Simulation of passive scalar transport using hybrid grid-particle method with improved particle shifting approach

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ABSTRACT

Passive scalar transport is a fundamental problem of a variety of industrial applications. One of the representatives is the fluid mixing process [1], which has been intensively studied as an important physical phenomenon in chemical engineering field. A number of numerical calculations of passive scalar transport problem have been carried out by means of the grid-based approach. However, the grid method generally suffers from the unavoidable numerical diffusion which causes significant numerical error at high Péclet number.

We have developed a hybrid grid-particle method for simulation of the passive scalar transport in incompressible laminar flow. The method uses both computational grid and particle systems and combines the grid-based (Eulerian) approach and the particle-based (Lagrangian) approach in the following manner. The finite volume method is employed to solve stably the flow field on the grid system. Each Lagrangian particle is moved according to the velocity field, and the passive scalar field is solved on the particle system, where the Laplacian operator is discretized based on the standard LSMPS scheme type-A [2].

Particle redistribution is a necessary operation to avoid numerical instability led by the highly anisotropic particle spacing. The particle shifting approach [3] has been found effective to remedy this issue; however, this approach is not suitable for high-Péclet number problems involving sharp interface, i.e. liquid mixing process, because it dissipates the interface. We have proposed a modification to the particle shifting approach for better preservation of the smooth sharp interface.

The proposed hybrid method is examined through several test cases. The results show that the method provides solution with minimal numerical diffusion for numerical analysis of passive scalar transport.

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