# Standardized Workflow For CFD Planing Hull Modelling
# X International Conference on Computational Methods in Marine Engineering

# MARINE 2023

**E. Begovic[1*], C. Bertorello[1], R. Ponzini[2] and F. Salvadore[3]**

[1] University of Naples Federico II, Department of Industrial Engineering, Via Claudio 21, 80125 Napoli, Italy. Email: begovic@unina.it, web: http://www.dii.unina.it

[2] CINECA, HPC Department, Milan Office, Via R. Sanzio 4, Segrate, MI, Italy Email: r.ponzini@cineca.it, web: https://www.hpc.cineca.it/

[3] CINECA, HPC Department, Cineca, Rome Office, Via dei Tizii 6/B, Roma, Italy. f.salvadore@cineca.it, web: https://www.hpc.cineca.it/

[*] Corresponding author: Ermina Begovic, begovic@unina.it

## ABSTRACT

This work shows the performances of LincoSim web-platform for high speed hull analyzing the suitability of the platform for a wide Froude number range. The calculations are performed for 1:10 scale model of 43 ft powerboat hull form in Froude number range 0.3 – 2.0. Experimental campaign has been performed at University of Naples Federico II and resistance, sinkage and trim have been measured. A comparison of the obtained hydrodynamic performances versus the experimental ones is performed and differences are discussed. Using the CFD data advanced post-processing, wetted length of keel and chine and wetted surface are obtained Percentage differences between CFD and EFD for whole speed range are: 1.84, 6.87 and 6.94 for resistance, dynamic trim and sinkage, respectively. These results confirm the maturity of standardized and automated CFD modelling for calm water hydrodynamic analysis at very high Froude numbers. This synergic interplay of EFD and CFD can link the advantages of both methods to support- hull design but also experiments planning and final data analysis to obtain physical parameters not easily measurable in laboratory such as wetted surface, wetted lengths, proper viscous contribution, pressure distribution.

**Keywords:** planing hull hydrodynamics; LincoSim; Computational Fluid Dynamics (CFD); Experimental Fluid Dynamics (EFD); High Performance Computing (HPC).

## NOMENCLATURE

| | |
|---|---|
| $B_C$ | Beam at chine [m] |
| $B_{OA}$ | Beam over all [m] |
| $Fr$ | length based Froude number $Fr = \frac{V}{\sqrt{gL}}$ |
| $g$ | Gravity acceleration 9.81 [m s$^{-2}$] |
| $L_C$ | Wetted length at chine [m] |
| $L_K$ | Wetted length at keel [m] |
| $L_{MEAN}$ | Mean dynamic wetted length [m] $L_{MEAN} = \frac{L_C+L_K}{2}$ |
| $L_{SPRAY}$ | Length of the whisker spray exit on chine [m] |
| $L_{WL}$ | Length at waterline [m] |
| $LCG$ | Longitudinal position of the Center of Gravity [m] |
| $m$ | Mass [kg] |
| $r_{44}$ | roll radius of gyration [m] |

$r_{55}$ pitch radius of gyration [m]
$T_{AP}$ Draft at aft perpendicular [m]
$VCG$ Vertical position of the Center of Gravity [m]
$V_M$ Model speed [m s$^{-1}$]
$\rho$ Fluid density [kg m$^{-3}$]
CFD Computational Fluid Dynamics
EFD Experimental Fluid Dynamics

## 1. INTRODUCTION

During last years the Computational Fluid Dynamics (CFD) technique has become a "standard" tool to address calm water resistance prediction and to study complex phenomena such as whisker spray, air trapping, and to identify pressure area and dynamic wetted surface, all characterizing the planing regime of small craft.

Some of the recent papers where the thorough verification and validation against available experimental data have been made are Park et al (2022), Cui et al. (2021a, b), Lee et al. (2021), Judge et al (2020) in which the authors show remarkable reproduction of the experimental data in the numerical towing tank. However, CFD modelling of planing hulls requires expert users to decide on different moving mesh techniques (overset/chimera and morphing grid), turbulence models, domain boundaries, convergence criteria to arrive at numerical set up which will give reliable results. Judge et al (2020) provided the review of the most recent works on high speed planing hulls and for a selected hull in a Froude number range from 1.14 to 2.50 performed calculation of numerical uncertainty of the resistance, trim and sinkage.

In Salvadore and Ponzini (2019) an automatic and web-based application of virtual towing tank, named LincoSim (https://lincosim.cineca.it) specifically designed to perform automatic CFD modelling of hydrodynamic performances in calm water was presented. The tool uses only open-source software and deploys High Performance Computing infrastructures to take advantage of well-established technological bricks. Validation and verification of the Lincosim has been performed in Ponzini et al. (2020) for the planing hull systematic series by Begovic and Bertorello (2012) showing how the same standardized workflow for every hull at every velocity condition was effective. The work shows clearly that if the mesh is topologically standardized then the stopping criteria and the solver setup are coherent, allowing for safe data comparison of different hulls at different flow conditions. In Salvadore et al. (2021) the same approach was tested using a catamaran experimental dataset including hull dynamics, resistance and wave pattern measurements. The main outcome was that the standardized and automated CFD workflow proposed in LincoSim was suitable also for multi-hull studies.

Today, with the increased computational capabilities and cloud computing, the implementation of the automatic CFD modelling concept can be proposed at larger scale. Completely automatic CFD modelling is of particular interest at the design stage for the non-expert CFD users who can be assisted by the platform to obtain a reliable results and correct trends of hydrodynamic properties in calm water when considering hull form modifications and optimization. As it was noted by Gatin et al. (2019) "*The main reason why CFD is not being applied widely in the marine industry is the cost of conducting accurate and reliable calculations, which is a consequence of high complexity of the method*." One of the greatest advantage of the "automatic CFD modelling" philosophy is the objectiveness of the comparative results, i.e. using a high fidelity tool which will, in the exactly same way, calculate hydrodynamic performances for different hull modifications, guarantees that the obtained results are consistent from the physical point of view in the same way as model testing and not influenced by modified numerical set-up. The common designer practice of using low fidelity methods based on Savitsky method (1964), on regression analysis or Artificial Neural Networks (ANN) reported in Radojcic (2019) is extremely fast but the assumptions of the mathematical model such as prismatic hull form (constant deadrise angle along the hull), pure planing condition and finally solution only for pitch and resistance are limiting when exploring small modification of hull form and in wide range of velocities. Using data from the existing systematic series (Keuning and Geritsma (1982, 1993, 2017a, b), USCG Series by Kowalyshyn and Metcalf (2006), Taunton et al. (2011), Begovic and Bertorello (2012), De Luca and Pensa

(2017)) is reliable solution but within the range of parameters covered by the systematic variation.
This work shows the performances of the LincoSim web-platform for high speed hull analysing the suitability of the platform for a wide Froude number range and discusses what could be the next future of the open libraries for the non-expert CFD user.

