From Curveballs to Global Shipping: The Impact of Surface Conditions on the Magnus Effect

Angiras, Vishnu (School: Shrewsbury High School)

Mishechkin, Misha (School: Tahanto Regional High School)

The Magnus effect is a phenomenon where a rotating sphere or cylinder generates a force perpendicular to the airflow. Smooth, vertical Magnus cylinders incorporated into cargo ships act like a sail to convert perpendicular crosswinds into thrust. Such applications have reduced net fuel consumption by 30%. Little research has investigated the impact of surface conditions, an important variable in fluid dynamics. We aimed to fill this research gap, hypothesizing that maximizing surface roughness and dimple density would yield the highest lift-to-drag ratio, a measure of efficiency. The setup consisted of a motor-driven spinning cylinder on a two-axis force detection system to measure downforce and drag in a wind tunnel. Surface roughness was altered by wrapping the cylinder in sandpaper and dimple density by using thin, 3D-printed, dimpled sheaths. Data was analyzed using a paired two-tailed t-test. For each variable, 3 trials were completed with each trial spanning 10 seconds, and collecting 100+ data points. Dimples did not show a significant increase in efficiency (SD 5%, $p=0.25$) while medium surface roughness (relative roughness of 0.048) increased efficiency by 120% compared to smooth (SD 3%, $p<0.03$). The benefits of surface roughness diminish at finer and coarser extremes. Utilizing our pre-established Reynold's number, we extrapolated our findings, projecting fuel savings of 55.8% for cargo ships that incorporate Magnus cylinders with appropriate roughness. Future work will focus on additional variables, such as raised dimples or a combination of dimples and roughness.