Model Aircraft Angle of Attack Sensor

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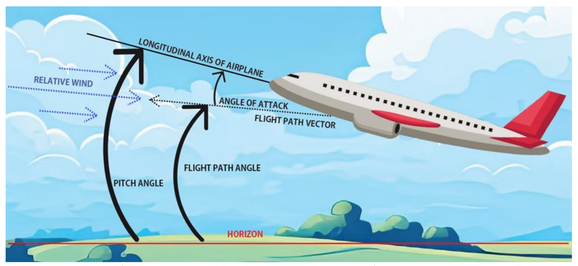
Abstract

This project focuses on designing a compact, lightweight, and affordable angle of attack sensor for model aircraft, thus providing real-time data to users. This sensor will be placed on the aircraft's leading edge, with easy installation and compatibility with standard controllers. The research explores various methods for determining the angle of attack, selecting the best system for integration into a small, cost-effective device. The sensor is not yet available in the market and is expected to appeal to aero-modelists, due to it enhancing flight dynamics in their models. Additionally, the project could have military applications as the demand for drones and small aircraft grows. By achieving a simple design with accurate data collection, the prototype is expected to significantly improve flight control without affecting aircraft performance. The sensor's marketability stems from its practicality, affordability, and potential use in both hobbyist and defense sectors.

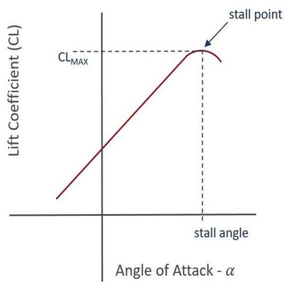
Introduction

Research will focus on studying various methods and systems of determining the angle of attack of an airplane and selecting the best one to employ in a compact invention for model aircraft. This sensor is something that is not available on the current market and could be something that many aero-modelists would want to purchase to include on their airplane.

Background



The angle of attack (AOA) is the angle formed by the relative wind direction and the aircraft's wing chord line and/or the longitudinal axis of the airplane [1]. The AoA is employed to assess aircraft stability and performance, which aids in identifying the aircraft's limits. Conventional aircraft use AoA instrumentation to assess flying safety. In big, heavy aircraft that often travel at a high speed, these devices aid in preventing stalling. Stalling occurs when the angle of attack of an airfoil exceeds the value which creates maximum lift [2]. There is a greater lift force when the AOA increases because of the increased coefficient of lift. At the critical angle of attack (stall point), the lift coefficient reaches its maximum and then starts to fall. Above the critical AOA, the approaching flow totally separates from the wing's surface which in turn causes a dramatic drop in lift, also known as the stall AOA.

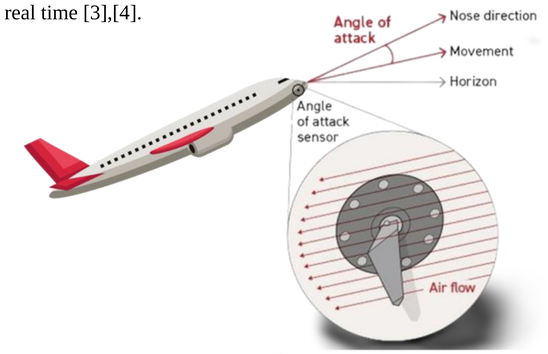


Problem

Model aviation has been lacking the option of knowing their angle of attack while flying or post flight. In this project we will solve this problem by designing a prototype of an angle of attack sensor with accurate reading precision which will be very simple to install on a model airplane and will not affect the aircraft's performance.

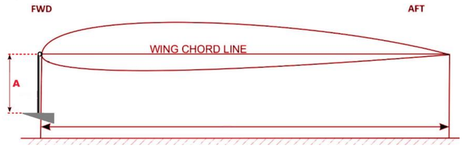
Methodology

Alpha vane transducer AOA indicators are the most used by commercial airplanes. These vanes are fixed to the aircraft and are free to rotate in response to the direction in which the wind strikes the aircraft (and therefore, the vane). Based on how the wind is pushing it, the vane measures the angle of attack precisely and in real time [3],[4].



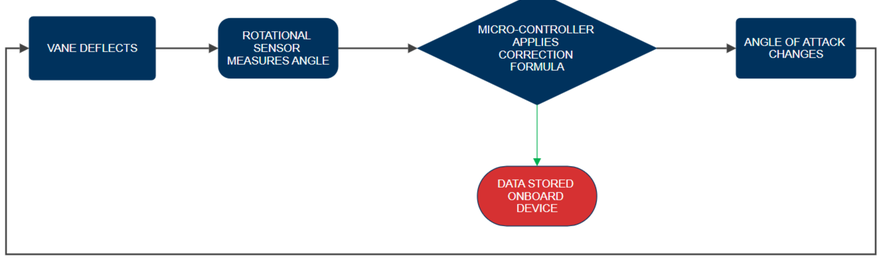
Sensor Placement:

- Firstly, it must not be in the slip stream of the propeller; this means that it should not be close to the fuselage but further out on the wing. As rule of thumb, it will have to be at least a spanwise distance of 1.5 the radius of the propeller.
- Secondly, it must be placed sufficiently forward into the free stream as to avoid being influenced by the air that's being separated by the airfoil. This Distance "A" will be given by CFD program validation.



