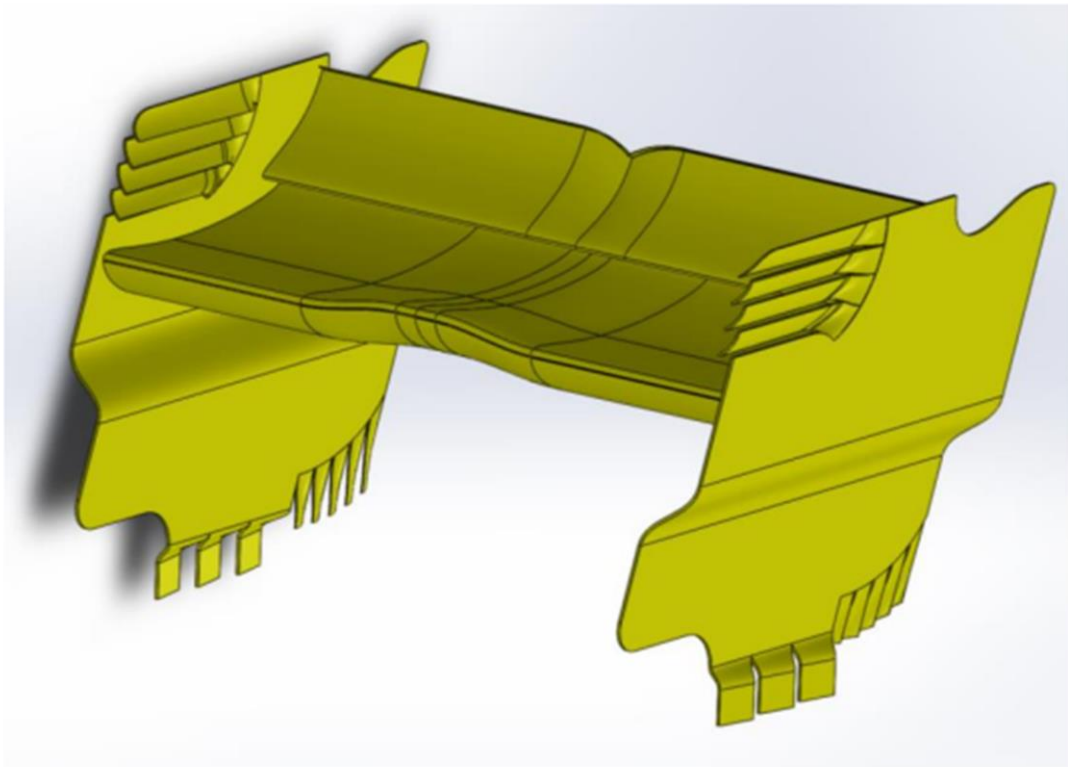


Designing a race car rear wing: Structural Design



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Introduction

The rear race wing stands out as a significant component that links mechanical creativity and aerodynamics in the context of motorsports, where minute variations can determine success (Collins, 2023). The race cars rear wing structural layout combines innovation and science, with form following function to improve performance (Collins, 2023).

This report will go into the fundamental elements that allow race cars to maintain grip on the track and manoeuvre through the air (Autosport, 2020). The report will go into detail and examine the structural design of the rear race wing. Sections of the report will discuss factors that affect material choice, geometrical arrangements, and mechanical interactions from the initial concept to manufacture (Campbel-Brennan, 2020). This is the point at which high-speed competitive demands and engineering converge.

The testing is also a key feature of design the rear race wing. It is important to understand the relevance of the environment the wing will be performing under (Easy composites, 2023). Testing can be carried out in multiple different scenarios such as destructive and non-destructive, where non-destructive is situations such as wind tunnel testing and CFD (Noble, IA assessing F1 rear wing flexibility test changes, 2020)

In relation to other sections of the document-it will go into detail on understanding the rear race wing's architectural essence as a symbol of controlled forces, equilibrium, and conquering obstacles (Vardhan, 2023). Development is key to understanding of a greater grasp of the engineering that controls the interaction of speed, downforce, and control on the racetrack and the complexities of design and innovation (Mitchell, 2023).

1. Discussing FEA optimisation techniques.

What is FEA?

FEA or finite Element Analysis utilises a numerical methodology (Brush, finite element analysis (FEA), 2019), is used in FEA. It divides an object's structure into several components, or elements, and then links the elements at nodes (Brush, finite element analysis (FEA), 2019). Engineers, programmers, and other designers can use the algebraic equations produced by the FEM to carry out finite element analysis. Parametric and non-parametric approaches to optimisation are also available (sdcverifier, 2023). With parametric, the software automatically determines that the natural design relates to the ability to handle big weights while minimising expenses (sdcverifier, 2023). The main benefit of this strategy is the ability to begin modelling from scratch without any original concept (Costen, 2019). Let's say that the best design relative to the beginning position must be picked. In that situation, it is necessary to choose several crucial factors or design variables and establish an acceptable range for each (Pretechnologies, 2023). The best design is then discovered using a parametric approach, where each parameter is modified within the allowed range (Pretechnologies, 2023). Like this, the final volume is minimised while the structural metrics are optimised.

