Study and Comparison Analysis of Conventional Light Weight UAV Airfoils using XFLR Analysis

Inamul Hasan M[1], Ramanan G[2] & Manishankar V[3]
[1] Assistant Professor, [2]Associate Professor, Department of Aeronautical Engineering
ACS College of Engineering, Bangalore
[3]Assistant Professor, KCG College of Technology, Chennai
DOI: *https://doi.org/10.34293/acsjse.v2i1.22*

Abstract - *In Aeronautical industries one of the very important issues in smart UAV is the duration of flight since the overall time uses standard power that may be an unusable product, includes a restricted life, and is cost. But, there's an enormous demand for exploitation, a limitless non-exhaustible supply of power. So an alternative source of power calculation is required to get efficient flying conditions for a UAV. This work is to study and analysis of solar energy UAV airfoil using XFLR analysis. A UAV with 2.98Kg of weight is studied for power calculation, implementation of solar cells, and design aspects, including airfoil, fuselage, and tail section. From analysis it is found that UAV flight performance at solar radiation intensities above 451.23 W/m2 for power system which worked to increase the battery life and works more efficiently at solar radiation intensities above 666.5 W/m2.*

Keywords: *UAVs; Airfoil; Solar energy; XFLR Analysi; Lift and drag coefficient*

1 INTRODUCTION

Over the years, UAVs are developed into the extremely subtle machines in use nowadays. Smart UAVs are being used for several vital applications as well as coast watch, news broadcasting, and also the most typical application in the defense field [1]. Today the flexibility to fly while not victimization typical vestige power is primarily centered in current days, each in the functional purpose of reading and technical area while the foremost considerations from a rise in heating and a reduce in usual resources [2]. From the literature review, it plays an important role since the study of historical developments of that exact subject or topic helps the US nation [3]. Noth et al. studied the design of solar energy UAVs which that can constantly fly all time has now turned into practicable. [4]. Hannes Ross et al. presented an increase in possible energy even it can be used after sunset to glide down [5]. Brusov et al. designed velocity and boundary layer properties using a multipoint inverse airfoil design method [6]. Jashnani et al. presented UAV Sizing and Hardware Testing from the power available from the solar rays at particular place and compare it to the power available from our system [7]. Oettershagen et al. developed a new methodology for the design of UAV with solar panels for improving meteorological conditions during flight [8]. From literatures and theoretical study, the objectives of the work are to realize of a solar craft absolutely independent in aerodynamic characteristic with structural conditions.

2 DESIGN METHODOLOGY

In preliminary design, the size, and weight and arrangements are calculated. From the requirements of UAVs, the development of the overall aircraft configuration can be designed

[9]. Table 1 presents the total estimation of aircraft is 2.928kg. Figure 1 shows the list of airfoils selected [3] and Figure 2 shows the lift and drag calculation flowchart [3]. Four airfoils were selected to study and compare the results. The optimized airfoil is used to design and validate in solar powered UAV. From study XFLR analysis is preferred for most excellent performance characteristics [10]. Fig 3 plots show the compared airfoils performance from literature [3] and Table 2 presents CL and CD data for different angle of attack (α) data.

Table 1 Mission Specifications

Parameter	Data
Gross Weight	2.928 kg
Take-off value	Hand Toss
Payload	0.5 kg
Altitude	25 – 55 m
Average Air Density	1.22 kg. m^{-3}
Clearness Factor	0.67(Clear Sky=1)

Table 2 Relation of the Selected UAV Airfoils

Parameter	WE3.55	S9037	Aquilla	Medium S9000
CL/ CD	72.8	69	59	81.5
CD	0.0215	0.231	0.021	0.0214
CL	0.89	0.78	0.79	0.82

