KAUNAS UNIVERSITY OF TECHNOLOGY
MECHANICAL ENGINEERING AND DESIGN FACULTY

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RESEARCH ON AERODYNAMIC CHARACTERISTICS OF A SUPER CAR

Master's Degree Final Project

Supervisor
Mantas Felneris

KAUNAS, 2017

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Master's Degree Final Project

Vehicle Engineering (621E20001)

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KAUNAS, 2017

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(Title and code of study programme)

"RESEARCH ON AERODYNAMIC CHARACTERISTICS OF A SUPER CAR"
DECLARATION OF ACADEMIC INTEGRITY

06 June 2017

I confirm that the final project of mine, **Sathyanarayanan Krishnakumar**, on the subject "Research on Aerodynamic Characteristics of a Super Car" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:

Head of Transport Engineering Department	*(Signature, date)*
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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme VEHICLE ENGINERING (621E20001)

1. Title of the Project

Research on Aerodynamic Characteristics of a Super Car

2. Aim of the Project

The aim of the project is to design the splitter in frontal area and insertion of spoiler at the rear end creates downforce. Analyse the design of vehicle with and without spoiler to find the forces acting on the vehicle.

3. Structure of the project

The main task which is handled on designing the spoiler and splitter is given below.

- Select the appropriate vehicle with technical data for considering the road vehicle aerodynamics and to calculate the forces acting on it. Find the suitable design of splitter for the selected vehicle.
- Making the design from 1:24 scale and analysis the car body with road surface in solid works simulation and mark the forces acting on the vehicle. After designing and analysis of splitter does not reduce the drag coefficient and downforce.
- So, propose the idea with spoilers at the rear end with different types of spoilers are based on the study and the dimensions are made as per the standards. Selection of spoilers are made and make simulation to check the forces acting on it.
- Numerical model of the vehicle is calculated, based on the book (Road vehicle aerodynamics**)** [20] and flow and turbulence model calculations are based on the journal [19].
- Compare the numerical results of suitable spoiler with simulation results of drag coefficient which is more suitable for calculation

4. Requirements

5.This task assignment is an integral part of the final project

6.Project submission deadline: 2017 June 6th

Task Assignment received	**Sathyanarayanan Krishnakumar**	________________
	(*Name, Surname of the Student*)	(*Signature, date*)
Supervisor	**Mantas Felneris**	________________
	(*Position, Name, Surname*)	(*Signature, date*)

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Research field and area: Technological Science, Transport Engineering (03T).

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SUMMARY

In this modern world aerodynamics plays vital role in super cars and it predominantly used in motorsports industry for achieving vehilce better performance.This master thesis portrays that can be viewed about the methods of aerodynamic characteristics and why aerodynamics plays a vital role in super cars in efficient way. By installing spoiler,splitter and drag reduction in super cars for achieving better performance of the vehicle. Propose a method of reducing the drag and increase the downforce in efficient way for the better function.As this mainly uses aerodynamic devices to affect the flow, a conventional spoiler is used here to spoil the oncoming flow with different types of spoiler design.Even in today's modern technique all the supercars are not able to reduce the drag in efficient way because of its overall weight of the vehicle.The most essential thing is replacing all the parts of vehilce‘s metal body by current efficient material will put super cars in question mark because it cannot be used for commericial purpose.So here a proposed method is to trim the side body in design and installing wind splitter and spoiler to achieve better performance in similar geometry shape. Nowadays, all the supercars have independent working of front and rear spoilers, but in this thesis splitter and spoiler are coliborated towards each other in efficient way.

KEYWORDS: Supercars, Aerodynamics, Dragforce, Downforce, Aerodynamic Devices, Simulation

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Kaunas 2017 64 p
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SANTRAUKA

Šiuolaikiniame moderniame pasaulyje aerodinamika užima svarbų vaidmenį ypač tarp superautomobilių ir yra itin plačiai naudojama automobilių sporte, norint pasiekti kuo geresnius rezultatus. Šiame darbe yra apžvelgiami metodai aerodinaminėms savybėms tirti, atrenkant efektyviausius aerodinaminio modelio panaudojimo būdus tiriamam automobiliui. Norint pasiekti geresnių rezultatų automobilis buvo tobulinamas sumontuojant oro aptaką ir vėjo nukreipiklį, leidžiantį sumažinti aerodinaminį pasipriešinimą. Buvo pasiūlytas metodas kaip efektyviausiu būdu sumažinti aerodinaminę pasipriešinimo jėgą bei padidinti prispaudimo jėgą. Oro srauto judėjimui pagrindinę įtaką daro tokie aerodinaminiai elementai kaip oro aptakas, kuris darbe buvo projektuojamas ir naudojamas kelių skirtingų formų. Net ir pažangių technologijų pagalba yra gana sudėtinga efektyviai sumažinti aerodinaminį pasipriešinimą superautomobiliuose, dėl jų didelės bendrosios masės. Šią masę būtų galima sumažinti pakeičiant visas kėbulo metalines dalis į kur kas lengvesnes medžiagas, tačiau atsirastų rizika dėl tokių automobilių komercinio panaudojimo. Todėl šiame darbe yra siūloma pagerinti automobilio aerodinamines savybes nepakeičiant automobilio konstrukcijos, įdiegiant oro aptaką ir vėjo nukreipiklį. Šiuolaikiniuose superautomobiliuose priekinis ir galinis oro aptakas veikia nepriklausomai, tačiau šiame darbe šie aerodinaminiai elementai yra susieti tarpusavyje pačiu efektyviausiu būdu.

RAKTINIAI ŽODŽIAI: Superautomobilis, Aerodinamika, Pasipriešinimo jėga, Prispaudimo jėga, Aerodinaminiai elementai.

ACKNOWLEDGEMENT

I take it as a honour to deliver my generous thanks to my much-loved Advisor Prof. **Dr. Arturas Kersys** of Transport Engineering Department**,** for his kind advices and encouragement which allow me to complete my master thesis.

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1.INTRODUCTION

The birth of automobiles goes back to 1886, when Karl Benz invented a 4-cylinder gasoline engine in Germany. This era was started at 20th century, when road vehicles have experienced its safety, speed, and technology. This was because of people who were passionate to build an advanced vehicle which is called performance cars. Currently motorsport has a huge market and it has become one of the most popular sports and it attracts many people. Some of the competitions are based on the super cars such as, GT Racing, European Championship, Tourist Trophy,24 Hours, Lemans Prototype, Supercars Championship, Australian Grand Prix, British grand prix. In all the sports cars, an aerodynamics influence in performance of the vehicle. The aerodynamic components are not only in race cars but also in super cars. One development that seems to very common these days is about producing the down force in the super car using various aerodynamic components. Downforce is defined as the downward vertical load that is produced due to aerodynamic load instead of mass of the vehicle **[1].** According to Arid (1997)," The tire coefficient of friction increases with increase in downforce, which means that lightweight car will be able to accelerate faster in straight as well as lateral direction" **[1].** Aerodynamic devices generate vertical load on the tires with little added mass will provide the tires additional control and stability to speed up the vehicle. The design of the aerodynamic components for super cars is difficult due to the body contact between various segments of the vehicle. The difficulty has been reduced, because start of many innovative tools.

Figure 1. Supercar with spoiler **[2]**

Current development in computational fluid dynamics has allowed the simulation of aerodynamics to exactly assume the downforce, flow structure and other air flow around vehicles **[3].**

This simulation flow patterns and other air around the vehicles. Spoilers is also a component i.e. an aerodynamic device is intended to remove or spoil the unwanted air movement within the moving vehicle. spoilers in super cars is to change the handling characteristics that are affected by the air in the surroundings. To the aerodynamic devices, the simulation tool can significantly decrease the time and cost required. This study focuses on the super cars specially Ferrari 458 Italia and to reduce its drag using the theoretical methods such as analysis over spoilers, designing of splitters and comparing the suitable spoiler's numerical results with simulation results.

1.1 SUPER CARS

A super car is a car that combines the speed, handling, unique design and represents the intelligence of the automakers creativity.it is a car equivalent of a supermodel or a race horse **[25].** There are some criteria to build a super car design, acceleration, top seed, handling, power to weight ratio, style, rarity, price. The term supercars were coined to describe very expensive and extremely beautiful and fast cars. Super cars are not muscle cars or tuned up sports car it may refer to factory built usually unmodified street-legal cars. And, heavily modified and potentially street –illegal vehicles do not come under super cars **[25].**

Figure 2. Modern supercar **[2]**

1.2 HISTORY OF SUPER CARS

Super cars have started to give the impression in the late 40's with the outline of 'sporting' road cars. Therefore, today well-known trademarks of sports cars such as Ferrari, Jaguar, Lotus, and Porsche **[25].** The attitude of the sports car was designed not only for the road but for motorsport race as well. Over the 50's and early 60's sports car performance was developed **[4].**

1954

The entrance of this super car was one of the best distinctive, The **Mercedes 300SL 'Gull Wing'**. It's fuel consumption was about 3 litre produced over 240bhp giving a top speed of 165mph **[4].**

1957

The **Chevrolet Corvette** can influence 60mph in below 6 seconds, however the Z102 from a least popular manufacturer **Pegaso** was alleged to be beneficial for 160mph! Before by the 60's began **Aston Martin and Ferrari** both obtained 150mph plus vehicles in the shape of the **DB4GT Zagato** and **400 Super America** vehicles **[4].**

1961

Jaguar made the world to be speechless with the introduction of the fabulous E-type cars. By that, Ferrari then produced a minimum number of cars, which is now the world's most appreciated model, the endless 160mph 250 GTO **[4].**

1964

At that point derives **The Lamborghini** which arrived the dispute with the 350GT, joined by **Iso** with the **Grifo** and **TVR** with the creative **Griffith**. But at that time, it was to be **Ford** who would altered the appearance of sport cars with what many people came to believe the first supercars is the GT40. **AC Cobra 4271965** saw one more aspirant for the title world's first supercar, the brutal AC Cobra 427. American racer Carol Shelby determined to shoe-horn a 427 cu in (Ford V8 into a lightweight British sports car, the AC Ace. The outcome was a car of astonishing performance -160mph, 0-60mph in 4.2 sec and 0-100mph in 10 (records acceleration figures that would stand for over 20 years) **[4].**

1966:

In this year, there were many introductions of super cars such as the, 165mph Ferrari 275GTB, the 7 litre Corvette Sting Ray and the first 4-wheel drive road car, the Jensen FF. However, to move further of these cars there comes the first true supercar made for the road, **the attractive Lamborghini Miura**. The Miura was the one for the first production car to feature a mid-mounted engine and so its appearance was radically different to any road, then the car that had come before **[4].**

Performance from the **V12** was equally radical, over 170mph was possible for those brave enough to face these cars. After the launch of miura, a few months later **Maserati** introduced the **Ghibli**.

More Gran Turismo that supercar, it had more advantage such as, the Ghibli offered 160mph performance but also coupled with a luxurious environment (it even had air con, rare at the time). And in the same year they introduced another **Giugiaro** styled Italian supercar, the **De Tomaso Mangusta** along with the Swiss made Monteverdi 375**[4].**

1971

Four years later the **Mangusta**, **De Tomaso** commenced which was to be the prime selling car yet, **the Pantera**. Its outline was focused Italian body housed the global **Ford V8**. The Pantera look like the 'wedge' style that was to become the trademark look of the supercar throughout the 70's, bought to the fore by leading stylists such as Bertone's Gandini and Ital Design's Giugiaro and echoed in the Maserati Bora **[4].**

1975

A few years later the summary of the creative **Porsche 911 Turbo** came into existence. Even though **BMW** have assumed us the first Turbo road car two years past with the 2002, it was Porsche who would become known for ground-breaking the technology. The 12-year-old design of the 911 was increased in the turbo using aerodynamic spoilers, the first road car to feature these now common styling features **[4].**

1980

Although maximum speed was good at around 150mph Lotus' entry into the premier league with the Turbo Esprit. it was with an acceleration and behaviour has defined it as a supercar. The early 80's also saw one of the trendiest cars ever to come out of Britain, the outrageous 192mph **Aston Martin Bulldog**. Even though only one was ever made, for its appearances and performance alone it deserves its place in supercar history. The mid 80's also saw new participants for the ongoing battle for authority between Ferrari and Lamborghini with the starting of 180mph **Testarossa** and the 455bhp improvement of the **Lamborghini Countach QV [4].**

1980's

The 80's, would be evoked for two things nevertheless - the economic affluent that sent elite car values soaring and, probably because of this, the birth of the hyper car. It all started with the development of the Group B racing class. To be eligible to compete, manufacturers had to produce at least 200 road going version of their competition cars. While short lived, it may have been, Group B provided us with a selection of awesome road cars **[4].**

2000 – present

The word supercar in future came to be known as GT or GRAND TOURING a type of car, with numerous outline of super cars.

1.3 USAGE OF SUPER CARS

GT competition

Super cars have some relatively performance restrictions. The crew must be comprising completely with a dynamic employee (including drivers) which places apparent limitations on accessible work hours, skill sets, experience, and presents sole challenges that professional race teams do not face with a paid, skilful staff. Comparing to skilled series of races with other series of races, professional series of races has more restrictions in regulation. proficient engineers are allotted to provide a guidance and blame the workers; however, employees create the car design by them. workers are also uniquely reliable for increasing funds, however most successful teams are based on curricular plans and have university-sponsored funds. The multiple strategies lead to success when the points system is structured. This leads to an extreme change between cars, and it makes more curiosity in the world of motorsports.

1.4. STATE OF ART IN SUPER CARS

Here it deals with classification of things to be considered for the supercars in motorsports.

1.4.1 IMPORTANTANCE OF AERODYNAMICS

GT cars distinguish themselves from other cars by being sports cars. Supercars models dependent on power and level of alteration are specified for GT cars. Sports car manufactures such as, ASTON MARTIN, PORSCHE NISSAN, AUDI, MASERATI, MCLAREN BMW, MASERATI, MACLAREN CHEVROLET, FERRARI, FORD, GINETTA, JAGUAR, LAMBORHINI, comes under this series.GT cars needs an innovative knowledge of all aspects of a vehicle such as handling, chassis, suspension, powertrain, aerodynamic and safety.

1.4.2 SUSPENSION

- Maximum track width
- Minimum un sprung weight
- Maximum tire contact patch and grip

- Increase the brake power(stop)
- Minimize the drive height
- Suitable springs, anti-roll bars and damping to achieve weight shifting and support the tires to track the surface of the road enhanced.

1.4.3 CHASSIS

In GT cars, mostly depends on the category, the production chassis may be altered to improve the torsional rigidity, reduce the weight of the vehicle, and enhance the safety.

1.4.4 POWERTRAIN

This includes extensive changes to engine components and driveline components. The main aim is to increase the horsepower and engine efficiency. This reduces combustion friction and removing power robbing accessories

1.4.5 AERODYNAMICS OF SUPER CAR

Aerodynamics maybe increases due to additional devices and mostly they are dependent on aero devices and bodyworks. Precedence of reducing the drag in Frontal area does not affect the production of vehicle. Aero devices are predominantly depending on Diffuser, underbody, spoilers, air splitter, etc. and they are designed by the rules and regulations.

1.5. PROBLEM DEFINITION

The chosen model of a super car has good aerodynamic design but we can consider the selected car for the commercial uses not for racing purposes. once the car has been participated in GT-2 racing and it was impressed on those days after that it lacks due to high speeds and metal body (**Aluminium, monocoque**).so the purpose of my study is to propose a material (**carbon-fibre**) but my aim is to concentrate on design of car and reduce the drag by proposing aerodynamic device not materials. Design variation and insertion of spoiler into the vehicle design makes the vehicle to achieve better performance.

2. LITERATURE REVIEW

Table 1 Previous Research Attempted

TITLE	EQUATION/ METHOD	DESCRIPTION
Description of flow fields in the wheelhouse of cars [5]	Reason of flow model. Characteristics of flow fields in the wheels Find the aerodynamics forces	Changing the geometric shape of rear spoilers, and mud flap behind the rear wheel.
Computational study of flow around a simplified car [6]	Flow solver Grid description Numerical results Results	The larger slant angle and computations with or without the stilts on which the body was supported in the wind tunnel give comparable results. The drag is increased due to the presence of the stilts. All turbulence models predict the topology of the flow correctly. The EASM model gives a better estimate of the drag **[6].**
The effect of vehicle spacing on the aerodynamics of a representative car shape [7]	Vehicle drag Selection of test models Experimental analysis Results	The lateral and longitudinal positioning of cars are relative to each other and the nature and relative direction of the atmospheric wind. To restrict the number of variables, the investigation is limited to a wind-tunnel simulation of a representative car geometry is

		in calm conditions and vehicles that are directly aligned **[7].**
CFD section characteristics of Formula Mazda race car wings [8]	Physical model of wings Computer model Analysis of wings results	The calculated results show the increase in force when the front air foils are considered with the flow effect. These results indicate, for design purposes, consideration of the front air foil should be taken with the effect of the ground for the proper overall consideration of the stability and handling of the Mazda race car. The values, along with experimental validation and an overall analysis of enhance the optimum handling of these vehicles **[8].**
3D viscous flow analysis on wing body aileron spoiler configurations [9]	Grid generation Numerical methods Results	Several investigations have been performed concerning aileron side gap representation, deflection of spoilers and ailerons, overall incidence of the configurations and Reynolds number effect. However, strong local effects in the gap vicinity and along the vortex cores arising from the aileron side gaps which, made the modelled gap approach essential for precise

		quantitative and qualitative assessments **[9].**
Effect of differential spoiler settings (DSS) on the wake vortices of a wing at high-lift-configuration (HLC) [10]	Experimental setup Twisting of the vortex Modification of span Effects of loading wing load distribution	A half aircraft model equipped with high lift devices was tested in a low speed wind tunnel facility. The highly oscillatory turbulent spoiler results in increase of meandering amplitude of the flap tip vortex. It reaches 2.17 times the flap tip vortex core radius; consequently **[10].**
Numerical Study of Aerodynamic Drag Reduction of Racing Cars [11]	Numerical Method Velocity on Drag Force Underbody Modification Exhaust Gas Redirection	Flow separation is responsible for the major portion of aerodynamic drag of racing cars. The aerodynamic drag coefficient is 0.3233. It was mainly designed consideration to reduce the drag of any bluff should be- keep the flow attached to the body. Aerodynamic drag reduction by rear under body modification results in up to 22.13 % and diffuser results 9.5 % reduction of drag coefficient. About 3.3% drag coefficient can be reduced by this procedure with ideal exhaust gas composition **[11].**

A study on aerodynamic drag of a semi-trailer truck [12]	Experimental methods Design modifications Wind tunnel testing	The aerodynamic fairings have notable impact on aerodynamic drag. The front fairing alone can reduce around 17 % of drag. Further drag reduction up to 26 % is probable using various combinations of aerodynamics. Therefore, the semi-trailer truck with maximum amount of surface area covered can enhance the drag reduction performance **[12].**
Aerodynamic study of formula sae car [13]	Numerical calculations Design modifications CFD simulation Results with contours	To increase the aerodynamic performance of race car, an attempt is made to modify the design of a Formula SAE car. Comparative study is done on three car models by carrying out CFD simulations. Cutting out the section of wall and providing wing at front end. The pressure at wall found to be reduced due to providing space to flow the air through cut out section, where flow remains attached and helps to decrease the drag. Thus, overall pressure near the driver head region is reduced from 340 Pa to 80 Pa. for the modified car with front wing **[13].**

Computational study of aero-acoustics analysis of a passenger car with a rear spoiler [14]	Governing equations numerical methods Design of spoiler CFD analysis Results	This approach is suitable for applications involving noise generation from dipole acoustic sources due to the pressure fluctuation of subsonic incompressible flows. The installation of a spoiler reduces the lift coefficient that leads to better conditions for high speed driving and improves the vertical stability of driving. These two spoiler configurations produce more significant velocity gradient and thus higher level of disordered flow **[14].**
Experimental and numerical analysis of the external aerodynamics-formula SAE racing car [15]	Experimental setup of wind tunnel Numerical setup Code validation CFD analysis	Every race car's downforce and drag have been reduced with the respective analysis.

Based on the research conclusions of literature survey are made, aerodynamics is heart of vehicle for the performance of achieving high speed, tuning fuel efficiency, stability, cooling, visibility, and more grip on tires.

Road vehicle aerodynamics is very important in this modern world because, vehicles does not provide stable speeds, while achieving high speeds they don't have stability of control and burn more fuel due to poor aerodynamic design. The poor aerodynamic design affects the overall resistance of the car in motion from lower speeds to high speeds. Fast moving vehicles would not be fast with poor aerodynamic design. Thus, the good aerodynamic design provides vehicle better performance.so, this shows how aerodynamics are important to road vehicles and used to save fuel and achieve better speeds with high performance of the vehicle.

Aerodynamic calculation and alteration is an endless method. An integral part of Motorsport engineering, in initial stage where design is not limited to the vehicle. Regular analysis and valuation tools are used in this method can includes wind tunnel testing, computational estimation, or track testing. Each of these approaches may be more appropriate for a specific need (for example, a wind tunnel or an experimental model can be used through the early design stage, previous stage in the vehicle being built. Once a vehicle exists, it can be measured and tested on the track.

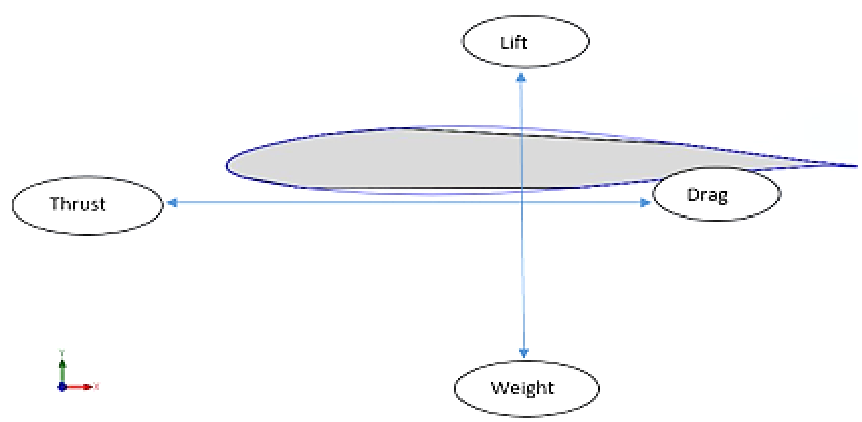


Figure 3 Aerodynamic Forces on Air Foil

The above-mentioned diagram portrays that possible aerodynamic forces of the air foil which is described fully in theoretical structure of the study.

