WHITE PAPER

How to Improve Hull Designs with Ansys SimAI

In this white paper, we show how Ansys SimAI, the latest generation of generative artificial intelligence (deep learning) applied to 3D physical fields, can be used to improve ship hull designs. First, we build a generic AI model with the SimAI platform, exploiting the full 3D information from computational fluid dynamics (CFD) simulations to assess the performance of new hull designs in a few seconds. A validation is then carried out against CFD results, including volume, surface, evolution curves, and coefficients. Once validated, the AI model is then used to quickly infer new solutions for efficient design iterations.

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/ Decarbonizing the Maritime Sector: All Hands on Deck

In 2018, the International Maritime Organization (IMO) adopted an initial strategy to achieve decarbonization of international shipping that will require ships to reduce their greenhouse gas emissions (IMO, 2021)[1]. Therefore, it requires designers to improve their energy efficiency. One of the methods is to reduce ship resistance by optimizing the hull form. This reduction directly translates into fuel saving and lower greenhouse gas emissions.

Figure 1. The decarbonization of maritime transport can be achieved through the development and the combination of energy-efficiency and clean solutions [Shutterstock/studio concept].

/ Simulating Fluid Behavior with Ansys SimAI

Historically, the maritime industry heavily relied on statistical approaches and regression analyses but these methods remain quite limited in terms of robustness and accuracy. Other methods often require a lot of computation time and effort. This is especially true in the case of CFD, which is needed to accurately assess the thick boundary layers in the aft part of the hull. Hence, CFD is often not directly applied in concept exploration studies, but rather for verification of a chosen design.

This is why Ansys developed the SimAI platform, which enables engineers to create AI models for any type of physics with minimal manual effort. In particular, SimAI can predict fluid behavior to assess the performance of new hull designs in a few seconds, including the 3D physical fields like wave patterns and pressure distributions on the hull.

/ Dataset Description

In the present case, an AI model has been created on the SimAI platform based on a database of 288 CFD simulation samples of hull designs at different operating conditions. It must be kept in mind though, that such a large dataset is not mandatory to take advantage of SimAI. A few dozen samples can lead to valuable AI models. The simulations are split into three sets:

- The **train set** is used to train the model and contains 244 simulations.
- The **validation set** is used to tune the model and contains 20 simulations.
- The **test set** is used when the training phase is completed to give an unbiased estimation of the model performances on unseen data. It contains 20 simulations.

Model Evaluation

The performances of the AI model are assessed by comparing the predictions of the test set with the corresponding CFD results. The first comparison is carried out on the forces integrated on the hull surface, showing a mean relative error of **4.88%** on the total resistance.

A second comparison is related to the assessment of the surface fields. An example of comparison is given below on one of the configurations in the test set and shows a good qualitative agreement between SimAI and CFD.

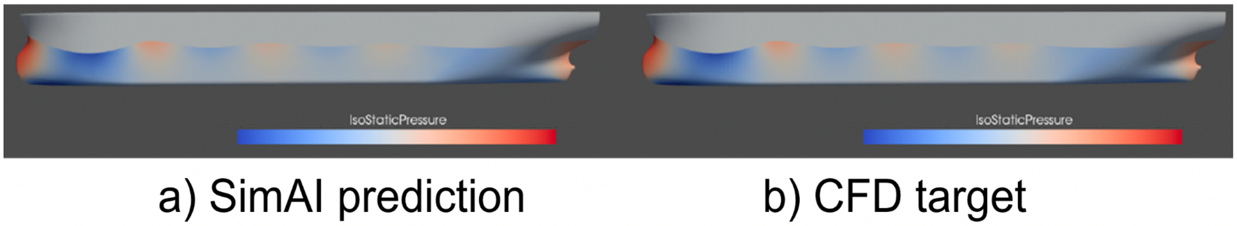

Figure 2. Qualitative comparison of the iso-static pressure surface distribution.

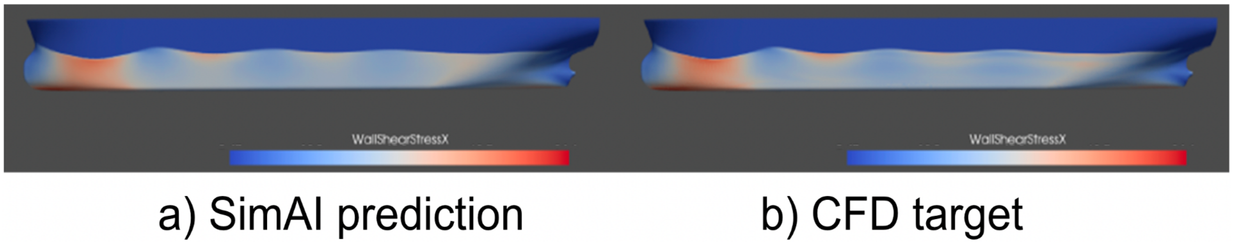

Figure 3. Qualitative comparison of the viscous stress surface distribution.

