Flow simulation around a rotating propeller with dynamic overset grid approach

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Abstract

It's getting more important to compute flow field around complex geometries such as energy saving devices (ESDs) for vessels in order to evaluate ship performance more rapidly and precisely. Overset grid approach is one of ways to deal with complex geometries, simplifying grid generation and it provides flexibility to rearrange geometries. Overset grid approach is also useful for a moving body problem since it can cope with change of arrangement of computational grids by just recomputing Domain Connectivity Information(DCI) without regenerating grids. UP_GRID and NAGISA are developed as an overset grid assembling system and a flow solver for overlapped grids based on URANS equation, respectively, at MPAT (National Institute of Maritime, Port and Aviation Technology, Japan). Flow simulation around Japan Bulk Carrier(JBC) with a rotating propeller are carried with dynamic overset approach by coupling the two codes. DCI is recomputed at each time steps by UP_GRID and flow field is updated by NAGISA using renewed DCI. Full multigrid method is used in order to get a fast convergence in NAGISA. It is confirmed that the system has capability to simulate unsteady flow field behind a ship with a rotating propeller by dynamic overset assembling approach practically.

Keywords: Overset Assembling, Dynamic Overset, Unsteady Flow, Propeller, Full Multi Grid

Introduction

1 Numerical Procesure

1.1 *Overset assembling*

Overset grid approach uses a set of grids that enclose the computational domain and overlap each other without requiring face-to-face matching between grids. An overset assembling system called UP_GRID [1] is developed at MPAT. The system is based on structured grid approach and covers comprehensive features for overset assembling, i.e., grid generation, grid modification, and computing DCI for overset interpolation. Ferguson spline curve is used to compute curves through grid points and cell centers for trimming grids and computing DCI robustly and accurately.

1.2 *NS solver*

The simulation is carried by a flow solver NAGISA[2], which is under development in MPAT. The solver can cope with overlapped grids with DCI generated by UP_GRID. Spatial discretization is based on a finite-volume method and inviscid fluxes are evaluated by the third order upwind scheme based on the flux- difference splitting. The evaluation of viscous fluxes are the second order centered differencing. Artificial compressibility approach is used to velocity-pressure coupling. For free surface treatment, an interface fitting approach and the level-set method are employed. One and two equations models are available for the turbulence model. NAGISA can cope with moving grid method and can call UP_GRID just after morphing grid points in each time steps to update DCI. Multigrid method and local time stepping for the pseudo time are adopted for the fast convergence. In addition, full multi grid method is also available [3] . Overset interpolation is carried in the finest level because it is hard to avoid occurrence of orphan cells in coarser levels due to difficulty of appropriate hole cutting. Cells belonging to coarser grids and including receptor cells of finest grid are treated as receptor cells.

Computational Conditions

The flow behind a hull called JBC(Japan Bulk Carrier) is computed. JBC is a bulk carrier designed for "Tokyo 2015, a Workshop on CFD in Ship Hydrodynamics" [4]. In the present study, no ESD is equipped.

The solution domain is composed of ten blocks, a rectangular parallelepiped grid ($-2.0 \leq x/L_{PP} \leq 3.5$, $-2.5 \leq y/L_{PP} \leq 2.5$ and $-1.56 \leq z/L_{PP} \leq 0.24$) which covers whole domain, an O-O type grid around hull, a grid around the the stern tube, a grid around the hub, five grids around each propeller blades and a rectangular parallelepiped grid behind ship for refinement. The intersections of solid surfaces are appropriately trimmed. The origin is located at midship on design water line. The axis x is positive streamwise and the vertical axis z is positive upward. Figure 1 shows schematic view of computational grids.

k - ω SST model is used for turbulence modeling and level-set approach is used for free surface computation. Non-dimensionalized Δt is set to 1.2×10^{-4} in which the propeller rotates about 2[deg].

