Preliminary Design and Analysis of World's Smallest Aircraft

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Abstract— In this study an initiative is taken to put focus on a special design of world smallest aircraft. Bumble bee-2 a Guinness recorded world smallest aircraft is a reference airplane for my design. My airplane MVP-TS has a wing span of 1.5m, 2m in length which is 18% less than that of Bumble bee- 2 aircraft. In this project a smallest single seater airplane MVP-TS is designed and analyzed. The aerodynamic characteristics such as coefficient of lift (C_L) and coefficient of drag (C_D) at different Angle of attack ranging from 8^0 to 20^0 is analysed. In today's world the aircraft manufacturing industry plays a major role in a profitable business with much of competitors, being one of the future competitor my ultimate aim is to manufacture the smallest aircraft which is much less in cost, so that an individual dream of flying will be true. Being a small single seater airplane with reduced cost, this airplane may take a more production in future. As an initiative the preliminary design aspects of my aircraft is designed using CATIA-V5R17 software and analyzed using ANSYS-14.2 software.

Keywords: MVP-TS, World's Smallest Aircraft, MAVs

I. INTRODUCTION

The subject of the smallest plane is a bit more complex since one must ask what class of aircraft to consider. For example, the remote controlled planes that you and I can buy in a store are obviously smaller than anything a human could fly aboard. A paper airplane flown by a child is even smaller than that, and many researchers are currently working on Micro Air Vehicles (MAVs) that rival insects in size. However, we will assume that this question is asking about the smallest manned plane in the world, or the smallest plane flown with a human pilot aboard. Even this category can be confusing since it could possibly include vehicles like hang gliders or ultra-lights, but we will limit our discussion to more conventional airplane types. This definition leaves us with three primary sets of aircraft designers who have competed against each other to build and fly the "world's smallest plane" since the end of World War II.

A. Wee Bee

It was an American ultra-light monoplane designed and built by Bee craft Associates. It was described as the world's smallest plane The Wee Bee was designed by William "Bill" Chana, Kenneth Coward, and Karl Montijo. They described it as big enough to carry a man and small enough to be carried by a man.

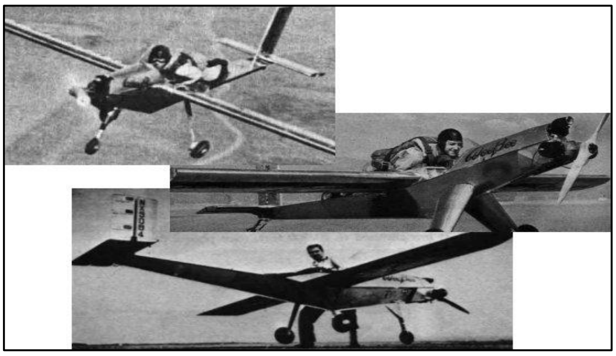


Fig. 1: Wee bee

B. Stits Junior

Following in the footsteps of the Wee Bee was an even smaller plane called the Stits Junior. Designed by Ray Stits [1] and Martin Young's, the junior was rebuilt from the components of a surplus World War II Taylor craft L-2. The junior was around 11 ft. (3.4 m) in length and had a wingspan that varied between 8.8 and 9.3 ft. (2.7 to 2.8 m).

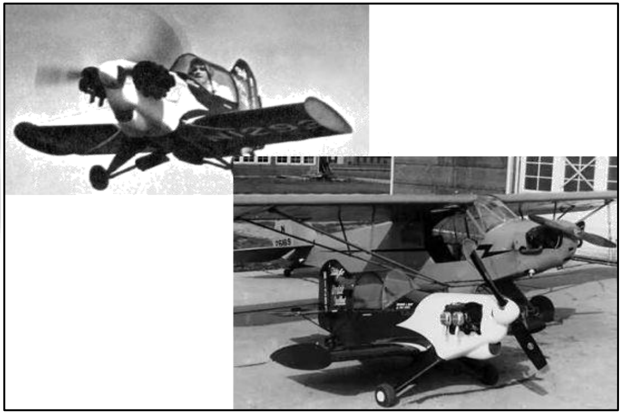


Fig. 2: Stits junior

C. Staib - Little Bits

Also competing against Stits to build the world's smallest plane during the 1940s was Wilbur Staib, an engineer living near Los Angeles. Believing he could build a plane even smaller than the junior, Staib set out to design and build a tiny monoplane called the Little Bit. Only 11 ft. (3.4 m) long and with a wingspan of just 7.5 ft. (2.3 m), the Little Bit weighed a mere 390 lb. (177 kg) empty.

