ANALYSIS OVER A BLENDED WING OF AN AIRCRAFT

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Abstract: **X-48b was taken as a reference aircraft (25% scale down version) with some modification was used as basis of our design and changes. The position of propulsion units is a major design change in our aircraft and is submerged inside the structure. Winglets are curved unlike a straight vertical component. The concept of split rudder is implemented for directional control along with alternate variation in the RPM of the motors. The dimensions are mostly based on 25% scale down X48-B with minor variations.**

The location of propulsion units is decided on the basis of requirement. A mission profile is designed to facilitate the selection of propulsion units. Coefficient of lift for cruise flight is calculated and the corresponding CD is obtained from the graphs of reference aircraft. Further, the drag at cruise is calculated which is nothing but the thrust required. Electric ducted fans (EDFs) with appropriate specification are selected based on the mission profile. The concept of Elevons is implemented for rolling and pitching moment. For designing the control surfaces, general guidelines are referred. Expanded Polystyrene (EPS) is used as the fabrication material along with plywood, balsa wood and carbon fiber rod for the structural integrity.14.8 volt lithium polymer power pack is used for power supply.

Servo actuators are used for control surface movements. After completing the fabrication, the aircraft was taken to flying field and the system functioning was checked thoroughly. The test flight was carried out successfully and a general behavior of the aircraft during the flight was observed. A 3D model was created in XFLR5 and was analyzed under flight conditions.

The graphs obtained were found to have similar pattern as that of the reference aircraft, which validates the analysis.

Keywords**: Winglets, propulsion, mission profile.**

I. INTRODUCTION

The desire to produce environmentally friendly aircraft that is aerodynamically efficient and capable of conveying large number of passengers over long ranges at reduced direct operating cost led aircraft designers to develop the Blended Wing Body(BWB)aircraft concept. The BWB aircraft represents a paradigm shift in the design of aircraft. The design provides aerodynamics and environmental benefits and is suitable for the integration of advanced systems and concepts like laminar flow technology, and distributed propulsion.

After emergence of rectangular-shaped body and then tube-shaped body, wings and cylindrical body have become two main characters of commercial flights since early 20th century. Aircraft manufactures remained loyal to them, and passengers, more or less, entered the cylindrical body to travel around the world. At the time of designing the B747, it has been believed a typical configuration with cylindrical body has reached its maximum performance, and further development for commercial transport could be a challenge. However, the Boeing Company came up with an innovative idea which was a practical substitute for addressing real requirements of the future commercial transport in 1998, in a conference in Reno, Nevada. Accordingly, the blended-wing-body configuration officially came into existence for the future generation. In general, aircraft configurations are classified according to conventional, blended wing body, hybrid flying wing, and true flying wing. In comparison with flying wing configuration with no central body also known as tailless fixed wing, in the BWB con-figuration, passenger cabins, cargo, and equipment are located in central structure of the wings and body. In other words, the BWB configuration combines features of the conventional configuration with the flying wing configuration. It has advantages in terms of performance, and construction in comparison with the conventional configuration. This configuration exploits thick airfoil-liked body in the center, and it accommodates cargo and passengers in the center with low compressibility drag. Meanwhile, it reduces total drag comparing with the conventional configurations because its airfoil-liked body with no tail is blended smoothly with outboard wings. Consequently, it increases lift-to-drag ratio and decreases fuel consumption for a long-range high-capacity missions. Moreover, those advantages are expanding on economical fuel consumption, reliability, maintenance period, and low cost for large-scale production.

There are several technical advantages in the BWB configuration. Among them, effective spanwise lift distribution is intended to be obtained by using a wide airfoil-liked body. Therefore, entire airframe in this configuration plays an effective role in lift generation that improves economical fuel consumption. Meanwhile, this configuration decreases aerodynamic load on outboard wings because of big central chord that bears major part of the span loading. In addition, because of the biggest chord in central body, it needs low lift coefficient to bear an elliptical spanwise load distribution. Therefore, central spanwise location can be thicken to acquire required space for accommodating passengers and cargo without large compressibility drag penalty. In this configuration, most trapezoidal area of planform is covered by the wings, which decreases wing area, and consequently the skin friction drag. Furthermore, shape of the airframe relatively weakens shock waves over the wings and body, and also subsonic flow region behind the shock waves provides appropriate area for engine installation. Besides, its low and effective load coefficient eliminates needs

for complex high lift devices because of trim effect. Therefore, it only needs leading edge slots in outboard wings and simple fowler flap along with elevons, which combines functionalities of elevator and aileron.

II. EVOLVING TRENDS IN BLENDED WING BODY

The design provides aerodynamics and environmental benefits and is suitable for the integration of advanced systems and concepts like laminar flow technology, jet flaps and distributed propulsion. However, despite these benefits, the BWB is yet to be developed for commercial air transport due to several challenges. The study finds that in order to harness the advantages and reduce the deficiencies of a tightly coupled configuration like the BWB, a multidisciplinary design synthesis optimization should be conducted with good handling and ride quality as objective functions within acceptable direct operating cost and noise bounds.

Fig 1. bwb 450 com pass

The **Boeing X-48** is an experimental unmanned aerial vehicle (UAV) for investigation into the characteristics of blended wing body (BWB) aircraft, a type of flying. Boeing designed the X-48 and two examples were built by Cranfield Aerospace in the UK. Boeing began flight testing the X-48B version for NASA in 2007. The X-48B was later modified into the X-48C version. It was flight tested from August 2012 to April 2013. Boeing and NASA plan to develop a larger BWB demonstrator. Boeing had in the past studied a blended wing body design, but found that passengers did not like the theater-like configuration of the mock-up; the design was dropped for passenger airliners, but retained for military aircraft such as aerial refueling tankers. McDonnell Douglas developed the blended wing concept in the late 1990s, and Boeing presented it during an annual Joint AIAA/ASME/SAE/ASEA Propulsion Conference in 2004. The McDonnell Douglas engineers were confident that their design had several advantages, but their concept, code named "Project Redwood" found little favor at Boeing after their 1997 merger. The most difficult problem they solved was that of ensuring passengers a safe and fast escape in case of an accident, since emergency door locations were completely different from those in a conventional aircraft.