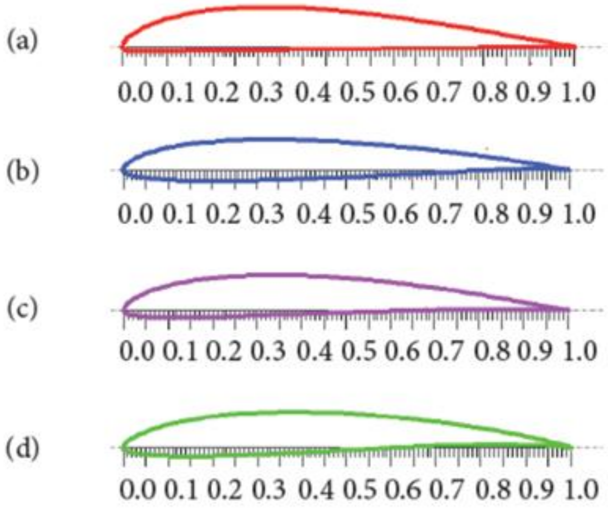


Figure 1: (a) Medium S9000 (9%), (b) Aquila 9.3%, (c) S9037 (9%) & (d) WE3.55 [3]

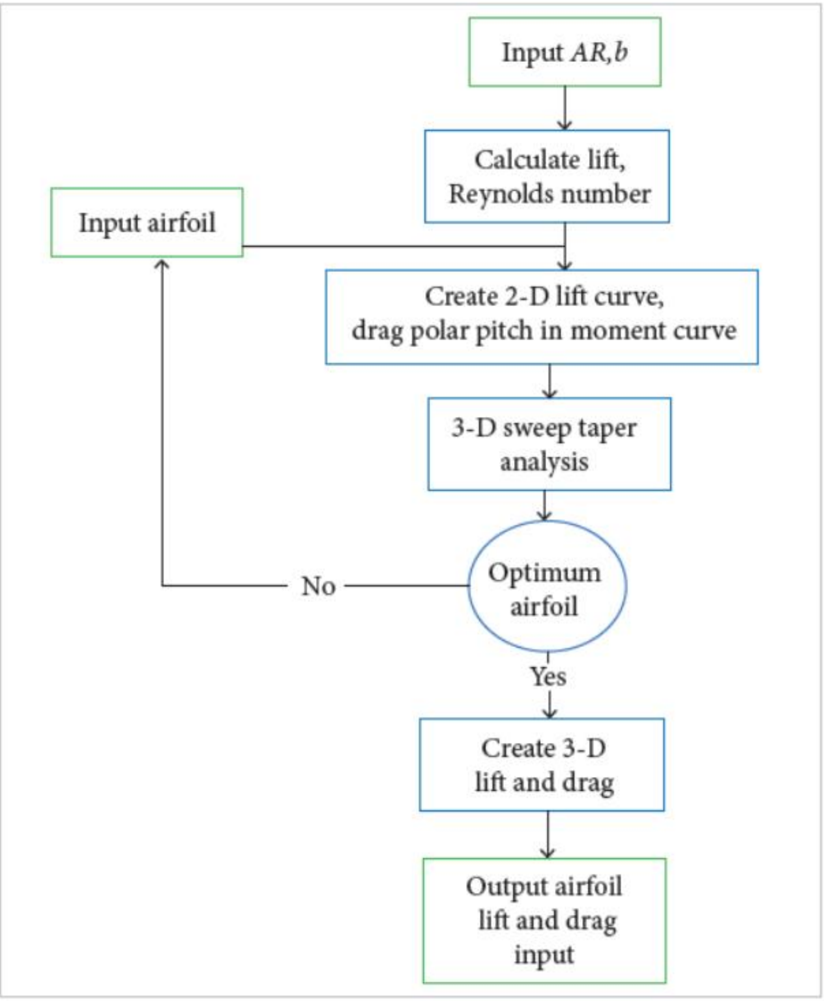


Figure 2: Calculation of Lift and Drag Coefficient [3]

