Aerodynamic Design And Analysis Of Small Scale Blended Wing Body

[1]Deepti Arahunashi, [2]Vishal Siddaramappa Laxmeshwar, [3]Ravikumar Vitthal, [4]Deekshitha H L

[1]Student, [2]Student, [3]Student, [4]Student
[1]Department of Aeronautical Engineering,
[1]Srinivas Institute of Technology, Mangaluru, India

Abstract:
The blended wing body (BWB) concept is a relatively new concept of an aircraft. In recent years there has emerged a significant increase of interest in design of blended wing body aircraft, specifically applied to large commercial transport aircraft. The wings and the fuselage blend into one integral structure greatly reduce drag and increases lift thus making it a highly efficient design. The BWB design has been proven to have significant improvements in aerodynamic efficiency as compared to the conventional wing fuselage design. In consideration of their lift and moment characteristics, NACA2418 and NACA0017 airfoils are selected. Centre of gravity will be placed ahead of aerodynamic centre to provide static and dynamic stability in pitch. In this project an attempt has been made to design a blended wing body using CATIA V5 and analyze it through CFD approach using 3D EXPERIENCE SOFTWARE by Dassult systems to analyze flow pattern. The results of CFD work is compared with the already available results of swept back wing. And the wooden model of BWB is made and tested for smoke flow visualization in low subsonic wind tunnel. The study is focused to find the aerodynamic efficiency (lift force to drag force ratio) by finding the lift and drag forces at different angle of attack. BWB is fuel efficient and environment friendly. Improving fuel efficiency is important for an environment as well as from economical perspective. BWB is fuel efficient and environment friendly. So the study is focused on increasing aerodynamic efficiency which will give fuel efficiency and environment friendly product.

I. INTRODUCTION

1.1 Blended Wing Body

BWB are hybrid wing body aircraft have a flattened and airfoil shaped body, where the fuselage is merged with a wing, a tail to form a single entity. BWB is a hybrid flying wing aircraft with a conventional aircraft fuselage where the body is designed to have a shape of an airfoil and carefully streamlined with a wing to have a desired platform. Blended Wing Body (BWB) aircrafts differ from usual conventional aircraft designs in the idea that the main body of the aircraft could help in the lift effort of the whole structure.

The wing in conventional aircraft is the main contributor to the lift generation. In the BWB the lift is generated by the blended wing as well as fuselage, thus increasing the effective lifting surface area. The streamlined shape between fuselage and wing intersection reduces interference drag, reduces wetted surface area that reduces the 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, and hence increases payload and fuel capacity.

The BWB concept aims at combining the advantages of flying wing with the loading capabilities of conventional airliner by creating a wide body in the centre of the wing to allow space for passenger and cargo. Especially, for large transport aircraft the BWB concept is often claimed to be superior compared to conventional configuration in terms of higher lift to drag ratio and less fuel consumption.

1.2 Key concept of blended wing body design

Since the initial design of BWB in1988, it has been refined to its current state. The principle concept behind the current iteration of the BWB is the blending of various components of the plane, including the fuselage, wings and the engines, into a single lifting surface. As a result the BWB fuselage is harder to distinguish from the wing (i.e.it is harder to tell where the wing ends and fuselage begins).

There are some key concepts to note about the design of BWB:

- **The BWB is tailless aircraft:** because of the disc shaped nature of the fuselage, the BWB does not have tail. As a result, BWB does not have the rudder.

- **The engine location of the BWB:** Another important characteristic of BWB design is position of the engines, are located at the aft sections of the plane. Because of weight and balance consideration of the plane, the engines needed to be placed at the rare of the plane. The fuselage can serve as an inlet for the intake of air.

- **Control surface:** The control surfaces of wing are located along the leading and trailing edges of the wing and on the winglets, the number of control surface can be varied from 14-20 depending on the BWB design.

1.3 Advantages of a blended wing body aircraft

The BWB has several distinct advantages over the convenience of the aircraft. Some of these advantages are outlined below:

- **Higher fuele fficiency:** initial testing of BWB aircraft has indicated that it can have up to a 27% reduction in fuel burn during flight.

- **Higher payload capacity:** due to the blended nature of fuselage, the fuselage is no longer distributed along the centre line of the aircraft. As a result, the fuselage is more spread out, allowing for greater volume and a larger payload capacity.

- **Lower take-off weight:** Early design concepts have a determine that the BWB can have up to a 15% reduction of take-off weight when compared to the convectional baseline.

