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EFFECT OF STALL ON BLENDED WING BODY AIRCRAFT

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Abstract- This paper represents the study of effect of wing sweep on blended wing body aircraft at different sweep angles with fixed planform design. A 3-D BWB model was designed in CATIA V5 and simulation was carried in ANSYS fluent . Twenty-three BWB geometries with varying sweep ranging from -40^0 (forward sweep angle) to 55^0 (backward sweep angle) were designed, with the aerofoil profiles and twist distribution unchanged from the original geometry. This gives insight on the planform of the design.

The simulations were carried out using Euler solutions of flow field.The body was meshed with unstructured grids with tetrahedral and triangular shapes .The best sweep angle BWB was found between forward and backward sweep angles .The best sweep angle was considered and the angle of attack of the whole body of the aircraft was changed. The stalling angle of attack of the aircraft was found using the best sweep angle.

Keywords – Blended wing body, wing sweep, Lift to Drag ratio (L/D), Coeffecient of lift (Cl), Coeffecient of drag (Cd), Lift (L), Drag (D) ,Coeffecient of lift /Coeffecient of Drag (Cl/Cd)

I. INTRODUCTION

Ever since the first aircraft designed and flown by Wright Brothers in 1903, many improvements were done to achieve better design and performances. But much of the advancements were made in the aerodynamics, propulsion systems, structures, materials and electronics and apart from the minor changes, the blueprint of the airplane geometry i.e. the classic tube and wing design has always been constant. With the increasing concern for the environment and the depleting fuels, research has been going on to develop a more efficient and environmentally friendly aircrafts, hence unconventional designs are gaining popularity in the recent decades.

Fig. 1: The BWB concept

The BWB concept has been inspired from the flying wing aircraft, it combined the aerodynamic advantages of flying wing with the loading capabilities of that of traditional aircraft, by increasing the volume of the wing at the center to act as a fuselage. This allows BWB aircraft to carry more passengers and cargos. Some conceptual Unmanned Air Vehicle (UAV) designed based on the blended delta wing-body configurations exhibit vortex-dominated flows. Research has reported some aerodynamic, stability and control issues for these configurations

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The present work focuses on the aerodynamic study of the blended wing body configuration at transonic speeds. The model was designed in CATIA V5 and then the analysis was done in ANSYS fluent .in the first analysis the best sweep angle was determined and with the best sweep angle the stalling angle of the aircraft was determined .

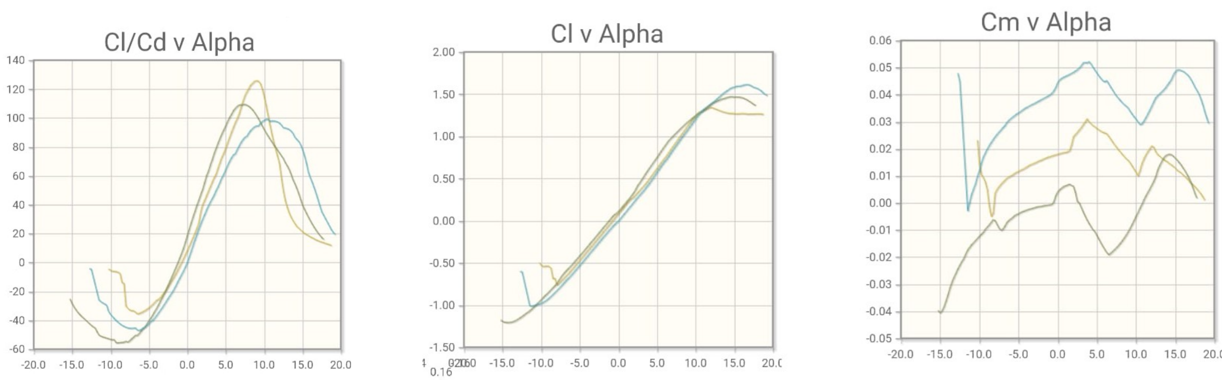
II. DESIGN METHODOLOGY

For the analysis the design was carried out in various ways . Mentioned below are the points of the whole design process.

