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# Design and Computational Fluid Dynamic Analysis of a 9-Seater Business Jet Aircraft

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***Abstract*:**
The Business jet aircraft are designed for transporting small groups of people. The aim of the project is to design and conceptualize a nine-seater business jet aircraft. This project shows the basic ideas and capabilities of the conceptual aircraft design. The parameters of this conceptual aircraft were obtained from a set of tentative values from the analysis of other business jets with similar specification. The main motivation for developing the business jets is to save the valuable time and cost for top level executives with efficient structure and effective aerodynamics. In this project the weight estimation to estimate the empty fuel weight and take-off weight, wing selection, aerofoil selection, thrust calculation and engine selection to produce the calculated thrust, Vn diagram and its calculations are done. The design of fuselage is modelled using CATIA V5 and wing is modelled using SOLIDWORKS Inc. and the computational fluid dynamic analysis of wing and fuselage was done in ANSYS 2019. Finally, the basic outline of our business jet aircraft was obtained and it is estimated that this business jet aircraft can provide good performance.

**Keywords:**Business jet, Analysis, Ansys, NACA 2412.

## 1. INTRODUCTION

Fundamentally, an aircraft is a structure. Aircraft designers designs the structure in such a way that it can provide desired aerodynamic characteristics. The Business jet aircraft are designed for transporting small groups of people. The main motivation for developing the business jets is to save the valuable time and cost for top level executives with efficient structure and effective aerodynamics. The other business jet aircraft studied to do this calculation are namely.,FALCON 900LX, CHALLENGER 6000, CESSNA CITATION XLS+, HAWKER 400XP, EMBRAER 500, FALCON 2000LXS, CESSNA SOVEREIGN PLUS, FALCON 7X, PIAGGIO 180 AVANTI and CHALLENGER 350. The design parameters of the aircraft are tabulated and with help of the tentative graph the design parameters of our business jet are chosen.

## 2. MISSION PROFILE

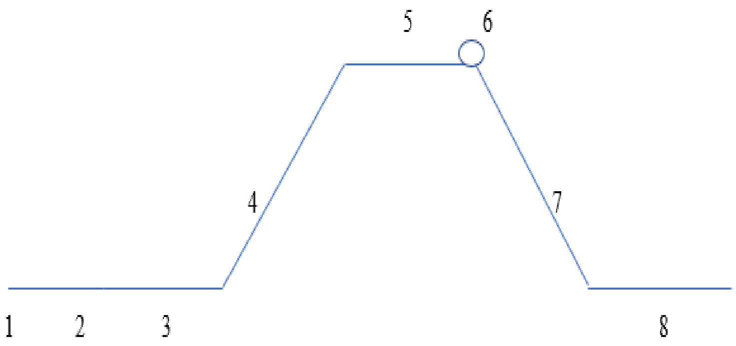


**Fig. 1.**Mission profile diagram for business jet

1 - Engine & warmup

2 - Taxing

3 - Take off

4 - Climb

5 - Cruise

6 - Loitering

7 - Descend

8 - Landing, Taxing, Shut off.

## 3. DESIGN PARAMETERS

The parameters of this conceptual aircraft were obtained from a set of tentative values from the analysis of other 10 similar business jets as discussed in the introduction.

**Table 1.** Design parameters for business jet

| PARAMETERS | VALUES |
|---|---|
| PASSENGERS | 9 |
| LENGTH | 20 m |
| HEIGHT | 6.5 m |
| WINGSPAN | 21m |
| WING AREA | 49 $m^2$ |
| ASPECT RATIO | 9 |
| TAKEOFF DISTANCE ($S_{LO}$) | 2 km |
| LANDING DISTANCE ($S_T$) | 1 km |
| RATE OF CLIMB (R/C) | 20.7 m/s |
| GLIDING ANGLE | 0.57° |
| TIME TO CLIMB | 11.2 min |
| MAXIMUM SPPED | 0.85 mach |
| SERVICE CELING | 14500 m |
| RANGE | 6000 km |
| WING LOADING | 510 $kg/m^2$ |
| CRUISING SPEED | 850 km/hr |

## 4. WEIGHT ESTIMATION

Calculation of weight is very important to understand the aircraft performance. The weight of the aircraft varies throughout the mission.

