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SnappyShip: A Computational Tool for Automatic Grid Generation for Hydrodynamic Calculations of Ship Calm Water Resistance

Abstract

This paper introduces a lightweight, open-source framework for automatic grid generation tailored to ship calm water resistance simulations within OpenFOAM. The approach couples Python scripting with the snappyHexMesh meshing tool, aiming to reduce manual input, minimize user-induced errors, and accelerate the preprocessing phase of computational fluid dynamics (CFD) workflows. A central dictionary file, shipDict, stores ship characteristics and grid parameters, ensuring consistency and scalability across cases. The framework automates key meshing tasks, including domain scaling, Kelvin wake refinements, anisotropic mesh generation, and boundary layer resolution based on prescribed y^+ values. By generating STL refinement volumes programmatically, the method eliminates time-consuming CAD operations and supports parameter-driven refinements. The system is validated through two case studies: a benchmark Wigley hull and a 10-meter planing hull. The Wigley hull test demonstrates excellent agreement between numerical and experimental resistance coefficients, with only a 4% discrepancy, while the planing hull case showcases robust handling of complex geometries. Results confirm that the automated grids enable reliable resistance predictions with minimal user intervention. Although grid automation addresses one major bottleneck in ship CFD, future work will extend the methodology toward seakeeping and propulsion simulations.

Keywords: OpenFOAM, ship hydrodynamics, numerical grid

1. Introduction

This paper presents a light, open-source framework for creation of numerical grids that conform to ship calm water computations within OpenFOAM. The main motivation for this work is twofold: firstly, decreasing the turnaround time for overall grid creation, and second, to reduce potential human-made errors in the process. Current implementation is based on coupling python and an embedded meshing tool within OpenFOAM [1], *snappyHexMesh*, with strong emphasis on ensuring a minimal user input in the grid creation process. This paper is organised as follows. Firstly, the main section is dedicated to the implementation methodology and the details of the automation process which is followed by two test cases. Wigley hull form is used as a simple geometry, while more industry-relevant case with a complex geometry is presented on a 10 meter planing hull.

2. Implementation methodology

In computational ship hydrodynamics based on RANS approach, numerical grids that are suitable for calm water resistance computations in most cases share the same characteristics:

- Extents of the domain as a function of L_{PP}
- Anisotropic refinements in the free surface area
- Kelvin wake refinements in the free surface area
- Boundary layer geometry for desired y^+ value

Therefore, a potential for automating grid creation within *snappyHexMesh* is investigated. In order to reduce the required input from the user besides the pre-processing of the geometry file, distinct dictionary is introduced in the system folder of the running case, appropriately named *shipDict*. Within the dictionary, both ship characteristics and certain grid features are stored as an input. Following the recommendations from ITTC [2], extents of the domain are dependent on the length of the ship which is from *shipDict* inherited to *blockMeshDict*, a dictionary for creating structured hexahedral grids. Basic cell size is also mandatory. As the default values, coarse grid topology which conforms to roughly six cells along the span of the length of the ship. For conducting mesh refinement studies, the user simply changes the starting cell size to satisfy wanted refinement ratio. After basic grid creation with *blockMesh*, first main step of the *snappyHexMesh* tool is executed – castellation phase. In this step, the grid is roughly carved to match the ship geometry with specific refinement levels set by the user. From the *shipDict*, castellation phase inherits main dimension of the ship in order to refine the aft and bow geometry, regions with high flow gradients that require finer grid size. For successful capturing the wave pattern, kelvin wakes need to be properly discretized. Usually, geometry that refines the kelvin wakes need to be manually created through manual CAD workflow which significantly increases time

consumption. To avoid this, python script is called, which creates refinement volumes in an .STL format that are also dependent on the ship dimensions. Furthermore, anisotropic grid refinement is implemented using *topoSet* and *refineMesh* workflows, as described in [2] which also inherits information from *shipDict*. Grid refinements for the kelvin wake are shown in Fig.1, on the case of a parametric Wigley hull form. Anisotropic refinements of the grid for the same case are shown in Fig.2.

