CFD- Based Method for Validation of DATCOM and Potential Flow Stability and Control Derivatives

Author: Willie Concepcion Morales | Advisor: Jose R. Pertierra

Polytechnic University of Puerto Rico | Mechanical Engineering Department

Abstract

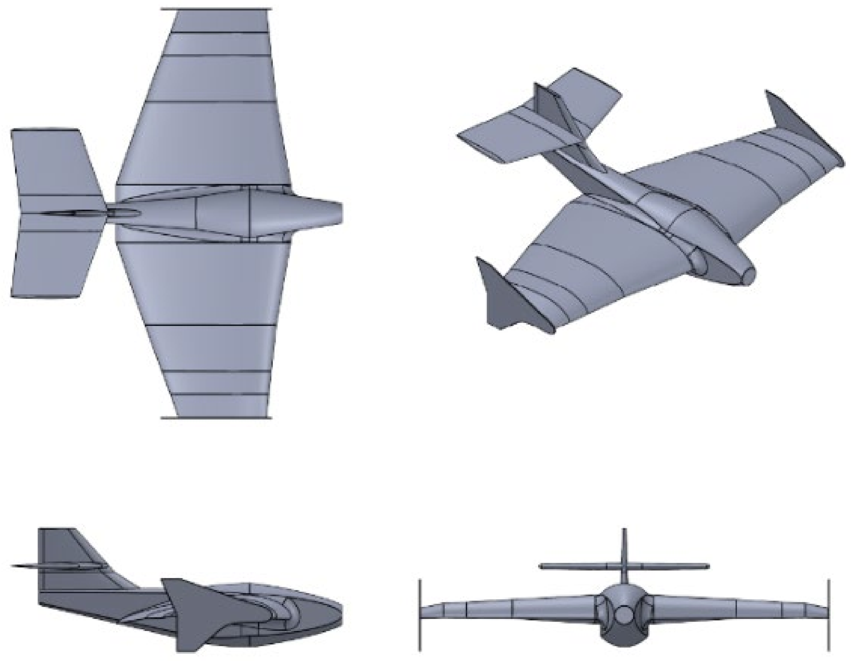
DATCOM was use traditionally as the method to determine the aircraft downwash, and longitudinal stability and control derivatives for small unmanned air vehicles conceptual design at the Polytechnic University of Puerto Rico. Computational fluid dynamic can be used to validate the DATCOM and the new downwash gradient method of Dr. Mondhler for low aspect ratios and low Reynolds number unnamed air vehicles. The results showed that the DATCOM empiric downwash law produces significant errors in longitudinal stability, while the downwash method of Dr. Mondhler predicts well the downwash behaviour. A code in MATLAB was developed to compare the longitudinal stability, and generate an in-house code that accurately represent the computational fluids dynamics predictions for the conceptual design process of small unmanned air vehicles.

Introduction

Low Reynold's number and low aspect ratio unmanned air vehicles (UAV) complex aerodynamics makes downwash gradient difficult to predict based on full-scale aircraft methods. There is a challenge where in comes to design small unmanned air vehicles since the viscous effect its a dominant factor in drag, tail size, and therefore handling qualities. The current methods of UAV design are based on empiric data of full-scale aircraft which can results in more errors. A computational fluids dynamics (CFD) based method is ideal to better predict the downwash and handling qualities of an UAV during the conceptual design process. As part of the validation process a low aspect ratio UAV was design to develop a package of codes in MATLAB from empiric data to better predict aircraft stability during the conceptual design process, validate aerodynamics, downwash, and stability and control derivatives using ANSYS FLUENT 2021 R2. By developing an in-house code, the iteration time during conceptual design is decreased substantially, while increasing fidelity in the stability and handling qualities during this phase.

