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***Vertical strakes design & simulation on an
Mygale F4 open-wheel racing vehicle***

Master's Project (ACFB7002)

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Abstract

Aerodynamic performance is a critical factor in motorsport, with the underbody representing one of the main generators of downforce. This project investigates the development of vertical strakes at the leading edge of the underbody of a Mygale F4 open-wheel vehicle, an area that has received limited attention in previous research. The main objective was to improve the performance of the car while providing further understanding of the influence of vertical strakes geometry and positioning on undertray flow.

A Computational Fluid Dynamics (CFD) methodology was developed using ANSYS Fluent, including domain and mesh independence studies and a baseline ride-height analysis. Five vertical strakes geometries were subsequently designed and evaluated, including straight, curved and hybrid configurations. The best-performing design was then selected for a parametric study analysing strake height and leading-edge position, followed by a ride-height study to assess its performance across different vehicle configurations.

The results showed that the hybrid strake configuration provided the greatest improvement, increasing aerodynamic efficiency by 2.50% compared with the baseline. The strakes increased the low-pressure region beneath the floor and generated stronger vortical structures that helped redirect the airflow towards the diffuser. The parametric study demonstrated that strakes height had a significant influence on aerodynamic performance, with a 70 mm configuration achieving a 6.21% efficiency improvement, whereas leading-edge position showed limited influence on overall performance. The final ride-height analysis confirmed an overall improvement in aerodynamic efficiency across most configurations, although with a forward shift in balance.

Overall, the study demonstrates the potential of leading-edge vertical strakes as an effective aerodynamic development for open-wheel racing vehicles.

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First and foremost, I would like to thank my family and my partner, who have been supporting me during all the process, all of them stayed by my side to keep going and complete this period. They have been my biggest help, pushing through my limits and lift me up when things got complicated. I will always be deeply grateful to them.

I would like to thank Tim Tudor and Chris Bull for giving me this amazing opportunity, being able to develop an aero device with all the tools to achieve, but also complete my biggest challenge, which has allowed me to grow personally and professionally, and prove my self that I can spend my life working with aerodynamic developments. Specially, I would like to express my immense gratitude to Tim, I have learnt a lot of from you, and you have helped me through all the process, guiding and supporting whenever it was necessary.

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1. Introduction

Aerodynamics is one of the key components in motorsport competitions, where any small development could make the difference and influence the performance of the car. Therefore, teams put effort in coming up with novelty designs that can create an advantage against their rivals.

In an article from 2013 by Sauber, a Formula 1 team, it was represented in a graphic the contribution from each principal component to the downforce and drag generated in the vehicle (W. Toet, 2013). Where the 52% of the overall downforce come from the underbody and diffuser.

Table 1.1. Percentage of aerodynamic forces generated by each component. (W. Toet, 2013)

Componet	Downforce (%)	Drag (%)
Front wing	30	20
Front wheel, Suspension and brake duct	-1	10
Chassis, bodywork	-10	10
Floor and diffuser	52	14
Rear wheel, suspension and brake duct	3	17
Rear wing	25	29

As the interest of develop a project around aerodynamics on motorsport vehicle, the opportunity to work in a Mygale F4 open-wheel car appear. Tim Tudor put in contact with Chris Bull, the aerodynamicist of the vehicle, to give the opportunity to help with the development of the car. Chris Bull started the development of the vehicle focusing on the rear part of the car, designing a new rear wing and diffuser. During this year, Ryan Boardman, a colleague from university, help on the develop of the new front wing for the vehicle.

After the initial meeting to understand the current point of the vehicle, it was decided to proceed with an aerodynamic design and simulation project using CFD to develop a new aero device to implement on the car and improve its performance.

Firstly, an initial analysis of the benchmark of the vehicle, thanks to the data provided by Tim and Chris (*Tudor and Bull, n.d*), help to understand the initial point and potential areas of improvement. In figure 1.1, it can be seen the pressure distribution around the vehicle and its current design.

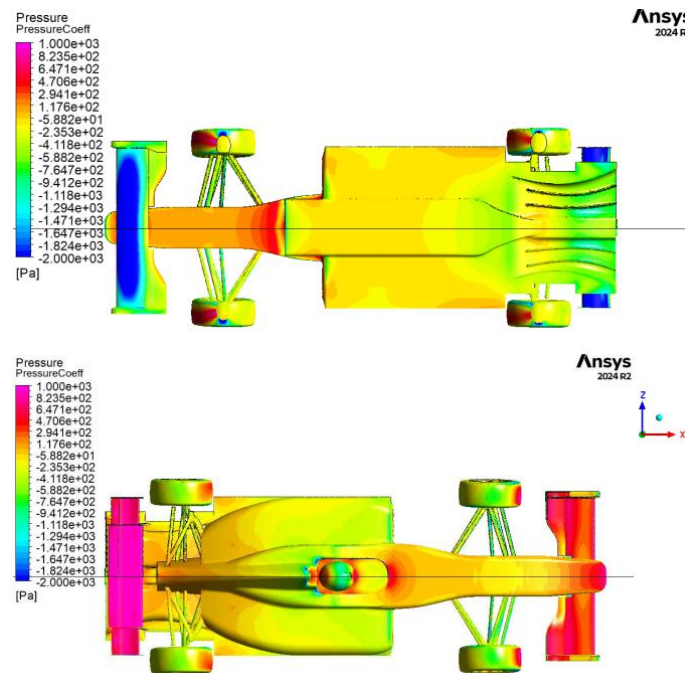


Figure 1. 1. Benchmark results of Mygale F4. (*Tudor and Bull, n.d*)

Here it can be seen that, compare to other parts of the vehicle, the underbody has a simple design despite the centre of it. Therefore, it was decided that would be the direction of the project, design a new aero device to implement on the underbody of the vehicle that could help to improve the performance and make an advantage.

To accomplish the objective, a methodology will be developed based on 3D iterative design combine with CFD simulations to understand the effects of the designs and their influence on the car.

1.1. Aims of the project

The aims of this project consist of three main objectives. Firstly, improve the performance of the vehicle implementing a vertical strakes design in the underbody. The idea of this development is helping to conduct the airflow to the rear part of the car in a better condition that helps to upgrade the overall work of the vehicle.

The second goal is to contribute with new data and research to underbody and vertical strakes developments field. As it would be presented in the literature review, the implementation of vertical strakes on leading edge seems to be a great opportunity to expand the field of study, as the most common use of these aero devices is focused on the diffuser.

As the third objective, a simulation combining the design from this project with the development from colleague Ben Ellis-Jones to study their iteration and the complexity of putting together different design on the vehicle and how can that affect the performance of each aero device and the car.

1.2. Regulations

The vehicle has been competing in the HAS sprint championship for a few years, an organised competition by the Hillclimb and Sprint Association of different events at England, Scotland, Wales and Northern Ireland. The event format for the principal championship title comprises, practice, qualification and two Run Offs for the fastest 12 qualifiers for each Run off (*Hillclimb and Sprint Association, 2026*). The regulations for the championship are presented on the Motorsport UK National Competition Rules 2026 Edition 3 (*Motorsport UK, 2026, Ch.14.4.17*), the restrictions for open wheel single seat racing cars can be found in chapter 14, Appendix 4, article 17. In the following figure the information is presented.

17. Regulations for Open Wheel Single Seat Racing Cars

17.1. Dimensions

17.1.1.

Maximum width ahead of front wheels	1500mm
Maximum width behind front wheels	1400mm
Maximum height of any part wider than 1100mm ahead of the front wheels	Not to exceed the top of the front wheel rim
Maximum height	900mm from the ground
Maximum rear overhang	1500mm behind rear wheel axis.

17.1.2. Maximum height is measured with the car in any condition and Driver aboard. Safety roll-over bars and air boxes are not included in this measurement.

17.2. Wheels

17.2.2. Twin rear wheels are permitted.

Figure 1. 2. Motorsport UK National Competition Rules 2026 Edition 3 3 (*Motorsport UK, 2026, Ch.14.4.17*).

It is important to follow these restrictions during the progress of the project and the development of the designs, as any misconduct could lead in a ban of the aero devices developed. In this case, regulations are quite flexible on the aerodynamic developments and allow a big freedom on the underfloor design with the limitation of minimum 40mm static ride height.

2. Literature review

The literature review in this project is divided in two parts. To begin with, the focus will be set on the latest studies and developments of the underbody of open-wheel racing cars, like Formula Student or Formula 1 vehicles. With this initial investigation, it is planned to understand the current technologies around undertray design and to find an advantage for the team against its competitors, as well as to contribute with new developments to the field. The second part, will be focus on the vertical strakes' literature, as this is going to be the development on the project

2.1. Underbody research

The literature review strategy consisted of the three following databases, SAE Mobilus, ProQuest and ResearchGate respectively. The key words for each search are “aerodynamic”, “flow” and “undertray OR floor” and were maintained during the investigation in each database. As one of the objectives is to focus on the newest developments in recent years, a filter was applied to each database search, from 1/4/2015 to 1/4/2026 to narrow down the research to the studies on the last decade.

SAE Mobilus

In SAE Mobilus it was possible to find 18 possible articles, 8 of them were discarded based on title and abstract because there were different approaches on them regarding underbody developments. Most of them were focused on characteristics and variables apart from aerodynamic upgrades. After reading the 10 remaining articles, only 4 of them are going to take into account as references for the project, as the articles discard were focused on underbody developments in automotive vehicles.

ProQuest & ResearchGate

For these databases, they are going to be presented together, as the result from their review only shows 2 articles from each resource that were not discard based on title and abstract. Therefore, the four articles were read to determine if they were useful for the project. One of the articles was discard after they were read in each database as they were focus on automotive development on the underbody. The other two are going to be used as they were useful and align with the ideas of this project, presenting different aerodynamic developments in the underbody that are usually implement.

Conclusions from underbody research

After the initial literature review was completed, it was possible to come with different conclusions. The first conclusion to highlight is that most of the studies and developments on the underbodies of vehicles are focused on the diffuser (*Hady, 2018; Nebot et al., 2025*) and not in the entrance part of the floor. This statement contributes to the value of this project for the underbody development field, as it could give another point of view and more information regarding the importance of the leading-edge of the floor of Formula racing cars. As mentioned before, the entire underbody is the biggest downforce generator on a racing vehicle, therefore, not only the diffuser but also the front area plays a critical role too.

Another conclusion obtained from the literature review is the performance from straight strakes versus curved strakes. While the studies on Formula student suggest a better performance from straight design (*Hady, 2018*), at Formula 1 level the implementation of curved strakes seems to be the preference (*Shaan et al., 2024*), although the more

complexity in this development. Taking everything into account, it is possible to come up with the possibility of implementing vertical strakes on the leading edge of the Mygale and contribute with more data to the field.

With the objective of understanding how vertical strakes work and the knowledge around them, a second literature review was performed specialized in the vertical strakes' field.

2.2. Strakes' literature review

In this case, it was challenging research. There are not a lot of articles and technical papers around developments of vertical strakes at the entrance of the floor, putting the focus for this aero device to be implemented in the diffuser. Because of that, it was necessary to include articles about the strakes implemented in the diffuser to have a better knowledge of how they work and affect the airflow.

The vertical strakes are defined as passive aerodynamic devices consisting of narrow, shallow vertical plates or vanes installed longitudinally on the vehicle underfloor, mainly arranged along the diffuser ramp channels. (Tohpati, 2021; Nebot et al, 2025; Kasimahanti, 2025)

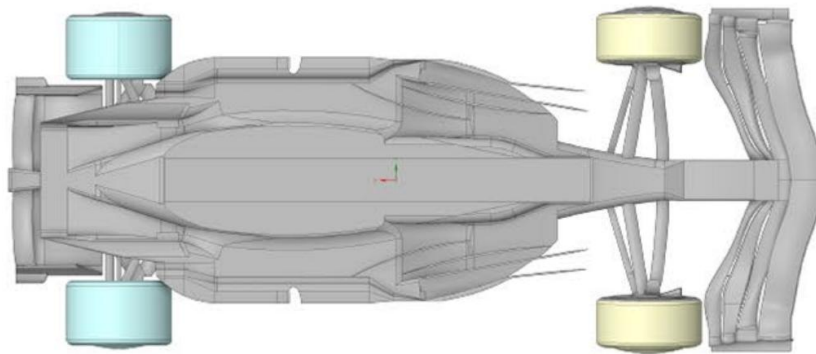


Figure 2. 1. Strakes design on RB18. (Shaan et al., 2024).

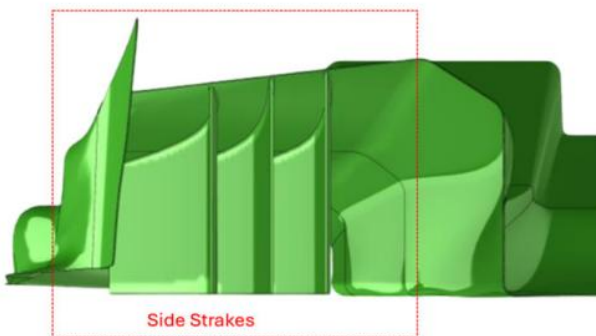


Figure 2. 2. Strakes design (Nebot et al., 2025).

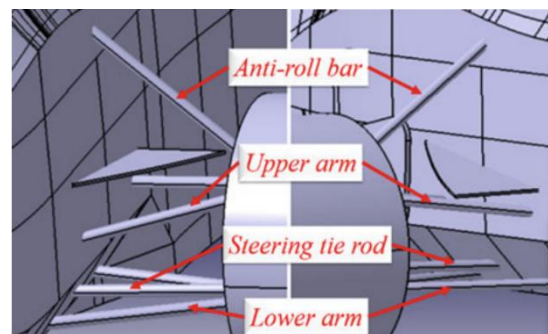


Figure 2. 3. Strakes design (Zhang et al., 2022).

For this literature review, SAE Mobilus, ProQuest and ResearchGate were also used for this specific search. However, due to the limitation on articles, databases from Universities were also included to expand the possibilities, including final projects and chapters from books.

The key words for the search were more flexible to be able to obtain a properly knowledge and studies. “Aerodynamic”, “vertical strakes OR vertical vanes”, “leading edge” and their synonyms. In addition, the date filter was also eliminated to get rid of the possibility of limited or loss articles or information. All these decisions were made and have some differences from the first literature review due to the low data around vertical strakes.

After completing the literature review, 13 additional articles were found that will support the project. 7 out of 13 articles talked about vertical strakes development, 3 of them at the forebody; one at the edges to seal the floor; another 3 at the diffuser. The other five articles talked about optimization process to develop an underbody the interaction between different components; and future development and studies in F1.

Conclusions from strakes literature review

Form this literature review there are findings around vertical strakes that support the ones from the initial review. First of all, the comparison between straight strakes and curved strakes keeps being an important area of study. With 3 out of 7 articles about straight ones and other 3 about curved ones. In these articles, the tendencies were similar to the previous ones, where the curve designs tend to have a greater aerodynamic efficiency (*Lasso-Parera et al., 2026; Kasimahanti, 2025*), a bigger pressure recovery on the diffuser (*Lasso-Parera et al., 2026*) and a greater acceleration in the diffuser channel (*Tohpati, 2021*).

On the other hand, the straight strakes reduce the boundary layer separation (*Handy, 2018*) and create simple and stable vortex (*Zhang, G. et al., 2018; Martinez Conde & Altmeyer, 2025*) that are easier to understand, making them a great design for Formula student vehicles as it was seen in the studies from the initial literature review.

From this research, it was found on the latest articles and development that hybrid designs are a great opportunity. Combining both developments (*Soares et al., 2018*) straights and curved or adding a slightly curvature to the straight designs (*Kasimahanti, 2025*).

Although all the information found, most of it is the combination of curve ones at the entrance and straight ones at the diffuser. Therefore, the objective of this project of coming up with a novelty design combining both at the entrance for the team is reinforced, but also the addition of new data and studies to the field.

Another important finding from both literature reviews is the minimum parametric studies around variables that define vertical strakes. All of them focus on comparing different designs and their performance, but not how a one variable change, like position, could affect that output. Therefore, that would be a new aim for the project with the final design to try give a better understanding and data on some of the variables that define vertical strakes.

3. Methodology

Talking about the methodology of the project, in the figure 3.1 it can be seen the workflow of the project with all the phases follow.

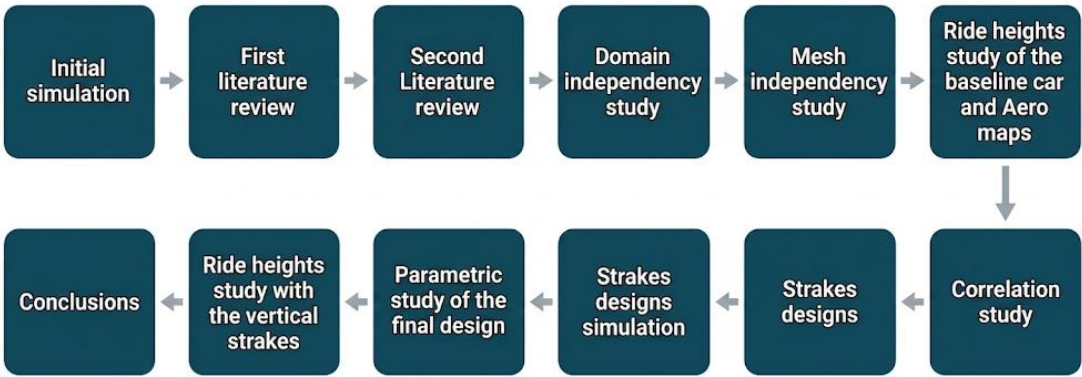


Figure 3. 1. Project Workflow.

In addition, in the next figure 3.2 it is presented the Gantt diagram of the project, this gives a better view of the time and evolution of the project during its development.

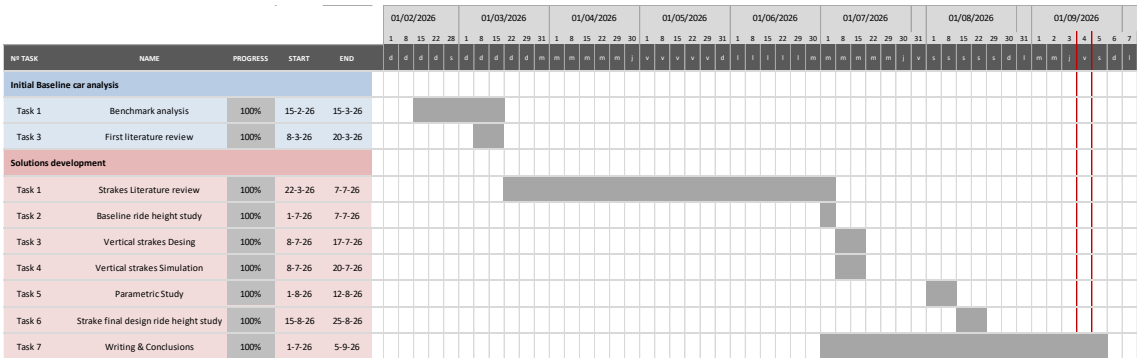


Figure 3. 2. Gantt diagram.

The first step presented in the workflow, “initial simulation”, represent a first analysis of the baseline of the car to search for areas of improvement as mentioned in the introduction. Alongside of this first analysis. the initial literature review was developed to find possibles upgrades and modifications in the vehicle, mainly focus on the underbody as it was found to be the less evolved part of the car. As the project continued, the literature review about vertical strakes was performed, explained in the previous chapter.

3.1. Project simulation set up

For the next step of the project, it began the preparation of the set-up and strategies for the simulations. All the simulations will be run in ANSYS, using its different modules for each step. SpaceClaim for the geometries and domain preparation, ICEM for the meshing strategy, Fluent to run the simulations and results to analyse all the parameters obtained.

Starting with an initial configuration to prepare all the parameters and boundary conditions. The characteristics of this set-up were:

- Initial Domain:
 - Dimensions:
 - Type of mesh H
 - Upstream 10m
 - Downstream 25m
 - Sides 3m
 - Top 3m
 - Wheels patch 5 mm
 - Body of influence:
 - From the centre of the car. Dimension on X 2.5 times, 1.3 on Y & Z times the dimension of the vehicle.
- Mesh:
 - Type of mesh: Quad
 - Fwheel and Rwheel 0.01
 - Body of influence Mesh size 0.1
 - Global mesh size 0.8
- Initial Boundary conditions:
 - Inlet → velocity 40 m/s
 - Outlet → pressure 0Pa
 - Ground → moving ground 40 m/s
 - Side → Symmetry
 - Top → Symmetry
 - Fwheel and Rwheel → moving wall 151.2476 rad/s
 - Front wheel Rotation Axis origin: centre of front wheel axis
 - Rear wheel Rotation Axis origin: centre of rear wheel axis
- Turbulence model → k-w SST
- Solution Methods:
 - Scheme → Couped
 - Flux type → auto select
 - Spatial discretization
 - Gradient → Least squares cell based
 - Pressure → Standard
 - Momentum → First order upwind
 - Turbulent kinetic energy → Second order upwind
 - Specific dissipation rate → Second order upwind
 - Pseudo Time Method → OFF
 - Y Warped-face gradient correction → Selected.
- Solution Controls:
 - Flow courant number → 50
 - Explicit relaxion factors:
 - Pressure → 0.25
 - Momentum → 0.25
 - Under relaxation factors:
 - Density → 1

- Body forces $\rightarrow 1$
- Turbulent viscosity $\rightarrow 1$
- Turbulent kinetic energy $\rightarrow 0.5$
- Specific dissipation rate $\rightarrow 0.8$

3.1.1. Boundary conditions

This first configuration was based on research data and studies that presented the most common and accurate boundary conditions and solver parameters in external aerodynamic simulations (*Lu et al., 2021*). Using an inlet velocity that makes the aerodynamic coefficients independent from the Reynolds number but also a value that the vehicle would be running in a real context (*Kuttasirisuk et al., 2025*). For the moving ground condition is one of the most important boundaries as it would lead the simulation to represent correctly the relative movement between the road and the car, avoiding the possibility of creating a boundary layer that interfere with the flow under the car (*Kuttasirisuk et al., 2025*).

The boundary condition at the outlet is define as pressure gauge 0 Pa as it is the common configuration to represent the ambient pressure in incompressible flow conditions. (*Kuttasirisuk et al., 2025; Lu et al., 2021*).

Selecting the Symmetry condition for the Top and Side areas of the domain help to reduce the iteration between the walls and the vehicle but also save computational resources (*Kirchberger, 2023*).

For the moving wall condition for the wheels, as a rotatory wall, the objective is to represent accurately the iteration between the wheels with the air and the floor, using the same velocity (*Kuttasirisuk et al., 2025*). Therefore, the wake behind the wheels would be well represented as it is one of the critical aspects in these simulations because it generated the bigger part of the drag of the vehicle (*Kirchberger, 2023*).

3.1.2. Turbulence model selection & Solver parameters

Talking about the turbulence model selected, based on the literature found (*Lu et al., 2021; Kirchberger, 2023*) the “k-w SST” model seems to be the most robust solver for the boundary layer behaviour, near the walls, and the flow separation (*Kirchberger, 2023*). Critical aspects for this project as it would study the behaviour of the flow around the underbody and the strakes design. However, a comparison study between the k-w and k-e model was performed to corroborate that would not be an important difference on the results. As k-e is the other common turbulence solver use in Formula vehicles simulations (*Kirchberger, 2023*). In appendix A is possible to see the results.

Regarding the parameters of the solver, the objective was to use a configuration that has a balance between, stability, accuracy and time-efficiency. Coupled is selected as a faster and reliable scheme for vorticity and separation on boundary layer, in addition with a great performance with low ride heights and big angles in the diffuser (*Ravelli, 2021*).

The combination of a gradient based on Least squares cell based with pressure and momentum using first order upwind and turbulent kinetic energy and specific dissipation rate with a second order upwind, follow that strategy of balance. While first order gives numerical stability and a correctly results to avoid a divergence in complex geometries

(Ravelli, 2021), second order improve the accuracy in critical data like the turbulent kinetic energy (Martinez Conde & Altmeyer, 2025). Despite combining a few first order iterations with a later change to second order usually gives more accurate results, there are studies of fast-turnaround CFD which have validated first order implementation to obtain robust tendencies (Desai et al., 2008).

The convergence controls and relaxing factors selection is aligned with the strategy, using save explicit relaxation factors to help the first order solvers make smoother steps and avoid losing precision (Ravelli, 2021).

3.1.3. Domain design

The domain design started with the initial configuration presented, where 25m downstream is a bigger length compared to the ones use on the literature found (Kuttasirisuk et al., 2025; Kirchberger, 2023) that would let the airflow to recover and catch the whole wake behind the car. The 10m upstream are higher than the minimum recommended for Formula Student vehicles (Kirchberger, 2023) allowing the flow to develop before interacting with the Mygale. Side and top dimension as 3m represent an enough space to ensure the walls do not influence the airflow around the vehicle (Kirchberger, 2023). Finally, a body of influence is included in the domain to increase the accuracy around the car of the boundary layers and vortex. In addition, with optimising the computer resources and creating an efficient domain.

As mentioned before, this was the initial configuration of the domain, an independency study of the domain was performed to be able to have the most efficient dimensions without penalizing the accuracy of the results. The strategy follows during the study can be seen in the next table 3.1:

Table 3. 1. Domain independency study.

Study	Variable Investigated	Domain Dimension	Fixed Domain Dimensions	Total Cells (Millions)	Remarks
General Setup	-	-		-	Mesh distribution: Global = 0.8; F4 Body = 0.02; Front Wheels = 0.02; Front Wing = 0.01; Rear Wheels = 0.02; Rear Wing = 0.01;
Rear Domain Length	Distance Downstream	25 m	Front = 10 m; Sides = 3 m; Top = 1.5 m	3.14	Reference case
		20 m	Same as above	3.09	

		15 m	Same as above	3.15	
Front Domain Length	Distance upstream	12.5 m	Rear = 20 m; Sides = 3 m; Top = 1.5 m	3.14	
		10 m	Same as above	3.09	
		5 m	Same as above	3.15	
Side Domain Width	Distance from vehicle sides	2 m	Rear = 20 m; Front = 10 m; Top = 1.5 m	3.09	
		3 m	Same as above	3.09	
		4 m	Same as above	3.11	
Top Domain Height	Distance above the model	1 m	Rear = 20 m; Front = 10 m; Sides = 3 m	3.10	
		1.5 m	Same as above	3.09	
		2 m	Same as above	3.17	

As it is presented, the study consists in the analysis of each dimension that define the domain, simulating three values for each of them. For the analysis, the mesh size was around 3.10 million of cells to be able to save time and computer resources on each simulation but having a fair level of accuracy. As the main objective here was analyse the influence of each dimension's value. In relation with this, it is important to highlight that in this study the body of influence was not include.

3.1.4. Mesh independency study

To continue with the workflow of the project, a mesh independency study was developed. In the next table 3.2 it can be seen the structure follow:

Table 3. 2. Mesh independency study.

Mesh Level	Cells (M)	Domain (U/D/S/T) [m]	BOI	Global	Body	Wheels	Wings
Coarse	1.83	10 / 20 / 3 / 1.5	Included	0.8	0.05	0.05	0.025
Medium	3.98	10 / 20 / 3 / 1.5	Included	0.8	0.02	0.02	0.01
Fine	5.44	10 / 20 / 3 / 1.5	Included	0.8	0.018	0.018	0.01
Extra Fine	7.41	10 / 20 / 3 / 1.5	Included	0.8	0.01	0.01	0.005

Abbreviations: U = Upstream, D = Downstream, S = Side distance, T = Top distance.

The strategy follows to study the sensitivity was start with a Coarse mesh and decreasing the mesh size in the critical points of the domain until the results variation is smaller than 5%. Those critical aerias are the Mygale's body, the wheels and the front and rear wings as are the zones of interest in the project. It is also important to highlight that the inflation function it was not implemented in the boundaries of those critical aerias, because in a few test simulations during the mesh study, the solution would not converge. The reason for this is in complex geometries this meshing tool could generate skewness (*Ravelli, 2021*), in addition, some studies validate the results where the y^+ value was around 150-200 (*Desai et al., 2008*) and with solid accuracy at boundary layers operations from the k- ω SST model it is possible to obtain robust results.

3.2. Ride heights study

Once the simulation strategy is prepared, a ride heights study would be performed to understand the aerodynamic behaviour of the vehicle. Moreover, this analysis will help to check if the simulation strategy is robust and repetitive without issues. In the following table 3.3 it can be seen the different ride height configurations that were simulated:

Table 3. 3. Ride Heights Configurations.

Ride Heights Configurations						
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70					
	75					
	80					
	85					
	90					

It makes a total of 13 configuration simulated that would give the data to interpolate and complete the whole matrix. To achieve that, a MATLAB script developed by Evans (2026) would calculate the blank spaces and generate the Aero maps of Lift, Drag, aero efficiency and forward balance of the Mygale to obtain a better understanding of its behaviour.

3.3. Correlation study

A comparative correlation study was performed to confirm the tendencies and results from the independency studies to validate them and the strategy selected for the simulations. It would be done comparing the results from the project with an assessment developed by Ben Ellis-Jones (2026) developing independency studies around a Mira vehicle.

As the results come from outside of the project and they are used as a complementary information with the literature review use for the definition of the simulation set-up. The results would be included in the appendix F for any review required.

3.4. Vertical strakes design

Now that every initial step is prepared and the understanding of the vehicle, following the workflow of the project it started the vertical strakes design process. In this phase, it began with an initial design (V1) based on the information from the literature review. In addition, two designs, pure straight strakes (V2) and pure curve strakes (V3), were developed to study the performance and compare the results with the data from the articles found in the research. At the end, another two designs are created, as an evolution combining straight and curve strakes in the same design (V4 & V5). Next each design would be presented with their characteristics and ideas behind the design.

3.4.1. Strakes V1

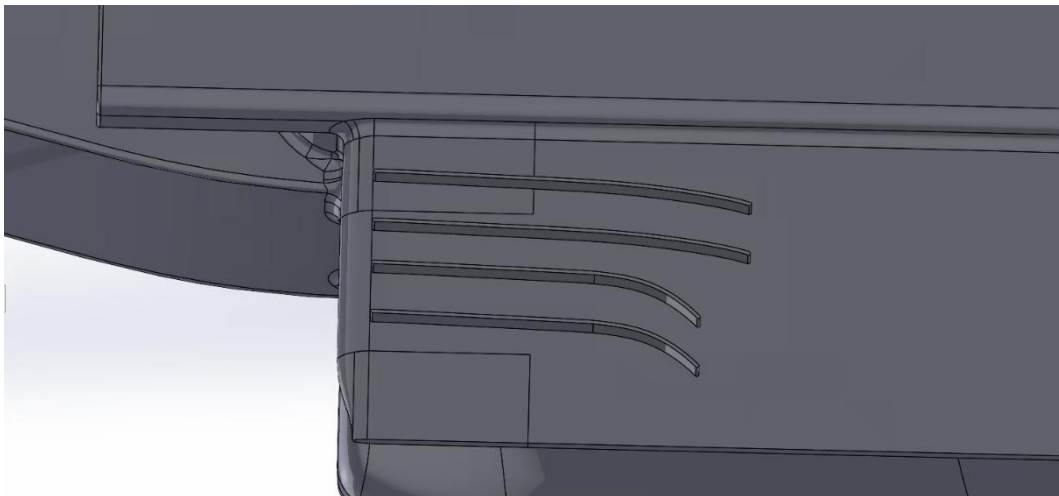


Figure 3. 3. Strakes V1 design.

Strakes V1 is the initial design obtained based on the resources found in the first literature review (Hady, 2018; Shaalan et al., 2024). It is divided in two parts, the external strakes with a higher angle at the end to get out the air from the wheels; and the internal strakes to lead the airflow to the diffuser. All of them start at the same point at the entrance of the floor and with the same space (0.07m) between each of them.

3.4.2. Strakes V2

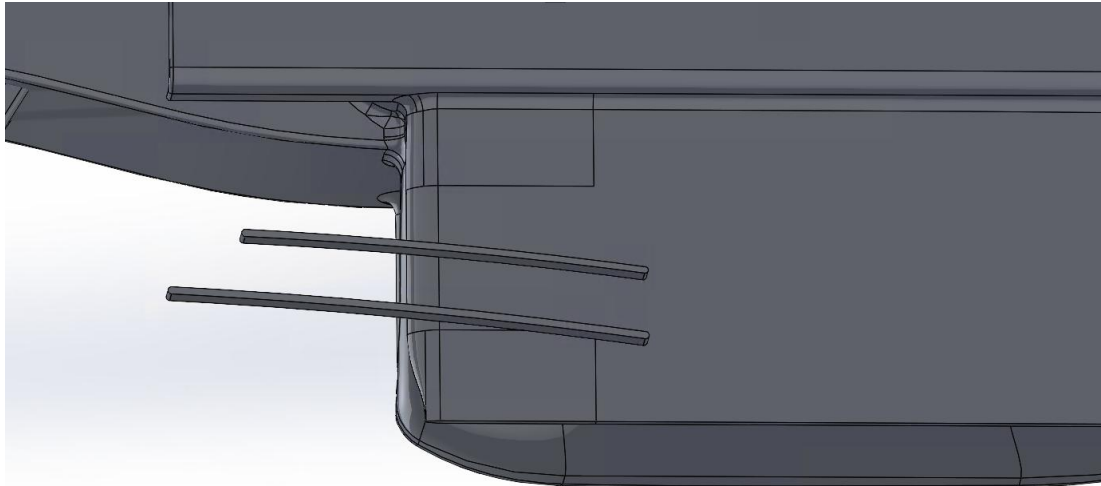


Figure 3. 4. Strakes V2 design.

The V2 design is defined with pure straight strakes to obtain more information regarding this configuration and compared with the literature review. This time, the starting point of the strakes is not the same and further along the leading edge with the objective of split up the stable flow and the wake from the front wheels as Shaalan et al. (2024) suggest. Straight designs seem to work better on Formula student's vehicles (Thom et al., 2019).