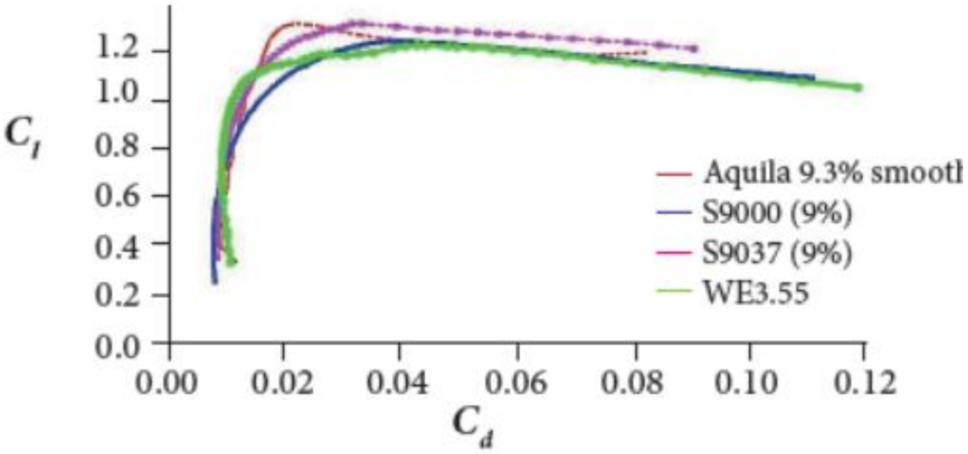


Figure 3: Plot for Airfoil Performance [3]

2.1 USAGE OF SOLAR CELLS

To design an efficient UAV design 3S battery has been chosen. They are lithium polymer (LiPo) cells. Table 3 shows the 23% efficiency of the C-60 was significantly better than typical silicon solar cells with efficiencies around 15% [11].

Table 3 Specifications of Sun Power C-60 Solar Cell

Parameter	Units
Rated Current	6A
Area	0.135 x 0.135 *m*
Solar Cell Efficiency	24%
Individual Solar Panel	0.0170 m^2
Weight	0.028 kg
Rated Voltage	0.62 V

Calculation of solar irradiance with an hour angle can be predicted for each hour. Theoretically measured values are presented in Table 4. From Fig. 4 and Table 4, it is noticed that a solar-powered UAV can make endurance up to seven hours duration with given data. As increment with flying, duration with this condition gliding, and storage energy also increased [12].

Table 4 Solar Parametric Values Calculation

Parameter	SI Units
Declination angle (δ)	3.6158^0
Daily average irradiance (Ho)	37537 $kJ\cdot m^{-2}day^{-1}$
length of day (S_{max})	12.35h
Monthly average daily radiation (H)	24,266 $kJ\cdot m^{-2}day^{-1}$
Hour angle (ωs)	89.1749^0

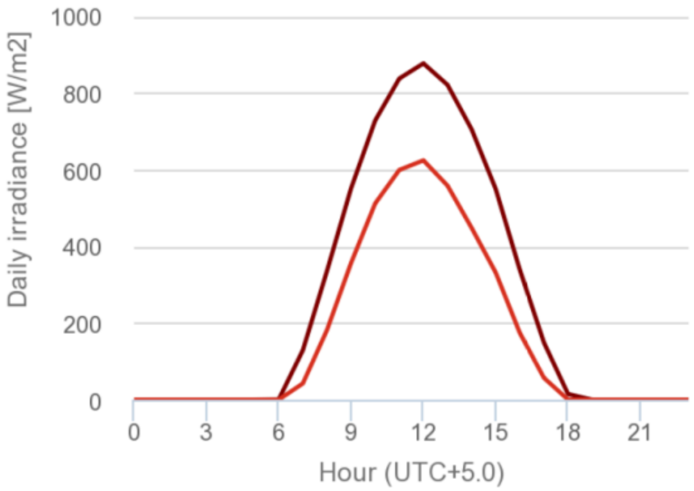


Figure 4: Plot of Duration of the Day (h) with Daily Irradiance ($W.m^{-2}$)

3 DESIGN ANALYSIS & DISCUSSION

In previous part selection of airfoil and estimation of weight and power source is done. To design and analysis a part arrangement of wing and fuselage part is to be studied. From Fig. 5, the wing part is perpendicular to the fuselage and Fig.6 shows the model for the wing position of the wing over the fuselage, this reduced interference drag and also having more payload.