The blended wing body (BWB) concept offers advantages in structural, aerodynamic and operating efficiencies over today's more conventional fuselage-and-wing designs. These features translate into greater range, fuel economy, reliability and life cycle savings, as well as lower manufacturing costs. They also allow for a wide variety of potential military and commercial applications. Boeing Phantom Works developed the blended wing body (BWB) aircraft concept in cooperation with the NASA Langley Research Center. In an initial effort to study the flight characteristics of the BWB design, a remote-controlled propeller-driven blended wing body model with a 17 ft. (5.2 m) wingspan was successfully flown in 1997. The next step was to fly the 35 ft. (10.7 m) wide X-48A in 2004, but that program was later canceled.

Research at Phantom Works then focused on a new model, designated X-48B, two examples were built by United Kingdom-based Cranfield Aerospace. Norman Prince, Boeing's chief engineer for the project, stated in 2006: "Earlier wind-tunnel testing and the upcoming flight testing are focused on learning more about the BWB's low-speed flight-control characteristics, especially during takeoffs and landings. Knowing how accurately our models predict these characteristics is an important step in the further development of this concept. "The X-48B has a 21-foot (6.4 m) wingspan, weighs 392-pound (178 kg), and is built from composite materials. It is powered by three small turbojet engines and is expected to fly at up to 120 KN (220 km/h) and reach an altitude of 10,000 feet (3,000 m). The X-48B is an 8.5% scaled version of a conceptual 240-foot wide design. Though passenger versions of the X-48B have been proposed, the design has a higher probability of first being used for a military transport.

III. FABRICATION ASPECTS

- Make the design more aerodynamic by submerging the propulsion units inside the structure of the aircraft

- Distance between two EDFs should cover 30% of the wingspan to generate internal volume for payload.
- The aircraft should cruise at 50kmph.This will form the basis of selection of appropriate thrust.
- The aircraft should achieve a top speed of 70 kmph during the flight. This will facilitate the selection of maximum thrust. Based on these requirements, the aircraft will be fabricated.

IV. CONCEPTUAL SIZING AND DESIGN

The aerodynamic forces acting on an aircraft in steady state level flight is shown below:

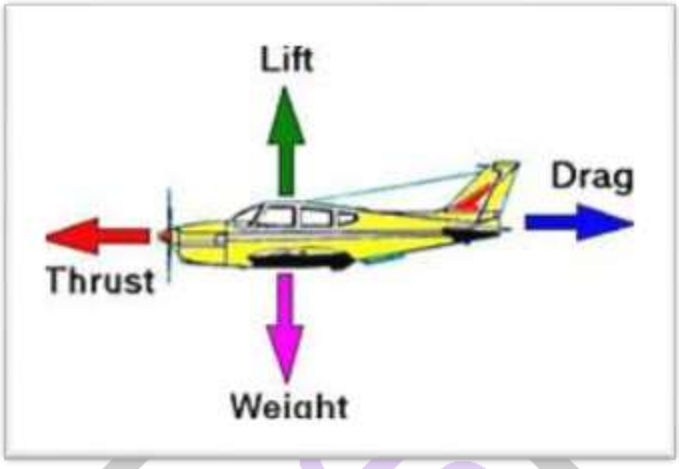


Fig. 2. Aerodynamic forces

Lift is the force that directly opposes the weight of an airplane and holds the airplane in the air. Lift is generated by every part of the airplane, but most of the lift on a normal airliner is generated by the wings. Lift is a mechanical aerodynamic force produced by the motion of the airplane through the air. Because lift is a force, it is a vector quantity, having both a magnitude and a direction associated with it. Lift acts through the center of pressure of the object and is directed perpendicular to the flow direction. There are several factors which affect the magnitude of lift.

SCALING

Scaling Ratio 1:4

Dimensions of x-48b	Dimensions of our aircraft
Span = 621.8cm	Span =170cm
Length = 460cm	Length = 115cm
Height = 90cm	Height =25cm
Thrust =72.5kg	Thrust =2.4kg
Weight =237kg	Weight =1.81kg
$\frac{\textbf{thrust}}{\textbf{weight}}$ =0.31	$\frac{\textbf{thrust}}{\textbf{weight}} = \frac{2.4}{1.81}$=1.32
v_{max} = 222kmph	v_{max} =70 kmph
Aspect ratio $=\frac{621.8}{460}$=1.35	Aspect ratio = 3.606

SCHEMATIC DIAGRAM OF A PROPOSED MODEL:

