A Synergetic Design Study of a Passenger-Hydrofoil Flapped Surface: Experimental and Computational Fluid Dynamics, Optimization, and Control

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ABSTRACT

A synergetic design study of a flapped surface for a passenger hydrofoil is presented. The concept is presented in Fig. 1a. The fore foil is attached to the hull by a single strut that embeds a vertical rudder. The fore foil has two independent flaps for the motion stabilization. The aft foil is attached by means of three vertical struts (equipped with independent rudder). The aft foil has two lateral and two central flaps. Experimental and computational fluid dynamics (EFD, CFD) are used to assess the design performance, which is optimized for maximum lift, minimum drag, and maneuverability/stability during take-off/turning via shape design and control.

EFD collects data for hydrodynamic characterization and CFD validation of the forward fully-submerged inverted T-foil (Fig. 1a,b). An in-house Finite Volume method is used for unsteady Reynolds-averaged Navier-Stokes equations calculations, exploiting overset grids capabilities and using the Spalart-Allmaras turbulence model. The free surface is taken into account through a single-phase level set algorithm. The agreement with the EFD data (Fig. 1b) indicates reliable predictions and suitability for simulation-based design optimization and control (by accurate definition of hydrodynamic coefficients). The shape design of the foil sections is achieved through optimization, combining automatic shape/grid modification, adaptive multi-fidelity metamodeling, and multi-objective optimization algorithms for maximum lift and minimum drag. Finally, flaps and rudders are commanded to stabilize roll and pitch motions, as well as steering the vessel during the desired maneuvers (see example in Fig. 1c).

The full paper will include a description of the design concept and operating conditions, associated decision-making problem, CFD (including validation based on EFD data), optimization, and control methods, along with results and discussion on original versus optimized designs.

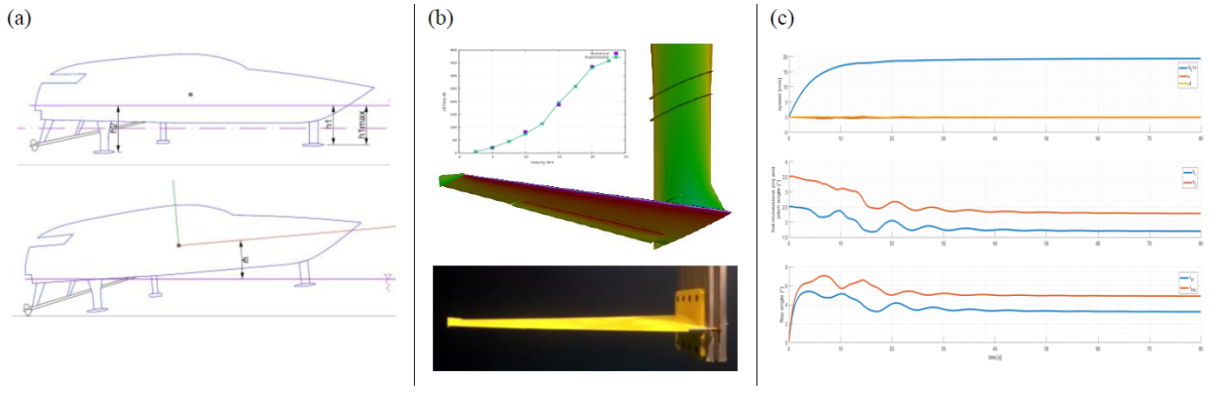

Figure 1: (a) scheme of the vessel at zero-speed and take-off conditions; (b) CFD versus EFD results; (c) speed, immersion of fore and aft foils, commanded angle of fore and aft central flaps for pitch control during combined take-off and turning maneuver.