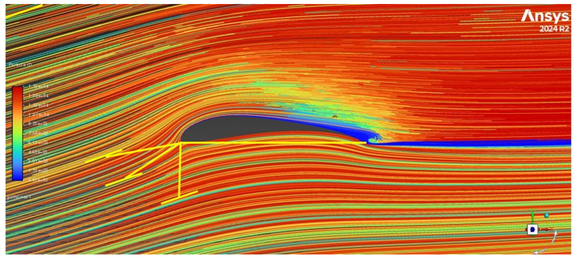
- Thirdly is balancing. Making sure the placement of the sensor does not significantly affect the weight balance or aerodynamics of the aircraft. The materials used will have to be the lightest possible and be as aerodynamically neutral as possible to avoid interference with the aircraft's performance.

WORKFLOW:



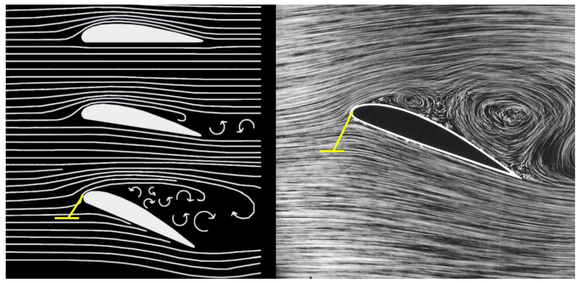
Results and Discussion

After several tests in CFD it is determined that for this airplane the vane's optimum location will be at the mean aerodynamic chord 44.875 inches spanwise. The mean aerodynamic chord (MAC) is the average chord length of a wing. Since most wings are tapered or have varying shapes and chord lengths along their span, the MAC provides a single value that represents the aerodynamic center of the wing as if the entire lift was generated by a constant-chord wing. This places the sensor just outside the interference with the propeller's slip stream and minimizes how far outward the sensor is placed since the sensor's weight will cause a lever effect in terms of longitudinal balance.



In the above image we can see the ANSYS rendering image, using the Aero Design's wing with the S-1223 airfoil. The complete wing was rendered and evaluated placing the sensor at different locations. We can clearly see that the free stream is not disturbed in all three positions.

The vane position was determined to be optimal coming out of the leading edge and normal to the wing chord in the downward direction half a chord's distance. Consequently, the distance "A" will be equal to half the chord's length, the chord length used will be that of the mean aerodynamic center.



$$A = \frac{chord}{2}$$

Conclusions

The successful completion of the angle of attack (AoA) sensor design marks a significant achievement in accurately measuring a model aircraft's AoA. By placing a vane at half chords length below the wing and running CFD simulations in Ansys, we were be able to accurately estimate the (free-stream) real angle of attack, avoiding the disturbances caused by the proximity to the airfoil. The selected AMS AS5600 magnetic rotary encoder, with its 12-bit high resolution angular measurement, combined with the Arduino Nano 33 BLE microcontroller will keep the system lightweight, power-efficient and provide reliable and precise angle of attack data throughout flight tests [5].

AMS AS5600

Arduino Nano 33 BLE

This system demonstrated its effectiveness in real-time applications, with outputs stored on a local SD card and transmitted wirelessly to a ground station. The data logging feature will enable detailed post-flight analysis, validating the system's performance in various flight conditions. The lightweight and aerodynamically designed housing will minimize interference with the aircraft's performance, proving that the sensor is practical for use on small-scale model aircraft without compromising their flight characteristics.

Future Work

The project offers a valuable tool for aerodynamic testing and performance optimization, particularly in the realm of model aircraft and other small UAVs. It provides a foundation for further improvements, such as enhanced data processing, integration with other flight systems, or adaptation to larger aircraft. Overall, the successful implementation of the AoA sensor opens new possibilities for flight analysis and real-time feedback, ensuring more accurate control and optimization in future aerospace applications.

Acknowledgements

I would like to express my deepest gratitude to Prof. Pertierra, who has been a great mentor and has always gone beyond the extra mile to teach and help his students. His vast knowledge and expertise in the field of aerospace engineering have provided me with invaluable insights and guidance since my bachelor's.

I also want to extend my heartfelt thanks to my mother Laura Ramos, her endless love and encouragement have made it possible for me to reach this milestone. Thank you for always being there and supporting me.

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