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AMITY UNIVERSITY

--------------------Uttar Pradesh--------------------

Major Project Report on

Aerodynamic Investigation and Design of High-Performance Glider

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

A glider or a sailplane is just another type of a fixed wing aircraft. Generally, they are used in the sport of gliding. This idea of flying gliders for sport was originated in Germany in 1910. Consequently, world's largest sailplane production company Alexander Schleicher GmbH & Co. is located in Poppenhausen, Germany.

The major difference between a sailplane and a conventional aircraft is engines. A sailplane lacks engine and that's why there isn't any forward force or thrust acting on the glider. As there is no thrust, force of drag goes unopposed which quickly brings the glider down. Therefore, while designing a sailplane, the most important thing that designing engineers have to keep in mind is to minimise drag as much as possible.

This project is divided into three parts: Selection of airfoils, Design of Sailplane, Optimization of the Design. In the first part, we selected many high-performance aerofoils and did their simulations on Ansys to find their glide ratios. Aerofoil which had the highest performance (Eppler 657) was used in the design of our sailplane. In the second part, we made a 3D design of a sailplane in Solidworks and did the flow visualization to find glide ratio of the sailplane. In the last part, we attempted to optimize our design so that we can get maximum value of the glide ratio.

Designing is basically done in three parts: fuselage, wing and tail, steps for which are written in section 3. Initially, we planned to design a rectangular wingspan of Aspect Ratio (AR) 38. But later we decided to make a tapered wingspan as it is known to be more efficient than the rectangular one. After we made our initial design, we optimized it by doing some changes in the design which are discussed in detail in Section 4.

In the following sections we will discuss about the performance and aerodynamics of high-performance sailplane, the external factors which affects the performance of sailplane and some other important terms that one must know while designing a sailplane.

2. Sailplane Aerodynamics

When we talk about conventional aircraft, there are four forces acting on it during steady and level flight. These are lift, weight, thrust, and drag. Lift counters gravity or weight force, while drag counters the forward force called thrust. During steady level flight, lift is equal to weight. Sailplanes which have engines installed can easily obtain thrust from that engine. So, during gliding, a pilot can switch on or switch off the engine according to the requirement. But what about the engineless sailplanes. They can glide for hours without any engine. So where does the thrust come from. The answer is that a sailplane uses the horizontal component of weight and lift to produce this forward force. That is the reason why the weight of sailplane is increased during gliding with the help of water ballast. That is also one of the reasons to maximise L/D ratio while designing the sailplane.

2.1. How Gliders stay aloft for long period of time?

We now know that while designing a sailplane, we attempt to maximize the L/D ratio for optimised performance. But that is not the only way for a sailplane to fly for hours. Pilot can also take advantage of the external factors. There are four kinds of convection (rising air); thermals, ridge lift, standing mountain waves, and convergence lift. Pilots can also make use of them in order to generate more lift in s sailplane. A thermal is created when the heat is absorbed by the ground from the sun. A column of hot and humid air rises from the ground which is used by the sailplane pilots to create lift. Thermals can make sailplanes reach altitudes of up to 18000 fts, but generally a rise 5000-6000 ft is observed. Ridge lifts are generated when high-speed wind strikes the irregular surface like cliffs and mountains. Air will try to flow past them by flowing above them and while doing so, provides lift to the sailplane pilots. Wave lift is the consequence of oscillatory motion of air. It is also called gravity waves by atmospheric scientists. These provides maximum altitude gain out of the three. Sailplanes can reach altitudes of as high as 45000 fts. For instance, the cited altitude record below was achieved in such a wave. Convergence lift is generated when two masses of air flowing in different directions collide, like sea-breeze and inland air mass. Such conditions generally exist near the ground between valleys of ocean waves or on the leeward side of ridges. The wind speed in the upper air mass is much greater when compared to the lower one and the two are separated by a steep speed gradient.

3. Sailplane Performance

3.1. Factors Affecting Performance

Sailplane performance during flight depends on many external atmospheric conditions. These are altitude, temperature and wind. The only important performance parameter that [15] can be controlled is weight of the sailplane during designing. These factors are explained in detail below:

3.1.1. Altitude

Density of air decreases as we go above the surface of the earth because at high [16] altitudes, atmospheric pressure acting on the air decreases and molecules of the air can [17] easily move further apart. As a result, number of molecules in the same volume of air will be lower than that at lower altitudes. As the density is reduced, the lift generated on the sailplane will also be reduced and hence sailplane's take-off and climb performance is reduced.

3.1.2. Temperature

As the temperature increases, distance between molecules will also increase due to thermal expansion. Therefore, increasing the temperature will have similar effects on the performance of the sailplane as increasing the altitude, that is, as temperature increases, take-off and climb performance is reduced.

3.1.3. Wind

Wind can affect the sailplane performance severely. During launch, headwind will decrease the take-off distance while tailwind will increase the take-off distance. And if there are crosswinds, proper controlling and correction procedure for sailplane heading is required for successful take-off. At the time of cruising flight, headwinds reduce the speed of the sailplane. For example, if the sailplane is flying at 20 m/s, and a headwind of 5 m/s appears, then the net speed will be 15 m/s. On the other hand, tailwind increase [18] the speed of the sailplane. If in the previous example, a tailwind of 5 m/s appears, then the net speed would become 25 m/s. Crosswinds during cruise phase have similar effects as in launch phase. It changes the sailplane heading due to which it needs to be corrected. It must be noted that crosswinds have some headwind or tailwind component which can also increase or decrease the speed of the sailplane. During landing, these wind effects must be taken into and corrections and allowances must be made for the same.

3.1.4. Weight

An important design parameter of the sailplane is obviously its weight. All other characteristics like lift, drag, and glide ratio of the sailplane are impacted solely by its design and construction, and can be predetermined at take-off. The only characteristic the pilot controls is the weight of the sailplane. In some cases, pilots can also control glider configurations with the help of flaps. However, flaps are not available in all the models of sailplanes. Therefore, weight is the only other characteristic that can be controlled. While it is true that increased weight won't be helpful during take-off and climb phase, but during cruise phase, a pilot can increase the net forward force by increasing the weight of the glider which ultimately increases the speed of the sailplane. During launch phase, a heavy glider would require more take-off distance to reach flying speed because a heavy glider has more inertia, which proves to be a problem while accelerating the sailplane. Due to similar reasons, the heavier sailplane takes longer to climb than the lighter glider.

3.2. Rate of Climb

Rate of climb directly depends on the ground-launching equipment for ground launching gliders. The greater the strength of ground launching equipment, the higher the rate of climb will be When ground launching, value of rate of climb can surpass 2,000 feet per minute (fpm) if the winch of the tow vehicle is powerful and the speed of the tow vehicle is high. When aerotowing, rate of climb is dependent on the power of the towplane. Therefore, it is important to select a high-performance tow vehicle to achieve high rate of climb.

3.3. Placards

Cockpit placards are like quick steps guides for pilots. These provide information regarding the safe operation of the glider to a pilot. All required placards are in the Glider Flight Manual/ Pilot's Operating Handbook (GFM/POH). If the design of the glider is very complex, then the amount of information provided in placards is also high and difficult to read. For example, a high-performance sailplane may be equipped with wing flaps, retractable landing gear, a water ballast system, and other features to optimize the performance of that sailplane. In such cases, it may require additional placards.

3.4. L/D Ratio

L/D ratio is the ratio of lift to drag. Value of this ratio is equal to the glide ratio. A glide ratio tells the horizontal distance covered by the sailplane per unit of altitude lost. For example, if a sailplane has the glide ratio of 50, then it will cover 50 feet of horizontal distance while losing 1 feet of altitude. While designing a sailplane, the objective is to make this value as high as possible.

3.5. Ballast

Ballast is non-structural weight that is added to a glider. In sailplanes, there are two ways in which ballast weight can be used. Trim ballast can be used to alter the CG of the glider and thus making the handling of the sailplane according to the requirement of the pilot. Another type of ballast is performance ballast which is loaded into the sailplane which can improve the high-speed cruise performance.

4. Types of Gliders

Table 1: Types of Gliders

	Paraglider	Hang glider	High Performance Gliders/Sailplanes
Undercarriage	Pilot's legs used for take-off and landing	Pilot's legs used for take-off and landing	Wheeled undercarriage or skids are used
Wing Structure	Entirely flexible	Generally flexible but supported on a rigid frame	Rigid wing surface which totally encases wing structure
Speed Range (stall speed-max speed)	Slower- typically 25-60 km/h hence easier to launch	Comparatively faster (up to 20-75 km/h)	Max speed up to 280km/h and stall speed up to 65km//h
Max Glide Ratio	About 10 relatively poor glide performance	About 17 with up to 20 for rigid wings	Typically, around 60 but for 15-18 m span GR between 30 to 60
Turn Radius	Tighter turn radius	Somewhat larger turn radius	Even greater turn radius but still able to circle tightly in thermals
Cost	For a brand new one, the cost is around 1,50,000 INR	2,75,000 INR (Data shown is for Aeros Fox 16)	2,00,00,000 INR for new and for used it is around 15Lakhs to 40Lakhs

5. Types of drags and their Contributions

Following figure shows the speed polar curve of the ASW-27 sailplane with the contributions of different drags, i.e., induced drag, wing profile drag, tailplane drag, and fuselage drag. the largest contribution is due to the wing; at low speed due to induced drag and at high speed due to profile drag.

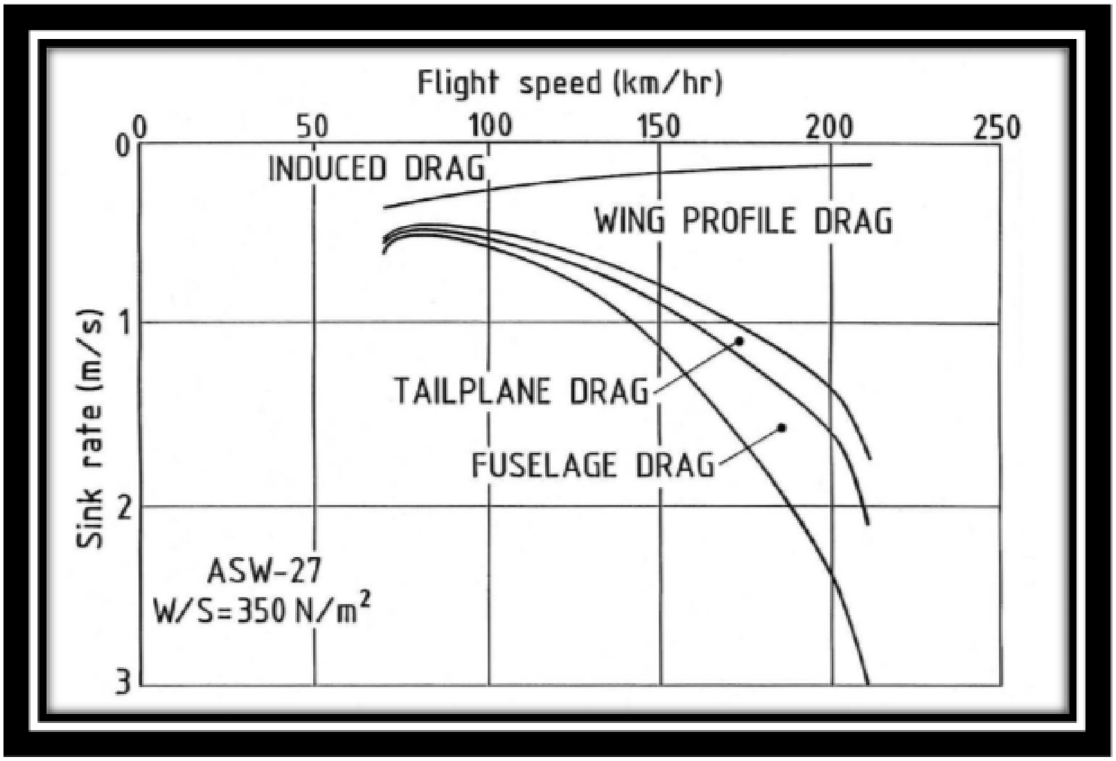


Fig. 1: Speed polar contribution curve of the ASW-27

5.1. Induced Drag

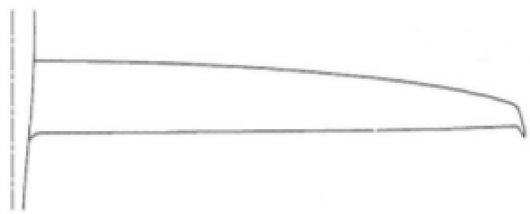


Fig. 2: Wing geometry with Winglets

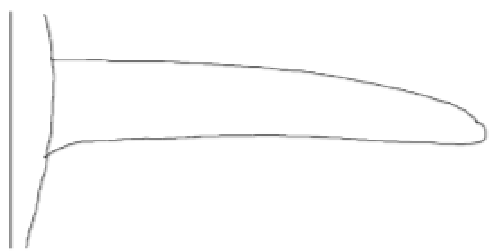


Fig. 3: Wing geometry without winglets

Induced drag has been minimized or decreased by optimizing the wing planform with integrated winglets. The upper two figures show the wing with and without winglets. Winglets makes it difficult for air to flow from lower surface to upper surface since the area of the wing increases. Hence, there is a small pressure difference which results in less induced drag.

