Researchers discover a new phenomenon in materials science by observing the compaction of puffed rice cereal

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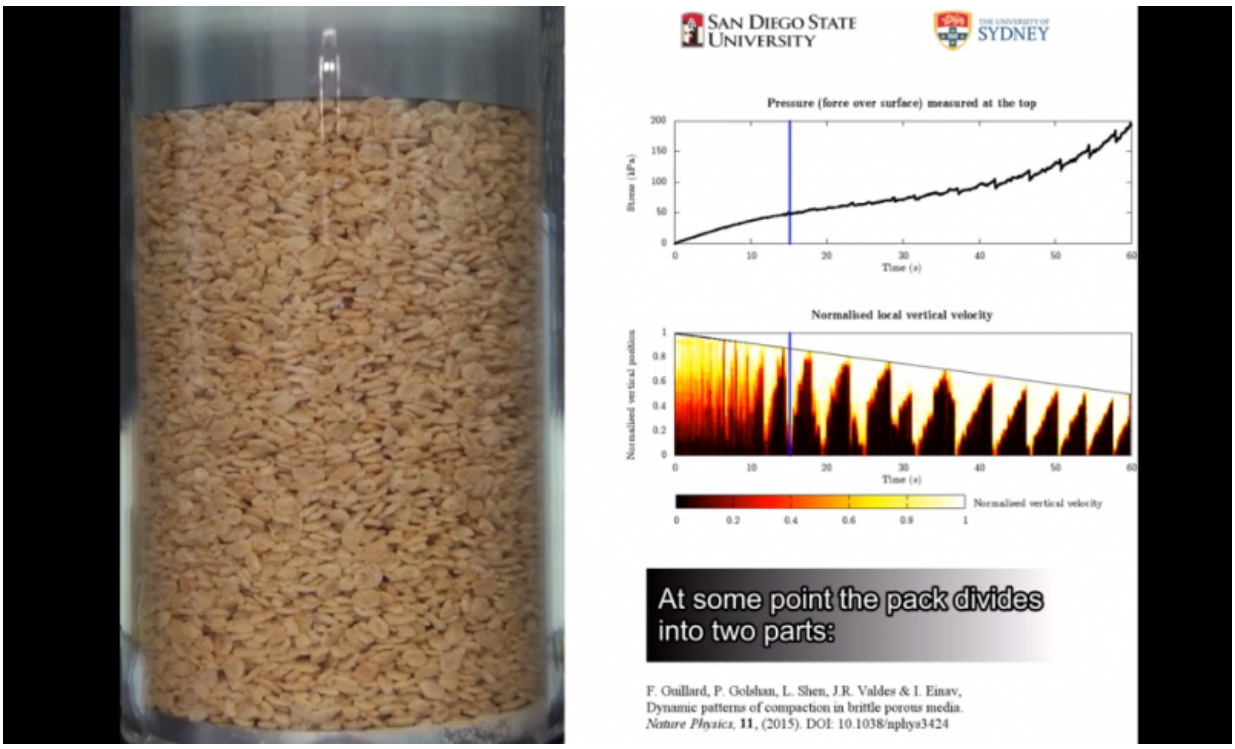

There's more to the snap, crackle and pop of Rice Krispies than meets the ear. A recent study by San Diego State University civil engineering professor Julio Valdes used the breakfast cereal to discover a new

phenomenon in materials science: highly porous, brittle materials can deform in different ways depending on compaction velocity. Put another way, the speed at which one crushes a tube full of cereal, for example, can have implications for manufacturing or even assessing the safety of snow after an avalanche.

In 2011, Valdes and former SDSU graduate student Johan Gallay were experimenting with compaction using Rice Krispies in an acrylic tube. As a piston crushed the cereal, the experimenter could see the material being compacted. The researchers came up with the idea of using microphones at both the bottom and top of the tube to record the crushing sounds and identify which parts of the cereal pack would crush when. Based on classic friction experiments, Valdes theorized that as the piston compressed the cereal, the top of the pack would compact and the bottom would not, given that the cereal would transfer force to the cylinder's sidewalls via friction; the microphones would provide evidence of this.

Gallay performed the experiments and came back to Valdes with something unusual. Instead of the crackling pattern they expected, the microphones recorded an alternating wave of popping.

"I said, 'Johan, you've clearly made some kind of mistake. Go run it again,'" Valdes recalled.

Rising action

So Gallay did, and the results were the same: a rising wave of snap-crackle-pop as the piston compressed the cereal. And this time, Gallay wanted Valdes to watch the experiment, not just listen.

The visual results were just as striking. As the cereal compacted, the researchers could see a rising band in the tube, indicating where the

material was being crushed, or deformed, in the materials science lingo. Check out the video that accompanies this story for a demonstration.

"It was the first time anyone had seen a propagating compaction band in granular matter," Valdes said. "We could see it clearly. It was beautiful."

Compaction, three ways

With support from the National Science Foundation, Valdes and graduate student Pouya Golshan recently repeated the original Rice Krispies–crushing experiment with the piston depressing at different velocities, and found that, depending on the velocity, they could see three different types of deformation in the cereal. At very low velocities, the cereal exhibited an erratic deformation pattern, crushing at various points within the tube. At very high velocities, it all crushed down fairly uniformly. And at in-between velocities, the researchers saw their rising propagating compaction bands. Working with collaborators at the University of Sydney, they recently published the first study to come from this funding in one of the field's leading journals, *Nature Physics*.

These results further explain the complex mechanics underlying porous, brittle material—a fairly new area of study which has been dubbed "crunchy matter." The findings could have applications in manufacturing, –in the pharmaceutical industry, for example, as well as in assessing the stability of snowpack after an avalanche.

And in case you're curious, the researchers have informally repeated the experiment with two different cereals, Cocoa Puffs and Cocoa Krispies, and found the same results. Interestingly, though, certain properties of the chocolate flavoring make these cereals stiffer, requiring a higher velocity to get a propagating band.

"You would predict to see that based on our model," Valdes said, "so the

fact that we did see it was good news."

More information: François Guillard et al. Dynamic patterns of compaction in brittle porous media, *Nature Physics* (2015). DOI: 10.1038/nphys3424

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