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A TWO–DIMENSIONAL MODEL FOR THE DYNAMICS OF GRANULAR AVALANCHES

Abstract

Zoning of avalanche risk areas is one important task of land–use planning in alpine areas. The lack of records, due to the low frequency of these events, makes it difficult to implement a statistical analysis. Simulations made with physical and mathematical models can improve the knowledge of the dynamics of these events.

In this thesis three different mathematical and numerical models, based on the rheological theory of Savage and Hutter for granular flows, are introduced. A one dimensional model with variable width, written in a curvilinear coordinate system, has been developed. New rheological hypotheses have been introduced in order to describe the frictional interaction with vertical sides. The model has been tested against experimental data, relevant to cases with constant width, collected in the literature. The results give a first confirmation of the rheology, but a campaign of laboratory experiments is necessary in order to verify the model in cases with variable width.

The two–dimensional model, implemented at the Department of Civil and Environmental Engineering, has been developed. It was originally written in an horizontal coordinate system, assuming a linear stress tensor distribution and the constancy of the velocity along the vertical instead of along the normal to the bottom direction. The model has been improved by defining a rotated absolute coordinate system, which best fits the sliding surface. This modification corrected the initial delay shown in the simulations of the original model, with respect to the experimental data reported by Gray et al.(1993) in literature. An experimental campaign has been carried out in order to calibrate the two–dimensional model. A two–axial moving system, carrying a laser distance sensor, has been added to the double slope chute of the Hydraulic Laboratory of the University of Trento, in order to automatically scan the final deposits. Alternative choices of the structure of the stress tensor have been tested against experimental data. The two–dimensional model cannot still be applied to real cases. The severe distortion of the mesh, due to strong planimetric gradients of velocity, causes the crash of the model in presence of complex topographies.

We focused our attention on meshless methods in order to solve this type of problems. In meshless methods, the computational nodes, which discretize

the fluid domain, are not bound by topological relations, as in finite difference and finite element methods. This make them suitable to problems characterized by mass separations, strong deformations and discontinuities. The Moving Least Square Particle Hydrodynamics (MLSPH) method, created by Dilts (1999, 2000), has been applied to the one–dimensional model developed at the Department of Civil and Environmental Engineering of Trento. In the MLPSH model the equations of motion are written in weak form and the field variables of the problem are approximated by means of the Moving Least Square Approximants (MLSA) (Lancaster and Salkauskas (19)). The one–dimensional MLSPH model showed a strong increase of the computational time with respect to its original version, not compensated by a significant improve of performances. Nevertheless, the extension to the two–dimensional case, where more strict constraints are imposed by the mesh, looks promising.

The avalanche site of Lavina Granda, in Vigolana range, has been equipped in order to measure the dynamic parameters of real avalanches. We set up three sections for velocity measurements, one section for flowing depth measurement, two graduated poles to estimate snow cover depth in the initiation zone. Wooden tracers were spread over the catchment in order to evaluate avalanche activity. During the winter season 2002–2003 no avalanche activity affected the channel. On summer 2003 a debris flow ran down along the channel. Its flowing velocity was measured and its paths were identified by means of the wooden tracers. During the winter 2003–2004 three granular avalanches and one powder avalanche took place in the channel. The final deposit of the first granular avalanche has been mapped through a detailed topographical survey. A quick topographical survey has been tested in order to evaluate the geometrical modifications of the sliding surface, due to the passage of the avalanches.