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Design and Development of Micro Aerial Vehicle

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Abstract

The aim of the study is to develop an inverse Zimmerman planform with bi-plane configuration for Micro Aerial Vehicles (MAV's). Micro Aerial Vehicles (MAV's) emerged in the early1990's and have been evolving rapidly ever since. Due to their small size they posed some new and quite challenges in the areas of aerodynamics, equipment integration and the design approach itself. MAV's are used for surveillance purposes, data relay or air sampling. The proposed bi-plane configuration gives better aerodynamic characteristics and can take more payloads during the flight at low speed. Xfoil progam is used for design and analysis of subsonic isolated airfoil of bi-plane configuration. Aerodynamic characteristics of proposed design are obtained and validated using Xfoil Program and Computational Flow Dynamics (CFD). Based on the results, it can be concluded that the proposed design has better aerodynamic characteristic than the existing inverse Zimmerman planform configuration.

Keywords: Bi-plane; mirco aerial vehicle; pressurecoefficient; lift; drag.

1. Introduction

Micro Aerial Vehicles (MAVs) emerged in the early 1990's and have been evolving rapidly ever since. Due to their size they posed some new and quite unique challenges in the areas of aerodynamics, equipment integration and the design approach itself. Although large unmanned aircraft such as the Hunter, Pioneer, and Predator have been successful for many years as theater-level military reconnaissance platforms, a need for a smaller, platoon-level unmanned aircraft exists. Small UAVs such as the Pointer, Sender, and more recently, the Dragon-Eye, have arisen to fulfill this need. An even smaller alternative is the micro air vehicle (MAV). MAVs have a maximum dimension of approximately 30 cm (~12 in), and be able to operate at short to medium ranges in the order of 10 Km (6.2 mi), with an endurance of approximately 15-20 minutes. In addition, MAVs should be capable of carrying a variety of sensing and/or surveillance payloads with a typical payload of 18g (0.63 oz). MAVs are being built primarily for close reconnaissance missions, but as market research has shown there are also other possible applications, both military and civilian, such as situational awareness, data relay or air sampling. The development of new, miniaturized electronic equipment such as video cameras, GPS receivers, autopilots etc. has been playing a major role in MAV progress as well. While there are many MAVs developed nowadays, only a few are really suitable and ready products for real-life operations. The design of efficient MAVs is hindered, however, by the lack of a thorough understanding of the aerodynamics associated with small airplanes flying at low speeds. The operating cruise speed of MAVs is typically between 16 and 80 KPH (10 and 50 MPH), yielding an operating Reynolds numbers range between roughly 70,000 and 200,000. A need exists for detailed aerodynamic analysis tools that are applicable to the Reynolds number and aspect ratio operating conditions found in MAVs. Comprehensive literature surveys of this area of research can be found in Mueller (1985) and Lissaman (1983).

2. Design and Devolpment of Micro Aerial Vehicle

The study of biplane configurations as a potential platform for MAV applications has been recently studied by several technological protagonists. General biplane theory was extensively documented in early 1920's (Munk). Several experimental studies were conducted in 1920's to evaluate the effect of various geometric configurations. It is very difficult to capture high quality visual data during the flight with mono plane MAVs. This is because the mono plane MAVs are required to fly at relatively high speed in order to produce significant lift from its limited wing area. This compromises the quality of data captured and reduces its effectiveness during missions. Therefore, to circumvent this problem, a MAV with bi-plane configuration is designed. Biplane configuration can increase the aerodynamic performance of the MAV by controlling the desired lift at significant low speed. The results show the promising potential for biplane MAVs as an alternative to monoplane platforms.

Selections of airfoil and wing planform are the most critical parts for any micro Aerial vehicle design. The proposed design is a blended wing body flying vehicle similar to B-2 bomber but with biplane configuration as shown in Fig. 1. There is no horizontal tail in the proposed design. BEZ05203715 Airfoil is selected for the proposed design due to its high aerodynamic characteristics. The selected airfoil has 5% camber at 20% chord, 3% reflex at 75% chord, and is 1% thick. The airfoil is generated in XFOIL as shown in Fig. 2.

Fig. 1: Bi-plane MAV.