History of FEA and what the future holds

Finite Element Analysis (FEA) was generally regarded to have started in the late 1800s, when John William Strutt Rayleigh created a method for forecasting the first natural frequency of simple structures (Tipton, 2017). Although there is no exact date for when FEA was originally invented, it is believed that this was the time (Tipton, 2017). Differential equations created in the 17th and 18th centuries were used to quantitatively describe the physical behaviour of structures (esrd, 2023). For instance, the differential equation for flexural beams and, consequently, the deformation and stress brought on by external loads, are provided by von Cauchy's theory of elasticity (esrd, 2023). NASA provided funding for Dick MacNeal's research in 1965 to create NASTRAN, a more competent FEA software programme (simscale, 2023). The development of this programme cost \$3,000,000, or almost \$30,000,000 in today's currency (simscale, 2023). Just by seeing this funding back during the 60's shows that FEA was really starting to provide substantial results when using the software.

Fast forward to the 21st century where FEA is used in practically any application. Some but not all uses of FEA are to test safety of products, performance of components such as a F1 racing wing or to evaluate components (formula1-dictionary, 2023) before final production starts. In relation to formula 1, FEA plays a huge role in gaining an edge against others. "When a structure is being planned, Finite Element Analysis enables computer-based evaluation of a complicated and intricate structure" (martins-rubber, 2020). The software allows for detailed optimisation to a component to show its potential when different parameters are applied (martins-rubber, 2020). There are two main types of optimisations within FEA. One being parametric-When using parametric optimisation, the natural shape is automatically identified by software as pertaining to heavy load carrying capacities while maintaining the expenses at a minimum (machinedesign, 2002). A primary positive of using parametric optimisation is that they frequently require less data to obtain a specific degree of accuracy because of the assumptions they make (machinedesign, 2002). Another promising advantage of this type of optimisation is that the use of this tool is that it allows the creator to start from scratch (machinedesign, 2002) as mentioned previously due to the minimal information required to set up a model. If the design doesn't need to be any specific standard requirements, then this is one of the most efficient ways to start (linkedin, 2023). In relation to non-parametric optimisation, this allows the user to increase overall Performance on a design that already has some

constraints that must be followed (linkedin, 2023). In a scenario such as designing a formula 1 wing, there are certain rules that must be adhered to (Boxall-Legge, 2023).

For example, some constraints are applied, such as the final flex should not exceed 3mm of flex (Somerfield, What's changed with F1's new rear wing deflection tests, 2022). " Studies have shown that non-parametric perform better on large datasets and are more flexible" (Somerfield, What's changed with F1's new rear wing deflection tests, 2022) knowing this means that large data requirements aren't going to negatively affect the outcome when large data sets are needed. Although in some cases some non-parametric models require large data inputs to get valid results unlike parametric (Somerfield, What's changed with F1's new rear wing deflection tests, 2022). This is when non-parametric is more suitable to this application of designing a F1 race wing.

With technology advancing along with softwares, FEA will become commonly used thanks to the power of A.I (artificial Intelligence) (enteknorate, 2023) predicting the behaviour of a structural or mechanical system under various conditions by learning from prior simulation data (enteknorate, 2023). By having A.I incorporated within FEA programmes it can greatly reduce simulations times and potentially offer more predictions when it comes to sampling and testing of components (enteknorate, 2023). Although it seems finite element analysis is for high performance product and components with highly technical specifications, the possibilities to use the software is becoming more popular. FEA is now being used in the bio-medical industry to test prosthetic limbs and implants to improve comfort and performance (exponent, 2023). The software has a very positive future ahead in product design and is constantly being revised and updated to allow the software to gain improved accuracy and efficiency (exponent, 2023). FEA is now also found to be branching more and more into the world of nanotechnology (Chandran, 2020).

The software has created some major breakthroughs within the industry thus showing how versatile its becoming (gmtrubber, 2023). With nanotechnology slowly being collaborated with polymers it may potentially have a role to play within the world of Formula 1! (Tibu, 2016).

2. Creating a model using design studio.

Below shows a F1 race wing going under a simulation process within DesignStudio. Pictured below is the start process of the putting a wing through simulation. By applying the below parameters, it will turn the material of the wing into carbon fibre.

