



EXPERIMENTAL ANALYSIS OF BLENDED WING BODY MODEL MICRO AIR VEHICLE USING WIND TUNNEL

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ABSTRACT

An experimental aerodynamic analysis is performed to obtain aerodynamic characteristics and performance of a blended wing-body aircraft (BWB) using Low Speed Wind Tunnel. The BWB design concept is a revolutionary way of understanding the hike of fuel cost, increase in air travelers and environmental concern. Recognizing the potential of the aircraft an experimental analysis is conducted on BWB to understand aerodynamic performance parameters like lift coefficient (CL), drag coefficient (CD) and the Lift-to-Drag (L/D) ratio. The aluminium BWB model is manufactured using CNC machine and is tested in Wind tunnel at different angle of attack varying from 0° to 16° at speed of 12 m/s, 25 m/s and 35 m/s velocity. The present BWB UAV design has achieved an unprecedented capability in terms of sustainability of flight at high angle of attack, low parasite drag coefficient and decent maximum lift coefficient. This study indicates some significant benefits for the BWB relative to the conventional aircraft configuration.

KEYWORDS: Blended Wing Body (BWB), Aerodynamics, Unmanned Aerial Vehicle (UAV), Wind Tunnel

1. INTRODUCTION

The current design of transport aircraft has not changed significantly in the past few decades; rather incremental design optimization has taken place on each new generation of aircraft. BWB is a hybrid of flying-wing aircraft and the conventional aircraft where the body is designed to have a shape of an airfoil and carefully streamlined with the wing to have a desired planform. If the wing in conventional aircraft is the main contributor to the generation of lift, the fuselage of BWB generates lift together with the wing thus increasing the effective lifting surface area.

The aerodynamic lifting body shape between fuselage and wing intersections reduces interference drag, reduces wetted surface area which reduces the skin

friction drag while the slow evolution of fuselage-to-wing thickness by careful design may suggest that more volume can be stored inside the BWB aircraft, hence, increases payload and fuel capacity. The purpose of this research is to understand the aerodynamic performance and efficiency of BWB aircraft with respect to a conventional aircraft. This concept aims at combining the advantages of a flying wing with the loading capabilities of a conventional airliner by creating a wide body in the center of the wing to allow space for passengers and cargo. Especially, for very large transport aircraft, the BWB concept is often claimed to be superior compared to conventional configurations in terms of higher lift-to-drag ratio and consequently less fuel consumption. The methodology used is the modeling of a

BWB aircraft using CATIA software and fabricated using CNC machine and then it is tested in the low subsonic wind tunnel.

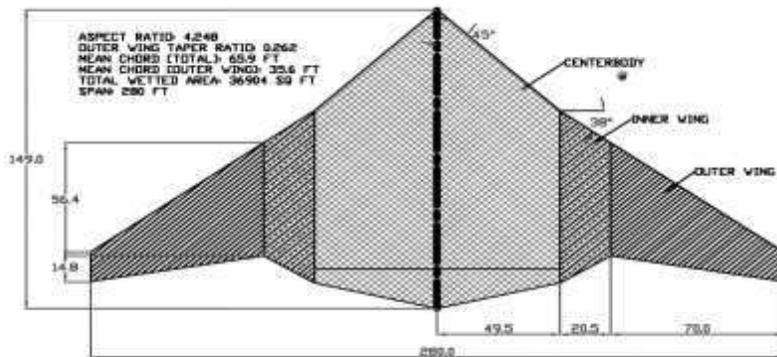


Fig.1 Planform View of BWB

2. DESIGN AND MODELING

The BWB body is considered as the lifting body itself, where every aerodynamic parts will contribute for the lift production. In this BWB design did not include engines and were tested according to aerodynamic capabilities. The total span length of the aircraft is 280 ft considered from left wingtip to right wing tip. The aspect ratio, which is the ratio of its span to its aerodynamic breadth or chord, is 4.248 ft. The outer wing taper ratio,

which is the ratio of the chord at the tip to the chord at the root, is 0.262. The total wetted area is 36,904 square feet. The scale used was 1:304. The first part which is modeled is the center body as shown in fig.2.1. The center body is the feature which makes blended wing body configuration unique. Not only does it house the payload, but it also generates lift.



