A Detailed Study of Two Different Airfoils on Flight Performance of MAV of Same Physical Dimension

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Abstract— *The paper presents a study of micro air vehicles (MAVs) with wingspans of 20 cm with two different airfoil configurations. MAVs have a vast potential application in both military and civilian areas. These MAVs are fully autonomous and supply real-time data. The paper focuses on two different designs of the MAVs one being N22 airfoil and the other a flat plate with similar dimension. As designed, the MAV would fly in a low Reynolds-number regime at airspeeds of 15 & 20 m/sec. Propulsion would be provided by an electric motor with an advanced lithium polymer battery, because of the close coupling between vehicle elements, system integration would be a significant challenge, requiring tight packaging and multifunction components to meet mass limitations and Centre of Gravity (C.G) balancing. These MAVs are feasible and within a couple of years of technology development in key areas including sensors, propulsion, Aerodynamics, and packaging these would be easily available to the users at affordable prices. The paper finally compares the flight performance of the two configurations.*

Keywords— Airfoil, CFD, MAV, Flight Performance, Endurance, Climb, Lift, Drag.

I. Introduction

To carryout outdoor missions a fixed-wing MAV is suitable due to its high forward flight efficiency [1-3]. Most modern MAVs are designed to be smaller than conventional UAVs, which are hand launched units, able to be transported and deployed by one individual, which would be an impossible scenario with larger UAVs [4-7]. Potential capabilities for this fixed wing MAV is that uses a data link, navigates independently and carries multiple sensors made up of organic materials too. Because of their small size and low power, such MAVs would be quite covert [8-11]. In addition, exploiting micro-fabrication technology would make possible the production in large quantities of MAVs at low unit cost. The micro -fabrication technology is also used in double aero shape irregular polygon slotted microstrip antenna for WI-FI applications [12-13].

II. Methodology

The paper focuses on the comparison of a Micro MAV (MB200) with N22 airfoil and a flat plate (FP) wing for a 20cm MAV rather than analysis and algorithm studies of the MAVs controller. The two configurations will have the same set of propulsion device, sensors and controller. Hence the discussion will be restricted in the area of optimization for application examples.

Table 1: Air foil data for MB and Flat Plate Configurations

MB 200		Flat plate	
Tip	0.10501	Tip	0.09
Root	0.17000	Root	0.14
Lambda	0.61771	Lambda	0.64286
MAC	0.140068	MAC	0.116812
C.G(X)	0.057	C.G(X)	0.054
AR	1.4	AR	1.3

III. Experimental methodology

CFD data is generated for 15m/s and 20m/s velocity at identical fluid properties. The aim of this paper is to compare the CFD data of FP and MB 200 and calculate the endurance and compare it with flight test data.

Table 2: Fluid Properties and Unit

Fluid Properties		Unit
Alt	920	m
P	90,752	Pa
R	1.12041	kg/m3
M	1.76E-05	kg/m-s
N	1.5709E-05	m2/s

Endurance is calculated by the current rating of the avionics. Current consumption of every component is estimated and summed up to find total current consumption for a cruise flight and hence estimate the endurance.

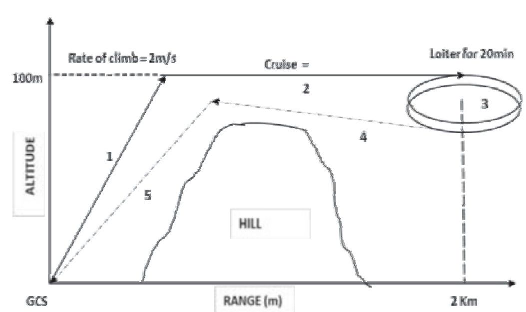

Fig. 1 Mission Profile

To calculate endurance the current drawn by individual avionic component is estimated at each flight condition i.e., take off, cruise, and landing.

Thrust produced by the motor, can be estimated from the static motor test data with the amount of current drawn from the motor and then extrapolated to dynamic results by keeping a margin of 33%.

