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Optimizing Aerodynamic Performance of RC Aircrafts And UAVs Through Modified Airfoil Design and Analysis

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Abstract

Unmanned Aerial Vehicles (UAVs) are becoming increasingly popular due to their ease of use, maneuverability, and access due to otherwise inaccessible areas. Their performance and stability are dependent upon the airfoil used which is dependent upon the goal of the UAV. Thus, the selection of an airfoil is an important process involved in the design of a UAV. Through this project what we aim to do is to create our own airfall compare and contrast with the airfoil(s1223) already being used and design it such that it is better than the already pre-existing ones by XFLR5 software. There will be a detailed compare/contrast between the currently used airfoil (s1223) and the modified airfoil.

Introduction

The growing interest in research of Unmanned Aerial Vehicles (UAVs) and Remote Control (RC) planes has sparked a need for advancements in their design. These aircraft are now being equipped with increased payloads, allowing them to carry heavier loads. Additionally, there is a demand for shortened take-off and landing distances, as well as lower stall speeds. To meet these requirements, the development of new airfoils with high lift and improved performance in low Reynold's number conditions is crucial. Not only are various military forces exploring the potential of UAVs, but private companies are also investing in their design. These companies aim to create UAVs capable of performing reconnaissance missions, rescue operations, and even firefighting applications. As a result, the importance of optimized and high-performing airfoils has become paramount in modern Aeronautical Engineering. Having an airfoil that is both optimized and high-performing offers numerous benefits. Firstly, it enhances the aircraft's maneuverability, allowing it to execute precise movements and navigate through challenging terrains. Moreover, it contributes to stability during flight, ensuring a smooth and controlled operation. These factors combined make the development of

advanced airfoils a crucial aspect of aeronautical engineering in the present era. The results obtained from the ongoing research in this field will have significant implications for aircraft, particularly UAVs and RC planes. The findings will enable the creation of more efficient and capable aircraft that can perform a wide range of missions. Furthermore, the outcomes will serve as a foundation for further advancements and innovation in this ever-evolving field.

Literature Review

Performing a study on pressure coefficients and lift generation in airfoils has shown that the upper surface has a lower negative coefficient of pressure at higher angles of attack and the lower surface has a lower negative coefficient of pressure at lower angles of attack. The difference in pressures between the lower surface of the airfoil and the incoming flow stream is significant to push the airfoil upward, normal to flow direction. [Sagat et al. (2012)]. A comparative study between existing high-lift airfoils by Reza et al. (2016) showed the best airfoils currently in use. These were; Selig 1223, Eppler 420, Eppler 423, Wortmann FX, and CH-10. This study also gave the max coefficient of lift, moment, stall angle, and coefficient of drag values. Karna et al. (2014) have reported their studies on NACA airfoils at different angles of attack and given the CFD analysis results with airflow and pressure contours. These indicate that the nose of the airfoil plays an important role in separating the airflow and that increment in the angle of attack results in an increase in lift as well as drag before stall. Benavent et al. (2013), in their studies, have given comparative studies between different NACA airfoils with different wing loading, speeds, length attributes, angles of attack, wing twist, and dihedral angles. This gives the optimum angles of attack with corresponding lift for different modes of flight like cruise, glide, land, take-off, etc.

Methodology

The pressure drop across the airfoil is based on fundamental fluid mechanics phenomena such as Bernoulli's principle and Newton's law of viscosity. The pressure gradient is explained by the difference in both static and dynamic pressures of the upper and lower airstreams due to the curved nature of the airfoil. This can be explained mathematically using Bernoulli's equation:

$$\frac{P_1}{\rho} + \frac{v_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{v_2^2}{2} + gz_2 \quad \text{... (1)}$$

The pressures P1, P2 are the static pressures of the airstreams above and below the airfoil respectively. The second terms of the equation with half the velocity squared indicate the dynamic pressure of the respective airstreams. The final terms indicate the pressure due to the gravitational head and it is affected by the difference in datum lines. The total pressure of a fluid is known as the sum of its static pressure, dynamic pressure and the pressure due to the gravitational head.

$$Ptotal = Pdynamic + Pstatic + Pgravitational \quad \text{… (2)}$$

This total pressure is constant across all airstreams in a closed system. Considering the area around the airfoil and the airstreams surrounding the airfoil as a closed system, the total pressure of the airstreams above and below can be estimated to be equal. The velocities of the airstreams are known as the velocity of the airfoil determines the airstream velocity. Using this data, the static pressure of the airstream at a point can be calculated by the data obtained from the dynamic and gravitational components of pressure. The difference in this pressure is drawn in a graph and can be used to explain the lifting and drag characteristics of an airfoil. For the selected airfoils, the freestream velocity, Reynold's number, density, and aspect ratio were given as the input parameters to the XFLR5 software. For the given input, the coefficient of lift has been found out with respect to the angle of attack. The coefficient of lift is an essential parameter for the effective performance of the flight.