Fig.2 NACA 0012-64 airfoil (center body)

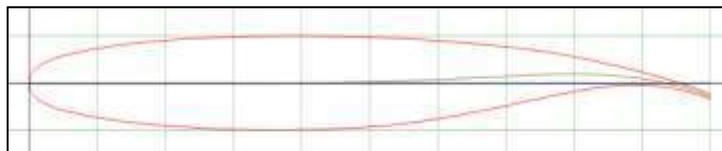


Fig.3 NACA SC (2)-0710 airfoil

The centre body section is designed with NACA 0012-64 airfoil as shown in Fig.2.which shows a closer view of the cross-section of the center body .The airfoil used for the wings is NACA SC (2)-0710 as shown in Fig.3. It is a supercritical airfoil. A supercritical aerofoil is an aerofoil for which the upper surface is flat and the lower surface is cusp shape lying at 60% of the chord.

A supercritical airfoil is an airfoil designed, primarily, to delay the onset of wave drag in the transonic speed range. Supercritical airfoils are characterized by their flattened upper surface, highly cambered aft section, and larger leading edge radius.

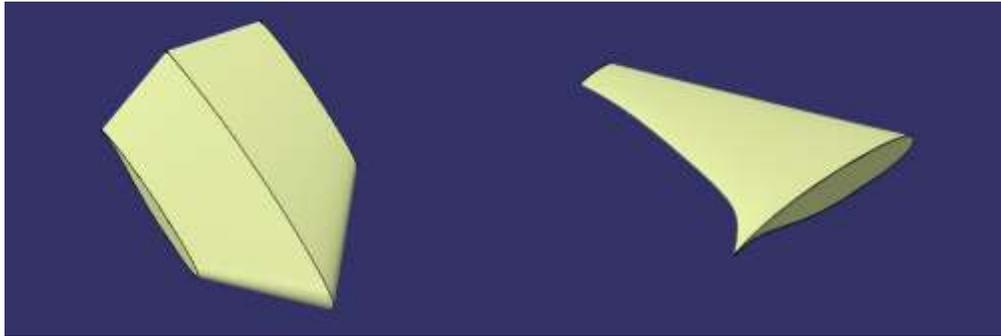


Fig.4 Blended wing body centre body and Wing

A winglet is a lift augmenting device which is attached at the wing tip of an aircraft. Winglets are used to improve the aerodynamic efficiency of an aircraft by lowering the

formation of induced drag which is caused by the wingtip vortices.

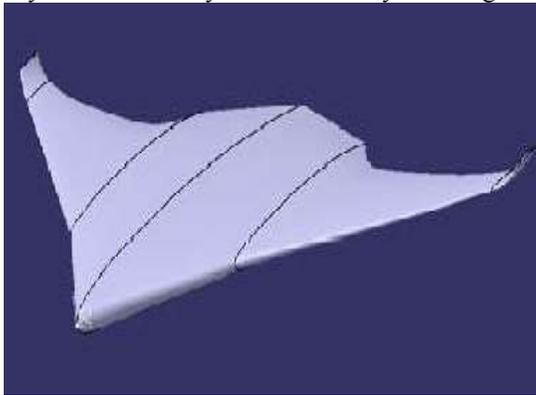


Fig.5 BWB aircraft CATIA model



Fig.6 CNC Aluminium BWB Scaled model

Since, Fig. 5 shows the final model which has been designed for further analysis. The engines are not included in the design because the focus of this study is on the aerodynamic effect of the overall configuration of the aircraft. The model is manufactured using

Aluminium material in the CNC machining process as shown in Fig.6. The aerodynamic forces, moments and Coefficients of forces and moment can be calculated using the below equations. The specification is shown in table 1.

