3D Model of Flow Behavior near Dermal Denticles from Shark Skin

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Introduction: Sharks are known to be exceptionally energy efficient swimmers. Many studies have linked this to microscopic structures on their skin[1,2]. The potential reductions in fuel consumption in the transport industries are substantial, provided a successful biomimetic shark skin surface-coating can be constructed.
The energy reduction is believed to be realized through vorticity structures created by riblets on the shark skin surface.
It is this effect which is examined through both computational and experimental methods.

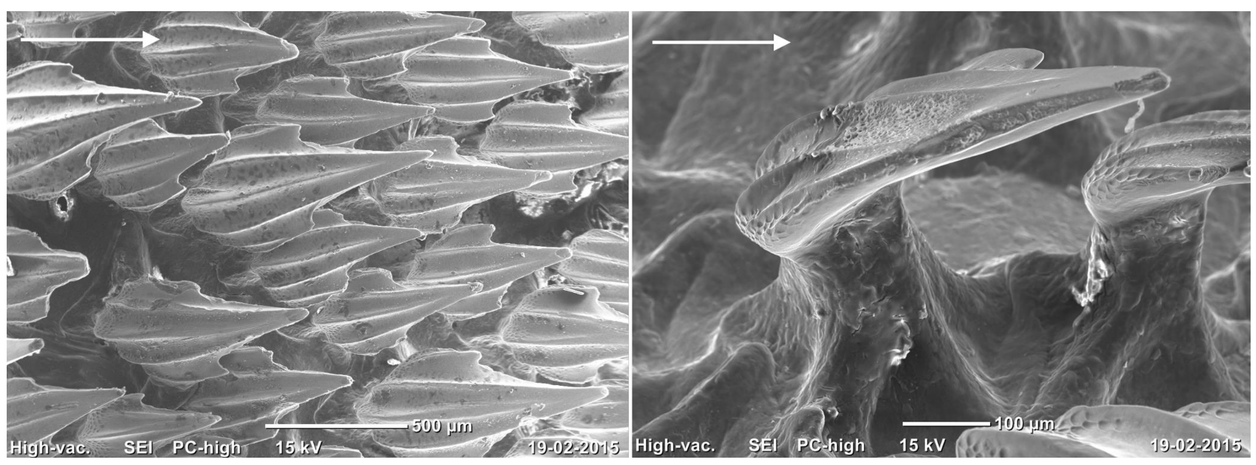

Figure 1. Scanning Electron Microscopy images of dermal denticles from the Smallspotted Catshark. Arrows indicate main flow direction. Reprinted from[3].

Computational Methods: A 3D model of the structures formed the basis for a k-ϵ model of the fluid flow. The model is designed to mimic the experimental set-up.
An inlet condition of a fully developed, turbulent flow profile of fresh water at 20 ºC with a mean speed of 6 m/s was employed.