D. Sky Baby

However, Staib's challenge only encouraged Stits and co-builder Robert Starr to build a new plane even smaller than the junior or the Little Bit. Known as the Sky Baby, this new plane differed from earlier entries into the arena by adopting a biplane design instead of a monoplane. This change allowed the wingspan to be reduced even further to just over 7 ft. (2.1 m). With a maximum length under 10 ft. (3 m).

Fig. 3: Sky baby

E. Bumble Bee

The Sky Baby remained unchallenged as the world's smallest plane until the 1980s when its former pilot, Robert Starr of Phoenix, Arizona, built the Bumble Bee [2]. The Bumble Bee biplane was heavier than the Sky Baby at 547 lb. (248 kg) empty and 725 lb. (329 kg) loaded. However, its dimensions were otherwise smaller with a length under 9.5 ft. (2.9 m) and a wingspan of just 6.5 ft. (2 m). As a result, the Guinness Book of World Records considered the Bumble Bee to be the smallest plane in the world following its first successful flight on 28 January 1984.

Fig. 4: Bumble bee

F. Baby Bird

Ray Stits son Donald set out to recapture the title by building an even smaller monoplane called the Baby Bird. At 11 ft. (3.4 m) in length, the Baby Bird was longer than the Bumble Bee but had a smaller wingspan of 6.25 ft. (1.9 m) and weighed less at only 250 lb. (115 kg) empty.

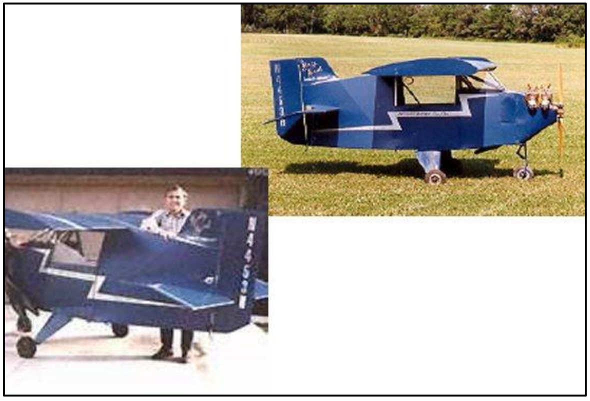


Fig. 5: Baby bird

G. Bumble Bee 2

However, Robert Starr believed he could go even smaller and completed a new Bumble Bee II [3] in 1988. The overall dimensions of the Bumble Bee shrank even further to 8.8 ft. (2.7 m) in length and a mere 5.5 ft. (1.7 m) wingspan. Its 85-hp piston engine made possible a maximum speed of 190 mph (305 km/h)

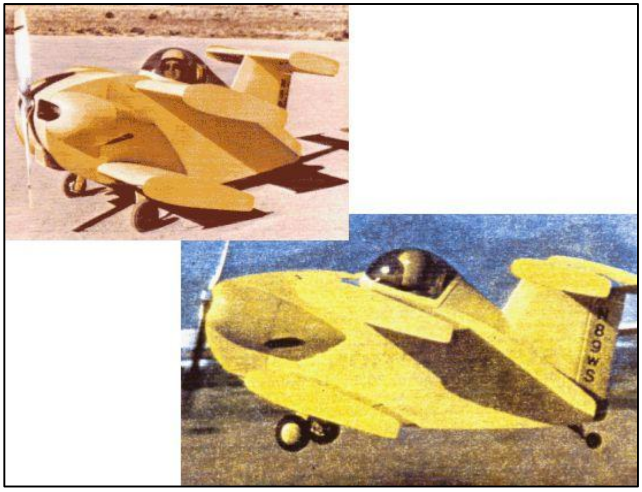
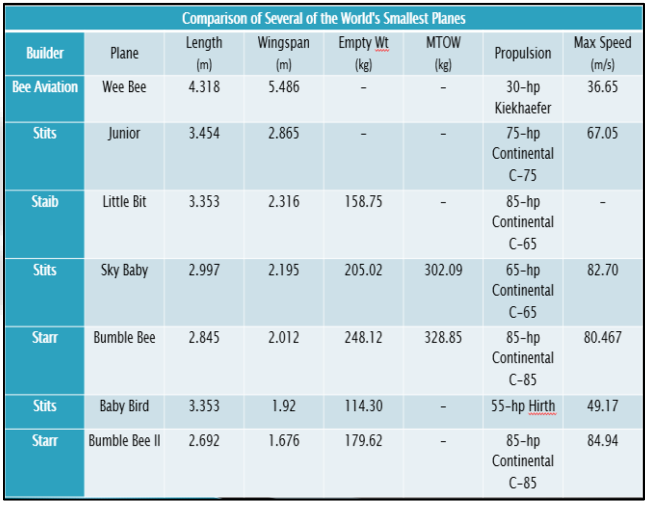


