8th. World Congress on Computational Mechanics (WCCM8)
5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 –July 5, 2008
Venice, Italy

BODY-FITTED CARTESIAN GRID METHOD FOR COMPLEX HIGH REYNOLDS NUMBER FLOWS

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Key Words: *Body-fitted Cartesian grid method, High Reynolds number flow, Complicated Geometry*

ABSTRACT

In order to improve turnaround time and usability of computational fluid dynamics (CFD) for conceptual aerodynamic design of space launch vehicles, CFD analysis method based on the body-fitted Cartesian grid is developed. As comparing with conventional unstructured hybrid grid method, this approach has strong advantages such as efficiency of filling space, faster convergence rate and robustness to handle complicated geometry[1, 2, 3, 4, 5, 6, 7]. In this approach computational grid is generated in the following process, 1) generation of volume Cartesian grids with keeping near surface space, 2) generation of the grid front which covers body, 3) smoothing of grid front, 4) grid front projection onto the surface, 5) geometric feature preservation and 6) clustering of layer grid. In order to receive the full benefit of this approach robustness of the feature preservation is key issue, and its improvement was conducted in past studies by present authors[8].

In this study, further improvement to handle small gap problem and to realize explicit grid resolution control is carried out. Body-fitted Cartesian grid generated over the rocket geometry is shown in Fig. 1. In order to capture small gap area such as inside of the nozzle and chamber, such area is detected and size of the Cartesian cells near this area is controlled to be sufficiently small. By using this treatment, this grid generation method can also be used for internal flows which includes small gaps such as rocket engine inducer.

Flow computations based on this grid system is applied to high Reynolds number flows such as airfoil, massive separated re-entry capsule configuration and aerodynamic analysis of an aircraft geometry. Computed pressure distributions for RAE2822 airfoil is compared with the experimental data in Fig 2. In the computation, solution adaptive grid refinement method is used to capture the local shock wave accurately, which results in the good agreement with experimental data. Most of the cells are Cartesian cell, and thus, grid quality does not degenerate by cell refinement. Therefore, it is easy to conduct grid refinement depending on the flow-field, which is strong advantages in the situation that flow structure is unpredictable.

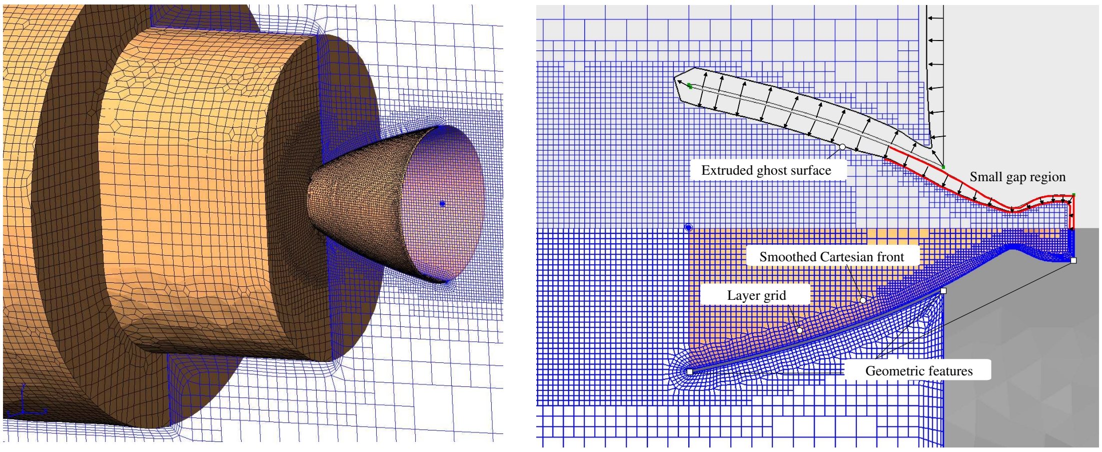

Figure 1: Body-fitted Cartesian grid over rocket geometry.

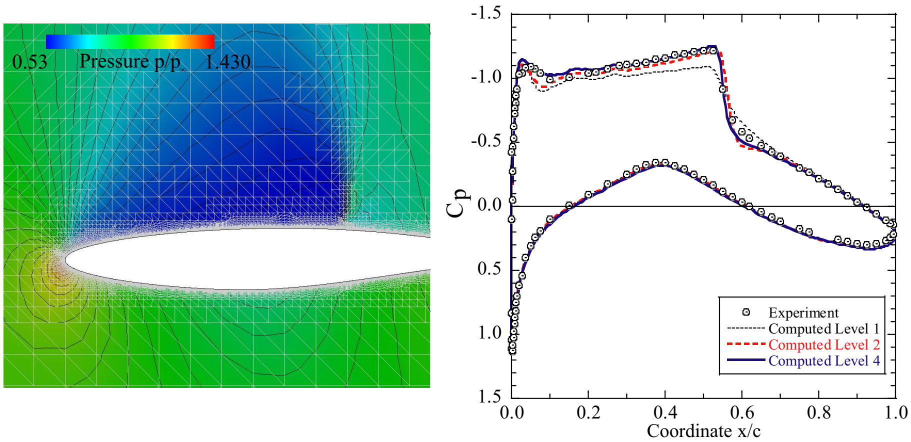

Figure 2: Solution adaptive grid refinement for the transonic flow over a RAE2822 airfoil at $M_\infty = 0.729,\ Re_\infty = 6.5 \times 10^6,\ \alpha = 2.31°$.

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