FLOW SEPARATION STABILIZATION IN FIXED WING UNMANNED AERIAL VEHICLE MODEL

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Abstract - This paper investigates the use of passive flow control methods for stabilizing flow separation on the wings of a fixed-wing unmanned aerial vehicle(UAV).Flow separation can significantly affect the performance and stability of the aircraft, particularly during low-speed flight and high angle of attack manoeuvres. Our aim of the project is to design a wing with vortex generator on the upper surface of the wing and analyse the results using design software CFD.The proposed approach involves the use of vortex generators and boundary layer fences to manipulate the airflow over the wing surface, enhancing its stability and reducing the likelihood of flow separation. The effects of these flow control devices on the aerodynamic performance are evaluated through a combination of wind tunnel testing and computational fluid dynamics simulations. The results demonstrate that the implementation of vortex generators and boundary layer fences can effectively stabilize flow separation and improve the UAV aerodynamic performance. The use of these passive flow control methods can significantly reduce drag and improve lift, making the aircraft more efficient and manoeuvrable during low-speed flight and high angle of attack manoeuvres. Overall, this provides a valuable insight into the potential benefits of passive flow control methods for UAVs, particularly in applications that require stable and efficient flight performance. with maximum and designed by CATIA V5 and analysed by Ansys.
Keywords: Flow separation, Dimples, Drag reduction and vortex generators.

Introduction

A fixed-wing unmanned aerial vehicle (UAV) may experience flow separation over the wing surface, particularly at higher angles of attack. Flow separation occurs when the airflow over the wing detaches from the surface, leading to reduced lift, increased drag, and decreased maneuverability. Active flow control systems use various actuation methods such as synthetic jets, plasma actuators, and micro-jets to manipulate the airflow over the wing surface and delay or prevent flow separation. However, active flow control systems can be more complex and expensive to implement compared to passive devices like vortex generatorsThis can help to reduce the likelihood of flow separation and improve the aerodynamic performance of the UAV. However, it is important to note that each UAV model may have specific aerodynamic needs, and the most effective technique for flow separation stabilization may vary depending on the design and application of the aircraft.Ultimately, without vortex generators, it may be necessary to use a combination of techniques to achieve optimal flow separation stabilization and aerodynamic performance for a given UAV model.

After the installation of vortex generators in a fixed-wing unmanned aerial vehicle (UAV), the aerodynamic performance of the aircraft can be improved by delaying or preventing flow separation over the wing surface. Vortex generators are small passive devices that are mounted on the surface of the wing in a specific pattern to generate vortices in the boundary layer. These vortices help to energize the airflow over the wing surface, reducing the likelihood of flow separation and improving aerodynamic performance. One of the main benefits of using vortex generators is that they can increase the maximum lift coefficient of the UAV. vortices generated by the vortex generators can help to energize the boundary layer and reduce the size of the wake behind the wing. This can result in reduced drag and increased speed, range, and fuel efficiency. Overall, the use of vortex generators in a fixed-wing UAV can significantly improve the aerodynamic performance, increasing lift, reducing drag, and improving stability and maneuverability in flight.

1.1 BOUNDARY LAYER:

1.1.1Boundary layer theory:

When a real fluid will flow over a solid body or a solid wall, the patches of fluid will cleave to the boundary and there will be condition of no-slip. However, also the haste of fluid patches adheres or veritably near to the boundary will also have zero haste, If we assume that boundary is stationary or haste of boundary is zero. However, the haste of the fluid patches will also be adding, If we move down from the boundary. haste of fluid patches will be changing from zero at the face of stationary boundary to the free sluice haste(U) of the fluid in a direction normal to the boundary.

