Manmade artificial shark skin boosts swimming

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People have thought for decades that the rough skin of sharks may give them a swimming boost and now scientists from Harvard University have made the first ever realistic simulated shark skin. They also measured that the fish's sharp scales boost swimming by up to 6.6% while reducing the energy cost.

Press release: It's only when you get up close to a shark that you realise how rough the sleek-looking skin really is: it is peppered with millions of microscopic overlapping tooth-like scales. These so-called 'denticles' disrupt the smooth flow of water over the animal's surface, reducing the drag that holds them back. Engineers and scientists have been mesmerised by the advantage that the razor-sharp surface gives sharks, but it is impossible to get to the nub of how denticles give sharks a boost without testing how alterations to the skin affect the fish. 'You can't modify real shark skin', explains George Lauder from Harvard University, USA. So Lauder and his colleagues Li Wen and James Weaver decided to try to create artificial shark skin instead.

They publish the result of their first successful manufacture of artificial shark skin and their discovery that the remarkable structure can increase shark swimming speeds by 6.6% in *The Journal of Experimental Biology*.

After finding a mako shark in a local fish market, Lauder took a small sample of the skin for scanning to get a high-resolution view of the surface. Next, he and Wen zoomed in on one representative denticle to build a detailed model of the structure before reproducing it thousands of times in a computer model of the skin. Then the team had to find a way to construct the model. 'After considering a number of approaches, we decided that the only way to embed hard denticles in a flexible substrate was the 3D printer', recalls Lauder, but this proved to be easier said than done. 'We had to figure out how to print them with multiple materials… The denticles are embedded into the membrane and overlap, which posed a key challenge for 3D printing,' recalls Lauder. However, after a year of testing different materials, printing protocols and enlarging the denticles and their spacing, Weaver finally produced a convincing sample with the denticles secured in a flexible support. 'Seeing the [scanning electron micrograph] SEM of the curved membrane with the denticles was a great moment for us', smiles Lauder, who admits that the image of the SEM in the research paper is one of his favourite research images of recent years. But how well would the artificial skin function in practice?

Wen and Lauder attached samples of the manufactured skin to both sides of a flexible foil that could be held stationary in flowing water or flapped to move like a swimming fish, and then measured the forces exerted on the swimming and stationary foil. After repeating the experiments with samples of the flexible membrane alone, so that they could dissect out the effect of the denticles on the swimming performance, they were impressed to see that the static shark skin mimic reduced the drag on the foil by 8.7% at the lowest flow speeds, although at the highest flow speed – almost 0.6 m s−1 – the shark skin produced 15% more drag than the smooth membrane. However, when the team began flapping the foil like a fish displacing its body by 1 cm as it wriggled at 1.5 Hz, the shark skin's performance improved significantly, increasing the foil's swimming speed by 6.6% and reducing the energy expended by 5.9%. 'This is the first time that anyone has measured the energetic cost of shark skin and the reduction in swimming cost relative to a smooth surface', says Lauder.

Reflecting on their success, Lauder attributes the breakthrough to the design, 'Artificial shark skin needs to have rigid denticles/scales on a flexible substrate so that the biomimetic skin can flex and bend like real shark skin', he says. And he is now keen to test how altering the arrangement of the denticles will affect performance. However, he doesn't think that we'll be wearing swimming costumes made from artificial shark skin soon: 'The manufacturing challenges are tremendous', he chuckles.

More information: Wen, L., Weaver, James C. and Lauder, G. V. (2014). Biomimetic shark skin: design, fabrication and hydrodynamic function. *J. Exp. Biol.* 217, 1656-1666. jeb.biologists.org/content/217/10/1656.abstract

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