A. Selecting the airfoils -

The BWB can be divided into – the body and the wing. The majority of the lift was to be produced by the center body and the wing would have the control surfaces to maneuver the airplane. A total of ten cambered and symmetry airfoils were selected the list was shortened to only four airfoils: LA 2573A, HS 522, MH78 and NACA 25111. out of which NACA 25112 and MH78 was used to design the BWB model. The NACA 25112 was used to generate high lift a high lift generating airfoil was required which has high lift coefficient of about 0.82 and also the L/D ratio of the airfoil was high compared to other airfoils .

The MH78 airfoil can give negative moment of coefficient (CM) thus the outer wing must have a positive CM in order to balance out its effects. CM contributes to the longitudinal stability. Since the BWB is a tailless aircraft they can counter the negative pitching moment. The airfoils coordinates were selected from airfoiltool.com and the variation of Cl, Cd, Cm and the graph of the variation was analyzed in the airfoiltools.com



(a) (b) (c)

Graph 1. (a) Cl/Cd vs Alpha (b) Cl vs Alpha (c) Cm vs Alpha

Table 1: Variation in aerodynamic characteristics of the airfoils

AIRFOILS	Cl	Average Cm	Max Cl/Cd
LA 2573A	0.62	0.02	123
HS 522	1.3	-0.01	100
MH78	1.4	0.04	105
NACA 25112	1.55	-0.01	122

B.Modelling(CATIAV5)

The following steps were involved in the process of modelling of CATIA:

- These coordinates were imported to GSD points plotter were the aerofoil coordinates can be imported to CATIA V5 .
- All the aerofoil coordinates were plotted and the surface or volume sweep was given to the aerofoil .
- Winglets were made with the help of the plane creation at a particular height.

- Out of all the sweep angles 43degree backward sweep was the best.
- Considering all this only 43degree backward sweep model was used to find the stalling angle of attack of aircraft.

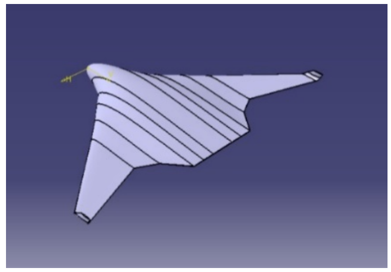


Fig 2**:** BWB 43 Degree Sweep Angle.

Table 2: Final plane configuration

Section	From center chord /in	Offset (from center)/ in	Chord in	Air-foil name	Thickness %
1	0	0	31.0	NACA 25111	11
2	2	3.5	27.5	NACA 25111	11
3	4	7.5	23.5	NACA 25111	10.6
4	6	9.5	21.5	NACA 25111	8.2
5	9	12.6	14.5	MH 78	6.9
6	12.3	15.8	9.5	MH 78	5.2
7	24	28.0	3.0	MH 78	4
Aspect ratio 4.6		CG 16.2 in from Y		Area :546.8 in^2	

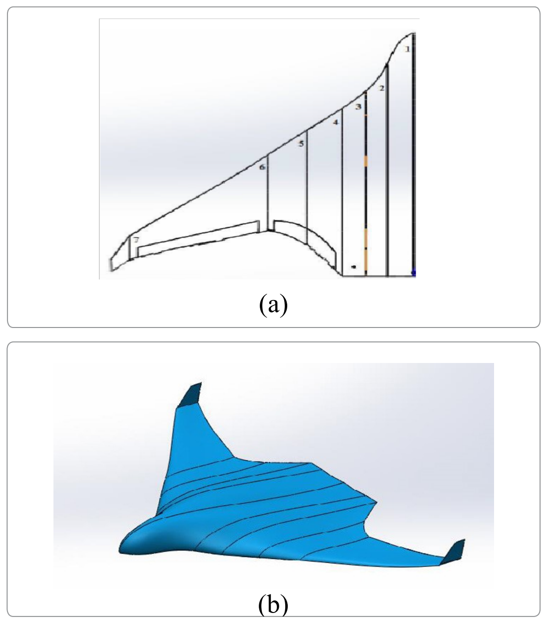
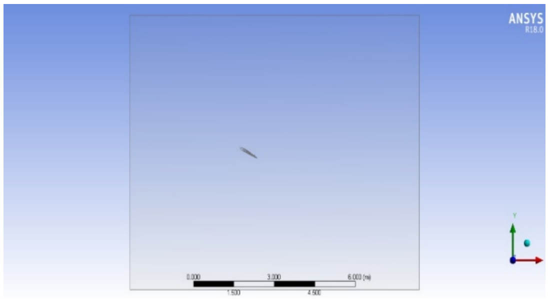


