How researchers solved a decade-long puzzle about friction

Sometimes, when it comes to friction, less is more – at least that's what several experiments over the last decade seem to have shown in the case of friction caused by layered materials. But it wasn't until recently that researchers at NTNU figured out what was actually going on.

Friction probably isn't something you think about on a daily basis, but as anyone who's ever slipped over on an icy pavement could tell you, it can play a crucial role in many situations. The downside of friction, though, extends far beyond icy pavements: along with wear, it is responsible for approximately 23% of the world's energy consumption.

Astrid de Wijn, Photo: Thor Nielsen/NTNU

"Friction is a huge technological problem," says Astrid de Wijn, a professor in the department of mechanical and industrial engineering at NTNU. "In industrialised societies, where we have machines that are moving constantly or very fast, friction is enormously costly."

Studying friction is not as simple as classroom physics demonstrations involving a wooden block on a ramp suggest. "What is really happening is that the surfaces are rough and they meet at some points that are typically quite small," says de Wijn. "When we study friction we are thinking about these contact points and how they behave."

In order to really understand what they can see happening at the real world macroscale, researchers need to be able to explain the complex behavior of the materials at the nanoscale. "Many different things are happening at different length and time scales, and it makes friction very interesting," says de Wijn.

Layered materials – such as graphene, which is a single layer of carbon atoms arranged in a honeycomb pattern – generally have low friction. They are already used in lubricants, but learning more about how they work could enable us to make the world's machinery run more smoothly and reduce our energy bill on a global scale.

But in the last decade, researchers studying how friction works in materials like graphene have found that a single layer actually creates more friction than several layers. "People didn't understand that, and for years they were struggling with it," says de Wijn. "They did simulations and they reproduced this behaviour but couldn't figure out what was really happening."

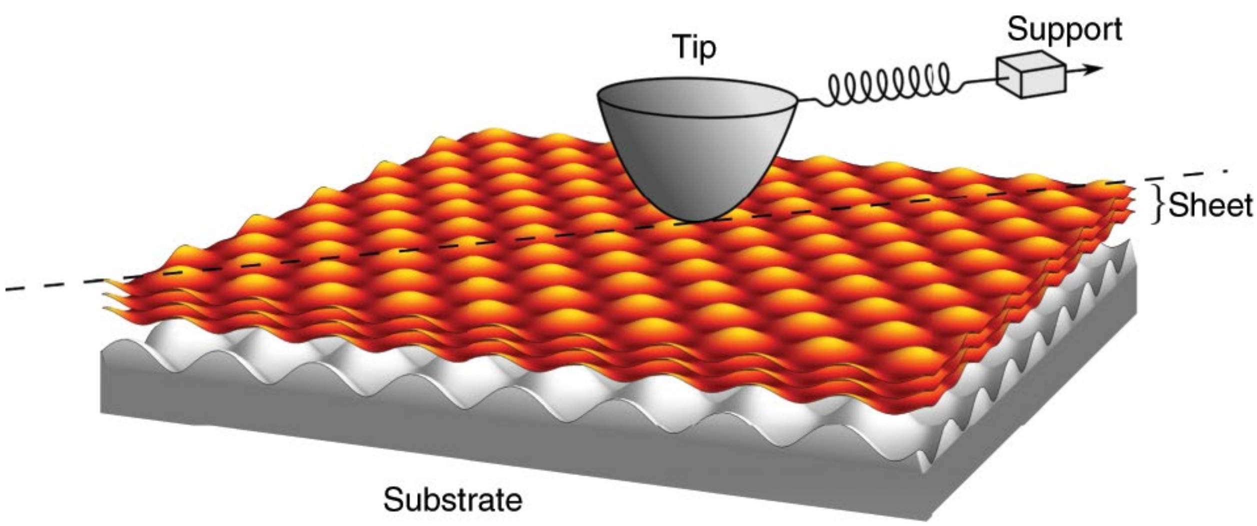
The problem was, while there were plenty of results apparently showing what was causing the material to behave like this in particular situations, the explanations proposed by different researchers seemed to contradict each other, and nothing stood out. “They all had good arguments and evidence that, in their system, it was their suggested mechanism that was doing it, says de Wijn.

David Andersson, Photo: Marcus Gidekull

In a recent paper published in Nature Communications, de Wijn and PhD student David Andersson solved the problem. It turns out that all of the proposed solutions are, in a way, right.

One existing model that often proves helpful for understanding friction was first proposed in 1928 and consists of three elements: a support, a spring and a tip. The friction is then the force required to pull the tip across a sheet. While that works well for explaining many situations, it falls apart when layered materials are involved. So de Wijn and Andersson added just one variable to describe what is happening inside the layers of the sheet that the tip is being pulled across. “We didn't specify what that variable meant exactly – if it was a scrunching up of some kind, or some bending or one of the many possible things that people had proposed,” she says.

That simple tweak turned out to be the key to explaining several previous results, both from real world experiments and computational models. “Suddenly all the pieces fell into place and we understood what was happening,” says de Wijn. “It could be different mechanisms giving rise to the same kind of dynamics.”



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Unfortunately, because of travel restrictions due to the coronavirus pandemic, de Wijn and Andersson have not been able to present the work at many conferences or discuss it with colleagues as widely as they would otherwise have done – at least not in person. Nevertheless, now this puzzle has finally been solved, it opens up new avenues for investigating how friction works in layered materials, and could pave the way for new technology to reduce it.

The work is not over yet, though. The next step for de Wijn is to figure out how thermal fluctuations affect the system. “It's not just an academic puzzle for us,” she says. “Solving this means that we are one step closer to making friction lower.”

Kelly Oaks, December 2020