Table 3: Static Test of motor

M: HK1612 8g , Prop : GWS 5x3, ESC : Turnigy :6A						
Throttle (%)	Voltage (V)	Current (A)	Power (W)	RPM	Thrust (g)	Efficiency (g/W)
5	8.49	0.12	1.0	3250	7.1	6.97
10	8.48	0.38	3.2	5800	23.5	7.29
15	8.47	0.72	6.1	7550	41.6	6.82
20	8.46	1.08	9.1	8775	56.7	6.21
25	8.45	1.49	12.6	9950	71.4	5.67
30	8.43	1.9	16.0	10975	86.8	5.42
35	8.42	2.25	18.9	11725	101.1	5.34
40	8.41	2.65	22.3	12550	116.4	5.22
45	8.4	3.09	26.0	13300	132.3	5.10
50	8.39	3.36	28.2	13800	142.8	5.07
55	8.38	3.69	30.9	14400	153.3	4.96
60	8.36	4.24	35.4	15300	173.2	4.89
65	8.34	5.16	43.0	16150	194.3	4.51
70	8.32	5.4	44.9	16625	206.9	4.61

By assuming the maximum l/d ratio for cruise flight from the CFD we can find the thrust required

$$Thrust = \frac{Wt}{l/d} \quad (1)$$

For a cruise, we know, at 15m/s wind speed

Lift = Weight (2)

Assuming l/d is 6.5 for cruise flight for MB 200

T = 130/6.5

=20 gms

Assuming l/d is 5.5 for cruise flight for FP

T= 130/ 5.5

=23.6 gms

For 25gms thrust throttle required for cruise condition is upto 15% consuming less than 0.38Amps of current for MB 200, For 23.6 gms thrust throttle required for cruise condition is around 15% consuming 0.38Amps of current for FP and in the same way, we assume at wind speed of 20m/s.

IV. RESULT & DISCUSSION

AOA for cruise flight is 4 degrees generating a drag of about 27gms at 15m/s.

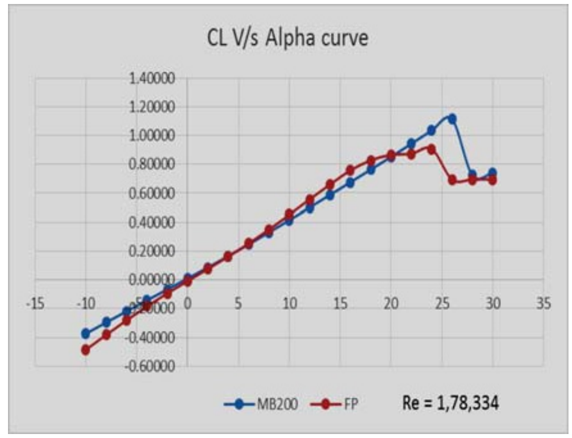

Fig. 2 CL vs Alpha Curve

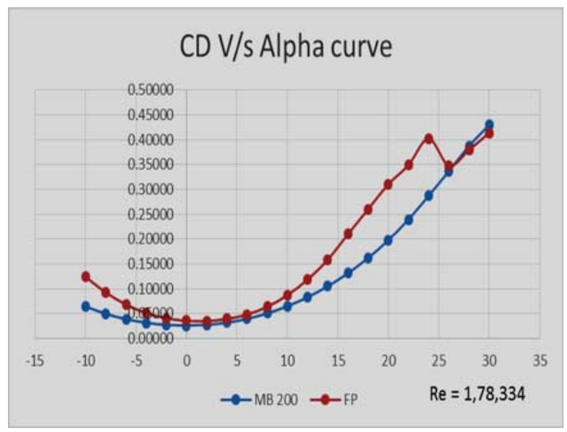

Fig. 3 CD vs Alpha Curve

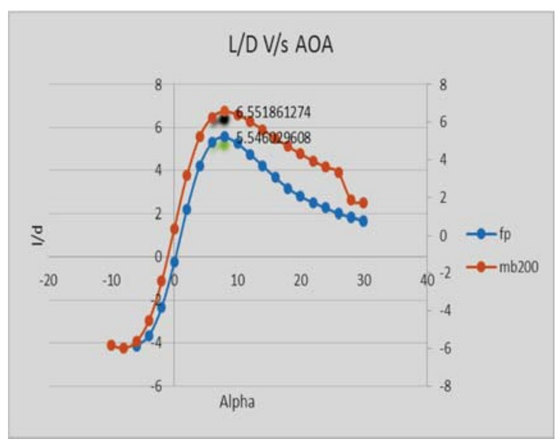

Fig. 4 L/D vs AOA

Max l/d is produced at an angle of attack of 8 degrees which would produce maximum endurance. At 8 degrees Cd is 0.06541 producing drag of 0.10 gms for FP and 0.0518 Cd drag of 0.0863gms for MB 200 at 15m/s Ground speed.