Fig. 6: Bumble bee 2



Comparison of Several of the World's Smallest Planes

Builder	Plane	Length (m)	Wingspan (m)	Empty Wt (kg)	MTOW (kg)	Propulsion	Max Speed (m/s)
Bee Aviation	Wee Bee	4.318	5.486	-	-	30-hp Kiekhaefer	36.65
Stits	Junior	3.454	2.865	-	-	75-hp Continental C-75	67.05
Staib	Little Bit	3.353	2.316	158.75	-	85-hp Continental C-65	-
Stits	Sky Baby	2.997	2.195	205.02	302.09	65-hp Continental C-65	82.70
Starr	Bumble Bee	2.845	2.012	248.12	328.85	85-hp Continental C-85	80.467
Stits	Baby Bird	3.353	1.92	114.30	-	55-hp Hirth	49.17
Starr	Bumble Bee II	2.692	1.676	179.62	-	85-hp Continental C-85	84.94

Table 1: Comparison of world's smallest planes

II. CATIA DESIGN

Reduction of wingspan and length of an aircraft from the mother plane of Bumble bee 2 is designed using Catia V5R17.

NAME OF AN AIRCRAFT	WING SPAN (m)	LENGTH (m)
BUMBLE BEE 2	1.68	2.7
MVP-TS	1.5	2

Table 2: Comparison between Bumble bee and MVP-TS aircraft

A. Wing Design

A wing is a type of fin that produces lift, while moving through air or some other fluid [4]. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as airfoils.

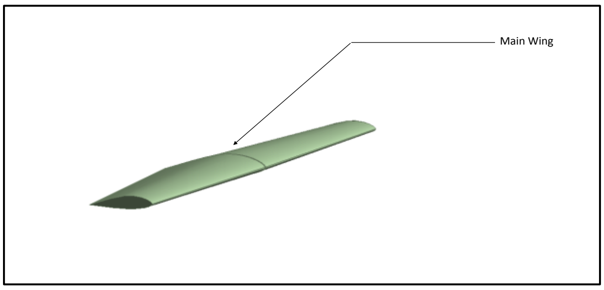


Fig. 7: Main wing

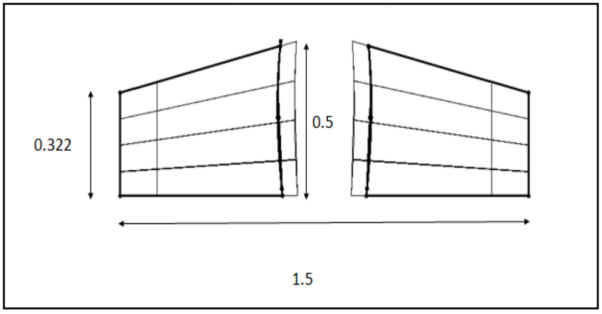


Fig. 8: Wireframe structure of main wing

Wing span	1.5m
Tip chord	0.322m
Root chord	0.5m
Wing area	0.615 m^2
Aspect ratio	3.65
Taper ratio	0.644

B. *Fuselage Design*

The fuselage is an aircraft's main body section. It holds crew, passengers, and cargo. In single-engine aircraft it will usually contain an engine, as well, although in some amphibious aircraft the single engine is mounted on a pylon attached to the fuselage [5], which in turn is used as a floating hull.