Young's Modulus in the longitudinal direction (E₁): 132 GPa

Young's Modulus in the lateral direction (E₂): 10.8 GPa

Poissons Ratio (Nu_12): 0.24

Inplane Shear Modulus (G_{12}): 5.65 GPa

Transverse Shear Modulus (1-Z plane) (G_{1z}): 5.65 GPa

Transverse Shear Modulus (2-Z plane) (G_{2z}): 5.65 GPa

Mass Density (Rho): 1540 kg/m³

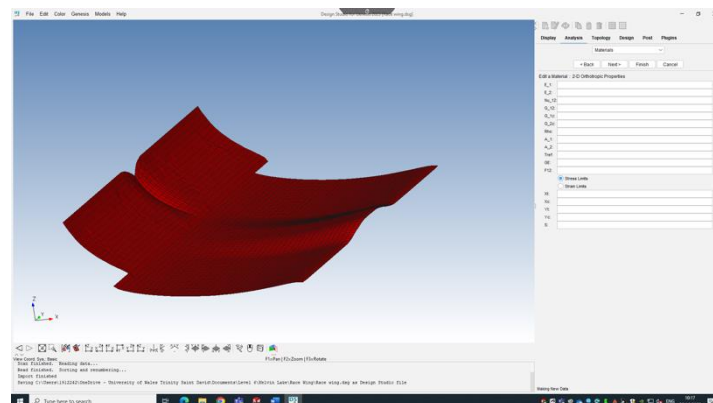
Allowable longitudinal stress in tension (Xt): 1513 MPa

Allowable longitudinal stress in compression (X_c): 1000 MPa

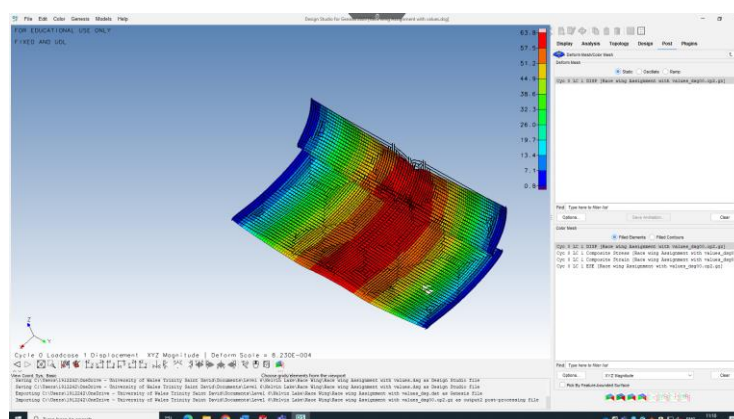
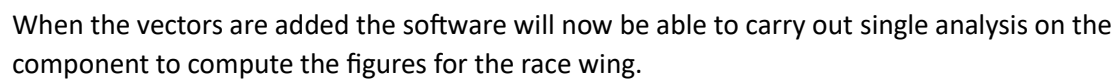
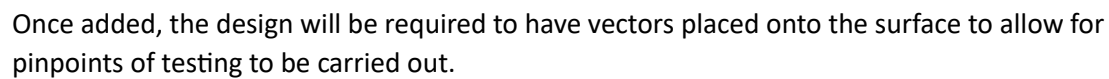
Allowable transverse stress in tension (Y_t): 43.4 MPa

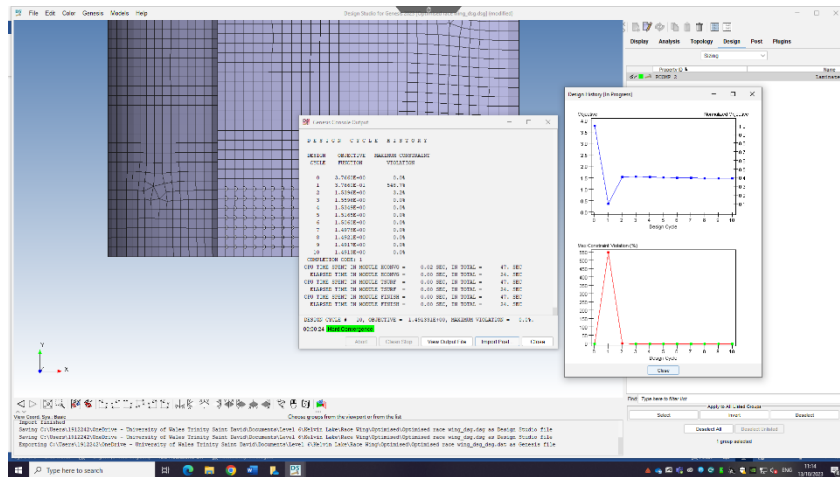
Allowable transverse stress in compression (Y_c): 43.4 MPa

Allowable inplane shear stress (S): 43.4 MPa



Once added the material will then be ready for testing.





It can be no seen that once the figures were applied to the wing it was found that it had hard convergence.