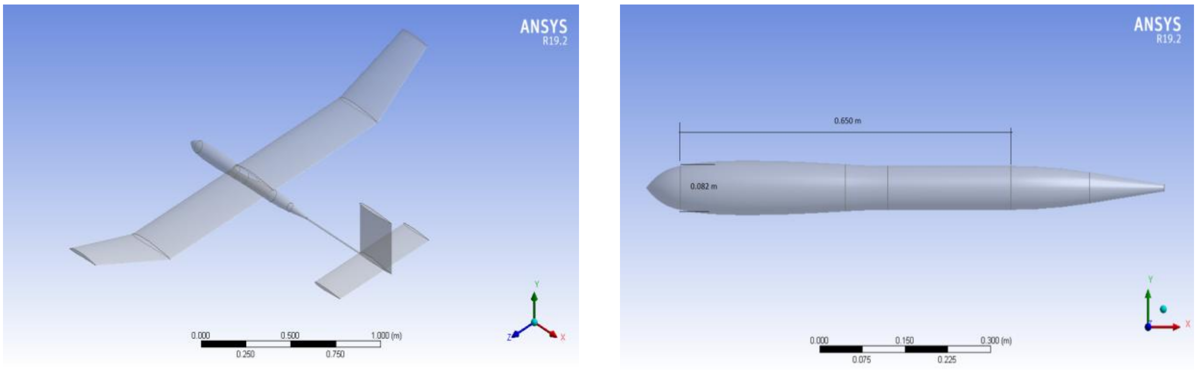
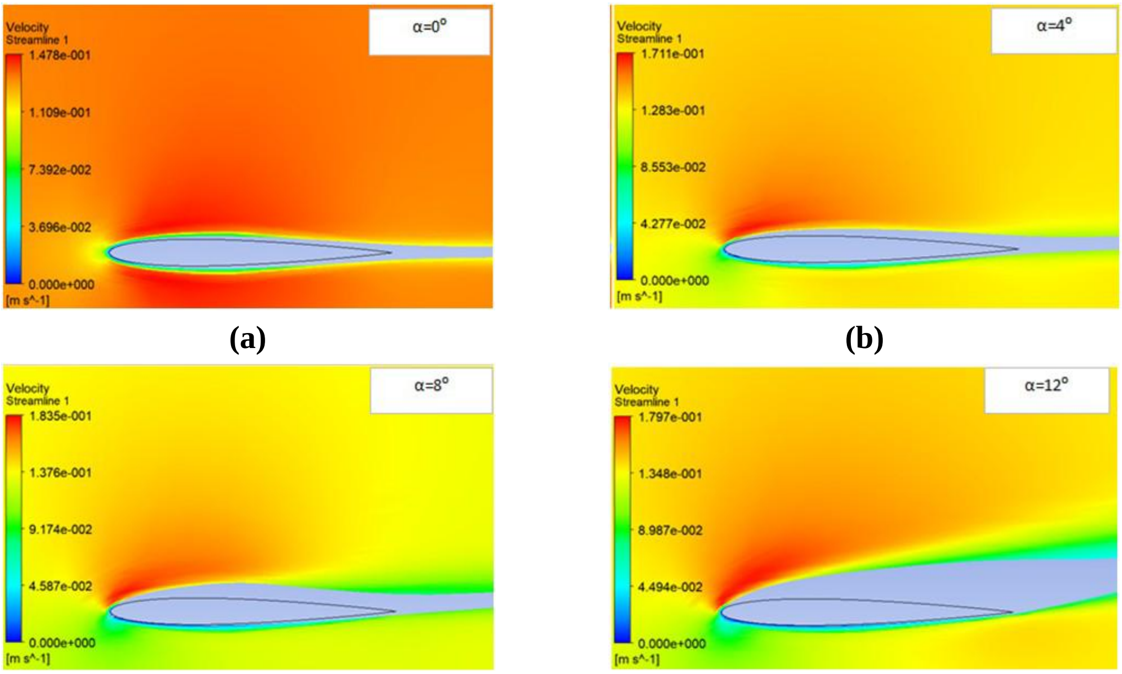


Figure 5: Model of UAV and Fuselage

NACA0009 airfoil is selected for UAV design. For wing sizing which has 4 × 2 mm with 6 × 4 mm carbon fiber (zoltac) material made spar. Mean chord length is 0.245m. Figs. 7 show the velocity streamline profile is 0°, 4°, 8° and 12° respectively. Flow separation occurs at low velocity and changes when angle of attack increases.