$$L = F_y \cos \alpha - F_x \sin \alpha \quad (1)$$

$$D = F_y \sin \alpha + F_x \cos \alpha \quad (2)$$

$$C_L = \frac{L}{\frac{1}{2} \rho V^2 S} \quad (3)$$

$$C_D = \frac{D}{\frac{1}{2} \rho V^2 S} \quad (4)$$

$$C_M = \frac{M}{\frac{1}{2} \rho V^2 S_{ref} l_{ref}} \quad (5)$$

$$C_{N\alpha} = \frac{C_N(\alpha_2) - C_N(\alpha_1)}{\alpha_2 - \alpha_1} \quad (6)$$

$$C_{M\alpha} = \frac{C_M(\alpha_2) - C_M(\alpha_1)}{\alpha_2 - \alpha_1} \quad (7)$$

Table 1. BWB specification parameters

Aerodynamic specification	inner wing	outer wing
AIRFOIL TYPE	NACA SC(2)-0710	NACA SC(2)-0710
SWEEP ANGLE	38	38
TAPER RATIO	0.6557	0.2627
ASPECT RATIO	0.42	2.45
WING AREA	1000 mm ²	2000 mm ²
MAXIMUM CHORD	86.01mm	56.4 mm
MINIMUM CHORD	56.4mm	14.819 mm
WING SPAN	20.5mm	70 mm

3. WIND TUNNEL TESTING EXPERIMENTAL SETUP

The tests are conducted using Low Speed Tunnel having test section area of 0.6 m x 0.6 m x 2 m. It is a suction type tunnel, equipped with a 6-component balance, capable of measuring lift force, drag force, yawing moment, pitching moment, rolling moment and shearing force. Hence, a full model of BWB is used for the tests. The BWB planform has been manufactured using CNC machine with a size reduction of 1/6. The tests are conducted at 3 different air speeds, i.e. 12 m/s,

25 m/s and 35 m/s. The Reynolds number, using base chord length as reference length, is of the order of 10⁵, and the Mach number ranges from 0.06 to 0.14. Initially the value is calculated using six component balance of the wind tunnel set up at wind off mode and then taking the reading at wind- on mode condition at different angle from attack 0° to 16 ° angle of attack. The BWB aluminium model is placed in test section of wind tunnel at different angle of attack as shown in Fig. 8(a) to Fig.8(f).



Fig.7 Low speed subsonic Wind Tunnel at Gitam University



Fig.8 (a) BWB at 0° angle of attack



Fig.8 (b) BWB at 2° angle of attack



Fig.8 (c) BWB at 4° angle of attack



Fig.8 (d) BWB at 8° angle of attack



Fig.8 (e) BWB at 10° angle of attack

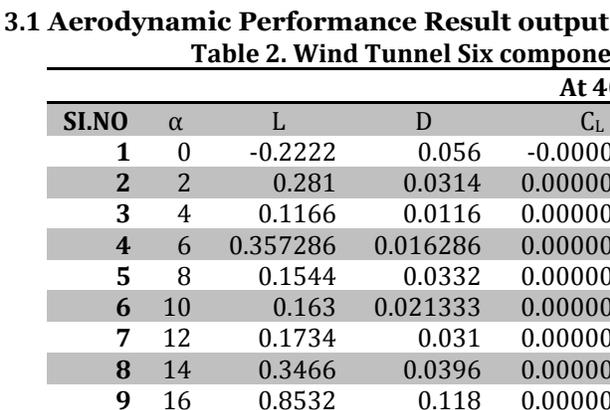
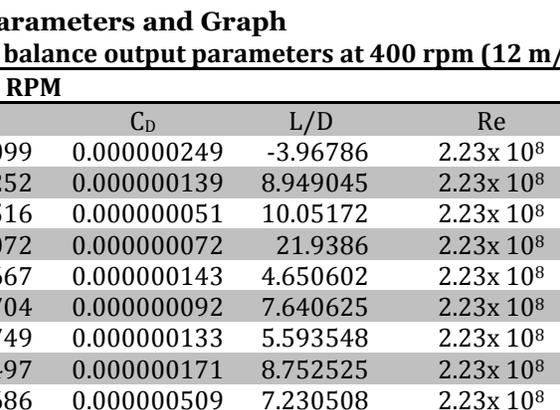


Fig.8 (f) BWB at 12° angle of attack



3.1 Aerodynamic Performance Result output Parameters and Graph

Table 2. Wind Tunnel Six component balance output parameters at 400 rpm (12 m/s)

