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XL1: Conceptual Design of Hybrid Machine

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Abstract
The aerodynamics of the Volkswagen XL1 is a crucial aspect of its design, contributing significantly to its outstanding fuel efficiency and overall performance. This report delves into the detailed analysis of the aerodynamic features and principles employed in the XL1 concept car, showcasing how they play a pivotal role in its ability to achieve unprecedented levels of energy conservation.
The abstract provides an overview of the XL1's aerodynamic design, which is a result of extensive research and development aimed at reducing air resistance and drag forces. It explores the incorporation of streamlined contours, lightweight materials, and innovative engineering techniques that enhance the vehicle's aerodynamic performance. By skilfully manipulating airflow around the vehicle's body, the XL1 can minimize energy losses and enhance its electric and hybrid propulsion systems' effectiveness.
Furthermore, the report investigates the utilization of active aerodynamic elements, such as adjustable spoilers and underbody panels, which adapt to different driving conditions to optimize aerodynamic efficiency. These dynamic features allow the XL1 to achieve impressive drag coefficients, significantly reducing the amount of energy required to propel the vehicle at various speeds.
The significance of the XL1's aerodynamic design is evaluated through empirical data, wind tunnel testing, and computational simulations, highlighting its positive impact on fuel consumption and range. The report also discusses the challenges faced during the development of the aerodynamic features, including balancing design constraints, structural integrity, and manufacturing feasibility.
In conclusion, the aerodynamic design of the Volkswagen XL1 stands as a paradigm of sustainable engineering and eco-friendly mobility solutions. Through meticulous attention to aerodynamics, the XL1 concept car showcases how innovative design and technology can contribute to a more environmentally conscious and energy-efficient automotive future.

INTRODUCTION

A hybrid vehicle was created by Volkswagen and is called the XL1 concept design. Volkswagen's XL1 symbolizes their concept of an incredibly fuel-efficient and environmentally friendly car, which was unveiled in 2011.
For great fuel efficiency, it incorporates components from both conventional and electric cars. The XL1 concept's salient characteristics and important design elements are as follows:

1. Electric motor and a small internal combustion engine work together to power the plug- in hybrid powertrain that powers the XL1. In contrast to the engine is a lithium-ion battery pack driven by an electric motor. two-cylinder diesel engine. By minimizing fuel usage, the hybrid technology enables effective power delivery.
2. The XL1 has an extremely aerodynamic design that lowers drag and boosts efficiency. It has a body that is aerodynamically efficient and has a low coefficient of drag. It also includes a rear diffuser and

covered rear wheels, among other design features. To minimize air resistance, the car's general design has been optimized.

3. Lightweight Materials: To increase the XL1's efficiency even more, it was built with lightweight materials. It has a monocoque structure made of robust and light carbon fiber-reinforced polymer (CFRP). Utilizing CFRP contributes to the vehicle's overall weight loss, which enhances its handling and fuel economy.
4. Tandem seating is provided for the two passengers in the XL1's two-seater version. With this design, the car's aerodynamics are enhanced while simultaneously being smaller and lighter overall.
5. Extremely high fuel efficiency is one of the main objectives of the XL1 concept. One of the most fuel-efficient cars ever made, the XL1 was touted by Volkswagen to have a fuel usage of about 0.9 liters per 100 km (about 260 mpg).

The XL1 concept was unveiled as a demonstration of Volkswagen's technological prowess and dedication to sustainability, which is crucial to mention. Even though the XL1 was only produced in a small quantity, it was more of a proof-of-concept than a car for the public. But the XL1 technology and design have helped the auto industry create more environmentally friendly and fuel-efficient vehicles.

We will examine the complexities of the XL1 concept design as we learn more about this undertaking, looking into its hybrid drivetrain, aerodynamic features, lightweight design, and other ground-breaking elements. We intend to contribute to the ongoing discussion about environmentally friendly transportation and stimulate additional innovation in the automobile industry by analyzing the technical marvels and sustainability principles of the XL1.

Research Aim and Objectives

The XL1 conceptual design of the hybrid machine project seeks to create a highly effective and adaptable machine that combines the advantages of combustion engine and electric technology. The main objective is to develop a hybrid vehicle that maximizes fuel efficiency, minimizes emissions, and offers outstanding performance for a variety of applications.

The XL1 conceptual design for the hybrid machine project has the following goals:

- A hybrid machine with the highest possible energy efficiency is what the project wants to create. This calls for the powertrain system to be optimized, the use of cutting-edge technology like regenerative braking, and a reduction in operational energy losses. In comparison to traditional machinery, a higher overall efficiency is what is sought for.
- Emissions Reduction: The project focuses on reducing the environmental impact of the machine by minimizing emissions. By combining electric and combustion engine technologies, the hybrid machine aims to significantly decrease greenhouse gas emissions and air pollutants. The objective is to meet or exceed stringent emission standards and contribute to a cleaner and healthier environment.
- Performance Improvement: The XL1 conceptual design intends to improve the hybrid machine's performance capabilities. This entails attaining high power and torque outputs, enhancing top speed and acceleration, and ensuring dependable performance under various operating circumstances. While embracing the advantages of hybrid technology, the goal is to provide performance that is on par with or better than that of traditional machines.
- Designing the hybrid machine to be versatile and adaptable to many uses is a key component of the project. The goal is to develop a machine that can efficiently execute a variety of activities in a variety of industries, including transportation, agriculture, and construction. This entails considering variables including load capacity, manoeuvrability, and compatibility with various attachments or equipment.
- The project is focused on guaranteeing the safety and dependability of the hybrid machine. To achieve this, strong safety measures, dependable braking systems, and structural integrity must be implemented. Making a machine that minimizes the possibility of mishaps or malfunctions by meeting or exceeding industry safety standards is the goal.
- User-Friendly Design: The hybrid machine's operators and users should have a pleasant experience thanks to the XL1 conceptual design, which focuses on this goal. Considerations for ergonomic design, simple controls, and practical maintenance techniques are involved. The goal is to design a machine that is simple to use, care for, and service, which will increase output and user pleasure.
- Efficiency in terms of money spent: The project views efficiency as a key goal.
  To reduce production costs without sacrificing quality or performance, the design and manufacturing processes must be optimized. Through lower fuel consumption and fewer maintenance needs during its lifetime, the hybrid machine also intends to generate cost benefits.
- integration of Technology: The project seeks to incorporate cutting-edge technologies into the hybrid machine design. This includes networking options, data-driven analytics to boost productivity, and sophisticated energy management systems. The aim is to improve the machine's overall functionality and capabilities by utilizing cutting-edge technologies.

By focusing on these goals, the hybrid machine project's XL1 conceptual design hopes to develop a cutting-edge, effective, and eco-friendly solution that satisfies changing industry demands while promoting sustainability and resource conservation.

Programme of Work
The project consists of several tasks:

Preface:
An organized and methodical methodology will be used in this research endeavour to guarantee the validity and dependability of the results. The three key stages of the methodology will include a literature review, data collecting, and data analysis. Each stage has a distinct function and adds to the overall goals of the study. By using this methodology, the study hopes to give readers a thorough comprehension of the subject at hand.

Literature Review:
An extensive literature review is carried out as part of the methodology's first step. Reviewing current scholarly works, research articles, books, and pertinent information sources on the research topic will be part of this process. A theoretical foundation for the study will be established as well as the present state of knowledge and research gaps through the literature review. The researcher acquires insightful knowledge and a strong framework for ongoing research by reviewing and assessing the body of existing literature.

Data Collection:
Data collecting is the main goal of the second stage. Depending on the type of research being conducted, this step involves collecting either primary or secondary data. While secondary data can be gathered from already-existing databases, records, or other published sources, primary data can be gathered through surveys, interviews, experiments, or observations. To guarantee the accuracy, applicability, and sufficiency of the data, the data collection procedure will be meticulously planned. During this phase, ethical issues and data privacy will also be taken into account.

Data Analysis:
Data analysis is involved in the methodology's final stage. The gathered information will be arranged, processed, and examined using the proper statistical or qualitative methods. Finding patterns or relationships in the data, as well as coming to meaningful conclusions based on them, are the goals of this phase. To ensure transparency and accuracy in the interpretation of the results, the data analysis procedure will be carried out methodically. With the aid of the proper visualizations or tables, the results will be presented in a clear and succinct manner.
The research project seeks to advance the body of knowledge in the topic and offer insightful information for future study or practical applications by adhering to this defined process. The methodical methodology makes sure that the study is thorough, trustworthy, and repeatable.

Project methodology
1. Research and Conceptualization: Research and conceptualization are the first steps in any endeavour. Studying consumer preferences, market trends, and technology developments in the areas of fuel efficiency and environmental friendliness are all necessary for this. The idea for the XL1, defining the main objectives and characteristics of the vehicle, would have been created based on this

research.

2. The XL1's appearance and interior must be designed in the subsequent step, which is called "design and styling." The goal of aerodynamic design is to reduce drag and increase efficiency. Designers and engineers collaborate to produce this shape. During this stage, it would also be taken into account to use lightweight materials and novel style components to improve both efficiency and beauty.
3. Engineers begin working on the vehicle's technical components as soon as the design is complete. As part of this, the two-cylinder diesel engine, electric motor, and battery pack must be chosen and integrated into the vehicle. To evaluate the design and guarantee it satisfies performance and efficiency goals, prototypes are constructed and tested.
4. Testing and Validation: The XL1 prototypes go through a battery of tests, including as performance, durability, and emission tests. This stage makes it possible to correct any design or engineering problems and aids in their discovery. The objective is to make sure the car satisfies the desired fuel economy and pollution regulations.
5. Display and Feedback: When the XL1 prototype is ready, it is displayed at auto shows and other events. Responses from potential clients and professionals in the field are gathered, then examined. This input enables the development team to assess the concept car's marketability and make any necessary adjustments.
6. Documentation and finalization: The design and engineering team makes any necessary last-minute alterations and improvements to the XL1 idea in light of the feedback it has received. Technical requirements, performance information, and any project reports or studies that might have been carried out during the development process are all included in the generated paperwork.

Dissertation Organization

- Five chapters make up The Structure; a modification could occur in the future.
- The introductory chapter is the first chapter. In this chapter, we'll talk about the methods for carrying out the project as well as the goals and objectives of the research.
- The literature review or critical analysis is covered in the second chapter. This chapter will cover the topic's fundamental idea while illustrating its definition, background, advantages, and difficulties. The topic of engaging with XL1 concept design or change in Aerodynamics in general is then followed by examples of prior research that has followed a similar course.
- Data gathering and analysis are covered in the third chapter. To meet the project's goal, this chapter will analyze and evaluate the data gathered from the surveys that should be given to the students. Additionally, examine and contrast the data that will be gathered.
- Results are covered in the fourth chapter. With comments on each outcome, this chapter will discuss the findings from the preceding chapter.
- The topic discussion and the research questions and objectives are covered in the fifth chapter. And then talk about whether the goal was accomplished. Compare the results with those of other study articles as well.
- The conclusion is in chapter six. The project's conclusion is presented in this chapter. After then, the project's limitations are discussed, and future research is suggested.

Project Background

There is no disputing the fact that the global temperature has risen because of the greenhouse effect. This impact is quickening the rate of ice melting in the Arctic Sea, which is raising water levels as a result. Additionally, when temperatures rise towards the equator, driving regions develop, which increases the extent of the deserts.

The combustion of fossil fuels for transportation and heating as well as land clearance for the construction of structures to accommodate the growing population are some of the key causes of the greenhouse effect. Today's cities like Beijing, Paris, and London are experiencing such high levels of air pollution that it is putting the public's health in peril. Governments across the world are continually creating and revising their climate policies due to these political considerations.

The primary consumer of fossil fuels, such as diesel and gasoline, is currently the transportation industry. The importance of increasing vehicle efficiency and decreasing energy losses is highlighted by the fact that 33% of worldwide consumption takes place in Europe (Eurostar, 2015). Automakers are starting to design vehicles in a more environmentally friendly way, placing more of a focus on electrification or hybrid technologies to reduce or eliminate the use of fossil fuels.

