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Optimization of Wing Design for UAV Models Using Vortex Generator

V. Rakshit[1*], M. Santhanakumar[2], H. J. Kavya[3], D. Lakshmanan[4]
[1,2,3]*Student, Department of Aeronautical Engineering, Bannari Amman Institute of Technology, Erode, India*
[4]*Assistant Professor, Department of Aeronautical Engineering, Bannari Amman Institute of Technology, Erode, India*

***Abstract*: Installation of vortex generators has less impact on drag compared to Conventional airfoil. In order to improve the performance of the flying vehicles, drag reduction through delaying the flow separation is considered in this project. Flow separation can be delayed by using dimple wings and vortex generators. The scope of this project is to test various simulation parameters of the vortex generator and establish a reliable baseline to obtain reasonable results for 2D computational fluid dynamics analysis using ANSYS Fluent software. The three different types of vortex generators such as parabolic, rectangular and triangular were developed and analysed for better results and enhanced the efficiency of UAV models.**

***Keywords*: Flow separation, Dimples, Drag reduction, Vortex generators.**

1. Introduction

When a real liquid flows over a solid or wall, patches of the liquid stick to the boundary, creating a non-slippery condition. Assuming the boundary is at rest or has zero velocity at the boundary, the velocity of fluid patches attached to or veritably near to the boundary will also be zero. The haste of liquid patches also increases as they move down from the boundary. The fluid flyspeck haste varies from zero at the face of the stationary boundary to the free-flowing haste(U) of the fluid in the direction vertical to the boundary. thus, there exists a haste grade(du/dy) due to the variation of the haste of the fluid patches. The change in fluid flyspeck haste from zero at the face of the stationary boundary to the free inflow haste(U) of the fluid occurs in a narrow region near the fixed boundary, and this narrow region of fluid is called the boundary subcaste. The wisdom and proposition that deals with boundary subcaste inflow problems is called boundary subcaste proposition.

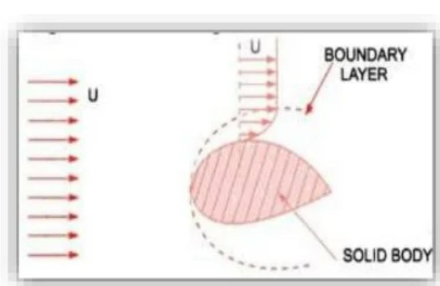

Fig. 1. Boundary layer separation

There are two types of boundary layers, laminar and turbulent. The laminar boundary layer is a very smooth flow, while the turbulent boundary layer contains eddies and 11 vortices. The boundary layer begins with a smoother laminar flow and eventually transitions to a turbulent boundary layer. Flow separation occurs when the boundary layer is forced against an opposing pressure gradient. These increases drag, especially pressure drag, creating pressure differentials across the fuselage as it travels through the air, and this drag reduces the aerodynamic efficiency and performance of the aircraft. 1.2 The present method to delay the boundary separation: The boundary layer is the primary cause of stall deceleration by increasing pressure drag and decreasing the stall angle of an aircraft. Most common methods are used, such as Vortex generators to delay the boundary layer separation.

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Model specification:

Airfoil Selection: MH 60 Airfoil:

Tailless aircraft require careful selection of profiles to improve performance. Although it is possible to use the same airfoils used in airliners and compensate by a combination of wing sweep and twist, there is a performance loss that can be overcome by choosing an airfoil with a near-zero moment coefficient. occurs. For unswept airfoils (slabs), a profile with positive moment coefficients is required to achieve a longitudinally stable model. Such profiles have recurved camber lines. Several backbend profiles were selected and analyzed with XFLR software to select the appropriate profile for the aircraft.

