Analytical Solutions of the Savage-Hutter Model for the Avalanche Dynamics in Inclined Channels

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ABSTRACT

The Savage-Hutter model is actively applied to describe the gravity driven shallow-water flows like the submarine and aerial landslides, debris avalanche and pyroclastic flows from volcano [1]. The number of the analytical solutions of the gravity driven shallow-water flow is limited. Savage and Hutter constructed some self-similar solutions called parabolic cap and M-wave similarity solutions. Such solutions are obtained for a chute of constant inclination and for a constant bed friction angle. Detailed description of the self-similar solutions for the evolution of the avalanche of symmetric shape along the inclined plate is given in book by Pudasaini and Hutter [1]. Mangeney et al. [2] found the analytical solution of a one-dimensional dam-break problem over inclined plane also taking into account the Coulomb friction. It was actively used to test the debris avalanche numerical models applied to evaluate the hazard of the volcano eruption in the Lesser Antilles. Fernandez-Feria [3] extended this analysis on the arbitrary bottom slopes. Rudenko et al. [4] found the exact solution that represented the simple (Riemann) wave in an ideal flow (neglected friction) along a plate of a constant slope.

Meanwhile, the real gravity driven flows move in the basins of complicated geometry. As a rule, they move in inclined channels (valleys on mountains and submarine canyons) which are generally diverging, converging or twisted on various parts. Anywhere some of them have straight parabolic-like shapes, at least in a part of flank. We provide here several new analytical solutions for the gravity driven shallow-water flow in inclined channels of the constant slope with the specific parabolic-like cross-section taking into account the Coulomb friction.

The Riemann invariants are found for the hyperbolic system described gravity flow in the inclined channels following [5]. Several analytical solutions described the nonlinear dynamics of avalanche are obtained: Riemann wave, dam-break problem, self-similar solutions (M-wave, parabolic cap and avalanche with linearly inclined surface) and the Carrier-Greenspan-like solutions. New effects in comparison with the known for the 1D avalanche motion on the inclined plate are related with the parabolic-like cross-section shape of the channel influenced on the avalanche dynamics.

They can be used to test the 2D numerical models of debris volcano avalanches, mountain flanks and landslides in submarine continental slopes.

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