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Computational Fluid Dynamics (CFD) Analysis of 3D Car Model to Understanding Key Aerodynamic Issues and Their Interaction with Other Motorsport & Automotive Vehicle System

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Abstract: Growing population of vehicles is one the biggest global concern and it led to traffic problems and creates congestion. People are not getting place to park their vehicles. Travel by car for shorter distance also stressful and time consuming because they have to face road traffic and usually cars are big at size so, to travel by car on road need more spacious and traffic free roads. that's why some manufacturers start designing & manufacturing One seater vehicle which can easily transportable and create less congestion. If a single person wants to ride somewhere then he doesn't have to take large car for one person, He can use single seater vehicle. In this assignment I have Designed and Tested a single seater electric vehicle which can easily transportable, compact and personal commuter vehicle (PMV).

Keywords: CFD analysis, Aerodynamics analysis, automotive vehicle system, 3D modelling, pressure plot, performance optimization, vehicle aerodynamics.

I. INTRODUCTION

Transportation is one of the important necessity of today's world and its changing rapidly. Lots of people use their own transportation vehicle for day to day travelling. As per recent studies researchers found that people use personal transportation vehicle more than public transportation. vehicles increased by 1.5 billion per year. That's creating more congestion on roads and creates more pollution. Also natural fuel resources are very limited. If we depend totally on fossil fuel and not found any other source of energy, then fuel will not be going to last long. To overcome this problem manufacturer now focusing on E-Vehicles (Electric vehicles). E-vehicles are going to use in near future and it is best option or its best substitute to IC engine vehicle. Battery powered vehicles(E-vehicles) are more efficient, nature friendly also it costs less. So in this assignment I have used electric drive-train in designed vehicle also this is single seater vehicle for day to day travelling. Although it comes under personal transportation but it will fulfill costumer requirements and reduce traffic. man

II. LITERATURE REVIEW

A. Wisnoe, Wirachman, Nasir, Etc…(Wisnoe et al., 2009)

In this paper author presented Two methods of analysis i.e. 3D computational fluid dynamics & steady state for testing aerodynamics behavior of a baseline design of blended body wing (BWB) of Mach 0.3 and Mach 0.1 aircraft. MARA university of technology conducted this experiments in wind tunnel. In this test they measure and compared drag force (CD), Lift coefficient (CL), Pitch moment coefficient (CM) with Mach number according to variation of angle of attack

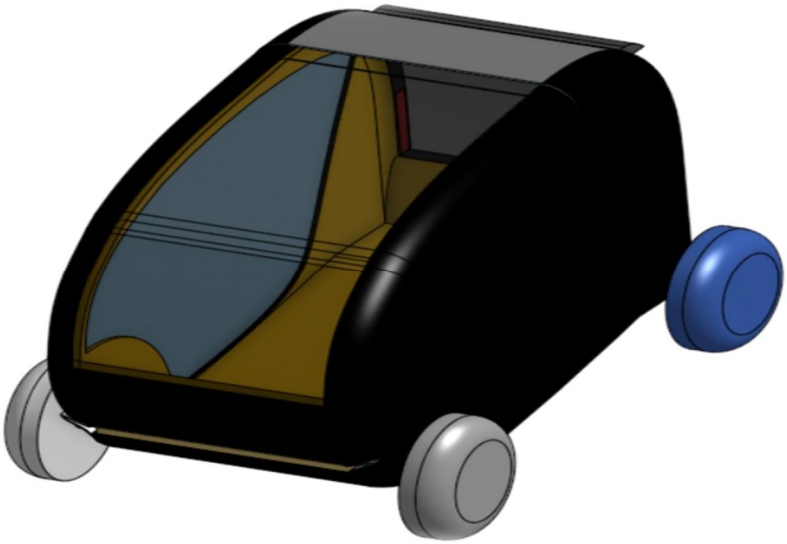
B. Corin, R.J, Etc...(Corin et al., 2008)

In this paper author explain that whenever any vehicle overtakes another then some aerodynamic force will have occurred to find this force they have tested vehicle with Computational fluid dynamic test also Called as CFD analysis. When vehicles are running on road that time velocity of the vehicles was varied. To study this unsteady vehicle author tested with quasi-steady and unsteady modelling approaches. They have also tested vehicle with different-different direction of wind flow like cross wind and whenever any another vehicle passes through how much wind pressure they create on vehicle. The dynamic variation in the aerodynamic forces was up to 400% greater than that predicted using quasi-steady analysis, indicating that the quasi-steady approach is totally unsuitable for modelling overtaking manoeuvres in a crosswind. These dynamic effects are likely to have a considerable impact on the stability of the vehicles involved. With little existing work on passing manoeuvres in a crosswind, these results highlight the importance of dynamic effects and the need for further investigation into the problem.

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1) *Part 1*

CAD Modelling Vehicle Concept



2) *Part 2*

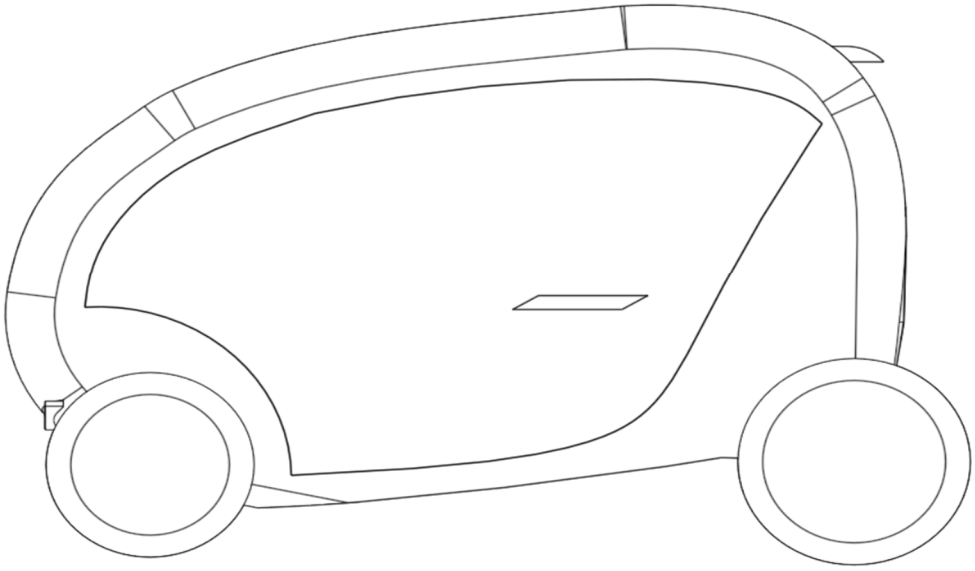
a) *CFD Methodology:* Before designing car, it was important to understand and know about costumer needs and requirements which is important to design any car. That's why I conducted small survey for better understanding. After gathering all data from survey, I started collecting technical data about vehicle designs so it will help while designing. According to survey costumer required small compact commuter vehicle which can easily carried out from one place to another and parking vehicle should be easy and grab less space. Talking about design some costumers required edgy modern look and some of them want simple curvy look car. Some people like to drive IC engine cars but many of the people want to try electric vehicle so I decided to make electric car which can be the future of automobile industry and also it will save fuel and tried to be best alternative source of energy.

After considering all requirements, I have started sketching cars and tried to fulfill costumer demands.

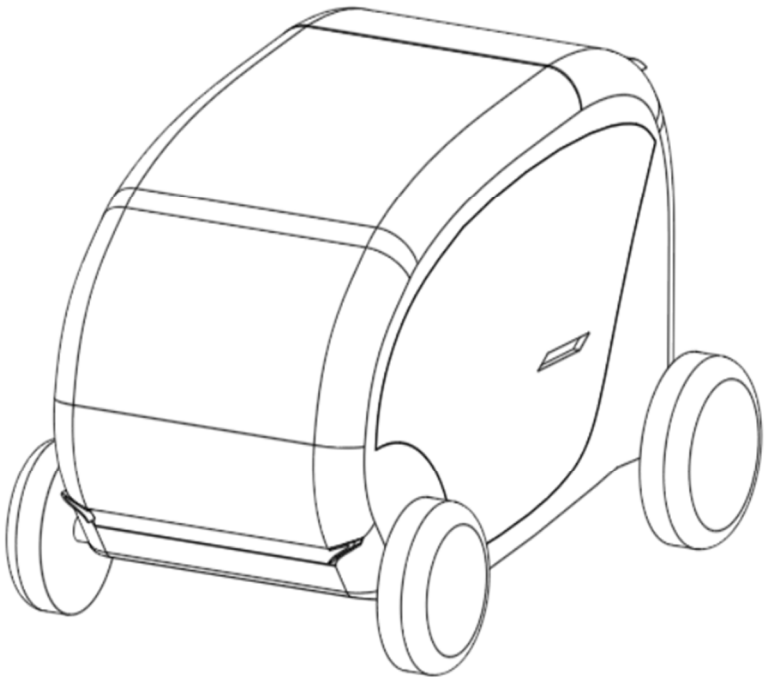
1)

This is my first design as a personal commuter vehicle. It is made as per costumer's requirement. This is small compact car with single seat inside vehicle cabinet which is in center of the car. So judgement while driving car will be more accurate and easy. But above design is not that compact as we required that's why I have rejected this design because it somehow lacks the stability at high speed and thigs like height and width ratio, Thin tyres are the evidence for the same. Though side design of vehicle looks little old it's not look like futuristic car.