There are now more sources of large energy losses as vehicles' drivetrains become more efficient. According to Barnard (Barnard, 2009), a major factor in the energy consumption of vehicles is the air resistance that a vehicle is subjected to. Air resistance may account for up to 48% of the total driving resistance of an electric car while travelling at highway speeds. Lohse- Busch and associates (2013)

The main benefit of increasing an electric vehicle's range is the reduction in air resistance, which is achieved through enhancing aerodynamics. According to research conducted by Tesla Inc., a 10% improvement in aerodynamic performance can result in a 5% increase in range. (2012) Palin and associates.

Historic Development of Vehicle Aerodynamics

When the subject of aerodynamics and its impact on vehicle design began to be researched, it was in the 1920s. Drag coefficient (Cd), a dimensionless metric used to compare the aerodynamic performance of cars, substantially dropped as streamlined automobiles proliferated on the road.

The earliest streamlined designs that started to be used more commonly in vehicle designs were created for the airship and airplane industries. Jaray, an engineer who worked for a business that produced Zeppelin airships, was a pioneer in the simplification of the automotive sector. Working on the aerodynamics of airships required a lot of Jaray's time in the wind tunnel. Investigations on passenger automobile aerodynamics were conducted after his aerodynamic discoveries. Marti (1931) and Brown and colleagues (1934) The effects of simple bodies' proximity to a ground surface and their aerodynamic efficiency were studied by Jaray and his colleague Klemperer in 1922. According to their research, a teardrop shape with wheels and a "half-body" generates a Cd value of 0.15, which is 20–25% lower than that of modern passenger cars. (Hucho, 1998) Figure 2.1 shows the chemicals under investigation and their coherence to Cd levels.

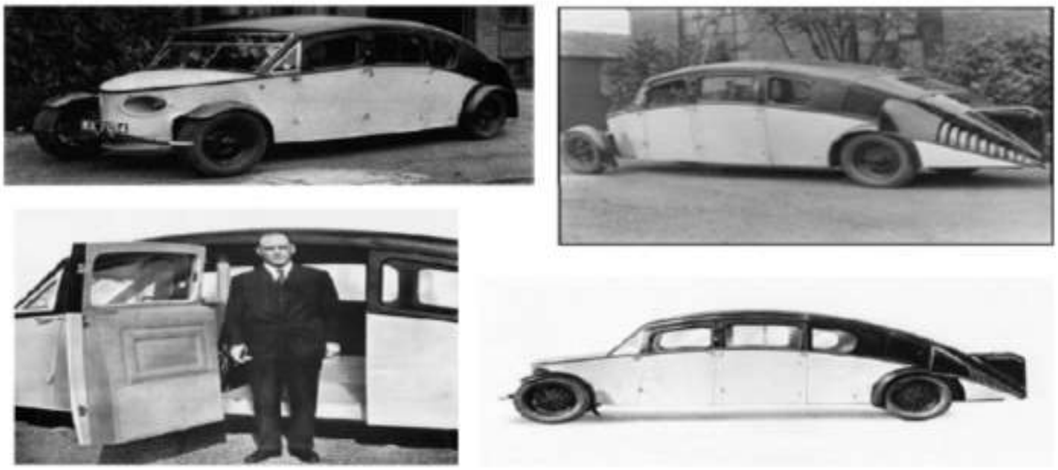
Jaray made the decision to leverage his expertise in the aerodynamics field based on the findings and began designing cars with an aerodynamics focus. The Tatra T77, which is seen in figure 2.2, is his most well-known design. In the 1920s, the Tatra T77 had the lowest drag coefficient with a Cd value of 0.21. (2011) Various (Good)

After Jaray's success, car companies like Fiat, Maybach, and Audi opted to work with him to include aerodynamics into a few of their vehicle designs. This was because the public had accepted aerodynamics. Various vehicles that Jaray has created are depicted.

The room for rear passengers was extremely constrained in Jaray's design, which was one drawback. This made it possible for other automakers to produce automobiles that were efficient and had adequate space. Chrysler, which began conducting wind tunnel studies in the late 1920s, was one of the first automakers to do this. A car design was the outcome. Relative to their original method of vehicle design, the Cd value was 0.56, which encountered 30% less wind resistance. Launched at the 1934 New York Motor Show, this vehicle was given the name Chrysler Airflow Coupé and is depicted in figure 2.4. According to Breer et al.

Sir Charles Dennistoun Burney, an aeronautical engineer, began researching vehicle streamlining in the late 1920s, about the same time as Jarrav. Sir Charles found success, and by 1927, thirteen of his design suggestions had been implemented. The concept cars designed by Sir Burney were distinct from modern-day mass-produced vehicles. The qualities of the body, which could grow as long as 6 meters, was one obvious distinction. As illustrated in figure 2.5, the front end of the vehicle had a little overhang while the rear had a large overhang due to the placement of the engine. This approach to vehicle design was striking at the time. Crossley Motors, who produced the sleek automobiles, worked with Sir Charles to create them. 2011's Good et al.

The front side shapes, roof curvature, and the underbody, which was clad in sheet metal, were improvements to Sir Burney's vehicles' aerodynamic performance. Despite using a compact front end, there are disadvantages. the nose, screen, and front wheels are responsible for 60% of the drag. Overall, with all these features, Sir Charles's streamlined vehicle design had a Cd value that was almost 50% greater than that of normal rival automobiles at the period. 2011's Good et al.



European and American automakers began equipping their new models with several essential features in the late 1930s, while they were still learning about automotive streamlining. Included in these characteristics were a curved body, a tapering tail, wheel housing inside the body, and a sloped windscreen. The Lincoln Zephyr, which had better aerodynamic performance and a Cd value of 0.45, is one of the Chrysler Airflow-inspired automobiles shown Due to World War II, the same design language was utilized for production cars throughout the 1940s and 1950s. 2011's Good et al.

Following World War II, the vehicle's aerodynamic improvement continued. Fiat, an Italian automaker, unveiled the Fiat Turbine concept car, which has a Cd value of 0.14 and is depicted in figure 2.7. The car was built for high-end performance and substitutes a jet engine for an ordinary internal combustion engine. The designers who worked hard on the aerodynamics and built the car that way benefited from this configuration. As a result, the Fiat Turbine has maintained its lead as the car with the lowest drag coefficient in the industry for 30 years and counting. (2006) Hemmings.

The three concept automobiles shown in figure 2.8 were developed and marketed in the late 1950s by Alfa Romeo, another Italian carmaker. The BAT 5 was the first vehicle unveiled, and it had a Cd value of 0.23. The models BAT 7 and BAT 9, which all have a Cd value of 0.19, came after it. The sleek appearance of the automobiles is completed by the massive tail fins and their curvature, which at the time were a distinguishing feature for Alta Romeo.

A study by Good (Good et al., 2011) found that several automakers started using Honcho's findings as the foundation for their aerodynamic designs after 1960. (1976; Boeheim, 1981; Hucho et al.) Automobile manufacturers now have ways to improve the aerodynamic performance of their present vehicle designs thanks to Honcho's study. These techniques allowed several researchers, like Ahmed, Gelhaus and Ren, Car, and Howell, to analyze and publish broad data that has long served as a reference for the automobile sector.

Based on these investigations, Boeheim created the Audi 100 in 1983 for the German automaker Audi AG. With a Cd value of 0.30, the car was said to have the lowest drag coefficient of any production vehicle at the time.

Another German automaker, Opel, introduces the Opel Calibri in figure 2.10 six years after the Audi 100 was first introduced. With a Cd value of 0.26, the Immelmann-designed Opel Calibri was the car on the market with the lowest drag coefficient. (2010) Immelmann. Another German automaker, Opel, introduces the Opel Calibri in figure 2.10 six years after the Audi 100 was first introduced. With a Cd value of 0.26, the Emmelmann-designed Opel Calibri was the car on the market with the lowest drag

coefficient. (2000) Emmelmann.
Automobile manufacturers began looking for new forms of powertrains to replace the internal combustion engine during and after the 1990s because of air pollution and rising oil prices. Electrifying the automobile was the best solution. The battery's capacity, which was a major issue at the time because it wasn't as advanced and durable as it is now, was a tremendous setback. The internal combustion engine was scaled back and paired with electric motors to develop hybrids as a solution to this problem. Due to the influence of this on fuel efficiency and extending the range of the electric battery, the efficiency of the powertrains rose, which led to an increase in effort and concentration on the aerodynamic performance of the cars.
The EV1 was consequently released in 1996 by American carmaker General Motors. The EV1 was an all-electric vehicle with a Cd value of 0.19. 2003's (Larmenier) The EV1 had fully closed front and covered rear wheelhouses, as seen in 2.11. In addition to the streamlined design. The low Cd value was mostly a result of this trait. Comparing these characteristics to classic conventional vehicles—which have a cooling package mounted on the front end and must thus keep the front open—results in a Cd reduction of more than 10%. (Honcho, 1998)

Aerodynamic engineers continued to develop and enhance the conventional cars' aerodynamic performance at the same time. Figure 2.12 depicts the 2001 Audi A2 and the 1999 Honda Insight, respectively. As the conventional vehicles with the lowest drag coefficient on the market, both car types shared first place with a Cd value of 0.25, knocking the Opel Calibri out of first place. (Audi, 1999) (Broke, 2010)
During and after the 1990s, as a result of air pollution and rising oil prices, automakers started exploring for new types of powertrains to replace the internal combustion engine. The best answer was to electrify the car. The battery's capacity, which at the time was a significant problem since it wasn't as sophisticated and robust as it is now, was a huge setback. Hybrid vehicles were created as a response to this issue by reducing the size of internal combustion engines and combining them with electric motors. The effect of this on fuel economy and the expansion of the electric battery's range increased the efficiency of the powertrains, which prompted an increase in effort and focus on the aerodynamic performance of the automobiles.
This led to the 1996 debut of the EV1 by American automaker General Motors. A car with a Cd value of 0.19, the EV1 was entirely electric. In 2003, Larminie The fact that the EV1 had a completely closed front and covered rear wheelhouses, aside from the streamlined design, as seen in 2.11, made a substantial contribution to the low Cd value. Comparing these features to classic conventional vehicles—which have a cooling package mounted on the front end and must therefore keep the front open—results in a Cd reduction of more than 10%. (Hucho, 1998)

Meanwhile, aerodynamic engineers continued to research and enhance the aerodynamic capabilities of conventional vehicles. Figure 2.12 illustrates the release of the 2001 Audi A2 and the 1999 Honda Insight, respectively. The Opel Calibra was pushed out of top place by both vehicle models, which both had a Cd value of 0.25, placing them in a tie for first among conventional cars with the lowest drag coefficient on the market. (Audi, 1999) (Broke, 2010)

Even though the Honda Insight and the Audi A2 had the lowest drag coefficients, they failed to satisfy consumer standards because they were sold in the compact car segment. Improved wind tunnel configurations and more computing power provided new and better testing tools to automakers, allowing for continued improvement of aerodynamic performance. The development of government rules and legislation about safety, compliance, and functionality, however, severely hindered the ability to design a fully streamlined vehicle.

The testing equipment provided to automakers was upgraded, allowing for additional advancements in aerodynamic performance. Though it was a serious obstacle that significantly limited the capacity to construct a totally streamlined vehicle, the creation of governmental regulations and legislation on safety, compliance, and functionality.

The 3 Series Sedan, depicted in figure 2.13, was released by the German automaker BMW at the end of 2004 during all of this. Compared to the Honda Insight and Audi A2, this vehicle's Cd value of 0.26 means that it not only complies with all laws and regulations but also meets customer requests because it has more passenger space and a bigger trunk. a Cd difference of just 0.01 makes this possible. In 2011 (Good et al),

Depicts the vehicle, which was given the name Prius. Customers who were concerned about the greenhouse effect and its mitigation were very interested in the hybrid vehicle. With improved aerodynamics and a Cd value of 0.25, the third generation Prius was introduced in 2006. (Broke, 2010)

The car makers have consistently tried to lower the Cd value of their vehicles, which can be used to summarize the historical history of vehicle aerodynamics. The reduction of Cd is quickly decreasing from the 1920s to the present. Since aerodynamic performance accounts for a sizable portion of energy losses, it is receiving increased attention as efforts are made to improve vehicle efficiency and reduce energy losses.

