A Simulation of Deformable Particles Falling through a Straight Channel

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In this abstract, we discuss the application of the Extended Immersed Boundary Method to the numerical simulation of deformable particles falling in an incompressible viscous fluid. The motion of the particles is not known a priori and is due to the hydrodynamical forces and gravity. We construct a fixed Eulerian grid for the fluid domain while the fluid-structure interaction with moving deformable particles is modeled with a collection of judiciously chosen nodal forces which are calculated using the finite element methods.

The immersed boundary method (IB) was originally developed by Peskin for the computation of blood flows interacting with the heart and heart valves [1]. In essence, it is a mixed Eulerian-Lagrangian scheme using a fixed Eulerian grid for the fluid motion, along with the immersed boundary represented with a set of moving Lagrangian points. In the Extended Immersed Boundary Method, recently proposed by Wang and Liu [2], *both the interior and the fluid-structure interfaces of the submerged structure are modeled as submerged material points,* where the nodal forces are calculated using finite element methods. We no longer have to identify and follow the fluid-structure interfaces. Although the *entire* submerged solid domain is decomposed into a collection of *submerged Lagrangian* points, due to the distributed nodal forces, the surrounding fluid will not penetrate into the structure interior and consequently, the fluid-structure interface will be automatically defined by the submerged material points enclosing the solid domain.

We consider the simulation of particles made of nonlinear rubber material in a channel of infinite length with channel width of 3 cm, which is contained in a computational domain of 10 x 10 cm. We assume a fluid with the density of 1 g/cm^3 and the viscosity of 1.13e-2 dyne/cm^2 ·s. In this example, the flexible particle is made of an incompressible rubber material with C_1 = 29300, C_2 = 17700, k = 141000 dyne/cm^2, and ρ = 3 g/cm^3. In the simulation, the particles are located close to the inlet of the channel, released, and fall freely in a gravitational field. The computed terminal velocities of one single ball, discussed in [2], are in good agreement with analytical terminal velocities in the similar computational configuration. A comparison of rigid particles passing through a channel branch will be reported in another abstract by Wei, Feng, Zhu, and Wang. In this case, there is no analytical expression for the motions of multiple deformable particles. Due to the viscous and inertia effects, the particles quickly separate from each other as illustrated in Fig. 2. The rotations of the particles are introduced by the vertex shedding effects as shown in Fig.1. Note that these rotations are naturally captured by the Extended Immersed Method because of the full-fledged deformable solid mechanics modeling of these particles.

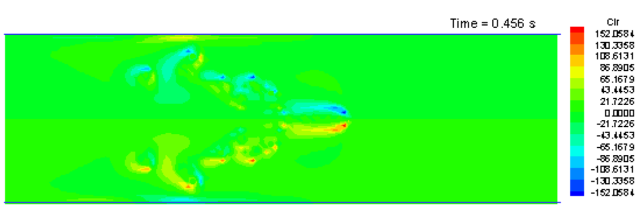

Fig.1 Circulation band plot at time 0.456 s.

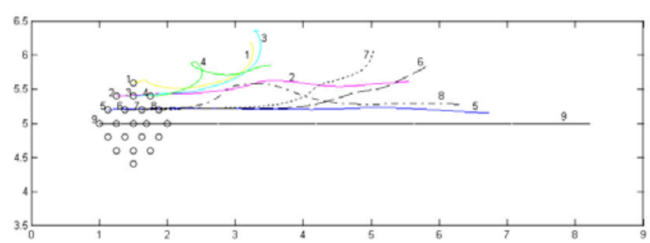

Fig.2 Trajectories of particles falling through a channel.

References

[1] C. Peskin, "Numerical analysis of blood flow in the heart," *Journal of Computational Physics*, v. 25, p. 220-252, 1977.

[2] X. Wang, and W. Liu, "Extended immersed boundary method using FEM and RKPM," *Journal of Computational Physics*, Submitted.