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AERODYNAMIC ANALYSIS OF DELTA WING AT LOW REYNOLDS NUMBERUSING COMPUTATIONAL SIMULATIONS

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Abstract:
The delta wing is best known for their contribution to stability and also, they have high structural advantages compared to other wings. Till now the delta wing has been used mostly in high speed or high Reynolds number flows. But no one concentrated on the low Reynolds number flows, here we have analyzed the flow at Re = 100000. Since we have taken the case of this Reynolds number range, the results obtained can be utilized in designing the Micro Air Vehicles (MAVs) which are mostly designed for low Reynolds number of range Re = 10000 to 100000. We have obtained Cl vs alpha and Cl/Cd vs alpha graphs using computational simulations. We used the CATIA software for designing the wing, it is a conceptual design based on delta wing and analyzed using XFLR 5 for ideal flows, here we used vortex lattice method – ring vortex method and ANSYS fluent software for realistic flows. We used Gamma – Re theta SST transition model for calculations in Ansys Fluent. We have expected CL to be start with smaller values and reach higher at higher angles of attack since, the delta wings have Low aspect ratio and also, they have sweep back wings which will naturally make the aircraft laterally stable.

Keywords: Reynolds number, delta wing, micro aerial vehicle, computational simulation

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1 INTRODUCTION

Delta wings are the swept back wings with a un angled trailing edge, it got its name due to its resemblance to Greek letter delta {Δ}, the sweep of the wing will help stabilizing the aircraft mostly in lateral & directional stabilities. Even though the swept back wings also provide the same stabilities, the delta wing is having advantage structurally. The delta wings are mostly used in the high-speed profiles or supersonic regime, due to its swept angle which delays the shock wave. on the opposite side of speed scale, it is practically proved by Rogallo flexible wing design that delta wings can also be used for ultra light aircraft and hang glider etc.UAV is an aircraft that flies without human interaction inside flight. UAVs are mostly used in both the defence and protection forces helps in situations where factor of the risk is high to send human pioletis unacceptable. conceptual designs are generated by iterative design process. And by analysing each component of design say aerodynamic, the scrap is removed from the designs. Logical factors considered include: the wing geometry, sizing, control surface size and location, centre of gravity location, and tail placement.

1.1HISTORICAL VIEW

The bench mark MAV which was designed and developed that has made land mark is black widow. The collaboration between DARPA and Aero environment led to development of black widow which took 4 years of research. The Black Widow has a 6-inch wingspan and 56 grams in weight. The aircraft had 1.8 kilometres flight range, 30 minutes flight endurance, and a maximum altitude of 769 feet. It carries surveillance camera as payload. In addition, it has computer-controlled systems for control. The Black Widow is made from foam, and many components are cut using hotwired CNC machine. There were many competitions kept for MAV design like payload 58.6 gms and like for surveillance with video recording and after surveillance should come back to operator. The University of Florida has been successful in the MAV competitions. At one time they won both heavy and surveillance categories. There plane was a plastic and carbon-fiber mixed structure. This resulted in a crash resistant air foil. Florida’s design was centred on its 90 grams thrust, COX TEE-DEE .01 internal combustion engine. When seen from their first design to last there are many similarities. COX .01 TEE-DEE engine was used in most of their designs and also a leading edge that is swept back from the propeller, which increased the thrust and made the engine slightly efficient in terms of thrust.

1.2THEORETICAL EXPLANATION

Micro air vehicles (MAVs), defined as UAV with span of not more than 15 cm and maximum speed of 15m/s, these qualities will make the vehicles to have a potential civilian and military applications. Based on their configuration, we can characterise al existing MAVs majorly into three groups: i.e., flapping wing, fixed wing and rotary wing MAVs. The obstacles faced by the researchers and developers in designing micro air vehicle is the stability and weight (even payload too). we need to design a robust wing configuration to balance the stability and weight, we need a trade of between these to have an efficient aircraft.

