Evaluation of a Multivariable Active Aero Wing Design

AP Research - STEM

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Abstract

Current automotive innovations are storming the world, making transportation more efficient and beneficial to the environment. Cars are now becoming electric, leaving little room for improvement directly to the vehicle as it stands in the engineering side of things, so new research suggests large benefits of efficiency by using a more well conformed aerodynamic model to reduce drag on vehicles in motion and save the environment from emissions. Using aerodynamic components to help the directional flow of air on the car has been a recent feat used by many racing development teams as well as race-inspired production cars. To compare the difference on how these components may affect an economy vehicle, models utilizing the vortex generator, rear diffuser, and both were tested in a computer aided 3D simulation to find the variables as to which the add-ons may benefit using the average total velocity of the air, total pressure, and a pressure drop in the total system. A two-variable F-test ($F \leq 0.05$) was then used to find the statistical significance in the addition of these features. This test resulted in proving the significance of aero components, showing the diffuser as affecting the air flow the greatest and proving a stacking effect as to how the components interact in terms of their benefits.

Key Terms

First, some key terms must be established for a better understanding of the paper and its interconnections. Fuel efficiency is the measurement that states the rate of fuel consumption compared to set standards. This measurement helps assess the efficiency of the vehicle and fuel consumption accounting for all factors. Aerodynamic components are those attached to moving objects used to increase or manipulate aerodynamic flow. Examples of these components mentioned include wings, canards, rear diffusers, and vortex generators. Wings are an aerodynamic component to diffuse air as well as to create downward pressure for control of the vehicle. Canards are components used to create downforce and guide air from the front of a vehicle. Rear Diffusers are underbody components used to diffuse air off the rear end of vehicles to break linearization and lessen negative drag. Vortex generators are overhead attachments for cars to linearize air and create high speed airflow. To measure the aerodynamic efficiency and assess an object's model through wind, we use a drag coefficient. The drag coefficient is a measurement in aerodynamics used to describe the rate to which a model creates drag at any certain velocity. Parasitic drag (Drag) is a frictional measurement to describe the acting force against the vehicle's movement, the variable that drag coefficients are dependent on. Carbon emissions are the emissions resulting from combustion, polluting the air with carbon monoxide, nitrogen oxides, and hydrocarbons (DEC NY 2022). Considering aerodynamic stability, there is uplift and downforce. Uplift is a force caused by the upward pressure caused by wind resistance below an object and downforce is a force caused by downward pressure from wind resistance above an object. Lastly, low pressure zones are negative pressure zones caused behind a moving vehicle in which two high pressure converging lines create a negative drag (pulling) and unpredictable air movement, creating a larger total drag.

Introduction

The automotive industry is ever growing as of the first mass production of cars, allowing mankind to automate transportation privately. The average household, a minimum of 93% of

American families, has at least one vehicle, a feat that may emit nearly 4.6 metric tons of carbon emissions per year (EPA, 2018; Federal Highway Administration, 2019). As gasoline costs per gallon increase, financial struggles, with regard to necessary means, arise and dedicate a problem for the common man. Gasoline consumption has a great amount of factors considering engines: wear, build, engine airflow, lubrication, metals, etc. However, aerodynamics, in terms of body shape, drag, and airflow design, is a largely overlooked factor in the fuel efficiency of the vehicle. Past efforts such as a smaller bored cylinder, 4-stroke engine methodology, reduced engine size, and hybrid technology have done a great deal in expanding the automotive industry to the world as well as maximize the amount of gasoline used and carbon emitted from each vehicle. As electric vehicles become more common, though a reduction in direct emissions is proven, 38.4% of all electricity is produced from natural gas, continuing this issue, which leads to a new study of vehicle efficiency for the consumer vehicle: aerodynamics (EIA 2021). Current implications made when designing a production model take into account the cost to manufacture, aesthetics, as well as fuel efficiency. While this may provide for a consumer friendly vehicle with good gas mileage, further research into the aerodynamic experiences of a vehicle will further improve the efficiency of natural fossil fuels as well as lowering the driving cost of cars.

