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Fictitious Domain Methods for Flows Containing Rigid Particles

Modelling of particulate flows is one of the most difficult and often misunderstood ares of Computational Fluid Dynamics. There is a variety of proposed models, however, none of them is based on a solid theoretical foundation, thoroughly verified in experiments. Therefore, it is very important to approach the problem by solving directly the incompressible Navier–Stokes equations in a domain filled with rigid particles and try to extract some useful average characteristics of such flows. This is an extremely difficult computational task and there are very few available methods that could be applied. In this talk we describe the variant of the fictitious domain method (FDM) which was proposed by our group. Several validation examples of flows with rigid particles are also presented. The focus of the talk will be on the development of a particular version of the algorithm for the simulation of micron-size particles in pipes and bifurcations whose characteristic size is of the order of millimeters. This particular application comes from the need to predict the deposition rate of drugs in the upper air ways. Because of the clear separation of scales, it was possible to develop a technique using two sliding grids (corresponding to the two different scales)—one linked with the particle and the other one with the pipe. The flow at the macro scale is first resolved without the particle and then the information is used as a boundary condition for the micro-scale problem. The two problems can be linked (if needed) in an iterative fashion to account for the effect of the particles on the flow. The numerical examples include particles of spherical and ellipsoidal shape.