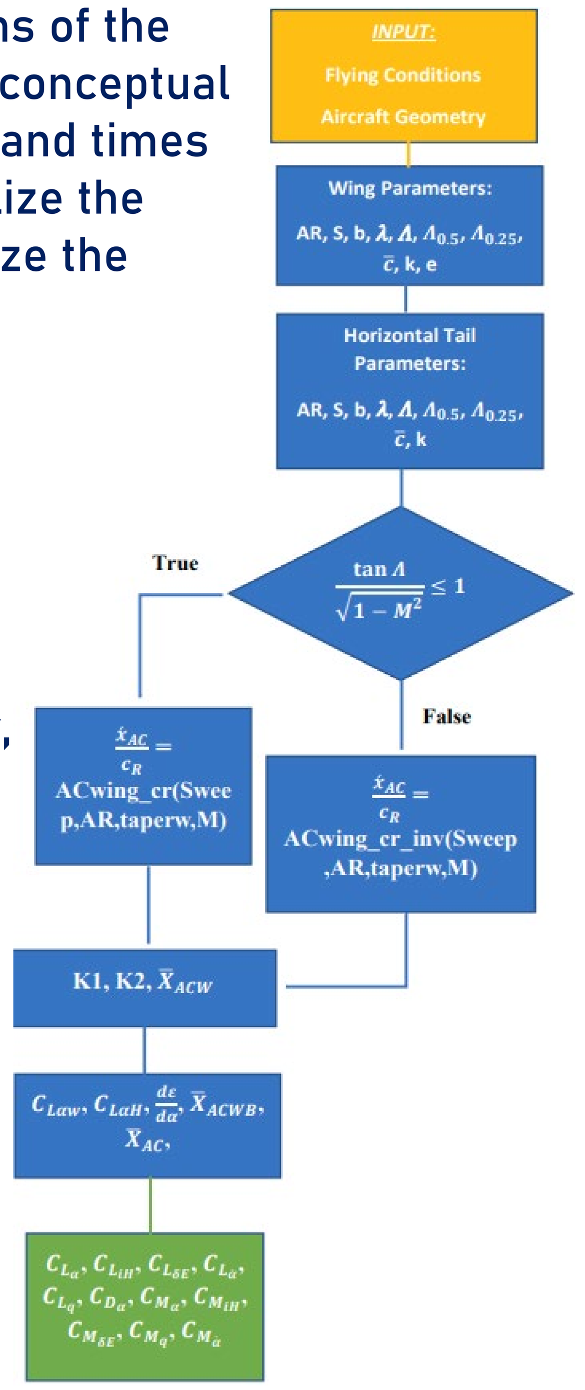
Aircraft Configuration

The unmanned air vehicle was designed based on the SAE Aero Design 2022 Regular Class competition requirements. The airplane has an aspect ratio of 2.99, and a flying Reynolds number of 600,000 using the airfoil S1223 for its high lift capacity at low Reynold's number.

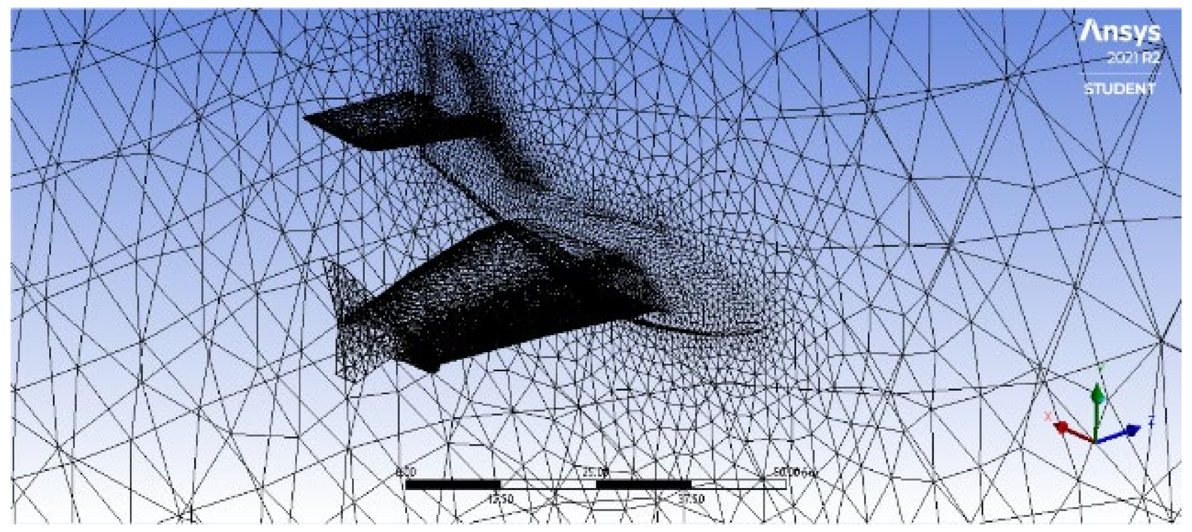


Methodology

A MATLAB code was created to facilitate the calculations of the longitudinal stability and control derivatives during the conceptual design. To mitigate wrongly reading charts coefficients and times loss during interpolation, a program was used to digitalize the charts and convert them as MATLAB function to automize the aircraft configuration process.