At 400 RPM							
SI.NO	α	L	D	C_L	C_D	L/D	Re
1	0	-0.2222	0.056	-0.00000099	0.000000249	-3.96786	2.23×10^8
2	2	0.281	0.0314	0.000001252	0.000000139	8.949045	2.23×10^8
3	4	0.1166	0.0116	0.000000516	0.000000051	10.05172	2.23×10^8
4	6	0.357286	0.016286	0.000000072	0.000000072	21.9386	2.23×10^8
5	8	0.1544	0.0332	0.000000667	0.000000143	4.650602	2.23×10^8
6	10	0.163	0.021333	0.000000704	0.000000092	7.640625	2.23×10^8
7	12	0.1734	0.031	0.000000749	0.000000133	5.593548	2.23×10^8
8	14	0.3466	0.0396	0.000001497	0.000000171	8.752525	2.23×10^8
9	16	0.8532	0.118	0.000003686	0.000000509	7.230508	2.23×10^8

Table 3. Wind Tunnel Six component balance output parameters at 800 rpm (25 m/s)

At 800 RPM							
SI.NO	α	L	D	C_L	C_D	L/D	Re
2	0	0.09625	0.08475	0.000000138	0.000000122	1.135693	3.92×10^7
3	2	0.623	0.054	0.000000906	0.000000078	11.53704	3.92×10^7
4	4	0.489	0.0498	0.000000704	0.000000071	9.819277	3.92×10^7
5	6	1.0255	0.065167	0.000001477	0.000000093	15.73657	3.92×10^7
6	8	0.6234	0.1022	0.000000897	0.000000147	6.099804	3.92×10^7
7	10	0.6432	0.1074	0.000000926	0.000000154	5.988827	3.92×10^7
8	12	0.7062	0.1318	0.000001017	0.000000189	5.358118	3.92×10^7
9	14	0.9176	0.1648	0.000001335	0.000000239	5.567961	3.92×10^7
10	16	1.6184	0.3124	0.000002354	0.000000454	5.180538	3.92×10^7

Table 4. Wind Tunnel Six component balance output parameters at 1000 rpm (35 m/s)

At 1000 RPM							
SI.NO	α	L	D	C_L	C_D	L/D	Re
1	0	0.5925	0.067833	0.000000563	0.000000064	8.734644	4.83×10^7
2	2	0.89725	0.07475	0.000000852	0.000000071	12.00334	4.83×10^7
3	4	0.7986	0.0784	0.000000759	0.000000074	10.18622	4.83×10^7
4	6	1.7116	0.0962	0.000001616	0.00000009	17.7921	4.83×10^7
5	8	0.9854	0.1554	0.000000093	0.000000146	6.341055	4.83×10^7
6	10	1.0332	0.1682	0.000000982	0.000000159	6.142687	4.83×10^7
7	12	1.0996	0.22	0.000001045	0.000000209	4.998182	4.83×10^7
8	14	1.3352	0.2614	0.000001269	0.000000248	5.107881	4.83×10^7
9	16	2.2504	0.4618	0.000002153	0.000000441	4.873105	4.83×10^7

3.1.1 Aerodynamic Performance curves

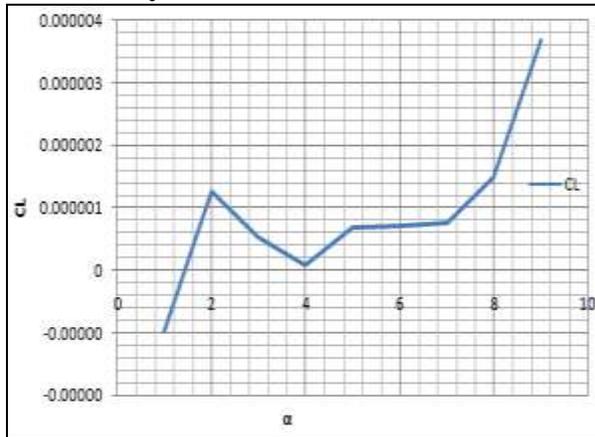


Fig. 9(a) C_L vs. α (400 RPM)

