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A novel and generalized quasi two-phase mass flow model: Full-dimensional channel flow simulations

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We employ full dimensional two-phase mass flow equations (Pudasaini, 2012) to develop a generalized quasi two-phase bulk model for a rapid flow of a debris mixture consisting of viscous fluid and solid particles down a channel. The emerging model, as a set of coupled partial differential equations, is characterized by some new mechanical and dynamical aspects of generalized bulk and shear viscosities, pressure, velocities and effective friction for the mixture where all these are evolving as functions of several dynamical variables, physical parameters, inertial and dynamical coefficients and drift factors. These coefficients and factors are uniquely constructed, contain the underlying physics of the system, and reveal strong coupling between the phases. The new model is mechanically described by an extended pressure and rate-dependent Coulumb-viscoplastic rheology of mixture (Domnik et al., 2013). The introduction of the velocity and pressure drifts makes it possible to reconstruct the two-phase dynamics.

We present full two-dimensional high-resolution simulations of mixture mass flow released from a silo gate down the channel for the flow geometry, mixture velocity and dynamic pressure, Froude number, and effective viscosity. The model simulates the velocities and pressure of the mixture much faster than the two-phase mass flow model. We show that the flow dynamics are strongly controlled by the initial material composition. Several technically important features are observed: The flow becomes thicker as solid fraction increases, the front head develops into bulking, and the main body shows depletion. The slip velocity increases along the slope and generally attains higher values for lower solid fraction and results in higher flow mobility. A strong velocity shearing develops through the flow depth. The full dynamic pressure exhibits strongly non-linear structures. It appears that the often used hydrostatic pressure may significantly underestimate the full dynamic pressure. The generalized Froude number changes substantially through depth. Simulations show that the process of flow release must be described by the full dimensional models. These novel results are in line with observed phenomena and highlight the application potential of the new model in appropriately designing the defense structures and thus provide important information for the hazard mitigation and planning.

References:

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