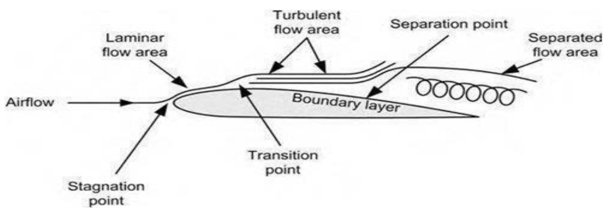

Fig1.1. Boundary layer separation

Thus, there will be presence of haste grade (du/dy) due to variation of haste of fluid patches. The variation in the haste of the fluid patches, from zero at the face of stationary boundary to the free sluice haste(U) of the fluid, will take place in a narrow region in the vicinity of solid boundary and this narrow region of the fluid will be nominated as boundary subcaste. Science and proposition dealing with the problems of boundary subcaste overflows will be nominated as boundary subcaste proposition.

When a solid body is immersed in a flow of fluid, A thin subcaste of fluid called the boundary subcaste is formed conterminous to the solid body. In this thin subcaste, the haste varies from zero to free sluice haste direction normal to free sluice haste, and also the consistence of the boundary subcaste increases along with the length of the object. The fluid subcaste conterminous to the solid face has to do work against face disunion at the expenditure of its kinetic energy and this loss in kinetic energy is recovered from the conterminous from the immediate fluid subcaste in contact with the subcaste conterminous to the solid face through instigation exchange process and at some point, the subcaste may not suitable to attach with the face and this point is called point of separation.

The force substantially depends on density of the fluid because the fluid progresses, the motes at the vicinity of the face gets attached to the face. The patches above the face is embrangle down due to the collisions with the face motes. Hence, they consecutively hinder the fluid inflow on the top. The heavier motes do piecemeal from the face, therefore lower is the collisions that's affected by the object face. Because of this effect the skinny subcaste of fluid is formed at the vicinity of the face. It's zero at the face subcaste and as it moves down it occurs as the free sluice value. Since is occurs on the boundary of the fluid it's nominated as the boundary subcaste. Any inflow in the boundary subcaste will beget the severe problems in aerodynamics which includes nanosecond drag on the object, sect cube, and also the heat transfer which will do in the high- speed flight. Grounded on the Reynolds number the boundary subcaste may be laminar or turbulent.

1.1.2The present method to delay the boundary separation:

The boundary layer is major cause in adding pressure drag and also in dwindling the cube

angle of an aircraft and hence to delay the inflow separation some styles have been espoused similar as whirlpool creator, leading edge bond also detention inflow separation at high angles of attack byre- energizing the boundary subcaste. Out of this system the whirlpool creators are substantially used.

When there's relative stir between the object and the fluid, the fluid at the vicinity of the object gets disturbed and it starts moving around the object. This effect is set up because of the aerodynamic force that's being created between fluid and the object. Magnitude of this force generally depends on numerous factors videlicet speed at which the object is moving, object shape, viscosity of the fluid, density of fluid, its compressibility and so on. In order to model this consequence, one uses the parameters which is the rates of these goods to other relative forces present within the issue. However, also the perspective of the forces is modelled, If any of the two trials generates an original value for the analogous parameters.

1.2VORTEX GENERATORS:

A vortex generator is an aerodynamic device consisting of small vane and they are used to create vortex and which help in delaying the boundary layer separation. This vortex generates create the turbulent boundary layer and the turbulent boundary layer is able to remain attached to the surface of the ball much longer than the laminar boundary and hence reduces the pressure drag. The vortex generator transports energy into the boundary layer from the outer flow, and is used mainly for control of already separated flow rather than for the prevention of separation on wings, diffusers, or bends in channels at subsonic and supersonic speeds.

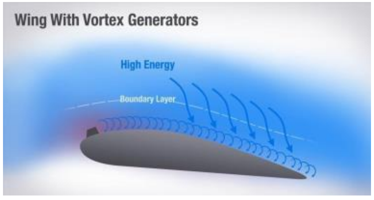

Fig.1.2 Vortex generator

1.2.1 Working principle:

When the air glides over the wing it gets attached to the surface and hence it cases the lift. If the angle incidence of attack is increased then it will cause the wing to stall. The generators generate their own vortices. The swirls of air energizes the surface above the wings surface that is layered with the air, and causes the air to remain attached to the airfoil for the longer duration of time.