Fig 3. (a) Top view of sections (b) Isometric view of final design

C. CFD (ANSYS fluent)

Geometric modelling

- In CFD process ansys fluent was used
- The CATIA model was then imported to the ansys software for analysis
- A rectangular grid domains of size 4 times the chord to the intake and 6 times the chord to the outlet and 6 times the chord to the upper and lower surface are generated around model to produce a unstructured grid in the computational domain.
- The BWB models Angel of attack was changed from 1 degree to 45 degree to find the best stalling angle.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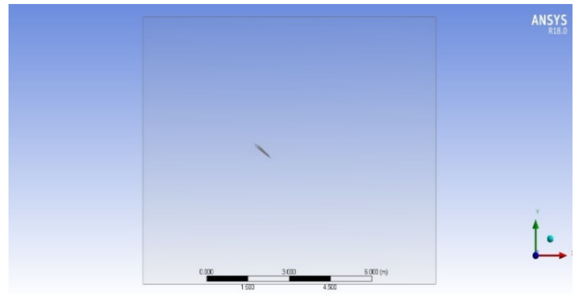
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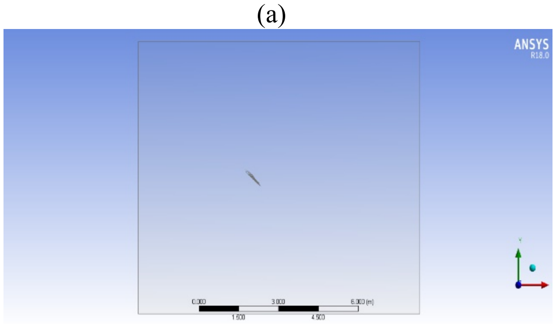
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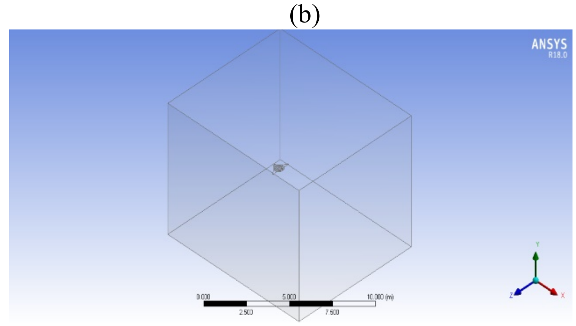
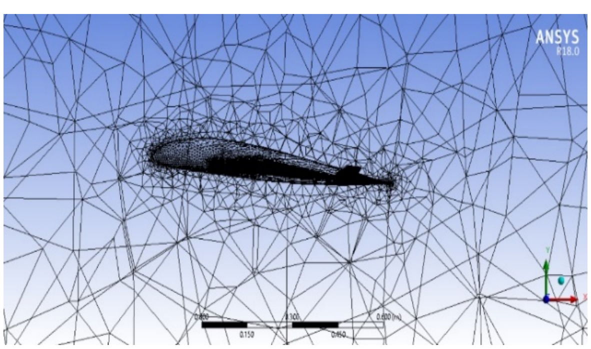

(d)

Fig 4. (a) Side view of Geometric model of BWB 43 Degree Sweep Angle 01 deg AOA
(b) Side view of Geometric model of BWB 43 Degree Sweep Angle 30 deg AOA
(c) Side view of Geometric model of BWB 43 Degree Sweep Angle 35 deg AOA
(d) 3D view of Geometric model of BWB 43 Degree Sweep Angle 45 deg AOA