The below figure shows the absolute minimum induced drag can be realized within 0.96% at all lift coefficients. Apart from that, the winglet aerofoils have been designed for low profile drag in their operational region of lift coefficients, obtained by 100% fully laminar flow on the lower surface and 50% on the upper surface of the aerofoil. Also, the ample reserve to separation for yaw has been applied, at significantly low speeds while circling in thermals.

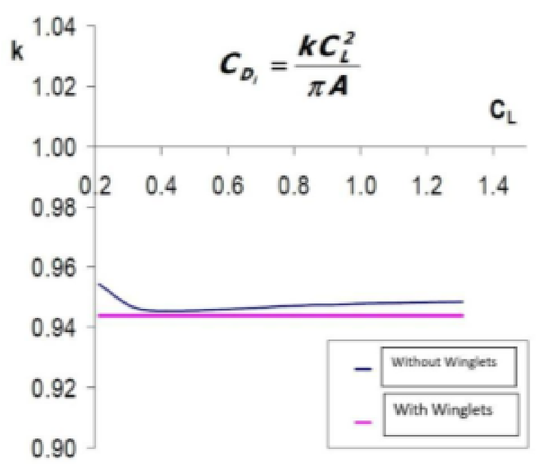


Fig. 4: k vs Cl curve of wings with winglets and without winglets

5.2. Profile Drag

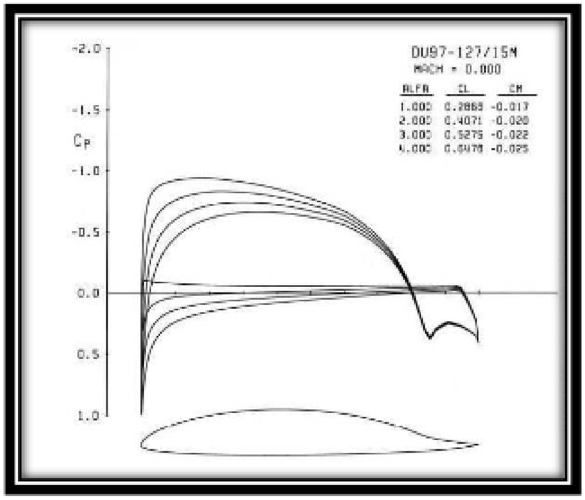


Fig. 5: Pressure distribution of aerofoil with 0° flap

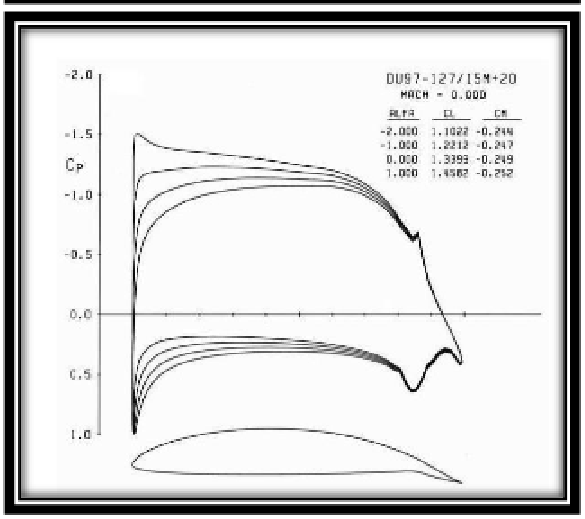


Fig. 6: Pressure distribution of aerofoil with 20° flap extended

Profile drag is caused by the separation of boundary layer resulting into wakes formation. It depends on the extent of the laminar boundary layer on the lower and upper surfaces of the aerofoils and on aerofoil thickness. The wing aerofoil has laminar flow up to 95% of the chord on the lower surface at the high-speed 0° flap deflection, and up to 75% of the chord on the upper surface at the low-speed 20° flap deflection, as indicated by the pressure distributions in the above figure. The lower and upper surface flap gaps have been sealed by flexible mylar strips. It allows and permits the boundary layer on the lower surface to remain laminar beyond the flap hinge position at the 0° flap deflection up to 95%. On the upper surface the sealing prevents low-pressure peaks and subsequent steep pressure gradients on the flap at 20° deflection, thus postponing separation. Consequently, the profile drag becomes very low over a large range of lift coefficients.

5.3. Fuselage Drag

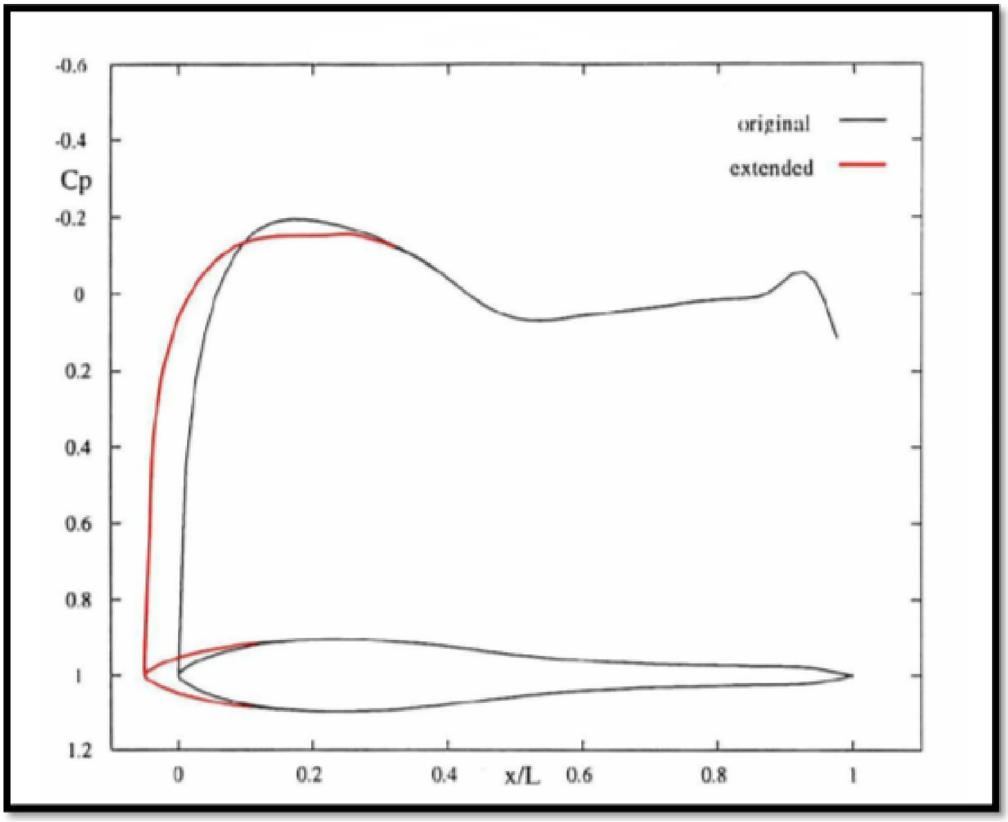


Fig. 7: Pressure distribution on a fuselage with cockpit extension

Fuselage drag as clear by its name depends mainly on fuselage thickness, contraction behind the cockpit, and streamline shaping. Fuselage frontal area should be very minimal. Contraction behind the cockpit and the corresponding pressure gradient is restricted because of flow separation when the boundary layer on the fuselage is completely turbulent, for example when flying in rain with heavy thunderstorms. For an undisturbed boundary layer development, continuity of curvature is required in flow direction. It is guaranteed by deriving the top, bottom, and line of largest width from aerofoil shapes.

A significant finding is that the fuselage length can be increased by 0.3 metres without any drag increase, as illustrated by the accumulative development of the drag coefficient on a rotationally symmetrical body in the figure. Transition occurs at 33% of the original fuselage length, and thus the total drag is found at the tail. This result grants the probability for improved crashworthiness measures as a longer crumbling nose cone and keeping the pilot's feet out of this zone.

6. Selection of Airfoil

Selection of airfoil for the sailplane design was carried out by performing 2D ansys simulations of various high performance airfoils. These airfoils are thicker than the conventional airfoils so that there can be a greater pressure difference and consequently more lift is generated. Simulations were performed at different chord lengths and different altitude conditions so that we can also find out optimized chord length of airfoil for the sailplane design. Pressure and velocity contour of the best airfoil 'Eppler 657' are given below:

