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# EXPERIMENTAL AND CFD ANALYSIS ON CAR WITH SEVERAL TYPES OF VORTEX GENERATORS

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***Abstract-*** *An experimental investigation was carried out to reduce the drag and lift force of the vehicles. Providing with an obstacle on flow separation at the rear end by using different shaped vortex generators at the roof end of a car was tested in this paper for simple type of car. A detailed comparison between different types of Vortex-Generators was presented in this project. The paper gives the valuable information on the drag and lift forces. It was reported here by the means of CFD analysis of a simple SolidWorks car model and this work was fabricated in the wind tunnel. The CFD code used Reynold-Average Navier-Stokes methods. The main goals of this project are to reduce the drag force which was associated with cost of fuel as well as reduce lift force associated with the grip of the vehicle with the ground by an add-on device which is "vortex generator".*

**Keywords:** Drag force, Lift force, Vortex generators, CFD analysis.

## 1. INTRODUCTION

In the modern age the main concern of the human being is time as well as money. In the case of vehicle, if we can reduce the drag force, we can be benefited in the both cases. Minimizing fuel consumption in an automotive development is the primary concern for the conservation of energy resources and the protection of the global atmosphere. Drag coefficient reduction is an essential process in vehicle aerodynamics to improve fuel consumption as well as the performance of vehicle driving. By using vortex generators, we can reduce the drag force. A passenger car has a more aerodynamically bluffed body shape for which flow separation occurs at the rear end of the car. When expressed by the drag coefficient, $C_D$ is generally between 0.2 and 0.5, the aerodynamic bluff of a passenger car body is greater than 1.0 for heavy bluff cubic objects and less than 0.1 for the least bluff bullets. By using the device vortex generators, we can reduce the drag force significantly [1].

The force which act in the direction of flow or the opposite direction of vehicle is called drag force.

$F_D = ½ C_D \rho A V^2$

The force which act in the perpendicular to the flow to the vehicle is called lift force.

$F_L = ½ C_L \rho A V^2$

Vortex generator is a device which actually delay the separation of streamline through the car and make the vortices at the rear end of the car. For this reason, the area of wake region has reduced.

From the 19th century there were many projects had done about the vortex generator. Some studies are going to be mentioned here:

Review of low-profile vortex generators study to regulate separation of boundary layers in July 2002. A thorough analysis of the boundary layer flow separation control is provided using a passive technique using low profile vortex generators. The turbines were described as those with a height of machine between 10% and 50% of the thickness of the boundary layer. Key findings have been provided in this article for several study initiatives, all of which have been carried out over the previous century and a half, where most of these works emphasize experimentation with some latest numerical simulation attempts. Discussion topics consisted of both fundamental fluid dynamics and applied studies on aerodynamics.

The study on fluid dynamics involves comparative st udies on the efficacy of separation control as well as cha racterization and correlation of the vortex induced by de vices. The comparatie studies the control of separate lo wspeed flows in the gradient of negative stress and the s eparation induced by supersonic shock [2].

Research on the decrease of aerodynamic drag by vortex generator had been performed in 2004. They discovered that a division of flow close the back end of the vehicle is one of the primary causes of aerodynamic drag for sedan cars [3]. Bump-shaped vortex generators are screened for implementation on a sedans roof end to delay flow separation. Commonly used on aircraft to prevent flow separation, vortex generators themselves create drag, but they also reduce drag by preventing flow separation at downstream [4]. They found the overall effect of vortex generators can be calculated by totaling the positive and negative effects. Since this effect depends on the shape and size of vortex generators, those

on the vehicle roof are optimized. This paper presents the optimization result, the effect of vortex generators in the flow field and the mechanism by which these effects take place installed at the immediate of the rare axel for separating the airflow. This paper is very much valuable for the other researches [5].