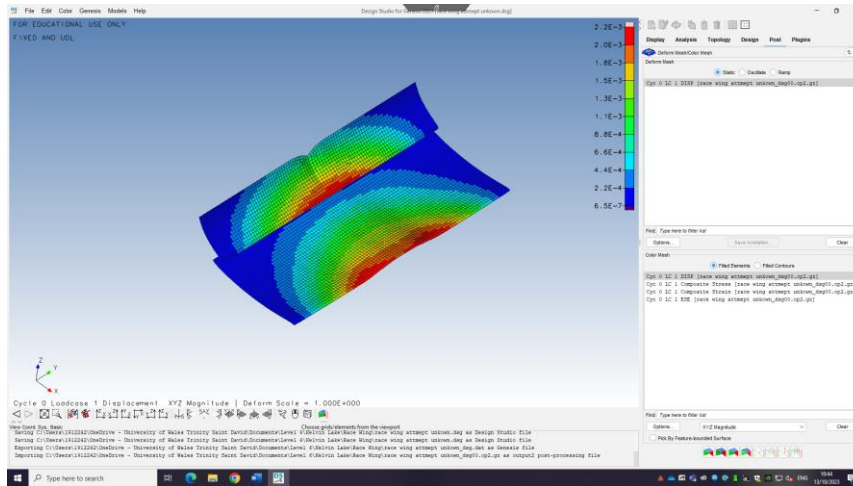
3.Optimising the model's structure.

Optimising the rear race wing was carried out by carrying out some research regarding how the wing performs, how they test the characteristics of the race wing and what the wing undertakes when performing on the track. These characteristics are variables such as the force acting down, the weight across the wing and the and how the material of the wing (carbon fibre) act when its run through different simulations.

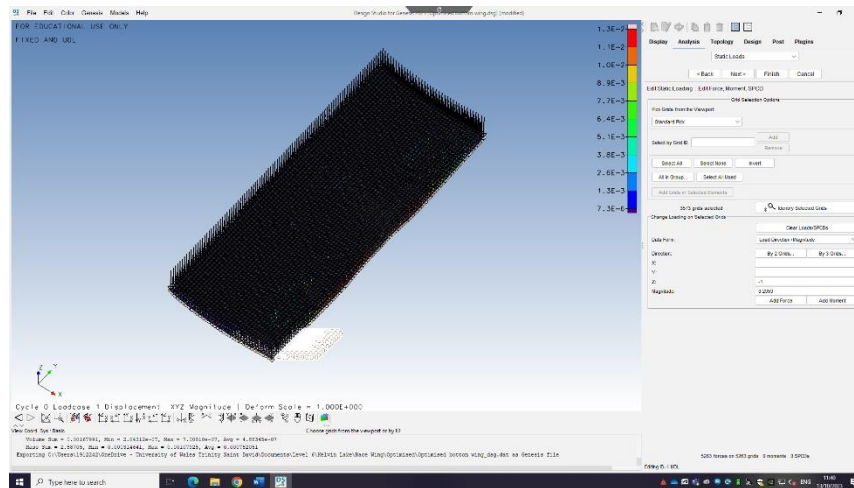
Relating the wing to current day formula 1 regulations there are some steps that needed to be taken into consideration when testing the wings performance. As mentioned above this is carried out by a force test (16). "The first test demands that the rear wing must deflect no more than 7mm horizontally when a 500N load is applied horizontally" (16) and "The second test demands that the rear wing can deflect no more than 2mm vertically when a 200N load is applied vertically" (16). These tests are carried out to ensure that all teams are on a level playing ground and that no one can outperform one another to gain an edge (17).

When it comes to applying the parameters to do the wing, what was changed was the force acting down (horizontally), this being the applied for 500n with the maximum load of 500N. Below are also the set boundaries for this simulation. Note that the lower boundary is set to 0.1mm which is specified within the assignments request.

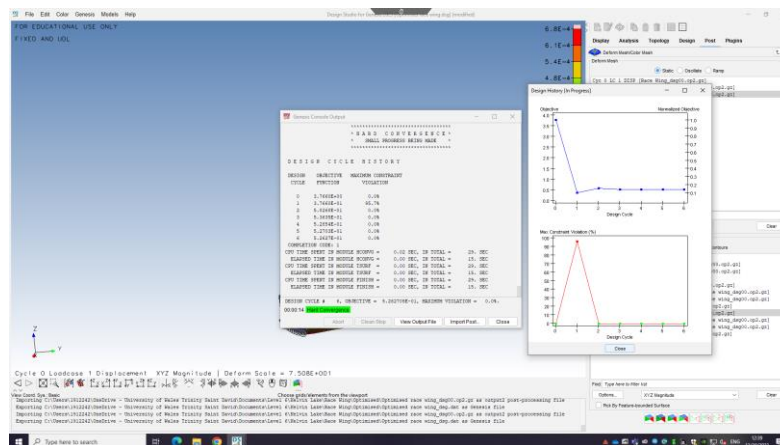
Variable Name	Initial Value	Lower bound	Upper Bound	Description
L1THK	1mm	0.1mm	3mm	thickness of layer 1
L2THK	1mm	0.1mm	3mm	thickness of layer 2
L3THK	1mm	0.1mm	3mm	thickness of layer 3
L4THK	1mm	0.1mm	3mm	thickness of layer 4
L5THK	1mm	0.1mm	3mm	thickness of layer 5



