Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. 4(3), 6-11, March (2015) Res. J. Engineering Sci.

BWB Aircrafts-the New Generation of Civil Aviation

Govind Yadav and Mohammad Anas
Department of Aeronautical Engineering, Bbdnitm, Lucknow UP, INDIA

Available online at: www.isca.in, www.isca.me
Received 7th November 2014, revised 21st February 2015, accepted 11th March 2015

Abstract

This research compares the BWB aircraft configuration with the conventional aircrafts on the basis of their aerodynamic and structural characteristics. We emphasizes on identifying some designing issues that determine the effectiveness of BWB aircrafts to meet the future requirements of civil aviation like rising passenger numbers, significantly reducing CO2 emissions, more comfortable flying and shorter travel time. Our study assess the developmental phases of newly developing BWB aircraft configurations, with large commercial transport aircrafts as they are predicted to be more fuel efficient and have high payload carrying capacity than current mega liners like AIRBUS-A380. We also investigate current designing programmes by various aviation giants such as NASA, BOEING, AIRBUS and various aeronautical institutes to estimate various advantages and challenges inherent by the BWB configuration in a highly cost-effective manner.

Keywords: Blended Wing Body (BWB), Configuration, Airfoil, (L/D) ratio, Aerodynamics, Payload, Lift, Wing span, Noise, Efficiency, Coefficient, Design, Conventional, Drag.

Introduction

Now a day's civil aviation sector is in great mess because current development in aircraft technology are not sufficient to mitigate the adverse effect of growth such as fuel crisis, their increasing rates, air pollution and many other reasons. With this fact there is an immediate need of a new aircraft configuration that have a potential to run an effective and more efficient commercial air transport system. Almost every aerospace industry is currently developing such technologies which could fulfil the future demands of this sector. But instead of this kind of advanced technological research we still need an aviation leap that secures the prominent growth of global aviation industry. Therefore in order to achieve a sustainable development in aviation sector a research is carried out on a new concept in aircraft design known as Blended Wing Body aircraft configuration (BWB).It is an alternative aircraft configuration where wings and fuselage are combined to create a hybrid flying wing shape.

All the researches on this configurations offer better efficiency in terms of aerodynamics, structure, fuel consumption, direct operating cost and noise reduction. But as there are some demerits of BWB over conventional aircrafts which has been taken into consideration and resolution has been done to make BWB better than conventional airlifter like A380.Due to its single lifting surface it becomes an aerodynamically clean configuration. In addition it has a higher lift to drag ratio(L/D) which makes it suitable for higher carrying capacity applications.

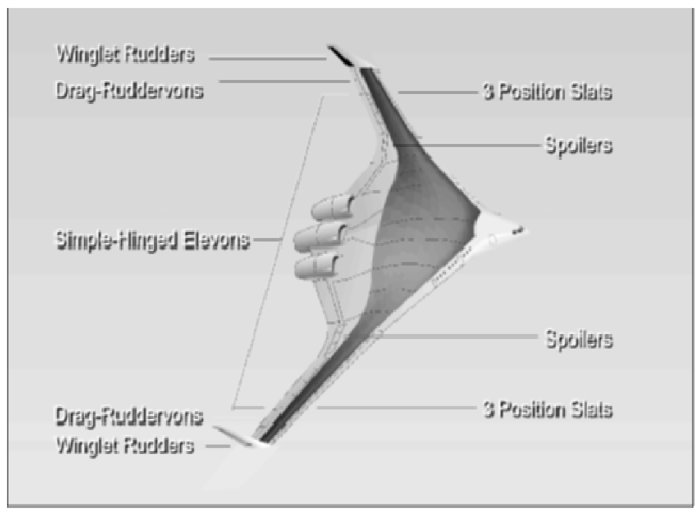

Figure-1
Flight control system architecture of the first generation BWB

Advantages of high (L/D) ratio: The following data is based on the A380 prototype research analysis. i. 10% increment in maximum lift leads to 22% to 30% increase of payload. ii. 2.5% increment of take of (L/D) ratio leads to 10% increase of pay load. iii. 4% increase of maximum lift in landing configuration leads to 16% increase of payload.