2)

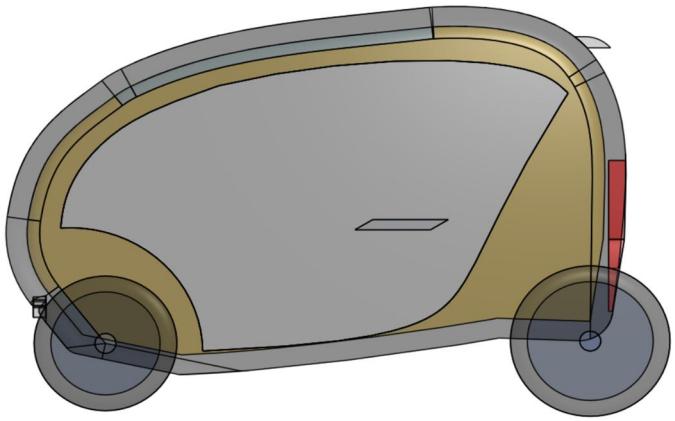


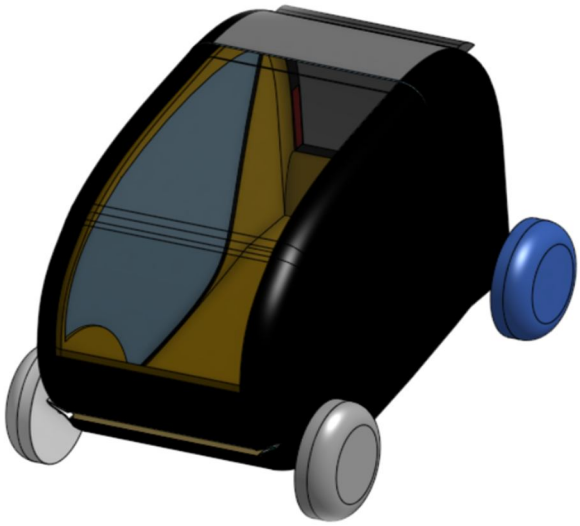
Then I have created this design and this design achieved all above criteria like this Car is Compact personal vehicle, better in aerodynamics and this is electric car too. In this design whole roof and doors are transparent which can change transparency according to drivers control. Also little spoiler is there to create some extra downforce for car so it will be stable on high speed. The design being futuristic is subtle at the same time so it will attract all kinds of customers which is the priority of all the car manufacturers. The design looks aerodynamically great. Since there are many aspects in which this car passes, this design was finalized and a 3D model was created in Onshape software.

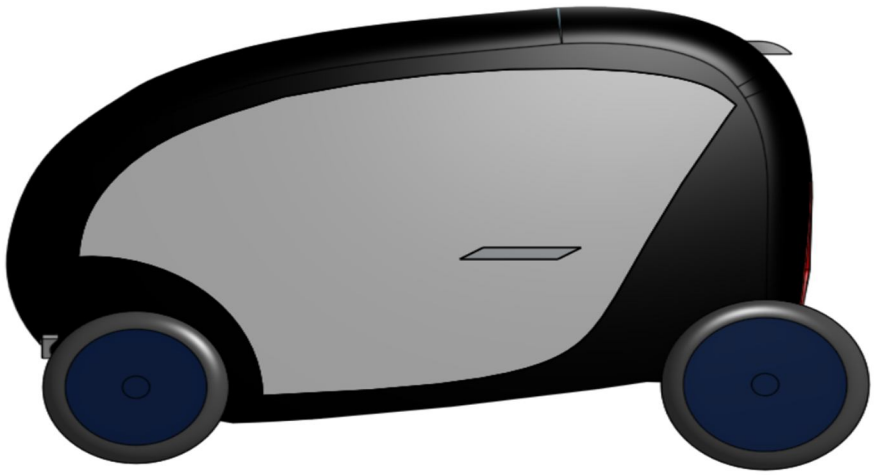


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This is the designed model. Yet even after the 3D model was made the car was not ready for production. It has to pass a few test like crashworthiness, stability, maneuverability, and ergonomics.

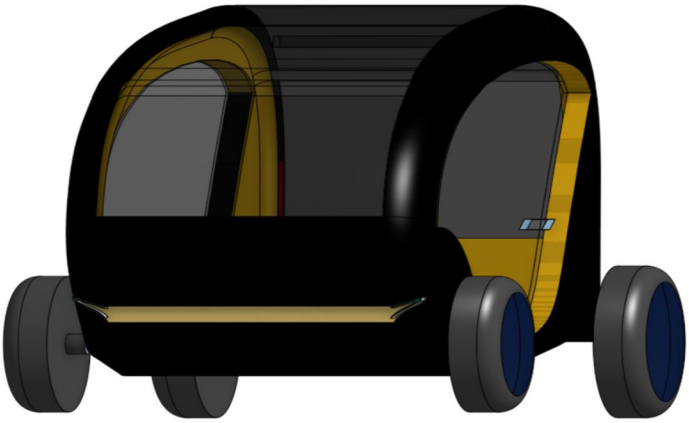




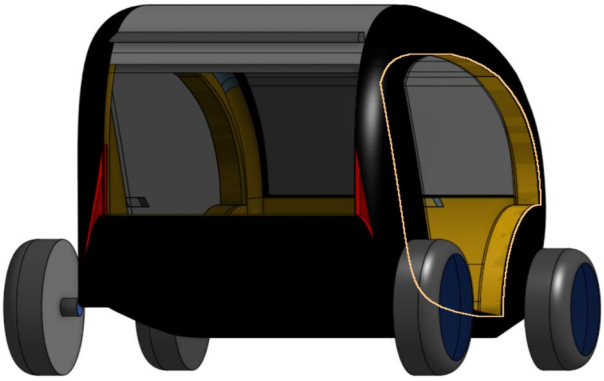


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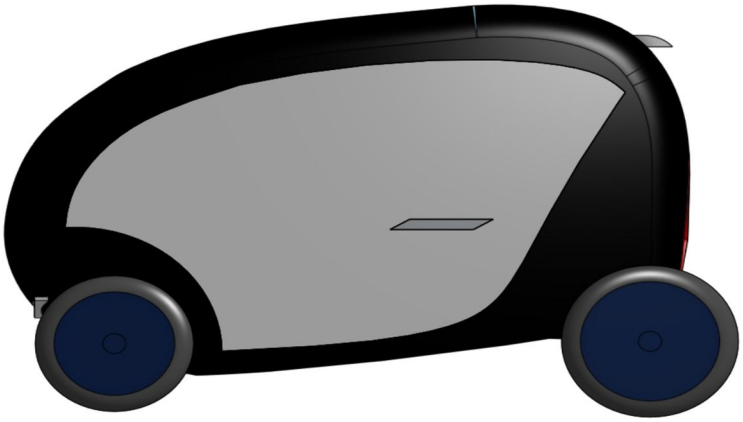
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Next stage was to clear the stability test. It can be seen that the car is quite wide and also has wide tires which aids in good stability at high speeds.



This car having just 1 wheel at the rear will surely have a small turning radius. This feature helped the car to pass the test of maneuverability. Having a smaller turning radius means that the car is quite maneuverable.



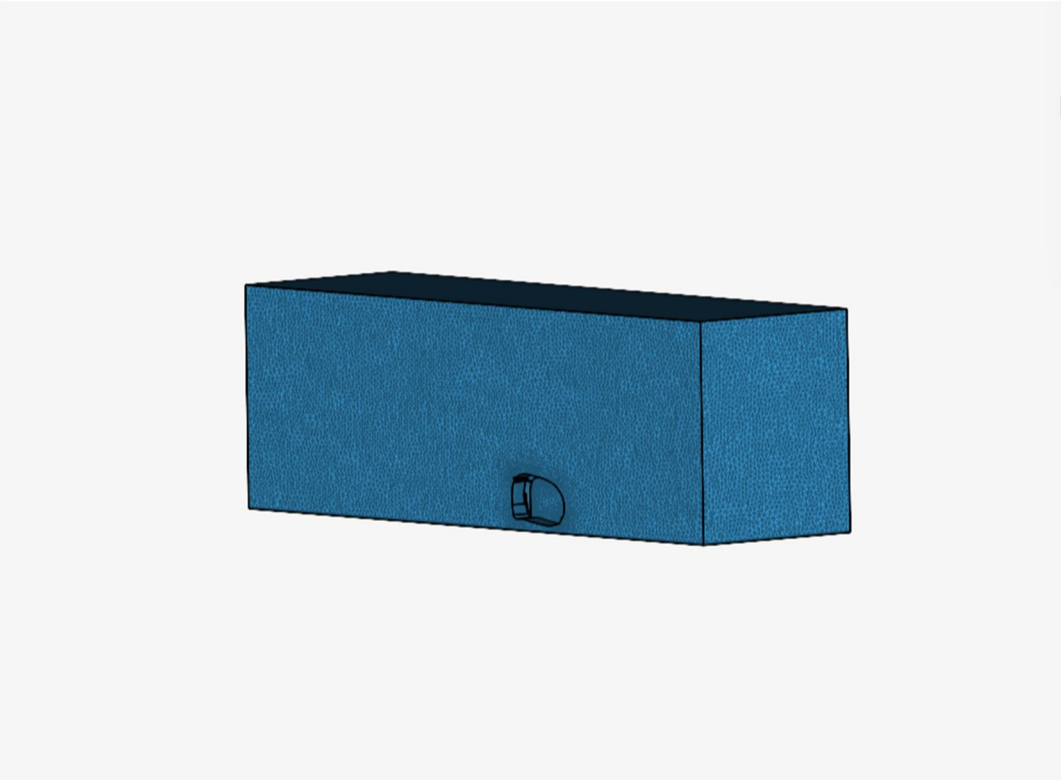
Next test was ergonomics. In this picture the body of the car has been made translucent so that the hidden parts can be seen. Here it can be seen that the dummy is sitting in very comfortable position. The steering wheel can be reached comfortably. Other than the driving posture a battery pack can be seen in the lower part of the vehicle. It is highlighted in red color. It is placed just next to the wheels so there are very less chances of it hitting to the road or the speed breakers. With this level of comfort offered the car cleared this test as well.