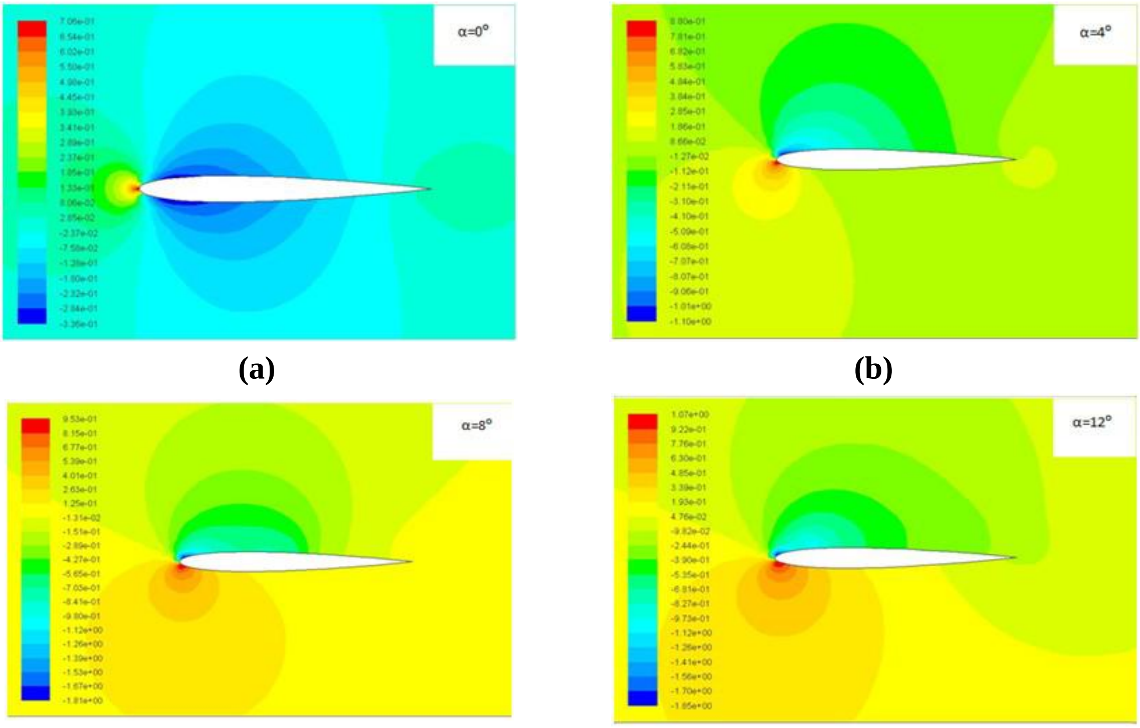


(a) **(b)**

(c) **(d)**

Figure 6: Plot of Velocity Streamline Contour for Cases (0°, 4°, 8° and 12°)

Figure 7 shows the pressure contour around the airfoil for all angle attack. The maximum pressure coefficient was 0.698 at the stagnation point. When it is increment with angle of attack the pressure point moved to the side of airfoil. From fig maximum coefficients for 4°, 8° and 12° angles of attack were 0.91, 0.895 and 1.10, respectively.