Takeoff Weight ($W_{TO}$) = 24947.58 Kg

$W_f = W_{fused} + W_{reserved}$

$W_{fused} = (1 – M_{FF}) * W_{toguess}$

$W_{toguess}$= 55000lb (24941.58kg)

$M_{FF} = 0.61$

$W_{fused}$ = 21450

$W_{reserved}$ = 10% of $W_{fused}$ = 2145 lb.

## 5. WING TYPE

Tapered swept back with monoplane configuration mounted as low-wing. Tapered wing is used due to its smaller tip chord to reduce induced drag. Swept is used to reduce the aerodynamic drag and improve the performance. Moreover, it gives structural convenience.

## 6. AEROFOIL CHOSEN

The chosen aerofoil is NACA 23012. It high α, high $(C_L)_{max}$, high $(C_L/C_D)_{max}$, low $C_D$, low pitching moment coefficient and moreover, the stall is gentle.

## 7. DESIGN OF WING

The wing for this business jet is designed with 11 ribs and 4 spars in solidworks. The material of the ribs, spars and skin is assumed to be Aluminum.

**Fig.2.** Isometric view of wing without skin

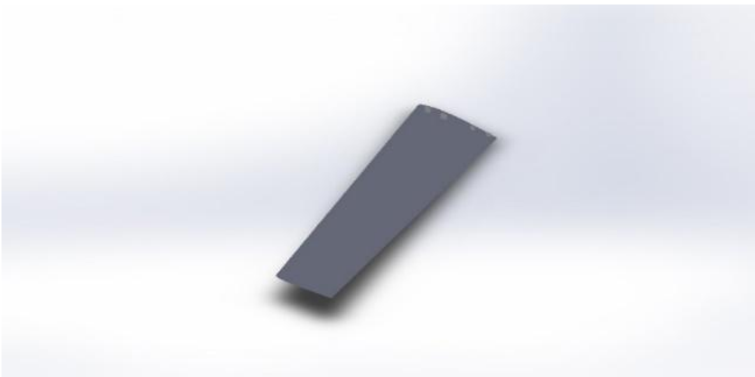

**Fig.3.**Isometric view of wing with skin

## 8. ANALYSIS OF WING

The CFD analysis of wing was done in 2D using ANSYS Inc Student version software. The flow over the aerofoil was analysed. Initially, the design was imported from Solidworks as an .iges file and structured meshing was done. Pressure based; turbulent flow model is chosen. The magnitude of free stream velocity is given as 250 m/s and the pressure is given as 23800Pa. Around 1000 iterations were carried out to get theresult. The analysis was done for two different Angle of Attack $0^o$ and $5^o$ and the pressure contour, velocity contour, velocity streamline was computed for the respective angle of attack.