3.4.3. Strakes V3

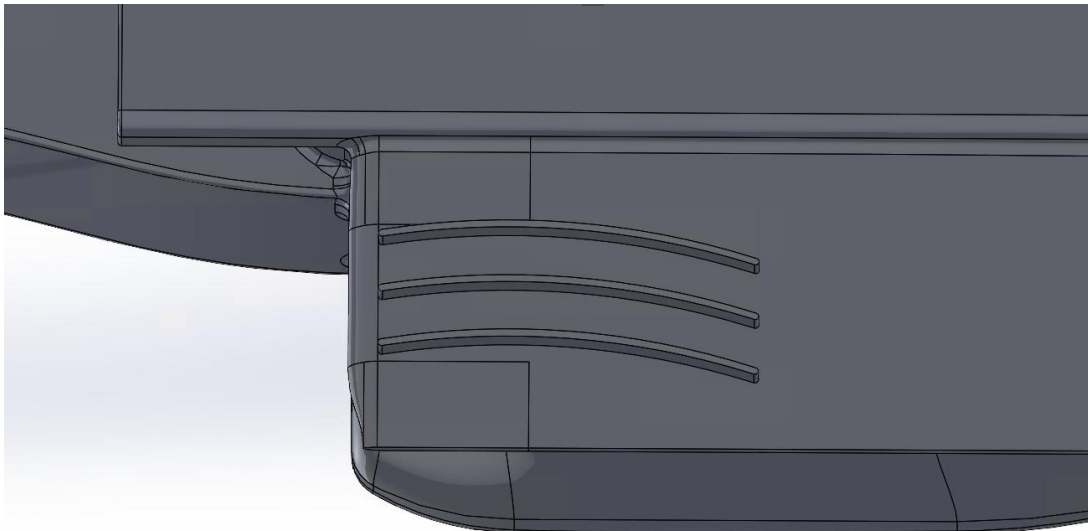


Figure 3. 5. Strakes V3 design.

V3 design is a pure curve configuration based on Nebot et al. (2025) design of turning vanes at the entrance of the underbody. Where all the strakes' starting point is at the entrance & same space between them (Hady, 2018). This configuration should accelerate the airflow creating low-pressure zones (Tohpati, 2021). The idea is compared V3 with V2 to see the differences between straight vs curve strakes and how influence the airflow of the underbody, trying to contribute with more data to the studies on the field.

3.4.4. Strakes V4

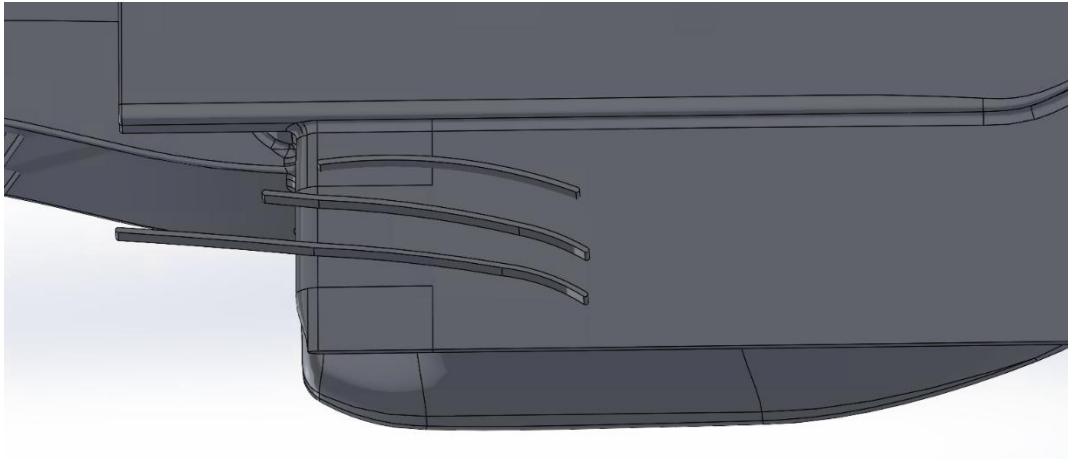


Figure 3. 6. Strakes V4 design.

V4 design is the first hybrid design combining the most interesting parts of V1, V2 & V3. The idea of this hybrid design came up as a novelty design, with the influence of Kasimahanti (2025) and Nebot et al. (2025) where it is mentioned the combination of turning vanes with vertical flaps. Moreover, in different articles from the research the hybrid design is presented as a combination of curve strakes at the underbody entrance and straight stakes at the diffuser (Ravelli, 2021; Soares et al., 2018; Nebot et al., 2025). In addition, stagger the strakes as Shaalan et al. (2024) suggested is implemented again in this design, having each strake a different starting point, one of the further along the leading edge to separate the stable airflow and the wake from the wheel.

3.4.5. Strakes V5

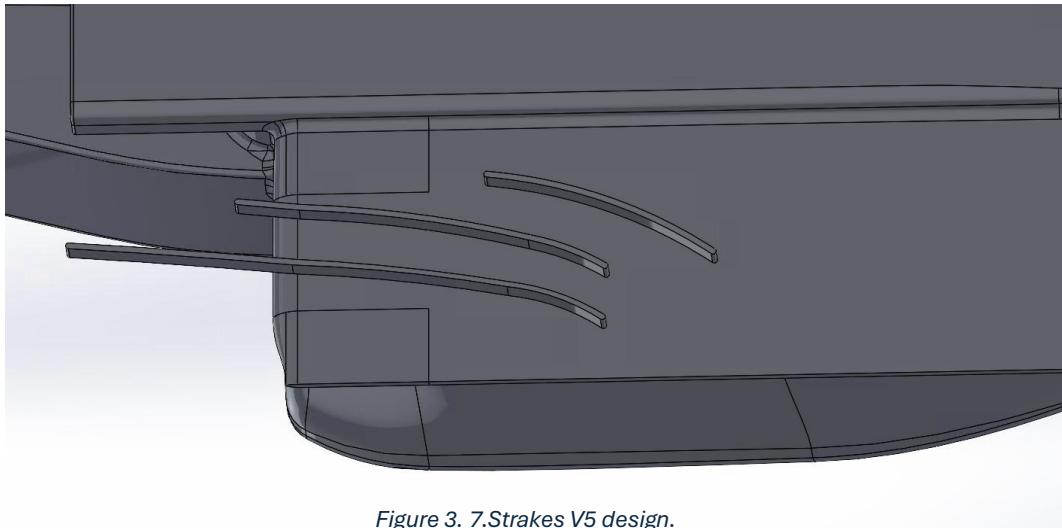


Figure 3. 7.Strakes V5 design.

V5 design is the second hybrid configuration, a variation from V4 where the third strake has a greater stagger to catch the airflow at the exit of the other ones and mover rearwards the low-pressure zone generated (Shaalan et al., 2024).

Regarding the simulation of the strake's designs, the variables that would be compare and analyse to select the final design are presented next:

- Forces:
 - Lift Force
 - Lift coefficient
 - Drag force
 - Drag coefficient
- Aero efficiency
- Forward Balance %
- Total pressure
- Pressure distribution on Symmetry plane
- Velocity distribution on Symmetry plane
- Pressure distribution on F4 car
- Vorticity on F4 vehicle and strakes
- Streamlines

3.5. Parametric Study

After all the simulations were completed, strakes V5 was selected as the final design. As mentioned before, due to the lack of parametric studies in the literature, it seems a great contribution to the field make one of them with two variables on the final design, to give a better understanding of how can affect the performance of the aero devices. The two variable that would be studied are the height of the strakes and the distance from the start of the third strake and the leading-edge entrance on the X axis. Firstly, the height is an interesting parameter that can affect the performance. On one hand bigger strakes generate greater drag, on the other hand bigger strakes means higher channels that can canalize more airflow and generate bigger vortex to seal the floor. For the position of the third strake from the leading-edge entrance, this position affect how rearward will the vortex generated arrived and where the low-pressure zone would be generated, both of them interesting aspects to control the airflow under the floor.

In the following tables, Table 3.4, are presented the range of values studied for each variable.

Table 3. 4. Parametric study strategy.

Parameter	Strakes V5 Height Study	Strakes V5 Leading Edge Distance (X) Study
Strakes design	V5	V5
Parametric variable	Strakes' height	Leading edge distance (X)
Values investigated	20, 30, 40, 50, 60, 70 mm	240, 290, 340, 390, 440, 490 mm
Number of configurations	6	6
Increment	10 mm	50 mm
Range	20–70 mm	240–490 mm

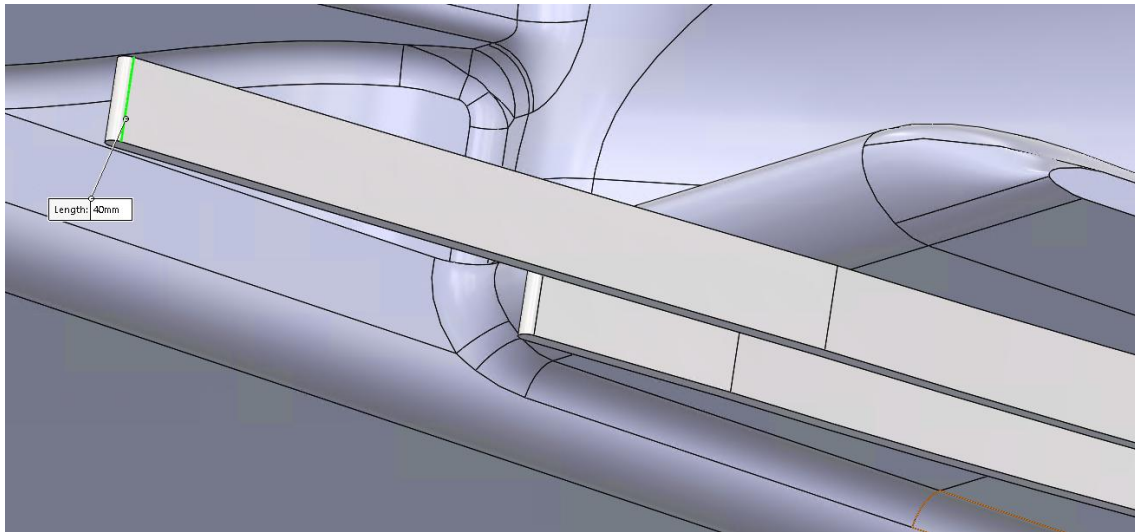


Figure 3. 8. Reference dimension of parametric height.

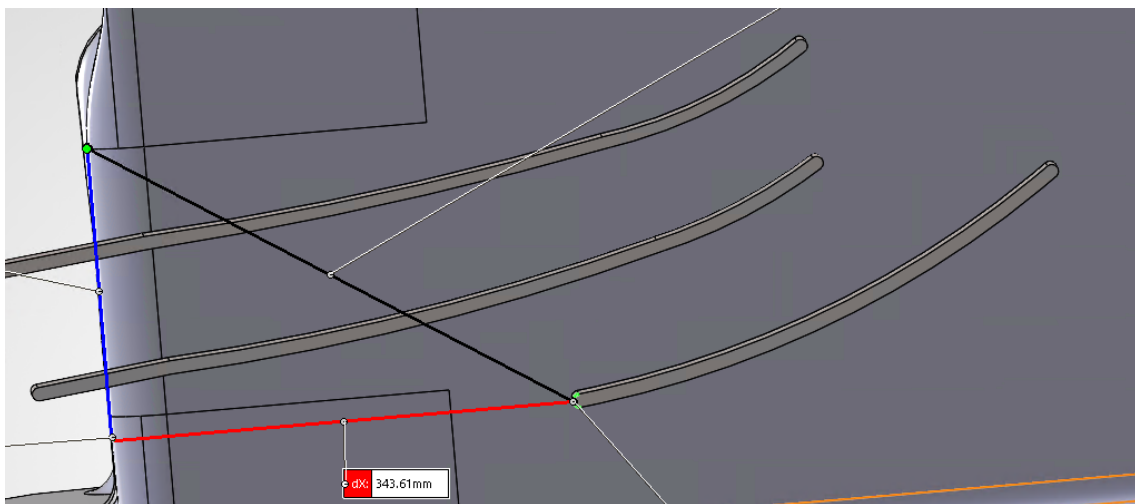


Figure 3. 9. Reference dimension of parametric leading-edge distance on X axis.

Figure 3.8 shows the distance define as the heights of the strakes. This figure 3.9 represent the distance selected, and the reference points to be able to measure it.

3.6. Ride heights study including vertical strakes design

Once the final design of the vertical strakes is defined, the ride height study from table 3.3 presented before would be performed again with the implementation of the device. In that way, it would be possible to compare both cases and obtain conclusions about the influence of the vertical strakes on the vehicle.

The main focus would be in the aero efficiency and the forward balance to analyse the sensitivity of the car to the implementation of the aero device. Moreover, other variables would be analysed such as lift and drag forces and coefficients with the objective of understand the overall influence of the design in the vehicle in different configurations.

3.7. Bargeboard & Strakes interaction

An additional case of study would be developed studying the interaction between the strakes design from this project, with the bargeboard design developed by a colleague Ben Ellis-Jones (2026) for the vehicle. Both devices would be analysed and investigate the conclusions of how they could affect each behaviour, but also the performance of the vehicle.

In the following figure is presented the bargeboards design:

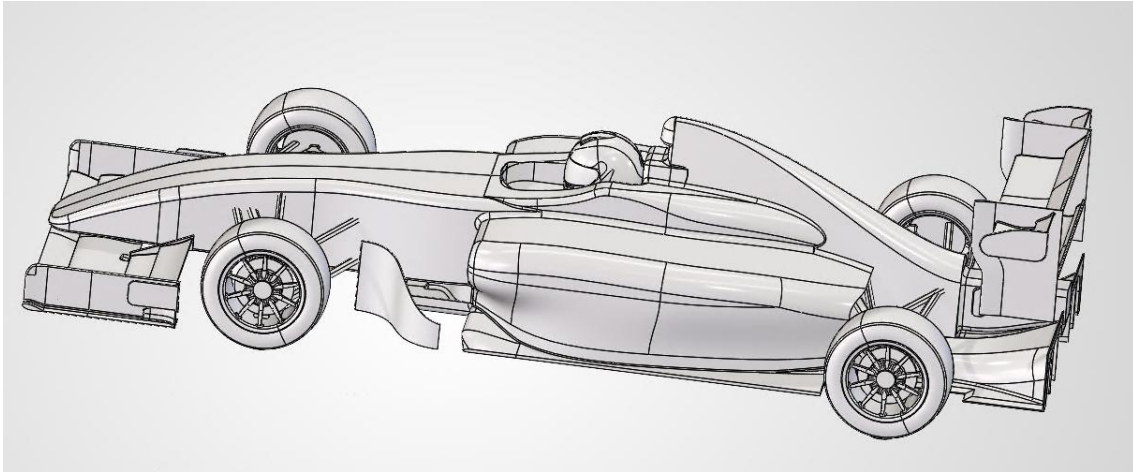


Figure 3. 10. Bargeboard design implemented on Mygale F4 (Ellis-Jones, 2026).

4. Results

4.1. Domain independency study

The results from the Domain independency study are presented in the following table 4.1:

Table 4. 1. Results from domain independency study.

Domain independence study							
	Upstream dimension (m)				Downstream Dimension (m)		
	5	10	12.5		15	20	25
Total cells (xMillions)	3.15	3.09	3.14	Total cells (xMillions)	3.15	3.09	3.14
Drag Coeff.	0.8462	0.7909	0.7639	Drag Coeff.	0.7871	0.7909	0.7912
% Difference	0.0000%	6.5351%	3.4138%	% Difference	0.0000%	0.4828%	0.0379%
Lift Coeff.	1.8078	1.6895	1.6558	Lift Coeff.	1.6831	1.6895	1.7067
% Difference	0.0000%	6.5439%	1.9947%	% Difference	0.0000%	0.3803%	1.0181%
	Side Dimension (m)				Top Dimension (m)		
	2	3	4		1	1.5	2
Total cells (xMillions)	3.09	3.09	3.11	Total cells (xMillions)	3.10	3.09	3.17
Drag Coeff.	0.8204	0.7909	0.7737	Drag Coeff.	0.7575	0.7909	0.8080
% Difference	0.0000%	3.5958%	2.1747%	% Difference	0.0000%	4.4092%	2.1621%
Lift Coeff.	1.7728	1.6895	1.6640	Lift Coeff.	1.6473	1.6895	1.7410
% Difference	0.0000%	4.6988%	1.5093%	% Difference	0.0000%	2.5618%	3.0482%

As the data shows, the domain dimensions selected for the future simulations are. 10m upstream, 20m downstream, 3m on the sides and 1.5m at the top. The difference percentage is obtain comparing the previous dimension with the current one simulated. For the upstream dimension, it is clear that from 5m to 10m the difference on the value is above 5% (the criteria selected to consider a valid result) but from 10 to 12,5m the difference is valid for both variables, however, is important to remark that in the drag result a 3% has to be taken into consideration. This tendency repeats for the side and top dimensions, where for the smallest value to the middle one there is at least one variable with a difference percentage near 5%, but for the next step the results can be considered valid. In the downstream study, the results show a clear consistency and independence, although it was selected the 20m value to ensure that the airflow can developed without any iteration with the limits of the domain.

4.2. Mesh independency study

The results from the mesh independency study are presented in the following table 4.2:

Table 4. 2. Results from mesh independency study.

Mesh independence study								
	Coarse Mesh							
Mesh Part	Global	BOI	F4body	Fwheel	Fwing	Rwheel	Rwing	Strakes
Mesh Size	0.8	0.1	0.05	0.05	0.025	0.05	0.025	0.0075
Total cells (xMillions)	1,83							
Drag Coeff.	0.7506							
% Difference	0.0000%							
Lift Coeff.	1.4934							
% Difference	0.0000%							
	Medium Mesh							
Mesh Part	Global	BOI	F4body	Fwheel	Fwing	Rwheel	Rwing	Strakes
Mesh Size	0.8	0.1	0.02	0.02	0.01	0.02	0.01	0.0075
Total cells (xMillions)	3,98							
Drag Coeff.	0.7587							
% Difference	1.0791%							
Lift Coeff.	1.6169							
% Difference	8.2697%							
	Fine Mesh							
Mesh Part	Global	BOI	F4body	Fwheel	Fwing	Rwheel	Rwing	Strakes
Mesh Size	0.8	0.1	0.018	0.018	0.01	0.018	0.01	0.005
Total cells (xMillions)	5,44							
Drag Coeff.	0.7513							
% Difference	0.9754%							
Lift Coeff.	1.7026							
% Difference	5.3003%							
	Extra Fine Mesh							
Mesh Part	Global	BOI	F4body	Fwheel	Fwing	Rwheel	Rwing	Strakes
Mesh Size	0.8	0.1	0.01	0.01	0.005	0.01	0.005	0.005
Total cells (xMillions)	7,41							
Drag Coeff.	0.7596							
% Difference	1.1048%							
Lift Coeff.	1.6907							
% Difference	0.6989%							

In this case, while the drag is stable, the lift seems to be more sensitive to the mesh size. The comparison between the cases will be against the previous one. In this case, the step from Coarse to a Medium mesh has a percentage difference higher than 5% (the criteria selected) and it happens the same for the analysis between medium mesh and Fine mesh but near the limit. The final step from Fine mesh to Extra Fine mesh there is not an appreciable variation on the results. However, simulation time would be another factor to take into account between these two possibilities.

Regarding the Y+ results in the following images are presented two different points of view of the contour of the variable around the car.

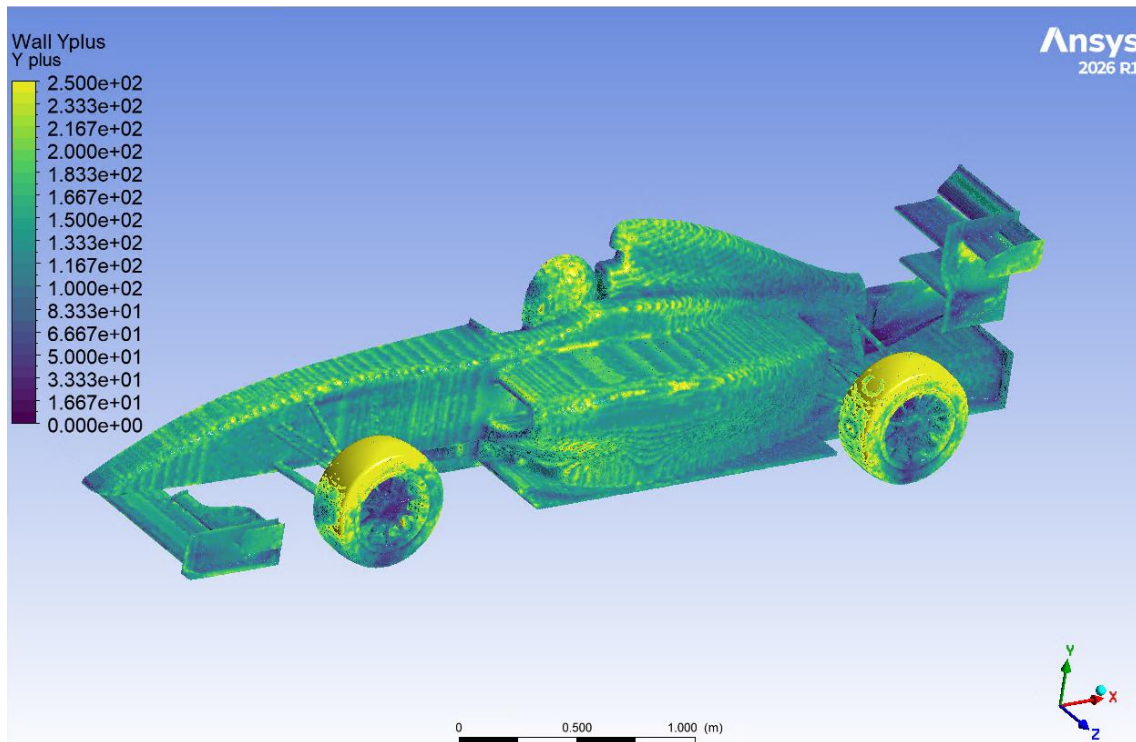


Figure 4. 1. Y+ results on Mygale F4 ISO view.

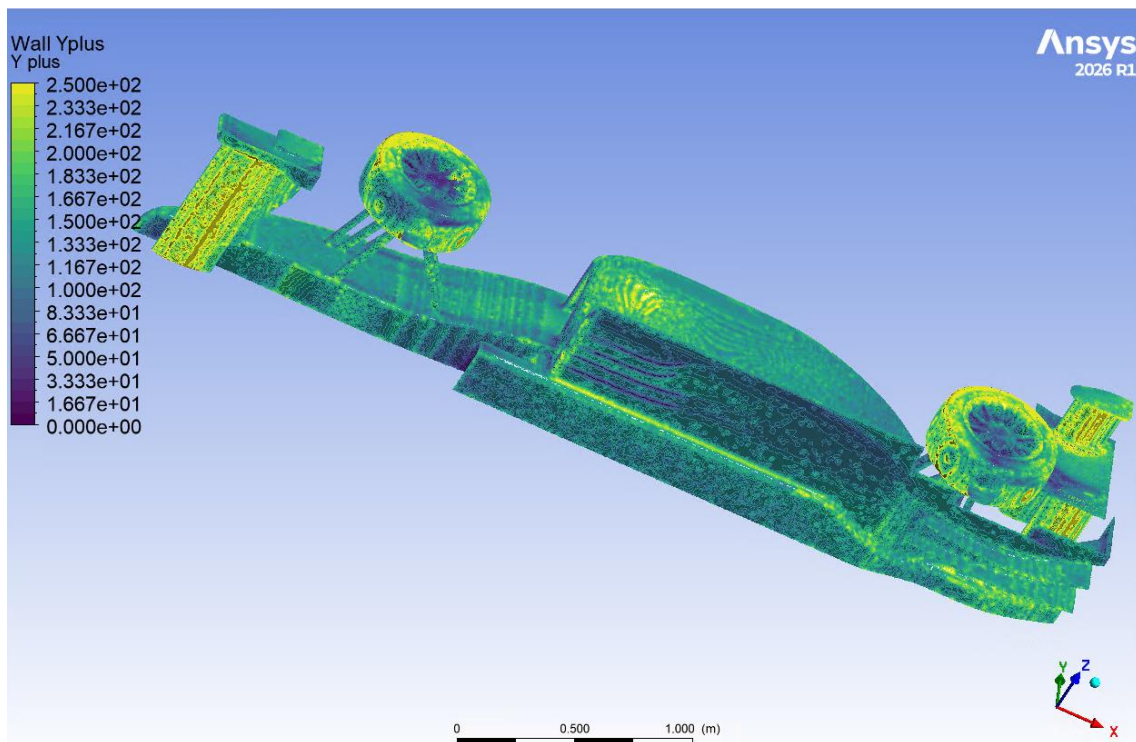


Figure 4. 2. Y+ results on Mygale F4 underbody view.

As it can be seen the majority of the car is below that value of 200 mentioned in the methodology section. It gives a solid confidence on the results that would be obtained in

future simulations. Moreover, the areas of interest for this project get below 100, what gives more reliance in the future tendencies and results around the floor.

However, despite being acceptable values, it would be important to take into account that the accuracy of the data could have slightly variations, as the common critical value of the studies is around 50 (Kirchberger, 2023).

4.3. Baseline ride heights study

The Aero maps obtained from the data of the simulations and the MATLAB code (Evans, 2026) can be seen in the following figures:

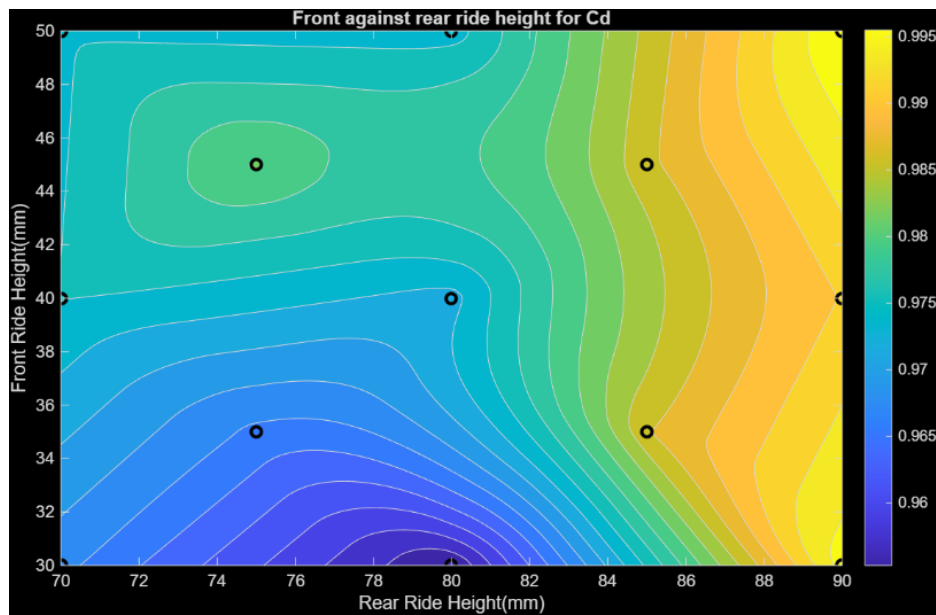


Figure 4. 3. Coefficient of drag aerodynamic map.

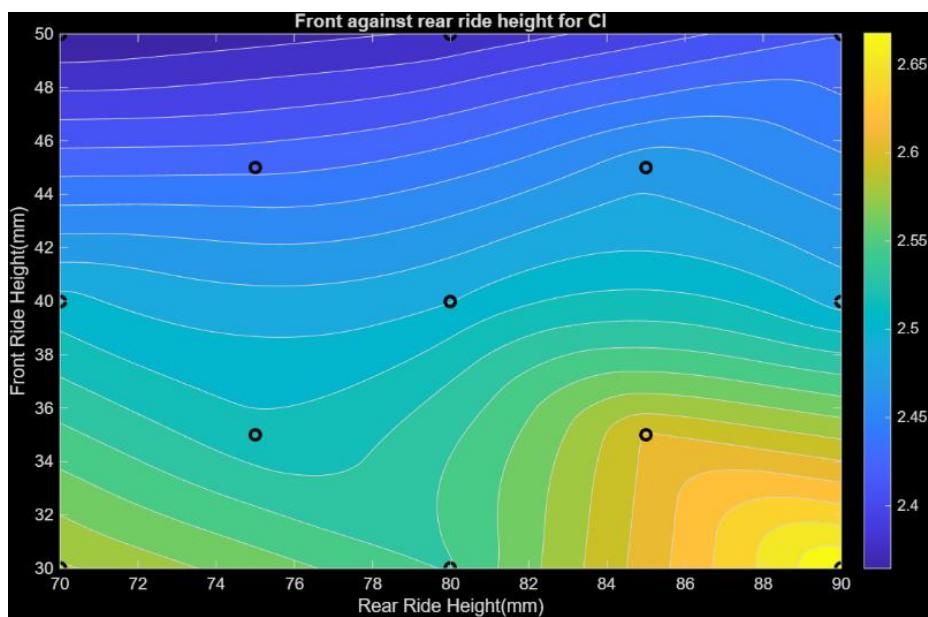


Figure 4. 4. Coefficient of lift aerodynamic map.

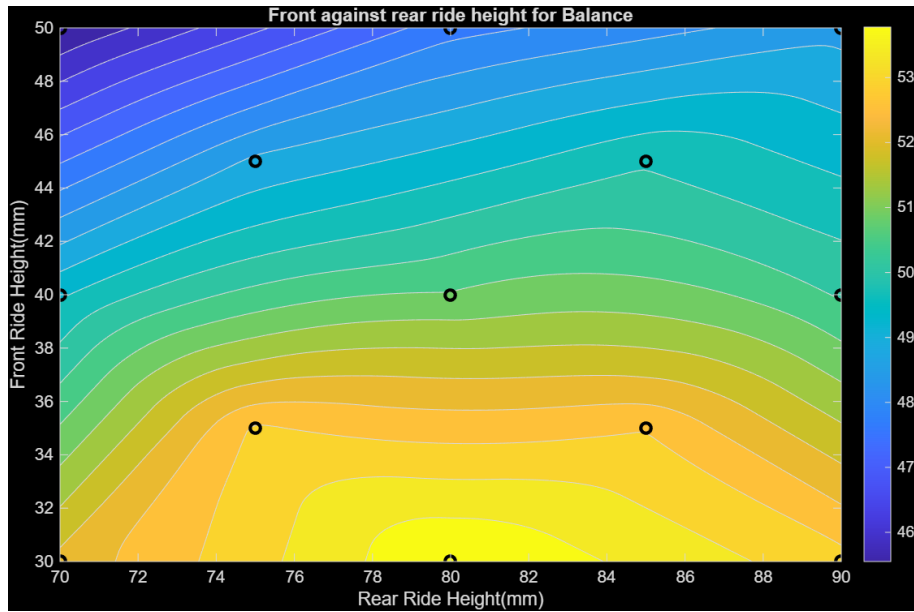


Figure 4. 5. Forward balance percentage aerodynamic map.

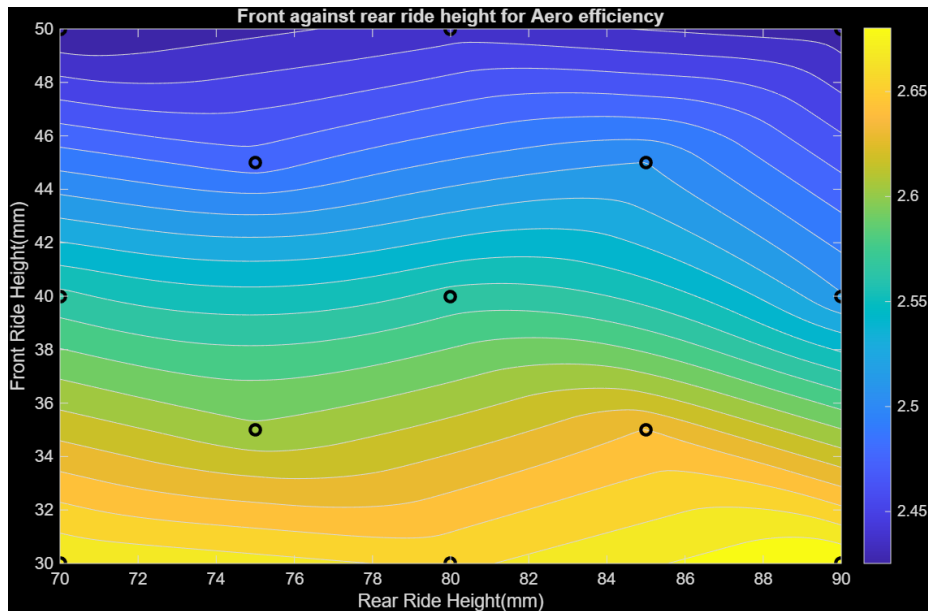


Figure 4. 6. Aerodynamic efficiency map.

In addition, the tables with all the data obtained from the simulations can be seen in the APPENDIX B.

From these results it is presented the performance and behaviour of the car in different configuration, what helps to understand its characteristics and evolution. All the aero maps present a homogeneous graphic and transition between values, which helps to represent a solid and robust simulation, in addition with a consistent performance from the vehicle. The results from coefficient of lift and forward balance are more sensitive to the ride heights configuration as the variation between maximum and minimum values is notorious (12% difference for the lift and around 10% for the balance). Greater values of lift lead to a better efficiency but also forward balance goes above the 50% what starts to make the vehicle more unstable.

On the other hand, for the drag coefficient it is more stable and with less difference as the colour representation shows a low colour gradient (% difference less than 5%).

4.4. Strakes designs

The results from the different designs of the vertical strakes would be compared. In order to make easier the organization of them, it would be showed by the variable analyse.

Firstly, in table 4.3, the data from forces and performance is presented:

Table 4. 3. Results from Vertical strakes designs.

Strakes Designs Data						
	Baseline Design	Strakes V1	Strakes V2	Strakes V3	Strakes V4	Strakes V5
Drag Coeff.	0.9755	0.9767	0.9690	0.9731	0.9770	0.9768
Drag Force	624.41	625.15	620.27	622.85	625.34	625.26
Lift Coeff.	2.5064	2.5465	2.4979	2.5491	2.5588	2.5727
Lift Force	1604.35	1629.95	1598.87	1631.65	1637.84	1646.76
Forward Balance %	49.60%	50.31%	51.02%	50.74%	50.91%	49.96%
Aero Efficiency	2.5694	2.6072	2.5777	2.6197	2.6191	2.6337
% improvement		1.4736%	0.3236%	1.9563%	1.9356%	2.5039%

The colours on each row represents a scale from the best (green) to the worst (red) from each variable of each design. All of them compared to the Baseline of the car, with a ride heights configuration of 70mm rear and 40mm front.