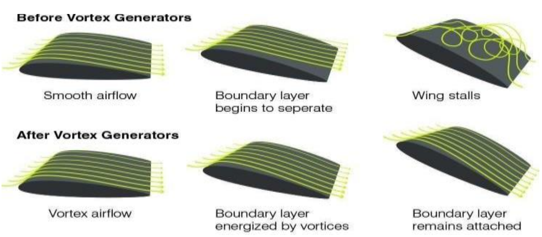

Fig1.3. Before and after vortex generator

1.2.2 Purpose:

The vortex generator transports energy into the boundary subcaste from the external inflow,and is used substantially for control of formerly separated inflow rather than for the forestallment of separation on bodies, diffusers, or bends in channels at subsonic and supersonic pets.

1.2.3 Types of vortex generator:

Vortex generators are of many types that gets its application in aircraft field. There are rectangular, triangular, gothic, ogive and the parabolic vortex generators. Among these, the gothic, rectangular and the triangular vortex generators are most widely used. As the name suggests, these are rectangular in shape and are the most commonly used vortex generators in aircrafts. These produce strong and big vortices with very high vorticity but also produce the highest drag, which gives it a slight disadvantage over the other types. The flow separation occurs in the leading edge of the vortex generator. Triangular Vortex generators are triangular in shape and widely used in aircrafts. At small angles of attack (0-10Â°), these vortex generators give the best drag reduction when compared to rectangular and gothic. The gothic vortex generator takes the shape of an acute arch like that of balance or spear.

These gives drag force ranging between that of rectangular and triangular vortex generators for similar angles of attack. The drag coefficient also lies in between that of Rectangular and triangular for the same range of angle of attack. The advantages of using vortex generators are increase in lift coefficient at high angle of attack, stall speed reduction, increased aileron authority, better aerodynamic behaviour at low speeds, minimum control speed reduction, take off distance reduction, landing distance reduction, steeper climbs and an inexpensive and easy way to improve aircraft performance. The disadvantages include generation of drag, cruise speed reduction, icing and abrupt stall behaviour if used incorrectly.

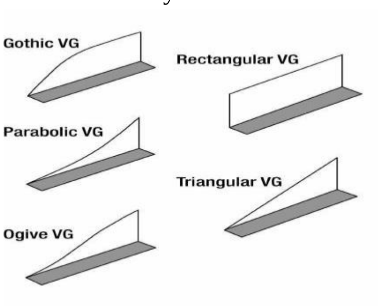

Fig1.4. Types of vortex generator

2. MODEL SPECIFICATIONS:

2.1 AIRFOIL SELECTION: MH 60 AIRFOIL:

In tailless aeroplanes to achieve better performance, the airfoil should be named precisely. It's possible to use the same airfoils used in marketable aircraft compensated by a combination of sect reach and twist but it leads to performance loss which can be overcome by choosing airfoil with moment portions close to zero. In an unswept sect(plank) an airfoil with a positive moment measure is needed to achieve a longitudinal stable model. similar airfoil has a reflexed camber line. We've named a many reflexed airfoils and analyzed them using XFLR software to elect a better airfoil for our aircraft. The MH60 airfoil is a type of airfoil generally used in the design of copter rotor blades. It's known for its excellent performance characteristics, including high lift, low drag, and good cube geste. Then are a many reasons why you might want to use the MH60 airfoil

High lift: The MH60 airfoil is designed to induce high lift at low pets. This allows the rotor to induce the lift demanded to keep the aircraft in the air and maneuverable.

Low drag: The MH60 airfoil has a low drag measure, which means it can maintain lift with lower power than other airfoils. This is important for UAV, which need to conserve energy and power.