3.THEORETICAL BACKGROUND

Aerodynamic drag reduction is based on the shape of the car and installing various aerodynamic devices into the vehicle to reduce the lift coefficient of the vehicle. Because lift and drag impacts more in the vehicle so reducing drag force by proposing a method in altering the values or main setup in experimental, numerical, simulation. Always drag acts in opposite direction of a moving vehicle and it pull the vehicle backwards at that moment it consumes more fuel and high speed is not achievable.

3.1 AERODYNAMICS FORCES:

"Aerodynamics is the study of motion of air or other gases particularly its contact with a solid object, such as an airplane wing" [16]. it is a part of aeromechanics that contracts with the force (resistance, pressure, etc..) makes use of air or other gases in motion. An example for aerodynamics is to regulate the probable speed of a vehicle, based on the method its shape will move through the air. when things move through the air, forces are produced by the relative motion between the air and surface of the body, the study of all these forces is called aerodynamics. There are four kinds of forces act upon a body [22].

3.1.1 LIFT

Lift is the force produced by the contact between the wings and the airflow. It continuously acts upwards and considered to be the most significant force, without lifting of vehicle it cannot fly from the ground and maintain its height.

- According to road vehicle aerodynamics, should minimize the lift as much as possible.
- Lift acts through the longitudinal axis with single point called pressure centre.
- Here Lift should not exceed the weight of vehicles.

3.1.2 DOWNFORCE

Downforce defines the down pressure created by the aerodynamic features of vehicle that permits it to moves faster through a corner with more grips. Thus, holding the track or road surface of a vehicle and improves the stability. Some parts increase the vehicle downforce and increase the drag every object moves with lift or downforce

3.1.3 DRAG

The drag will act in the lateral axis of the vehicle and it will pull the vehicle or create resistance through air medium and it will reduce the fuel economy and minimize the speed of the vehicle. Drag includes largely, three forces

- In frontal area, the vehicle produces the high pressure drives the air outwards.
- The effects produced by the air in the vehicle rear body is not capable to fill the hole.
- Air velocity with slow moving air effects the Boundary layer at the surface of the vehicle body.

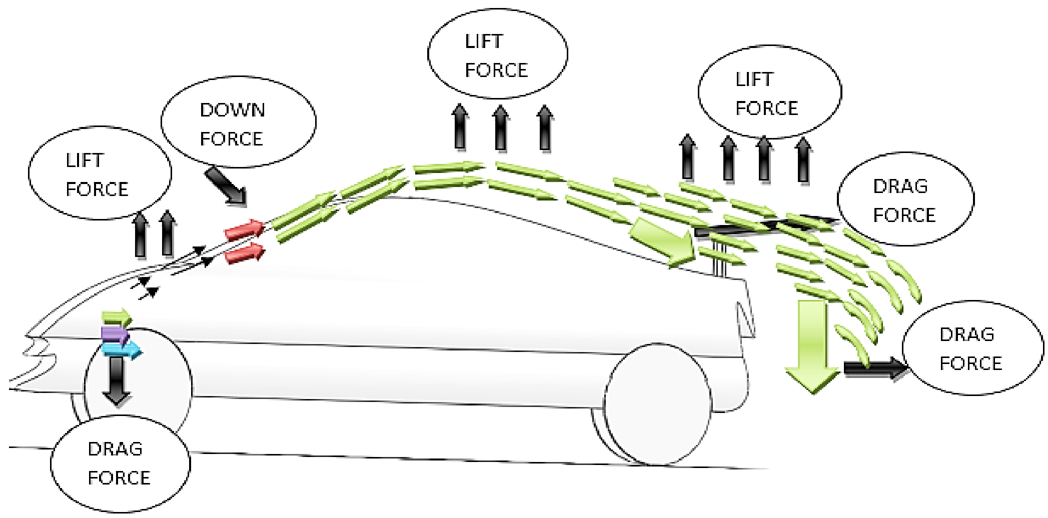


Figure 4 Forces Acting on The Vehicle

Causes of drag forces in vehicle

The drag forces in vehicle causes due to poor aerodynamic design, shape of the vehicle, due to more weight of the vehicle and more lift forces makes the vehicle lift in the frontal area.

3.1.4 LIFT AND DRAG RATIO

The prompt ratio of lift to drag of an aerodynamic object such as a wing or an entire aircraft

3.1.5 FRONTAL PRESSURE

The air produces frontal pressure, i.e. lots of air particles methods in front of the car, they started to compress the high air pressure in front of the car. Simultaneously the air particles in the side, lower the pressure compared to particles in the front of the car.

3.1.6 REAR VACCUM

Air resistance passes through the vehicle in lateral axis, at that time it produces the Rear vacuum due to hole. The lack of ability to fulfil the hole created by the vehicle passes left by the car is mechanically called as Flow Detachment. Hence, the force produced by the rear vacuum surpasses that created the high pressure in frontal area, so it is suitable to minimize the ratio of vacuum produced at the rear body.

3.2 METHODS FOR AERODYNAMIC CHARACTERISTICS

There are various approaches to minimize the air resistance and increase the downforce in road vehicles of aerodynamics.

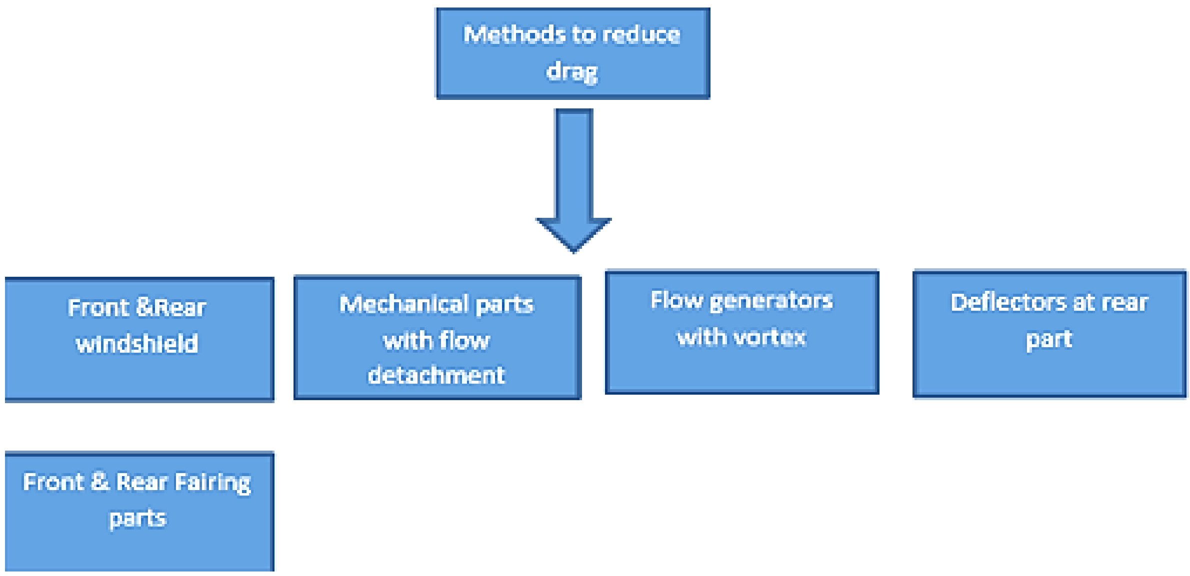


Figure 5 Approaches to Reduce Drag

3.2.1 WINDSHIELD

Wind shield generates more pressure, generally it helps to prevent from the wind. This is mainly used is motorsports to reduce drag and it acts to safeguard the from the wind. High pressure is created in frontal area of the car and it has two types of wind shields are Front & rear windshield

3.2.2 FLOW DETACHMENT WITH MECHANICAL PARTS

Flow detachment is the process to separate the flow from vehicle body and it recirculates in the centre of the vehicle with mechanical parts. The boundary layer moves fast against pressure gradient where velocity of boundary layer is zero when flow separation occurs. The flow is separated from the surface not with eddies and vortex. The vehicles work lower than distinctive speeds, air flow rate, direction of air, condition of road. Not at all other streamline body will reduce the drag for all conditions. Therefore, there is essential to improve the submissive devices that will keep drag coefficient small for high range of conditions or dynamic approaches that can actively alter the configuration to encounter different speeds.

3.2.3 FLOW STRUCTURE

Considering the road vehicle aerodynamics, vehicle cannot operate at low speeds without wind, so air plays key role in vehicle aerodynamics. At top speed **air resistance** (drag) has a fabulous result on the method the vehicle accelerates that manage and attains the fuel mileage, here comes the science of aerodynamics. Engineers have established many ways of applying this method to reality.

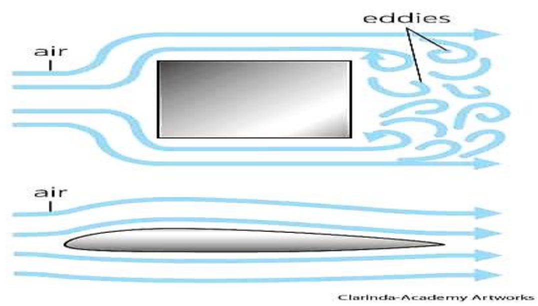


Figure 6 Air Flow Structure **[17]**

For example, Flow field around with low drag is achievable, when the vehicle can travel through air with Circular design and shapes on outer surface of the vehicle body. The underbody of the car is flat round shape due to high performance of the car parts, which may involve the **spoiler** also known as rear wing which prevent the air from lifting the vehicle wheel and making it unbalanced at top speed. The general science of aerodynamics based on the **DRAG,** because it has absolute results on acceleration. Air resistance is produced inside the solid substances and travels through fluid medium, and the drag increases with velocity when it travels faster. The air resistance can be calculated using **wind tunnels OR CFD Analysis by any commercial packages (Ansys, solid works simulation etc.,).** wind tunnel is an enormous tube with rotating blades that generate airflow above an object inward. Altering the road conditions influences air resistance in the wind tunnel and it is determined that use of flat steady shield gives good outcome for relative tests. The rearmost part of the vehicles make great influence on the overall drag and other forms of vehicle rear parts.

3.2.4 SPOILERS

Spoilers is defined as an aerodynamic device is to minimize the lift and improve the downforce with stability. Installing the spoiler will increase the downforce as well as drag force, so selecting the spoiler is based on the conditions and circumstances of the vehicle and track circuit.

Spoilers acts as an obstacle to spoil the oncoming air flow, to create the high air pressure in front face of the spoiler. Thereby, higher pressure will act above the deck to deliver downforce.

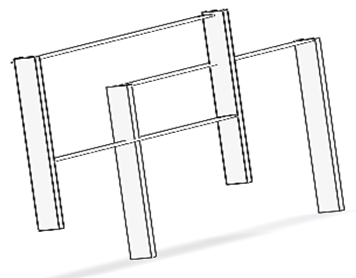


Figure 7 Spoilers

3.2.5 WINGS

The most essential part of aerodynamics is wings and it can produce more downforce in vehicle aerodynamics for a low portion in drag. spoilers are not effective because mostly they are used in sedans, while wings are less effective. “According to Bernoulli’s principle, the higher volume of air pressure to lower volume of the air pressure to speed up the air flow” [18].

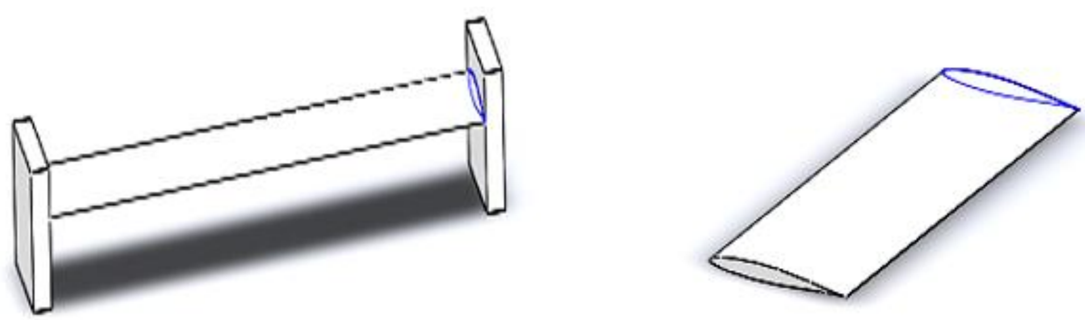


Figure 8 Wings Without & With Endplates

The air molecules travel from leading edge to trailing edge according to Bernoulli’s Principle and the extended underbody needs extra air flow on the side to travel at top speed than the lower side of the upper wing.

The wings with high pressure exists on top of the wings and low pressure acts downwards is also indicated in above mentioned diagram.

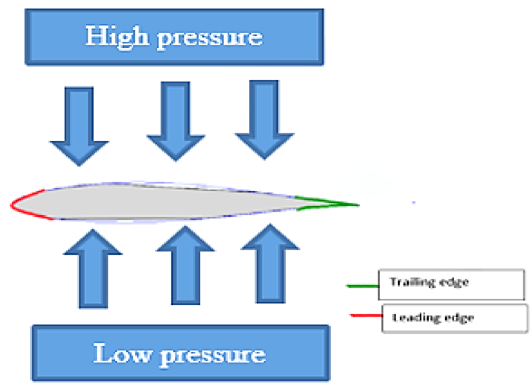


Figure 9 Wings with Pressure Indicated

3.2.6 DIFFUSER

A diffuser is related to the venturi tunnel, it creates the curve like structure in underneath of the wings, under the low-pressure zone of the wings and it produces the downforce. Diffuser and venturi tubes regular the low-pressure zone after the vehicle and occasionally influence the top speed to use the exhaust gases expelled into the diffuser to produce even more lower pressure.

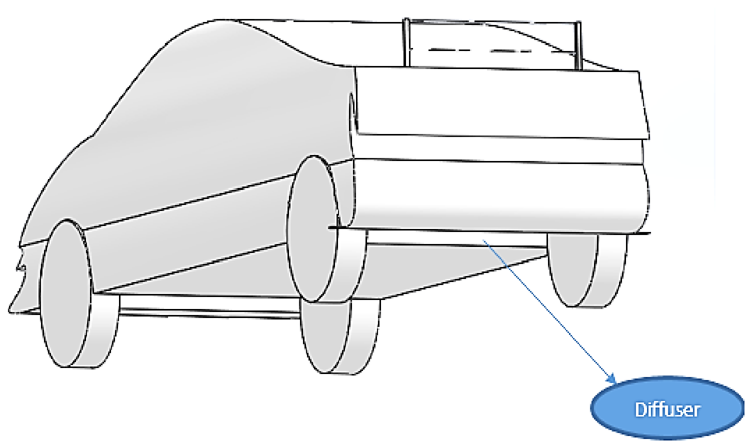


Figure 9 Diffuser

This clearly states that diffuser forces the airflow velocity in underbody and it decreases the pressure with increasing velocity and it produces the stability in control

4.RESEARCH METHODOLOGY:

According to the study, it is found that by altering the frontal area and reducing the drag coefficient are the most preferred methods carried out. The methods which are followed in the Previous research are

- Governing equations
- Numerical methods
- Proposed design
- CFD Analysis
- Experimental methods
- Results
- Comparison of both results
- Conclusions

4.1 PROPOSED METHODS FOR REDUCING THE DRAG COEFFICIENT:

The aim of the research is find out the drag coefficient and increase the downforce by designing the splitter & spoiler and simulation and analytical methods.

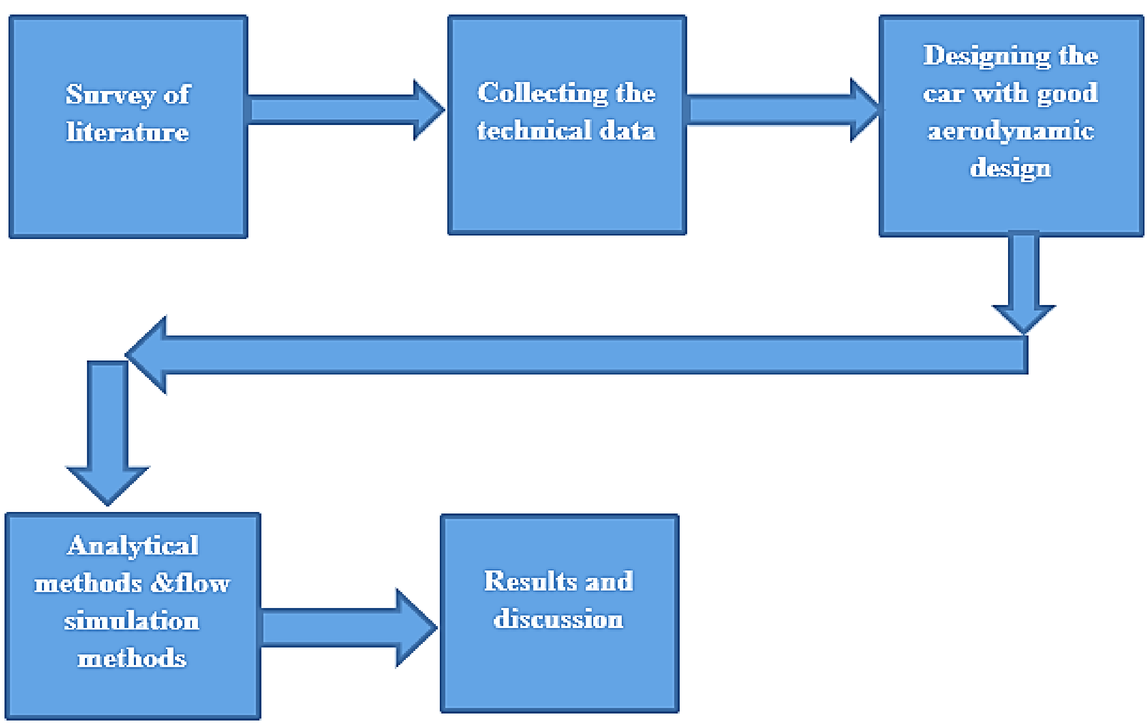


Figure 10 Proposed Methods of Research

4.2 TECHNICAL SPECIFICATION:

Collecting the technical data for similar types cars and choosing the suitable vehicle for your research methodology. The below mentioned table shows the comparison of similar technical data.

Table 2 Technical Specifications of Vehicle [19]

NAME	FERRAI 458 ITALIA	PORCHE 911	ASTON MARTIN VANQUISH	PAGANI ZONDA
LENGTH	4527mm	4499mm	186.1in	4605mm
WIDTH	1937mm	1808mm	75.3in	2036mm
HEIGHT	1213mm	1294mm	50.9in	1169mm
CURB WEIGHT	1380Kg		38833kg	1250kg
ENGINEDISPLACEMENT	4497cm³	2981cm³		
WHEELBASE	2650mm	2450mm	107.9	2795mm
TORQUE	540Nm/6000rpm	450Nm	465Nm	570Nm
POWER	570hp/9000rpm	272kW(370hp)	568hp	5200rpm
ACCELERATION	3.4sec	4.6sec		
ENGINE	4.5 v8(570hp)		6.0LV12	
WHEELRIM SIZE	8.5J*20;10.5J*20			

Based on the possible technical specifications of vehicle is mentioned above. Reference model dimensions for the FERRARI 458 ITALIA is chosen from the table, because it has more drag coefficient compared to other models and it is scaled due to further analysis of the model. This study is to reduce the drag coefficient for the scaled model not to real model so it will vary with the real vehicle for the analysis. After the technical analysis, initial step of the project design is to frame the dimensions for scaled model. scaled modelled ratio is 1:24 with dimensions.

4.3 DESIGN

- Altering frontal area by designing and installing wind splitter
- Propose an aerodynamic device called spoiler to install into the vehicle to spoil the oncoming flow

4.3.1 DIMENSIONS OF REFERENCE MODEL

The model is taken for shape of car to be design in the further process.

Length = 4527 mm

Width = 1937 mm

Height = 1213 mm

Wheelbase = 2650 mm

Curb Weight = 1565 kg [19]

Figure 11 Ferrari 458 Italia [20]

4.3.2 SCALED MODEL

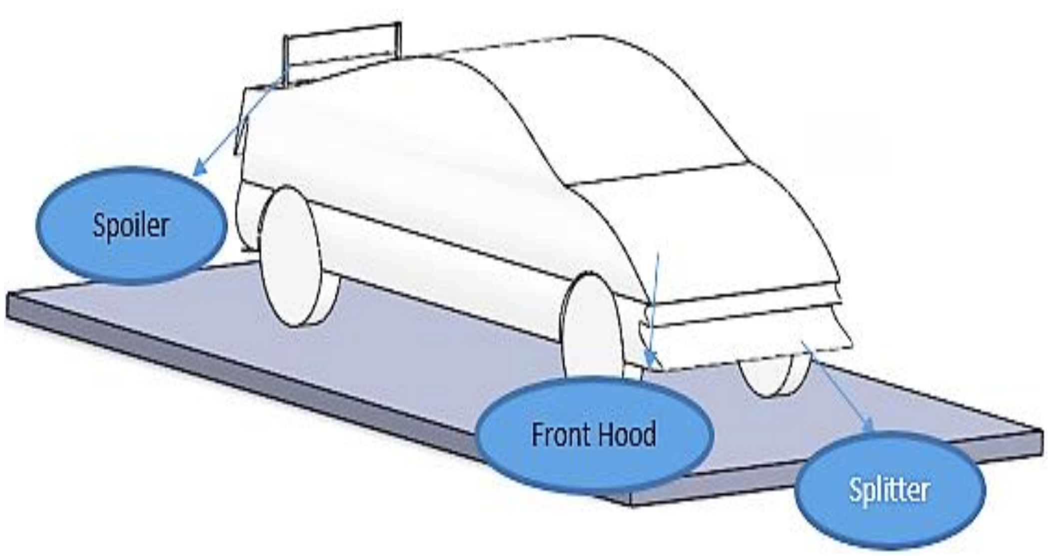


Figure 12 Proposed System of a Project

Length = 188.25 mm

Width = 80.70 mm

Height = 50.5 mm

Wheelbase = 110.41 mm

Here the Ferrari dimensions are taken for the design but it is not fully focused on the Ferrari cars and model is scaled due to experimental analysis in the future process.

