CFD Analysis of a Formula One Car to Determine the Halo's Affect on the Car's Performance

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Introduction

In 2018, Formula One mandated that the halo, a ring-shaped frame mounted above the driver's head in the cockpit, be implemented to increase drivers' safety. Critics worried that the halo would impede driver's vision or even be an eyesore to fans; however, the increase in safety was severe enough that it could not be ignored. Instead of discussing the known safety metrics of the halo, the goal of this project was to see how the halo impacts the car's performance. Using a computational fluid dynamics (CFD) simulation, the halo's aerodynamic effects were determined without need for a complicated experimental setup.

Methods

For this test, two CAD models were used. The first was a model of a 2021 Formula One car containing a halo. The second was an identical model except the halo was removed and the resulting gaps were filled in. Additionally, the models were split in half since according to symmetry, the aerodynamics of the car are identical on either side of its midplane. Cutting the model in half simplifies the test and shortens its run time. The program SimScale, a computer-aided engineering cloud-based software was used for the CFD simulation. Identical fluid flow regions were created in the form of a box around the car to simulate a wind tunnel, and identical meshes were created around the two models through which the computer can analyze the movement of air. The simulation is set up as a steady state test where the car is neither accelerating nor turning. The speed is set to 85 m/s, the speed of a Formula One car on a straight.

