Abstract

Scalable fixed-mesh method for massively parallel simulations of solid and fluid problems

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In recent years, in the automotive industry, weight reductions are indispensable for complying with carbon dioxide emission regulations. Although automotive companies have been mainly using steel sheets, they want to employ multi-material structures including extrusions, castings, or 3D printings of aluminum alloy or resin to achieve weight reductions. However, the structural design will be more complex because multi-material structures have a higher degree of geometric freedom than sheet metal structures. Therefore, numerical simulations need to play a more critical role in designing optimal vehicle structures.

For the last several decades, a Lagrangian finite element method (FEM) using mainly shell formulation has been the de facto standard in the automotive industry. However, shell formulation cannot numerically model the multi-material structures mentioned above because they do not have a constant thickness. Thus, the continuum formulation has to be applied, but this approach poses two computational problems.

The first problem is that an enormous number of finite elements using continuum formulation is required to discretize the multi-material structures spatially. A scalable method in a massively parallel environment is indispensable for this simulation. Secondly, we need to spend more than a month to generate the finite element mesh of a car body. Therefore, it is challenging to investigate many patterns of vehicle structures.

Considering the background as mentioned above, we focus on a Eulerian finite volume method (FVM) [1] based on continuum formulation [2] using a scalable hierarchical Cartesian mesh method [1]. This Eulerian FVM [1] has the following three advantages. The first one is good scalability [1] in a massively parallel computing environment. Secondly, we can easily generate the computational mesh of a car body only within 10 minutes. We will demonstrate the stiffness analysis of a body-in-white structure, which is spatially discretized by approximately 200 million cells and was computed using 104,520 cores on the K computer. Thirdly, the proposed Eulerian method is easy to couple a conventional finite volume fluid solver.

In future work, we plan to conduct car crash simulations using many patterns of multi-material vehicle structures to study ultralight vehicle structures.