4.4.1. Pressure distribution on F4 Mygale

In the following figures it would be presented the pressure distribution around the floor of the car and the strakes for the baseline and every design presented.

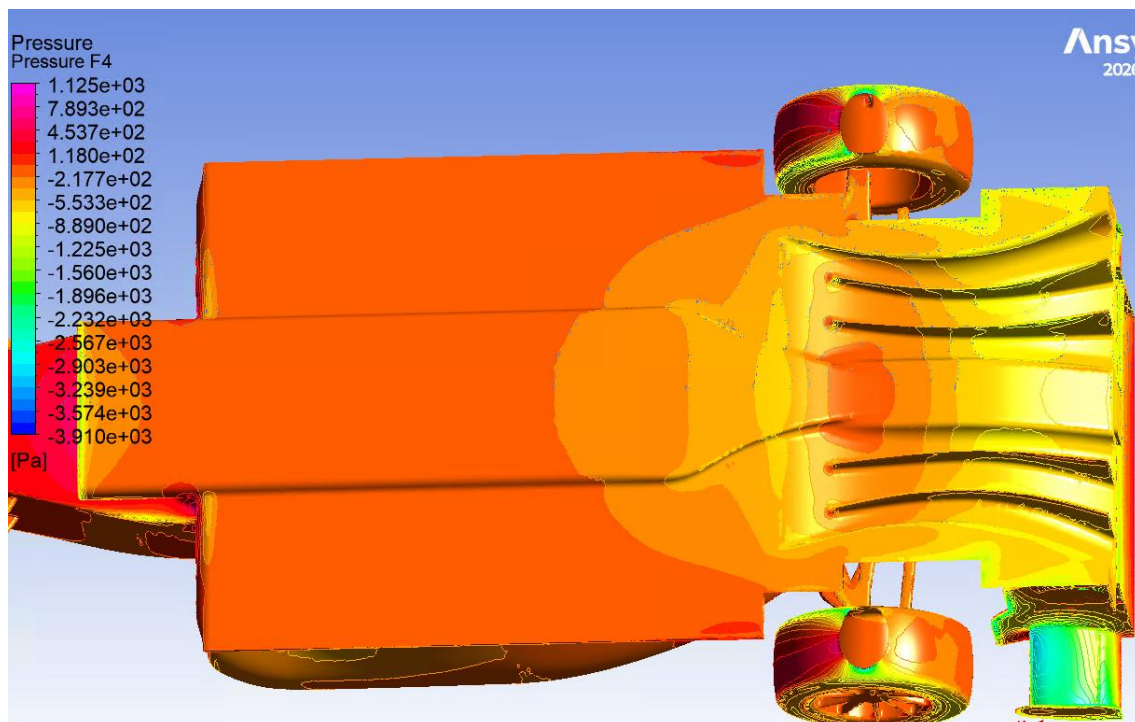


Figure 4. 7. Baseline pressure distribution.

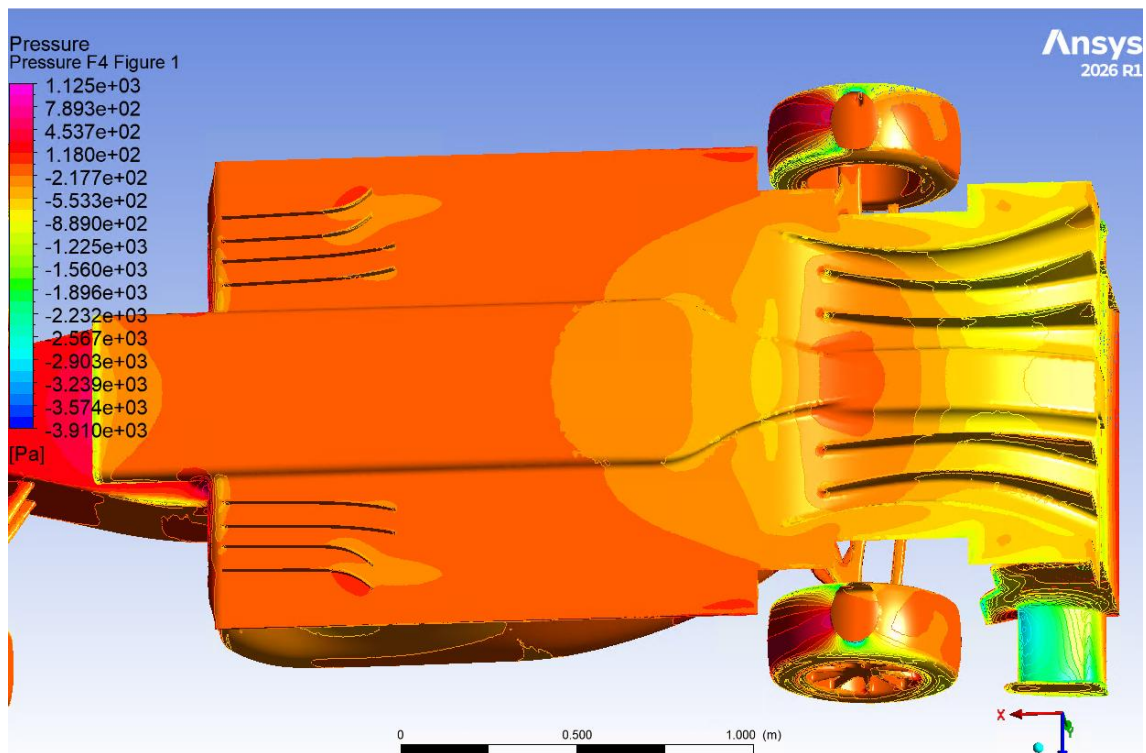


Figure 4. 8. Strakes V1 design pressure distribution.

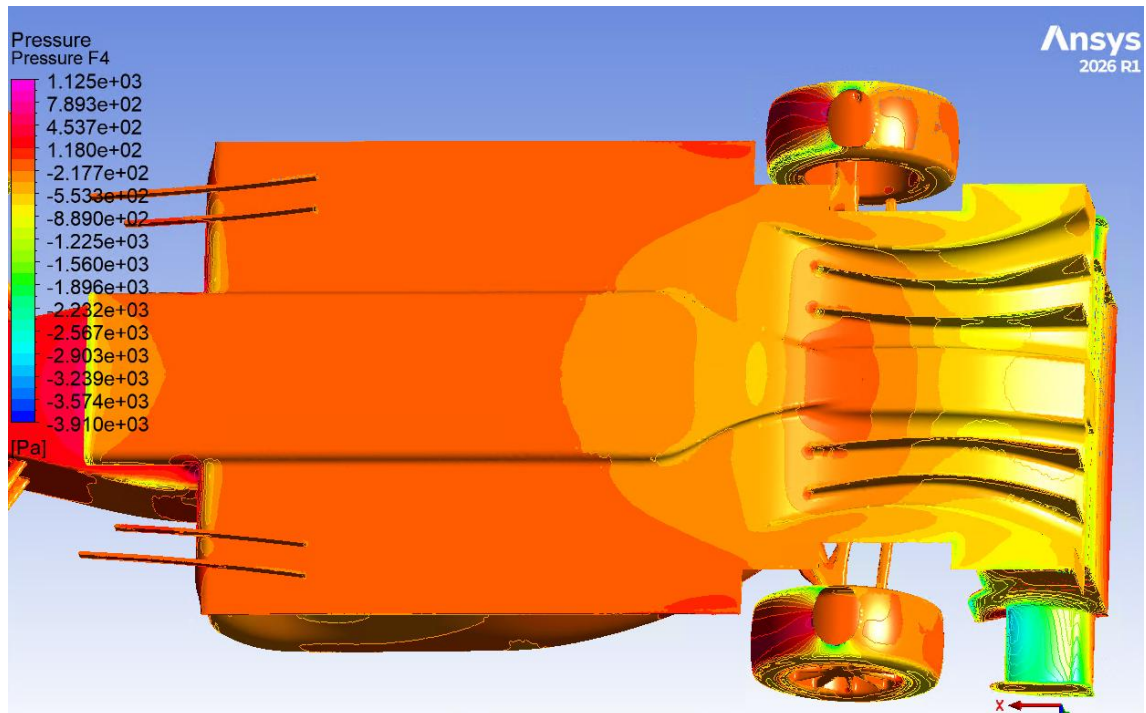


Figure 4. 9. Strakes V2 design pressure distribution.

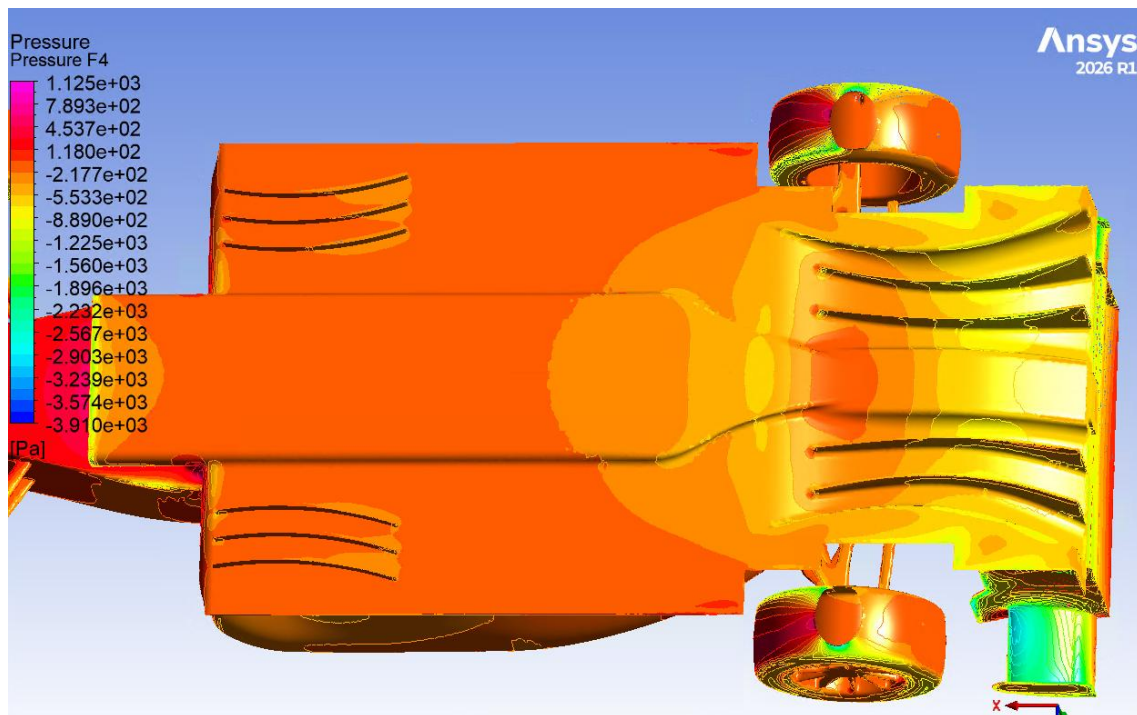


Figure 4. 10. Strakes V3 design pressure distribution.

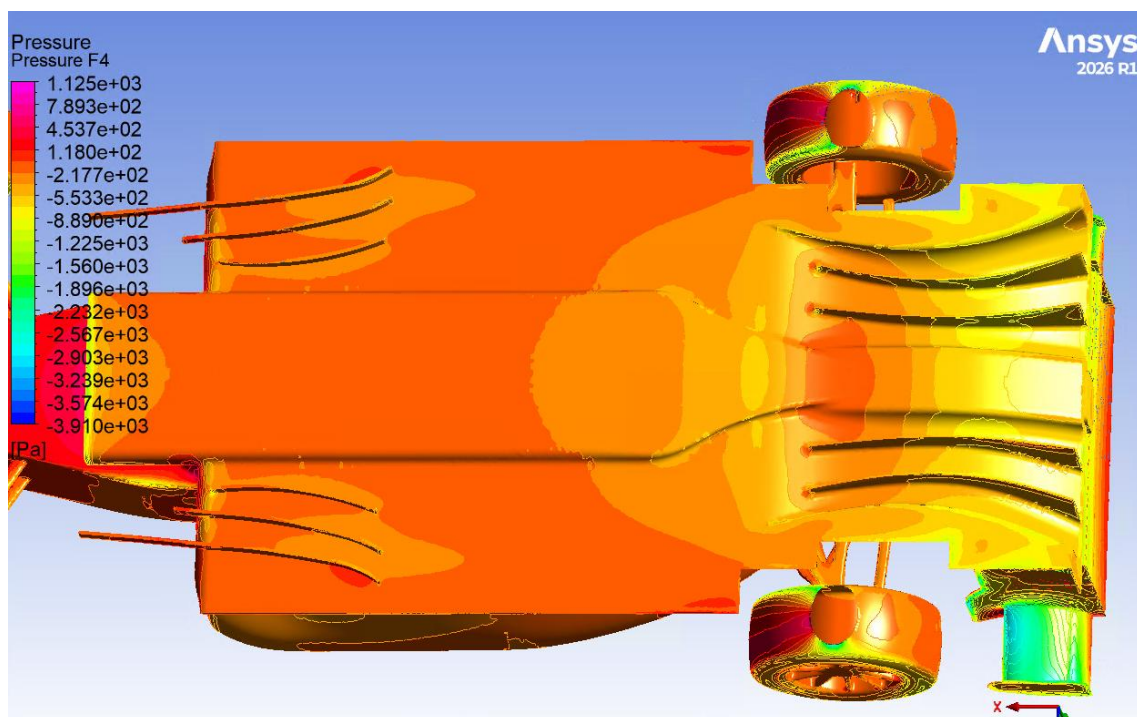


Figure 4. 11. Strakes V4 design pressure distribution.

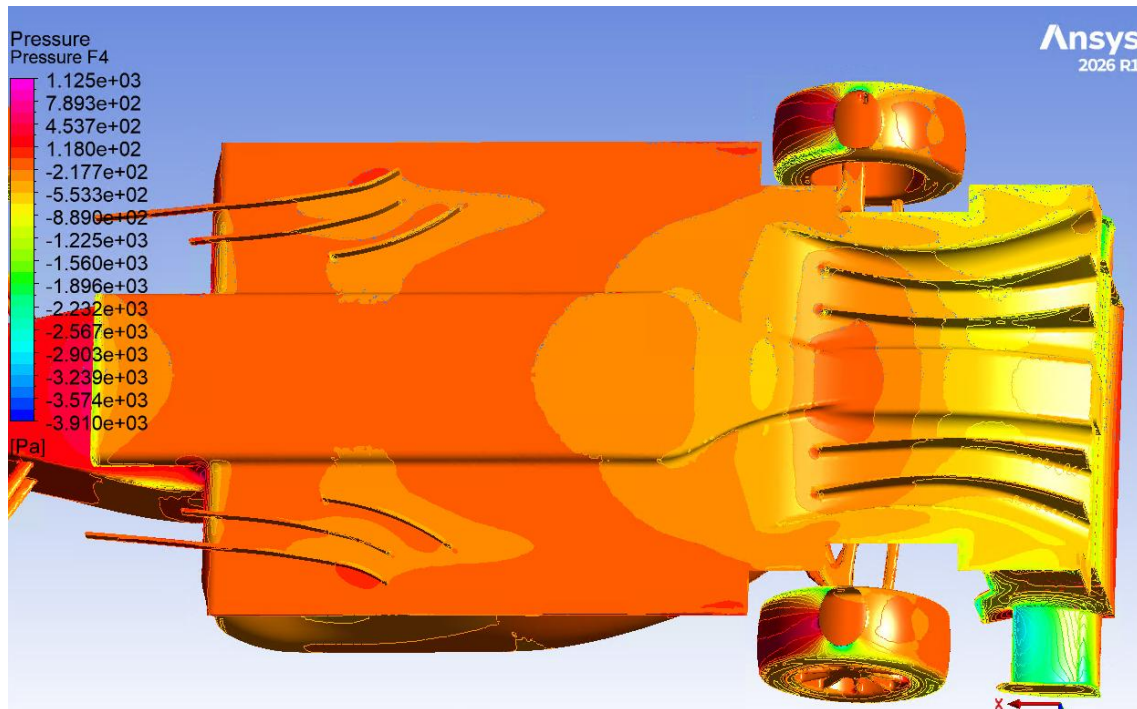


Figure 4. 12. Strakes V5 design pressure distribution.

Strakes V5 generated the bigger low-pressure area from all designs. The pure straight strakes did not generate any changes, on the other hand the pure curve strakes create small pressure areas near them. Hybrid designs generated the bigger changes on the underbody's pressure distribution; however, V4 design disrupt the low-pressure area at the entrance.

4.4.2. *Streamlines and vorticity*

In the following figures it would be presented the streamlines and vorticity around the floor of the car and the strakes for the baseline and every design presented. It is interesting to analyse these variables together as both of them help to explain the flow direction under the body and how it behaves, but also how you can control it.

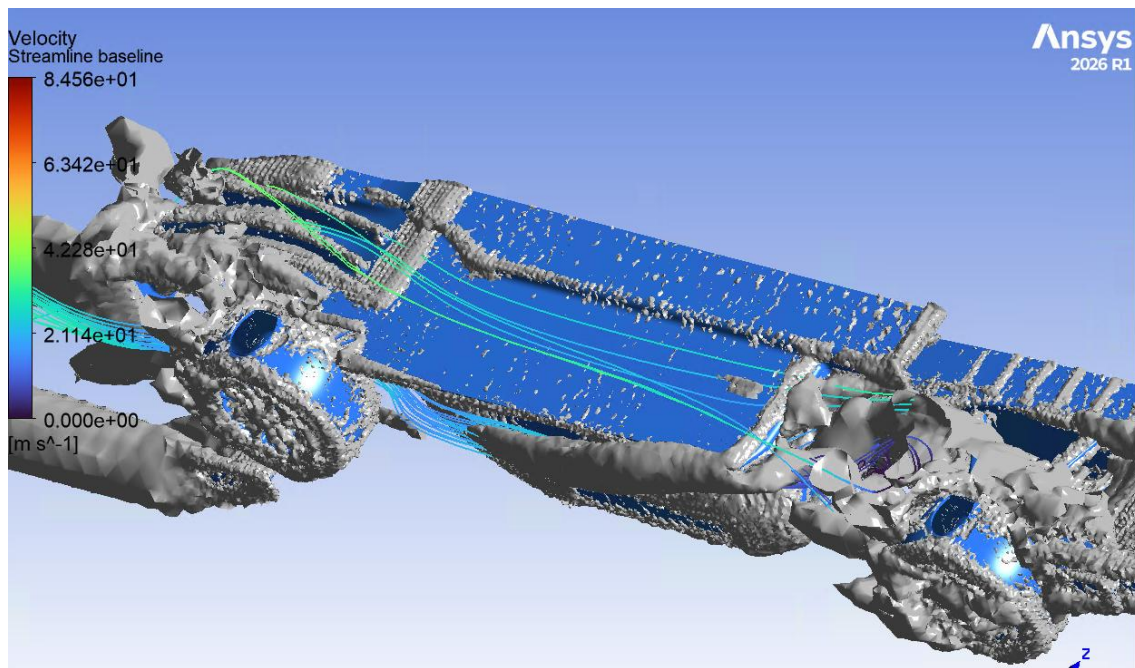


Figure 4. 13. Baseline vorticity and streamlines.

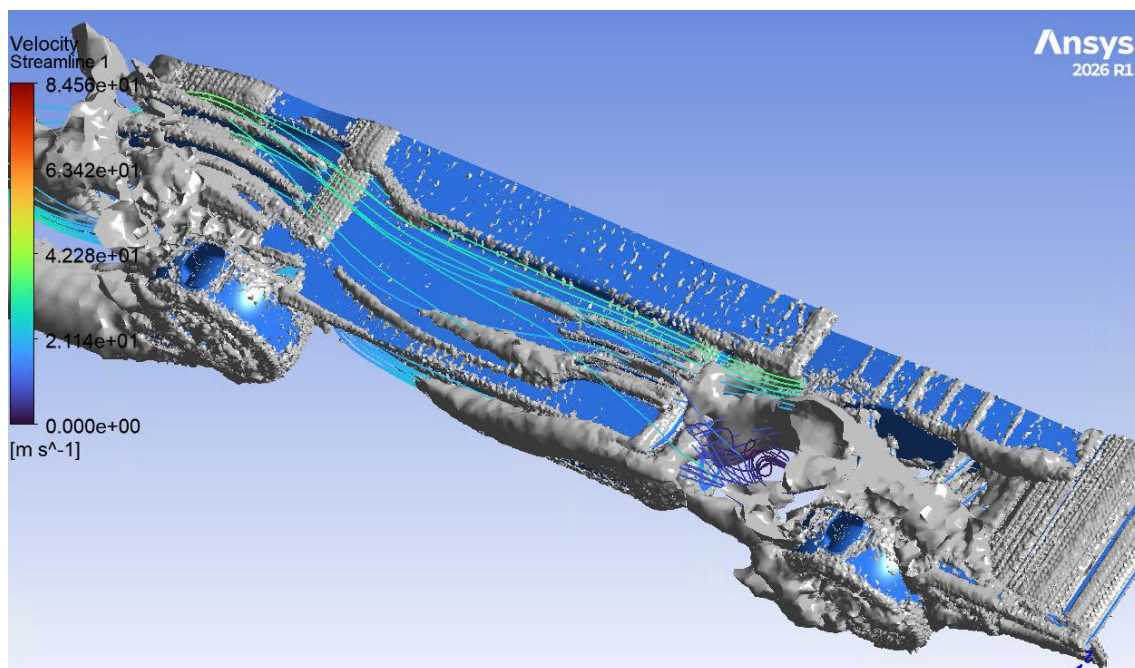


Figure 4. 14. Strakes V1 design vorticity and streamlines.

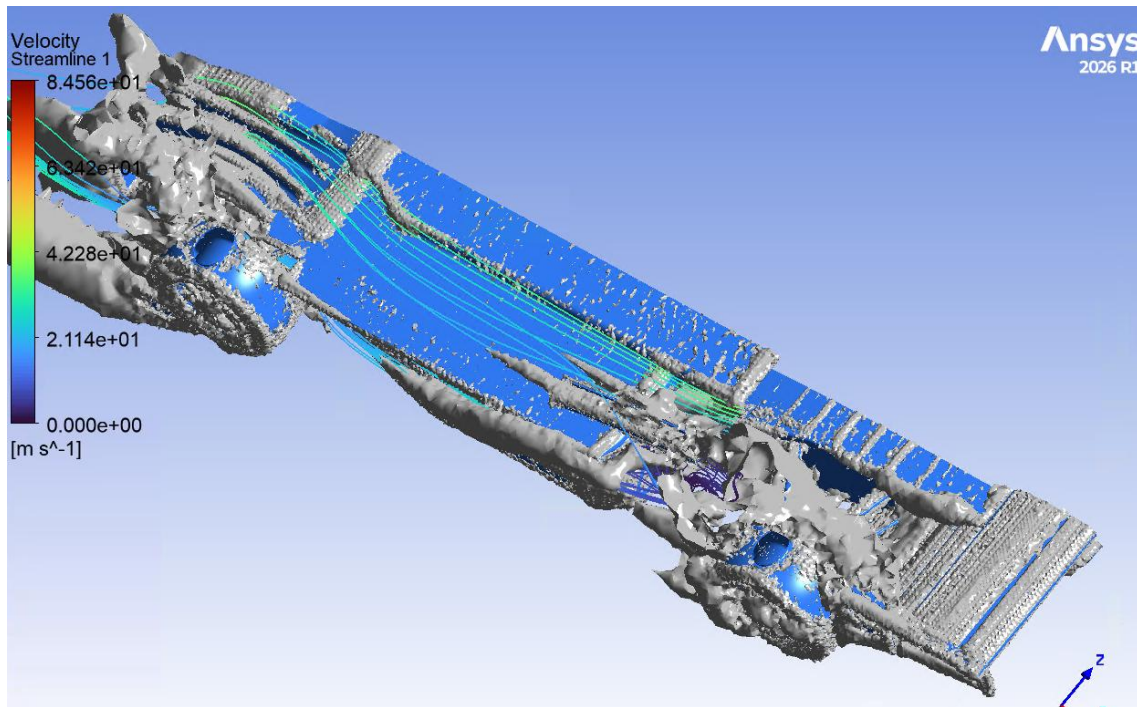


Figure 4. 15. Strakes V2 design vorticity and streamlines.

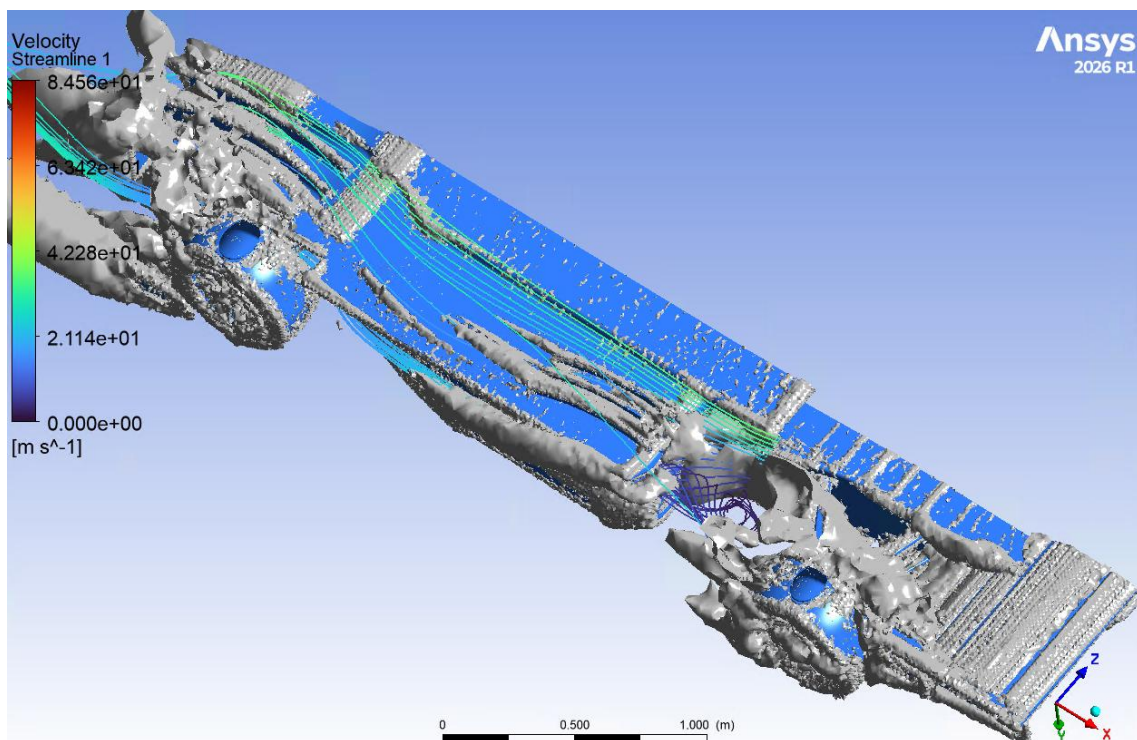


Figure 4. 16. Strakes V3 design vorticity and streamlines.

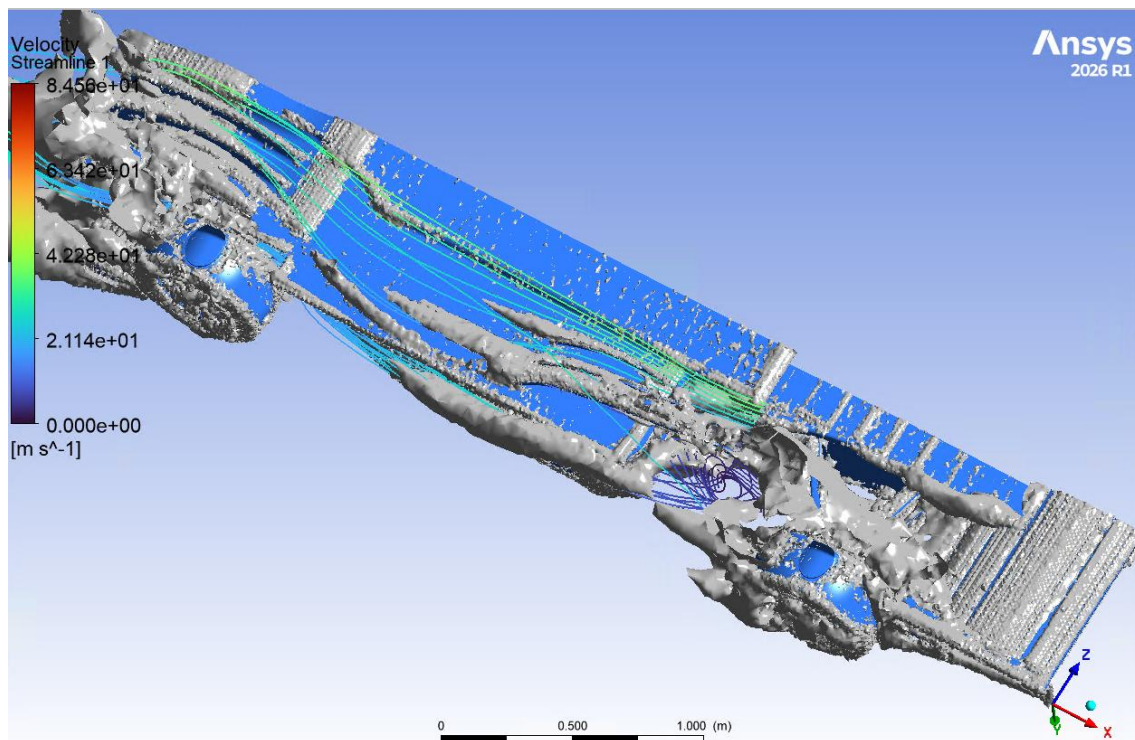


Figure 4. 17. Strakes V4 design vorticity and streamlines.

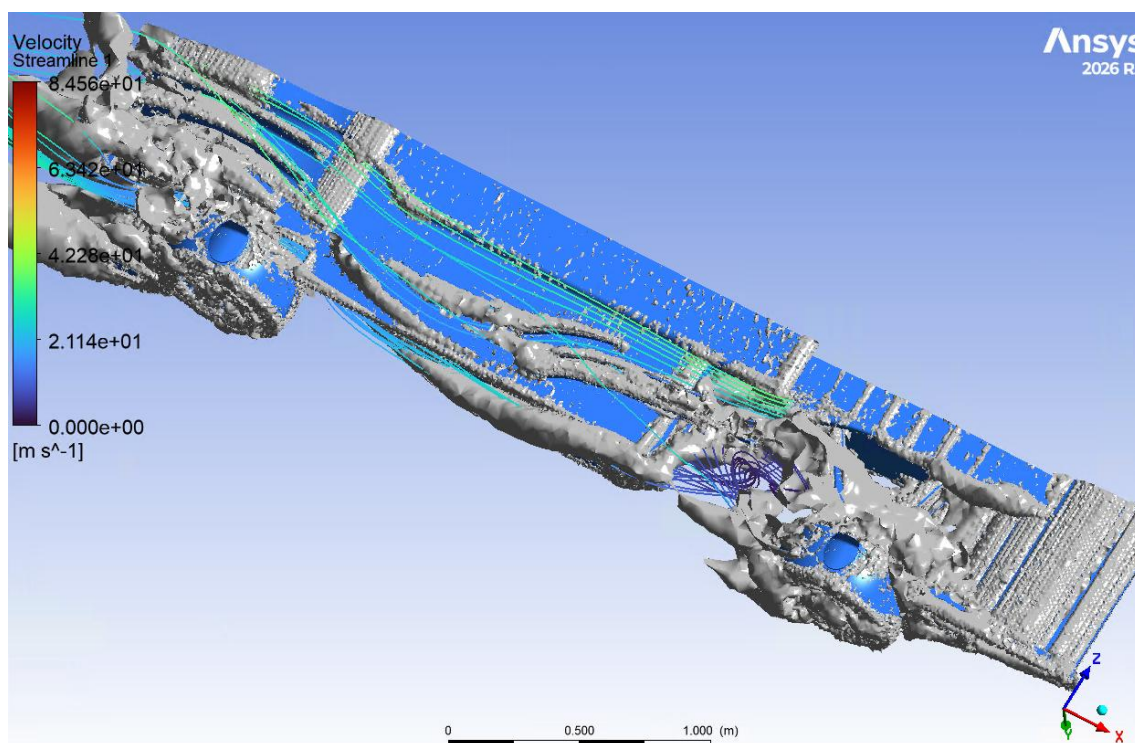


Figure 4. 18. Strakes V5 design vorticity and streamlines.

Vorticity evolves with the designs, with V4 and V5 creating the biggest vortex and seal effect in the underbody. In V1 is possible to see this effect in a minor grade. Regarding V2 and V3 designs, that effect is reduced.

Talking about the streamlines, all strakes' designs help to keep the internal flow from the front wing stable and conducted to the diffuser. Moreover, strakes reconducted airflow that was going out of the floor with the help of the vortex generated with the seal effect explained previously.

Analysing V2, V4 and V5 designs, starting ahead of the leading-edge help to separate the wake from the wheel from the stable airflow as the images shows compared to the ones from V1 and V3.

4.4.3. Pressure cut planes

The next images represent the pressure distribution along the underbody in different planes of the strakes, at the entrance, at the middle and at the end of the strakes.

Leading-edge entrance plane

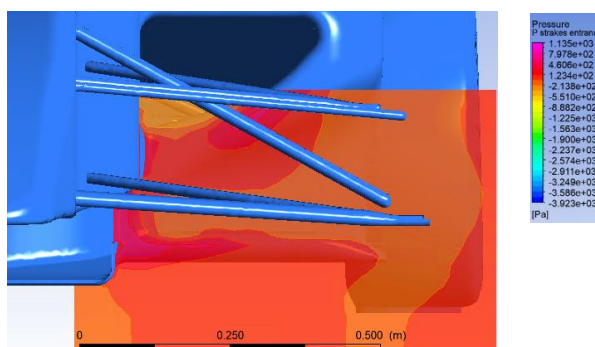


Figure 4. 19. Baseline entrance plane.