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Now since the car has passes all he test which can be inspected visually it was ready to be tested for the aerodynamic efficiency. For this test, the car had to be tested in a CFD software. To get it ready for the testing, the model had to be first simplified. Below is the picture of the simplified model.

Now as the model was simplified it was the time to export in another software for CFD analysis. It was exported to Simscale.



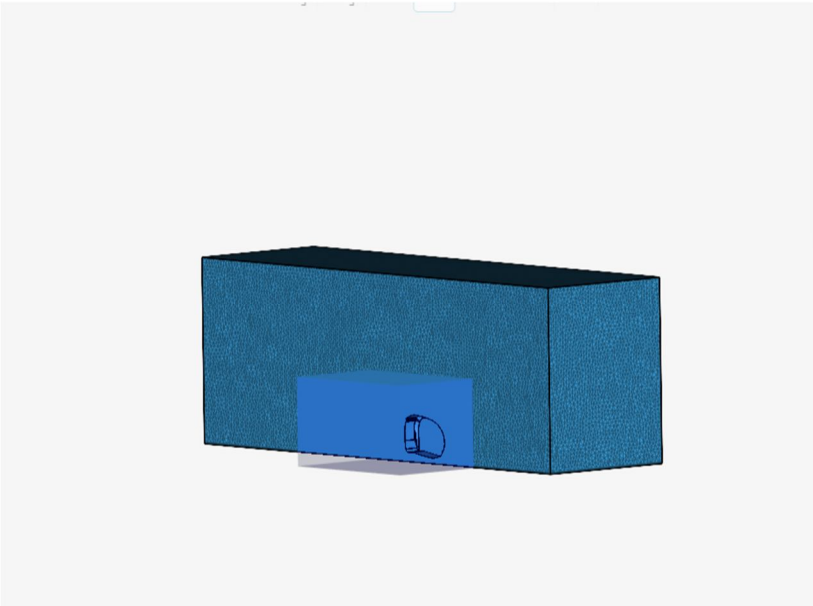
The first step was to create an enclosure for the geometry. It is said that the enclosure has to be 40 times the length of the car but keeping in mind the computation time it would take for generating the grid and the results, the enclosure's length was restricted to 20 times the length of the car. The enclosure was also designed in such a way that it cuts the geometry exactly into two pieces again for reducing the computational time. After selecting air as the material boundary conditions were allotted. Boundary conditions included:

- Velocity inlet
- Pressure outlet
- Slip wall for the top and the backside surface.
- Moving wall for the bottom surface.
- No slip wall for the body of the car.
- Rotating walls for the front and rear wheel.
- Symmetry wall for the surface in the front in the above screen shot.

There were Three simulations conducted. The variable set was the inlet velocity. The velocities at which the results were recorded were 75kmph, 90kmph and 100.8kmph.

It is said that once a speed of 75kmph is reached the aerodynamics plays a role, for the simulations 75kmph was set as the base velocity. These cars are said to have an average top speed of 90kmph. Though a simulation is done at 100.8kmph, it was only done to study how the car would perform at extreme conditions. After setting the boundary conditions it was now, the time to generate a grid.

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Region refinement (Small & big box)

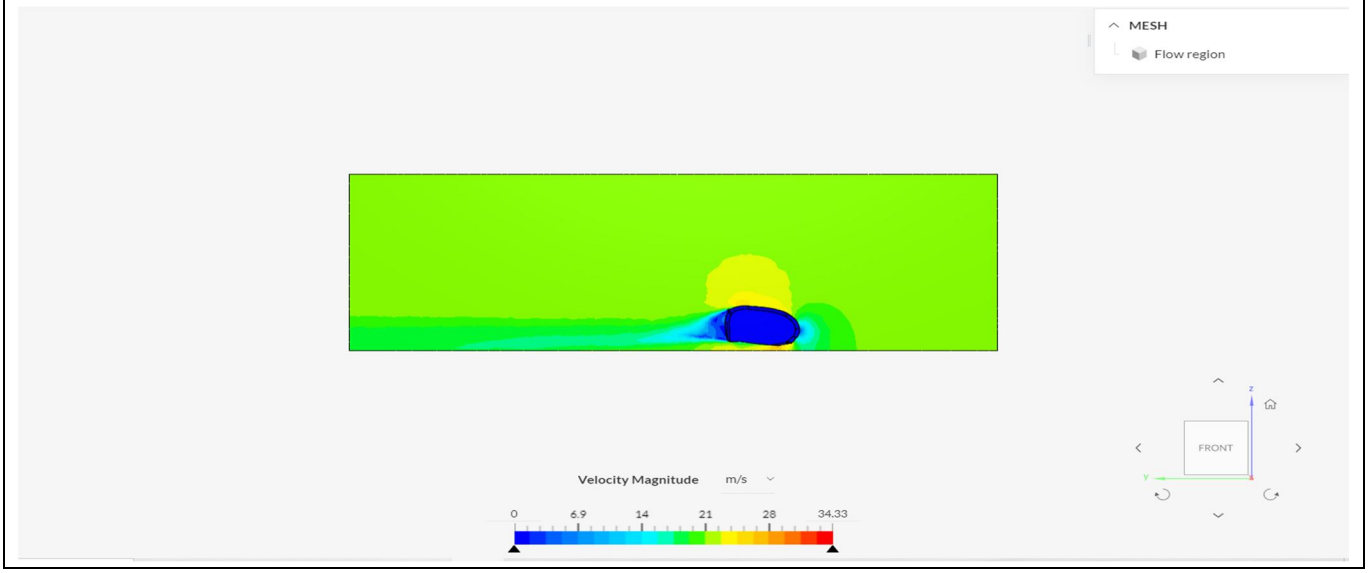
The grid had 3 refinement levels. The outer box can be seen have a course mesh, where the element size can be seen is bigger comparatively. Two Cartesian boxes were made having refinement levels in ascending order as seen in the picture above. The size of the Cartesian boxes, the maximum and minimum edge length was kept standard for all the simulations for a fair test. After the mesh was generated it was recorded that there were 3.1 Million elements and 965900 number of nodes. The meshing log showed that the average aspect ratio was 1.36, though this number is not very impressive as it is also counting the aspect ratio of the course mesh. The lowest aspect ratio recorded was 0.053 which is very good and could be taken into account as the place having the highest number of deflection is having a very fine mesh so it is assumed that the aspect ratios recoded there would be near to 0.053. After the grid was generated the simulation was run. The recorded results and images are shown in the results section