(a) (b)

(c) (d)

Figure 7: Plot of Pressure Coefficient Contour for Cases (0°, 4°, 8° and 12°)

Figure 8 shows deformation of the mid wing segment is attached to the main component of fuselage and a variation of 0.9 cm is noted. Fig 9 shows a deformation of 0.554 mm is observed. As per the evaluation 33.6962 MPa is predicted for von mises stress and it is shown in Fig.10 which is acceptable because the limit of vms is 40MPa. The analysis gives best results under maximum solar radiation [14]. From the study UAV flight performance at solar radiation intensities above 451.23 W/m2 so which works more efficiently at solar radiation intensities above 666.5 W/m2. The poor MPPT performance low solar radiation is likely to be caused by an incompatible MPPT model with the battery [15]. It is recommended to be used with a 12V 4S lithium–iron–phosphate battery, but the battery used in the power system is a 12.4 V 3S lithium–polymer battery.

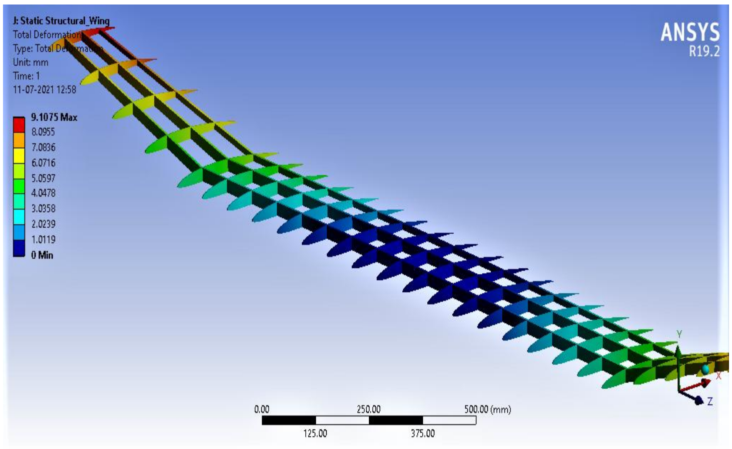


Figure 8: Image of Wing Deflection Study

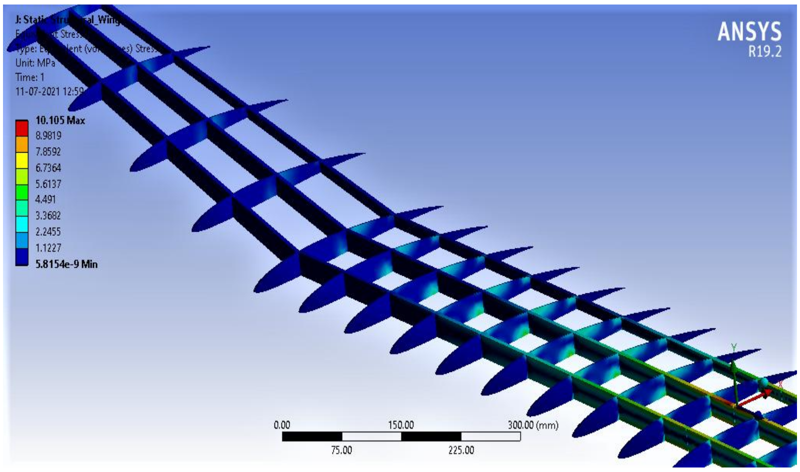


Figure 9: Image of Wing Von Mises Stress Analysis

From the analysis the system is not performing well with MPPT internal sensing algorithm. But the experimental data are changing stored battery capacity, and also the use of solar power on UAV can reduce the performance of stored battery capacity during flight. The study also presented that the use of UAV solar power system imported to a minimum rate of decrease in battery voltage during flights, consequently the battery life during flights and improving the flight period [14].