In past few years, attention was made on examining the low Reynolds number flows around the Low Aspect Ratio (LAR) wings which has similarity to small bird’s wing aspect ratio. There was a large experimental data as proof for low aspect ratio wings to have a potential to have high lift coefficients at higher angles of attack. Smaller sweepback angle which is less than 35, increases maximum lift coefficient and delays stalling (8).Pelletier and Mueller. (10), on experimenting cambered and thin low aspect ratio plates or wings at low Reynolds number flows and obtaining the lift, drag and pitching moment characteristics concluded that, cambered plates or wings were showing better performance at low Reynolds number flows. Based on the above experimental results, Torres and Mueller (9)further analysed the influence of aspect ratio and wing plan form on LAR wing at low Reynolds numbers (range from 7×10^3 to 2×10^5) and concluded that, there were large nonlinearities in the lift curves, especially for aspect ratios below 1.25. Wings of such LARs were also found to have high values of maximum lift coefficient and corresponding angle of attack. From the perspectives of mentioned above experimental studies, using particle image velocimetry (PIV) flow visualization of LAR wings has been conducted. (11).

The delta wing has low aspect ratio and strong structural integrity. Previously, the delta wings were not used for low Reynolds number flow. Here we are trying to design a delta wing configuration.

The delta wings will be having a sweep angle which will help them in stabilizing the aircraft. So, for the micro aired vehicles by using the DELTA wing we can reduce the stabilizing surfaces like vertical and horizontal tail. This will save us the weight which is a major parameter for a small flying aircraft to be efficient. For designing the delta wings we need a low Reynolds's number airfoil to analyze and compute the effects of the wings at Re = 1 x 10^5. The best airfoil known to work at Re = 10^5 range is NACA 4415. (1)

From (2) analysis of low aspect ratio wing at low Reynolds number, the 3-d flow field over the wings has showed variations of flow from flow separation to reattachment simultaneously. This was also seen in recent PIV studies of Khambatta and Ukeile (3)on LAR wings at low Reynolds number, which showed the flow structure around the wing.

2 METHOD AND METHODOLOGIES

2.1 AEROFOIL SELECTION:

In this case, we have taken the Reynolds number of 1 x 10^5 and Based on the literature survey we have opted NACA 4415 Air foil, which gave the best results at this Reynolds number range. And also, this is a large thickness air foil which allow us to facilitate internal components of aircraft in wings. It proved to have greater stall angle in previous case studies.

