HIGH SCHOOL EDITION
Journal of Student Research
Volume 11 Issue 3 (2022)

Biomimetic Research of Fish Mucus and Cargo Ships

Madison Wood

Mira Costa High School, Manhattan Beach, CA, USA

ABSTRACT

The goal of this research was to determine if one could increase the efficiency of drag and energy loss of containership hulls in the water by utilizing the principlesof biomimetics. All species of fish contain a coat of mucus which makes the surface of the fish slippery and reduces drag, adds external protection and many additional advantages. The mucus layer fills the gaps of a body to make a smooth and slippery surface for minimum drag while also providing hydrodynamic advantages by increasing velocity from which the surrounding fluid hits the surface of the fish. Increase in efficiency during movement on water was determined by the different travel speeds using 2 cargo ship model boats (one was coated with fish mucus on the hull and the other one was left uncoated). It was observed that the ship with fish mucus on its hull increased in speed and decreased the drag force, thus making the travel more efficient. The data obtained in this experiment supports the hypothesis that cargo ships would use less fuel and waste less energy with a fish mucus like synthetic on their hulls.

Introduction

Various approaches have been explored to achieve drag reduction between liquids and solids. Synthetics akin to Fish mucus have been developed including Leidenfrost effect drag reduction and polymer additives drag reduction. Scientists are similarly making more progress in their researches because the above mentioned methods have been faced with major drawbacks such as pollution, high energy consumption, high temperatures, and complexity in manufacture and manipulation. Adequately researched natural examples in the drag reduction studies include: dolphin-skin drag reduction regulating turbulence in liquid by viscos-elastic body; Lotus effect, also super hydrophobic drag reduction with low adhesive force to water molecules and very low friction force applied on to the liquid flow; Shark-skin drag reduction arising from uniquely arranged placoid scales which can decrease turbulence and friction thereby increasing speed and agility; and the penguin feather-induced micro bubble drag reduction, which can change the density of the surrounding fluid medium and decrease turbulence (Brooks et al., 2018)

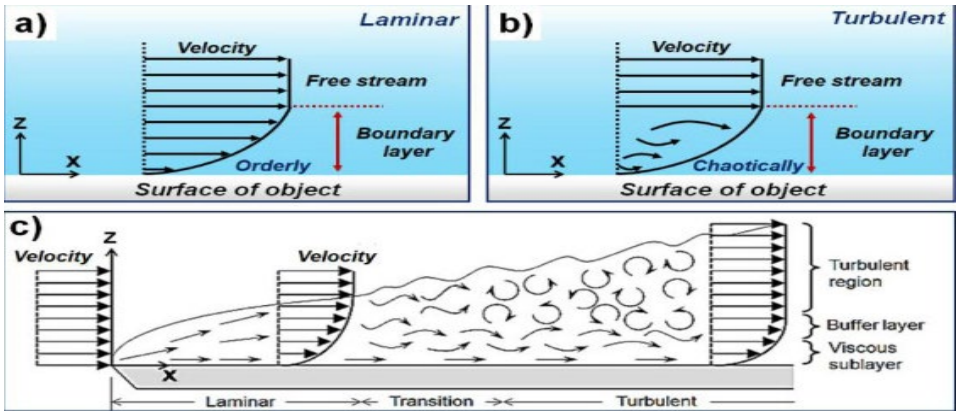

Figure 1. Fluid flow in boundary layer. a) Laminar flow. b) Turbulent flow. c) Transition between laminar and turbulent flow in fluid over a flat plate. (McGraw-Hill Education, 2016).

90% of the world's goods are transported by sea with over 70% as containerized cargo. Oceans are the main transport artery for all globaltrade, and sea transport is the backbone of international trade and the global economy. It's interesting to note that in the consumer goods industry all product travel fees are amortized into product costs which means that all shipping costs are passed directly onto the consumer. Average container ships carry between 1.5 - 2 million gallons of fuel and consume 63,000 gallons of fuel per day. This is a world-wide crisis that few people are paying attention to, yet our aquatic friends have had the solution to this for hundreds of millions of years. All species of fishes contain a coat of mucus which makes the surface of any fish slippery. This mucus has many benefits such as reducing drag, reducing water resistance, external protection, and many more advantages. The purpose of the mucus is to fill in the gaps between the borders of neighboring cells to make the fish's entire body a smooth and sleek surface for minimum drag. The mucus provides hydro-dynamic advantages by lessening the velocity from which the surrounding fluid hits the surface of the fish (Kebede & Winger, 2020). Fish scales provide a variety of purposes, including physical defense, the prevention of skin folding and most importantly, the flow changes across the body. A thin boundary layer andminimal turbulence are necessary to be hydrodynamic. Turbulent flow isa type of fluid flow in which the fluid fluctuates or mixes irregularly Contrary to laminar flow, in which the fluid moves in smooth paths. Aboundary layer is the layer of fluid in the immediate vicinity to a boundary surface.