The calculations are performed for the 1:10 scale model of 43 ft hull form in the Froude number range 0.5 – 2.0. The hull form is the one studied in Bertorello and Olivieri (2009), Fossati et al. (2013), and Begovic et al (2016). New tests have been performed at University of Naples Federico II and resistance, sinkage and trim have been measured. A comparison of the obtained hydrodynamic performances against the experimental ones, is discussed and connected to the automatic CFD model definition at different speed regimes in solver set up. Also, thanks to CFD data advanced post-processing, the values of the wetted length on keel and chine are obtained to have correct prediction of the full scale resistance, as well as pressure distribution along the hull are given, showing possible design applications. Further ongoing and possible developments of LincoSim are discussed.

## 2. LincoSim WEB PLATFORM

The web application named LincoSim, firstly developed in 2018 for the Horizon 2020 project LINCOLN (http://www.lincolnproject.eu/) has been refactorized and updated today to support early design analyses within the Horizon 2020 e-SHyIPS (https://e-shyips.com/). The e-SHyIPS project aims to define the new guidelines for an effective introduction of hydrogen in maritime passenger transport sector and to boost its adoption within the global and EU strategies for a clean and sustainable environment, towards the accomplishment of a zero-emission navigation scenario. With respect to the functionalities included into the LincoSim web application as available at the end of the LINCOLN project, several new functionalities have emerged as requirements to face the specific activities related to the e-SHyIPS project. The reason behind the necessity of adding new functionalities is strictly related to the signature of the e-SHyIPS project: the presence of H2 based propulsion systems. In particular, at the original stage LincoSim allowed to perform calm water analysis while new functionalities will support also sea keeping analysis thus including the presence of regular waves. If, in extreme synthesis LincoSim was a suitable tool to obtain calm water data form 3D RANS CFD standardized and automated simulation for a given hull shape, the evolution contains also new functionalities such as hydrostatic analysis, stability analysis, wave hull interaction. These novel tools open the possibility to perform numbers of early design evaluations that are fully coherent to other more computationally expensive activities related to calm water and seakeeping simulations avoiding any possible input-related misleading submission. Also, the availability of necessary evaluation tools within a single environment is a relevant value for the end user learning curve and long-term usability.

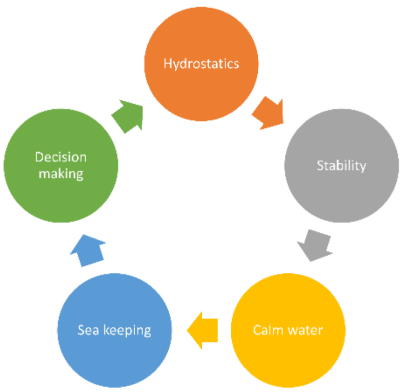


**Figure 1.** Design flow chart: iterative decision-making loop.

In fact, as represented in Figure 1, from the designer point of view, after a suitable configuration in terms of hydrostatic and stability is identified, two main computational tools are necessary to perform calm water and sea-keeping analysis. Both these two tools are required to be designed following the driving criteria of LincoSim web application that are:

- the usage of only open-source codes/libraries,
- the adoption of a High-Performance Computing infrastructure,
- the standardization into a parametric workflow of a suitable ‘way-of-doing’ that fits the typical working activities performed by ship designers avoiding to requires any parameter other than those strictly related to the physics of the case of interest,
- the providing of highly automated data processing and visualization tools necessary to facilitate ship performance ranking and thus allowing for decision making activities.

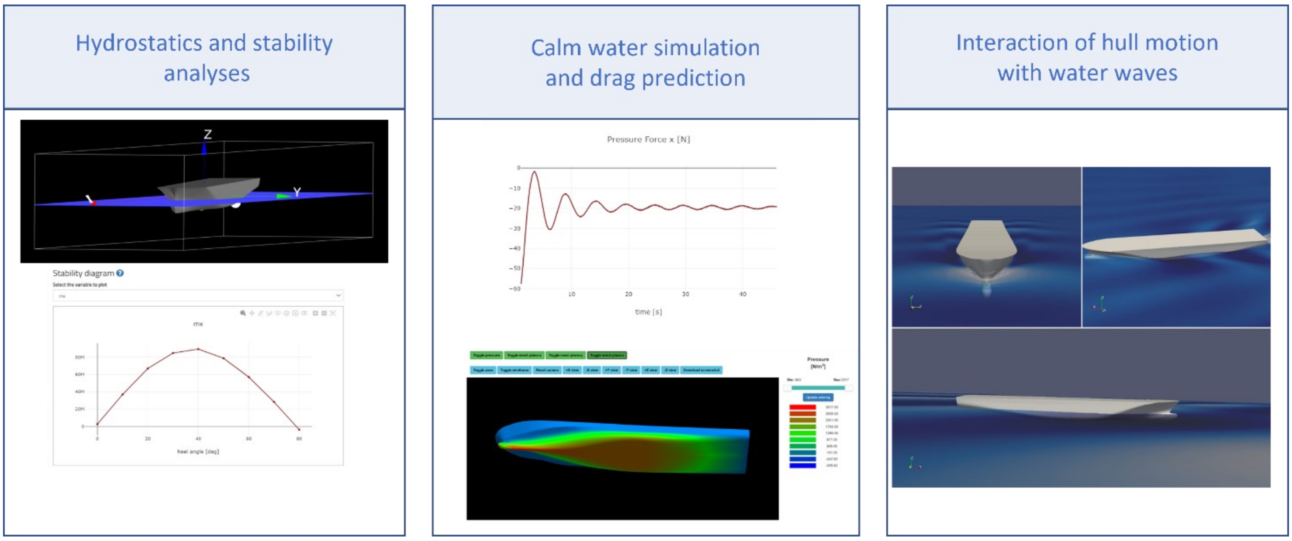


**Figure 2**. Types of simulations included in the Virtual Towing Tank platform: hydrostatic and stability analyses (left), calm-water simulations (middle), seakeeping simulations (right).