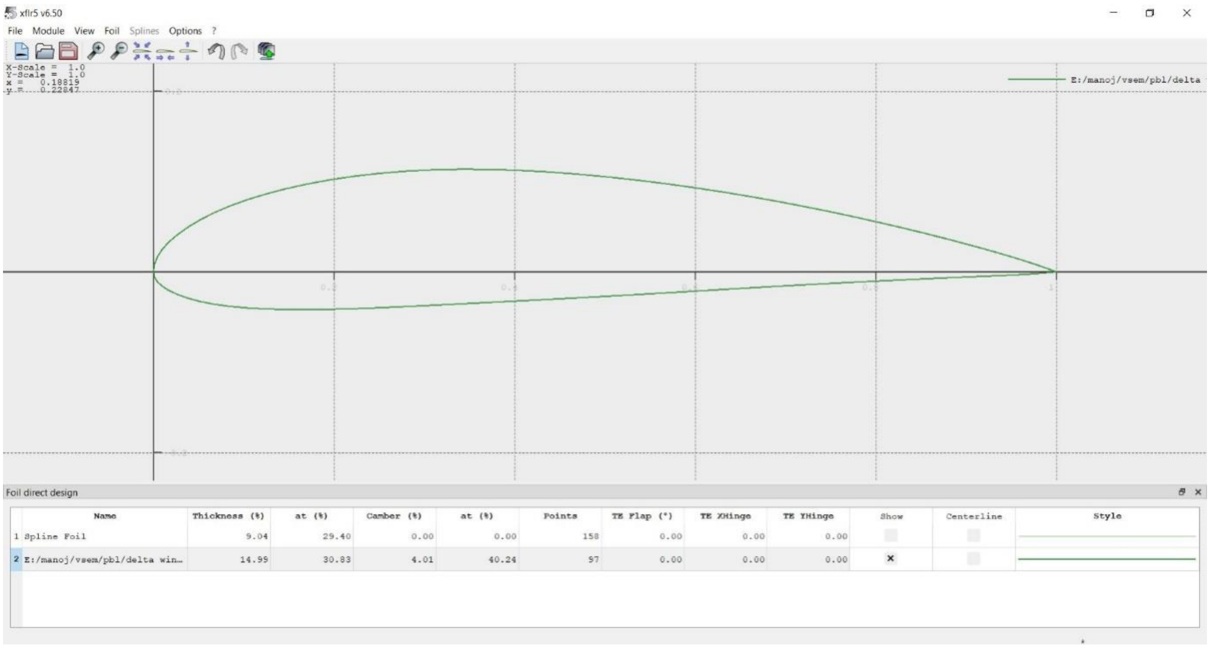

Fig 1: NACA 4415 air foil using for delta wing design in XFLR5 software

2.2 VLM METHOD:

We have used XFLR5 software to obtain basic aerofoil data and also wing. In the XFLR file, the solver used is the vortex lattice method – ring vortex in XFLR 5. In this vortex lattice method, ring vortex is used for wing. This generally begins with the two-dimensional analysis of geometry than it will superimpose a grid on the top of the wing and calculate the parameters for each cell in the grid and gives the final results by combine each cell results.

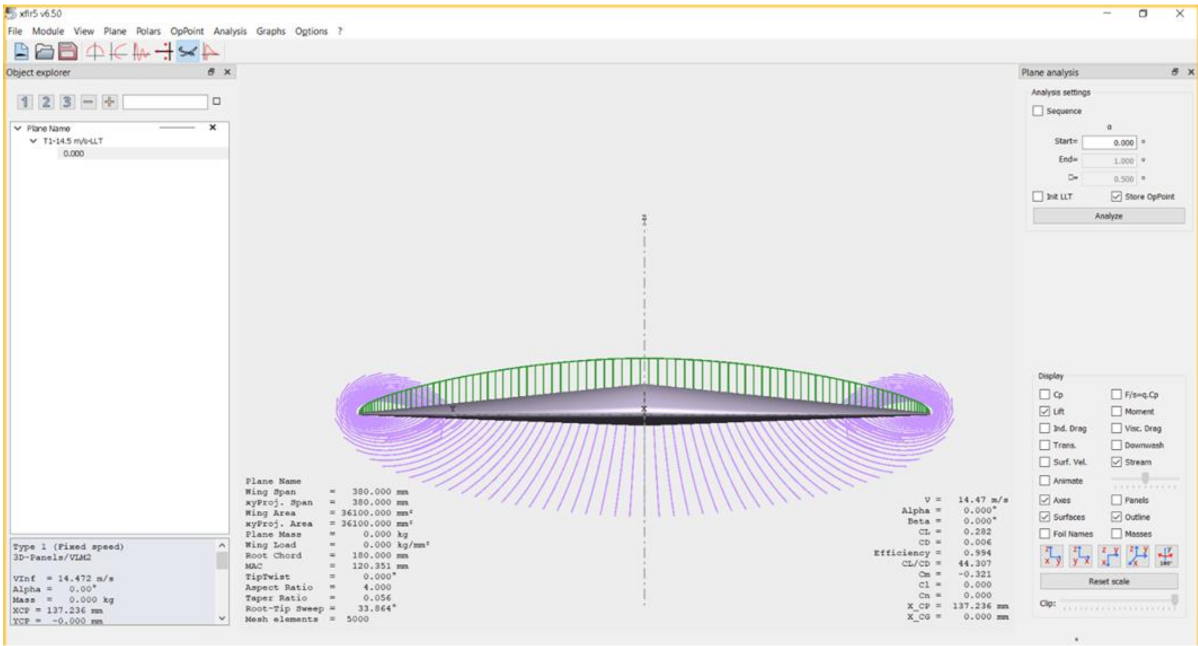

Fig 2: the streamlines flow simulation over delta wings in XFLR5

2.3 CAD:

For Computer Aided Design (CAD), CATIA v5 software is used for the delta wing made from NACA 4415 aerofoil. In this we have used two different chord length aerofoils, with one being root aerofoil of chord length 180mm and the other being the wing tip aerofoil of 10mm of the chord length. for the perfect sweep angle, we have used guideline to ensure no curved surfaces are generated between the leading edges of the tip of the aerofoil this helps us to obtain a smooth computer-aided designed delta wing.