4.3.4 DESIGN

The model is designed in solid works according to the dimensions and here its shape and some design alterations are made to reduce the drag coefficient of car.

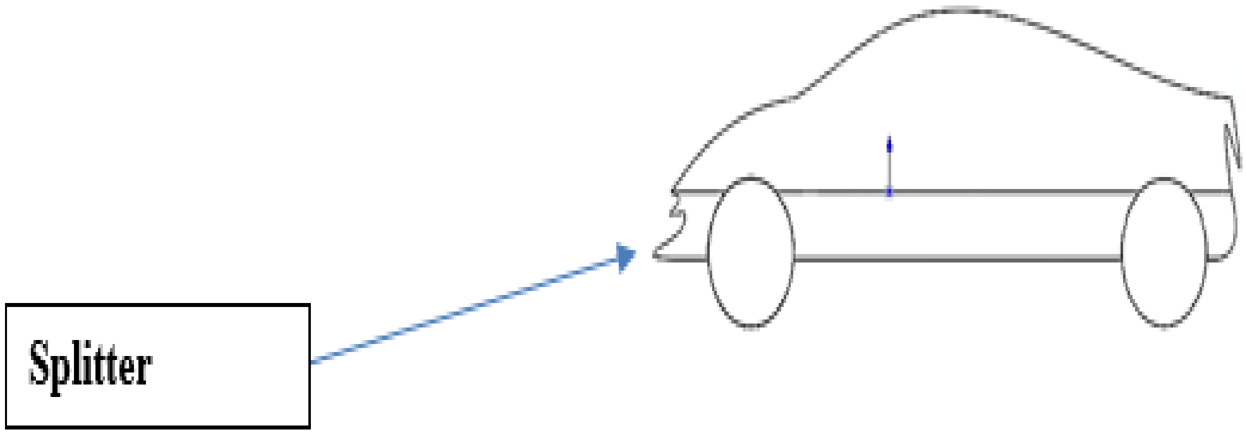


Figure 13 Design of Proposed Model

Drag affects mostly in frontal area of the car so to reduce that altered the design and insert the wind splitter in the front side of car

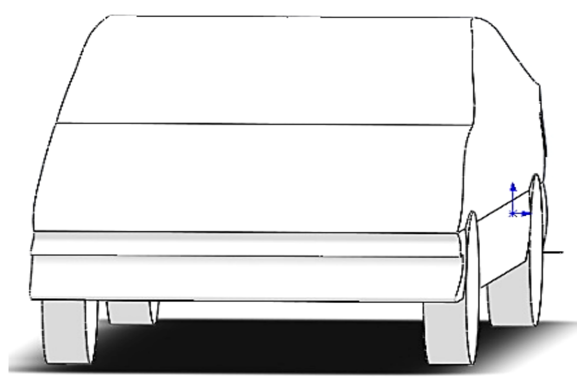


Figure 14 Front View of the proposed model

4.3.5 DESIGN OF SPOILER

The design of spoiler is based on the standards and types are based on the previous research attempted. To install the spoiler in the vehicle to spoil the oncoming flow and to generate the downforce. There two criteria to design the spoiler.

- **Air foil shape**
- **Elevated angle**

AIR FOILS

Air foils can be explained as the outline of the wings in a cross sections **[21]** Here the following air foil shape is chosen for the design because it is more compatible for race cars.

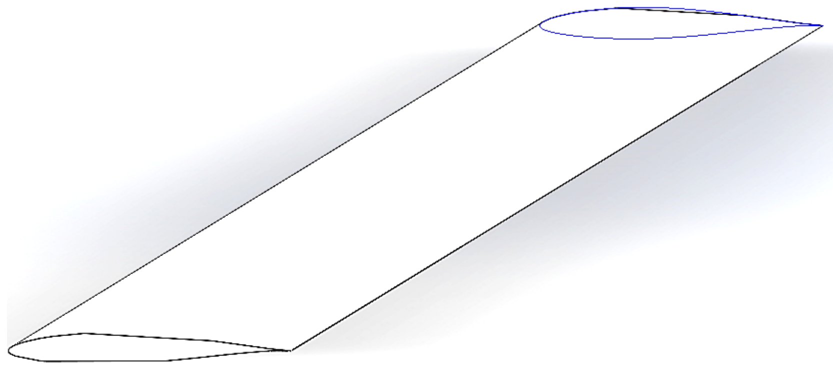


Figure 15 Naca 63212 Air foil

Air foils can be described in following terms

- The chamber line is drawn in centre among the higher and lower surface.
- The predominant technique of frontward and backward of camber line are leading and trailing edge
- The chord line is drawn between leading and trailing edge and the line measured along the length is known as chord length
- The distance between higher and lower camber surface is known as thickness

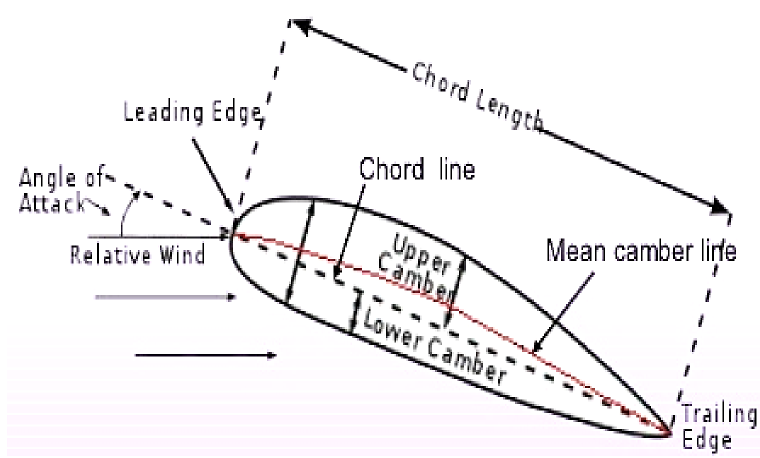


Figure 16 Detailed View of Air foil [21]

The figure 16 represents detailed view of air foil with camber line and chord length are the key factors of air foil measurements.

This diagram shows that trailing edge and leading edge of the air foil shape. According to flight aerodynamics leading edge contacts the air first and separates the flow.

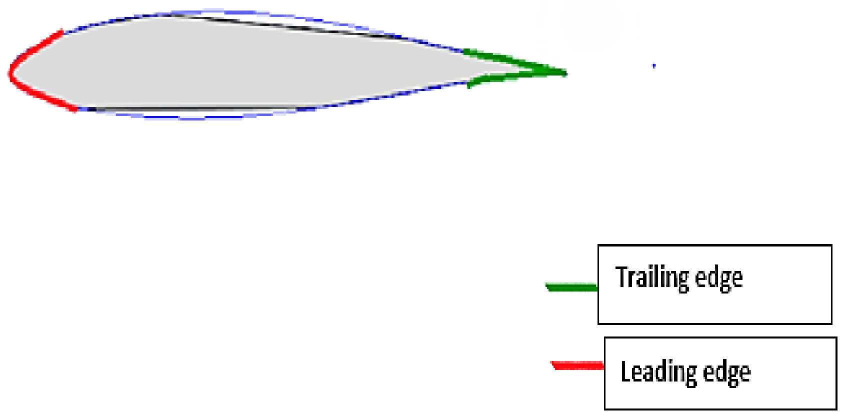


Figure 17 Leading & Trailing Edge

Henceforth reverse engineering concepts in motorsports industry is implemented as trailing contact first to generate downforce and acts in the vertical direction.

4.4 TYPES OF SPOILERS

Here spoiler design is based on the above-mentioned journal [14] designs with slightly altered design based on reverse engineering methods. Flaps are designed to generate the flow and it is designed with rigid and flexible flaps depends on the circumstances. Here the rigid flaps are chosen with elevation for without contacting the vehicle body.

- **Case 1 single flap with elevation**
- **Case 2 Two flaps with elevation**
- **Case 3 Down flap tilted with elevation**
- **Case 4 Top flap tilted with elevation**

The design of spoiler is made in the solid works commercial packages and finally it is assembled with the fastback geometry in rear end of the vehicle.

Case 1

The single flap with elevation has only one flap with elevated angle and this design is based on reverse engineering concepts to generate the downforce**.**

Figure 18 Single Flap with Elevation

Case 2

The design of double plate has two flaps with elevation and causes more effect in the design when compared to double plate spoiler.

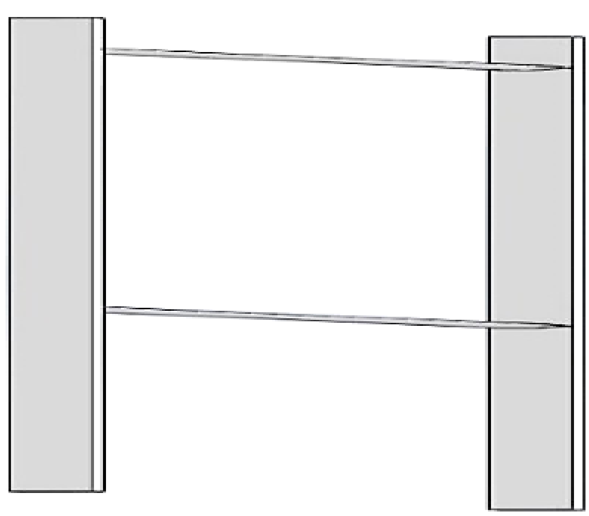


Figure 19 Two Flap with Elevation

Case 3

The down flap is tilted front with reverse engineering concepts because trailing edge contact here first to generate the downforce and reduce the lift force

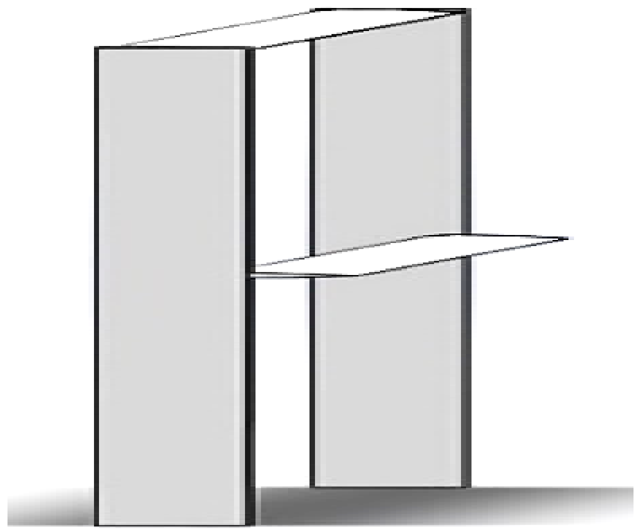


Figure 20 Down Flap Titled with Elevation

Case 4

The top flap is tilted front with reverse engineering concepts because trailing edge contact here first to generate the downforce and reduce the lift force

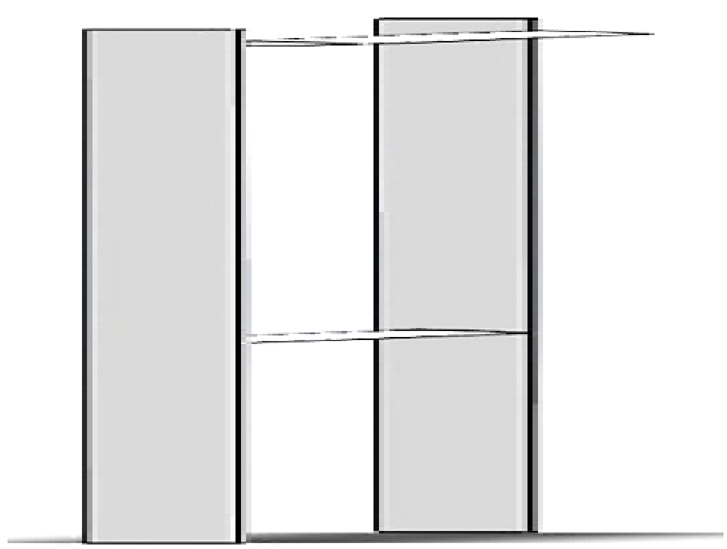


Figure 21 Top Flap Titled with Elevation

ASSEMBLY 1

Here the assembly of spoiler and the car is done for single plate with elevation for the further process. The spoiler is fitted at the rear end of the vehicle at the vehicle.

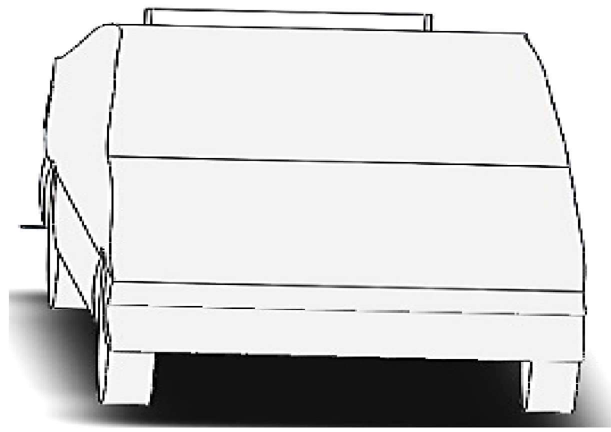


Figure 22 Single Flap with Car

ASSEMBLY 2

Here the assembly of spoiler and the car is done for double plate with elevation for the further process. The spoiler is fitted at the rear end of the vehicle at the vehicle.

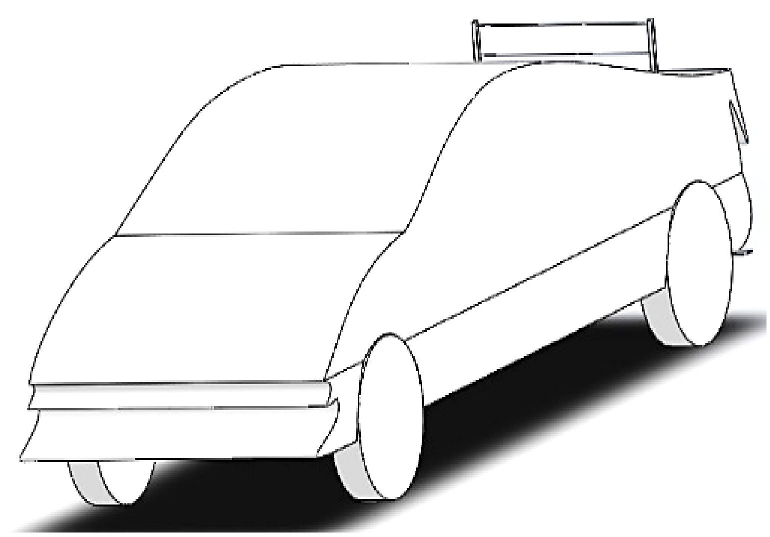


Figure 23 Double Flap with Car

ASSEMBLY 3

Here the assembly of spoiler and the car is done for down flap is tilted with elevation frontwards to reduce the lift for the further process. The spoiler is fitted at the rear end of the vehicle at the vehicle.

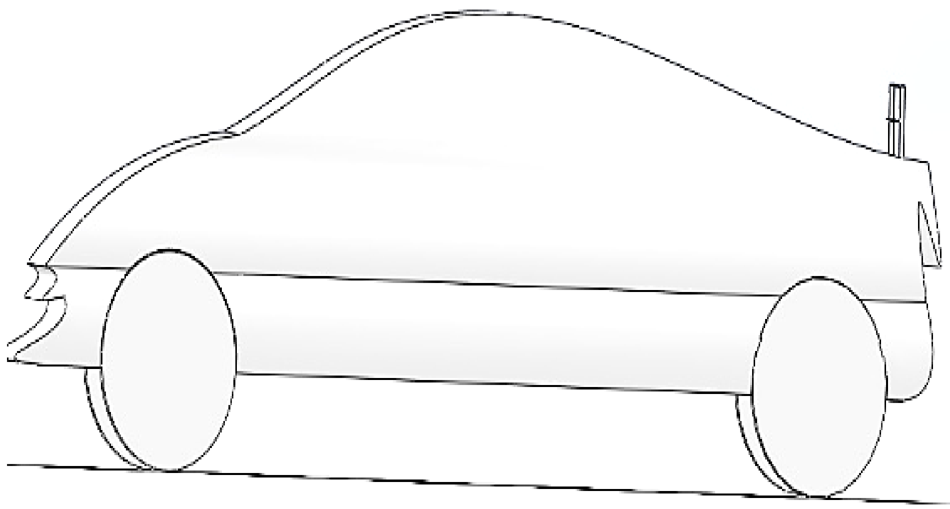


Figure 24 Down Flap Titled with Elevation

ASSEMBLY 4

Here the assembly of spoiler and the car is done for down flap is tilted with elevation frontwards to reduce the lift for the further process. The spoiler is fitted at the rear end of the vehicle at the vehicle.

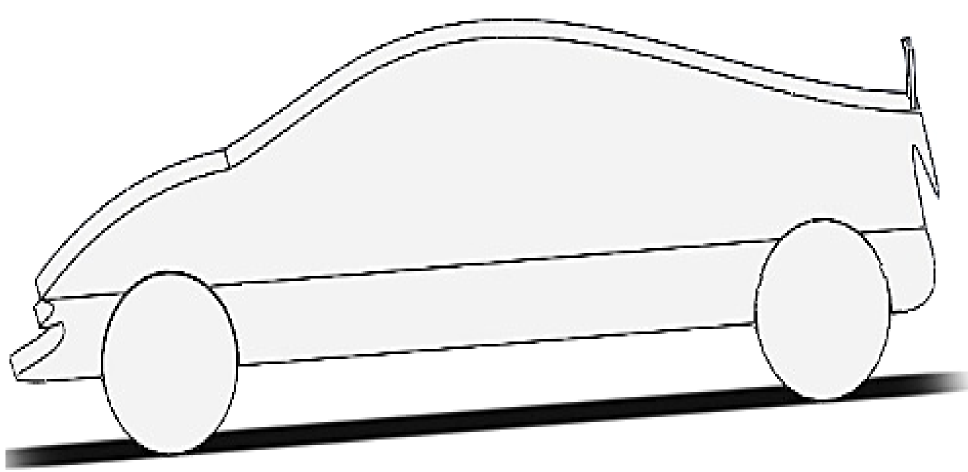


Figure 25 Down Flap Titled with Elevation

5. CALCULATIONS

5.1 GOVERNING EQUATION

The flow field around a super car with exterior flow can be laminar or turbulent and it mostly depends on speed of the car **[14].** Meanwhile this study examines the design characteristics of the car, when the car travels at different speeds with increasing Reynolds numbers. Here compute the set of equations for the flow in the form of continuity equation **[14].**

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_a)}{\partial x_a} = 0; \; a = 1, 2, 3; \qquad (5.1)$$

Where, ρa= air density

T= Time

X_a= coordinate

U_a= velocity component

5.1.1 NAVIER STROKE EQUATION

$$\frac{\partial(\rho u_a)}{\partial t} + u\frac{\partial(\rho u_a)}{\partial x_b} = -\frac{\partial p}{\partial x_b} + \frac{\partial}{\partial x_b}\left(\mu\frac{\partial u_a}{\partial x_b}\right) + \rho F_a \; ; \; a = 1,2,3; \; b = 1,2,3; \qquad (5.2)$$

Where, p= pressure

μ_{v} =effective dynamic viscosity

F_a= force per unit mass

5.1.2 K-∈ TURBULENCE MODEL

Generally, the predominant method to use the turbulence modelling methods to be more accurate. In fact, the advantage of these models not only dependent on problem nature and simulation but also the experience of CFD analysis **[14].** The study based on K-E turbulence models to compute the aerodynamics features of the vehicles with spoiler **[14].**

REYNOLDS AVERAGED NAVIER STROKE EQUATIONS

$$\frac{\partial \overline{u_a}}{\partial t} + \overline{u_a}\frac{\partial \overline{u_a}}{\partial \overline{x_a}} = \frac{1}{\rho}\frac{\partial \overline{p}}{\partial x_a} + \frac{\partial}{\partial x_b}\left(v\frac{\partial \overline{u}_a}{\partial \overline{u}_b} - \overline{\tau_{ab}}\right); \; a = 1,2,3; \; b = 1,2,3; \qquad (5.3)$$

Where, bar = average time quantity

5.1.3 RNG K-∈ TURBULENCE METHOD

$$\frac{\partial(\rho k)}{\partial t} + u_a \frac{\partial(\rho k)}{\partial x_a} = \frac{\partial}{\partial x_a}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_a}\right) + G - \rho E;\ \text{a=1,2,3} \quad (5.4)$$

$$\frac{\partial(\rho E)}{\partial t} + u_a \frac{\partial(\rho E)}{\partial x_a} = \frac{\partial}{\partial x_a}\left(\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_a}\right) + q\frac{E}{k}B - q^{*}{}_{1\varepsilon}\rho\frac{E^2}{k};\ \text{i=1,2,3} \quad (5.5)$$

Where [14] k= turbulence kinetic energy E= kinetic energy dissipation rate

E_k=Prandtl number of turbulence kinetic energy

σ_E= Prandtl number of turbulence kinetic energy dissipation rate **[14]**

5.1.4 PRANDTL CALCULATIONS

The equations are based on the above-mentioned calculations **[14].**

$$B=2\mu_a S_{ab} S_{ab}, \quad (5.6)$$

$$q^{*}{}_{2E}=q_{2E} + q'{}_{2E}, \quad (5.7)$$

$$q'{}_{2E} = \frac{q_\mu \rho \eta^3(1-\eta/\eta_0)}{1+\beta\eta^3} \quad (5.8)$$

$$\mu_t = \rho q_\mu \frac{k^2}{E}, \quad (5.9)$$

$$\eta = T\frac{K}{E}, \quad (5.10)$$

$$T=\sqrt{2S_{ab}S_{ab}}\ , \quad (5.11)$$

Where S_{ab}= shearing rate tensor, g_a=body force in the $\boldsymbol{x_a}$ direction **[22].** The following equations are made for the type of flow is made in the analysis and based on the flow type is detected in the simulation with air medium is compressible for the following equation. sometimes the air is incompressible below 220 miles per hour **[24].**

5.2 SIMULATION

Make the simulation for the proposed design for with and without spoiler to check the forces acting on it and measure the drag coefficient

5.2.1 CFD (COMPUTATIONAL FLUID DYNAMICS)

The CFD (computational fluid dynamics) method can be used for measuring the huge models in the wind tunnel under intensified requirements. The industries like aerospace, biomedical, road vehicles, marines, power generation, oil & gas they are using CFD for analysis. The benefits of using CFD for analysis in road vehicles are measuring the large body analysis and it cannot be achieved in wind tunnel test because it requires more space and time. CFD is the predominant method used as an introductory design tool for flow simulation It is used as a preliminary design tool or to complement experimental method. To redesign the air foil wings CFD is the efficient method. An effective tool for computing oncoming flows to deliver useful visualizations and it delivers an exceptional result for the wind tunnel measurements. The results of CFD depends on user-defined function such as generation of grid lines, turbulence models. The large-scale flows mostly depend on the probability of turbulence models to finish the flow without economically.