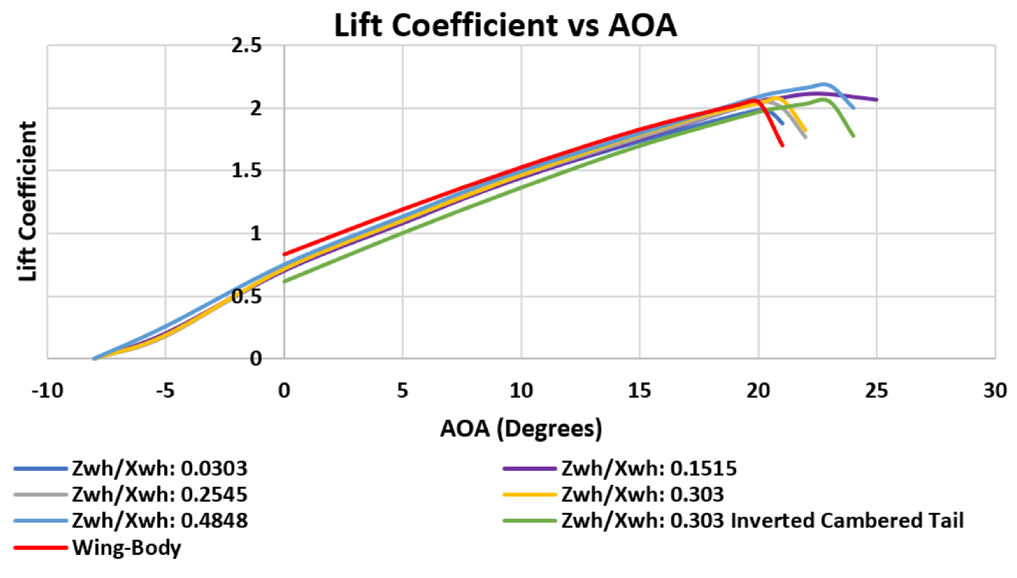


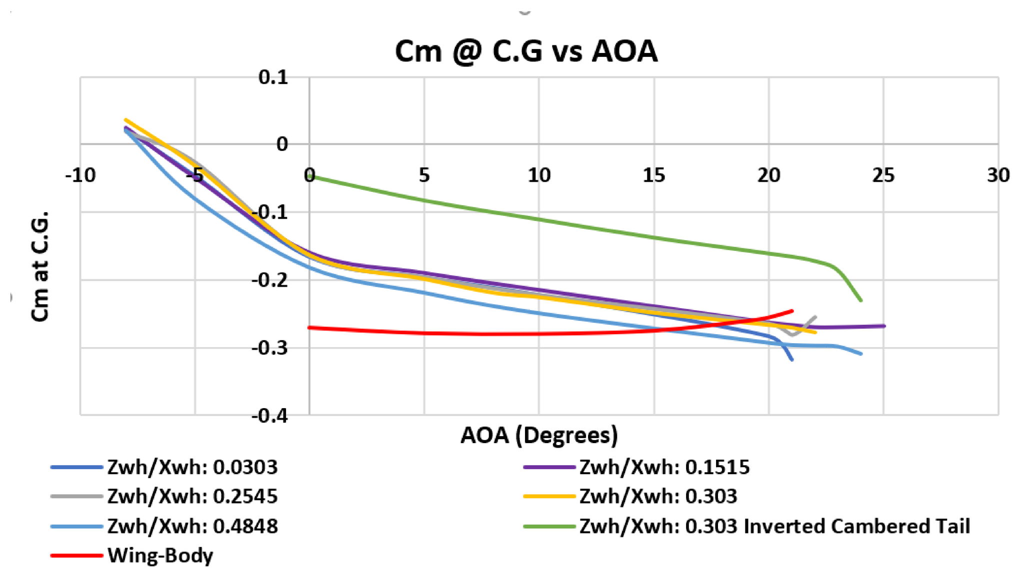
To evaluate the external aerodynamics of the aircraft ANSYS FLUENT was used as the CFD method to validate the downwash and the longitudinal stability derivatives. FLUENT has been a proven method is the past at the Polytechnic University of Puerto Rico to determine the aerodynamics of small Reynolds number, when wind tunnel testing is not available. The mesh grids were refined by dividing the airplane in section increasing the number of elements at the leading edge, trailing edge, and wing-body connection surface