Current efforts to improve aerodynamics are very few when it comes to consumer vehicle production. Automobile companies, when in the process of vehicle design, use computer simulations and calculations to determine the most efficient base aerodynamic figure as well as lowest drag coefficients for the body of their design. Due to the effort to reduce manufacturing and design costs, aerodynamics such as uplift, downforce, and low pressure zones are vastly overlooked and are therefore the main issues in consumer vehicle drag, therefore reducing the efficiency of driving. Current efforts looking towards this are mostly directed toward performance vehicles with a cosmetic and aerodynamic package attached to the body, commonly utilizing wings, canards, rear diffusers, and vortex generators to guide air in a path that reduces air resistance. These aerodynamic components, however, have not been applied to consumer vehicles in mass production. Research suggests that utilizing techniques to guide the air using wings, canards, rear diffusers, vortex generators, etc; drag coefficient differences are significant. Just using air dams on a luxury sedan vehicle proved an improvement in air flow by 19% along the body (Kang 2012). Full underbody covering provided a 17.78% increase in drag reduction, providing evidence to the simplicity of how car manufacturers can reduce emissions as well as gas efficiency (Katsoulos 2010).

Air resistance accounts for a very large portion of fuel efficiency. Aerodynamics proves of the utmost importance along the vector of wind resistance on fuel consumption. Utilizing computer simulations and following a constant trend of wind resistance and airflow, an extra 10 miles an hour will result in a 16% increase in wind resistance, creating a higher drag coefficient by 16% (Dayman, 1979). As a result of that 16% increase in highway speeds, gas mileage is reduced by 4.34%, with a 15 mph wind speed reducing gas mileage by 11.66%, providing evidence of the importance of good base aerodynamics (Dayman, 1979). Assuming a common MPG of 25, an extra 15 miles per hour wind would decrease that by around 2.9 miles per gallon, not accounting for natural fluctuations and speed resistance. As part of natural wind aerodynamic issues, the lack of underbody airflow as well as wheel well underbody drag causes high resistance as well as uplift of the body, which may in turn reduce traction and heighten the current drag coefficients of the car (Mokhtar and Pervez, 2012). A study based on the underbody drag of semi trucks provides evidence of the resistance's effect on vehicle performance utilizing a model truck as well as particle image velocimetry, a method using a laser to determine the movement of titanium dioxide gas, to determine the aerodynamic efficiency of the model. Resulting of this study was a heavy amount of air resistance stuck within wheel wells causing the highest drag coefficient, closely followed by a lack of airflow around axles and the crossing points of the subframe attached to the semi-trailer (Stephens et al., 2016). This study proves the importance of the physical limitations of a factory-built vehicle, exposing its lacking components. Using methods such as digital wind tunnels, wind tunnels, and simulations, a study from 2006 provides evidence as to the success of the efficiency and speed of Formula 1 racing vehicles, comparing the aerodynamic efficiency to the consumer as well as NASCAR vehicles. Designs such as open wheel wells and body inlets allow for a minimal amount of drag other than common surface wind resistance. A computational fluid dynamics (CFD) simulation, that in which the test uses a computer aided design (CAD) 3D model and computations to provide a simulation of drag as well as to predict the aerodynamics, provides evidence to suggest a far greater amount of underbody drag than that of an Formula 1 (F1) car due to the F1 implementation of smooth underbody panels. While the body shape of a Formula 1 car has a lower drag coefficient, the balancing of downforce utilizing front splitters and wings also provides evidence to suggest the importance of staying low to the ground when considering coefficients of drag (Katz, 2006). Underbody, as well as body drag, proves data of the air resistance issue, but a current overlooked issue involves low-pressure zones behind the vehicle, an area where air flow reverses upon lack of physical surface, resulting in a back force and increasing drag. This research provides evidence of the usefulness of rear diffusers and vortex generators to diffuse the air coming off the rear of the vehicle. This in turn will allow for air to linearize on a common line, diffuse and result in a smoother airflow and a far smaller low-pressure zone, reducing drag in totality (Nath et al., 2021).

Current aerodynamic efforts in consumer vehicles are very limited, resulting in a good-looking car but lacking in performance and functional aerodynamics. Recent research has proven numerous overlooked issues when considering the inefficiencies of common consumer vehicle designs such as underbody drag, wheel well air trap, lack of airflow, low-pressure zones, excessive uplift, excessive downforce, and many other factors involving high drag coefficients due to lack of design effort and/or manufacturing cost reduction at the cost of the consumer. The following study provides evidence as to how automobile companies may utilize aerodynamic components and design to reduce parasitic drag and increase fuel efficiency to help the environmental pollution issues and financial problems considering gas prices. This research may be applied to any vehicle as seen in the differing trials of drag measurements.