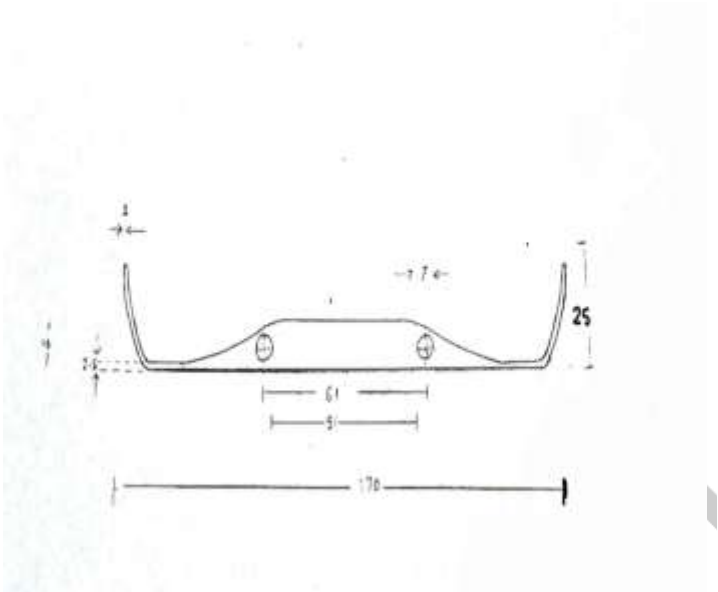


Fig. 3. Hand sketch front view

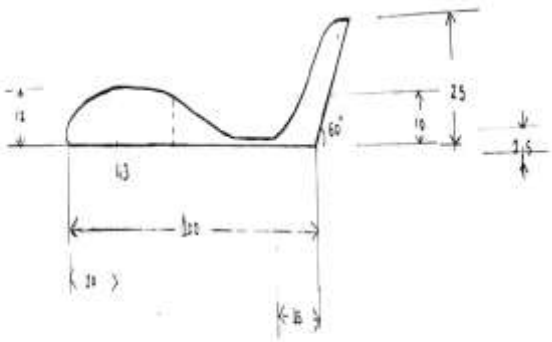


Fig. 4. Hand sketch side view

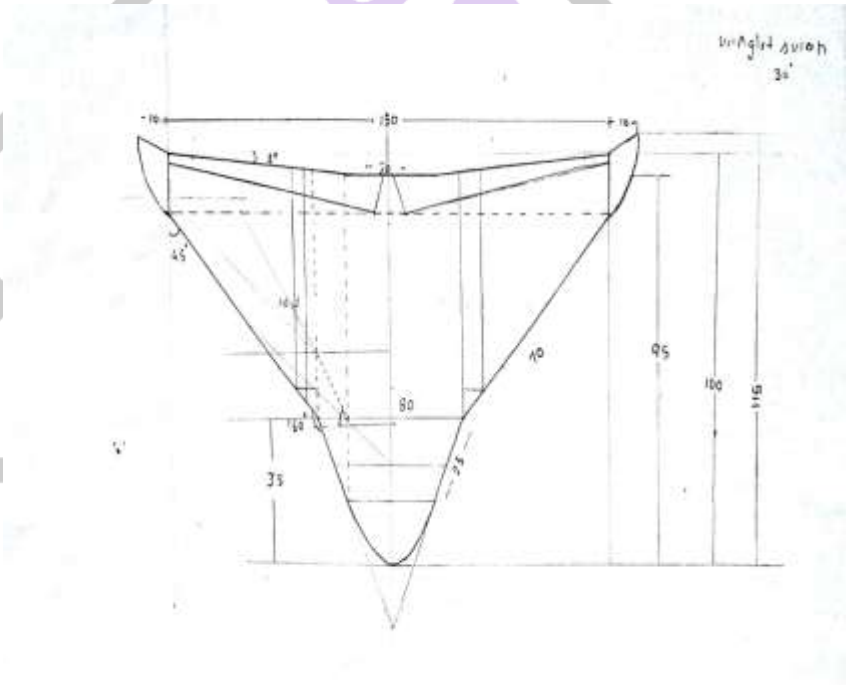


Fig. 5. Hand sketch top view

CAD 3 VIEWS OF 2D MODEL

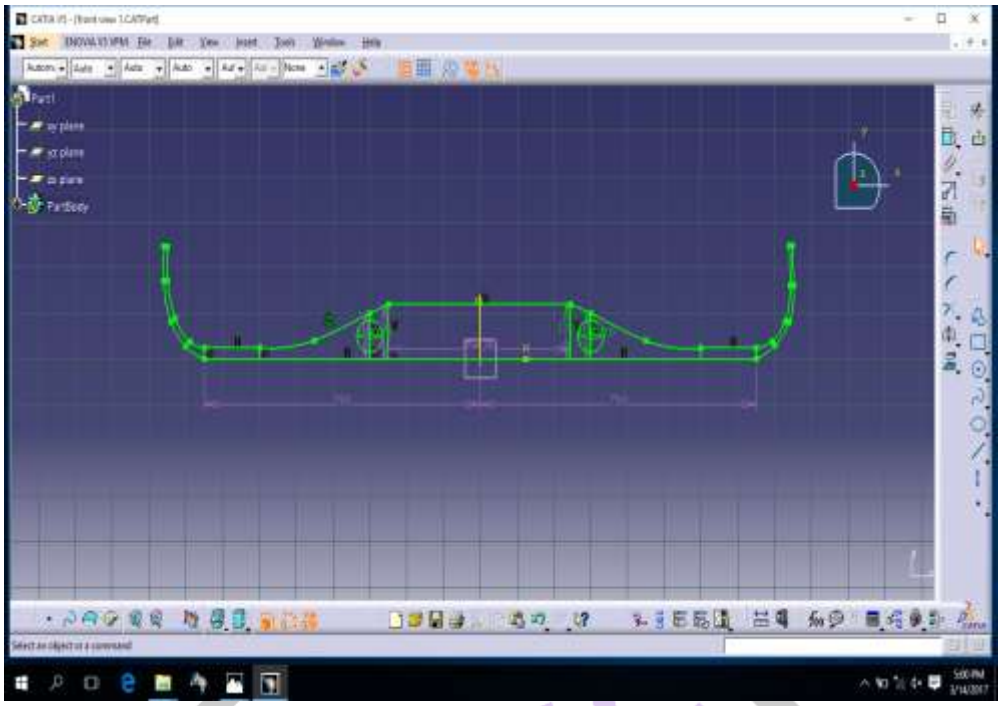


Fig. 6 CAD 2-D Front view

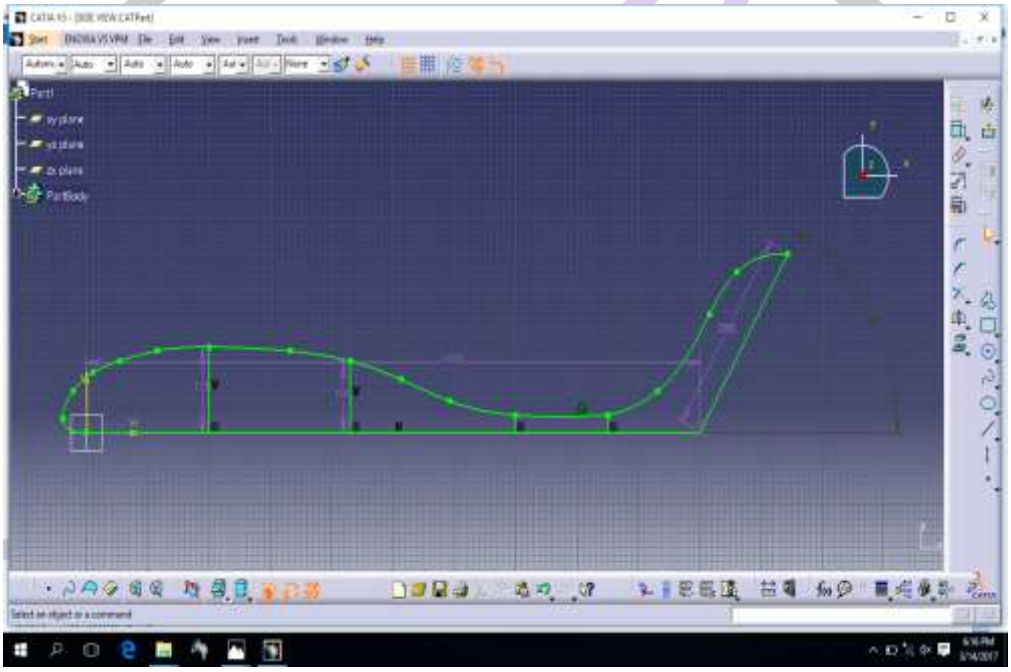


Fig. 7. CAD 2-D Side view

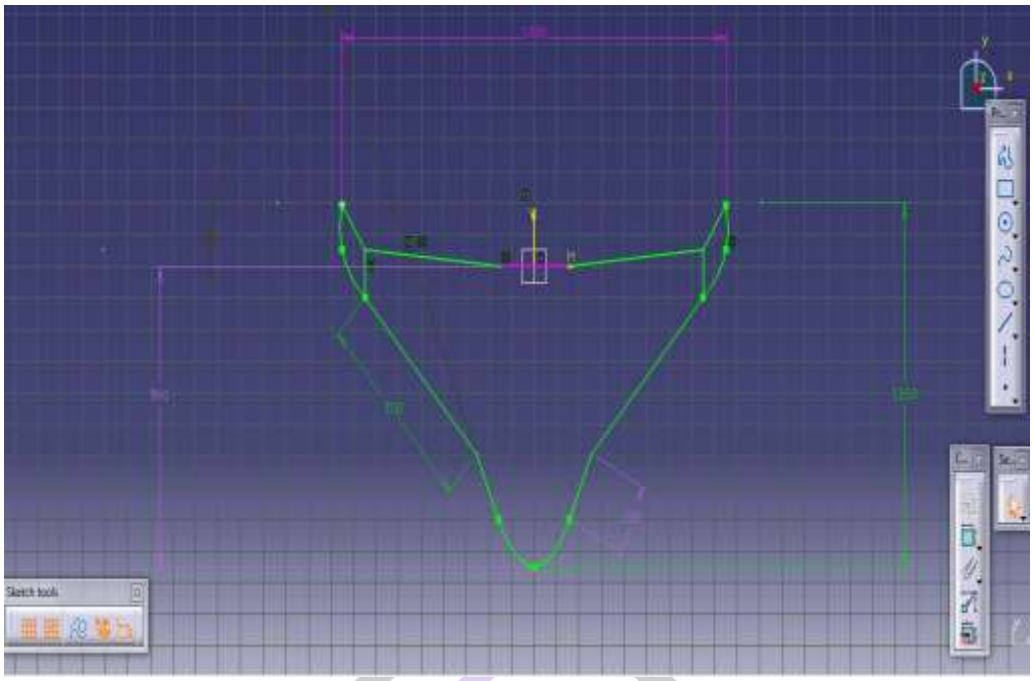


Fig. 8. CAD 2-D Top view

V. DETERMINATION OF LANDING GEAR LOCATION

Landing gear is the undercarriage of an aircraft or spacecraft and may be used for either takeoff or landing. For aircraft it is generally both. For aircraft, the landing gear supports the craft when it is not flying, allowing it to take off, land, and taxi without damage. The landing gears are positioned such that the nose gear is ahead of C.G. and the rear gears are behind the C.G.

VI. CALCULATIONS OF GEOMETRIC PARAMETERS

Root chord length=95cm
Divided the aircraft into 3 spanwise sections 15cm ,10cm, 50cm.
Chord lengths 95cm ,80cm, 60cm, 15cm.

SYSTEM INTEGRATION

SN	COMPONENTS	QUANTITY	SPECIFICATION
1.	EDF motor	2	Internal diameter :- 70mm Weight :- 139g No. of blades :- 6 Operating voltage :- 14.8v Output power :- 550w Max. current :- 36A Thrust :- 1.2kg
2.	Power pack	1	14.8v, 2200mah
3.	Speed controller	2	45A
4.	Actuators	4	9g
5.	Receiver	1	7 channel
6.	Transmitter	1	2.4ghz futaba
7.	Landing gear	3	dia: 5cm

Table 5.2 System integration

VII. FLIGHT TESTING

The mission profile consists of take off, climb, cruise at 50kmph, and attain a top speed of 70 kmph, approach for landing and landing. The take off is carried out placing the aircraft in the head wind. Then the throttle is increased when the aircraft starts to roll down the runway .When the throttle is increased to 100%, the elevator is pulled up when the nose of the aircraft is raised and the aircraft leaves the ground. The constant rate of climb is maintained until the aircraft attains a safe altitude above the ground.

Then a smooth left turn is carried out to bring the aircraft into a predetermined circuit. The throttle is then reduced to attain a cruising velocity of nearly 50kmph.A level flight is carried out after which the throttle is opened to 100%, which according to the calculations should give a maximum velocity of 70 kmph. The throttle is then reduced to the cruising velocity; a turn is carried out while decreasing the altitude to attain a landing approach. The throttle is further decreased while the alignment of the aircraft with the runway is maintained. When the aircraft is just about to touch the runway, the elevator is slightly pitched up to reduce the landing load. The aircraft finally touched down and comes to a halt.