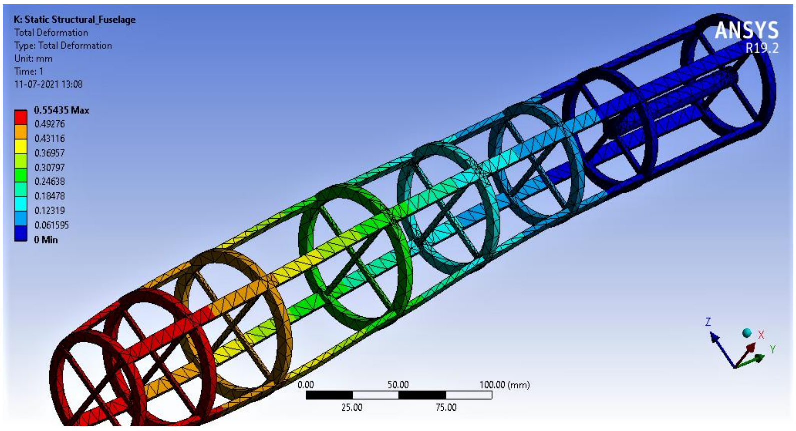


Figure 10: Analysis of Fuselage Deflection

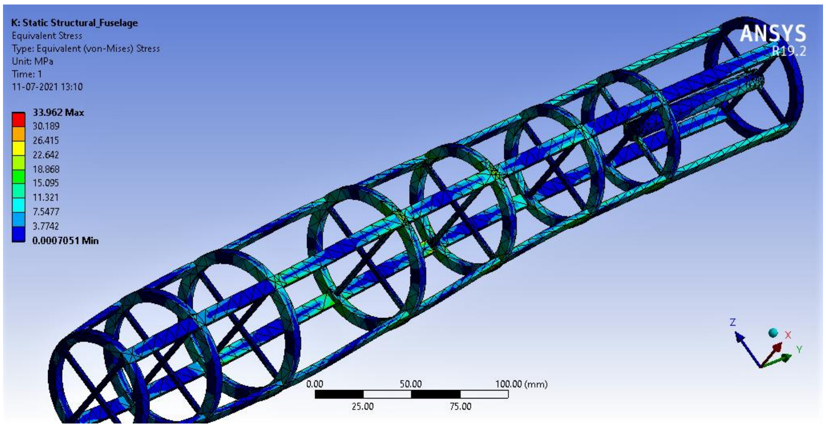


Figure 11: Analysis of Fuselage using Von Mises Stress

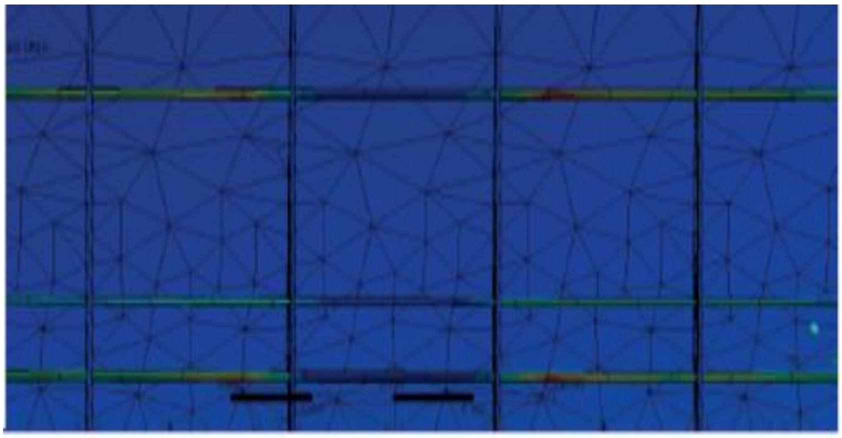


Figure 12: Enlarged view of Mid Portion of Wing

From design and analysis part, it is observed that the deformation of the wing in the software analysis we got maximum deflection of 9.562 mm, which is approximately equal to only 1cm. A deflection 0.55 mm has been observed on the fuselage section. Similarly for the tail boom, the deflection is 10.14 mm. Figure 12 presents the stress analysis has been calculated using the design software as shown in the above section [15]. On comparing the results from the software analysis and the results from the calculations it shows Medium S9000 airfoil gives best results and minimal differences between all other airfoils.