In the span of this research, the goal is to study the maximal effect on lowering drag coefficients to which modifying aerodynamic components can change. Within the research will be the utilization of CFD simulations and 3D modeling platforms such as Thingiverse to design variations of body variables and implementing aerodynamic changes in the form of vortex generators and a rear diffuser, followed by comparing the data to prove the hypothesis.

Within the CFD simulations will be a common sedan 3D model to determine an average effect on drag reduction along with describing the efficacy of aerodynamic components on the sedan body type. As seen in numerous studies conducted to research maximal efficacy aerodynamic models, a CFD simulation will provide the necessary information to conclude the research question: "What are the implications of aerodynamic components on exterior air flow of cars?". This data will be collected and organized into bar charts as well as computational charts to display the realistic impact on vehicle performance including total pressure, minimum total pressure, pressure drop, and average velocity. Along with this, the research conducted is supported by the external literature review above. The research provided will prove numerous trials as being effective or disadvantageous, exposing to the highest beneficial upgrade for manufacturers to make, benefitting the consumer with higher gas mileage, the manufacturer with higher pricing, and the environment with a reduction in carbon emissions[9].

Research Importance

Developing better aerodynamics for consumer vehicles may have a number of positive implications for both individuals and society as a whole. A car with better aerodynamics is able to move more easily through the air, which reduces the amount of energy required to maintain speed. This can also lead to significant fuel savings for individuals, which can result in both financial and environmental benefits. As vehicles use less fuel, they also produce fewer emissions.

This can help to reduce air pollution and improve public health, particularly in urban areas where vehicle emissions are a major contributor to poor air quality. Vehicles with better aerodynamics have a greater safety coefficient and are also often more stable on the road, which can help to reduce the risk of accidents (Englar 2001). By reducing the amount of fuel consumed by vehicles, better aerodynamics can help to reduce our dependence on fossil fuels, which are finite resources and contribute to climate change. Overall, developing better aerodynamics for consumer vehicles has the potential to bring significant benefits for individuals and society; also, being a key step towards a more sustainable transportation future.

Vehicle companies for years have been changing internal components with many benefits of efficiency, however, neglecting the airflow patterns in trade for the cost to the manufacturer. The following research will provide evidence of the environmental and social benefits of increasing fuel efficiency by utilizing aerodynamics. Studies of this information will be evidenced using tables and graphs comparing wind speed with the defined measurements at a surface level along with comparing the total pressure drop in the system as well as the negative drag resulting from the rear. This research will help save money on gas for the consumer, allow for a heightened purchasing price for the company, reduce carbon emissions per unit, and save fossil fuels.

Overview and Methodology

The following research will be conducted as an experimental study, digitally estimating drag as well as aerodynamic component's efficiency on a vehicle. Results shown compare fluid dynamics with realistic air resistance approaches. This study helps in proving the effectiveness of aerodynamic components on economy vehicles, however, failing to account for outliers such as divergent wind patterns, angular winds, suspension, engine power, weight, etc. The hypothesis for the simulation is that the addition of the diffuser and vortex generators will help linearize and increase airspeed, as well as reduce air resistance about the body of the car. The null hypothesis states that aerodynamic components will have no effect on air resistance or air direction.

To prove a hypothesis, the experiment will be conducted using the Ansys Fluid Flow Analysis simulation software as well as 3D computer aided design (CAD) models from Thingiverse, a free CAD model database. This methodology provides a feasible, accessible, as well as effective form of experimentation, allowing the data to be collected accurately due to the heavily studied technology put in the Ansys software, often used for industry engineering simulations. After simulated, using the flow marks about the vehicle and graphs providing aerodynamic efficiency, the data will be analyzed using a two sample F-test for variance.

The model for the base vehicle evaluated in the experiment, provided from Thingiverse, was an E36 Bmw (1990-2000), which uses a modern body style to help represent a general consensus of all sedans. This model was configured as four different stages, being a base model, without modifications, a model with a vortex generator, a model with a diffuser, and a model with both a vortex generator and a diffuser. The models for the aerodynamic components were also provided by Thingiverse creators and used in conjunction assuming logical proportions.

Using Ansys, the models were assessed in the Fluid Flow (Fluent) Analysis System, a simulation to predict likely aerodynamics regarding air speed, wind resistance and design, as well as calculating lines of drag and force of resistance. The models were then evaluated to certain values measuring drag at 15 mile an hour inlet air flow intervals between 15 and 75 MPH. This simulation allowed for me to see the lines of air flow as well as visually see the velocity of the wind about the body of the car. Using the digital Ansys simulation, I was able to analyze the data far greater than any other method by seeing how the wind interacts with the car as well as seeing the color differences to represent the pressures of air flowing. Along with these features, Ansys allowed for me to see the digital impact of the car's aerodynamics, representing flow lines to show its influence on the air flow from and to the environment.

