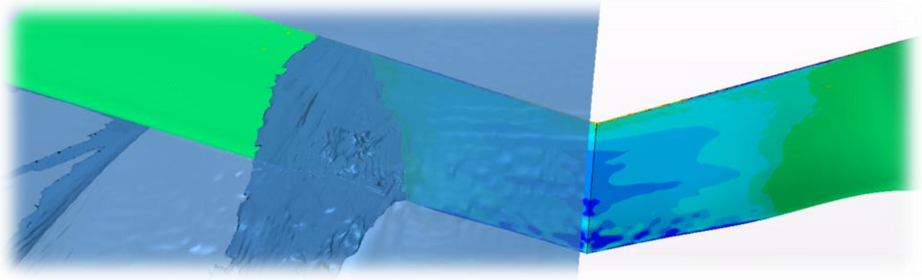

ABSTRACT

We address the physics of a complicated, not fully unveiled yet, multiphase flow problem by numerical simulations: the ventilation inception and growth of surface piercing (SP) hydrofoils. Understanding the mechanisms of ventilation [1] is essential for the design of different types of high-speed marine crafts, which increasingly use shallow-submerged or surface-piercing lifting surfaces to improve their resistance and seakeeping performances at sea. An emblematic example being the most recent America's cup hydrofoil supported class of sailing catamarans (AC72/AC45).

Early experiments of Swales et al. [2] highlighted three different mechanisms for ventilation occurring on vertical surface piercing struts with different section shapes (blunt, sharp and rounded nose): separation bubble near the tail, near the nose or full separation at high angles of attack or for blunt bodies. Inception happens quite abruptly at critical speed, once the air finds its way and breach through a thin unseparated (energetic) flow stream that seals the low energetic (separated) flow region on the hydrofoil from the free surface. Ventilation is initially very unstable and in some cases it shows undulations, similar to Taylor instabilities, in the internal ventilated free surface.

This proposed work concerns the analysis of a surface-piercing 20deg dihedral V-shaped hydrofoil, designed to work in the stern of an innovative planing craft [3] for very high speeds (50-70 knots). The hydrofoil has been optimized by a new lifting line theory, modified to account for ventilation and free surface effects and features a new kind of super-cavitating (SC) section with improved hydrodynamic performance at both fully ventilated and fully wet regimes [4]. We will show that multi-phase (air/vapor/water) DNS simulations are able to accurately capture and follow the physics of ventilation inception, growth and interaction with cavitation as a function of the angle of attack and speed. Many of the phenomena noted in the experimental work by the referenced authors are found also in the numerical simulations, although with different phenomena, due to the different flow pattern occurring in the super-cavitating hydrofoil. Adequate mesh resolutions seem to indicate the resolution of Taylor-like instabilities at the free surface noted in the experiments. The discussion includes the particular setup of the numerical and physical models, in terms of convergence with grid resolution, special temporal discretization schemes and volume of fluid scheme to treat the three-phase flow with sharp interface.

References

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