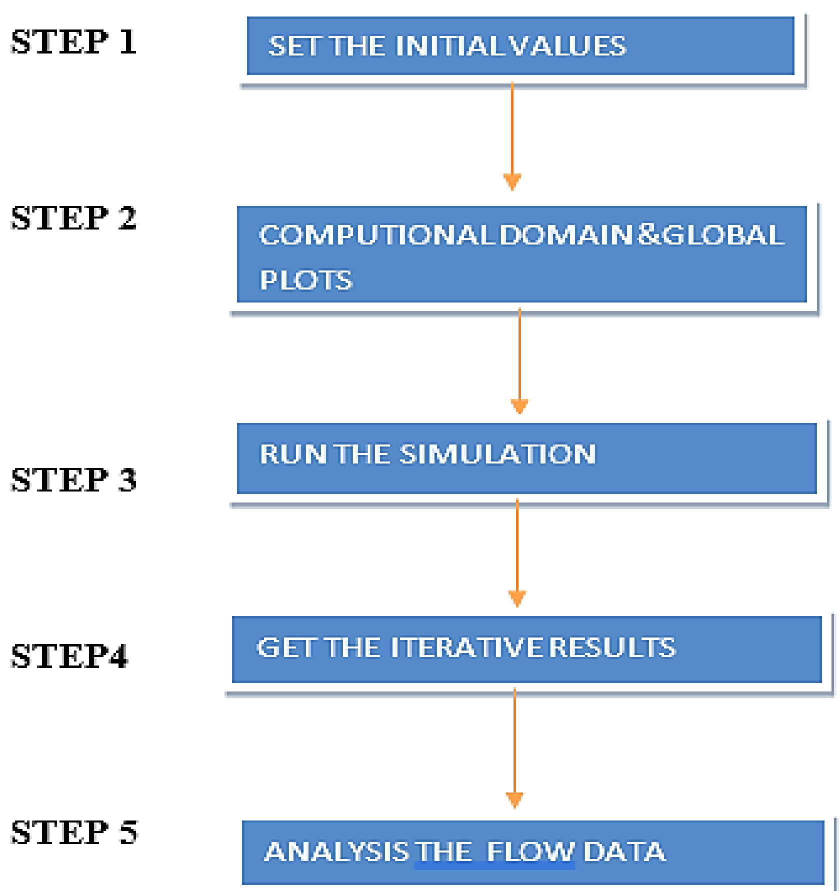


Figure 26 Methods of Simulation

5.2.2 METHODS OF FLOW SIMULATION

Flow simulation methods of a car body with and without spoiler

- Initial values in this step, units are described with analysis type which is given as external and fluid medium is also mentioned as Air, and velocity in x direction is also mentioned for the further process.
- Computational domain set up the domain for the external analysis is carried out in the simulation
- Here the plots are mentioned where the force acts on the vehicle (normal force was mentioned in x and y direction). Equation goal is also mentioned for finding the drag coefficient in simulation methods
- Here the mesh is carried out as advanced mesh in computational domain
- Run the program with advanced mesh of the design to get the iterative results
- After the results pressure distribution was calculated, there are certain results obtained as cut plots, surface plots, flow trajectories, graphical goal plots etc.
- Insert the cut plots to view the pressure distribution around the car in sectioned view.
- Insert the surface plots to view the pressure distribute in all the surfaces of the car and check the high-pressure region in front side of the car.
- Insert the flow trajectories to the view the flow direction around the car.
- Obtain the values of global plots with tabular and graphical method to solve the calculation
- Insert the flow trajectories with applying spheres to view the flow field around a car.

5.2.3 VALUES FROM THE SIMULATION

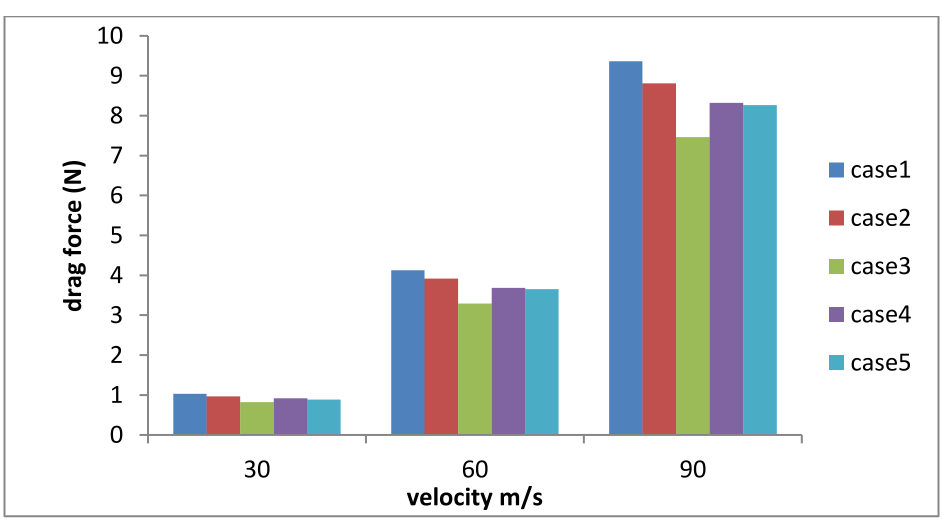
The table shows that forces acting on the vehicle after simulation is done in a computational domain, where the forces are taken from the simulation to compute the drag coefficient

Table 3 Simulation Values

Velocity(m/s)	**Drag force (N)**	**Down force (N)**
30	**1.030**	**0.568**
60	**4.124**	**2.298**
90	**9.365**	**5.167**
Velocity	**Drag force**	**Down force**
30	**0.967**	**0.526**
60	**3.921**	**2.141**
90	**8.809**	**4.827**
Velocity	**Drag force**	**Down force**
30	**0.820**	**0.597**
60	**3.295**	**2.0533**
90	**7.467**	**5.594**
velocity	**Drag force**	**Down force**
30	**0.920**	**0.609**
60	**3.684**	**2.408**
90	**8.323**	**5.634**
velocity	**Drag force**	**Down force**
30	**0.889**	**0.563**
60	**3.651**	**2.342**
90	**8.265**	**5.281**

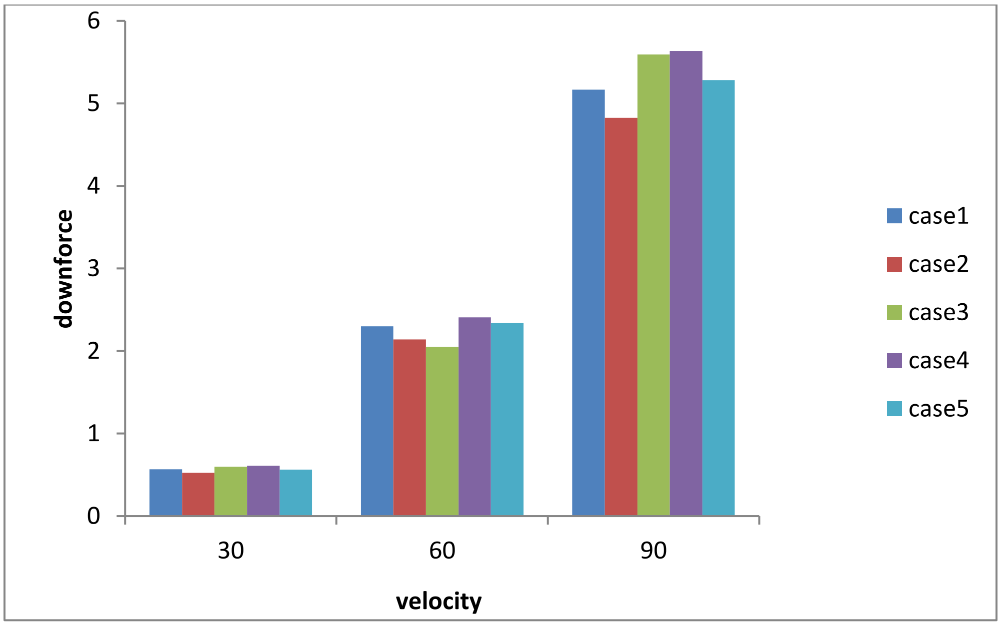
5.2. GRAPHICAL DATA FROM SIMULATION

The below mentioned graph shows that where the velocity increases with drag force. The values are obtained from the simulation for the further process



Graph 1 drag force vs velocity

The below mentioned graph shows that where the velocity increases with downforce due to installation of spoiler. The values are obtained from the simulation for the further process



Graph 2 downforce vs velocity

5.3 NUMERICAL CALCULATION FOR SIMULATION RESULTS

The numerical calculations are computed from the obtained value of drag and down force from simulation.

Drag force coefficient

The drag force coefficient is computed to reduce the drag acting in the vehicle to achieve better performance by increasing speed. The formula for drag coefficient is expressed as **[23]**

$$C_D = \frac{D}{\frac{\rho v^2}{2} * A} \quad \textbf{(5.12)}$$

Where

C_D = Drag coefficient

D = Drag force

ρ = Air density (1.225 Kg/m^3)

V = Velocity m/s with different velocity (30,60,90)

A = Frontal area m^2

Frontal area is calculated using width and height of the vehicle

Width = 1937 mm => 1/24 ratio => 80.70 mm

Height = 1213 mm => 1/24 ratio => 50.5 mm

Frontal area=Width * height **(5.13)**

A=0.003341m^2

Lift coefficient

The lift coefficient is computed using downforce to reduce the lift acting in the vehicle. The formula for drag coefficient is expressed as **[23]**

$$C_L = \frac{downforce}{\frac{1}{2}\rho v^2 bc} \quad \textbf{(5.14)}$$

Where, b = span (m) c = chord length (m)

ρ = Air density (1.225 Kg/m^3)

V = Velocity m/s

Chord length (c) = 0.1 m, Span (b) = 40 mm = 0.04m

Reynold's number

The Reynolds number is calculated to predict the flow patterns around the vehicle body. The formula for drag coefficient is expressed as **[23]**

$$Re = \frac{\rho V C}{\mu} \quad \textbf{(5.15)}$$

Where ρ = Air density Kg/m^3

V = Velocity m/s

C = Chord length (m) = (0.1m) μ = dynamic viscosity (Kg/m^3) Constant value = (1.81×10^{-5})

5.4 COMPARISON OF BOTH THE METHODS FOR SUITABLE CASES:

Values from the simulation for drag coefficient is obtained from the solid works simulations and it is compared with numerical and simulation methods.

5.4.1 CASE 5 FROM SIMULATION

The table 4 shows the simulation values for drag force, downforce and drag coefficient

Table 4 Simulation Values

Velocity (m/s)	Drag force(N)	Down force(N)	Drag force coefficient
30	**0.887**	**0.566**	**0.4818**
60	**3.627**	**2.333**	**0.4924**
90	**8.296**	**5.265**	**0.5007**

Frontal area

The value is obtained from the above mentioned (Equation 5.13) $A=0.003341m^2$ from the simulation table

Downforce

The downforce is calculated from the (Equation 5.14) for the values obtained from the simulation

Reynold's number

The Reynolds number is same for this method and it is also calculated using (Equation 5.15) for the simulation values.

6. RESULTS AND DISCUSSION:

The values of drag force and downforce values are computed using the above-mentioned equation to obtain drag coefficient and lift coefficient

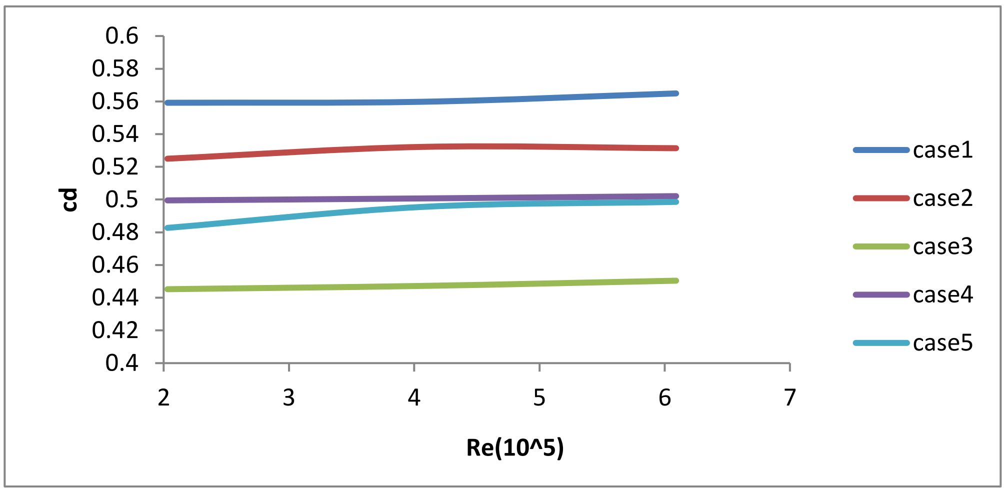
Table 5 values of coefficient of drag and lift

Case1 velocity (m/s)	Drag force coefficient	Lift coefficient	Reynold's no
30	0.5592	0.2575	$2.0303*10^5$
60	0.5598	0.2605	$4.0607*10^5$
90	0.56498	0.2603	$6.0911*10^5$
Case2 velocity	**Drag force coefficient**	**Lift coefficient**	**Reynold's no**
30	0.5250	0.2385	$2.0303*10^5$
60	0.5322	0.2427	$4.0607*10^5$
90	0.5314	0.2452	$6.0911*10^5$
Case 3 velocity	**Drag force coefficient**	**Lift coefficient**	**Reynold's no**
30	0.4452	0.2707	$2.0303*10^5$
60	0.4472	0.2871	$4.0607*10^5$
90	0.4504	0.2818	$6.0911*10^5$
Case 4 velocity	**Drag force coefficient**	**Lift coefficient**	**Reynold's no**
30	0.4995	0.2761	$2.0303*10^5$
60	0.5007	0.2730	$4.0607*10^5$
90	0.5021	0.2839	$6.0911*10^5$
Case 5 velocity	**Drag force coefficient**	**Lift coefficient**	**Reynold's no**
30	0.4827	0.2507	$2.0303*10^5$
60	0.4955	0.2655	$4.0607*10^5$
90	0.4986	0.2661	$6.0911*10^5$

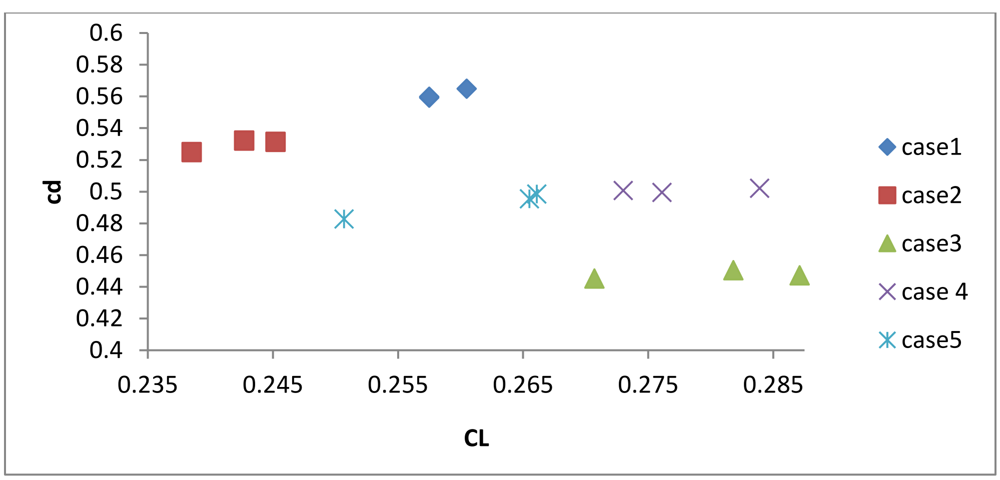
The table clearly shows that values of drag coefficient and lift coefficient for all the cases. The aim of the project is to select the suitable case for the desired fastback geometry of the car. Here states the description of all the suitable cases for the vehicle. Case 1 has high drag coefficient with moderate lift coefficient so It has more lift forces and it is not preferred here. case 2 has low lift coefficient with high drag coefficient the study is about aerodynamic characteristics of the car not fully focused about downforce so it is preferred for super cars. case 3 has low drag coefficient with high lift coefficient so It will lift the car upwards so it is not preferred here. Case 4 has moderate drag coefficient with high lift coefficient so it is also not preferred. Case 5 has moderate lift coefficient and moderate drag coefficient so it can achieve great speed with stability in control. GT 2 circuits are moderate circuits which has more curves and straighter lane so case 5 has great downforce value and great drag coefficient value so it is suitable for the further process and suitable for similar types of super cars.

6.1 GRAPHICAL DATA FROM CALCULATION

The graph shows that comparison of drag coefficient and Reynolds number. The Reynolds number depends on the velocity of the flow to predict the type of flow indicated in the domain. The drag coefficient also depends on the velocity of the vehicle.



Graph 3 drag coefficient vs Reynolds number



Graph 4 drag coefficient vs lift coefficient

The Graph 4 shows that comparison between lift coefficient and drag coefficient. The graph can be shown with possible ways because the above parameters are interchangeable depends on the circumstances of the track circuit. if the track is curvier vehicle should produce more downforce.in other hand track has more linear path than curve path vehicle should have more drag coefficient.

6.2. CASE 5 AT VELOCITY 30 M/S

The vehicle Top flap tilted with elevated spoiler is setup for the initial stage of the simulation. Apply the velocity at 30 m/s in cut sectioned view to indicate the high-pressure region in frontal area

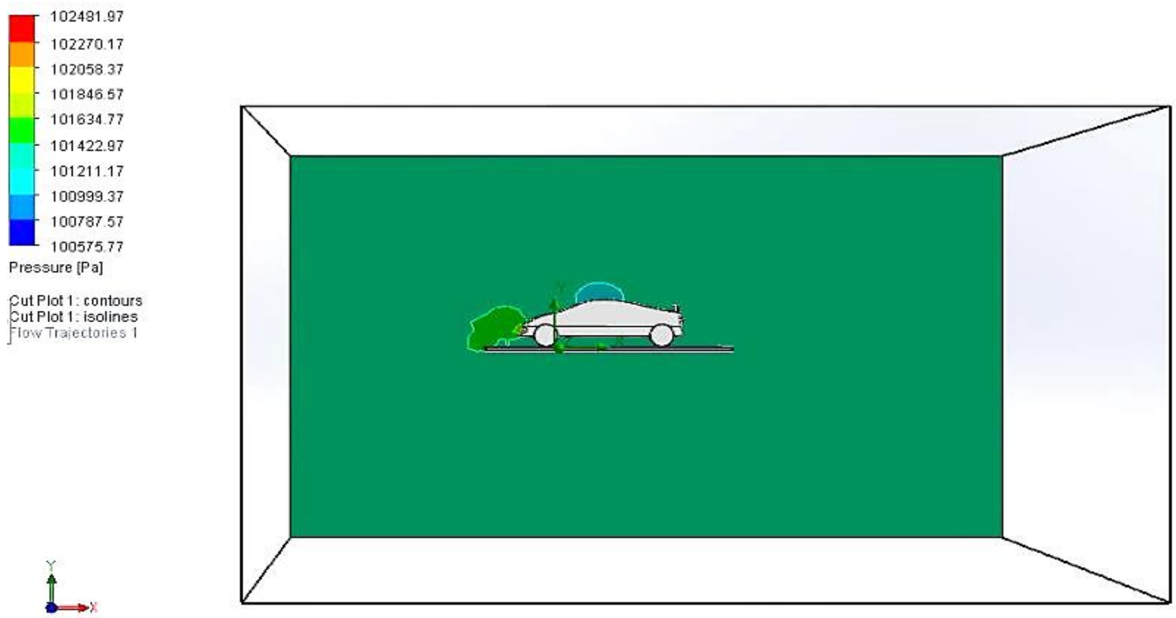


Figure 27 Cut Plots

The vehicle Top flap tilted with elevated spoiler is setup for the next stage of the simulation. Apply the velocity at 30 m/s at all the surfaces of the model to indicate the high-pressure region.