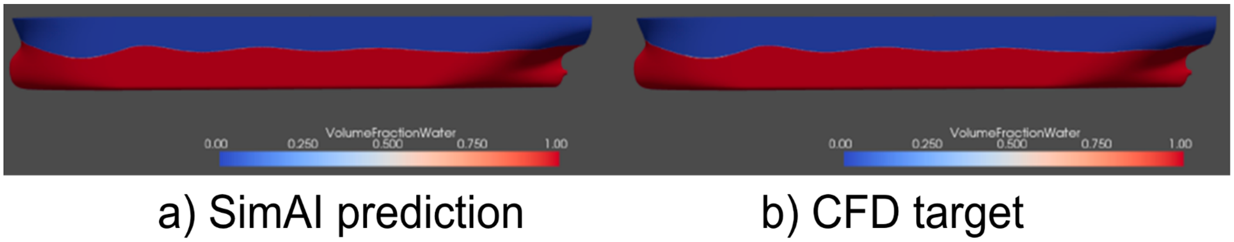

Figure 4. Qualitative comparison of the volume fraction water surface distribution.

This can be quantitatively checked by computing the absolute error on each cell of the hull mesh, namely the mean absolute error is lower than **15 N.m-2**.

As a consequence of the correct surface distribution, the global resistance curve evolution on the longitudinal axis is showing a very good match with CFD.

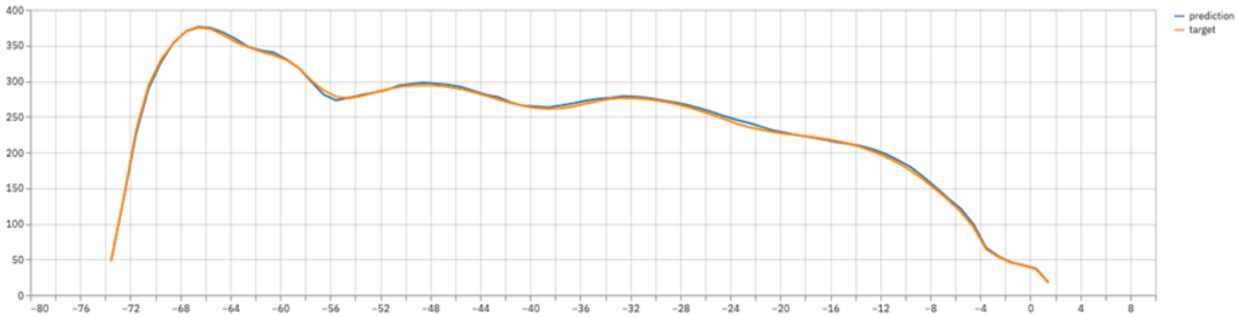

Figure 5. Quantitative assessment of the resistance force evolution along the hull. *Blue:* SimAI. *Orange:* CFD

The AI model also provides access to the full volume and some comparisons can be made within different slices, as shown below in a horizontal plane exhibiting the vertical velocity, showing a good agreement of the wave pattern between SimAI and CFD.

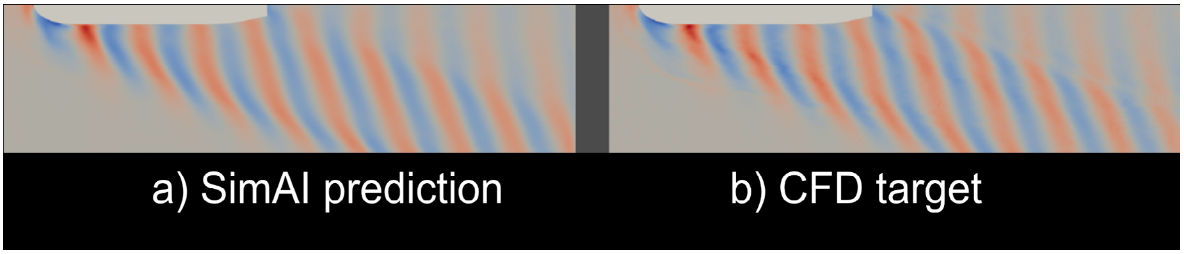

Figure 6. Slice with normal=z, origin=[0, 0, 0], and colored by Vz.

/ Application to Ship Hull Optimization

One important advantage of the SimAI platform is the negligible pre-processing time needed to make a prediction, since no meshing or solver setup is required. This can represent from minutes to hours of savings depending on the process automation and design complexity. **Each prediction made with this AI model takes around 8 seconds.** This opens new perspectives for efficient design iterations.

In the following, this model was applied successfully to explore a fundamental parameter of a 1:2 scaled model of the Japan bulk carrier (JBC) to achieve minimum resistance. By incrementally shifting the longitudinal center of buoyancy (LCB) of the hull forward or backward, it is possible to reduce the wave amplitudes of one design and hence the resistance of the vessel can be optimized. This is confirmed below in the wave patterns and pressure distributions on the hull for different positions of the LCB.