2.4 CFD:

In this, firstly the analysis of wing was done in XFLR, but it is constrained for in viscid flows. So to obtain a realistic low Reynolds number (1 x10^5) flow we need a software to complete the task. For this we have used Ansys fluent in this we analysed the design obtained in CAD software. first we will import the geometry and created an enclose which acts as a test section. Meshing is done to generate nodal point which will help us in calculating the parameters at that point, and for this low Reynolds number case, γ-Re_θ SST Transition model is used as solver for analysis, which gave Reliable results at low Reynolds number flow in previous studies (12).

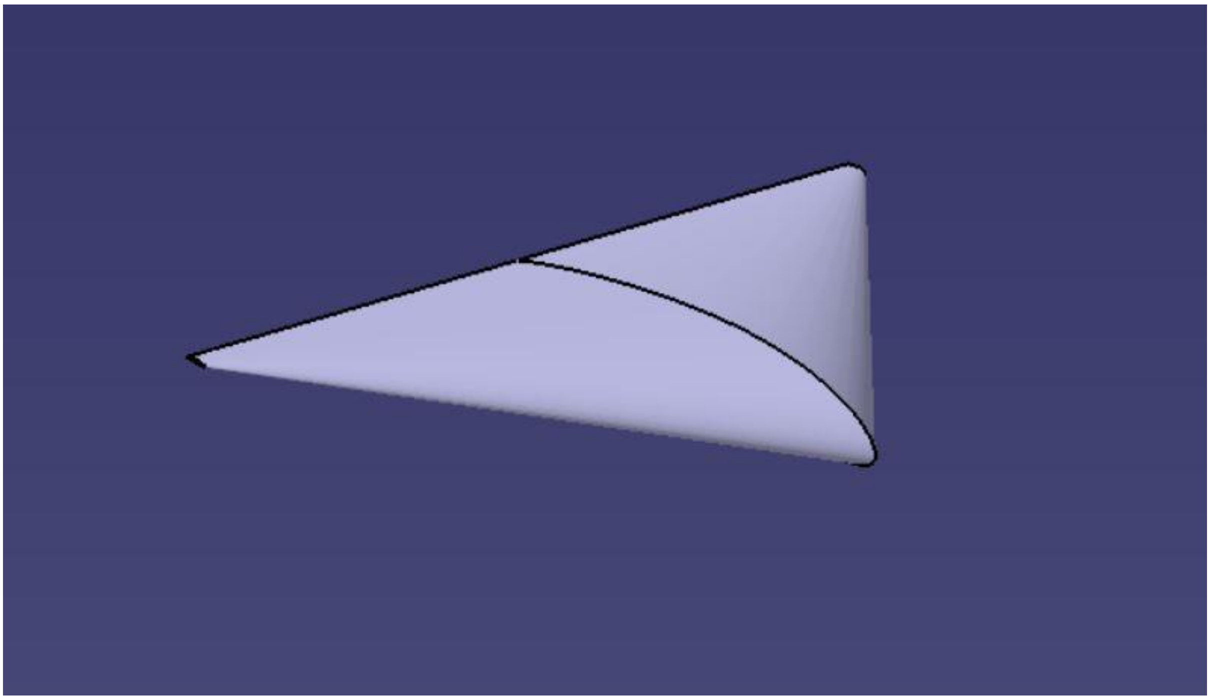

Fig 3: the computer aided designed delta wing using NACA 4415 in CATIA

3 RESULTS AND DISCUSSIONS

We have used the XFLR5 software and generated a delta wing of NACA4415 aerofoil. while analysing we have defined the parameters as, density = 1.224 kg/m^3, viscosity = 1.79x10^-5, speed of 14.72m/sec and this results in Reynolds number 1x10^5. The XFLR% computations were done by considering an in viscid flow over the model. since the in viscid flow nature will not let the software to analyse the parasite drag, which is reflected in the drag coefficient values. But the C1 values were almost same as of values in the realistic simulations.