In Figure 2 we show the three types of simulations addressable within the LincoSim platform, namely: hydrostatic/stability, calm-water, seakeeping simulations. Seakeeping simulations i.e., wave-hull interaction, present particular automation challenges and their implementation within the LincoSim is still ongoing.

In this work, we are focusing only on calm water analyses. For this reason, from now on we will describe only relevant information about this kind of application. In Figure 3 the schematic representation of Input requirements and of the Output provided by the standardized CFD for calm water analyses is shown. As underlined Input data are related only to physical properties of the hull and no CFD information are requested to start the analysis. This kind of implementation choice is of fundamental interest when a non-expert CFD user is approaching the LincoSim interface for the first time.

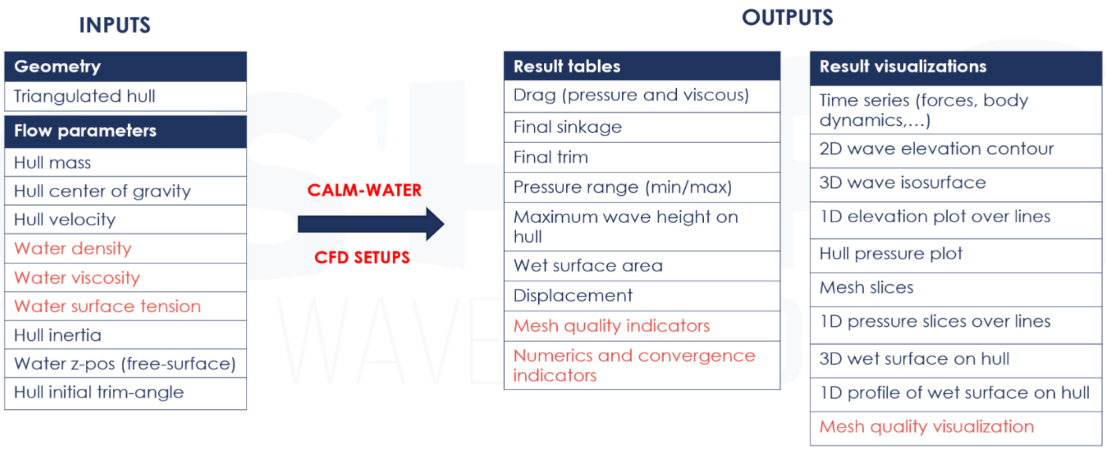


**Figure 3**. Standardized inputs and outputs using LincoSim web application for calm-water simulations (novelties respect to the original implementation are depicted in red).

As explained in Ponzini et al. (2020) and in Salvadore et al. (2021), where all CFD settings and modelling details are discussed, the standardization of the CFD modelling is based on the physics of the problem that defines the computational domain and the mesh cell sizes according to a given standard mesh topology. In Figure 4 the domain sizes and the mesh topology are shown for the P43 hull which characteristics are reported in Table 1.

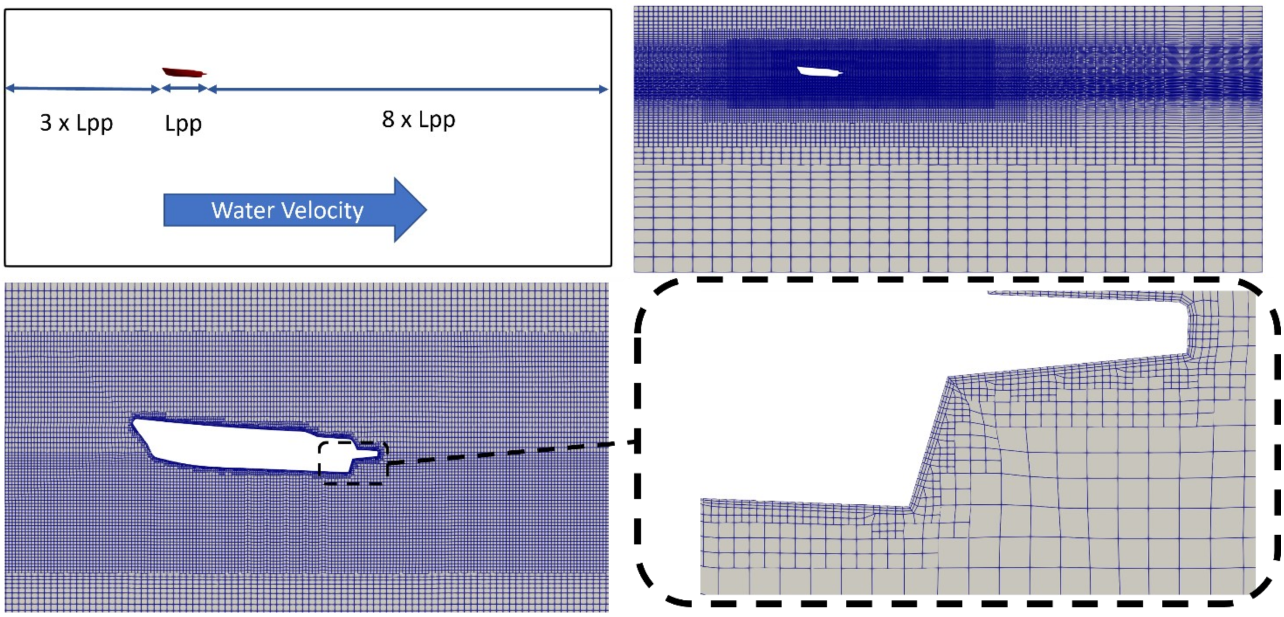


**Figure 4.** Domain extensions and mesh topology for the P43 hull at *Fr* = 1.392.

Notably the proposed approach based on a meshing strategy tailored to satisfy the given mesh topology and requirements for each given velocity, thus adjusting the domain size, the mesh cells size and the boundary layer cells, has never been tested on Froude number greater than 1.7. The Froude number range studied for this application from 0.3 to 2.0 is therefore a new validation, useful to assess the performances of the platform.