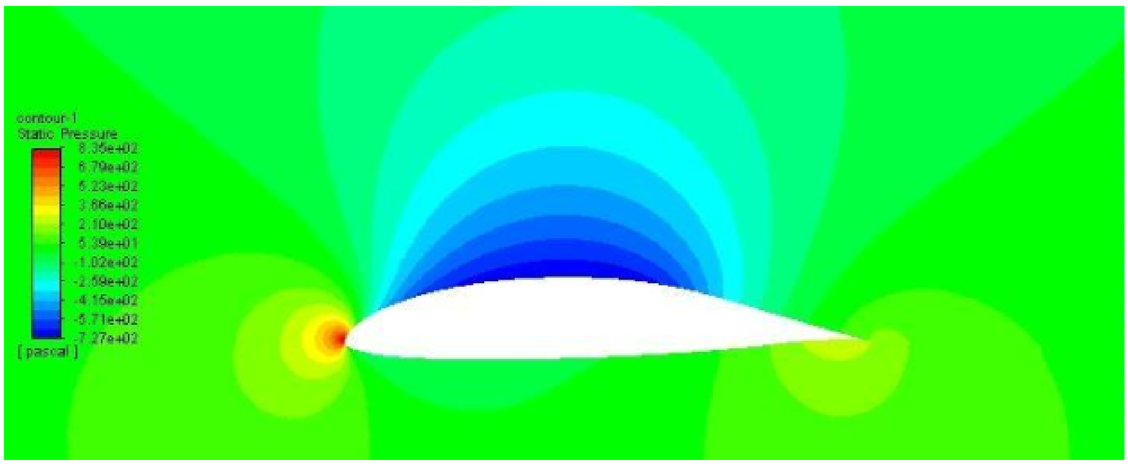


Fig. 8: Pressure Contour at 0.5 m chord and 5000 fts altitude

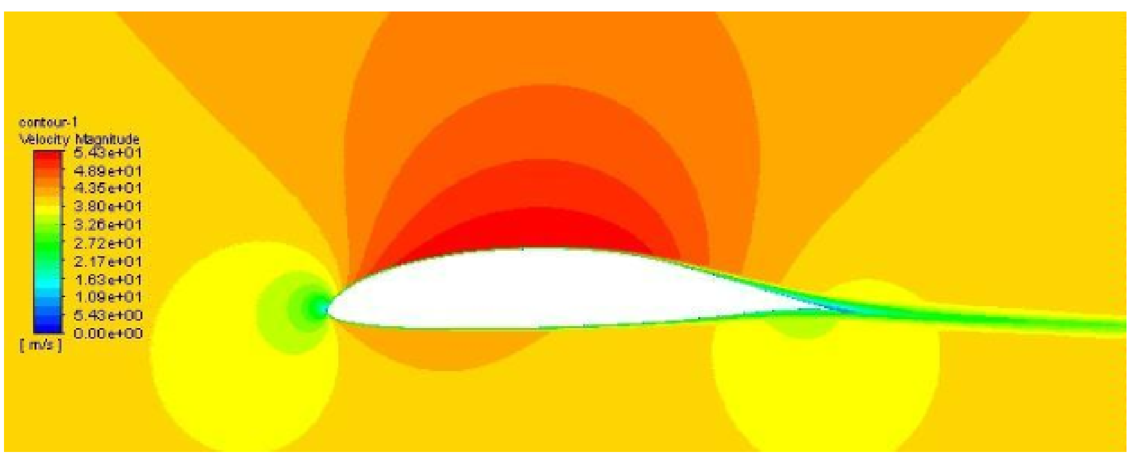


Fig. 9: Velocity Contour at 0.5 m chord and 5000 fts altitude

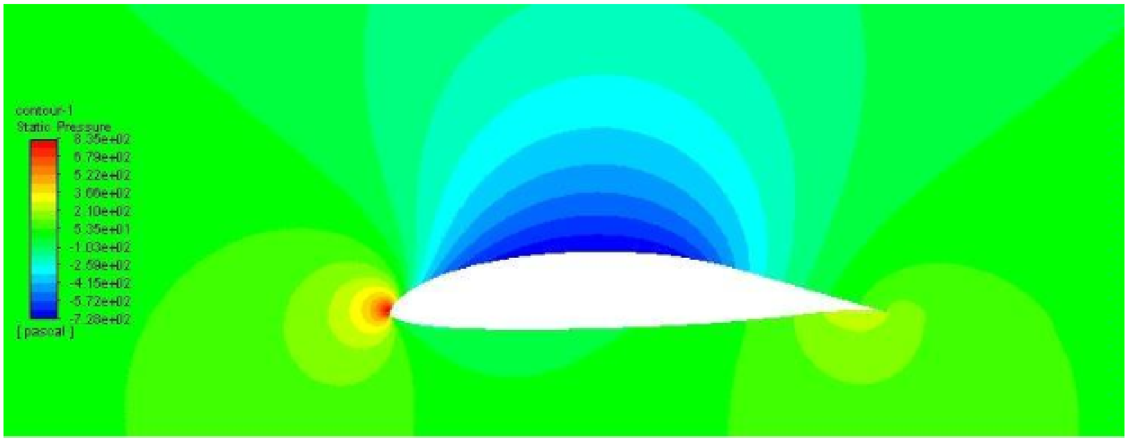


Fig. 10: Pressure Contour at 0.7 m chord and 5000 fts altitude

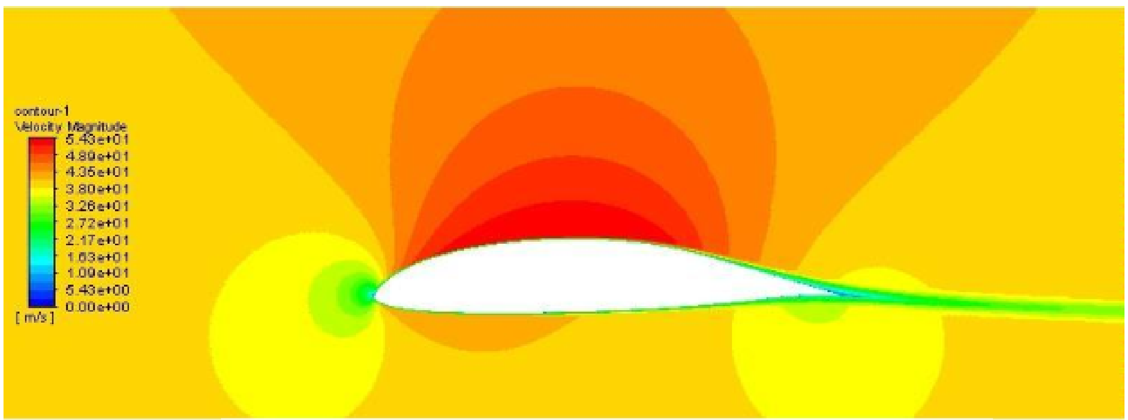


Fig. 11: Velocity Contour at 0.7 m chord and 5000 fts altitude

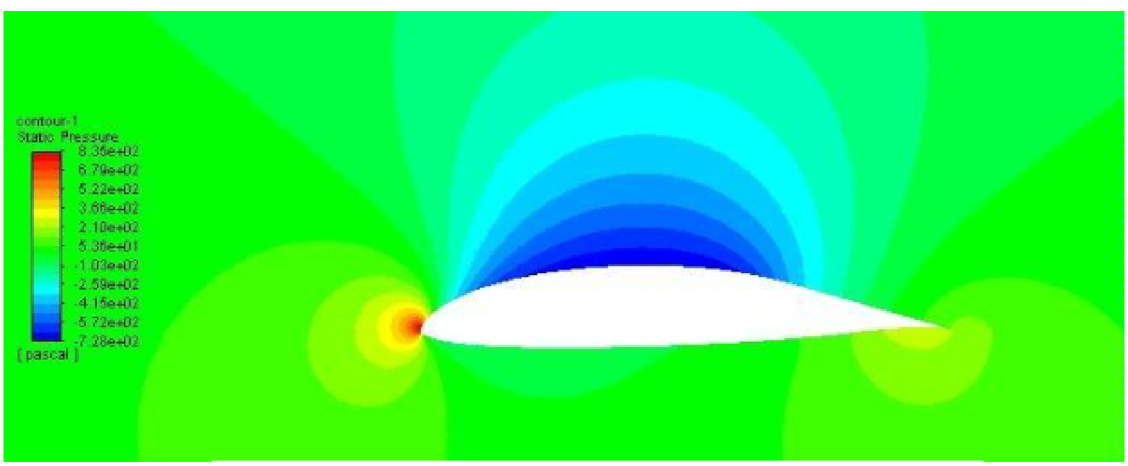


Fig. 12: Pressure Contour at 1.0 m chord and 5000 fts altitude

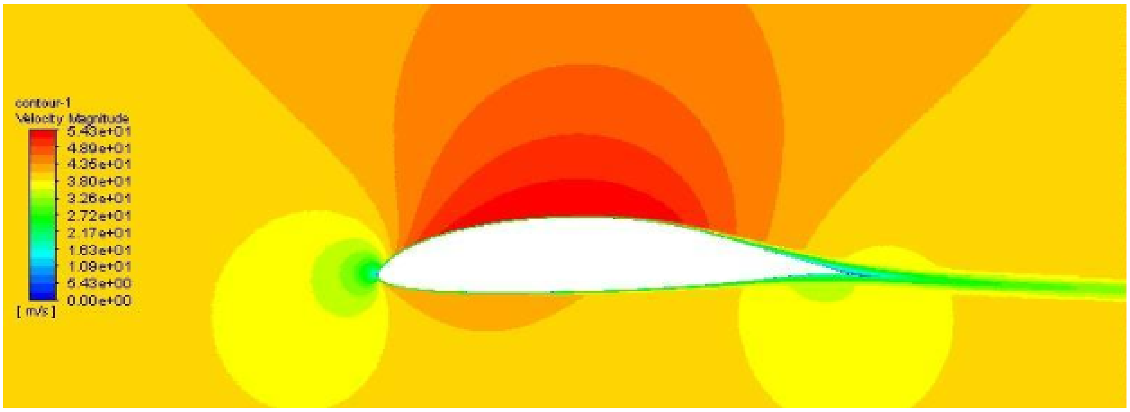


Fig. 13: Velocity Contour at 1.0 m chord and 5000 fts altitude

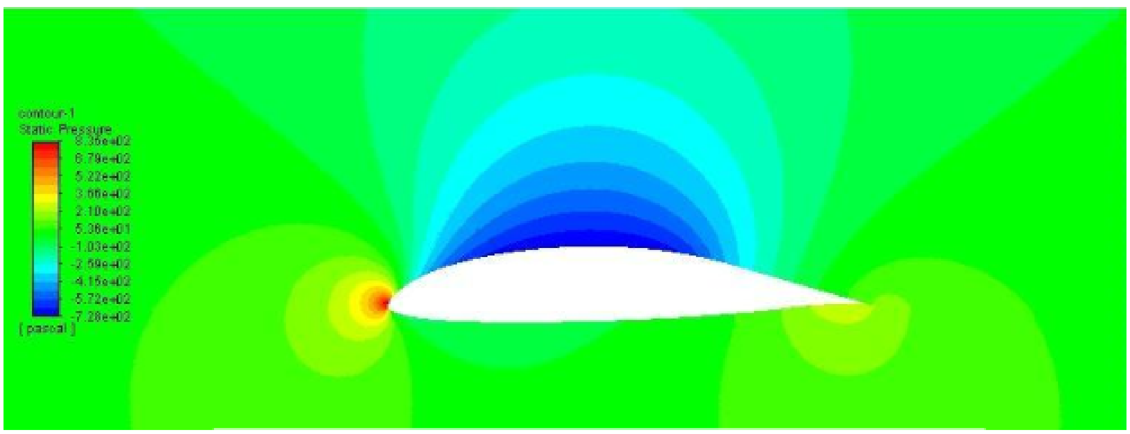


Fig. 14: Pressure Contour at 1.2 m chord and 5000 fts altitude

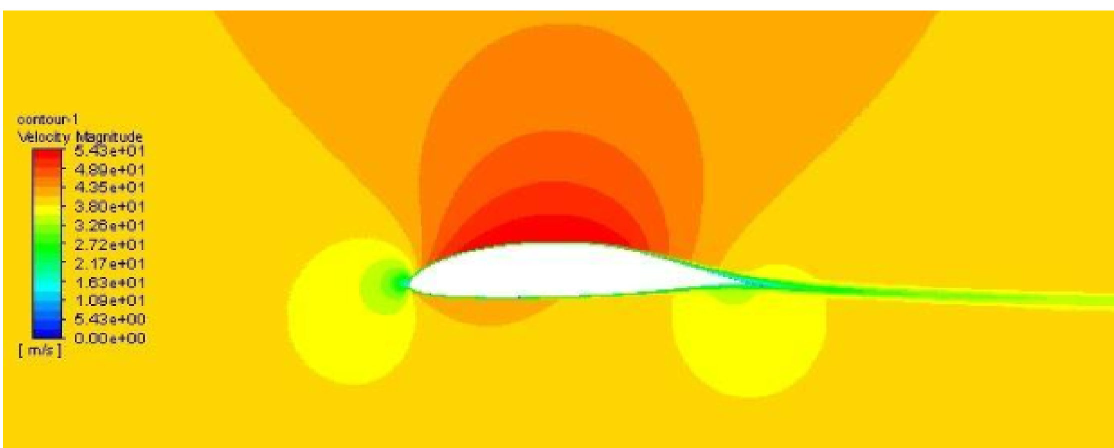


Fig. 15: Velocity Contour at 1.2 m chord and 5000 fts altitude

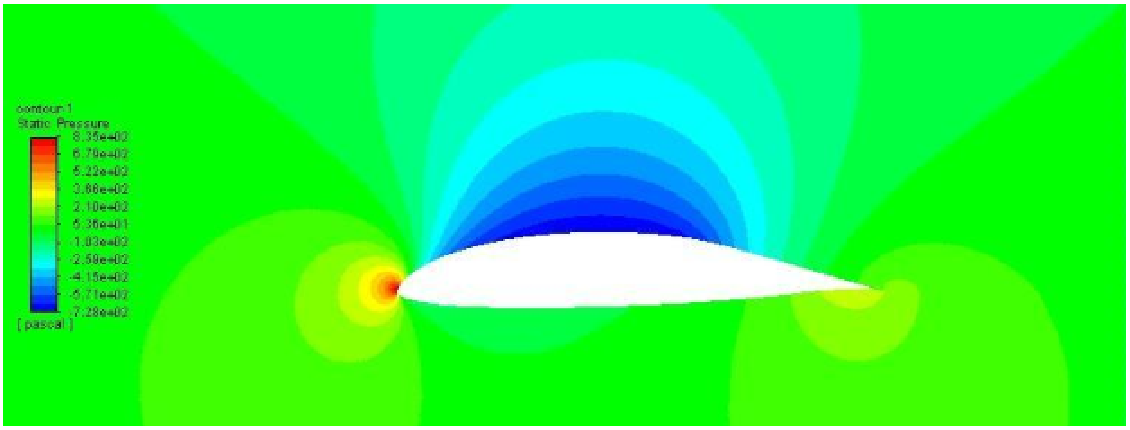


Fig. 16: Pressure Contour at 1.5 m chord and 5000 fts altitude

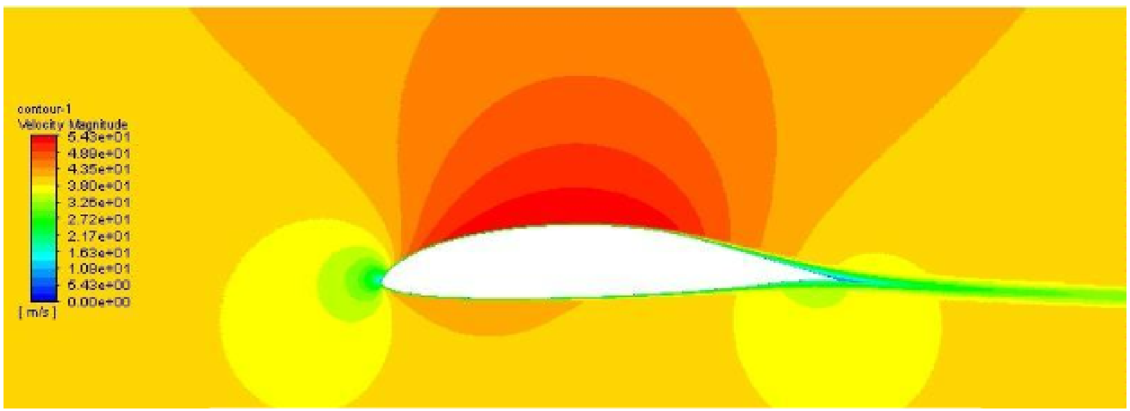


Fig. 17: Velocity Contour at 1.5 m chord and 5000 fts altitude

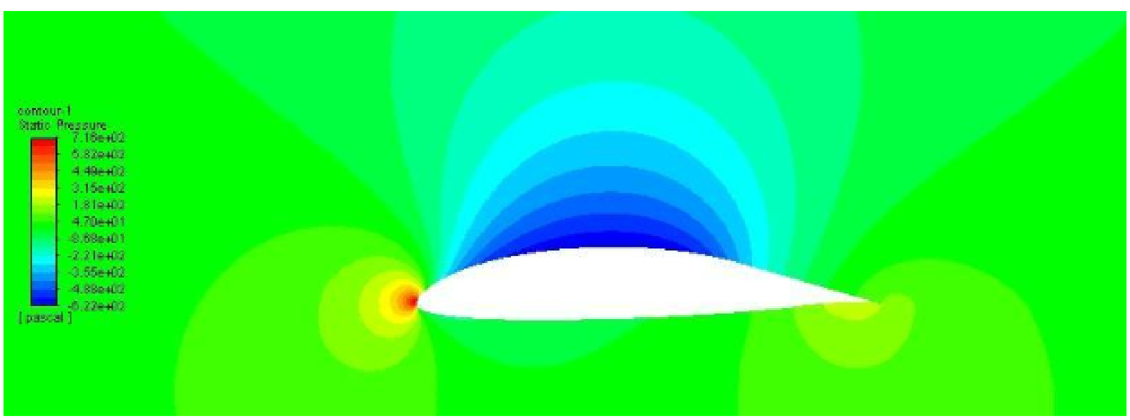


Fig. 18: Pressure Contour at 0.5 m chord and 10000 fts altitude

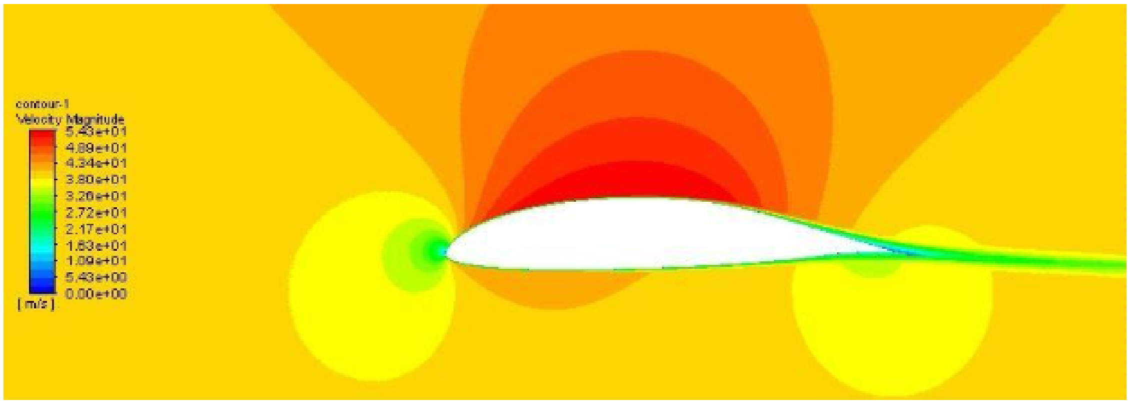


Fig. 19: Velocity Contour at 0.5 m chord and 10000 fts altitude

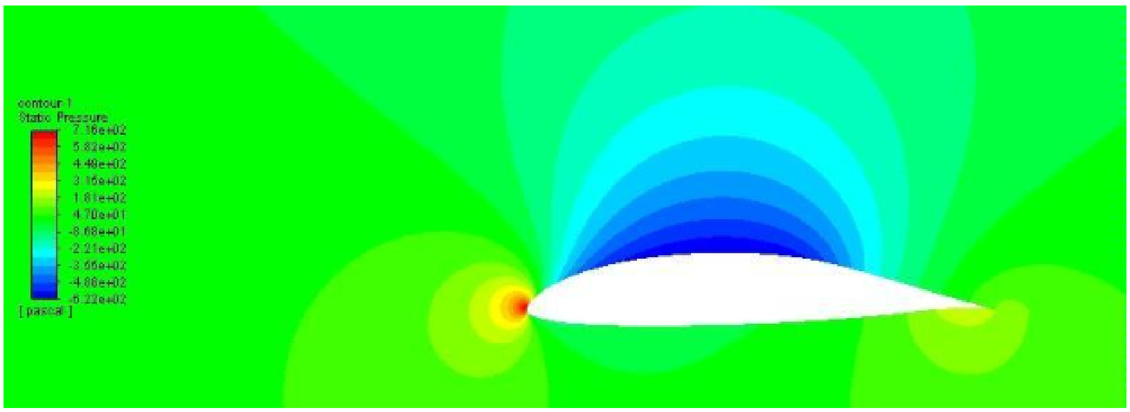


Fig. 20: Pressure Contour at 0.7 m chord and 10000 fts altitude

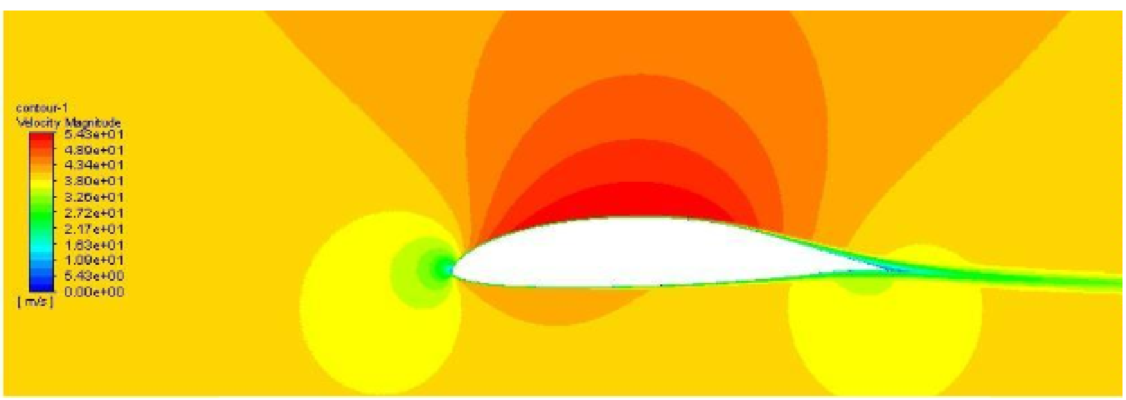


Fig. 21: Velocity Contour at 0.7 m chord and 10000 fts altitude

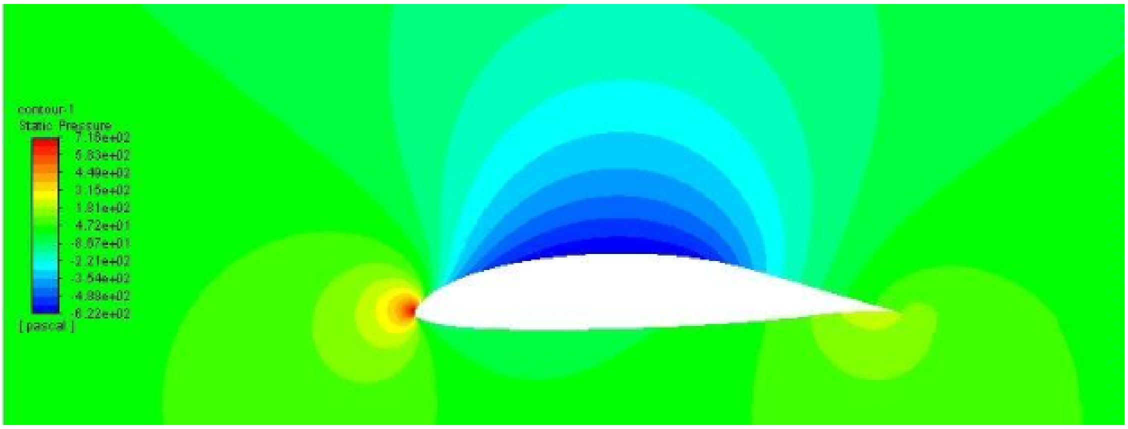


Fig. 22: Pressure Contour at 1.0 m chord and 10000 fts altitude

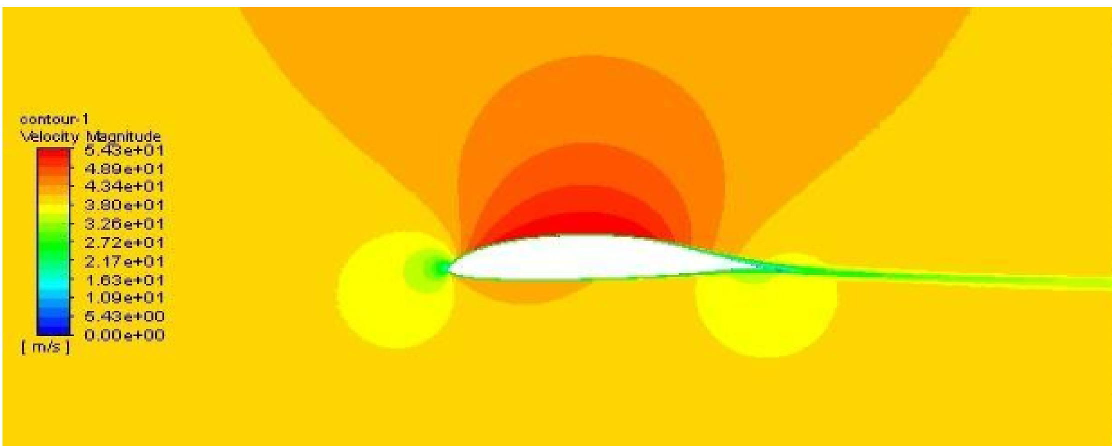


Fig. 23: Velocity Contour at 1.0 m chord and 10000 fts altitude

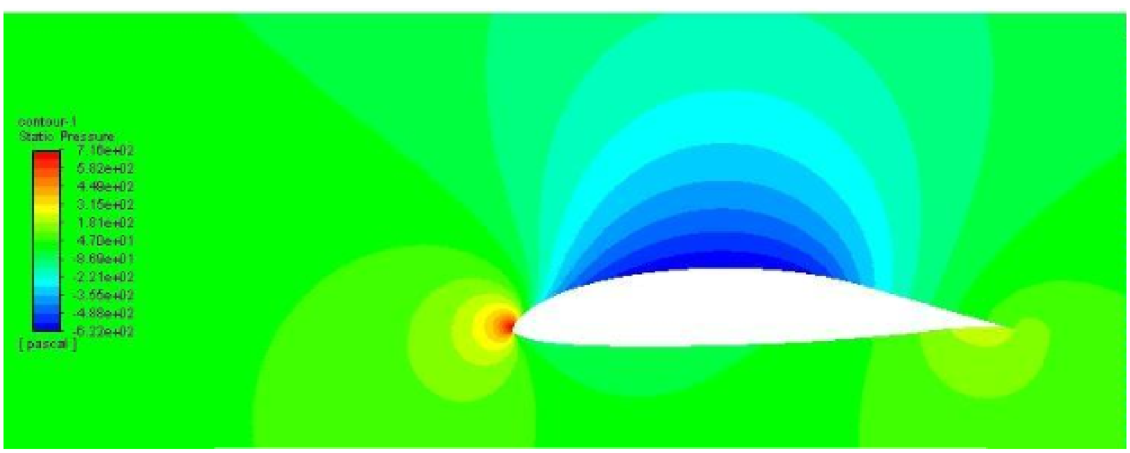


Fig. 24: Pressure Contour at 1.2 m chord and 10000 fts altitude

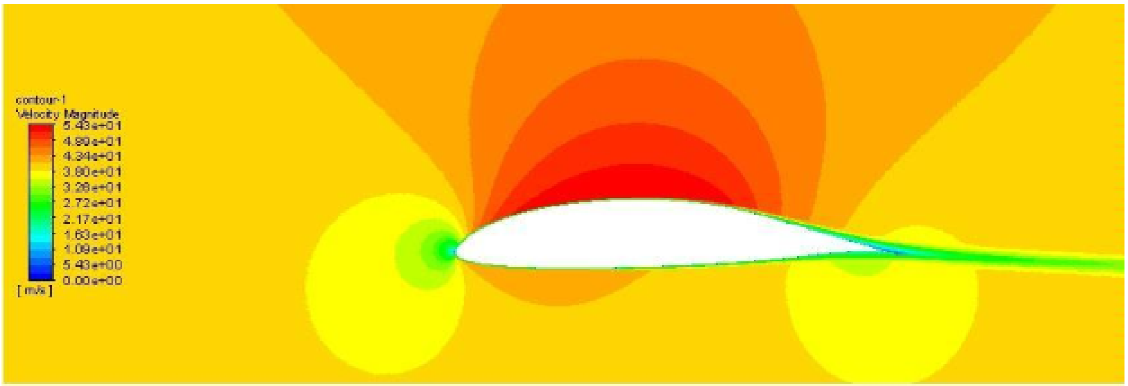


Fig. 25: Velocity Contour at 1.2 m chord and 10000 fts altitude

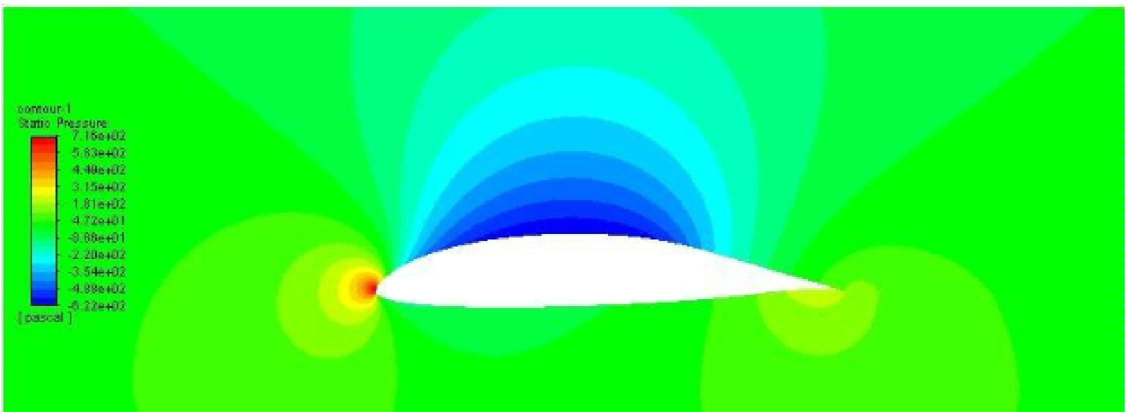


Fig. 26: Pressure Contour at 1.5 m chord and 10000 fts altitude

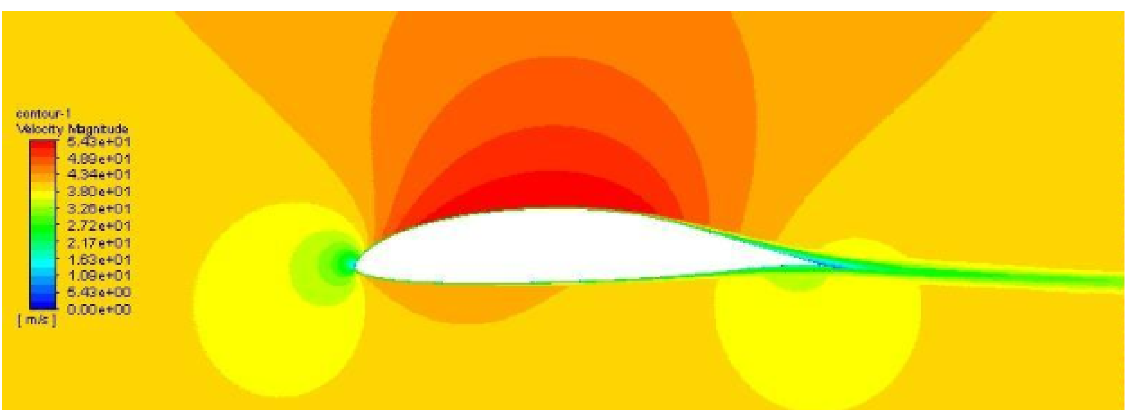


Fig. 27: Velocity Contour at 1.5 m chord and 10000 fts altitude

