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Stall Characteristics Study of Aircraft Wing with Fence

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***Abstract*— In the present work, we studied aerodynamic characteristics of lift, drag and stalling characteristics. . The accumulative stalling angle is a greater mission in the wing. But our examination is primarily focused on the behavior of lift. A computational study, to improve the stall characteristics of NACA 0012 wing at high angles of attack, with and without fence configuration is done here. Wing fences, also known as boundary layer fences and potential fences are fixed aerodynamic devices attached to aircraft wings. Single Fence was fixed in the exactly middle of the wing span and two fences are fixed at 25 percentage of wing span from their corresponding wing tip. The main aim of the project is to improve the lift and stalling angle. A rectangular wing with different angles of attack is used. Modeling was done in CATIA V5 R20 and meshing and analyzing was taken in ANSYS workbench and CFX. Then the graph is drawn for C_L and C_D for various angles of attack and various models.**

Keywords: Stall, Lift, Naca 0012, Ansys And Fence

I. INTRODUCTION

A fixed-wing aircraft is an aircraft, such as an airplane, which is capable of flight using wings that generate lift caused by the vehicle's forward airspeed and the shape of the wings. A stall is a condition in aerodynamics and aviation wherein the angle of attack increases beyond a certain point such that the lift begins to decrease. The angle at which this occurs is called the critical angle of attack. This critical angle is dependent upon the airfoil section or profile of the wing, its platform, its aspect ratio, and other factors, but is typically in the range of 8 to 20 degrees relative to the incoming wind for most subsonic airfoils. By obstructing span-wise airflow along the wing, they prevent the entire wing from stalling at once, as opposed to wing, which increase aerodynamic efficiency by seeking to recover wing vortex energy.

An improved winglet design will significantly yield a better performance of an aircraft and reduce the fuel consumption. Winglets although can produce a low drag wing, they add to the cost and complexity of construction. They also modify the handling and stability characteristics [1]. The drag breakdown of a typical transport aircraft shows that the lift-induced drag can make-up as much as 40% of the total drag at cruise conditions and 80-90% of the total drags in the takeoff configuration [2]. The important parameters govern the aircraft performance are Lift, Drag, Weight and Thrust. The required performance can be achieved by improving the aerodynamic configuration, weight reduction and system up gradation (like an engine, fuel system etc.) [3]. The Reynolds number is in the range of 20 to 100 and the fence subtended angle between 10° to 30°. The location of the fence from throat varies from 0.2 to 2.6. The effects of fence subtended angle, location of the fence from the throat and Reynolds number on typical diffuser properties has revealed several features [5]. Study of aerodynamic and aero acoustic effects are studied by using flat fences are also studied [6].

ADVANTAGES OF WING FENCE

- Wing fence reduces induced drag up to 20% and thus reduce the engine power and hence the fuel consumption up to 10%-12%.
- Improves the performance parameters of an aircraft like range, rate of climb, time of climb, etc.

II. WING DESIGN

The design of the wing and the wing fence model has been done by using the CATIA V5 software. For meshing ANSYS workbench was used as a tool to mesh all those models. Final analysis has been taken in ANSYS CFX to obtain the flow analysis results. Wing model was four digit series that is a NACA 0012 with the wing span of 30 cm and chord length of 10 cm. Fences are in dimension same as the airfoil which has length up to only 70% of chord, its thickness is about 1.25 mm and height of the fence was 1 cm only. Initially work was taken in plain or base airfoil to find out the stalling angle. Once the stalling angle was found out, then the next step is to carry out our investigation in single fence with wing and two fences with wings.

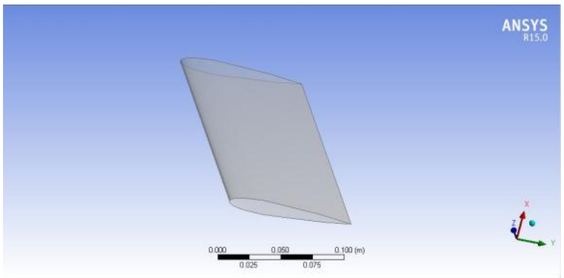

Figure 1: Plain wing section of NACA-0012

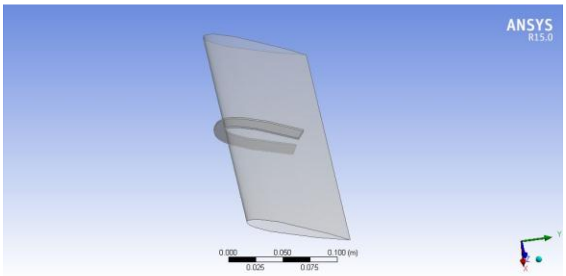

Figure 2: Single fence over the wing section

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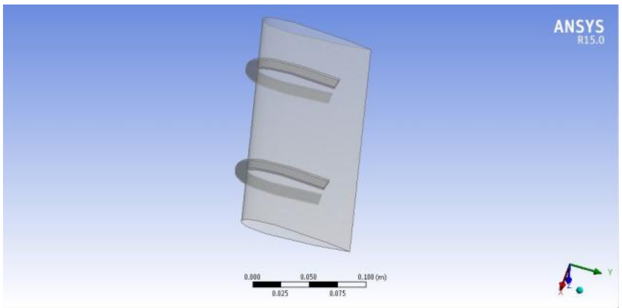


