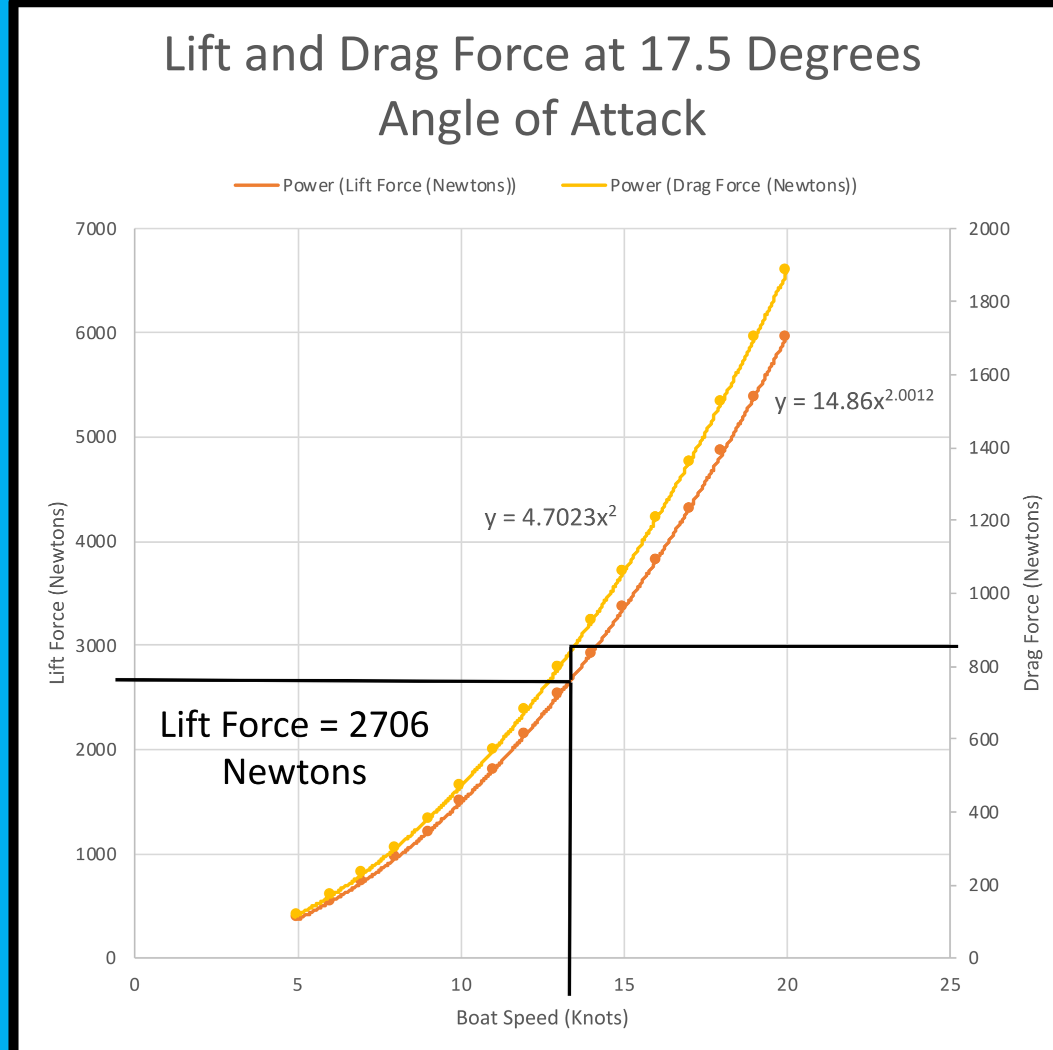
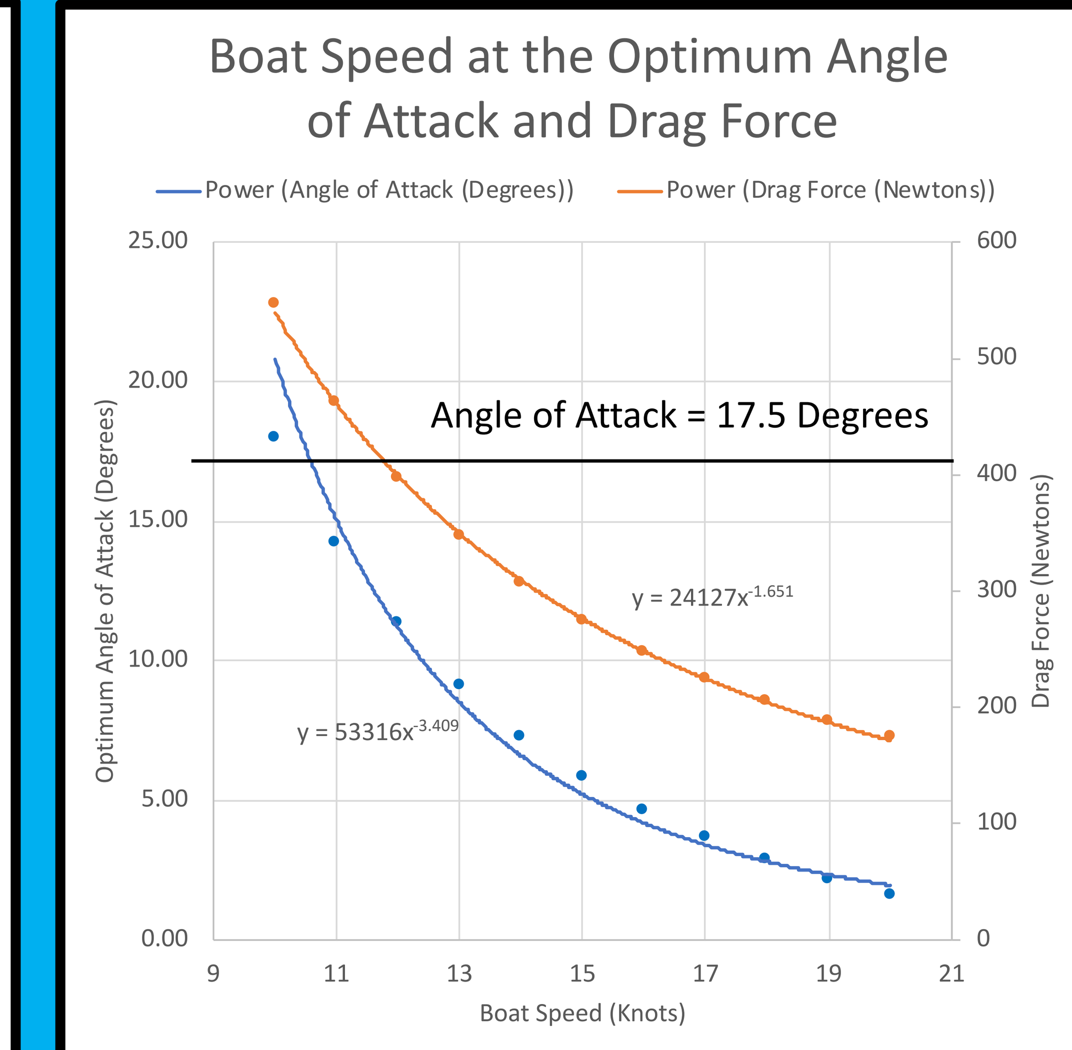
HOW IS THE PERFORMANCE OF A NACRA 17 HYDROFOIL AFFECTED BY THE SYSTEMATIC APPROACH

