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ANALYSING THE DRAG OF VARIOUS VORTEX GENERATORS BY USING CFX

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Abstract-Design and analysis of vortex generator by using Computational Fluid Dynamic (CFX) on Four wheeler vehicle (FWV) model will be carried out on this project. One of the main causes of aerodynamic drag for vehicle is the separation of flow near the vehicle‟s rear end. To control the flow separation, Different shapes of vortex generator are tested for application to the roof end of vehicle. A vortex generator (VG) is an aerodynamic surface, consisting of a small vane that creates a vortex. The objective of the project is to determine the drag reduction by using different VGs.The VG‟s are designed by Computational Aided Design (CAD) in CATIA V5. Vortex generator themselves create drag, but they also reduce drag by preventing flow separation at downstream. The overall effect of vortex generators can be calculated by totaling the positive and negative effects. Drag force value can be obtained by using CFD. Besides that, CFD simulation results such as contour plot also used to analyze the characteristic of streamline flow at the rear end of FWV model. Comparison of drag force values with various vortex generators must be done to achieve the project objectives.

Index terms - Vortex generators, Aerodynamics, Drag, Lift, Flow separation, Sedan, Computational fluid dynamics (CFD)

I. INTRODUCTION

With increasing oil price and concern for global environment in the recent years the primary concern of the automotive development is the reduction in fuel consumption. One obvious way of improving the fuel economy is to reduce the aerodynamic drag by optimizing the body shape. Also, with the improvement of current road conditions, the vehicles are being driven at a speed higher than ever before. This calls for a need to improve the vehicle‟s driving stability and increase the traction at high speeds. This can be achieved by reducing aerodynamic lift on a vehicle.[1]

This is where Vortex Generators (VGs) come in. A vortex generator (VG) is an aerodynamic device, consisting of a small vane usually attached to a lifting surface (or airfoil, such as an aircraft wing or a rotor blade of a wind turbine. VGs may also be attached to some part of an aerodynamic vehicle such as an aircraft fuselage or a car.

As experimental studies have shown that 40% of the drag generated is concentrated at the rear geometry, the vortex generators are tested only at the rear end (roof of the rear windshield). When a golf ball, an airplane, or any solid object moves through the air, a small layer of air called a boundary layer surrounds the object. Since the boundary layer is somewhat viscous, or sticky, and slow-moving compared to the moving golf ball or flying plane, it falls behind and separates from the object, creating a wake.

This wake creates drag on the object and slows it down, resulting in shorter drives for golfers and higher energy requirements, as well as the potential for loss of lift,

To combat this problem, the dimples on the golf ball and the vortex generators on an airplane's wings can delay the separation of the boundary layer by creating minor turbulence, which gives the boundary layer more energy and enables it to move a little faster to keep up with the object. Similar effect is expected when vortex generators are fitted onto a car.

II. AERODYNAMICS OF A CAR

It is extremely difficult to determine an aerodynamically ideal body shape for a car. Due to various stylistic constraints, a car cannot have a streamline shape but must have an aerodynamically bluff shape. However, the sedan car used for analysis is among the less bluffed passenger cars. For such an aerodynamically bluff car the flow region which greatly contributes to the car‟s drag is the wake flow behind the car. The coefficient of drag (CD), for a aerodynamically bluff passenger car is generally between 0.25 and 0.45 [2, 3]. A body can have any value of CD depending on its bluffness, varying from a CD greater than 1 for a cubic object and \0.1 for less bluff bullets. Degree of taper at the rear end of a car has a major influence on the drag coefficient [2]. This can be easily construed from Fig.

1. It schematically shows the flow around a sedan. Due to the taper at the rear the flow separation occurs in more downstream and for this reason, a sedan have a

smaller drag coefficient value than wagon type car. In other words, the taper at the rear plays a vital role of delaying flow separation. Pressure drag is the major source of drag on aerodynamically bluff bodies.