- **Lower wetted surface area:** the concepts design results in a total wetted difference of 14300 ft2, a 33% reduction in wetted surface area. This difference implies a substantial improvement in aerodynamic efficiency.

II. METHODOLOGY

2.1 Airfoil selection

For 2D airfoil selection in computational domain, a basic and simple approach was adopted by studying few published papers. After studying and analyzing, NACA 2418 and NACA 0017 airfoils are selected. The airfoil selection process was focused on the airfoil components to achieve favorable pressure distribution and maximum lift and minimum drag coefficients.NACA 2418 airfoil has Max thickness 18% at 30% chord and Max camber 2% at 40% chord. NACA 2418 gives, comparatively high lift coefficient, can be used at Reynolds number 10,000 and NACA 0017 is a symmetric airfoil.

Table 1 Airfoil details of NACA 2418

Parameters	Dimensions	Parameters	Dimensions
Thickness	18%	Max Cl angle	15 degree
Camber	2%	Max L/D	7.157
Leading edge radius	4%	Max L/D angle	7.5 degree
Trailing edge angle	36.4%	Efficiency	36.8
Lower flatness	4.6%	Stall angle	7.5 degree
Max CL	0.459	Zero lift angle	4.5 degree

2.2 3D modeling using CATIA

CATIA (computer aided three dimensional interactive application) is a multi-platform CAD/CAM/CAE commercial software suite developed by French company Dassault systems. CATIA facilitates collaborative engineering across disciplines, including surfacing and shape design, mechanical engineering, equipment and systems engineering. Using this user friendly software the Designing of the BWB aircraft is done. Figure 1 shows the designed BWB model in CATIA software.

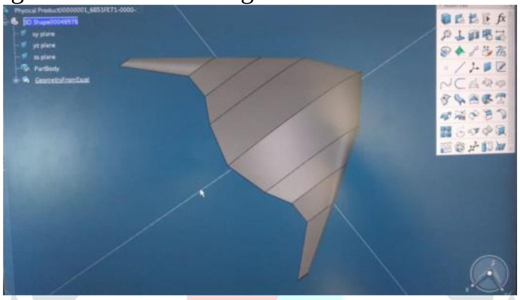


Figure 1 BWB Model Designed in CATIA

2.3 Computational fluid dynamics using 3D EXPERIENCE software by dassault system

The 3D EXPERIENCE platform is a business experience platform. With a single easy-to-use interface, it powers industry solution experiences-based on 3D design, analysis, simulation, and intelligence software in a collaborative, interactive environment. Dassault systems offers industry-leading applications delivered on 3D EXPERIENCE platform: design and engineering, manufacturin and production, simulation, governance and lifecycle, 3D design experience for professionals. Here the flow analysis over the BWB is done in the 3D EXPERIENCE software.

Figure 2 logo of 3D EXPERIENCE software

Boundary conditions:

Boundary conditions for aircraft at different angle of attack are considered as follows:

Velocity inlet= 50 m/s

Pressure outlet= 0 MPa

2.4 Wind tunnel testing

Wind tunnel is a tool used in aerodynamic research to study the effects of air/smoke(in case of smoke flow visualization) moving past solid objects. A wind tunnel consists of a tubular passage with the object under test mounted in the middle. Air is made to move past the object by a powerful fan system. The test object, often called a wind tunnel model, is instrumented with the suitable sensors to measure aerodynamic forces, pressure distribution, or other aerodynamic related characteristics.