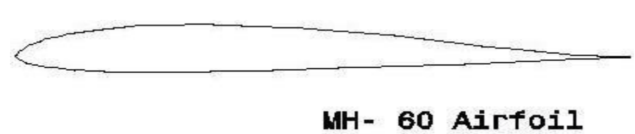

Fig. 2. MH-60 Airfoil

*Corresponding author: rakshit.ae19@bitsathy.ac.in

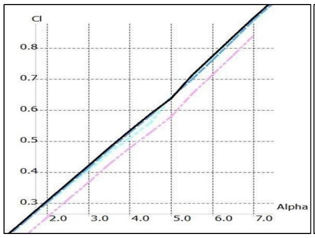

Fig. 3. C_L vs. Alpha

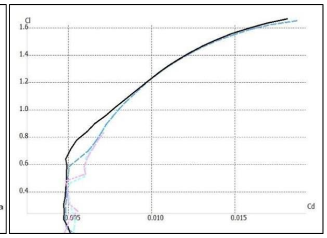

Fig. 4. C_L vs. C_d

We have analysed MH60, MH61, MH45, and MH44 and came to a conclusion to have MH60 represented in the black-coloured line in the figure above for our aircraft. It produces a maximum lift coefficient at a given angle of attack (AOA).

Table 1
Maximum lift coefficient at a given angle of attack

Maximum C_L	Stall angle	$\alpha = 5^{\circ}$	$\alpha = 6.5^{\circ}$
1.15	13˚	0.65	0.8

Aerodynamic analysis:

Finite element analysis (FEA):

Analysis of 2D analysis:

Finite element analysis is a branch of fluid mechanics that uses numerical analysis and data structures to solve problems related to fluid flow. The interaction of liquids and gases with surfaces defined by boundary conditions is resolved in a computer that performs computations. FEA is a technical subject that includes the numerical solution of the governing equations that characterize fluid flow, the Navier-Stokes set of equations, continuity, and additional conservation equations such as energy and species concentrations using computational techniques. FEM is characterized as a connection between pure theory and pure experiment.

MH60 Airfoil: Characteristics:

Thickness: 10.122%

Relatively high maximum coefficient of lift.

Low moment factor of cm c/4=0.0140.

Reynolds's number exceeds 150,000.

At 0 and 5 degrees of angle of attack variation from (NACA)Airfoil tool.

Table 2
Degree, C_L and C_d

Degree	C_l	C_d
0	0.1 - 0.12	0.008 - 0.01
5	0.6 - 0.8	0.01-0.02

Results from FEA

Table 3
At '0' degree Angle of attack and at '5' degree Angle of attack

Solver	Degree	Cl	Cd
kk-omega SST	0	0.13973929	0.017574079
kk-omega SST	5	0.63178408	0.028456887

Meshing (Triangle type- mesh method):

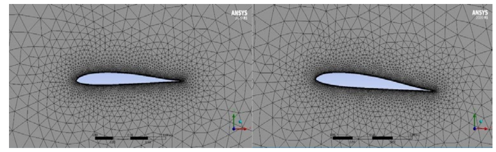

Fig. 5. Meshing

Pressure contour:

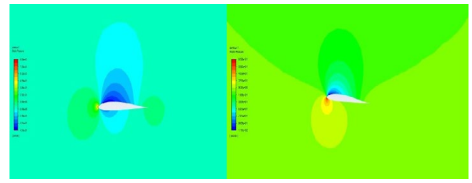

Fig. 6. Pressure contour

Velocity contour:

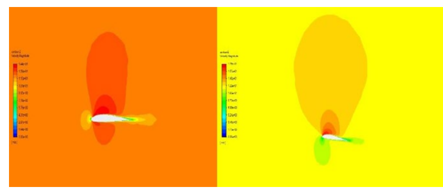

Fig. 7. Velocity contour

Vortex generators:

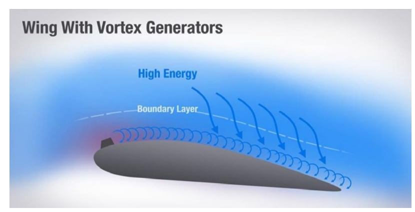

Fig. 8. Wing with vortex generator

The Vortex Generator is an aerodynamic device consisting of small vanes used to create vortices to slow down the boundary layer separation. This created vortex creates a turbulent boundary layer that can stick to the surface of the sphere much longer than the laminar boundary, reducing pressure drag. Mainly used to reduce the stall.