We all know by using the vortex generator we can reduce the drag force. In this study we have discovered the best type of vortex generator. We have done our experiment in basically two steps. At first, we assume some types of vortex generators by doing the simulation through ANSYS Fluent. Then among the several vortex generators we have chosen four types of it. After then we did the experiment in the AF-100 subsonic wind tunnel. Then we took our decision.

## 2. METHODOLOGY

To do the experiment first of all the car of wooden model has been made in SolidWorks 2017. Then the vortex generators were also made. The materials of vortex generators are PVC or low gloss plastic. Then all the models were simulated in the ANSYS 2019 student version. Then the whole procedure was done in the wind tunnel AF-100 subsonic wind tunnel. The all procedures have taken place in a manner of numerical and experimental analysis.

### 2.1 SolidWorks Models

We have made four types of model to experiment. The four types are: Parabolic type, Gothic type, Triangular type and Rectangular type. The all types are shown in Figure 1 to Figure 4

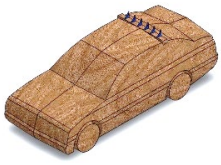

Fig.1: Parabolic Type

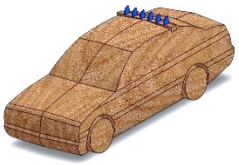

Fig.2: Gothic Type

Fig.3: Triangular Type

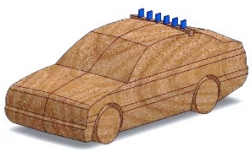

Fig.4: Rectangular Type

### 2.2 Simulation Process

The flow chart of whole simulation process is given here:

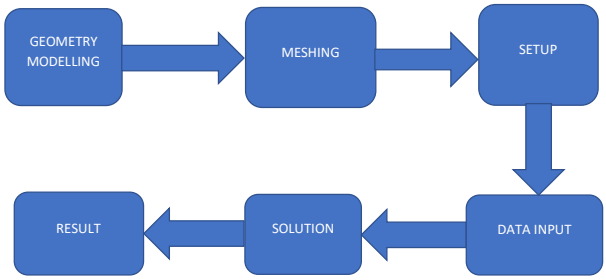


Fig.5: Flow-Chart of Simulation

In the geometry modelling we did import the SolidWorks model in the IGS format. Then I did the mesh with relevance +56, which was the best for this model. Here is the figure of meshing:

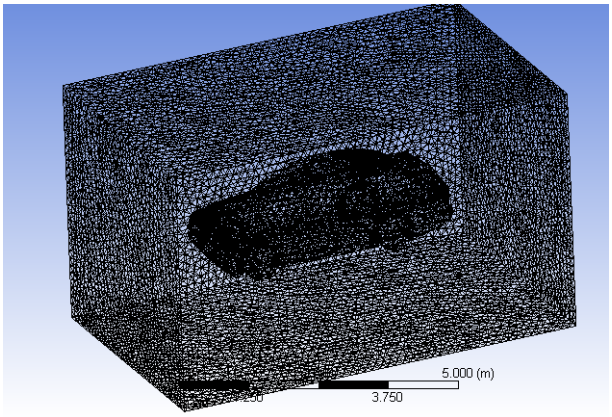


Fig.6: Meshing

### 2.3 Simulated Results

In the simulation we got the value of all forces. The simulation was done by following parameters:

- The fluid will be assumed as incompressible.
- Fluid type: Air.
- Test object Material: wood
- Temperature: 298 K.
- Pressure: 101325 Pa.
- Velocity for air: 15 m/s.
- Air density: 1.225 kg/$m^3$.

