BIOMIMETIC MATERIALS: HOW SYNTHETIC SHARK-SKIN IS MAKING AIRCRAFT CARRIERS MORE HYDRODYNAMIC

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WHY SHARK-SKIN?

Shark-skin has long been known to exhibit hydrodynamic properties and reduce the drag experienced by sharks as they swim through the water. However, it has only been in recent years that engineers have begun developing synthetic materials designed to completely mimic the properties of shark-skin. The riblet skin that sharks have is riddled with microscopic grooves, called denticles. Denticles are flat, scaly, tooth-like protrusions made of a hard material called dentin and are embedded in the flexible dermis of the shark. Furthermore, these denticles each flex individually, allowing for the shark's skin to naturally adapt to its surroundings to increase hydrodynamic efficiency (as shown in the bottom middle figure).

Shark-skin also has an antimicrobial property that prevents algae, barnacles, and other organisms from latching on to the shark as it maneuvers through the water. As a result of the anti-biofouling properties and the unique riblet skin exhibited by shark-skin, scientists all around the world have been working toward developing a synthetic material that effectively mimics the properties of true shark-skin. This material is being designed to be used for swimsuits, ship coatings, and much more.

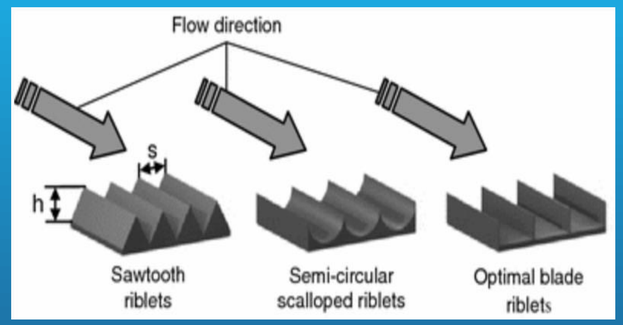
WHY DO WE NEED SHARK-SKIN?

One of the main reasons for the development of biomimetic shark-skin, a synthetic material that is designed with the biological components and structure of true shark-skin in mind, is to provide a solution to the problems that ships face regarding hydrodynamic and fuel efficiency and environmental cautiousness.

Marine life, such as barnacles, has the tendency to attach to the hulls of ships. This is called biofouling. Biofouling causes an increase in drag experienced by the ship as it moves through the water, especially at higher speeds.

Biofouling also causes issues regarding maintenance of ships. A large part of this marine growth forms during the long months that the ship is docked. This poses a significant financial burden on the U.S. Navy as the cost of putting aircraft carriers in dry docks, to clean them, is incredibly expensive.

A current solution is the use of biocides, poisonous substances that kill the organisms on the ship. However, the UK Marine Special Areas of Conservation division reports that the use of biocides is severely detrimental to the environment due to the amount of harmful chemicals that it releases in to the surroundings.



Examples of different types of riblet geometries.

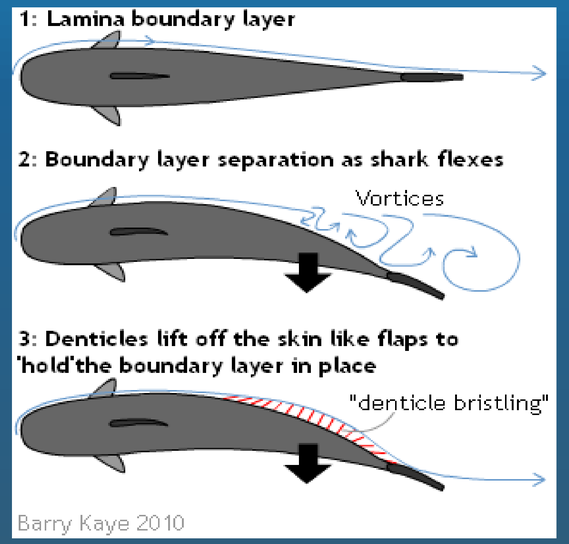
THE CREATION & APPLICATION

The creation of this technology is based on the complex solutions nature has come up with. That is why, aside from mimicking the geometry of shark-skin, one part of the solution being researched is the use of zwitterionic compounds, which shark-skin contains. This coating, dubbed "Gator Sharkote", has reduced the presence of the Ulva spores, a common type of green seaweed algae, on ships by 85% during lab testing. The zwitterionic compounds reduce biofouling naturally, without the use of biotoxins and without harming the environment.

The second part of the development of the material is focused on mimicking the riblet geometry and the denticles present in shark-skin. Reducing denticle size has been found to maximize hydrodynamic efficiency. Engineers have also been searching for the optimal denticle geometry to reduce drag. The options shown in the figure to the left have been found to be most efficient. Although much research has been done toward the perfection of a biomimetic shark-skin material, there has yet to be one that perfectly combines the microbial anti-biofouling properties and the riblet surface.

WHAT WORKS?

The biomimetic shark-skin that a team in Florida is researching has proven to be the most effective solution to date regarding the biofouling problem on aircraft carriers. This material, made from flexible elastic silicone, also does not contribute harmful chemicals to the marine ecosystem. Biomimetic shark-skin will be the better solution in comparison to copper-based paint and TBT because it is not harmful to the environment and is more effective.



(Above) An explanation of how riblet's reduce drag

(Right) A scanning electron image of the denticles that the Florida team modeled.

SUSTAINABILITY

Current Solutions:
Biocides harm the ecosystem by inhibiting the reproductive systems of many animals it comes into contact with, as well as being generally toxic to many types of marine life. Replacing it with biomimetic shark-skin will promote the longevity of marine ecosystems by removing a major source of toxins from ecosystems in the areas around where aircraft carriers dock regularly.

Fuel Efficiency:
One of the major goals of this technology is to decrease drag on ships. This will lead to improved fuel efficiency for the ships that the coating is applied to. Having a more fuel efficient fleet of aircraft carriers, and eventually even cargo ships, will mean that less pollution is created in order to power these ships. The end result of this is that, by adding this coating to ships, pollution could be reduced worldwide and these ships would have less of an impact on the environment.

Economic Sustainability:
By decreasing maintenance costs and increasing fuel efficiency, the cost to operate aircraft carriers, and even cargo ships, will be reduced. This means that the money currently being spent on these items by the US Navy would be able to be allocated to more important goals elsewhere, which will promote the long-term sustainability of the US's military. In addition, reduced transportation costs would make goods worldwide cheaper, which would benefit both our current generation and ones to come.