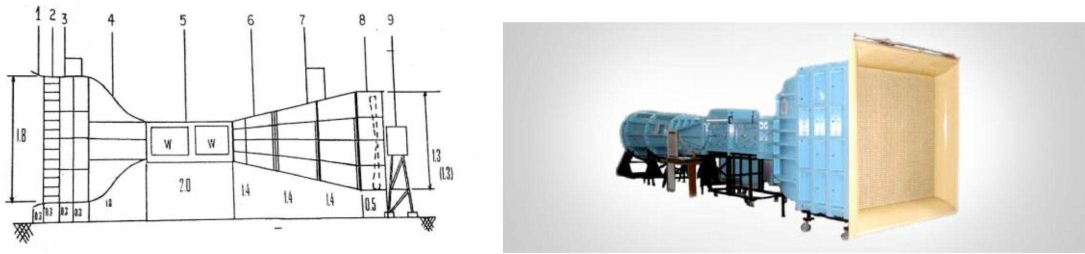


Figure 3 Wind tunnel used for smoke flow visualization

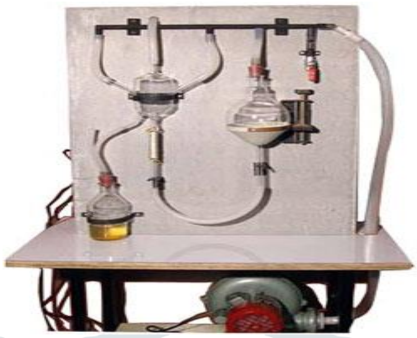
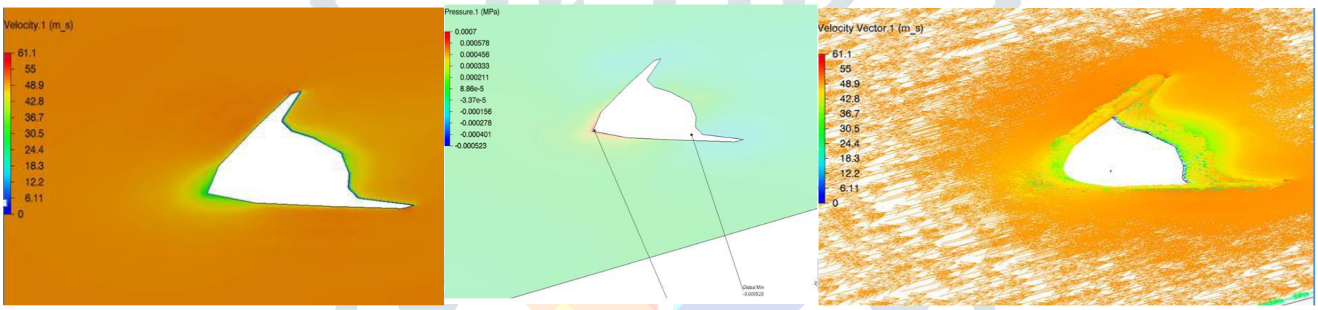


Figure 4 Smoke generator

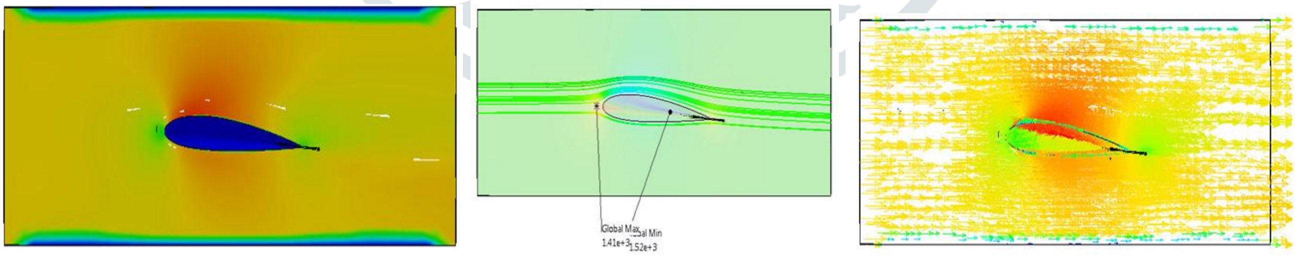
III. RESULTS AND DISCUSSION



(a) (b) (c)

Figure 5: (a) velocity contour for AOA=0, (b) Pressure contour for AOA=0, (c) Velocity vector plot for AOA=0

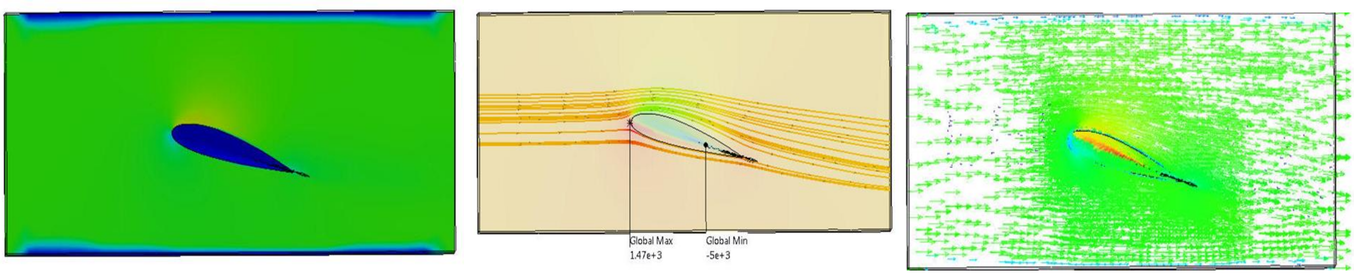
The above figure shows the contour and velocity plots at zero angle of attack. The velocity at the leading edge and trailing edge of the aircraft is slightly lesser than the velocity of air around it. The pressure at leading edge is minimum when compared to the pressure at the wing portion. The vector plot shows there is no flow separation and wake formation around the aircraft.