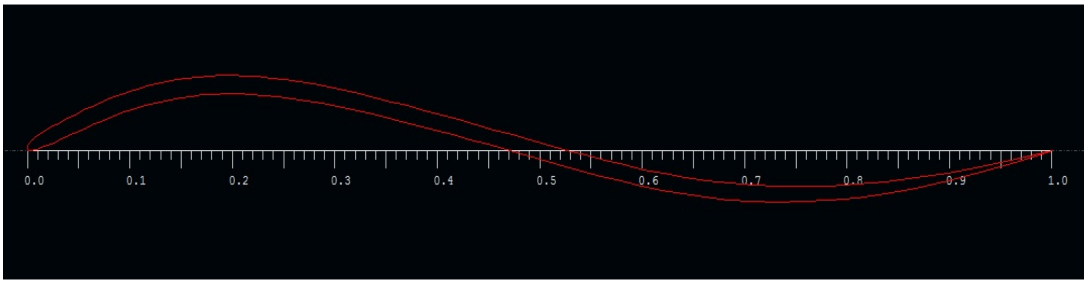

Fig. 2: Airfoil generated in XFOIL.

The values of force and moment coefficients and lift to drag ratio at various angle of attack obtained using XFOIL are given in Table 1. From the Table 1, it is observed that the slope of pitching moment versus angle of attack is negative. Therefore, selected airfoil will provide longitudinal stability to MAV. In a series of wind tunnel experiments performed (Torres and muller), aerodynamic characteristic for four wing shapes with aspect ratio of 1 and 2 are obtained. The wings had zero chambers and a thickness-to-chord ratio of 1.96%. The obtained values of lift coefficient drag coefficient with respect to angle of attack for all four wing types (Fig. 3) of aspect ratio 1 and 2 are shown in Fig. 4. A short examination of the obtained result reveals that the inverse Zimmerman planform offers the shape for an MAV. For a given maximum dimension and aspect ratio, the inverse Zimmerman planform has the lowest required angle of attack and lowest value of drag coefficient than the other planform shapes tested in the wind tunne. Based on above results, the inverse Zimmerman is selected for MAV. The inverse Zimmerman shape, which is a combination of two half-ellipses of different sizes at the ¾ chord, also has a maximum linear dimension to surface area ratio of 0.236.

Table 1: The caption comes before.

α (deg)	**0**	**2**	**4**	**6.3**	**8**	**12**
CL	-0.25	-0.011	0.257	0.713	0.943	0.807
CM	0.128	0.127	0.118	0.079	0.051	0.030
CD	0.040	0.032	0.028	0.018	0.042	0.108
L/D	-6.258	-0.337	9.292	40.444	22.515	7.459

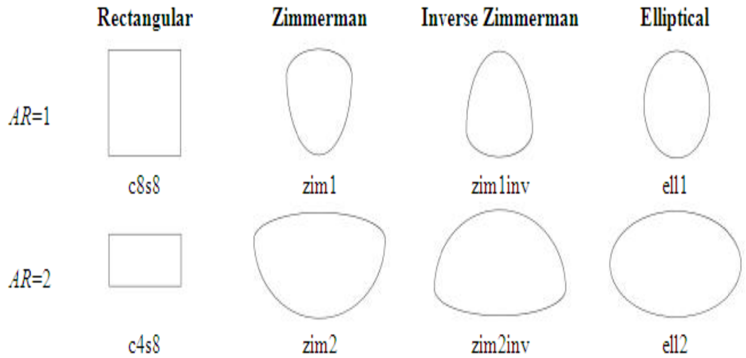

Fig. 3: Shapes of the wings tested in the wind tunnel experiments.