Lift coefficient (Cl), drag coefficient (Cd) and glide ratio (GR) values of two best airfoils: ‘Eppler 657’ and ‘NASA LRN 1015’ are given in the following tables:

Table 2: Eppler 657 Cl, Cd and GR values at 5000 ft and 10000 ft

Altitude: 5000 ft				
Chord (m)	**Reynolds Number**	**Cl**	**Cd**	**Glide Ratio**
1.5	3635006.317	0.3584478	0.007938822	45.15125796
1.2	2908005.053	0.44816089	0.009929578	45.13393253
1	2423337.545	0.53784733	0.01191934	45.12391877
0.7	1696336.281	0.76840628	0.017029451	45.12219918
0.5	1211668.772	1.0758313	0.023842847	45.12176335
	Altitude: 10000 ft			
1.5	3209219.858	0.35611034	0.008103336	43.94613804
1.2	2567375.887	0.44508347	0.010127606	43.94754989
1	2139479.905	0.53346778	0.012135627	43.95881482
0.7	1497635.934	0.76277986	0.017350654	43.96259991
0.5	1069739.953	1.0680627	0.024297826	43.95713016

Table 3: NASA LRN 1015 Cl, Cd and GR values at 5000 ft

Altitude: 5000 ft				
Chord (m)	**Reynolds Number**	**Cl**	**Cd**	**Glide Ratio**
1.5	3209219.858	0.34434175	0.007805298	44.11641241
1.2	2567375.887	0.43037382	0.009754048	44.12258718
1	2139479.905	0.51636219	0.011703033	44.12208271
0.7	1497635.934	0.73794276	0.016726915	44.11708674
0.5	1069739.953	1.0331899	0.023421528	44.11283073

6.1.Results

From Table 1 and Table 2 it is clear that Eppler 657 is the airfoil that will give maximum glide ratio to the sailplane.

Since there was not much difference in the glide ratio values for different chord lengths, we will choose a chord length of 0.7 m. This is so because in the current practice average chord length is taken around 0.7 m only.

7. Designing of Sailplane

This section describes how the sailplane was designed in Solidworks:

- Open the part section < Create a circle 2D sketch of required dimension < Boss extrude the sketch to create a sphere of 1mm < Create another sphere of the same dimension and align them symmetrically with respect to the Right Plane and save it as “Passenger”. This body is referred to as the space and mass occupied by the passenger in the sailplane.
