Mechanical Engineering Department Seminar

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1130 Mechanical Engineering
111 Church Street SE, Minneapolis, MN 55455

Development of Unstructured CFD Model for Interfacial Multiphase Flows Based on Multi-Moment Finite Volume and THINC Methods

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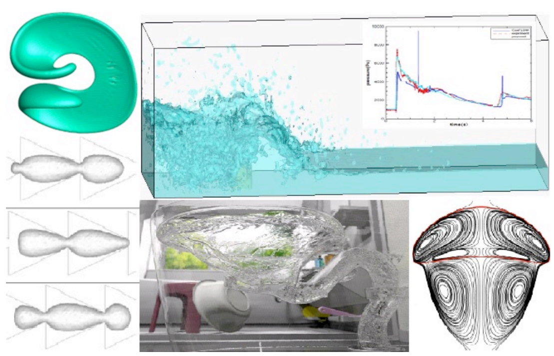
This talk presents a numerical solver newly developed for interfacial multiphase fluid dynamics on unstructured grids of arbitrary element shapes.

The fluid solver is based on a multi-moment finite volume formulation, 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 rigorously 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 and robustness. Using properly designed interpolation functions, the cell-wise reconstructions can be built for different types of cell elements, such as triangular or quadrilateral in 2D, and tetrahedron, hexagon, pyramid or prism in 3D. A completely conservative pressure-projection procedure is adopted to solve fluid dynamics, which makes the model uniformly applicable to flows of all Mach numbers. Without much increase in algorithmic complexity, this method is well-balanced between solution quality and computational cost.

In order to capture free interfaces in multiphase flows, we have developed an algebraic type volume of fluid (VOF) schemes, so called THINC (tangent of hyperbola interface capturing) method. 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 and other physical models on the OpenFOAM platform, we developed a multi-functional numerical solver on unstructured grids for interfacial multiphase flows. Numerical verifications demonstrate the applicability of the present model as a promising tool for practical use in real-case applications.



Bio: Dr. Xiao got his Ph.D degree from Tokyo Institute of Technology (Tokyo Tech) in 1996, and has joined Tokyo Tech as an associate professor since 1999 in the department of energy sciences.

He has been recently engaged in developing numerical schemes and models for complex flows, geophysical fluid dynamics, as well as engineering applications. He has authored or co-authored over 100 peer-reviewed papers in academic journals and over 200 presentations in international and Japanese conferences and symposia.

Dr. Xiao is a fellow of the Japan Society of Mechanical Engineers (JSME). He is a recipient of Award for Computational Mechanics from Japan Association for Computational Mechanics (JACM) in 2013; Computational Mechanics Achievements Award from Japan Society of Mechanical Engineers (JSME) in 2011; Fellow award from Japan Association for Computational Mechanics (JACM) in 2009. He was honored as a visiting fellow of Isaac Newton Institute for Mathematical Sciences (Cambridge) in 2012.

Dr. Xiao is currently serving the associate editor of Journal of Computational Physics (JCP), the managing editor of International Journal of Computational Methods (IJCM) and the general council member of International Association for Computational Mechanics (IACM).