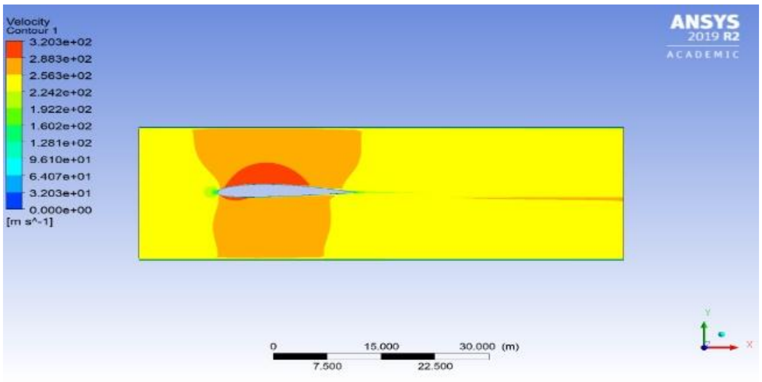


**Fig.4.**Velocity contour over the aerofoil at AOA $0^o$

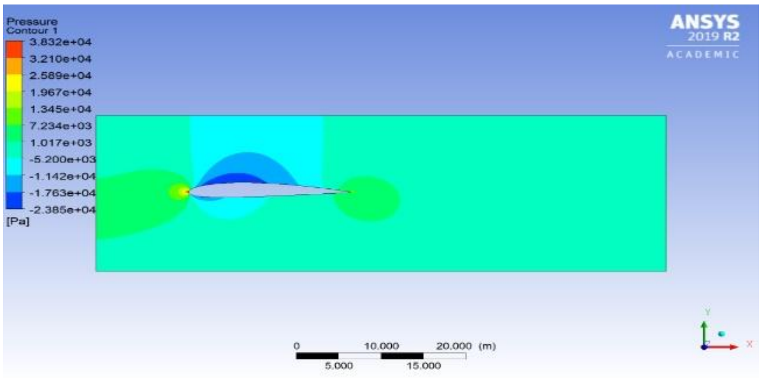


**Fig.5.**Pressure contour over the aerofoil at AOA $0^o$

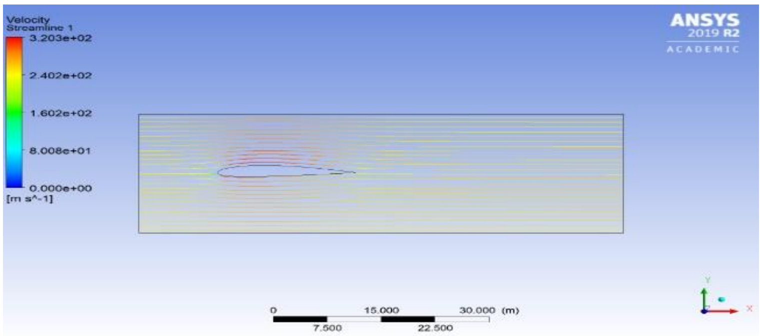


**Fig. 6.**Velocity Streamline over the aerofoil at AOA $0^o$

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From the Fig. 5,6 and 7 it is concluded that, for the aerofoil at zero angle of attack, the pressure is maximum at the leading edge. The pressure is less at the upstream of the aerofoil and comparatively high at the downstream of aerofoil. A uniform stream line is observed without any flow disturbance. The velocity becomes almost zero at the stagnation point and increases at the upstream of the aerofoil and comparatively decreases at the downstream of the aerofoil. The similar results are obtained for angle of attack $5^{o}$ and shown in Fig. 8,9 and 10.