Results And Discussion

The analysis and design process are then performed using a free software called XFLR5. The Reynold's number is entered and also the angle of attack at which the aircraft is estimated to be flown is also entered. Then the following important graphs are obtained

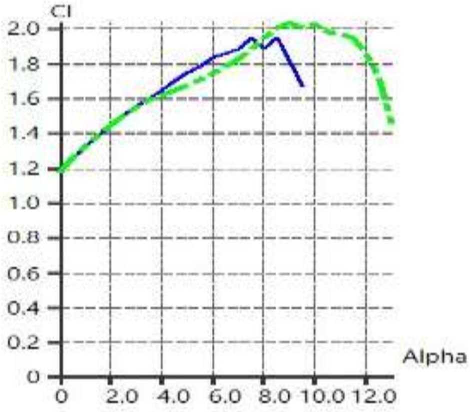

Fig.1. Cl vs Alpha (S1223 vs modified Airfoil)

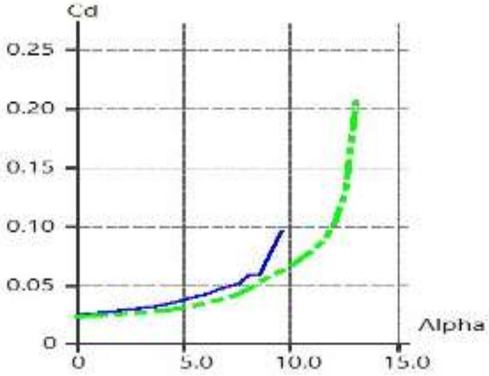

Fig.2. Cd vs Alpha (S1223 vs modified Airfoil)

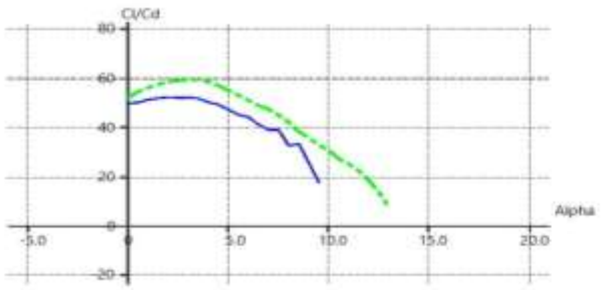

Fig.3. Cl/Cd vs Alpha (S1223 vs modified Airfoil)

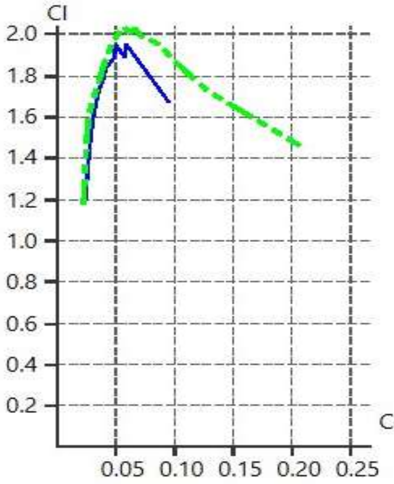

Fig.4. Cl/Cd (s1223 vs modified Airfoil)

The coefficient of lift and drag are the two most commonly used parameters in the design of an aircraft. The ratio of the coefficient of lift to the coefficient of drag gives the aerodynamic efficiency. The greater the aerodynamic efficiency, the greater the performance of the aircraft. The maximum angle of attack the aircraft can reach safely without stalling is given by the Cl Vs Alpha curve. The drop in the curve of the Cl Vs Alpha curve denotes stalling. The maximum angle of attack at which the aircraft is to be flown is given by the Cl/Cd vs Alpha curve. The coefficient of drag can be calculated from the Cl Vs Cd graph shown for the given conditions. The stability of an aircraft can be partially determined from the shown graphs. The pitching moment coefficient has to be negative and be decreasing with increase in angle of attack. This cannot be completely determined as the airfoil is a two-dimensional object with no thickness and a wing has very different pitching moment characteristics than its airfoil based on the wingspan. The drag and lift forces exerted by the fluid medium on the object can be determined. From the Cl vs alpha curve of the S1223 airfoil the maximum coefficient of lift at the stalling angle of 9°. The coefficient of lift of the modified airfoil at the stalling angle of about 15°. This gives the best lift performance for the specified input parameters. The results were compared for two airfoils and the characteristics of the modified airfoil which matched the purpose of the UAV was selected. The design goal was to create an UAV that could carry a high payload at subsonic speeds at low angles of attack. The higher coefficient of lift at low angles of attack and low Reynold’s number is required for an UAV which carries a heavy payload.

