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On the dynamics of nonlinear, unsteady landslide flow within the smoothed particle hydrodynamics

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In the present study the idea of landslide modeling by particle method is described. Smoothed particle hydrodynamics was invented in 1977 by Leon Lucy and independently by Bob Gingold and Joe Monaghan [1]. It was used for astrophysics phenomena's simulation. Later it was adapted for hydrodynamics, gas dynamics and solid body problems.

Landslides can be caused by the influence of different factors. Landslides occur when the angle of inclination of the slope of the slope or if the slope is burdened with loose material. A landslide flow is a thin homogeneous layer of nearly incompressible fluid. It is considered that at the initial moment shifted part of a ground mass is splitting and turning into liquid of several layers which then is streaming down along the slope.

The landslide flow motion is described with the Navie-Stocks set of equations:

$$\frac{D\vec{u}}{Dt} = -\frac{1}{\rho}\nabla P + \mu\nabla^2\vec{u} + g \tag{1}$$

$$\frac{D\rho}{Dt} = 0, \tag{2}$$

where u is velocity vector, t is time, ρ is a flow density, P is a pressure, μ is a viscosity coefficient, g is gravity.

Continuum discretization by finite number of lagrangian particles is the main idea of SPH [2,3]. Particles moves with the flow and arbitrary connectivity is allowed. Therefore, SPH does not need a grid to calculate spatial derivatives. For any field $A(r)$, involved in equation (1), e.g. pressure, density, viscosity etc., we consider an approximation with a finite function:

$$A(r) = \int\limits_{\Omega} A(r')W(r - r', h)dr' \tag{3}$$

where A is a desired field, r is a radius-vector, W is an interpolating kernel.

The free boundary condition problem is discussed. Finding the particles on a free surface is described. Also the surface tension force defining is shown.

Described method is implemented and mathematical modeling of landslide flows motion along slope is simulated. Different types of slopes are considered: with constant and variable steepness, long and wide. Wave-breaking effects near the wall are shown. Findings are analyzed within other models.

The presented numerical model differs from the known implementations of SPH: we used the Tait equation of state, the calculation of the density from the continuity equation, the calculation of viscosity using the Laplacian, used the kernel function for each unknown function.

On three-dimensional formulation problems presented, major strengths of SPH can be identified: a high degree of physicality due to the modelling by Lagrangian particles; also SPH can expect problems with large deformations. So SPH is relevant to describe the continuous, with a massive violation of connected computational domain, and modelling the traditional grid methods is impossible.

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