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Computational Analysis for Different Sorts of Vortex Generator Over Aircraft Wing

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Abstract—The continuous focus of flight aerodynamics mainly falls to enhancethe aerodynamic characteristics and maneuverability of the aircraft. Thisenhancement includes the reduction of drag and stall phenomenon. The airfoil which contains vortex generator will have comparatively less drag than the plain airfoil.Introducing Vortex generator on the aircraft wing will create turbulence by creatingvortices which delays the boundary layer separation resulting in decrease ofpressure drag and also increase in the angle of stall. In addition, wake reductionleads to reduction in acoustic emission. The overall objective of this paper is toimprove the aircraft maneuverability by delaying the flow separation point at stall and thereby reducing the drag by applying the Vortex generator effect over theaircraft wing. This project includes both computational analysis ofvortex generator on aircraft wing, using NACA 0018 airfoil. Vortex generator of triangular delta, semi-sphere, hexagon, cylinder, square is selected for the analysis; airfoil istested under the inlet velocity of 30m/s and 60m/s at different angle of attack (5˚, 10˚, 15˚,20˚, and 25˚). This analysis favors the vortex generator by increasing L/D ratio andthereby providing the maximum aerodynamic efficiency, which provides the enhanced performance for the aircraft.

Keywords—Aerodynamic Efficiency, Boundary layer, Flow separation, Stall reduction, VG - Vortex generator.

I. INTRODUCTION

An aircraft is basically a machine which can able to fly by gaining support from the air with in the earth atmosphere. Enhancing the aerodynamic efficiency (L/D) is one of the key parameter that determines performance of an aircraft.Improved aerodynamics is critical to both commercial and military aircraft. This is achieved by concentrating on reducing the drag.Hence, improved stall angle to ensure the safe landing of an aircraft. Stalling is the strong phenomena during landing because reduction in dynamic pressure has to be compensatedby increasing the angle of attack.

(Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014, Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

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Short take-off and landing (STOL) designs are implemented in the aircraft which contains slots on the wing's leading edge together with flaps on the trailing edge, which gives high lift co-efficient and remarkable slow flying capabilities by allowing greater angle of attack without stalling, but it prevents the stall up to approximately 30 degree. After passing the critical angle of attack means the wing is now unable to produce sufficient lift to balance weight, if this angle exceeds it leads to flow separation, thereby increase in drag, which reduces the L/D ratio. Vortex generator create turbulence by creating vortices as shown in figure 1, which delays the boundary layer separation resulting in decrease of pressure drag and also increase in angle of stall. It helps to reduce the pressure drag at high angle of attack and also increases the overall lift of the aircraft. On analyzing the vortex generator aerodynamics results in experiencing drag force smaller than the smooth aircraft. *In deep, vortex generator delay the flow separation point by creating turbulent boundary layer by reenergizing potential energy in to kinetic energy*. Modifying the aircraft wing structure by means of placing delta VG will reduce the drag to considerable amount from the total drag, and helps to stabilize the aircraft during stall.Stall may occur during Take-off or Landing. Considering when the airspeed is low, increasing the altitude at low airspeed, the lift Co-efficient increases by lifting the aircraft nose at a too low airspeed which may exceed the critical angle of attack and stall occurs. At high airspeed with full of throttle, the elevator is excessively moved up, then the aircraft will rotate upwards, sue to aircraft's inertia, it may continue flying in the same direction but the wings at an angle of attack may exceed the stall angle.

In this study, effect of different sorts of VG as a conventional vortex is studied computationally; VG are quite effective at different angle of attack and also can change angle of stall to a greater extent.In order to verify the effect of Vortex Generator, the different shapes of VG are analyzed by placing over NACA 0018 airfoil at the effective location to delay flow separation point. Aerodynamic analysis for this airfoil is carried out using computational fluid dynamics (CFD).Through this study we aim at making aircrafts more maneuverable by implementing VG over the wing.