Working:

The Vortex Generator creates tiny wingtip vortices that spiral through the boundary layer and free airflow. These vortices form a boundary layer and upcoming airflow passes through the vortices formed boundary layer which creates an attached flow.

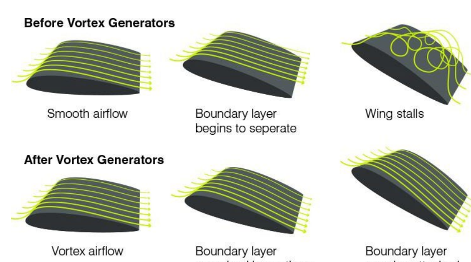

Fig. 9. Working of vortex generator

Types of Vortex Generators

Triangular Vortex:

Table 4
Length and height the of triangular vortex generator

AIRFOIL	MH-60
Length from leading edge	45mm
Length	3mm
Height	2mm

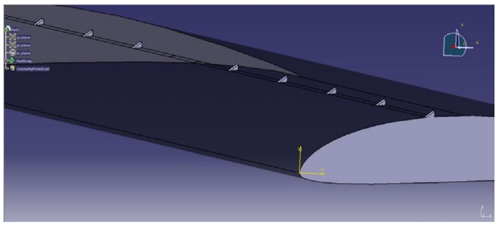

Fig. 10. Design of triangular vortex generator

Rectangular Vortex:

Table 5
Length and height the of rectangular vortex generator

AIRFOIL	MH-60
Length from leading edge	45mm
Length	3mm
Height	2mm

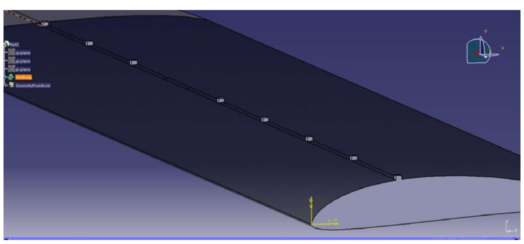

Fig. 11. Design of rectangular vortex generator

Parabolic Vortex:

Table 6
Length and height the of parabolic vortex generator

AIRFOIL	MH-60
Length from leading edge	45mm
Length	3mm
Height	2mm
Radius	3.74mm

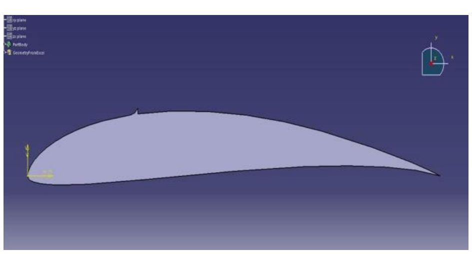

Fig. 12. Design of parabolic vortex generator

Aerodynamic analysis:

