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Computation of Steady Viscous Flows around Ship with Free Surface by Overset Grids Techniques in OpenFOAM

Zhirong Shen, Decheng Wan
State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering
Shanghai Jiao Tong University, Shanghai, China

ABSTRACT

This paper presents the implementation of overset grid capability into the open source toolbox, OpenFOAM, and a validation case for steady viscous flows of a benchmark ship DTMB 5512 by the overset grid technique with URANS methods. The procedure of the overset implementation is discussed in this paper, including the basic procedure and parallelization. Examples of how to use the overset library developed to modify OpenFOAM solvers with overset capability are introduced. In order to validate the overset code in OpenFOAM, static computations of the DTMB 5512 are carried out. Two Froude numbers (*Fr*=0.28 and 0.41) are considered. The computational results including resistance, free surface and wave profile on the hull surface are compared with experimental data. Good agreements are achieved and the results indicate the overset ability of the code. It also confirms that the code can be used for primary ship hydrodynamic problems.

KEY WORDS: OpenFOAM, overset grid, DTMB 5512, URANS.

INTRODUCTION

Although Computational Fluid Dynamics (CFD) has experienced unprecedented developments in the past decade, it still has limitations and difficulties in solving the moving boundary problems. Many solutions have been proposed to treat this problem, including deforming mesh, sliding grid, re-meshing and so on. However, deforming mesh is limited to small-amplitude motions since large deformation of the mesh cells will reduce the quality of grid and even lead to divergence. Sliding mesh does not has such limitation, but it usually handles only one degree of freedom or rotations. Re-meshing technique does not seem to have such limitations of deforming and slide meshes but costs huge amount of time to regenerate mesh and the quality of mesh is very difficult to control. It is not an efficient solution. Compared with these solutions discussed above, overset grid technique is one of the most efficient and robust methods to handle moving boundary problems. Overset grid method can be used to handle large-amplitude motions, such as 6DOF motions and capsize, and maintain good mesh quality since no grid deformation occurs during the computations. It has good capability to capture complex fluids motions in the near wall region.

In the past decade, the overset grid technique gained the popularity in the field of computational ship hydrodynamics and showed strong efficiency, flexibility and robustness. Maki et al. (2013) investigated the calm water resistance of a surface effect ship by overlapping grid approach. Orihara and Miyata (2003) predicted the ship motions and added resistance of a of a container carrier using overlapping grid system by the solver WISDAM-X. The heave and pitch motions of DTMB model 5512 in head waves were investigated by Carrica et al.(2007) using the solver CFDShip-Iowa V4 to demonstrate the flexibility of overset grid technique for the prediction of large-amplitude ship motions. In additions to resistance and seakeeping, the overset grid technique was extended to solve other complex ship hydrodynamic problems, including self-propulsion (Carrica et al., 2010) and maneuvering (Carrica et al., 2013).

The aim of this work is to implement the overset grid technique into the open source code OpenFOAM and perform a validation case to test the code. An incompressible unsteady Reynolds-Averaged Navier-Stokes (URANS) solver, naoeFoam-os-SJTU, has been developed with the overset grid capability based on OpenFOAM. This solver is an upgrade version of the previous one naoeFoam-SJTU (Shen and Wan, 2013) but with the new capability of overset grids.

In order to validate the code, a 3D static problem with two-phase flow is performed to validate this solver and the overset grid approach. Although the overset grid method is designed for dynamic situations, in the preliminary stage, the solver should be validated for static problems first, in which the object is fixed and no relative motion is produced. The DTMB model 5512, a US combat ship in calm water, is chosen for the validations. This model is one of the benchmark cases in the recent Gothenburg CFD Workshop in 2010 (Larsson et al., 2014) . The model has a ship length of 3.048 m. Two speeds (*Fr*=0.26 and 0.41) are performed by overset grid method. The resistance, free-surface, wave profile and boundary layers are investigated numerically and compared with measurements.

MATHEMATICAL MODELS

The incompressible unsteady Reynolds-Averaged Navier-Stokes