Tracking Big Particles

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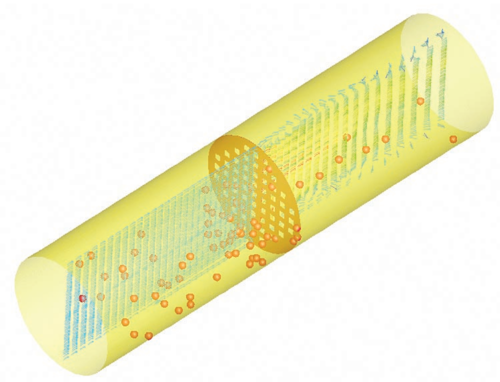
Particle tracking models in most commercial CFD software, such as the discrete phase model (DPM) in FLUENT, assume that particles are point masses that do not interact. Large particles immersed in the fluid flow cannot be modeled using this type of approach. The modeling of large (macroscopic) particles requires special treatment to take into account effects such as the blockage of fluid volume, the proper evolution of the drag force and torque experienced by the particles, particle-particle as well as particle-wall collisions, and friction dynamics.

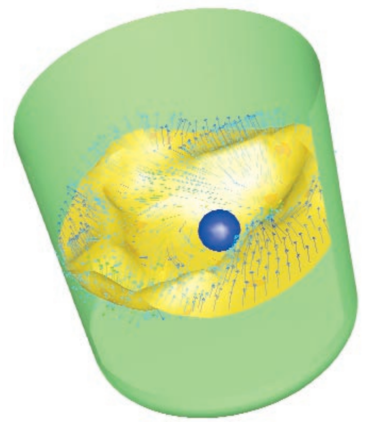
To account for these effects, a macroscopic particle model (MPM) has been developed for FLUENT 6 using user-defined functions (UDFs) and a customized graphical user interface (GUI). In the MPM approach, particles are treated in a Lagrangian frame of reference. Each particle is assumed to span several computational cells. A solid body velocity that describes the particle motion (translational and rotational) is patched in these cells. The volume fraction of the particle is also taken into account. By patching the rigid body motion of the particle, momentum is effectively added to the fluid. The integral of the momentum change, linear as well angular, gives the drag force and torque for each particle. These are used to compute the new positions and velocities of the particles at the next time-step. Additional forces, such as body forces, can also be included in the model. To detect a particle-wall collision, the model identifies the boundary faces (wall surfaces) the particle intersected during the previous time-step, if any. If a collision with a stationary wall is detected, the incoming particle velocity is projected onto the normal and tangential components of the reflected particle velocity, applying the coefficient of restitution and friction factor, as appropriate. In the same way, the model detects particle-particle collisions, and applies the principle of conservation of momentum to obtain the final velocities of both particles. The particle-wall collision algorithm also takes into account rotating or moving walls, so it can be used with both the sliding and deforming mesh models in FLUENT. The MPM UDF has been parallelized and works well with the FLUENT parallel solver.

The customized GUI is used to define all user inputs for the macroscopic particle model. The initial particle properties (positions, velocities, mass, radius) for each particle stream can be entered in the panel or read from a formatted ASCII file. MPM postprocessing tools have been coupled with FLUENT's DPM visualization tools, which allow particles to be displayed as shaded spheres with a defined radius. Transient particle data can also be saved in a Fieldview data file format.

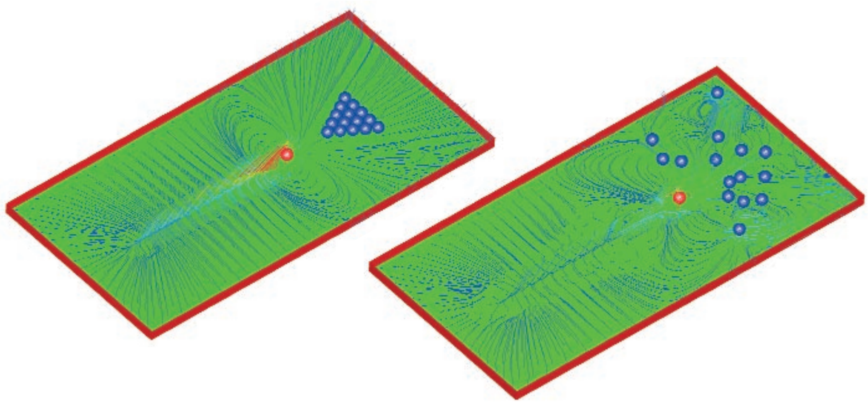
The macroscopic particle model has many industrial applications, especially in the pharmaceutical, chemical, material handling, and sports industries. Several validations have been performed. The tests have shown that a large number of particles (up to 1000) can easily be handled without the need for excessive computation time. ■



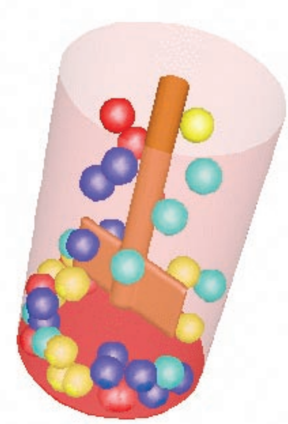
Macroscopic particles continuously injected through a filter element



A spinning heavy ball dropped in water disrupts the liquid surface



Pathlines show the air flow (including recirculation) generated by the cue ball as it rolls towards the rack on a pool table (left) and just after it strikes and disperses the balls (right)



Balls of different mass continuously injected into a rotating paddle-type mixer