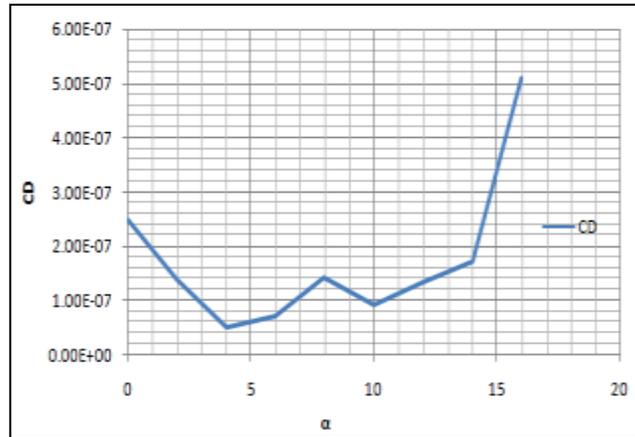


Fig. 9(b) C_D vs. α (400 RPM)

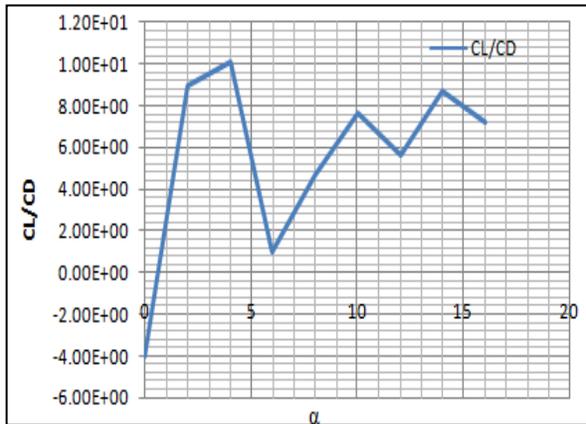


Fig. 9(c) C_L/C_D vs. α (400 RPM)

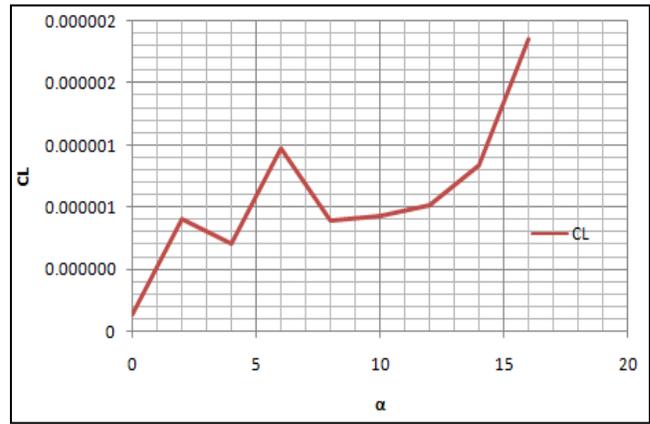


Fig. 9(d) C_L vs. α (800 RPM)

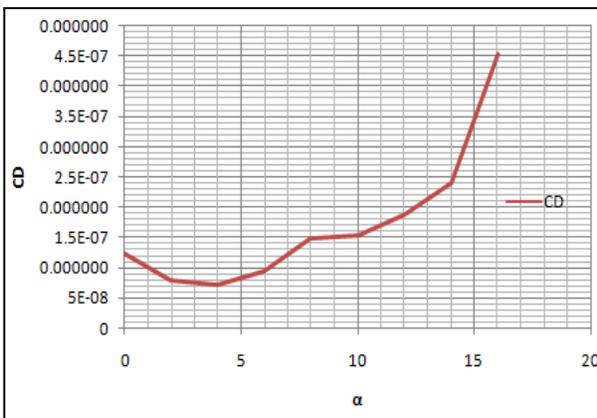


Fig. 9(e) C_D vs. α (800 RPM)