D. Meshing

- Mesh is generated around the full model using the commercial meshing software ANSYS with the solver fluent .
- The grid used for the simulation is tertrahedral unstructured grid everywhere except the tip of the wing where triangular type is generated.
- The adjacent plane to the model act as symmetry plane.The mesh contains 3-6 lakhs cells and was generated and nodes were upto 48000-120000 .
- Face meshing was done with a relevance of 100 and relevance centre -medium.
- The far field was in fluid state condition.
- The figures below show the meshed model and differences in Angle of attack of the aircraft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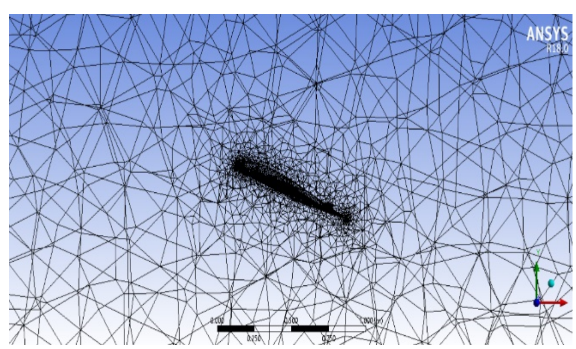
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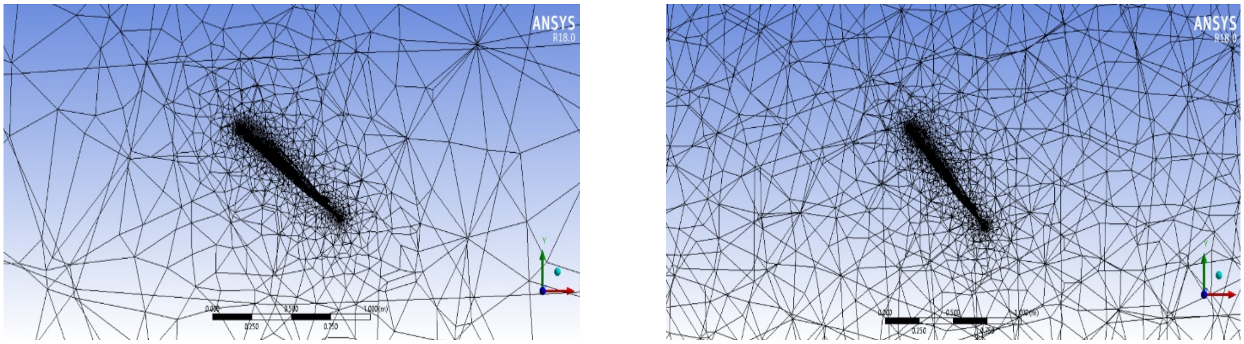


(c) (d)

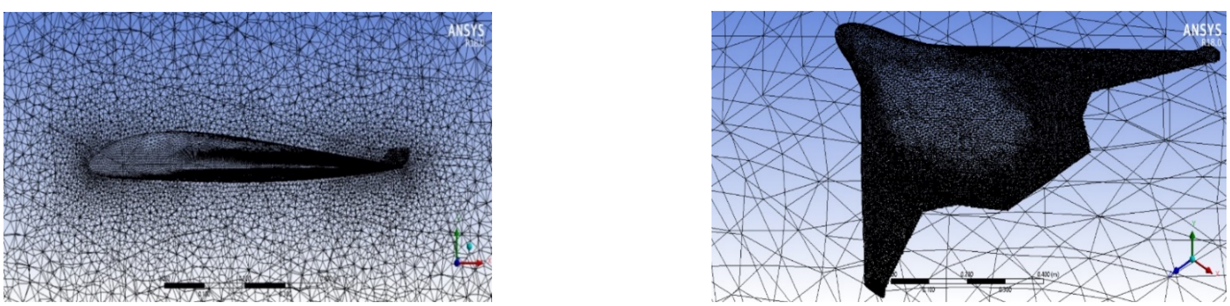
Fig 5. (a) Side view of meshed model of BWB 43 Degree Sweep Angle1 deg AOA
(b)Side view Of meshed model of BWB 43 Degree Sweep Angle 20 deg AOA
(c)Side view Of meshed model of BWB 43 Degree Sweep Angle 30 deg AOA
(d)Side view Of meshed model of BWB 43 Degree Sweep Angle 45 deg AOA

E. Grid Adaptation

Grid adaptation is a method by which cells are refined in areas of large gradients of properties, which help in pressure, velocity and density counters. By grid adaptation, these truncation errors can be reduced to provide a more accurate and reliable solution due to a more even distribution of errors.