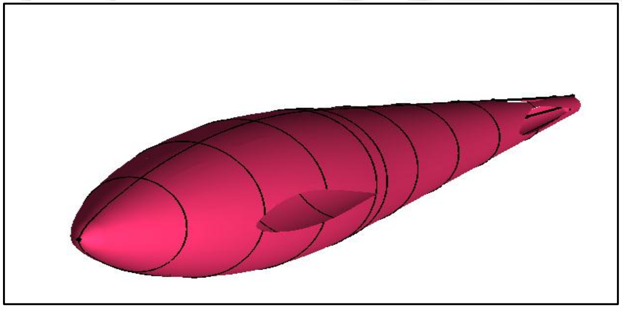


Fig. 9: Fuselage

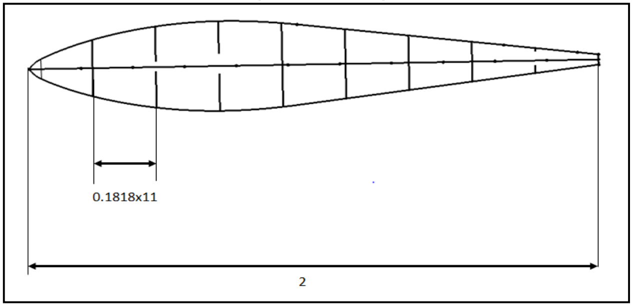


Fig. 10: Wireframe structure of fuselage

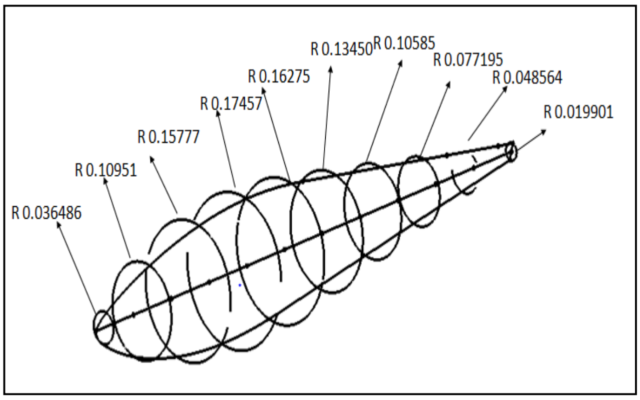


Fig. 11: Wireframe Radius of a fuselage

C. *Tail Design*

The empennage also known as the tail or tail assembly, is a structure at the rear of an aircraft that provides stability during flight, in a way similar to the feathers on an arrow.