Current Development of Vehicle Aerodynamics

When thinking about the aerodynamic element, there are drawbacks because of the demands for safety, comfort, and functionality as well as governmental regulations and laws. The development of more aerodynamic automobiles is a constant goal for automakers. The adoption of new features, such as active aerodynamic characteristics, is another development brought on by technology. When necessary, such as during a highway drive, an active aerodynamic element is only activated. For example, a front grille used to cool the engine coolant in typical automobiles is an example of a passive feature. As observed in the historical development of aerodynamics, the main area of study to minimize the drag coefficient was in the passive aerodynamic section, which is where vehicle design is discussed.

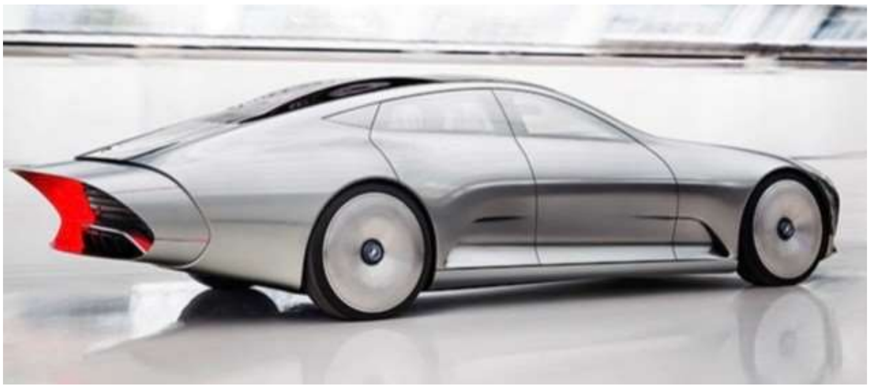
 

In 2013, Mercedes-Benz introduced the car with the lowest market drag coefficient. The automobile was called as the CLA and had a Cd value of 0.23. This automobile included both passive and active aerodynamic components. Daimler AG in 2017. His car's primary active element is the active grille shutter mechanism. When this system is engaged, which may occur when the engine and brakes don't need to be cooled, front grille flaps in the vehicle close.

With this function, as described for the EV1 automobile, a 10% reduction in drag coefficient can be attained. In addition, the Mercedes CLA boasts better A-pillar curvature, a well- designed rear end, and a diffuser at the end of the underbody. It also has side mirror housings that have been aerodynamically tuned.

American electric car company Tesla INC modified their flagship Model S, which is seen in figure 2.17, in 2016. The vehicle has an aerodynamic Cd value of 0.24 and utilises features like a closed front because electric vehicles don't require as much cooling as do conventional vehicles, air curtains in the front bumper to direct air past the front tyres, and a flat underbody panel to lessen airflow disturbance along the underbody. Passive aerodynamic components are employed to reduce the wave behind the automobile, such as floating C-pillars, aerodynamic wheel rims, and concealed door handles.

Tesla unveiled the Model X, the first completely electric SUV to ever be sold on the market, at the same time as the model S received a facelift. The only aerodynamic difference between the Tesla Model X and Model S is the rear roof spoiler, which is utilized to increase downforce at the back of the car at greater speeds. The Model X has a sportier visual back than a typical SUV.

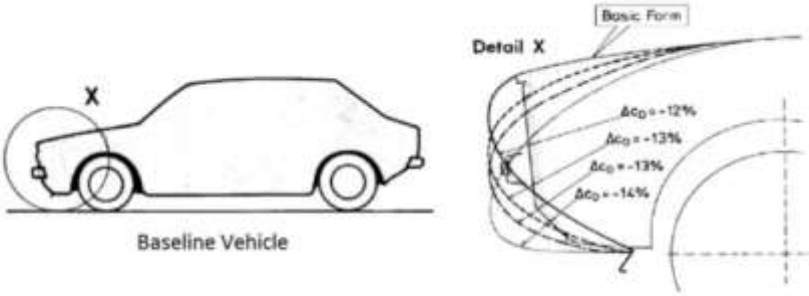


BMW debuted the vehicle with the current lowest drag coefficient in 2017. The brand- new 5 Series Sedan is shown in Figure 2.19. The 5 Series is aerodynamically competitive, and BMW employs both active and passive aerodynamic techniques to reduce the drag coefficient. Its Cd value is 0.22. (BMW

AG, 2017) The front grille shutter is once again active, there is considerable underbody panelling with additional covers over the rear axle, and there are front-end air curtains. aerodynamic wheel rims and ventilations at the front wheelhouse.

Design of the XL1 Aerodynamics

The study and investigation done in preparation for the system's design are presented in this section. The various scenarios of future use of this research will be presented in the first paragraph. Following that, attention will turn to the selection of the structure for aerodynamics based on The design of XL1



XL1 Aerodynamics : The world's most fuel-efficient vehicle, according to Volkswagen, is the XL1. The economy of this vehicle is largely attributable to its remarkable design, a marvel of free-flowing lines, as well as its ingenious plug-in hybrid powertrain (more on that later). A typical automobile, such as the Volkswagen Golf, has a drag coefficient (Cd) of 0.312 and a frontal area of 2.22 m2, resulting in a total drag figure of 0.693 m2 (CD. A). These numbers stand alone as being very good. The Mercedes-Benz E-Class Coupe, with a drag coefficient (Cd) of 0.24, is the market's most aerodynamic vehicle. However, the Volkswagen XL1, which has a Cd value of 0.186 and a frontal area of 1.5 m?, performs far better. Total drag, which is the result of multiplying these two quantities, or A number for Cd that is 2.5 times less than the Golf's is 0.277 m2. The XL1, which only weighs 1793 pounds, can travel at a steady speed of 62 miles per hour (100 kilometres) with only 6.2 kW (8.4 horsepower) of power.

This XL1 idea is unlike any other car; it is more akin to a bicycle.

A lot of effort, as well as deliberate decisions, led to the minimal drag. Only 45 inches high, the Volkswagen XL1 is extremely low. Furthermore, it is 65 inches wide. More so than the body, the greenhouse area is smaller. So much so that the passenger seats somewhat behind the driver to avoid feeling like they are sitting too close to one another. The passenger seat is not completely in the back as shown in the photo; it is in its typical position.

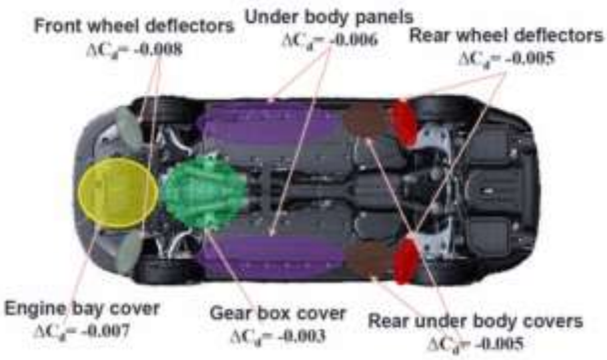
Along with the low and rounded front end, there is also the incredibly quick back—could someone consider adding a window there? As you may have observed, there are cameras in place of the usual rear-view mirrors. The entire underbody is covered, the rear wheels are covered, and small spoilers are placed in front of and behind the wheels to further improve airflow.

Future travel will be in that direction. Every car will need to have a highly slippery design whether it has an electric, hybrid, or gasoline engine train, and I like that. Furthermore, it gives cars the appearance of being capable of 200 mph in addition to improving their efficiency.

Plug-in hybrid concept

The new XL1 from Volkswagen has a plugin hybrid system that makes use of the great fuel economy of the common rail turbodiesel (TDI) engines and dual clutch gearbox (DSG). The TDI needs only 0.8

litres of displacement to provide its stated maximum output of 35 kW/48 PS. The vehicle's whole hybrid system is mounted above the driven back axle. The actual hybrid module, which swaps the standard flywheel for an integrated electric motor and clutch, is located between the TDI and the 7-speed DSG. A built-in lithium-ion battery provides power for the E-motor. The 220 volt power electronics regulate the high voltage energy flow away from and towards the battery or E-motor. A Volkswagen XL, that is. A converter DC/DC



E-motor and TDI engine interaction: The E-motor boosts the TDI's acceleration but, as mentioned, it is also capable of driving the XL1 Concept for up to 35 km on its own. In this mode, a clutch is disengaged to detach the TDI from the drivetrain and turn it off. The DSG is fully engaged with the electric motor because the clutch on the gearbox side is still closed. Important: The Volkswagen XL1 can be driven exclusively on electric power (if the battery is fully charged). The automobile only uses electrical power to move forward once the electric mode button on the instrument panel is activated. The TDI engine may be started in a highly smooth and pleasant manner by "pulse starting" it while the car is moving. This involves speeding up the rotor of the electric motor and swiftly coupling it to the engine clutch. By doing so, the TDI is sped up to the desired speed and started. The driver rarely notices the TDI engine restarting because nothing jars during the entire procedure.

Battery regeneration is the process by which the XL1's E-motor acts as a generator to use the braking energy to recharge the battery. Under specific operating circumstances, the load distribution between the TDI engine and the electric motor can be changed, allowing the turbodiesel to function at its optimal efficiency level. Additionally, the 7-speed DSG's automatically shifting gears are constantly chosen to minimize energy use. All energy flow and drive management operations are controlled by the engine controller, which also takes into consideration the driver's current power requirements.

Accelerator pedal position, engine load, energy supply, and the ratio of kinetic to electrical energy are a few of the variables taken into account while determining the best propulsion mode for the circumstances.

The mass production method is used by the two-cylinder TDI: The 1.6-liter TDI, which powers vehicles like the Golf and Passat, gave rise to the 0.8-liter TDI (35 kW/48 PS). Cylinder spacing (88 mm), cylinder bore (79.5 mm), and stroke (80.5 mm) are identical between the 0.8 TDI and the 1.6-lite TDI common rail engine. Furthermore, both the two-cylinder and the four-cylinder engines used in the Volkswagen XL1 Concept are equipped with important internal engine technologies that lower emissions. For multiple injection, they include specific piston recesses, and each injection jet is oriented differently. The two cylinder engine was given the superb, slick-running characteristics of the common rail engines. Furthermore, an engine's smooth operation is enhanced by a balancer shaft that is powered by the crankshaft rotating at the same speed.

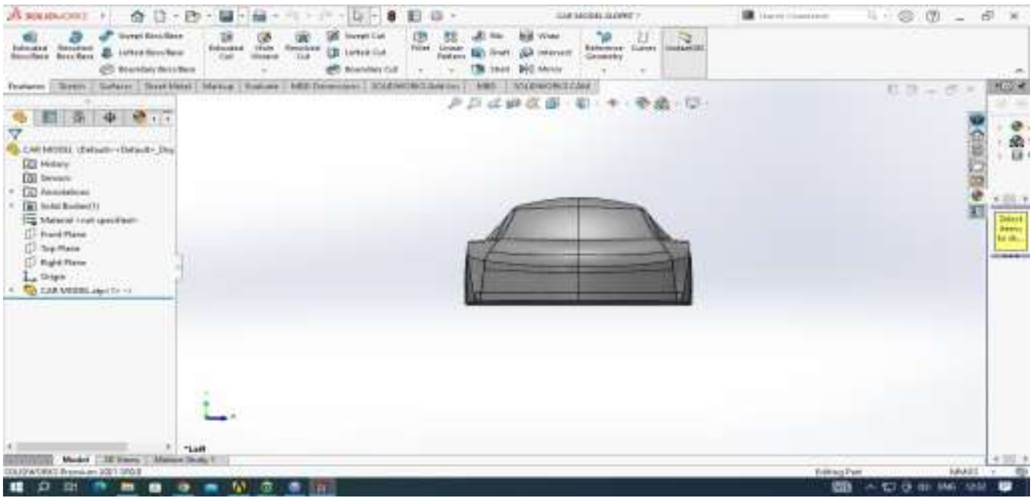
Mass production technology is used in the two-cylinder TDI: From the 1.6 litter TDI, which powers vehicles like the Golf and Passat, the 0.8 litter TDI (35 kW/48 PS) was created. Cylinder spacing (88 mm), cylinder bore (79.5 mm), and stroke (80.5 mm) of the 0.8 TDI are identical to those of the 1.6-lite TDI common rail engine. Additionally, the two-cylinder Volkswagen XL1 Concept and the four-cylinder mass-produced engine share important internal engine features for decreasing emissions. For multiple injection, they include specific piston recesses, and each injection jet is oriented differently. The two cylinder engine was given the superb, slick-running characteristics of the common rail engines. Furthermore, an engine's smooth operation is enhanced by a balancer shaft that is powered by the crankshaft rotating at the same speed.