III. AERODYNAMICS ANALYSIS

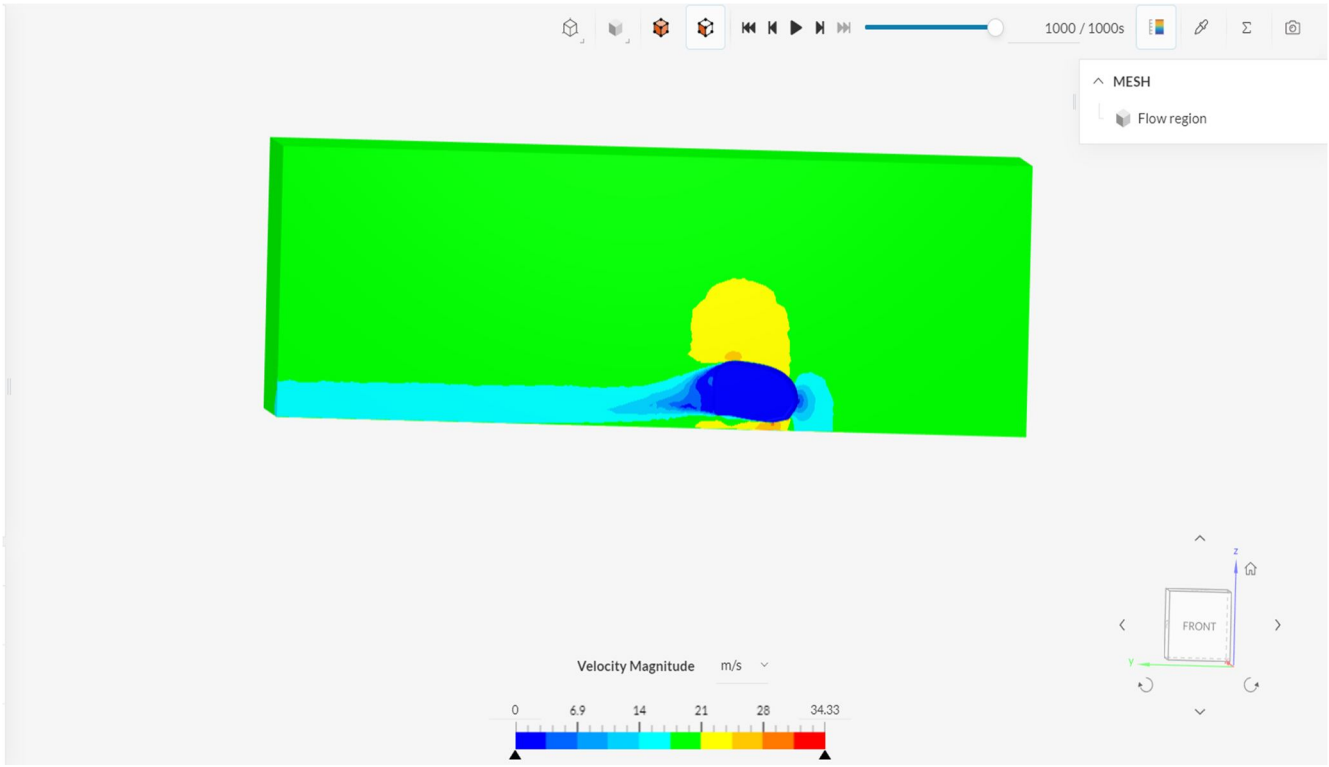
A. Results Discussion

velocity plot

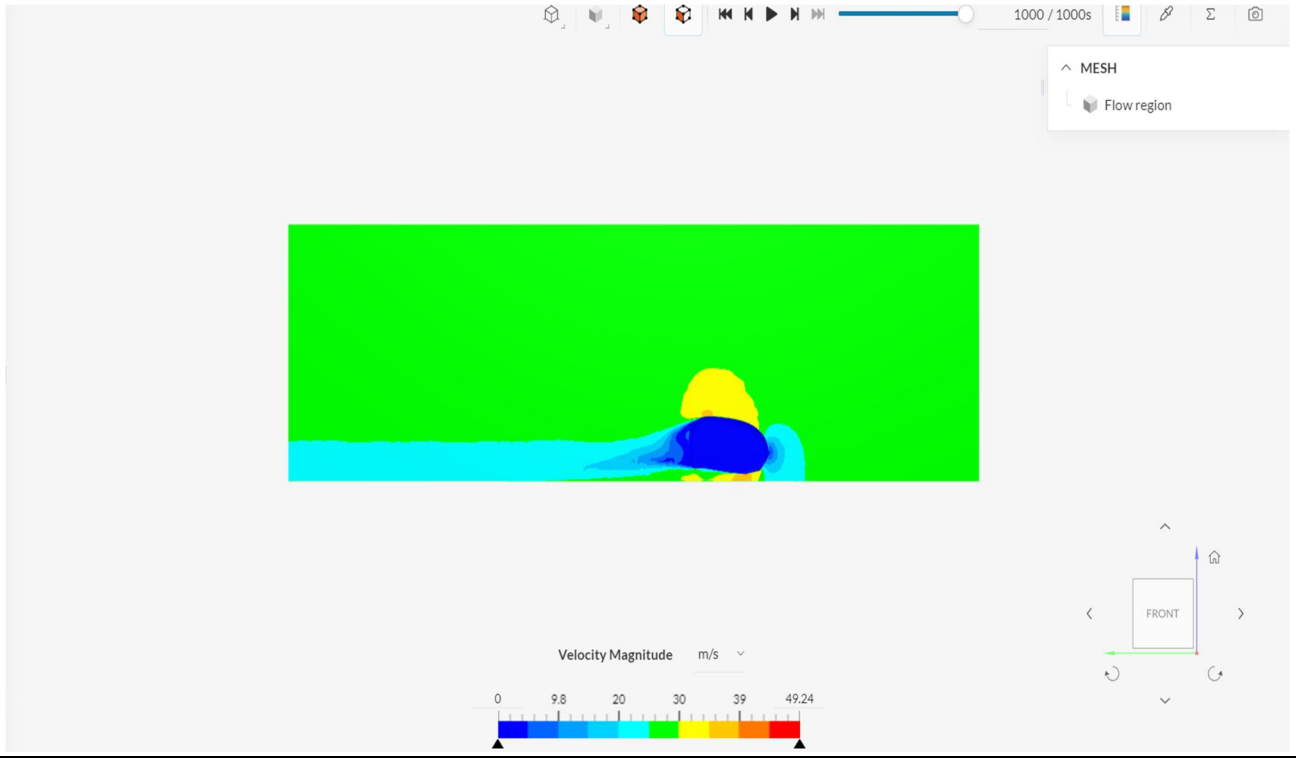
1) For 20 m/s or 75km/hr



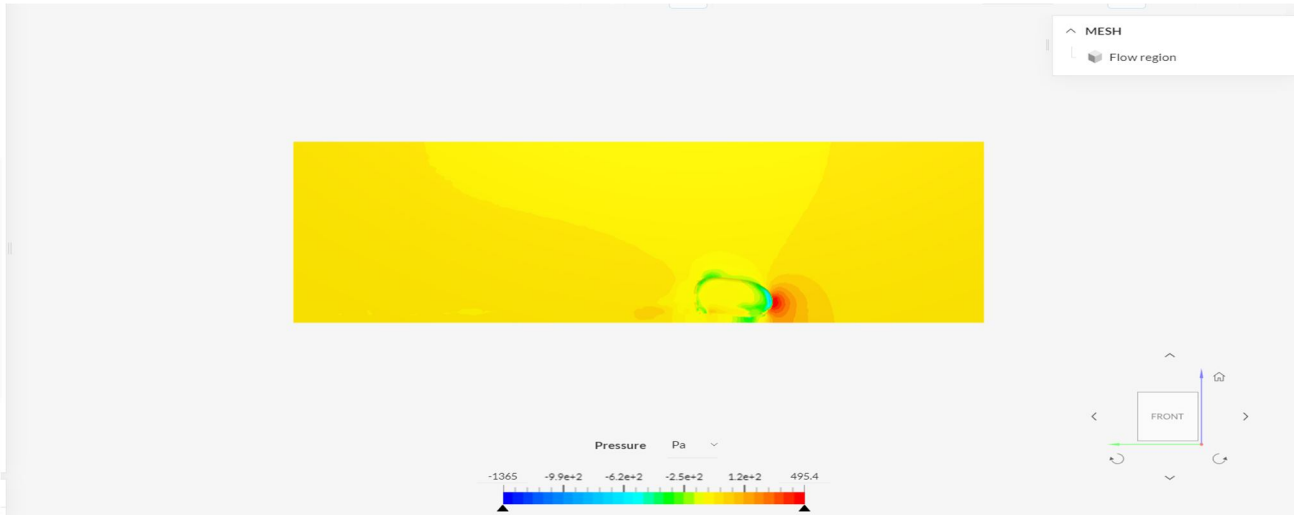
2) For 25 m/s



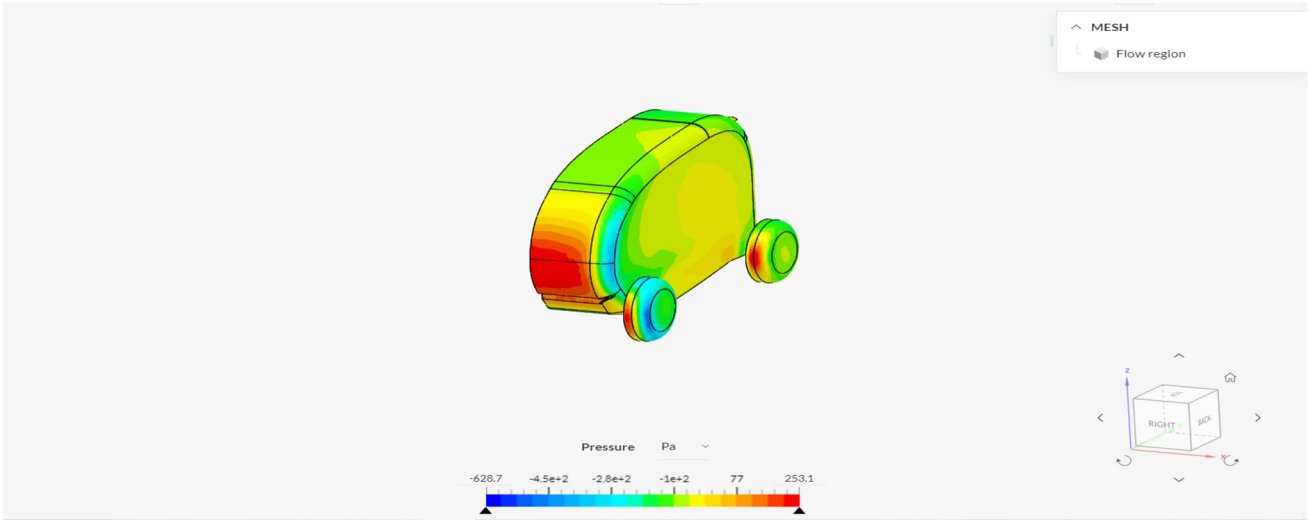
3) For 28 m/s



