Particle tracking in fluid flow: a numerical approach for complex geometries

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Abstract

This talk reports a joint effort that is presently undertaken by four research teams, working at: (*i*) the "Laboratório de Aerodinâmica Industrial, LAI" of the University of Coimbra, Portugal; (*ii*) the University of Aveiro, Portugal; (*iii*) the University of McGill, Canada; (*iv*) the "Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur, LIMSI" of the University Pierre et Marie Curie, Paris, France. The basic aim is to numerically model dilute, three-dimensional, turbulent, incompressible fluid-solid particle flows that are bounded by impermeable walls of complex shape. The common motivation of the four teams is based on the wide variety of engineering applications involving particle dispersion in turbulent flows, including interior dust and particle pollutant control systems, separation processes, pneumatic transport systems, particle combustion in industrial furnaces or energy converters, sediment transport, erosion, some surface treatment procedures and development of new materials, safety and fire suppression systems, and food production processes, among others. In such applications, CFD is being increasingly used as an efficient, accessible and affordable way of making numerical predictions in support of design and optimization.

In numerical simulations of fluid-particle flows, the continuous (fluid) phase is typically modelled via an Eulerian approach, while the dispersed (solid particle) phase is predicted using either an Eulerian or a Lagrangian approach. The Lagrangian approach is well suited for the description of the dispersed phase in the so-called *dilute* fluid-particle flows, in which the particle dynamics is controlled primarily by surface and body forces acting on the particle, rather than by particle-particle collisions or interactions. For the simulation of the continuous phase, control-volume finite element methods (CVFEMs) combine the merits of well-established finite-volume methods for regular geometries (easy interpretation of the formulation in terms of fluxes, forces, sources; satisfaction of local and global conservation requirements; and efficient techniques for handling the pressure-velocity coupling) and Galerkin finite element methods (mathematical models formulated in the Cartesian coordinate system even for irregularly shaped calculation domains).

A formulation based on a CVFEM for the simulation of the carrier phase in a model for particle dispersion in dilute, two-dimensional, turbulent flows was recently reported by the present team (Oliveira *et al.* [1]). In that work, the motion of the solid (particulate) phase is simulated using a Lagrangian approach. An efficient algorithm is used for locating the particles in the finite element mesh. In the demonstration problem, which involves a particle-

laden, turbulent plane mixing layer, a modified k-ε turbulence model is used to characterize the velocity and length scales of the turbulent flow of the fluid phase. The effect of turbulence on the particle trajectories is accounted for through a stochastic model. The effect of the particles on the fluid time-mean velocity and turbulence (two-way coupling) is also addressed.

The three-dimensional extension of the work reported in reference [1] is now available (see Oliveira *et al.* [2], [3]). In the present talk, a description of the numerical global procedure that is used in this research will be briefly presented, together with a demonstration problem that was selected for validation purposes.

Even though the results reported in references [2] and [3] are rather encouraging, there is still obvious room for further improvement and development. The talk's conclusion includes a brief mention to the main topics that should be addressed in the joint team's future work.

Keywords: CFD, CVFEM, multiphase flow, particle dispersion, Lagrangian-Eulerian, stochastic approach, two-way coupling.

References

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[3] L.A. Oliveira, V.A.F. Costa, and B.R. Baliga, *Numerical model for the prediction of dilute three-dimensional, turbulent fluid-particle flows, using a Lagrangian approach for particle tracking and a CVFEM for the carrier phase*, accepted by Int. J. Numer. Meth. Fluids (already available in the Journal's site), 2008.