Nature-Inspired Designs to Improve Vehicle Fuel Efficiency

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Automotive spoilers are critical for vehicle safety, reducing pressure drag and generating downward force to increase tire traction and stability. However, spoilers inherently create aerodynamic drag, reducing the vehicle's overall fuel efficiency. To address this fundamental trade-off, my project investigates whether nature-inspired surface texture applied to spoilers can optimize their downforce-to-drag ratio compared to traditional smooth spoiler designs. Biomimetic experimental spoilers and a smooth control spoiler were 3D modeled and printed alongside a standardized test vehicle. Aerodynamic performance was evaluated in a custom built and designed, open-loop wind tunnel utilizing a honeycomb flow straightener to ensure laminar airflow. Drag was measured using a single-point load cell, while downforce was measured using a digital scale. Real-time drag force data was captured via an Arduino microcontroller across five replicated trials per design at a constant wind speed. Simulations of flow fields around spoilers were conducted to generate further numerical optimizations. Two biomimetic designs demonstrated improved aerodynamic efficiency over the control. Notably, the shark skin-inspired microtexture achieved the highest performance, yielding a 12.4% improvement in aerodynamic efficiency. Biomimetic surface textures significantly enhance the aerodynamic efficiency of automotive spoilers compared to standard smooth profiles. If implemented in cars across the United States, the 12.4% efficiency improvement observed in the shark skin inspired model could save an estimated 4.9 billion gallons of fuel, offering substantial economic and environmental benefits.

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