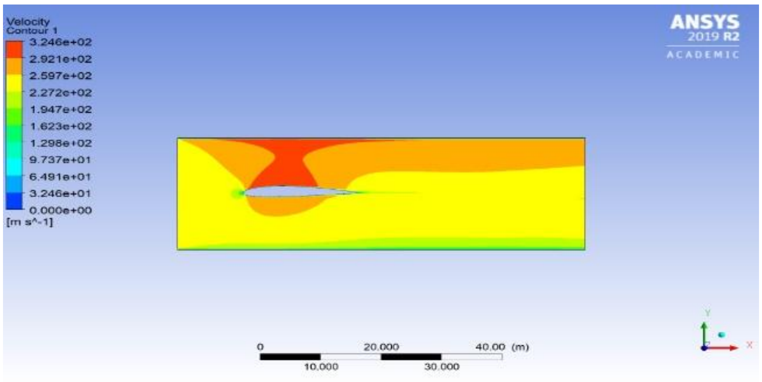


**Fig. 7.**Velocity contour over the aerofoil at AOA $5^{o}$

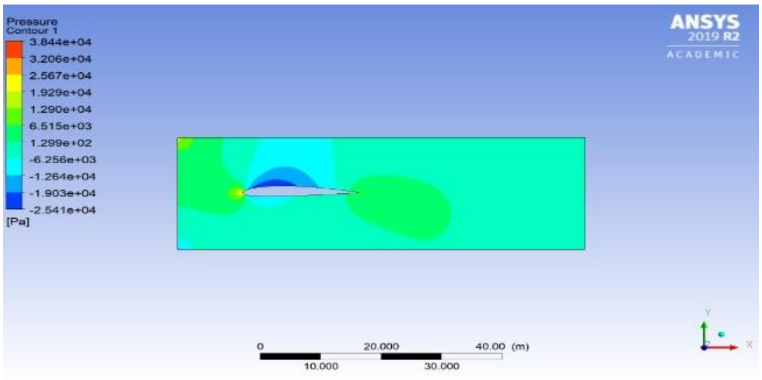


**Fig. 8.**Pressure contour over the aerofoil at AOA $5^{o}$

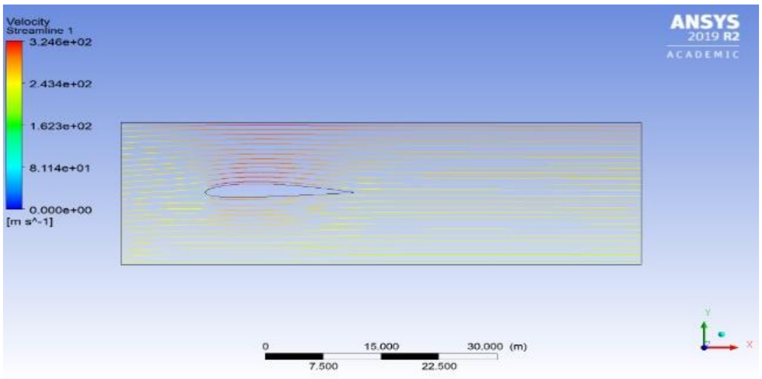


**Fig. 9.**Velocity Streamline over the aerofoil at AOA $5^{o}$

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## 9. FUSLAGE TYPE

A semi-monocoque fuselage has been constructed. They add strength and rigidity to the fuselage since, its construction depends on many structural members.

## 10. DESIGN OF FUSELAGE

The fuselage for this business jet was designed with 10former and 5 stringers and 2 bulkheads in Catia V5.