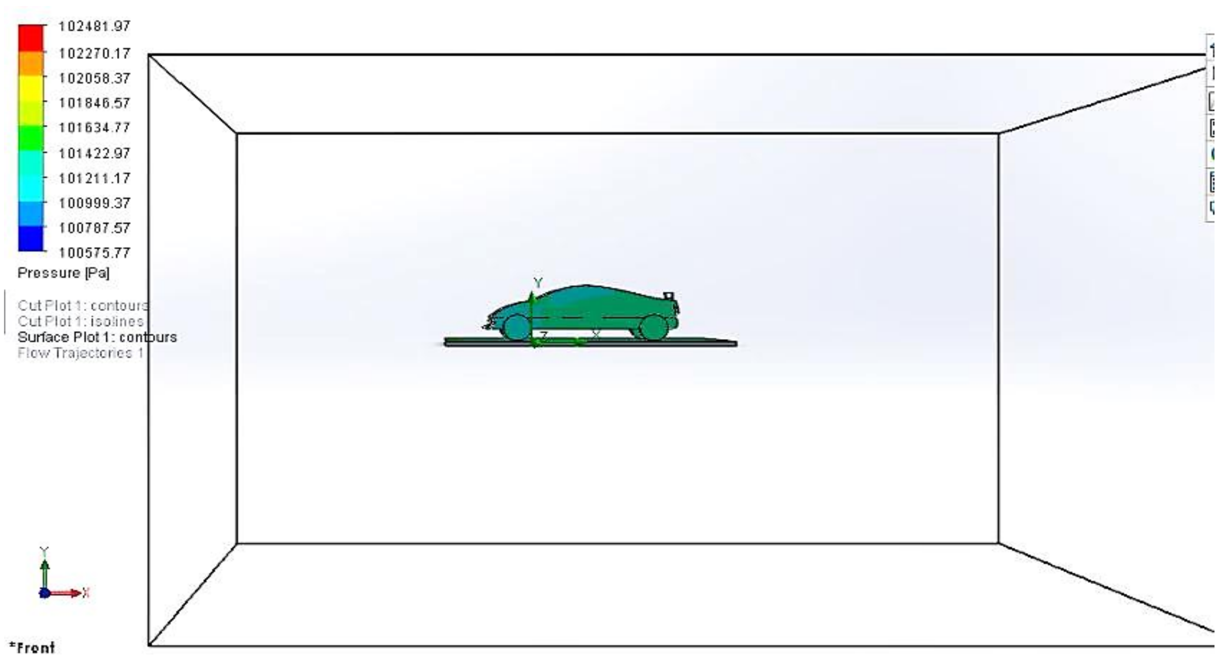


Figure 28 Surface Plots

Apply the velocity 30 m/s at the vehicle with Top flap tilted elevated spoiler is setup with lines and arrows by applying density and thickness to indicate the flow travels around the vehicle.

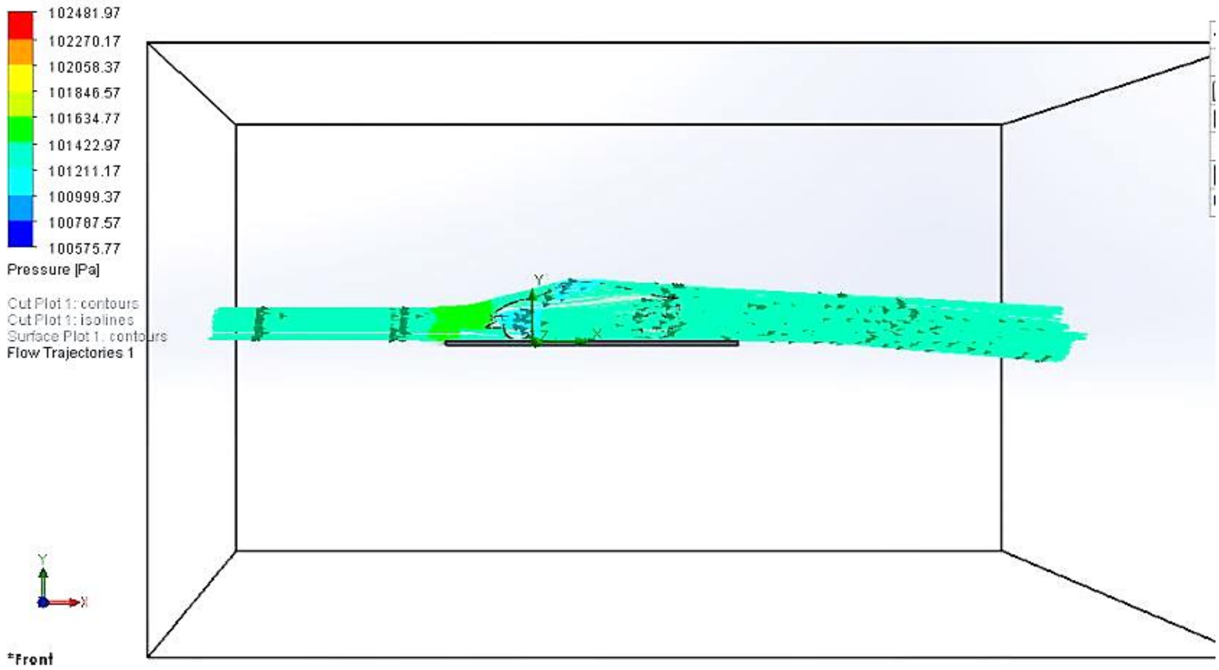


Figure 29 Flow Trajectories with Lines and Arrows

Apply the velocity 30 m/s at the vehicle with Top flap tilted elevated spoiler is setup with spheres by applying density and thickness to indicate the flow travels around the vehicle.

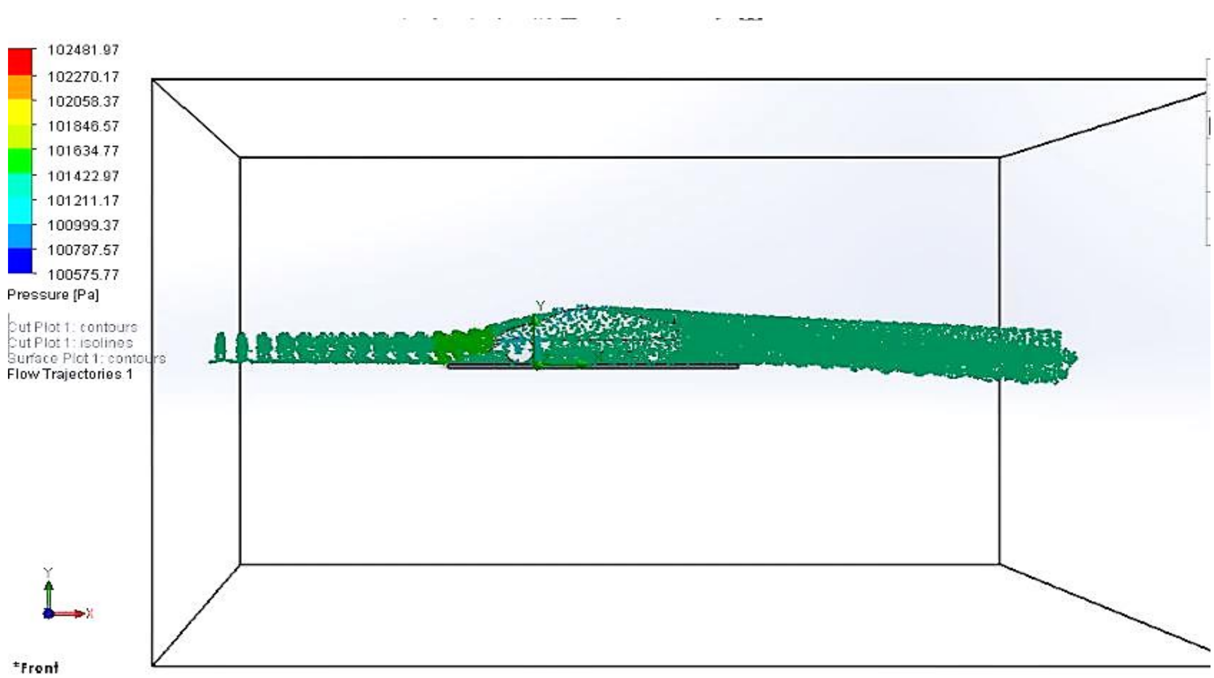


Figure 30 Flow Trajectories with Spheres

CASE 5 AT VELOCITY 60 m/s

The vehicle Top flap tilted with elevated spoiler is setup to apply the velocity at 60 m/s in cut sectioned view to indicate the high-pressure region so that pressure decreases with high velocity.

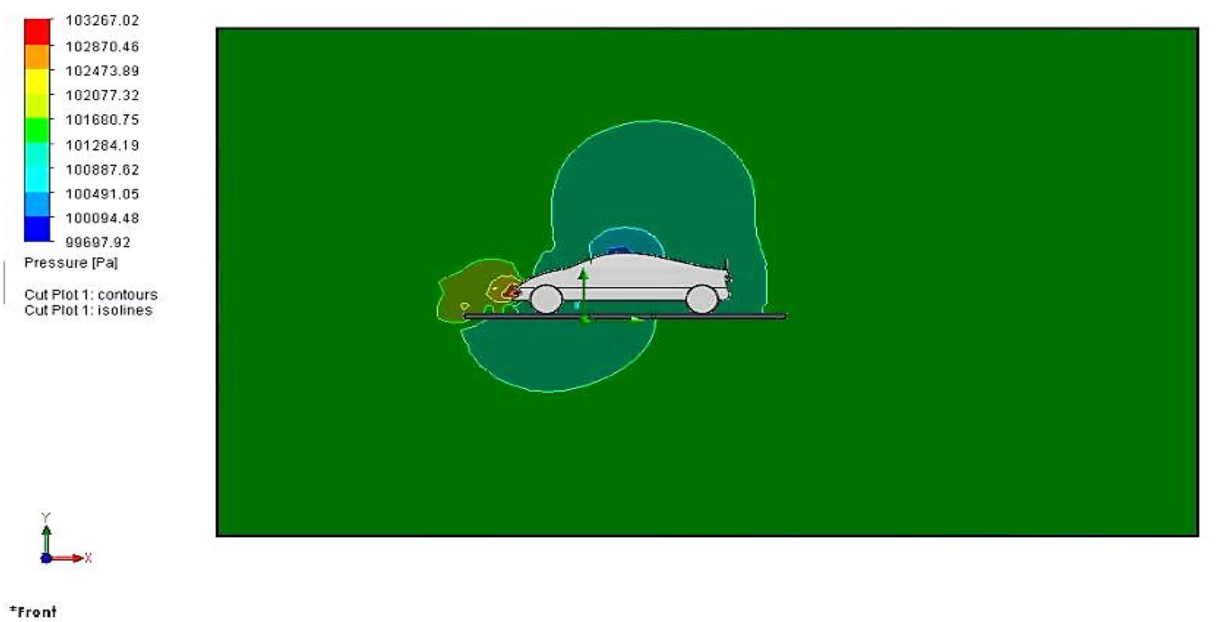


Figure 31 Cut Plots

The vehicle Top flap tilted with elevated spoiler is setup to apply the velocity at 60 m/s at all the surfaces of the model to indicate the high-pressure region so that pressure decreases with increase in velocity

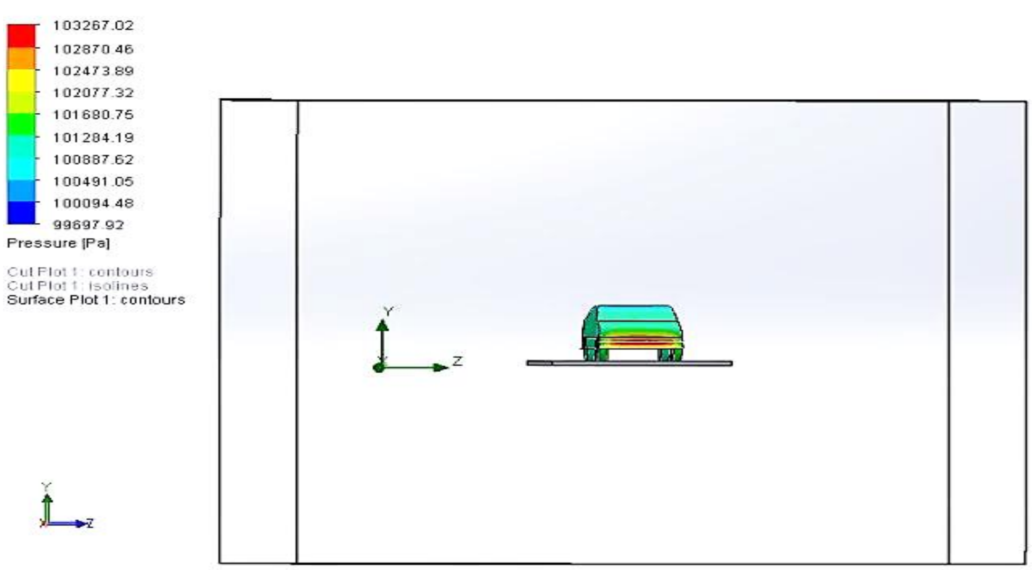


Figure 32 Surface Plots

Apply the velocity 60 m/s at the vehicle with Top flap tilted elevated spoiler is setup with lines and arrows by applying density and thickness to indicate the flow travels around the vehicle.

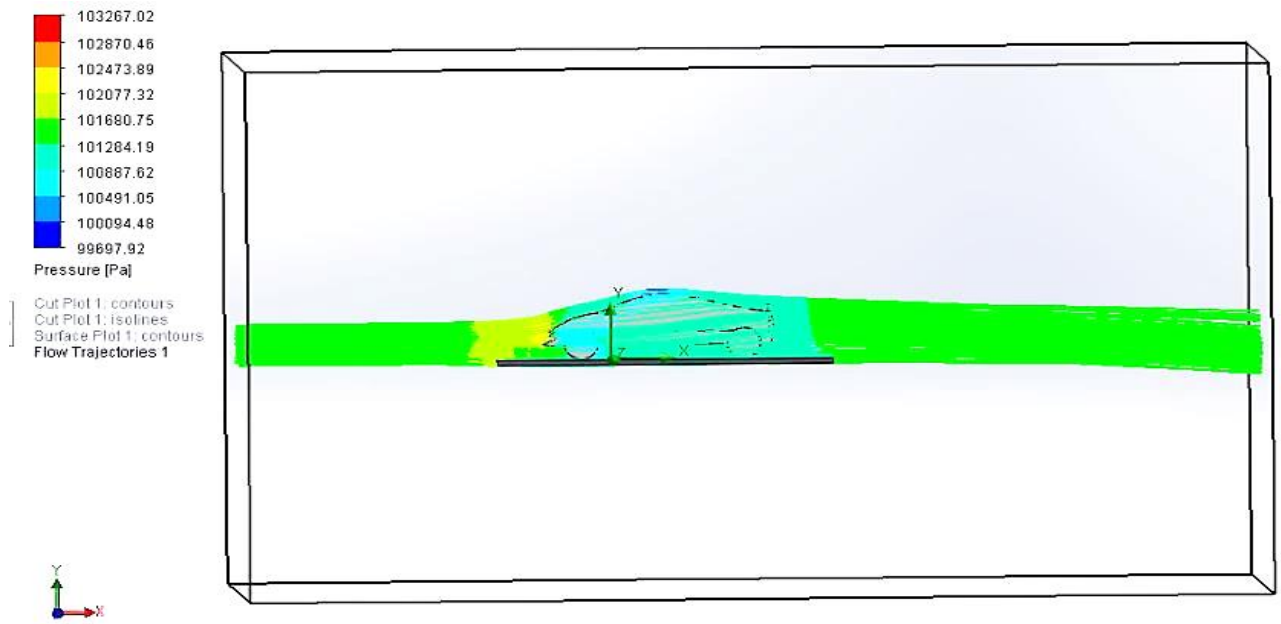


Figure 33 Flow Trajectories with Lines and Arrows

Apply the velocity 60 m/s at the vehicle with Top flap tilted elevated spoiler is setup with spheres by applying density and thickness to indicate the flow travels around the vehicle.

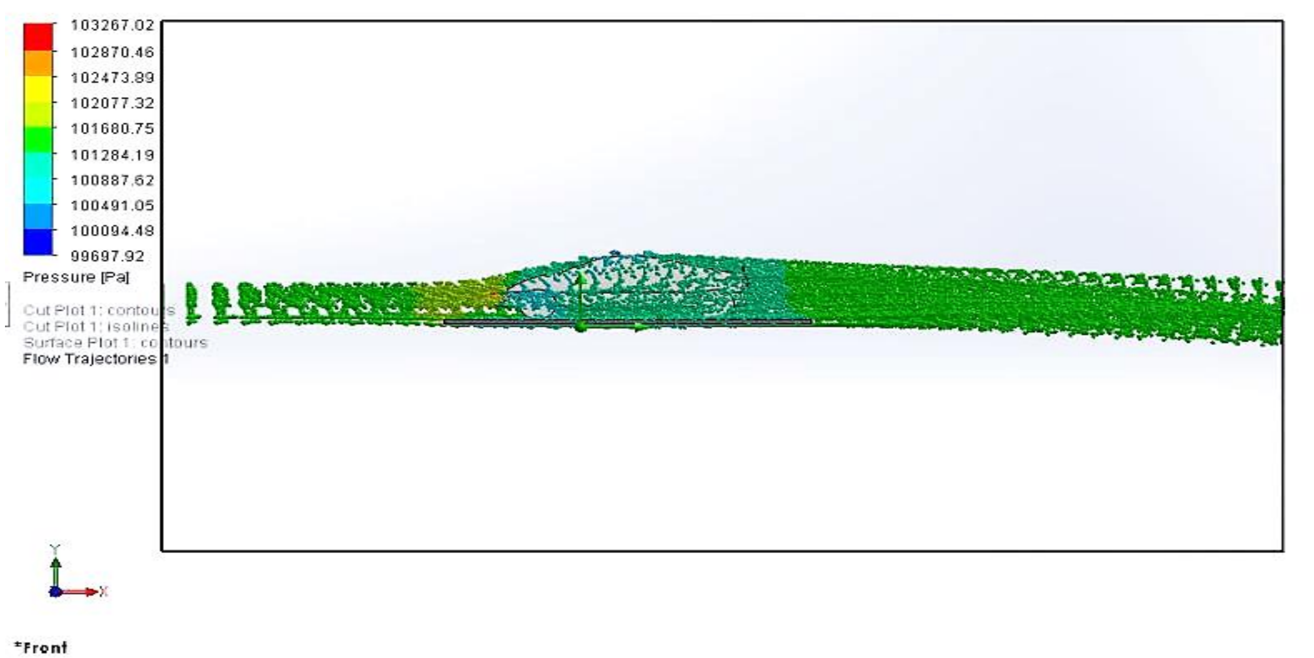


Figure 34 Flow Trajectories with Spheres

CASE 5 AT VELOCITY 90 M/S

The vehicle Top flap tilted with elevated spoiler is setup to apply the velocity at 90 m/s in cut sectioned view to indicate the high-pressure region so that pressure decreases with high velocity

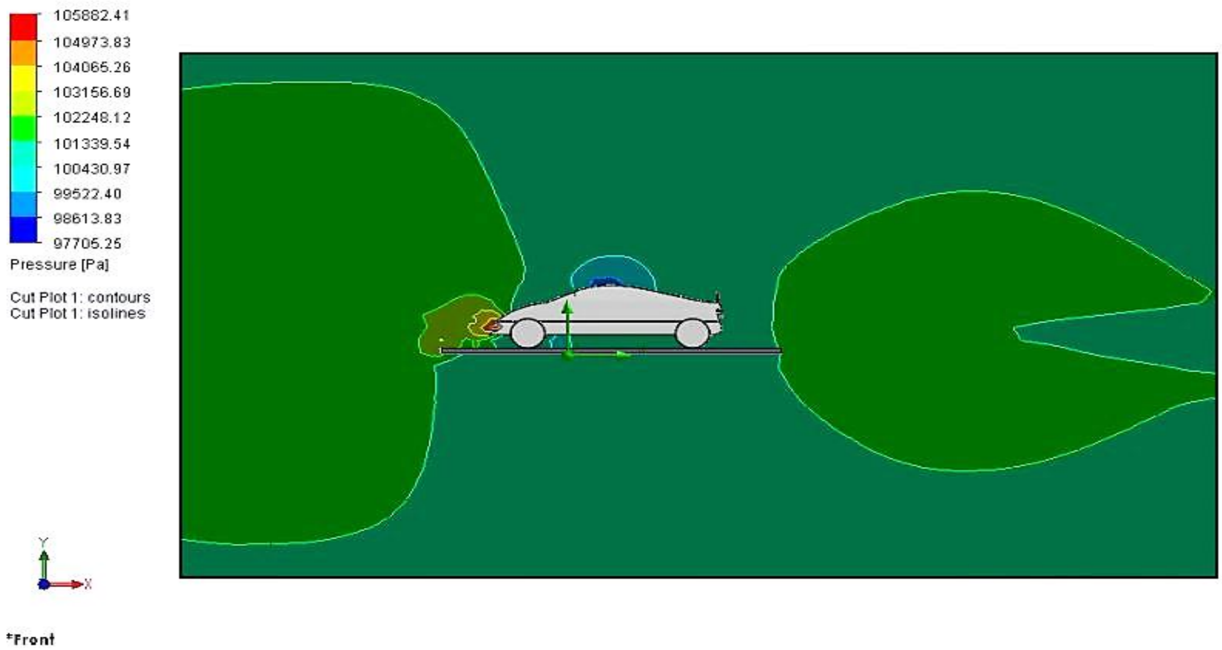


Figure 35 Cut Plots

The vehicle Top flap tilted with elevated spoiler is setup to apply the velocity at 90 m/s at all the surfaces of the model to indicate the high-pressure region so that pressure decreases with increase in velocity

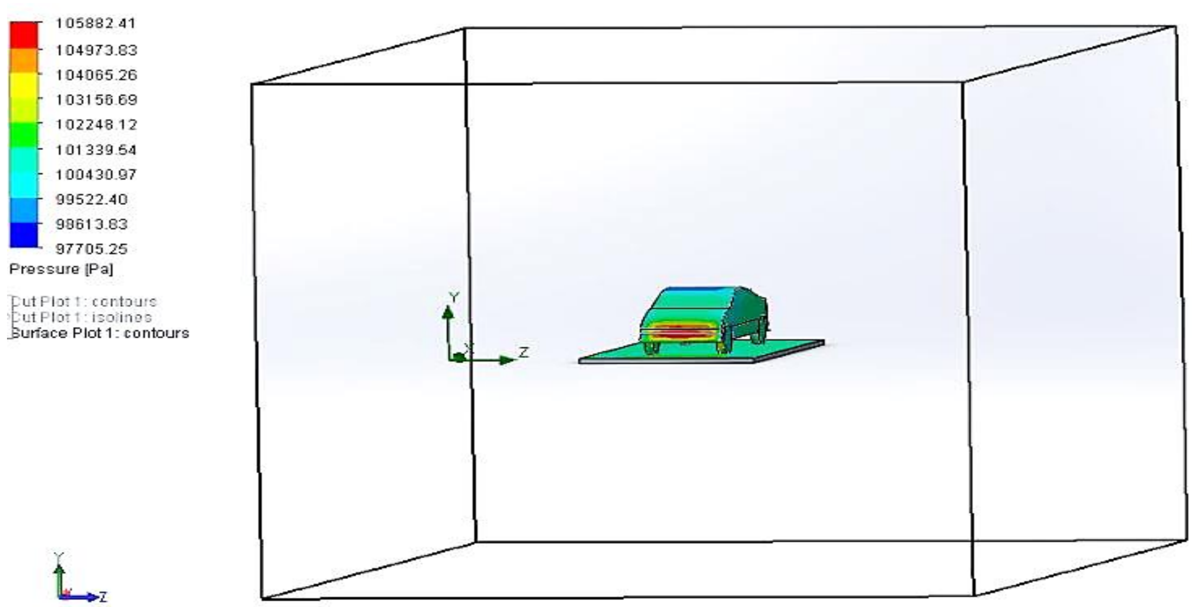


Figure 36 Surface Plots

Apply the velocity 90 m/s at the vehicle with Top flap tilted elevated spoiler is setup with lines and arrows by applying density and thickness to indicate the flow travels around the vehicle.

