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Study of Laminar Flow Control Aerofoil with Thrust Generator

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ABSTRACT

Present study is to make the laminar flow over the aerofoils usingsuction and to utilizing suctioned air as the input to the thrust generator. An aerofoil model is fabricated for experimental study in the wind tunnel. The aerofoil model fabricated has perforation in the leading edge up to quarter chord on the upper surface such that the suction is made at the first quarter surface over the aerofoil with an optimum suction rate obtained through CFD analysis. The lift and drag characteristics are studied for the aerofoil profile with and without suction. The flow separation is visualized by tuft technique. The suction air employed for generating thrust through a thrust generator which is capable of producing thrust through entrainment and inducement of air. The data obtained from the experiments the results of the aerodynamic performance with and without suction are obtained. This result is also compared with the CFD results. For CFD analysis an aerofoil model was created using the CATIA and imported to ANSYS CFX. From the experimental data obtained with and without suction, the changes in the aerodynamic efficiency are found. The range under which the Laminar flow control is more efficient has been identified. The mechanism used for suction itself is capable of generating larger thrust making it much more efficient and feasible to employ the MAV in future.

Keywords: Laminar flow control, Skin friction drag, Suction type aerofoil, Thrust generator, MAV in future.

INTRODUCTION

In an airplane, the energy required to overcome the frictional force is a substantial part of the total energy required to move the airplane in the air. In case of a transport airplane flying at subsonic speed, approximately one half of the energy (fuel) required to maintain level flight[1]in cruise results from the necessity to overcome the skin friction from the boundary layer, which is mostly turbulent. Therefore the overall efficiency of the aircraft can be increased by making the flow laminar over the wing. Laminar flow is difficult to attain and retain for the entire chord length under most conditions, but it is possible to maintain the flow laminar for a major extent along the chord[2]. Two basic techniques are available to delay transition from laminar to turbulent flow –**Passive laminar flow control** - designing the surface cross-sectional contour so that the local pressure initially decreases over the surface in the direction from the leading edge towards the trailing edge**. Active laminar flow control** - Active laminar flow can be obtained byremoval of small of the boundary layer air by suction through porous materials, multiple narrow surface slots, or small perforations.The method in which both active and passive flow control methods are used is known as **hybrid laminar flow control** (HLFC)[1]. The hybrid laminar flow control is achieved in this Project.

The reduction in drag due to laminar flow control is nearly 40%. This major advantage of making the flow laminar canbe well adapted to the MAV than in the conventional aircraft. The design of the wing structure in the conventional aircraft has a great deal in fuel storage and thereby making the suction very difficult to adopt[6], due to two major reasons, the firstbeing the structural difficulty and space to be accommodated by the suction lines and second is the risk in leakage of such a high mass flow of air near to the fuel store which may lead to explosion[2].

In the MAV design, the major factor is endurance and range. The decrease in drag directly means increase in the range. The difficulty of fuel store can overwhelm in MAV through facilitating fuel store in the fuselage and shifting the electronics to the wing structures. Thus this project aims in enhancing the aerodynamic performance of the laminar series aerofoil by employing the suction. The flow associated with the MAV is of low Reynolds number, the behavior of flow in low Reynolds no is very different and the drag characteristics vary highly from the behavior at high Reynolds number

Experimental setup

The airfoil model[3] 66_2415 is fabricated using teak wood with the pressure tapings as shown in figure 1.1. The pressure tapings are provided with tubing to multi-tube manometer. The Porosity

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is brought over the slots by patching the slot with canvas cloth.

The slots are inter connected and are provided with an opening on one side of aerofoil to allow tubing of the suction line. The suction is employed by using the vacuum pump and the flow rate of the vacuum pump is measured using a venturi meter. From the mass flow rate across the venturimeter, the suction on the porous layer is determined.

In-order to measure the pressure distribution on the surface of aerofoil it is necessary to have pressure tapping, totally 15 pressure tapping are made among which seven tapings are distributed on the upper surface and seven on the lower surface, one pressure tapping is made on the leading edge. The tapings are distributed with spacing of 2 cm between them in the chord wise direction. The Pressure tapings are made at two locations in the span in order to obtain an averaged distribution of pressure.

2. RESULTS AND DISCUSSION

(a) Lift Characteristics:

Co-efficient of lift[6] of the laminar flow airfoil with and without suction can be seen in the following Plot obtained from experiments as shown in figure 1.2.

Figure 1.1

Alpha	**C_L without suction**	**C_L with suction**	**% increase in C_L**
0	0.149543	0.230289	53.99542
5	0.352808	0.454716	28.88502
10	0.422425	0.571418	35.27088
15	0.537962	0.662984	23.23987
20	0.506625	0.674871	33.20918
Average			34.92

Table-1.1

The above table shows the laminar flow control through suction is found to be increased by **34.92%** of C_L and the laminar control postpones the stall to the higher angle of attack.

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(b) Drag Characteristics:

Co-efficient of Drag[6] of the laminar flow airfoil with and without suction can be seen in the following Plot obtained from experiments as shown in figure 1.3.