The aluminium crankcase of the TDI was built with high levels of precision and rigidity, which results in extremely little friction loss. Recirculation of exhaust gases, an oxidation catalytic converter, and diesel particle filters are all employed to lower emissions. The 0.8 TDI is already equipped to meet the requirements of the Euro-6 emissions standard.

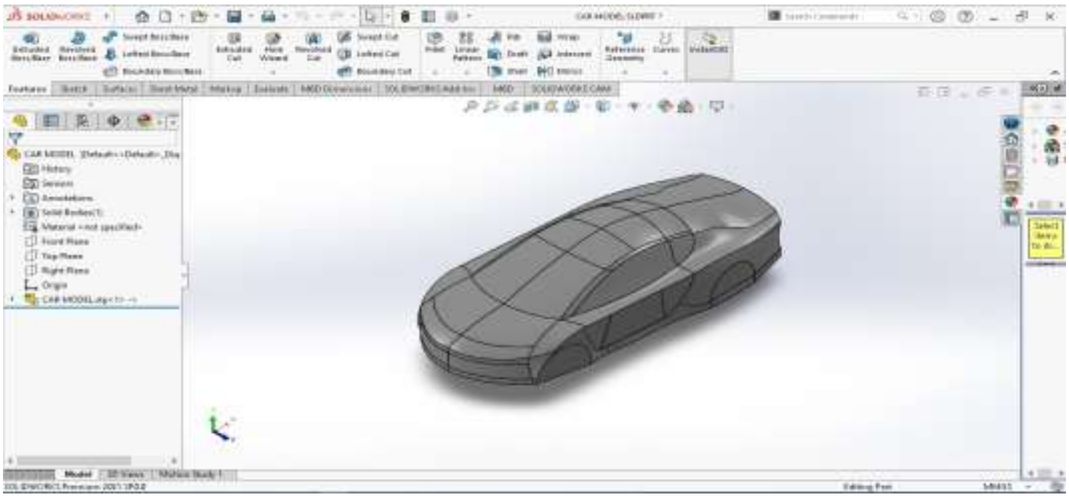
The car's cooling system was likewise constructed with efficiency in mind. When the TDI needs to be cooled because of engine operating circumstances, engine management solely uses an externally supplied electric water pump. The front of the car includes an automatic air intake system for this cooling system. This system reduces the drag of the cooling system. Reduced fuel usage is another benefit of this thermal control approach. To cool the starter generator and power electronics, a second electric water pump, which is also only utilized when necessary, circulates a different lower temperature coolant loop.

CFRP body is a technical stature

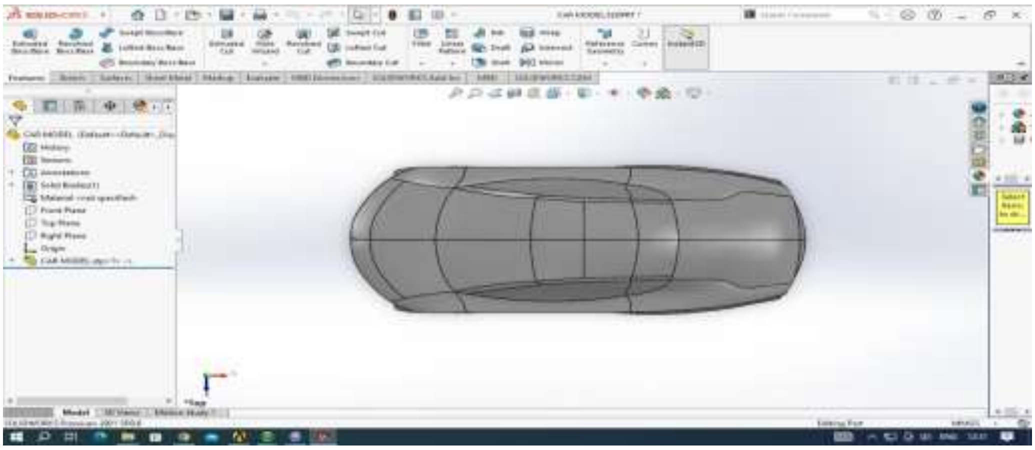
In terms of both its lightweight design and aerodynamics, the development team made amazing advancements when designing the CFRP body. The new XL1's body concept is so unique that it can be best understood by reference to the Golf.



The enormously well-liked Golf has a great drag coefficient for its size class: Cd (0.312) A (frontal area 2.22 m2) equals a total drag figure of 0.693 m2 (CD. A), offering this vehicle industry-leading aerodynamic credentials. The Volkswagen XL1, in comparison, performs better with a Cd value of 0.186 and a frontal area of 1.50 m2. By multiplying these two factors, total drag, or Cd, is created. A figure of 0.277 m2, which is 2.5 times smaller than the Golf's.

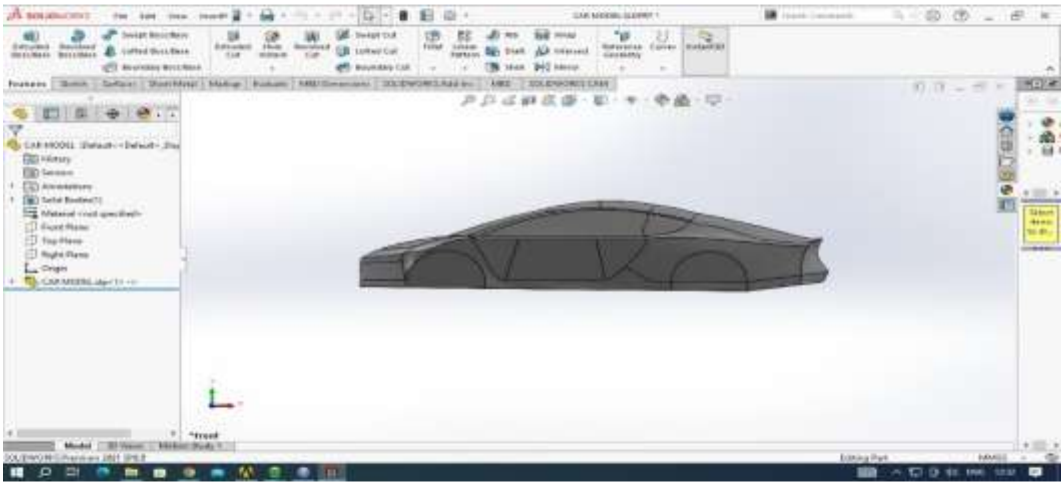


Design for the modern era: The VW XL1 is only 1,156 mm tall and 3,888 mm long, with a 1,665 mm wide body. These have very large size. Similar in length (3,970 mm) and breadth (1,682 m), the Polo is noticeably higher (1,462 mm). The new XL1 stands 1,184 mm tall, which is almost equal to the height of a Lamborghini Gallardo Spyder. Being as long and broad as a Polo but with a low profile like a Lamborghini, it is simple to imagine how beautiful such a Volkswagen would look on the road.
The new Volkswagen XL1 also has wing doors that are like those of a high-end sports car. They swivel not just upwards but also somewhat forwards thanks to the two places at which they are hinged: low on the A-pillars and immediately above the windscreen in the roof frame. As far as the roof goes, the doors are also. They provide a remarkably big amount of entry and exit space once they are opened.



Visually, the new XL1 shares styling cues with the L1 unveiled in 2009; nevertheless, the wider design of the current prototype gives it a more dynamic look. Laws of aerodynamics were rigidly applied to the body's design. The VW XL1 Concept is widest up front before getting narrower as it moves to the back. When viewed from above, the XL1's shape resembles that of a dolphin, particularly in the rear, where the

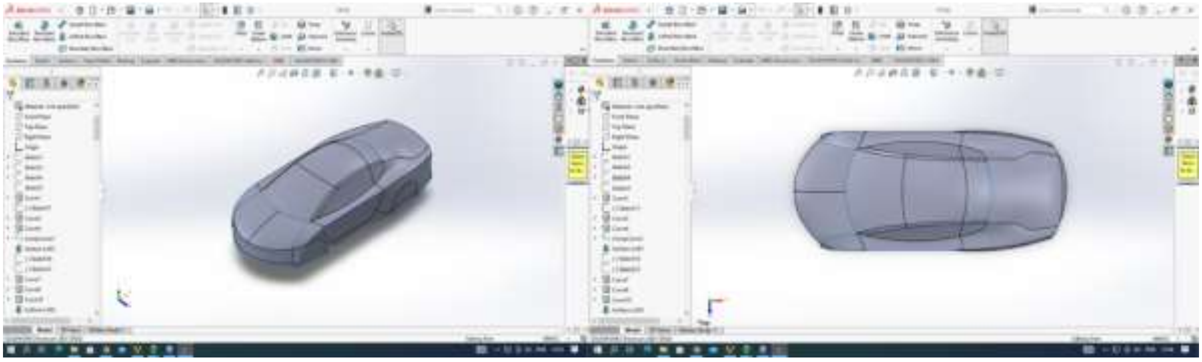
lines optimally conform to the air flow over the car body to reduce the aerodynamic drag of the Volkswagen.
The roofline inside profile displays stylistic lines that follow an arc from the A-pillar back to the rear. To reduce air turbulence, the rear wheels are completely covered. Additionally, there are small spoilers in front of and behind the wheels to improve airflow in this area. Visitors will be ineffectively searching for door mirrors because they have been replaced on the wing doors by tiny cameras that function as digital outside mirrors and transfer photos of the environment behind the car to two monitors within the car.



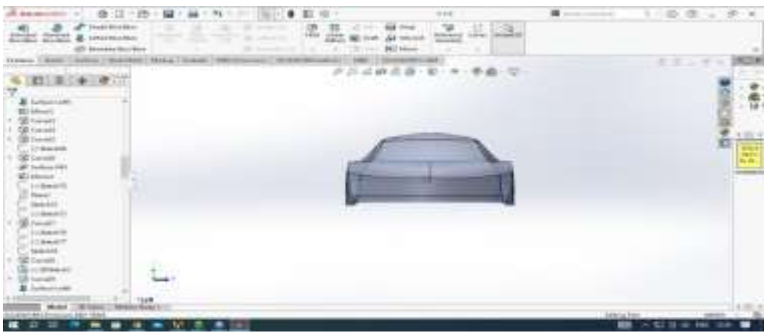
The radiator grille is no longer present on the new Volkswagen XL1 Concept's front end, but it nevertheless embodies the "design DNA" of the brand today with a predominance of horizontal lines. A continuous band is created by the energy-efficient twin LED headlamps and a black cross-stripe that is located where the radiator grille once was (in this case, on the front of the vehicle). The real air intake for cooling the TDI engine, battery, and interior is in the lower part of the front end and incorporates electrically operated louvres. The thin turn indicators are also made with LED technology; they are shaped like a "L" and run parallel to the headlights horizontally and vertically. This results in a front end with extraordinary
dimensions and a completely new form, but its clean lines instantly identify it as a Volkswagen design.

- The design completely changes course at the back, reinterpreting the precision and craftsmanship of the brand. Here, Volkswagen style took on a whole new level. There are four distinct traits.
- Once more, the dolphin body shape with extremely fine trailing edges for ideal aerodynamics, which becomes narrower towards the rear.
- lack of a rear windscreen on the coupe's roofline. The broad rear boot lid, which covers the drive unit and a 100-liter luggage compartment, merges into the roofline.
- The back part is framed on the top and sides by a strip of red LEDs. This LED strip includes brake lights, rear lights, rear fog lights, and reverse lights.
- A black diffuser that glides almost imperceptibly to the fully covered underbody.