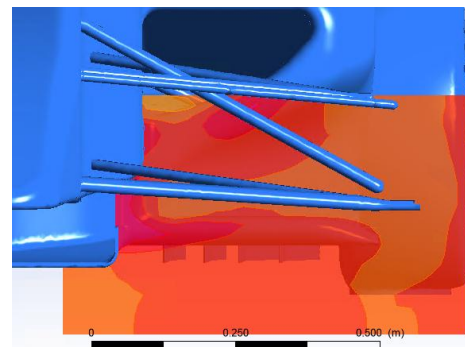


Figure 4. 20. Strakes V1 entrance plane.

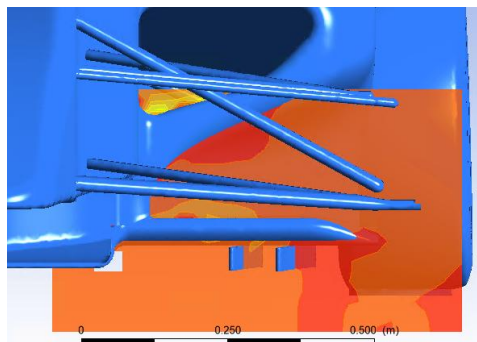


Figure 4. 22. Strakes V2 entrance plane.

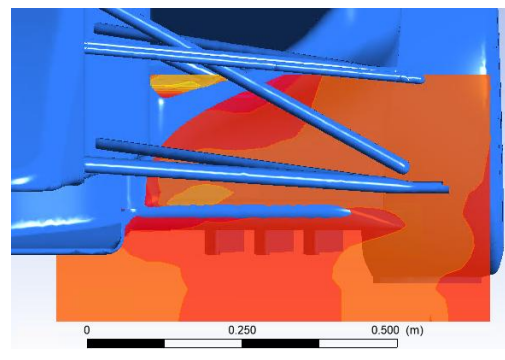


Figure 4. 21. Strakes V3 entrance plane.

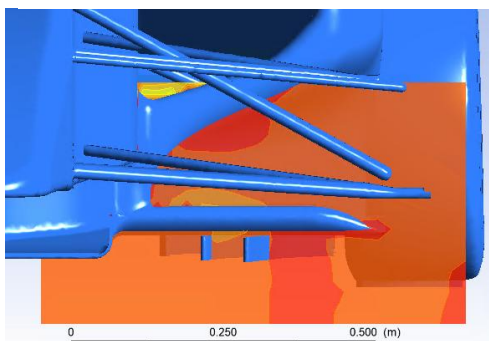


Figure 4. 23. Strakes V4 entrance plane.

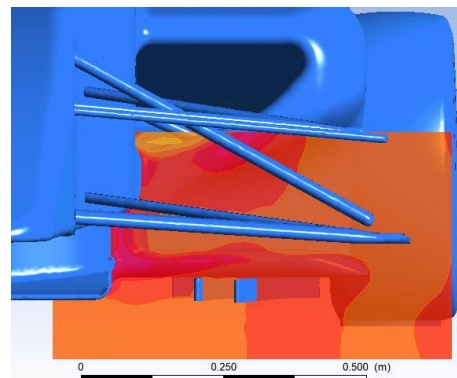


Figure 4. 24. Strakes V5 entrance plane.

The entrance planes show how vertical strakes reduce the pressure area at the beginning of the floor, specially V2, V4 and V5, moving outside the high pressure from the wake of the front wheel.

Strakes middle plane

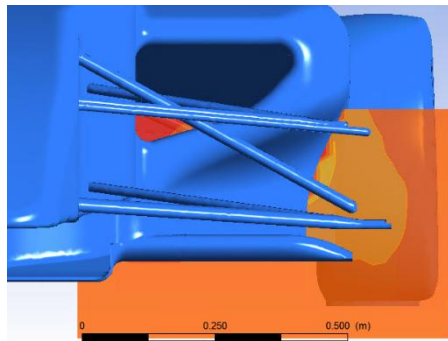


Figure 4. 25. Baseline middle plane.

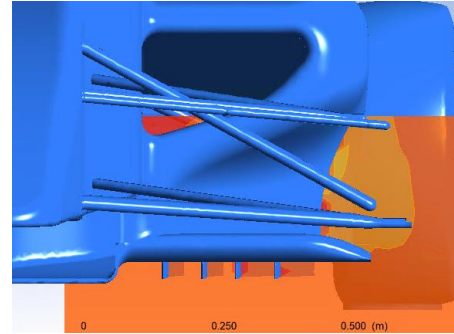
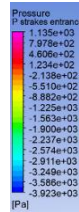


Figure 4. 26. Strakes V1 middle plane.

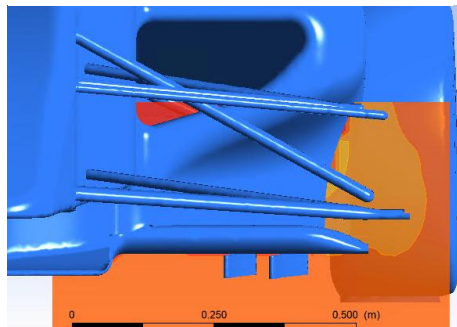


Figure 4. 27. Strakes V2 middle plane.

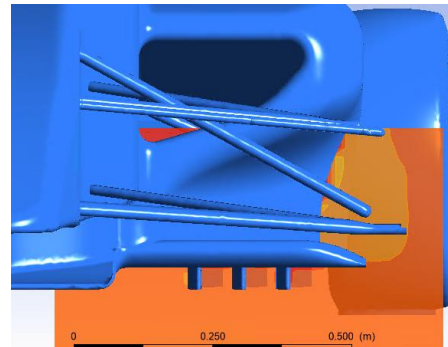


Figure 4. 28. Strakes V3 middle plane.

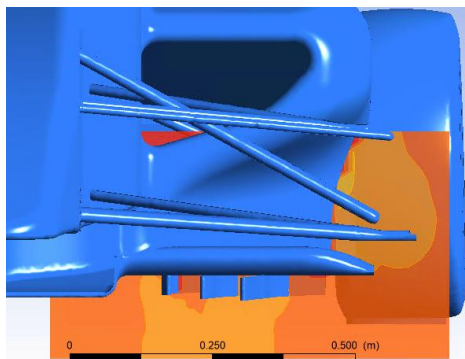


Figure 4. 30. Strakes V4 middle plane.

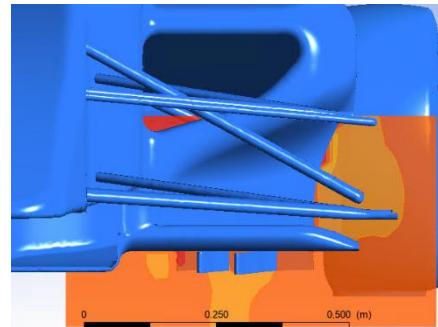


Figure 4. 29. Strakes V5 middle plane.

Regarding the results at the middle plane, they show a consisted behaviour throw the first designs. Where a difference starts to appear with V4 and V5, a low-pressure area around the strakes.

Another point from these images, at the right it is possible to see that high area of pressure that was sent outside of the underbody at the entrance and seems to go without going back under the floor.

Strakes end plane

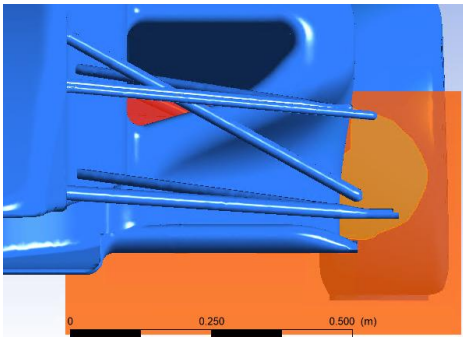


Figure 4.31. Baseline end plane.

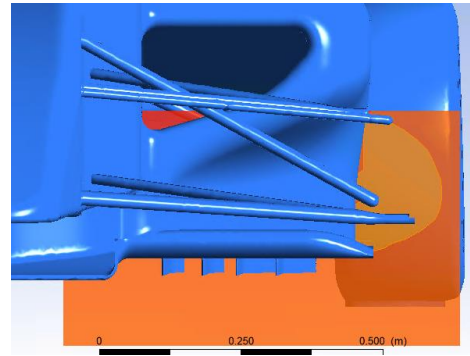


Figure 4.32. Strakes V1 end plane.

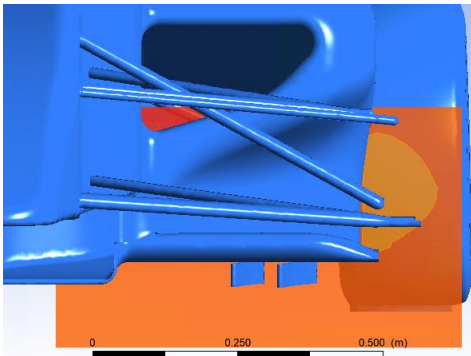


Figure 4.33. Strakes V2 end plane.

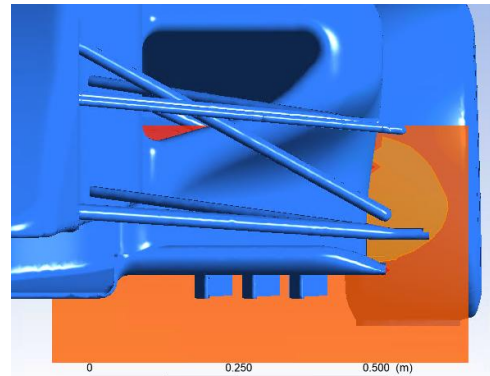


Figure 4.34. Strakes V3 end plane.

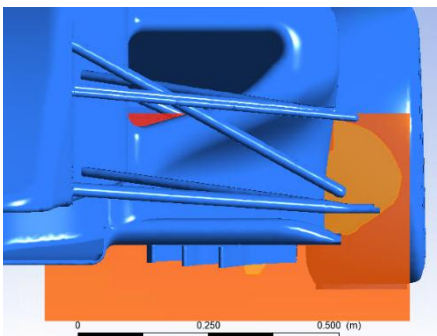


Figure 4.36. Strakes V4 end plane.

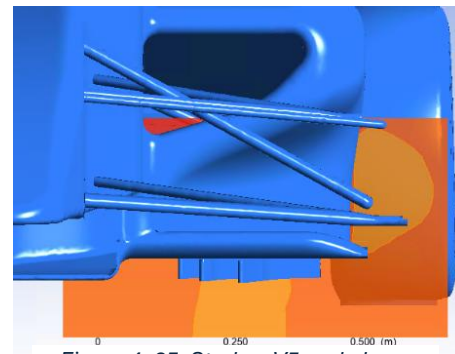


Figure 4.35. Strakes V5 end plane.

From the end planes, it shows no differences between most of the designs at the end of the vertical strakes. V5 design is the only one that keeps low-pressure zone extended rearwards.

4.4.4. Pressure symmetry plane

The following figures represent the pressure distribution along the symmetry plane of the vehicle.

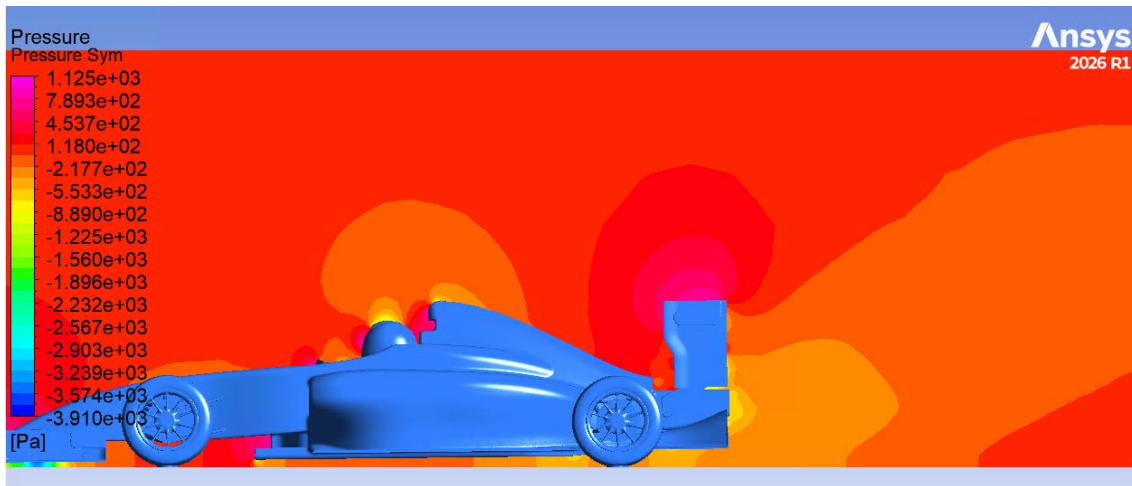


Figure 4. 37. Pressure distribution on symmetry plane Baseline.

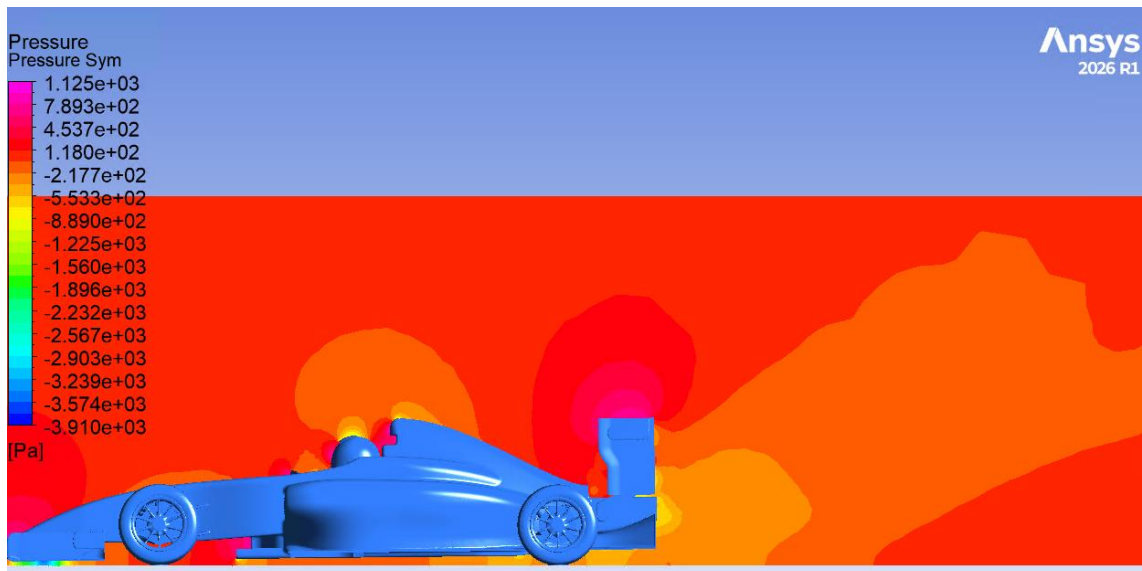


Figure 4. 38. Pressure distribution on symmetry plane Strakes V1.

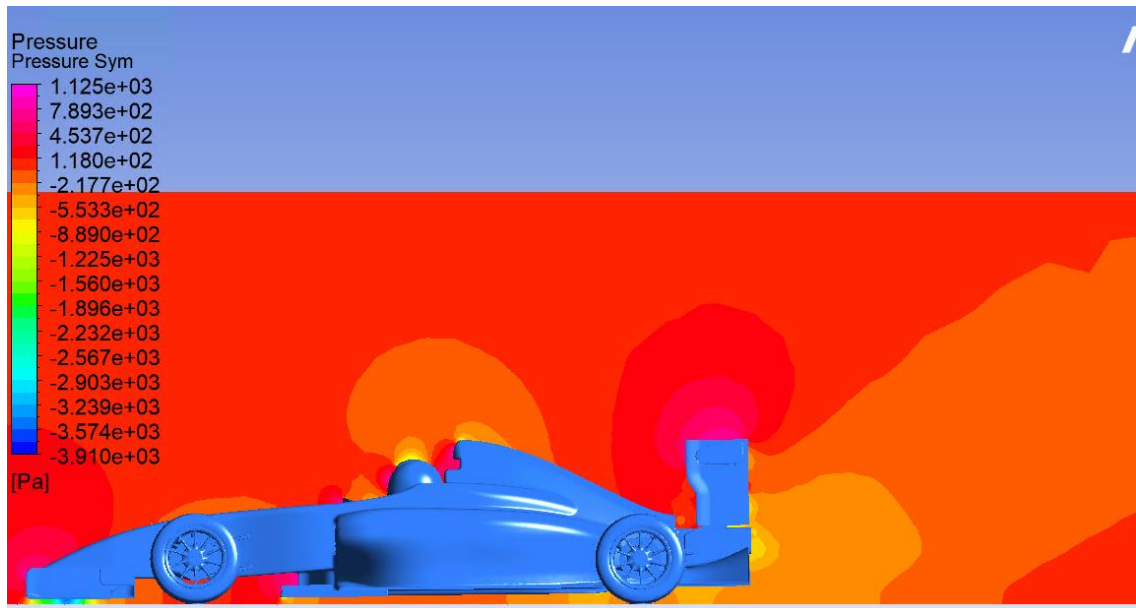


Figure 4. 39. Pressure distribution on symmetry plane Strakes V2.

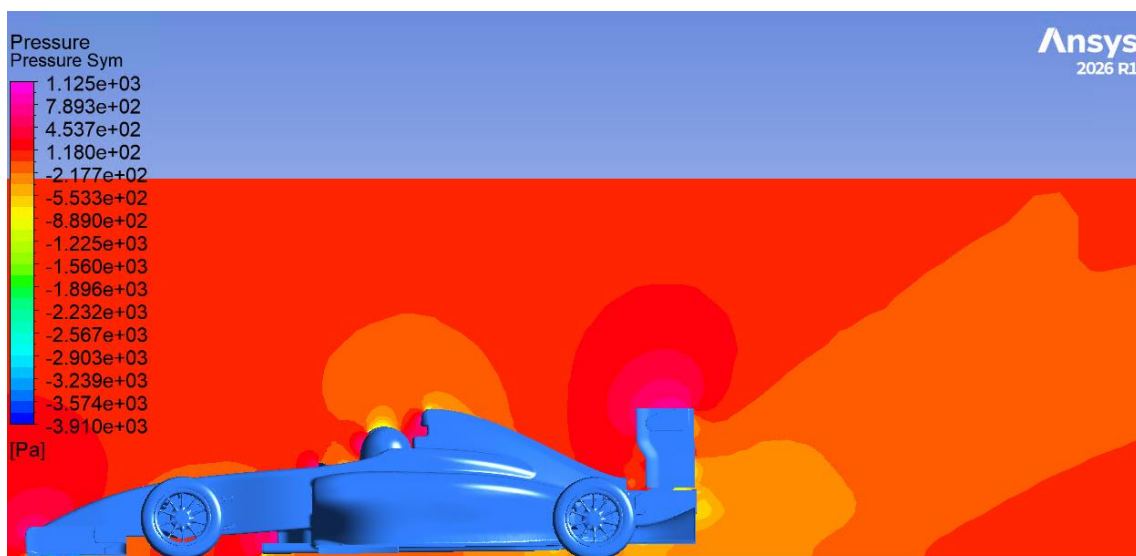


Figure 4. 40. Pressure distribution on symmetry plane Strakes V3.

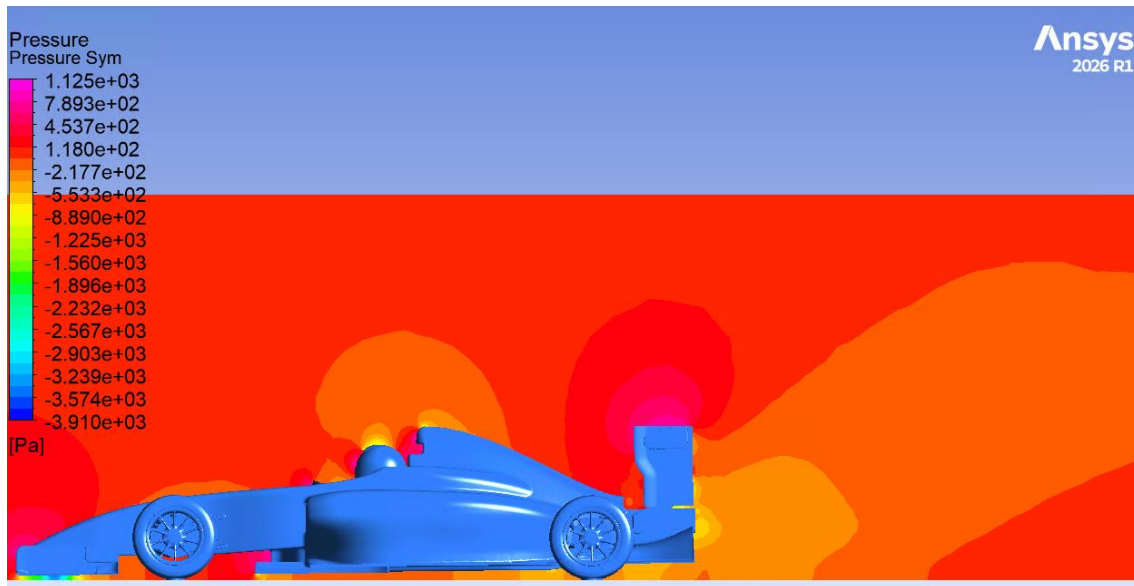


Figure 4. 41. Pressure distribution on symmetry plane Strakes V4.

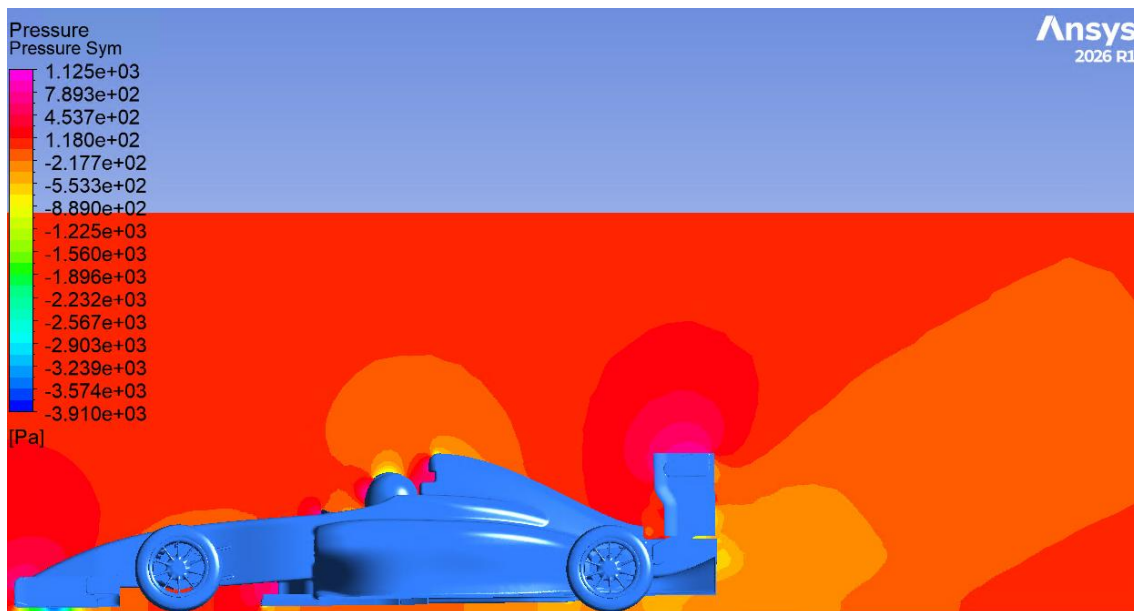


Figure 4. 42. Pressure distribution on symmetry plane Strakes V5.

From the results at the symmetry plane, it can be seen three effects. Vertical strakes increase the low-pressure area at the entrance rearwards, in addition, they reduce the low-pressure area behind the vehicle, at the diffuser's exit. What is related with the pressure evolution in the diffuser getting more homogenise.

4.5. Parametric study

4.5.1. Height

The results from the parametric study of the height of the vertical strakes would be presented in the same structure as the previous sections, following the different variables studied. Beginning with the forces and performance values, they are presented in the next table 4.4:

Table 4. 4. Results from parametric study of the height.

Strakes V5 Height Parametric Study						
Height (mm)	20	30	40	50	60	70
Drag Coeff.	0.9779	0.9708	0.9768	0.9715	0.9763	0.9765
Drag Force (N)	625.95	621.37	625.26	621.83	624.95	625.0300
Lift Coeff.	2.5296	2.5136	2.5727	2.5742	2.6660	2.7314
Lift Force (N)	1619.17	1608.89	1646.76	1647.72	1706.49	1748.37
Forward Balance %	50.74%	50.72%	49.96%	51.36%	51.19%	51.89%
Aero Efficiency	2.5867	2.5892	2.6337	2.6498	2.7306	2.7973
% improvement	-1.7838%	-1.6902%	0.0000%	0.6102%	3.6785%	6.2094%

The baseline for the analysis is the initial design with 40mm. The colours identification work as the previous results presented during the project. During the simulation of the six heights, the value for the leading-edge distance on X axis was keep it at 340mm.

There is a clear tendency regarding the lift evolution against the height of the strakes, where higher height directly gets higher lift values. Moreover, it seems that lift coefficient and force are more sensitive to the height of the strakes, with a 139.48N difference between highest and lowest value.

On the other hand, drag data keeps stable on every configuration, with only a 4.58N of difference, which seems these variables do not get affect by the height of the strakes.

With aerodynamic efficiency, it follows the same tendency as the lift variables, being the 70mm configuration the biggest value. However, forward balance goes above 50% in every height except 40mm (baseline), while the objective is to keep the balance under that 50%.

a) Pressure distribution on F4 Mygale

In the following figures it would be presented the pressure distribution around the floor of the car and the strakes based on the different values of height.

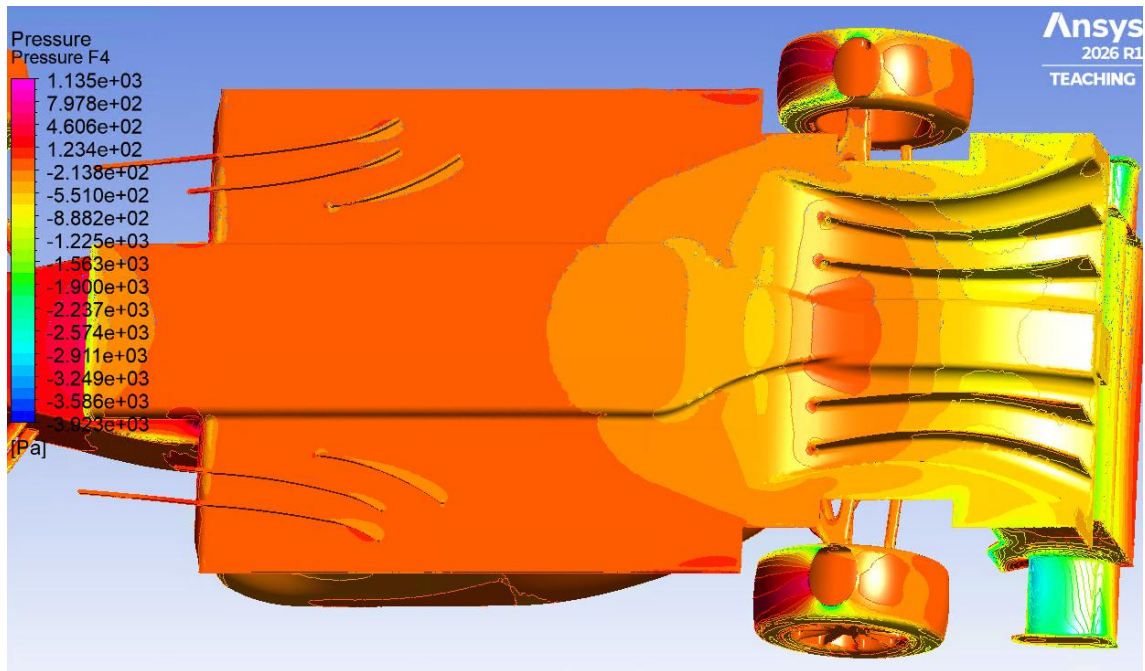


Figure 4. 43. Pressure distribution with 20mm of height.

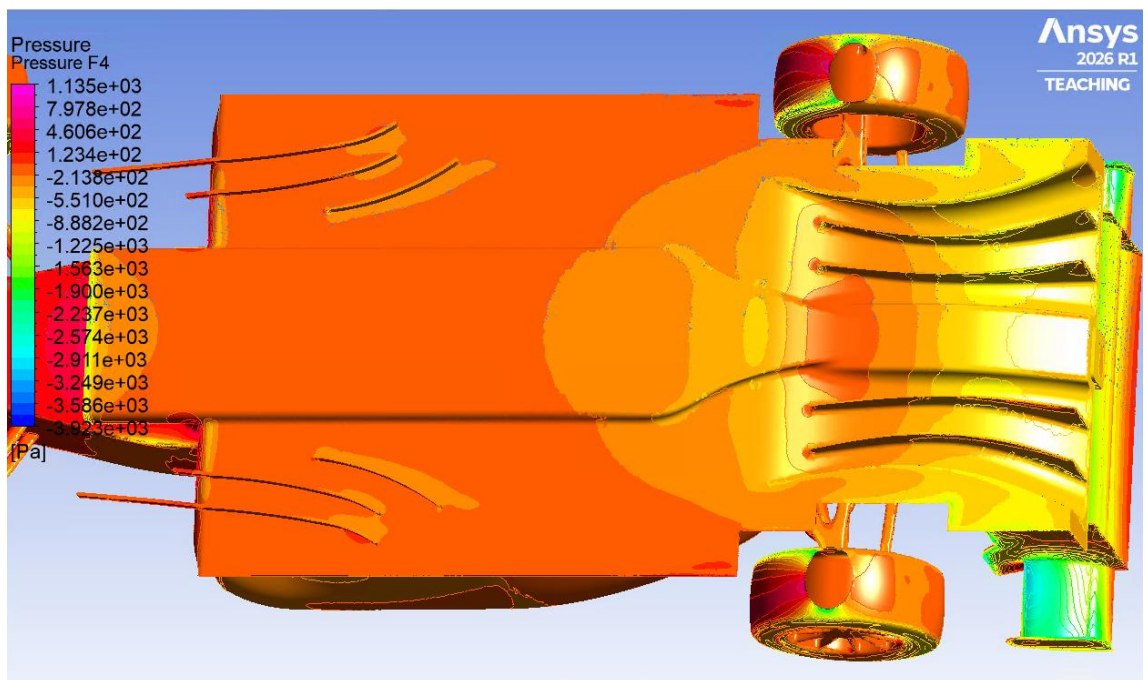


Figure 4. 44. Pressure distribution with 30mm of height.

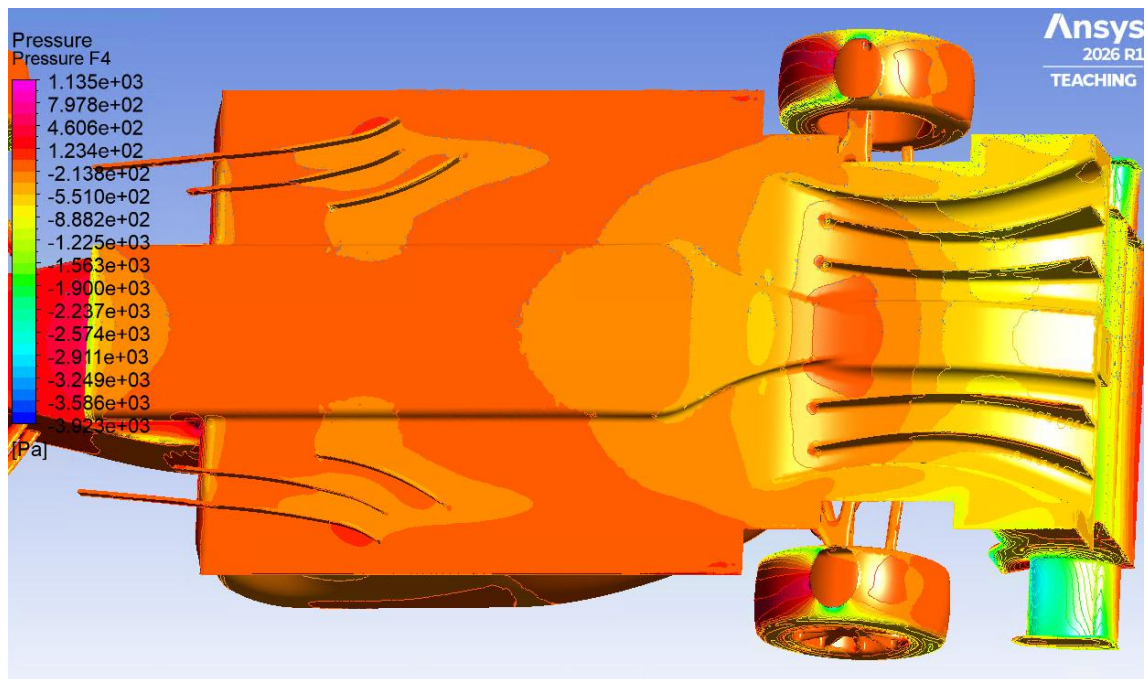


Figure 4. 45. Pressure distribution with 40mm of height.