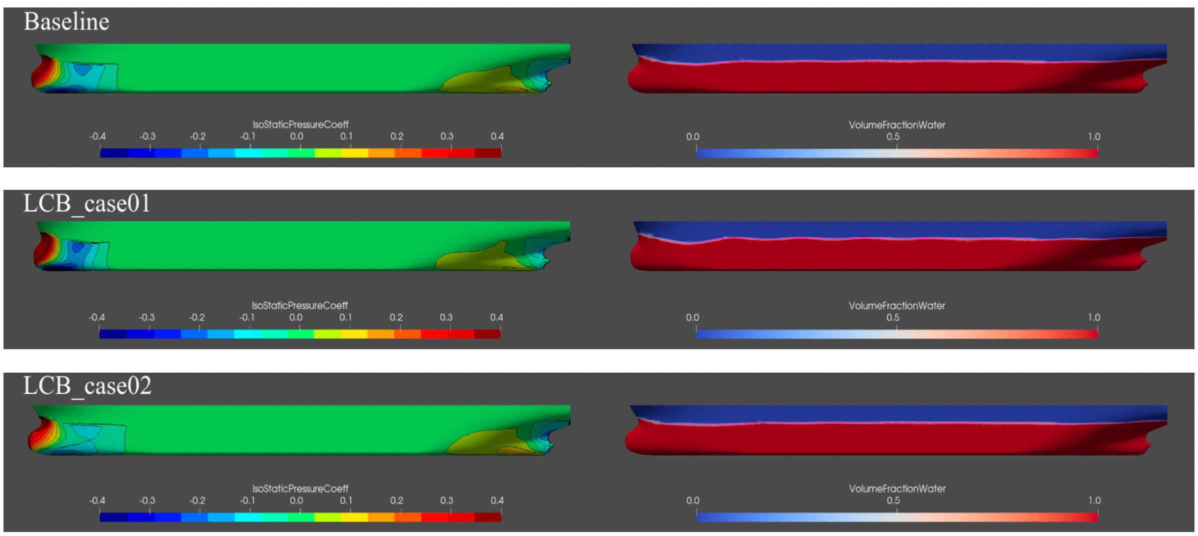

Figure 7. *Left:* hydrodynamic pressure force coefficient. *Right:* wave height along the hull colored by the volume fraction water.

The results suggest the existence of a minimum resistance for the LCB located at -0.6% relative to its baseline. If we had to set up and run each one of these with CFD, it would involve a significant amount of engineering time and would most likely cut into our productivity.

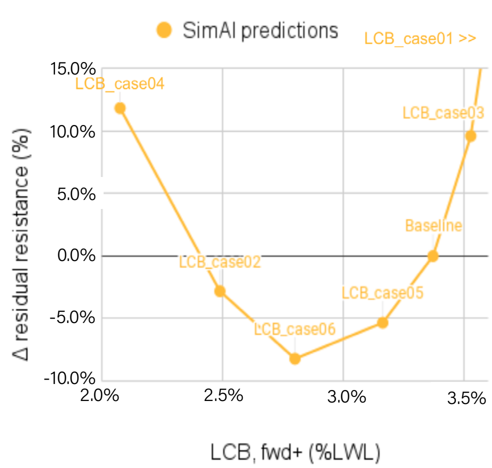

Figure 8. Diagram showing the relation between hull resistance and LCB.

The results below show a good agreement with CFD on the resistance reduction, including similar trends and order of magnitude. The friction resistance remains almost unchanged when varying the position of the LCB. Because the Froude number is relatively low (Fn = 0.141), the portion of wave resistance is relatively low and further gain can be expected at higher speeds.

Results	Total Resistance (kN)	Friction Resistance (kN)	Residual Resistance (kN)
SimAI	86.2 (-2.6%)	59.8 (0.0%)	26.4 (-8.0%)
CFD	78.0 (-3.2%)	55.6 (+0.2%)	22.4 (-10.8%)

Table 1. Validation of the results obtained with SimAI. Numbers in parentheses represent the resistance reduction with respect to the baseline design.

/ Benefits for the Maritime Industry

Hull form optimization has a large potential for fuel savings. Saving just 5% of fuel will save up to $100,000 per year from one vessel, given a cost of 30 tons per day at a price of $250 per ton and 280 days at sea[2]. By using the SimAI platform, it is possible to leverage the full 3D information from CFD simulations to assess the performance of new hull designs in a few seconds.

In this study, the resistance of the vessel was calculated for different positions of the LCB, and minimum resistance was achieved in 10 minutes.

While CFD often requires a lot of computation time and effort, with SimAI, it is possible to drastically reduce the amount of hours and computational time needed to optimize a hull form. This result can easily be obtained by one engineer within one working day.

/ Bibliography

[1] IMO, 2021. "Further shipping GHG emission reduction measures adopted." Available online at: https://www.imo.org/en/MediaCentre/PressBriefings/pages/MEPC76.aspx

[2] Marine Digital. "Fuel Optimization System allows a shipping company to reduce fuel consumption." Available online at: https://marine-digital.com/article_fuel_consumption

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