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ROBUST MULTI-PHASE FLOW SOLVERS WITH MESH-FREE ADAPTIVE GRID CIP METHOD

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ABSTRACT

For Computation of fluid-solid interfaces, which is one of the most challenging classes of problems in computational engineering and sciences, has been receiving much attention in recent years. The numerical challenges include (i) accurate representation of the flow field near the interface, (ii) accurate advection of the vortices, (iii) grid generation and motion, (iv) robustness and accuracy of the fluid-solid coupling technique, and (v) computational efficiency. The challenges increase further when the computation also involves fluid-fluid interfaces (including free-surface and multi-fluid flows).

We provide an overview of the key aspects of a CIP[1,2,3]-based adaptive grid approach for computing fluid--solid and fluid-fluid interfaces. In this approach, the CCUP technique[4], which is based on the CIP method, is combined with the adaptive Soroban grid technique[5,6]. The approach has a number of superior features. Even though the grid system is unstructured, it still has a simple data structure, and that gives us very good computational efficiency. A single interpolation process is used for both calculating the advection terms and estimating the values at the new grid points from the old grid points, and therefore there is no additional computational overhead associated with the grid motion. Because the Soroban grid technique does not have any elements or cells connecting the grid points, the approach is free from mesh (or grid) distortion limitations. The CIP method represents the solution between the grid points very accurately, and therefore despite the unstructured nature of the grid, the technique has high-order accuracy (the importance of the interpolation procedure was demonstrated by comparing the linear and CIP interpolations). Although the solution technique is based on a collocated-grid approach, high-order accuracy and robustness are maintained.

This Soroban-grid CIP method can also be applied to Vlasov-Boltzmann equation and Maxwell equation. In the former case, the velocity space might dynamically change according to the acceleration and hence the fixed grid spacing in velocity space is not economical. In the Soroban grid, the velocity grid can be chosen independently in each coordinate space and thus the velocity space grid behaves like the particles. In this sense, the Soroban grid is a combination of particle method and grid-based method.

The Maxwell equation can be split into several advection equations and hence such equation is the best example of the Soroban grid CIP method.

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