Dense flow avalanche pressure on obstacle studied with DEM

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Snow avalanches are a major hazard in mountainous areas and have a significant impact on infrastructures, economy and tourism of such regions. Obtaining a thorough understanding on the pressure exerted by avalanches on infrastructures is crucial for the development of design criteria so that they can withstand avalanche impact. Avalanches are characterized by two main pressure regimes depending on flow dynamics and snow properties: in the inertial regime the pressure is proportional to velocity, while in the gravitational regime it is proportional to flow depth. Today, the knowledge on avalanche impact relies mostly on empirical equations and it is not clear yet how to describe the coefficients of proportionality, namely the drag coefficient and the amplification factor in the inertial and gravitational regimes, respectively. In order to investigate the origin of these coefficients, we developed a Discrete Element Model (DEM) [1] capable of resolving the three-dimensional avalanche flow field around a generic infrastructure. To allow a direct comparison of the simulation results with experimental data, the obstacle geometry in the DEM model reproduces the pylon at the Vallée de la Sionne test site [2], where most of the measurements are performed. In our simulations, the pylon is forced to travel through a bed of particles at rest. The pylon is divided into discrete sections, which can move independently at arbitrary speeds. This allows to impose a given profile of relative velocity between the snow and the pylon while avoiding any complex rheological flow description. The speeds of the sections are chosen to mimic velocity profiles measured in real avalanches for different flow regimes. The 3D DEM simulations are performed varying velocity profiles in terms of shape, magnitude and snow depth, as well as particles cohesion. The results show that, velocity has the most significant impact on pressure. Hence, the shape of the velocity profile governs the shape of the pressure distribution on the pylon, independently of the cohesion between the particles. Indeed, constant velocity over the entire flow height results in a pressure profile linearly increasing with flow depth. This corresponds to the observations made in full scale experiments in the gravitational flow regime. For sheared velocity profiles, which are present in inertial avalanches, the pressure distribution is largely proportional to the velocity. Cohesion was found to play only a pressure amplifying role from a certain cohesive strength to velocity ratio. Below a critical cohesive strength value the flow exhibits a cohesion-less behavior. Most likely, this happens when the kinetic energy of the flow is high enough to break the cohesive force chains building upstream of an obstacle. When transitioning from a non-cohesive to a cohesive behaving flow the pressure increases dramatically as a result of a larger volume of particles mobilized upstream of the pylon.

REFERENCES

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