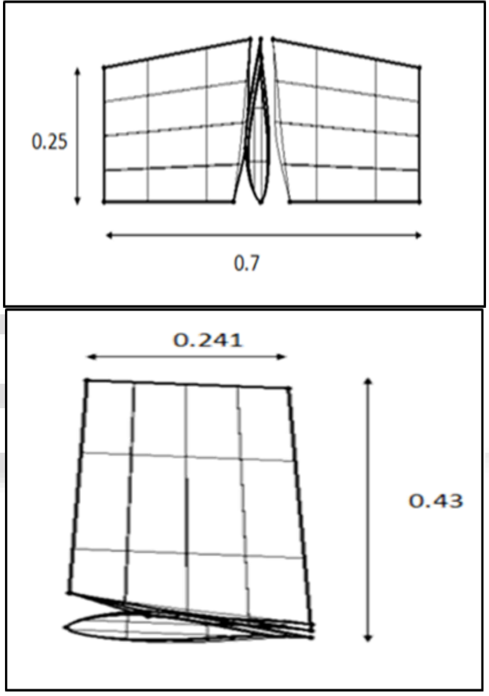


Fig. 12: Wireframe structure of tail wing

D. *Assembled 3D view of aircraft*

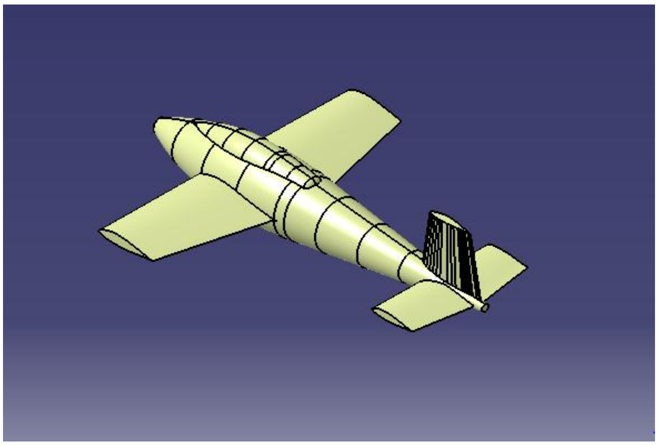


Fig. 13: Catia design of an aircraft

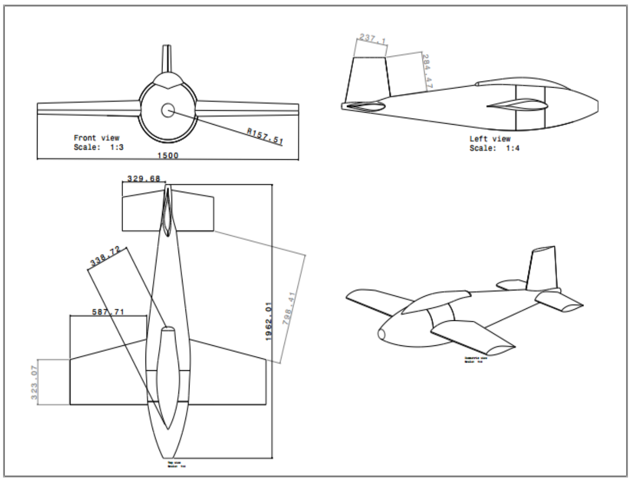


Fig. 14: Drafting of an aircraft

III. ANALYSIS

A. *Analysis of an Aircraft*

1) *Geometry*

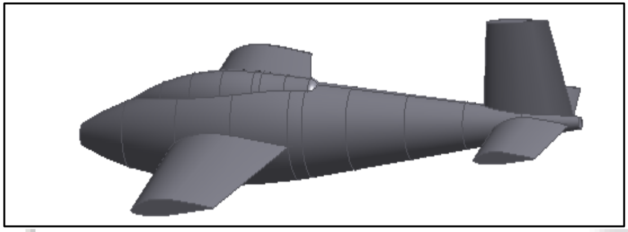


Fig. 15: Import of Aircraft design

