Smashing fluids... the physics of flow

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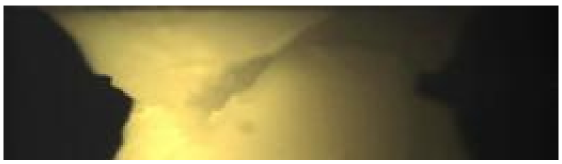

(PhysOrg.com) -- Hit it hard and it will fracture like a solid... but tilt it slowly and it will flow like a fluid. This is the intriguing property of a type of 'complex fluid' which has revealed 'new physics' in research by scientists at The University of Nottingham.

The new findings will be highly useful to the manufacturing industry because the processing and dispensing of everyday products like toothpaste, cosmetics, pharmaceuticals and foodstuffs depends on an understanding of the physical properties and behaviors of these fluids.

The research just published in *Nature Communications* by Dr. Michael Smith from the School of Physics and Astronomy, with collaborators at the University of Edinburgh and Politecnico di Torino, has used new methods to try to understand the flow properties of these concentrated solutions of particles.

Previous research has tried to measure flow properties by pressing the fluid between two circular rotating plates, called a 'shear rheometer', but this has limited applications relating to industrial manufacturing processes.

The new experiments tested various complex fluids in a different way using an 'extensional rheometer'. Instead of squashing the substance, this device stretches it out between two plates at varying speeds to measure the flow properties. The method and the results gathered have revealed new physics which will have much better applications in manufacturing, for example, in the packaging and dispensing designs of many household products.

Dr. Smith said: "Our observation of the fluid with a high speed camera revealed some intriguing effects depending on the concentration of particles and the speed at which the plates were moved. At low velocities the fluid is observed to behave like a liquid but at higher velocities and concentrations of particles the fluid can actually fracture like a solid. This happens if you dissolve a large amount of cornflour in some water, for example. The high concentration of tiny particles inside the fluid jam into one another forming clusters which lock solid if disturbed at a high enough speed.

"It is a bit like trying to move through a street crowded with an enormous number of people. If you move slowly enough you can make progress and the crowd and you 'flow'. However, if you try and sprint down the street you will just knock into so many people that you'll never be able to move at the speed you want to and hence everything becomes grid locked."

The research was able to show that whilst many features of this kind of system were independent of the geometry of the flow examined, some effects due to the exposed fluid surface were much more important than had previously been thought. In particular an effect known as 'dilatancy' in which some of the particles poke through the surface of the liquid was found to play a crucial role in the jamming of the particles.

Dr. Smith added: “The most incredible results were observed when the fluid was stretched at a velocity just below that required to form a jammed fluid. The fluid was found to form a thin filament which narrowed until it was about hundred particles in diameter. At this point the fluid was observed to recoil elastically, like a rubber band!

“This is particularly fascinating since the particles are specifically designed to behave like hard spheres with no attractive forces. Where does the elasticity come from? The liquid drains from the filament faster than the particles causing them to poke through the surface as before. The liquid surface forms a meniscus around the particles. It is this curved surface of the fluid which the researchers believe stores the energy and results in the unusual behavior.

“We hope this research provides an important initial step in understanding how the physics in common industrial flows may differ from the carefully controlled set up found in conventional academic studies”

More information: The full research report can be found online at *Nature Communication*s at: www.nature.com/ncomms/journal/ … full/ncomms1119.html

Provided by University of Nottingham