3D numerical simulation of large scale landslides using a Lagrangian PFEM approach

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ABSTRACT

As a consequence of climate changes, the frequency with which landslides occur is continuously increasing. The extreme consequences of these natural phenomena can be seen in terms of the large number of casualties and the extensive damage to structures and infrastructures. Consequently, the hazard and risk assessment of landslides with potentially long run-out distance is becoming more and more important. Numerical techniques can be used to better dominate these problems and to help experts in evaluation of critical sites.

In this work, a numerical tool to simulate the macroscopic behaviour of an evolving landslide is proposed. The Particle Finite Element Method [1,2] is here reconsidered and adapted to the specific case of landslide run-out. The Lagrangian essence of the method allows for a natural treatment of free surfaces undergoing large displacements and of fast propagating interfaces, making the method particularly suitable for these types of problems. Due to the excessive distortion of the mesh, typical of Lagrangian approaches for fluids, a continuous remeshing, based on a fast 3D Delaunay triangulation, has been introduced. A 3D version of the alpha-shape technique is used to define the position and the evolution of the free-surfaces.

The Lagrangian Navier-Stokes equations of incompressible fluids are used to describe the macroscopic landslide behaviour. An elastic-visco plastic law based on a non-Newtonian, Bingham-like fluid, is used to characterize the constitutive behaviour of the flowing material. Ad-hoc slip conditions are introduced at the interfaces between the flowing mass and the slope to better represent the real landslide slip.

The proposed approach has been validated against numerical benchmarks and experimental tests, showing a good agreement with the physical measurements. The real potential of the approach can be seen considering real case scenarios. 3D geometries of critical sites, where landslides have occurred, have been reconstructed allowing for the simulation of real cases. Results are compared with other numerical approaches and with post-event images showing the accuracy and the capability of the method.

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