Measurements used include coefficients of average air velocity, minimum and average total pressure about the vehicle, and the pressure drop of the system. The average air velocity measures the overall average velocity of the wind blowing around the vehicle. This measurement is attained by measuring the speeds of each line of wind flow, measuring how fast it goes, slowing the speed if there is more drag. A higher number will show a lower amount of drag on the body. The minimum total pressure is used to measure, in pascals, the reverse drag on the vehicle caused by air wrapping around the low-pressure zone and pulling the car back, away from the direction in which it is moving. A higher number is better due to the negativity of them. The average total pressure measures the drag forced on the car when moving forward. This measurement is gained from measuring the force in pascals to which the air hits the surface of the car. A lower number for this measurement is more favorable for a lower drag. The final measurement is the total pressure drop in pascals of the system. This takes into account the inlet air pressure and the outlet, finding the difference between the two. A higher number in this would be favorable for a lower drag. These measurements will be taken into account and compared using charts to display how each component affects the vehicle's aerodynamics.

A two variable F-test analysis for variation was used to assume the effectiveness of each addition on the vehicle, comparing initial pressure drop to the modified vehicle's pressure drop values. An F-test analysis was used because it can handle multiple variables as the research provides, as well as showing the variance in the data, evidenting to how much each component may affect the vehicle and to what extent it may benefit. The data was testes comparing the system pressure drop's, showing direct evidence as to how the car moves differently through air using components rather than how the air interacts with the car to show how each component increases the effective aerodynamics. This analysis uses a significance as a F-value of 0.05 or less, meaning that if the value is less than 0.05, the data was significant, would assess the importance of the data by comparing variances of values to produce an F value. This number will then help the data be assumed as valuable by claiming a value of 0.05 or less.

Results

Table. 1 This table shows the drop in pascals between the inlet and outlet air pressures, the average velocity of air moving around the vehicle, and average total pressure of air resistance on the body for the base model sedan at flow inlet speeds between 15 and 75.

Flow Inlet (Mph)	Pressure Drop (Pa)	Avg. Velocity (m/s)	Avg. Total Pressure (Pa)
75	68.7	31.4	467
60	44.3	24.8	293
45	25.5	18.6	163
30	11.8	12.2	70.6
15	3.3	6.0	17.1

Table. 2 This table shows the drop in pascals between the inlet and outlet air pressures, the average velocity of air moving around the vehicle, and average total pressure of air resistance on the body for the sedan with vortex generators at flow inlet speeds between 15 and 75.

Flow Inlet (Mph)	Pressure Drop (Pa)	Avg. Velocity (m/s)	Avg. Total Press (Pa)
75	70.3	32.3	520
60	45.5	25.8	331
45	26.9	19.3	186
30	12.7	12.8	82.5
15	3.45	6.28	20.2

Table. 3 This table shows the drop in pascals between the inlet and outlet air pressures, the average velocity of air moving around the vehicle, and average total pressure of air resistance on the body for the sedan with a diffuser at flow inlet speeds between 15 and 75.

Flow Inlet (mph)	Pressure Drop (Pa)	Avg. Velocity (m/s)	Avg. Total Press (Pa)

75	70.2	33.1	526
60	44.3	26.4	334
45	26.4	19.7	187
30	12.4	13.1	82.6
15	3.44	6.46	20.3

Table. 4 This table shows the drop in pascals between the inlet and outlet air pressures, the average velocity of air moving around the vehicle, and average total pressure of air resistance on the body for the sedan with the diffuser and vortex generators at flow inlet speeds between 15 and 75.