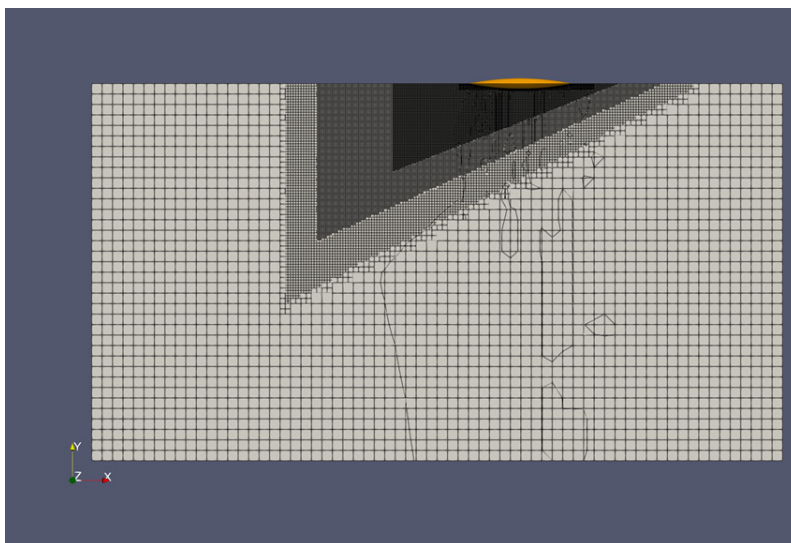


Figure 1: Kelvin wake refinements

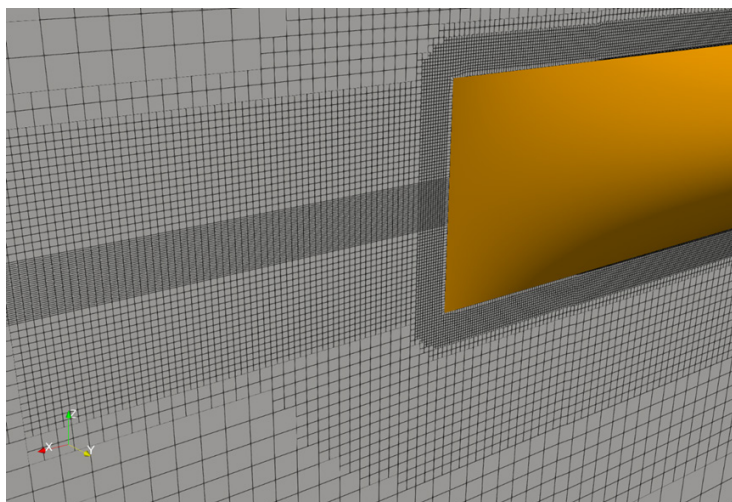


Figure 2. Anisotropic grid refinements

Castellation phase of the *snappyHexMesh* is followed by snapping phase in which rough, carved geometry is smoothed out to fit onto the actual surface. This step is independent of any variable from *shipDict*. Last step in the grid creation process is the insertion of high aspect ratio cells in the near-wall region in order to capture the highly nonlinear flow in the boundary layer. Geometrical characteristics of the boundary layer are determined from the *shipDict* with a prescribed y^+ value. The thickness of the first adjacent cell from the hull wall is determined as:

$$t_{BL} = \frac{y^+ \cdot \mu}{\tau} \quad (1)$$

Where μ is the kinematic viscosity of water and τ is estimated frictional velocity, dependent on the Reynolds number. The calculation is based on a well-established approach covered in literature, for example in [3]. Also, it is important to stress that wall-modeled viscous stresses, i.e. using wall functions, are highly sensitive to the prescribed equivalent sand grain roughness. Recently, Sulovsky et al [4] successfully validated full-scale sea trials using an equivalent sand grain roughness of 100 microns within the $k-\omega$ SST turbulence model. Based on the achieved results, this automation procedure uses this value for roughness modeling as it showed promising results both in model and full scale. Boundary layer refinement can be seen in Fig. 3

