

## FLOW OF A CONCENTRATED SUSPENSION DOWN A ROUGH PLANE

Cyril Cassar, Maxime Nicolas, Olivier Pouliquen

\*Groupe Écoulement de Particules, Institut Universitaire des Systèmes Thermiques Industriels  
UMR 6595 CNRS-Université de Provence, 5 rue Fermi 13453 Marseille cedex 13 France

**Summary** Submarine landslides have a great importance in geophysics because of their consequences (submarine canyons, tidal waves). They occur when a large amount of granular material (sand) flows downslope. But the rheology of the sand and water mixture is still not well understood. We lead experiments of submerged granular flows in a water tank. The particles are spherical glass beads and flow down a rough inclined plane from a reservoir with a controlled opening. Thickness, velocity and interstitial fluid pressure of the avalanche are measured, as well as the deposit thickness when the flow is over. Results show that the flow behavior changes abruptly for a small angle variation. Indeed, for a small variation of inclination angle above 36 degrees, the avalanche velocity increases rapidly. We suspect that a transition between a contact regime and a suspension regime occurs.

### EXPERIMENTAL SETUP AND MEASUREMENTS

A sketch of the experimental setup is shown on Fig. 1a. We use a rectangular  $49 \times 14 \text{ cm}^2$  PVC plate roughened by glued glass beads. The flow starts from a  $1120 \text{ cm}^3$  parallelepipedic reservoir. The opening of the reservoir is a rectangle with controlled height  $h_g$ . The glass beads are similar to those used for the flow : spherical glass beads with a mean diameter of  $d = 112 \pm 20 \mu\text{m}$  and a density  $\rho = 2.47 \pm 0.01 \text{ g.cm}^{-3}$ .

A 5 mm pressure hose was drilled at 25 cm from the reservoir gate. The hole was covered with a  $50 \mu\text{m}$  metallic mesh to prevent particles from falling in the hose. A second pressure hose was placed beside the rough plane at the same depth from the water surface. Both hoses were connected to a differential pressure transducer with 5mm inner diameter flexible tubes.

The plane was lightened with a He-Ne laser sheet with a small angle from the rough plane. When the flow occurred, the laser line was distorted, and its horizontal displacement was proportional to the flow thickness after calibration with an object of known thickness. The flow was recorded using a DV camera and a DV recorder placed above the water tank. Image analysis of the movie gave measurements of the front velocity  $u(t)$  and the flow thickness  $h(x, t)$ .

After filling of the reservoir with wetted particles, the gate of the reservoir was then opened gently to avoid surface waves which could perturb pressure acquisition and flow visualization. Once the reservoir was empty, a small layer of particles remained on the rough plane. Its thickness  $h_s = \langle h(x) \rangle_x$  was measured with the same technique.

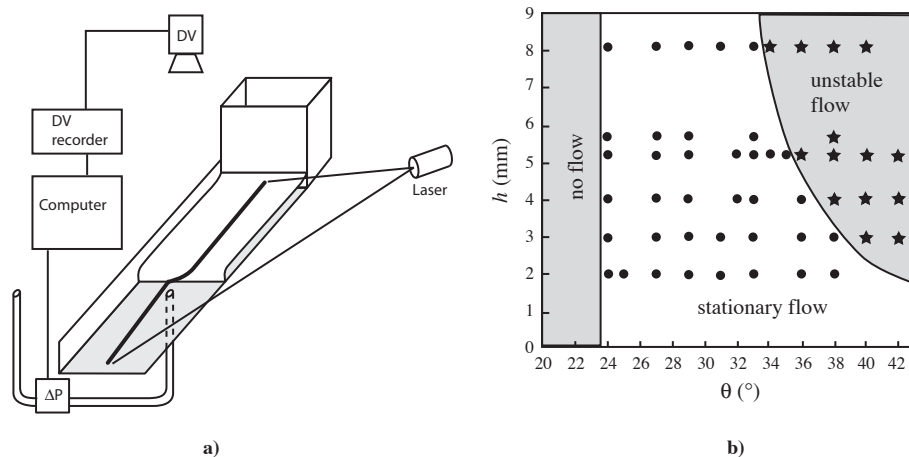


Figure 1. Experimental setup (a) and map of flow regimes (b).

### RESULTS

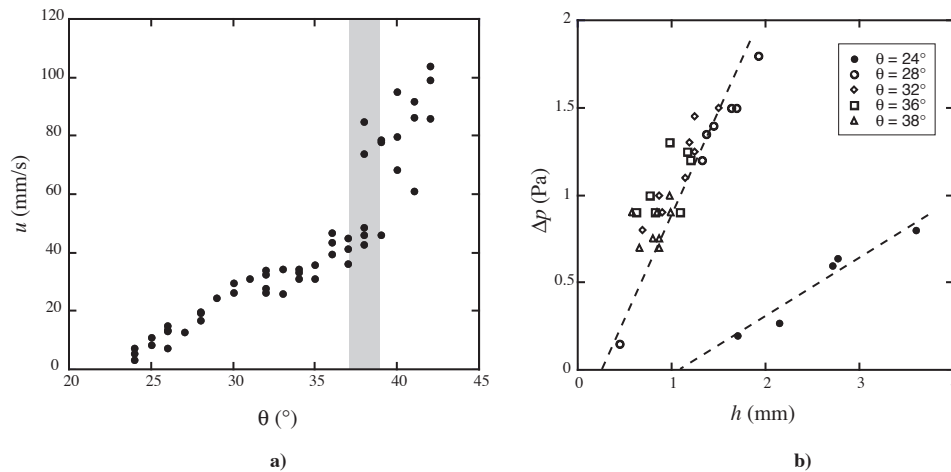
Three different regimes were observed depending on the inclination angle  $\theta$  and the gate opening  $h_g$  (see Fig. 1b). No flow could be observed for an inclination angle  $\theta$  below  $24^\circ$ . A stationary flow was observed for  $\theta$  in the  $[24^\circ; 36^\circ]$  range and an unstable flow was observed for  $\theta \geq 36^\circ$ . The unstable flow is characterized by a wavy free surface and a sudden increase of the front velocity for an angle varying from  $36^\circ$  to  $38^\circ$ .

The front velocity increases with inclination angle, and experiences a sudden increase when the flow becomes unstable. This is clearly shown on Fig. 2a for a gate opening  $h_g = 5.22$  mm. Moreover, in the instability regime, velocity measurements are not reproducible. This suggests a transition between a frictional regime and a suspension regime where basal friction is reduced.

Careful measurements of the pressure shows that the basal pressure is strongly correlated with the flow thickness. Fig. 2b shows that the basal pressure is linear with the flow thickness  $h$ . However, the linear trend is different for very slow flows ( $\theta = 24^\circ$ ) than for more rapid flows ( $28^\circ < \theta < 38^\circ$ ). It must be noted that the basal pressure vanishes when the thickness is equal to the static layer thickness  $h_s$ . Thus the basal pressure can be scaled as

$$\Delta p \propto \phi(\rho - \rho_{water})g(h - h_s)$$

where  $\phi$  is the rate of suspended particles during the flow.



**Figure 2.** Front velocity versus inclination angle for  $h_g = 5.22$  mm (a) and pressure versus thickness for various angles and gate openings (b).

## CONCLUSION

Through measurements of basal pressure under an immersed grain flow, this experimental study gives a new sight on concentrated suspension flows. Two different flow regimes can be present at the same time : a contact regime and a suspension regime which contributes to a non zero basal pressure and a reduction of the friction coefficient.