## 3. EXPERIMENTAL TESTS OF P43 POWERBOAT

The experimental campaign of the tested model has been performed at the towing tank of University of Naples, Department of Industrial Engineering, whose dimensions are 135x9x4.2 m. The towing carriage speed ranges from 0.1 to 7 m/s. The investigated hull form is non-monohedral deep V hard chine form with transom deadrise angle of 14 degrees up to 45 degrees at the bow. The 1:10 scale GRP built model completed with the deck but without superstructure and appendages was fixed to the carriage by the metallic arm, shown in Figure 5 and towed by a horizontal force applied at the position of 0.278 m from the transom, at the height of 0.08 m above waterline. Model was free to pitch and to move on the vertical axis, but constrained for surge, sway, roll and yaw and drift. Model main characteristics are reported in Table 1.

**Table 1.** Principle data of P43 powerboat model.

| | |
|---|---|
| $L_{WL}$ | 1.090 m |
| $B_C$ | 0.360 |
| $B_{OA}$ | 0.425 |
| $T_{AP}$ | 0.069 m |
| Mass | 11.38 kg |
| Static Trim | 2.32 deg |
| LCG | 0.390 m |
| VCG | 0.118 m |
| $r_{44\text{-}Air}/B_C$ | 0.284 |
| $r_{55}/L_{OA}$ | 0.259 |

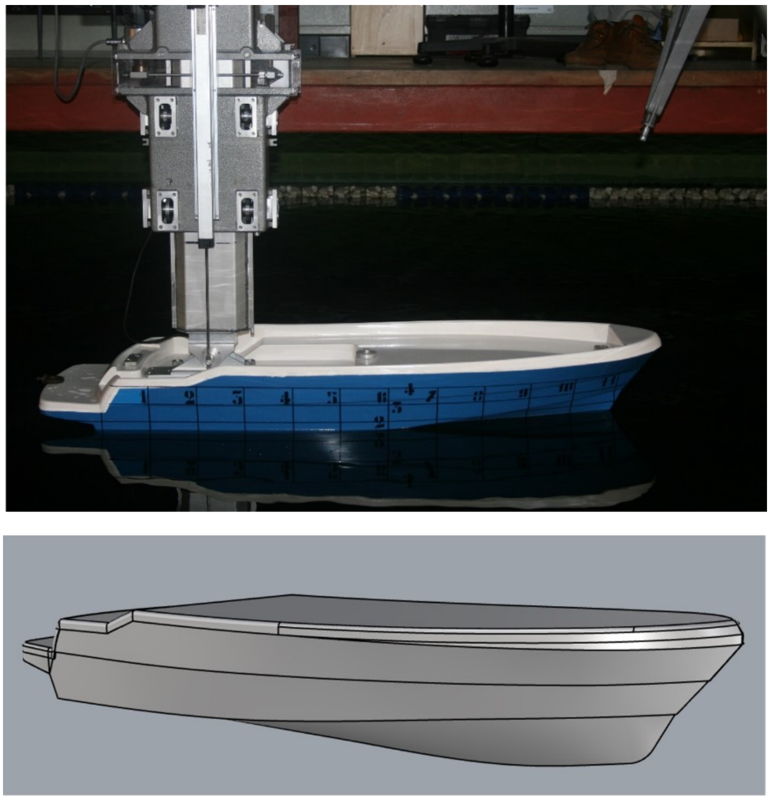

**Figure 5.** Experimental set up and bare hull CAD 3D model.

### 3.1 Experimental Results

Data acquisition is done at sampling frequency of 500 Hz. All experimental results are given in Table 2 as measured with the relative uncertainties.

**Table 2.** Experimental results.

| $V_M$ | $Fr$ | $R_T$ | Running Trim τ | Sinkage | $UA_R$ | $UA_T$ | $UA_S$ |
|---|---|---|---|---|---|---|---|
| (ms-1) | (-) | (N) | (deg) | (mm) | % R | % τ | %S |
| 0.98 | 0.30 | 2.82 | 0.4 | -4.97 | 1.0088 | 1.0050 | 0.1001 |
| 1.30 | 0.40 | 5.75 | 1.14 | -11.62 | 1.0026 | 1.0001 | 0.1094 |
| 1.63 | 0.50 | 12.46 | 3.73 | -21.6 | 1.0009 | 1.0001 | 0.1016 |
| 1.95 | 0.60 | 15.42 | 4.97 | -21.74 | 1.0006 | 1.0000 | 0.1042 |
| 2.28 | 0.70 | 17.04 | 5.40 | -13.84 | 1.0012 | 1.0000 | 0.1292 |
| 2.60 | 0.80 | 19.11 | 6.26 | -9.12 | 1.0009 | 1.0000 | 0.1042 |
| 2.93 | 0.90 | 20.43 | 6.69 | -1.25 | 1.0011 | 1.0000 | 0.4061 |
| 3.25 | 0.99 | 20.14 | 6.45 | 4.91 | 1.0006 | 1.0000 | 0.2141 |
| 3.58 | 1.09 | 19.59 | 5.95 | 13.13 | 1.0004 | 1.0000 | 0.1212 |
| 3.90 | 1.19 | 19.11 | 5.38 | 18.4 | 1.0009 | 1.0000 | 0.1102 |
| 4.23 | 1.29 | 18.94 | 4.81 | 23.6 | 1.0005 | 1.0000 | 0.1108 |
| 4.55 | 1.39 | 18.94 | 4.32 | 24.6 | 1.00216 | 1.0000 | 0.1438 |
| 4.88 | 1.49 | 19.04 | 3.91 | 24.4 | 1.0011 | 1.0000 | 0.1127 |
| 5.20 | 1.59 | 19.56 | 3.57 | 26.4 | 1.0007 | 1.0000 | 0.1200 |
| 5.52 | 1.69 | 20.38 | 3.28 | 28.1 | 1.0011 | 1.0000 | 0.15048 |
| 5.83 | 1.78 | 21.26 | 3.00 | 28.1 | 1.0014 | 1.0001 | 0.13262 |
| 6.16 | 1.89 | 22.16 | 2.83 | 30.2 | 1.0025 | 1.0001 | 0.14545 |
| 6.49 | 1.96 | 23.44 | 2.63 | 31.1 | 1.0032 | 1.0003 | 0.15689 |