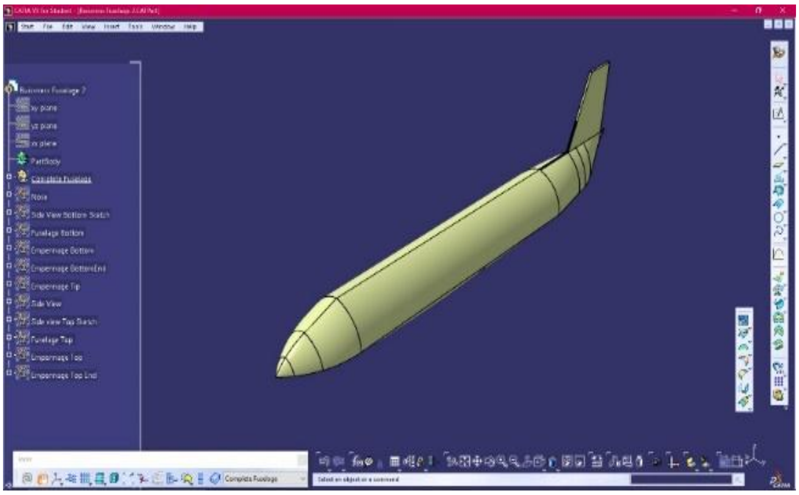

**Fig.10.**Isometric view of fuselage

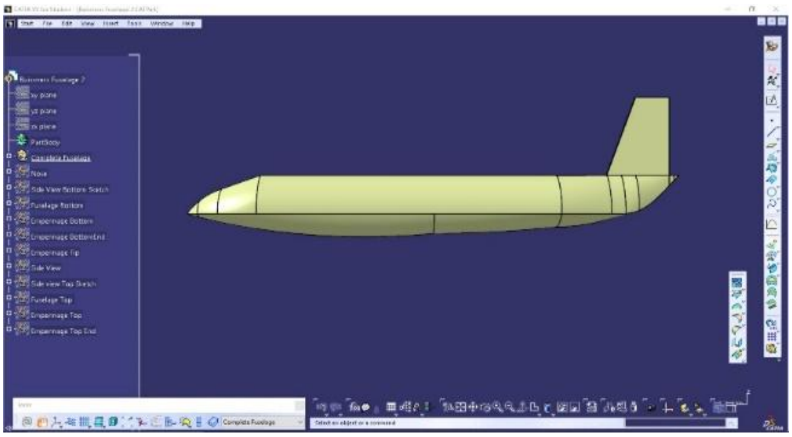

**Fig. 11.**Front view of fuselage

## 11. ANALYSIS OF FUSELAGE

The analysis of the aircraft fuselage was done in 3D using ANSYS Inc Student version software. The design was imported from CATIA V5 as an .iges file and structured meshing was done.Density based; turbulent flow model is chosen. The magnitude of free stream velocity is given as 250 m/s and the pressure is given as 26500Pa with temperature 225K. Around 1000 iterations were carried out to get the result. The pressure contour and velocity streamline were computed.

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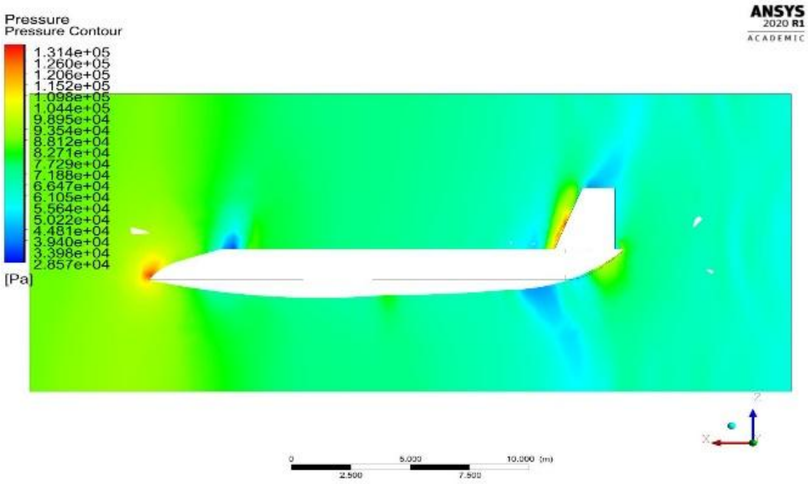