Conclusion

The obvious conclusion that can be drawn is that by changing the airfoil shape i.e., by increasing the crown area on the front and making its ends more curved and thinning its ends you get better results and that of the airfoils Selig 1223 is the best when modified and it will be the sole focus core of our project. XFLR5 analysis done on the SELIG modified proves that thinned and curved airfoils were better and give better lift and lower drag the ends of the modified airfoil are lower than (0,0) and it gives a higher lift and good drag and higher stall angle. The potential for future work can be said to include U.A.V and R.C aircraft which when made will use this airfoil as their working airfoil and will find that their performance has increased and the efficiency has also increased.

References

1. Ankan Dash, CFD Analysis of Wind Turbine Airfoil at Various Angles of Attack IOSR Journal of Mechanical and Civil Engineering Volume 13, Issue 4 version II.
2. Bragg, M. B. and Lu, B., 2000. Experimental Investigation of Airfoil Drag Measurement with Simulated Leading-Edge Ice Using the Wake Survey Method, AIAA Paper2000-3919.
3. Chandrakant Sagat, Pravin Mane and B S Gawali, October 2012. Experimental and CFD Analysis of Airfoil at Low Reynolds Number IJMERR, Vol. 1, No. 3.
4. Guglielmo, J. J., July–August 1996. Spanwise Variations in Profile Drag International Journal of Progressive Research in Science and Engineering Volume-1, Issue- 2020 www.ijprse.com 10 for Airfoils at Low Reynolds Numbers, Journal of Aircraft, Vol 33, No. 4, pp. 699–707.
5. Lin, J. C. M. and Pauley, L. L., Low-Reynolds Number Separation on an Airfoil, AIAA Journal, Vol.
6. Jan Roshkam, C. T. Lan, 2003. Airplane Aerodynamics and Performance Third Edition.

7. J. Morgado, R. Vizinho and M.A.R. Silvestre, March 2016. XFOIL and CFD performance Prediction for high lift row Reynolds number airfoils.
8. Karna S. Patel et al., March 2014. CFD Analysis of Airfoil International Journal of Engineering Research, Vol. 3 Issue 3.
9. McCormick, B. W., 1995. Aerodynamics, Aeronautics, and Flight Mechanics, 2nd ed., John Wiley & Sons, New York.
10. McGhee, R. J., Walker, B. S., and Millard, B. F., October 1988. Experimental Results for the Eppler 387Airfoil at Low Reynolds Numbers in the Langley Low-Turbulence Pressure Tunnel, NASA TM-4062.
11. Lin, J. C. M., and Pauley, L. L., “Low-Reynolds-Number Separation on an Airfoil,” AIAA Journal, Vol. 34, No. 8, 1996,
12. Md. E. A. PaponKh, MDFaisal, A.M.Nafi, April 2014.Performance analysis of aerofoil for unmanned aerial vehicles. MD. Safayet Hossain et al. A Comparative Flow Analysis of NACA 6409 and NACA 4412 Aerofoil International Journal of Research in Engineering and Technology.Mirza Md Symon Reza, Samsul Arfin Mahmood, Asif Iqbal, December 2016.
13. Performance Analysis and comparison of High Lift Airfoil for Low-Speed Unmanned Aerial Vehicle International Conference on Mechanical, Industrial and Energy Engineering.
14. J. Morgado, R. Vizinho and M.A.R. Silvestre, March 2016. XFOIL and CFD performance prediction for high lift row Reynolds number airfoils.
15. Selig, M. S., Lyon, C. A., Gigu`ere, P., Ninham, C. N., and Guglielmo, J. J, Summary of Low-Speed Airfoil Data, Vol. 2, SoarTech Publications, Virginia Beach, Virginia. 1996.
16. Chao, H., Cao, Y., Chen, Y: Autopilots for small unmanned aerial vehicles: a survey. Int.
17. J. Control, Autom. Syst. 8(1), 36–44 (2010)
18. Lin, J. C. M., and Pauley, L. L., “Low-Reynolds-Number Separation on an Airfoil,” AIAA Journal, Vol. 34, No. 8, 1996