Pressure drag is created when the shape of the surface changes abruptly, as at the point where the roof of an automobile ends. Because of the streamline curvature of the front top portion of a car, the flow rounds this area resulting into decrease in pressure. The pressure reaches a maximum at the base of the windshield, again as a result of the streamline curvature. Low-pressure regions also occur at the windshield head and over the top of an automobile again due to the same reason. The air speed across the top reaches up to 30 % higher than free-stream air speed [4]. Additional objects like antenna can further increase the drag. The drop from the roof increases the space through which air stream flows. This slows down the flow and, by Bernoulli‟s principle, increases the static pressure. The air stream is unable to flow against this sudden increase in pressure and the boundary layer gets detached from the surface creating an area of low-pressure turbulent wake or flow. Since the pressure in the wake is much lower than the pressure in front of the car, a net backward drag or force is exerted on the car. Also, since there is a low pressure region at the top of the car, an upward lift is exerted on the car. Fig. 2 shows a schematic of pressure profile on the vehicle‟s centerline plane. The pressure at the front of the vehicle is higher than that at its rear, thus resulting in pressure drag.

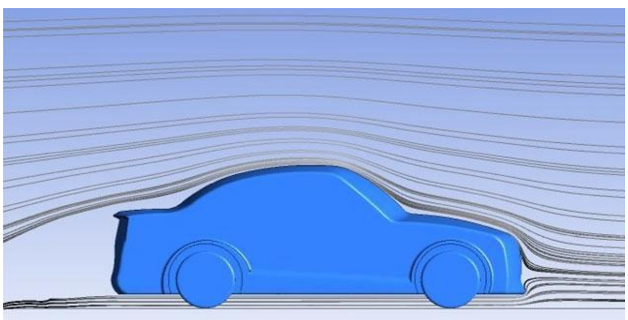

Figure 1: Flow around a Sedan

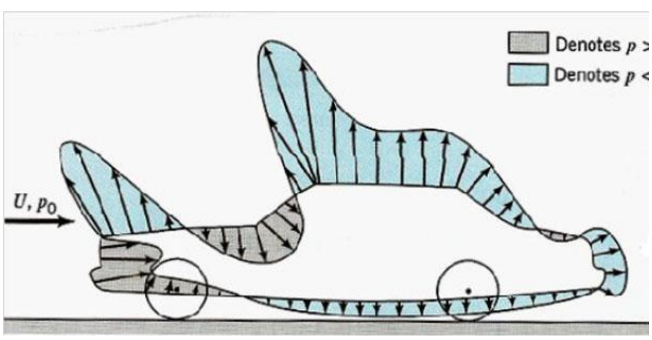

Figure 2 : Pressure distributions on the surface of an Automobile

III. FLOW SEPERATION MECHANISM OF VORTEX GENERATORS

The Air Flow velocity over the car centre line plane near the roof end is shown in Figure 3. As the height of the car at rear end reduces the flow area increases, due to which the air expands and thus its velocity drops and pressure increases. This increased downstream pressure creates the force in opposite direction generating the reverse flow at point „C‟, acting against the air movement. There is no reversal of air flow at point „A‟ which is upstream of point „C‟ since momentum of the boundary layer is prevailing over the pressure gradient (dp/dx) [5]. At point „B‟ the momentum of the boundary layer and pressure gradient balance each other. The airflow near the lower end and close to the vehicle surface, within boundary layer losses its momentum due to the viscosity.

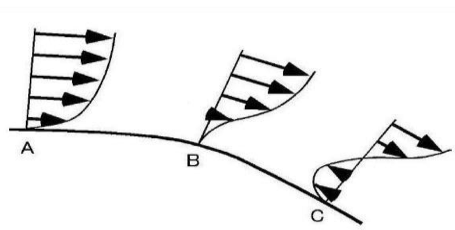

Figure 3: Schematic of velocity profile around rear end

The Vortex Generators placed just before the separation points, supply the loss in momentum by generating stream wise vortices. Thus separation point will be shifted further into the downstream and allows the expanded airflow to persist proportionally longer and hence the velocity of flow at the separation point reduces with an increase in static pressure. This static pressure reduces the control of overall pressure in the entire flow separation region. As a result of increased back pressure, the drag force is reduced. Thus shifting the separation points provides advantage in drag reduction first is to narrow the separation region in which low pressure constitutes the cause of drag; another is to raise the pressure of the flow separation region. A combination of these two effects reduces the drag acting on the vehicle. But the Vortex Generators itself produces the drag. So the total effect is calculated by subtracting the drag produced by itself from the reduction in drag caused by shifting of the separation point downstream. Larger the size of Vortex Generators larger is the effect. But the effect will be optimized for a certain size of the Vortex Generator.

