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Application of dynamic overlapping grids to the simulation of the flow around a fully-appended submarine

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Abstract

The hydrodynamic characterization of control appendages for ship hulls is of paramount importance for the assessment of maneuverability characteristics. However, the accurate numerical simulation of turbulent flow around a fully appended maneuvering vessel is a challenging task, because of the geometrical complexity of the appendages and of the complications connected to their movement during the computation. In addition, the accurate description of the flow within the boundary layer is important in order to estimate correctly the forces acting on each portion of the hull.

To this aim, the use of overlapping multi-block body fitted grids can be very useful to obtain both a proper description of each particular region in the computational domain and an accurate prediction of the boundary layer, retaining, at the same time, a good mesh quality. Moreover, block-structured grids with partial overlapping can be fruitfully exploited to control grid spacing close to solid walls, without propagation of undesired clustering of grid cells in the interior of the domain. This approach proved to be also very useful in reducing grid generation time.

In the present paper, some details of the flow simulation around a fully appended submarine is reported, with emphasis on the issues related to the complexities of the geometry to be used in the simulations and to the need to move the appendages in order to change the configuration of the various appendages.

Keywords: Dynamic overlapping grids; CFD; Maneuvering submarine; Fully-appended ship

1. Introduction

Nowadays, fluid dynamic studies concerning complex-shaped moving bodies (typically: ships, airplanes, missiles, etc.) are commonly performed by both experimental and numerical tests. The use of numerical simulations as a valid alternative to experiments has been gaining consensus in the course of last decades, due to both the improvement in the numerical techniques and the augmented CPU performances. Moreover, numerical simulations have become

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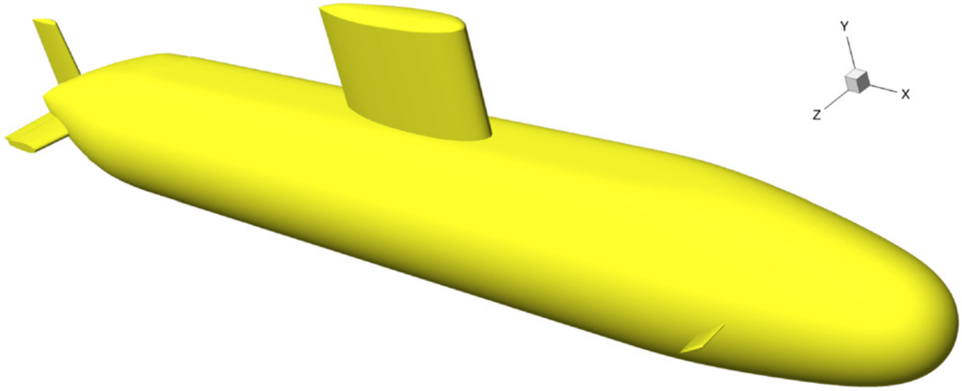
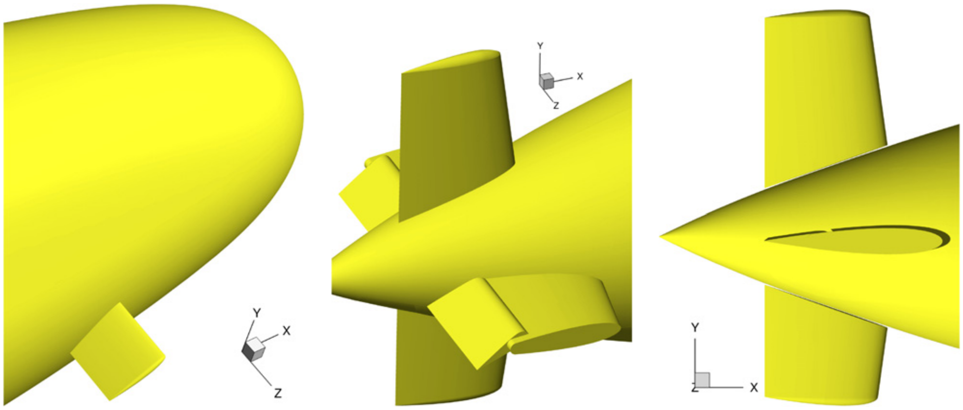


(a) Global view.



(b) Fore canards. (c) Aft horizontal planes. (d) Aft vertical rudders.

Fig. 1. Geometry overview of the simulated submarine.

attractive because of the possibility to obtain a detailed description of the flow field and an accurate estimation of the forces acting on the body (including the possibility to easily compute forces on each individual appendage and local stress distributions). Another important advantage in favor of numerical simulations is their favorable accuracy-to-cost ratio when compared to analogous experiments in wind tunnels or naval towing tanks. This is particularly true, for example, when the aim is the characterization of the hydrodynamic performances of the control surfaces for fully appended hulls, for which experiments would require very complex and expensive instrumentations and setup, and very long time for each single test.

Of great interest is the case of submarine hulls, for which the capability to maneuver efficiently (not only, like ships, in the horizontal plane, but also in the vertical plane) is of paramount importance. For this reason, submarines are generally equipped with three different kinds of control surfaces: fore canards and aft horizontal planes (used for trajectory control in the vertical plane), and aft vertical rudders (for motion control in the horizontal plane). For the submarine considered in this work (Fig. 1), the fore canards and aft vertical rudders are completely free to rotate around their axis, whereas the aft horizontal planes are made up of a mobile and a fixed part. This last configuration can be a source of serious troubles from the point of view of grid handling: in fact, the small gap existing between the two parts must be properly discretized, as the details of the flow around this region can be crucial in determining the hydrodynamic performances of the wing. Moreover, the discretization must be such that the local details and characteristics of both the boundaries and the flow inside the gap and in the surrounding region are well captured when moving the wing surface for control simulation.

A possible approach to solve the geometric difficulties would be the generation of an unstructured grid; at present, a lot of efforts are devoted to this kind of technique (see for example [14,12,22]). Nevertheless, the unstructured