The structure of the BWB aircraft is consist of a non-cylindrical section which is fixed within the wings, which reduces the total wetted area of this aircraft which enhances its wing span loading that provide an improved aerodynamic and structural efficiency.

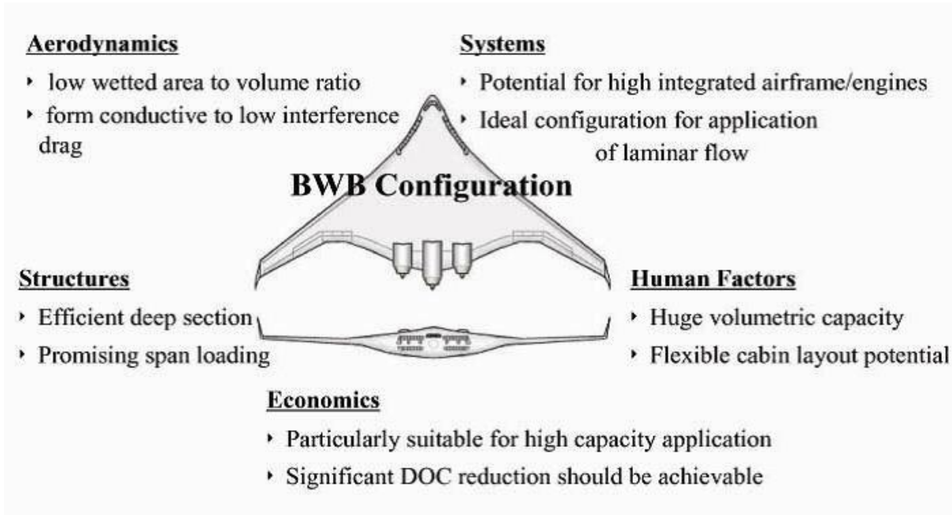

Figure-2
BWB characteristic

The designs of aircraft manufacturing giant like NASA and BOEING suggest that BWB concept configuration for passenger flight could achieve higher fuel saving as compared to the same flight missions of conventional aircrafts[1]. The BWB design has larger passenger capacity for example its volumetric size is 60% larger then A380[2]. We also worked on various calculative aspects which enable us to derive vast number of advantages and challenges during their designing cycle.

Methodology

Weight estimation: Total weight of any aircraft is calculated by the equation given below:

$$W_{take\ off} = W_{pay\ load} + W_{fuel} + W_{empty} \quad (1)$$

$$W_{empty} = W_{cabin} + W_{aft-body} + W_{fixed} \quad (2)$$

Where: W $_{takeoff}$→ Take-Off gross weight. W $_{cabin}$ →weight of cabin section of BWB. W $_{aft\text{-}body}$ → weight of the aft-body. W $_{wing}$→ weight of the outer wing. W_{fixed}→weight of various components such as furnishings, etc.

The following equation is used for the weight of the pressurized cabin portion of the BWB:

$$W_{cabin} = (5.698865)(0.316422)(W_{take\ off})^{0.166552}(S_{cabin})^{1.061158}$$

Where: (S $_{cabin}$) is the cabin plan form area (ft^2).

The following equation is used for Aft-Body portion:

$$W_{aft\ body} = (1 + 0.05N_{eng})(0.53S_{aft}W_{take\ off}{}^{0.2})(\lambda_{aft} + 0.5)$$

Where N_{eng}=number of engines on the central body,S_{aft}=plan form area of the aft central body (ft^2), and λ_{aft}= taper ratio.