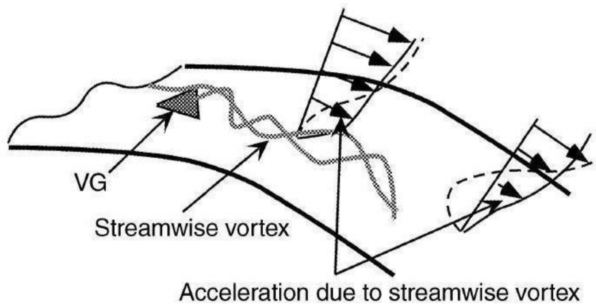

Figure 4: Schematic of flow around vortex generator

IV. THE RELATIONSHIP BETWEEN DRAG AND FUEL ECONOMY

In order to decrease the aerodynamic drag on a vehicle, the sources of drag must be analyzed. As mentioned previously, aerodynamic drag is the force that opposes the direction of thrust of a car and is not a desirable force. Given a set of vehicle conditions, the drag force can be calculated. Drag is a function of the frontal area of the vehicle, the density of the air, the coefficient of drag of the vehicle, and the vehicle speed squared . The effects of drag on a vehicle become even more prominent, however, when the engine power needed to overcome drag forces is realized. The engine power needed as a function of drag depends on the frontal area of the car, the density of the air, the coefficient of drag of the vehicle, and the vehicle speed cubed . The fact that the vehicle speed has a cubic relation to the force of drag reveals that a small change in the speed of the car can require an enormous amount of engine power to overcome the forces of drag. In addition, the relation between drag and speed shows that aerodynamics of vehicles do not matter so much at lower speeds; they have a much more profound effect at highway speeds .

While the density of air and the vehicle speed cannot be altered by the design of the vehicle, the frontal area and coefficient of drag can. Reducing the height and width of the car can reduce the frontal area, but there is a limit to how small this area can be since people must be able to sit comfortably inside the vehicle. Therefore, the easiest method of decreasing drag is to lower the coefficient of drag of the car. The coefficient of drag of a vehicle depends predominantly on the shape . Therefore, vehicle designers change specific aspects of the shape of the body of the vehicle in order to reduce the total aerodynamic drag and thus increase fuel economy.

V. TYPES OF VORTEX GENERATORS

The various model of vortex generators are analysed and few types are considered for this project. In this project we using different shapes of Vortex generator, and minimizing flow separation and also drag force values for all shapes and also find out pressure gradient and make compare with all shapes values and tell result about which shapes will give minimum drag force values.

Vortex Generator Shapes used

- Triangular
- Parabolic shapes
- Stepped Triangular
- Delta Wing Shapes

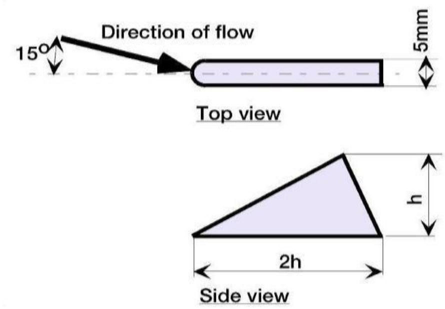

Figure 5: Basic dimension of a vortex generator

VI. DESIGNING IN CATIA

Here we have chosen Honda city as our base reference. Here we have designed a 3d model using Catia V5 using the following dimensions as in Figure 6-9. These dimensions are reduced into a lower scale of 1:3.

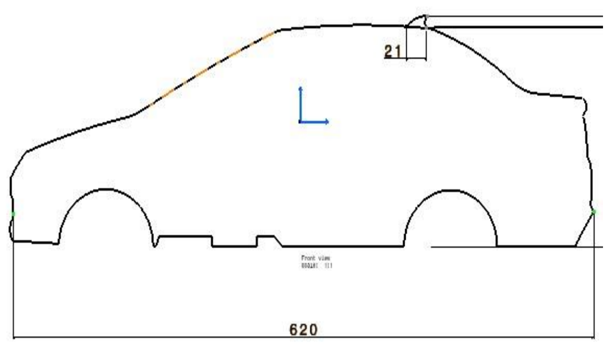

Figure 6: Dimensions of Delta wing structure.

