Shark-inspired design could make air travel faster and more efficient

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The same principles that allow sharks to swim through water could help airplanes travel faster and more efficiently. Credit: Stefanie Goodwiller/University Marketing and Communications

The same flow dynamics that allow sharks to swim easily through Earth's oceans could also allow humans to fly faster through the air, according to a University of Mississippi professor. His research aims to prove it.

Wen Wu, assistant professor of mechanical engineering at Ole Miss, plans to improve air flow dynamics for flight, potentially reducing energy consumption while making air travel more efficient.

"Sharks are special because their dermal denticles are different from the scales of the other fish," Wu said.

Wu will partner with Louis Cattafesta, the John G. and Jane E. Olin Endowed Department Chair in mechanical, materials and aerospace engineering at the Illinois Institute of Technology, on the study.

"We have a concept that is based on shark skin that, based on some preliminary simulations, can lead to drag reduction in a way that was not previously considered," Cattafesta said.

Shark skin is made up of hundreds of millions of scales—called denticles—that are shaped like a three-toed dinosaur track. The curved bottom of the "foot" faces outward, while a cylindrical column at the base anchors the denticle to the shark's body.

The outward shape of denticles was long believed to reduce drag, helping sharks swim faster to catch their prey. This belief was so prevalent that every Olympic swimmer in 2016 used swimsuits designed with the ridge-like top of the shark denticles in mind.

"Actually, when researchers really study shark skin, it does not show any improvement on drag in common flow conditions," Wu said. "So why did the swimming suit work? It turns out that if you take a piece of that fabric and put it in the test facility, it does not reduce drag.

"But it's really tight, so the swimming suit covers the full body and squeezes the body of the swimmer, making it more streamlined and meanwhile promoting blood circulation.

"Then how does this work for sharks? People have started to focus on another significant drag-producing phenomena in fluid mechanics, which is flow separation."

Shark bodies taper from head to tail, and as streams of water travel over that narrowing surface, they do not cling to the shark's body. Instead, the flow of water tends to detach from the body. During maneuver, this detached flow may create a swirling stream of water near the surface of the body.

Wu found that a backward flow of water slips under the top crown of the denticles and pushes against their cylindrical base, effectively using the water's force to propel the shark forward. He published a paper on this discovery in the *Journal of Fluid Mechanics* in December.

Integrating this design into airplanes, ships and other crafts could reduce the amount of energy used while improving aerodynamics, Cattafesta said.

"If you can reduce drag by even a fraction of a percent, you can have tremendous savings in energy costs associated with flying an aircraft," he said. "Then there's the added beneficial effect that you'll have reduced emissions and climate impact."

Wu will lead numerical simulations of how denticle-inspired materials perform in different wind conditions, and Cattafesta will perform experiments based on the results of those simulations.

"If we're going to optimize this, then we have to know what size the denticles have to be, the spacing of the necks, all of those details that we need for advanced manufacturing technology," Wu said.

"We're going to develop surface coatings or add-ons structures based on the findings from denticles, improve them to exceed the biological limit of sharks and optimize them so that we can maximize the subsurface reverse flow and use it in cars, airplanes or even the bodies of athletes."

More information: Benjamin S. Savino et al, Thrust generation by shark denticles, *Journal of Fluid Mechanics* (2024). DOI: 10.1017/jfm.2024.978

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