VIII. OBSERVATIONS

Although obtaining the numerical data was not feasible, following characteristics were observed during the flight.

- The take off distance was nearly 30 m with 100% throttle.
- The climbing was smooth and steady.
- The cruising condition was found to be at 60% of the throttle which is fairly close to the calculated value.
- The aircraft was also flown at 100% throttle to obtain a maximum velocity of 70kmph.However, there were no reliable means to measure the velocity accurately, except the visual observation.
- The aircraft was made to climb at a high rate at 100% throttle to obtain a good height after which the throttle was brought down to 0%.This is called as the gliding phase and the aircraft showed good gliding characteristics until it sunk low closer to the runway.
- Besides the normal turning radius, the turn radius with higher control inputs was carried out and it was observed that the aircraft was capable of turning at an extremely less radius.
- We also wanted to check the maneuvering characteristics of the aircraft and decided to carry out a vertical loop and a horizontal roll. It was observed that the aircraft carried out both the maneuvers smoothly at 100% throttle and recovered to a straight and level flight.
- When the aircraft approached for landing, it was observed that 10 % throttle was required to maintain a safe height above the runway without stalling the aircraft. The landing distance also was observed to be very less.

ANALYSIS

The analysis of our aircraft was carried out in XFLR5 Software. The creation of 3D model was carried out in the following way.

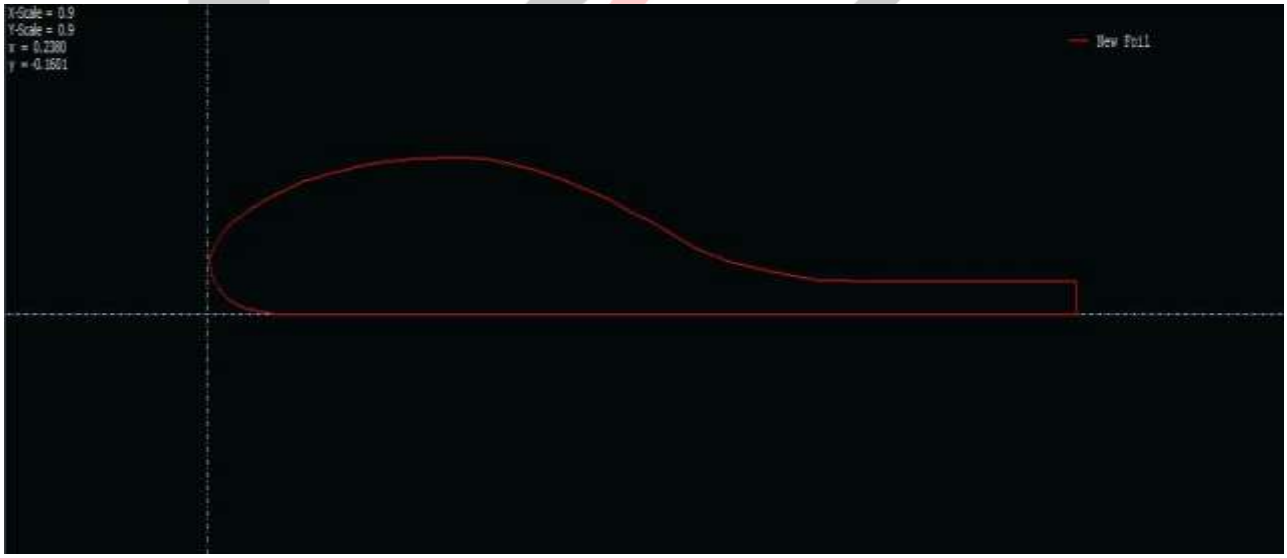


Fig 9: Creation of airfoil.