**Fig. 12.**Pressure distribution over the fuselage

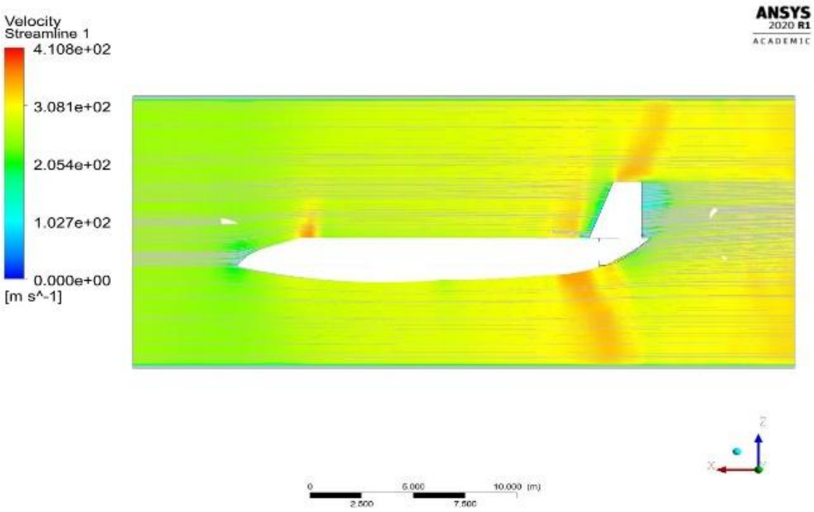


**Fig. 13.** Velocity Streamline over the fuselage

## 12. EMPENNAGE TYPE

T-tail configuration is mounted.It makes the vertical area more effective by the end plate effect of the horizontal tail. This allows a slightly smaller vertical tail area. Moreover, the horizontal tail has plenty of ground clearance.

## 13. ENGINE TYPE

Tail mounted tri-engine is used.The tail mounted engine aircraft's wing is easier to design. It simplifies the wing design. The tri engine enables the aircraft to travel from India to Europe without stopping at any airport in between. It helps the pilot to easily handle the engine failure.

## 14. LANDING GEAR TYPE

Retract actable, tricycle landing gear is constructed. Since, it is the most prevalent landing gear configuration. The nose wheel is at the forward end of the fuselage will absorbs shock.

## 15. VN DIAGRAM

$$V_{max} = \sqrt{\frac{2Wg}{\rho S C_{L_{max}}}}$$

$V_{max}$ for positive zone

W = 24947.58 kg, $C_{L_{max}}$ = 1.6

$$V_{max} = 74.1\ m/s$$

$V_{max}$ for negative zone

W = 24947.58 kg$C_{L_{max}}$ = 1.25

$$V_{max} = 80.8\ m/s$$

$$V_c = \sqrt{\frac{2Wgn_{max}}{\rho S C_{L_{max}}}}$$

$V_c$ for positive zone

W = 24947.58 kg$C_{L_{max}}$ = 1.6$n_{max}$= 4.4

$$V_c = 150\ m/s$$

$V_c$ for negative zone

W= 24947.58 kg$C_{L_{max}}$ = - 1.25$n_{max}$= - 1.8

$$V_c = 108.36\ m/s$$

$V_d$ = 1.5 × $V_{cruise}$

= 1.5 × 236.111

= 354.17 m/s

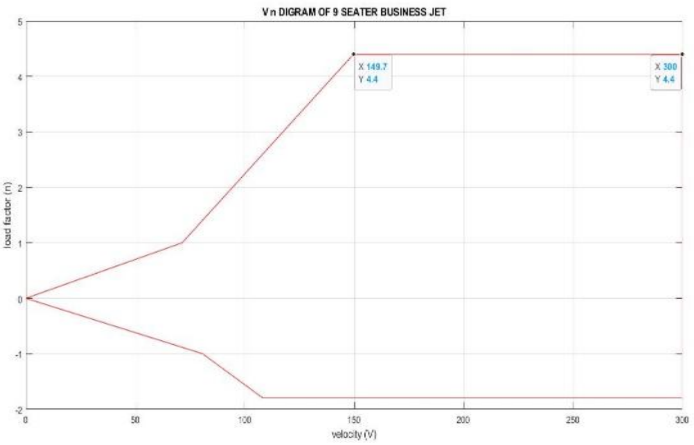


**Fig. 14.**Vn diagram of the 9-seater business jet aircraft.

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**16.3 - VIEW OF AIRCRAFT**

A 3-view diagram of the business jet aircraft was modelled using the **AutoCAD** software to show the design of the aircraft with dimension. The front view, top view and side view are shown in Fig. 15, Fig. 16 and Fig. 17 respectively.