4 CONCLUSION

This paper presents about XFLR software analysis conducted for evaluating different airfoils for good L/D quantitative relation. This work is the simplest way to calculate level of power needed for share required power to around 2.98*kg* weight UAV, which may extend also. The analysis gives best results under maximum solar radiation [14]. From the study UAV flight performance at solar radiation intensities above 451.23 W/m2 so which works more efficiently at solar radiation intensities above 666.5 W/m^2. All the components of the UAV was verified with estimation power and weights for better performance, and analyzed for deflection and stress to stay within the safer limit. The work is recommended to use with a 12 *V* 4S lithium–iron–phosphate battery, but the battery always preferred used in the power system is a 12.4 *V* 3S lithium–polymer battery.

5 REFERENCES

[1] Petrova, T., & Petrov, Z. (2020). Analysis on the Leading Trends and Capabilities of UAV ‘S and Their Application in the European Cooperation Projects. International E-Journal of Advances in Social Sciences, 6(16), 137-144.

[2] Merino, L., Caballero, F., Martínez-de Dios, J. R., Ferruz, J., & Ollero, A. (2006). A cooperative perception system for multiple UAVs: Application to automatic detection of forest fires. Journal of Field Robotics, 23(3-4), 165-184.

[3] Sri, K. R. B., Aneesh, P., Bhanu, K., & Natarajan, M. (2016). Design analysis of solar-powered unmanned aerial vehicle. Journal of Aerospace Technology and Management, 8, 397-407.

[4] André, N. O. T. H. (2008). Design of solar powered airplanes for continuous flight. DISS ETH, 18010.

[5] Ross, H. (2008, September). Fly around the world with a solar powered airplane. In The 26th Congress of ICAS and 8th AIAA ATIO (p. 8954).

[6] VS, B., Petruchik, V. P., & Kuznetsov, A. V. (2013). Investigation of wing airfoils for low-speed high-altitude unmanned aerial vehicles. Aircraft Engineering, 20(3), 19-31.

[7] Jashnani, S., Nada, T. R., Ishfaq, M., Khamker, A., & Shaholia, P. (2013). Sizing and preliminary hardware testing of solar powered UAV. The Egyptian Journal of Remote Sensing and Space Science, 16(2), 189-198.

[8] Oettershagen, P., Melzer, A., Mantel, T., Rudin, K., Stastny, T., Wawrzacz, B., & Siegwart, R. (2017). Design of small hand-launched solar-powered UAVs: From concept study to a multi-day world endurance record flight. Journal of Field Robotics, 34(7), 1352-1377.

[9] Panagiotou, P., Kaparos, P., & Yakinthos, K. (2014). Winglet design and optimization for a MALE UAV using CFD. Aerospace Science and Technology, 39, 190-205.

[10] Gryte, K., Hann, R., Alam, M., Roháč, J., Johansen, T. A., & Fossen, T. I. (2018, June). Aerodynamic modeling of the skywalker x8 fixed-wing unmanned aerial vehicle. In 2018 International Conference on Unmanned Aircraft Systems (ICUAS) (pp. 826-835). IEEE.

[11] Lee, B., Park, P., Kim, K., & Kwon, S. (2014). The flight test and power simulations of an UAV powered by solar cells, a fuel cell and batteries. Journal of Mechanical Science and Technology, 28(1), 399-405.

[12] Fan, B., Li, Y., Zhang, R., & Fu, Q. (2020). Review on the technological development and application of UAV systems. Chinese Journal of Electronics, 29(2), 199-207.

[13] Suzuki, K. A., Kemper Filho, P., & Morrison, J. R. (2012). Automatic battery replacement system for UAVs: Analysis and design. Journal of Intelligent & Robotic Systems, 65(1), 563-586.

[14] Klippstein, H., Hassanin, H., Diaz De Cerio Sanchez, A., Zweiri, Y., & Seneviratne, L. (2018). Additive manufacturing of porous structures for unmanned aerial vehicles applications. Advanced Engineering Materials, 20(9), 1800290.

[15] Chu, Y., Ho, C., Lee, Y., & Li, B. (2021). Development of a solar-powered unmanned aerial vehicle for extended flight endurance. Drones, 5(2), 44.