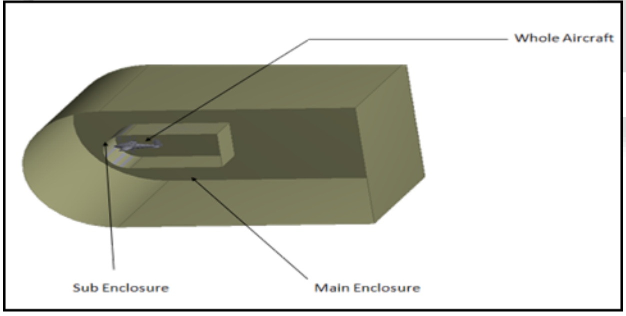


Fig. 16: Aircraft with enclosure

2) *Mesh*

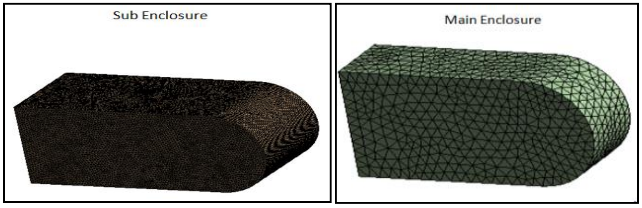


Fig. 17: Mesh file of an aircraft

3) *Mesh report*

Domain	Nodes	Elements
Default Domain	245912	1375062

4) *Boundary Condition*

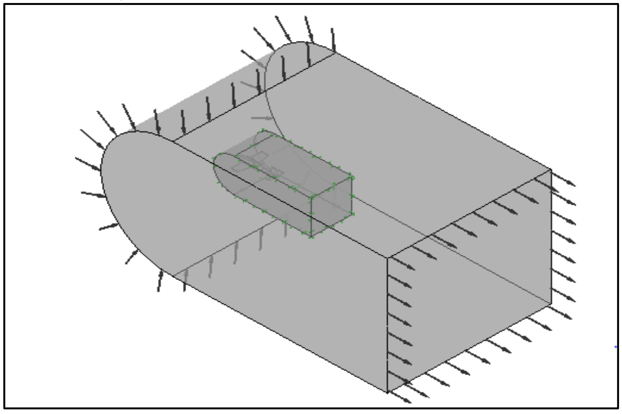
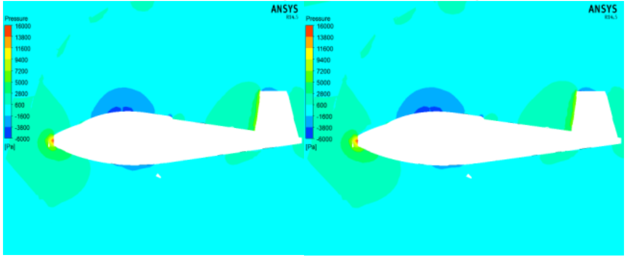


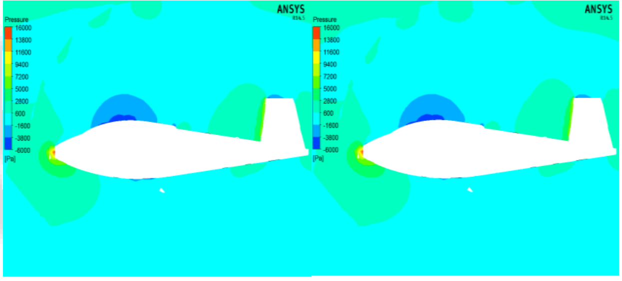
Fig. 18: Boundary condition of inlet velocity 140m/s