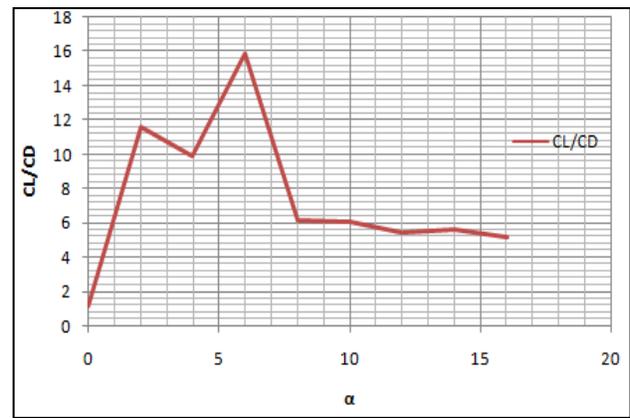


Fig. 9(f) C_L/C_D vs. α (800 RPM)

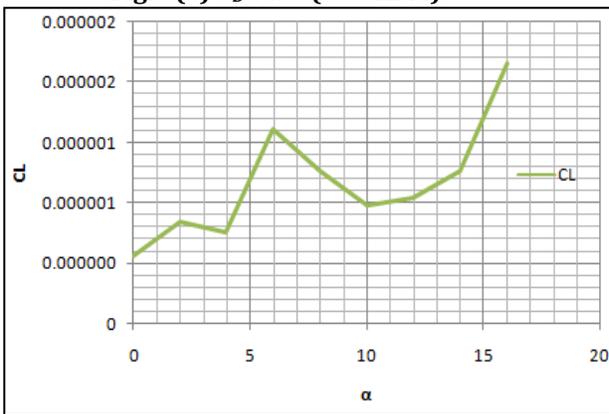


Fig. 9(g) C_L vs. α (1000 RPM)

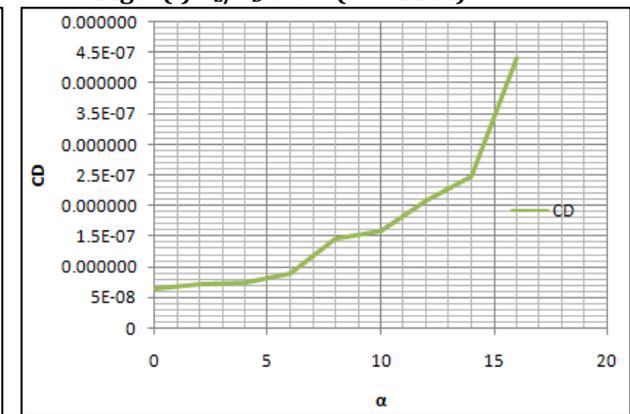


Fig. 9(h) C_D vs. α (1000 RPM)

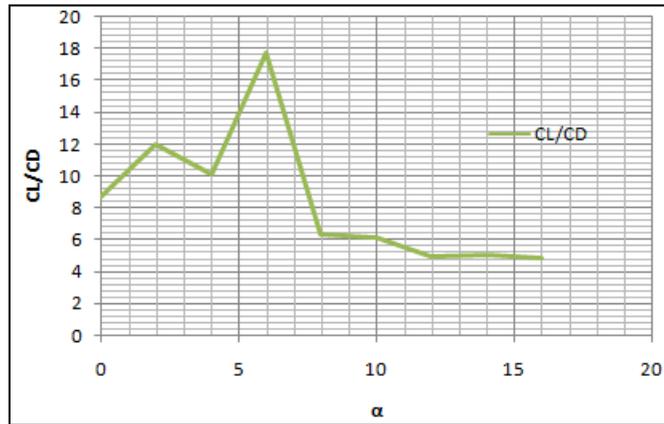


Fig. 9(i) C_L/C_D vs. α (1000 RPM)

