Scientists clarify aspect of thin film solid-fluid interactions

June 3 2020

A thin film on the surface of liquid, which is pulled taut at the interface. As it is gently peeled away, marks of stress are revealed. A team of physicists recently clarified the question about how much the thin film is being stressed. Credit: University of Massachusetts Amherst

Recent correspondence in *Nature Materials* by a team of campus researchers answers a long-time question that experimental physicist Narayanan Menon says is "one of those things you should be able to look up in a textbook, a very basic question. But when you do look into the literature, there's confusion, and it has been going on for decades. Our work isn't screaming 'new discovery,' but this basic question is what we have clarified."

In addition to Menon, the team included theoretical physicist Benny Davidovitch, polymer scientist Thomas Russell and a former UMass postdoctoral physics researcher, Deepak Kumar. He led the experiments and analysis for the report and is now starting as a new faculty member at the Indian Institute of Technology, Delhi.

Menon explains, "Deepak's work addressed an assumption not tested carefully until now," he says. "Nobody got upset enough to devote a year to figuring it out."

Co-author Davidovitch writes that "the scientific question involves a mechanical response of tin films and filaments at fluid interfaces, which are affected by elasto-capillary stresses." Further, "The crux of the matter here is the subtle way by which surface energies of solid-liquid interfaces combine to generate stresses in a solid body."

To clarify, Menon explains, "Imagine something light and flexible, the thin film, floating on the surface of liquid—a leaf, the wing of a fly, a flower petal on a pond. It will stretch out and lay flat, pulled taut at the interface where it touches the water. You can try it out in your kitchen with a piece of plastic in a glass of water."

The question is how much the thin film is being stressed, or "tensed," he adds. "There are two answers found in the literature. One says that the tension depends on wha the liquid is, the other says it depends both on that and how the solid and liquid interact. Both assumptions cannot be correct, so we had to get to the bottom of it. Our experiments show with no doubt that only one of these answers is right."

Kumar's experiments revealed that the solid-fluid interaction—where a meniscus, or lens-shaped interface forms at the liquid surface—"only depends on what the liquid is, not on the solid. That doesn't matter," Menon reports. "To some people, that is going to be deeply upsetting, but to others it will be sort of obvious. This is the kind of thing that you might expect would already be known."

Russell adds, "When Deepak pulled a thin film from the surface of a liquid and showed us that the meniscii on the liquid and film-covered side were absolutely identical, we were amazed, but this is an unambiguous proof of one assumption."

Davidovitch says there was a need to clear this up because "a recent surge of interest in elasto-capillary phenomena, where nanometrically-thin solids exploit capillary forces to interact at fluid surfaces," is underway in soft robotics, drug delivery and tissue engineering with responsive surfaces, among other areas. Researchers are increasingly applying thin coatings to surfaces for biomedical or materials applications where they want to change the surface properties to control function.

Menon reflects on the outcome, "It doesn't look spectacular but it clears up something that has been muddy for a while. I always feel happy when you can do something in a simple way. The encouraging thing is that there are lots of simple things to figure out in science, which I find satisfying. You think that there is no space left for simple naive questions, but that is not true. This project was a nice reminder of that."

More information: Deepak Kumar et al. Stresses in thin sheets at fluid interfaces, *Nature Materials* (2020). DOI: 10.1038/s41563-020-0640-9