## 4. RESULTS COMPARISON

### 4.1 Measured vs calculated results

The most simple analysis of data is the direct comparison of measured total resistance, sinkage and trim. These data have been compared graphically in Figures 6,7 and 8. Experimental uncertainty is around 1% for resistance and dynamic trim and 0.5% for sinkage. The error bars are drawn inside makers of experimental data. It has to be commented that in Fig. 8 the sinkage data calculated by LincoSim for the center of gravity position, has been reported to the measured position, ie. X = 0.278 m from transom. In Figures 9, 10, 11 and 12 examples of data elaboration used for the assessment of wetted surface and wetted length on keel and chine are given. Tabular data of LincoSim is given in Table 3.

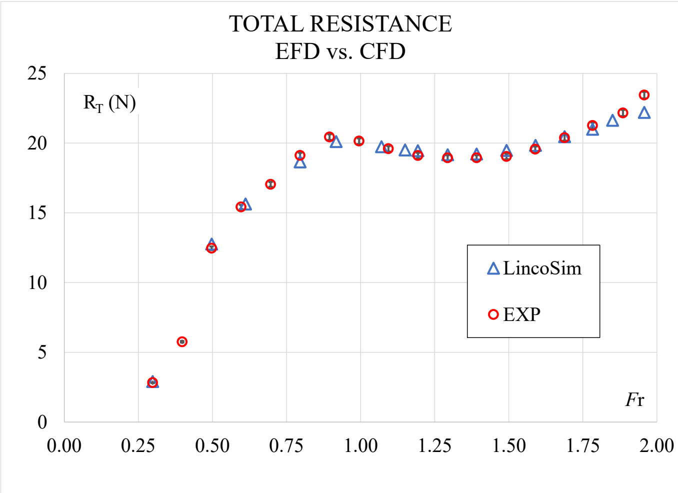


**Figure 6.** Comparison of total resistance experimental and numerical results.

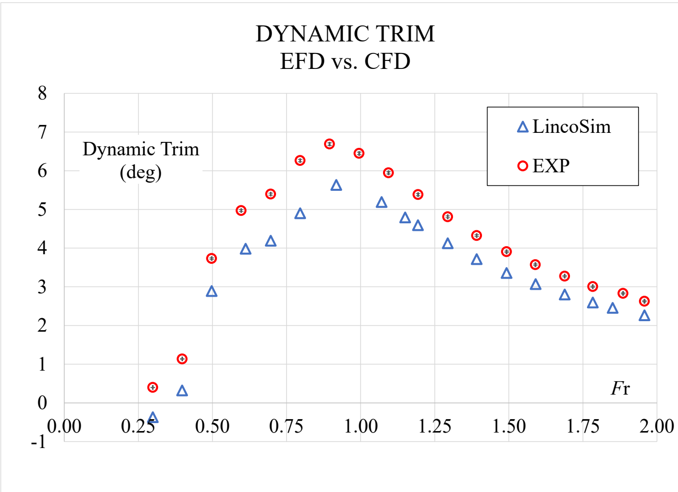


**Figure 7.** Comparison of dynamic trim experimental and numerical results.

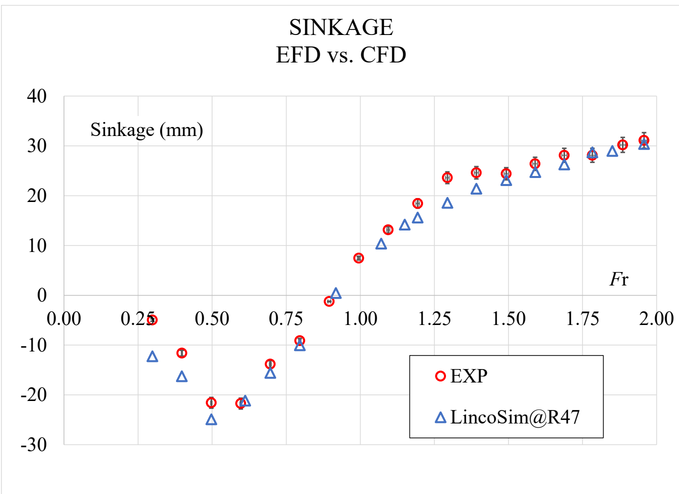


**Figure 8.** Comparison of sinkage experimental and numerical results.

## 4.2 Wetted surface, pressure area and whisker area analysis

Even though the experiments are very reliable for the total resistance measurement, the power prediction of full scale planing boat requires a precise assessment of the dynamic wetted surface. This value is possible to assess from experiment from the underwater photography (example in Judge et al) or using the transparent model bottom. Up to 2006, the majority of the ship-model correlation was based on the simple approach of prismatic (monohedral) hull and Savitsky formula of projected wetted pressure area. If the wetted length on chine and on the keel are known, then the pressure area can be easily determined. In 2006, Savitsky and Morabito (2006) proposed the distinction of the pure pressure area and whisker spray area calculated assuming the angle of separation as double as the angle of pressure area. This concept was discussed and further contribution has been given in Begovic and Bertorello (2012) when it has been shown how this angle of separation of whisker spray area depends on the deadrise angle. Clearly Savitsky and Morabito work is always based on the assumption of the full planing where the walls are completely dry while in Begovic and Bertorello the values are obtained for the Fr range 0.2 -1.5. Even in the case the dynamic wetted surface is photographed as underwater projection or using transparent bottom, the uncertainty of this "measurement" is not often discussed and remains relatively large with respect to other directly measured values, such as resistance, trim and sinkage. For these not easily measurable parameters, the use of CFD is intrinsically advantageous because the pressure and viscous contributions are calculated separately, the wetted lengths and dynamic wetted surface are one of the first results of the calculations and the transfer to ship scale is straight forward.