- Now open another part section < Create a rectangular 2D sketch on the Front Plane < Boss extrude the sketch of 1*1*2 cubic millimetres < Save it as “Payload”. This body will be referred to as the mass and space occupied by the payload in the sailplane.
- Now open the assembly section < Mate together the “Passenger” and “Payload” part sections and align it properly with the Right Plane < Save the assembly section as “Sailplane” and close it.
- Now open part section for the design of sailplane 3D sketch and save it as “Part1”. Further the sketch is divided into 3 parts:

a) Fuselage Design
b) Rudder and Tail Design
c) Wing Design

7.1. Fuselage Design:

- Go to Reference Geometry < Plane < Create 5 different planes with reference to Front Plane at offset distances of 0.5 inch, 3 inches, 10 inches, 17 inches and 20 inches.
- On every plane, sketch a semicircle or spline for just half a side. These different sketches are the boundaries provided for the fuselage surfaces which is to be lofted further.
- Go to Loft Surface < Select every sketch in the order from left to right and align the starting and end points properly < Click on the tick mark. Now we get a lofted surface for a fuselage.

7.2. Rudder and Tail Design:

- Go to Reference Geometry < Plane < Create a plane 4 inches with reference to Top Plane.
- Now sketch a curved spline as required on Top Plane as well as on the plane mentioned above.
- Go to Loft Surface < Select both the mentioned sketches and click on tick mark. This will create a lofted surface also known as rudder.
- Now save the file.

- Open a new part and go to Front Plane < Curves < Curve through xyz points < Input the file coordinates of Eppler 657 aerofoil and insert. This input file can be downloaded from airfoiltools.com
- Create a centerline of 1 inch and fit this centerline as chord on the aerofoil.
- Go to Tools < Blocks < Make < Select the sketch and save it as EBlock.
- Open the Part1 < Blocks < Insert < Select the EBlock < Select the required dimensions of the block and sketch it on Right Plane as well as on a new plane from reference to right plane at 7 inches.
- Now go to Loft Surface < Select the blocks and click on the tick mark. This will create the tail of the sailplane.

