Research Journal of Applied Sciences, Engineering and Technology 10(3): 262-266, 2015
DOI: 10.19026/rjaset.10.2486
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: December 10, 2014 Accepted: March 7, 2015 Published: May 30, 2015

Research Article

Design Optimization of a Micro Air Vehicle (MAV) Fixed Wing

D.V.A. Rama Sastry, K.V. Ramana and K.L. Narayana
Department of Mechanical Engineering, KLEF (KL University), Vaddeswaram-522502, India

Abstract: Micro air vehicles are gaining attention due to their wide range of applications in civilian and defense fields. The wings of these vehicles generate a particular flow regime which is to be explored further. Since the theories on the aerodynamics of all affects are still to be investigated, simulation based computational fluid dynamics is a good approach rather than wind tunnel experiments which involves cost and long periods of experimentation. This study mainly emphasize on the lift, lift coefficient, drag and drag coefficient with respect to Reynold's number and angle of attack, by modelling and analyzing the fixed wing of a micro air vehicle. The analysis has been done selecting NACA25411 air foil. Modelling has been done in Gambit and analysis is taken up using Fluent. Angle of attack and Reynold's number have been optimized to increase the lift and decrease the drag.

Keywords: Angle of attack, drag, lift, micro air vehicle, Reynolds number

INTRODUCTION

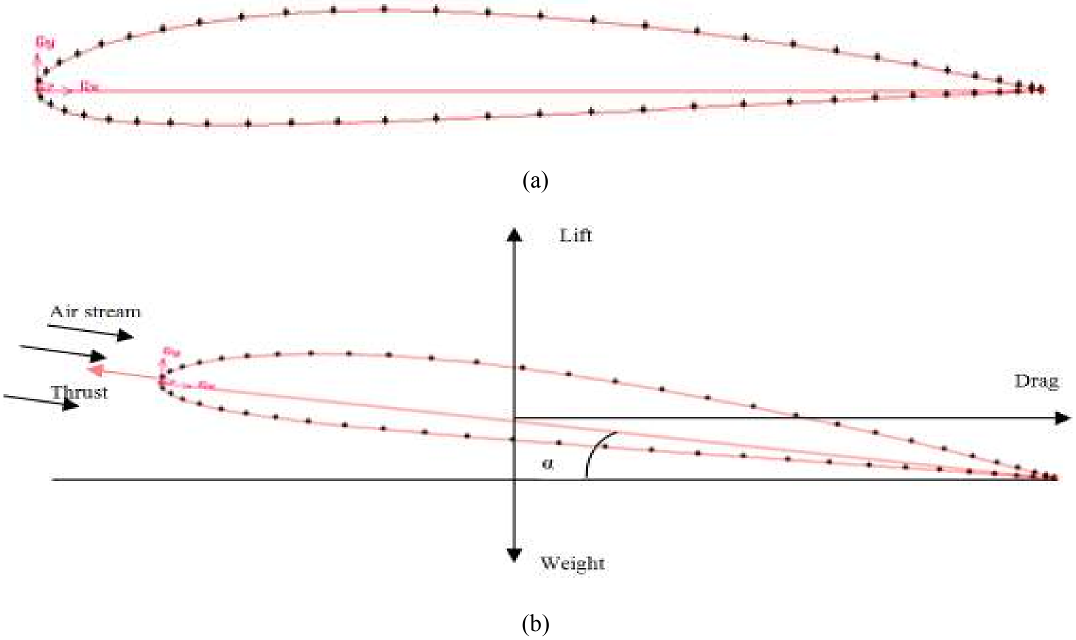
Over the past decade, Micro Air Vehicles (MAVs) have received an increasing amount of attention due to their unique capabilities in missions as covert imaging, biological and chemical agent detection, battlefield surveillance, traffic monitoring and urban intelligence gathering. MAVs are barely detectable to the naked eye at 100 yards. MAVs generally fly in the Reynolds number (R_eN_o) range of 1000 to 120000. Their performance is poor at low R_eN_os due to induced losses. A comprehensive study on low R_eN_o can be found in the work of Carmichael (1981). Mueller (1999) has conducted extensive experimental studies on 2D and 3D flow around flat plates and cambered airfoils at ReNos ranging from 60000 to 200000. The data show that cambered plates offer better aerodynamic performance characteristics than flat plates. Additionally, it is shown that the trailing edge geometry has little effect on the lift and drag on thin wings at low ReNos. Selig *et al*. (1996) has published a large and consistent amount of 2D experimental data on low ReNo airfoils. Results show that increasing the ReNo increases performance while decreasing the aspect ratio decreases performance due to tip vortex effects. Sathaye *et al*. (2004) investigated a NACA 0012 wing with an aspect ratio of unity in the ReNo range of 30000 to 90000. Lowson (1999) claimed that the airfoils that offer the best performance are thin, cambered blades with sharpened leading edges. O'Meara and Mueller (1987) analyzed laminar separation bubble length and height with respect to ReNos and angle of attacks in the range of 50000 to 200000 and from 10° to 12°, respectively. A good airfoil choice for MAVs will try to accomplish several goals such as to delay the onset of the laminar separation and therefore flow separation, to achieve a maximum lift coefficient and to keep induced as well as profile drag at a minimum. Thus, the selection of air foil is of paramount importance. Theoretical investigation carried out in this study has emphasized the design optimization of fixed wing of Micro Air Vehicle.

