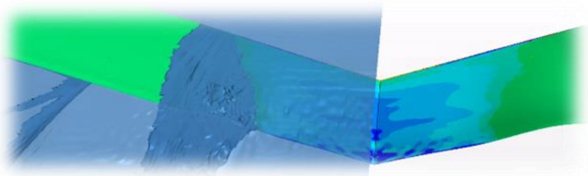
CFD Investigation of Ventilation-Cavitation Coupling on Surface-Piercing Super-Cavitating Hydrofoils

Stefano Brizzolara*

* iShip lab., Department of Aerospace and Ocean Engineering
Virginia Tech, Blacksburg, VA, 24061, USA
e-mail: stebriz@vt.edu, web page: http://www.cimne.com

ABSTRACT

The physics of ventilation inception and growth on surface piercing (SP) hydrofoils is still not completely understood. Predicting ventilation [1] mechanisms is essential in the design of modern high performance high-speed marine crafts, more and more equipped with shallow-submerged or surface-piercing hydrofoils to improve resistance and seakeeping performances.



Early experiments of Swales et al. [2] and more recently [3] 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.

The paper summarize results of numerical study on a surface-piercing 20deg dihedral V-shaped hydrofoil, designed to work in the stern of an innovative planing craft [4] at very high speeds (50-70 knots), i.e. in partially or super-cavitating (ventilated) conditions. The hydrofoil has been optimized by a new non-linear lifting line theory [5], 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 [6], in order to ensure good lift over drag ratio in both flow regimes.

Multi-phase (air/vapor/water) URANSE simulations seem to adequately 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 referenced work are found also in the numerical simulations, manifesting different interactions due to the different flow pattern triggered by the particular shape of 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 setup of the numerical and physical models, grid convergence study, effect of temporal discretization schemes and volume of fluid schemes adapted to adequately follow the sharp interface of the three-phase flow.

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