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Development of new numerical algorithm to predict the ships squat and hydrodynamic forces acting on ships' hull sailing in very confined water

Keywords: **Computational Fluid Dynamic (CFD), ship hydrodynamics, fluid-structure coupling, added mass, proper orthogonal decomposition (POD), inland waterways**.

1) Introduction

The transport by inland waterway is an alternative and complementary transport mode to the rail and road transport. These lasts years this mode of transport has seen a significant progress by the arrival of the new generation of ships (big size and more powerful). However, this new generation of ship encounter major problems of maneuverability with the existing infrastructures (harbors, locks, Inland waterways, ...). In order to study the compatibility of these ships with these infrastructures, the CFD method is often used on one side to predict the squat of ships according to their speed as well as the confinement of the navigation environment and on the other hand to predict the hydrodynamic forces acting on the hull of ships. Indeed, it is essential to estimate these two phenomena with a better precision in order to avoid accidents as well as the overconsumption of the fuel.

Recently, CFD methods have shown their ability to predict with some accuracy the ships squat in deep waters. However, in a confined and very confined waters, the prediction of the squat by this method poses some numerical difficulties that lead in most cases either to a divergence of the calculations or to a very significant reduction of the time step which leads to an excessive computation time. These difficulties are mainly related to the poor estimation of the added mass caused by the displacement of ships. These problems become more serious with the arrival of the new generation of ships whose draft is larger which reduces the under keel clearance (distance between the ship bottom and the channel bed) hence, the increase in the effect of the added mass. This effect increases even more when the propulsive system is taken into account in the simulations.

The main subject of the proposed thesis is firstly to develop, verify and validate a new numerical module that can improve the existing numerical models (CFD codes) by taking into account the effect of the confinement in the computation of the squat of a self-propelled ships. Consequently, the accurate estimation of the hydrodynamic forces acting on the ships hull. Secondly, basing on the developed numerical codes a large number of simulations will be performed forming a big data base. In order to reduce the size of this data base the Proper Orthogonal Decomposition (POD) method will be used. The objective of this reduction is to make the obtained numerical results easily exploitable by ships bridge simulators that operate in real time.

2) Work plan

The proposed thesis subject is divided into three main parts:

The first part concerns the development of a new numerical module based on innovative algorithm for an accurate calculation of the added mass due to the ships displacement. This module will be implemented later in the CFD code OpenFoam in order to predict the squat for different ship types in sever navigation conditions.

The second part of this thesis will be experimental. The PhD student will be responsible for setting up a series of measurements on self-propelled models ships (scale : 1/20), these ships models are the property of our research team: LHN). Two types of ships will be tested for various speed and various channel configurations. In fact, these measurements will be used for the validation of the numerical modulus developed in the first part.

In the third part of this thesis, the candidate will set up a larger database that contains a snapshot of pressure field repartition over the ships' hull as a function of the water depth, the ship speed as well as the ship squat. This large size of computed data have to be analyzed to gain a better understanding of different physics considered in the simulated cases and to be simply represented. Hence, the Proper Orthogonal Decomposition (POD) method […] will be adapted and applied on this problem in order to reduce the number of characteristics data. The Proper Orthogonal Decomposition (POD) is a post-processing technique consisting in the determination of an orthogonal and ordinated base. It takes a given set of data and extracts basis functions that optimally approximates data known from a large size set. The objective of using this method is to make the results obtained numerically easily exploitable in real time by ships bridge simulators. The quality of these results will improve the prediction of the ships behavior under the various maneuvers done by pilots during the simulations.

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4) References

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