7.3. Wing Design:

- Go to the Top Plane < Sketch a 2D ellipse of b = 30 inches and a1 = 1.02 inches. This sketch should be created on the sailplane as per the required dimensions satisfied by the stability analysis of the sailplane.
- Sketch another 2D ellipse with same centre of b = 30 inches and a2 = 0.51 inches.
- Now trim the half part of the 1st sketch from the outside and half part of another sketch from the inside.
- The leftover trimmed sketch will give the elliptical wing dimensions with minimum drag and maximum aspect ratio.
- Now create different sections in the sketch for putting aerofoils in it. If required winglets can also be put at the end 2 inches above the Top Plane.
- Now go to Loft Surface < Select the aerofoils and click on the tick mark. This will give the elliptical wing required for the sailplane.

Now mirror the different parts about the Right Plane. This will give the complete 3D sketch of the aircraft. Now trim the surface of the wings inside the fuselage and surface of the rudder inside the fuselage. Create a filled surface on the top of the rudder and planar surface at the ends of tail. Now knit the surface and select the "Create Solid" section and click ok. This will give the 3D solid surface of the required sailplane.

7.4. Assembly:

Go to Mate < Select the parts, i.e., "Passenger", "Payload" and " Part1" and click ok. This will give the assembled section of different bodies as a single sailplane.

7.5. Flow Simulation:

- Go to Flow Simulation < Wizard < Give the required name of the project.
- Now select the required conditions to be given at the condition for flying. For example: Air as medium, Gravity in negative y axis, Velocity in the negative z axis as 36 m/s.

- Select the reference coordinate axis as Z axis since the nose of the sailplane is in the Z axis.
- After all the required conditions are satisfied click ok.
- Now the project is created.
- Select the computational domain and give the required dimensions to it such that 20 lakh cells are created within the domain.
- Open the Input Data < Calculation Control Options < Select number of iterations < 20000.
- Goals < Select the given inputs to be calculated or simulated such as pressure, temperature, forces, etc.
- Mesh < Global Mesh < Select the required level of meshing as per the choice.
- Run

7.6. Output:

The result is thus obtained after a certain time and number of iterations.

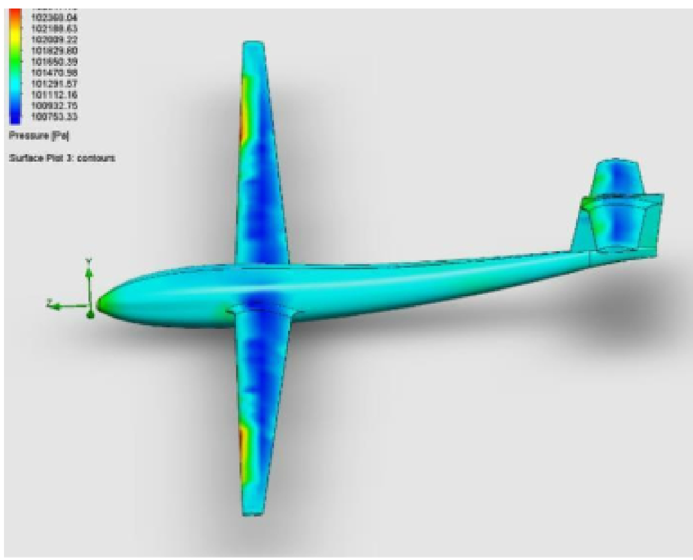


Fig. 28: Pressure Contour of complete sailplane (Initial Design)

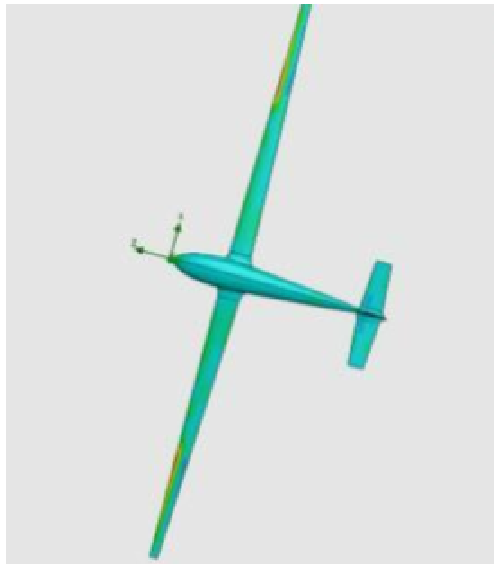


Fig. 29: Pressure Contour of complete sailplane (Bottom view)

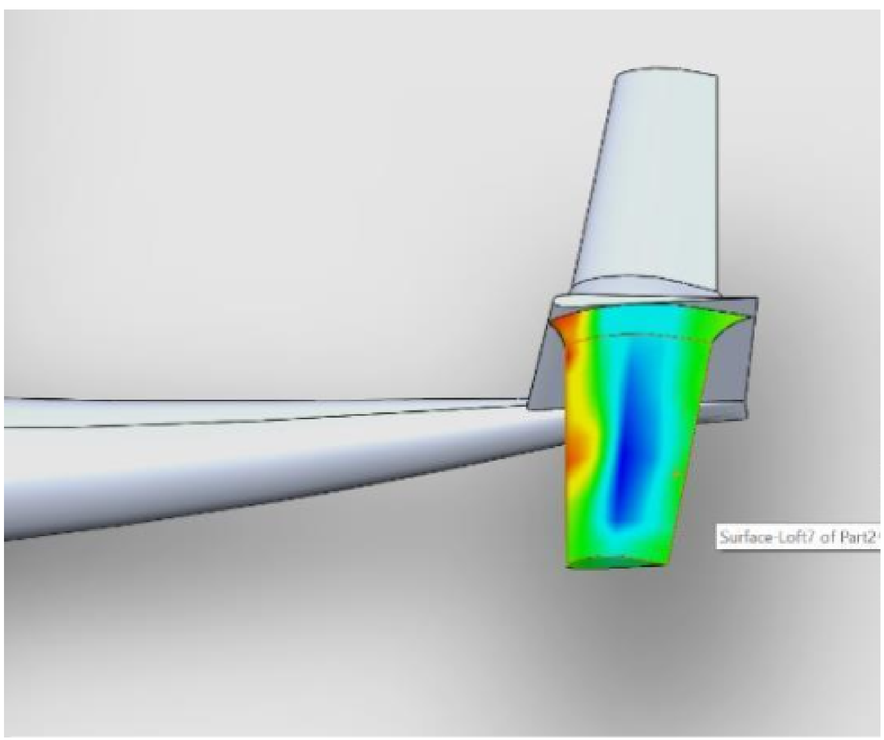


Fig. 30: Pressure Contour of tail section (Top view)

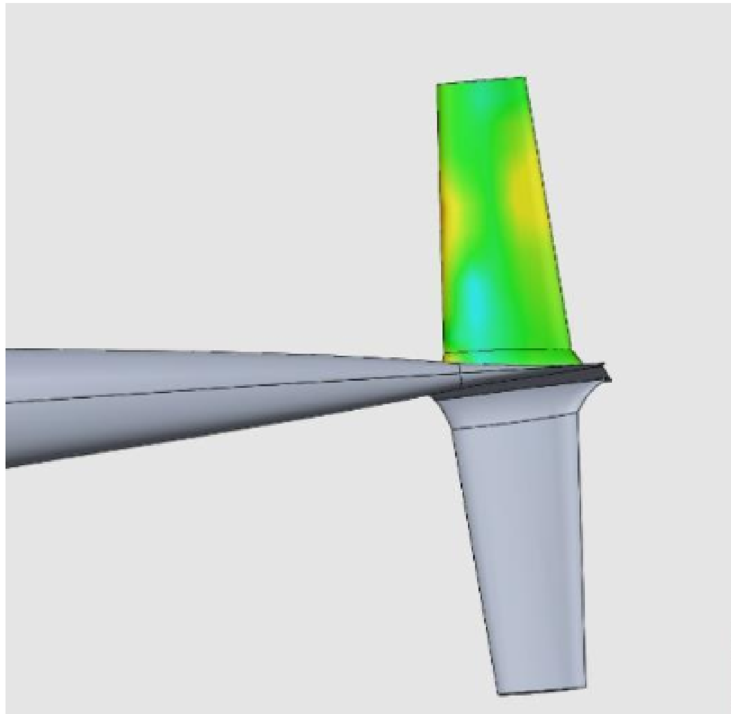


Fig. 31: Pressure Contour of tail section (Bottom view)

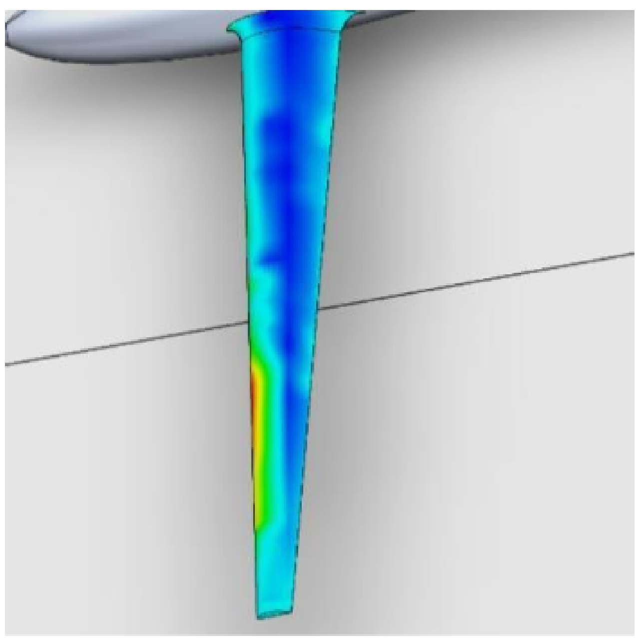


Fig. 32: Pressure Contour of wing section (Top view)

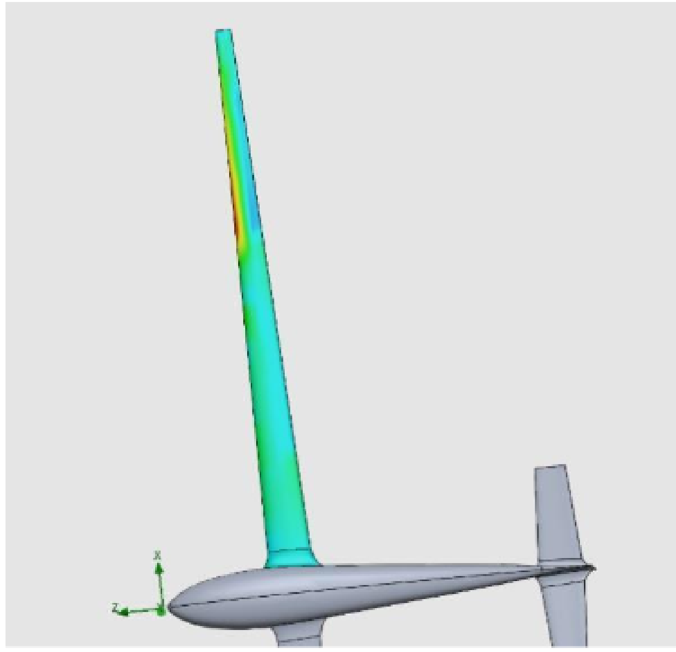


Fig. 33: Pressure Contour of wing section (Bottom view)