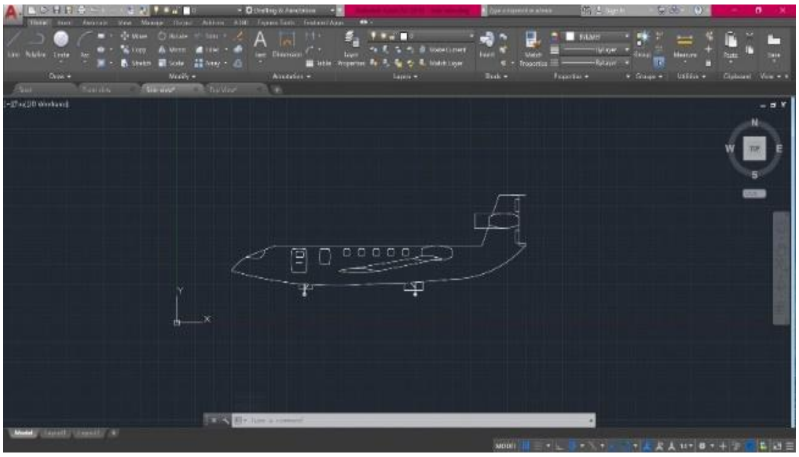

**Fig. 15.** Front view of the aircraft

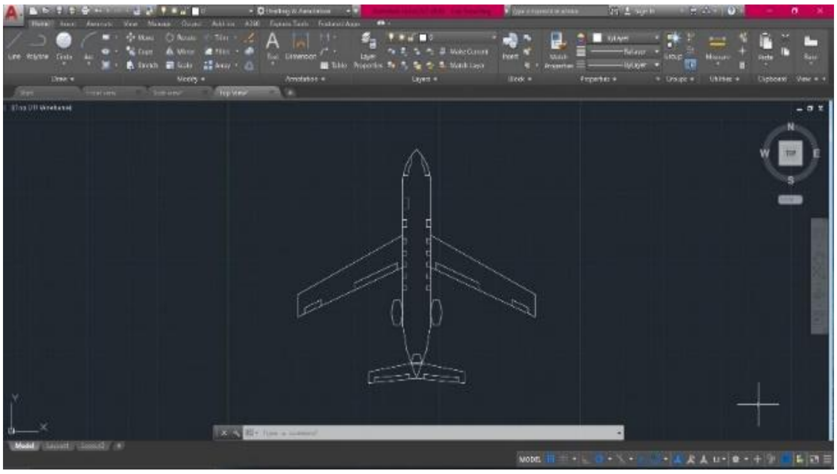

**Fig. 16.** Top view of the aircraft

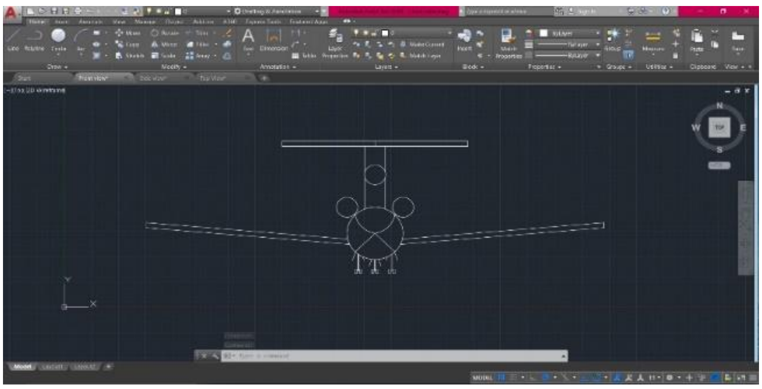

**Fig. 17.** Side view of the aircraft

## 17. CONCLUSION

The primary design of 9-seater business jet was done and also analysed. Some performance parameters of the business jet aircraft were calculated. Thedesign values and results are not an exact reflection of the aircraft's actual design. However, the basic outline was developed andthe final design can produce a good performance as discussed in the analysis part. This is not afinal design and is highly subjected to improvements and innovations to make the design as real as possible.

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