Figure 3: Two fence over the wing section

This portion will deliberate about the boundary conditions used for this present analysis. Velocity inlet is used at the inlet of the boundary with the free stream velocity of 30 m/s, for constant Reynolds number. Wing section is considered as solid wall with no-slip boundary condition. Turbulent model is chosen from k-w with standard wall functions.

Computational analysis is carried out in order to predict the values of lift and drag co-efficient of wing section at 30 m/s free stream velocity. After that, normal and axial forces derive from the ANSYS CFX post.

$$L = N \cos \alpha - A \sin \alpha$$

$$D = A \cos \alpha + N \sin \alpha$$

After that coefficient of lift and coefficient drag is calculated by

$$C_L = (L) / (0.5*\rho*V^2*S)$$

$$C_D = (L) / (0.5*\rho*V^2*S)$$

III. RESULT AND DISCUSSION

Now, is the discussion about in what way coefficient of lift and coefficient drag differently according to various angles of attack. Originally we did the work for the base airfoil to find out the stalling angle.

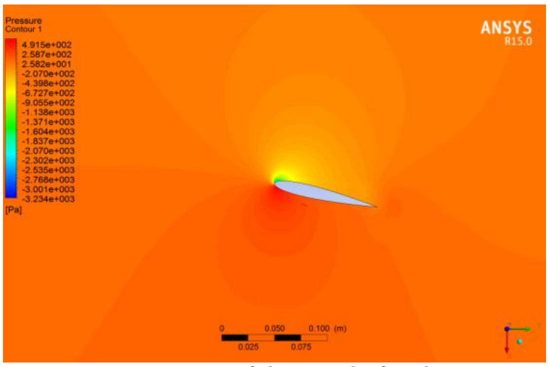
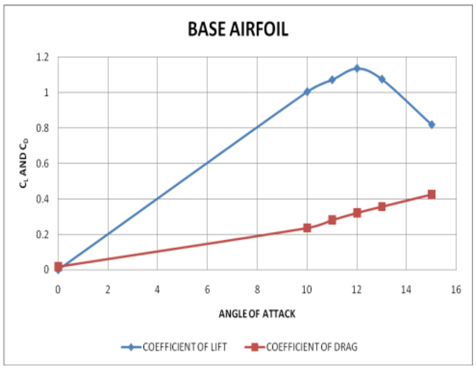


Figure 4: Base airfoil at 13° angle of attack

S.NO	ANGLE OF ATTACK	BASE AIRFOIL (C_L)	BASE AIRFOIL (C_D)
1	0	0	0.01856387
2	10	1.0047479	0.236858582
3	11	1.071806113	0.28114351
4	12	1.136190887	0.321926252
5	13	1.075538189	0.357173418
6	15	0.819103571	0.425733763

Table 1: Co-efficient of lift and drag for base airfoil

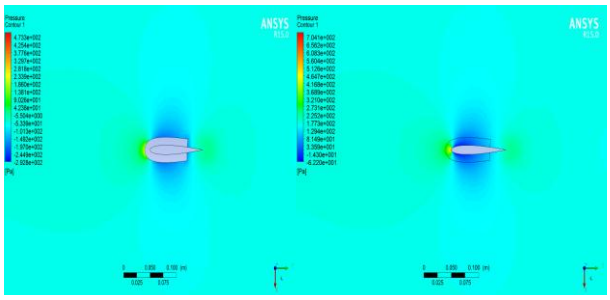


Graph1: C_L AND C_D for base airfoil

In the base airfoil work was done with constant velocity at 30m/s and different angle of attack that is 0, 10, 11, 12, 13 and 15 degrees. This base airfoil produces a maximum lift coefficient of 1.13 and stalled at 13 degree angle of attack.