L/D estimation: $\frac{L}{D} = \frac{\frac{1}{2}\rho v^2 s C_L}{\frac{1}{2}\rho v^2 s C_D} = \frac{C_L}{C_D}$

At the time of Crusing ; W=L

$$C_L = \frac{w}{\frac{1}{2}\rho v^2 s}$$

$$T = \left\{C_{D_P} + \left(k + \frac{1+\delta}{\pi A.R}\right)C_L^2\right\}\frac{\rho}{2}v^2 s. \quad (3)$$

Where: T-efficiency of the aircraft. w-takeoff gross weight. C_{D_P} −parasite drag coefficient. k −aircraft shape factor. δ −parameter of wing shape. A.R-Aspect ratio. ρ −density. v −velocity. s −reference area of wing (S_w)

For the aircraft with high aerodynamic performance k is close to 1.
Current aircraft have k in b/w 0.009-0.012
C_{D_P} −0.015-0.025
$C_{D_P} = C_{D_{min}} + kC_L^2$ (parasite drag)
$C_{D_I} = \left(\frac{1+\delta}{\pi A.R}\right)C_L^2$ (induced drag)
So $C_D = \frac{C_{D_P}}{C_{D_I}} = \frac{C_{D_{min}} + kC_L^2}{\left(\frac{1+\delta}{\pi A.R}\right)C_L^2}$

From the above equation,

$$C_{D_I} = \left(k + \frac{1+\delta}{\pi A.R}\right)C_L^2$$

$$e = \frac{1}{1 + \delta + K\pi A.R}$$

Hence: $T = \left(C_{D_P} + \frac{C_L^2}{e\pi A.R}\right)\frac{\rho}{2}v^2 s$ (4)

$\frac{L}{D} = \frac{\sqrt{\pi}}{2} \cdot \frac{b\sqrt{e}}{\sqrt{C_{D_P} s}}$ (5)

b-wing span. s- wing reference area

Parasite drag is related to skin Friction drag: i. The comparison b/w wetted area and wingspan can be restated as a wetted aspect ratio. ii. Wetted aspect ratio=$\frac{b^2}{A_{wetted}}$. iii. For the reliable early estimation of L/D, the wetted aspect ratio is a feasible parameter.

The Breguet Range Equation: Relates the aerodynamic (L/D) ratio and propulsion capacity efficiency (V/c). This equation is given as follows:

$$R= \int_{W1}^{W2} \left(\frac{V}{c}\right)\left(\frac{L}{D}\right)\left(\frac{1}{W}\right) dW \quad (4)$$

OR

$$R=\left(\frac{V}{c}\right)\left(\frac{L}{D}\right) \ln\frac{W2}{W1}. \quad (5)$$

Where: R→ Trip range. C → Specific fuel consumption (SFC). (L/D)→ lift to drag ratio. (W1/W2)→ Mission segment weight fraction. V→ velocity of the air craft

In order to obtain a rough weight estimate for the target lift coefficient, the combination of above equation plays an important role. Now the weight values of various parts can be calculated by equation (1) and the Mission Range can be calculated by using equation (2). The following data can be produced by using weight estimation formulations.

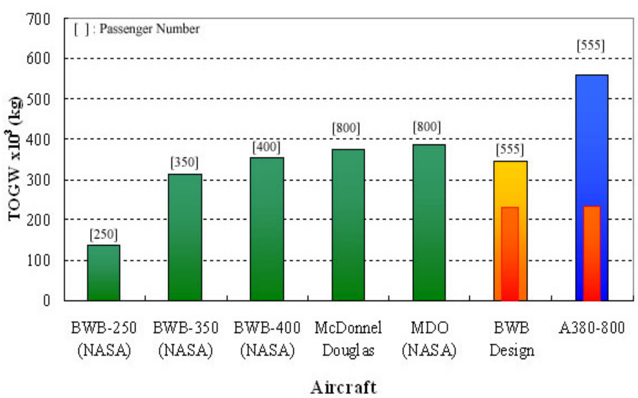

Figure-3
Lists of Aircraft TOGW vs. Number of Passengers (Orange Bar: Project BWB Design, Red Bars: Empty Weight)

Aspect Ratio: If we practically increase the L/D ratio for an aircraft wings, then the design must induces effectively greater aspect ratio .Which reduces the strength of the tip vortex. Mathematically this ratio can also be written in the form of their respective coefficients as follows,
[$L / D = C_L / C_D$]

Where: C_L is coefficient of lift and C_D is coefficient of drag.