Table 1: Characteristics of the airfoil

Airfoil	NACA25411
Thickness	0.1100
Camber	0.2500
Leading edge radius	0.0133
Trailing edge angle	14.5600

Selection and modeling of airfoil: The configuration of airfoil selected is NACA 25411 and its characteristics are presented in Table 1. It would give an airfoil with a maximum thickness of 11% chord, maximum camber located at 27% of the chord, with a decision lift coefficient of 0.3. Airfoil is modelled as 2D wing, since it will have the same cross sectional shape over the length. It is modeled in GAMBIT, which is capable of creating meshed geometries that can be read easily with FLUENT. The model generated is shown in Fig. 1a. There will be 25 simulations in total for five numbers of Re and 5 angles of attack. The primary forces which influence the effectiveness of airfoil are shown in Fig. 1b. Meshing has been done based on cluster points near the leading and trailing edges, keeping in mind the transition in mesh size to be

Corresponding Author: D.V.A. Rama Sastry, Department of Mechanical Engineering, KLEF (KL University), Vaddeswaram-522502, India



(a)

(b)

Fig. 1: (a) Airfoil generated in gambit (b) forces acting on airfoil

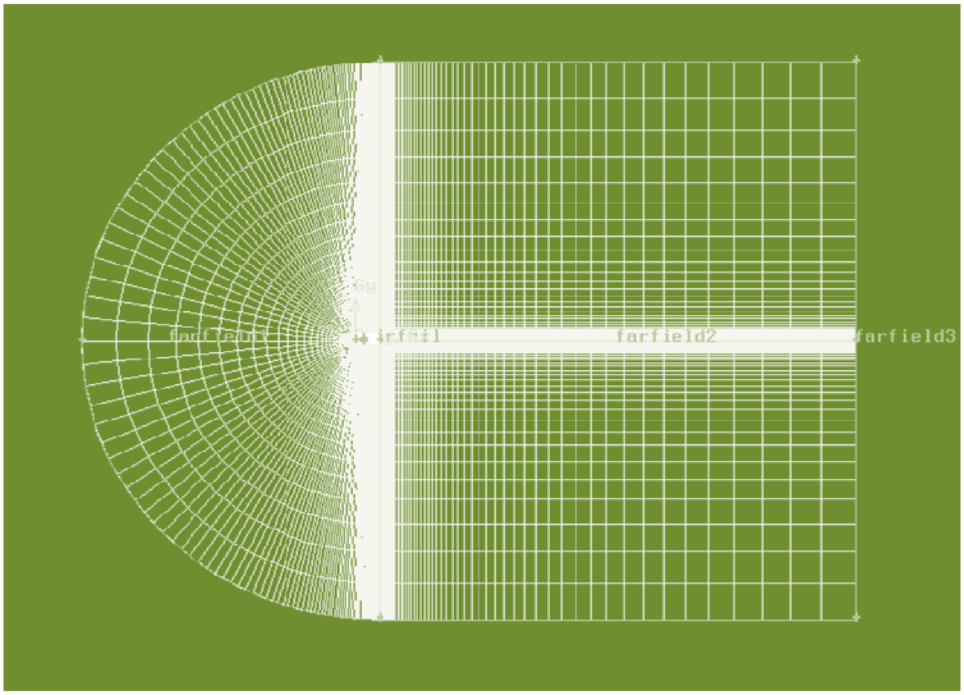


Fig. 2: Meshed airfoil

smooth. After meshing the edges, the faces are meshed by matching the number of nodes on both the edge of the face. The meshed airfoil is shown in Fig. 2.

METHODOLOGY

The following basic parameters are given as input for the analysis of airfoil in FLUENT.

Reynolds number (R_eN_o): The laminar separation bubbles occur at R_eN_o above 50000 and below 95000. Hence, ReNos55000, 65000, 75000, 85000 and 95000 were selected, respectively.

Angle of Attack (AA), α: The drag on MAV occur more intensively at lower angle of attack. Thus, the angles 0, 5, -5, 10 and -10 were selected, respectively.

Initial conditions: The performance of the MAV in the air is considered in the free stream at the height of 2000 ft.

Thus, Initial pressure of free stream : 7.9501 N/m^2
Initial temperature of free stream : 275.16 K
Density of the free stream : 1.0068 kg/m^3
Free stream velocity : 17.77778 m/sec are considered

Since the focus is on lift and drag; lift, lift coefficients, drag and drag coefficients are computed for each of the selected R_eN_o.

RESULTS AND DISCUSSION