3.1 XFLR PLOTS:

Cl vs alpha and Cl/Cd vs alpha and Cl vs Cd graphs were plotted in XFLR5 software. In the first plot the cl was increased gradually with angle of attack without showing any stall conditions, so it is believed that in viscid nature of flow didn't allow the flow to separate. which is obvious as the fluid doesn't have viscosity. We can see in the second plot the cl/cd values gradually decreased with increase angle of attack. same as cl vs alpha graph we didn't see sudden deflection in the graph. So, for all the graphs, due to in viscid nature the stall might be beyond 20 degrees which we can see in fig 4 . And from the previous studies we knew that stall angle is at 18 degrees for NACA 4415.

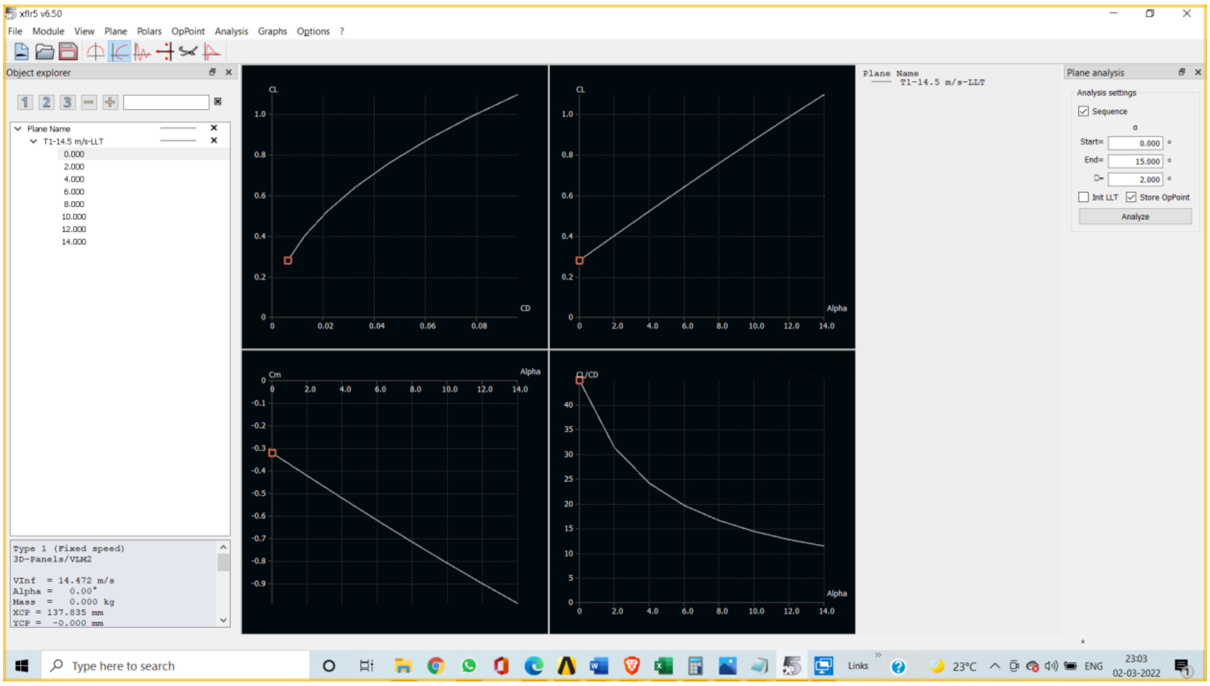

Fig 4: The Cl/Cd vs Alpha and Cl vs Alpha and some other related graphs.

3.2 ANSYS PLOTS

In ANSYS we have used the reference values for computing the analysis as, wing area of 83978 mm^2, Density as 1.225 kg/m^3, length as 145 mm, pressure as 101325 N/mm^2, temperature as 288.16 K, velocity as14.47246 m/s, viscosity as 1.86 x 10^{-5}, specific heat ratio (γ) at the inlet as 1.4.

