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HPC-LES FOR UNSTEADY AERODYNAMICS OF ROAD VEHICLES

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ABSTRACT

In vehicle aerodynamics, recently greater attention is going to be paid to unsteady aerodynamic force generated from sudden steering action, overtaking, or cross wind; all of which are difficult to estimate by a conventional wind tunnel test. Computational Fluid Dynamics (CFD) will be a powerful tool for this problem, because it can provide enormous amount of information of 3D flow field around a vehicle body. However, the Reynolds-Averaged Navier-Stokes (RANS) model, which is commonly used for vehicle aerodynamics, is fundamentally difficult to capture the unsteady flow characteristics, owing to its basic concept of averaging. Large Eddy Simulation (LES) will be an encouraging solution for this matter, because it can reproduce unsteady turbulence characteristics with high accuracy, but in turn it requires excessively large computational resources. Consequently only few attempts have been made so far to apply LES to the assessment of vehicle aerodynamics.

In the previous study[1], we intensively modified and optimized the unstructured-grid LES code “FrontFlow/red (FFR)”, which had been originally developed by us under the national project called “Revolutionary Simulation Software (RSS21)”, for the execution on the Earth Simulator (ES) in Japan. We successfully applied our High Performance Computing (HPC) LES to a formula car[2] using 125 million (world-largest class engineering LES) numerical elements, and showed the validity of the method compared with the conventional RANS, with regard to the prediction of steady aerodynamic forces.

The main objective of this study is firstly to investigate capability of our HPC-LES for reproducing 3D unsteady eddy structures around vehicles, then to reveal the relationship between the unsteady aerodynamic forces and the eddy structures acting on a vehicle in dynamic motion.

We first applied the method to the production vehicle, Mazda Atenza, to investigate how HPC-LES properly reproduce eddy structures appearing around the vehicle by comparing the results with reliable wind-tunnel data obtained at Mazda Motor Corp. Total of about 40 million numerical elements were required to properly reproduce the complicated shapes such as the engine room and the underbody geometry. About 500 CPU with 300GB memory and 40 hours of real computational time were consumed on the ES.

We then studied the unsteady aerodynamic forces acting on the vehicle during the dynamic yaw-angle change, and their relationships with transient flow structures. The measured yawing moment and the snapshots of pressure distributions around the vehicle obtained by our HPC-LES at four typical moments are shown in Fig. 1 and 2, respectively. The unsteady yawing-moment was found to be relatively large during the vehicle dynamic motion (T=0.10~0.15s, 0.20~0.25s) compared with the case when the motion is static during T=0.15~0.20s. In fact, significantly asymmetric pressure distribution is observed at T=0.25 just after the vehicle dynamic motion, even though its yawing angle is 0 degree.

As a result, we have demonstrated that HPC-LES can be a dominant aerodynamic assessment tool especially for the unsteady vehicle aerodynamics, which would contribute to the innovative aerodynamic vehicle design in the near future.

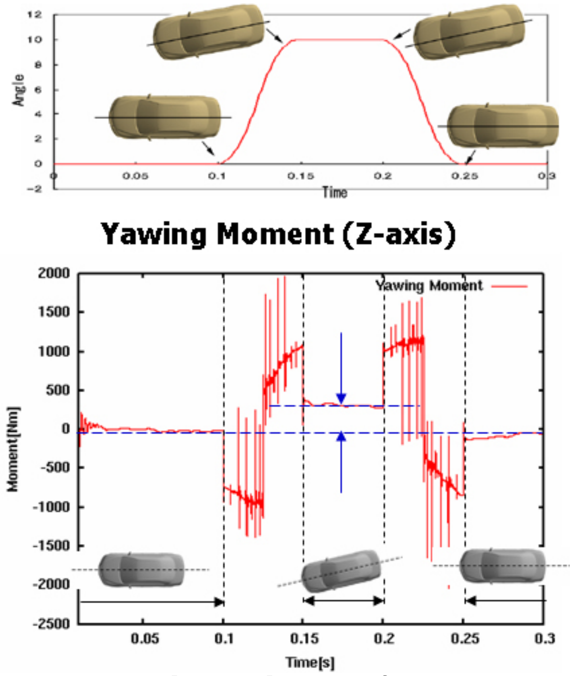

Fig.1 Unsteady aerodynamic force (yawing moment) acting on the dynamic yaw-angle change

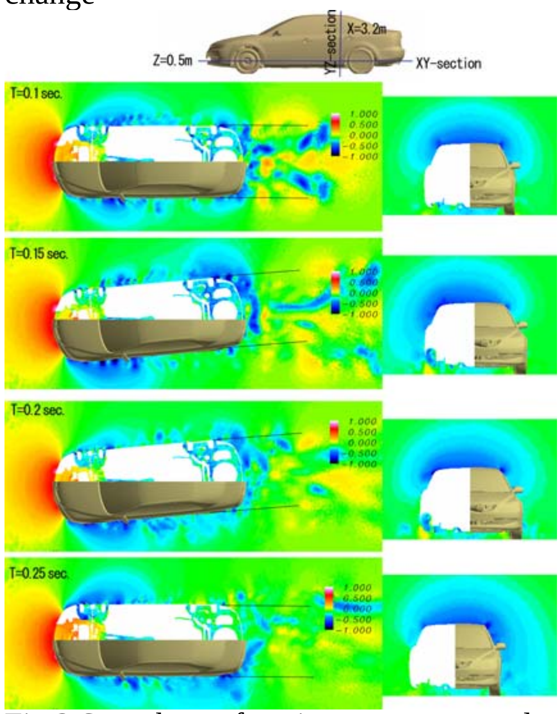

Fig.2 Snapshots of static pressure around the vehicle.

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