Flow Inlet (Mph)	Pressure Drop (Pa)	Avg. Velocity (m/s)	Avg. Total Press (Pa)
75	70.3	32.3	520
60	45.5	25.8	331
45	26.9	19.3	186
30	12.7	12.8	82.5
15	3.45	6.28	20.2

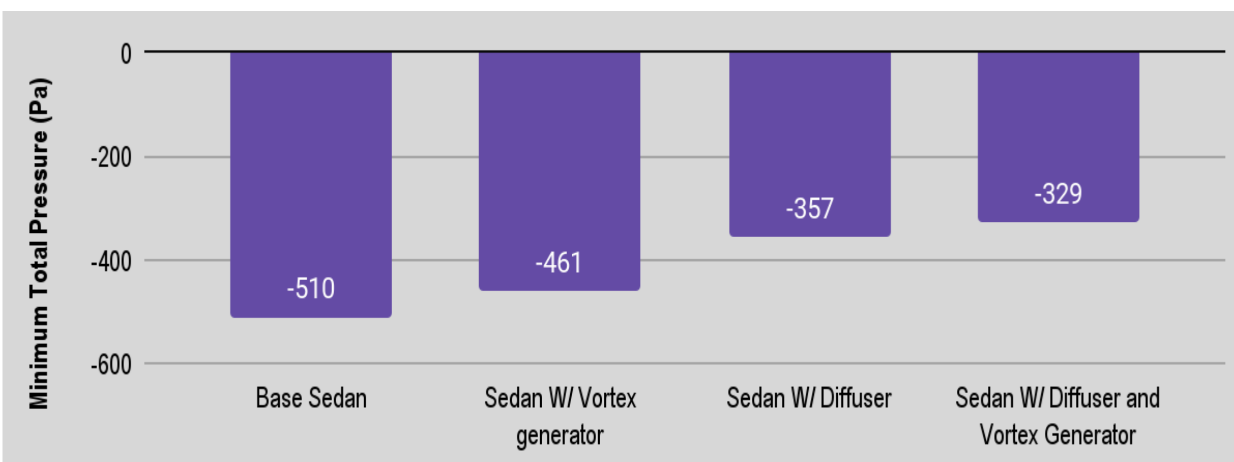

Figure. 1 This graph represents the minimum total pressure of all sedan models set at an inlet air velocity of 60 miles an hour to compare the effectiveness of the low pressure zone created behind the model.

Table. 5 This table shows the f-test analysis between the base model sedan and sedan with vortex generator's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop	*Pressure Drop W/ Vort*
Mean	30.72	31.77
Variance	691.27	715.62
Observations	5	5
df	4	4
F	0.9660	
P(F<=f) one-tail	0.4870	
F Critical one-tail	0.1565	

Table. 6 This table shows the f-test analysis between the base model sedan and sedan with vortex generators and diffuser's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop	*Pressure Drop W/ Diff + Vort*
Mean	30.72	32.89
Variance	*691.27*	*732.48*
Observations	*5*	*5*
df	4	4
F	0.9437	
P(F<=f) one-tail	0.4783	
F Critical one-tail	0.1565	

Table. 7 This table shows the f-test analysis between the sedan as a base model and the sedan with a diffuser's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop (Inlet-Outlet Press (Pa))	*Pressure Drop (Inlet-Outlet Press (Pa)*
Mean	31.77	31.348
Variance	715.6195	709.89952
Observations	5	5

df	4	4
F	1.00805745	
P(F<=f) one-tail	0.4969905965	
F Critical one-tail	6.388232909	

Table. 8 Table. 8 This table shows the f-test analysis between the sedan with both vortex generators and diffuser and the sedan with the diffuser's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop (Inlet-Outlet Press (Pa))	*Pressure Drop (Inlet-Outlet Press (Pa)*
Mean	31.348	32.886
Variance	709.89952	732.47648
Observations	5	5
df	4	4
F	0.9691772219	
P(F<=f) one-tail	0.4882614955	
F Critical one-tail	0.1565378117	

Table. 3 This table shows the f-test analysis between the sedan with the Wings and the Stock Sedan's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop (Inlet-Outlet Press (Pa))	*Pressure Drop (Inlet-Outlet Press (Pa))*
Mean	30.716	31.734
Variance	691.26628	714.36678
Observations	5	5
df	4	4
F	0.96766297	
P(F<=f) one-tail	0.4876754356	
F Critical one-tail	0.1565378117	

Table. 9 This table shows the f-test analysis between the sedan with both vortex generators and diffuser and the sedan with vortex generator's pressure drop values. This data represents the mean drop, variance, as well as importance values in terms of F.

