An accurate and practical unstructured solver for multi-phase interfacial flows and fluid-solid interactions using multi-moment finite volume method and THINC scheme

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ABSTRACT

The capability to deal with complex geometry is one of the most important issues in computational fluid dynamics (CFD) because most practical applications are associated with complex geometrical configurations. Found in nearly all commercial CFD (Computational Fluid Dynamics) codes is the "finite volume method (FVM) + unstructured grids" paradigm that gains a great popularity among the industrial users. However, the existing codes of this sort seldomly benefit from high-order numerical formulations and more substantially show poor robustness to the quality of computational meshes. Another problem which has not been satisfactorily resolved for unstructured grids is the computation of moving interfaces, which separate different fluids in multi-phase flows and need to be captured or tracked with adequate accuracy in numerical models.

This talk presents some of our recent efforts toward an accurate, robust and efficient CFD model for moving interfacial flows with fluid-solid interactions on unstructured grids.

The fluid solver is based on a multi-moment finite volume formulation, so-called VPM (Volume integrated average and Point value based Multi-moment) method [1], where both the volume integrated average (VIA) and the point value (PV) are treated as the computational variables and updated simultaneously at each time step. The VIA is computed from a finite volume scheme of flux form, and is thus numerically conserved. The PV is updated from the differential form of the governing equations in an efficient way. Including PV at the cell vertices as the additional degrees of freedom enables us to make higher-order reconstructions over compact mesh stencil to improve the accuracy. More importantly, the resulting numerical model is more robust for unstructured grids.

In order to capturing free interfaces in multiphase flows, we have developed a set of algebraic type volume of fluid (VOF) schemes, so called THINC (tangent of hyperbola interface capturing) method [2]. Without the need of explicit geometric representation of the interface, like the piecewise linear interface calculation (PLIC) algorithm in conventional VOF method, the THINC algorithm is very computationally efficient and easy to use, moreover, its implementation to unstructured grid is straightforward. Variants of THINC method have been devised to compute moving interfaces on unstructured grids with elements of different shapes. The results of benchmark tests show that the THINC method is an appealing approach of interface capturing particularly for unstructured grids.

Integrating these component schemes into the open CFD platform, OpenFOAM [3], we developed a high fidelity numerical solver on unstructured grids for interfacial multiphase flows including the fluid-solid interactions. Numerical verifications demonstrate the applicability of the present model as a promising tool for practical use in real-case applications.

REFERENCES

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