We had set these parameters in the ANSYS solution which is called fluent solver. Then we initialized the solution. We did 500 iteration of each type. Then the values of the forces have found. Then in the result section the velocity profile and pressure profile have found also. We can easily get an explanation to see the profile. The profiles are shown below:

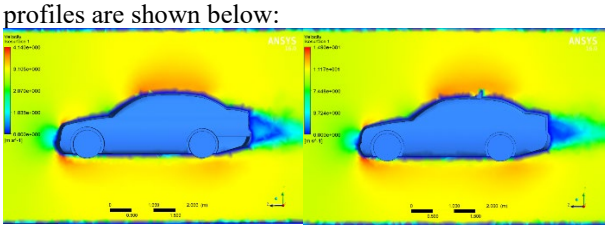

Fig.7: Difference Created by Parabolic Type

Here the velocity profile for parabolic vortex generator has shown. There we are seeing the complete distinction between two figures. The area of wake zone has significantly reduced by using parabolic type. Since the wake has been reduced so low back pressure region has also reduced. So, the tendency of moving backward of vehicle has been reduced. That's why drag forces has reduced.

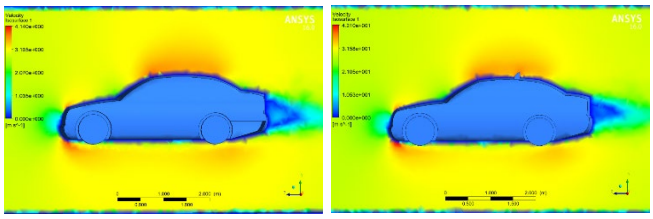

Fig.8: Difference Created by Gothic Type

Here the velocity profile for gothic vortex generator has shown. There we are seeing the complete distinction between two figures. The area of wake zone has significantly reduced by using parabolic type. Since the wake has been reduced so low back pressure region has also reduced [6]. So, the tendency of moving backward of vehicle has been reduced. That's why drag forces has reduced.

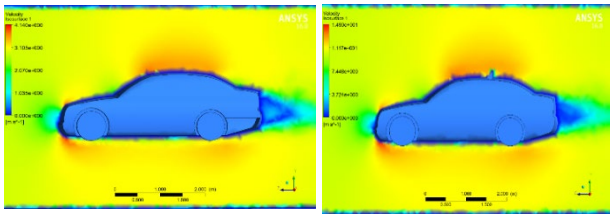

Fig.9: Difference Created by Triangular Type

Here the velocity profile for gothic triangular generator has shown. There we are seeing the complete distinction between two figures. The area of wake zone has significantly reduced by using parabolic type. Since the wake has been reduced so low back pressure region has also reduced. So, the tendency of moving backward of vehicle has been reduced. That's why drag forces has reduced.

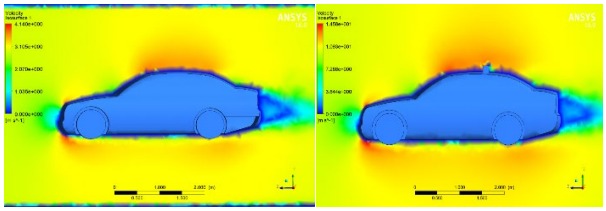

Fig.10: Difference Created by Rectangular Type

Here the velocity profile for gothic rectangular generator has shown. There we are seeing the complete distinction between two figures. The area of wake zone has significantly reduced by using parabolic type. Since the wake has been reduced so low back pressure region has also reduced. So, the tendency of moving backward of vehicle has been reduced. That's why drag forces has reduced.

### 2.3 Wind Tunnel Experimentation

We worked in the AF-100 subsonic wind tunnel. We have performed my experiment in the AF-100 subsonic wind tunnel. Here actually we had taken the values of drag and lift force. We performed each and every operation in respect of time. I had taken 10 operations and every operation needs 2 seconds. We found the all data in the Microsoft excel file. At first, we will take a look on the wind tunnels were attached in the wind tunnel:

Fig.11: Vehicle with Triangular VG in Wind Tunnel

In the above figure we are seeing the triangular type of vortex generator with car was set in wind tunnel. The models of all types were subjected to sit in the wind tunnel. After the mass balancing, we got the result. But before that the air of the certain velocity was provided. There are four types of vortex generators with the car were examined in the wind tunnel. To conduct the experiment, we needed to support the object in the space of wind tunnel.