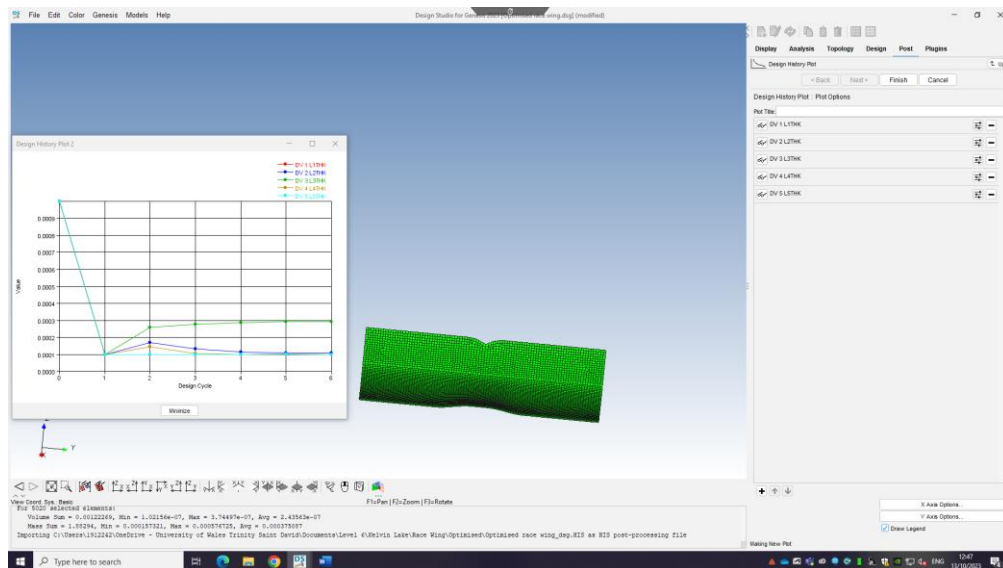
As seen pictured above with the correct figures applied, the wing had a maximum bend of 2.2 mm. Next will be the wing with the applied load of 500N in the horizontal plane.



Pictured above shows where and how the forces have been applied. It can be seen that the max deflection is 13mm which in total is 5mm over what the F1 regs states.



After altering the figures, the wing now has a maximum bend of 6.8e-4 which is well within the regs of the formula 1 rules.



Finally, by using the above graph it allows us to physically see how each individual layers reacted when the rear wing was put through genesis how the variables changed each layer.

4. Discussing experimentation techniques.

During development of components testing is crucial to increase performance and possibly decrease the overall cost of the project. Below can be found crucial steps to take to create an ideal test scenario.

Prototype Preparation

Building to prototype is essential to starting the experiment. It is crucial to ensure that the correct parameters have been included within a design to ensure that when the real testing commences the correct values can provide reliable results. Once this is done, the team carrying out the testing can then produce a physical wing that can be used for testing and collection of data.

Laboratory Setup

The set up of the test should be carried out in a controlled laboratory environment equipped with the necessary equipment and instrumentation. A rig must then be used that can hold the wing firmly and can withstand the force of 500 newtons. Lastly it is important to ensure that the measurement of the deflection can be measured accurately. This can be carried out by using correct measuring instruments such as strain gauges, displacement sensors and other instrumentation that can be relevant to this situation.

Data Acquisition

To obtain the best possible data, there are positions that the measuring instruments must be placed. In this scenario the instruments must be placed at the edge of the wing as this is here the deformation will occur. To ensure the data is as accurate as possible it is good practice the make sure that they tools have been calibrated to the manufacture's specification. When applying the force ensure that its being applied correctly and apply it gradually as a sudden application of force may snap the rear wing. A sudden application of force wouldn't happen in real world circumstances. Once the forces applied have been applied ensure proper recording of data for later conclusions.

Safety Measures

It is always good practice to warrant good health and safety when carrying out any form of testing. Applying high forces may potentially cause sudden and severe shattering in which case if good health and safety is practiced then minimal accidents can occur.

