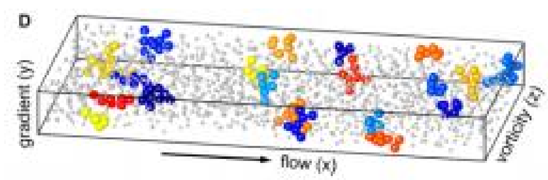
PHYS.ORG

Physicists capture microscopic origins of thinning and thickening fluids

September 1 2011, By Anne Ju



A snapshot of the configuration of particles suspended in fluid. The colored spheres indicate the presence of hydroclusters, which form at high rates of shear.

(PhysOrg.com) -- In things thick and thin: Cornell physicists explain how fluids – such as paint or paste - behave by observing how micron-sized suspended particles dance in real time. Using high-speed microscopy, the scientists unveil how these particles are responding to fluid flows from shear – a specific way of stirring.

Ever wonder why paint is thick enough to stay on a wall but thin enough to spread evenly with a brush? Or, how people can run across a swimming pool filled with a cornstarch-water mixture without sinking? They're both examples of what happens when particles are suspended in fluids.

Cornell scientists led by Itai Cohen, associate professor of physics, have explored why these fluids behave like they do by watching how micron-sized suspended particles dance in real time and space. Their observations are the first to link direct imaging of the particle motions with changes in liquid viscosity under shear -- or equivalently, when the fluid is stirred.

The research is published online Sept. 2 in the journal *Science*.

"What we want to find out is the microscopic origin of these non-Newtonian properties," said first author Xiang Cheng, a postdoctoral associate in physics. Such fluids are called non-Newtonian, because, unlike water or other Newtonian fluids, their viscosities change depending on how fast they're being sheared: think toothpaste, which is solid in the tube but flows like a liquid when squeezed or sheared.

Combining high-speed 3-D imaging techniques with a sensitive force-measuring device, the researchers tracked the motions of tiny particles suspended in the fluids while monitoring the thinning or thickening behaviors under shear. They found that fluids become thinner, or less viscous, when the random thermally induced darting motions of the particles could no longer keep up with their displacements due to the shear flows.

In addition, they showed fluids became thicker or more viscous when particles were driven past one another too quickly for the fluid between them to drain or get out of the way. At such high speeds, the particles form clusters that lock together and make the fluid more viscous. This result could partially explain why running (fast shear) across a cornstarch-water mixture doesn't cause the person to sink, but standing in the mixture (slow shear) does.

Their observations refute theories that such changes in fluid viscosity result from the formation and destruction of particle layers under shear. The idea behind these theories is that, like lanes on a highway, streamlining particle trajectories reduces random collisions and enables particles to flow past each other more smoothly. When the particles form layers at low shear rates, the viscosity decreases, causing the fluid to thin; when the particle layers break up at high shear rates, the viscosity increases, causing the fluid to thicken.

However, by directly imaging the layering and measuring the fluid viscosity, the Cornell scientists found that while the amount of layering and delayering was comparable, the changes in viscosity were substantially different in the thinning and thickening regimes. Moreover, the delayering occurred at shear rates much lower than those leading to thickening. Hence, they produced evidence that layering is not the major reason for viscosity changes in these suspensions.

Grasping the physics of shear thinning and thickening isn't just good for at-home science experiments; such non-Newtonian fluid phenomena are important for industry.

"In industry, understanding the thinning and thickening of materials is crucial for almost any transport process," Cohen said. These findings will improve the ability of scientists and engineers to handle complex fluids ranging from such industrial materials as paints, detergents and pastes, as well as such biological liquids as lymph and blood.

More information: The research article, "Imaging the microscopic structure of shear thinning and thickening colloidal suspensions," is published in *Science* (Sept. 2, 2011).

Provided by Cornell University

microscopic-thinning-thickening.html