The meshed model shown below is the model with 3-6 lakh nodes and lakh elementsThe meshed model shown below has element – 4400000 and nodes -1200000 and it had a skewness of 0.79 and aspect ratio of 6.7 which was best for getting accurate results .It was not able to be solved as it would take 3 to 4 days for solving 1 model and the computers couldn't handle the heat . So, the elements and nodes with less number were used. As the Software was cracked version and student version some of the operations were not valid and some restrictions were found for better meshing.

Shocks could have been found if the model had structured grid and a better version of the software.



(a) (b)

Fig 6. (a) Side view Of meshed model of BWB 40 Degree Sweep Angle
(b) 3D view of Meshed model of BWB 40 Degree Sweep Angle

F. Setup and Solver

- The solve is used to solve the meshed model of the BWB.
- The model to use density based solver and the speed was transonic (0.8 Mach)
- The turbulent model was SST K-omega for the transonic speeds and if the speed is subsonic then k-epsilon could be used.
- The Boundary conditions are given below

1)Boundary inlet

Type	Pressure farfield
Location	D_INLET
Flow regime	Transonic
Mach no	0.8
Total temperature	3.00e+02 [K]

2) Boundary outlet

Type	Pressure outlet
Location	D_OUTLET
Flow Regime	Transonic
Gauge pressure	0 Pascal

3) Boundary of wall and aircraft

Type	Wall
Mass and Momentum	No Slip Stationary wall
Wall Roughness	Smooth wall Standard condition

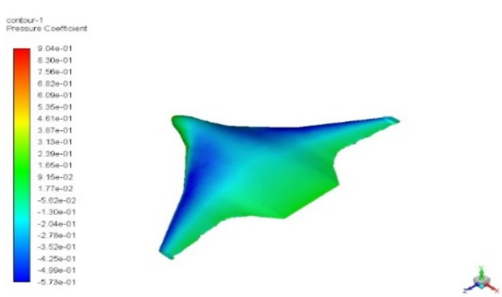
III. RESULTS AND DISCUSSION

- The best sweep angle at 43 degree has an L/D ration o 15.23 which was best obtained from 22 different models.
- This best sweep angle was considered and the stalling Angle of attack was determined
- The pressure counters shown below are the variation in Angle of attack from 1 degree to 45 degree
- We can see that the pressure on the upper surface of the aircraft goes to a maximum of about 3.29*E005 for 35 degree where the aircraft stalls at a Cl max of 0.369.
- From lift equation we can say that velocity Sq increases coefficient of lift decreases.

  Since velocity is inversely proportional to coefficient of lift.
- The lift coefficient C_L equation is given by

$$C_L \equiv \frac{L}{q\,S} = \frac{L}{\frac{1}{2}\rho u^2\,S} = \frac{2L}{\rho u^2 S}$$

For Stalling Angle of Attack



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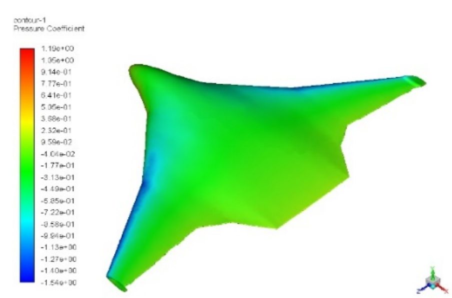

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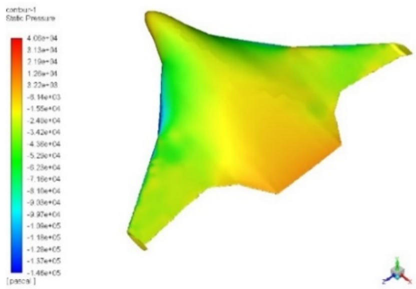