	Pressure Drop Vort	*Pressure Drop W/ Diff+Vort*
Mean	31.77	32.89
Variance	715.62	732.48
Observations	5	5
df	4	4
F	0.9769	
P(F<=f) one-tail	0.4913	
F Critical one-tail	0.1565	

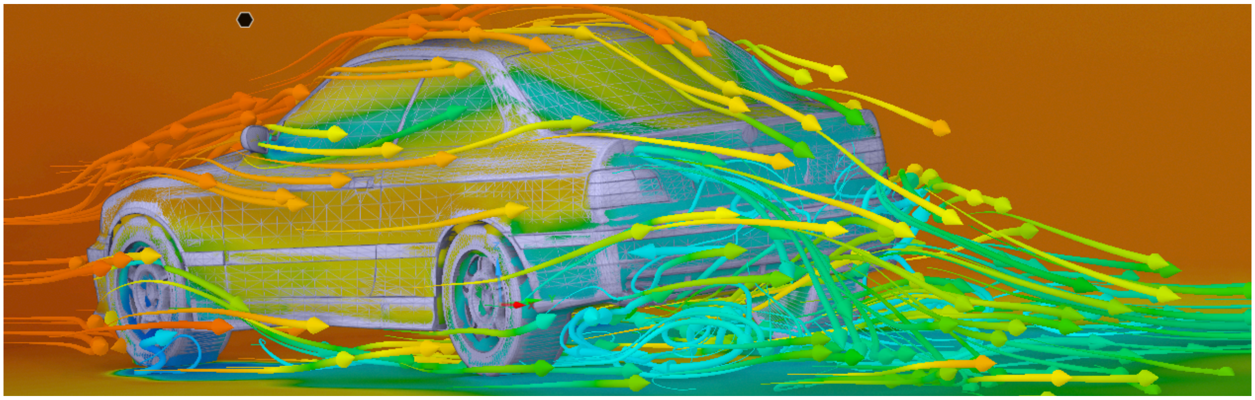

Figure. 2 This simulation shows the base model vehicle's aerodynamics and provides evidence to the shortcomings of the original design. It shows high measures of drag as well as large amounts of air vortexing and divergence.

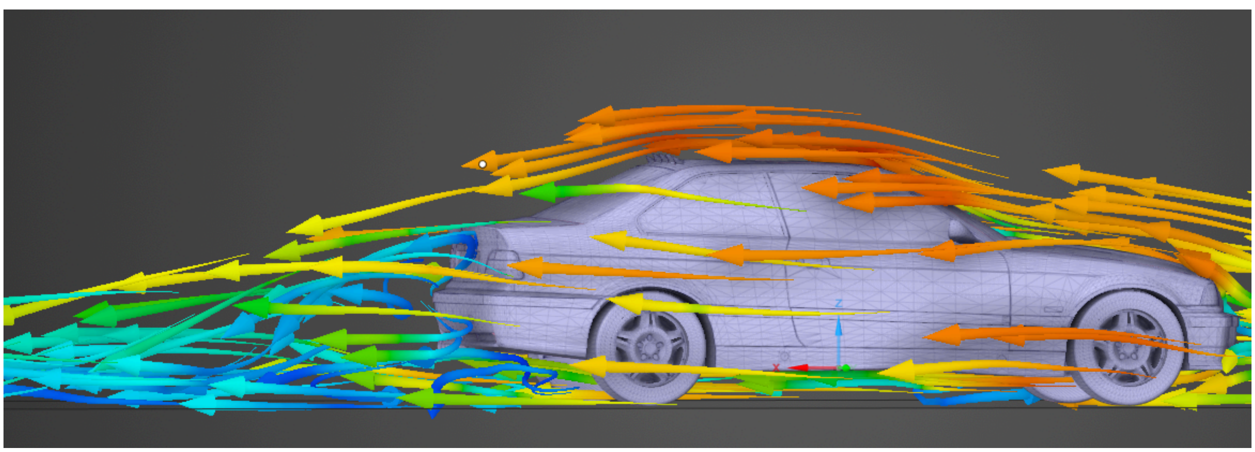

Figure. 3 This simulation shows the model with vortex generator's aerodynamics, displaying little air divergence as well as smoother flowing lines about the top of the vehicle, providing better aerodynamics.