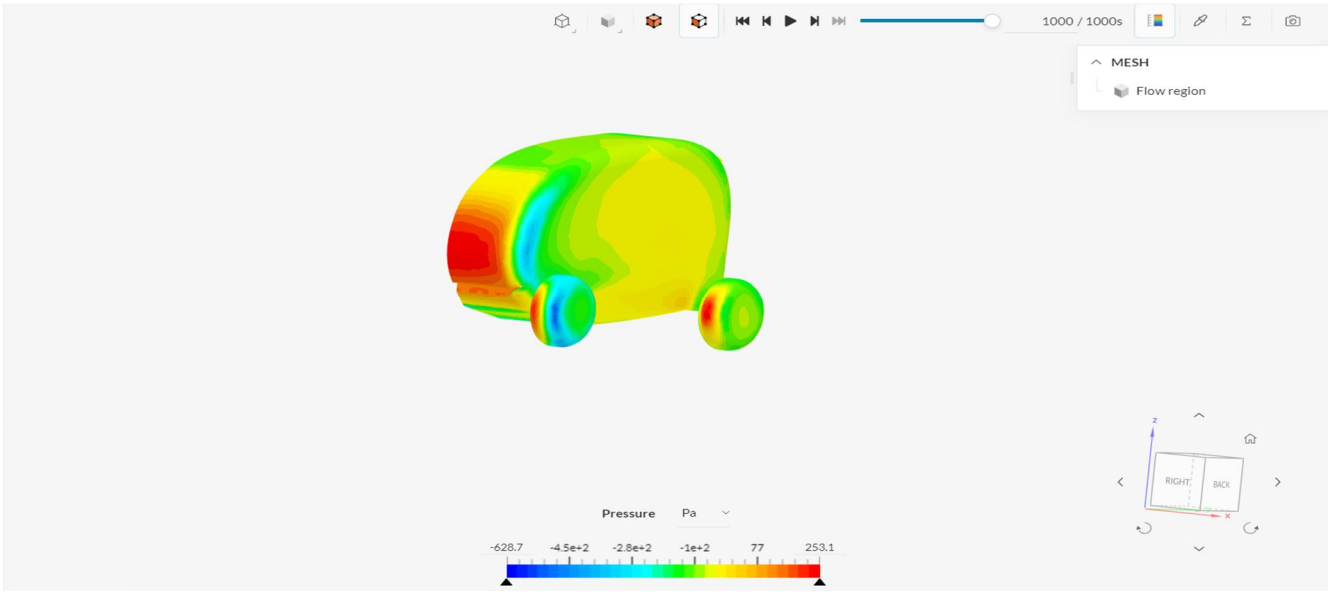
 # Pressure Plot



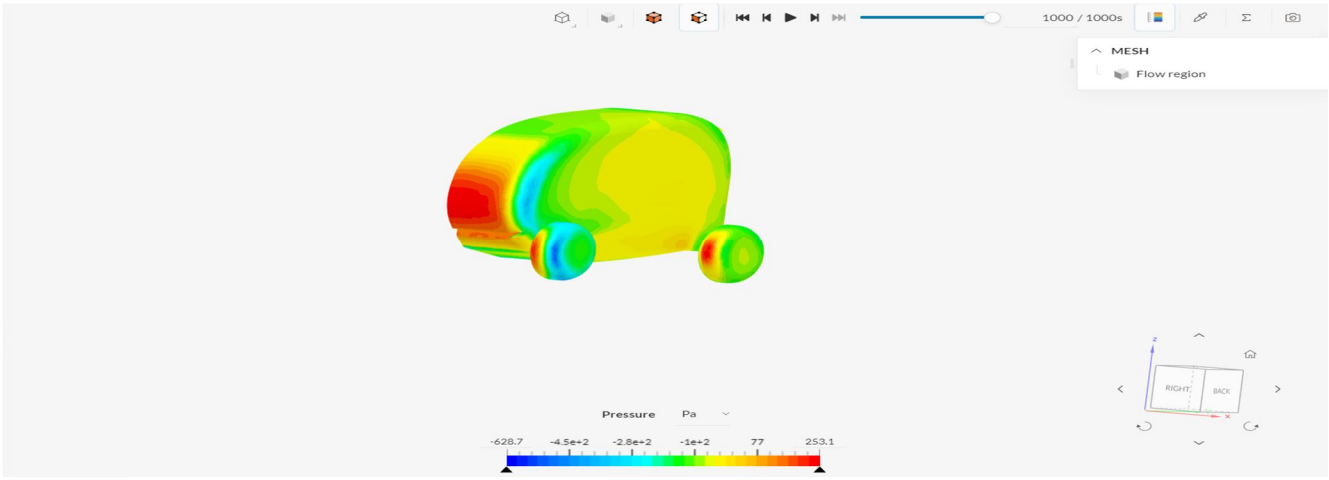
Speed: 20 m/s or 75km/hr

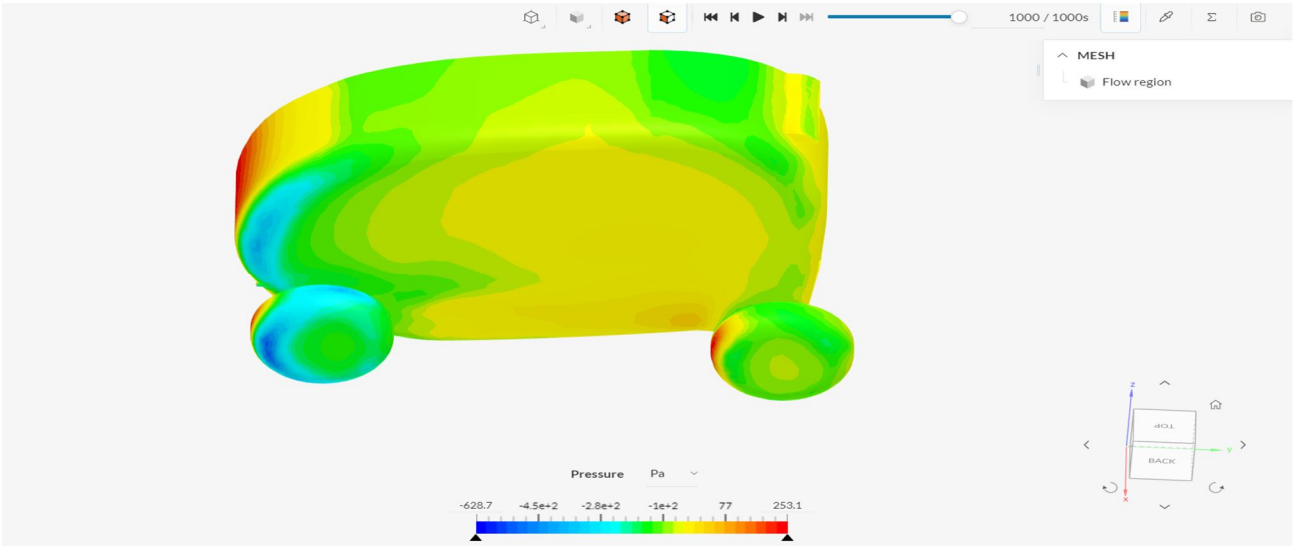


Speed: 25 m/s



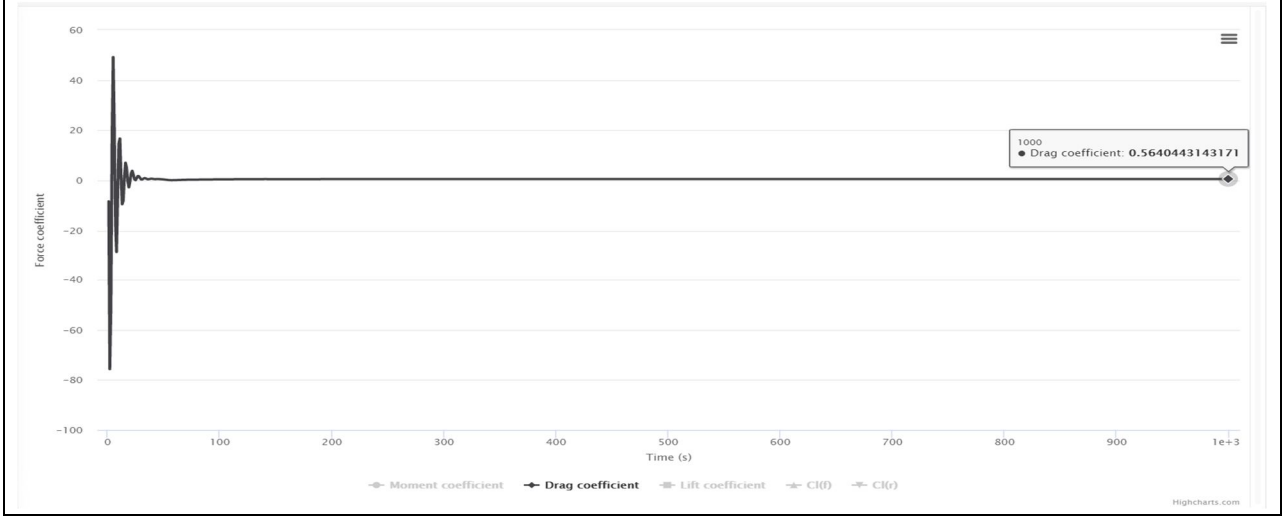
Speed: 28 m/s



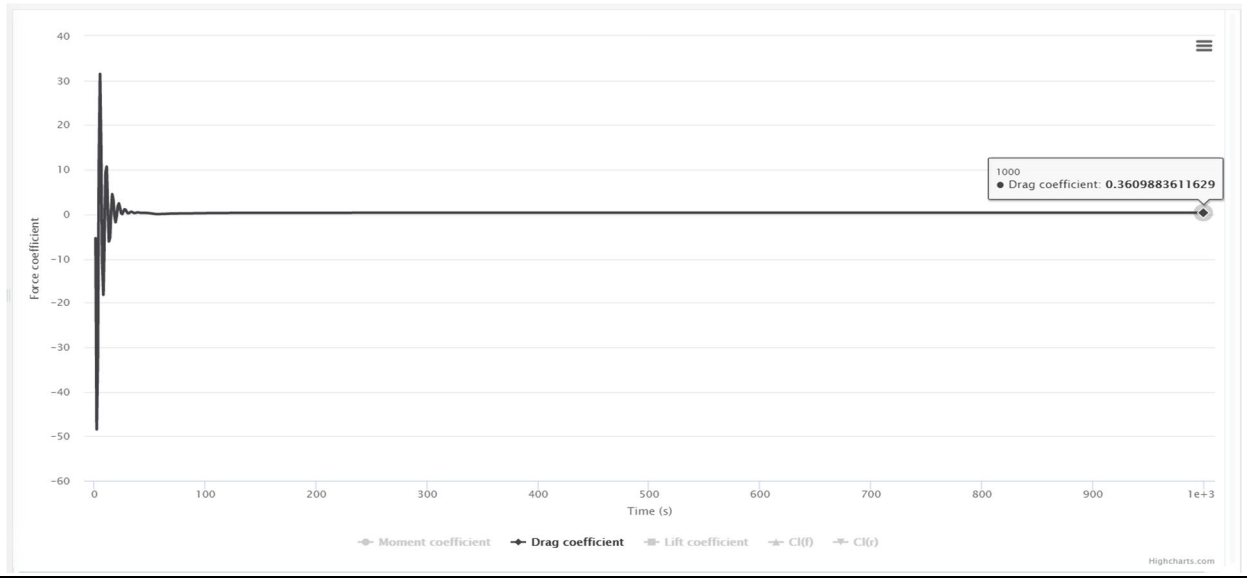