Lightweight design that is more systematic than ever. Carbon fibre reinforced polymer (CFRP), which is strong and lightweight, makes up a sizeable component of the new XL1's body. Specifically, the monocoque with its slightly offset driver and passenger seats and all of the outside body components are made of CFRP. The layers of carbon fire are used to build items with an epoxy resin system that are aligned with the directions of forces. This material combination results in an extremely robust and lightweight composite. A CFRP body, like the one on the brand-new Volkswagen XL1 Concept, was long thought to be challenging to build to industrial standards. However, as part of the XL1 research project, Volkswagen found a productive



Due to its small weight, CFRP is the appropriate material for the new XL1's body. It only weights 795 kg, the XL1 Concept. The total driving unit weighs 227 kilogrammes, the running gear weighs 153 kilogrammes, the equipment weighs 80 kilogrammes (including the two bucket seats), and the electrical system weighs 105 kilogrammes. The body, which was mostly composed of CFRP and included the very secure monocoque, wing doors, and front windscreen made of thin-glass technology used in motorsport, makes up the remaining 230 kg, which is exactly the weight of the vehicle. With a CFRP percentage of 21.3%, the new Volkswagen XL1 weighs 169 kg. Additionally, 22.5 percent of all Volkswagen parts (179 kg) are made of lightweight metals. The new XL1 is only made of steel and iron materials in the amount of 23.2 percent (184 kg). Other polymers (such as polycarbonate side windows) and metals, as well as materials used in the production process and electronics, make up the remainder of its weight.



safer than ever because to lightweight design: In addition to being incredibly secure, the new XL1 is also quite light. As was already mentioned, this is partially due to the use of the material CFRP. Like race vehicles used in Formula 1, the Volkswagen's monocoque is incredibly sturdy. Contrary to Formula 1, its safety capsule's top is sealed for security. Depending on the sort of collision, the load path could pass via the A and B pillars, can't rails, and sills, all of which operate as impact energy absorbers. Additional side members and crossmembers at the front and back of the vehicle further increases passive safety.

Athletic footwear with ESP uses cutting-edge materials.

Anti-roll bars are installed in the front and back of the running gear, which is distinguished by its lightweight design and high level of safety. A double wishbone suspension is used up front, while a semi-trailing link system is used at the back. The front and rear suspensions both provide a high level of driving comfort and are built very compactly. In certain places, the running gear parts bolt directly to the monocoque made of CFRP.

Aluminium parts, CFRP parts, ceramic parts (brake discs), magnesium parts (wheels), brake callipers, dampers, steering gear housing, and plastic parts (steering wheel body) have all been used to minimize the weight of the running gear. a totally new generation of MICHELIN's optimized low rolling resistance tires (front: 115/80 R 15; rear: 115/80 R 15), friction- optimized wheel bearings, drive shafts, and other components. The Volkswagen XL1 Concept uses little energy thanks to its low-energy tires (145/55 R 16). Electronic stabilization program (ESP) and anti-lock brake system (ABS) safety improvements are made possible. This is since sustainability without the highest level of safety would merely be a step backward. How these two criteria can be balanced is demonstrated by the new VW XL1.

Under-Body

Some of the parts that could be located under the body of a standard automobile are the gas tank, mufflers, exhaust pipes, and, in some vehicle layouts, a gearbox and a propulsion shaft. These parts significantly increase the overall drag because they obstruct airflow that passes over an object's underbody. According to Sebben (Sebben, et al., 2016), adding different underbody panels and covers to a standard passenger automobile can reduce drag coefficient. mounting of underbody panels. According to Sebben (Sebben, et al., 2016), the use of different underbody panels and coatings for a conventional passenger automobile can reduce drag.

Due to the battery package's location between the underbody's wheelbase and the wheelbase of electric vehicles, as opposed to conventional automobiles, a flat underbody is utilized.

Because of the low centre of gravity, this placement of the battery not only enhances the handling, stability, and comfort of the ride, but also helps with aerodynamic performance.

Although research has been done to further improve it, the aerodynamic performance of a vehicle with a flat underbody is pretty good. Nissan Leaf is a pure electric car, and its underbody has been optimised to employ a range of underbody panels, according to research by Ishihara (Ishihara, 2011). It shows the underbody panels of the Nissan Lega. Among the panels are a diffuser with gigantic fins, a wide flat floor cover with fins along the panel, and a large front undercover with an aerodynamic convex.

To lessen drag, these features are employed to efficiently distribute and direct air flow along the underbody.

The research of the diffuser is another area of emphasis to improve the aerodynamic performance of the underbody. At the end of the underbody, a diffuser is utilized to enhance base pressure at the back of the vehicle, which in turn reduces the size of the wake by slowing the airflow velocity exiting the underbody.

The ideal diffuser angle for a sedan and estate back configuration, is the subject of a study conducted by Löfdahl (Löfdahl et al., 2013). The study demonstrates that a sedan's diffuser angle reduces drag substantially more than an estate backs.

The various phases of a fluid give it character. These describe a laminar, turbulent, and laminar- turbulent transition condition, respectively. Additionally, a Reynold's number, Re, which is expressed in formula 6.1 where U is the fluid velocity, L is the distance between the fluid flow and the geometry, and an is the flow's viscosity, characterises the different fluid states.

Re > 500 000 is associated with a turbulent flow, whilst Re 500 000 is associated with a laminar flow. It has no dimensions, the Re number. A laminar condition is distinguished from the other phases by a smooth flow that is easy to predict since the streams follow the flow velocity. But the chaotic three-dimensional flow behaviour of the turbulent state makes it challenging to predict. 2016 saw Anderson et al.

A three-dimensional air flow that is extremely turbulent is applied to a moving car on a roadway. The flow is laminar before it hits the front of the car, so it moves at the speed of the wind in the area. After impacting the vehicle's front end, the fluid's laminar state changes along the vehicle surface to a turbulent state towards the back of the vehicle because of vehicle deformation and disruptions in the flow path.

The automobile is modelled in this thesis driving at 120 kph on a highway, producing a Re number of over 9 500 000.

Compressibility

The compressibility of the fluid flow must be established before choosing which calculation model to apply to the CFD setup. The Mach number is employed in this. Ma, a number that describes how compressible a fluid flow is. Where U is the flow velocity and is the speed of sound, expression 6.2 demonstrates how to compute Ma. A fluid flow is deemed to be incompressible, in accordance with Anderson (Anderson et al., 2016), if its Ma number is less than 0.3. The Ma number in this thesis is calculated to be 0.098, which makes the flow incompressible as the vehicle is traveling at 120 kph.

Turbulence Model

Since the flow is incompressible, the Reynold's Averaged Ivoire-Stokes equations, or RANS model, is the primary and most used turbulence model to simulate and evaluate the behaviour of the flow (Anderson et al., 2016). In expression 6.3, the governing equation for RANS is given.

Turbulent and non-turbulent states are blended in a fluid flow. The RANS equations separate these two fluid states and use a statistical approach to determine the velocity and turbulent behaviour of a fluid flow to simplify calculations and cut down on computation times. 2016 saw Anderson et al.

A two-equation transport equation is employed to complete the turbulence model, increasing accuracy.

Two-equation Transport Model

Considering the available computing resources and NEVS standards, the k-w was chosen as a two-equation model due to its performance in recons with negative pressure gradients and independent flows (Anderson et al., 2016). In terms of external aerodynamics, these zones correspond to the intricate boundary between flow and surface.

An extremely fine mesh situated close to the surface of the geometry is required for the k-w model to be able to resolve the kinetic energy, k, and the turbulent frequency. It is necessary to have a wall value under 5. As of 2016, Anderson et al. When a no-slip condition is present in a near-wall region, the y value determines the inner stresses in that area (Anderson et al., 2016). The inner stresses are shear stresses that are created because of the fluid's viscosity interacting with a surface.

The k-w model is supplemented by the Shear Stress Transport equation (SST), which uses the k-omega model in the near-wall area but the k-€ model in the free flow stream. As a result, it is easier to calculate the flow separation when there is a negative pressure gradient.) (Anderson and others)

Energy Model

Using either a connected flow model or a segregated flow model, StarCCM+'s energy modeling can be done in one of two ways. for a flow that is incompressible. The segregated flow model, which is the most popular strategy, is utilized in this thesis. (2006) Pascau et al The segregated flow model also has the benefit of solving the energy equations sequentially, which reduces the need for significant computational resources.

Porous Medium

The Driver model's heat exchanger kit comes with a radiator. The tiny radiator channels cause the bulk flow of the air to be slowed down, which results in a pressure decrease between the radiator's input and output. Expression 6.4 illustrates how Darcy's Law is used to construct a porous material in a CFD environment to replicate this pressure drop.

where the radiator width is Ax and the pressure drop is represented by Ap. The formulae for the inertial and viscous porous resistances are both put as constants in StarCCM+. The data utilized to calculate these constants corresponds to a general radiator pressure loss, and the results are provided in appendix A.

Air Resistance Forces

A moving vehicle experiences air resistance as a source of opposing forces at all speeds. Friction and pressure on the geometry combine to produce this resistance force. A geometry produces less air resistance the more streamlined it is. Aerodynamic behaviour refers to the change in air resistance over time.

In order to evaluate the aerodynamic performance of various shapes. Consider the usage of a dimensionless parameter for vehicle designs. Calculated using the forces acting on the shape as indicated in equation 6.5, this quantity is known as the drag/lift coefficient, or Cd/CI.

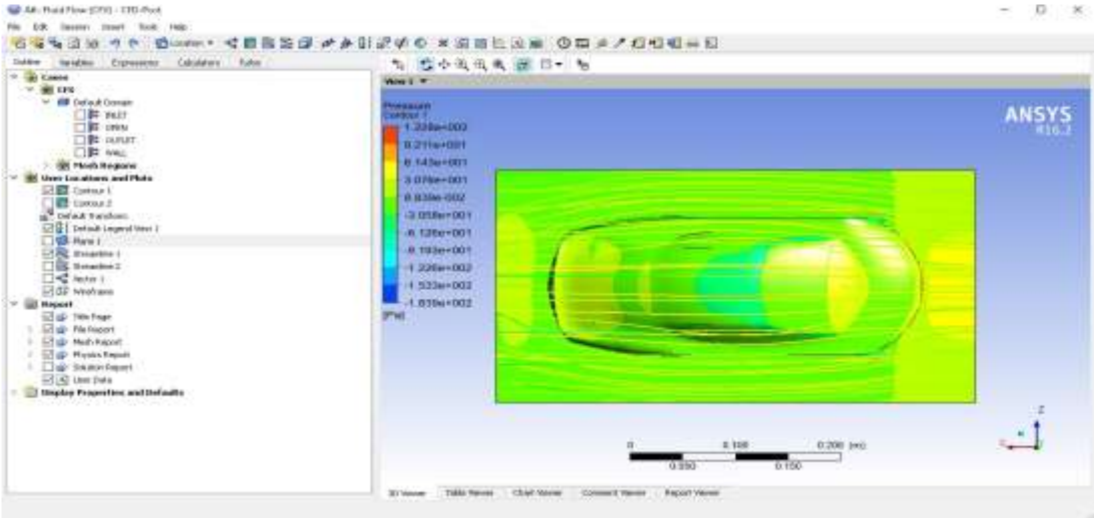
The frontal area varies between geometries, yet vehicle velocity and density are frequently fixed values because of uniform testing procedures. Because the Cd/CI values are frequently quite small, it is common to refer to these parameters as counts, with 1 count equalling
0.001 Cd/Cl, in order to make them easier to show and understand.

Methods

Cleaning up and Preparing CAD

Cleaning is required in order to prepare the Driver model for simulation. Cleaning the model entails redesigning and fixing faces and surfaces that overlap and intersect. The model becomes topographically accurate as a result, making meshing and the simulation setup easier. Further improvements have been made to the mesh quality.