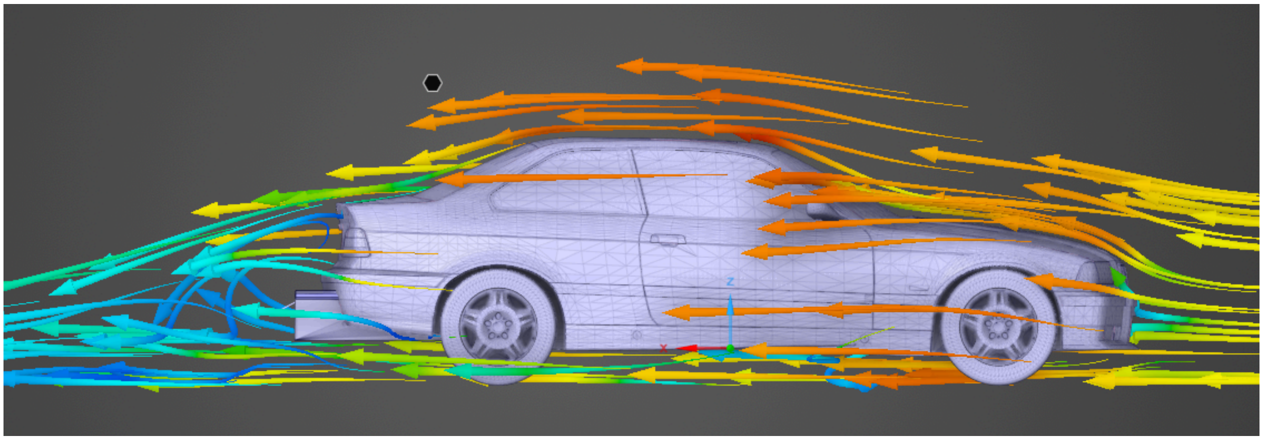

Figure. 4 This simulation shows the aerodynamics of the vehicle model with the diffuser attached only, showing smooth, fast-flowing lines about the entirety of the vehicle as well as no air divergence.

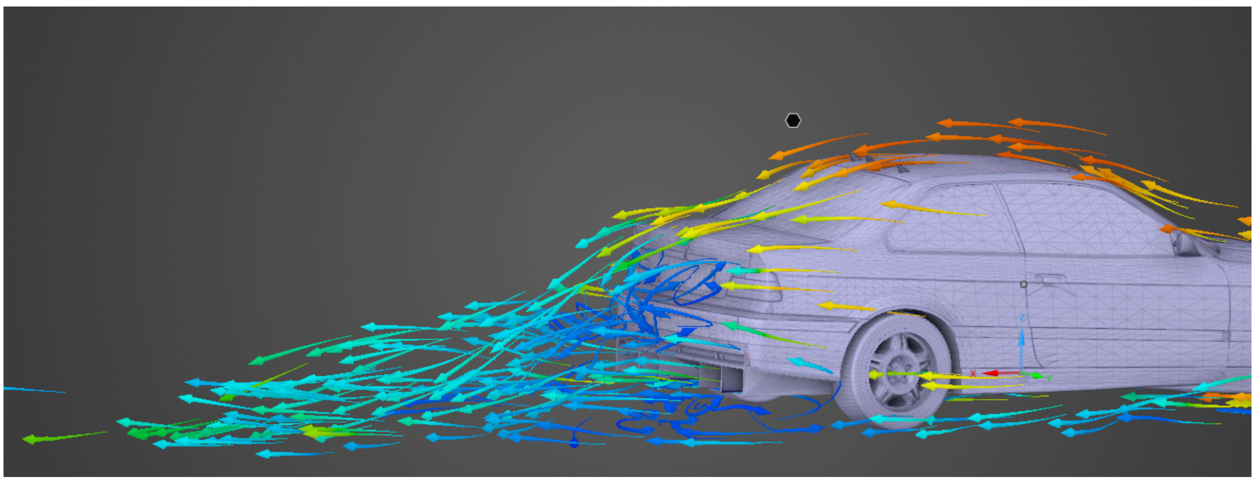

Figure 5 This simulation shows the aerodynamics of the model combining both aerodynamic components, the diffuser and the vortex generators. This model proves to have fast-flowing lines about the entirety of the vehicle as well as little air wrapping and little to none low-pressure zone.

Discussion

The data collected from the experiment proved the hypothesis that the aerodynamic components used, the diffuser and vortex generators, increased aerodynamic efficiency and helped airflow about the body of the vehicle to an extent. The values above, along with the two-sample F-test for variance show an increase in airspeed as well as a decrease in total pressure on the body of the car while maximizing the total minimum (negative) pressure. The data successfully proves the rejection of the null hypothesis.