5) *Pressure contour of aircraft at various Angle of attack*

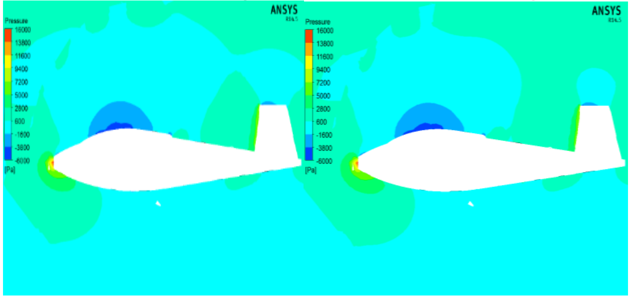
AOA at 8 deg AOA at 9 deg



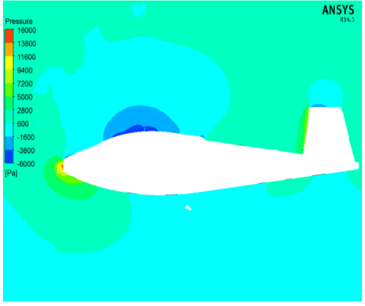
AOA at 12 deg AOA at 13 deg



AOA at 14 deg AOA at 16 deg

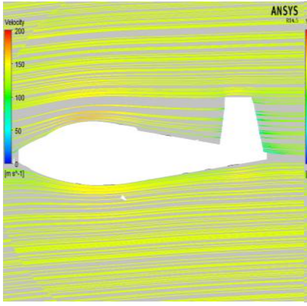


AOA at 18 deg

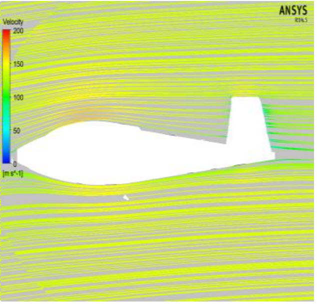


6) Velocity streamlines of aircraft at various angle of attack

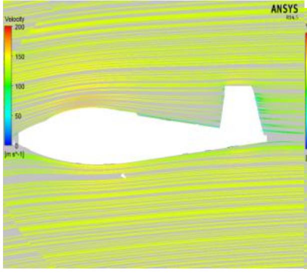
AOA at 8 deg



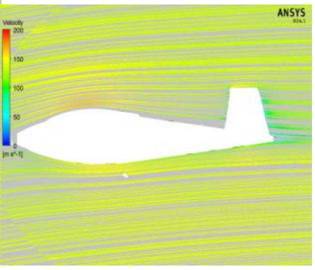
AOA at 9 deg



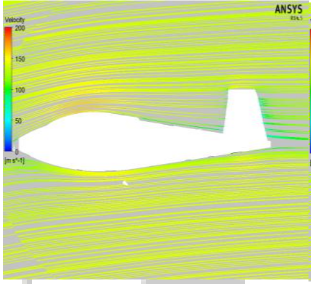
AOA at 12 deg



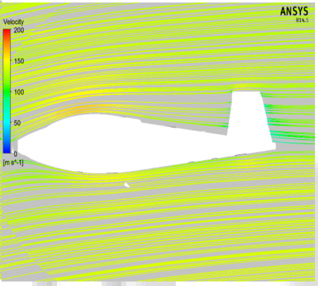
AOA at 13 deg



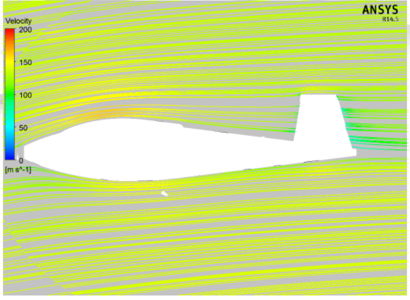
AOA at 14 deg



AOA at 16 deg



AOA at 18 deg



IV. RESULT AND DISCUSSION

A. Lift

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.

1) Coefficient of Lift

The lift coefficient (C_L, C_N or C_z) is a dimension less coefficient that relates the lift generated by a lifting body to the fluid density around the body, the fluid velocity and an associated reference area [6].

AOA	C_L	C_L Fuselage	C_L Main wing	C_L Tail wing
8	5.57E-01	1.69E-02	1.63E-01	-9.43E-03
10	1.34E-01	4.15E-02	1.87E-01	2.33E-04
12	1.52E-01	4.79E-02	2.10E-01	-5.32E-03
13	1.61E-01	5.13E-02	2.21E-01	-5.76E-03
14	1.69E-01	5.49E-02	2.30E-01	-5.77E-03
15	1.77E-01	5.86E-02	2.40E-01	-5.31E-03
16	1.85E-01	6.25E-02	2.48E-01	-4.57E-03
17	1.92E-01	6.64E-02	2.56E-01	-3.16E-03
18	1.99E-01	7.05E-02	2.64E-01	-1.25E-03
19	2.06E-01	7.47E-02	2.70E-01	1.23E-03
20	**2.12E-01**	**7.89E-02**	**2.76E-01**	**4.19E-03**
21	2.00E-01	7.36E-02	2.68E-01	4.39E-03

Table 3: Coefficient of lift at fuselage, main wing, and tail wing different Angle of attack

2) Calculation

Maximum coefficient of lift (C_L) = 0.212
Angle of attack (α) = 20^0

$$\text{Lift (L)} = \tfrac{1}{2}\,\rho\, S\, V^2\, C_L$$

Where,
CL - Co-efficient of Lift
ρ - Density of air (1.225 kg/m^3)
v - Velocity of aircraft (140m/s)
S - Wing area (m^2)

Since the tapered wing is chosen the surface area can be calculated by using this formula,

Wing area(s) = Average chord * wing span
Average chord= $(C_t+C_r)/2$
Where,
C_t – Length of a chord at tip (0.32m)
C_r – Length of chord at root (0.5m)
Average chord= (0.32+0.5)/2 = 0.41m
Wing span (b) = 1.5m
Wing area(s) = 0.41*1.5 = 0.615m^2
Lift (L) = $\tfrac{1}{2}\,\rho\, S\, V^2\, C_L$
=$\tfrac{1}{2}$*1.225*140^2*0.615*0.212
Lift (L) = 1565.2N

B. Drag

In fluid dynamics, drag is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid.

