Numerical simulation of sediment dynamics in free surface flows

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Sediment transport is becoming a crucial question in hydraulic and environmental engineering. In addition to sharp interfaces between immiscible phases such as water and air, the modeling of sediments introduces an additional miscible phase in the liquid with diffuse interfaces. Challenges range from the physical modeling of the poly-dispersed sediments, the design of appropriate numerical methods for the coupled model, to the large-scale three-dimensional simulation of reservoirs and lakes.

We present a numerical model for the simulation of 3D poly-dispersed sediments transported in a water flow involving free surfaces between the liquid and the ambient air. The physical model is based on a mixture model for multiphase flows. The Navier-Stokes equations for incompressible non-Newtonian flow are coupled with the advection and vertical deposition of the particles' concentration, and a Eulerian approach for the tracking of the free surfaces.

The numerical algorithm relies on an operator-splitting method that decouples diffusion, advection and sedimentation processes. A well-chosen mix of finite elements, finite volumes and characteristics methods are dedicated to each sub-step of the time evolution algorithm. A volume-of-fluid approach to track the free surfaces between water and air. A two-grid discretization allows to treat the diffusion phenomenon on an unstructured finite element mesh, and the advection and vertical sedimentation phenomena on a Cartesian grid.

The numerical model is validated through numerical experiments. A comparison with experimental results in various situations for mono-disperse and poly-disperse sediments, and the calibration of deposition fluxes, are performed.

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