Table 1, along with Figure 2 represents the sedan's base model efficiency and its analysis of aerodynamics. The data provided shows a low drop in pressure between inlet and outlet as well as a low average velocity and a high total pressure. Shown in the figure, a large cluster of reversing air flow can be seen behind the car representing a large low pressure zone and heavily diverging lines of drag. As seen, the aerodynamics can be assessed as very poor. Table 2 shows the data resulted from the simulations using only the vortex generators. This data proves an immediate increase in pressure drop, velocity, and total pressure. Along with this, it provides direct evidence to the importance of the addition, backed by a significance value of 0.0340, meaning that it is a significant change ($F<0.05$) in the data of aerodynamics for the model (Table 4). Along with a higher velocity of air, a result of this addition was a smaller low pressure zone, evidenced by graph 1, providing a higher minimum total pressure, which directs to a lessened pull from the rear of the vehicle.

The addition of the diffuser also resulted in an increase of aerodynamic efficiency, however, on a much larger scale. In comparing tables 2 and 3 independently to table 1, as well as evidence from graph 1, the benefits of the addition of components were much more prominent in the diffuser alone. The pressure drop and average total pressures were consistent, however, as a result of adding the diffuser to the base model, the average velocity as well as minimum total pressure were benefited to a higher extent. Along with this, figure 4 shows the lines of drag as being far smoother as well as bringing together a much smaller low pressure zone as well as a greater linearization in the air patterns. This overall brought a significance value of 0.008 as seen in table 7. The addition of the diffuser proves the hypothesis as well as proving the effects and benefits of aerodynamic components on vehicles.

The final data proved the effects of combining the rear diffuser with vortex generators and the advance in vehicle efficiency. Comparing table 1, table 4 and graph 1, as well as figures 2 and 5, the addition of both aero components provided results of the greatest pressure drop, the greatest minimum total pressure, and lowest average total pressure. Adding both components helped greatly in linearizing the wind patterns as well as providing a very small difference in the top and bottom pressures, reducing the low pressure zone and allowing for the finest air flow at the rear of the car. Using the f-test, the significance value proved that of 0.0231, proving the greatest significance of change within the research. Along with this, the data provided the greatest mean difference in pressure drops compared to table 1.

Limitations

With the use of simulations, the amount of limitations is very broad due to the thousands of factors contributing to overall drag and air resistance. A major limitation considering simulations is accurate scaling and proportions used for the CAD model, which may change the way air flows and catches on the body. Weight distribution and age of the vehicle may drastically affect the shape of the vehicle, how much force is applied on the top versus the bottom, the way one side moves versus the other, there are hundreds of possibilities considering this. Another limitation using a simulation for researching aerodynamics is constants, which in this case is the wind. Natural atmosphere has an unpredictable form which will push air from all directions at different pressures, again, affecting the aerodynamics far differently from constant air pressure. Ansys' fluid dynamics analysis simulation does account for this, partially, computing tens of different wind patterns from differing heights and spread pressures, averaging the data from each simulation, however, real world applications are not fully accounted. This data, however, proves a standard and basis of the aerodynamics of the model used, showing an increase in independent variables added or removed, making it an effective way to test for the efficiency of adding and removing components.

Further Work

Due to the limit in time as well as the many limitations of using a simulation, further work to be conducted would be a real-world application using variables on a car, taking data from a wind tunnel, average miles per gallon, and user experience using the car with and without the aerodynamic components. Work that could be conducted to apply a large effect in the world would be calculating, building, and testing a certain aerodynamic component to perfect the aerodynamics of a vehicle. Figuring out a basis as well as finding a pattern of current vehicle body aerodynamics to certain dimensions and angles of one component could be highly beneficial in world applications to increase range, fuel economy, car feel and speed.

Conclusion

Within this simulated research in comparing the aerodynamic efficiency of a car model to the addition of aerodynamic components, the null hypothesis was rejected, accepting that utilizing rear diffusers and vortex generators positively impacted the aerodynamic efficiency and air flow about the body model of the tested car. The greatest difference in the research was shown when both components were combined on one model, proving an increase in efficiency, minimizing the low pressure zone, and linearizing lines of drag to the highest degree of each test. In comparing the pressure drop of the inlet and outlet pressures, the average air velocity, and the average total air resistance pressure, the addition of both the vortex generators and the diffuser greatly increased the efficiency, aerodynamically speaking, to the base model. While the changes of the vortex generator provided a basis as a solid upgrade in aerodynamics, the diffuser proved to be a far more significant upgrade when considering the flow of air to decrease the limits of a car. An increase in aerodynamic factors within this research proved a benefit towards the efficacy of the body model of the car. This research may be used in the future to increase the range of vehicles, lowering costs of transportation, help in racing applications, and many other issues giving consideration to the path of air around an object and the reduction of wind resistance in any application.

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