Enhanced Descriptions of Real Two-phase Landslides and Debris Flows

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1 Introduction

Landslides, debris flows and tsunamis are some examples of mass transport phenomena that are widely found in nature (Savage and Hutter, 1989; Hungr, 1995; Iverson and Denlinger, 2001; Pitman and Le, 2005; Pudasaini and Hutter, 2003; Pudasaini et al., 2005; Takahashi, 2007; Pudasaini, 2011; Pudasaini and Miller, 2013). These are large mass movements and extremely destructive natural hazards that often occur as the motion of the mixture of soil, rock and fluid down mountain slopes. So, reliable methods are needed to accurately predict the flow evolution, run-out distances, inundation areas, deposition behavior, impact forces, and the overall flow dynamics from inception to standstill. This is required for the prevention measures and enhanced mitigation strategies in geo-hazard-prone areas (Pudasaini and Hutter, 2007). Depending on the material involved and the flow dynamics and the momentum transfer between the constituents, these flows can be effectively single phase, or must be described by applying the real two-phase mass flow models (Pudasaini, 2012). As these flows are advective-diffusive processes, these events are modeled by some complex hyperbolic-parabolic partial differential equations (Pitman and Le, 2005; Pudasaini et al., 2005). For the correct and reliable description of flow behavior, we need the exact description of eigenvalues of the system (Pudasaini and Hutter, 2007). From eigenvalues, we extract wave speeds and determine the Froude number (Fr). As the wave speeds for both the solid and fluid are very important information in the simulation, their accurate knowledge plays vital role in correctly describing real two-phase flows. Fr determines the nature of mass flows by distinguishing subcritical (slow), critical (moderate) and supercritical (rapid) regimes (Domnik and Pudasaini, 2012; Domnik et al, 2013).

2 Exact eigenvalues and enhanced modeling of debris flows

Accurate knowledge of Fr is very desirable in the design of the defense structures that may be hit by the geophysical mass flows. So, for two-phase mass flows, the determination of the general and complete eigenvalues, wave-speeds, and Fr are of special interest in landslide and debris flow community. For the first time, we present the exact and complete eigenvalues for both the solid- and fluid-phase for the real two-phase, general mass flow model presented by Pudasaini (2012). We call them: solid-phase-eigenvalues and fluid-phase-eigenvalues (or, simply phase-eigenvalues). The associated Froude numbers are called the solid-phase Froude numbers and fluid-phase Froude numbers (phase-Froude-numbers). Similarly, solid- and fluid-phase wave speeds are defined and determined. Simple eigenvalues, wave speeds and Fr are deduced from the general ones. The derived eigenvalues, wave speeds and Fr are applied in the unified and high resolution simulation codes to appropriately determine the enhanced flow dynamical quantities, including the evolution of the solid- and fluid-phase, fluid volume fraction, total debris and landslide height, inundation area, phase velocities, and the impact forces exerted by debris flows on the civil structures, e.g., buildings, bridges and power transmission lines, and forests and trees (Pudasaini and Hutter, 2007).

3 Concluding remarks

Here, we analytically derive the solid- and fluid-phase eigenvalues, wave-speeds and Froude numbers for the real two-phase debris flow model (Pudasaini, 2012). Debris mass flow is considered as the movement of mixture of solid particles and the viscous fluid. There are strong couplings between the solid- and the fluid-phase momentum transfers in the real two-phase mass flows. So, the complete, general and exact descriptions of the eigenvalues, wave-speeds and Froude numbers is very important in the correct and enhanced descriptions of the mass flows as these quantities must be derived simultaneously by including the solid and the fluid properties of the mixture. This is one of the main aspects of this contribution. High-resolution, shock-capturing scheme is implemented to solve the model equations numerically (Tai et al., 2002; Pudasaini and Hutter, 2007; Pudasaini, 2011). Advanced computational results are presented and compared with the new and the pre-existing eigenvalues and wave speeds. Importance of the new eigenvalues, wave speeds and Froude numbers over the classical ones is discussed in detail in connection with the different dynamical quantities, such as the solid- and fluid-phase, fluid volume fraction, debris and landslide height, inundation area and phase velocities and dynamic impact forces and flow obstacle interactions associated with the real two-phase debris flows.

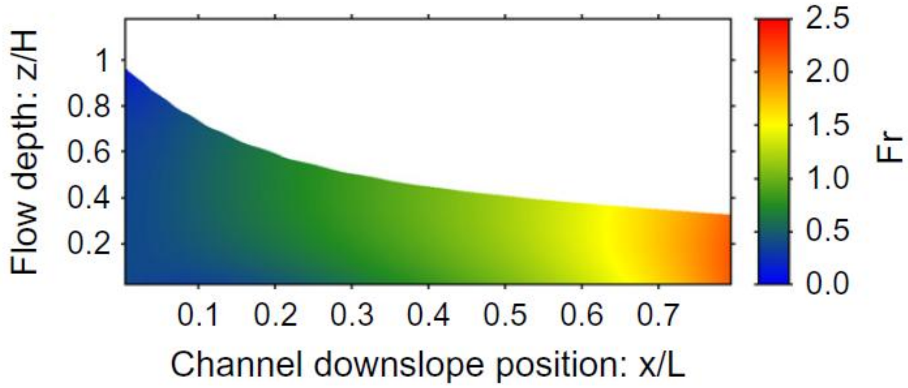

Fig. 1: Generalized Froude number for rapid flows of granular material down an inclined chute. The material enters into the channel from a silo gate. The channel is inclined at an angle of 50° with the horizontal. At *x/L* = 0.4, the flow passes from the sub-critical to super-critical regime. So, the granular and debris flows in inclined channels are characteristically supercritical flows (Domnik and Pudasaini, 2012).

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