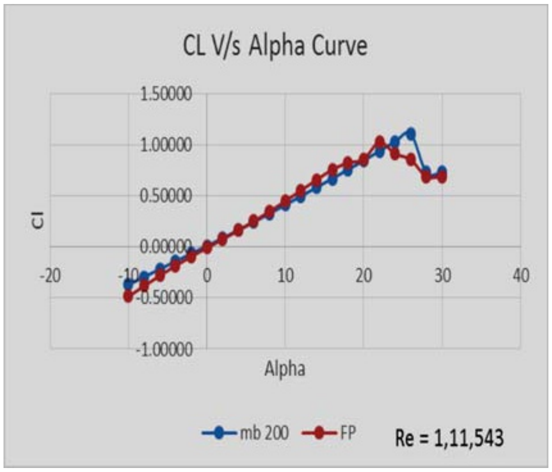

Fig. 5 CL vs Alpha Curve

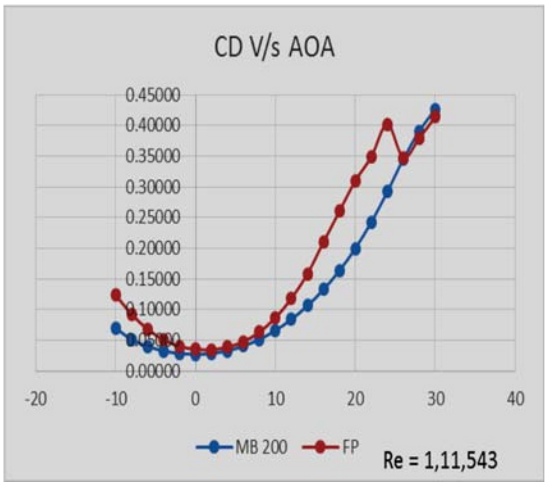

Fig. 6 CD vs AOA

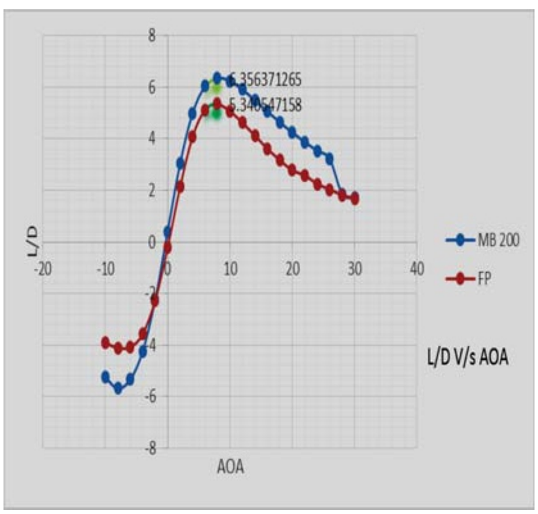

Fig. 7 L/D vs AOA

AOA for cruise flight is 10 degrees generating a drag of about 19 gms for MB200 and 23gms for FP where l/d is 6.2 and 5.0 which would reduce the efficiency of the MAV. At 10 degrees Cd is 0.0648 producing drag of 0.192 gms for FP and 0.0648 Cd drag of 0.192gms for MB 200.

V. Power Consumption

Power consumption for avionics is calculated and shown in below table.

Table 4: Avionics Current Consumption

CRUISE ALTITUDE	100.000	m					Mission Time	T=	12.106	min
CLIBM RATE	5.380	m/s								
DESENO RATE	10.000	m/s								
MOTOR CONSUMPTION							SERVO CONSUMPTION			
TAKE OFF							Voltage	4.800	6.000	V
Current Drawn	I1=	5.000	A	80%			Speed	0.120	0.100	sec
Time to takeoff	t1=	20.000	sec	0.333	min		Torque	0.700		Kg-cm
Total Current	C1=	28.000	mAh				Power=Torque x Angular Velocity			
							Power	P=	0.599	W
CRUISE							Assuming 80% efficiency			
Current Drawn	I2=	4.000	A	60%			Power	P=	0.479	W
Distance	Dis=	2.000	Km				Current I = P / V			
Velocity	V=	18.000	m/s				Current	C=	100.000	mA
Time to Cruise	t2=	111.111	sec	1.852	min		For 2/3 servos for mission time			
Total Current	C2=	123.000	mAh				No of Servos	No=	2.000	
							Total Current	Cservo=	40.354	mAh
LOITER										
Current Drawn	I3=	4.000	A	60%			AUTOPILOT CONSUMPTION			
Velocity	V=	18.000	m/s				Current Drawn	I=	100.000	mA
Time to Loiter	t3=	480.000	sec	8.000	min		Total Current	Cap=	20.000	mAh
Total Current	C3=	533.000	mAh							
							CAMERA CONSUMPTION video tx			
RETURN				60%			Current Drawn	I=	300.000	mA
Current Drawn	I4=	4.000	A				Total Current	Ccam=	60.000	mAh
Distance	Dis=	2.000	Km							
Velocity	V=	19.000	m/s							
Time to Return	t4=	105.263	sec	1.754	min		TOTAL CURRENT REQUIRED			
Total Current	C4=	117.000	mAh				Ctotal=Cmotor+Cservo+Cap+Ccam			
							TOTAL =	929.354		mAh
LANDING										
Current Drawn	I1=	2.500	A	40%						
Time to Landing	t1=	10.000	sec	0.167	min					
Total Current	C1=	7.000	mAh							
MOTOR CURRENT	Cmotor=	808.000	mAh							