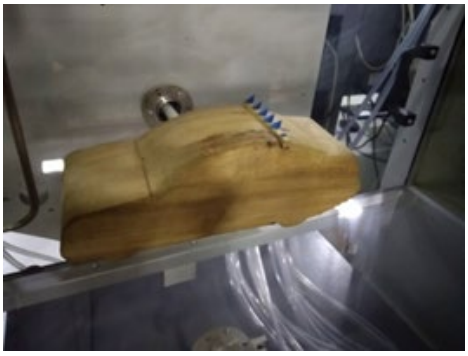

Fig.12: Vehicle with Parabolic VG in Wind Tunnel

In the above figure we are seeing the parabolic type of vortex generator with car was set in wind tunnel. The models of all types were subjected to sit in the wind tunnel. After the mass balancing, we got the result. But there are four types of vortex generators with the car experiment, we needed to support the object in the space of wind tunnel.

Fig.13: Vehicle without VG in Wind Tunnel

We needed to experiment on the vehicle without vortex generators. It was for the comparison among different types of data. Without vortex generators the car was set in the same manner.

## 3. COMPARISON

In this particular study we took several data to find the best type of vortex generator. For this we need to compare the value of drag force generated in every single experiment. To evaluate the thing at first, we are going to see the reduction of drag by vortex generators in several times:

### 3.1 Comparison among Different VGs

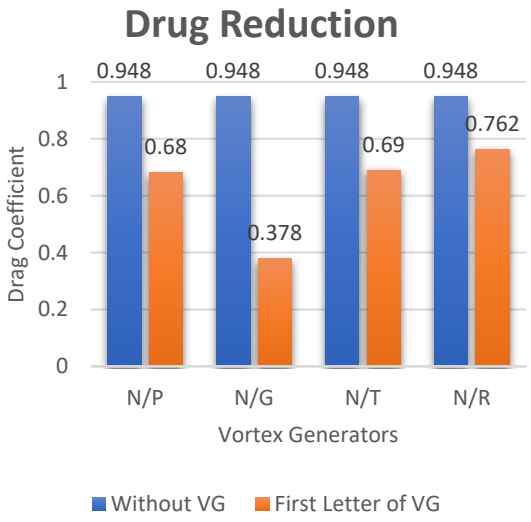


Fig.14: Drag Coefficient Reduction by VGs

We are seeing that; every type is helpful for the reduction of the drag force. But gothic type is much more beneficial for the vehicle. It minimized the drag force by 150%. That was incredible. We are seeing that; every type is helpful for the reduction of the drag force. But gothic type is much more beneficial for the vehicle. It minimized the drag force by 150% [7]. That was incredible.

Gothic type vortex generator really plays an important role in the era of aerodynamics. It is good for the drag forces as well as lift forces. It also reduces the lift coefficient. Reducing the lift force is also very important thing in the field of aerodynamics. It creates the negative lift forces. The negative lift force improves the traction of the car with the road. For the limitation of the experiment and other things we had to omit the experiment related to the lift forces.

From the above description, we have made a decision that the gothic type of vortex generator is the efficient one for both the drag and lift forces. So, we should use vortex generator as the gothic type for its efficiency and effectiveness.

### 3.2 Error between Simulation and Experiment

There are some errors has been occurred. They are not intentional. We assumed the surface was smooth in the simulation, but in practice it was not smooth enough. The temperature was fluctuating. There were some other reasons which actually played a great role for these unexpected distortions.