Therefore the numerical results have been further analyzed, to report the wetted lengths and wetted surface in the whole speed range. The visualization in ParaView© is performed using the free surface 3D obtained with an iso value of 0.5 for the *alpha.water* field and the hull pressure distribution. The numerical values for total drag, sinkage calculated at CG and reported to the measured position are reported in Table 3. Two examples of data elaboration in ParaView, together with the photo from the towing tank at *Fr* = 1.39 and 1.96, are given in Figures 9 and 11. Wave elevation in whole computational domain, for the same *Fr* are given in Figures 10 and 12. The obtained values of dynamic wetted surface are summarized graphically in Figure 13, while wetted lengths on keel, chine and whisker spray on chine are reported in Figure 14.

**Table 3.** Numerical results.

| $V_M$ [ms-1] | *F*r [-] | $R_T$ [N] | sinkage [mm] | Sink@R47 [mm] | pitch [deg] |
|---|---|---|---|---|---|
| 0.976 | 0.30 | 2.902 | 0.106 | -12.25 | -0.368 |
| 1.301 | 0.40 | 5.725 | 0.1034 | -16.26 | 0.321 |
| 1.626 | 0.50 | 12.756 | 0.1 | -24.91 | 2.89 |
| 2 | 0.61 | 15.632 | 0.106 | -21.15 | 3.985 |
| 2.277 | 0.70 | 16.678 | 0.112 | -15.57 | 4.191 |
| 2.602 | 0.80 | 18.648 | 0.119 | -10.03 | 4.901 |
| 3 | 0.92 | 20.104 | 0.131 | 0.46 | 5.633 |
| 3.5 | 1.07 | 19.738 | 0.14 | 10.37 | 5.192 |
| 3.76 | 1.15 | 19.506 | 0.143 | 14.19 | 4.792 |
| 3.902 | 1.19 | 19.452 | 0.144 | 15.60 | 4.592 |
| 4.23 | 1.29 | 19.166 | 0.146 | 18.56 | 4.126 |
| 4.55 | 1.39 | 19.218 | 0.148 | 21.40 | 3.717 |
| 4.88 | 1.49 | 19.47 | 0.149 | 23.13 | 3.358 |
| 5.2 | 1.59 | 19.832 | 0.15 | 24.73 | 3.069 |
| 5.52 | 1.69 | 20.456 | 0.151 | 26.27 | 2.803 |
| 5.83 | 1.78 | 20.992 | 0.153 | 28.70 | 2.595 |
| 6.05 | 1.85 | 21.634 | 0.153 | 28.98 | 2.456 |
| 6.4 | 1.96 | 22.196 | 0.154 | 30.37 | 2.264 |

