Now, you can 3-D print clay, cookie dough – or solid rocket fuel

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A new 3-D printing technique allows materials with the consistency of clay or cookie dough to be used to manufacture a variety of shapes. Purdue Univeristy assistant professor Emre Gunduz used ultrasonic vibrations to maintain a flow of the material through the printer nozzle. Credit: Purdue University photo/Jared Pike

It's now possible to 3-D print extremely viscous materials, with the consistency of clay or cookie dough with fine precision, thanks to work done at Purdue University. This development may soon allow the creation of customized ceramics, solid rockets, pharmaceuticals, biomedical implants, foodstuffs, and more.

"It's very exciting that we can print materials with consistensies that no one's been able to print." says Emre Gunduz, assistant research professor in the School of Mechanical Engineering. "We can 3-D print different textures of food; biomedical implants, like dental crowns made of ceramics, can be customized. Pharmacies can 3-D print personalized drugs, so a person only has to take one pill, instead of 10."

By applying high-amplitude ultrasonic vibrations to the nozzle of the 3-D printer itself, the Purdue team was able to solve a problem that has bedeviled manufacturers for years.

Most proposed solutions to this problem involve changing the composition of the materials themselves, but the Purdue team took a completely different approach.

"We found that by vibrating the nozzle in a very specific way, we can reduce the friction on the nozzle walls, and the material just snakes through," Gunduz says.

The Purdue team has been able to print items with 100-micron precision, which is better than most consumer-level 3-D printers, while maintaining high print rates.

"The most common form of 3-D printing is thermoplastic extrusion," Gunduz says. "That's usually good enough for prototypes, but for actual fabrication, you need to use materials with high strength, like ceramics or metal composites with a large fraction of solid particles. The precursors for these materials are extremely viscous, and normal 3-D printers can't deposit them, because they can't be pushed through a small nozzle."

It's difficult to visualize the 3-D printing process, because the materials used are opaque and the surfaces are hidden inside the nozzle. So the team traveled to Argonne National Laboratory, outside Chicago, to conduct high-speed microscopic X-ray imaging. They were able to see inside the nozzle and precisely measure the flow of the clay-like material for the first time.

"The results were really striking," Gunduz says. "Nobody has ever characterized a viscous flow through a channel this way. We were able to quantify the flow, and understand how our method was actually working."

The research is being conducted at Purdue's Zucrow Labs, the largest academic propulsion lab in the world. As such, the first practical application being explored is for solid rocket fuel.

"Solid propellants start out very viscous, like the consistency of cookie dough," says Monique McClain, a Ph.D. candidate in Purdue's School of Aeronautics and Astronautics. "It's very difficult to print because it cures over time, and it's also very sensitive to temperature. But with this method, we were actually able to print strands of solid propellant that burned comparably to traditionally cast methods."

McClain tested the combustion by printing two-centimeter samples, igniting them in a high-pressure vessel (up to 1,000 pounds per square inch) and analyzing slow-motion video of the burn.

For solid rocket fuels, 3-D printing offers the opportunity to customize the geometry of a rocket and modify its combustion. "We may want to have certain parts burn faster or slower, or something that burns faster in the center than the outside," McClain says. "We can create this much more precisely with this 3-D printing method."

More information: I.E. Gunduz et al. 3D printing of extremely viscous materials using ultrasonic vibrations, *Additive Manufacturing* (2018). DOI: 10.1016/j.addma.2018.04.029

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