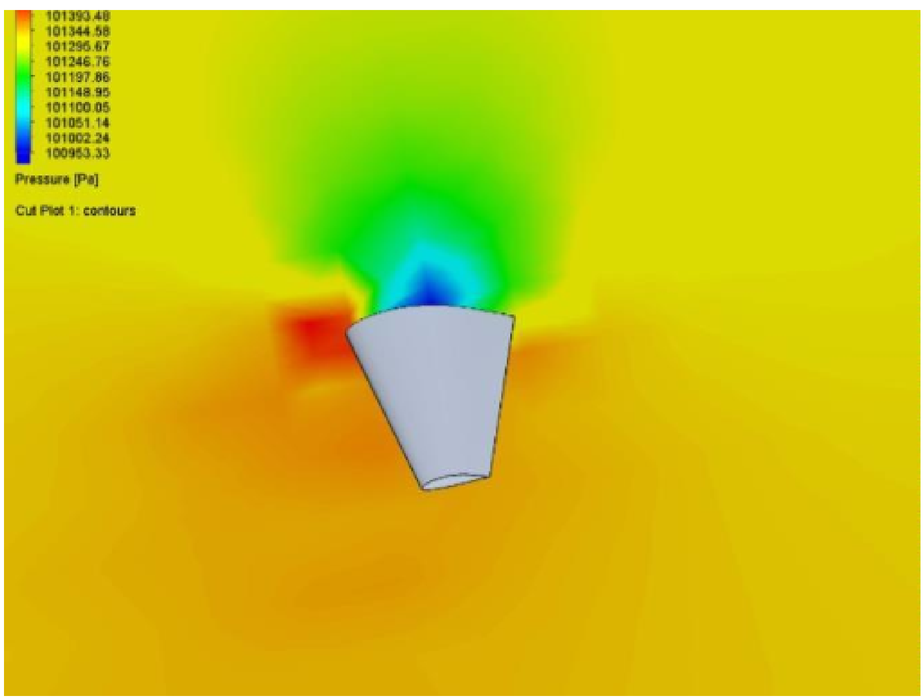


Fig. 34: Pressure Contour of 1/4th wing span (Side view)

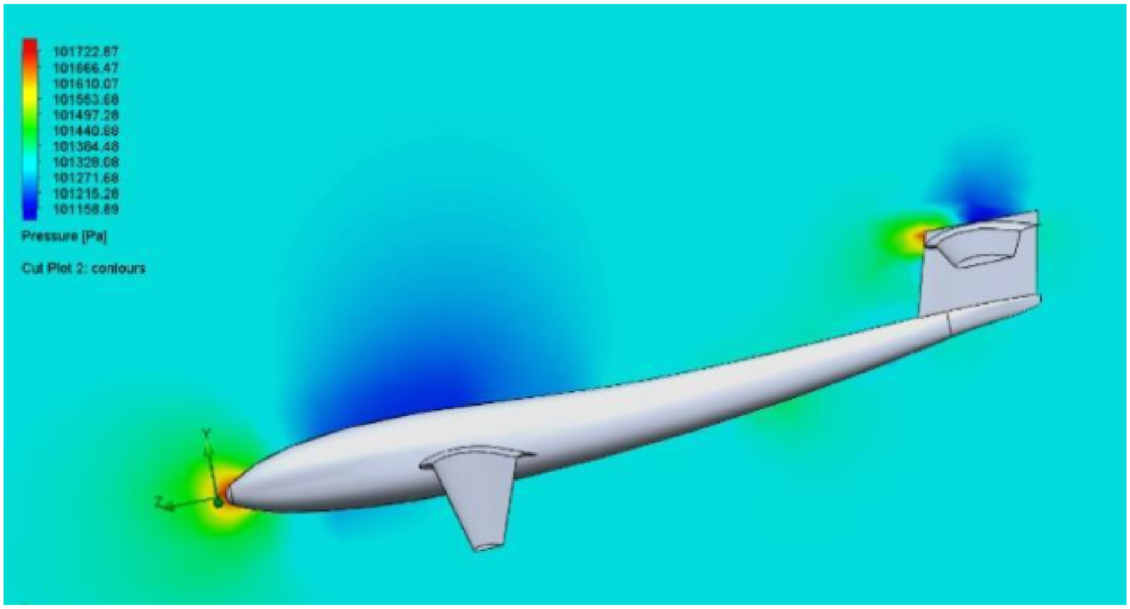


Fig. 35: Pressure Contour at centerline of fuselage (Side view)

Glide Ratio: 7.84152

8. Optimization of Design

As seen in the previous section, glide ratio value obtained after flow visualization in Solidworks was very low even after changing shape of wingspan from rectangular to tapered. Therefore, a change in the design was necessary.

A major change made in the design was the shape of wingspan. We changed the tapered wingspan to elliptical wingspan. This increased the glide ratio value from 8 to around 10. This increase in the glide ratio value was good, however, it still was not enough. Another major change in the design of the sailplane was necessary.

A major mistake we were doing while designing our sailplane was that we were designing the fuselage like that of a conventional aircraft. But a sailplane is different from aircraft. Conventional aircrafts have engines through which they can produce thrust to propel faster. So, if all the engines of an aircraft are turned off, then their glide ratio are generally between 8 to 15. If we analyse our sailplane design from this perspective, then glide ratio value of 10 is pretty reasonable.

But we are designing a sailplane and in sailplanes, there is no engine. Therefore, they need a completely different fuselage design to produce high glide ratio values. Usually, glide ratio of a high-performance sailplane is between 50-60. Even the glide ratio of 30 is considered good for general recreational use.

Fig. 36: Diana 3 Sailplane

If we would look at a modern sailplane like Diana 3 (Fig. 29) for reference, then the fuselage design is quite distinguishable from a conventional aircraft. A sailplane's fuselage is very aerodynamic. Its shape is almost identical to a fish.

So, the next optimization we did was the design of fuselage. We too tried to emulate the design of modern sailplane's fuselage to make it more aerodynamic.

Another change we did was to reduce the aspect ratio. Due to some miscalculation, previously the AR of our wing was absurdly high (92). AR is the ratio of square of wingspan to the area of wing. We made necessary changes in the wing design and brought the AR down to 50.

So, to sum up we firstly changed the shape of wing from tapered to elliptical, made the fuselage more aerodynamic and reduced the AR of the wing.

8.1.Results

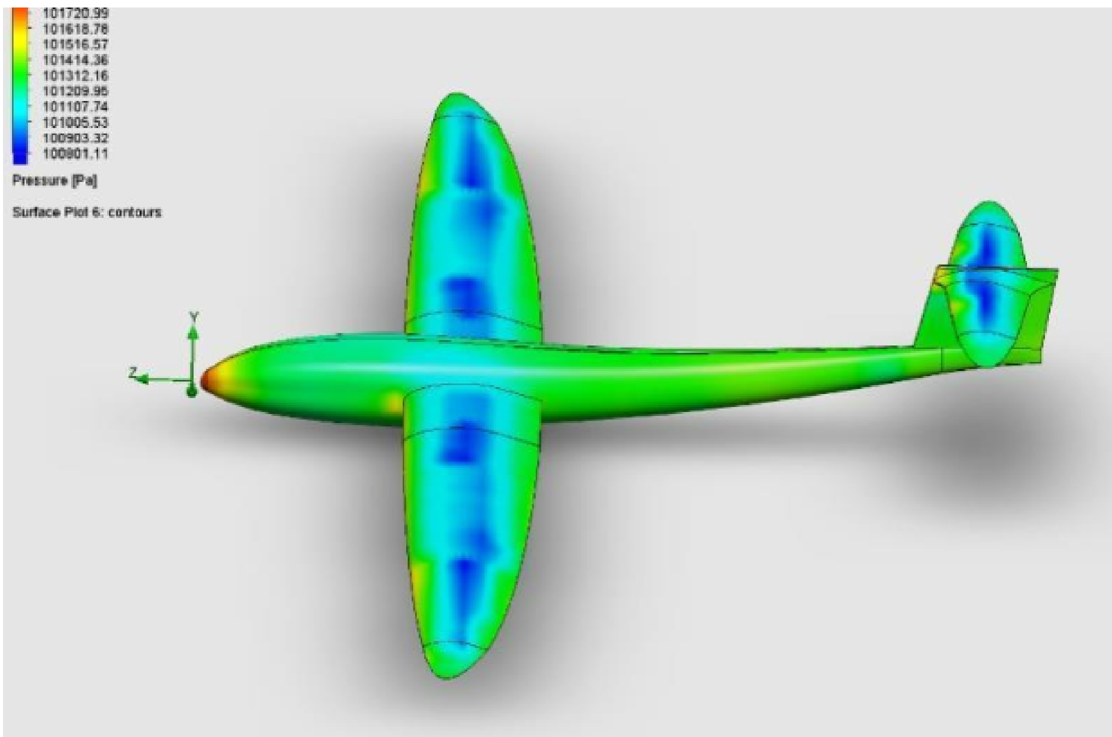


Fig. 37: Pressure Contour of Complete Sailplane (Elliptical wing)

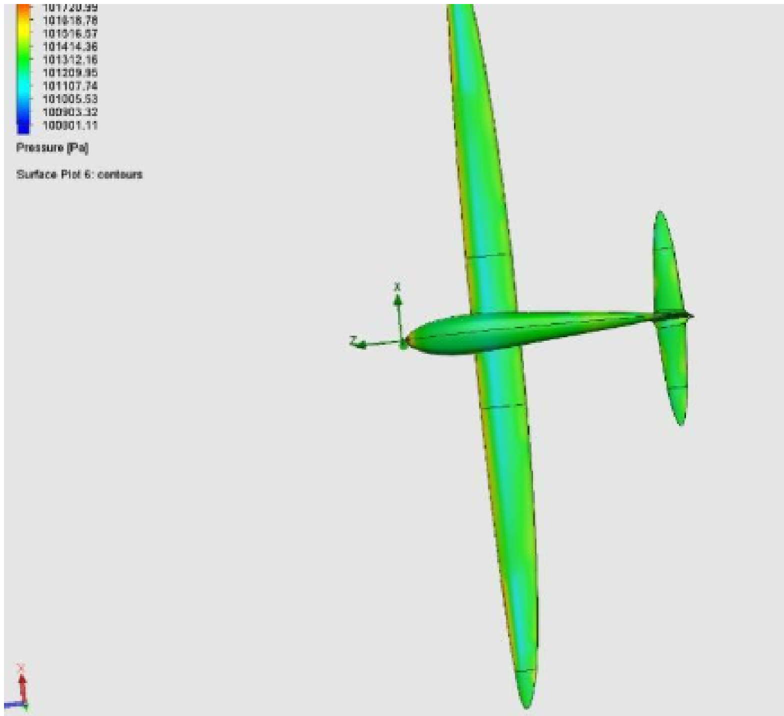


Fig. 38: Pressure Contour of Complete Sailplane (Bottom view)

