Granular Impact Dynamics: Effect of Intruder Shape
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Introduction
• Granular materials are large scale collections of discrete macroscopic particles.
• The collective motion of granular particles can cause granular materials to behave like solids, liquids, or gasses, and therefore are considered by some to be another form of matter.
• Two intrinsic properties cause this unique behavior:
  • Granular materials are not affected by thermal fluctuations.
  • Particle interactions are dissipative and repulsive due to static friction and inelastic collisions.

Motivation/Objective
• When an intruder impacts a granular material the resistive force from the particles increases (relatively) with impact energy.
• Typical scaling law for spherical intruder-particle interactions:
  \[ d \sim AH^\alpha \]
  • \( d \) is the depth beneath the particles.
  • \( A \) is the total drop height which is equal to the distance the intruder is dropped above the particles.
• This scaling law has yet to be experimentally proven for impacts on non-spherical intruders.
• Objective: Examine how the motions of the intruder and the particles change with intruder shape and how the scaling law can be modified to account for such differences.

Grain Trajectories
Using the Crocker & Grier particle tracking algorithm, particles for 2cm drop heights are tracked and the scatter angle after impact is plotted against the probability density of the particles for intruders 1 through 7.

The experimental setup for each drop is as follows:
- Electromagnet
- Index-Matched Fluid
- Laser
- High Speed Camera
- Adjustable Wall

Experiment

Experimental Procedure
• Jnm glass beads are mixed with a refractive index matched fluid composed of Dimethyl Sulfoxide (DMSO), water, Nile Blue 660 perchlorate dye, and hydrochloric acid.
• Nile Blue 660 perchlorate dye fluoresces under 660nm light causing the fluid to fluoresce.
• Two 450 nm lasers illuminate a plane within the beads and fluid. The fluid in the plane is illuminated while the beads are not.
• Seven aluminum cylinders with constant mass and varying slant angles are dropped by an electromagnet at three different heights (2cm, 7cm, 20cm).
• The slant angles range between 0° for intruder 1 to 71° for intruder 7.
• For each impact a 200fps camera captures video and image data.

Scaling and Penetration Depth

Future Work
• Examine how the shape affects the rotation/tilting of the intruder.
  It was observed that intruders with greater slant angles tended to rotate more.
• Examine how tilting/rotation affects particle scale rearrangements.
• Examine particle scale rearrangements for higher drop heights.

Conclusions
• The scaling exponents of all seven intruders were not 1/3, the common scaling exponent of spherically intruder-particle impacts.
• The shape of the intruder does influence the final depth and therefore the scaling law needs to be modified for non-spherical shapes.
• The intruders with greater slant angles reached greater final depths.
• For all intruders particles are most likely to move in the 120° and 150° range, rather than radially outward.
• There was no observed correlation between intruder shape and the angles of scatter.

References