(a) (b) (c)

Figure 6: (a) velocity contour for AOA=5, (b) Pressure contour for AOA=5, (c) Velocity vector plot for AOA=5

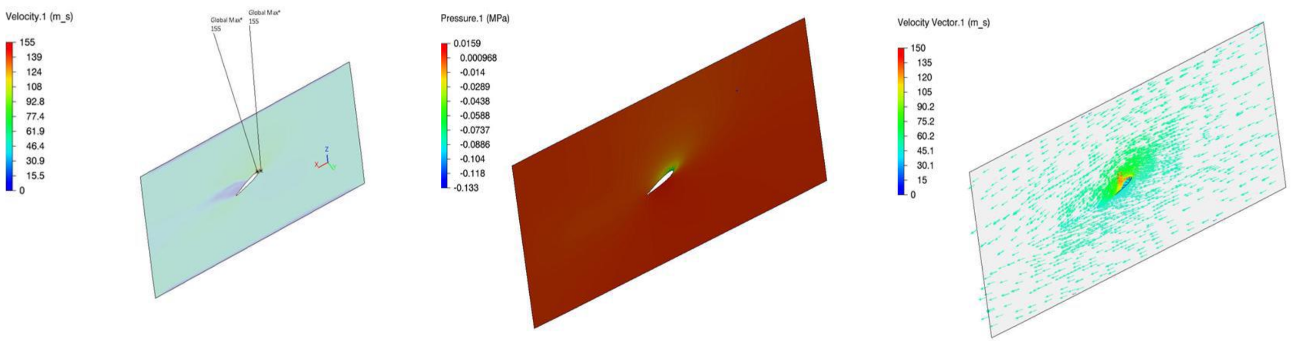
The above figure shows the contour and velocity plots at 5 degree angle of attack. The velocity at the leading edge and trailing edge of the aircraft is slightly lesser than the velocity of air around it. The pressure at leading edge is minimum when compared to the pressure at the wing portion. The vector plot shows there is no flow separation and wake formation around the aircraft.



(a) (b) (c)

Figure 7: (a) velocity contour for AOA=15, (b) Pressure contour for AOA=15, (c) Velocity vector plot for AOA=15

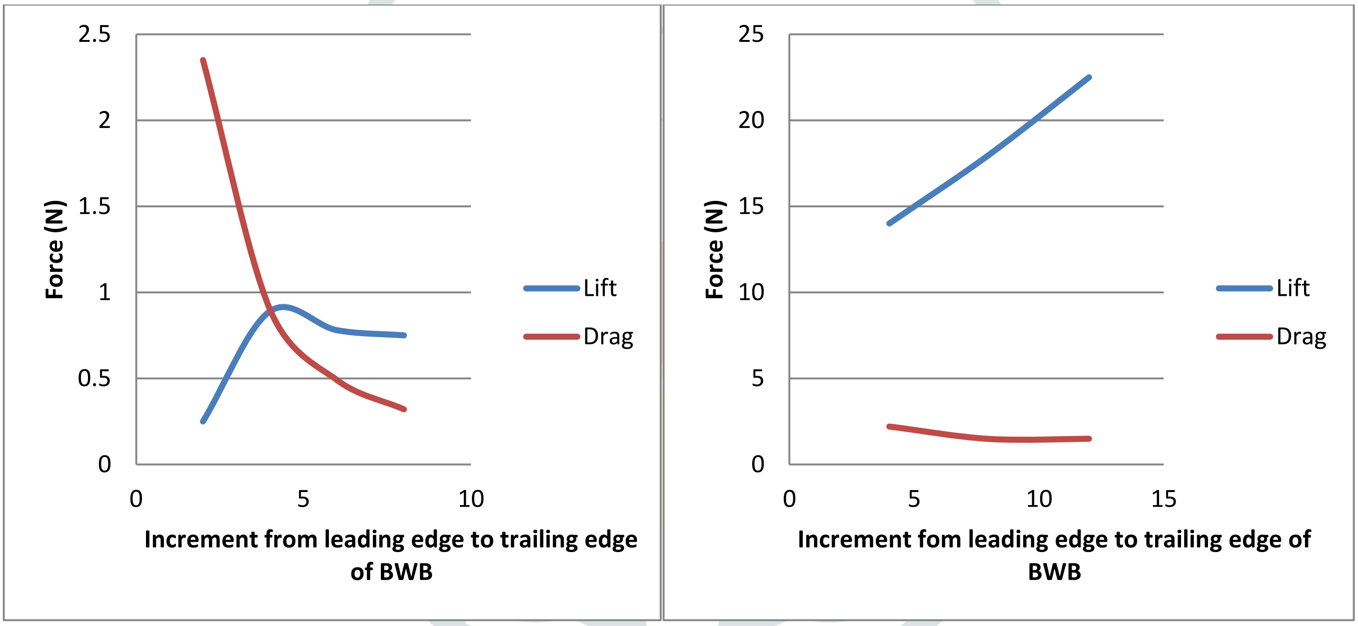
The above figure shows the contour and velocity plots at zero angle of attack. The velocity at the leading edge and trailing edge of the aircraft is slightly lesser than the velocity of air around it. The pressure at leading edge is maximum when compared to the pressure at the wing portion. The vector plot shows there is no flow separation and wake formation around the aircraft.