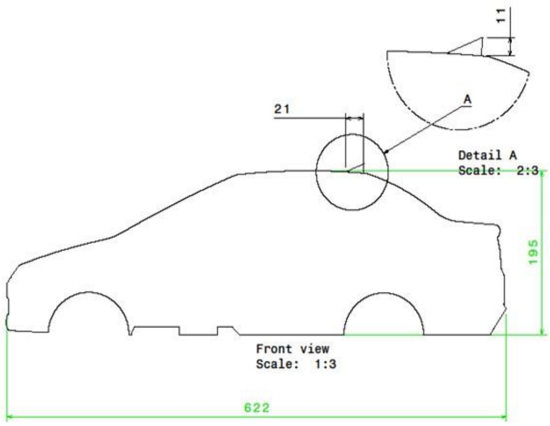

Figure 7: Dimensions of Triangle structure.

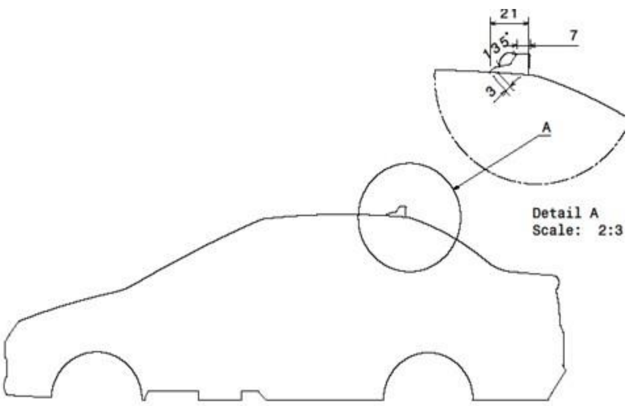

Figure 8: Dimensions of Stepped triangle structure.

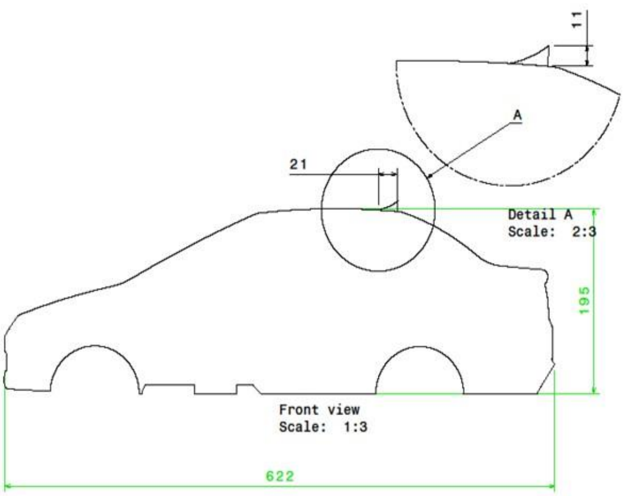

Figure 9: Dimensions of Parabolic Structure.

These are the dimensions of the vehicle with vortex generator that we use to design in catia v5. Where Honda city uses delta wing structure in their vehicle, here we will be analyzing the delta wing structure and calculate the drag values and also we will be analyzing all those other three structures and comparing them, the main objective is to compare those values and suggest a better and efficient structure that eliminates more drag and make the vehicle more aerodynamically efficient.

Figure 10 : Delta wing structure designed in Catia V5.

i. The analysis includes process of five steps such as

Geometry

Mesh

Setup

Solution

Results.

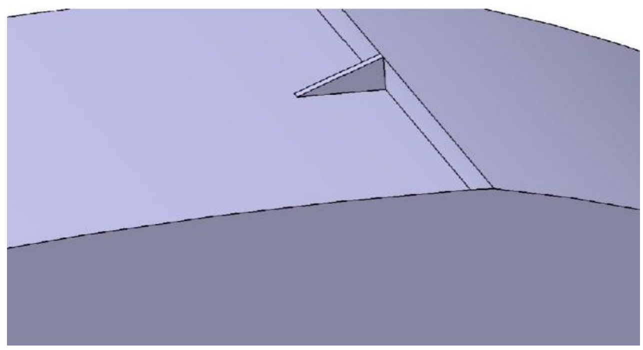

Figure 11 : Triangle structure designed in Catia V5.

