A Smoothed Particle Hydrodynamics Particle Suspension Mixture Model and its application to Turbulent Sediment Transport

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Abstract

We present results from an on-going research effort which aims at applying the Smoothed Particle Hydrodynamics (SPH) method [1] to various cases of complex flows involving particle-suspension / structure interaction. The proposed method relies on the description of particle suspensions via a mixture model [2] which was adapted to the Lagrangian framework of SPH. Particle transport is modelled through the convection-diffusion of the sediment volume fraction. This accounts for particle sedimentation and turbulent diffusion which can be related to turbulent viscosity, the latter being extracted from the solution of a $k - \omega\, SST$ URANS turbulence model. Moreover, the non-Newtonian nature of particle suspensions is consider by means of generalised Newtonian viscosity models such as Herschel-Bulkley's or Papanastasiou's models. Hence, the rheological properties of the sediment suspensions are specified as functions of local particle concentration and shear rate.

The proposed model is first assessed on available experimental results on particle-driven gravity currents [3], where results for the current front evolution and particle deposition profiles are reported. Considering the wide range of concentrations covered (2.5% up to 15%) and although some uncertainties exist regarding the high concentration suspension rheology and particle impact on turbulence, satisfactory agreement with experimental results is obtained. Moreover, several key features reported to occur in gravity currents such as the slumping phase and the large turbulent wakes upstream of the current head, are indeed observed in our simulations. A second application to this modelling work is related to the perspective of estimating the disturbance created by a moving harvesting device near the seabed for deep-sea applications. With this perspective in mind, a laboratory-scale setup comprising a horizontally translating inclined plate partially immersed into a layer of clay sediment was constructed. The behaviour of the bentonite clay sediment layer was characterised by means of rheological measurements and is modelled as a shear-thinning fluid with yield stress. The induced sediment dispersion is investigated for various cases and the SPH predictions are compared with visual experimental observations, highlighting the capture of various flow and sediment transport characteristics and overall, good agreement with the experiments.

Keywords: **SPH, mixture model, particle-driven gravity currents, sediment turbulent transport, non-Newtonian rheology.**

References

[1] J.J Monaghan, Smoothed Particle Hydrodynamics and its diverse applications. Annu. Rev. Fluid Mech. 2012. 44:323–46.
[2] M. Manninen et al. On the Mixture model for Multiphase Flow. VTT publications 288, Finland, 1996.
[3] M.A. Hallworth et al. Abrupt transitions in high-concentration, particle-driven gravity currents. Phys. Fluids 1998 10:1083-1087.