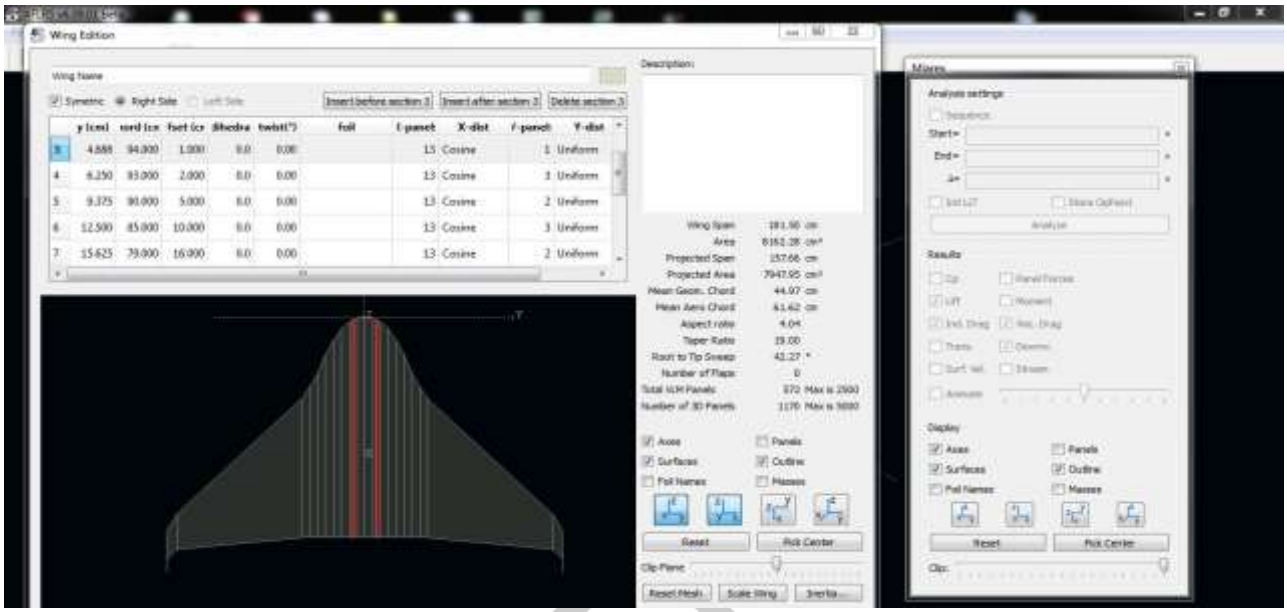


Fig: 10. Body creation

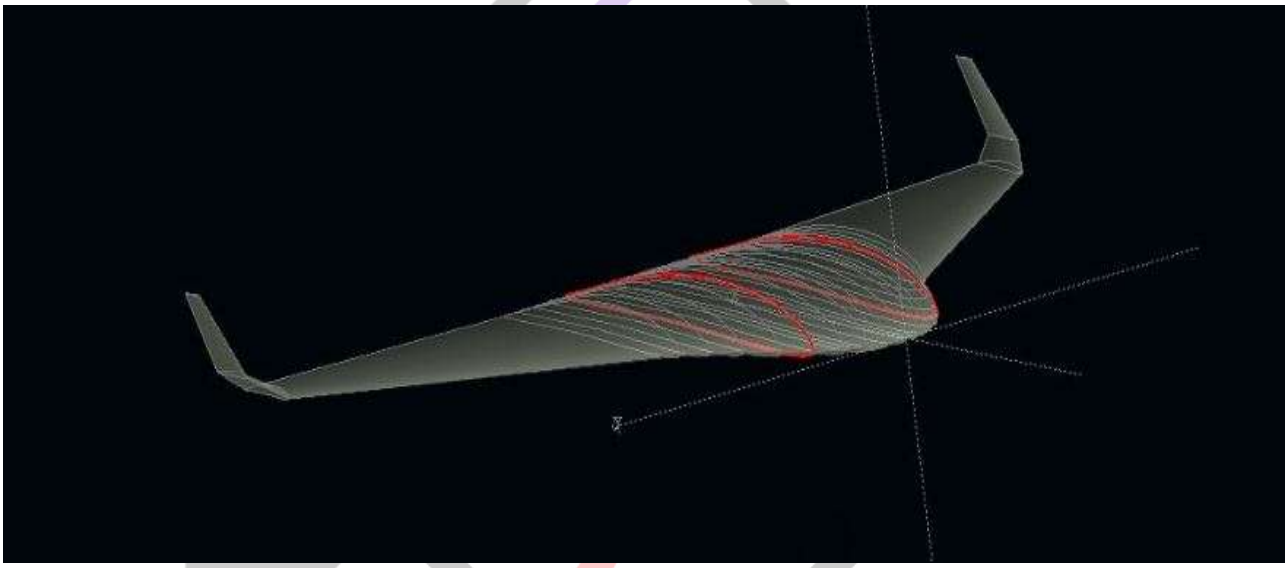
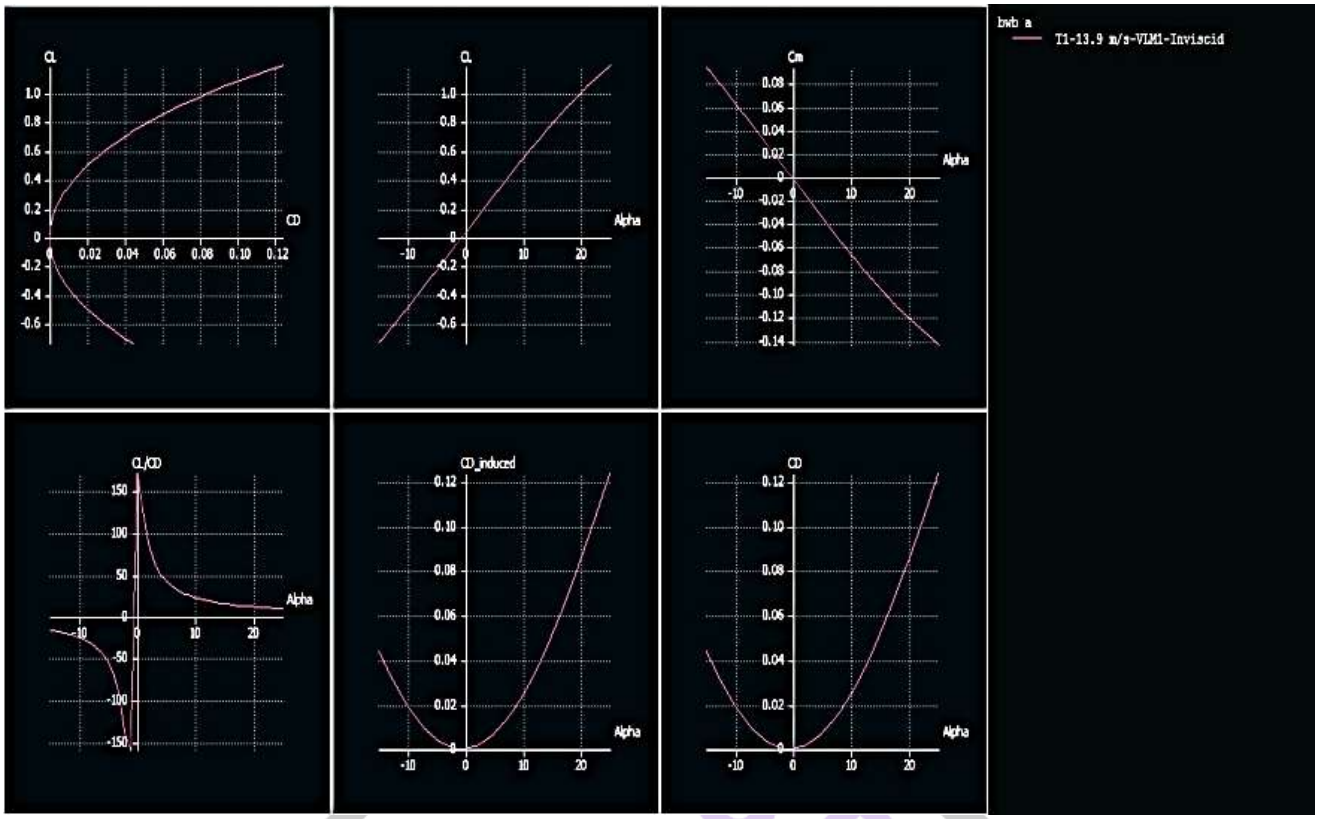