 # Drag Coefficient

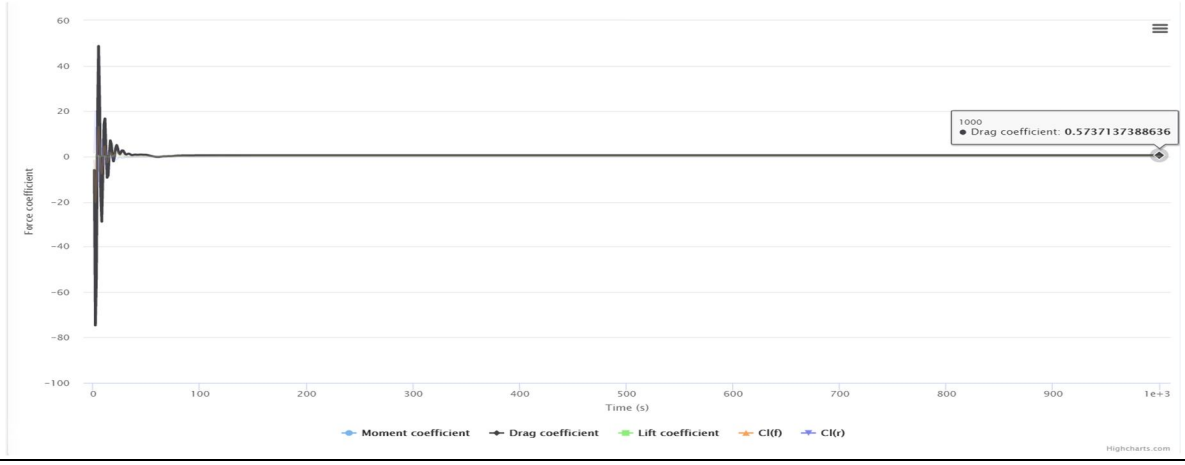
Drag for 20 m/s or 75km/hr.



Drag for 25 m/s or 90km/hr

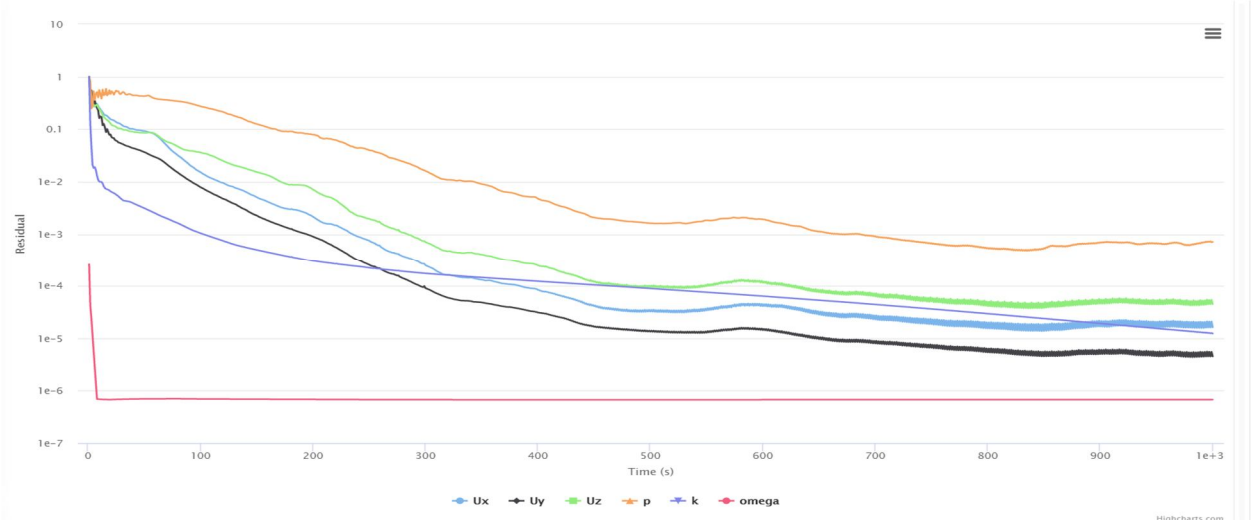


Drag for 28 m/s or 100.8km/hr

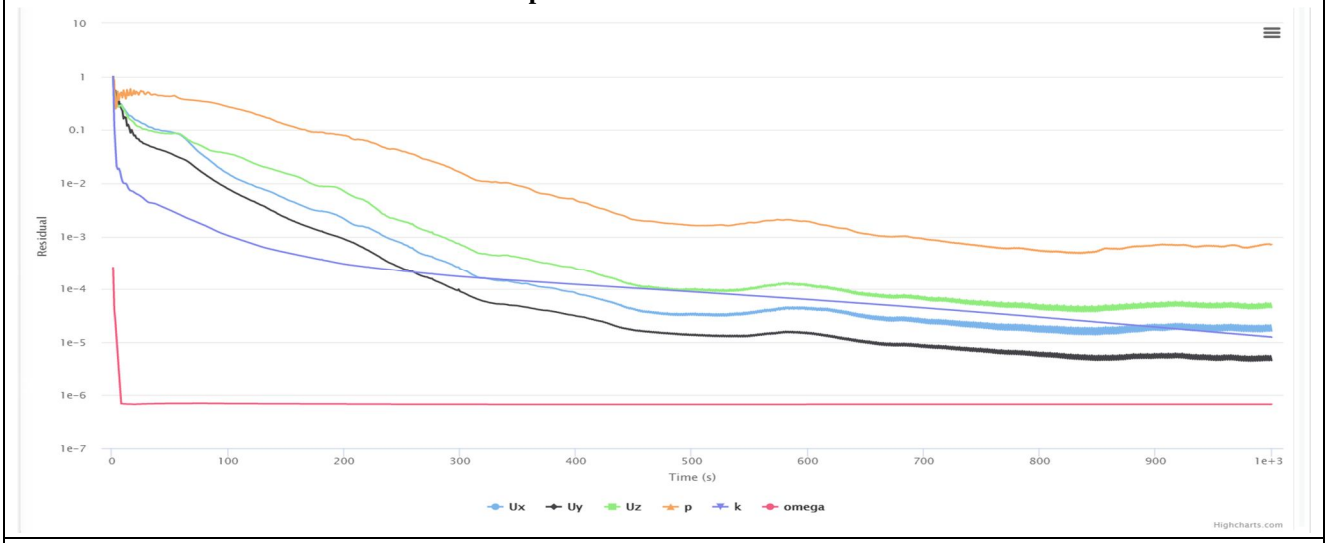


Residual plot

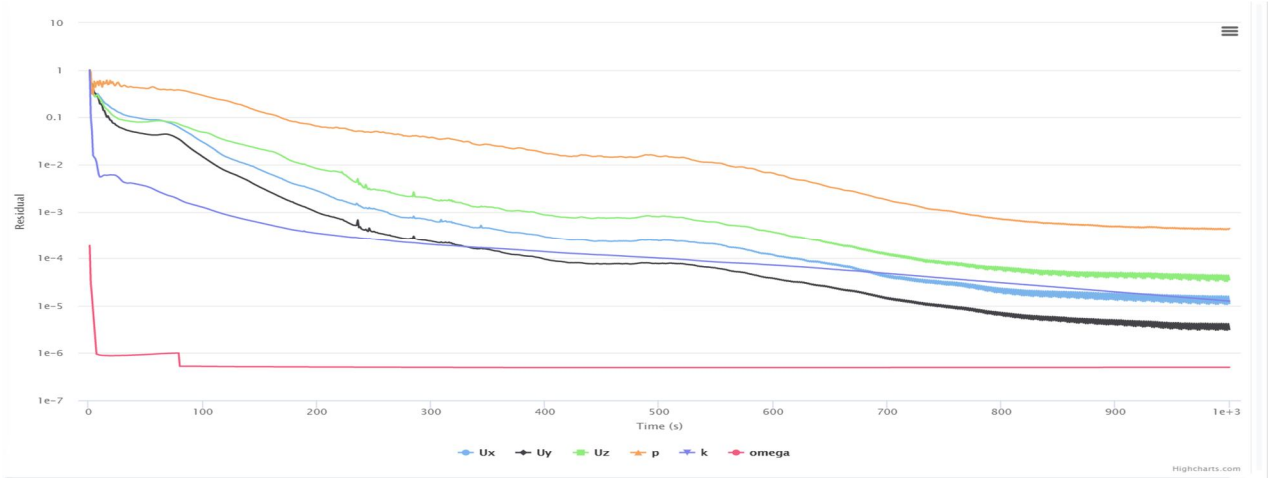
Speed: 20 m/s or 75km/hr.