Introduction:

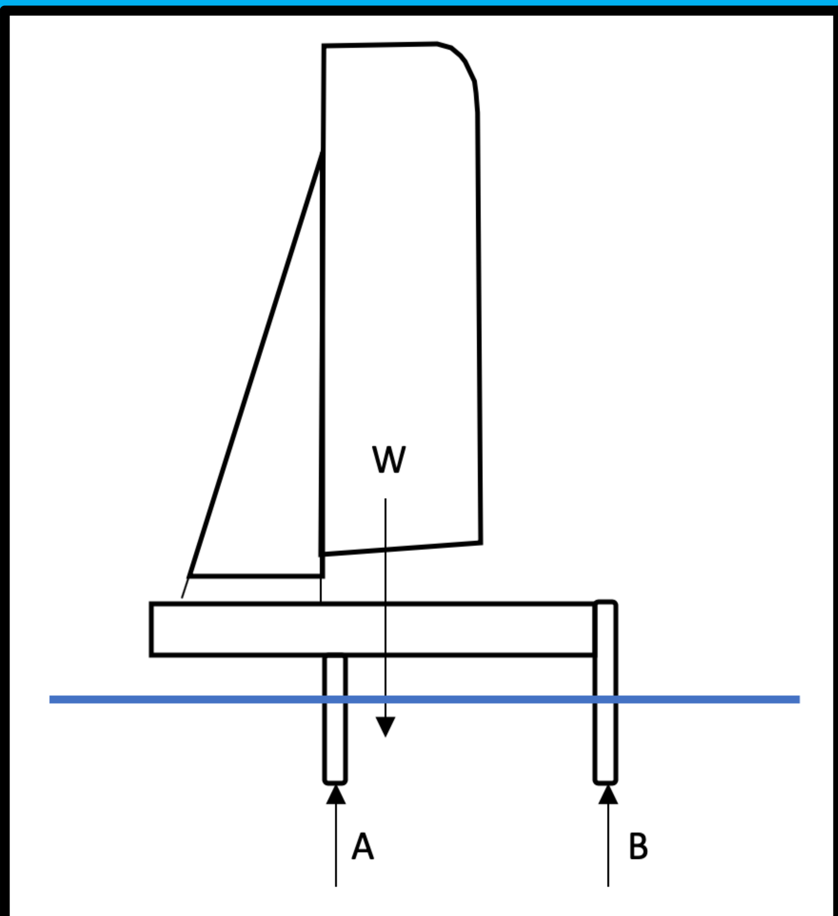
The NACRA 17, shown in the image to the right, is an Olympic class foiling catamaran designed for high speed competitive racing by some of sailing's top athletes across the world. The foiling aspect is supported by two c-shaped hydrofoils, with two further supporting rudders at the stern of each hull. The NACRA 17 is a relatively new design, with only a finite amount of knowledge in its foiling performance, leaving uncertainty in its optimum set-up in developing boat speed. The investigation aims to answer some of the undisclosed theories in developing hydrofoil performance, focusing in terms of generating greater boat speed through the hydrofoils for various wind speeds. The main assumption in the investigation stated by (Falkovich, 2018), is that when a fluid's flow is laminar, the drag is known to be proportional to the boat speed, thereby reducing drag the speed of the boat can be increased.