This fascinating concept could be bio-mimetically applied to a multitude of engineering mysteries, questions, and experiments. Biomimetic is the creation of materials, synthetic systems, or machines with functionalities that mirror biological processes using principles from biology, engineering, or chemistry. Lauder et al., (2016) found that in swimming fishes, the interface between the fluid environment and the body surface is crucial for hydrodynamic activities. It has long been known that the mucus of a fish reduces drag and aids the increase in the fish's speed butjust how well does it work? Despite the possible groundbreaking outcomes, little has been paid to whether this be applied to anything man-made. This concept could be used in marine vehicles to further improve the speed and reduce drag of a ship. The goal of this proposed project is to use biomimetic to mimic fish mucus and apply it to a shiphull. From this it can be determined if mucus improve hydrodynamics of a ship by reducing the friction between the hull and the water to savefuel and reduce emissions while also increasing efficiency.

Methods

First, two of the exact same radio controlled ships that mimic the design of acontainer ship were used in this experiment. On one of the models, the hull of the ship was covered with a synthetic fish mucus. Synthetic fish mucus was made out of a combination of protein, lysosomes, and many other components that exactly matched

the composition of real fish mucus. The two radio control ships were to be tested individually in a rectangular water tank over a distance of 20 feet in sea water at room temperature. The rectangular tank had a decreasing depth across to introduce turbulence at different degrees as experience in real sea conditions. The qualitative data was a chart comparing the speeds of the 2 ships over the 20 foot distance.

Speed data (miles per hour) was recorded over 20 feet in a rectangular seawater tub.

Figure 2. Radio controlled boats were used for simulation

	Mucus Level 1cm	No Mucus
	4.4	4.8
	5.1	5.3
	3.9	4.2
4	4.1	4.4

5	4.3	4.7
6	4.0	4.5

Figure 3. Data table for cargo ship with mucus versus without

Analysis

There were two different outcomes of this experiment. In one the results observed was; the ship with the hull covered in a thin layer of fish mucus had a boundary layer that was thinner and caused less turbulent flow making it more hydrodynamic. The Results support the hypothesis by proving that fish mucus as a marine layer on a ship's hull would be more hydrodynamic and reduce drag, and can be applied to a man-made ship saving both money and time to travel plus energy expended into the atmosphere.

The second control ship with the hull with no protein layer at all travels slower than the mucus covered ship hull. These results shows that fish mucus is very effective in decreasing drag and improving hydrodynamics and could be adopted by scientists to solve some of the marine turbulence problems all other factors remaining constant.

Conclusion

The experiment showed that the mucus coating can reduce fluid friction.These coatings will mean that ships will require less power and energy when travelling long distances, which means that fuel energy will be saved. This could help reduce emissions of harmful Sulphur compounds and CO2 produced by the exhausts that power propellers.

Typically, long distance cargo ships lose propulsive power due to fluid friction, which is caused by the exposure of their large hulls to seawater.The biomimetic research using fish mucus simulated protein composition can reduce drag and improve flow just like it does for fish in the sea. Utilizing the calculations below, this could save either a day in transit using the same fuel and fish mucus. The cargo ship could now travel at a faster pace because of reduced drag and fuel expenditure and maintenance at the same time. This experiment proves the hypothesis right. Please note estimated cost savings below:

Fuel Costs:

225 tons of fuel/day @ 24 knots

7 days * 225 tons = 1575 tons/trip from China port to USA (CA port) * $150/ton or fuel=$236,250

Using my test results, the fish mucus saved 3.5 seconds over 20 feet which calculated from China to USA port (5,910 miles) would be:

5910 miles from China to USA port1 mile = 5280 feet

5910 miles * 5280 feet/mile = 31,204,800 feet

31,204,800 feet/20 feet = 1,560,240 (20 foot sections) * 3.5 seconds = 5,460,840 seconds saved

Divide by 60 for minutes = 1516 minutes faster/60 minutes/hour = 25.27 hours faster

The physics behind this technique will help save the planet by affecting how much fuel a cargo ship

needs. This could help slash emissions of harmful Sulphur compounds and CO2 produced during hull in the sea and thus prevent water pollution.

Work Cited

1. Brooks, H., Haines, G. E., Lin, M. C., & Sanderson, S. L. (2018).Physical modeling of vortical cross-step flow in the American paddlefish, Polyodon spathula. *Plos one*, *13*(3), e0193874.
2. Kebede, Gebremeskel & Winger, Paul. (2020). A comparison of hydrodynamic forces in knotted and knotless netting, using both helix and conventional ropes for midwater trawls. Aquaculture and Fisheries.6. 10.1016/j.aaf.2020.04.002.
3. Lauder, G. V., Wainwright, D. K., Domel, A. G., Weaver, J. C., Wen, L.,& Bertoldi, K. (2016). Structure, biomimetics, and fluid dynamics of fish skin surfaces. *Physical Review Fluids*, *1*(6), 060502.