Good cube geste: The MH60 airfoil is designed to have good cube geste, which means it's less likely to stall suddenly and lose lift. This is important for copter blades, which need to maintain lift indeed in turbulent air or during unforeseen changes in direction.

Overall, the MH60 airfoil is a popular choice for copter rotor blades because of its excellent performance characteristics. Its high lift, low drag, and good cube geste make it a dependable and effective choice for copter contrivers.

with a strong computer. Software failures or insecurity might affect from it. To achieve a balance between mesh size and calculation time for this work, snare size and length were employed. To make the procedure easier in the future, the rotating boundary, stationary boundary, bay, outlet, and walls are chosen and added to the sphere. Face meshing, body sizing, and affectation sizing were added to the chosen figure to manage mesh refinement.

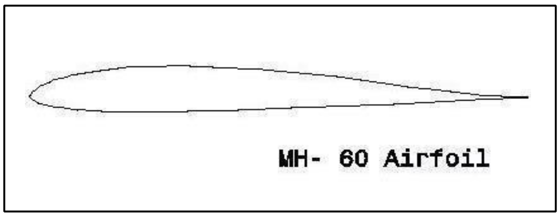

Fig2.1.**MH60** airfoil

2.2 MH60 AIRFOIL: CHARACTERISTICS

Thickness: 10.12%

Comparatively high maximum lift coefficient.

Low moment coefficient of cm c/4 = +0.0140.

Can be used at Reynolds numbers of 150'000 and above.

Has been used successfully in F3B tailless model airplanes.

2.3 DESIGN OF VORTEX GENERATOR:

2.3.1 Wing design:

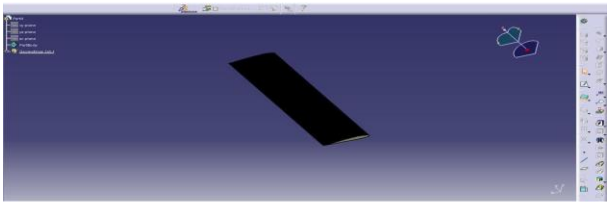

Fig2.2 wing design of normal wing

Table2.1. Wing geometry

WING GEOMETRY	
Wing span	1200 mm
Chord Length	350 mm

2.3.2 Triangular vortex generator:
Triangular vortex generator is placed at 25 percentage from the leading edge and the dimension are shown in fig 2.3

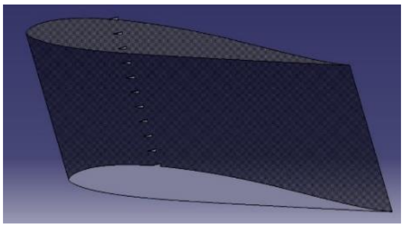

Fig 3.5. Triangular vortex generator

2.3.3 Parabolic vortex generator:
Parabolic vortex generator is placed at 25 percentage from the leading edge and the dimensions are shown in fig 2.4

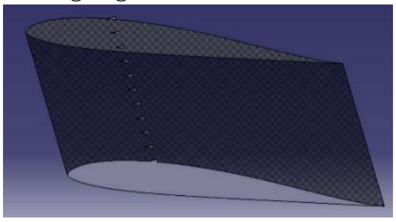

Fig 2.4. Parabolic vortex generator

3.AERODYNAMICAL ANALYSIS:

3.1 3-D ANALYSIS:

All simulations of MH 60 bodies i.e., airfoil bodies are carried out at different angle of attacks for better understanding of inflow. Inlet haste taken to be 12 m/ s. One of the objects of this computational study is also to lower take off distance by adding lift at minimal accessible drag at low haste. This is the reason for opting such a low haste. The study starts with inflow visualization analysis of MH 60 sect section with plain and whirlpool creator face. After chancing transition point on the face, whirlpool creator is placed at 25 of the passion which detainments flow separation in satisfactory manner. For this the models are designed in CATIA V5 and also analyzed in ANSYS. The results of these modified bodies are studied and analyzed independently after which they're compared with reference plain MH 60sect. Analysis is done at degrees of angle of attacks and 15 degrees.

