'Ay, there's the rub': Researchers strive to identify the atomic origins of wear

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To slide; perchance to fatigue. "Wear is so common in sliding systems that it has acquired this air of inevitability," says Greg Sawyer, a professor in mechanical engineering at the University of Florida who leads a team of researchers hoping to overturn this assumption. Sawyer and his collaborators have succeeded in modifying polytetrafluoroethylene (PTFE), the ubiquitous, already low-friction material also known as Teflon, to make it "nearly a million times more wear-resistant." By applying the lessons learned from this and other such success stories, the researchers are attempting to identify, and then eliminate, the atomic and molecular origins of wear. If they reach their goal, moving assemblies such as joint replacements might last, if not forever, then at least until their owners "have shuffled off this mortal coil."

Any device that has moving parts – be it a lawn mower, a dishwasher, or a drive train – experiences friction. "Friction is a beautiful, complex thing" that steals energy and efficiency from a system, but doesn't, by default, result in wear, says Sawyer. The characteristics of an entire system, as opposed to any inherent properties of the sliding materials, determine how much wear will result when two surfaces move past one another. Sawyer and his team have come up with a number of hypotheses to explain how frictional forces might rip off or grind away bits of material in particular sliding systems. A surface could erode through a slow rearrangement of the atoms and molecules; through small, discrete breaking events that add up over time; through rare, but catastrophic, cleaving events; or through other, unknown methods. "We don't have near all the answers yet," Sawyer says.

To test their hypotheses, the scientists use atomic force microscopes to create atomic-scale images of surfaces and use finely tuned instruments to measure the minute forces that occur as materials slide against each other. Once the researchers identify a factor that contributes to system wear, they try to design a way to stop it. In the instance of the ultra-low-wear PTFE, the researchers embedded nanoparticles made of alumina in the polymer, which dramatically reduced wear. And this effect isn't limited to PTFE. Other nanoparticle-filled plastic composites have been shown to display a decreased sliding coefficient of friction, although scientists are still investigating the precise mechanisms that result in the reduced wear. At the AVS Symposium in Nashville, Tenn., held Oct. 30 – Nov. 4, Sawyer will present results from a number of ultra-low-wear systems studied in his lab, including polymers, metals, and ceramics.

Other than obsolescence, wear is the number one cause of end-of-product life, Sawyer notes. Scientists and engineers from Da Vinci onward have been exploring ways to minimize it, he says, and his team is continuing the quest. Asked about the future, Sawyer envisions a world where myriad products might never wear out: "Can you imagine only ever owing one car? Ultra-low-wear systems could change everything."

More information: The AVS 58th International Symposium & Exhibition will be held Oct. 30 – Nov. 4 at the Nashville Convention Center.

Presentation TR-WeA7, "Going No Wear?," is at 4 p.m. on Wednesday, Nov. 2.

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