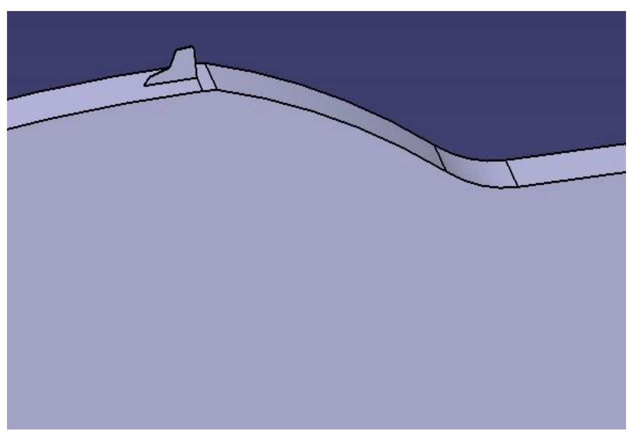

Figure 12 : Stepped triangle structure designed in Catia V5.

VIII. GEOMETRY

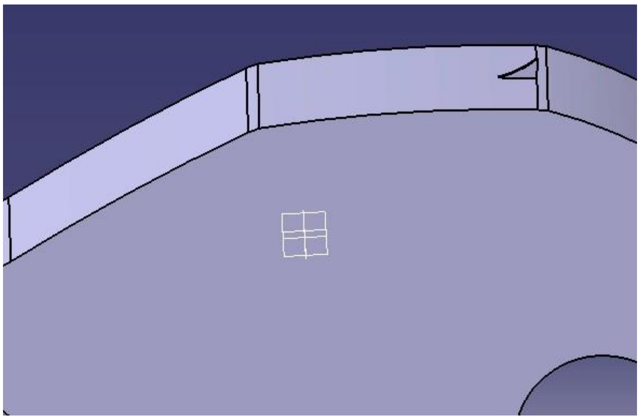

Figure 13 : Parabolic structure designed in Catia V5.

The modelling of the car was completed in Catia V5 and the .stp file format was then imported to Design Modeller in ANSYS.

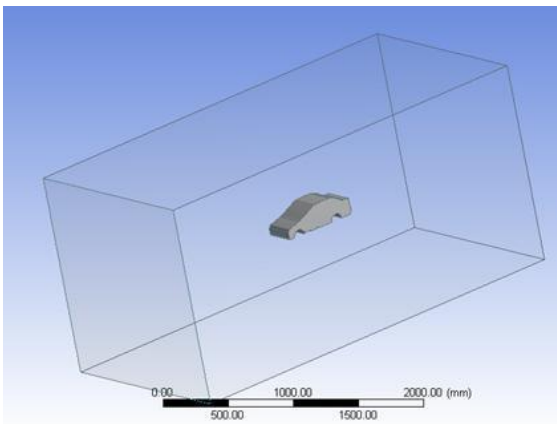

Figure 14 : 3D model imported into Domain

IX. MESH

The imported file geometry is imported into the Meshing module of Ansys. Here, the default mesh given by Ansys is modified such that the Orthogonal quality of the modified mesh is closer to unity. Ansys Meshing allows the user to control every element of the mesh, but it also has a predetermined settings template for ready-to-use purposes. The following image will you give you an idea of the settings we used for meshing our specimen car.

These are the 3D Designs of various vortex generators performed in Catia v5. These are converted in .stp files and imported to CFX.

VII. ANALYSIS USING CFX SOFTWARE

The Analysis is carried out at various speeds such as 20m/s, 30m/s, 40m/s and 60m/s in ANSYS-CFX and the results such as contours, vector plots, and turbulent kinetic energy and streamlines plots are plotted. The surface pressure contour is also observed in the analysis.

Figure 15 : Meshing of our model

X. SETUP

After the meshing, the CFX module is used to set the testing environment parameters such as Boundary conditions, Solution Methods, Solution initialization, Monitors, Calculation activities, etc..

XI. RESULTS

A. Drag Values for Delta Wing Vortex Generator

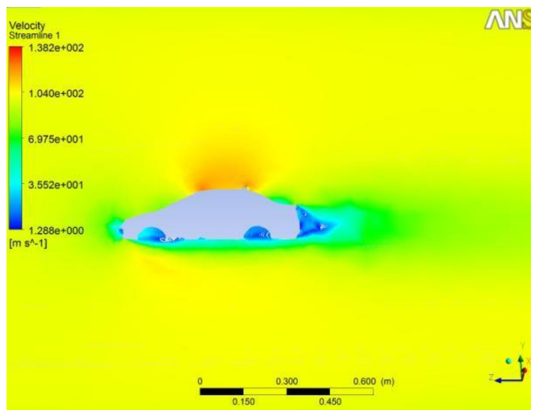

Figure 16 : velocity Distribution for Delta wing

Drag Force for Delta Wing Shapes Vortex generator is**541.504 N.** This force values had taken from numerical analysis