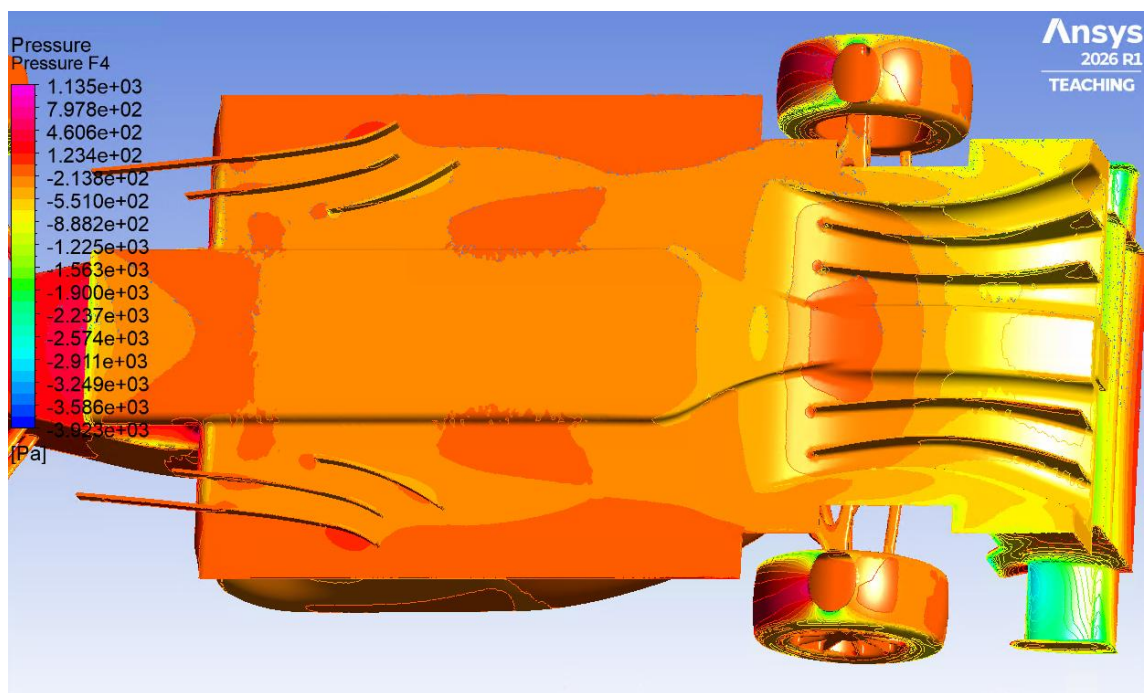


Figure 4. 46. Pressure distribution with 50mm of height.

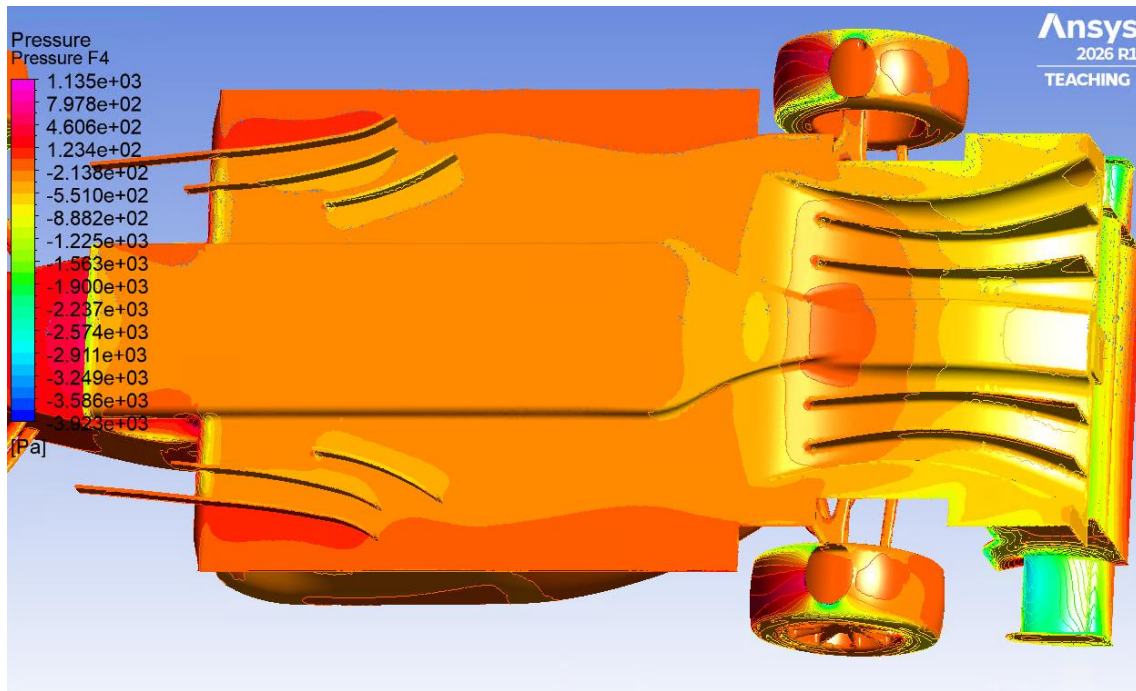


Figure 4. 47. Pressure distribution with 60mm of height.

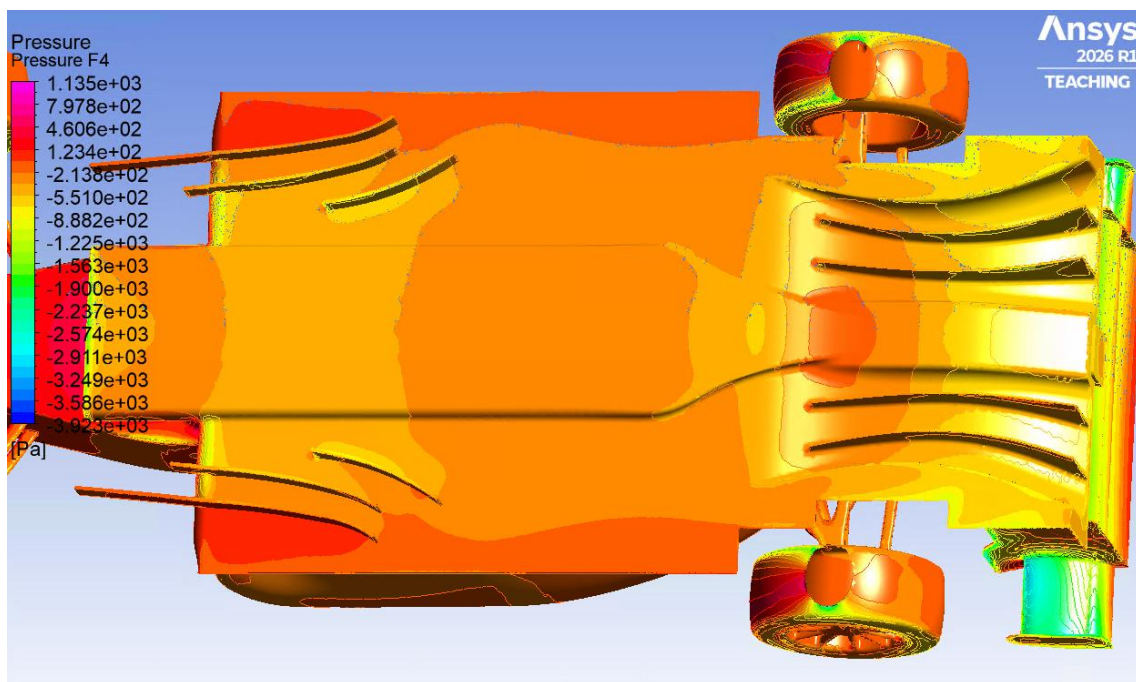


Figure 4. 48. Pressure distribution with 70mm of height.

The first view comparing the pressure distribution under the floor of the vehicle, it is clear the increase of the low-pressure area based on the greater height of the strakes. Dropping considerably all along the undertray and creating homogeneous areas. Moreover, the steps from 40mm to 70mm increase the different for every 10mm growth compared to the low heights.

In addition, low-pressure zones at the entrance of the leading edge also increase their area and drop their values, that could lead to the increase in the forward balance. However, important to highlight the high-pressure areas appearing in the external strake mainly in 60 and 70mm cases.

b) Streamlines and vorticity

In the following figures it would be presented the streamlines and vorticity around the floor of the car and the strakes based on the height values.

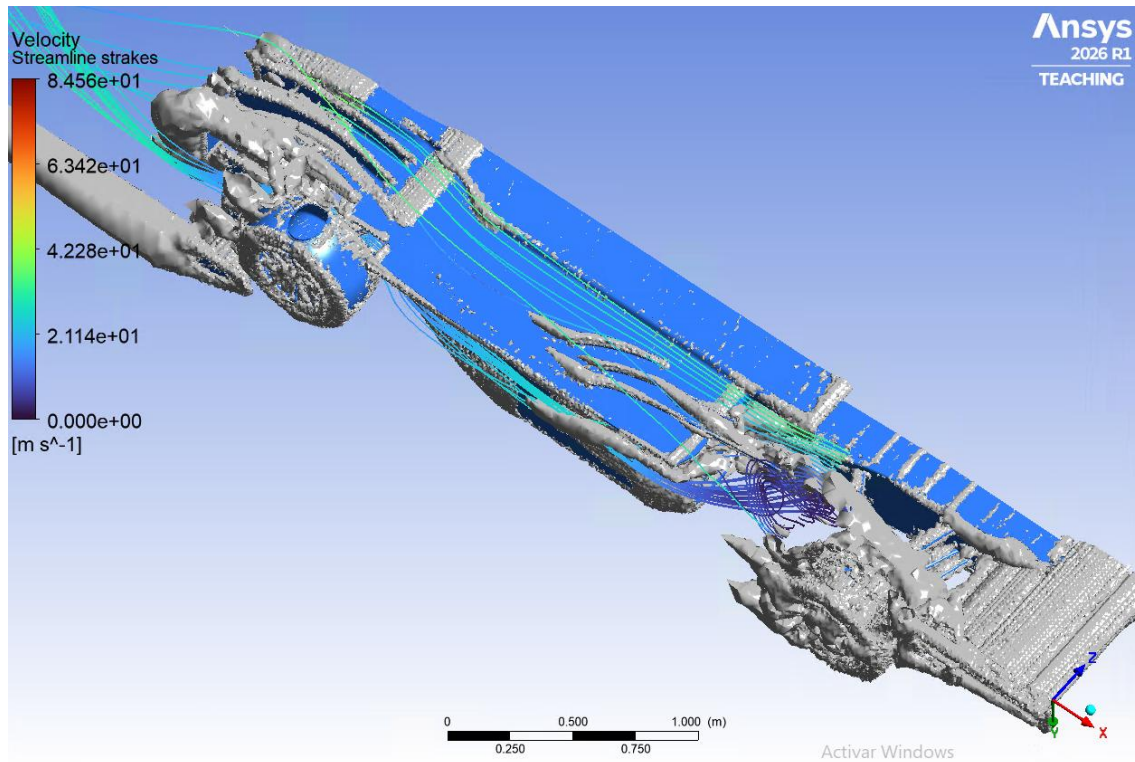


Figure 4. 49. Vorticity and streamlines with 20mm of height.

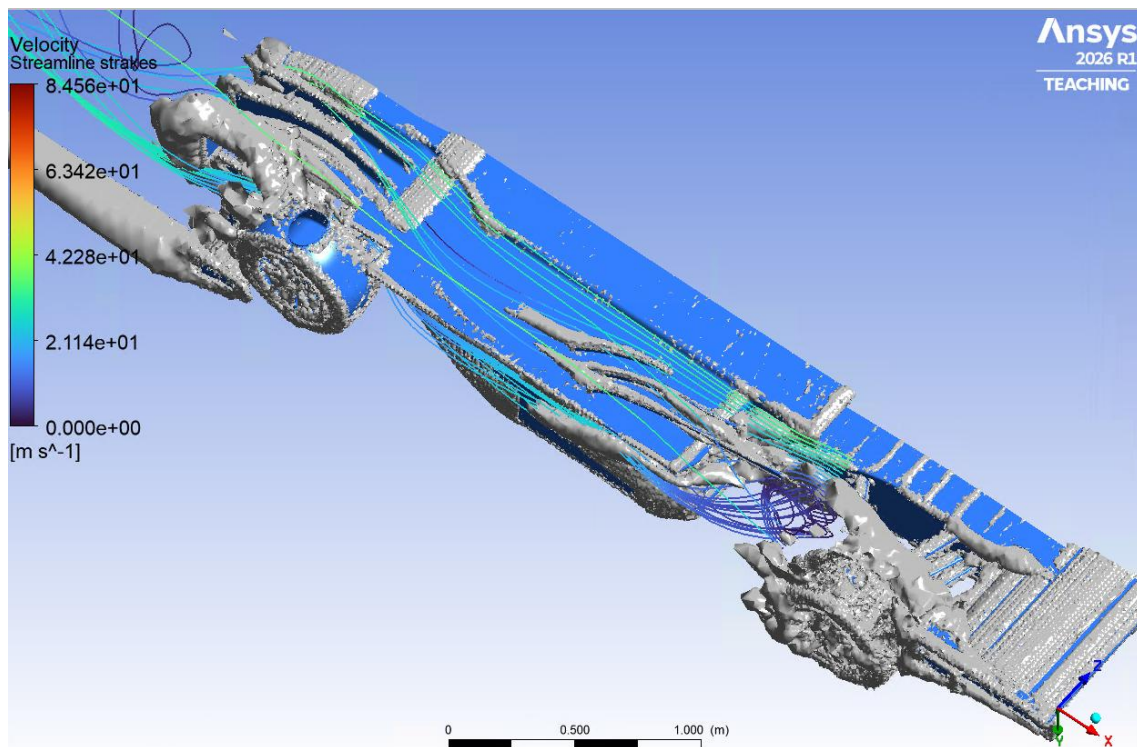


Figure 4. 50. Vorticity and streamlines with 30mm of height.

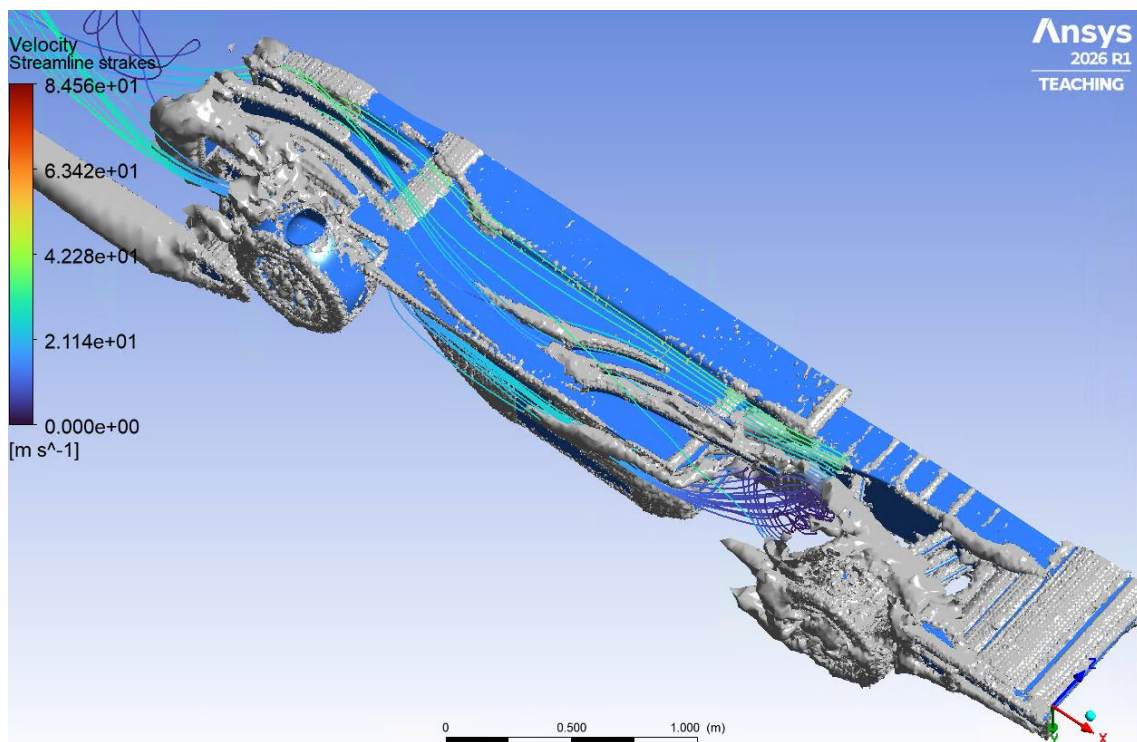


Figure 4. 51. Vorticity and streamlines with 40mm of height.

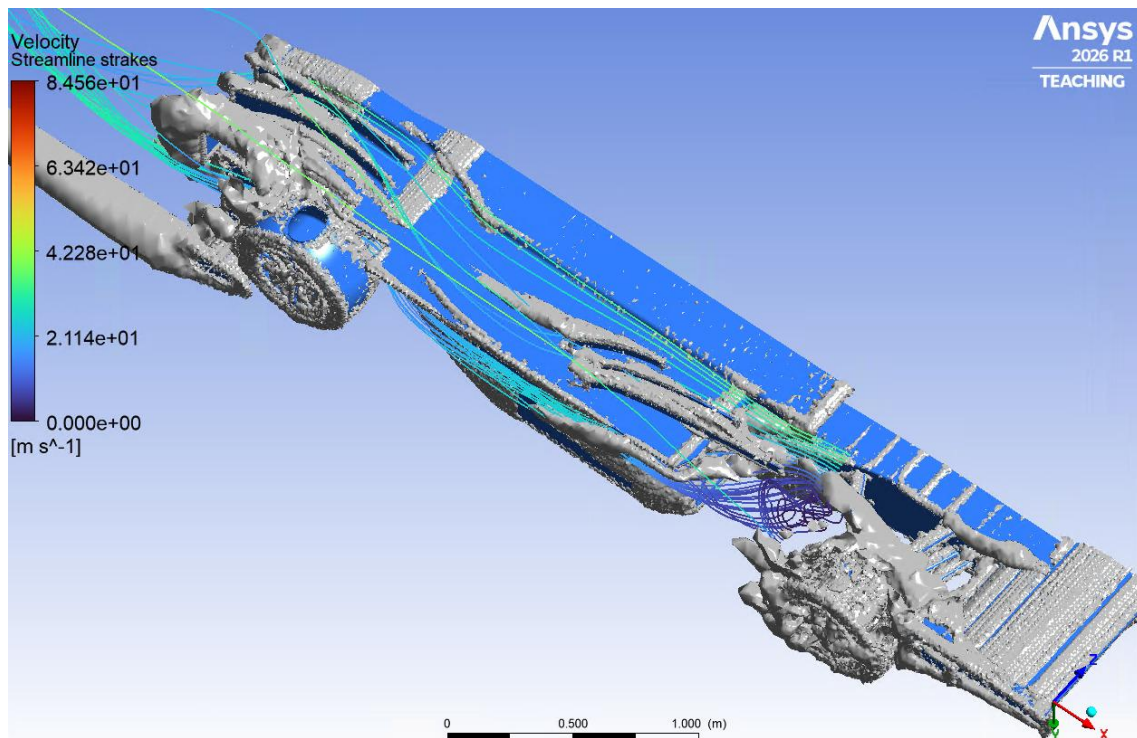


Figure 4. 52. Vorticity and streamlines with 50mm of height.

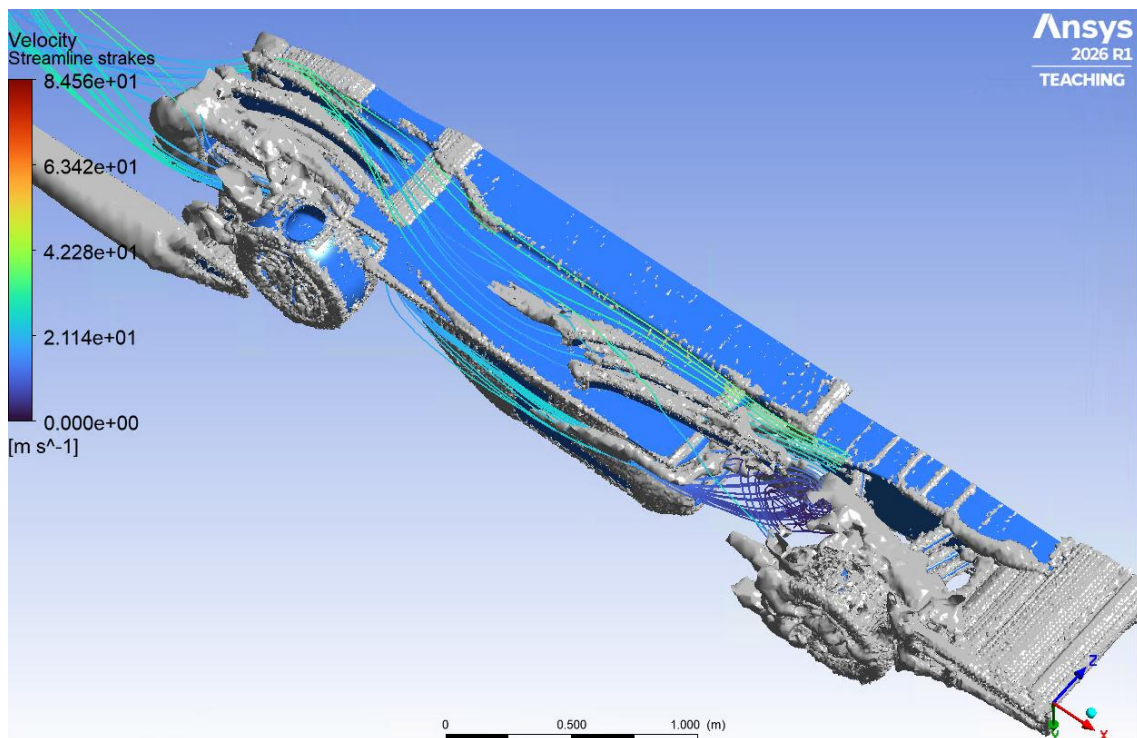


Figure 4. 53. Vorticity and streamlines with 60mm of height.

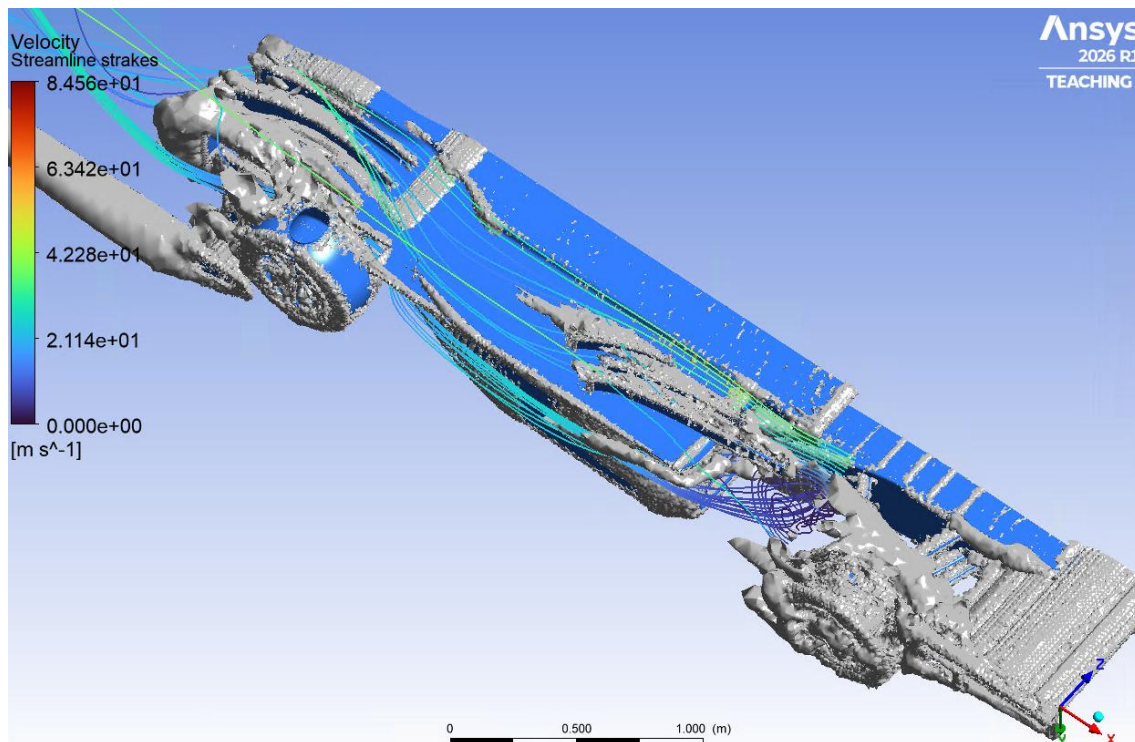


Figure 4. 54. Vorticity and streamlines with 70mm of height.

The tendency on the vorticity follows the previous analysis, where higher strakes increase both vortex and seal effect, that helps to reconduct the airflow that goes away to the diffuser as the streamlines show.

Another find out from these data is bigger strakes help to separate better the wake of the wheel from the stable flow, such as 40 to 70mm but, because of the increase of vorticity the airflow under the floor seems to be more unstable, especially on 60 and 70 mm cases. However, this effect does not seem to have an impact on the performance based on previous results presented.

c) Pressure cut planes

The next images represent the pressure distribution along the underbody in different planes of the strakes, at the entrance, at the middle and at the end of the strakes.

In this case, the biggest point to remark is that the ability to move out the wake coming from the wheel increases with the height of the strakes. As the high pressure are at the entrance starts to move out while the height increases.

Another point to highlight is at the middle plane where it continuous the analysis from previous results where the low-pressure area extended and increased, in this case with higher strakes. At the end plane, similar results to the middle plane came out.

Leading-edge entrance planes

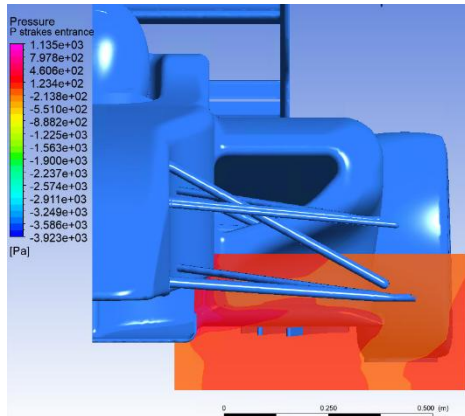


Figure 4.55. Pressure distribution entrance plane with 20mm of height.

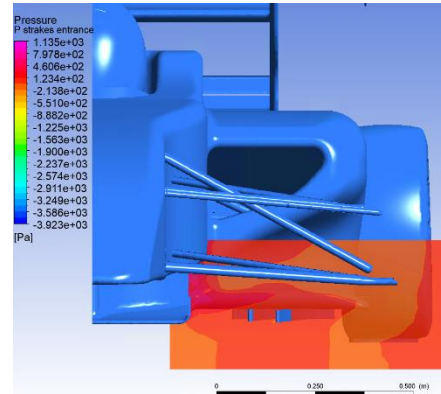


Figure 4.56. Pressure distribution entrance plane with 30mm of height.

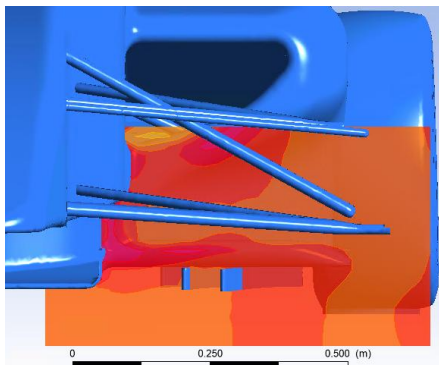


Figure 4.58. Pressure distribution entrance plane with 40mm of height.

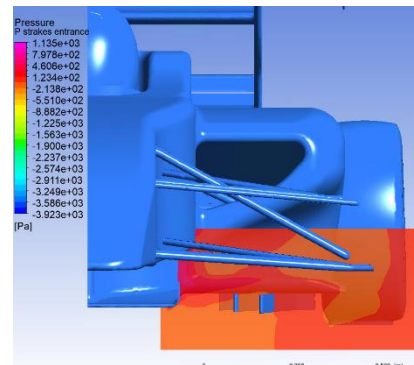


Figure 4.57. Pressure distribution entrance plane with 50mm of height.

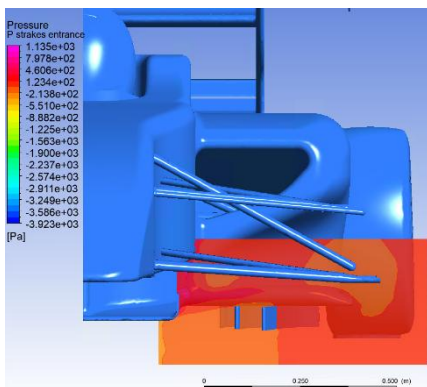


Figure 4.59. Pressure distribution entrance plane with 60mm of height.

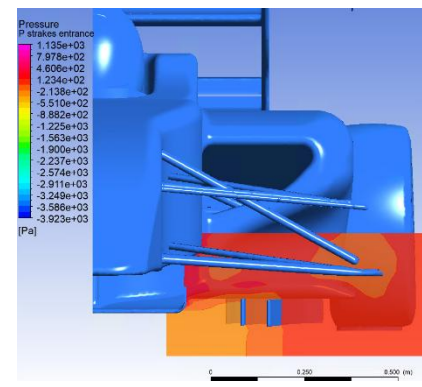


Figure 4.60. Pressure distribution entrance plane with 70mm of height.

Strakes middle plane

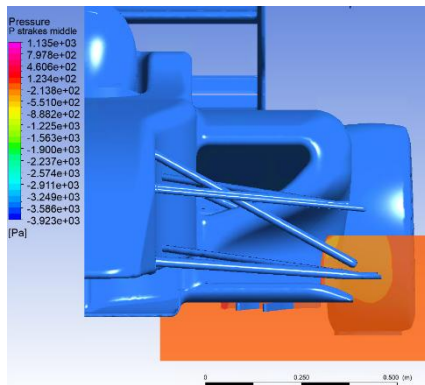


Figure 4. 61. Pressure distribution middle plane with 20mm of height.

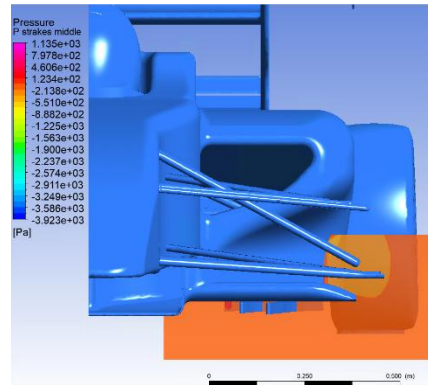


Figure 4. 62. Pressure distribution middle plane with 30mm of height.

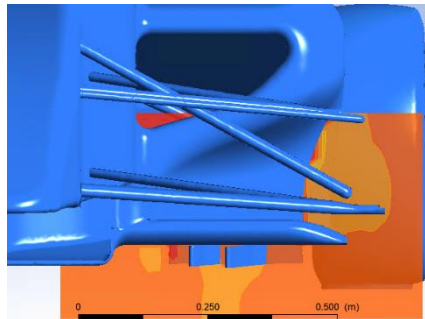


Figure 4. 63. Pressure distribution middle plane with 40mm of height.

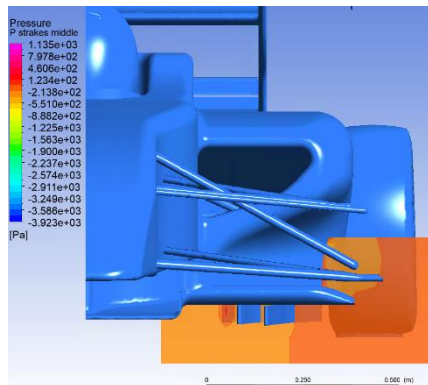


Figure 4. 64. Pressure distribution middle plane with 50mm of height.

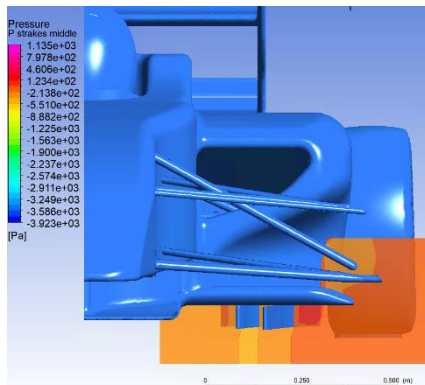


Figure 4. 65. Pressure distribution middle plane with 60mm of height.

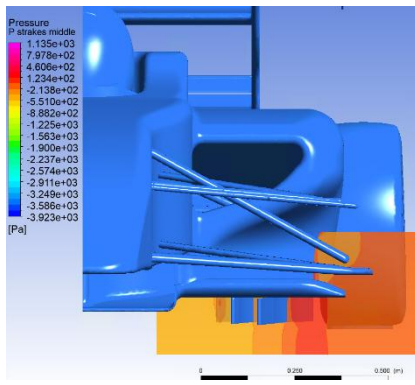


Figure 4. 66. Pressure distribution middle plane with 70mm of height.

4.5.2. Leading edge distance

Regarding the second variable studied, the distance between the starting point of the internal strake and the leading edge on the X axis (like in figure 3.9), forces and performance results are presented in the table 4.5:

Table 4. 5. Results from parametric study of the leading-edge distance on X axis.

Strakes V5 leading edge distance (X) Parametric Study						
Distance (mm)	240	290	340	390	440	490
Drag Coeff.	0.9787	0.9733	0.9768	0.9795	0.9765	0.9722
Drag Force (N)	626.47	623.01	625.26	626.99	625.06	622.30
Lift Coeff.	2.5817	2.5618	2.5727	2.5776	2.5736	2.5482
Lift Force (N)	1652.51	1639.78	1646.76	1649.90	1647.33	1631.06
Forward Balance %	51.05%	50.97%	49.96%	51.03%	50.72%	50.23%
Aero Efficiency	2.6378	2.6321	2.6337	2.6315	2.6355	2.6210
% improvement	0.1554%	-0.0624%	0.0000%	-0.0858%	0.0666%	-0.4823%

In this case, the baseline selected is the initial distance on the design, 340mm. As mentioned for the previous variable, colourmap strategy represents the same aspect. During the six simulations, the value of the height of the strakes was selected as 40mm.

Based on the results obtained, this variable does not influence the performance of the vertical strakes. As every result stays around the same compared to the baseline from V5 design, where drag maximum difference is 4.69N and lift is 21.45N, this one lower that the result from height study.