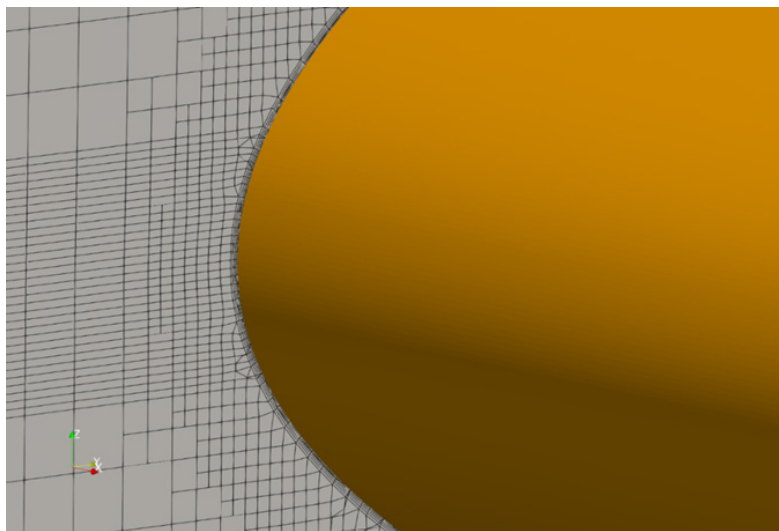


Figure 3. Boundary layer on Wigley hull

Simplified schematic workflow of the automatic grid creation is depicted in Fig.4. Also, the inertial properties of the ship are parametrized with respect to main dimensions, approximating the mass moments of inertia accordingly.

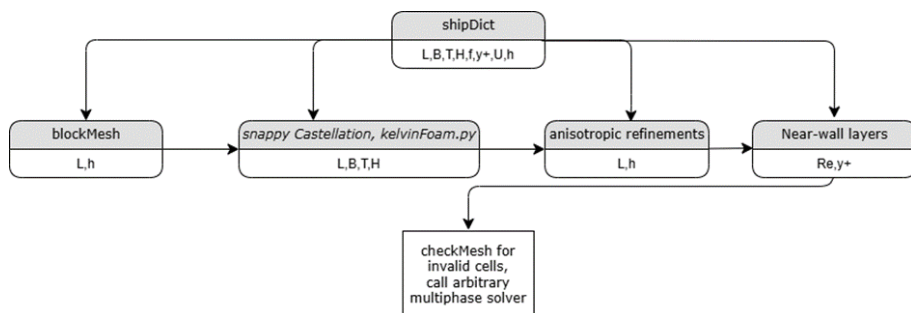


Figure 4. Automatic grid creation workflow

The methodology of automatic grid creation is shown in next chapter on two distinct case studies

3. Case studies

Two case studies on ship calm water resistance study with automatic grid creation are explored in this section. In the first case, parametric Wigley hull form is subjected to automatic grid creation where numerical results are compared to the experimental one. In the second case, a 10 meter planing hull is investigated with two degrees of freedom (pitch and heave) in the simulation. The grid for the first case can be seen in the previous chapter, therefore only the results are presented. In Table 1., numerical results are compared with experimental data, showing an excellent agreement with a discrepancy of just 4%.

