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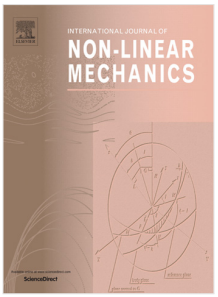

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An extended quasi two-phase mass flow model

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Abstract: Employing a physics-based full dimensional two-phase mass flow model (Pudasaini, 2012), we construct an extended quasi two-phase bulk mixture model for a debris flow as a mixture of non-Newtonian viscous fluid and solid particles down a channel. The newly derived model is a set of highly non-linear, coupled mass and momentum balance equations together with virtual mass force induced extended pressure Poisson equation. The model includes mechanically very important first order, and novel effects of drag, virtual mass force and mobility of the fluid at the interface with solid particles in the mixture flow. These aspects were not included in the previous simple bulk mixture models. We demonstrate that these new mechanical aspects of drag, virtual mass and mobility play dominant role in the mass flow dynamics; as seen in the extended inertial coefficients, mixture viscosities, mixture and phase velocities and pressure. This shows that we must retain these effects to obtain physically more accurate results for wider application potential. There are additional contributions to the mixture viscosity due to mobility and diffusion of mass fluxes. Diffusion process seem to be much more complex for the bulk mixture flow than for the two-phase flow. The new extended model leads to the exclusive emergence of diffusion and anti-diffusion fluxes and the associated diffusion- and anti-diffusion viscosities, and mass flux enhancement. The system could be diffusion only or, simultaneously could also include important anti-diffusion process. Comparison between the diffusion and anti-diffusion viscosities reveals fundamentally different mechanical processes in mixture mass flows. Typically, anti-diffusion process is pronounced for higher solid fraction. Furthermore, the main mechanics governed by the extended mixture viscosity, and dynamical variables (mixture pressure and velocities) are all controlled by the drag, virtual mass and mobility. The drag intensity in bulk mixture