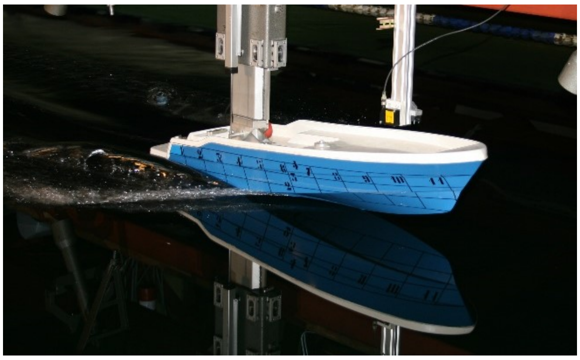

**Figure 9a.** Experimental dynamic wetted surface and wetted length at *Fr* = 1.39.

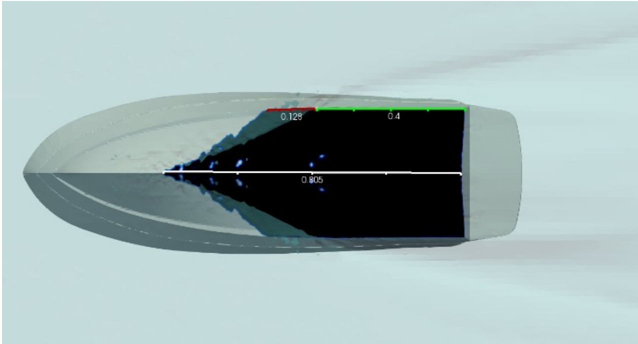

**Figure 9b.** Numerical analysis of dynamic wetted surface and wetted length at *Fr* = 1.39.

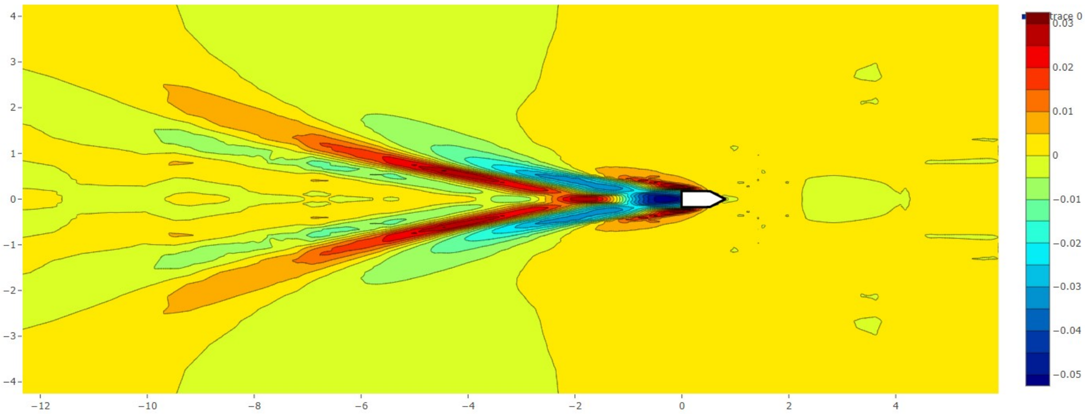


**Figure 10.** Wave elevation at Fr = 1.39.

**Figure 11a.** Experimental dynamic wetted surface and wetted length at *Fr* = 1.96.

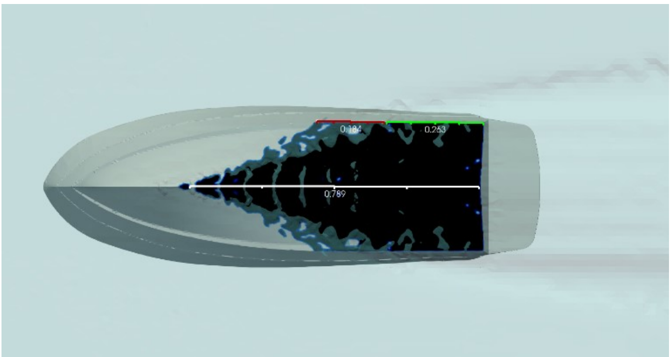

**Figure 11b.** Numerical analysis of dynamic wetted surface and wetted length at *Fr* = 1.96.

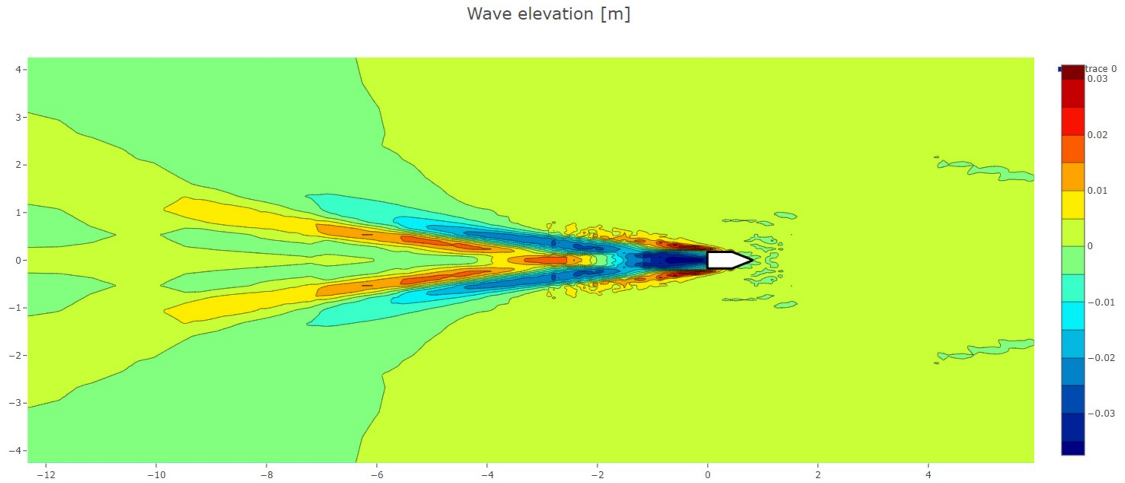


**Figure 12.** Wave elevation at Fr = 1.39.

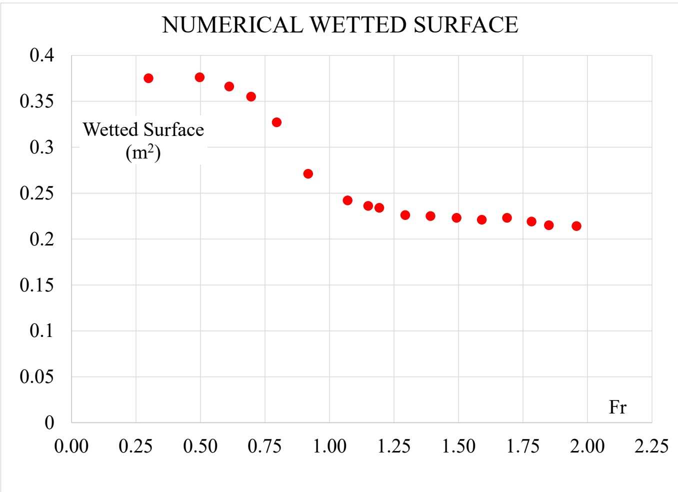


**Figure 13.** Numerical wetted area at different Froude number.

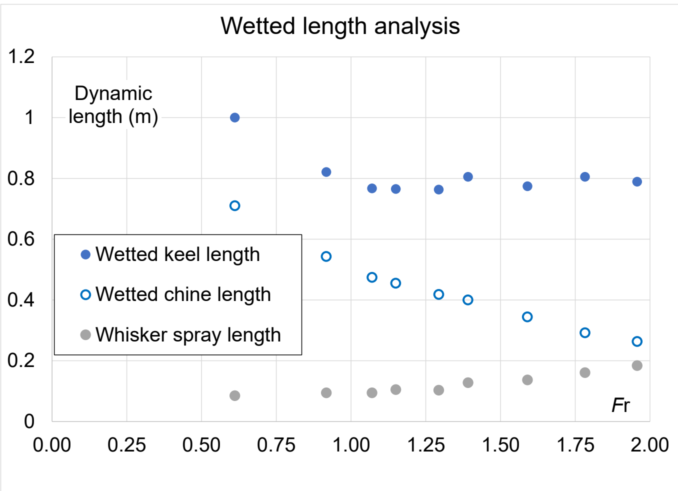


**Figure 14.** Wetted length on chine, on keel and spray length.

## 5. CONCLUSIONS

This paper presented validation of LincoSim platform for model of warped planing powerboat up to the ship velocity of 40 knots. The simulations are performed in the length based Froude number range from 0.3 to 2.0, testing the computational platform over the maximum *Fr* values achieved before. The numerical differences in percentage between CFD and EFD are: 1.84, 6.87 and 6.94 for resistance, dynamic trim and sinkage, respectively. Total drag being an integral value shows the better agreement, sinkage, even if in good agreement as seen in Figure 8, for some points at low Fr shows larger differences. Dynamic trim trends from EFD and CFD are perfectly aligned with constant offset. In absolute values the maximum difference is 0.63 deg at *Fr* = 0.80 where the hull has its maximum trim of 6.2 deg. Different studies underlined CFD sensitivity that small differences in the hull geometry, ballasting conditions, and tow point location can have significant effects on the running trim. From the visual observation of the photos from experiments and analysis of wetted length on chine and spray length on chine, CFD simulations describe accurately the phenomenon what is confirmed by the excellent agreement of total resistance.

