Parallel Finite Element Analysis of the Drag of a Car under Road Condition

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Abstract

A parallelized FEM code based on domain decomposition method has been recently developed for a large scale computational fluid dynamics. A 4-step splitting finite element algorithm is adopted for unsteady computation of the incompressible Navier-Stokes equation, and Smagorinsky LES(Large Eddy Simulation) model is chosen for turbulent flow computation. Both METIS and MPI library are used for domain partitioning and data communication between processors respectively. Tiburon of Hyundai-motor is chosen as the computational model at Re = 7.5×10^5 , which is based on the car height. It is confirmed that the drag under road condition is smaller than that of wind tunnel condition.

Keyword: *Splitting Finite Element Method, Parallel Computing, Road Condition, LES*

1. Introduction

For the last two decades, most of numerical researches on automotive external flows have been performed by FVM and two-equation turbulence model. Carr[4], Ramnefors et al. [5] and Han et al.[6] conducted the numerical experiment of the external flow around a car using FVM and turbulence model of $k-\varepsilon$ version. They predicted drag coefficient with approximately 10~20 % error. More recently, Krajovi and Davidson[7] performed unsteady large eddy simulation of the turbulent flow around a bluff-body model using FVM. On the other hand, the group of Tezduyar et al.[2] has simulated the external turbulent flow around a real car(Saturn) with the help of both fast-growing parallel architecture and a novel parallel algorithm available on parallel machine. Recently, a parallel FEM code for the simulation of the unsteady incompressible Navier-Stokes equations has been developed by Choi et al.[3]. The code is parallelized by the domain decomposition method. Optimal domain decomposition is executed by Metis-lib[8] for both load balance and small communication time. In the present study, the turbulent external unsteady flow around Tiburon model of Hyundai-motor has been calculated and compared with an available experimental result for both wind tunnel and road conditions.

2. Numerical Methods

The governing equations are the incompressible Navier-Stokes equations with the divergence free constraint. The P1P1 4-step splitting finite element method devised by Choi et al.[9] has been adopted for the solution algorithm. The unstructured mesh generated by ICEM CFD package is partitioned by Metis library such that both load balance and the minimum communication time between processors is satisfied. Block ILU parallel preconditioner has been adopted for both the momentum and pressure equation in order to enhance the overall efficiency of the parallel computation.

3. Results and discussion

The simulation of wind tunnel condition has been performed during about 21 seconds with the time step size of 0.003 sec. Fig. 1 represents the drag coefficient variation with time during about 20 seconds for both the find and coarse grid. The drag coefficients obtained from the fine and coarse grids are 0.318 and 307, respectively. Those values are about 5~10 % larger than the experimental value of 0.29. The road condition has been simulated with the fine grid consisting of about 3.8 million nodes. From Fig. 2, it has been shown that the averaged computed drag coefficient of the road condition decreases about 10% compared to that of wind-tunnel condition, which is obtained by averaging the last 10-second simulation. It should be noted that the present result agrees well with the experiment result by Per Elofsson and Mark Bannister[10]. They have reported by experiment that the drag of the road condition is smaller than that of the wind tunnel condition by about 10 % although the exact value is a little varying according to the shape of the model.

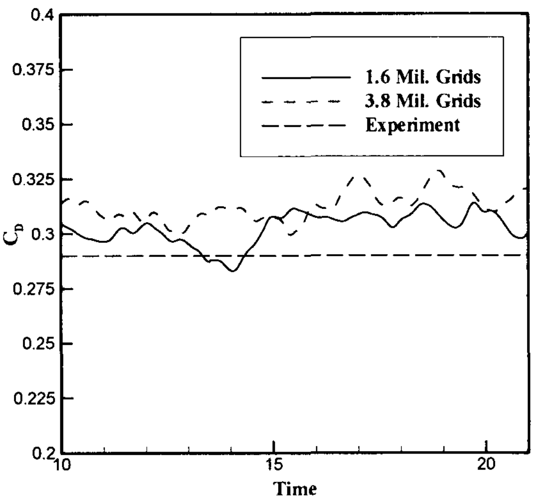

Fig. 1 Drag history for the wind tunnel condition

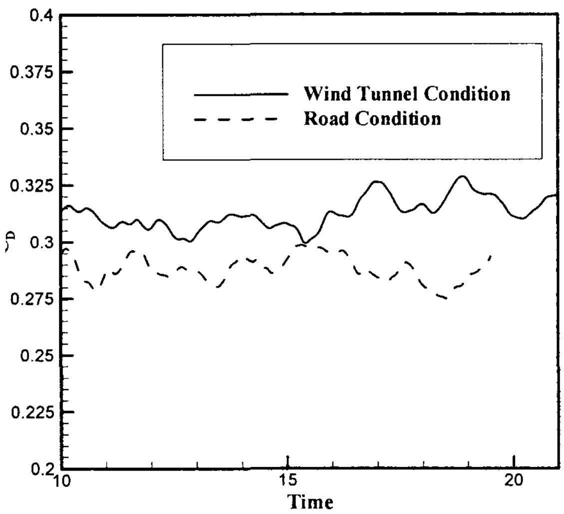

Fig. 2 Drag history of the road condition

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