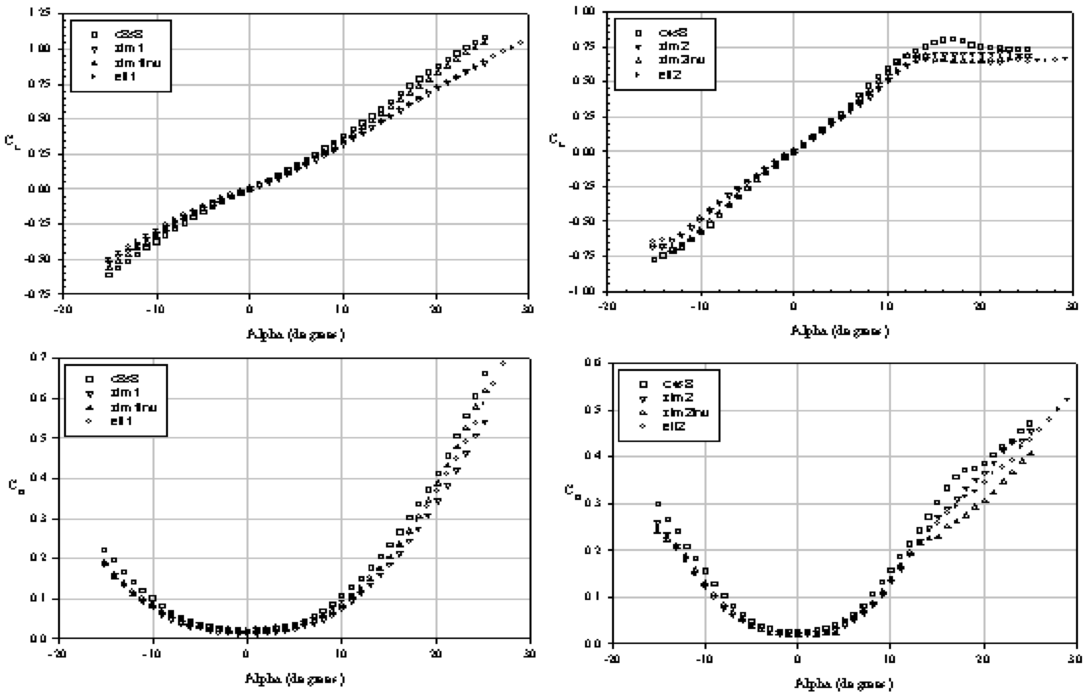

Fig. 4: Lift and drag coefficients versus algle of attack.

DS CATIA V5 was used to construct the model that could be analyzed in ANSYS. It also provides an accurate scaled representation of the MAV with different projections. Since fabrication of the model was a challenging task due to its complexity and maximum allowable thickness to chord ratio was only 1.5 % i.e. 3 mm. Therefore, aluminium 2021 was chosen for fabricating the model. It was fabricated through an aluminium slab of dimensions (650 x 250 x 22) mm. As Aluminium was chosen for fabrication, it was a difficult task to fabricate the complex model through milling as it needs high skills and ability. Therefore computer numerical control (CNC) machine was best suited for the fabrication which gives the finest model of the prototype as shown in Fig. 5.

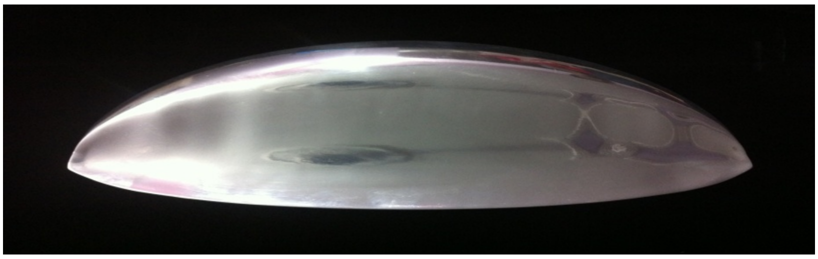

Fig. 5: Upper surface of the CNC model.

XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils. Given the coordinates specifying the shape of a 2D airfoil, Reynolds and Mach numbers, XFOIL can calculate the pressure distribution on the airfoil and hence lift and drag characteristics. The program also allows inverse design - it will vary an airfoil shape to achieve the desired parameters. It is released under the GNU GPL. Pressure distribution over the airfoil and variation of pressure coefficient at different angles of attack are obtained in XFOIL xflr5 and shown in the Fig. 6 for six degree angle of attack. From the results obtained at various angles of attack, it is observed that as the angle of attack increases above 8^o, the flow separation point shifts from quarter chord point to leading edge. At 6^o and 8^o angles of attack, flow remains attached for most of the profile. For these two angle of attack, maximum values of L/D are obtained.