We have analysed the delta wings using Gamma – Re Theta SST transition solver in the ANSYS fluent. We gave the resulting parameters as coefficient of lift (Cl) and coefficient of Drag (Cd) and then we took different angle of attacks of the model and analysed the same as above. By taking the Cl and Cd values as output parameters and plotted graphs using MATLAB. Here we have plotted Cl versus Alpha and Cl/Cd versus Alpha. The below graphs are obtained.

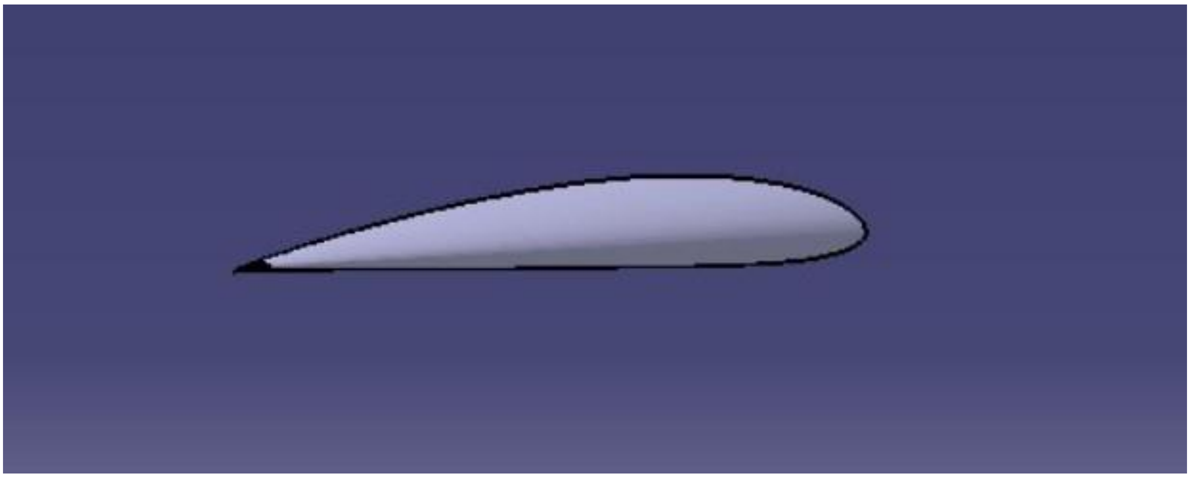

Fig 5: side view of the delta wing designed in CATIA