Data Comparison

Once a good range of data has been recorded, the next step is to compare the data to the simulation that was run during the first steps of the test. Virtual testing can provide a good base of what may potentially happen to the model but in real world, the material used to make the wing may have some defects which could cause a completely different reaction as what happened during the simulation. If the data collected from the simulation is related to the physical test carried out, then the material selected has been successful and will allow the next step of the testing to be carried out.

As we are in the 21st century measuring equipment such as displacement sensors and strain gauges are electronic meaning that they are hard wired into computers which will generate live graphs whilst the test is occurring. By having this setup, it will prove the engineers with solid and accurate information regarding the test.

Data Analysis

Referring to the maximum deflection being 7mm, it is important that the wing doesn't exceed that limit as it states in the Formula 1 regulations that a rear race wing must not exceed 7mm when a load of 500 newtons is applied horizontally.

Iteration and Optimisation

If the results received from the test don't correlate back to the simulated results, then compulsory changes must take place to make industry standards. As a simulation will produce ideal figures - understandably it's not always possible to replicate but if the standards are to be adhered to then the real-world test results must as identical as possible.

Documentation

Once all data has been collected it is important to clearly and completely describe the experiment's methods, data, and results, including any variations from the simulation.

5. Relating created model to standards set in the real world.

The created model has been done by following the formula 1 regulations of the most recent changes. In order to compete the teams must adhere to the set rules that have been put in place by the F1 governing body. If not, then teams have the potential to gain extra advantages over their opponents (Straw, 2023). Formula 1 is a highly competitive sport where teams are always looking for an advantage in competition (Straw, 2023). By placing restrictions on what teams may do in terms of design and technology, regulations ensure fair competition (Somerfield, How F1's new rules era has impacted front wing philosophy, 2023). Teams may perform very differently if their rear race wings were designed in an unrestricted manner, which could hurt the sport's ability to compete (Somerfield, How F1's new rules era has impacted front wing philosophy, 2023).

Another key point to be made is safety. Understandably the teams would want to design a race wing that is as light as possible to reduce overall weight of the car. By looking at the simulated results within this report it can physically be seen that a lighter wing will increase the flex as the wing doesn't have enough rigidity to withstand some of the forces these wings undergo (Noble, Flexi-wing push motivated by weight saving - Alpine, 2021).

When it comes into the testing structure of the rear wing, carry out data collection on software will allow teams to get a good idea on how their finished component may act in the rear world (Szczygiel, 2022). Similarly, as used above, design studio was utilised to physically see the extremities a rear race wing could potentially undergo when used on a racetrack. By using these techniques, it allows teams to save money by creating a model before spending costly amounts on create the physical wing (electronicsforu, 2013)

Conclusion. (ADD SOURCES, CURRENTLY NO SOURCES IN THE CONCLUSION)

Finite Element Analysis (FEA) is revealed as a crucial tool in the complex field of Formula 1 rear wing design, to sum up. These wings are essential for maximising speed, stability, and safety on the track; they are more than just aerodynamic elements (Brush, finite element analysis (FEA), 2023).

Engineers may analyse and comprehend the complex problems related to these components using FEA (Brush, finite element analysis (FEA), 2019). Finite Element Analysis assists in the investigation of intricate fluid-structure interactions by determining how air currents place stresses and pressures on the surfaces of the wing. Teams can adjust the size, angles, and components of the rear wing for optimum performance by simulating these scenarios. This optimisation includes structural integrity in addition to aerodynamics.

Along with downforce generation, rear wings must be able to endure tremendous forces generated by braking and turning at high speeds (continentalautosports, 2023). The FEA contributes to making sure that these wings are not just lightweight but also strong and able to handle the demanding requirements of Formula 1 racing. Additionally, FEA supports iterative design processes, allowing teams to experiment with various changes and swiftly assess their impact (Sloan, 2008). This iterative process enables ongoing innovation and refinement in rear wing design. In the end, FEA gives Formula 1 teams the freedom to push the limits of safety and performance, aiding in the continued development of this legendary race (Sloan, 2008). The FEA will stay at the vanguard of Formula 1 engineering as technology develops, driving teams to ever-greater successes on the racecourse.