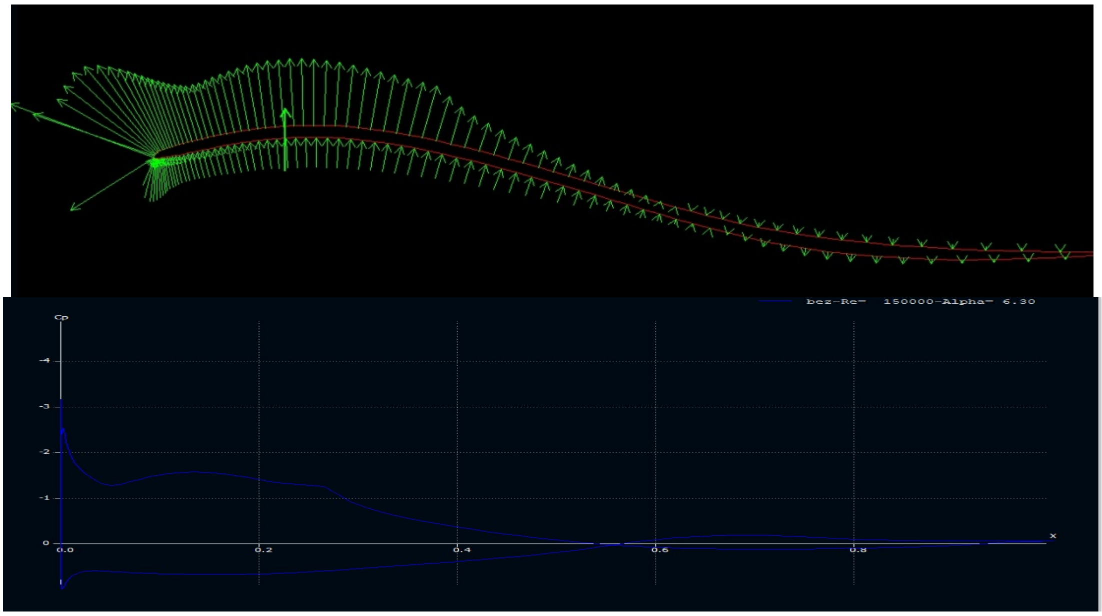

Fig. 6: Pressure distribution over the airfoil and variation of pressure coefficient at different angles of attack.

The CFD Analysis of geometry is carried out at Mach number 0.03M. The results shown in Fig. 7 and Fig. 8 clearly show that the stagnation point form in front of the planform at the leading edge tip. The flow remains laminar for most of the planform as the Reynolds number is very low. The inverse Zimmerman due to its large aspect ratio acts like a delta wing, at the side tips the difference in pressure between upper and lower surface causes vortices. The Mach number contours shown in Fig. 9 clearly indicate that the flow above the inverse Zimmerman planform moves at a faster rate as compared to lower surface which satisfies Bernoulli's theorem. This pressure graph is in lines with XFoil analysis of the airfoil.

The vorticity graph shows that at the end of the trailing edge there vortices formed are minimum when compared to the front of the planform as they diminish the strength of the vortices decreases to bare minimum hence the drag due to vortices also decreases. It can be concluded that the planform is suited for higher angle of attacks cruise condition, which is one the requirements of MAV, for its small flight envelop and higher AOA it experiences during flight.

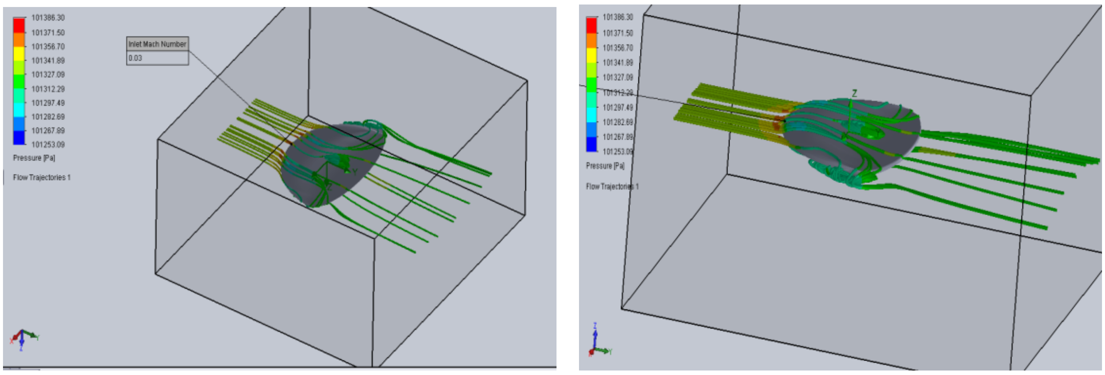

Fig. 7: Flow Trajectory Views.