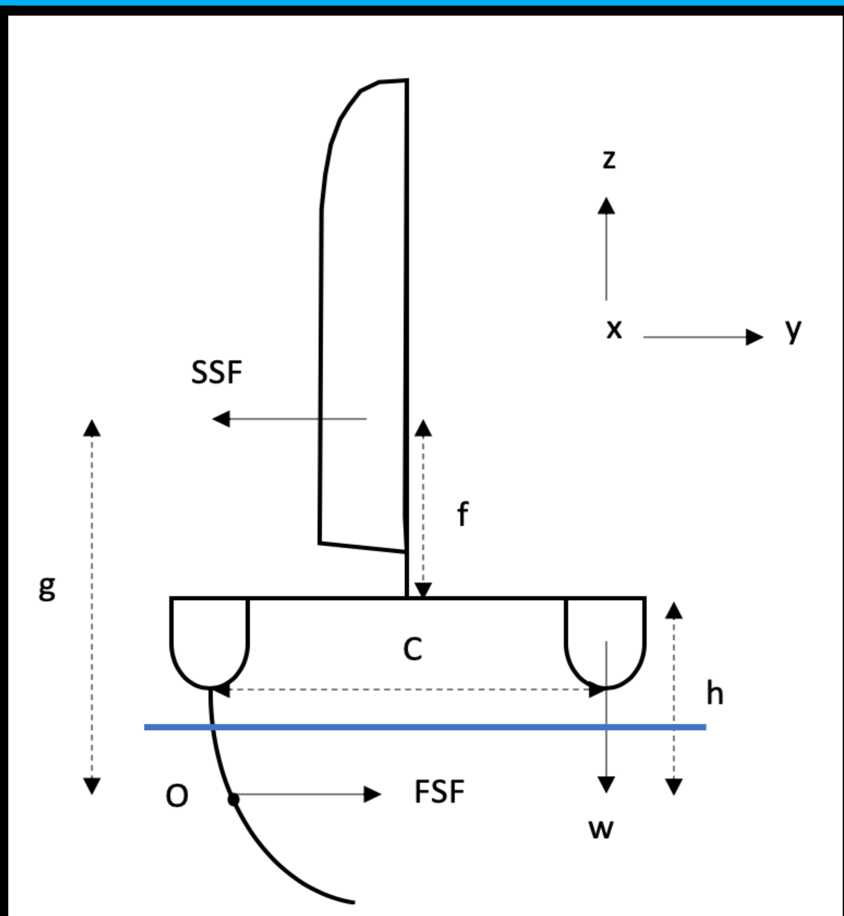




Theory and Methodology:

Developing boat speed is related to the drag component across the general wetted surface area of the hull and hydrofoils, although when considering the drag, other components such as lift also need to be considered. Technically speaking, the speed is considered insignificant if the lift force to raise the boat out of the water has not been met. Therefore, an evaluation of the forces present shown in the image below of the NACRA 17 equilibrium sailing state was conducted to give a required force of 2706 newtons to be produced by the hydrofoils in order to foil. With the requirements stated, the collection of data could proceed using Solidworks for construction of the NACRA 17 hydrofoil, for simulations to be completed in Computational Fluid Dynamics (CFD) using ANSYS CFX Fluid Flow. The analysis at this stage was completed in a 2D format, and then later the calculated 2D coefficients were taken and converted into 3D coefficients.





Lift Force:

The graph of the lift and drag forces at 17.5 degrees angle of attack helps show the results from the simulations and calculations; as the angle of attack increased, so did the lift force that was produced. This statement was valid up to an angle of 17.5 degrees angle of attack, with this reading showing the maximum lift force as well as the point of stall along the flow of the hydrofoil. As previously identified in the theoretical analysis, the ideal value of lift was approximately 2706 newtons, indicating that lift forces below this value could be considered invalid. The ideal force could be assumed to be 2706 newtons, as having an excess amount of lift can only produce a larger value of drag in conjunction with the extra unnecessary lift force, and thereby reducing boat speed. The lift generated upon the 2D geometry was significantly larger than the 3D geometry, as the calculations use a coefficient of lift to produce a force. The coefficient of lift is related to the amount of lift produced by the planform area, where both hydrofoils produced their relative lift. Although the 2D hydrofoil is smaller, it produced a larger amount of lift for its planform area than the 3D hydrofoil. Therefore, the actual amount of lift is smaller on the 3D hydrofoil.

Drag Force:

As previously stated by (Falkovich, 2018), lowering the drag force would result in an increase in boat speed. Therefore, the aim was for each wind speed to find the angle of attack that generated the lowest drag force, whilst also meeting the required 2706 newtons of lift. For this investigation, it showed that the 3D hydrofoil drag force was significantly larger than the 2D hydrofoil drag force. Like the lift force analysis, the reasoning behind these trends can be found within the calculations and the same graph as the lift force above. Generally, fully scaled 3D hydrofoils experienced multiple types of drag, with one of them being induced drag, which is caused by rectangular cross-sectional profiles at the edge of the hydrofoil. These designs produce tip vortices, and generate extra drag, something that the 2D hydrofoil cannot experience. Although in this investigation there is no way of reducing the level of recorded drag, designers can future develop hydrofoils to produce an edge and tip of a more elliptical form. The lines on the graphs above indicate the method of data extraction for each value.

Summary:

Using the graph of boat speed at the optimum angle of attack and drag force to summarise, the results show that as the boat speed is increased, the force of the drag is reduced, whilst also simultaneously reducing the angle of attack. This statement can only be considered valid for an angle of attack up to 17.5 degrees, as beyond this value the lift decreases due to the stall of the flow over the hydrofoil. Theoretically, the setting that will produce the greatest boat speed is an angle of attack of 1.58 degrees at 20 knots, because the value of drag produced is approximately 180 newtons and is known to be the smallest force across the hydrofoil and would therefore generate the greatest speed. It could also be deduced that the areas of the graph with the steepest points of the curves indicate that the ability to foil is far less likely, due to the drag force that the hydrofoil experiences, indicating a smaller achievable boat speed.

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