References

- Autosport. (2020, May 21). *How does a Formula 1 car work? Wings, diffusers and more explained*. Retrieved from Autosport: <https://www.autosport.com/f1/news/how-does-a-formula-1-car-work-wings-diffusers-and-more-explained-4982275/4982275/#:~:text=The%20rear%20wing&text=When%20activated%2C%20the%20system%20lifts,boost%20to%20the%20top%20speed.>
- Boxall-Legge, J. (2023, July 31). *AlphaTauri reveals extreme interpretation of F1 rear wing rules*. Retrieved from autosport: <https://www.autosport.com/f1/news/alphatauri-reveals-extreme-interpretation-of-f1-rear-wing-rules/10498114/#:~:text=The%20FIA%20regulations%20governing%20the,with%20no%20remaining%20overlapping%20surfaces.%22>
- britannica. (2018, June 17). *Wind Tunnel*. Retrieved from britannica: <https://www.britannica.com/technology/wind-tunnel/additional-info#history>
- Brush, K. (2019, November). *finite element analysis (FEA)*. Retrieved from TechTarget: [https://www.techtarget.com/searchsoftwarequality/definition/finite-element-analysis-FEA#:~:text=Finite%20element%20analysis%20\(FEA\)%20is,vulnerabilities%20in%20their%20design%20prototypes.](https://www.techtarget.com/searchsoftwarequality/definition/finite-element-analysis-FEA#:~:text=Finite%20element%20analysis%20(FEA)%20is,vulnerabilities%20in%20their%20design%20prototypes.)
- Brush, K. (2023, October 15). *finite element analysis (FEA)*. Retrieved from techtarget: [https://www.techtarget.com/searchsoftwarequality/definition/finite-element-analysis-FEA#:~:text=Finite%20element%20analysis%20\(FEA\)%20is,vulnerabilities%20in%20their%20design%20prototypes.](https://www.techtarget.com/searchsoftwarequality/definition/finite-element-analysis-FEA#:~:text=Finite%20element%20analysis%20(FEA)%20is,vulnerabilities%20in%20their%20design%20prototypes.)
- Campbel-Brennan, J. (2020, February 4). *How to Design a Rear Wing*. Retrieved from LinkedIn: <https://www.linkedin.com/pulse/what-makes-effective-rear-wing-iterative-design-campbell-brennan>
- Cavanaugh, M. (2020, September 15). *Wind Tunnel Testing Doesn't Have to Cost Millions of Dollars*. Retrieved from LinkedIn: <https://www.linkedin.com/pulse/wind-tunnel-testing-doesnt-have-cost-millions-dollars-mike-cavanaugh#:~:text=Similar%20to%20home%20insurance%2C%20a,significant%20technical%20or%20safety%20risk.>
- Chandran, R. (2020, June 15). *Finite Element Analysis in Nanotechnology Research*. Retrieved from intechopen: <https://www.intechopen.com/chapters/73935>
- Collins, S. (2023, August 17). *DRS: The Drag Reduction System explained*. Retrieved from Race Car Engineering : <https://racecar-engineering.telegraph.co.uk/articles/f1/drs-the-drag-reduction-system/>
- continentalautosports. (2023, October 15). *What is Downforce?* Retrieved from continentalautosports: <https://www.continentalautosports.com/ferrari-information/what-is-downforce/>
- Costen, E. (2019, May 15). *Design Optimization with FEA | Deliver Cost Effective Solutions*. Retrieved from asrengineering: <https://asrengineering.com/2019/05/15/design-optimization-with-fea/#:~:text=Design%20optimization%20is%20one%20of,and%20attain%20desirable%20performance%20attributes.>

- Easy composites. (2023, August 17). *Motorsport rear wing destruction test* . Retrieved from Easy Composites : <https://www.easycomposites.co.uk/learning/motorsport-wing-destruction-test>
- electronicsforu. (2013, May 23). *Simulation Before Prototyping*. Retrieved from electronicsforu: <https://www.electronicsforu.com/buyers-guides/simulation-before-prototyping>
- enteknorate. (2023, October 15). *Integrated Artificial Intelligence (AI) & Machine Learning - Deep Learning with CFD & FEA Simulation*. Retrieved from enteknorate: <https://enteknorate.com/artificial-intelligence-cae-simulation-ai-ml-cfd-fea-machine-learning/>
- esrd. (2023, October 15). *A Brief History of FEA*. Retrieved from esrd: <https://www.esrd.com/simulation-technology/brief-history-of-fea/>
- exponent. (2023, October 15). *Finite Element Analysis for Medical Devices & Biomaterials*. Retrieved from exponent: <https://www.exponent.com/capabilities/finite-element-analysis-medical-devices-biomaterials>
- formula1-dictionary. (2023, October 15). *FEA - Finite Element Analysis*. Retrieved from formula1-dictionary: <https://www.formula1-dictionary.net/fea.html>
- gmtrubber. (2023, October 15). *The Advantages of Finite Element Analysis2023*. Retrieved from gmtrubber: <https://www.gmtrubber.com/finite-element-analysis/>
- linkedin. (2023, October 15). Retrieved from linkedin: <https://www.linkedin.com/advice/3/what-some-common-tools-methods-performing>
- machinedesign. (2002, November 15). *Parametric FEA*. Retrieved from machinedesign: <https://www.machinedesign.com/3d-printing-cad/article/21812801/parametric-fea>
- martins-rubber. (2020, March 20). *How our Finite Element Analysis testing is used in the motorsport industry*. Retrieved from martins-rubber: <https://www.martins-rubber.co.uk/blog/finite-element-analysis-in-motorsport/>
- Mitchell, S. (2023, August 17). *How AWS Optimize F1 aerodynamic geometries via Design of Experiments and machine learning*. Retrieved from RaceCar Engineering: <https://racecar-engineering.telegraph.co.uk/articles/optimize-f1-aerodynamics-using-machine-learning-and-design-of-experiments/>
- NASA. (2023, October 13). *What Are Wind Tunnels?* Retrieved from NASA: <https://www.nasa.gov/learning-resources/for-kids-and-students/what-are-wind-tunnels-grades-k-4/#:~:text=Wind%20tunnels%20are%20large%20tubes,models%20of%20aircraft%20and%20spacecraft.>
- Noble, J. (2020, July 17). *IA assessing F1 rear wing flexibility test changes*. Retrieved from Auto Sport: <https://www.autosport.com/f1/news/fia-assessing-f1-rear-wing-flexibility-test-changes-4981060/4981060/>
- Noble, J. (2021, June 5). *Flexi-wing push motivated by weight saving - Alpine*. Retrieved from Motorsport: <https://www.motorsport.com/f1/news/flexi-wing-push-weight-saving-alpine/6536116/>