(b) **(b)** **(c)**

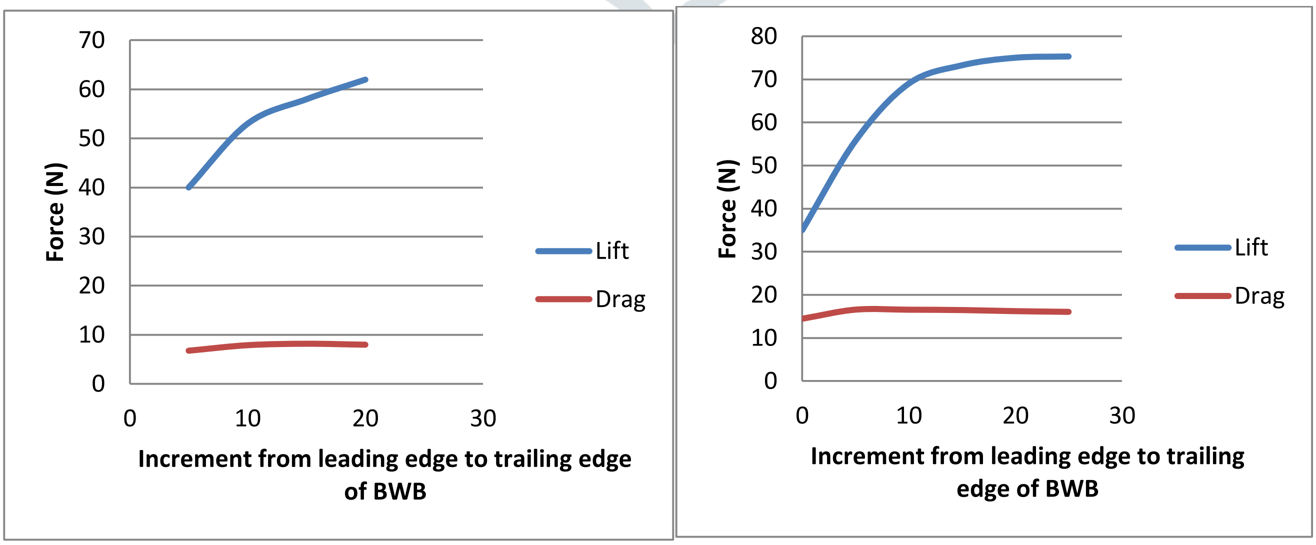
Figure 8: (a) velocity contour for AOA=20, (b) Pressure contour for AOA=20, (c) Velocity vector plot for AOA=20

The above figure shows the contour and velocity plots at zero angle of attack. The velocity at the leading edge and trailing edge of the aircraft is slightly lesser than the velocity of air around it. The pressure at leading edge is minimum when compared to the pressure at the wing portion. The vector plot shows there is no flow separation and wake formation around the aircraft.