Airfoil Selection: Achieving higher L / D ratio is our primary objective for a level flight .Which needs an efficient airfoil selection.

We analysed H_Quabeck and Epplerairfoil series for designing BWB aircraft wings.

With almost negligible angle of attack we achieve a value of approximately 0.38 for the lift coefficient corresponding to our selected airfoils.

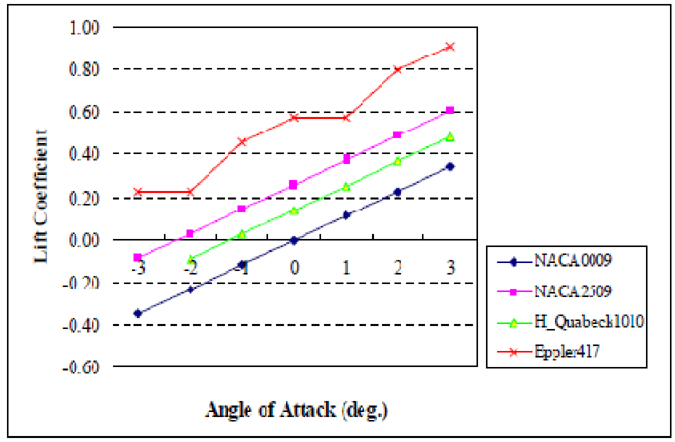

Figure-4
Comparison of lift coefficient

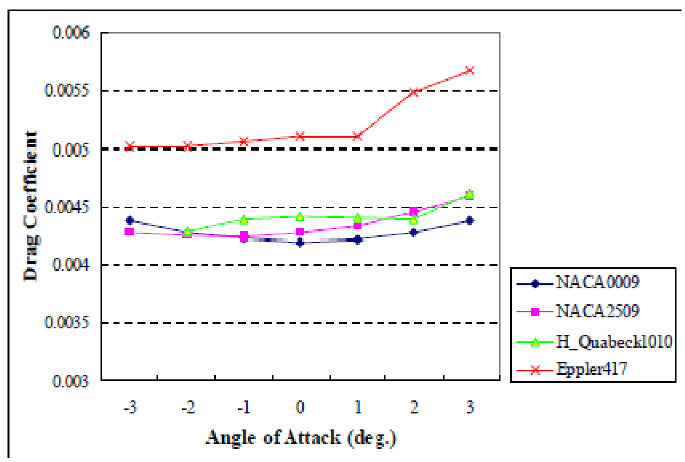

Figure-5
Comparison of drag coefficient

For the root section of the BWB, we tested some symmetrical airfoil with minimized value of maximum thickness to locate the cabin compartment at the maximum thickness of the selected airfoil. However the root section was yet not feasible to ease the passengers. We redesigned the root section of our wing to create more cabin space, as well as to improve its aerodynamic performance. We also shifted the location of the maximum thickness to the airfoil chord, precisely 13% backward. Eppler 417 was selected for the wing of the BWB configuration.

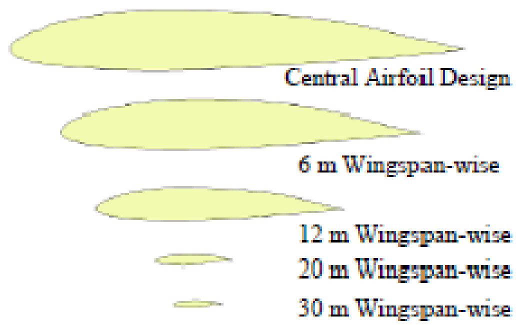

Figure-5
Airfoil geometry of BWB

Estimation of C.G location: The following approximation was made regarding the aerodynamic centre and centre of gravity for BWB configuration.