The C_L wind shows effect of angle of attack on Measure of lifts of all configurations. It shows the significant lift enhancement over the different angle of attacks. The loftiest lift measure attainedis1.115 by inward dimple sect configuration at 100 angle of attack. outside dimple sect configuration also follows inward dimple configuration giving alternate loftiest measure of lift1.126 at same angle of attack. Inward dimple showing nonstop improvement in lift right from starting of the wind and has better wind characteristics than the other two vide licet reference and modified outward dimple configuration. The modified whirlpool creator model specifically shows advanced values of C_L for angle of attacks 0,3,6,9,12 and 15 degrees independently compared to the outside dimple configuration and normal plain sect configuration.

3.2MESHING:
Mesh is a conception used to define a flyspeck size dimension that's generally used to estimate the distribution of a grainy substance's patches by size. One of the most pivotal ways in fluid simulation is entrapping since it affects how directly the computer produces results. The mesh size is lower and finer the further exact the affair. still, the too-fine mesh may beget extremely lengthy calculation times, indeed.

3.3 ANALYSIS OF WING:
3.3.1 VELOCITY CONTOUR OF NORMAL WING:

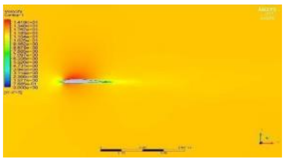

Fig3.1.0degree(AOA)

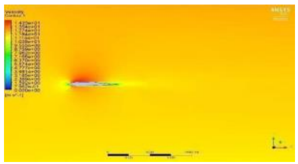

Fig3.2.3degree(AOA)

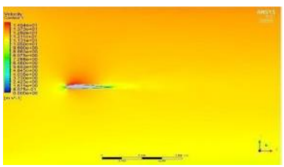

Fig3.3.6degree(AOA)

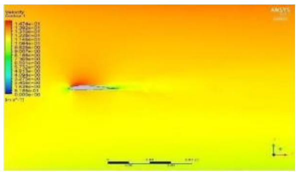

Fig3.4.9degree(AOA)

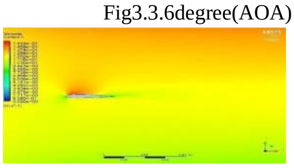

Fig3.5.12degree(AOA)

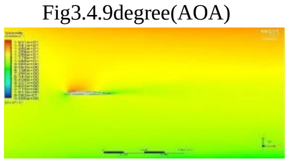

Fig3.6.15degree(AOA)

From the above figure we come to know that the velocity gradually increasing at higher angle of attack (AOA), because the kinetic energy is exhausted and the air come to a rest relative to the wing. This results in upstream flow with increasing angle of attack (AOA).

3.3.2COEFFICIENT PRESSURE OF NORMAL WING:

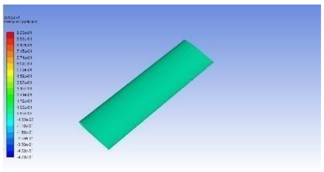

Fig3.7 .0degree(AOA)

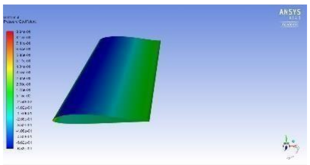

Fig3.8.3degree(AOA)

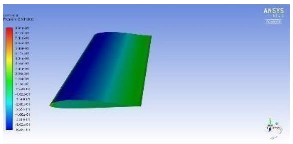

Fig3.9.6degree(AOA)

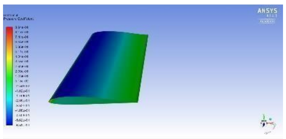

Fig3.10.9degree(AOA)