(a) **(b)**

Figure 9: Variation of lift and drag for (a) AOA=0 and (b) AOA=5



(a) **(b)**

Figure 10: Variation of lift and drag for (a) AOA=15 and (b) AOA=20

From the graph we can say that the lift increases and drag decreases from leading edge to trailing edge of the aircraft. Hence this gives good aerodynamic efficiency to the aircraft.

3.2 Comparison between swept back wing and BWB aircraft

Table 2 L/D ratio for different angle of attack

Angle of attack	L/D ratio for swept back wing	L/D ratio for Blended Wing Body
0	-	0.280557
5	11.23338	4.645265
15	3.676471	6.150846
20	2.7458881	4.154673

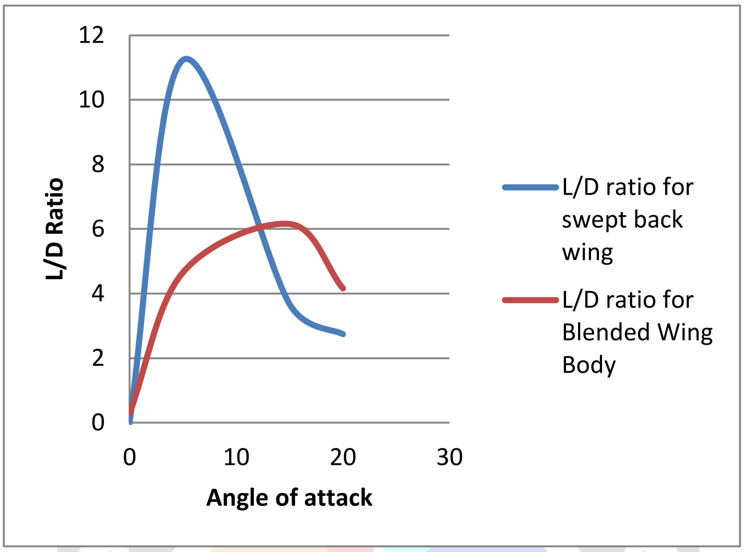


Figure 11 Variation of L/D with different AOA for BWB and Swept back wing

From the above graph we can observe that, for Swept back wing the L/D ratio is more for lesser AOA and decreases gradually. For BWB the L/D ratio increases as AOA increases and decreases little. So compared to BWB the Swept back wing has less aerodynamic efficiency.

The results of smoke flow visualization also shows that the flow around the aircraft is smooth even at higher angle of attack and there is no wake formation or flow separation.

IV. CONCLUSION

In present study the simulation is carried out for sub-sonic flow on scaled model at different angle of attack in 3D EXPERIENCE software. The results are shown in various means including velocity streamlines, pressure contours, x-y plots for lift, drag etc.. With increase in angle of attack the lift coefficient tends to increase and with increase in angle of attack drag coefficient first increases then start decreasing. So that increase in lift coefficient and decrease in drag coefficient, we get good aerodynamic efficiency. The comparision between BWB and swept back wing also gives the inference that BWB gives good aerodynamic efficiency compared to the normal swept back wing aircraft.The smoke flow visualization also shows that there is no smoke flow visualization at higher angle of attack. The present work can be used for making the BWB drones due to small dimensions. However, in future this work can also be extended for the higher Mach numbers and bigger models. Optimization testing for BWB can also be done in future. This is overall promising since the BWB still has a lot of 0ptimizations to do and it might just present an interesting challenge for the coming years

V. REFERENCE

[1]. R. H. Liebeck, "Design of the Blended Wing Body Subsonic Transport," Journal of Aircraft, vol. 41, pp. 10-25, 2004.
[2].L. Bolsunovsky, N. P. Buzoverya, B. I. Gurevich, V. E. Denisov, A. I. Dunaevsky, L. M. Shkadov, et al., "Flying wing—problems and decisions," Aircraft Design, vol. 4, pp. 193-219, 2001.
[3]. N. Qin, A. Vavalle, A. Le Moigne, M. Laban, K. Hackett, and P. Weinerfelt, "Aerodynamic considerations of blended wing body aircraft," Progress in Aerospace Sciences, vol. 40, pp. 321343, 2004.
[4]. A New Methodology for Aerodynamic Design and Analysis of a Small Scale Blended Wing Body Baig AZ, Cheema TA*, Aslam Z, Khan YM, Sajid Dar H and Khaliq SB Department of Mechanical Engineering, GIK Institute of Engineering Sciences and Technology, Topic, 23460, KPK, Pakistan
[5]. Journal of Development of blended wing body aircraft design