Acoustic energy harnessed to soften shear-thickening fluids

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From left, Itai Cohen, professor of physics, Ph.D. student Prateek Sehgal and Brian Kirby, the Meinig Family Professor of Engineering in the Sibley School of Mechanical and Aerospace Engineering, use acoustic energy to control the viscosity of shear-thickening materials, which are a class of materials that flow like liquid but solidify when squeezed or sheared quickly. Credit: Jason Koski/Cornell University

Researchers are using ultrasonic waves to manipulate the viscosity of shear-thickening materials, turning solids to slush—and back again.

The study, "Using Acoustic Perturbations to Dynamically Tune Shear Thickening in Colloidal Suspensions," was published Sept. 17 in *Physical Review Letters*.

Shear-thickening fluids are a class of materials that flow like liquid but solidify when squeezed or sheared quickly, such as quicksand and Oobleck, the children's play slime. Technical applications for the material range from soft body armor and astronaut suits to 3-D printing metals and ceramics.

But the shear-thickening process can be uncooperative: The more you manipulate the material, the more it solidifies, which in the case of 3-D printing and the manufacture of concrete can lead to gunked-up nozzles and jammed hoppers.

Itai Cohen, professor of and the paper's co-senior author, previously found a way to manipulate—or "tune"—the material by breaking apart the rigid structures or force chains formed by the particles in these suspensions through perpendicular oscillation. But that method proved to be impractical. It isn't easy, after all, to shake and twist a factory pipe.

Cohen and Ph.D. student Meera Ramaswamy partnered with Brian Kirby, professor of engineering, and Ph.D. student Prateek Sehgal, who have been using acoustic transducers to manipulate micro- and nanoscale particles in Kirby's lab.

Sehgal developed a simple but effective device that consists of a bottom plate with an acoustic transducer—called a piezo—that generates ultrasonic waves.

"When you excite that piezo at a specific frequency and a specific voltage, it emanates the acoustic waves through the bottom plate to the suspension. These acoustic disturbances break the force chains responsible for shear-thickening," said Sehgal, co-lead author of the paper with Ramaswamy.

"The disturbances you're inducing are actually really, really tiny, so it doesn't take much to break the contact forces between the micro-particles," Cohen said. "This is the key insight that allowed us to think about applying these kinds of perturbations and getting it to work. Basically, any geometry where you have a flow that's thickened, you can now just slap a piezo on and de-thicken that region. This strategy just opens up the applicability to a much broader range of applications."

The researchers developed the approach by manipulating particles in substances up to 1.3 mm thick, but because ultrasound waves can propagate long distances in material, Kirby anticipates it being used on pipes as wide as a foot. Potential applications include food processing, particularly for materials that have particulate suspensions like pastes, the manufacture of concrete, as well as the 3-D printing of ceramics and metals.

The use of acoustic energy is also a valuable scientific tool for researchers who are studying a material's thickening behavior and system dynamics. Typically, to study thickening, one needs to start with a relaxed suspension and ramp up the flows. This process, however, can take a long time.

More information: Prateek Sehgal et al. Using Acoustic Perturbations to Dynamically Tune Shear Thickening in Colloidal Suspensions, *Physical Review Letters* (2019). DOI: 10.1103/PhysRevLett.123.128001

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