Fig 11. importing the airfoil

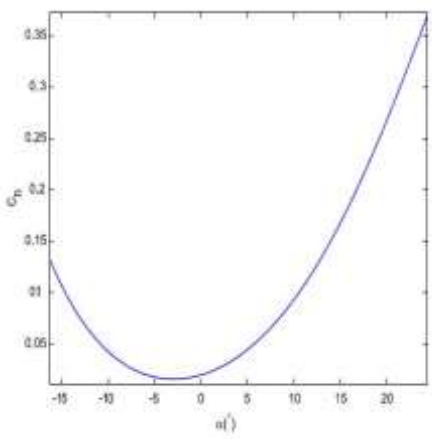
INPUT PARAMETERS AND FLIGHT CONDITIONS

Velocity	13.89 m/s
Mach number	0.04
Solution method	Vortex lattice method
Calculation type	Fixed speed
Atmospheric conditions	Sea level

RELATIONS OBTAINED BETWEEN VARIOUS PARAMETERS.



COMPARISON WITH REFERENCE GRAPHS



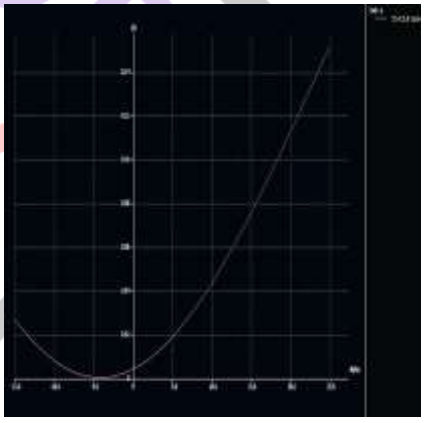
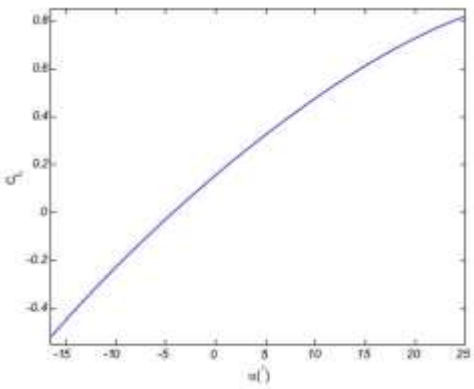


Fig 12. C_D vs. α



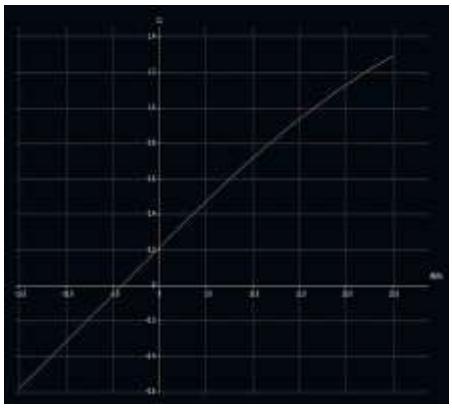


Fig.13 C_L vs. α

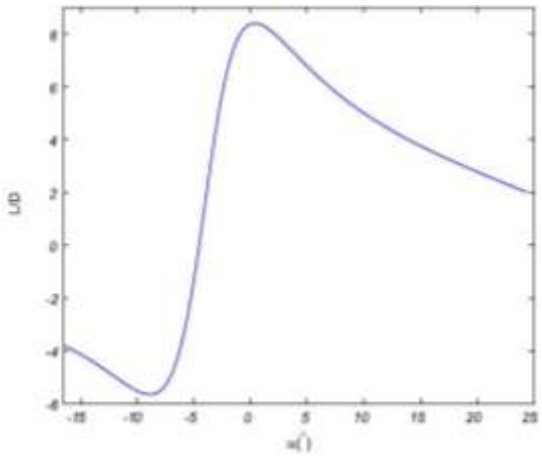
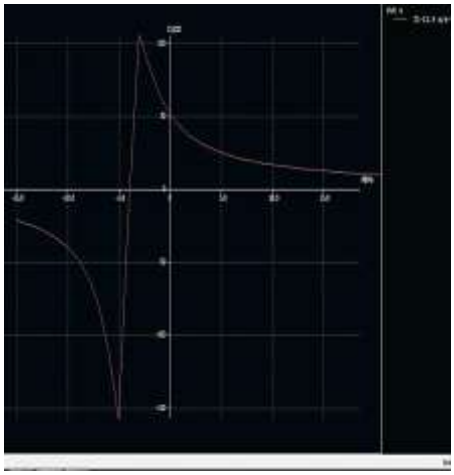


Fig 14. C_L/C_D vs. α



IX. VISUALIZATION:

Avery basic flow visualization was performed in XFLR5 to visualize patterns of various forces acting on the aircraft and the streamlines on the aircraft at various angles of attack were observed without numerical interpretations.