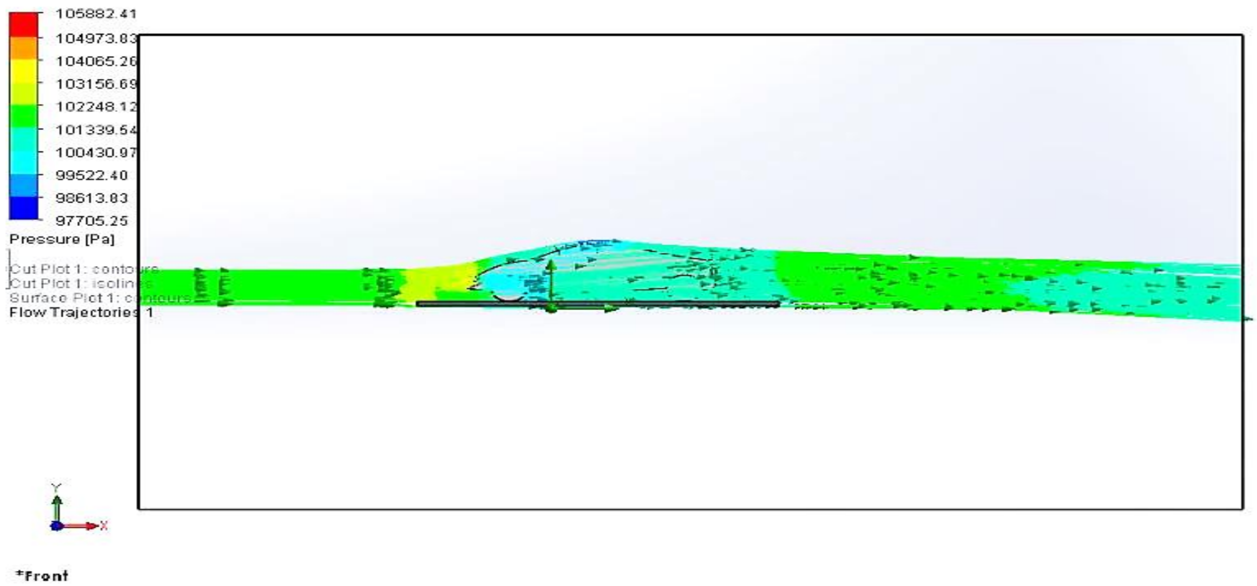


Figure 37 Flow Trajectories with Lines and Arrows

Apply the velocity 90 m/s at the vehicle with Top flap tilted elevated spoiler is setup with Spheres by applying density and thickness to indicate the flow travels around the vehicle.

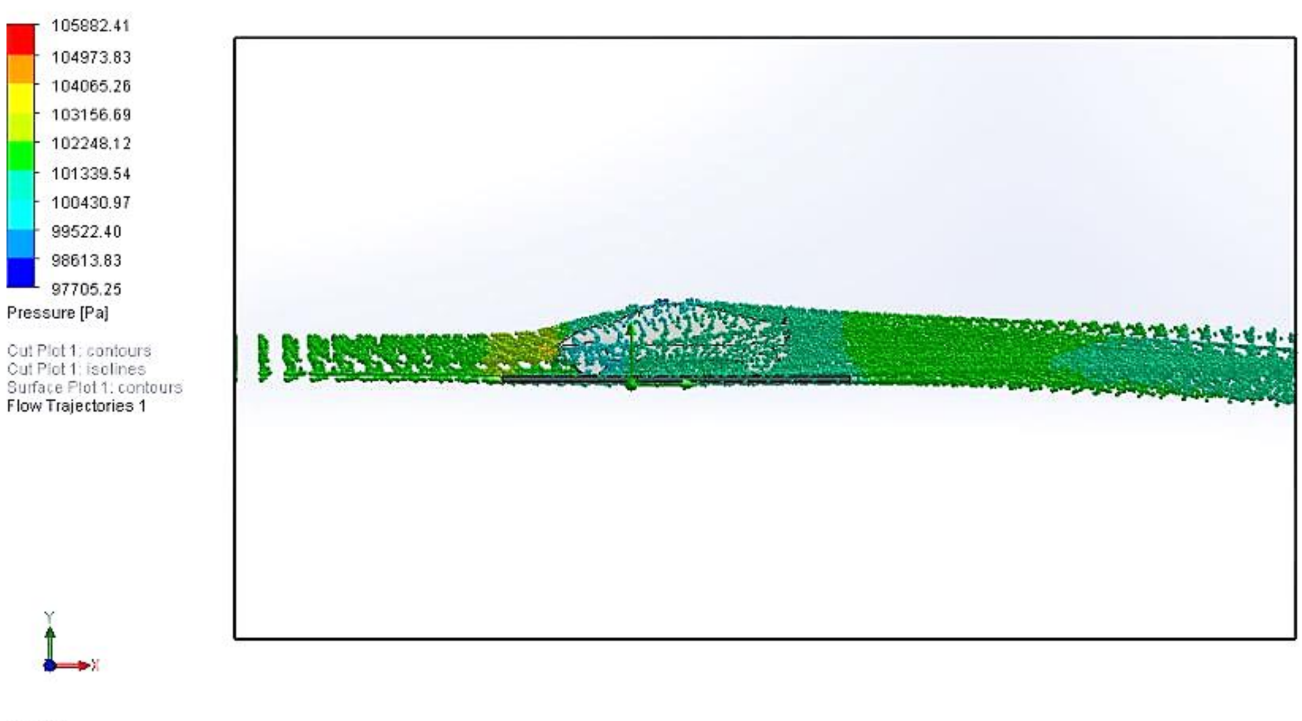
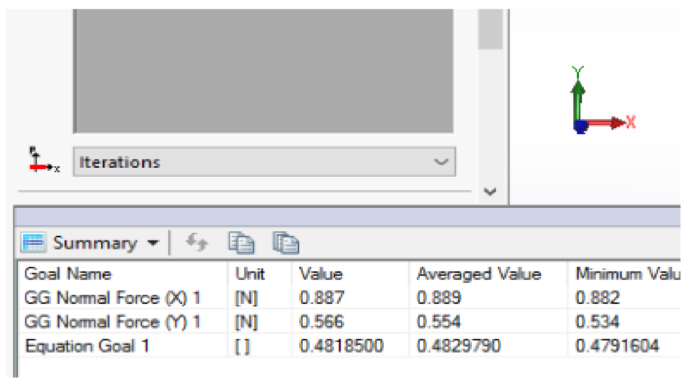


Figure 38 Flow Trajectories with Spheres

The Results of Case 5 is Chosen from the Tabular Column 5 and It is Selected because of the Vehicle and Track. The results of other cases are mentioned in **Appendix A** and the same procedure is applied for the other cases with varying velocity as 30 m/s, 60 m/s and 90 m/s.

6.3 COMPARISON OF BOTH METHODS

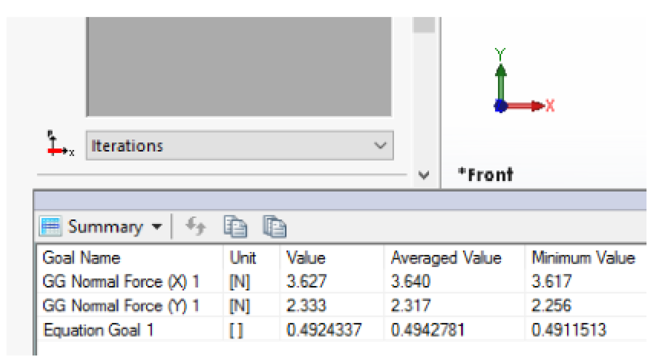
The comparison between numerical and simulation methods shows which method is preferred for the calculation. The Figure 39 shows that values obtained from the simulation for drag coefficient by inserting the equation goal in the goal plots. Here the comparison method is done for suitable (case 5) spoiler design by applying at velocity 30 m/s, therefore the values obtained from the results are plotted as graph.



Goal Name	Unit	Value	Averaged Value	Minimum Valu
GG Normal Force (X) 1	[N]	0.887	0.889	0.882
GG Normal Force (Y) 1	[N]	0.566	0.554	0.534
Equation Goal 1	[ ]	0.4818500	0.4829790	0.4791604

Figure 39 simulation value for Cd

The Figure 40 shows that values obtained from the simulation for drag coefficient by inserting the equation goal in the goal plots. Here the comparison method is done for suitable (case 5) spoiler design by applying at velocity 60 m/s, therefore the values obtained from the results are plotted as graph.



Goal Name	Unit	Value	Averaged Value	Minimum Value
GG Normal Force (X) 1	[N]	3.627	3.640	3.617
GG Normal Force (Y) 1	[N]	2.333	2.317	2.256
Equation Goal 1	[ ]	0.4924337	0.4942781	0.4911513

Figure 40 simulation value for Cd

The Figure 41 shows that values obtained from the simulation for drag coefficient by inserting the equation goal in the goal plots. Here the comparison method is done for suitable (case 5) spoiler design by applying at velocity 90 m/s, therefore the values obtained from the results are plotted as graph.

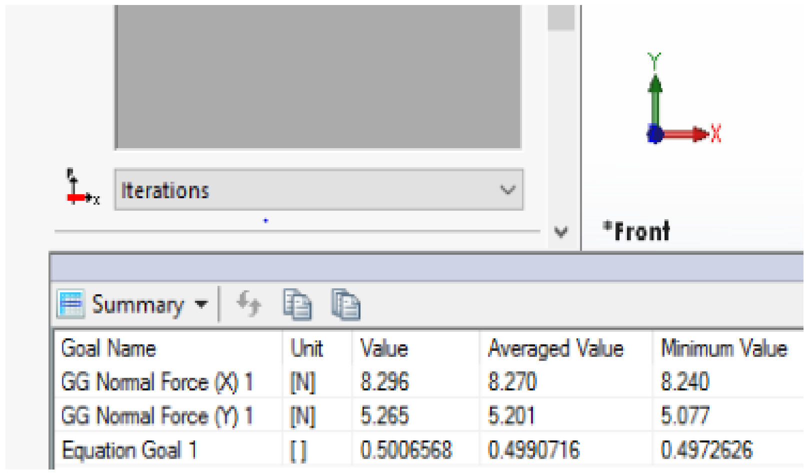


Figure 41 simulation value for Cd

6.4 CALCULATION FOR SIMULATION VALUES

The Table 6 shows that tabulation for lift coefficient, drag coefficient and Reynolds number with different velocity. The lift coefficient values and Reynold numbers are computed using equation 5.14 & equation 5.15 for the obtained values in the below mentioned table

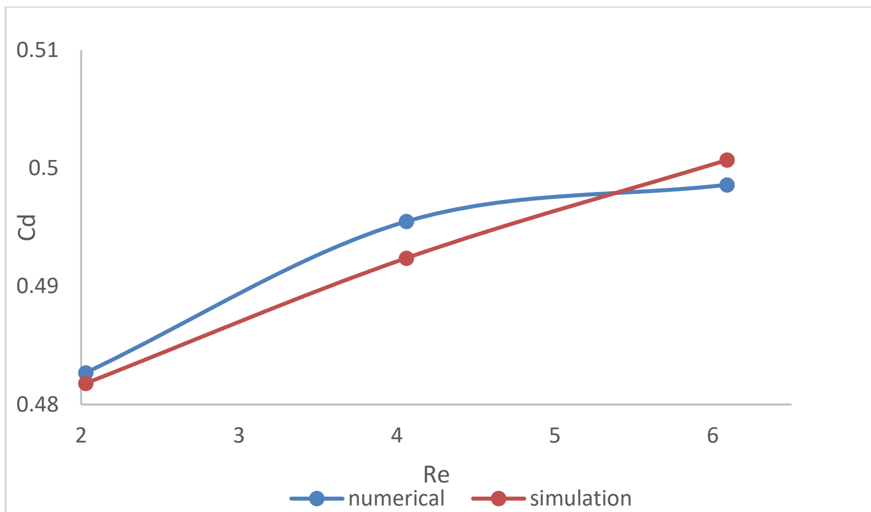
Table 6 values from calculation

Case 5 Velocity m/s	**Drag force coefficient**	**Lift coefficient**	**Reynold's no**
30	**0.4818**	**0.2566**	**$2.0303*10^5$**
60	**0.4924**	**0.2645**	**$4.0607*10^5$**
90	**0.5007**	**0.2653**	**$6.0911*10^5$**

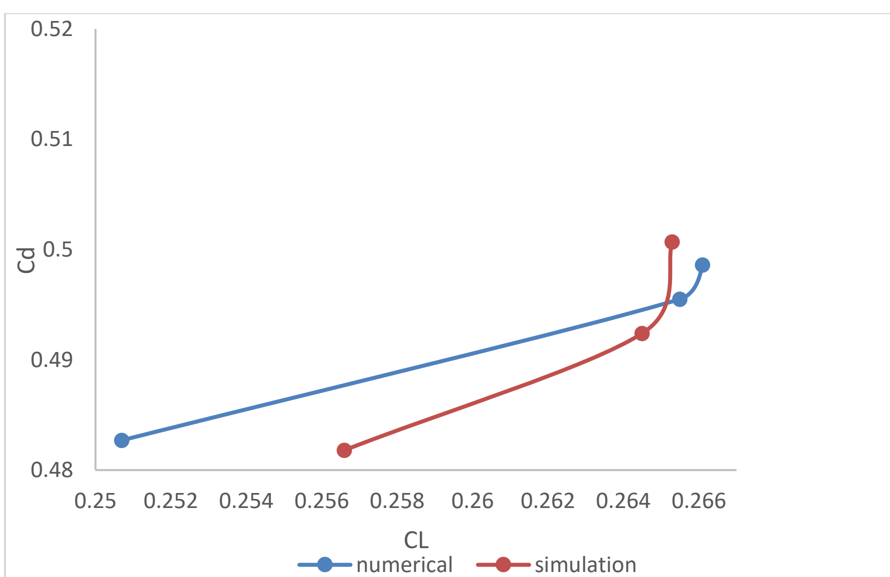
The values obtained from the simulation are compared with case 5 (Top flap tilted with elevation) numerical values to determine which method is preferred for the calculation. Comparing the results states that Reynolds number and velocity is constant for the methods, so the drag force coefficient and lift coefficient varies with varying vehicle velocity.

6.5 COMPARISON GRAPH FROM RESULTS

The below mentioned graph shows that comparison between drag coefficient and Reynolds number for the numerical and simulation methods. The numerical graph varies from the results because It does not have dynamic loop and it's not in steady state condition but It has accurate results so it preferred for the tedious calculation. The simulation results are said to be approximation results and it has dynamic loop and it is also preferred for approximate results and time saving process.



Graph 5 Drag Coefficient Vs Reynolds Number



Graph 6 Drag Coefficient Vs Lift Coefficient

The above-mentioned graph shows that comparison between drag coefficient and lift coefficient for the numerical and simulation methods. The numerical graph varies from the results because It does not have dynamic loop and it's not in steady state condition but It has accurate results so it preferred for the tedious calculation. For the GT racing series, balanced lift coefficient and drag coefficient is chosen because it has curvier and straight lane so case 5(top flap tilted with elevation) is chosen for the similar types of circuits. In case 3 is chosen for achieving more speed and case 1 is chosen for low lift coefficient due to GT track circuits the case 5 is suitable ahead of other cases.so this clearly states that suitable spoiler design is based on the vehicle and selecting the cases of spoiler which are proposed in this project are not poor aerodynamic design, it selected based on the circuit design. The selection of spoiler cases depends upon the circumstances due to better vehicle performance.

6.6 APPROACHES:

The below mentioned table 7 clearly shows that merits and demerits of various approaches

Table 7 Advantages and Disadvantages of Approaches

Approach	Advantages	Disadvantages
Experimental	More Accurate Results	Components Essential for Scaling Difficulties with More Effort and It Comprises Functional Cost
Theoretical	Over-All Data in Numerical Method	Controlled to The Simple Difficulties and Using for Linear Difficulties
Computational	Detailed Complex Flow Structure	Truncation of Faults with Boundary Conditions

According to the tabular column experimental results are more accurate due to practical experiments and numerical results are focused on calculations and its said to be tedious calculations only numerical method is calculated. Simulation results are approximate results which is preferred for time saving process and the real vehicle is scaled and designed to measure the values in simulation. Combination of these approaches gives more accurate results to increase the performance of the vehicle

7. CONCLUSION

This study proves that design of super car to deliver numerous information which is necessary to design the spoiler with improved performance. Based on the obtained results, suitable conclusions are made

1. Based on the technical specification, the material which is used in the real-car model is ALUIMINIUM MONOCOQUE and which is not suitable for GT racing due to more weight. Carbon fibre can replace the aerodynamic devices such as wind splitter, spoiler, side mirrors, diffuser, and front hood.

2. According to the simulation results all the cases were mentioned and case 5 (Top Flap with elevation) is suitable for the future process of my work because it has suitable drag coefficient and lift coefficient for GT racing compared to other cases.

3. In case 3 (double flap with elevation), drag coefficient value with velocity 30 m/s is 0.4452 less compared to chosen case 5 but it has high lift coefficient 0.2707 and it his more suitable for when the track has linear path

4. In case 2, drag coefficient value with velocity 30 m/s is 0.5250 high compared to chosen spoiler case 5 but it has low lift coefficient 0.2385 and it his more suitable when the track has curved path and it cannot achieve the maximum speed.

5. Now, the case 5 is chosen because it has stable lift coefficient 0.2507 and stable drag coefficient 0.4827 at velocity 30 m/s and it can achieve great speed with more stability control in tires. The downforce acts vertical direction in tires for more grips. Installation of spoiler increase the drag with increase of downforce but the splitter and altered design will induces the drag and increase the downforce.

6. The numerical results and simulation results are compared for the preferred method. Here the values of drag coefficient are 0.4827 and 0.4818 so there is slight decrease in drag coefficient of simulation result when the velocity is at 30 m/s. The values of drag coefficient are 0.4986 and 0.5006 so there is increase in drag coefficient of simulation result when the velocity is at 90 m/s

7. Finally, the possible results of aerodynamic characteristics are obtained from the results to increase the downforce and achieving great speed compared to other cases. The spoiler is chosen based on type of car and racing circuit.