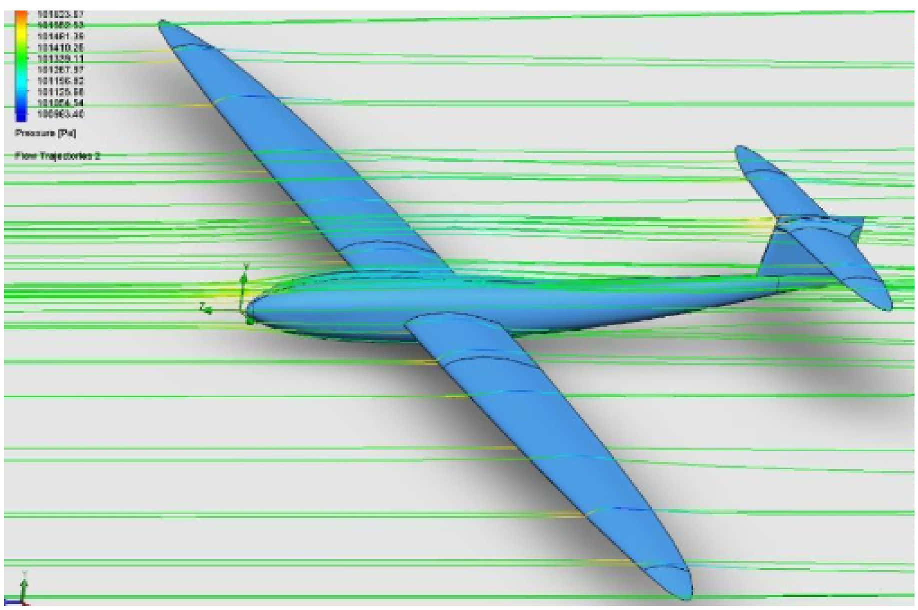


Fig. 39: Pressure Streamlines of Complete Sailplane

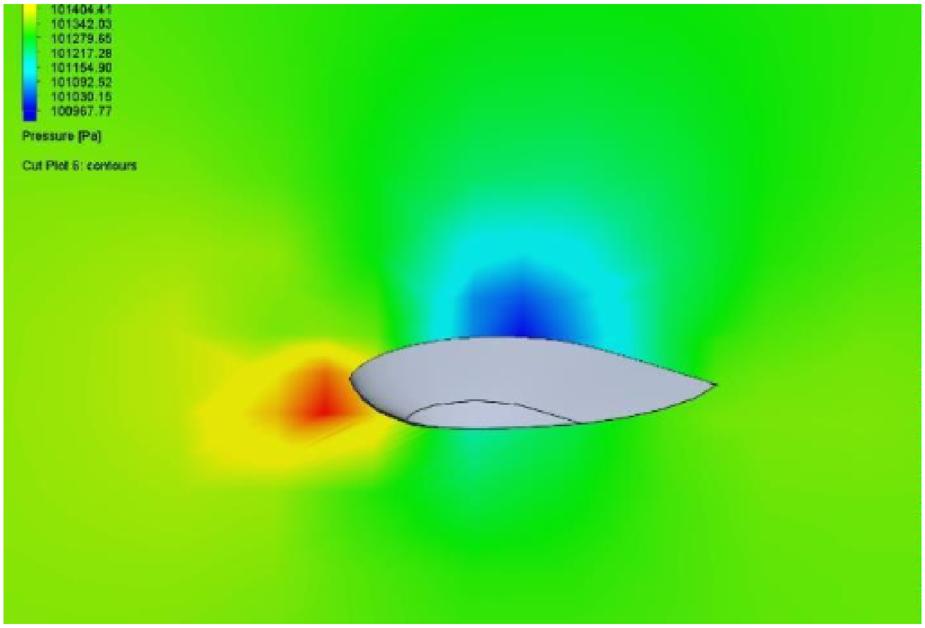


Fig. 40: Pressure Contour at 1/4th of wingspan (Side view)

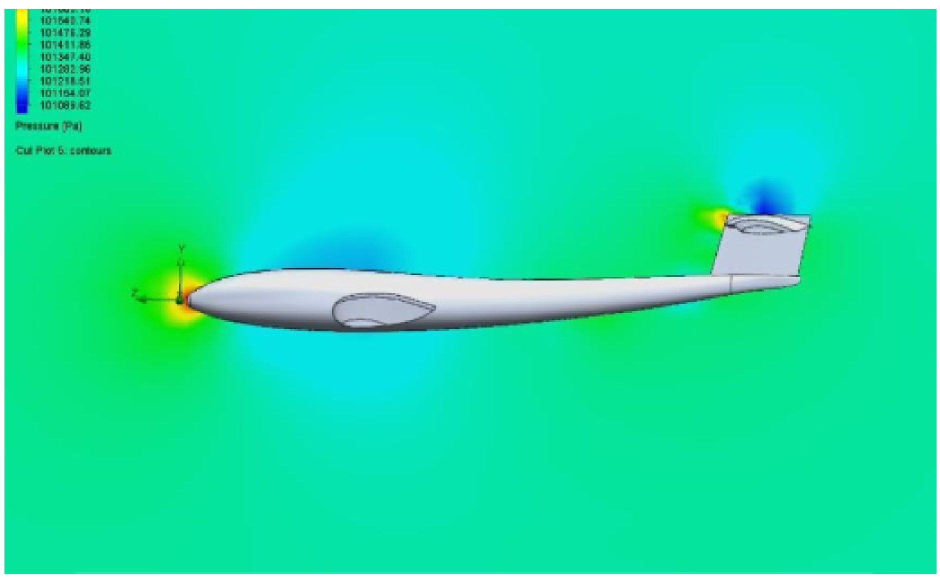


Fig. 41: Pressure Contour at centerline of fuselage (Side view)

Glide Ratio: 10.01928

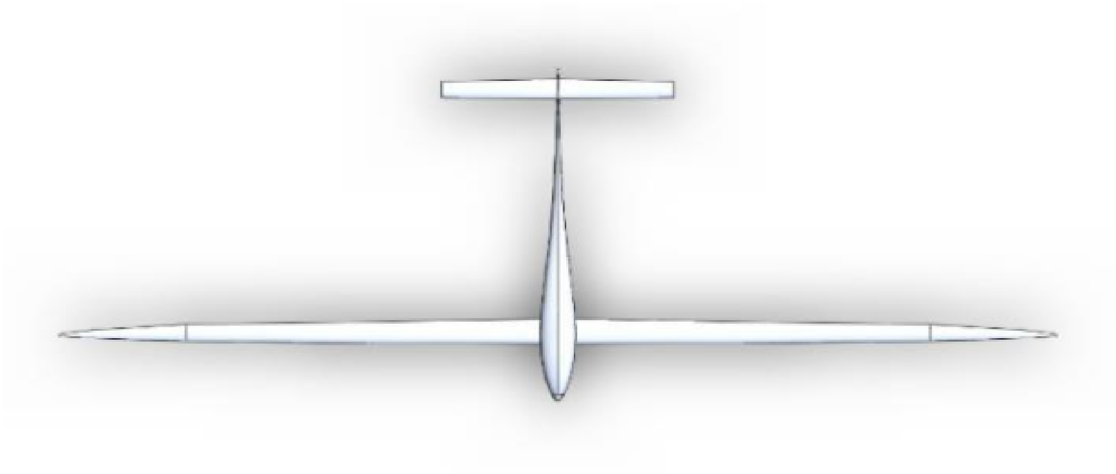


Fig. 42: Final design with modified fuselage and wing AR (Top view)

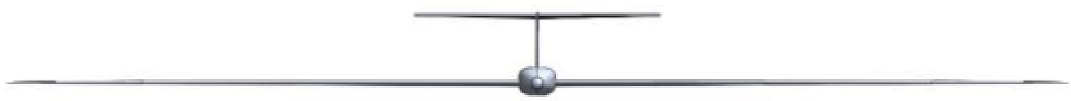


Fig. 43: Final design with modified fuselage and wing AR (Front view)

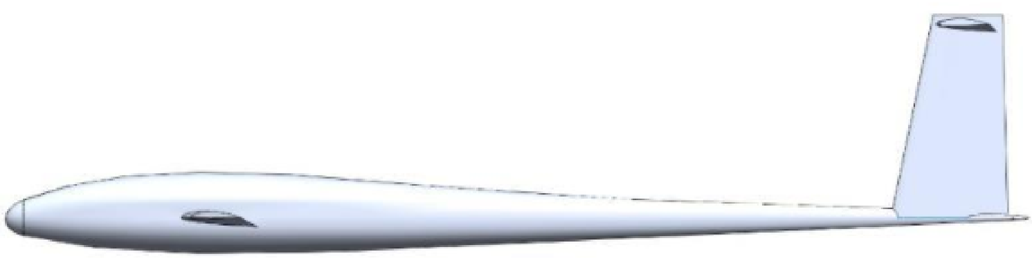


Fig. 44: Final design with modified fuselage and wing AR (Side view)

Glide Ratio: 34.68721

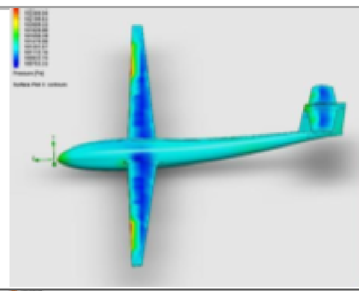
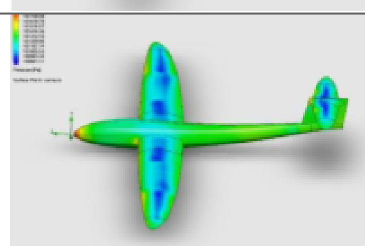
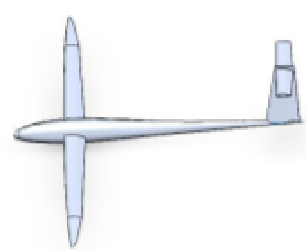
9. Analysis and Verification:

After the mentioned major and subtle changes that we made in our sailplane design, our glide ratio increased significantly. It rose from 10 to almost 35. This value of glide ratio is acceptable. Also, the glide ratio of sailplanes during actual flight depends majorly on wind and other atmospheric conditions. Because as mentioned in previous sections, a sailplane uses thermals to stay aloft for hours. These thermals are basically the extra upward force that is being imparted to the sailplane. Therefore, when a sailplane flies in thermals, lift coefficient increases drastically and consequently, value of glide ratio also shoots up.

So, if we fly our sailplane in presence of thermals, value of glide ratio can easily increase up to more than 40.

In the below table, glide ratio values of our different sailplane designs are mentioned for comparison:

Table 4: Glide Ratio of different sailplane designs

Wingspan shape	**Sailplane Design**	**Glide Ratio**
Tapered		7.84152
Elliptical		10.01928
Elliptical with modified fuselage		34.68721

Let's compare the specification of our final sailplane design with some other sailplane which has maximum glide ratio of 38

Table 5: Comparison of our final design and Schweizer SGS 1-35

Parameters	Final Design	Schweizer SGS 1-35
Length (m)	4.5	5.84
Wingspan (m)	15	15
Wing area (m^2)	4.46	9.54
Aspect Ratio	50	23.29
Airfoil	Eppler 657	Wortmann FX 67-K-170/150
Gross weight (kg)	250	300
Glide Ratio	34.68	38

As we can see from above table, a sailplane with similar design parameters has almost same glide ratio as our final design. Therefore, our results are verified.

10. Conclusion

We first selected the airfoil for our sailplane design by performing Ansys simulations of many different airfoils. The two best airfoils that we obtained from our results were 'Eppler 657' and 'NASA LRN 1015'. Out of them we selected Eppler 657 for our design and the average chord length we chose was 0.7 m.

After the selection of airfoil, we made our design in Solidworks. Initially we wanted to make our wingspan rectangular but later decided to make it tapered in hopes of better performance of our sailplane. We did the flow simulation of our initial design and glide ratio was coming out to be 8. Now we had to optimize our basic design to increase the glide ratio.

The major changes that we made are the shape of wingspan, we modified its shape from tapered to elliptical wing. Secondly, we made our fuselage design more aerodynamic and lastly, we decreased the aspect ratio of the wing to 50. These changes increased the glide ratio to 35. This value of glide ratio is acceptable.

With this project, we learned to use Solidworks. There are many designing tools like AutoCAD, Solidworks, etc. which can be used to make complicated designs of any automobile, aircraft, machine equipment, electrical equipment, etc. and then analyse them for their practical usage. Simulation softwares like Ansys, Star CCM+ goes hand in hand with the designing softwares. Nowadays, these softwares are high in demand as they save so much time, money and labour as we don't have to make actual model of any conceptual design to test its performance. Therefore, industries these days recruit students in great number who have skills in these softwares as it saves them production cost as well as time. And so, if we are skilled in using these softwares, we gain an advantage over those who are unskilled.

Therefore, with the help of this project, we gained an important industrial skill of using Solidworks and Ansys.