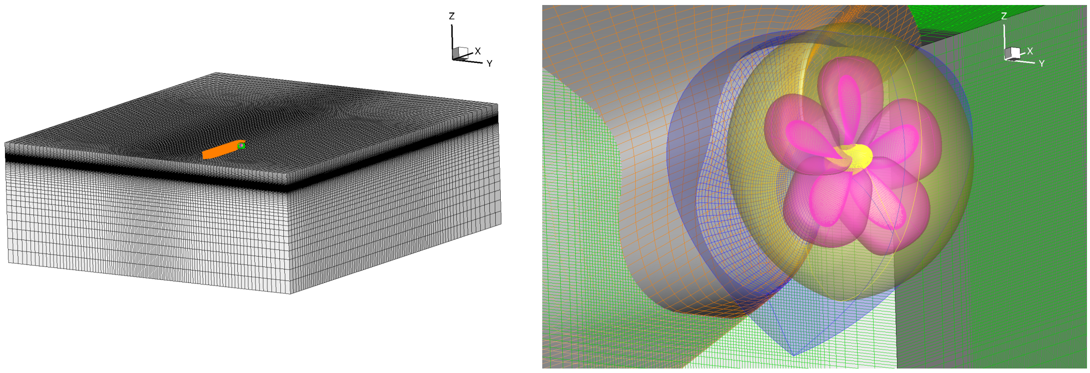

Figure 1: Schematic view of computational grids. The whole domain and the ship hull(left) and grids around the propeller(right).

Results and Discussions

Case 1.7a (self-propelled condition without rudder and without duct, F_r=0.142, $R_e = 7.46 \times 10^6$) of the workshop[4] is studied. Full multigrid method with three levels, coarse, medium, fine are adopted. Figure 2 shows surface grids and streamlines in coarse and fine level, respectively. In both levels, no discontinuity in flow field occurred and overset interpolation carried appropriately. The authors continues the computation and further analysis for detailed flow will be presented in the conference.

Concluding Remarks

The overset assembling system UP_GRID and the structured grid Navier-Stokes solver NAGISA, which are under developing in MPAT, are coupled for dynamic overset computation and applied to free surface flow of JBC. Self-propelled condition with discretized propeller are com-

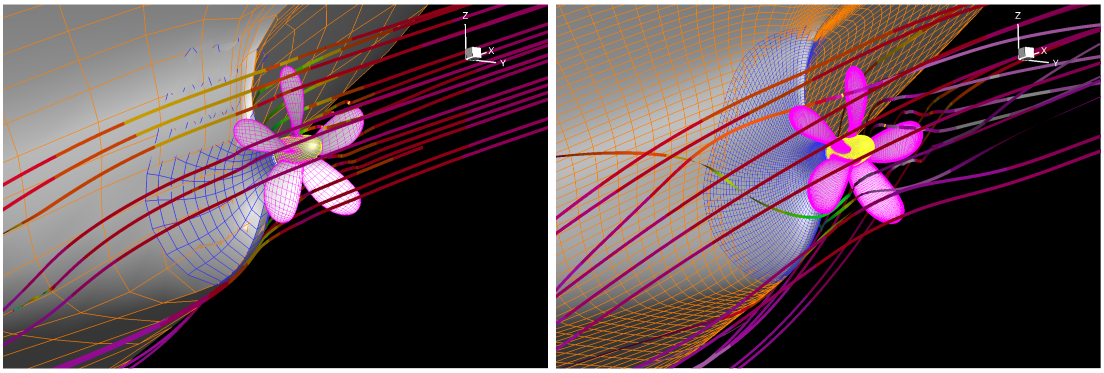

Figure 2: Flow around propeller. The coarsest grid (left) and fine grid (right).

puted with full multigrid method. It is confirmed that the system has capability to simulate flow field behind a ship with a rotating propeller with overlapped multiple grids practically.

Acknowledgements

This work has been supported by JSPS(Japan Society for the Promotion of Science) KAKENHI (Grant-in-Aid for Scientific Research) (C), Grant Number 26420834

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