8. FUTURE WORKS

- 3D printing of the model is executed for the experimental analysis.
- Experimental analysis will be done for the suitable case of spoiler.
- Comparing the simulation methods and experimental methods for the preferred calculation
- Finally, the work is compared with the real model for reducing the drag for further process.
- Apply the carbon fibre material for front hood, diffuser, side mirrors, spoilers etc., to reduce the drag further for vehicle performance.
- Reduce the weight of the vehicle for the achieving better speed and stability in control
- Vertical short fins can be inserted with diffuser to create the more downforce before sending to the spoiler, and short fins should be rigid to produce un-balanced forces.
- For further development of the vehicle, implement the reverse engineering concepts in rear end of the spoiler

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APPENDIX A

Case 1

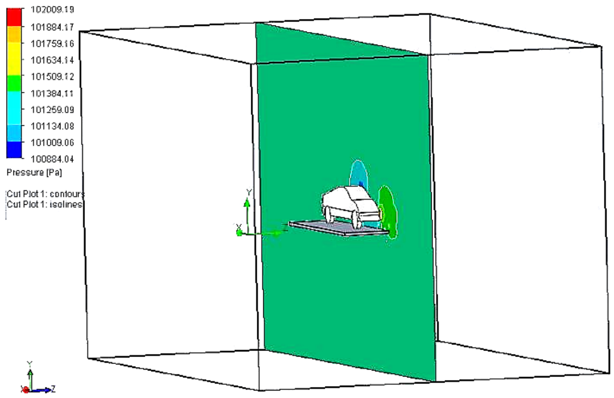


Figure A1 Cut plots

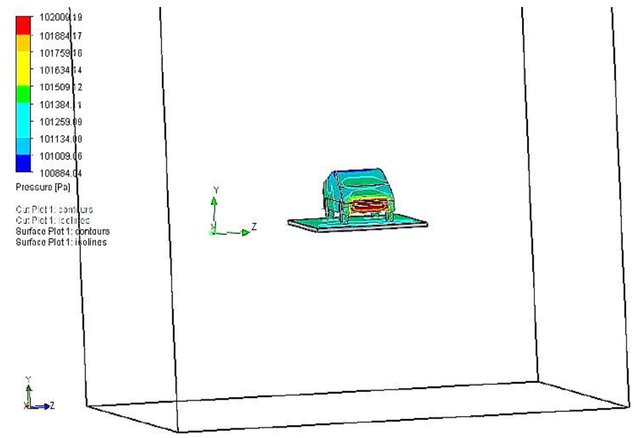


Figure A 2 Surface plots

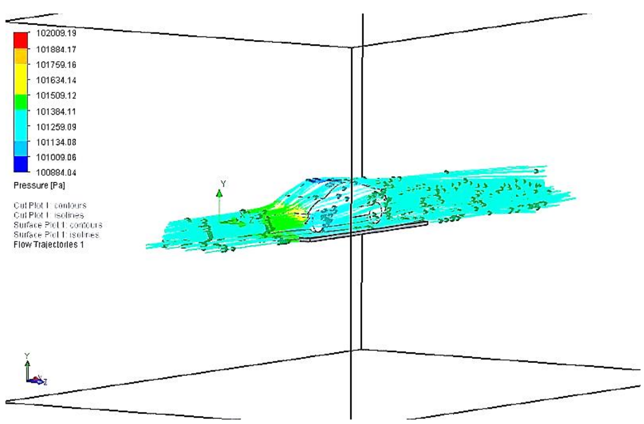


Figure A3 Flow trajectories with lines and arrows

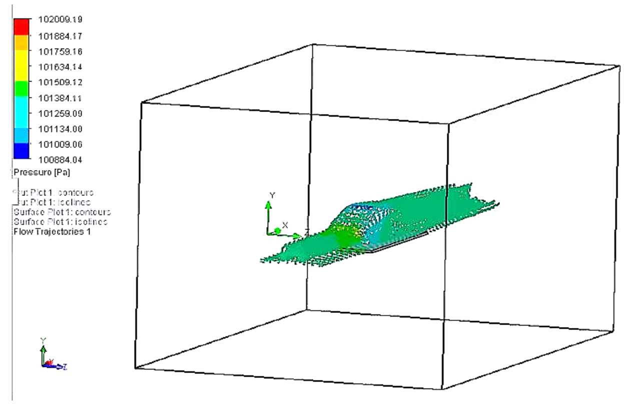


Figure A4 Flow trajectories with spheres

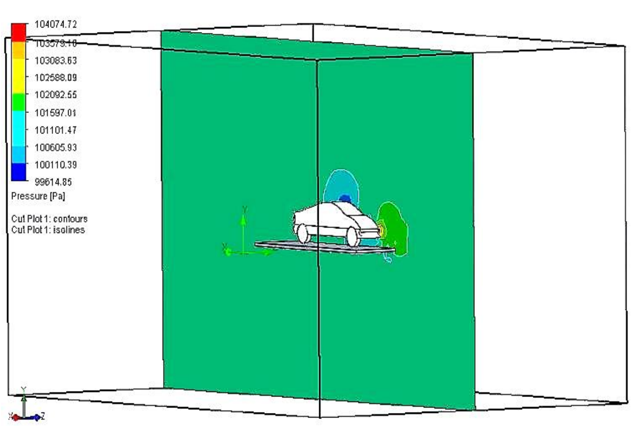


Figure A5 Cut plots

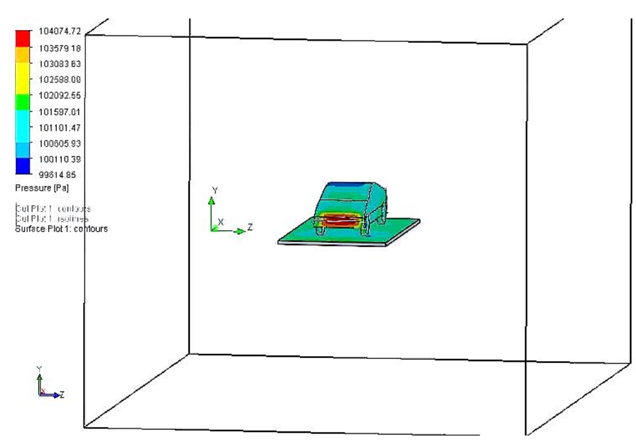
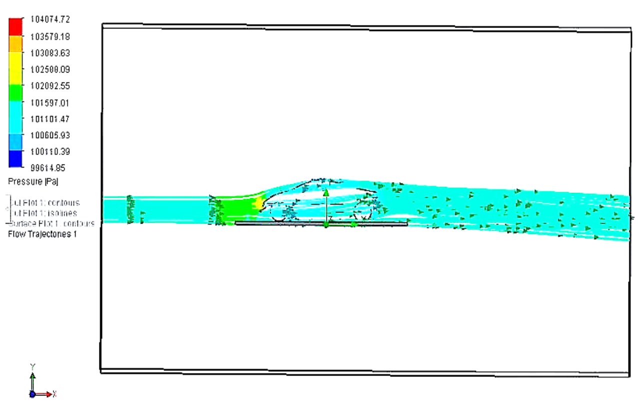


Figure A6 Surface plot



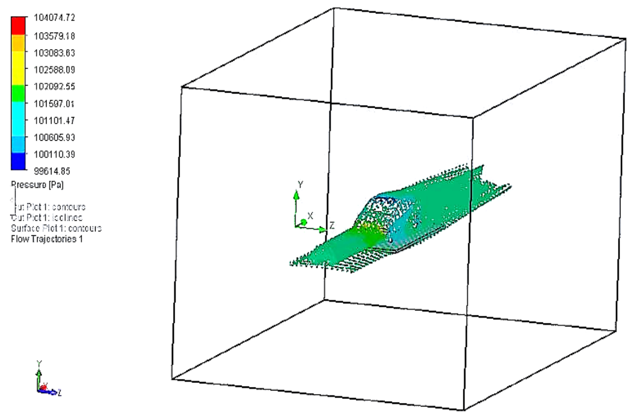
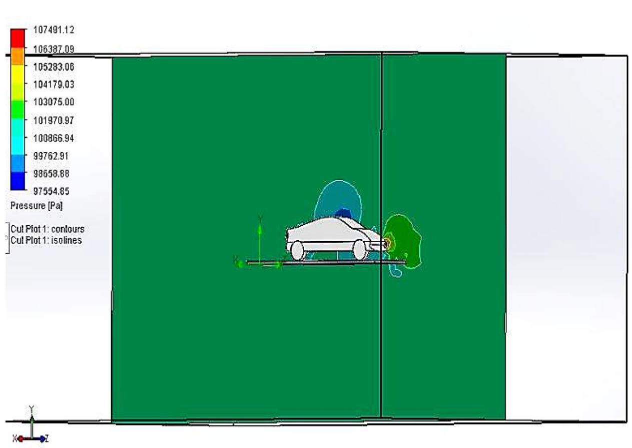


Figure A7 Flow trajectories with lines and arrows

Figure A8 Flow trajectories with spheres



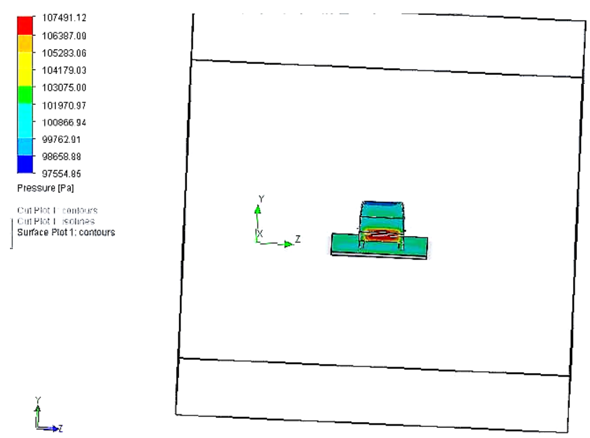
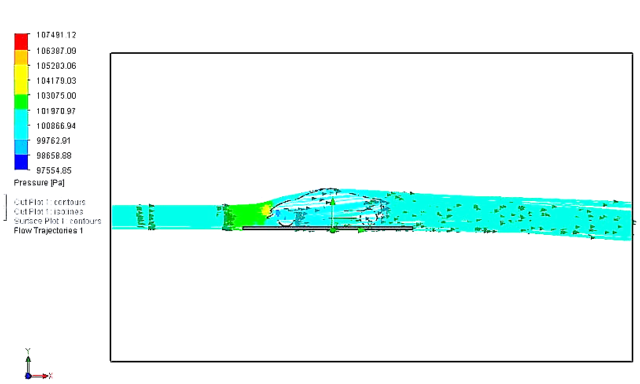


