Biomimicry of Sharkskin to Improve Hydrodynamics

K.A. Keriazes and J.L. Chuang

***Abstract*- The purpose of this study was to observe whether the application of biomimicked sharkskin can improve hydrodynamics of boats by reducing drag, increasing speed, and increasing efficiency. The Speedo Fastskin material, which biomimicks sharkskin was most effective in decreasing the drag coefficient of the model boat used in this study as compared with other drag-reducing surfaces.**

I. INTRODUCTION

A study has shown that 16% of the total energy consumed in the United States is used to overcome drag in transportation systems; for underwater vehicles, 90% of total drag is due to skin friction drag [1].

Using new innovations in the biomimicry of sharkskin, drag reduction has been found to increase to a rate of about 24.6 % [2]. Sharks, such as the Shortfin Mako, are able to swim at speeds up to 43 miles per hour due to their hydrodynamic skin. Sharkskin has riblets, ridges on each scale, which decrease drag by creating vortices, areas of low pressure. These riblets help channel water and create a greater separation between the shark and the boundary layer of the water. [3]

II. PROCEDURE

Small-scale model rowing shells were developed using a 3D printer and were used to test different drag- reducing products. The control boat had a smooth surface in which no additional material was applied. Variable 1 was the Speedo Fastskin material (biomimicked sharkskin) and Variable 2 was the HullSpeed paint, a commonly used drag-reducing product. Clay was placed on the inside of the boats to equalize their masses. A ten-foot long water tunnel was used to conduct the trials and included a system of two pulleys and a drop weight, which were used to propel the boat across the tunnel. A PASCO motion sensor recorded the velocities at different points during movement, specifically during the time the boat was in dynamic equilibrium. Three hundred trials were conducted for each group. The average velocities at dynamic equilibrium were then substituted into the drag equation (1) in order to calculate and compare the drag coefficients of each group. In addition, the Reynolds number (2) was calculated to determine the type of flow, laminar or turbulent, of water around each boat. Laminar flow is a smooth flow of water around the boat whereas turbulent flow is an irregular flow of water around the boat.

$$D = \tfrac{1}{2} \rho V^2 A C_D \qquad (1)$$

D is the drag force (drop weight = 0.294 N), ρ is the mass density of water (999.97 kg/m^3), V is the velocity (averaged velocity from each trial), A is the wetted surface area of the boat (0.00849676 m^2), and C_D is the drag coefficient, the unknown dimensionless variable which was calculated.

$$Re = \rho VL / \mu \qquad (2)$$

Re is the Reynolds number, ρ is the mass density of water (999.97 kg/m3), V is the velocity of the fluid, L is the length of the water tunnel, which was 3.048 meters), and μ is the kinematic viscosity at 20ºC (1.004 m^2/s x 10-6).

*Research supported by Manhasset Secondary School.
Manhasset Secondary School, Manhasset, NY 11030 USA

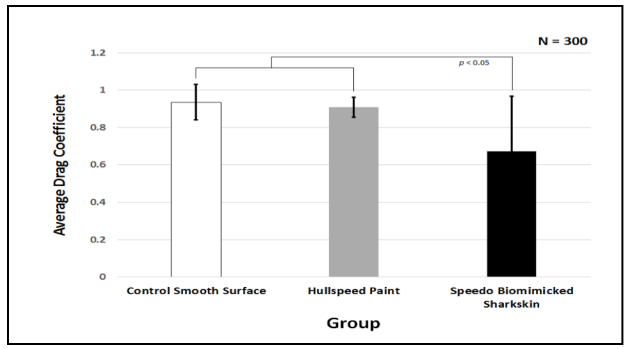

Figure 1. Average Drag Coefficients

III. RESULTS AND DISCUSSION

Figure 1 shows that the boat with the Speedo biomimicked sharkskin surface had the lowest average drag coefficient of 0.67 when compared to that of the control group, which was 0.93, and that of the Hullspeed group, which was 0.90. This means that the Speedo group produced the least drag due to the ability of the riblets to speed up and channel the slower water, creating less of a speed discrepancy and a decrease of turbulence [3]. After statistical analysis was conducted in IBM SPSS 20 with a one way ANOVA (Analysis of Variance) followed by a post-hoc Scheffe test, a significant difference of 0.0001 was found between the control boat and the Speedo boat, and a significant difference of 0.0001 was found between the Speedo boat and the Hullspeed boat. In addition, the boat with the Speedo biomimicked sharkskin surface had the greatest Reynolds number of 97.6 and all groups exhibited laminar flow. Objects with larger Reynolds numbers travel at higher velocities which reinforces the conclusion that the Speedo material reduced the most drag while maintaining a smooth flow of water around the boat.

Since the Speedo biomimicked sharkskin material was most effective in decreasing the drag coefficient of the model boat, the alternate hypothesis was supported. The works of past researchers, such as Oeffner [4], support these results in that they found biomimicked sharskin to most effectively reduce drag as well.

IV. ACKNOWLEDGEMENTS

Research was conducted in Manhasset High School under the guidance of Mr. Peter Guastella and Ms. Alison Huenger. A 3D simulation of the model boats used in this study was developed by boat engineer Jody Culbert and the models were printed by Skinner Models.

V. REFERENCES

[1] Peet, Yulia, and Pierre Sagaut. "Turbulent Drag Reduction Using Sinusoidal Riblets with Triangular Cross-Section." *American Institute of Aeronautics and Astronautics Paper* (2008): n. page.

[2] Zhang, Deyuan, Yuanyue Li, Xin Han, Xiang Li, and Huawei Chen. "High-precision Bio-replication of Synthetic Drag Reduction Shark Skin." *Chinese Science Bulletin* 56.9 (2011): 938-44.

[3] Dean, B., 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 (2010): 4775-806.

[4] Oeffner, J., and G. V. Lauder. "The Hydrodynamic Function of Shark Skin and Two Biomimetic Applications." *Journal of Experimental Biology* 215.5 (2012): 785-95.