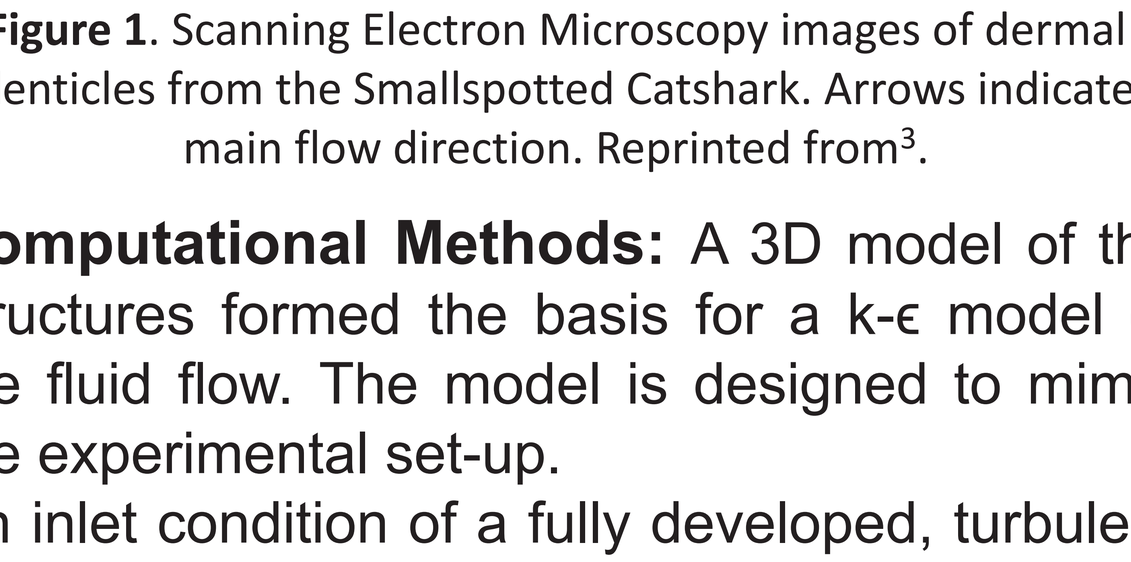

Figure 2. Model of a dermal denticle from the Smallspotted Catshark. Perspective, side, top and back view.

Results: Fluid flow velocity and vorticity along three planes were extracted. The friction reducing vorticity happens in the plane normal to the main flow direction. This plane is not accessible by current measurements but can easily be evaluated using the model.

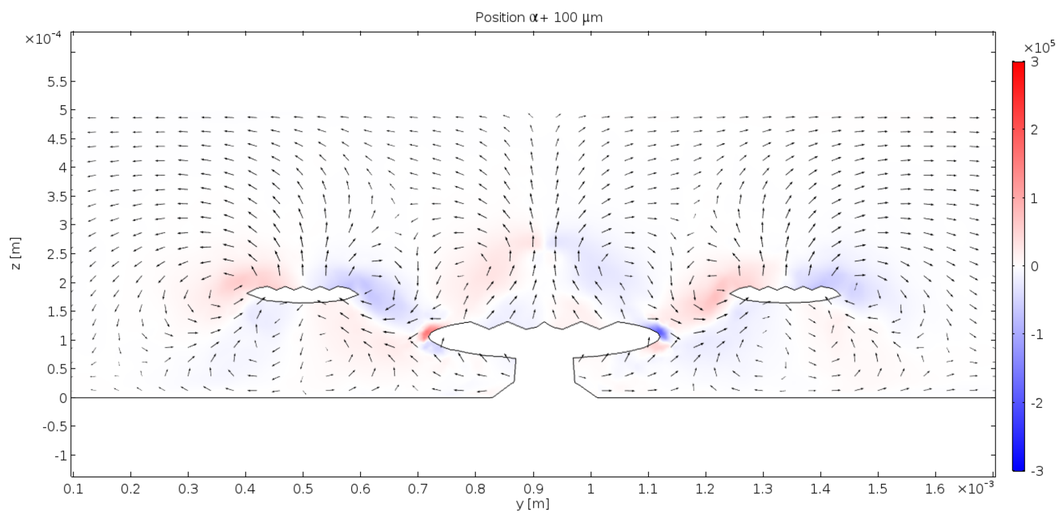

Figure 3. Vorticity around the denticles. Measured in the plane normal the main fluid flow direction.

The vorticity in all planes indicate the presence of counter-rotating vortices in the flow.

Conclusions: The results show good agreement with the expectations from theory and to a lesser extent with the experimental work.
Further work on this project will include a more refined model of the biological structures as well as simulation with a Low Re model to get a simulation which mimics reality more closely. Ultimately, a finer spatial resolution is desired.

References

1. B. Dean and B. Bhushan. “Shark-skin surfaces for fluid-drag reduction in turbulent flow: a review”. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 368.1929. 4775-4806 (2010).*
2. S.J. Lee and S. H. Lee. “Flow Analysis of a turbulent boundary layer over a riblet surface”. *Experiments in Fluids Journal.* 30.20. 153-66 (2001).
3. T. E. B. Smithshuyen and E.C. Jensen. “Micro particle image velocimetry analyse af flowdynamik over hajskin”. Student Project, DTU Physics. Unpublished. (2015).