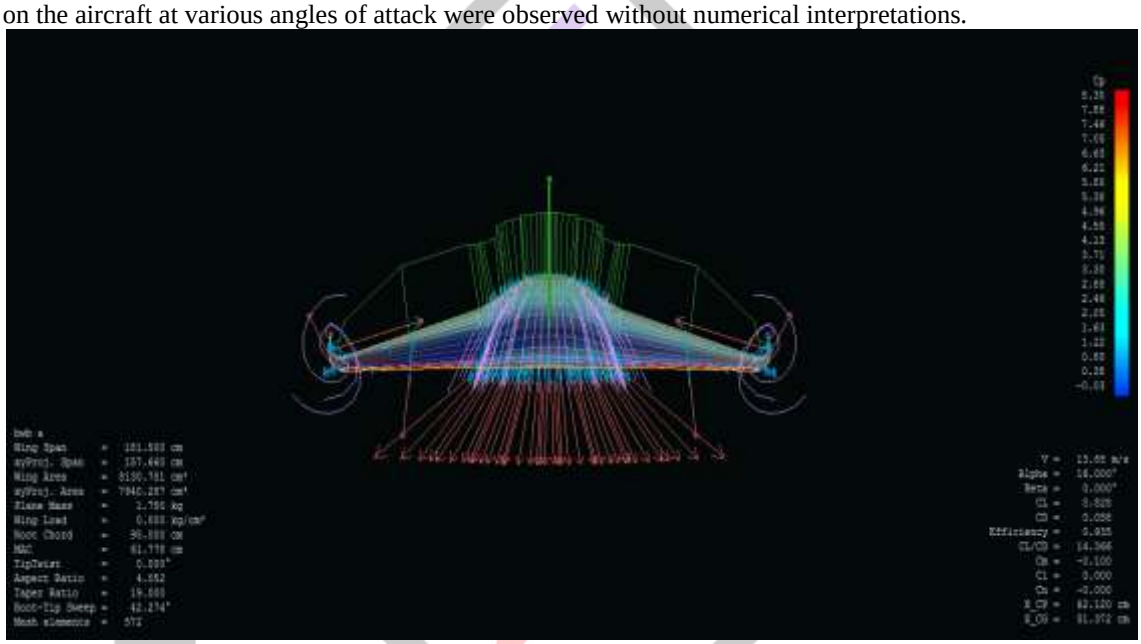


Fig 15. Lift distribution, vortices and downwash.

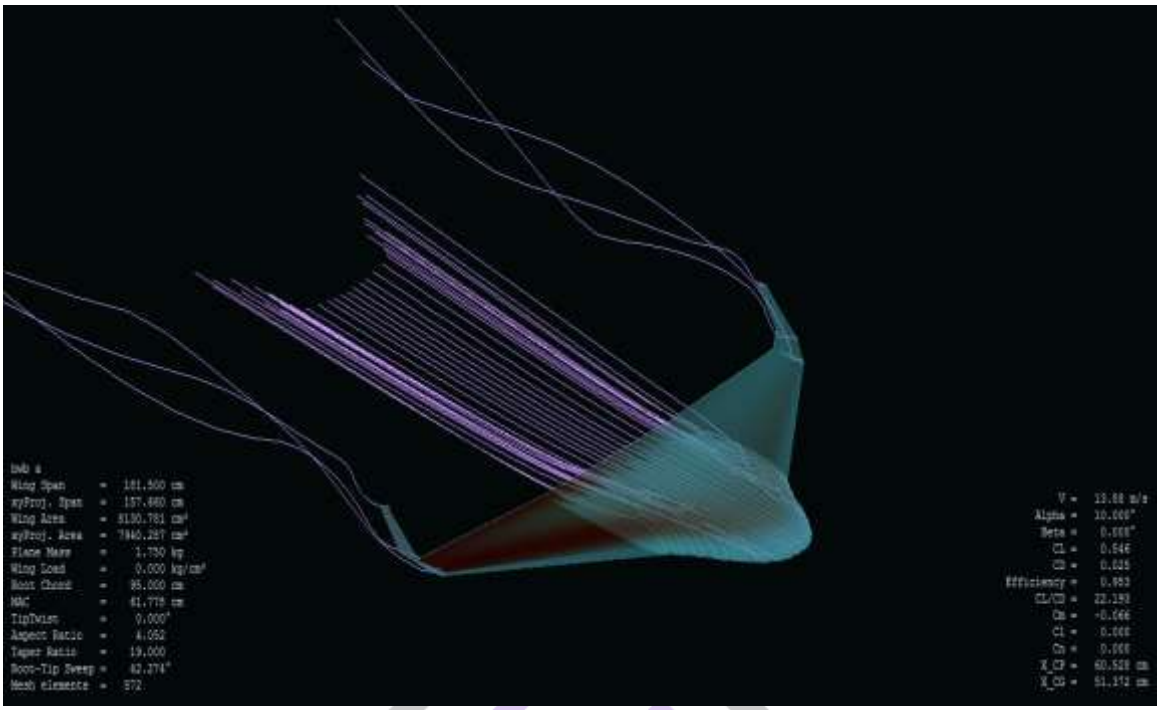


Fig 16. Wingtip vortices at the winglets.

X. CONCLUSION

Combining wing and body in the blended-wing-body configuration is an innovative idea which benefits from its inherent aerodynamic potential. In this work, a reference aircraft was chosen for dimensions with some design changes. The fabrication of the aircraft was successfully carried out using the specified material and electronic systems. The test flights of the aircraft were also performed according to the mission profile and found to satisfy all the requirements. Analysis of the aircraft was carried out and the graphs obtained after analysis were found to show similar pattern as that of the reference aircraft which validates our analysis.

XI. FUTURE SCOPE

- The changes made in the design yielded positive result and the use of this design for various applications seems promising.
- The design, fabrication and flight testing of this aircraft were carried out with minimal analysis. Nevertheless, the aim of flying the aircraft was achieved successfully. Therefore, it is implied that with detailed calculations and software analysis, the design can be optimized while the capability and flight performance of the aircraft can be enhanced.
- The aircraft can be equipped with telemetry systems to downlink real time flight data which can be used to compare and analyze software results.
- The aircraft has the potential to be used as an Unmanned Aerial Vehicle(UAV) , can be equipped with navigation system in both remotely controlled and autonomous version .The increased internal volume will facilitate increased payload carrying capacity without creating excess drag.
- Materials with higher strength to weight ratio can be used for fabrication to minimize the weight while maintaining the structural integrity.
- This design can be modified to have symmetry about the horizontal plane for higher speed characteristics.