A Fluid-Structure Interaction Problem on Unstructured Moving-Grid using OpenMP Parallelization

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ABSTRACT

Fluid-structure interaction problems are seen in various field of industry, and they are also researched in computational fluid dynamics. In this paper, we treat a coupled problem fluid and moving body for compressible flow. It is calculation model that a body moves with pressure of fluid and a motion of the body affects fluid again, and it is calculated in body-fitted coordinate system. To solve such the problem, it is necessary to move grid points according to motion of bodies. Thus, it is important to also satisfy a geometric conservation law in addition to satisfy a physical conservation law. To assure both conservation laws, we introduce the scheme " Unstructured Moving-Grid Finite-Volume Method[1] ", which adopts a control volume in a space-time unified domain on an unstructured grid system. Then the method is implicit and is solved iteratively at every time-step in order to estimate interaction between fluid and body and to assure both the conservation laws and numerical accuracy.

In this paper, a fluid-structure interaction problem is computed using three-dimensional unstructured moving-grid finite volume method. The method is featured treatment of a control volume on the space-time unified domain (*x, y, z, t*), which is four-dimensional for three-dimensional flows, in order that the method satisfies the geometric conservation laws. The present method is based on a cell-centered finite-volume method, thus we define flow variables at the center of a cell in unstructured mesh. So the cell is tetrahedron in three-dimensional (*x, y, z*)-domain. When grid moves, the control volume becomes a complicated polyhedron in the (*x, y, z, t*)-domain as shown in Fig.1. It is formed when the tetrahedron sweeps space which is built by grid points $\mathbf{R}_1^n$, $\mathbf{R}_2^n$, $\mathbf{R}_3^n$, $\mathbf{R}_4^n$, $\mathbf{R}_1^{n+1}$, $\mathbf{R}_2^{n+1}$, $\mathbf{R}_3^{n+1}$ and $\mathbf{R}_4^{n+1}$. We estimate numerical flux in this control volume. The scheme uses the unknown variables at (n+1)-time step to estimate fluxes, and thus the scheme is completely implicit. We introduce subiteration strategy with a pseudo-time approach[2] to solve the implicit algorithm. Then flux vectors are evaluated using the Roe flux difference splitting scheme[3] with second order spatial accuracy approach as well as the Venkatakrishnan limiter[4].

In this paper, the method is applied to a gun-tunnel problem. This is a fluid-structure interaction problem, which is built air and a piston. The piston is placed in a cylinder, and high pressure air is filled in space between the piston and the cylinder wall. In another space, low pressure air is filled. At time=0, the piston begins to move by air pressure, and a motion of the piston afects to air pressure again. Figure 2 shows the result of the flow field (pressure contours) at t = 0.0, 2.4, 6.0 and 8.0 respectively. It can be confirmed that the method can calculate flow field, in which the piston moves by air pressure using the unstructured moving grid. Then, the method promises to develop a complicated body problem. And the paper presents a solution of the flow field on the problem in an OpenMP parallel environment.

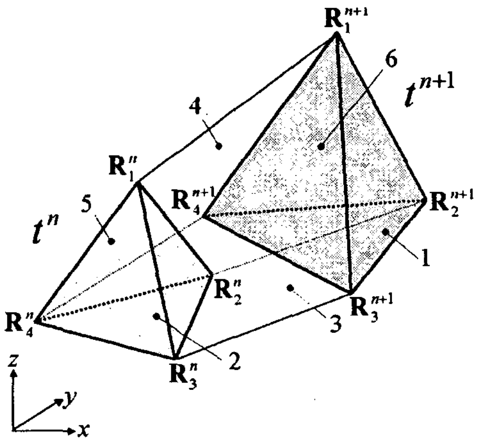
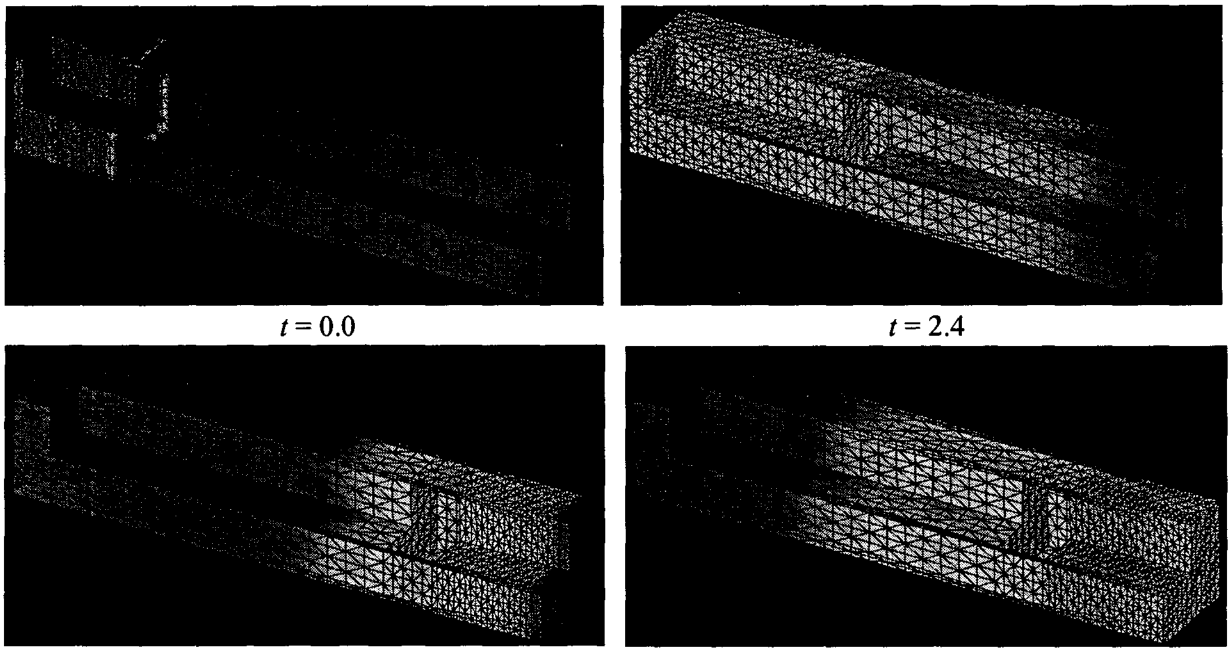


Fig.1 Control volume in space-time system



$t = 0.0$ $t = 2.4$

$t = 6.0$ $t = 8.0$

Fig.2 Guntunnel problem (Pressure contours)

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