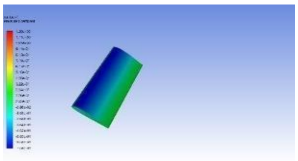

Fig3.11.12degree(AOA)

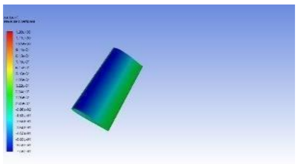

Fig3.12 .15degree(AOA)

Table 3.1. Normal wing of C_L, C_D and C_P

Degrees	Without vortex generator		
	C_L	C_D	C_P
0 degrees	0.0380	0.0063	-0.130
3 degrees	0.0549	0.0058	-0.1305
6 degrees	0.0734	0.0049	-0.130
9 degrees	0.0938	0.0036	-0.1288
12 degrees	0.1419	-0.0012	-0.1254
15 degrees	0.1158	0.0016	-0.1276

From table 3.1 we have calculated the Coefficient of lift (C_L), coefficient of drag (C_D), coefficient of pressure (C_P) for the wing without vortex generator from this table we have come to know that at 12degree AOA we got higher C_L and lesser C_D value where we have already mentioned in table 1that for mh-60 airfoil stall angle is 13degree.

3.4 ANALYSIS OF TRIANGULAR VORTEX GENERATOR:

Table 3.2: Inflation boundary of triangular vortex generator

Inflation boundary	Wing
Inflation option	First layer thickness
First layer height	2.0192e-005 m
Maximum layers	20
Growth rate	1.2

Table 3.3: Triangular meshing of triangular vortex generator

Mesh method	Triangular meshing
Domain element size	0.01 m
Nodes	557534
Element	1075893

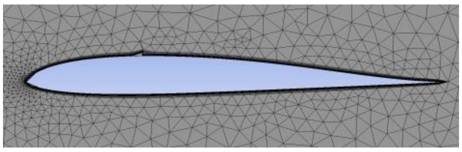

Fig3.13. Triangular meshing of triangular vortex generator

3.4.1 VELOCITY CONTOUR OF TRIANGULAR VORTEX GENERATOR:

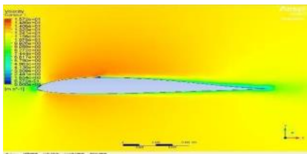

Fig3.14 .0degree(AOA)

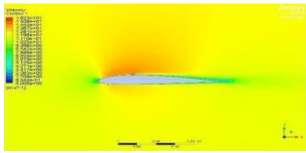

Fig3.15.3degree(AOA)

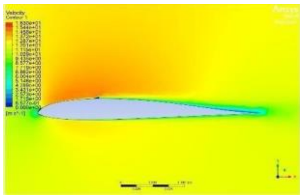

Fig3.16.6degree(AOA)

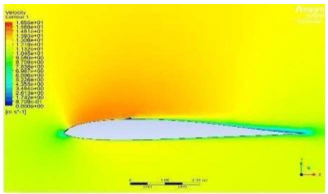

Fig3.17.9degree(AOA)

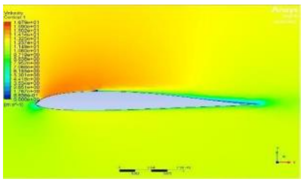

Fig3.18.12degree(AOA)

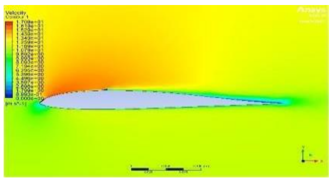

Fig3.19.15degree(AOA)

From the above figure we come to know that the velocity gradually increasing at higher angle of attack (AOA), because the kinetic energy is exhausted and the air come to a rest relative to the wing. This results in upstream flow with increasing angle of attack (AOA).