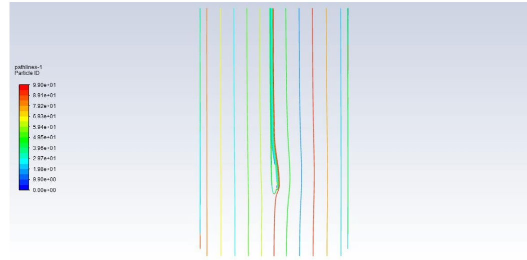

Fig. 13. Results of triangular vortex generators

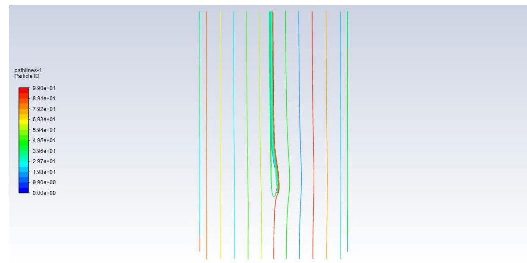

Fig. 14. Results of parabolic vortex generators

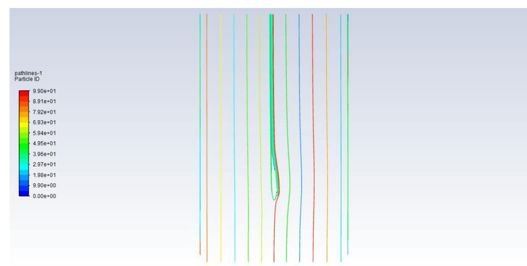

Fig. 15. Results of rectangular vortex generators

Comparison of Vortex Generators:

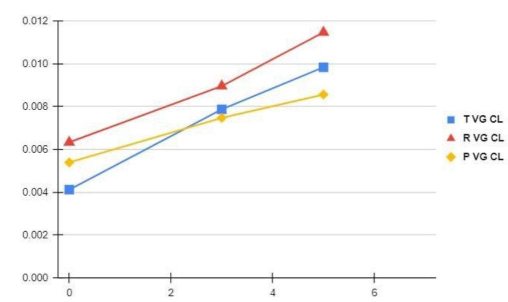

Fig. 16. C_L vs. AOA

By comparing the three-vortex generator such as triangular, rectangular and parabolic vortex generator, we came to a conclusion that the rectangular vortex generator has more co-efficient of lift. Case 1. In rectangular vortex generator at 0 angle of attack the coefficient of lift 0.0063 and at 3 degree the C_L is 0.0089,at 5 degree C_L is 0.0114. Case2 In triangular vortex generator at 0 degree AOA C_L is 0.0041, at 3 degree the C_L is 0.0078, at 5 degree the C_L is 0.00983 case3 in parabolic vortex generator at 0 degree AOA the C_L is 0.0053, at 3degree of AOA the C_L is 0.00747, at 5 degree of AOA the C_L is 00856. By comparing above cases parabolic vortex generator has C_L at 0 degree compared to triangular vortex generator and at 3 degree and 5 degree parabolic vortex generator has lesser value of C_L compared to triangular vortex generator. But the rectangular vortex generator has higher C_L value compared to triangular and parabolic vortex generator as shown in the fig 38, hence rectangular vortex generator has more co-efficient of lift compared to other two vortex generator shapes.

Table 9
Comparison of vortex generators

Triangle VG					
angle of attack	velocity	Cl	Thrust (N)	Cd	Lift(N)
0	12	0.0041191145	0.7989462	0.0090583609	0.36330533
3	12	0.0078726942	3.6352081	0.041215528	0.69437134
5	12	0.0098367417	6.3758612	0.072288677	0.86760056
Rectangular VG					
angle of attack	velocity	Cl	Thrust (N)	Cd	Lift(N)
0	12	0.0063302852	0.79685444	0.0090346318	0.55833107
3	12	0.0089612044	3.6644604	0.041547175	0.79037815
5	12	0.011467025	6.021543	0.068271481	1.0113913
Parabolic VG					
angle of attack	velocity	Cl	Thrust (N)	Cd	Lift(N)
0	12	0.0053919191	0.74189079	0.0084114587	0.47556731
3	12	0.0074738092	3.2888482	0.037288524	0.65919006
5	12	0.0085632736	5.3172812	0.060286634	0.75528073

2. Conclusion

Based on the literature, a wing configuration was chosen as the base case and studied at various angles of attack and constant velocities. There was a different pressure distribution on the wing compared to a simple wing. The drag coefficient of the simple airfoil is lower compared to his other two airfoils. A comparison of three vortex generators showed that the rectangular vortex generator gave better results for fixed-wing UAVs. As shown in the comparison graph above, rectangular vortex generators have a higher lift coefficient compared to other vortex generators

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