Figure A9 Cut plots

Figure A10 Surface plots



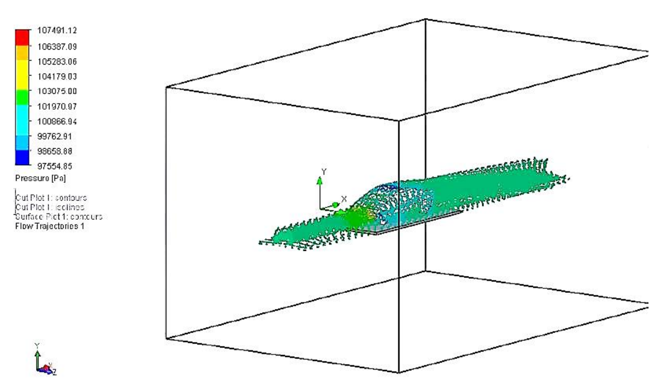


Figure A11 Flow trajectories with lines and arrows

Figure A12 Flow trajectories with spheres

Case2

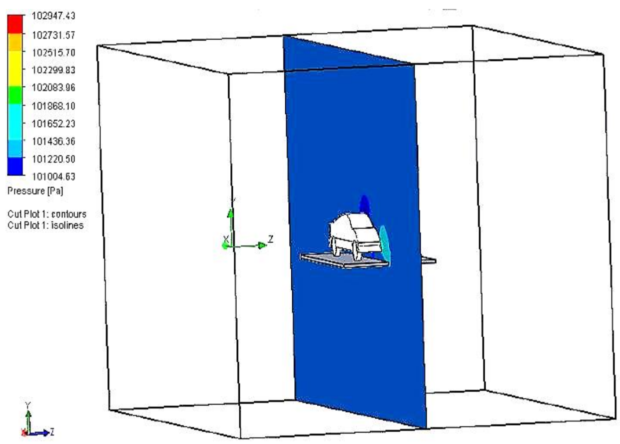


Figure A13 Cut plots

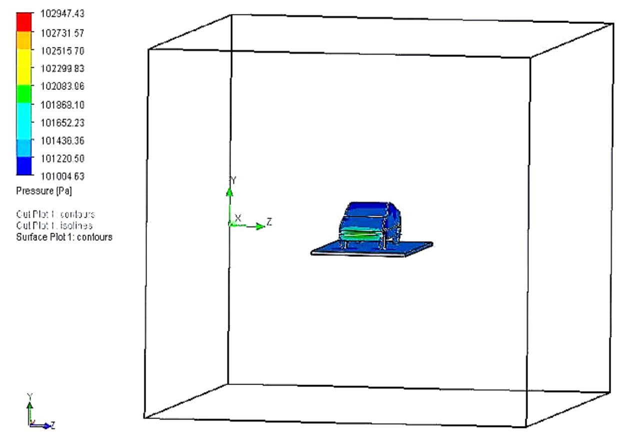


Figure A14 Surface plots

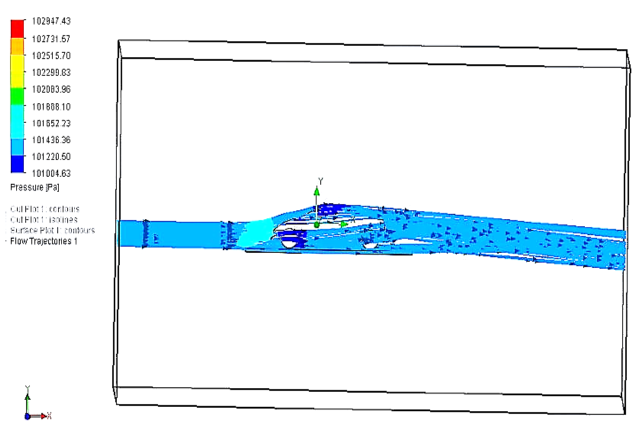


Figure A15 Flow trajectories with lines and arrows

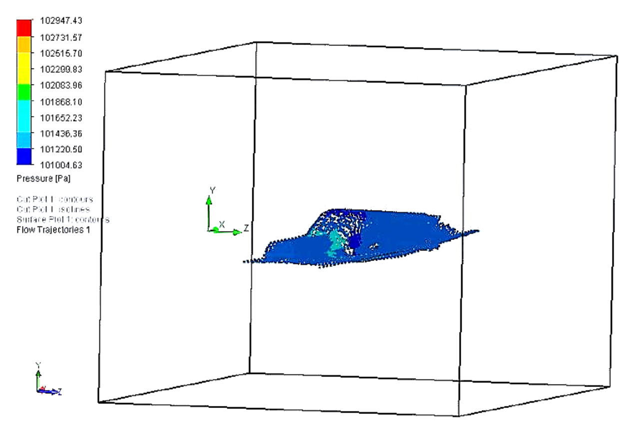


Figure A16 Flow trajectories with spheres

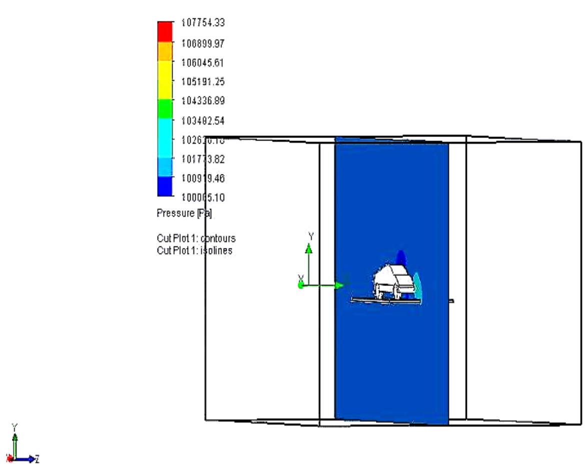


Figure A17 Cut plots

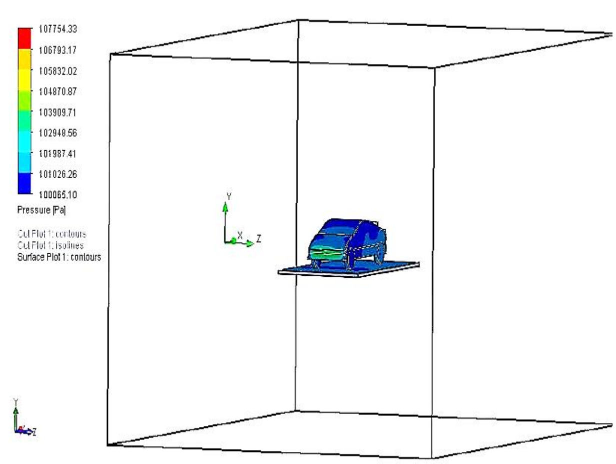


Figure A18 Surface plots

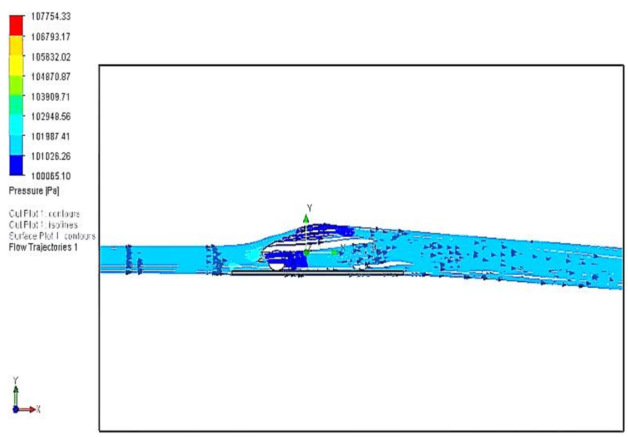


Figure A19 Flow trajectories with lines and arrows

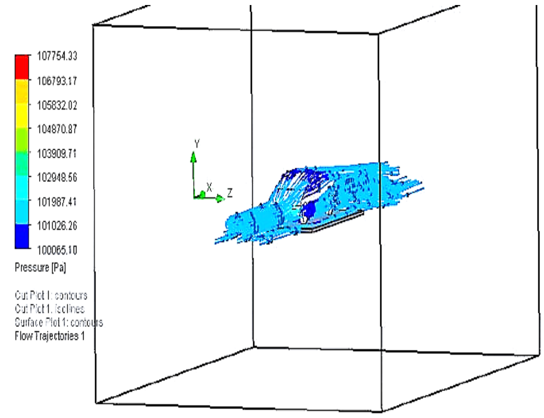


Figure A20 Flow trajectories with spheres

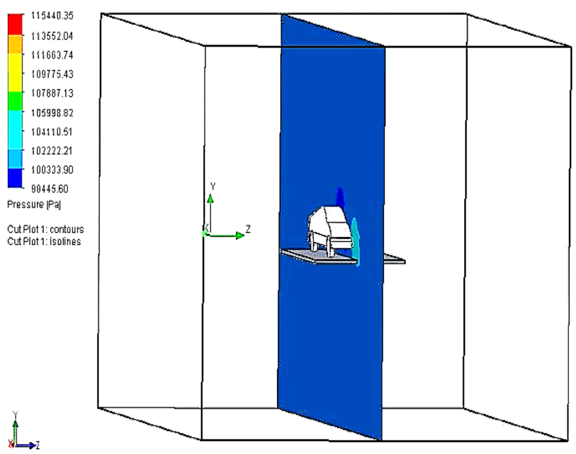


Figure A21 Cut plots

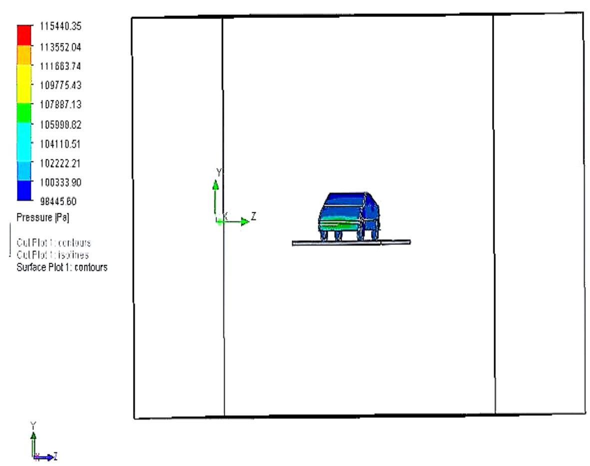


Figure A22 Surface plots

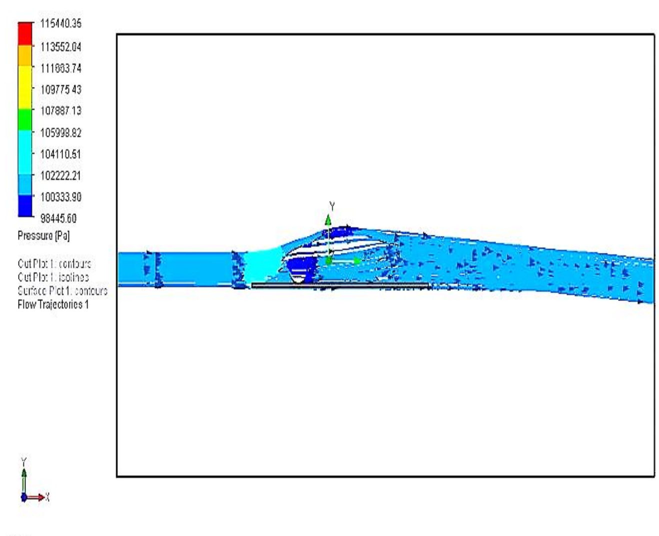


Figure A23 Flow trajectories with lines and arrows

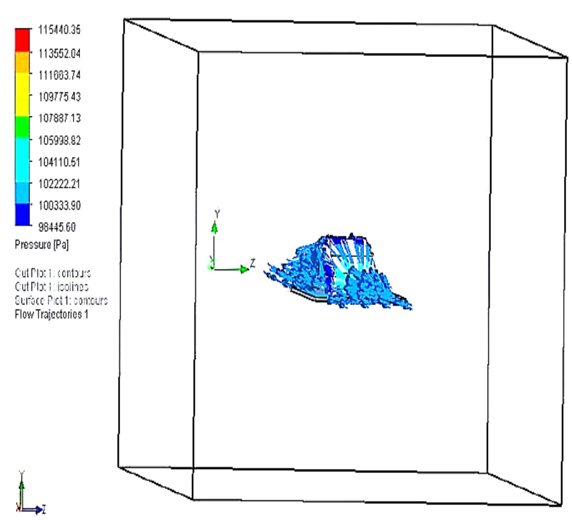


Figure A24 Flow trajectories with spheres

Case3

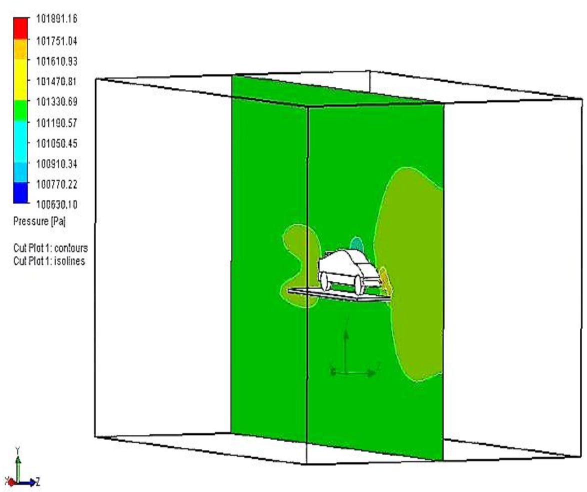


Figure A25 Cut plots

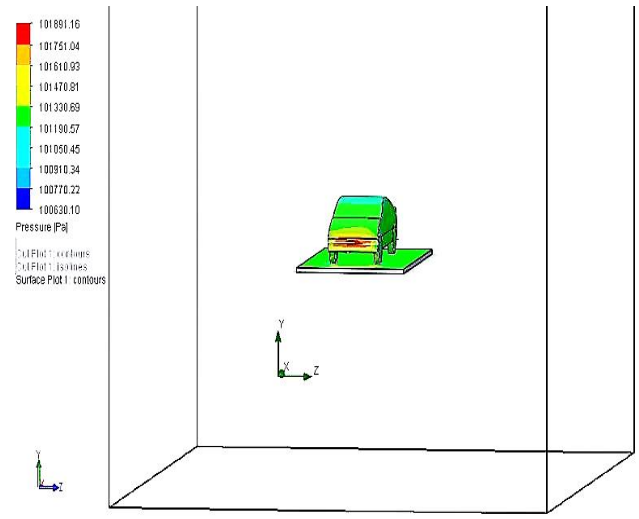


Figure A26 Surface plots

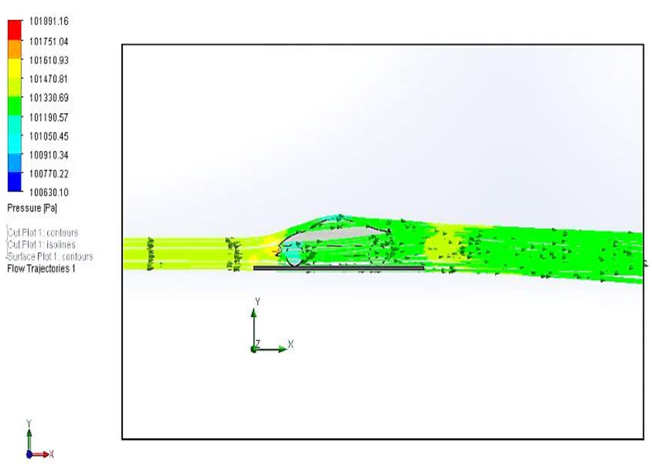


Figure A27 Flow trajectories with lines and arrows

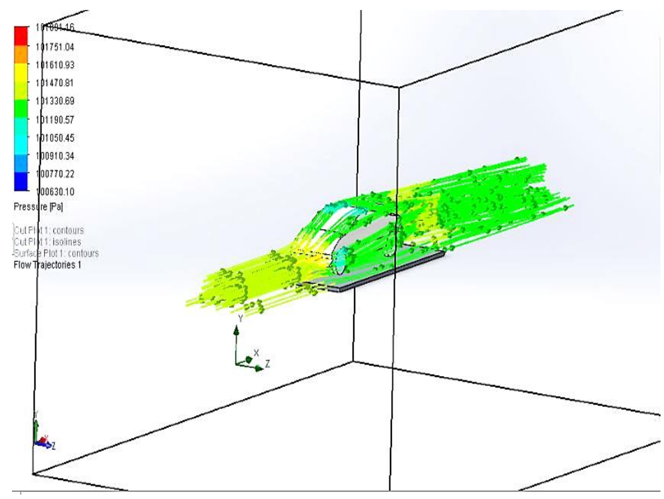


Figure A28 Flow trajectories with spheres

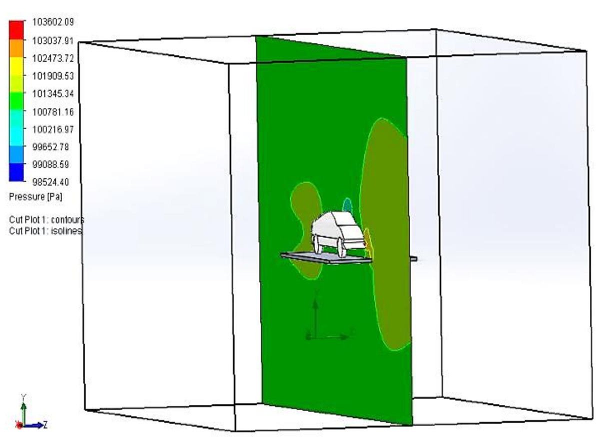


Figure A29 Cut plot

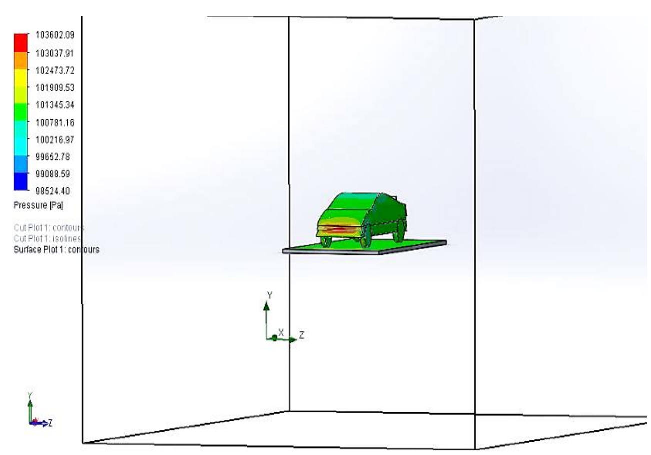


Figure A30 Surface plot

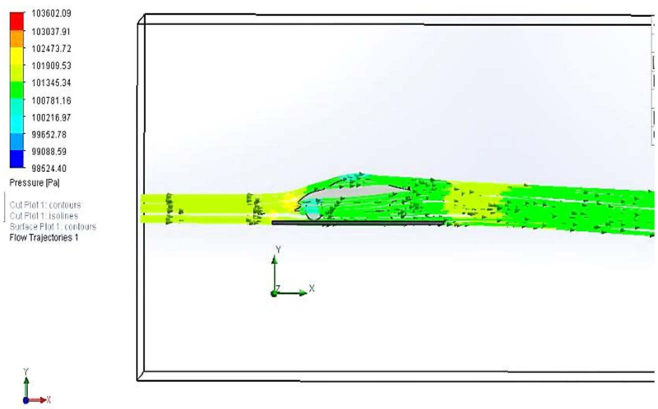


Figure A31 Flow trajectories with lines and arrows

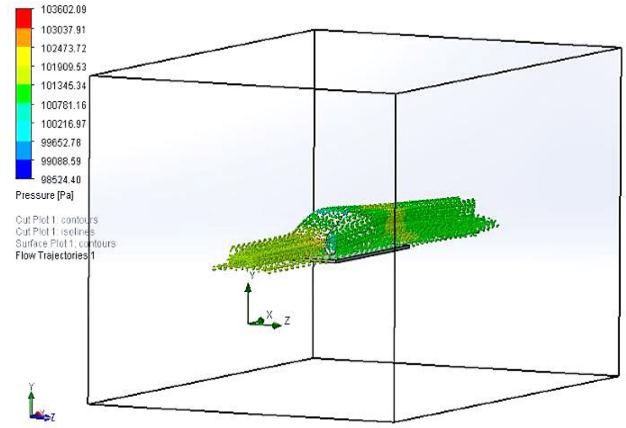


Figure A32 Flow trajectories with spheres

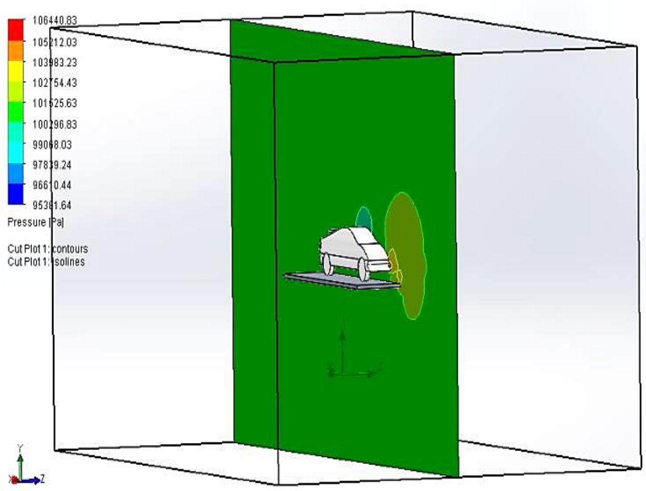


Figure A33 Cut plot

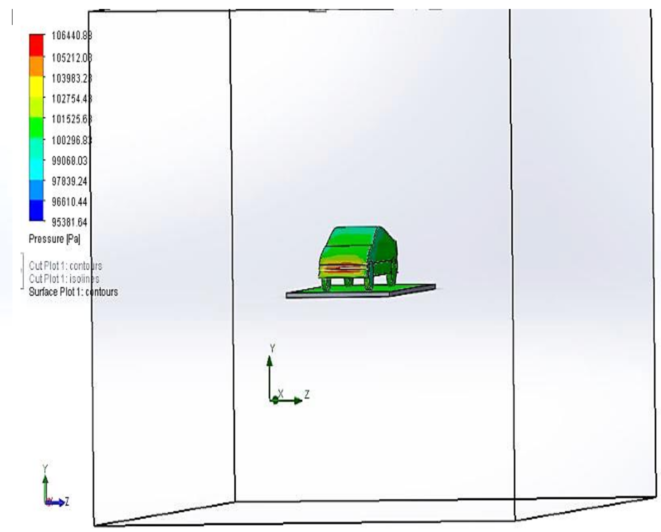


Figure A34 Surface plot

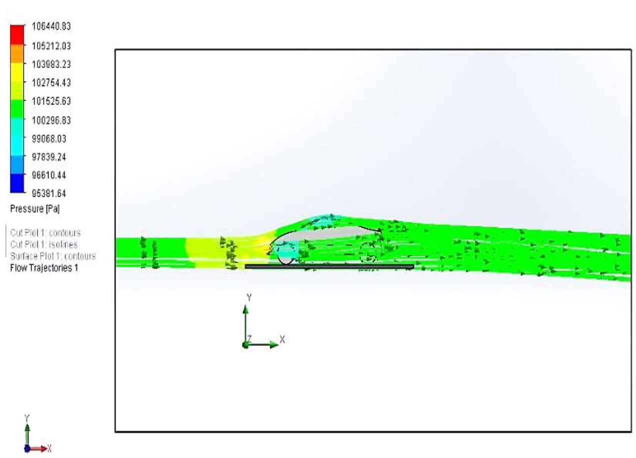


Figure A35 Flow trajectories with lines and arrows

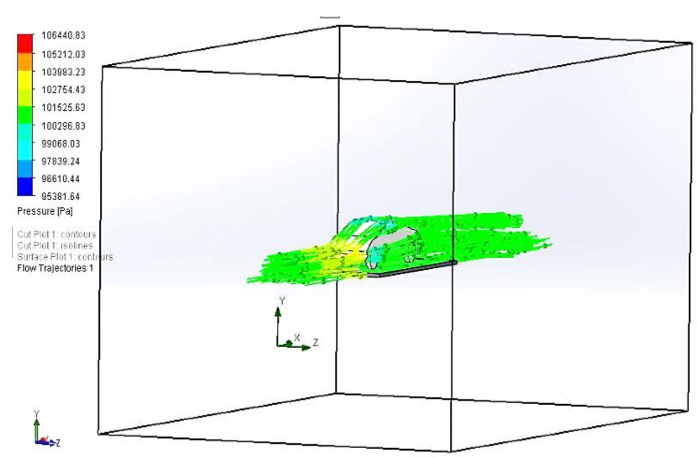


Figure A36 Flow trajectories with spheres

Case4

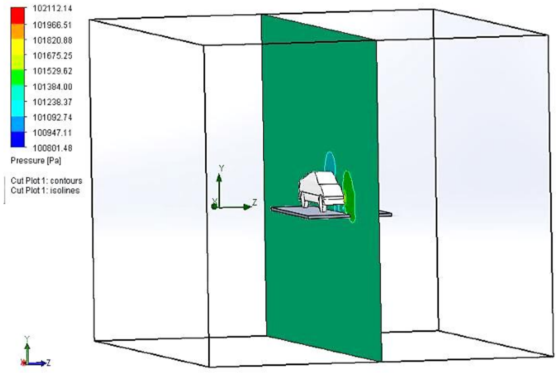


Figure A37 Cut plot

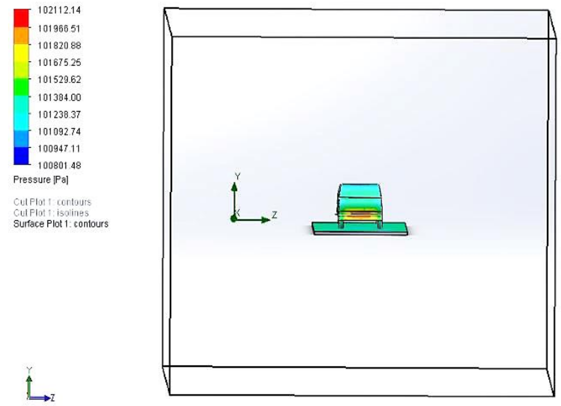


Figure A38 Surface plot

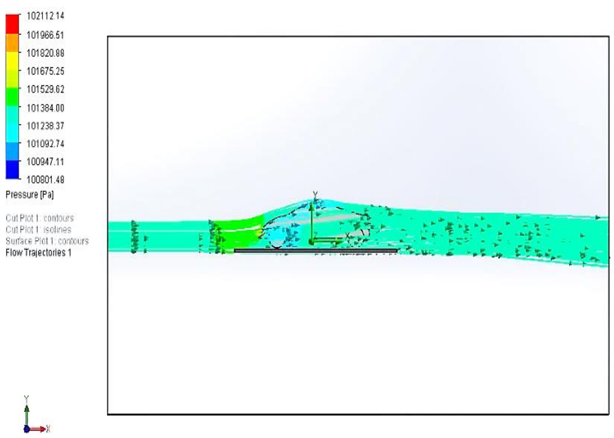


Figure A39 Flow trajectories with lines and arrows

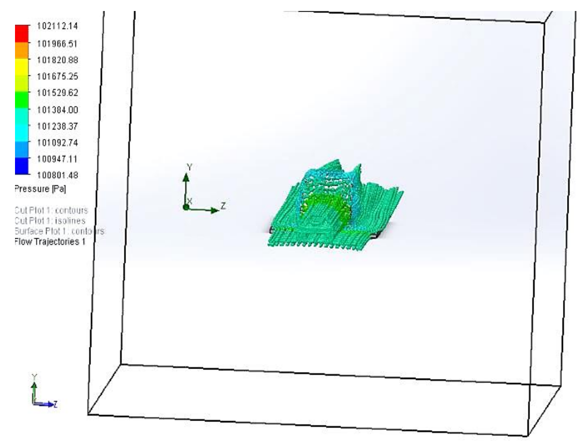


Figure A40 Flow trajectories with spheres

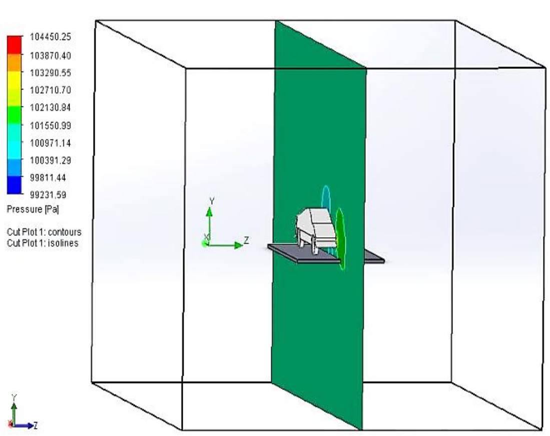


Figure A41 Cut plot

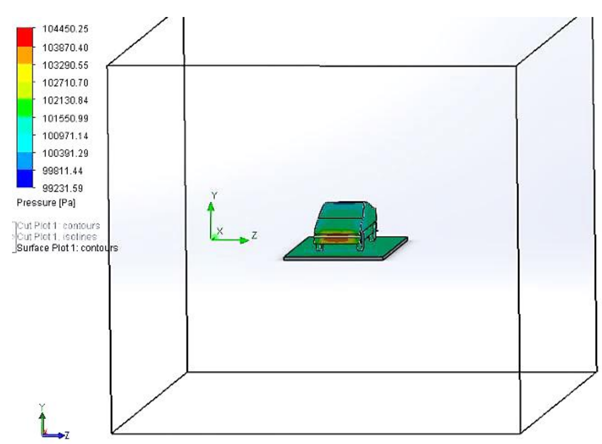


Figure A42 Surface plot

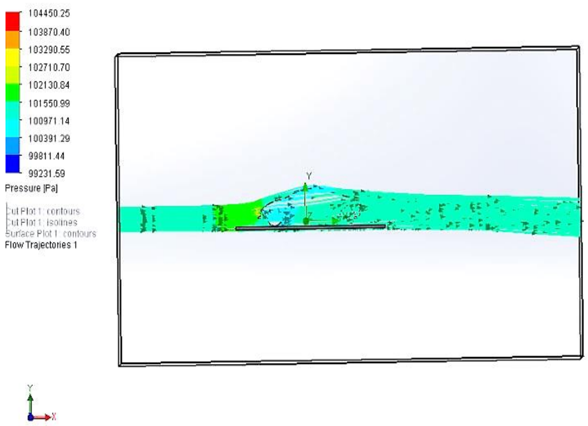


Figure A43 Flow trajectories with lines and arrows

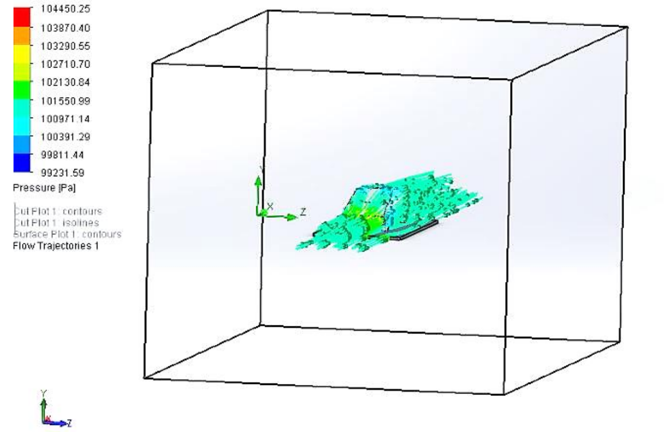


Figure A44 Flow trajectories with spheres

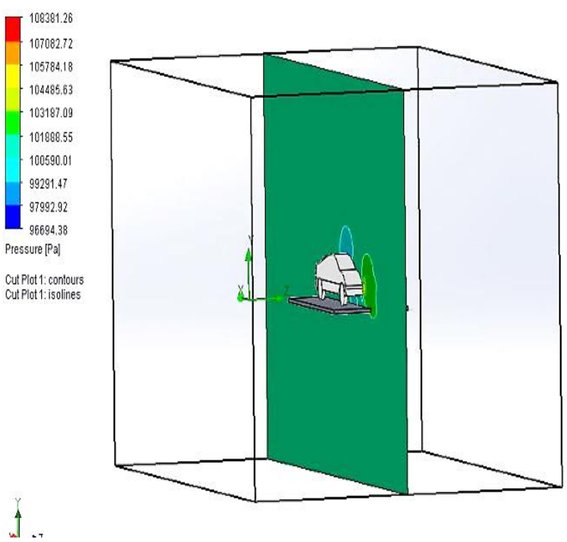


Figure A45 Cut plot

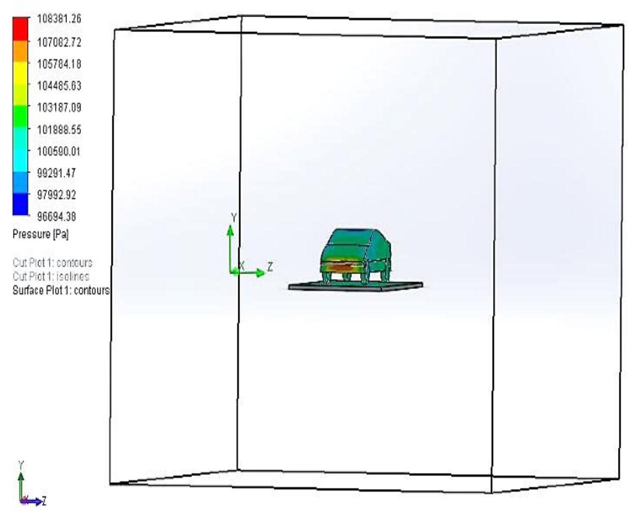


Figure A46 Surface plot

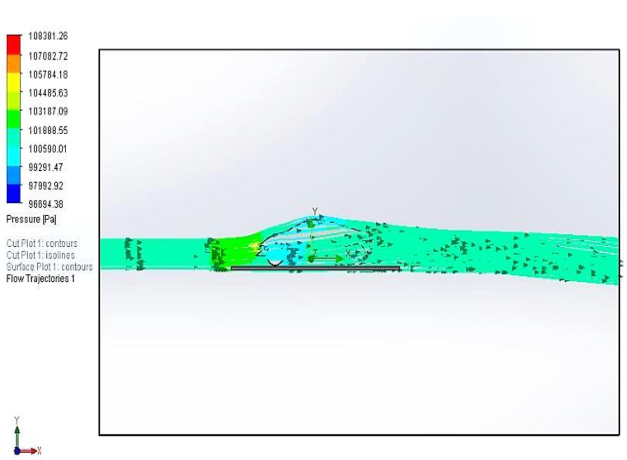


Figure A47 Flow trajectories with lines and arrows

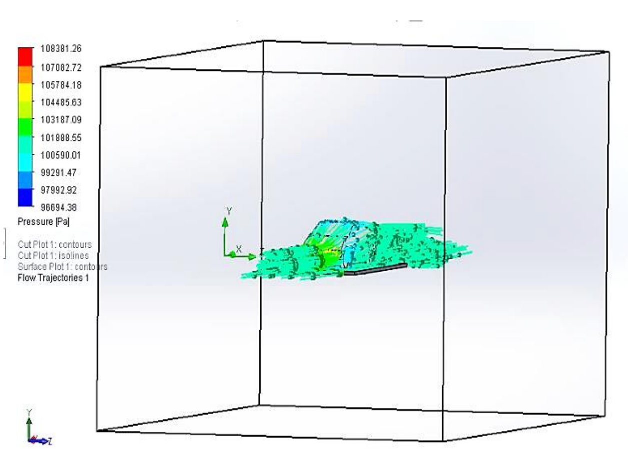


Figure A48 Flow trajectories with spheres