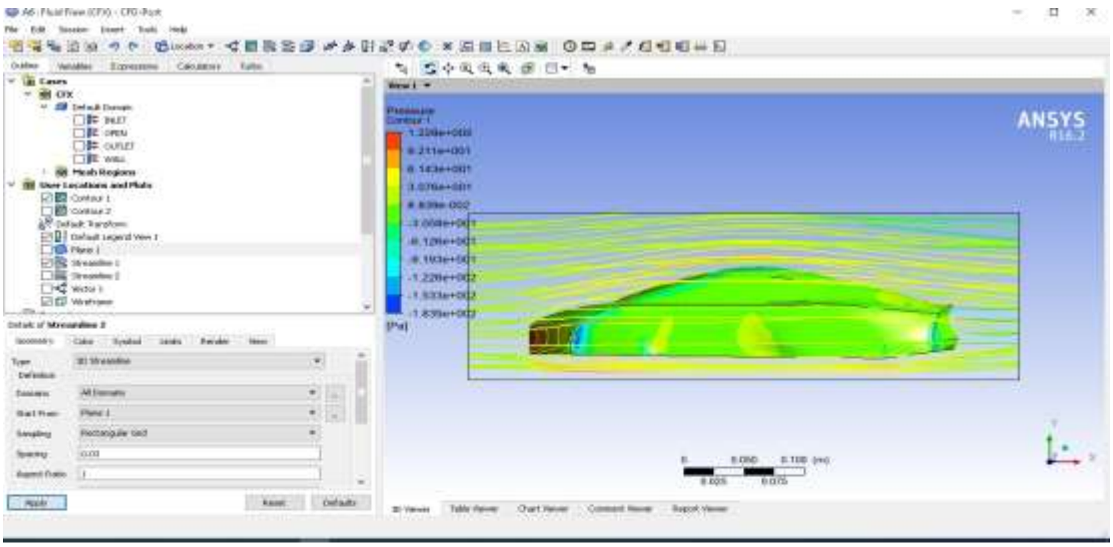
The geometry is checked for closeness, intersections, and unwanted gaps in ANSA (ANSA, 2017), which also does CAD cleaning. In order to export the geometry in a ST format, which only keeps the individual components of the mesh and not the surface of the geometry, a surface mesh is created when this is complete. Every CAE/CFD tool is compatible with this HLE format, which is widely used.



The car geometry is broken down into various part ID:s to improve the meshing produced by the CFD program StarCCM+ (StarCCM+, 2017), as well as to record the simulation results by, for example, examining forces applied to various sections or following the air flow along particular places.

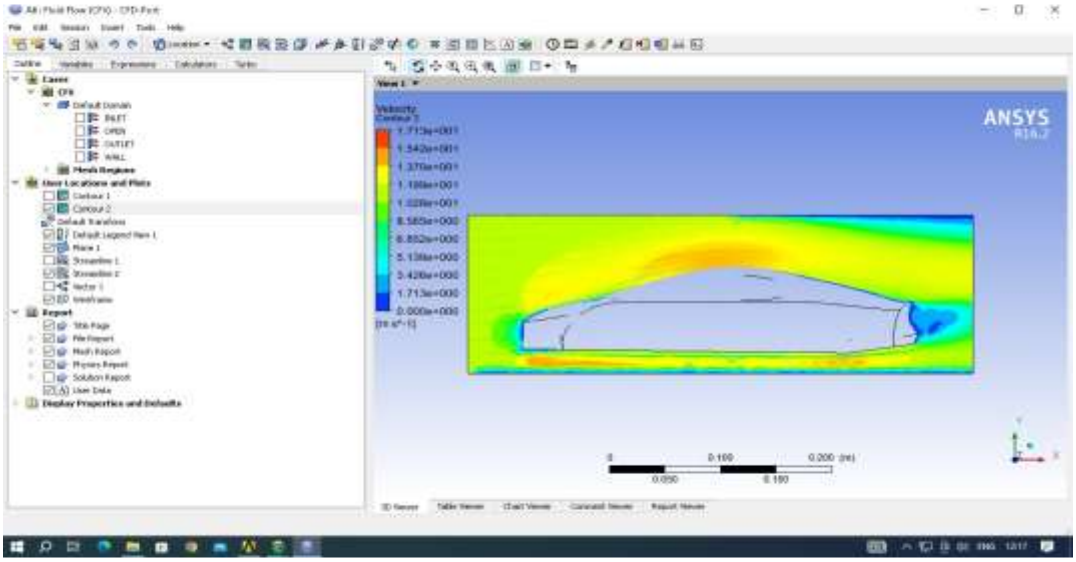
Windtunnel Setup

A windtunnel is constructed in the CFD environment to capture the flow behaviour around the automobile during a highway drive. Starcom’s documentation, which it supplied in 2017 (Star- CCM+), the wind tunnel's dimensions and the location of the vehicle model have been specified. By making the windtunnel large enough, these dimensions are taken into consideration, as is the influence of the domain boundaries. This is a significant advantage of CFD over a wind tunnel. Due to capacitance and available space, it is difficult to exclude the influence of domain boundaries in a wind tunnel test.



Creation of Meshes

In order to represent flow phenomena that interact with a geometry's surface and the flow in the domain, a mesh generation includes a volume mesh and a surface mesh.



Surface Mesh

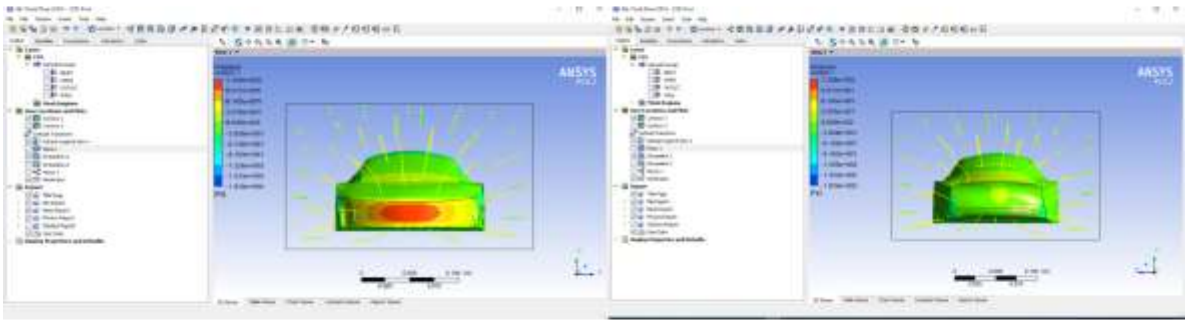
A surface mesh is created using a surface wrapper and a surface remesher. Gaps in the geometry of the vehicle are sealed with a surface wrapper when an airflow is not desired. Due to this technique, the vehicle shape is "waterproof". A surface remesher, on the other hand, can enhance the mesh quality of a surface wrapper. The surface remesher improves the mesh quality by re-triangulating the surface mesh created by the surface wrapper..

The surface wrapper and the surface remesher are both used by the StarCOM+ surface mesh option, which also controls them. Surface mesh is generated by setting a basc cell size throughout the whole vehicle shape. To enhance the mesh if there are complex geometries or components that are smaller than the base cell size. Surface controls are available. In ANSA, the vehicle geometry was separated into several PID, and each PID: was given a particular cell size to improve the mesh quality.

Quantum Mesh

The trimmer approach is used to generate the volume mesh, as advised by the Star-CCM+ literature. Hexahedral cells are used in the Trimmer approach, which also allows for refinement boxes to improve simulation accuracy in regions with very complicated flow behavior.

The difference in drag coefficients and trends between concepts are stressed more in this thesis than an exact Cd value, which makes it less significant. Simulations using the Iwo baseline were run. two with volume meshes of 25 million and 45 million cells, respectively. Given the computational time, the 25 million cells example's outcomes compared to the 45 million cells case are deemed adequate. It was determined that a volume mesh with 25 million cells would be used for all simulations.



Layers in a prism and y+ values

The air friction causes a significant amount of drag at the vehicle surface, also known as the near-wall boundary. The v-values are used, and are set and controlled by building prism lavers, to record the flow-to-surface interaction.

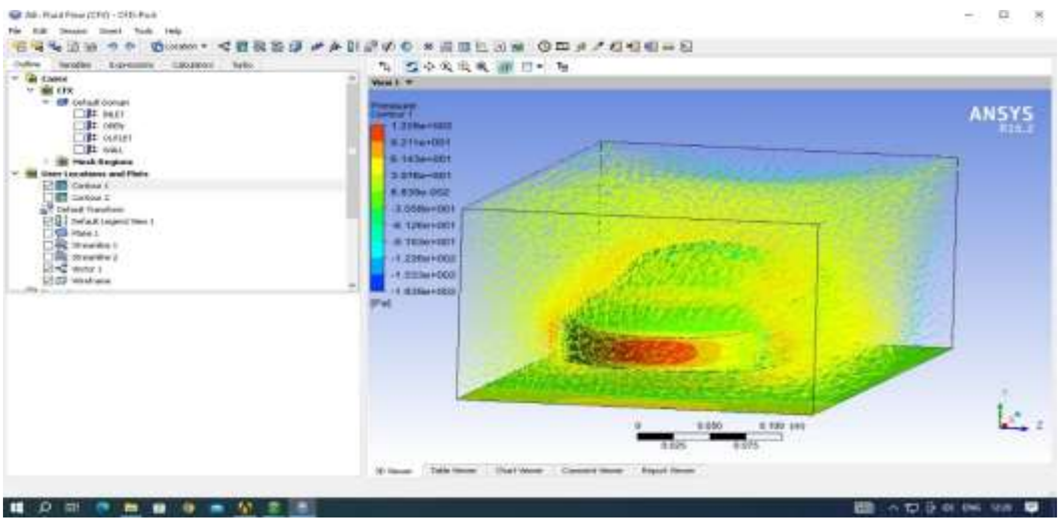
Making use of the k-omega turbulence model, as explained in the theory chapter. The bounder laver must be resolved using a v+-value between 0 and 5. According to figure 7.3, the overall thickness of the prism layers is 3.5mm, with the first layer's thickness being fixed at 0.05mm. To do this, the growth rate is set at 1.3, just like for the refinement boxes. An abrupt increase in the volumetric cell size should not occur between the prisms.

It displays the wall yt values that were produced for both the estateback and fastback configurations. The majority of the values are between 2-3, as shown in the figure, but the wall y° value in the mirror and on a few of the front tires exceeds the maximum of 5. Given the given computational resources, this is deemed adequate.

Boundary and Physics Setup

The simulations show a car traveling straight ahead at a speed of 120 kph. To simulate a moving vehicle, a 120 kph tangential velocity in the x-direction is applied to the ground border. A rotational speed is specified to make the wheels, brake disks, and driveshafts match the simulated instance. W, as calculated and displayed in expression.

where r is the wheel radius and v are the velocity.



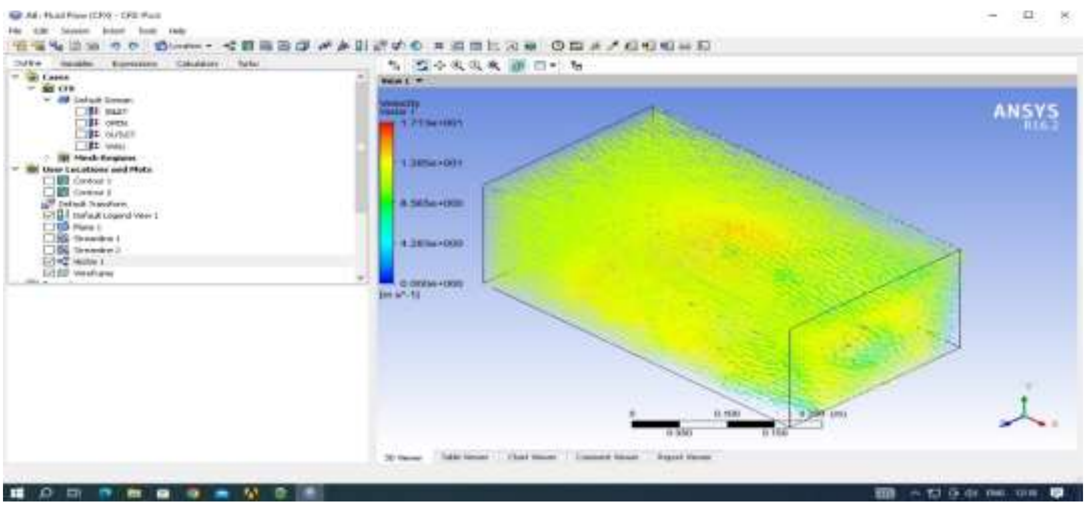
about the limits of the windtunnel. A velocity inlet border that has the same direction and speed as the ground surrounds the inlet. The outlet is set to a pressure outlet boundary with a physics value of U to keep the outlet pressure at the same level as in the domain. The side walls and the sky are given symmetrical bounds, and the windtunnel's temperature has been set to 25°C. Since the k-w model is used to compute fluid dynamics and capture the flow behavior while interacting with the vehicle in the domain, additional in-model techniques are available to increase accuracy.