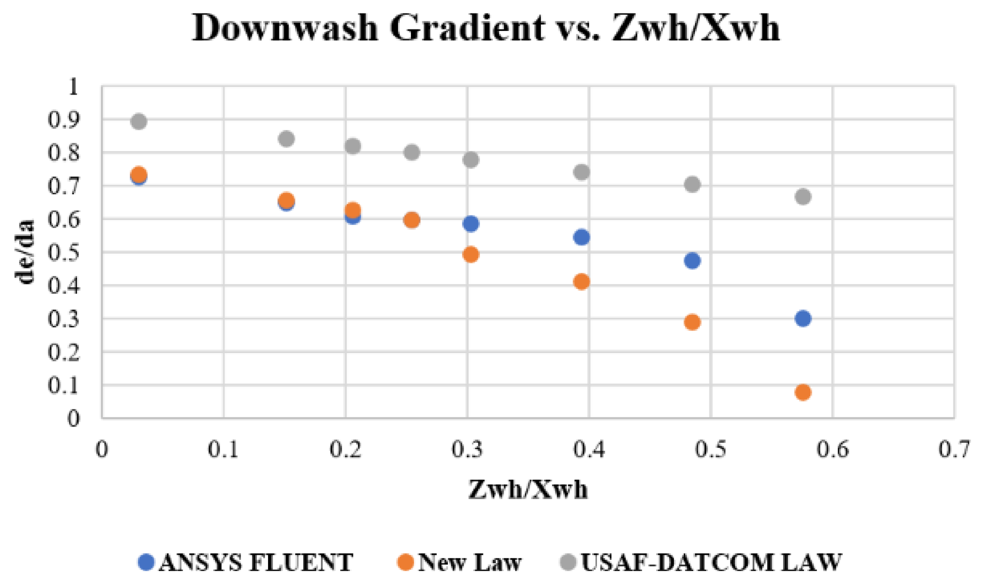
Results

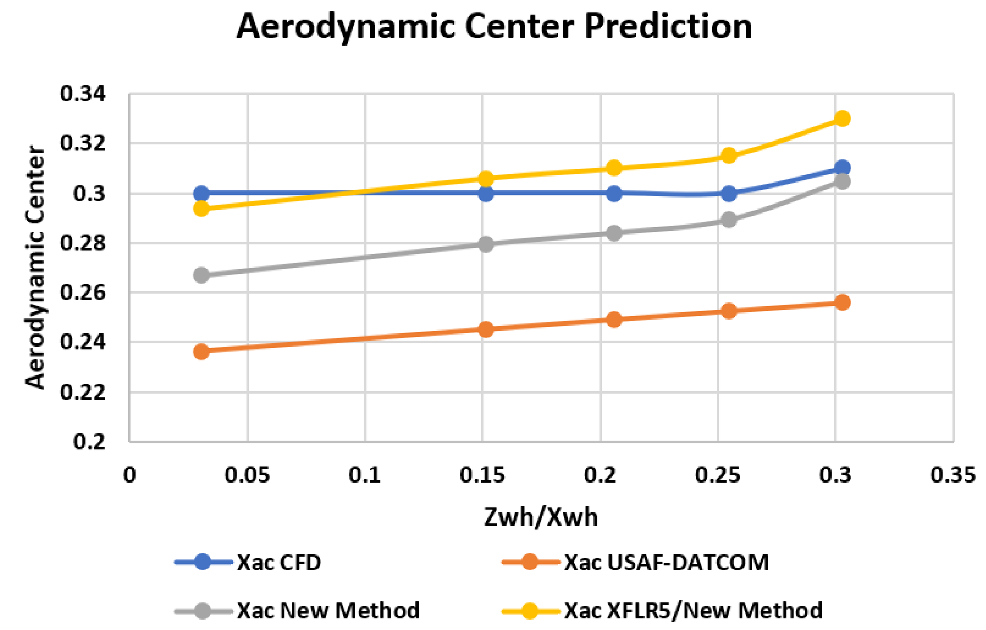
Due to the high lift capacity of the airfoil, there is a significant amount of nose down pitching moment. A special case was run using a NACA 6412 inverted cambered airfoil at the tail to investigate how efficient is this configuration to reduce the nose down pitching moment. This configuration reduces the Cm0 from -0.16 to -0.04. The aerodynamic center prediction comparison shows that the USAF-DATCOM predicts the AC by a minimum 17.2% and maximum 23.76% of difference with respect of the CFD method.





The new method of downwash predicts the AC by a minimum and maximum difference of 1.26% and 11.7% respectively. A special case combining XFRL5 and new downwash law method, to calculate the AC and longitudinal stability. This hybrid method and shows an AC difference between 1.98% and 6.25%.





Conclusion

Four methods (CFD, DATCOM, Dr. Mondhler downwash, and XFLR5 hybrid) were used to determine the aircraft aerodynamic center and longitudinal stability derivatives of a low aspect ration aircraft flying in low Reynolds number, based on the Aero Design 2022 competition requirements. Dr. Mondhler dowwash method successfully predicts the downwash gradient, with a maximum difference of 3.5% for "m" between 0 to 0.2.

The aircraft aerodynamic center is best to use the XFLR5 hybrid method with a maximum of 5% difference overpredicting stability when the Zwh/Xwh is larger than 0.3. The new method of downwash produces an average 10% of difference underpredicting stability, conservatism can be applied by running both methods and stay between their predictions.

Future Work

Further work can be done by implementing the propwash in the computational fluid dynamics method to determine how the downwash and tail effectiveness is affected, and the best configuration for the airfoil S1223 to reduce the nose down pitching moment.

Acknowledgements

Special thanks to my mentor, Jose R. Pertierra for his dedication to the Aerospace program and this project.