For this case, most additional parameters presented in other sections would be omitted due to the low variation between cases. Vortex generation combine with streamlines would be in the following pictures:

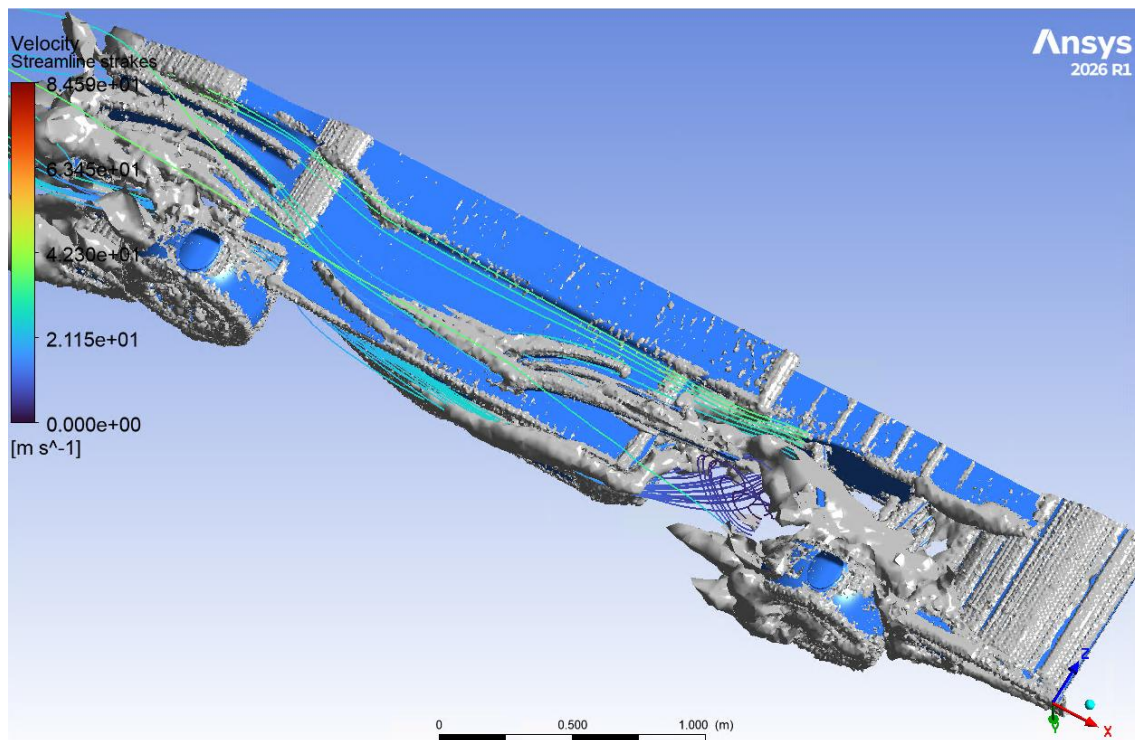


Figure 4. 67. Vorticity and streamlines with 240mm of leading-edge distance on X axis.

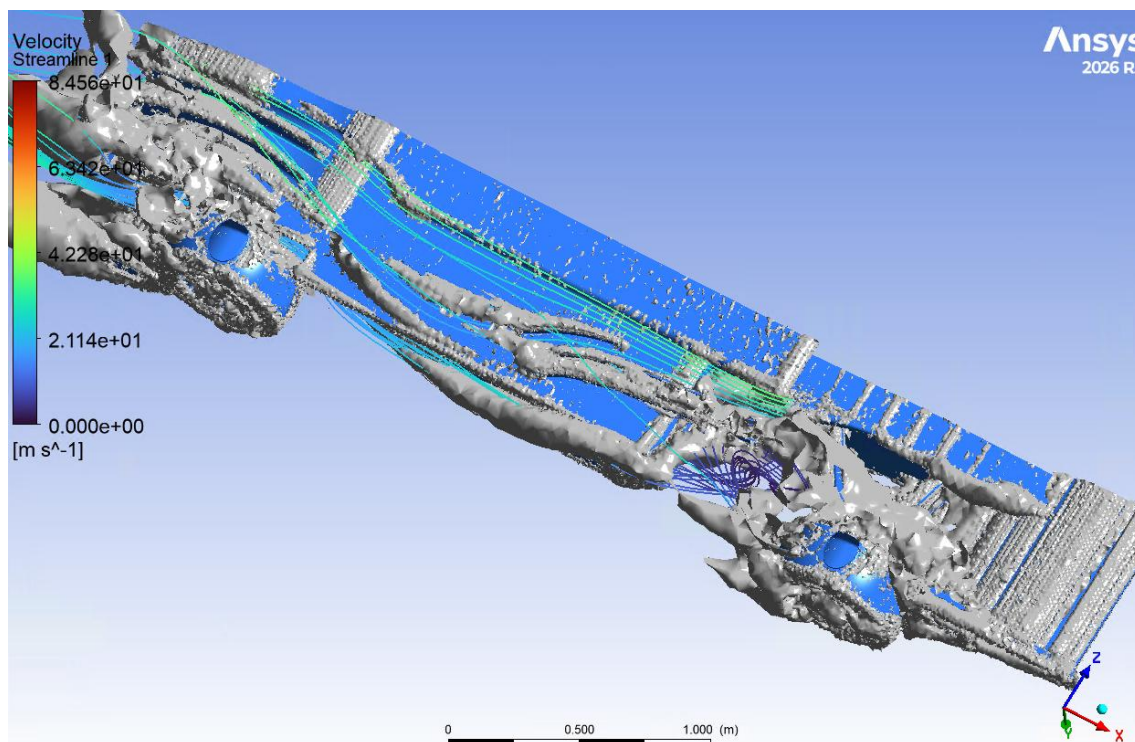


Figure 4. 68. Vorticity and streamlines with 340mm of leading-edge distance on X axis.

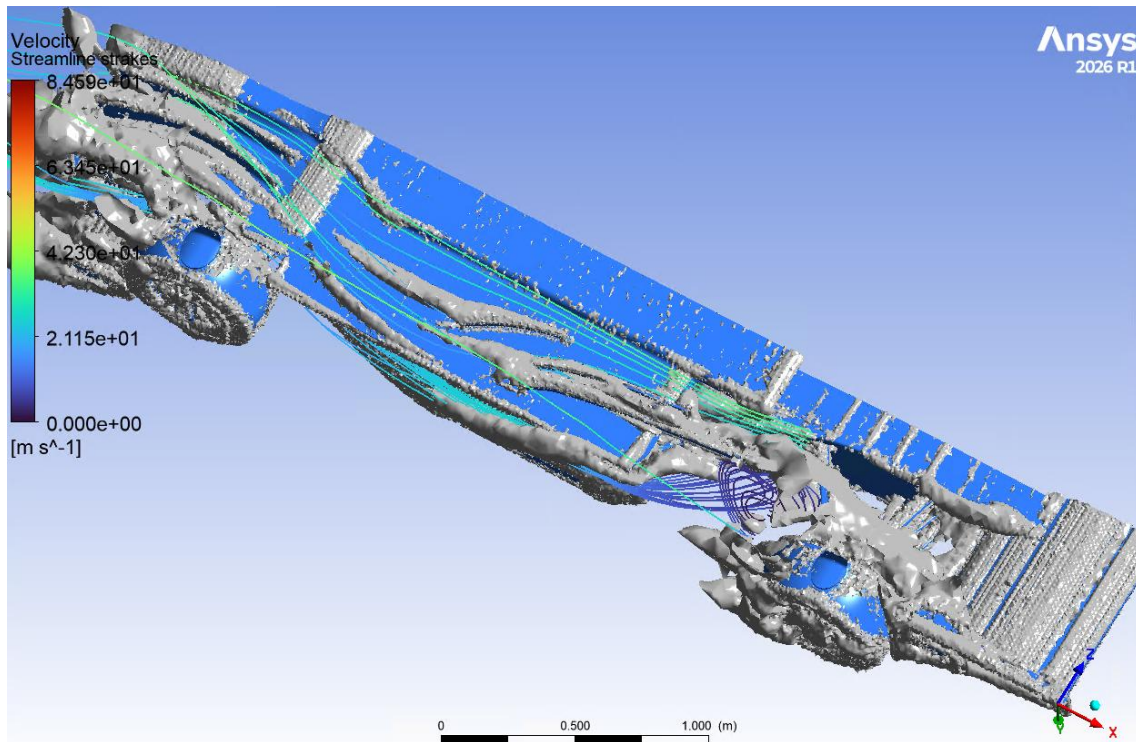


Figure 4. 69. Vorticity and streamlines with 490mm of leading-edge distance on X axis.

At the vorticity the main differences appear, as rearwards the strakes go, that final vortex generated manage to extend to the diffuser, mainly in 490 and 440 mm cases. On the other hand, for lowest cases, 290 and 240 mm, the vortex generated tend to combine in one.

4.6. Ride heights study including vertical strakes design

In the following pictures are presented the aero maps from the vehicle in different ride heights configurations, same ones as section 4.3, with the additions of the final vertical strakes design.

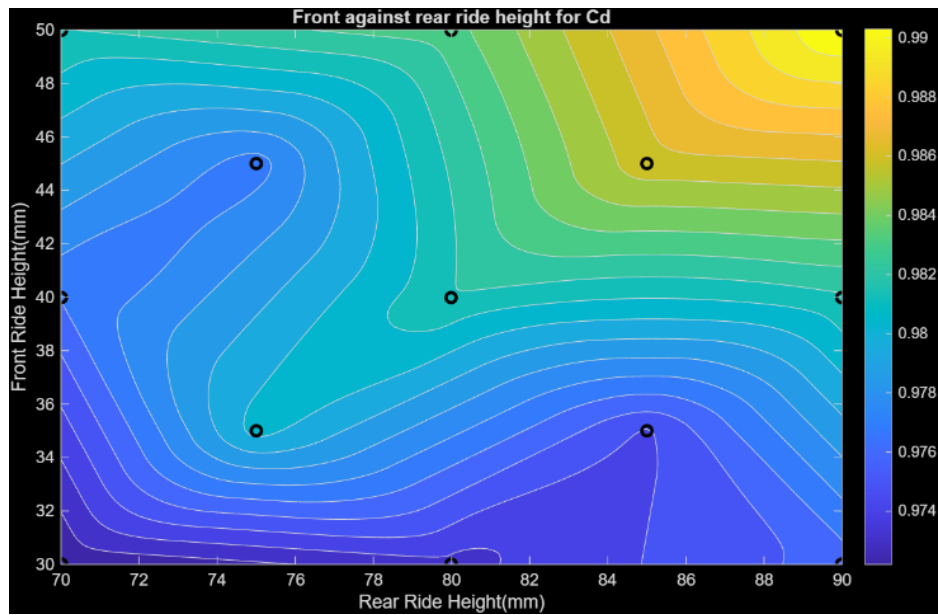


Figure 4. 70. Coefficient of drag aerodynamic map with strakes.

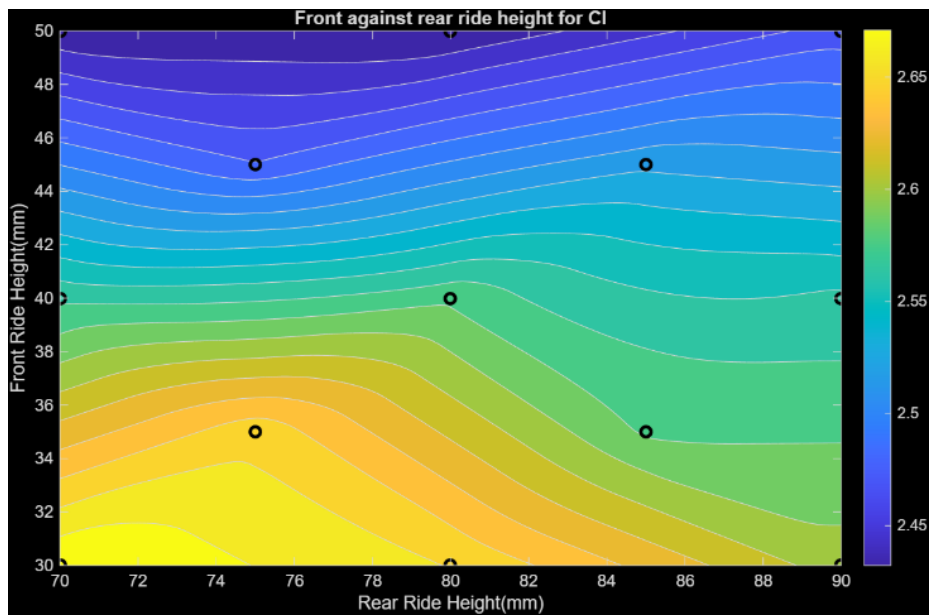


Figure 4. 71. Coefficient of lift aerodynamic map with strakes.

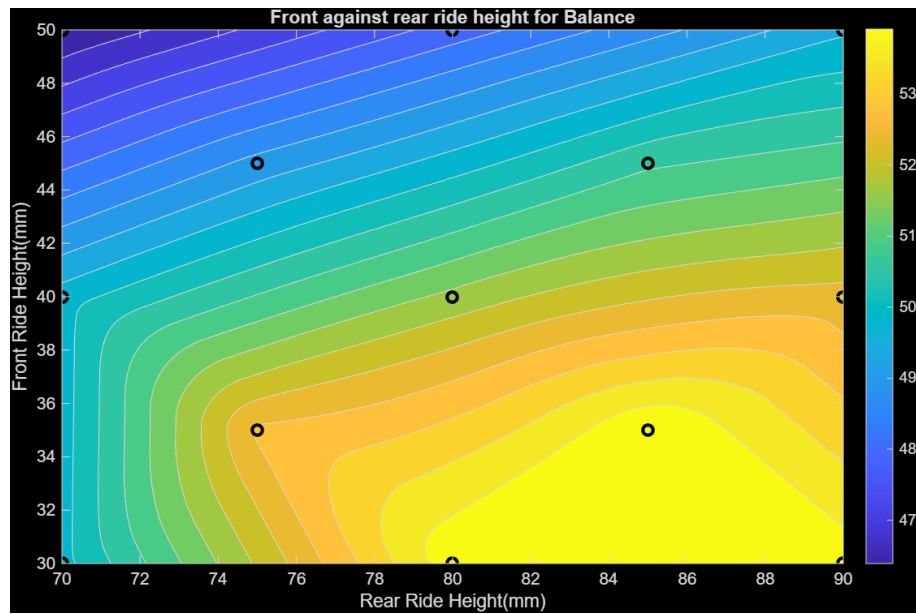


Figure 4. 72. Forward balance percentage aerodynamic map with strakes.

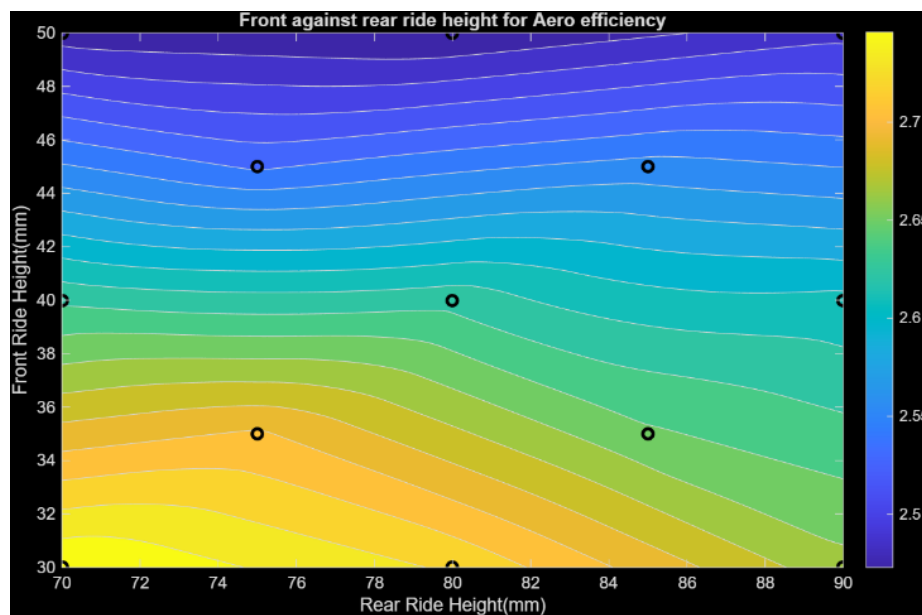


Figure 4. 73. Aerodynamic efficiency map with strakes.

These figures would help to understand the influence of the design on vehicle's behaviour and performance comparing them with the maps from baseline design. The tables with all the data obtained from the simulations would be included in the Appendix E.

Regarding the main effects of the implementation of the strakes, beginning with the lift, it has increased in almost every ride height configuration (except RRH 90mm FRH 30mm) compared to the baseline results, creating now a smoothly transition between different configuration, where three clear areas are distinguished.

For the drag coefficient of the car, the main different is the reduction of the area of higher values. However, the overall results represented a minimum difference compared to the baseline results. Therefore, the variable seems to be low sensitive with the strakes addition.

Both results lead to an increase of the aerodynamic efficiency of the car in every configuration (apart from RRH 90mm & FRH 30mm) compared to baseline, increasing the performance. However, it also means that the balance of the car has moved forward around 1-2%, going above the 50% in a bigger range.

In the following figures, these differences are represented visually with the help of aero maps that show the variation from the baseline to the implementation of the strakes:

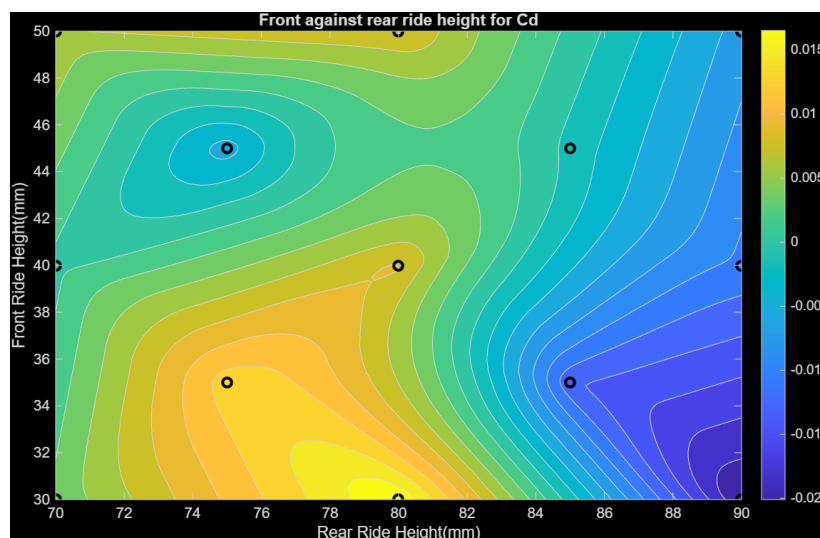


Figure 4. 74. Coefficient of drag difference aerodynamic map.

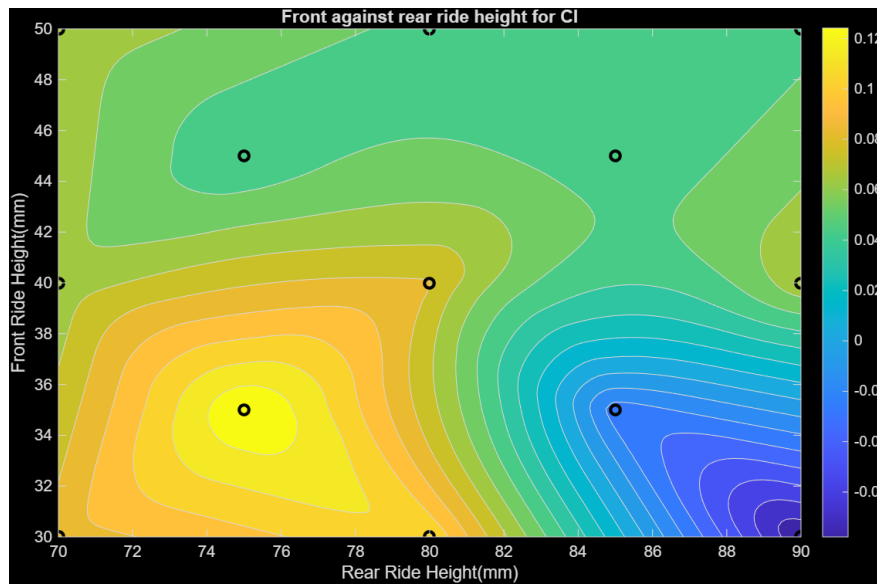


Figure 4. 75. Coefficient of lift difference aerodynamic map.

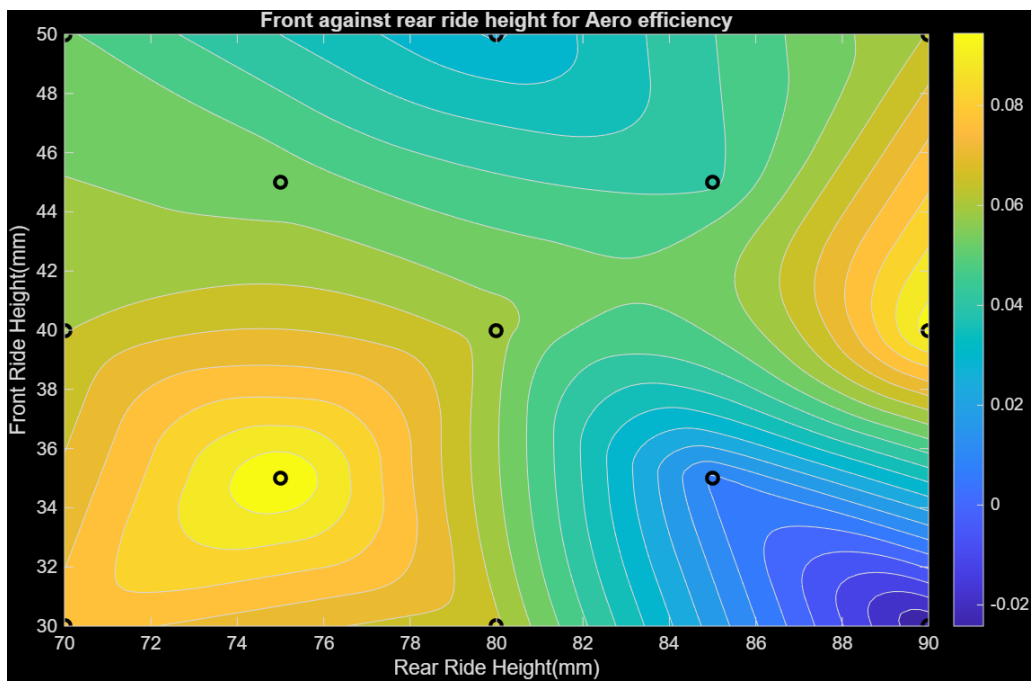


Figure 4. 76. Aerodynamic efficiency difference map.

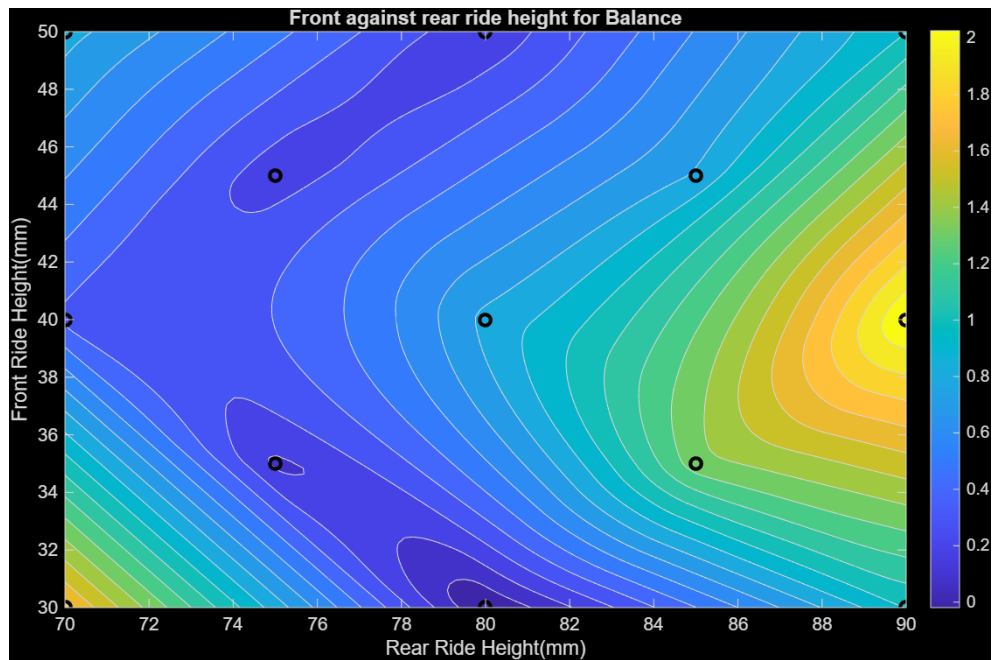


Figure 4. 77. Forward balance percentage difference aerodynamic map.

4.7. Results from Bargeboard & Strakes interaction

In the following table 4.6 are presented the results from the last simulation combining the bargeboard design developed by Ben Ellis-Jones (2026) and the vertical strakes from this project.

Table 4. 6. Bargeboard and strakes combination results.

Extra simulations			
Height (mm)	Baseline	Strakes V5	Strakes & BB
Drag Coeff.	0.9755	0.9768	0.9795
Drag Force (N)	624.41	625.26	626.9400
Lift Coeff.	2.5064	2.5727	2.5389
Lift Force (N)	1604.35	1646.76	1625.10
Forward Balance %	49.60%	49.96%	50.73%
Aero Efficiency	2.5694	2.6337	2.5921
% improvement	0.0000%	2.5039%	0.8846%

As it can be seen combining both designs shows regression on the performance variables, especially on the lift force and coefficient, the aero efficiency and increasing the forward balance above 50%.

5. Discussion

The results during the project have shown that the aerodynamic performance of the Mygale F4 is heavily influenced by the interaction between the implementation of the vertical strakes at the leading-edge, the underbody flow and the ride heights configuration. Although the introduction of the vertical strakes resulted in an overall improvement, the data obtained from the simulation suggest that their effectiveness is strongly dependant on different factors, such as their geometry and height. These effects influence growths with the vehicle rake that affects the airflow entering the devices and diffuser. The following discussion will analyse the validation and robustness of the simulations set-up, the influence and effect of vertical strakes at the entrance of the floor on the performance of the vehicle, strakes sensitivity to variables studied (ride heights, height and position) and the iteration between two developments

5.1. Numerical reliability

To begin with the validation of the simulation strategy, for this project domain and mesh independency studies has been made to analyse the sensitivity of the data to the computational environment and the grid resolution respectively. With the objective of ensure that the tendencies and variables of the developments do not get affect by other components outside of changes in the vehicle and strakes geometry. Moreover, turbulence model and solver parameters were taken into consideration for the convergence behaviour and near-wall resolution.

Domain

Starting with the domain study, it helps to understand that the selected computational environment provided enough space around the car to minimise the effect of the domain boundaries on the solutions. For this project, this analysis was performed for each dimension. As the table 4.1 shows, the values selected for the final configuration differ in less than 5% compared to the next level of resolution (extra fine). Comparing with other domains configuration and criteria on different studies from the literature (*Kirchberger, 2023*), this value is a common benchmark. Moreover, the parameters of the dimensions are in the range of magnitudes for aerodynamic simulations on open-wheel vehicles (reference).

Therefore, it is possible to sustain that the computational domain selected for the project does not affect the results from the simulations and allow the airflow around the vehicle to be completely develop. However, it is important to highlight the possibility of slightly variation due to the fact of the mesh resolution, as in the methodology it was remarked at a 3.10 million of cells, while this value can be correct for the domain study, the possibility of use a fine mesh during the analysis is presented in other research us a more accurate strategy (reference). Due to the project schedule, the project followed the time saving-efficiency strategy.

Mesh

Moving onto the mesh independency study, there were define four different mesh, from coarse to the extra fine. The criteria follow for the selection of the mesh size was comparing the coefficients of lift and drag against the previous mesh and see if the difference was less than 5%. In this project, because of the strategy follow for the set-up, it seems that the

values of lift were more sensitive against the mesh resolution, while the drag stays stabilize in each run. This difference is aligned with the cases in some of the studies from the literature review, for example Jacob Thom (2019) compared two different mesh where the drag variation was around 2.3% and the lift 6.5%. In Lasso-Parera et al. (2026) is mentioned that in aerodynamic configurations that are dominate by the ground effect, lift variables tend to be more sensitive to mesh resolution, which follows the behaviour in this project. The reason why this happen is because lift depends on the difference of pressure from two surface, specially to the leading-edge suction peak, as well as to regions of flow separation and vortex formation (Martinez Conde & Altmeyer, 2025; Felekos et al., 2022). While this value for the criteria seems to be a balance selection, in high level simulations such as F1 (Shaalán et al., 2024) they go below the 1%. Therefore, it would be an important aspect to take into account while obtaining conclusions from the results, as for the scope of this project it was necessary to have a balance between accuracy, timesaving and use of the computer resources efficiently.

5.2. Strakes design

As outline in the project objectives, one of the aims of this study was to contribute with new data and research to the underbody and vertical strakes fields. This is directly related to the design development of the vertical strakes for the vehicle, where a total of five designs were developed to embrace the latest information and present a novelty device following an evolution during the process.

Beginning with the first design, V1, V2 and V3 were developed based on the information from the literature review as it was explained in the methodology, V4 and V5 designs were an evolution combining the three first. Having this in mind, the discussion about the performance and data from them can be developed.

Starting with the results from table 4.3., it is clear that from the three first design, the curve pure strakes outstand against V1 and V2, with the last one has the worst efficiency with less lift and increasing the forward balance. The reasons why this difference occurs can be explained thanks to the vorticity and streamlines contours in figures 4.14, 4.15 and 4.16. While V2 splits better the stable flow of the front wing from the wake coming from the front wheel because of the start of the strakes is forward from the leading edge (Shaalán et al., 2024), V1 and V3 accelerate better the airflow creating bigger low-pressure areas (as figures 4.8 & 4.10 show) therefore increasing the lifts and efficiency. In addition, analysing the streamlines, they are distributing better the airflow throw the diffuser in specially in V3. This main difference must be because of the curvature implemented on the V1 and V3 designs, as the literature review showed (Nebot et al., 2025) and other articles found (Viswanathan, 2021), that bend on the structure help to compress the air on top, accelerate it and generate those low-pressure zones explained. Moreover, that curvature increase the seal effect of the underbody because of the vortex generated as figure 4.16 shows and confirmed with other studies (Zhang et al., 2022).

However, that structure bending is not perfect and could be an area of study, as the results form table 4.3 present, V1 has a slightly increase in the drag compared to the baseline while V3 reduce it, the reason why is visible in figures 4.8 & 4.10, in the pressure distribution around the strakes, in V1 there is a high pressure area in the external strake at the end due to the aggressive curvature design, while V3 presented a smoother design.

Moving onto V4 and V5 designs, they come up as a combination of the strength of the three first developments, creating a hybrid design of straight and curve strakes. Incorporating the starting point of the strakes ahead of the leading edge to separate the wake of the wheel from the stable airflow and adding that smoother curvature to keep the flow attach to the surfaces and conducted. The main difference between V4 and V5 designs is the stagger on the third strakes (internal one) based on the conclusions from Shaalan et al., (2024). The reason why this approach was taken, it is because the third strake in V4 was disrupting the low-pressure area at the entrance as figure 4.11 shows.

Comparing the results from V4 and V3, there is not a strongly difference on the performance, mainly because of that disruption generated at the entrance, as V5 manages to obtain another improvement step on the aero efficiency of the vehicle. Moreover, V5 design manages to increase less the forward balance at the same time, reinforcing the selection of this design. The explanation of this difference compared to the other designs regards in, V5's strakes not only generate bigger low-pressure areas, but also the third strakes generate it rearwards, displacing the lift generated to the rear of the car (Soares et al., 2018) and creating vortex that help to energizes the flow and the pressure recovery on the diffuser (Haoran Sun, 2025).

Moving onto the vorticity and streamlines of these hybrid designs, comparing them with the previous ones, they increase the sealing effect of the underbody thanks to the end curvature that generates the vortex, especially in V5 as the vortex generated with the third strake manage to get further rear and increase the seal effect all along the floor. Furthermore, these hybrid design generate a controlled vortex at the left end coming from the edge of the underbody, possible to see in figures 4.17 & 4.18, that helps to reconduct the airflow that tries to go outside of the undertray as the streamlines shows. All these conclusions reinforce the implementation of that curvature specially at the end of the strake.

To end with the strakes design, different pressure distribution planes are show in section 4.6.3. at the entrance of the leading edge, middle of the strakes and the end of the strakes, to show another point of view of the evolution of the pressure and airflow through the floor. Starting with the plane at the entrance, strakes designs reduce the static pressure around the entrance generating two zones, low-pressure that goes under the floor and higher pressure that shows the direction of the wake from the wheel to the outside, especially in V2, V4 & V5 (figures 4.22 4.24 4.25). This can be related that in those designs they split better the wave region from the wheel from the stable airflow, thanks to start further ahead as it been presented during the discussion.

Analysing the middle plane, the major difference come with the low-pressure generated by V4 and V5 design compared to the previous three due to the vortex generated and the seal effect that prevent the outside air to renter the undertray.

Regarding the end plane view, the only strakes design that makes a difference in the pressure distribution is V5 keeping a low-pressure zone around the strakes further rear, thanks to the turbulence generate by the device that manage to get to the end of the underbody because of stagger the third strake.

To sum up everything, V5 design is the most interesting design because of the overall improvement on the performance and behaviour of the airflow under the vehicle, but also because it controls the increase of the forward balance of the vehicle. In addition, it

presents a novelty design focus on the hybrid structure combining the strengths from the most common builds in the literature.

5.3. Parametric study

Following with the discussion of the results from the parametric study, it would be divided into two parts, first the height study and second the leading-edge distance on X.

Height

Regarding the results obtained for the parametric study of the height of the strakes, in section 4.7.1. and table 4.4 are presented the results and their tendencies. There are directly relations to justify those evolutions on the results, for instance the pressure distribution under the vehicle it can be seen on the figures 4.43 to 4.48 from section 4.7.1.a) where the lower-pressure zones generated by the strakes decrease their values and increase their area with the growth of the height. Furthermore, from 20 to 40mm there are not big changes while 40 to 70mm each step makes a bigger effect on the pressure distribution. These shows that smaller strakes could reduce the performance of the car and work as an obstacle for the flow (aero efficiency decrease and higher values of drag for 20 & 30 mm. As mentioned in the literature review, there are not parametric study around vertical strakes at the entrance of the floor, Soares (2018) define three sizes (small, medium, large) where the results suggest only and increase in the drag without a relevant increase in the downforce, however, those devices are allocated on the forebody of the vehicle, therefore would not be a strong comparison.