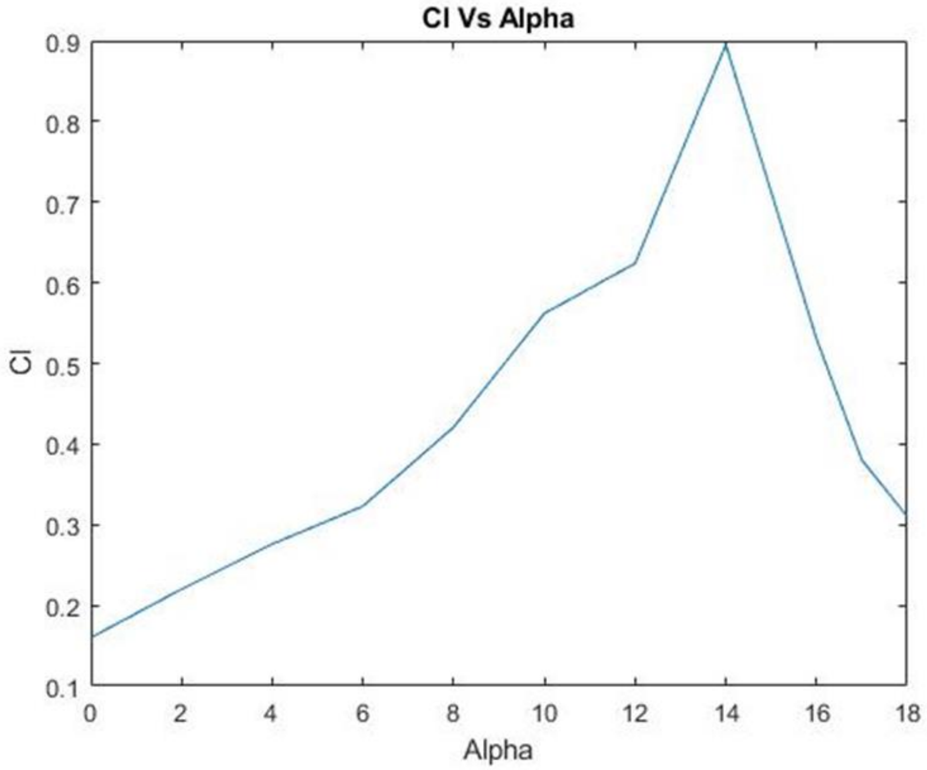

Fig 6: CL vs alpha graphs obtained by simulations in ANSYS

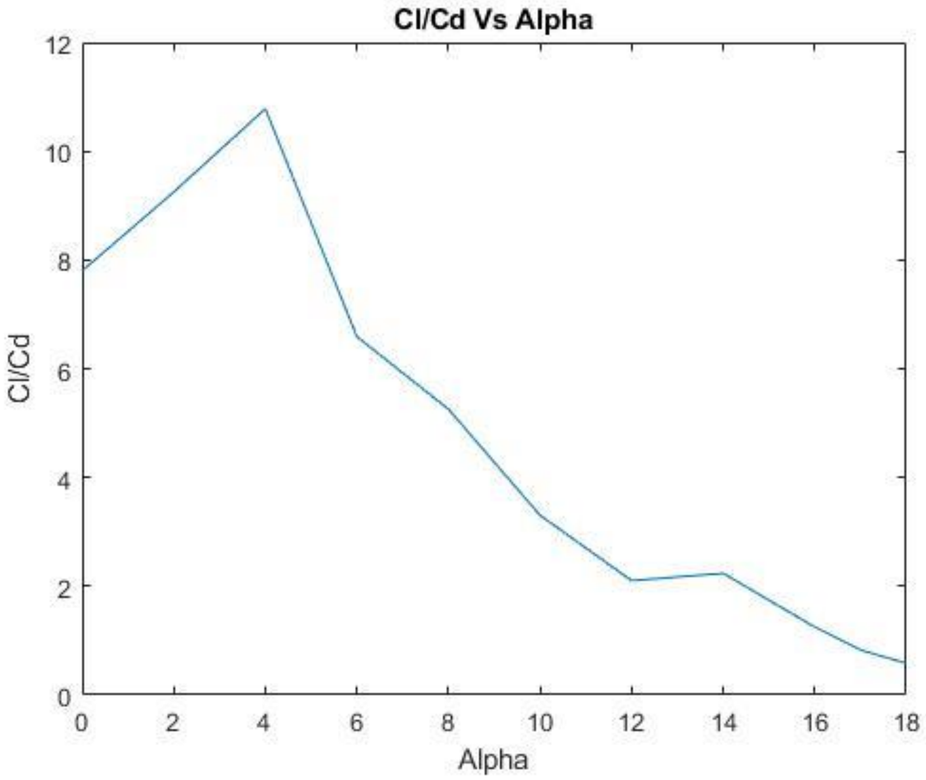

Fig 7: Cl/Cd vs alpha graphs obtained by simulations in ANSYS

In Cl versus alpha graph the Cl was increased till 14 degrees and due to stall of the wing the Cl values were suddenly dropped significantly as seen in fig 6

In Cl/Cd graph the values were increased at the start of the plot, but they started decreasing in a conventional way. The Cl/Cd values were impressive then expected in fog 7.