Current required for the complete mission is calculated to around 900 mAh for 12-minute mission time.

VI. Experimental Results

Experiments were conducted in nil wind speeds but all parameters could not be simulated as per the requirement due to changes in weather conditions.

The data below shows that the two mav's were flown with same configurations and at same altitude of 30mts at semi-autonomous mode.

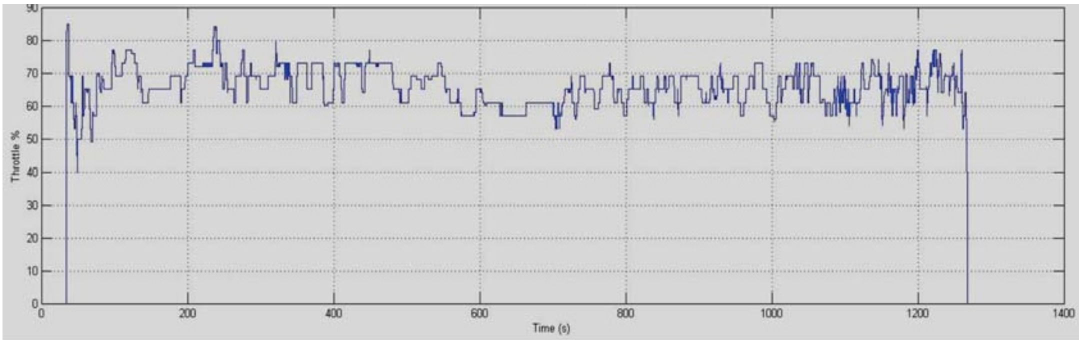

Fig. 8 Throttle vs Time for MB 200

The results indicated following observation for MB 200.

Throttle mean = 65.1483%.
Throttle median = 65%
Throttle range = 85%
Throttle mode = 65%

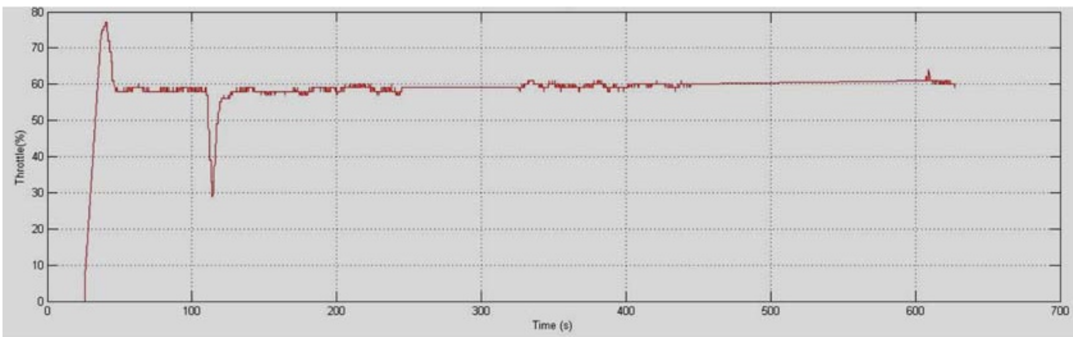

Fig. 9 Throttle vs Time for FP

The results indicated following observation for FP.

Throttle mean = 59.83%.
Throttle median = 60%
Throttle range = 85%
Throttle mode = 60%

VII. Conclusion

From the Computational results we can say that Cd MB200 is 0.0518 and for FP 0.06541 hence L/D is more for MB200 at 15m/s. Also, at 20m/s l/d is 6.2 for MB200 and 5.0 for FP. From the experimental data we can concur that flat plate has given less endurance than MB200.Few parameters such as atmospheric conditions are considered to be uncontrollable hence there can be a variation of 10%.

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