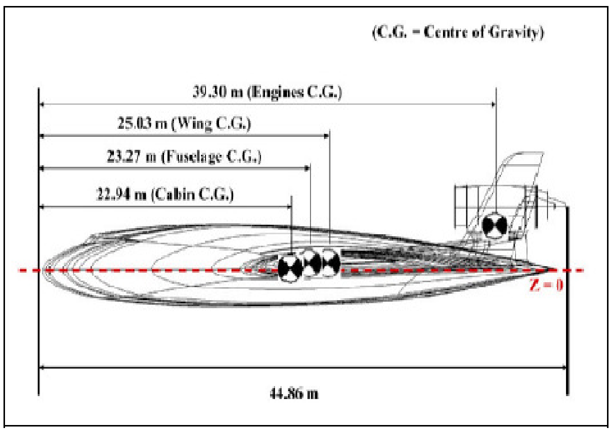

Figure-6
C.G location of the BWB Configuration

Results and Discussion

Aerodynamic key findings: i. A key aspect of the BWB is its lift-generating central body which improves the aerodynamic performance by reducing the wing loading[12-14]. ii. The decrease in wetted area, via a smaller outer wing, relative to a similar sized conventional aircraft translates into an increased lift-to-drag ratio, since it is proportional to the wetted aspect ratio, the aspect ratio increases[6, 2, 7, 15]. iii. We observed an considerable reduction in interference drag due to the elimination and reduction of junctions which exist between the wings and fuselage on conventional aircraft[14-18,12], which generate better streamlined shape for this configuration. iv. This aircraft design do not involve any horizontal tail that results a evident reduction in the corresponding friction and induced drag penalties, which additionally increases the lift-to-drag ratio[9]. Due to the variation in BWB's fuselage area r its body gets minimum wave drag due to volume[20]. v. Engines are partially located on the BWB aft-body, which effectively balance the airframe and offset the weight of the payload, furnishings, and systems, but it also raises the potential for boundary layer ingestion from a portion of the central body upstream of the engine inlet[19]. Through the reduction of ram drag, this new engine location would provide a more fuel efficient system[21, 22] and also increases the thrust to burn ratio[23].

Aero structural key finding: i. Due to the span wise expansion of the lift generating fuselage, the lift and payload are much more linear with each other on the BWB than on a conventional aircraft[18] and in addition the wing bending space provides an extra passenger cabin which increases the carrying capacity. ii. We distributed the aircrafts weight along the span by reducing the cantilever span of the thin outer wing. After combining the thick central body with the outer wing offer reduced bending moments and thus reduced structural weight[15, 18, 14]. Because of the above advantage the values of peak bending moment and shear for BWB configuration becomes half than that of conventional configuration. iii. This blended design reduces the total wetted area and allows for a maximized wingspan[3,2]. As a result, the optimal aspect ratio of the outer wing can be slightly greater than that for conventional wings[9]. iv. The BWB configuration has a low acoustic signature[6]. For this reason, the BWB was selected for the MIT/Cambridge Silent Aircraft Initiative project (SAI), which had the goal of designing an aircraft with reduced noise[19,8]. v. Decreased loading and off-loading times due to the wider cross sectional area than the conventional cargo transporter. vi. For conventional air carriers the engines are located bellow the wings but in BWB aircrafts the engines are embedded on the upper -rear body. Which make it more of a noise-shielded configuration than current conventional aircraft on which the engines hang below the wing, with this new location the inlets are hidden from below by the central body, which gives shielding effect for forward radiated fan disturbance. With conventional under-wing location of engine the exhaust noise is reflected from the under surface of the wing, which is a problem for both the passengers and areas surrounding airports., but BWB propulsion system erases these disturbance[2,6,9]. Airframe noise is further reduced through the absence slotted flaps.