These conclusions suggest that the height of the strakes is an area of study with great potential that could have more opportunities and findings. Important to highlight, in this project the limit of the height was established as 70mm because of the restriction due to the ride heights configuration, to avoid choking the air and scrape the ground, despite the positive tendency as the height increase.

Another point to remark is the high-pressure zones that appear on the 60 and 70 mm cases in the external strake, these zones could be generating some drag and preventing the value to reduce but also seal the floor at the beginning of the floor. Additional relevant points are the growth of the low-pressure areas at the very entrance of the floor because of the increase in the acceleration of the airflow with higher strakes as figures 4.47 & 4.48 suggest. Moreover, the increase on the forward balance could be explain as the pressure has decreased almost in the entire underbody, hence the effect of the third strake being rearward has lost relevance.

The pressure distribution on the symmetry plane suggests that the values under the floor homogenize with the increase on the height until the diffuser, however, those appreciations are small and not enough support to be sure.

Moving onto the vorticity variable and streamlines, the ability to separate the stable airflow from the wake of the front wheel improves with the bigger strakes and the capacity of reconducted airflow. On the other hand, smaller strakes manage to keep the flow more stable until the diffuser.

Due to the fact that bigger strakes generate bigger vortex, this directly effect on the seal effect of the floor, where in figures 4.51 to 4.54 more streamlines keep the path as the vortex

on the edge growth. However, it is important to highlight that at 70mm some vortices tend to be more unstable and could affect the performance (Porcar et al., 2021).

To end with the pressure planes at the underbody, there are two main point to remark. Firstly, at the entrance plane it makes clearer how strakes with higher height move out the wake from the wheel better. The other remarkable aspect appears at the middle plane how the pressure evolves lowering its value but also appear that high pressure area at the edge of the floor.

Despite the lack of literature to compare and support the results from the parametric study, it is also remarkable that a lot of information a potential areas of study are presented from these cases and could help to understand better the influence of the height parameter that seems to be sensitive and influence the strake performance.

Leading edge distance on X

Following with the second variable study, in contrast with the heigh, this second variable does not seem to influence on the strakes performance as the performance result on table 4.5 suggest. Moreover, on the contour's figures, the only remarkable aspect to present is the behaviour of the vortex depending on the position of the third strakes, as rearward goes the final vortex extends to the entrance (figure 4.69) of the diffuser affecting the performance. On the other hand, moving the strake forward on X, as it gets near the other strake, the vortex generated combine in one (figure 4.67).

While the selection of the variable was with the objective of isolate the influence of other directions move to simplify, it is possible to conclude that the position on the strakes should be analyse with changes in the three axis, as the results from the design evolution prove that stagger the third strake improve the performance, besides research from the literature support the statement (Shaan et al., 2024).

Therefore, it is possible to suggest the changing only the distance on X of the third strake does not have a proper influence on the performance, as a result, there are other variables of interest to propose, such us change the three directions, that could present additional information to the field. They would be mentioned on the future work section as they are out of the scope of this project due to time limitations.

5.4. Ride heights comparison

With the final definitive geometry of the vertical strakes developed, V5 design with 40mm of height and the third strake at 340mm from the leading edge, based on the previous results and their analysis, it is possible to proceed with the study and comparison of the ride heights configurations with the strakes and without them to understand their influence on the performance.

Comparing the aero maps from the baseline (figures 4.3 to 4.6), the ones with the strakes design implemented (figures 4.70 to 4.73) and the difference ones (figures 4.74 to 4.77) that represent the difference between the first two, it is possible to come up with remarkable conclusions. Firstly, an immediately effect from the strake on the car aerodynamic behaviour is the improvement in almost every case the aerodynamic efficiency of the vehicle putting all the configurations above 2.5 value (near 4% of max upgrade) while at the baseline near half of them were below. Similar influence occurs on the coefficient of lift, where there are improvements above 0.1 (5.36% of upgrade) while the drag is stable and, in

some cases, reducing its value. However, it is necessary to highlight the effect on the forward balance, as the improvement in lift leads to an increase in the forward balance above the 50% which makes the vehicle more difficult to drive.

These results are directly related with the physics interaction and influence coming from the strakes as it was explained and discussed in previous sections and supported by literature. The reduction of the pressure under the floor thanks to the acceleration and suction effect, makes a bigger difference with the upper surfaces increasing the downforce, similar to the behaviour on Porcar et al. (2021) and Soares et al (2018) results from the literature for vertical strakes implemented in the diffuser; the ability of the strakes to move out the wake from the front wheel that helps to control the drag and keep airflow stable under the floor, as different studies such as Zhang et al. (2018) showing the influence of a stake allocated between the suspension arms, a different approach with a similar effect; and last but not least the help of the vortex generated to seal the underbody from the entrance of external flow, as Liu (2026) shows with the a Red Bull racing design to generate that secure effect with structures similar to the strakes from this project.

As the result and discussion sections show, it is possible to determinate that the vertical strakes implementation on the leading-edge of the underbody help to improve the performance of the vehicle, increasing its efficiency and developments in the most common work zone, allowing to obtain similar result with less aggressive configuration. However, it is important to remark the negative effect on the balance of the car, as it makes necessary a rebalance of the vehicle, for instance reducing the angle of attack of the front wing, to move the centre of pressure rearwards and go below the 50%. This analysis could not be developed in this project due to the time limitation and project dates but would be an interesting work on the Mygale F4 to find the most efficiency configuration.

Therefore, the other main objective presented at the beginning of the project was achieved, improving the performance of the vehicle with a new development on the floor of the car. To continue with, next steps should be the manufacturing of the design and the test of them on the car to evaluate the real effect and the correlation with the CFD simulations.

5.5. Bargeboard and strakes interaction

As the preliminary results shown on table 4.6, there is a regression on the performance of the vehicle with the addition of the bargeboard design. Because of the time limitation, there was not enough time to make deeply analysis, however, there are some hypotheses that could explain the decline on the efficiency of the car. Firstly, both design were developed separately by their own engineers, without the influence of the other one, this shows the importance of co-developing aero devices that interact together but also perform an optimization study to be able to find the most efficient configuration.

Furthermore, the strakes design was moved rearwards 100mm due to them overlapping with the bargeboard design. For this reason, the aerodynamic efficiency could have been diminished (Liu, 2026).

6. Conclusions

The main conclusions obtained from the project would be presented in this section. To begin with the CFD as a tool for design development, it is demonstrated that CFD is a powerful instrument, as it let you test different design and analyse results in an efficient way. However, it is important to mention that it requires a balance between time and computer resources with the accuracy of the results and the timetable dates.

Another conclusion obtain during the project was the low number of parametric studies and short information around vertical strakes design at the entrance of the underbody, while at the diffuser has been used and study for so long. This reinforces the contribution of the project to the field with novel and relevant information regarding an aerodynamic device with potential.

Continuing with the conclusion from vertical strakes, the influence they have on the aerodynamic behaviour of the car is prove with the results presented affecting all the performance variables of the vehicle. In addition, the important sensitivity to the ride heigh configurations and the height of the structure, requiting to be careful with the area where the car is going to work, as it could be necessary to make a rebalance of the vehicle to obtain the best performance.

Ultimately the co-analysis of the bargeboard and strakes has not shown this far any benefit compared to implement only the vertical strakes design. For this reason, it would be necessary as stated before, to perform a deeply co-study of the interaction between both designs implemented on the Mygale F4.

7. Limitations and future work

As the last section of the project, there will be presented the limitation found during the development and possible studies that could complement this project but also increase the knowledge around vertical strakes and underbody developments.

The main limitation for the project was the time, while it was possible to cover an important rage of analysis and simulations to expand the information regarding vertical strakes, there are some additional cases that would be useful and interesting to cover at the end of the project. Because of that time limitation, it leads to explain another constrain the trade-off between accuracy of the results and time-computational resource efficiency. This balance, despite of making studies and try to minimise the error on the results, there are some percentages of differences and variations that must be taken into account and understand de possibility of a slightly offset with the real case.

The next limitation is related with this possibility of variations, as for this project, it was not possible to correlate the results of the strakes in a real case test, the only possibility was comparing with literature and similar developments. That's the reason why a correlation study of the domain using Mira car was developed to double check the simulations would be independent from other factors outside of geometrical variations on the object of study.

Regarding the future works around the project, there are different possible directions for further research. Starting with the last set-up of the car, an interesting work would be analyse the interaction between the new front wing developed by Ryan Boardman, the

bargeboard from Ben Ellis-Jones and the vertical strakes developed during this project, with the objective of find the most efficiency and balance configuration of the car with the recent developments. As at this moment, the car is working above the 50% forward balance but has a wide range of margin to retreat it, for instance reducing the angle of attach of the front wing, which should reduce the drag an maintain an interesting efficiency.

Other possible studies that could not be include in this project due to the time limit would be analyse the 70mm of height configuration of the vertical strakes. This case was interesting because of the great aerodynamic efficiency while keeping a forward balance similar to the other ones, that suggest a bigger potential could be achieved with this geometry.

One of the most interesting research projects that could be developed is keep going with the parametric analysis of more variables that can affect the vertical strakes behaviour. As mentioned during the project, there is an important hole in the field here, especially for strakes at the entrance. The position of the strakes could be a really big area of study, moving around all of them combining the directions, as the results from this project suggest that analyse them in an isolate way does not seem to have an effect. As with this variable, several other parameters could be investigated and keep increasing the knowledge around vertical strakes.

Overall, the project successfully fulfilled the objectives established at the beginning of the investigation. The finding obtained have provided valuable knowledge of the aerodynamic effect of vertical strakes and demonstrated the importance of their geometry, positioning and interaction with the vehicle underbody. Although further research would be required to fully assess their behaviour under a wider range of operating conditions, the present study contributes with a solid a solid foundation for future developments and additional research in this area.

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9. Appendices

Appendix A: Comparison between turbulence models

In the next graphics are represented the results from the simulation with SST k-w and K-e turbulence models for aerodynamic forces and coefficients. Where it seems to be clear that the difference between them is negligible. Following the information obtained during the literature review and the preparation of the simulation set-up, it is possible to declare that using SST k-w model is correct for the development of this project.

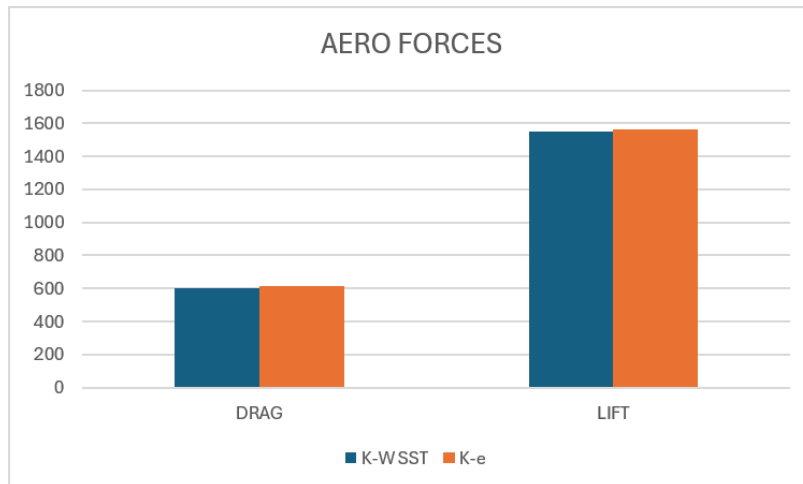


Figure A. 1. Turbulence models aero forces.

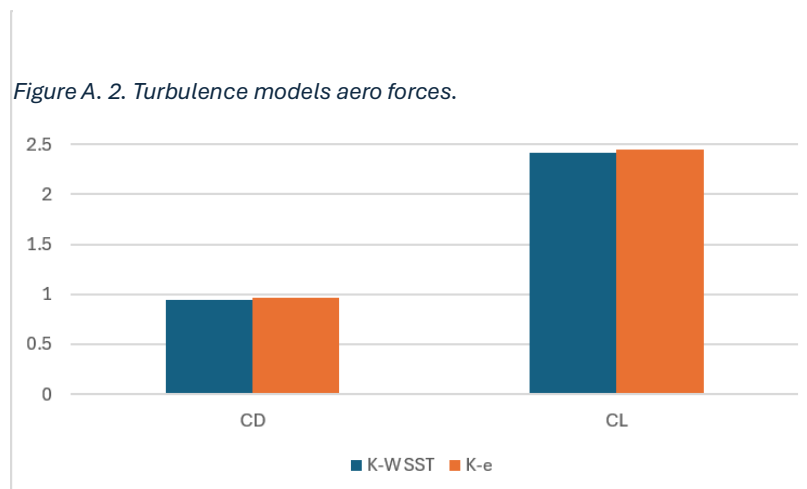


Figure A. 2. Turbulence models aero forces.

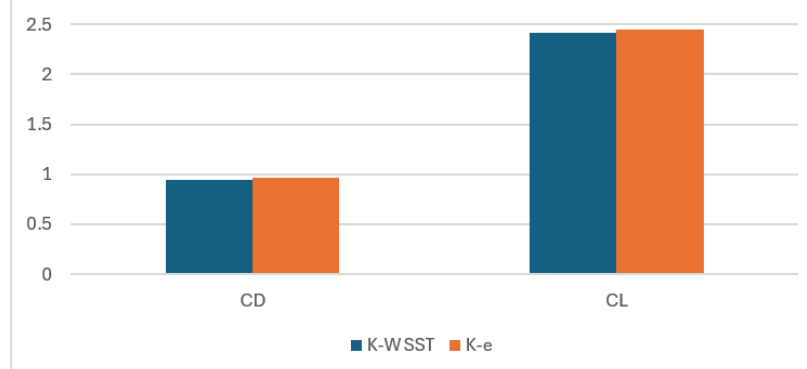


Figure A. 3. Turbulence models aero coefficients.

Appendix B: Data from Baseline ride height study

		Lift				
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	2.5943		2.5064		2.3644
	75		2.5199		2.4368	
	80	2.5449		2.5002		2.3820
	85		2.6090		2.4818	
	90	2.6830		2.4946		2.4242

Table B. 1. Coefficient of lift ride heights data.

		Drag				
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	0.9680		0.9755		0.9749
	75		0.9669		0.9817	
	80	0.9552		0.9726		0.9744
	85		0.9873		0.9869	
	90	0.9963		0.9916		0.9975

Table B. 2. Coefficient of drag ride heights data.

		Aero Efficiency				
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	2.680062	#DIV/0!	2.569349	#DIV/0!	2.425274
	75	#DIV/0!	2.606164	#DIV/0!	2.482225	#DIV/0!
	80	2.664259	#DIV/0!	2.570635	#DIV/0!	2.444581
	85	#DIV/0!	2.642561	#DIV/0!	2.514743	#DIV/0!
	90	2.692964	#DIV/0!	2.515732	#DIV/0!	2.430276

Table B. 3. Aero efficiency ride heights data.

		Forward Balance %				
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	52.27%		49.60%		45.55%
	75		53.02%		48.94%	
	80	54.20%		50.93%		47.86%
	85		52.93%		50.03%	
	90	53.12%		50.43%		48.70%

Table B. 4. Forward Balance ride heights data.

Appendix C: Strakes results

C.1. Velocity symmetry plane

The next pictures represent the velocity on the symmetry plane with the vector showing the direction of the flow.

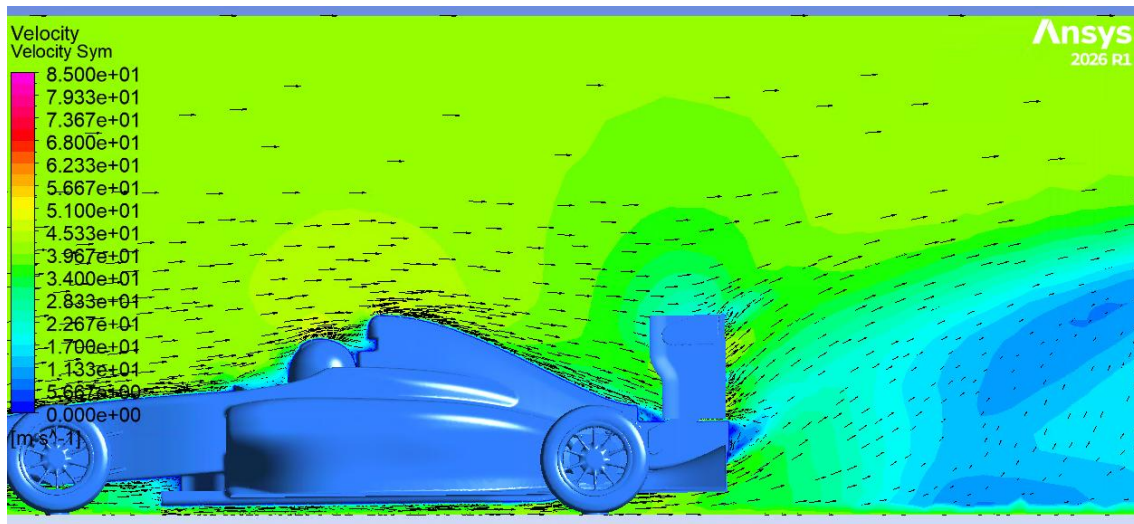


Figure C. 1. Velocity on symmetry plane Baseline.

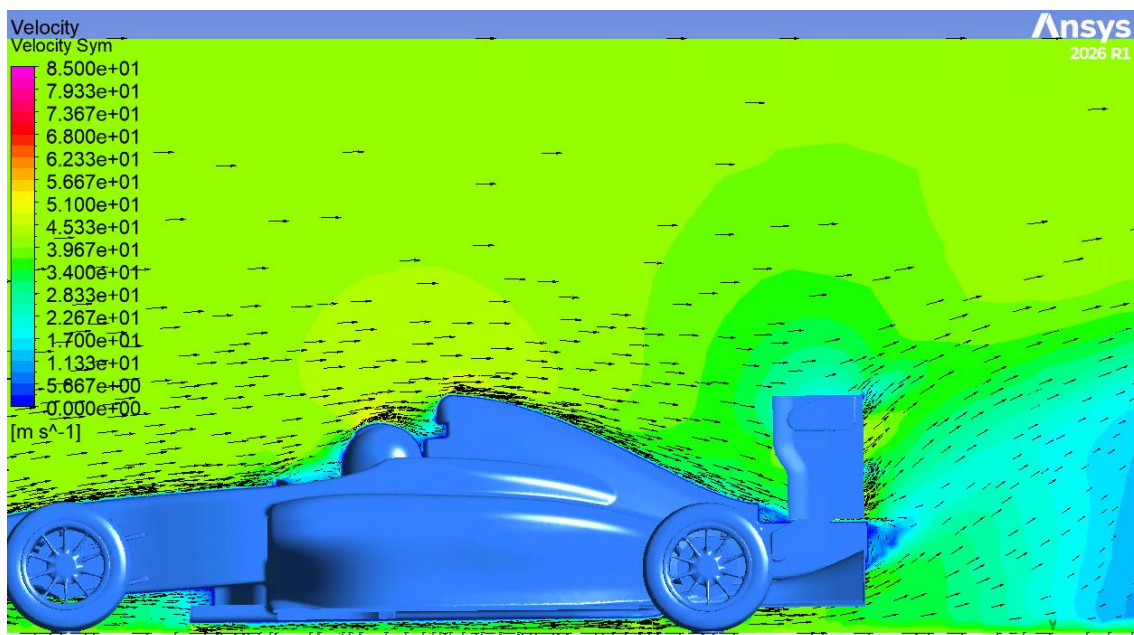


Figure C. 2. Velocity on symmetry plane Strakes V1.

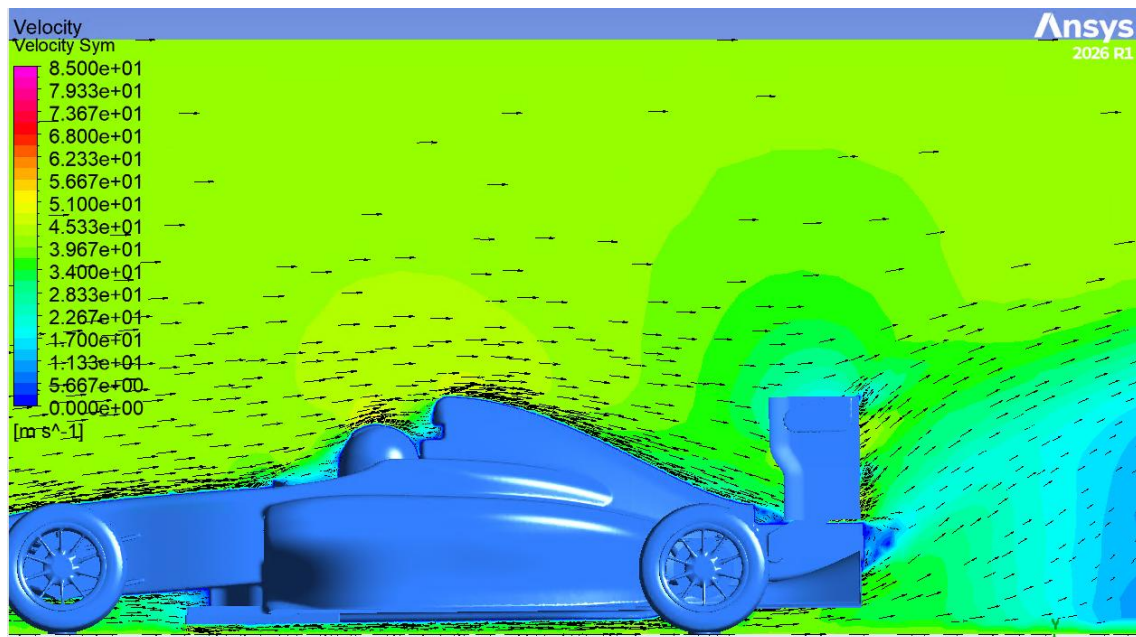


Figure C. 3. Velocity on symmetry plane Strakes V2.

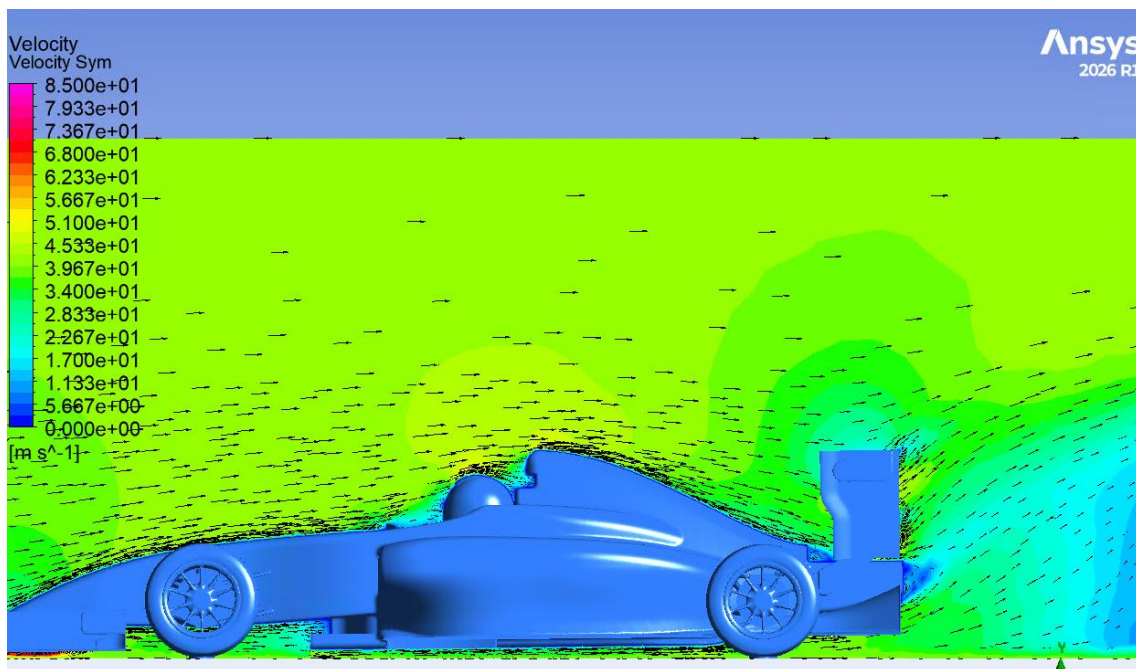


Figure C. 4. Velocity on symmetry plane Strakes V3.

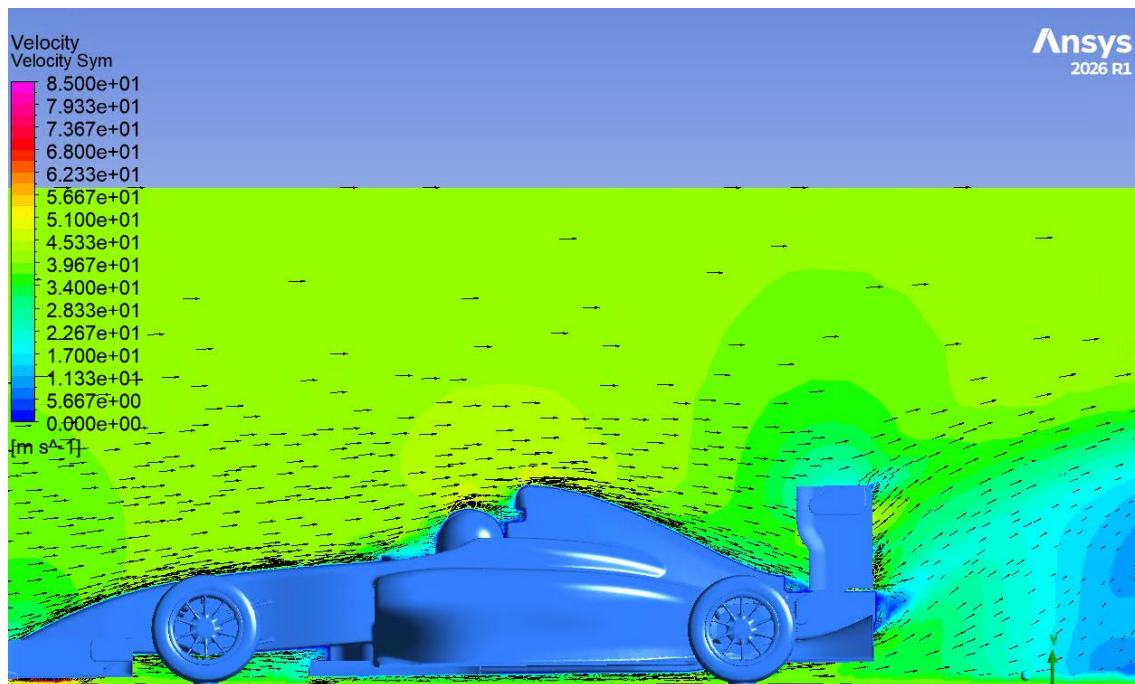


Figure C. 5. Velocity on symmetry plane Strakes V4.

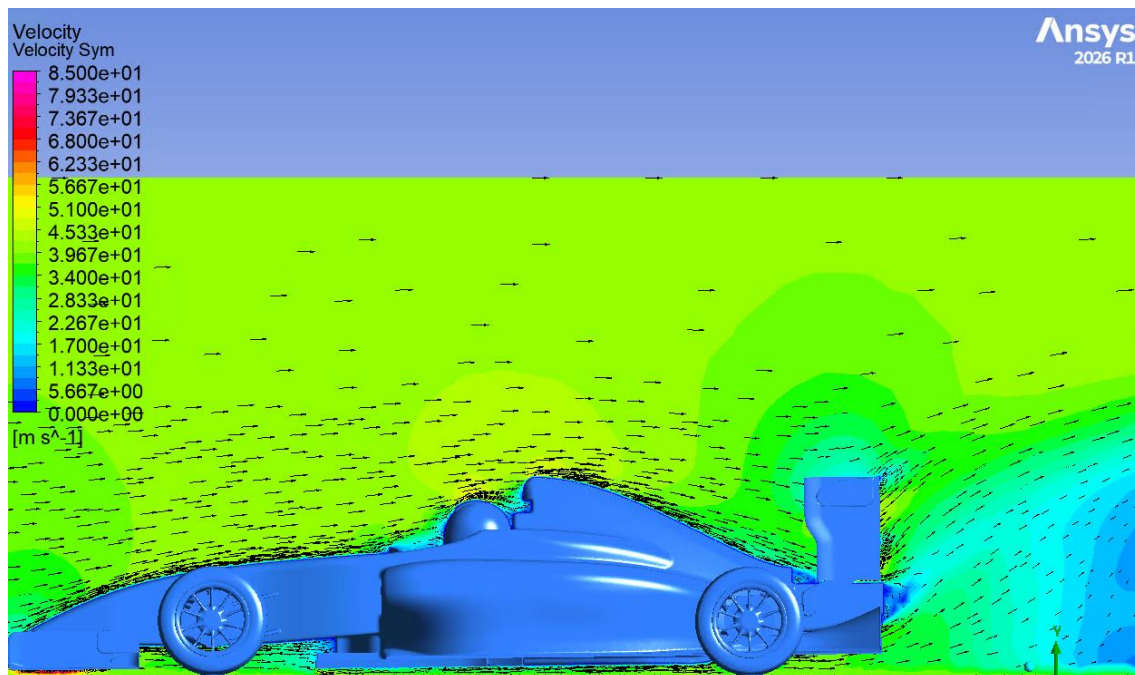


Figure C. 6. Velocity on symmetry plane Strakes V5.

Appendix D: Parametric study Results

D.1. Height results

Strakes end plane

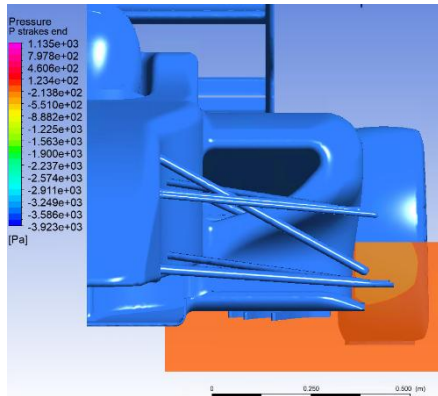


Figure D. 1. Pressure distribution end plane with 20mm of height.

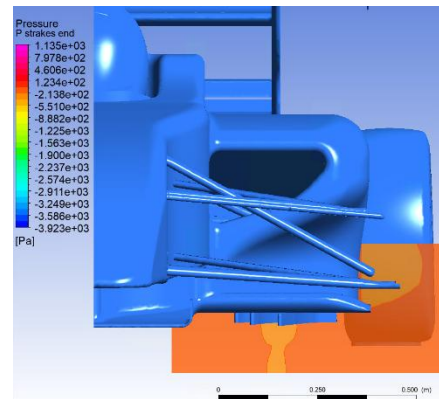


Figure D. 2. Pressure distribution end plane with 30mm of height.

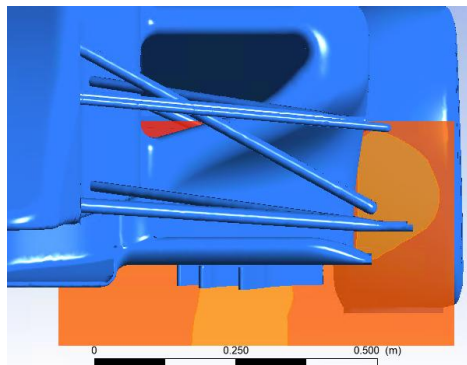


Figure D. 4. Pressure distribution end plane with 40mm of height.

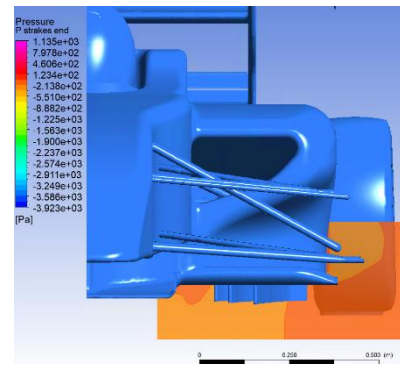


Figure D. 3. Pressure distribution end plane with 50mm of height.

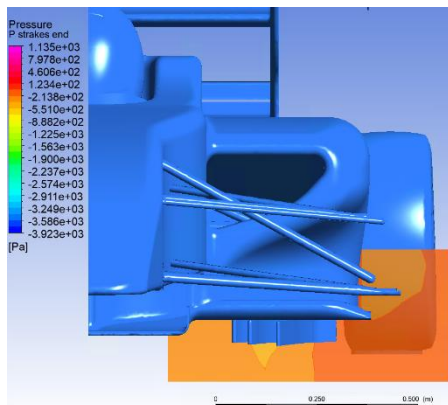


Figure D. 6. Pressure distribution end plane with 60mm of height.

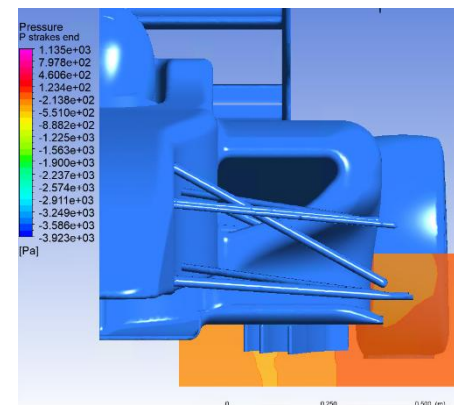


Figure D. 5. Pressure distribution end plane with 70mm of height.

a) *Pressure symmetry plane*

The following figures represent the pressure distribution along the symmetry plane of the vehicle.