These results confirm the maturity of standardized and automated CFD modelling for calm water hydrodynamic analysis at very high Froude numbers. This synergic interplay of EFD and CFD can link the advantages of both methods to support- hull design but also experiments planning and final data analysis to obtain physical parameters not easily measurable in laboratory such as wetted surface, wetted lengths, proper viscous and pressure contributions and pressure distribution

## ACKNOWLEDGEMENTS

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 101007226. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.

## AUTHOR'S CONTRIBUTION

Ermina Begovic: experiments design and elaboration, writing -original draft, review & editing, Formal analysis, data curation, formal analysis. Carlo Bertorello experiments design, writing - review & editing, formal analysis. Raffaele Ponzini: software development, writing - original draft, review and editing, editing, Data curation, Formal analysis, Francesco Salvadore: software development, writing - original draft, review and editing, editing, Data curation, Formal analysis.

## REFERENCES

Begovic, E. and Bertorello, C. (2012). Resistance assessment of warped hullform. Ocean Engineering 56, 28–42. doi:10.1016/j.oceaneng.2012.08.004.

Begovic, E., Bertorello, C., Pennino S., Piscopo V. and Scamardella A. (2016). Statistical analysis of planing hull motions and accelerations in irregular head sea, Ocean Engineering 112 (2016) 253–264 doi.org/10.1016/j.oceaneng.2015.12.012

Bertorello C. and Oliviero L. (2009). Hydrodynamic resistance assessment for not monohedral planing hull form', Vol. 2 pp. 703-707, IMAM 2009 13th International Congress of International Maritime Association of Mediterranean 12-15 October 2009, Istanbul Turkey, 2009

Cui L., Chen Z., Feng Y., Li G. and Liu J. (2021a). An improved VOF method with anti-ventilation techniques for the hydrodynamic assessment of planing hulls-Part 2: Applications. Ocean Engineering 237 (2021) 109505

Cui L., Chen Z., Feng Y., Li G. and Liu J. (2021b). An improved VOF method with anti-ventilation techniques for the hydrodynamic assessment of planing hulls-Part 1: Theory. Ocean Engineering 237 (2021) 109687

Fossati F., Muggiasca S. and Bertorello C. (2013). Aerodynamics Of High Speed Small Craft. FAST 2013 - 12th International Conference on Fast Sea Transportation

Gatin, I., Vukcevic, V. and Jasak, H. (2019). Fully automated CFD analysis for full-scale ship hydrodynamics. In: 4th Hull Performance & Insight Conference. HPIC, Gubbio, 2019.

Keuning J.A. and Geritsma J. (1982). Resistance tests of a series of planing hull forms with 25 degrees deadrise angle. Int Shipbuilding Prog 29 (337)

Keuning J.A. and Hillege L. (2017a). The results of Delft systematic deadrise series. In: Proceedings of 14th international conference on Fast Sea Transportation (FAST 2017), Nantes

Keuning J.A and Hillege L. (2017b). Influence of rocker and twist and the results of the Delft systematic deadrise series. High Speed Marine Vehicles Conference (HSMV 2017), Naples

Keuning J.A, Gerritsma J. and Terwisga P.F. (1993). Resistance Tests of a series planing hull forma with 30° deadrise angle, and a calculation model based on this and similar systematic series. Int Shipbuilding Prog 40(424)

Kowalyshyn D.H. and Metcalf B. (2006). A USCG systematic series of high speed planing hulls. SNAME Trans 114

Lee E.J., Mousaviraad M., Weil C.R., Jiang M.J., Fullerton A.M. and Stern F. (2021). Assessment of experiments and CFD for the semi-planing R/V Athena Model in calm water. Ocean Engineering 236 (2021) 109254

Park S., Wang Z., Stern F., Husser N., Brizzolara S., Morabito M. and Lee E. (2022). Single- and two-phase CFD V&V for high-speed stepped planing hulls. Ocean Engineering 261 (2022) 112047

Ponzini, R., Salvadore, F., Begovic E. and Bertorello C. (2020). Automatic CFD analysis of planing hulls by means of a new web-based application: Usage, experimental data comparison and opportunities, Ocean Engineering 210 (2020) 107387, doi.org/10.1016/j.oceaneng.2020.107387

Radojcic, D. (2019). Reflections on Power Prediction Modeling of Conventional High-Speed Craft. Springer International Publishing. https://doi.org/10.1007/978-3-319-94899-7.

Salvadore, F. and Ponzini, R. (2019). LincoSim: a Web Based HPC-Cloud Platform for Automatic Virtual Towing Tank Analysis. Journal of Grid Computing 17, 771–795. doi:10.1007/s10723-019-09494-y.

Salvadore F., Ponzini R., Duque J.H., Alcántara Reinaldos C. and Mas Soler J. (2021). CFD analysis of a multiplatform catamaran by means of a web-based application: Experimental data comparison for a fully automated analysis process, Applied Ocean Research, Volume 116, 2021, doi: https://doi.org/10.1016/j.apor.2021.102886.

Savitsky D. (1964). Hydrodynamic design of planing hulls. Marine Technology 1(1)

Savitsky D., De Lorme M.F. and Datla R. (2006). Inclusion of "Whisker Spray" Drag in Performance Prediction Method For High-Speed Planing Hulls, Technical Report SIT-DL-06-9-2845, Presented at Meeting of New York Metropolitan Section The SNAME March 14, 2006

Savitsky D. (2012). The effect of bottom warp on the performance of planing hulls. In: SNAME's 3rd Chesapeake Power Boat symposium, Annapolis

Taunton, D.J., Hudson, D.A. and Shenoi, R.A. (2011). Characteristics of a Series of High Speed Hard Chine Planing Hulls - Part I:Performance in Calm Water. International Journal of Small Craft Technology, Vol.153.

E-SHyIPS project web site: https://e-shyips.com/

Lincoln Project web site: http://www.lincolnproject.eu/

LincoSim Web Platform: https://lincosim.cineca.it