UC SANTA BARBARA

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Sonia Fernandez

# It's Kind of a Drag

Imagine walking from one side of a swimming pool to the other. Each step takes great effort — that’s what makes water aerobics such effective physical exercise.

The resistance you feel is caused by fluid friction — or drag — and it is the same force that acts upon boats and other objects as they move through water. However, seafaring vessels have evolved into shapes aimed at minimizing drag, and ships are designed with powerful engines that overcome drag to propel them faster and more smoothly across the ocean.

More recently, super hydrophobic surfaces (SHS) have caught the attention of scientists who see their potential for reducing fluid friction. But as UC Santa Barbara mechanical engineering professor Paolo Luzzatto-Fegiz noted, while the basic theory of these surfaces is sound, their real-world performance leaves much to be desired.

According to Luzzatto-Fegiz, an expert in fluid dynamics, SHS combine water-repelling chemistry with micro-scale patterning in a way that essentially reduces the surface contact with water. However, they have proved to be unreliable at best, often functioning erratically or not working at all.

And now, in research highlighted in the Proceedings of the National Academy of Sciences, Luzzatto-Fegiz and his colleagues at the University of Cambridge and the University of Manchester have identified a key reason why.

Theoretically, super hydrophobic surfaces are effective because they contain tiny air pockets. Air is much less viscous than water, Luzzatto-Fegiz noted, so decreasing the

amount of water that comes in contact with the surface will decrease the resulting drag.

The benefits of reducing drag bear directly on fuel economy: The less fluid friction a ship experiences, the less fuel is necessary to overcome drag. And because drag increases with speed, the faster the ship moves the more fuel it requires to counteract the resulting resistance.

However, in testing the hypothesis, which could, in theory, show a significant reduction in drag, results by other researchers often found no reduction at all, and in some cases, demonstrated a slightly worse performance.

This was the problem that had the scientists scratching their heads — until it occurred to Luzzatto-Fegiz that surfactants could be to blame. While researchers before him had identified this possibility, he and his team were the first to demonstrate the concept. According to numerical simulations and tightly controlled experiments, Luzzatto-Fegiz, et al, found that even tiny trace amounts of surfactants — compounds that reduce surface tension, such as soap — were enough to cause an imbalance in the flow of water along its interface with the surface, resulting in drag.

Mystery solved. But can the problem be fixed?

“The key idea is that no liquid is pure,” Luzzatto-Fegiz said. Oceans and rivers contain multitudes of natural and man-made surfactants. But it may be possible to design a way out of the problem by changing the patterning of the SHS, he said. For example, by creating longer grooves in the patterning aligned with the flow of water, the surfactant buildup that prevents the reduction of drag on the surface accumulates farther down the line of the interface, reducing some of the drag.

The results of this experiment could provide valuable knowledge to those who design oceangoing vessels with an eye toward fuel efficiency. Especially in the shadow of impending regulations that will require the global fleet of merchant ships to purchase more expensive but cleaner burning fuel, reducing drag could go a long way toward keeping costs down for ships that ply the world’s oceans, as well as reduce the polluting byproducts of burning fossil fuels.

“Reducing drag cuts on fuel consumption and therefore on emissions — including sulphur compounds and CO2,” Luzzatto-Fegiz said.

Research on this project, titled “Traces of surfactants can severely limit the drag reduction of superhydrophobic surfaces,” was conducted by lead author Francois J. Peaudecerf, and Raymond E. Goldstein at the Center for Mathematical Sciences at University of Cambridge and Julien R. Landel at the School of Mathematics at University of Manchester.

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