Size matters: Friction, adhesion change on atomic level

June 29 2005

Physicists have a pretty good idea of what to expect when friction and adhesion occur in the visible world. You jam on the brakes, for instance, and your tires and the highway interact to stop your car. You glue two pieces of wood together, and they stick.

But how slippery or sticky are things that are too small to see? When solid surfaces no more than a thousand atoms across brush past each other, will they respond like the rubber and the road? Will they adhere like the wood and the glue?

The answer turns out to be "It depends," according to Johns Hopkins physicists who used computer modeling to examine how friction and adhesion operate on the atomic level.

"Any surface made of individual atoms has 'bumps' of atomic dimension, and being able to vary the placement of atoms [in the computer models] allowed us to quantify the influence of atomic structure," said Mark O. Robbins, a professor in the Henry A. Rowland Department of Physics and Astronomy in the university's Krieger School of Arts and Sciences.

The modeling showed that surfaces from a few to a thousand atoms across, with the same shape, but with different local structures, or "bumps," behave quite differently, even if those surfaces are made of the same material, Robbins said. Local stresses and adhesion forces can vary by a factor of two or more, and friction can change tenfold, he said.

The research is reported in the June 16 issue of the journal *Nature* by Robbins and graduate student Binquan Luan. Their findings could one day help in the successful design of nanomachines, the name given to devices built by manipulating materials on an atomic scale.

"Everyone knows that matter is made up of discrete atoms, yet most models of mechanical behavior ignore this and think of atoms as being 'smeared' into an artificial continuous medium," Robbins said. "This approach works well when describing the behavior of larger machines, but what happens when the whole machine is only a few to a thousand atoms across? The answer is crucial to the function of man-made nanomachines and many biological processes."

Robbins' and Luan examined contact between solid surfaces with "bumps" whose radii varied from about 100 to 1,000 atomic diameters. Bumps that size might be typical of nanomachine surfaces or the tips of atomic force microscopes used to measure mechanical properties at the atomic scale.

Using computer simulations, the team followed the displacements of up to 10 million atoms as the solid surfaces were pushed together. They then compared these displacements and the total adhesion and friction forces to calculations of the same forces using the standard "continuum theory," the model that views matter as having smeared rather than discrete atoms.

"Knowing the exact atomic structure and how each atom moved allowed us to test the two key assumptions of continuum theory," Robbins said. "While it described the internal response of solids down to nearly atomic scales, its assumption that surfaces are smooth and featureless failed badly" at the atomic level.

In a "News and Views" paper accompanying the Nature article, Jacob

Israelachvili of University of California, Santa Barbara, noted that these results have fundamental implications for the limits of theories that try to "smear out" atomic structure, as well as indicating "how surfaces might be tailored in desirable ways ... if atomic-scale details are taken into consideration." This work is important because of the growing interest in nanotechnology, in which unwanted adhesion and excessive friction can cause devices to malfunction or just not to work, Robbins said. "Hopefully, this will help in the creation of new tools needed to guide the design of nanotechnology" he said.

Source: Johns Hopkins University

Citation: Size matters: Friction, adhesion change on atomic level (2005, June 29) retrieved 18 April 2024 from https://phys.org/news/2005-06-size-friction-adhesion-atomic.html