3.4.2 COEFFICENT PRESSURE OF TRIANGULAR VORTEX GENERATOR:

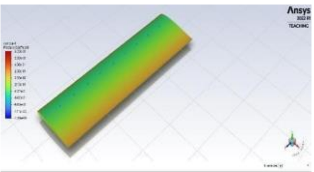

Fig3.20 .0degree(AOA)

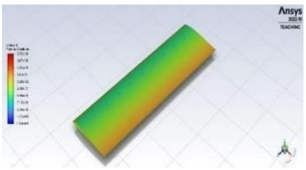

Fig3.21.3degree(AOA)

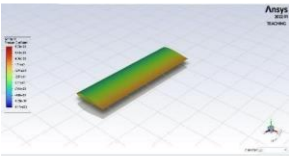

Fig3.22.6degree(AOA)

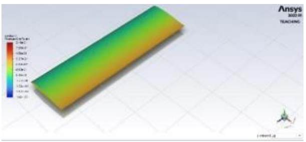

Fig3.23.9degree(AOA)

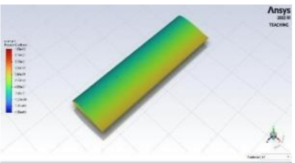

Fig3.25.12degree(AOA)

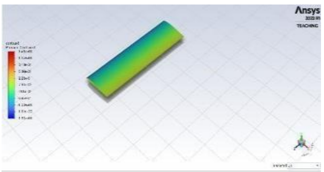

Fig3.26.15degree(AOA)

3.4 triangular vortex generator C_L, C_D and C_P

Degrees	Triangular vortex generator		
	C_L	C_D	C_P
0 degrees	0.0410	0.0064	-0.1280
3 degrees	0.0660	0.0057	-0.1294
6 degrees	0.0914	0.0046	-0.1307
9 degrees	0.1175	0.0028	-0.1318
12 degrees	0.1456	0.0001	-0.1335
15 degrees	0.0914	0.0046	-0.1307

From table 3.4 we have calculated the Coefficient of lift(CL), coefficient of drag (CD), coefficient of pressure (CP) for the wing with triangular vortex generator from this table we have come to know that the values of coefficient of lift (CL) is improved compare to normal wing without vortex generator and coefficient of drag (CD) grade duly decreeing with different angle of attack (AOA) and also coefficient CD values lesser than normal wing.

3.5ANALYSIS OF PARABOLIC VORTEX GENERATOR:

Table 3.4: Inflation boundary of triangular vortex generator

Inflation boundary	Wing
Inflation option	First layer thickness
First layer height	2.0192e-005 m
Maximum layers	20
Growth rate	1.2

Table 3.5: Triangular meshing of triangular vortex generator

Mesh method	Triangular meshing
Domain element size	0.01 m
Nodes	557534
Element	1075893

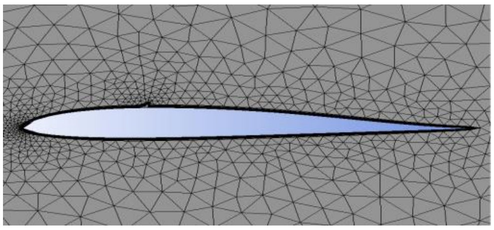

Fig3.27Triangular meshing of parabolic vortex generator

3.5.1VELOCITY CONTOUR OF PARABOLIC VORTEX GENERATOR :

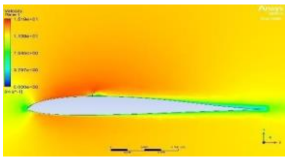

Fig3.28 .0degree(AOA)

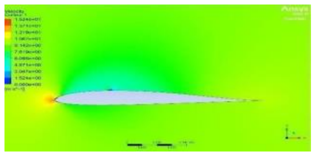

Fig3.29.3degree(AOA)

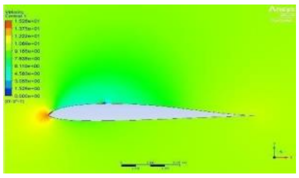

Fig3.30.6degree(AOA)