3.1.2 Result Comparison Graph

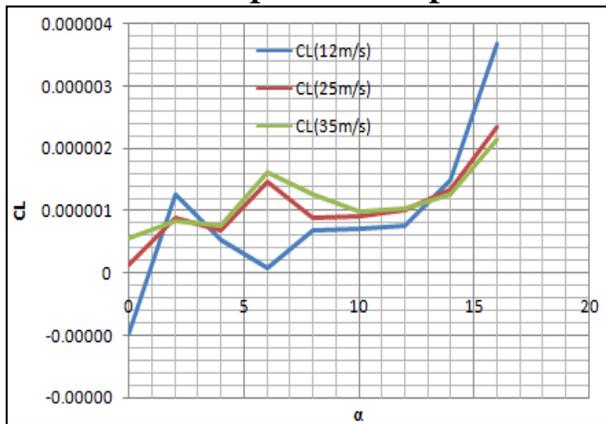


Fig. 10 (a) C_L vs. α

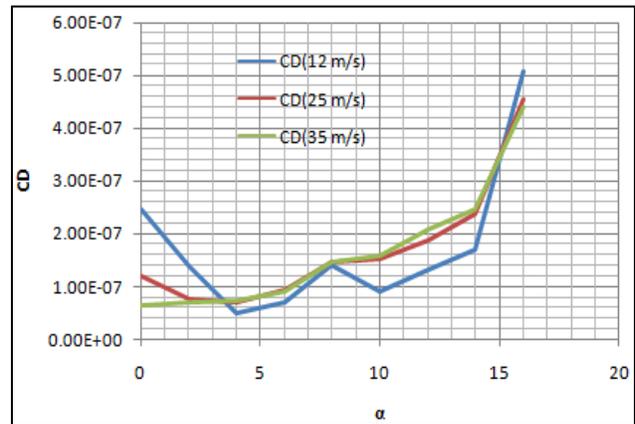


Fig. 10 (b) C_D vs. α

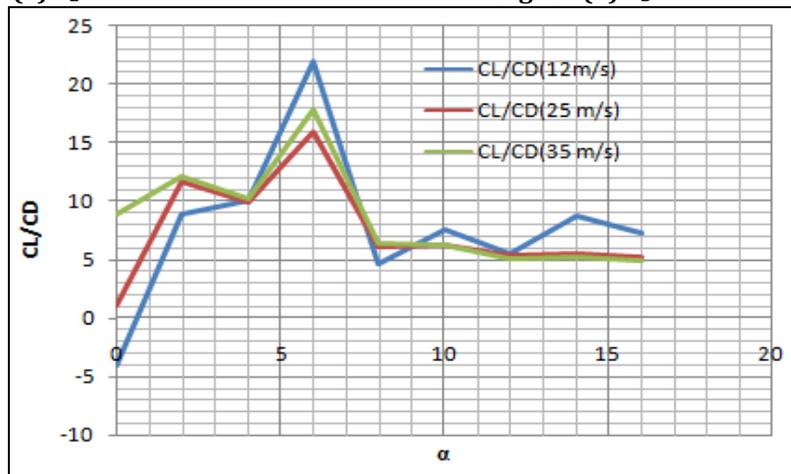


Fig. 10 (c) C_L/C_D vs. α

For the given free stream speed, the value of C_L increases as the angle of attack increases as shown in Fig. 10 (a). With increase of velocity C_D decreases initially then it increases as shown in fig. 10 (b). The lift-to-drag ratio (L/D) is a very significant parameter to pay attention to during the design process. It is the amount of lift generated by a wing or vehicle, divided by

the aerodynamic drag it creates by moving through the air. A higher or more favorable L/D ratio is typically one of the major goals in aircraft design. The L/D ratio is maximum at 6° angle of attack as shown in Fig. 10 (c). A higher lift means that more weight is allowable, which in turn means a higher payload capacity (which is very important for transport aircraft). A lower drag value

means less thrust will be required and hence lower fuel consumption (which is often the operators' largest operating cost).

4. CONCLUSION

The BWB is tested in wind tunnel to calculate the aerodynamic performance parameters which plays an important role in the design and sustainability of the Blended wing body aircraft. From experimental analysis we understand that, the BWB design configuration is much better compared to conventional aircraft. It has been found that the blended wing body can obtain better efficiency and high performance at subsonic speeds.. The lift generated by the blended wing body was found to be more than the conventional aircrafts. There was also a reduction in drag for the BWB. One of the most significant differences between conventional aircrafts and the BWB is that the body or the fuselage of the BWB generates lift which was confirmed by the analysis of the center body. The BWB having a higher (L/D) ratio and the higher L/D ratio the potential to become the future of commercial transport aircraft.

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