Solution to beading-saliva mystery has practical purposes

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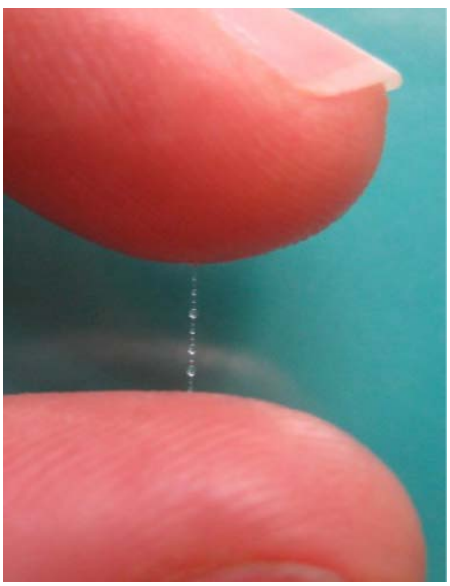

Stretching a bit of saliva between the thumb and forefinger demonstrates a long-mysterious phenomenon that causes some fluids containing long molecules called polymers to form beads, while others do not. Now engineers and scientists at Purdue University, the Massachusetts Institute of Technology and Rice University have solved the riddle. The findings could have many applications in industry and medicine. (Gareth H. McKinley/MIT)

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WEST LAFAYETTE, Ind. - Researchers have discovered precisely why strands of some fluids containing long molecules called polymers form beads when stretched, findings that could be used to improve industrial processes and for administering drugs in "personalized medicine."

"Any kindergartner is familiar with this beading phenomenon, which you can demonstrate by stretching a glob of saliva between your thumb and forefinger," said Osman Basaran, Purdue's Burton and Kathryn Gedge Professor of Chemical Engineering.

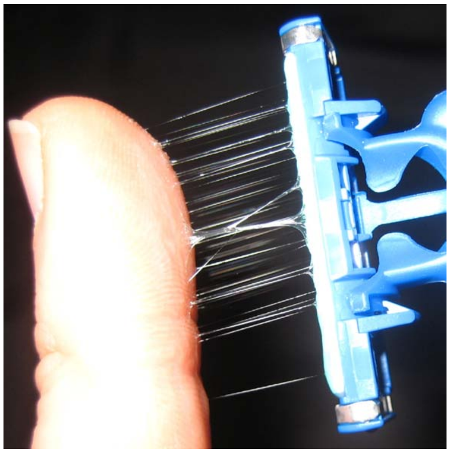
Before the strand of spittle breaks, a string of beads is formed.

"The question is, why does this beading take place only in some fluids containing polymers but not others?" Basaran said.

Now engineers and scientists at Purdue, the Massachusetts Institute of Technology and Rice University have solved the riddle in work led by Purdue postdoctoral researcher Pradeep Bhat. The researchers have determined the mechanism behind the beading and created a computational model to simulate the phenomenon.

Knowing the answer to this question might enable researchers to design systems that precisely control bead formation, leading to improvements in various technologies such as inkjet printing. The information also might be used in a system that precisely dispenses the correct dose of medications for individual patients based on simple blood tests.

Findings are detailed in a paper published online this week in the journal *Nature Physics*. The paper was written by Bhat; Purdue graduate student Santosh Appathurai; Michael T. Harris, a Purdue professor of chemical engineering; Matteo Pasquali, a professor in chemical and biomolecular engineering at Rice; Gareth H. McKinley, a professor of mechanical engineering at MIT; and Basaran.



Stretching a moistened material contained in a strip on the leading edge of disposable razors demonstrates a long-mysterious phenomenon that causes some fluids to form beads while others do not. Whereas beads form when a bit of saliva is stretched, they do not form when the material on the razor strip is stretched. Researchers have learned why the beading occurs, which could help improve industrial processes and for administering drugs in "personalized medicine." (Gareth H. McKinley/MIT)

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Saliva and other complex "viscoelastic" fluids like shaving cream and shampoo contain long chains of molecules called polymers. In the case of saliva, the polymers are proteins known as mucopolysaccharides. In comparison, liquids such as water and other so-called "Newtonian" fluids do not form the beads because they lack polymers.

Conventional wisdom has held that all fluids containing polymers should form the beads, but researchers have shown that assumption to be wrong and have demonstrated why.

The researchers tested saliva and a material contained in a strip on the leading edge of disposable razors.

"You moisten the razor strip with water, which causes it to swell, press it against a finger and pull it," Basaran said. "Unlike saliva, you see strands of liquids formed but no beads."

A key factor in the beading mechanism is fluid inertia, or the tendency of a fluid to keep moving unless acted upon by an external force.

Other major elements are a fluid's viscosity; the time it takes a stretched polymer molecule to "relax," or snap back to its original shape when stretching is stopped; and the "capillary time," or how long it would take for the surface of the fluid strand to vibrate if plucked.

"It turns out that the inertia has to be large enough and the relaxation time has to be small enough to form beads," Bhat said.

The researchers discovered bead formation depends on two ratios: the viscous force compared to inertial force and the relaxation time compared to the capillary time.

Because smearing "satellite" beads form around droplets produced by an inkjet printer, learning how to control bead formation might be used to improve printing. Findings also may help to improve an industrial process called electrospinning, used to make a variety of products, and spray coating used in painting.

"The idea is that, if you are operating an inkjet printer, for example, you would be able to control these ratios to prevent the bead formation," Basaran said.

Findings may help to perfect a new type of drug-dispensing technology being developed for "personalized medicine" through an Engineering Research Center for Structured Organic Particulate Systems, funded by the National Science Foundation and made up of researchers from Purdue, Rutgers University, the New Jersey Institute of Technology and the University of Puerto Rico.

The technique involves using an inkjet-printing nozzle to deposit drops of medication onto an edible substrate, such as paper or a sugar pill. The approach might be used by patients with disorders that require precise doses of medication depending on daily blood measurements.

"Patients might be able to do this even at home," said Basaran, whose research, carried out in collaboration with Harris, is affiliated with the NSF-funded center. "The patient will perform a routine sort of blood analysis, similar to blood-glucose monitoring, and then use this device to 'print' the exact quantity of drug based on the blood measurement, which would be done every day."

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Note to Journalists: Journalists can obtain a copy of the research paper by contacting Emil Venere, Purdue News Service, at 765-494-4709, venere@purdue.edu, or by contacting Nature at press@nature.com, 212-726-9231.

ABSTRACT

Formation of beads-on-a-string structures during break-up of viscoelastic filaments

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Break-up of viscoelastic filaments is pervasive in both nature and technology. If a filament is formed by placing a drop of saliva between a thumb and forefinger and is stretched, the filament's morphology close to break-up corresponds to beads of several sizes interconnected by slender threads. Although there is general agreement that formation of such beads-on-a-string (BOAS) structures occurs only for viscoelastic fluids, the underlying physics remains unclear and controversial. The physics leading to the formation of BOAS structures is probed by numerical simulation. Computations reveal that viscoelasticity alone does not give rise to a small, satellite bead between two much larger main beads but that inertia is required for its formation. Viscoelasticity, however, enhances the growth of the bead and delays pinch-off, which leads to a relatively long-lived beaded structure. We also show for the first time theoretically that yet smaller, sub-satellite beads can also form as seen in experiments.

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