Speed: 25 m/s or 90km/hr.

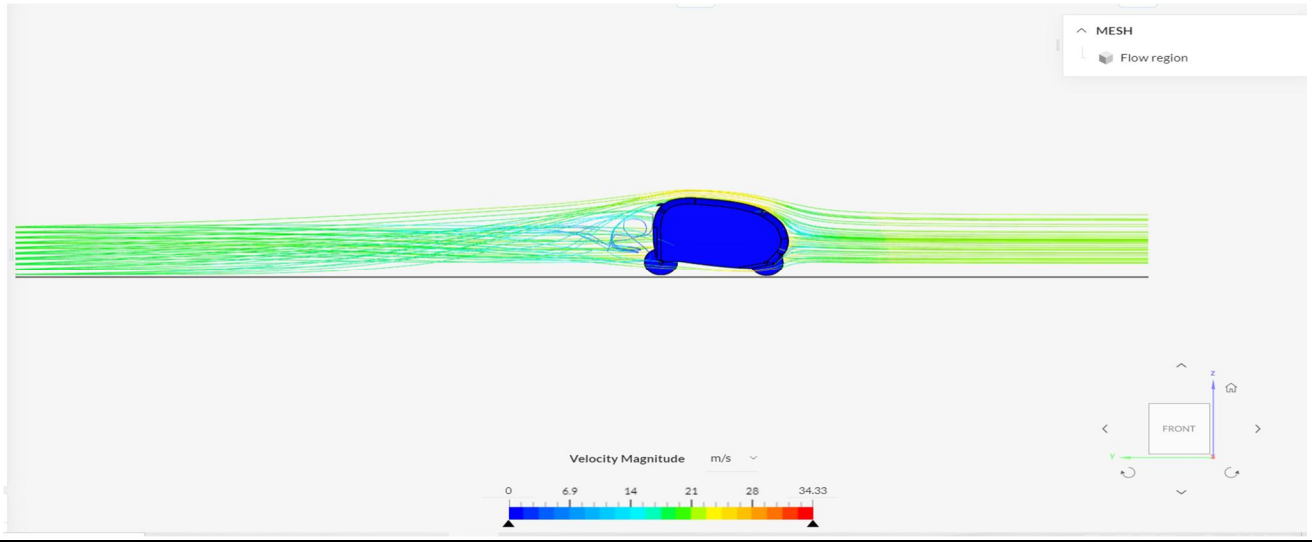


Speed: 28 m/s or 100.8km/hr.

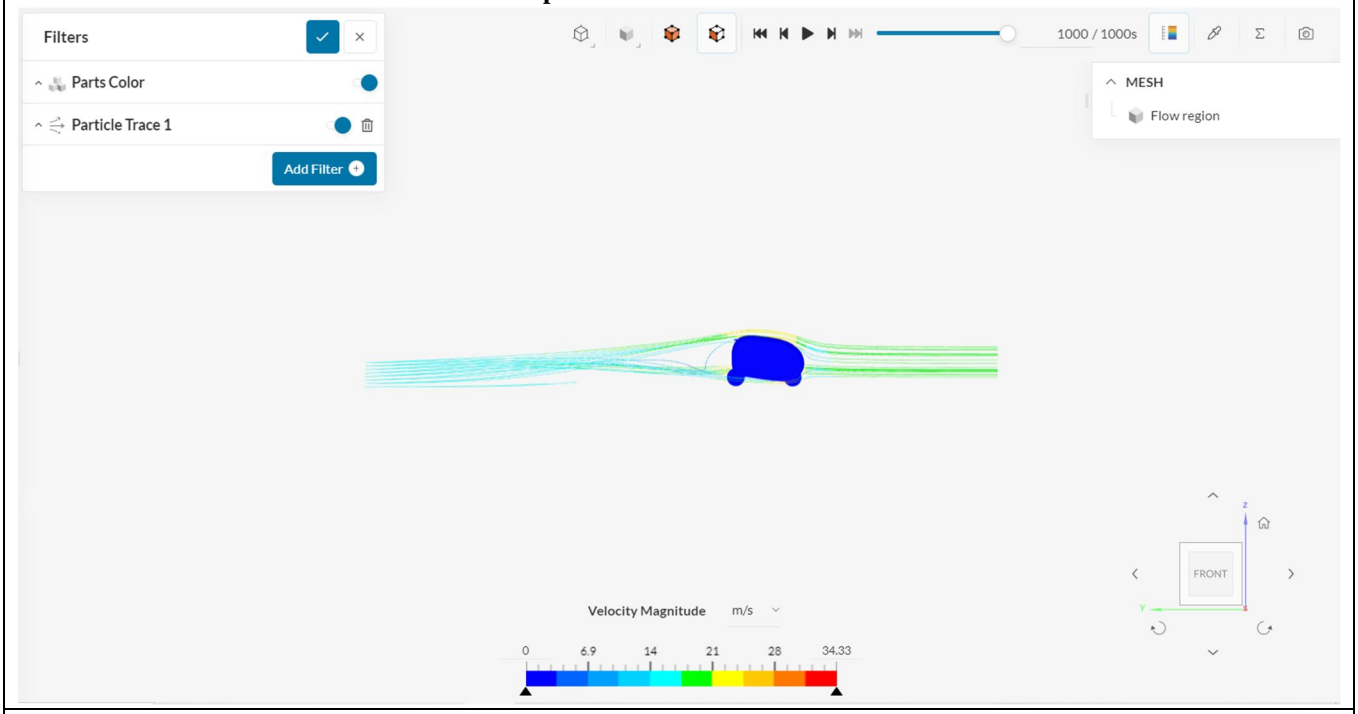


Streamline for velocity

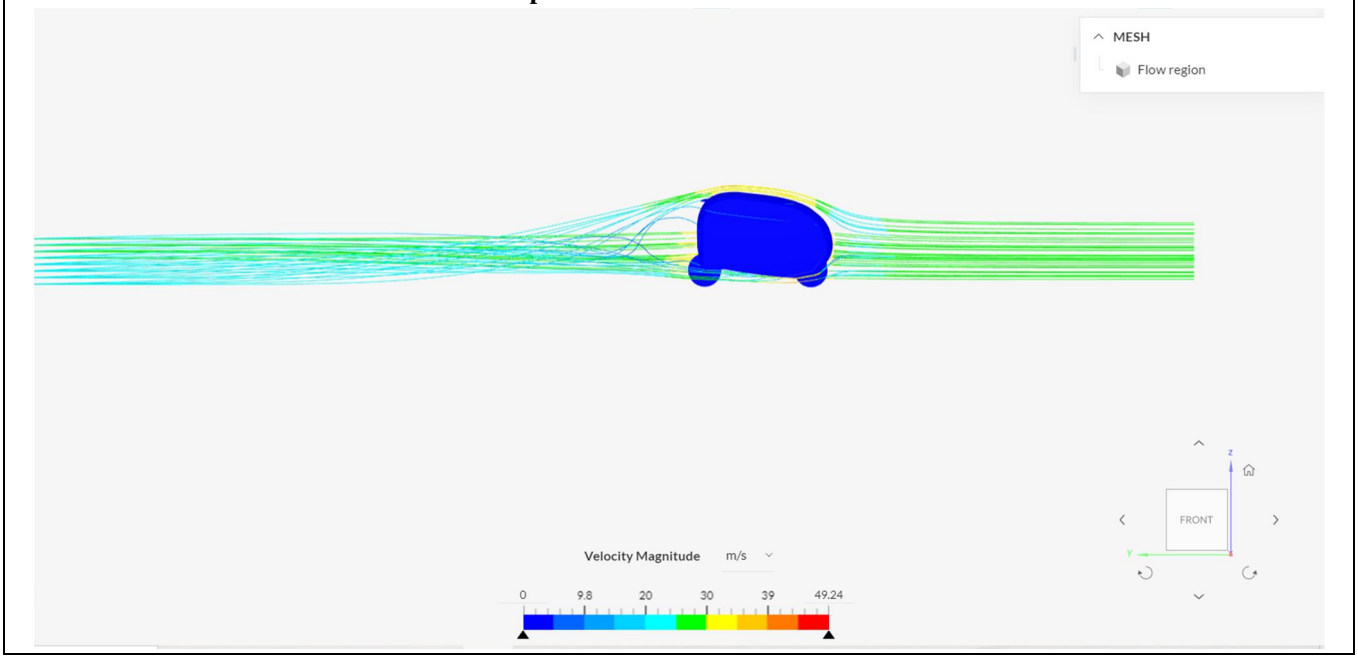
Speed: 20 m/s or 75km/hr.



Speed: 25 m/s or 90km/hr.