It isperceived that the laminar flow control has decreased the drag by a large value till 15 degrees. The following plot graph shows

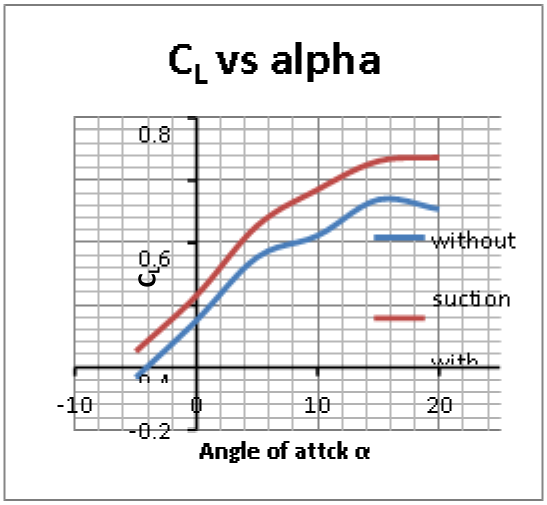

Figure 1.2

It is perceived that the laminar flow control has improved the lift characteristic by a large value.Beyond 15 degree the convention aerofoil stalls and the lift curve falls rapidly whereas the aerofoil with suction shows a steady tendency which indicates that reasonable lift is generated even at very high angles of attack where the conventional aerofoil fails. The following table shows the percentage increase in C_L of the laminar flow controlled airfoil.

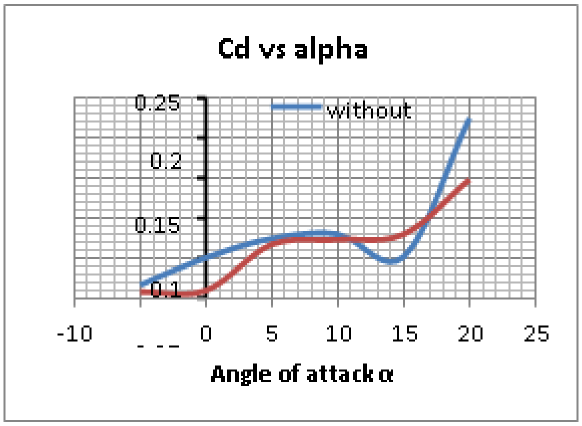

Figure 1.3

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The percentage decrease in C_D of the laminar flow controlled airfoil.

TABLE 1.2

Alpha	**C_D without suction**	**C_D with suction**	**% decrease in C_D**
-5	0.016835	0.0075474	55.16839917
0	0.050515	0.009044	82.09640701
5	0.0745775	0.0665272	10.79454259
10	0.0801025	0.0725258	9.458755969
15	0.0520965	0.07938	-52.37108059
20	0.22492775	0.147924	34.23488209

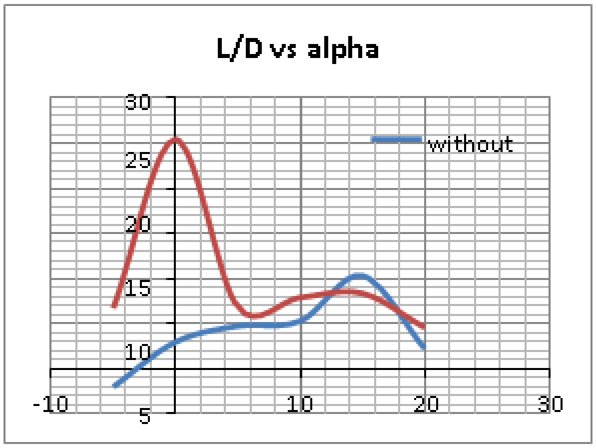

Figure 1.4

TABLE 1.3

AOA	**L/D without suction**	**L/D with suction**	**% Increase in L/D**
-5	-2.0106	6.690251	432.7485
0	2.960358	25.46314	760.137
5	4.73075	6.835039	44.48109
10	5.273556	7.878824	49.40249
15	10.32626	8.352028	-19.1186
20	2.25239	4.562282	102.5529

The above table 1.2 shows that the laminar flow control has decreased the drag by a large value.In an airplane, the energy required to overcome the drag force is a substantial part of the total energy required to move the airplane in the air, so this large decrease in the drag directly reflects on the efficiency and the fuel required[1].

(c) L/D ratio:

The Comparison of L/D of the laminar flow controlled airfoil with the airfoil without suction can be seen in the following Plot which is obtained through experiments.

It is perceived that the laminar flow control has increased the L/D ratio by a large value. The following table 1.3 shows the percentage increase in L/D of the laminar flow controlled airfoil.

From the above table it is clear that the laminar flow control has increased the aerodynamic efficiency to a great extent. We know that the range is directly proportional to the L/D, from Brequet range formula[4]Range α K*(C_L/C_D)*V where K is the product of thermal and structural efficiency. These shows that the laminar flow control decreases drag to nearly 50
% in operating range which nearly increase the range to 25%[5].

3. CONCLUSION:

The experimental data obtained with and without suction, are evaluated, the most efficient range under which the LFC was efficient has been identified. The following results were inferred.

- Laminar flow control postpones the stall which helps the aircraft to be stable even at higher angle of attack and also 34.92% increase Cl is observed.
- Laminar flow control decreases the drag thereby increasing the efficiency and decreasing the fuel consumption as a result it reduces the fuel cost and operating cost of the aircraft.
- Laminar flow control increases the range approximately 25%, whichindicates thatlesser fuel required for the entire range.

This methodology is very useful because leading edge suctioned air is used to generate Thrust thus conserving the energy spent on suction.Employing this improves the performance characteristics, efficiency and range to a great extent and also generates a part of total thrust making its contribution indispensible for MAV's in future.

4. NOMENCLATURE:

L – Lift D – Drag

K – Product of structural and thermal efficiency V – Velocity of aircraft

C_L – Coefficient of Lift C_D – Coefficient of Drag

LFC – Laminar Flow Control

HLFC – Hybrid laminar flow control CFD – Computational Fluid Dynamics MAV – Micro Air Vehicle

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