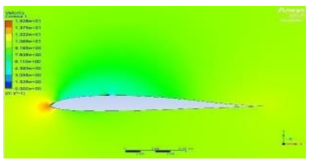

Fig3.31.9degree(AOA)

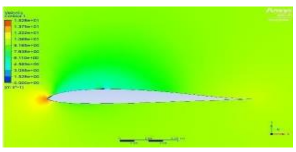

Fig3.32.12degree(AOA)

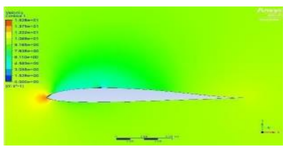

Fig3.33.15degree(AOA)

From the above figure we come to know that the velocity gradually increasing at higher angle of attack(AOA), because the kinetic energy is exhausted and the air come to a rest relative to the wing. This results in upstream flow with increasing angle of attack(AOA).

3.5.2COEFFICENT PRESSURE OF PARABOLIC VORTEX GENERATOR:

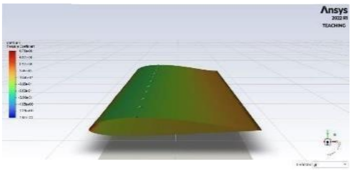

Fig3.34.0degree(AOA)

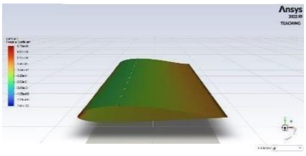

Fig3.35.3degree(AOA)

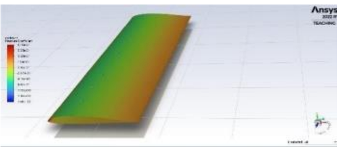

Fig3.36.6degree(AOA)

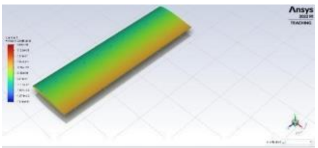

Fig3.37.9degree(AOA)

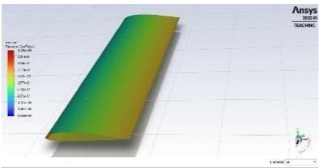

Fig3.38 .12degree(AOA)

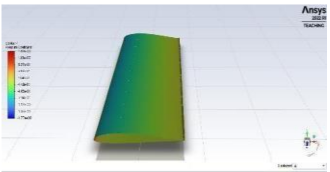

Fig3.39.12degree(AOA)

3.5 Parabolic vortex generator of C_L, C_D and C_P

Degrees	Parabolic vortex generator		
	C_L	C_D	C_P
0 degrees	0.0403	0.0065	-0.1278
3 degrees	0.0653	0.0058	-0.1292
6 degrees	0.0905	0.0046	-0.1304
9 degrees	0.1165	0.0029	-0.1314
12 degrees	0.1783	0.0026	-0.1330
15 degrees	0.1444	-0.0036	-0.1359

From table 3.5 we have calculated the Coefficient of lift (C_L), coefficient of drag (C_D), coefficient of pressure (C_P) for the wing with parabolic vortex generator from this table we have come to know the values of coefficient of lift (C_L) is comparatively higher than the triangular vortex generator wing and the normal wing. By comparing the coefficient of drag is lesser than the triangular vortex generator wing and the normal wing.

4.CONCLUSION:

The golf ball theory is studied to understand the effects of dimples on its surface. Based on the literature, a wing configuration was chosen as a baseline case and studied at different angle of attacks and at constant velocity. The pressure distribution was seen to be changed on the wing as compared to the simple air foil. As compared to normal wing, vortex generator wing has more coefficient of lift and lesser coefficient of drag values. We also notice that the parabolic vortex generator is more efficient than triangular vortex generator wing and the normal wing. This leads to the delay flow separation and increasing the aerodynamic efficiency.If you have a Table, simply paste it in the box provided below and adjust the table or the box. If you adjust the box, you can keep the table in single column, if you have long table.

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