

Looking inside granular jumps down inclines thanks to dynamic X-ray radiography

Ségolène Méjean^{1,2}, François Guillard², Thierry Faug¹, Itai Einav²

¹ *Irstea Grenoble Unit. ETGR, Univ. Grenoble-Alpes, 38000 Grenoble, France*

E-mail: segolene.mejean@irstea.fr, thierry.faug@irstea.fr

² *School of Civil Engineering, The University of Sydney, Camperdown 2006, Australia*

E-mail: francois.guillard@sydney.edu.au, itai.einav@sydney.edu.au

Keywords: Granular jump, dynamic X-Ray radiography, laboratory tests

When rapid shallow (supercritical) flows become thicker and slower (subcritical), the medium forms a transition region that is typically called a jump. The properties and dynamics of such jumps in water have been widely studied in hydraulics studies; similar jumps have been observed in granular media [1, 2]. A general relation based on the depth-averaged mass and momentum equations was recently proposed and checked against a wide range of laboratory data in order to predict the relative height of the jump [3]. However, the predictability of this relation requires the knowledge of several properties, including the length and effective friction of the jump, and its density evolution.

Discrete Element Method numerical simulations have been developed [4], which recreate standing granular jumps observed in recent laboratory tests [2]. All the micro and macro parameters inside the jumps are accessible, thus allowing us to study how the geometry and flow regimes (with or without recirculation) of the jump depend on the various parameters, such as the slope, mass discharge, grain diameter and the interparticle friction.

In laboratory experiments it is less obvious how to access the interior of tested media, particularly in fast dynamic experiments of flowing granular jumps. An innovative non-invasive dynamic technique using X-ray radiography [5] has been recently developed to enable such measurements. This technique avoids boundary layer effects owing to the fact that the X-rays penetrate through the entire width of the flume, which gives a width-averaged value, in contrast to optical methods that measure grain motion along the walls. This allows to recreate a two dimensional map of the width-averaged local density within the fast varying free-surface flow that occurs through the jump. A series of carefully designed experiments have been carried out under different input conditions.

References

- [1] Savage, S.B., "Gravity flow of cohesionless granular materials in chutes and channels," *Journal of Fluid Mechanics* **92** (1979)
- [2] Faug, T, Childs, P., Wyburn, E. and Einav, I., "Standing jumps in shallow granular flows down smooth inclines," *Physics of Fluids* **27** (2015).
- [3] Mejean, S., Faug, T. and Einav, I., A general relation for standing normal jumps in both hydraulic and dry granular flows, *Journal of Fluid Mechanics*, **816**, 331-351 (2017).
- [4] Mejean, S., Faug, T. and Einav, I., Discrete Element Method Simulations of standing jumps in granular flows down inclines, *EPJ Web of Conferences* **140**, 03054 (2017).
- [5] Guillard, F., Marks, B. and Itai, I., "Dynamic X-ray radiography reveals particle size and shape orientation fields during granular flow," *Scientific Reports* **7**, 8155 (2017).