The lift, lift coefficients, drag and drag coefficients obtained by varying R_eN_o at a constant angle of attack are given in Table 2 to 6.

Figure 3 and 4 shows the effect of angle of attack on lift and lift coefficient for the selected R_eN_os. The influence of angle of attack on drag and drag coefficients for the R_eN_os considered for the present investigation as presented in Fig. 5 and 6.

From Fig. 3, it is observed that lift is more for an angle of attack of -5°, for the selected Reynolds numbers and also at 10°. The same observation is made for the lift coefficient with reference to Fig. 4. As the angle of attack is changing from -10° to +10°, the lift is increasing gradually and then decreasing for the values of angle of attack. It is further observed from Fig. 5 that drag is minimum at -10°. As the angle of attack is changing from -10° to +10°, the drag coefficients are increasing as shown in Fig. 6. The same trend is observed in the selected range of Reynold's numbers, which implies that the angle of attack is the criteria for the design optimization of fixed wings for micro air vehicles.

CONCLUSION

In this study an attempt has been made to optimize the angle of attack to attain high lift and low drag for

Table 2: Angle of attack (α) = 0°

Reynolds no	Drag (N)	Lift (N)	Drag coefficient	Lift coefficient
55000	0.801945865	5.600826263	0.005039278	0.035794550
65000	0.747205734	5.600826263	0.004695301	0.036143143
75000	0.703888776	5.600826263	0.004423099	0.036526541
85000	0.668542206	5.600826263	0.004200995	0.037471343
95000	0.638895214	5.600826263	0.004014698	0.037965431

Table 3: Angle of attack (α) = +5°

Reynolds no	Drag (N)	Lift (N)	Drag coefficient	Lift coefficient
55000	1.072028399	17.785326	0.006736426	0.00075967
65000	1.072028399	17.785326	0.006736426	0.11175967
75000	1.072028399	17.785326	0.006736426	0.11175967
85000	1.072028399	17.785326	0.006736426	0.11175967
95000	1.070228399	17.785326	0.006736426	0.11175967

Table 4: Angle of attack (α) = -5°

Reynolds no	Drag (N)	Lift (N)	Drag coefficient	Lift coefficient
55000	32.62454224	31.41979980	0.205006525	0.197436154
65000	32.72281265	31.04759407	0.205624044	0.195097283
75000	32.81976318	30.73695564	0.206233263	0.193145290
85000	32.93829346	30.65446472	0.206978083	0.192626938
95000	33.10306549	30.49176598	0.208013475	0.191604570