Initial Run and Conceptual Design

The design parameters for the concepts are demonstrated and explained in this chapter. The baseline results for both the estateback and fastback configurations served as the foundation for the concept concepts. Most of the concept designs are produced and simulated using the same parameters because the geometry of both vehicle types is comparable, except for the rear upper body. The phase 4 investigation of a roof spoiler extension for the estateback configuration and a trunk spoiler extension for the fastback configuration is the only distinction between the concept designs for the two configurations.

Air Curtain

The front end's corner has a narrowing channel for an air curtain that accelerates the air stream and directs it past the front wheelhouse. Therefore, it is feasible to limit the contact of the front of the tire with the surrounding airflow, which lowers drag. Since there isn't much information about air curtains, the air curtain used in this study was created by comparing how they're used in contemporary automobiles and by looking at the results of the baseline model simulation. The pressure coefficient of the front surface of the vehicle. The areas that are indicated draw attention to the low-pressure areas, which correspond to high-velocity airflow. By designing an inlet channel with an outlet in the wheelhouse, the concept idea uses the high velocity airflow.



The location of the air curtain's inlet and outlet is chosen first, and then the concept's size and alternate designs are chosen. For all concepts, the air curtain's inlet has dimensions of 20 mm in width by 150 mm in height. The intake and outlet are both the same height. Three distinct widths are produced, though. They are 10mm, 20mm, and 30mm in size.

ventilation in a wheelhouse

The goal of a wheelhouse ventilation is to give the flow in the wheelhouse an additional escape route. Because there is a lack of quality literature on wheelhouse ventilation, the concept design is based on benchmarking and the baseline result. The pressure coefficient distribution of the back portion of the wheelhouse.

As can be observed, the airflow entering the wheelhouse causes significant stagnation zones, which increases drag contribution. A wheelhouse ventilation with an inlet with to is built close to the wheelhouse arc in order to lessen these stagnation zones. 50mm. The only variable that varies depending on the situation is the ventilation height; the outlet and inlet widths are kept constant. It is chosen to investigate four possible heights: 100mm, 200mm, 300mm, and 400mm. The wheelhouse ventilation concept is depicted.

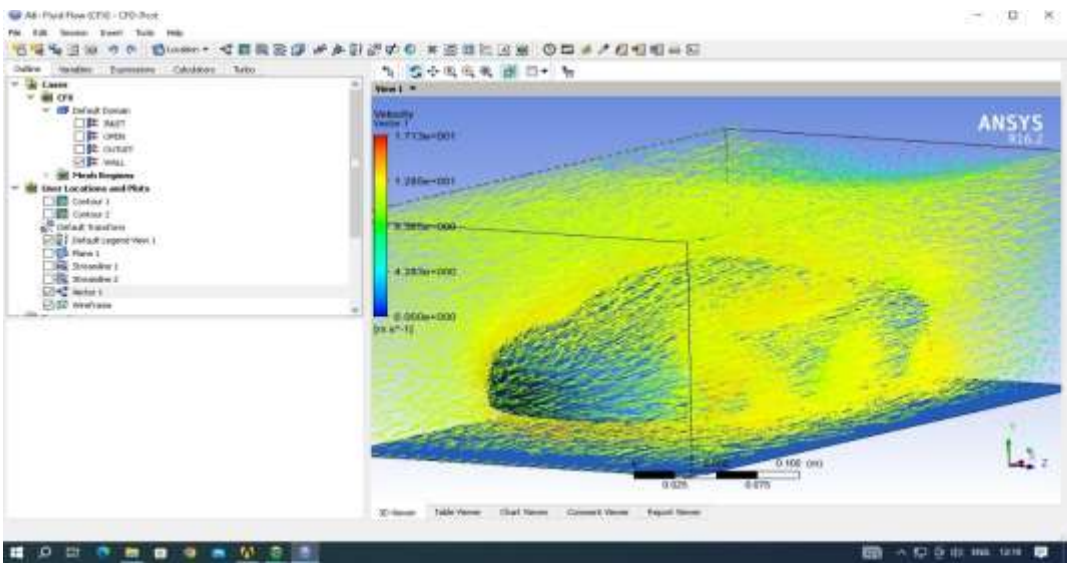
Package with front spoilers.

The airflow along a conventional vehicle's underbody is mostly reduced by the front spoiler/splitter package. Robinette's research served as an inspiration for a study that examined the impact of a spoiler/splitter package in an electric vehicle.

- The only variable that varies is the spoiler height, which is set to 40mm, 80mm, and 120mm.
- The splitter width is fixed at 50mm and is kept constant in all scenarios.
- The spoiler/splitter package's design is seen on the picture.
  The concept's 80mm and 120mm cases enhance the frontal area of the car for both the estateback and fastback configurations.

Vanes for the undercarriage

Directing vanes were created to optimize the dispersion of the underbody how. The baseline runs for the estateback and fastback setups both show the identical streamlines that describe the underbody flow behavior, as can be shown in figure 8.b. As shown in the image, the direction of the fluid flow is towards the right side of the car and the back part of the underbody.



This behavior is brought on by a discrepancy in the airflow mass flow from the engine-bay exits, which are situated in each front wheelhouse. The iso surface of the wake for both setups is depicted in figure

8.7. It is obvious that the flow on the right and left sides is asymmetrical.

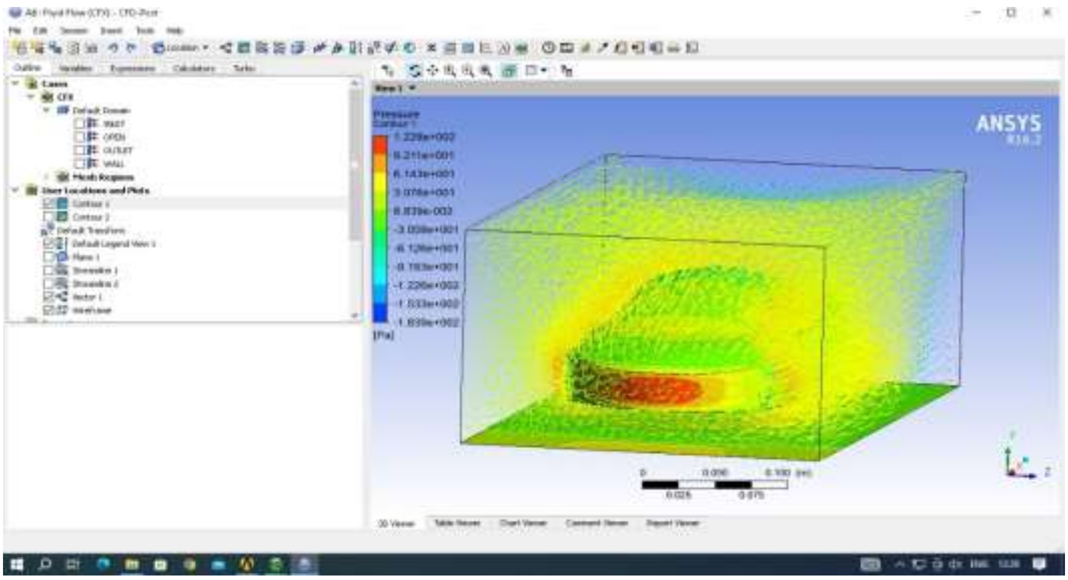
As seen in figure 8.8, Because of the differing massflows, there are differences in the pressure distribution between the right and left sides of the vehicle. Due to the left side acquiring a higher total pressure than the right side, the flow shifts from a region of high pressure to one of low pressure. The underbody flow tends to go to one side and begins near the end of the front wheelhouses. Since the airflow is not interacting with the rear-end separation, there is no obvious substantial flow deviation to the right of the automobile.

The guiding vanes were made in accordance with the benchmarking and baseline results. minimize the number of variable parameters to only one. For all circumstances, a beginning point and fixed width and height were established. The only variable is how long the vanes.

Four separate examples measuring 250, 500, 1000, and 1500 mm will each be the subject of an examination. When the flow deviation becomes noticeable, the starting position of the vanes is determined and presented as x, y, and z coordinates in the nurse with the width of the vanes set to 50mm and the height of the vanes simulating the flat underbody panel (without accounting for the diffuser).

Diffuser Extension

Based on benchmarking and literature reviews, the diffuser extension's design parameters were developed. According to the findings of Lodahl’s investigation of various diffuser angles and their capacity to reduce drag, the diffuser angle of the Driver model is left alone because it is approximately 5°, which equates to a high level of drag reduction.



The distance between the rear tires is used to determine how wide the diffuser extension should be. It has been agreed to study extensions that are 200mm, 300mm, and 400mm in length.

Extended Roof and Trunk Spoiler

Like the diffuser extensions, the roof and trunk spoiler extensions were also created using literature reviews and benchmarking data. every vehicle configuration. There are three extensions built, measuring 100mm, 200mm, and 300mm. Following the vehicle's curvature, both the roof spoiler extension and the trunk spoiler extension are illustrated in.

Results

The findings for the air curtain compared to the reference model are shown for both estateback and fastback configurations. Most of the time, behavior that is constant across multiple settings lowers drag. The estate back's biggest drag reduction is achieved with the 10mm concept and results in a 6-count drop, while the quickest back has a 20mm idea with a drag reduction of counts.

displays the baseline simulation's pressure distribution on the wheel and the 10-mm concept simulation's pressure distribution. You can see by examining the regions that have been highlighted that the pressure coefficient has been lowered at the front of the tire for the concept simulation. According to this result, the flow velocity through the tire is increasing. Because the airflow is accelerated by the air curtain function, drag has lowered.

illustrates how to visualize the magnitude of the airflow's velocity by cutting a plane section at 100mm in the direction of the flow. In contrast to the baseline example, the air flow through the tire's outer edge and past the wheelhouse in the idea case is more closely related to the vehicle surface.

To follow the change in airflow direction, the velocity direction is represented in the same graphic using vectors. The airflow past our front area and wilceiliouse is being disrupted by the engine bay's exhaust because the engine bay outlet is inside the wheelhouses.

Wheelhouse Ventilation

Results from the baseline model and proposals for wheelhouse ventilation are shown. This is done for both estateback and fastback setups. Applying the principles to the estateback results in a 4-6 count reduction in drag. The fastback's reduced drag is 1-3 counts, or around 50% less, as compared to the estateback.

The concepts with 10umm and 30mm wheelhouse ventilation aperture produce the biggest drag reduction when the correlation between the configurations is examined. Figure 9.3 shows the pressure distribution at the back of the wheelhouse (highlighted surfaces) using a ZY-plane cut.

The lack of a simple departure channel causes a high-pressure location in the back of the wheelhouse where it acts as a wall that the air flow hits. The flow has two waves that are outside of its purview. A person can either leave to the sides (in a positive negative Y-direction) or under the car (in a negative Z-direction). In this situation, the flow will continue to always hit the back of the wheelhouse. The air flow has a third departing path (positive X-direction) when the wheelhouse ventilation is implemented. The 'wall' in this passage has an entrance where the flow can depart, limiting the air Flow egress and lowering the pressure coefficient at the back of the wheelhouse.

The reduced interior pressure in the wheelhouse is immediately apparent. This suggests that the wheelhouse is losing more air than in the original model. When one looks at the rear edge of the wheelhouse arch, there is higher pressure due to a more connected flow. By adding the wheelhouse ventilation aperture, the flow was switched from leaving in the sides (positive or negative Y-direction) to leaving through the opening. By allowing for a more surface-attached flow and lowering the Cd, this decreases the separation that occurs at the rear wheelhouse arc.

The air flow follows the shape of the car from front to back, therefore any flow irregularities or flow behaviors result in a base wake. Figure 9.5 illustrates how the estateback and fastback setups in this situation wake the base. Baseline to concept base wake size change is not much different. The base wake for the upper section of the vehicles remains the same, but the base wake for the lower section is significantly lowered, causing higher pressure at the rear-end and a higher drag red.