Results

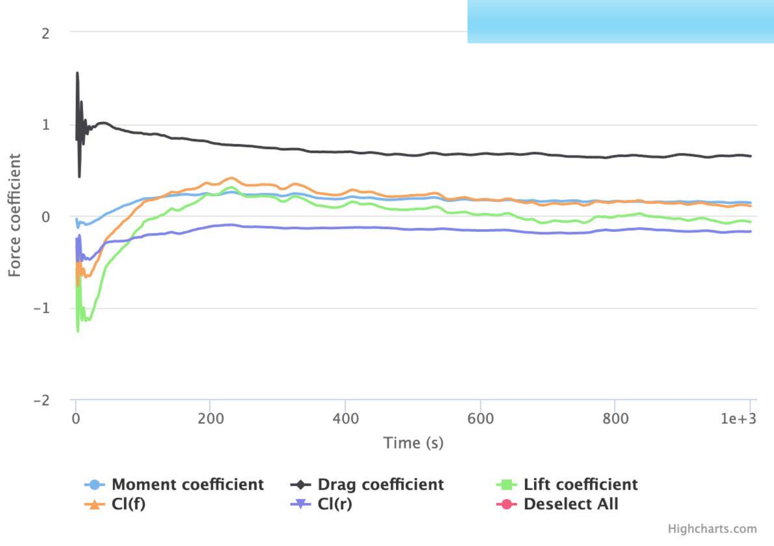

Figure 1: Force coefficients for f1 car with halo

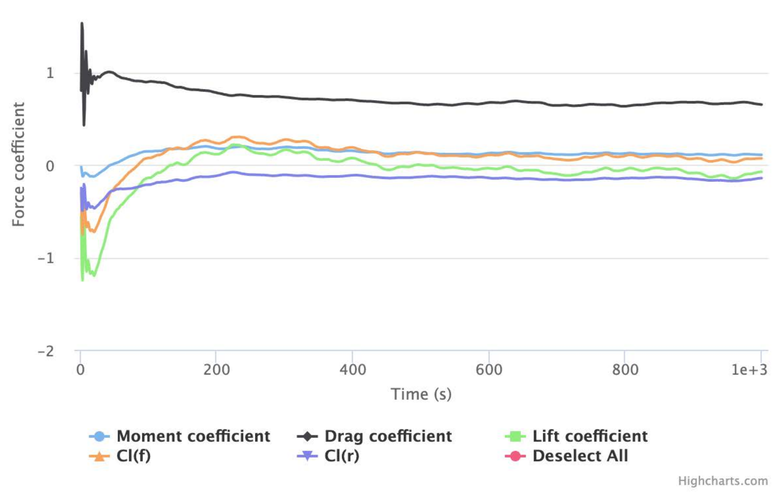

Figure 2: Force coefficients for f1 car with no halo

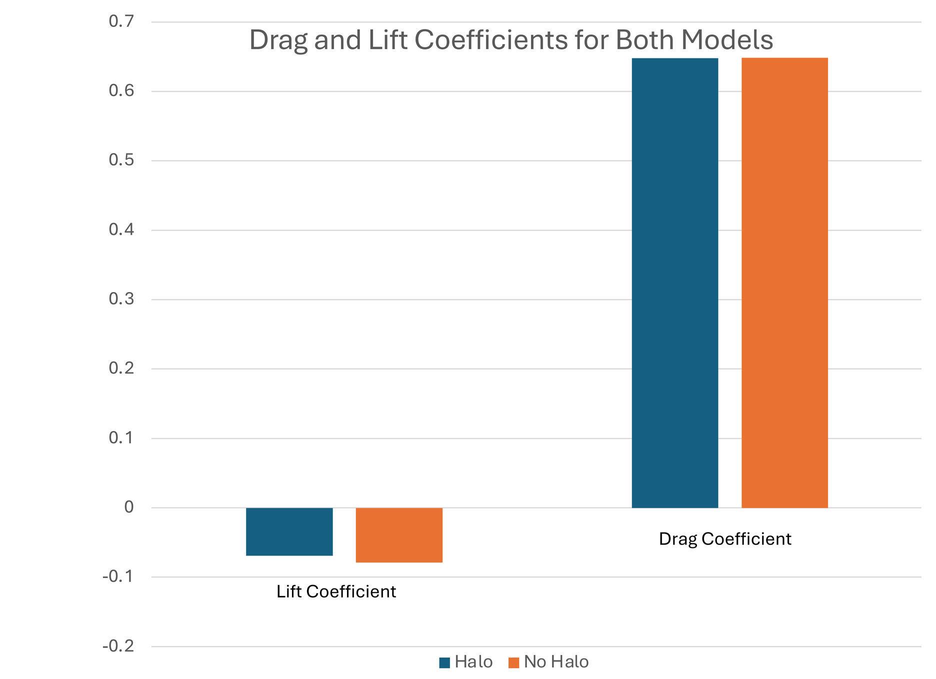

Figure 3: Drag and lift coefficients for both models of the car

Given the frontal area of the car, the simulation was able to determine force coefficients such as lift and drag coefficients which are vital when determining the performance of a Formula One car. As seen in figures 1 and 2, the coefficients plots for the car with the halo and without the halo look almost identical. Given the steady state nature of the test, ideally the lines in the graph should be perfectly flat after converging as no factors are changing throughout the test. When looking specifically at the drag and lift coefficients, the aerodynamic factors most highly correlated with a car's performance at top speed on a straight, the two numbers are almost identical.

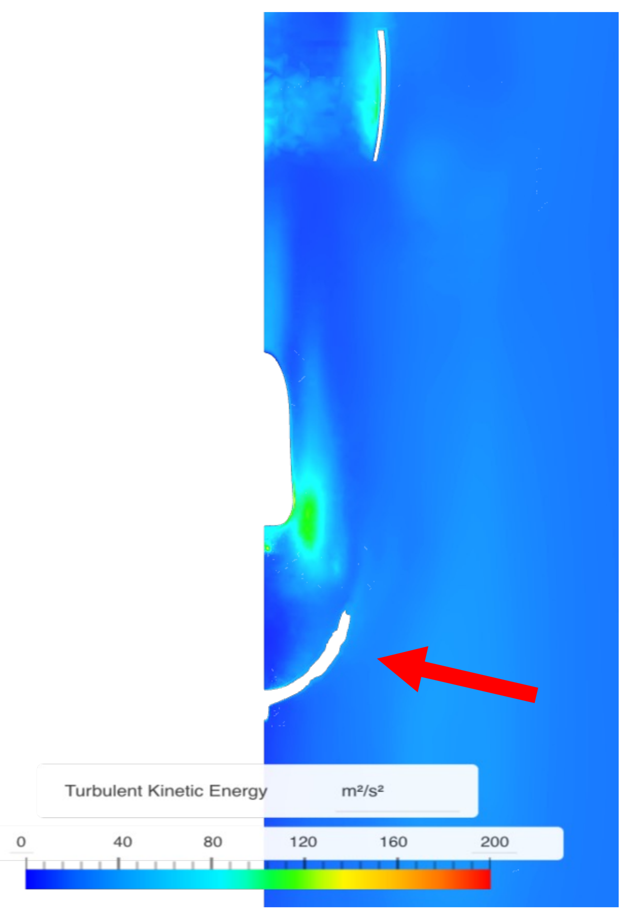

Figure 5: Cutting plane depicting the turbulent air surrounding the halo

Figure 5 depicts a cutting plane intersecting the vehicles halo. It is evident that there is no vortex shedding created by or near the halo which could cause instability for the car. Thus, the halo does not result in any negative side effects.