Table 1: Resistance study for a Wigley hull

	C_T , resistance coefficient
Experiment [5]	0.005
OpenFOAM	0.0052

Wave field induced by the Wigley hull can be seen in Fig.5 and Fig.6

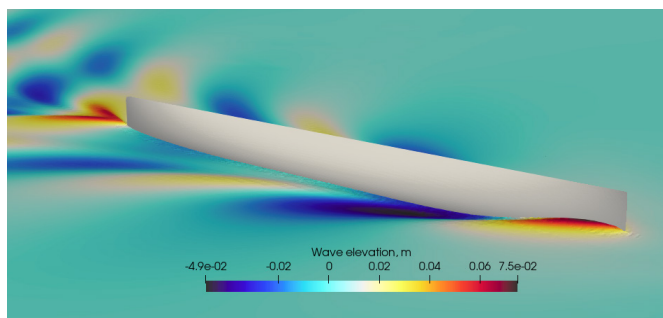


Figure 5. Wave field around Wigley hull - perspective

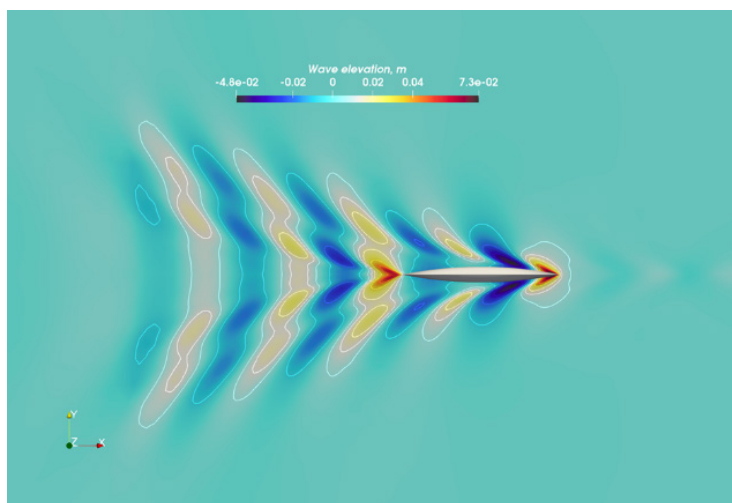


Figure 6. Wave field around Wigley hull – top view

Close match of the numerical results and high-resolution wave field show the effectiveness of the automatic grid creation process. It is however, impossible to quantify the exact time savings with automatic grid creation since building the grid manually varies significantly between users. Wigley hull form exhibits very simple hull lines, rarely seen in practical use. Therefore, second case involves a 10 meter hull, operating in a planing regime at a Froude number of 1.3. Moreover, second case study involves much more complex geometry that includes a V-shaped bottom, spray rails and a bow thruster recess. Such hull features still need additional care in the grid creation process in terms of feature edges and volumetric refinements. Surface grid of the planing hull is shown in Fig. 7. and Fig. 8.

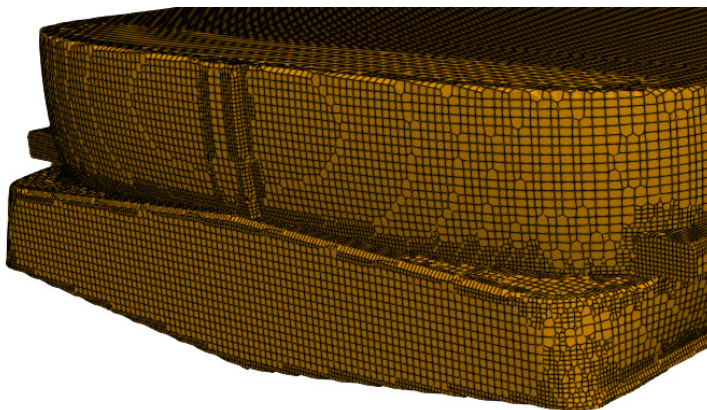


Figure 7. Surface grid of the planning hull - aft

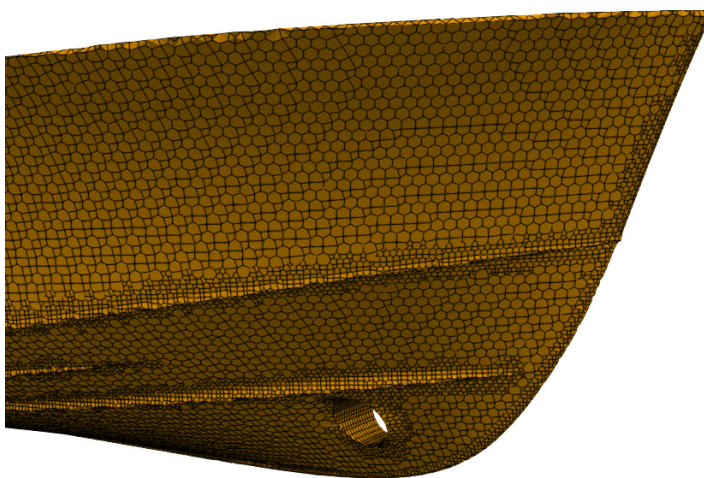


Figure 8. Surface grid of the planning hull - bow

Resulting resistance force, normalised with average value on the planing hull is shown in Fig.9, showing sharp convergence of the signal.