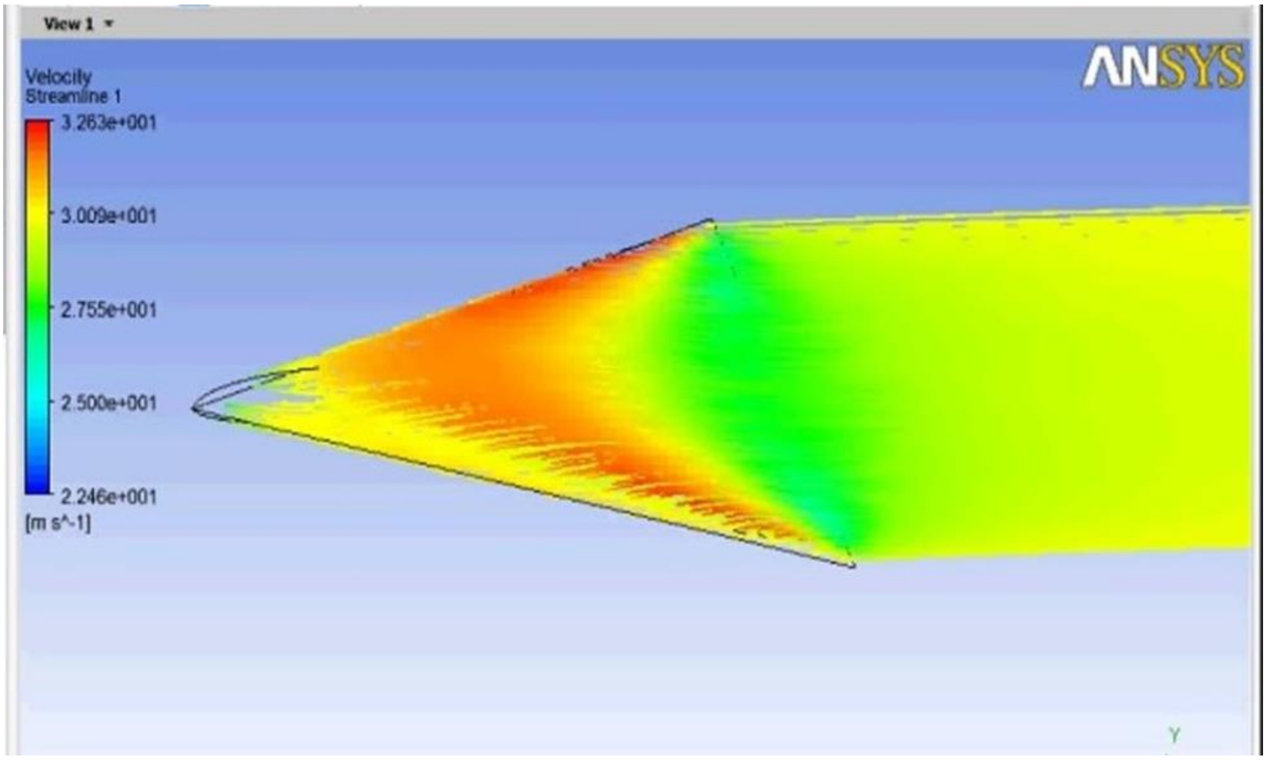

Fig 8: This is a streamline flow simulated in ANSYS for Delta wing

CONCLUSIONS

From the graphs, we can say that in XFLR there was no stall point seen till 20 degrees in plots from ANSYS we found that stall point was between 14 to 15 degrees of angle of attack And Cl/Cd vs alpha graphs in XFLR 5 and ANSYS were identical except for higher values in XFLr 5 due to in viscid flow.

The lift coefficients in both cases were small and they may not give sufficient lift. But Cl/Cd values were impressive. The cl Values were small and they may be not enough to sustain an efficient flight. But Cl/Cd values were in good range which increases flights efficiency.

So, we can say that, delta wings didn't generate good amount of lift at low Reynolds number. And also, the drag generated was also less. Since, the delta wings are known to generate a stable leading edge vortex with sharp leading edge. Though the leading vortices are generated at higher angle of attacks, the efficiency reduces. So, introducing passive vortex generator or an active vortex generator (like alula of a bird) might be a chance of increasing lift. So, this study can be continued by introducing a passive vortex generator or an active vortex generator (like alulae of a bird) for improvement in lift.

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