Rheology of unconsolidated granular bed mobilized by oscillatory flow

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Two-phase models of sediment transport obtained by volume averaging the momentum equations for the solid and fluid phases include stress terms that require empirical rheological closures. Previous investigations have proposed two rheological regimes a viscous regime dominated by fluid forces where the stresses scale linearly with the shear rate and a grain-inertia regime dominated by collisional forces where the granular stresses scale quadratically with the shear rate. Here, we investigated the rheology of dense layers of spherical particles mobilized by oscillatory bottom boundary layer flow using direct numerical simulations [1] that fully resolve the flow around particles and dynamically model the particle contact forces. The flow conditions correspond to intermittently turbulent bottom flows caused by sea waves and the particles correspond to medium size sand. The computed instantaneous granular stresses, particle volume concentration and velocity were sampled with high frequency O(2000) per cycle and coarse-grained in thin horizontal layers over the whole domain to obtain one-dimensional fields describing the rheology of the moving particle layers. The numerical results (e.g. Figure 1) were used to evaluate the existing rheological models and their application to sediment transport in oscillatory flow.

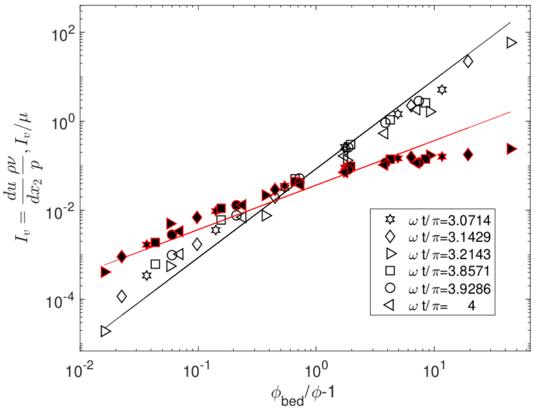

Figure 1: The inverse normal viscosity I_v (open symbols) and shear viscosity I_v/μ (solid symbols) in the dense mobile bed as a function of $\phi_{bed}/\phi-1$ for six phase intervals surrounding the maximum velocity phase, μ denoting the effective friction coefficient and ϕ the solid volume fraction reaching the value ϕ_{bed} in the resting bed. The slopes of the straight lines are 1.0 (red) and 2.0 (black).

References

[1] Mazzuoli, M., P. Blondeaux, G. Vittori, M. Uhlmann, J. Simeonov, and J. Calantoni, 2020, Interface-resolved direct numerical simulations of sediment transport in a turbulent oscillatory boundary layer. *J. Fluid Mech.*, **885**, A28.