Table 5: Angle of attack (α) = +10°

Reynolds no	Drag (N)	Lift (N)	Drag coefficient	Lift coefficient
55000	2.147793770	25.97515869	0.013496335	0.163223043
65000	2.099525213	26.25291824	0.013193024	0.164968431
75000	2.061300755	26.48557091	0.012952829	0.166430384
85000	2.031265469	26.48732185	0.012952607	0.166441381
95000	2.003419876	26.84104435	0.012589117	0.168664113

Table 6: Angle of attack (α) = -10°

Reynolds no	Drag (N)	Lift (N)	Drag coefficient	Lift coefficient
55000	2.470116138	-14.78484917	0.015521749	-0.092905231
65000	2.431528568	-14.78457633	0.015279272	-0.092903137
75000	2.379936646	-14.83279133	0.014955076	-0.093206488
85000	2.347278118	-14.84975624	0.014749858	-0.093313098
95000	2.319741488	-14.85272772	0.014576823	-0.093394600

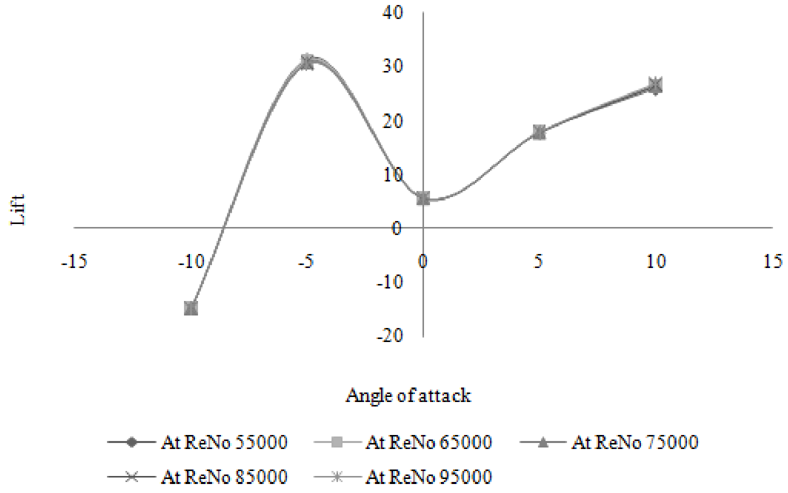


Fig. 3: Effect of angle of attack on lift

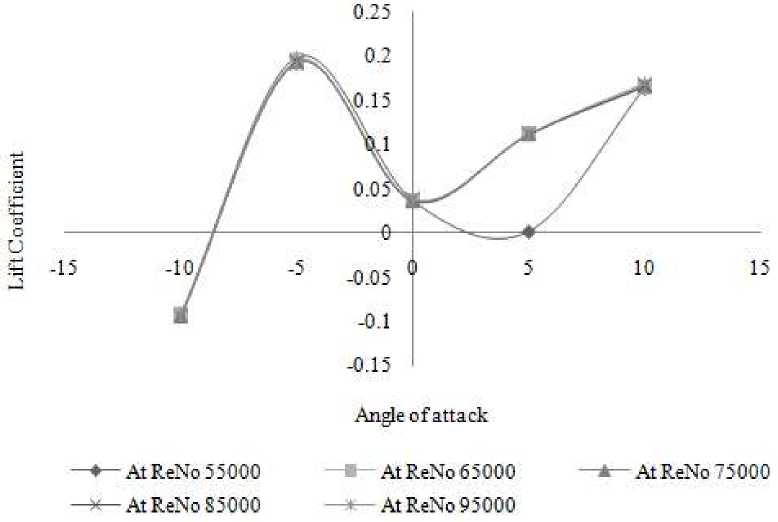


Fig. 4: Effect of angle of attack on lift coefficient

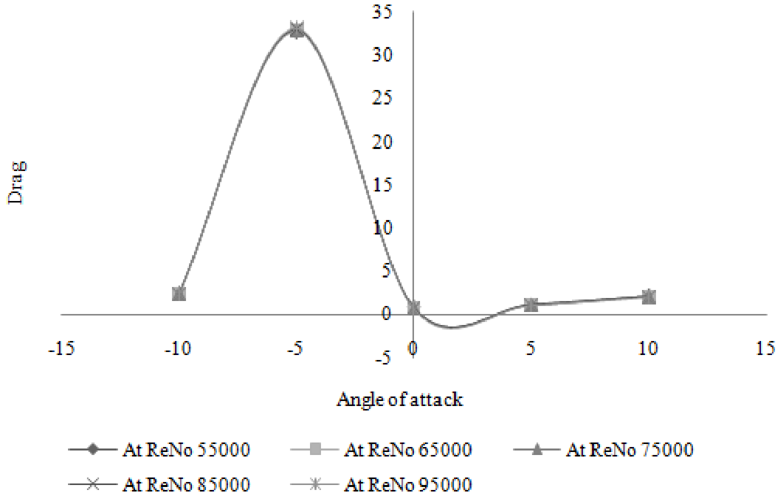


Fig. 5: Effect of angle of attack on drag

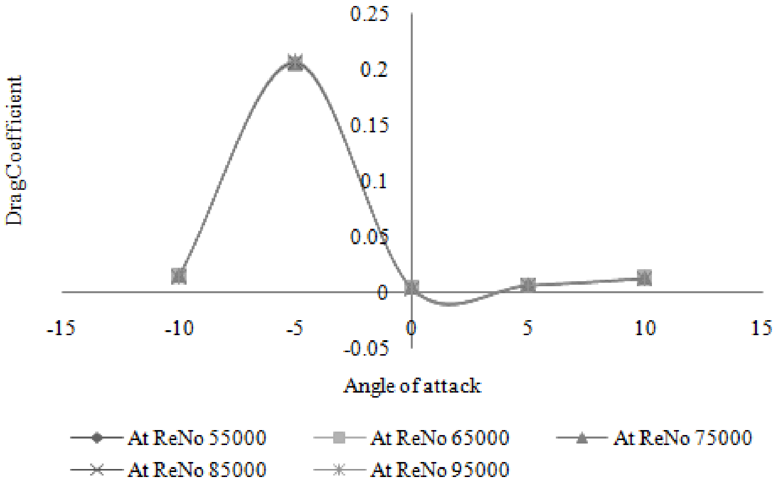


Fig. 6: Effect of angle of attack on drag coefficient