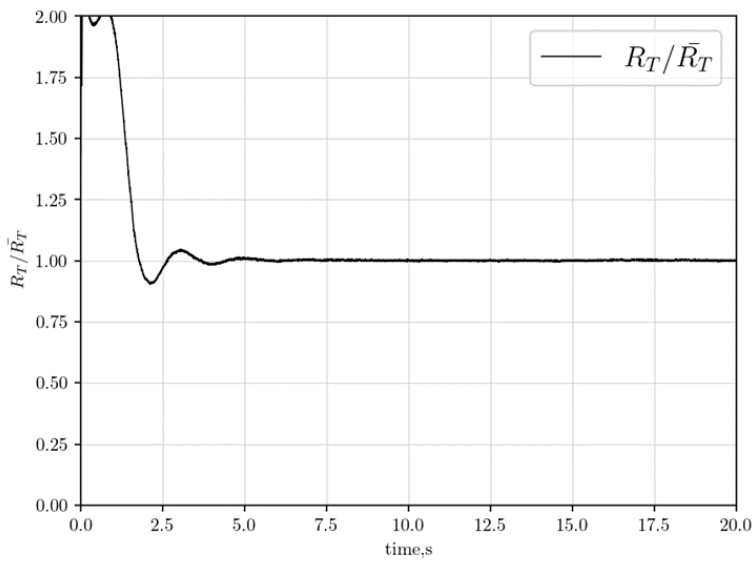


Figure 9. Normalised resistance force on a planing hull

Resulting wave elevations of the planing hull are shown in Fig. 10

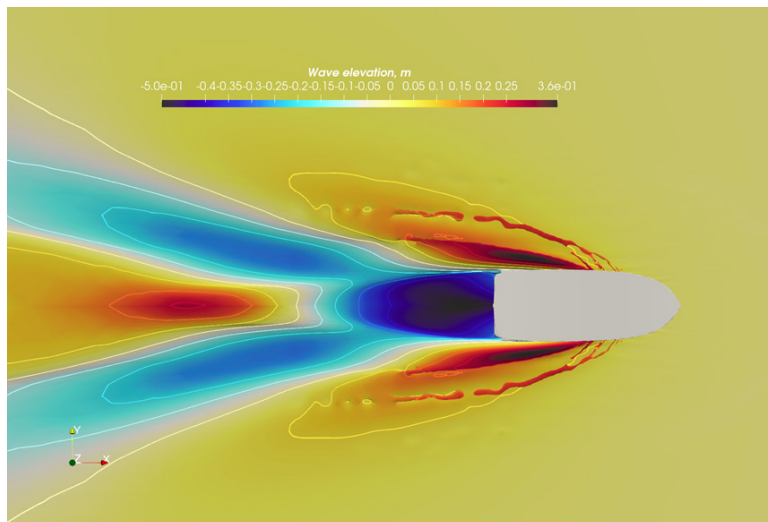


Figure 10. Wave elevations around planing hull

4. Conclusions and future developments

The developed framework demonstrates that ship calm water grid generation can be effectively automated through parameter-driven workflows in OpenFOAM. The coupling of Python script with *snappyHexMesh* successfully eliminates manual calculations and geometric pre-processing, while maintaining grid topological requirements for accurate RANS computations. Grid generation with results are shown through both academic (Wigley hull) and practical (10m planning hull) test cases which confirms that automated grids produce reliable resistance predictions with minimal user intervention. The automated approach addresses the primary bottlenecks in ship CFD preprocessing: time-intensive manual setup and potential human errors in parameter specification. By centralizing all geometric scaling in a single dictionary file, the framework ensures consistency across different ship sizes while significantly reducing the expertise barrier for new users. The automatic generation of Kelvin wake refinement volumes and boundary layer sizing based on target y^+ values represents a substantial improvement over traditional manual workflows. However, it should be noted that automated grid creation represents only one component of the complete CFD workflow, with numerical schemes, physical models, and convergence criteria still requiring manual specification and expert judgment. Future development will focus on extending the automation framework to encompass broader ship hydrodynamic applications. Priority areas include seakeeping analysis automation, where the systematic generation of grid based on targeting wave height and period. Additionally, propulsion simulations that incorporate simplified actuator disk modelling with only a few parameters is to be developed.

5. Acknowledgements

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6. References

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