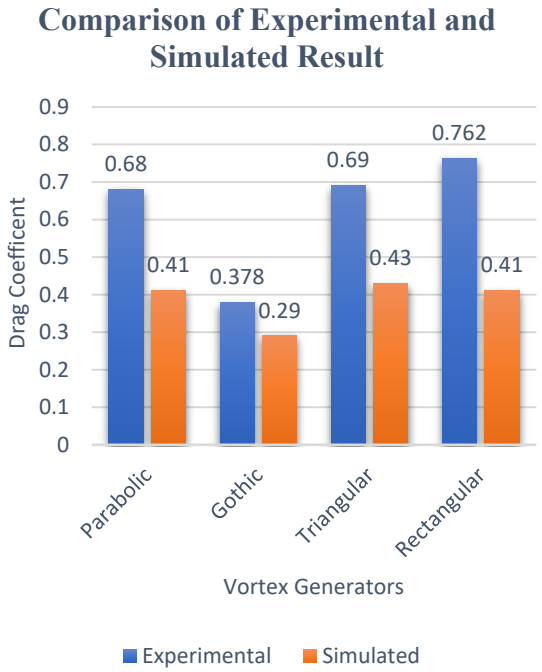


Fig.15: Comparison between Experimental and Simulated Data

## 4. GOVERNING EQUATIONS

Here actually we have used k-ξ model. In this model the two equations were used. The equations are given below:

Continuity Equation:

$$\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right)=0 \quad (1)$$

Navier-Stoke Equation:

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right) \quad (3)$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right) \quad (4)$$

## 5. DECISION

The results acquired from the simulations are dependent on the quality of mesh and the accuracy of the setup. The best possible mesh could not be used because of the unavailability of enough computational power. The main source of the error in experimental values is the rough wooden surface but the surface was made as smooth as possible. In the flow simulation we saw that wake has been created at the rear end of car. This results the decrease of back pressure. That's why the car is

tending to backward. To overcome these phenomena, if vortex generator is used it will reduce the drag as well as lift for sure. Eventually we saw that the drag and lift both are reduced significantly. Though another add-on device spoiler is doing the similar thing, nevertheless vortex generator was bit more efficient. We saw the effectiveness of VGs and GOTHIC type of VG is more efficient than others. A suitable design of vortex generator has reduced the drag is about 150% and lift 2.47% and the content of this paper may play significant role in this field. We had found some vital decision from previous works. The gothic type is best which is told in the paper [8]

## 6. CONCLUSION

To delay the flow separation, vortex generators are used. And by doing the above experimentation, we saw that the gothic type is the best type of all others. It reduces the drag coefficient as well as drag force. The results acquired from the simulations are dependent on the quality of mesh and the accuracy of the setup. The best possible mesh could not be used because of the unavailability of enough computational power. The main source of the error in experimental values is the rough wooden surface but the surface was made as smooth as possible. In the flow simulation we saw that wake has been created at the rear end of car. This results the decrease of back pressure. That's why the car is tending to backward. To overcome these phenomena, if vortex generator is used it will reduce the drag as well as lift for sure. Eventually we saw that the drag and lift both are reduced significantly. The gothic type is the best type of vortex generator which is also stored for the low velocity profile. In many works Ogive vortex generator was prioritized [9]. But have worked a lot in this particular topic and after that we come in a decision that the gothic vortex generator is the most efficient on the car. There are many experiments have done on the particular car types [10].

## 7. ACKOWLEDGEMENT

I would like to begin by thanking my Honorable Supervisor Dr. Kazi Afzalur Rahman, Professor, Department of Mechanical Engineering, Chittagong University of Engineering and Technology (CUET), for his continuous supervision and guidance through my job and for promoting me to work on my subject of concern. I would also like to mention sir Md. Mehedi Masud Talukder and sir Prasanjit Das for sharing their time and expertise. I am also grateful to all my department, including all the members of the faculty and stuff, who left no stone untu rned to assist me out whenever I was confronted with an y problems whatsoever. It is my privilege to work with them

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## 9. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| $F_D$ | Drag Force | Newton (N) |
| $F_L$ | Lift Force | Newton (N) |
| $C_D$ | Drag Coefficient | ---- |
| $C_L$ | Lift Coefficient | ---- |
| $A$ | Frontal Area | Meter$^2$(m$^2$) |
| $V$ | Velocity of Fluid | ms$^{-1}$ |
| $P$ | Density of Fluid | kgm$^{-3}$ |