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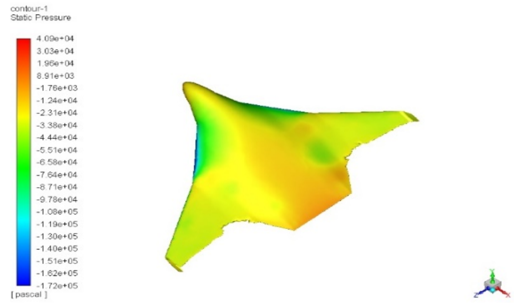

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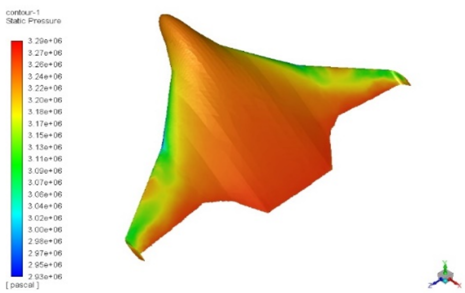

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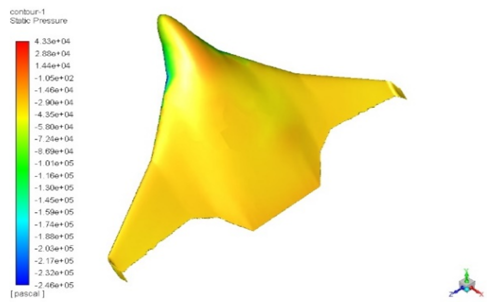


(f)

Fig 7. (a) pressure counter of 1 deg AOA (b) pressure counter of 5 deg AOA
(c) pressure counter of 15 deg AOA (d) pressure counter of 20 deg AOA
(e) pressure counter of 35 deg AOA (f) pressure counter of 45 deg AOA

Table.3 :Obtained and calculated forces for BWB aircraft

Alpha	Lift(N)	Darg(N)	Cl	Cd
0	859.87	113.87	0.02498	0.002165
1	1554.15	131.17	0.0336	0.00284
2	2943.48	162.74	0.06381	0.003528
3	3948.85	200.38	0.08561	0.00434
4	4457.51	216.49	0.09663	0.004693
5	5309.69	303.23	0.1151	0.00657
6	6491.56	376.59	0.140	0.0081
7	7428.7	483.1	0.1610	0.001047
8	8602.55	600.82	0.18650	0.01302
9	8980.95	690.45	0.19578	0.0156
10	9953.50	862.84	0.21587	0.0187
15	12355.9	2312.6	0.26787	0.05013
20	13974.4	3811.5	0.30296	0.08263
25	14309.6	5207.3	0.311023	0.112895
30	14894.6	7211.3	0.33291	0.15634
35	**17053.7**	**9080.6**	**0.3697**	**0.19686**
40	14768.4	10729.0	0.32017	0.2326
45	14070.6	12344.9	0.3050	0.2676

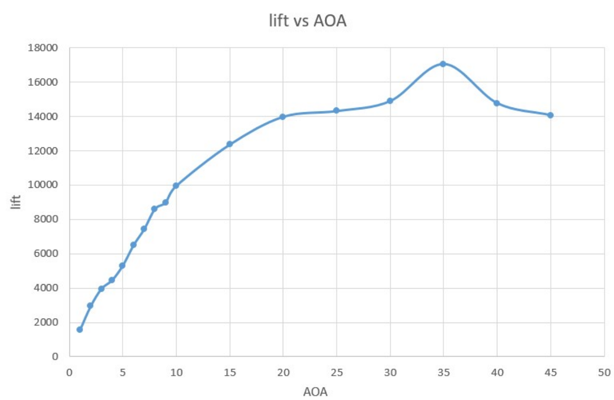
IV. AERODYNAMIC CHARECTERISTICS OF BWB

The below graphs shows the variation of lift and drag vs Angle of attack

- Max lift was obtained at 35 degree AOA of 17053.721 N
- Max drag was obtained at 45 degree AOA of 12344.956 N
- Stalling angle of attack was obtained at 35 degree (cl-0.3697)

