NUMERICAL SIMULATION OF INCOMPRESSIBLE FLOWS BY SPH

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Smoothed particle hydrodynamics (SPH) is a meshless, free lagrangian particle method, which was originally proposed to solve astrophysical problems without boundaries in three-dimensional space. SPH employs a collection of smoothed particles that have physical parameters as interpolation points to represent the state of a flow system. It has some straightforward advantages over traditional numerical methods especially in simulating problems involving in large inhomogeneities, deformable boundaries, moving material interface and free surfaces for its meshless, free lagrangian and particle method feature. The great success and wide application of SPH in the astrophysical area give rise to its extension to the simulation of practical computational fluid dynamics problems.

However when simulating incompressible flows, the standard SPH encounters difficulties. In standard SPH for solving compressible flows, the particle motion is driven by the pressure gradient, while the particle pressure is calculated by the local particle density and internal energy through the equation of state. However for incompressible flows, there is no transportation equation for pressure just as in the traditional grid-based methods. Moreover, the actual equation of state of the fluid will lead to prohibitive time step. Though it's possible to easily include the constraint of the constant density into the SPH formalism, the resultant equations is too cumbersome to be solved.

In this paper, the standard SPH is extended to simulate incompressible fluid flows by using an artificial compressibility technique to model the incompressible flow problems as slightly compressible through a suitable quasi-incompressible equation of state. Some modifications are made to the standard SPH to suit for the needs of incompressible flow applications. Four numerical examples, Poiseuille flow, Couette flow, shear driven cavity problem, and a simulation of a collapsing dam are presented. The good agreement of the numerical results with the exact solution and experiment data shows the feasibility and accuracy of applying the present method to incompressible simulations.