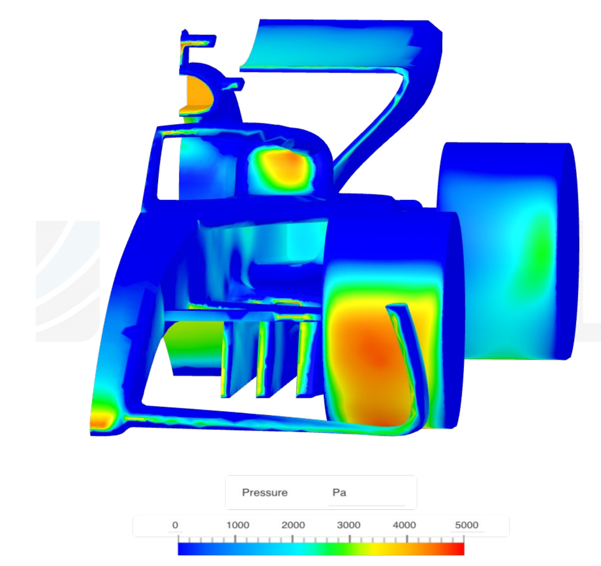

Figure 6: Air pressure distribution along car with halo

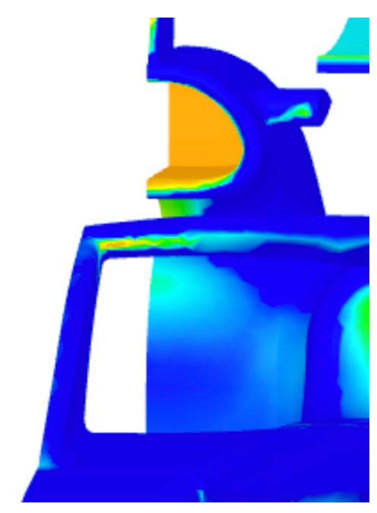

Figure 7: Zoomed in image of pressure along halo

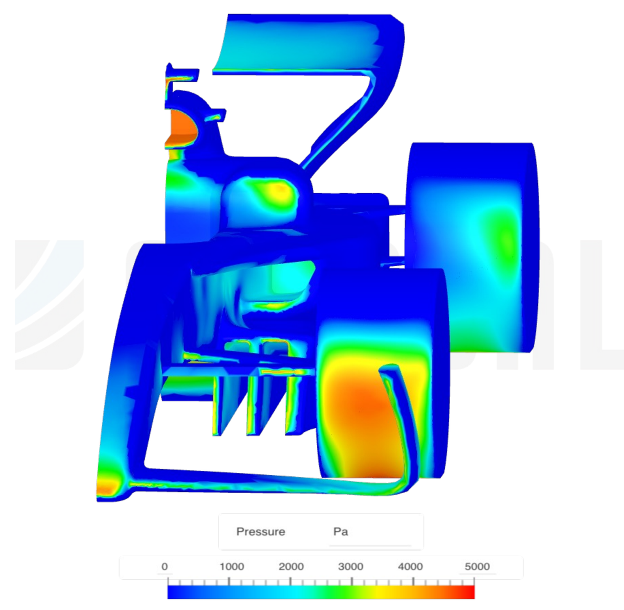

Figure 8: Air pressure distribution along car with no halo

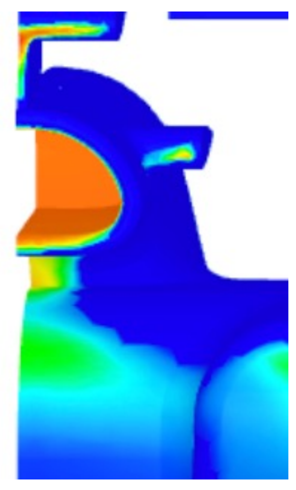

Figure 9: Zoomed in image of pressure with no halo

The overall air pressure distribution on the car is shown in figures 7 though 9. As shown in figure 7, there is a small pressure point right at the center point of the halo; however, this pressure point is greatly overshadowed by the pressure experienced by the front tire, nose of the car, and sidepod. Comparing figures 6 and 8, the pressure distribution around the car is almost entirely unaffected by the addition of the halo.

