Physicists break theoretical time barrier on bouncing droplets (w/ Video)

November 20 2013, by David Chandler

Centre-assisted recoil from butterfly wing structures repels drops faster. Credit: Adam Paxson, Kyle Hounsell, Jim Bales, James Bird, Kripa Varanasi

Those who study hydrophobic materials—water-shedding surfaces such as those found in nature and created in the laboratory—are familiar with a theoretical limit on the time it takes for a water droplet to bounce away from such a surface. But MIT researchers have now found a way to burst through that perceived barrier, reducing the contact time by at least 40 percent.

Their finding is reported in a paper in the journal *Nature* co-authored by Kripa Varanasi, the Doherty Associate Professor of Mechanical Engineering at MIT, along with James Bird, a former MIT postdoc who is now an assistant professor of mechanical engineering at Boston University, former MIT postdoc Rajeev Dhiman, and recent MIT PhD recipient Hyukmin Kwon.

"The time that the drop stays in contact with a surface is important because it controls the exchange of mass, momentum, and energy between the drop and the surface," Varanasi says. "If you can get the drops to bounce faster, that can have many advantages."

For example, in trying to prevent the buildup of ice on an airplane wing, the contact time of raindrops is critical: The longer a droplet stays in contact with a surface before bouncing off, the greater its chances of freezing in place.

According to the theoretical limit, the minimum time a bouncing droplet can stay in contact with a surface—first spreading out into a pancake-like shape, then pulling back inward due to surface tension and bouncing away—depends on the time period of oscillations in a vibrating drop, also known as the Rayleigh time. The way to achieve that minimum contact time, the conventional wisdom holds, is to minimize interaction between the water and the surface, such as by creating low-adhesion superhydrophobic surfaces.

But Varanasi's team found that increasing the surface interaction in a particular way can speed the process beyond that previous limit. To facilitate this interaction, they added macroscopic features—such as ridges that break a droplet's symmetry and can serve to split it, causing it to recoil in highly irregular shapes. These ridged surfaces can have contact times that are 40 percent shorter than control surfaces.

"We've demonstrated that we can use surface texture to reshape a drop as it recoils, in such a way that the overall contact time is significantly reduced," says Bird, the paper's lead author. "The upshot is that the surface stays drier longer if this contact time is reduced, which has the potential to be useful for a variety of applications."

With this reduction in contact time, the researchers were able to show that droplets bounced off before freezing on these symmetry-breaking surfaces; on control surfaces, droplets arrested and solidified on the surface. "We can reduce it further," Varanasi says, through optimization of the texture. "I hope we can manage to get a 70 to 80 percent reduction."

Varanasi's team's findings may also have implications for ecology: The researchers found that some butterfly wings naturally produce the same effect, limiting the likelihood that water will spread out over the wings and curtail their aerodynamic properties—a clear survival advantage. (In the case of the wings, it is the veins within that create the droplet-busting surface ridges.)

Similarly, the veins of nasturtium leaves, unlike those of most leaves, are on top, where they serve to break up droplets that land there. The MIT researchers found that drops bounced off both butterfly wings and nasturtium leaves faster than they bounced off lotus leaves, which are often considered the "gold standard" of nonwetting surfaces.

Varanasi points out that creating the needed surface textures is actually very simple: The ridges can be produced by ordinary milling tools, such as on the surface of an aluminum plate, making the process scalable to industrial levels. Such textures could also be created on fabric surfaces, he says, as a potential replacement for existing waterproof coatings whose safety has been called into question by the Environmental Protection Agency.

In addition to waterproofing and prevention of surface icing, the technique could have applications in other areas, Varanasi says. For example, the turbine blades in electric power plants become less efficient if water builds up on their surfaces. "If you can make the blades stay dry longer, you get a bump up in efficiency," he says. The new technique could also reduce corrosion on surfaces where droplets, especially if they are acidic or contain contaminants, contribute to degradation.

More information: Paper: dx.doi.org/10.1038/nature12740

Provided by Massachusetts Institute of Technology