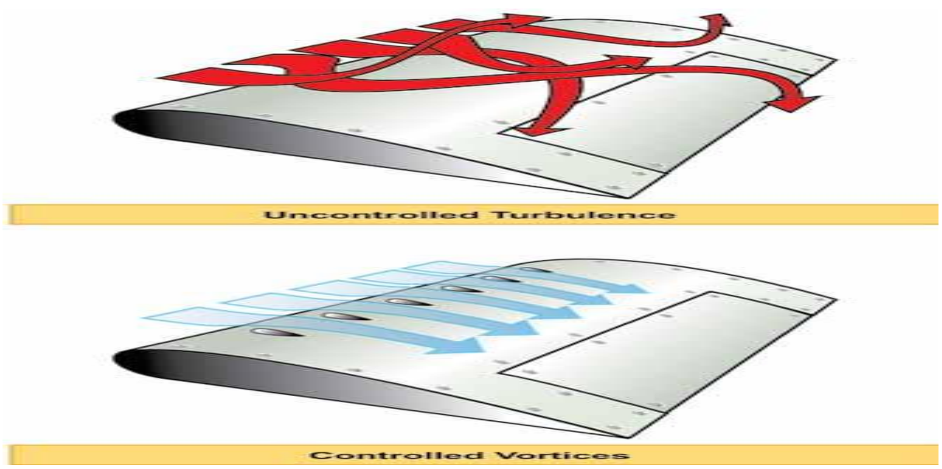

Fig. 1 Controlled Flow due to presence of Vortex generator shows the Delay of Flow Separation

II. RESEARCH METHODOLOGY

The complete study is focused on determining the effective vortex generator, by examining the selected number of VG shapes. The VG which is responsible for the flow control over the wing during the critical maneuver is analyzed by varying the types and shapes at different angle of attack overNACA 0018 to obtain the less drag co-efficient (C_D). In order to ensure an efficiency of the adopted computational technique, validation should be done from the slandered reference research paper.

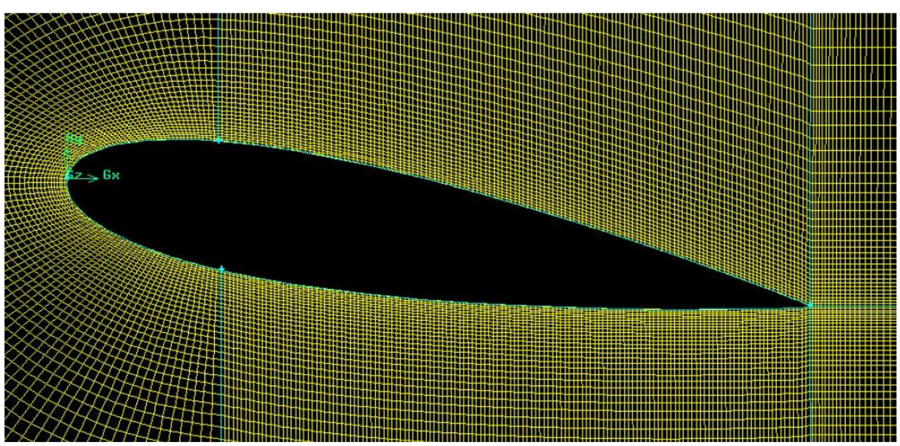

Fig.2The figure shows Closer View of quad meshed plain airfoil over NACA 0018 series

The similar airfoil is analyzed with the same velocity inlet (i.e. 20m/s) for the selection of airfoil. The airfoil with respective domain is meshed using Quad element with the skewness of less than 0.3. Comparative study of Coefficient of Lift and Coefficient of Drag between reference and present computational values are carried out as follows .As a final of validation, result shows that the airfoil with NACA 0018 is suitable for our modification in terms of dimples to improve the aerodynamic

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efficiency.From Graph.1, It is clear that both reference computational as well as present computational matches very well. Only *slight deviation (i.e.5%) was observed at 5deg*, Angle of attack.The effects in the airfoil NACA0018 after its modification by placing varying vortex generator geometry over it are studied by following tabulations indicating the coefficient of lift and drag and aerodynamic efficiency values for different inlet velocities and different angle of attack. The solver uses the K-ε, to predict the turbulence effect of the modified airfoil.