PRESSURE CO-EFFICIENT CONTOURS

Distribution of pressure around of NACA 0012 was shown in Fig. 5 from 0° to 20° for both single and double fences.



a) b)

0^0 angle of attack

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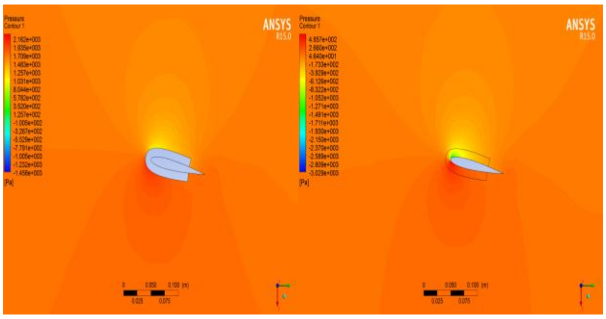
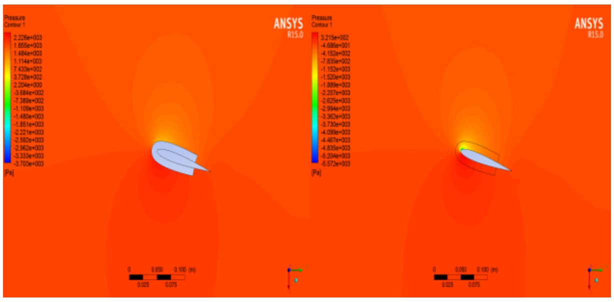
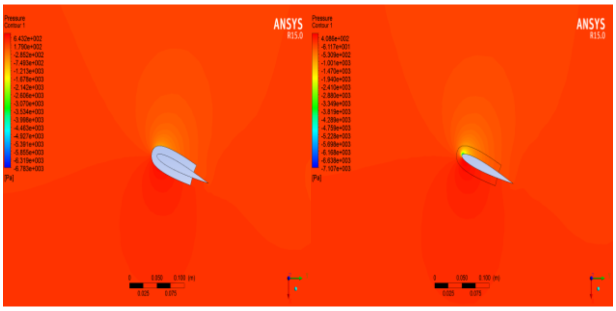


a) b)
10^0 angle of attack



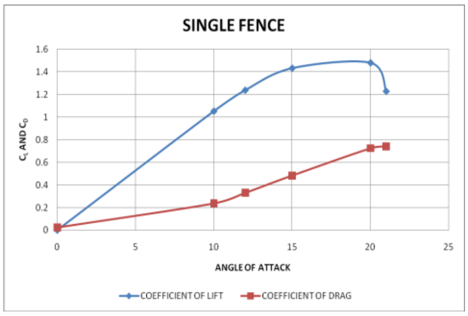
a) b)
15^0 angle of attack



a) b)
21^0 angle of attack

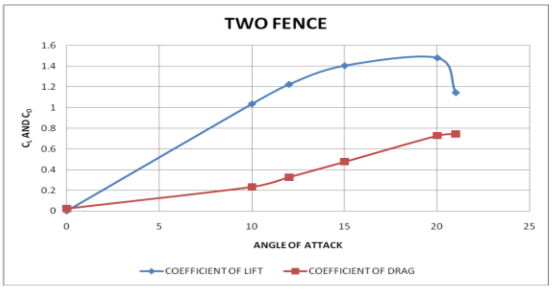
ANGLE OF ATTACK	SINGLE FENCE (C_L)	TWO FENCE (C_L)	SINGLE FENCE (C_D)	TWO FENCE (C_D)
0	6.04686E-05	6.04686E-05	0.0225548	0.024187453
10	1.050953143	1.033652487	0.23597782	0.23415607
12	1.236050225	1.222102446	0.329366772	0.3275148
15	1.43077935	1.402493769	0.482453485	0.475876336
20	1.478293551	1.477961578	0.723192816	0.727640381
21	1.226658661	1.142199444	0.739783704	0.744022271

Table 2: co-efficient of lift and drag for single and double fence



Graph2: C_L AND C_D for airfoil with single fence

In the airfoil with single fence work was done with constant velocity at 30m/s and different angle of attack that is 0, 10, 12, 15, 20 and 21 degrees. This single fence airfoil produces a maximum lift coefficient of 1.478 and stalled at 21 degree angle of attack. This gives the greater variation because the introduction of fence with these specifications gives a greater effect that was the increment of lift as well as increasing stalling angle.



Graph3: C_L AND C_D for airfoil with two fences

In the airfoil with single fence work was done with constant velocity at 30m/s and different angle of attack that is 0, 10, 12, 15, 20 and 21 degrees. This single fence airfoil produces a maximum lift coefficient of 1.477 and stalled at 21 degree angle of attack. This also gives the similar results as like as single fence, but a little bit loss in lift coefficient and increasing in drag coefficient.

IV. CONCLUSION

Computational works show that the introduction of fences gives positive results when compared to base airfoil in these specifications. The following results are produced based on this current analysis:

- Introduction of the fence gives greater control stalling angle and increase in lift coefficient.
- For base airfoil it has the maximum coefficient of lift was 1.13, for single fence it was 1.478 and two fences it was 1.477.
- With the help of fences it increased in lift coefficient by 30.7 percentage.
- Stalling angle of base airfoil has the value of 13 degrees, but the introduction of fences leads to 21 degrees. It gives a variation up to 8 degrees.
- Among the number of fences, single fences give effective results when compared to all.

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