Speed: 28 m/s or 100.8km/hr

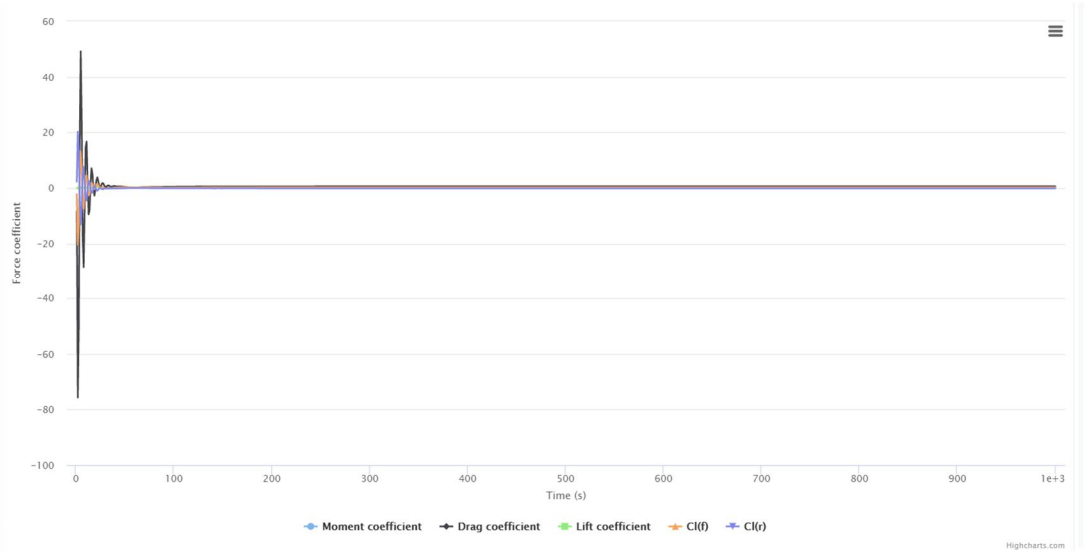


B. Force And Coefficient Plot Result

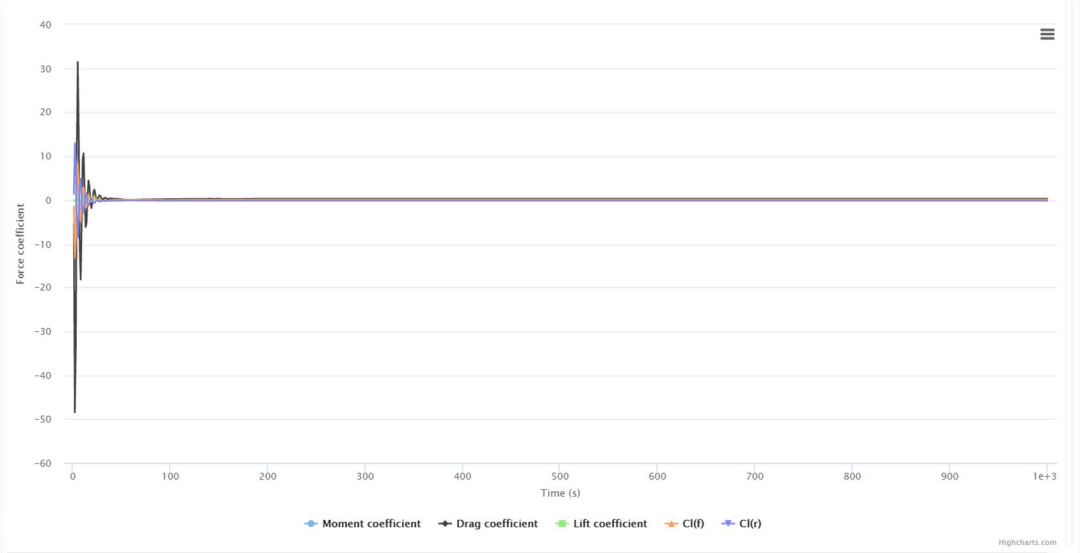
Speed	Moment coefficient	Lift Coefficient	Cl(f)	Cl(r)
20 m/s or 72km/hr.	0.190	0.0877	0.0234	-0.146
25 m/s or 90km/hr.	0.121	0.056	0.149	-0.093
28 m/s or 100.8km/hr.	0.189	0.0788	0.22	-0.150

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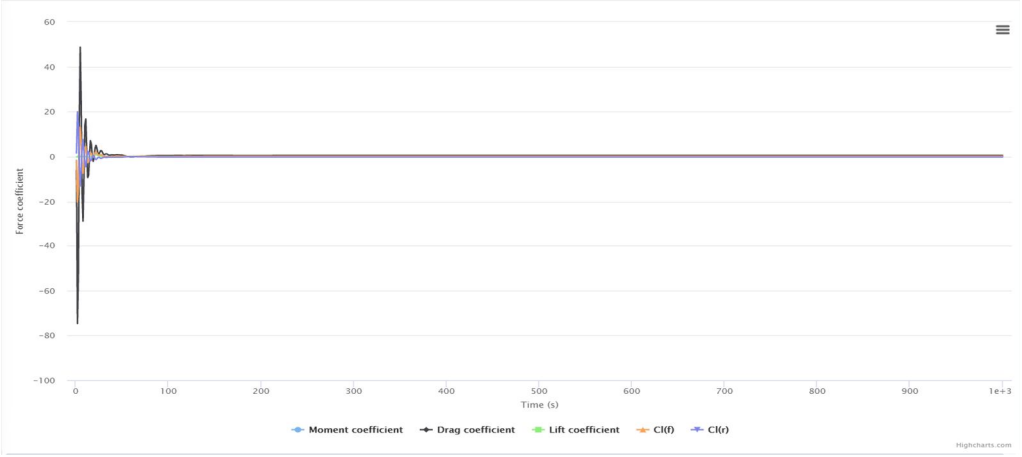
Speed: 72kmph



Speed: 90kmph



Speed: 100.8kmph



IV. CONCLUSION

After analyzing all the results, we found that

A. The maximum speed of the air was very proportional to the inlet velocity. As and how the inlet velocity increased the maximum recorded velocity also increased, However the increase percentage was highest when the inlet velocity was changed from 75 to 90kmph.

B. The turbulences also showed proportionality. As the inlet velocity increased the turbulences increased.

C. The drag coefficient was almost the same throughout the varied speeds. Although the recorded value of the drag coefficient was quite high for such a vehicle. The car definitely has to go under changes to get a better value of the same.

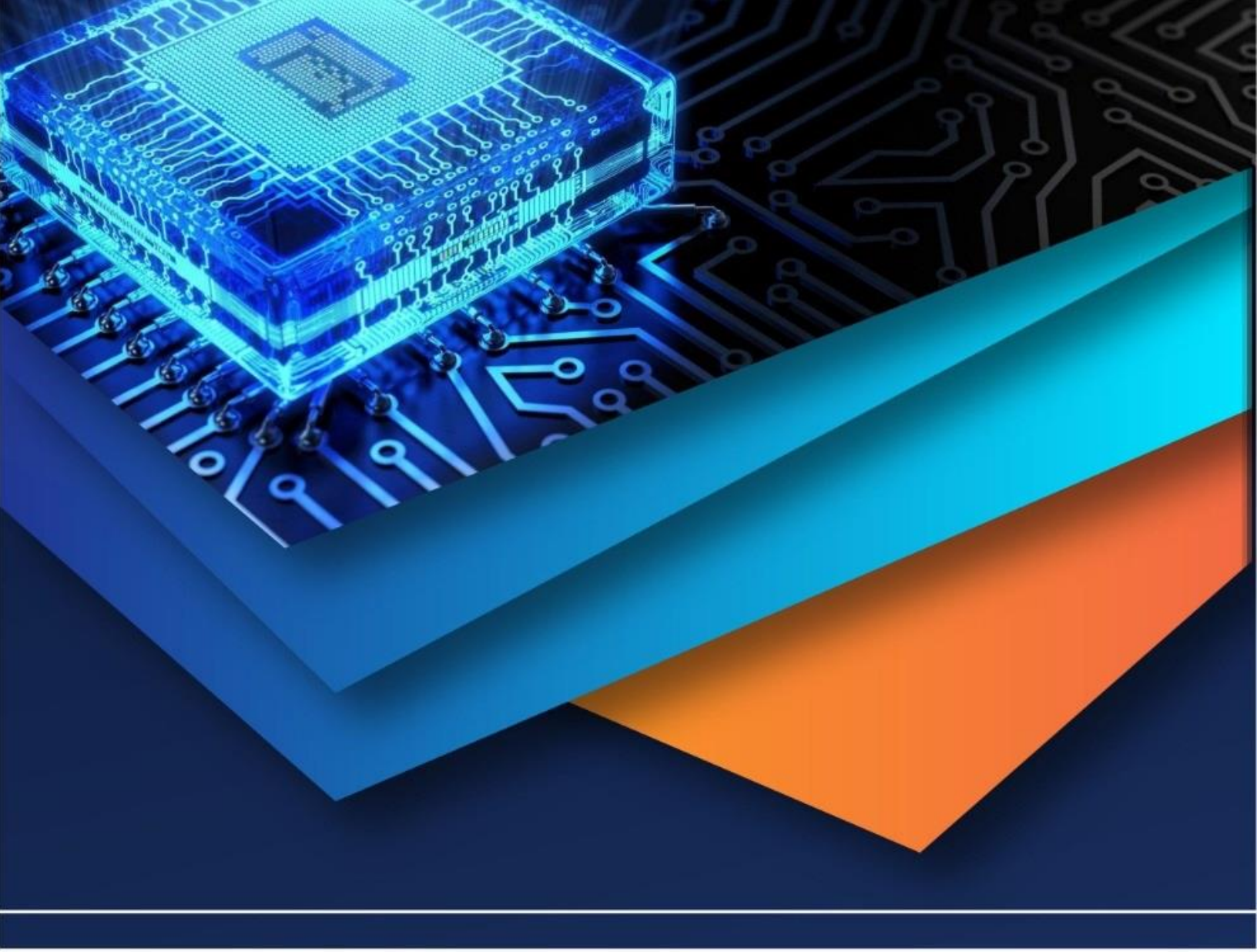
D. Last but not the least the constant of the residuals. It did not show any uniform pattern but always ended near to or above 1*10^6 which is always considered as a reasonable value.

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