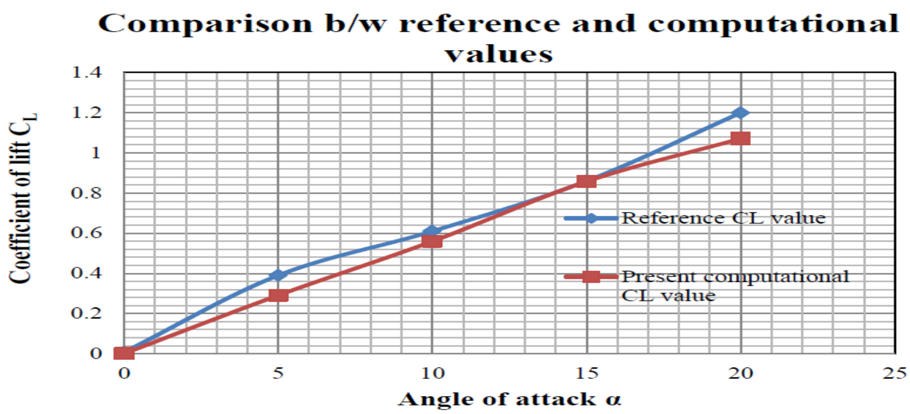

Fig. 3 The figure shows that coefficient of liftvs. Angle of Attack for the comparison between reference and present computational value.

Based on the feasibility of wind tunnel requirement for the future scope of the objective to be tested experimentally and to have varying inlet conditions for comparative study purpose two inlet velocity 30m/s and 60m/s are selected for the further analysis complete analysis of this current work. Objective of our study is to visualize the stall, thus selection of symmetry airfoil will helps to show clearly the effective stall. To select appropriate shape and size of a dimple which disturbs the flow separation efficiently with less production of drag is important to achieve objectives. Concentrating on the shape, the effective shape is to beexamined which produce flow separation at greater extent. The VG shapes of different configuration with triangle (delta), semi-sphere, square are analyzed with aerodynamic influence. The reason for choosing delta shaped VG, is that it is a highly streamlined body produce secondary vortex, so when it is placed in flow separation regime, it would gain some turbulent kinetic energy to stick to the surface of the wing. Hence the pressure drag on the wing would be reduced. With the referenceof IPCSIT Journal named "Flow Control over Airfoils using differentshaped dimples" the semi spherical VG has been selected. The paper resulted that semi spherical shaped vortex generator achieves the objective e and improves the aerodynamic characteristics of the aircraft.

efficiency effectively. Also an idea of introducing compound VG (semi-sphere followed by square VG) is to achieve effective drag reduction and increased aerodynamic efficiency.

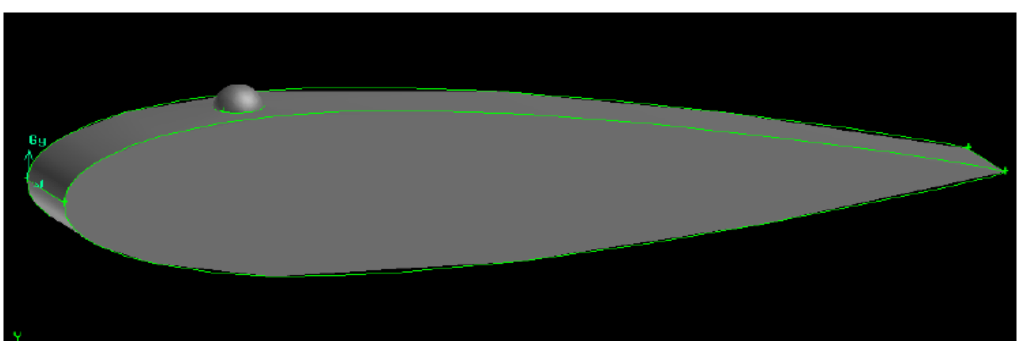

Fig. 4The figure shows that outwardly placed sphere shaped vortex generator at the flow separation point

Geometry is drawn using Gambit2.3.16. An idea of introducing double VG in the place of VG dimple is done by comparing the Coefficient of drag value.Both single and double dimple for a particular angle of attack by 30m/s.Boundary conditions for computational analysis are discussed as follows. Velocity Inlet boundary condition was set as a inflow. Pressure outlet boundary condition was set to the outflow (Surface from which the flow leaves), where the variables will be extrapolated from the interior cells. Adiabatic walls boundary condition was assigned for the modified airfoil

III. RESULT AND DISCUSSION

All simulations of NACA 0018 are carried out at different angle of attack, taking inlet velocity 30 m/s and 60 m/s. U_y and U_z are taken to be zero. One of the objectives of this computational study is also to shorter the take-off distance of the aircraft by creating sufficient lift with minimumdrag at low velocity. For this reason airfoil model is simulated at such low velocity.A2-D simulation is carried out to draw comparison between different shaped VG, also both are compared to plain airfoil NACA 0018 without any presence of vortex generator.Analysis is done at 0˚, 5˚, 10˚, 15˚, 20˚ degrees of angle of attack. Fig. 5 illustrations that the variation of the Drag coefficient with respect to the Angle of attack for different shapes of vortex generator.