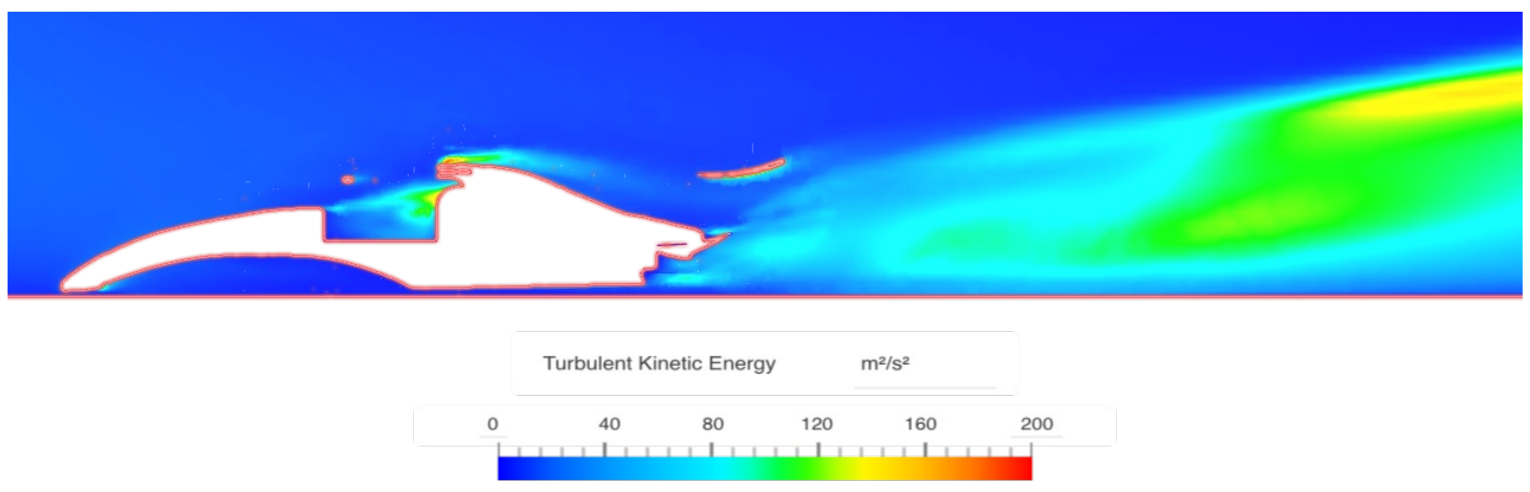

Figure 10: Turbulent kinetic energy in air for car with halo

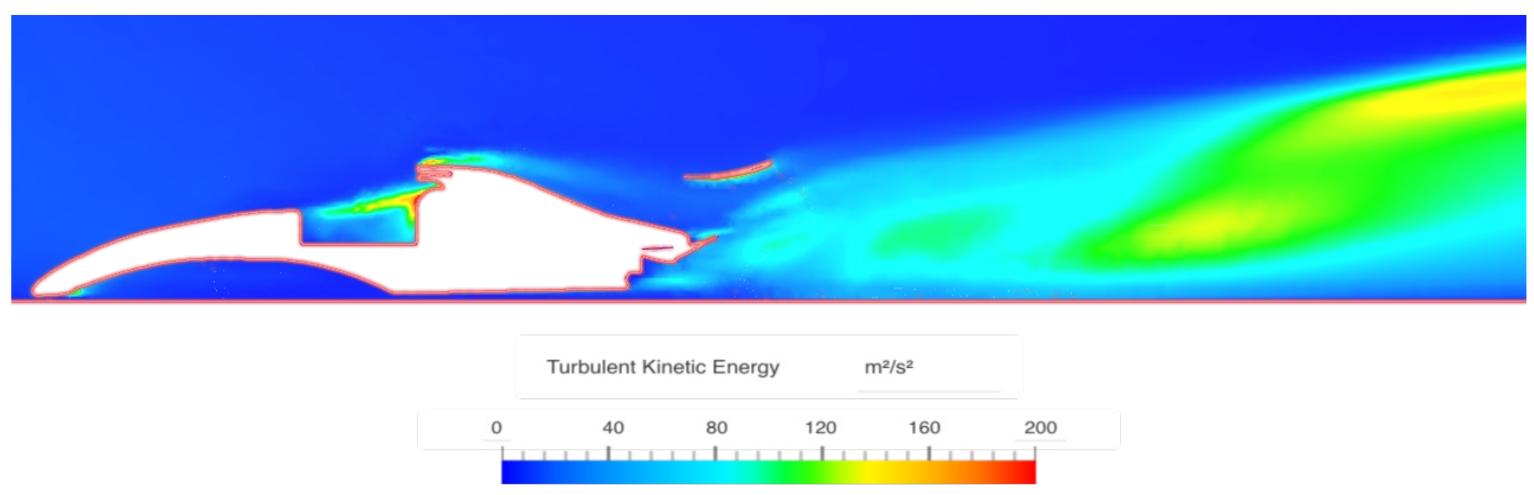

Figure 11: Turbulent kinetic energy in air for car with no halo

In figures 10 and 11, a cutting plane, positioned near the cars center point depicts the turbulent, high-energy air flowing around the car. There is highly disturbed air flowing upwards and behind the car. There is also highly disturbed air inside the cockpit and right above the cockpit. However, the air inside and above the cockpit appears the same and unaffected by the halo in figures 9 and 10. Looking closely at figure 10, a cross section of the halo is visible at the front portion of the cockpit which is seen causing minimal disturbance to the air.

Conclusion

The goal of this simulation was to determine the effect that a Formula One car's halo has on its driving performance. After evaluating force coefficients such as lift and drag, the pressure distribution of air along the car, and the turbulent kinetic energy created in the air flowing around the car, it is evident that the halo has very little effect on the car's performance. If anything, the halo offers some protection from some of the high velocity air that would be coming directly in contact with the driver. While the halo has a great impact on increasing the driver's safety, it does not trade safety for performance.

References

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