A granular thermometer

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ABSTRACT

There is growing evidence that an additional state parameter of granular temperature may be required to properly describe the dynamics of a granular medium that is subjected to arbitrary loading [1, 2, 3]. Here, we present an X-ray based experimental technique that is capable of resolving the three-dimensional velocity field within a granular medium [4]. By coupling this technique with high precision tracer particle tracking from the same X-ray data, it is then possible to infer the velocity fluctuations at all points within the bulk material. We have applied these techniques to a vibro-fluidised bed of various near-monodisperse particles, which revealed a variety of convection cells. These results have been extensively compared with discrete element simulations for the case of near-monodisperse spherical particles and good agreement is shown.

Furthermore, in order to quantify the precision of this new experimental technique, we present an error analysis of measurements based on [5]. This error analysis reinforces our hypothesis that granular temperature measurements can be used to model granular flows using continuum frameworks such as Reynolds Averaged Navier-Stokes, Granular Solid Hydrodynamics [2], or granular fluidity [3]. These new measurements present an excellent dataset with which to validate new theories against experimental data.

REFERENCES

[1] Goldhirsch, I. Introduction to granular temperature, *Powder Technology*, Vol. **182**(2), pp.130–136, (2008).

[2] Jiang, Y. and Liu, M. Granular Solid Hydrodynamics (GSH): a broad-ranged macroscopic theory ofgranular media, *Acta Mechanica*, Vol. **225**(8), pp.2363–2384, (2014).

[3] Zhang, Q. and Kamrin, K. Microscopic Description of the Granular Fluidity Field in Nonlocal Flow Modeling, *Phys. Rev. Lett.*, Vol. **118**(5), pp.58001, (2017).

[4] Baker, J., Guillard, F., Marks, B. and Einav, I. X-ray rheography uncovers planar granular flows despite non-planar walls, *Nature Communications*, Vol. **9**(1), pp.1–9, (2018).

[5] Xu, H., Reeves, A. P. and Louge, M. Y. Measurement errors in the mean and fluctuation velocities of spherical grains from a computer analysis of digital images, *Review of scientific instruments*, Vol. **75**(4), pp.811–819, (2004).