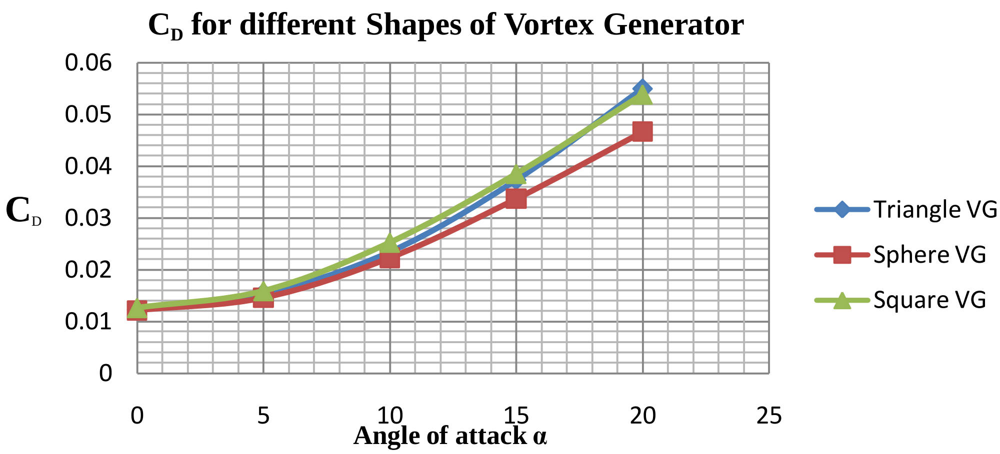

Fig. 5 Variation of C_L value of different vortex generator configuration

As expected, placing Vortex generator would bring drag value down to minimum. Plain airfoil experiences the maximum drag value of nearly 0.28 at 20 deg AOA, but for the case of semi semi-spherical and compound VGit drops to 0.05. From the observation double semispherical inward configuration experiencing the minimum drag co-efficient among these vortex generator shapes. Square configuration of vortex generator produce bit higher value of drag at 20 degree AOA,that of other shapes. It also explains the drag behavior of sphere as well as compound shapes at the inlet velocity of 30m/s. When compare with the square configuration, rest of shapes are experiencing little higher value of drag at all Angle of attack. Compound outward configuration follows the square inward up to 15 deg AOA, slight mismatch at the 20 deg AOA(i.e.10%), from the two analysis it clear that compound configuration of vortex generator also quite effective like double square, semi-spherical double configurations.

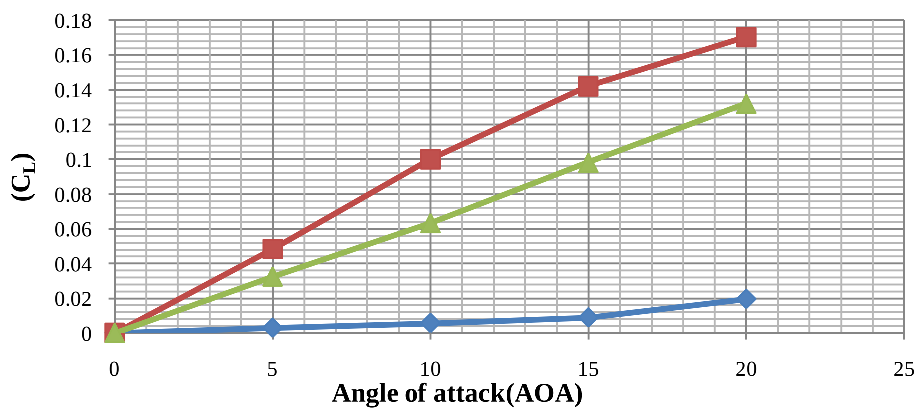

Fig. 6 Variation of C_L value of different dimple configuration

The graph shows the significant improvement of lift increment over the different values of angle of attack. Semi-spherical configuration gives the maximum value of co-efficient of lift

is 0.17, compound configuration also follows the Semi-spherical configuration. Compound VG shows the maximum lift co-efficient of 0.13(i.e.,30% lower from peak lift co-efficient). Small amount of irregular jump is observed compound VG configuration at 10degree AOA.

