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Simulating Lahars Using A Rotating Drum

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A large (0.5 m in diameter, 0.15 m wide) rotating drum is used to investigate the erosion and deposition mechanics of lahars. To systematically simulate the conditions occurring in natural mass flows our experimental setup differs from the common rotating drum employed in industrial/engineering studies. Natural materials with their typical friction properties are used, as opposed to the frequently employed spherical glass beads; the drum is completely water-proof, so solid/air and solid/liquid mixtures can be investigated; the drum velocity and acceleration can be precisely controlled using a software interface to a micro-controller, allowing for the study of steady, unsteady and intermediate flow regimes.

The drum has a toughened glass door, allowing high-resolution, high-speed video recording of the material inside. Vector maps of the velocities involved in the flows are obtained using particle image velocimetry (PIV). The changes in velocity direction and/or magnitude are used to locate the primary internal boundaries between layers of opposite flow direction, as well as secondary interfaces between shear layers.

A range of variables can be measured: thickness and number of layers; the curvature of the free surface; frequency of avalanching; position of the centre of mass of the material; and the velocity profiles of the flowing material. Experiments to date have focussed on dry materials, and have had a fill factor of approximately 0.3. Combining these measured variables allows us to derive additional data of interest, such as mass and momentum flux. It is these fluxes that we propose will allow insight into the erosion/deposition mechanics of a lahar.

A number of conclusions can be drawn to date. A primary interface separates flowing and passive region (this interface has been identified in previous studies). As well as the primary interface, the flowing layer separates into individual shear layers, with individual erosion/deposition and flow histories. This complex flow geometry and process of erosion and deposition seen in our high speed videos is more complicated than previously reported in the literature. We identify two layers only in the slowest flows (< 0.5 rad s^{-1}), while faster ones (< 4 rad s^{-1}) include between three and five. As the rotational velocity of the drum increases, the curvature of the free surface increases. In the central part of the drum, the primary interfaces occasionally merges into an elliptical zone rather than a linear shear boundary. Inside this zone is a complete circulation of material. These zones' size and number appears to be a function of the rotational velocity of the drum. These "Neather cells" (as we tentatively name these phenomena) can reach as large as 20 mm in thickness. The centre of mass' deflection from vertical is linearly dependent on rotational velocity, whilst the typical flow regimes as identified by Mellmann [2001] show no influence. The frequency of avalanches increases with velocity up to a critical velocity (approximately 1.1 rad s^{-1}), after which the avalanche frequency remains constant.

1 References

J Mellmann. The transverse motion of solids in rotating cylinders—forms of motion and transition behavior. Powder Technology, 118(3):251–270, 2001.