fixed wing of a micro air vehicle, selecting NACA25411 airfoil. From the observations it can be concluded that negative angles of attack in the range of -5° to 0° will increase the lift and decrease the drag, in the R_eN_o range of 55000 and 95000.

REFERENCES

Carmichael, B.H., 1981. Low Reynolds number airfoil survey. NASA Contractor Report 165803, Vol. 1.

Lowson, M.V., 1999. Aerodynamics of aerofoils at low Reynolds numbers, UAVs. Proceeding of 14th Unmanned Air Vehicle Systems International Conference, United Kingdom.

Mueller, T.J., 1999. Aerodynamic measurements at low reynolds numbers for fixed wing micro-air vehicles. Proceeding of the RTO AVT/VKI Special Course on Development and Operation of UAVs for Military and Civil Applications. VKI, Belgium.

O'Meara, M. and T.J. Mueller, 1987. Laminar separation bubble characteristics on an airfoil at low Reynolds numbers. AIAA J., 25(8): 1033-1041.

Sathaye, S., J. Yuan and D.J. Olinger, 2004. Lift distributions on low-aspect-ratio wings at low Reynolds number for micro-air vehicle applications. Proceeding of 22nd AIAA Applied Aerodynamics Conference. Providence, RI, June.

Selig, M.S., J.J. Guglielmo, A.P. Broern and P. Giguere, 1996. Experiments on airfoils at low Reynolds numbers. Proceeding of 34th AIAA Aerospace Sciences Meeting and Exhibit. Reno, NV.