A. Lift vs Angle of attack

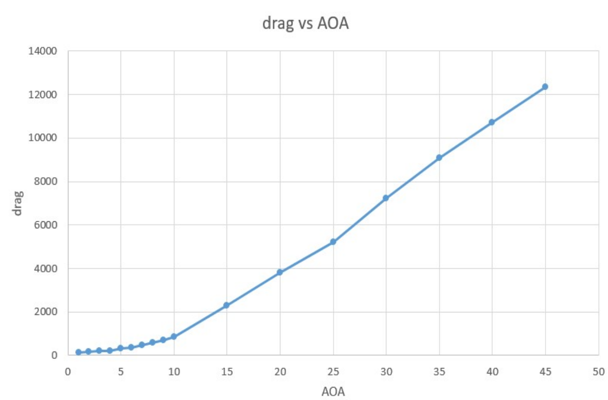
The lift vs Angle of attack (α), for deflection from 05 to 45 degree. The curves have similar trends where lift coefficient increase as angle of attack increase until it reaches its maximum value at around 35°. Beyond this angle, the lift coefficient decreases as angle of attack increases.



(a)

B. Drag vs Angle of attack

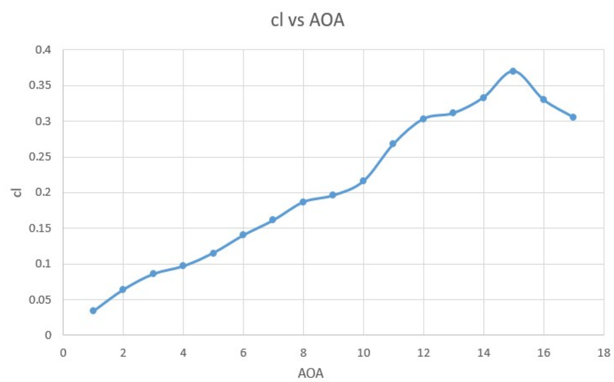
The variation of D (Drag) with respect to angle of attack (α).The drag increases as the angle of attack increases.



(b)

C. Lift Coefficient vs Angle of attack

The Lift Coefficient vs Angle of attack (α), the results obtained are as follows, Value of CL (Lift Coefficient) increases as the angle of attack increases until its maximum value at around α = 35° and decreases with lower slope. Value of CL max increases as the air velocity of wind tunnel increases. Hence CL max increases with increase in Reynolds number.



(c)

Graph 2. (a) Lift vs AOA (b) Drag vs AOA (c) Coeffecient of lift vs AOA (d) Lift/Drag vs AOA

V.CONCLUSION

The aim of the project was to design a small scale BWB aircraft for different sweep angles (forward and rearward). In consideration of their lift and moment characteristics, NACA 25111 and MH78 were selected for the center body and the wing respectively. The aerofoils were used to construct a model in CATIA V5 and then it was exported to ANSYS software for the analysis. The coefficient of lift, coefficient of drag and coefficient of moment of the BWB aircraft were investigated in steady state CFD at Mach no regime at transonic flow.9

From the above analysis we got to know the best sweep angle is 43^0 and stalling angle of attack was 35 degree and the Cl max= 0.3697 for the best sweep angle and we can still give twist and dihedral dimensions to this geometry so that better design will give the best performance.

- The L/D ratio of a BWB aircraft at different sweep angle is identified.
- The best sweep angle is determined.
- The stalling angle for the best sweep angle is determined**.**

VI. FUTURE WORK

From the above analysis we got to know the best sweep angle is 43^0 and stalling angle of attack was 35 degree and the Cl max= 0.3697 for the best sweep angle and The BWB can still be given twist and dihedral dimensions to this geometry so that better design will give the best performance.

For the future work the body of the aircraft can be modelled and tested in wind tunnel and compare the theoretical value to the practical value for further references.

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