Square inward configuration shows the maximum lift co-efficient of 0.18 at 20 deg AOA. Around 10% lift enhancement over the semi-spherical inward configuration. All the graphs show that inward position of dimples shows the better aerodynamic efficiency than that of outward configuration. Compound outward as well as square outward only mismatches the squareinward at 20 deg AOA.

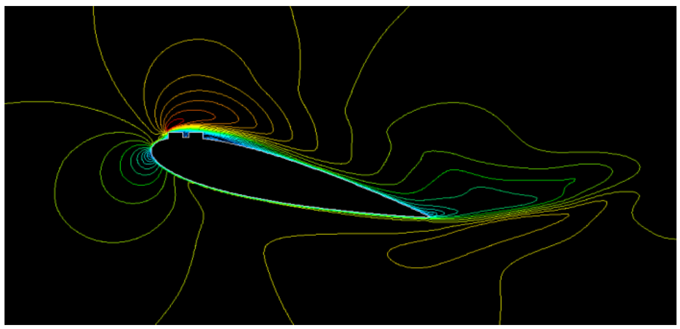

Fig. 7 Delay of Effective Flow separation over Square shaped vortex generator

Compound square shaped vortex generator placing at the flow separation point will experiences the drop of drag nearly at stalling angle, which is clearly visible at Fig. 7. From the analysis it is clear that square shaped vortex generator produces maximum (L/D) ratio. Hence compound square shaped vortex generator configuration is chosen best among the others. The following figure shows the placement of vortex generator over the wing of the aircraft which helps to guide the flow during stalling at high angle of attack

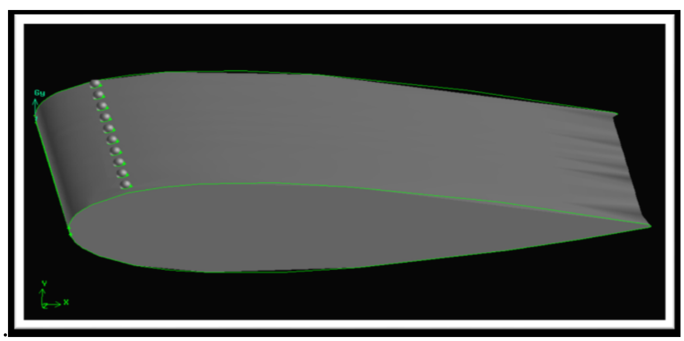

Fig. 8Three Dimensional view of Modified Wing with vortex generator.
(Manikandan et.al., 2016, Sethuraman et.al., 2016, Senthil Thambi et.al., 2016).

CONCLUSION

The concept of adding vortex generator has an extreme benefit of making an aircraft more maneuverable by changing flow characteristics. Implementation of dimple over NACA 0018 has proven to be more effective in altering various aspects of the flow structure with varied lift and drag forces. Results obtained through the computational are discussed in previous chapter. The following conclusions have been drawn from the work presented here.

i. When the flow along the surface of the airfoil enters a vortex generator, a small separation bubble is formed in the cavities. The consequence of the bubble formation is the acceleration of the flow between the VG on the surface of the airfoil and boundary layer undergo a transition from laminar to turbulent. This transition leads to delay of separation of flow from the airfoil causing a substantial reduction of drag force.

ii. Modification in terms of vortex generator creates turbulence in order to delay flow separation, which increases the stall angle at which the aircraft is no longer controllable when air is not flowing over the wing properly.

iii. The study shows that use of vortex generator is purely natural process, helps to achieve valid aerodynamic performance improvements for airfoil- sectioned elements, without the need of drag penalty.

iv. The Results of the study confirmed that placing of Vortex generator can effectively delay the trailing-edge separation and subsequent stall to higher angle of attack, thereby increasing C_L and C_L/C_D with the 30% reduction in drag force.

v. Effective mixing near the wall is possible to produce higher momentum flow from the external flow in to the boundary layer.

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