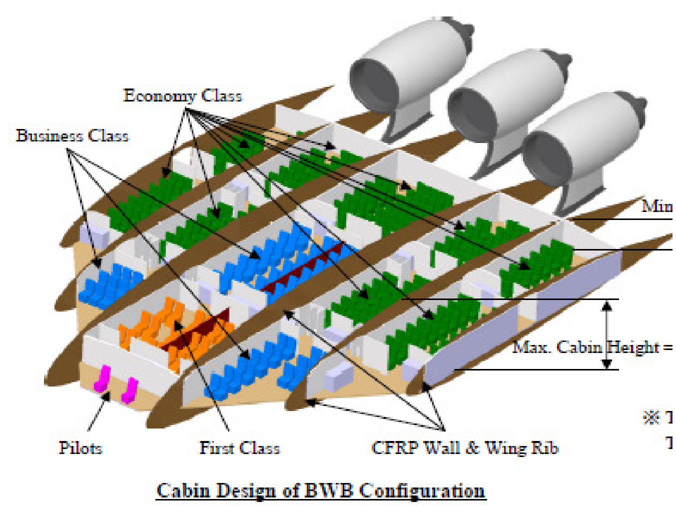

Figure-3.1
Cabin design for a BWB configuration

Marketing and Manufacturing: i. BWB aircrafts offer approximately 12% lower direct operating cost than current conventional designs. ii. The design of the BWB configuration becomes very much simpler than conventional aircrafts, due to the elimination of fillets and joints of highly loaded structures. Which brings a significant part reduction for BWB[5,6]. iii. With respect to the commonality of applications, aircraft applications have also been demonstrated for a variety of military applications including freighter, stand-off bomber, troop transport, and tankers[5]. iv. The designs of BWB aircrafts shows that they can be stretched laterally, which enables them to maximize their span and wing area with simultaneous increase in the payload. Whereas conventional aircraft can't afford this capability due to their longitudinal expansion to increase payload[6]. v. Since the interior configuration of a BWB is no longer a challenge. In contrast, a conventional aircraft with a varying cross-section will also have varying seats abreast along the area-ruled portion of the fuselage[5]. vi. The increased aerodynamic and structural efficiency are features which could help offset potentially higher operating costs of a silent engine design[17].

Stability and Flight Control: Rolling axis shows more fluctuations than the other axis. This is due to the vibrations of the model about the roll axis on the load cell.

Health issues: i. According to Aerospace Medical Association- The aircraft windows are good for the travellers, it helps them helping them to enjoy relaxed viewing and natural sun light in flight. But window installation is quite difficult in the BWB layout due to its design restriction. The cabin is embedded between the wings and the structural strength will be damaged if window are employed on the surface. ii. With a wider cabin design, the travellers may experience motion sickness, which is considered to be a health issue. Which could influence the travellers during flight. The bank angle for BWB are much more steeper than the conventional aircrafts.

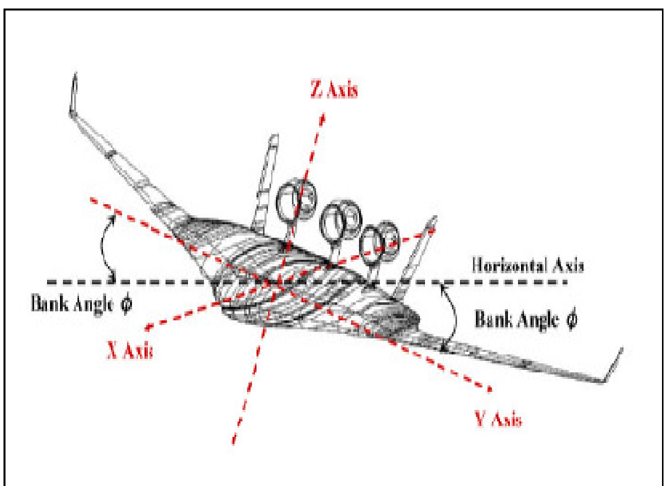

Figure-3.2
Typical Flight Rotation Profile with BWB Configuration

The BWB configuration may produce several medical complications for passenger, such as motion sickness, pulmonary embolism (caused by space restriction) and claustrophobia, exacerbated by fewer windows.

Conclusion

i. This new species of aircraft have a great potential to enhance the structural and aerodynamic characteristics than the conventional aircraft with the same flight profile. ii. This research suggests that the BWB preliminary design phase will require more detailed study. iii. The CFD analysis of this configuration shows some aero dynamical and mechanical difficulties, which needs to be eliminated for more credibility. iv. With booming growth in airways demand. BWB aircrafts has the calibre to compete in the global aviation market, due to their magnificent advantages over conventional passenger air carriers. And surely BWB aircrafts are the next generation of civil aviation.

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