Front Spoiler/Splitter Package

A front spoiler/splitter package increases the frontal area in cars when a reduction in total drag would not be possible when considering the frontal area coupled with the Cd value. The results for the front spoiler/splitter packages, as well as the baseline and both vehicle configurations, The Cd values for the various instances are based on the frontal area of the baseline to compare the results with confidence.
In the estateback configuration, the drag coefficient was decreased by the 120 mm casing. Five counts of drag have been reduced. A front spoiler splitter with a length of 40 mm reduced drag more than one with an 80 mm length did for both configurations, according to the similar trend between the examples. The 120mm casing, which among the cases offers the highest savings, comes next. When the frontal areas of the various examples are considered, it is demonstrated by the CdA values that no drag reduction is achieved.
The estateback configuration's cumulative drag illustrates this point, demonstrating that for the drag-reducing idea, the front-end makes up much of the difference. A bigger frontal area results in more drag being created at the front-end than at the baseline. The drag coefficient significantly decreases at X=1250mm compared to the starting point. Along the rest of the vehicle, there is little difference in drag coefficient between the baseline and the idea. However, the drag coefficient varies towards the vehicle's back due to the addition of the drag coefficient along the vehicle.
The front spoiler/splitter kit shields the tires, reducing the area where the front tires stagnate. The front spoiler is where the stagnation is transferred.
The main airflow is changed to pass on the sides (pos-itive/negative Y-direction) by using a splitter and a spoiler combined. Due to the splitter's proximity to the ground, airflow that is traveling underneath it and into the vehicle is accelerated. Figure 9.8 demonstrates that the pressure coefficient in the concept's wheelhouse area is lower than it is in the baseline. This is due to the high flow velocity both past and beneath the wheelhouse, which led to the creation of a low-pressure area inside the wheelhouse.
The air flow follows the shape of the car from front to back, therefore any flow irregularities or flow behaviors result in a base wake. Figure 9.5 illustrates the basic wakes for both the estateback and fastback configurations in this instance. Baseline to concept base wake size change is not much different. The basic wake for the upper section of the vehicles remains the same, but it is somewhat lowered for the lower section, causing higher pressure at the rear-end and giving.

Discussion

The air curtain designs significantly reduced drag despite the lack of study or publications in the field. There is no way to relate this to a situation in the actual world. The findings after postprocessing, however, could not be changed in a significant way. The apparent bending of the flow path in a general direction by the air curtain seems to have resulted in a flow that is more surface attached. Since the engine bay cooling flow exits via the wheelhouses, the high velocity of the outgoing flow is interacting with the outer flow past the wheelhouse and decreasing the air curtain's ability to reduce drag. Air curtain designs and installation locations have been researched during the benchmarking study, and by contrasting the results. use the Driver model. It is shown that the front end of the Driver model was not designed with the use of an air curtain in mind. Before adding other characteristics to a vehicle to further improve its performance, the geometry must first be optimized. This was not the case when the air

barrier was included in the DrAer model.
Due to insufficient publications, the results for the wheelhouse ventilation idea cannot be compared to existing research or prior studies like those for the air curtain. However, the CED results demonstrate that substantial amounts of drag can be decreased. The wheelhouse ventilation opening length did not significantly affect the drag coefficient value, which is an intriguing behavior between the cases. The location of the wheelhouse ventilation aperture may have a greater impact on the drag coefficient than the actual wheelhouse design, it would seem. Another finding that is noteworthy is that the geometries are what account for the differing drag reduction magnitudes between the two designs. The estateback produces a greater wake size than the fastback at the rear upper-body, notwithstanding civil engineering a Laurier volume in which an aerodynamic reconstruction occurs.
Even though one design was able to reduce the drag coefficient, the front spoiler/splitter package did not reduce the amount of air resistance that was put on the car. One reason for this is the flat underbody used in the Driver model. The flat underbody allows the airflow to keep a constant high velocity along it, therefore the baseline configuration is already optimal. According to a document that was found on the front spoiler/splitter package for a conventional automobile with a sophisticated underbody, a 20% decrease in drag would be possible. This cannot be supported by the thesis because there is no decrease in overall air resistance and only a 1.88% reduction in drag.
Analysis of the patterns in the various front spoiler/splitter scenarios demonstrates that the drag coefficient can decrease or rise as the spoiler length increases. A detailed analysis must be conducted where the lengths and shapes of spoilers are researched to create a front spoiler/splitter combo that performs at its best. Another noteworthy result is the reduction in engine bay pressure caused by the suction action at the cooling flow exit. This behaviour was unanticipated, thus a more thorough examination to determine whether the flow striking the front end is channelled under the wheelhouse or to the sides might further reduce drag and influence lift forces.
Even though the literature review and benchmarking revealed that although the underbody vanes have different designs, they are all used to guide and control the flow along the under- body. The Driver model's underbody vanes were created using the findings of the baseline analysis. It was decided to only employ guiding vanes where a guiding vane is required, as opposed to many cars that use guiding vanes that reach from the front section of the underbody till the conclusion. It was necessary to distribute the flow more evenly. Considering that the Driver model has a flat underbody, it is possible to reduce the drag coefficient by up to 6 drag counts. However, the performance of the guiding system has decreased because of the influence of the varied massflows along the sides of the vehicle. Despite having different designs, the underbody vanes are all used to guide and control the flow along the under-body, as seen in the literature review and the benchmarking. Designing the underbody vanes for the Driver model was based on the findings of the baseline investigation. It was decided to only employ guiding vanes where a more even distribution of the flow was necessary, in contrast to many vehicles that use guiding vanes that run from the front portion of the underbody to the end part. Considering that the Driver model has a flat underbody, it is possible to reduce the drag coefficient by up to 6 drag counts. However, the performance of the guiding system has decreased because of the influence of the varied massflows along the sides of the vehicle.
Simulations of diffuser extensions are carried out to provide a better understanding of an active aerodynamic component and its potential to reduce drag. According to research on a study that examined this kind of feature and utilized benchmark diffuser lengths and angles, it is possible to reduce drag by up

to 20 drag counts. By delaying the separation of the vehicle's rear ends, this innovation aimed to lessen the amount of the wake behind the vehicle. These objectives were accomplished for both vehicle designs, and a 3–9 drag count decrease was achieved. It is a noteworthy discovery that the diffuser extension lengths did not provide the same outcomes for the estate back and fastback. The highest reduction in drag was accomplished with the longest configuration for the estate back, which reduces as extension length grows. In contrast, for the fastback, the best reduction in drag was obtained with the shortest configuration, which increases as diffuser length lowers. This demonstrates how certain aspects behave differently when compared between several automobile models.
In the same way as the dafter extension. An active feature that can be employed soon is revealed by simulating a root and trunk extension. In cars like the Mercedes IAA and the Audi E-Tron Quattro, it has been shown that an active rear-end extension may reduce drag. Studies and benchmarked vehicles show that a roof expansion creates drag. A drop of ten counts is possible. The roof and trunk additions in this thesis produced findings that were equivalent and indicated an 8–9 count reduction in drag.' The essential argument is addressed using an alternate vehicle model. The ideal decrease varies in different cases. For the estateback configuration, a 300mm roof extension yields the greatest results; for the fastback layout, a 100mm extension yields the best outcomes. When the amount of the decrease is up to 9 drag counts, an aerodynamic performance may be deemed greatly enhanced. This suggests that, with the proper angle and design, these trunk/roof extension concepts can be much more effective.
To estimate the amount of drag reduction that might be accomplished with the best examples of each notion, it is not accurate to add together all the drag reductions. As a result, the concepts are combined in both the estateback and fastback setups. The design with the lowest overall performance has a faster back layout that reduces drag by 5 counts. This result shows that certain ideas don't mimic well with other ideas. With a drag reduction of 15 drag counts for the estateback configuration, the combined concept vehicle offers the best drag reduction when compared to the drag reduction of the single concept. It has been firmly shown that a better concept design might minimize these effects even more..
The concept study concludes with a futuristic concept vehicle simulation that draws inspiration from concept cars created by automakers. Today's aerodynamically effective concept cars have Cd values between 0.19 and 0.22. With a Cd value of 0.236 for the estateback and 0.216 for the fastback, the estateback and fastback configurations reduced drag by 33–35 counts. Considering that the Driver model is a few years older than current car models,

Conclusion

This study's findings suggest that modern automobiles' aerodynamic performance has not yet reached its full potential. As seen in the benchmarking study, as new technologies and innovations are adopted, the vehicle design incorporates an increasing number of aerodynamic characteristics. Due to more affordable hardware and widespread software use in automobiles, active aerodynamic elements have gained popularity recently. This creates opportunities for new kinds of aerodynamic features to control airflow and hence lessen drag.
The emphasis in this thesis has been on various aerodynamic aspects. The drag of a vehicle is discovered to be greatly reduced with the application of several characteristics.
For electric vehicles, this increases range while reducing energy losses.
The diffuser and roof/trunk spoiler extension designs provided the greatest drag reduction. There is a great chance that these ideas may soon be applied to automobiles. As active features, the diffuser and

root/trunk spoiler extensions are only activated when necessary to maintain the vehicle's high levels of safety and appeal.

Although the concepts that were studied do not completely exploit their aerodynamic potential, the primary emphasis should be placed on improving the vehicle shape when planning and creating an aerodynamic vehicle.

Last but not least, the performance of aerodynamic characteristics is only applicable to the specific vehicle model for which they were designed. In most cases, transferring the function to a different car model won't result in the same performance; further research is necessary.

Upcoming Work

The key suggestion for additional research into this thesis is to adopt an entirely closed vehicle body when looking into novel innovations. Even while a closed vehicle body doesn't exactly match a real-world scenario where, for example, cooling flow is needed, it does lessen airflow disruption, which increases the likelihood of obtaining a very accurate performance of the researched concept.

Further research into the concept design characteristics is advised to further the investigation into the decrease of aerodynamic drag on electric cars.

References

1. Academic Databases: Use Google Scholar, IEEE Xplore, Scopus, or other academic databases to search for research papers and articles related to the Volkswagen XL1 concept.
2. Automotive Engineering Journals: Investigate journals that focus on automotive engineering and technology advancements; they might have articles discussing the XL1 Volkswagen concept.
3. Automotive Industry Magazines: Check magazines and publications dedicated to the automotive industry, as they often cover innovative concepts and technologies like the XL1.
4. Official Volkswagen Publications: Explore Volkswagen's official website and publications, as they may have released technical papers or reports about the XL1 concept.
5. Conference Proceedings: Search for conference proceedings related to automotive engineering or green technologies, where the XL1 concept might have been presented.
6. University Repositories: Many universities have online repositories where they publish research papers, theses, and dissertations. Look for relevant materials in these repositories.
7. Books and E-books: Check library catalos or online bookstores for books or e-books discussing the XL1 Volkswagen concept.
8. Technical Reports: Look for technical reports from research institutions or automotive organizations that may have studied or analysed the XL1 concept.
9. Expert Interviews: If available, consider using interviews with experts in the field who have insights into the XL1 concept.
10. Citations from Other Sources: Review the reference lists of the sources you already have ~ to find additional relevant references.
11. Expand Keyword Search: Use various combinations of keywords related to the XL1 Volkswagen concept, such as "Volkswagen XL1 hybrid," "VW XL1 specifications," "XL1 Volkswagen design," etc.
12. Explore Research Gateways: Check platforms like ResearchGate, where researchers often upload their papers and publications related to specific topics.

13. Look for Technical Reports: Some automotive institutions or governmental bodies publish technical reports on advanced vehicle concepts, including the XL1 Volkswagen. Look into relevant databases or websites for these reports.
14. Institutional Repositories: Explore the websites of universities, automotive research centres, or environmental institutes, as they may have published research papers or reports related to the XL1 concept.
15. Request Help from Experts: Reach out to automotive engineering experts or researchers who have worked on similar projects. They may provide you with valuable unpublished insights or materials.
16. Consider White Papers: Some automotive manufacturers or research organizations release white papers on advanced vehicle technologies. Check if there are any related to the XL1 concept.
17. Industry Magazines and News: Stay updated with automotive industry magazines and news websites, as they may cover the XL1 concept and its technological innovations.
18. Patents and Patent Applications: Investigate patent databases to find patents related to the XL1 concept, as they often contain detailed technical information.