- Pretechnologies. (2023, September 1). *Advantages of finite element analysis (FEA)*. Retrieved from pretechnologie: <http://www.pretechnologies.com/services/finite-element-analysis/advantages>
- sdcoverifier. (2023, September 1). *Why do you need to optimize your FEA model?* Retrieved from sdcoverifier: <https://sdcoverifier.com/articles/why-do-you-need-to-optimize-your-fea-model/#:~:text=Optimization%20in%20finite%20elements%20is,Shape%20and%20Sizing%20Optimization%20examples>
- simscale. (2023, October 15). *What Is FEA | Finite Element Analysis?* Retrieved from simscale: <https://www.simscale.com/docs/simwiki/fea-finite-element-analysis/what-is-fea-finite-element-analysis/>
- Sloan, J. (2008, May 1). *Formula 1 team accelerates design-to-track speed*. Retrieved from compositesworld: <https://www.compositesworld.com/articles/formula-1-team-accelerates-design-to-track-speed>
- Somerfield, M. (2022, June 30). *What's changed with F1's new rear wing deflection tests*. Retrieved from autosport: <https://www.autosport.com/f1/news/whats-changed-with-f1s-new-rear-wing-deflection-tests/10330470/#:~:text=The%20new%2C%20more%20stringent%20tests,of%20the%20local%20trailing%20edge>.
- Somerfield, M. (2023, January 20). *How F1's new rules era has impacted front wing philosophy*. Retrieved from Autosport: <https://www.autosport.com/f1/news/how-f1s-new-rules-era-has-impacted-front-wing-philosophy/10422705/>
- Straw, E. (2023, September 8). *EVERYTHING YOU NEED TO KNOW ABOUT F1'S WING RULES CLAMPDOWN*. Retrieved from The Race: <https://www.the-race.com/formula-1/everything-you-need-to-know-about-f1s-wing-rules-clampdown/#:~:text=It's%20well%20known%20that%20flexible,speed%20to%20high%20speed%20corners>.
- Szczygiel, S. (2022, February 26). *Design and strength analysis of the rear wing of a Formula 1 car*. Retrieved from LinkedIn: <https://www.linkedin.com/pulse/design-strength-analysis-rear-wing-formula-1-car-szymon-szczygie%C5%82>
- Tibu, F. (2016, May 24). *F1 Nanotechnology Arriving in MotoGP?* Retrieved from autoevolution: <https://www.autoevolution.com/news/f1-nanotechnology-arriving-in-motogp-107777.html>
- Tipton, R. (2017, January 4). *A Brief History of Finite Element Analysis*. Retrieved from nlsde: <http://nlsde.com/2017/01/04/a-brief-history-of-finite-element-analysis/#:~:text=FEA%20was%20developed%20in%20the,Clough%2C%20H.C>.
- Vardhan, H. (2023, March 4). *The Aerodynamics of an F1 Rear Wing*. Retrieved from LinkedIn: <https://www.linkedin.com/pulse/aerodynamics-f1-rear-wing-harsha-varadhan#:~:text=The%20rear%20wing%20is%20a,ways%20to%20improve%20its%20performance>.
- Wind Tunnel's In Formula 1*. (2023, February 12). Retrieved from WheelSports: <https://wheelsports.co/wind-tunnels-in-formula-1/#:~:text=Wind%20tunnels%20in%20Formula%20One,would%20experience%20during%20a%20race>.

