A FULLY IMPLICIT-FULLY COUPLED APPROACH TO STUDY LIQUID FLOWS WITH SUSPENDED PARTICLES USING LAGRANGE MULTIPLIERS

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Flows with suspended rigid particles occur in many different applications, from sedimentation, fluidized beds to the manufacturing of ordered monolayer of micro and nano particles. The evolution of the particles position is a central point in the complete understanding of these processes. One way of analyzing the flow is to use a moving grid to discretize the Navier-Stokes equation that wraps around all suspended particles. This method requires remeshing and is not very efficient in the case of many particles. An alternative, known as fictitious domain, was proposed by Glowinski et al (1999). The Navier-Stokes equation is solved on a fixed grid and the particles move over this grid. This approach avoids the need to grid around the rigid particles, solving the entire problem on a single fixed mesh. The Navier-Stokes equation is solved on the entire domain, but inside each particle, the flow is constrained to be a rigid body motion using Lagrange multipliers.

This paper presents a fully implicit-fully coupled finite element formulation for the direct numerical simulation of incompressible fluid flows with suspended rigid particles based on the fictitious domain method. At each time step, the resulting non linear system of equations is solved by Newton's method, with quadratic convergence. This makes the iterative procedure very efficient and only a few Newton's steps are necessary to obtain the solution at each time step.

The method is validated by comparing the predictions with results in the literature for the sedimentation of one and two cylindrical particles in a two-dimensional box. The approach is then used to study how a set of particles move towards and are arranged in a liquid-gas interface.