B. Drag Values for Stepped Triangular Vortex Generator

Drag Force value of Delta wing Shapes Vortex Generator is **549.77 N.** This value could taken from calculation section under force parameter, which is measured from normal Fluid values

D. Drag Values for Triangular Shape Vortex Generator

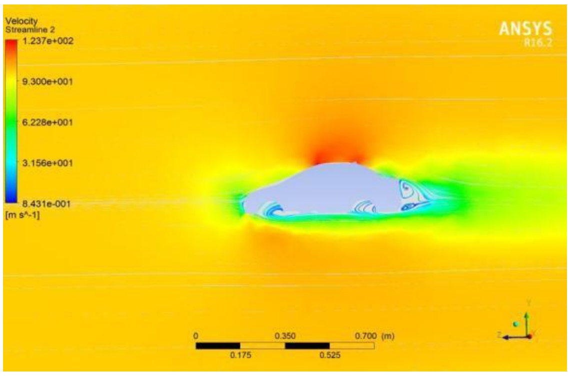

Figure 19 : velocity Distribution for Triangle

Drag Force value of Delta wing Shapes Vortex Generator is

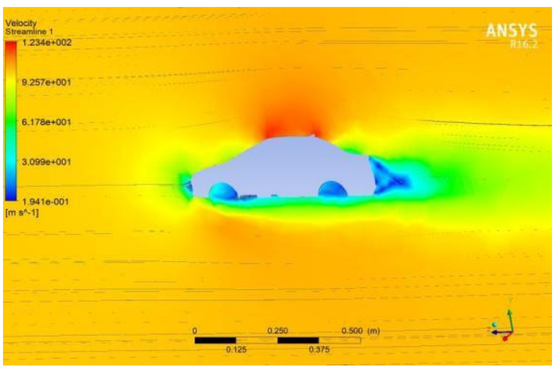

Figure 18 : velocity Distribution for Parabolic shape

A vortex generator (VG) consisting of a small vane usually attached to a lifting When the airfoil or the body is in motion relative to the air, the VG creates a vortex, which, by removing some part of the slow-moving boundary layer in contact with the airfoil surface, delays local flow separation and aerodynamic stalling, thereby improving the effectiveness of wings and control surfaces, such as flaps, elevators, ailerons, and rudders

In this project we using different shapes of Vortex generator, and minimizing flow separation and also drag force values for all shapes and also find out pressure gradient and make compare with all shapes values and tell result about which shapes will give minimum drag force values

552.225N. This value could taken from calculation section under force parameter, which is measured from normal Fluid values

XII. CONCLUSION

In aerodynamics, flow separation can often result in increased drag, particularly pressure drag which is caused by the pressure differential between the front and rear surfaces of the object as it travels through the fluid. For this reason much effort and research has gone into the design of aerodynamic and hydrodynamic surfaces which delay flow separation and keep the local flow attached for as long as possible Drag Force value of stepped triangle Vortex Generator is **462.411 N.** This value could taken from calculation section under force parameter, which is measured from normal Fluid values.

C. Drag Values For Parabolic Shape Vortex Generator

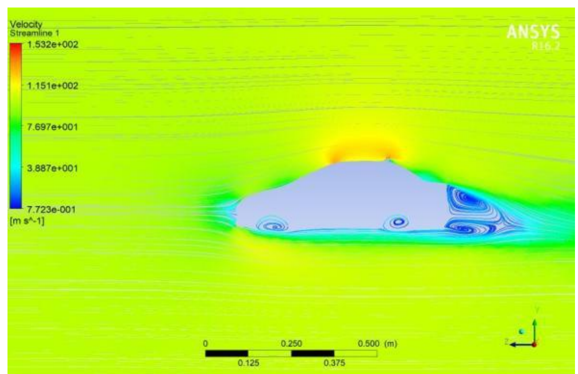

Figure 17 : velocity Distribution for Stepped triangle

S.NO	Vortex Generator Shapes	Drag Force
1	Triangular	552.225
2	Parabolic shapes	549.77
3	Stepped Triangular	**462.411**
4	Delta Wing Shapes	541.504

Table 1: Drag Force comparison

From the table above, stepped triangle is more efficient than other types and is efficient than delta wing structure which is currently used in Honda city car so, we suggest stepped triangle as a better option for choosing Vortex generator.

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