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# Granular flow visualization using non-invasive imaging

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## Abstract

Despite its ubiquity, a complete theory to describe the underlying rheology of granular flows remains elusive. Central to this problem is the lack of detailed, in-situ measurements of the granular flow field. To this end, we present two non-invasive imaging techniques currently employed to measure the flow of individual grains within granular flow systems that span simple mono-sized flows of plastic beads to complex industrial mixture flows of rocks and slurry. The first technique employs diagnostic X-rays operated in biplanar mode to triangulate the motion of low-density granules in simplified flow systems to within a 3D spatial accuracy of 0.15 mm at tracking frequencies up to 100 Hz. The second—arguably the workhorse of our research operation—is the nuclear imaging technique of Positron Emission Particle Tracking (PEPT) which triangulates the back-to-back gamma rays emanating from radiolabeled particles to within a millimeter in 3D space at a millisecond timing resolution. PEPT can track the motion of any particle with a diameter greater than 30 microns. Both techniques are well suited to studying the flow of granular materials after the data is cast into volume and time averages consistent with the continuum framework. In this talk I will explore the many interesting analysis techniques employed to mapping out the complex flow regimes found in typical granular systems, and the insights they offer towards better understanding their rheological character. Examples explored will include rotating drum flows (wet and dry), shear cells and their industrial counterpart the IsaMill™, hydrocyclone separator flows, and the motivation for tracking of multiple particles—a technique that we have recently developed. The validation offered to numerical schemes like the Discrete Element Method will also be explored wherein we highlight the complimentary role that measurement and simulation play in unravelling the secrets of granular flows.

**Keywords:** Granular flow, Positron Emission Particle Tracking (PEPT)

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