Missile and meteorite impacts are more complex at the granular level than scientists previously thought

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The way a meteorite or missile transfers the energy of its impact to sand and dirt grains is far more complex than scientists thought. Impact illustration courtesy of NASA.

(Phys.org)—High-speed video of projectiles slamming into a bed of disks has given scientists a new microscopic picture of the way a meteorite or missile transfers the energy of its impact to sand and dirt grains.

The transfer is jerky, not smooth. "It was surprising just how unsmooth the slow-down of the intruding object was," Duke physicist Robert Behringer said. His team describes their new videos and impact analysis in the Dec. 7 Physical Review Letters. The research may change the way scientists model meteorite and missile impacts and their effects.

Scientists previously assumed that the slowing down would be smooth and that any sound wave would travel through a granular material in a regular, uniform pattern, similar to the way noise from a clap of the hands diffuses evenly in all directions through the air. But using high-speed video, Behringer, his graduate student Abram Clark and Lou Kondic of the New Jersey Institute of Technology have shown a very different behavior for the sound wave and grains during a collision.

In the study, supported by the Defense Threat Reduction Agency, the team shot bronze disks into a narrow bed of photoelastic grains and used an ultrafast camera to track the collision energy as it shifted from the disk to the beads. The footage shows that the bronze disk loses most of its energy in intense, sporadic acoustic pulses along networks of grains, or force chains, in the bed of beads.

"This phenomenon was so hard to observe before because of how fast the force chains travel," Behringer said. The standard movie rate is about 30 frames per second. To capture the path of energy down the force chains, the scientists had to use a camera that could capture 40,000 frames per second, 1300 times faster than a normal video, because the sound pulses move at such high speeds.

The scientists shot the intruding disks into the photoelastic grains at speeds up to 6.5 meters per second, about 15 miles per hour. On impact, the force chains in the disks started moving the energy away from the intruding object, dumping it down deep in the bed of disks like the drainpipes of a septic system carrying water and waste away from a house, Behringer said.

The speed of the bronze disk was well under sonic or super-sonic speed, which could make the patterns of energy transfer substantially different, the team noted in the paper. "For supersonic speeds, it's kind of like the car chases that happen in markets in movies. People can't get out of the way fast enough. Similarly the pulses wouldn't clear the chain networks and the forces would back up rather than get carried away from the intruder," Behringer said.

Studying the impacts at sonic and supersonic speeds, however, is a set of experiments that requires different grain particles, Behringer said, adding it's one the team may try soon. He also explained that once a missile or meteor drops below sonic speeds, the grains absorbing its impact would carry the energy and momentum away jerkily and sporadically, just as the team's new microscopic picture shows.

More information: Clark A., Kondic, L., and Behringer, R. Particle Scale Dynamics in Granular Impact. *Physical Review Letters* 5:137 (2012). DOI: 10.1103/Physics.5.137

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