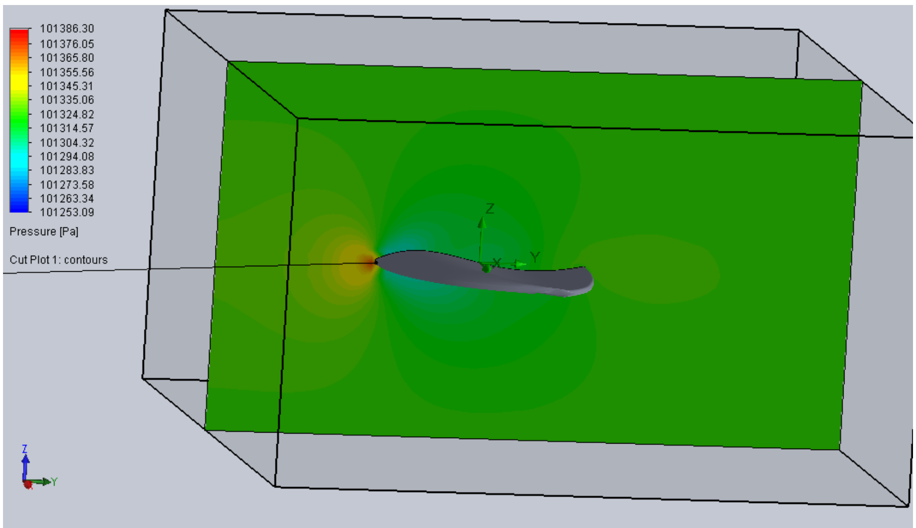

Fig. 8: Static Pressure Cut Plot Static Pressure Cut Plot.

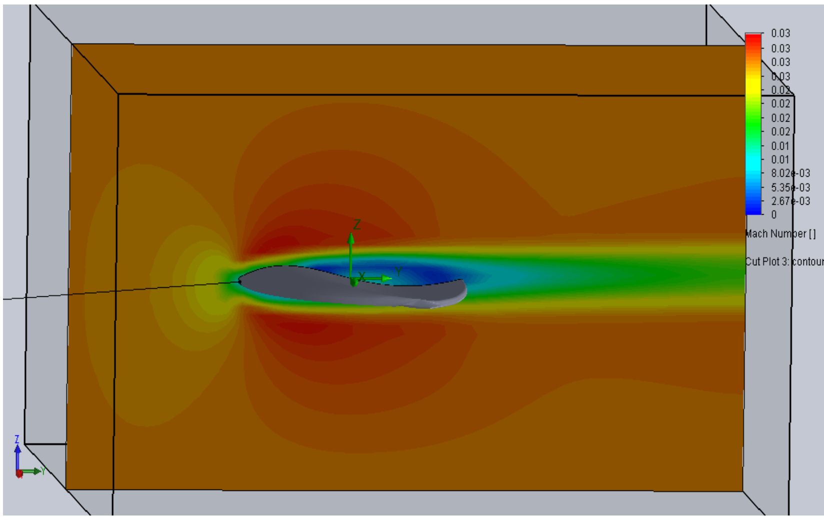

Fig. 9: Mach number contours.

3. Conclusions

The aim of the project was to develop an inverse Zimmerman planform with bi-plane configuration for Micro Aerial Vehicles (MAV's). Micro aircraft present a number of unique challenges such as aerodynamics and systems integration and thus require a different design approach from those applied to standard-sized aircraft. The aerodynamic theory used to predict performance of MAVs still needs to be investigated in greater detail as it does not allow the designer to predict the performance with sufficient accuracy in some cases. The comparisons of various planforms were also performed and it was found that Inverse Zimmerman is the best planform for designing an MAV. Extensive use of 3D CATIA also contributed to the design process of both wind tunnel test rig and the prototype as well. The CFD analysis, which was carried out, has shown sufficient agreement with the theory. The influence of the angle of attack on the *L/D* of the MAV have also been investigated and analyzed. Also the pressure distribution over the BEZ052037515 airfoil was studied at different angles of attack.

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