Development of a moving artificial compressibility solver on unified coordinates

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Abstract

Based on the unified Eulerian and Lagrangian coordinate transformations, the unsteady incompressible Navier–Stokes equations with artificial compressibility effects are developed. As we know, the Eulerian coordinates cause excessive numerical diffusion across flow discontinuities, slip lines in particular. The Lagrangian coordinates, on the other hand, can resolve slip lines sharply but cause severe grid deformation, resulting in large errors and even breakdown of the computation. Recently, Hui et al. (J. Comput. Phys. 1999; 153:596–637) have introduced a unified coordinate system that moves with velocity hq, q being the velocity of the fluid particle. It includes the Eulerian system as a special case when h=0, and the Lagrangian when h=1, and was shown for the two-dimensional unsteady Euler equations of compressible flow to be superior than both Eulerian and Lagrangian systems. In the framework of unified coordinates, our work will derive the unsteady incompressible flow equations and moving geometry equations, when hq equals grid velocity in conservation form and is updated simultaneously during each time step. Thus, the accurate estimation of geometry conservation and controlling the grid velocity or the h value based on the unified approach can keep numerical stability and avoid computation breakdown caused by moving body or boundary layers (considered as slip lines in Lagrangian

coordinates). Also, the existing highresolution Riemann solver can be extended to discretize the current unified incompressible flow equations.
Our benchmark tests including the lid-driven cavity flow and backward step flow, oscillating flat plat and pulsating stenotic tube are used to validate the computations. The results verify the accuracy and robustness of the unified artificial compressibility solver on the moving body simulation.

Keyword：unified coordinates; incompressible flow; moving body simulation; geometry conservation law; artificial compressibility fluid–structure interaction