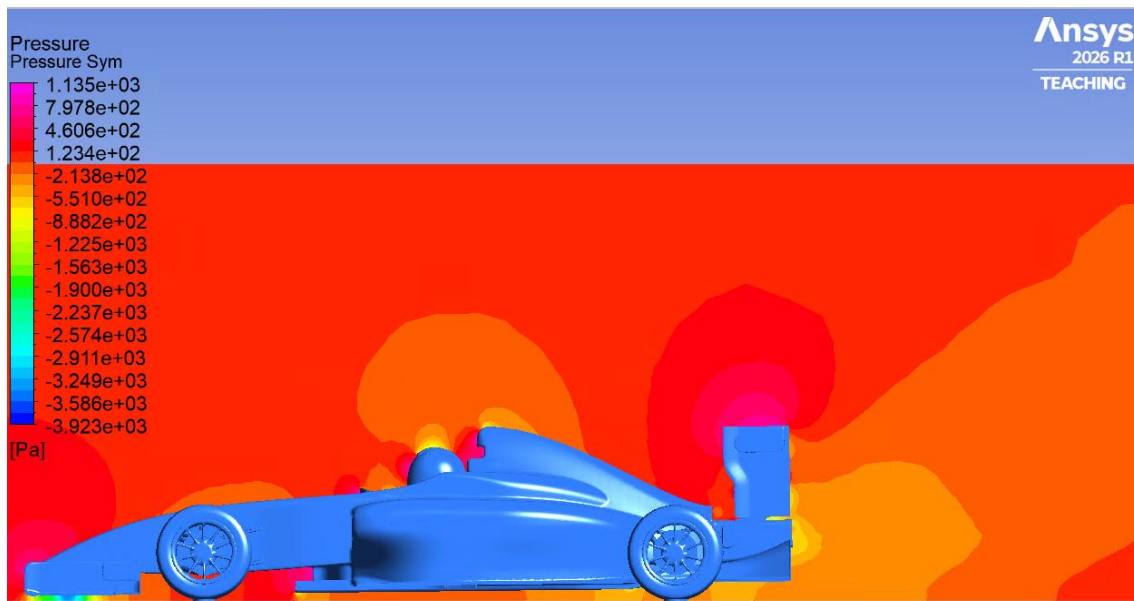


Figure D. 7. Pressure distribution on symmetry plane with 20mm of height.

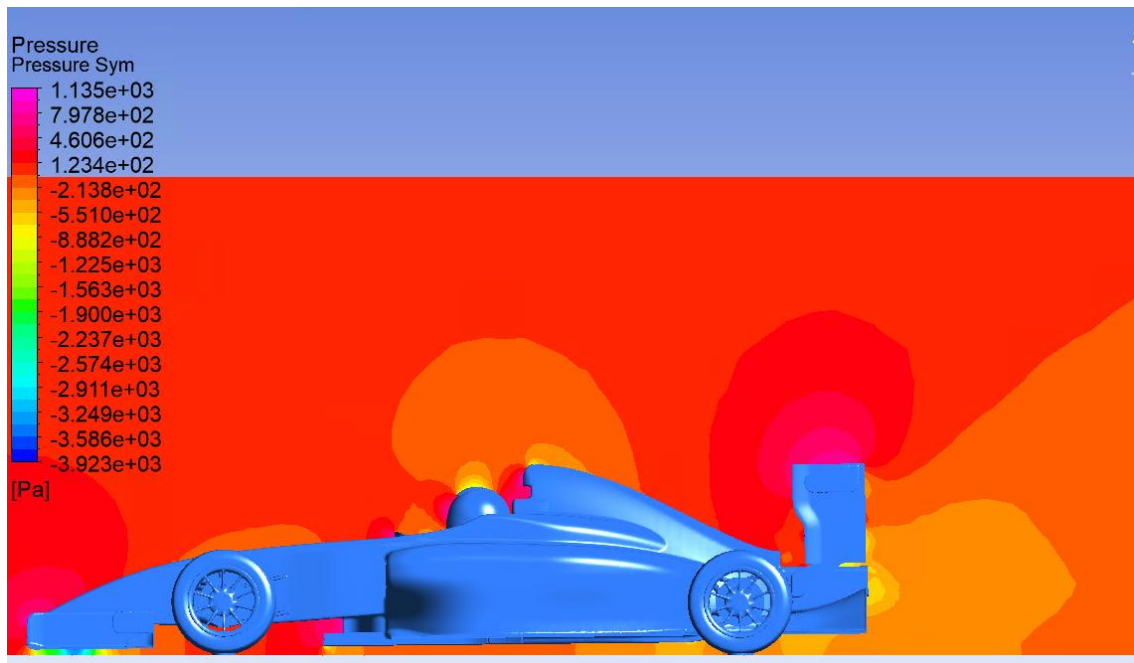


Figure D. 8. Pressure distribution on symmetry plane with 30mm of height.

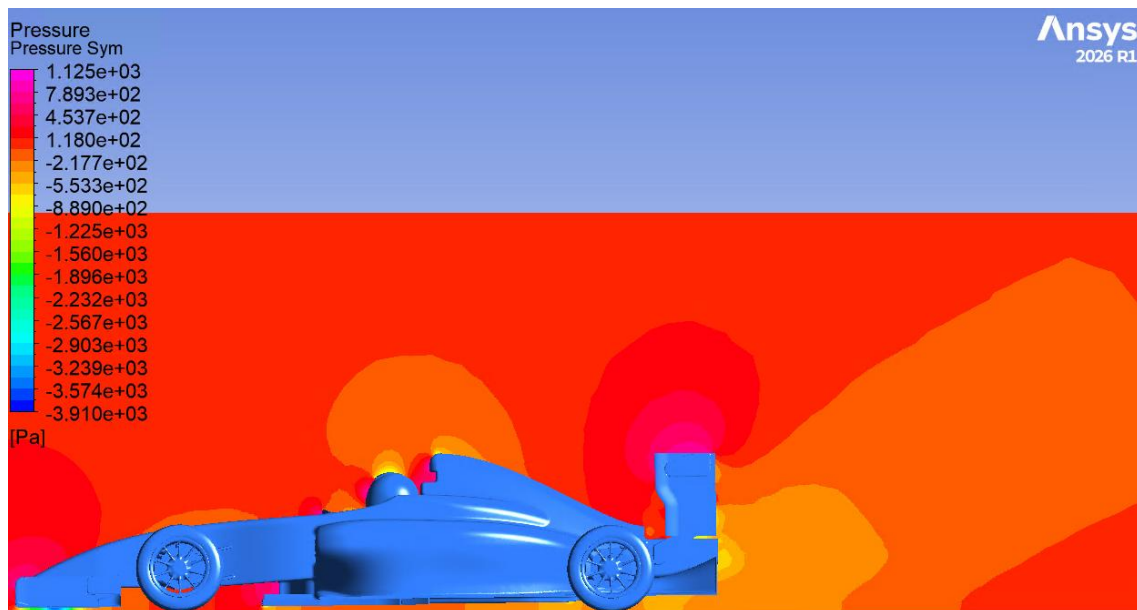


Figure D. 9. Pressure distribution on symmetry plane with 40mm of height.

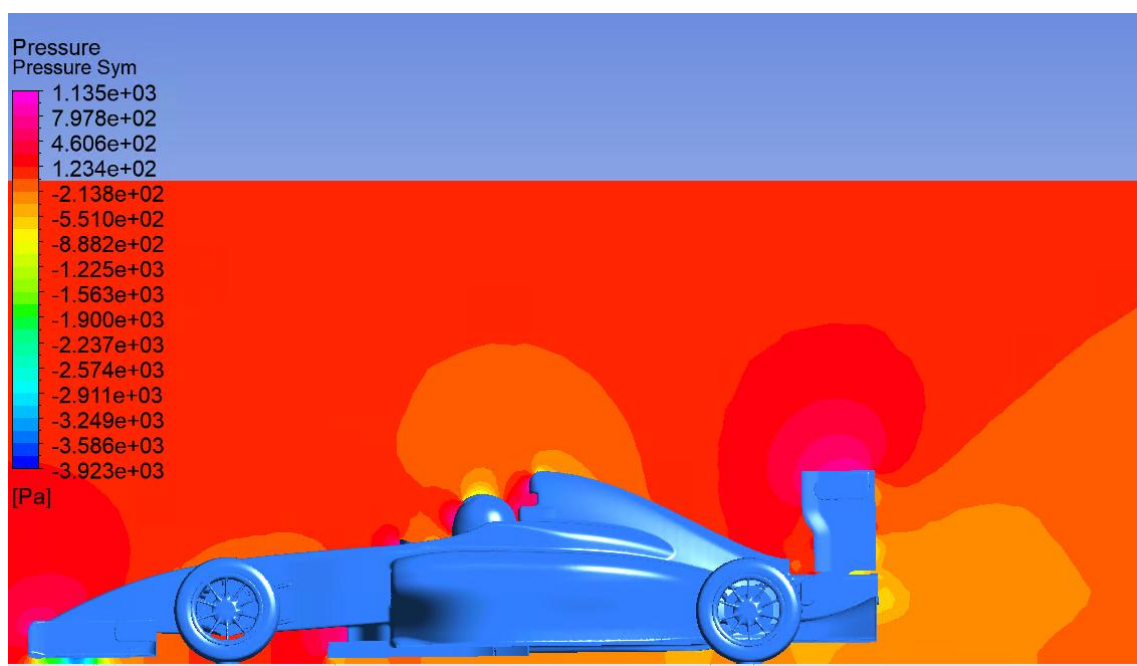


Figure D. 10. Pressure distribution on symmetry plane with 50mm of height.

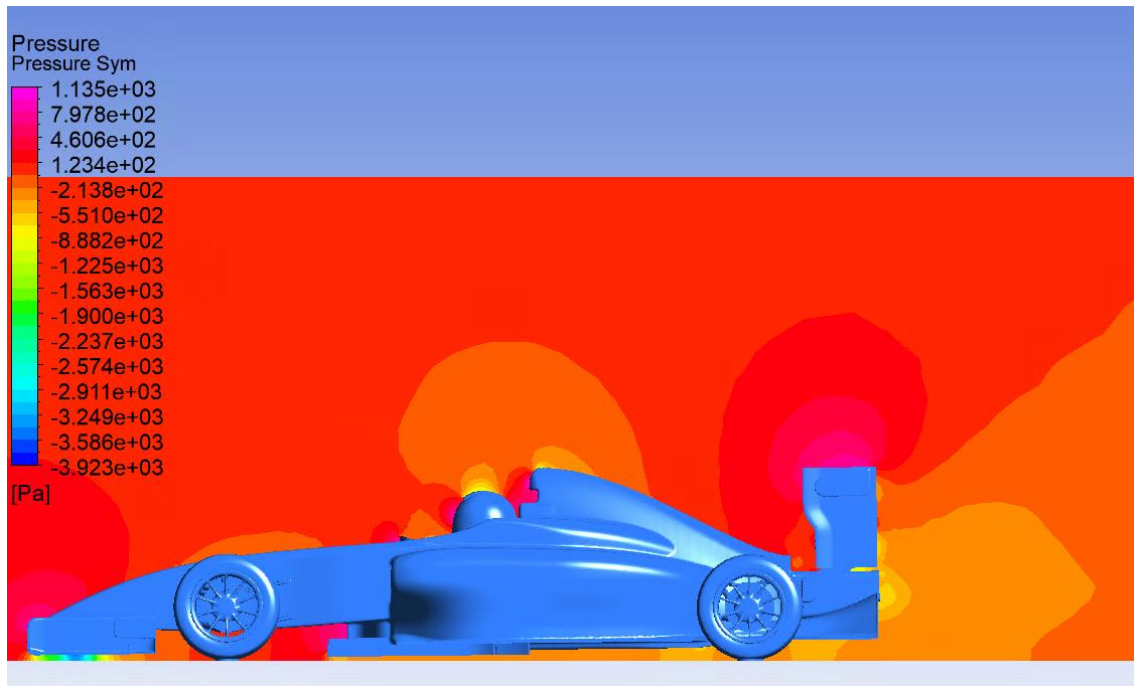


Figure D. 11. Pressure distribution on symmetry plane with 60mm of height.

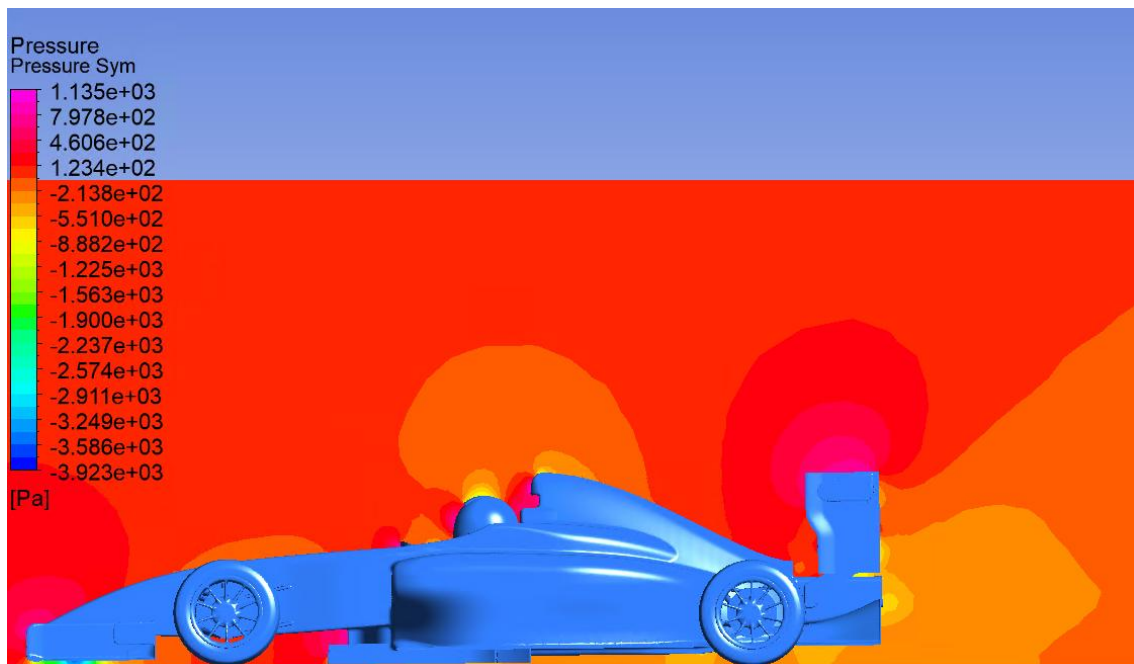


Figure D. 12. Pressure distribution on symmetry plane with 70mm of height.

There is not a remarkable different on the pressure distribution at the symmetry plane, apart from bigger height at the vertical strakes help to homogenize the pressure all along the undertray until the diffuser.

b) Velocity symmetry plane

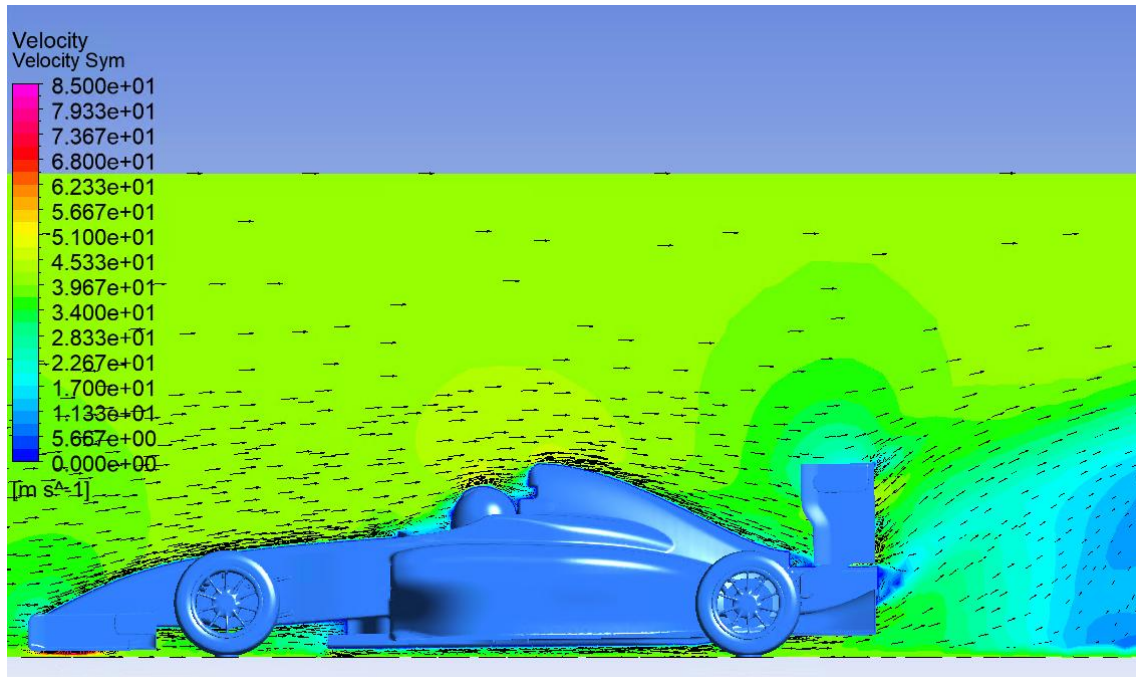


Figure D. 13. Velocity on symmetry plane with 20mm of height.

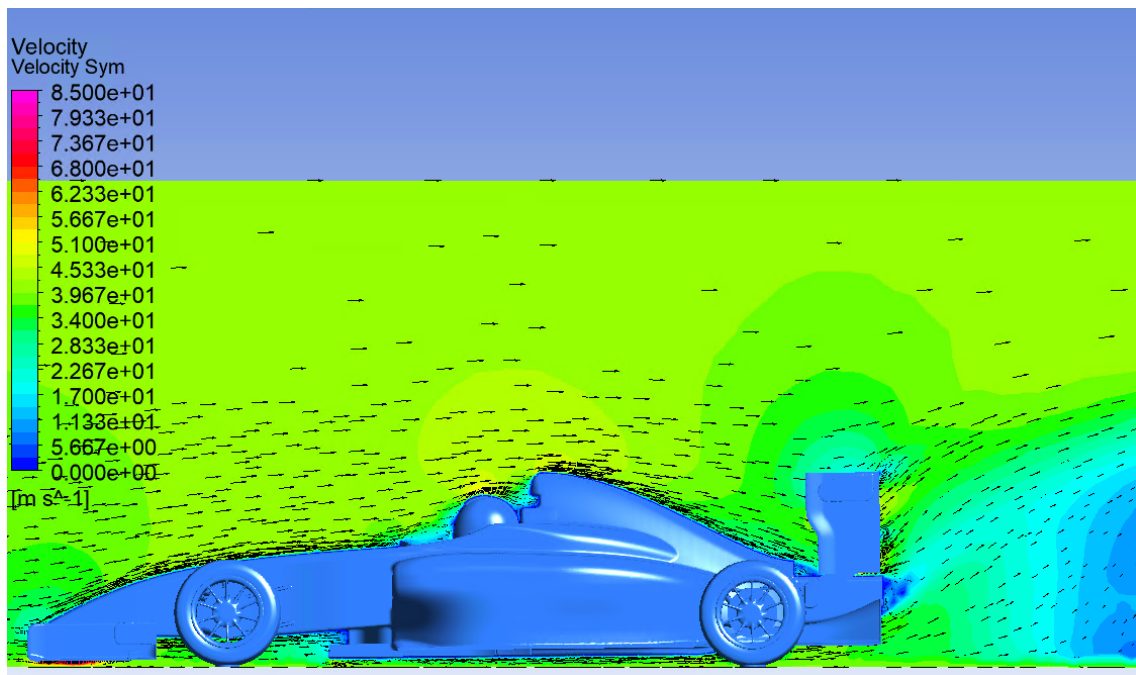


Figure D. 14. Velocity on symmetry plane with 30mm of height.

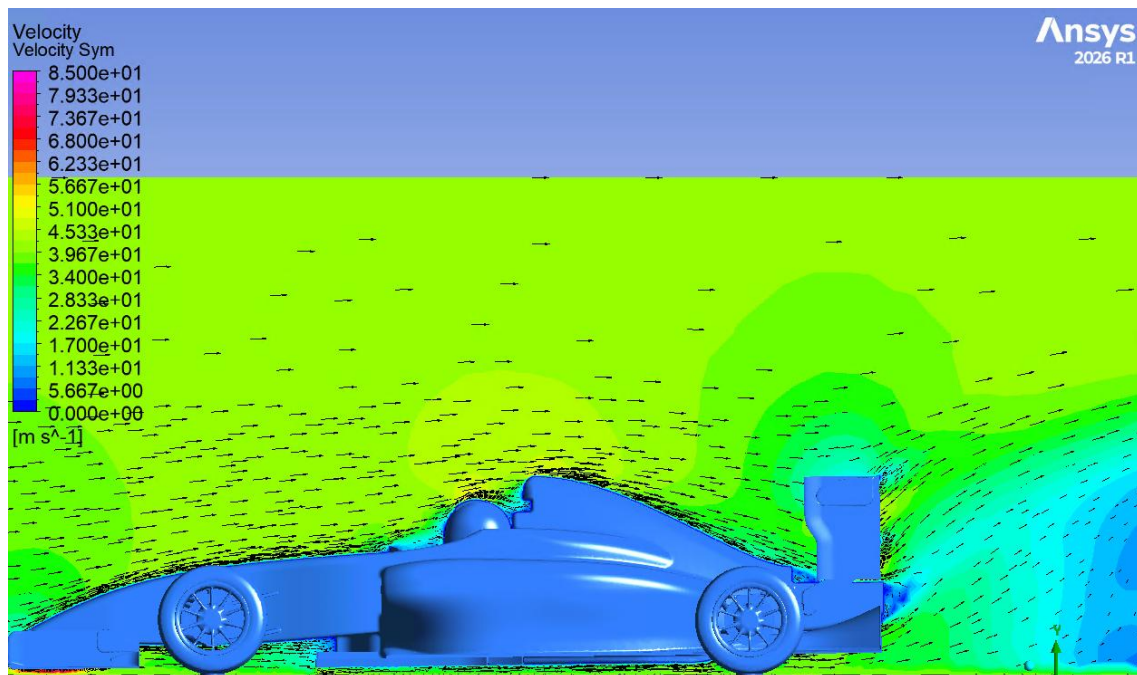


Figure D. 15. Velocity on symmetry plane with 40mm of height.

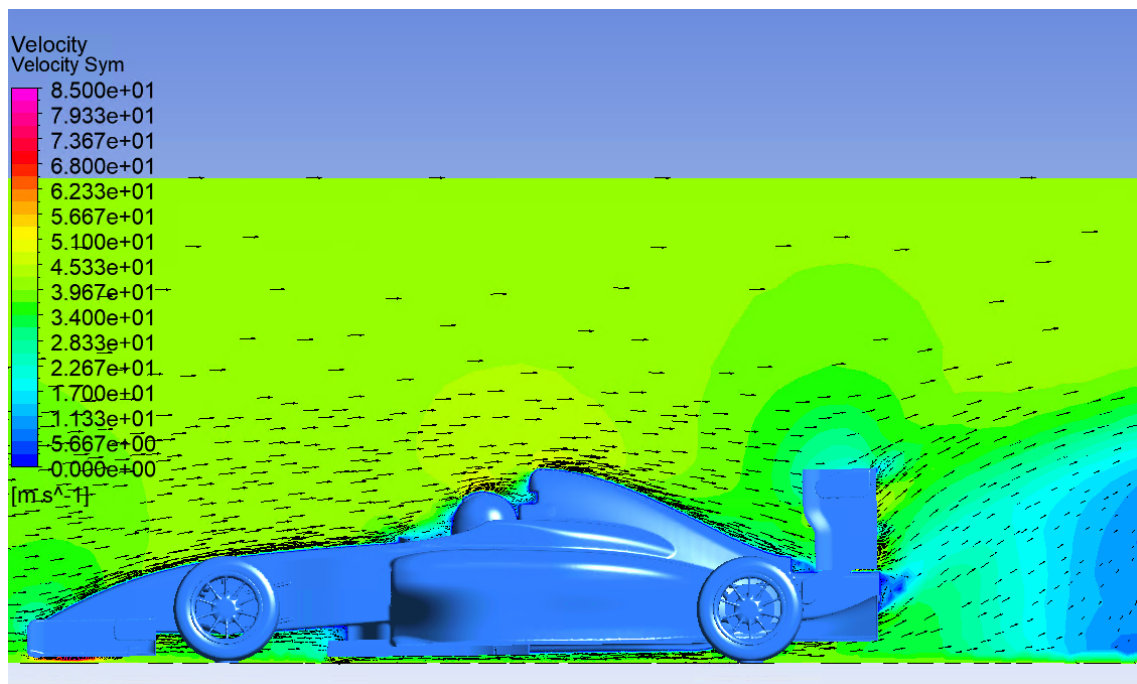


Figure D. 16. Velocity on symmetry plane with 50mm of height.

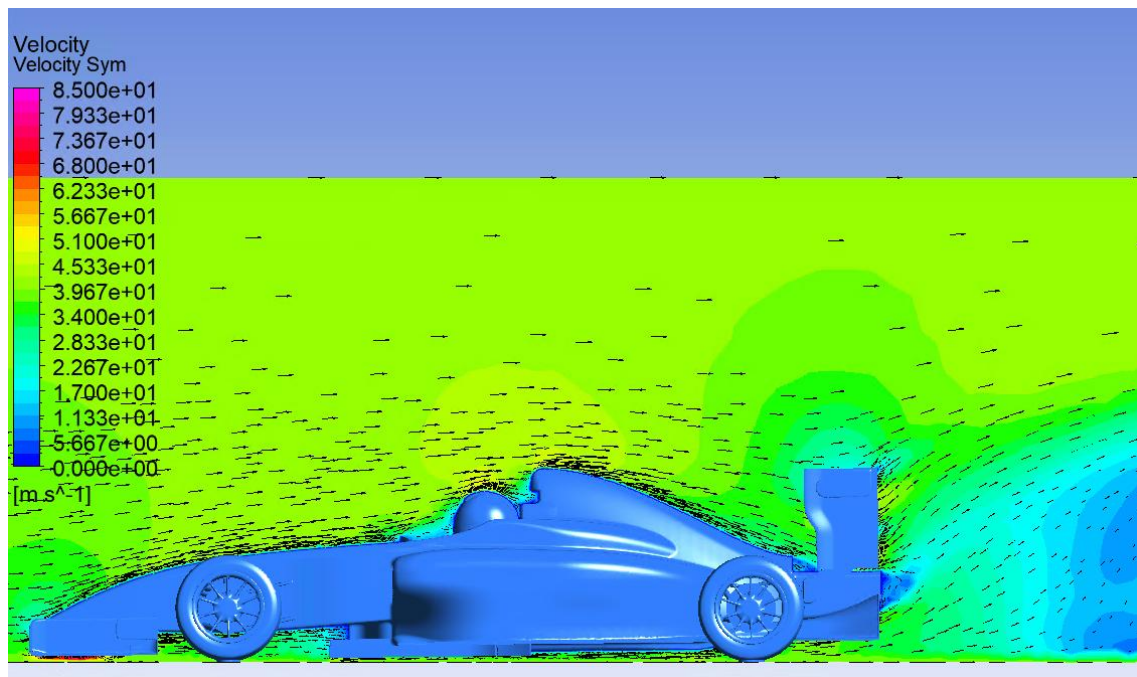


Figure D. 17. Velocity on symmetry plane with 60mm of height.

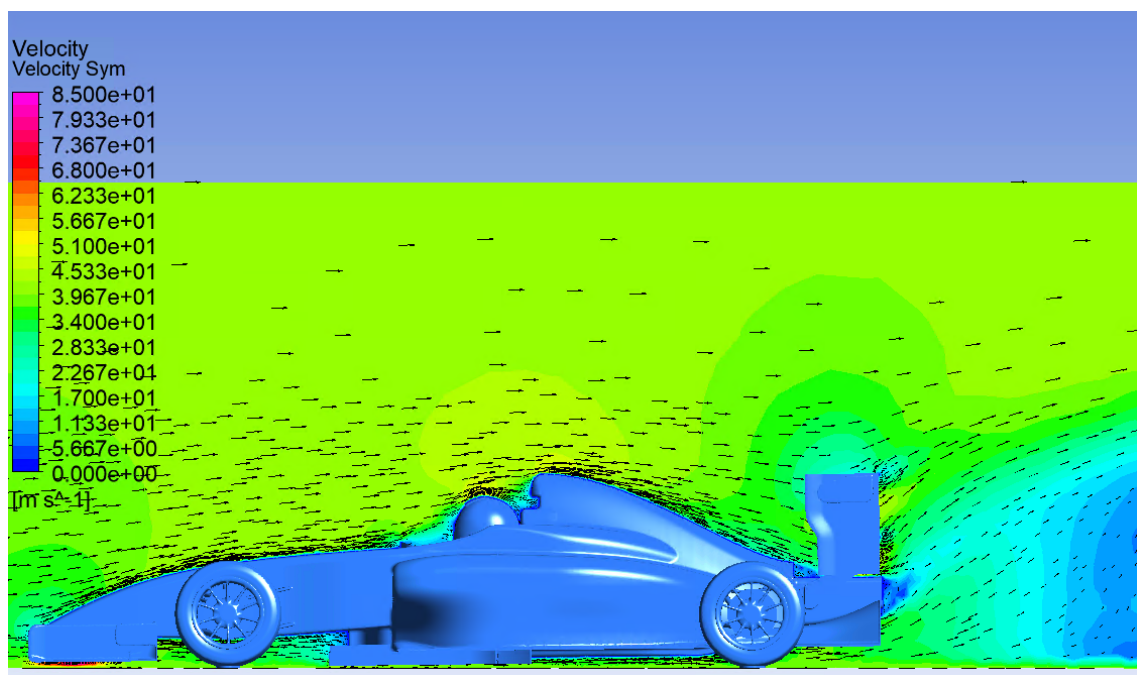


Figure D. 18. Velocity on symmetry plane with 70mm of height.

Appendix E: Data from Strakes ride height study

Lift						
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	2.6829		2.5727		2.4346
	75		2.6549		2.4809	
	80	2.6585		2.5851		2.4323
	85		2.5856		2.5252	
	90	2.6052		2.5664		2.4735

Table E. 1. Coefficient of lift ride heights data.

Drag						
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	0.9722		0.9768		0.9821
	75		0.9807		0.9772	
	80	0.9737		0.9821		0.9836
	85		0.9748		0.9863	
	90	0.9762		0.9820		0.9912

Table E. 2. Coefficient of drag ride heights data.

Aero Efficiency						
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	2.759617	#DIV/0!	2.633804	#DIV/0!	2.478974
	75	#DIV/0!	2.707148	#DIV/0!	2.538784	#DIV/0!
	80	2.730307	#DIV/0!	2.632217	#DIV/0!	2.472855
	85	#DIV/0!	2.652442	#DIV/0!	2.560276	#DIV/0!
	90	2.668715	#DIV/0!	2.613442	#DIV/0!	2.49546

Table E. 3. Aero efficiency ride heights data.

Forward Balance %						
		FRH (mm)				
		30	35	40	45	50
RRH (mm)	70	54.01%		49.96%		46.39%
	75		52.86%		49.16%	
	80	54.17%		51.76%		48.06%
	85		54.30%		50.84%	
	90	54.13%		52.57%		49.70%

Table E. 4. Forward Balance ride heights data.

Appendix F: Correlation study results

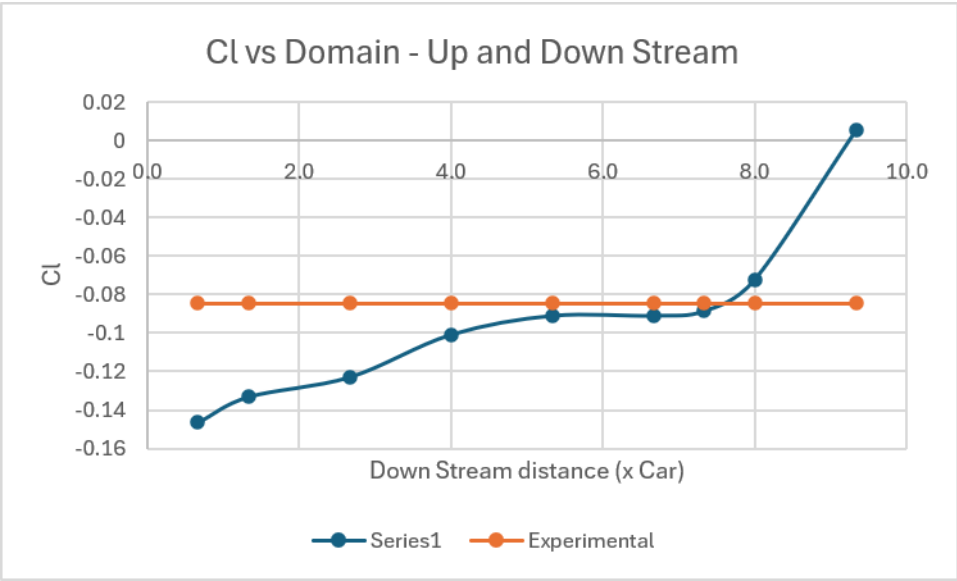


Figure F.1. Up and down stream (Ellis-Jones, 2025).

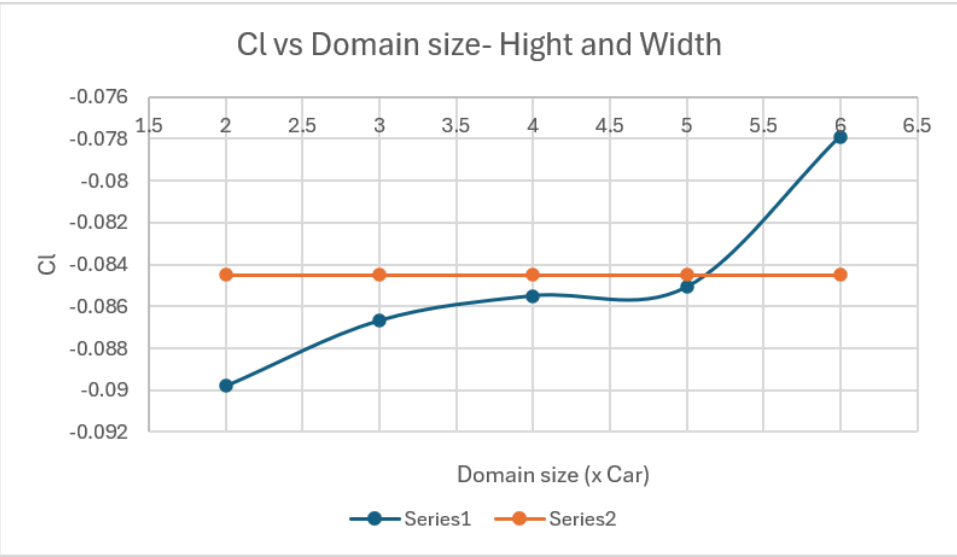


Figure F.2. Hight and width stream (Ellis-Jones, 2025).