



Postdoctoral position

Modeling and numerical simulations of granular flows.

Application to pyroclastic density currents.

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Salary : the gross salary is 2589.88 € (net income 2085.58 €).

Starting date : between september 1st 2017 and january 1st 2018.

Duration : 12 months with possible renewal for 12 additional months.

Required qualifications : applicants should have a PhD either in Applied Mathematics (numerical analysis, scientific computing), Fluid Mechanics (numerical simulations) or Computer Science. Experience in High Performance Computing (parallel programming with MPI) will be welcome. The candidate must be interested both in numerical analysis and programming aspects (efficient implementation of numerical schemes).

The scientific context. Pyroclastic density currents occurring during volcanic eruptions, when for instance the volcanic plume collapse on the ground under the effect of gravity, are complex by nature and the physical mechanisms involved are not well understood. These gravity flows, which are mixtures of gaz (air), rocks and dusts, are dense as the volume fraction of solid matters is closed to the packing limit. Nevertheless, they behave like fluids and have the ability to carry out heavy pieces of rocks over large distances, of the order of one or several (up to fifty) kilometers. A possible explanation to describe this phenomenon relies on the role played by the fluidization of the mixture during the eruption process, namely the pore pressure (due to the presence of air) could, combined with gravity, reduce the strength of the particle interactions and then decrease the energy dissipation. In order to assess the role of the fluidization, collapse of granular columns were experimentally studied in the *Laboratoire Magmas et Volcans* (see [1]). The results show indeed that an initially fluidized column of granular matter flows over a distance about twice longer than a non-fluidized column.

A dense granular flow seems to behave like a fluid. However, unlike fluids, granular flows stop in finite time. It is therefore reasonable to use visco-plastic models of Bingham type. In [2], a mathematical model based on the incompressible Navier-Stokes equations for homogeneous fluids, *i.e.* with both constants viscosity and density, with a visco-plastic rheology has been proposed and studied. Unlike for classical Bingham fluids, the yield stress here depends on the hydrostatic pressure, which is computed as a function of the density of the granular material, the height of the column and a pore pressure obtained as the solution of an advection-diffusion equation. Iverson in [3] introduced a similar pore pressure in a depth averaged one-dimensional model. The pore pressure aims to control the fluidization level during the column collapse and hence acts on the energy dissipation. The diffusion coefficient

depends on the physical properties of the studied granular material and has been estimated by Roche in [1] using experimental measurements.

The model studied in [2] has then been extended in order to account for the presence of the ambient air, *i.e.* we have two non-miscible phases : the air and the granular column. They have completely different physical properties and behaviours : the density of the granular flow is 2500 times larger than the air density and the plastic viscosity of the granular matter is about 10 000 times bigger than the air viscosity.

The aim of this project is to develop a robust and efficient code in order to perform numerical simulations of the collapse of dense fluidized as well as non-fluidized granular columns. The numerical results will be systematically compared with experimental results provided by the *Laboratoire Magmas et Volcans*.

Research project. A parallel code, written in Fortran 90 and using the PETSC and MPI libraries, has been developed at the *Laboratoire de Mathématiques Blaise Pascal* in order to solve a mixture of two-phase fields, one being an incompressible newtonian flows and the other one an incompressible visco-plastic of Bingham type flow. The spatial discretization is achieved with second-order centred finite difference schemes on staggered grids and a projection method is employed to enforce the incompressibility condition. The constitutive equation for the visco-plastic medium is solved with the bi-projection scheme recently proposed and studied in [4]. The transport equation for the density is discretized in space with a 5th order finite difference WENO scheme [5] combined with a third order TVD Runge-Kutta scheme for the time discretization [6].

The postdoctoral fellow will first implement in the code a *level set* method (see [7] for a review) in order to accurately compute the interface between the two phases. Validations by comparing numerical and experimental results will be conducted in the case of collapses of non-fluidized granular columns.

The second part of the project is focused on the development and implementation of a model for fluidized granular flow. The approach used in [2], which consists in modeling this effect by adding a pore pressure, solution of an advection-diffusion equation, in the definition of the yield stress of the granular medium, will first be implemented and tested. As previously the final goal is to validate the numerical simulations by reproducing the experimental results.

Related questions will be investigated. Namely, a delicate but crucial points is the use of realistic, *i.e.* physically relevant, boundary conditions on the ground surface on which the granular column slides. The simplest conditions both from a mathematical and numerical point of view are the Dirichlet or Neumann boundary conditions. In practice, both conditions are not well suited : the former tends to slow down the flow while the latter induces a non realistic sliding. More sophisticated boundary conditions should be proposed, implemented and tested.

Bibliography

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