1) Coefficient of Drag

AOA	C_D	C_D Fuselage	C_D Main wing	C_D Tail wing
8	2.15E-01	1.69E-02	4.95E-02	1.37E-01
10	3.85E-02	4.15E-02	5.71E-02	1.58E-01
12	4.53E-02	4.79E-02	6.59E-02	1.82E-01
13	4.90E-02	5.13E-02	7.06E-02	1.95E-01
14	5.29E-02	5.49E-02	7.56E-02	2.09E-01
15	5.70E-02	5.86E-02	8.07E-02	2.23E-01
16	6.14E-02	6.25E-02	8.60E-02	2.38E-01
17	6.59E-02	6.64E-02	9.15E-02	2.53E-01
18	7.06E-02	7.05E-02	9.70E-02	2.68E-01
19	7.55E-02	7.47E-02	1.03E-01	2.84E-01
20	8.06E-02	7.89E-02	1.09E-01	3.00E-01
21	8.43E-02	8.67E-02	1.14E-01	3.16E-01

Table 4: Coefficient of drag at different Angle of attack

In fluid dynamics, the drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment, such as air or water.

2) Calculation

Maximum coefficient of Drag (C_D) = 0.00806
Angle of attack (α) = 20^0

$$\text{Drag (D)} = \tfrac{1}{2}\,\rho\, S\, V^{2}\, C_D$$

Where,
C_D - Co-efficient of drag
ρ - Density of air (1.225 kg/m^3)
v - Velocity of aircraft (140m/s)
S - Wing area (m^2)
Wing area(s) = 0.41*1.5 = 0.615m^2
Drag (D) = ½*1.225*0.615*140^2*0.00806

$$\text{Drag (D)} = 59.50\text{N}$$

AOA (deg)	C_L	C_D	L (N)	D (N)
20	0.212	0.00806	1565.2	59.50

Table 5: Lift and drag value

3) Coefficient of lift (C_L) vs. Angle of attack (α)

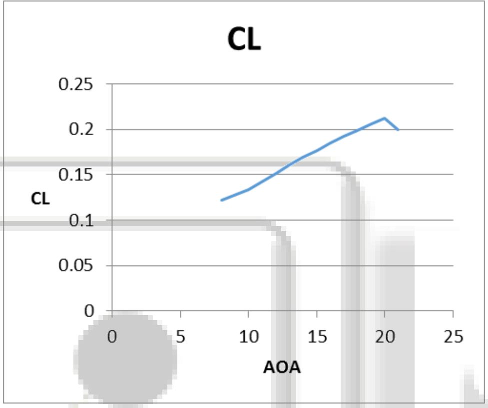


Fig. 19: Coefficient of lift

4) Coefficient of drag vs. Angle of attack

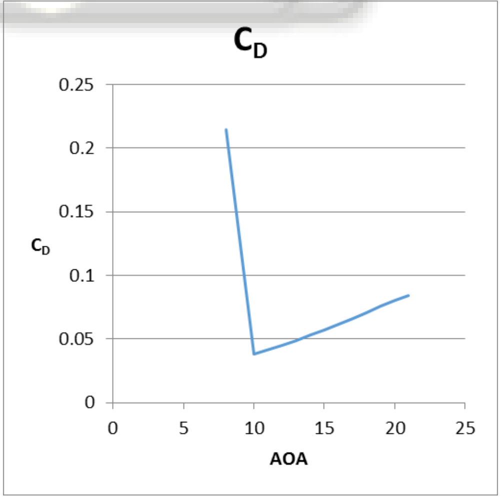


Fig. 20: Coefficient of drag

V. CONCLUSION

This project can be concluded with the completion of the initial sizing of MVP-TS aircraft. The project as to extend further with lot of numerical and iterative procedures to optimize and achieve the design proposal. The initial design and analysis process carried out in this project gives the value of Coefficient of lift (CL) and coefficient of drag (CD) for different angle of attack which is ranging from 80 to 210. By using the maximum CL and CD at a corresponding angle of attack the amount of lift force and drag force is numerically calculated

This project can be worked on further at the next level, as numerous optimization have to be carried out to get the conceptual design completed. The CAD model and Analysis result can be further modified with the complete design.

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