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Methods and Purposed of Aerodynamic Correlation in Formula Student

First aired in 2019, Netflix's show "Drive to Survive" has sparked interest for Formula 1 among millions of people in the last few years. Formula 1 is the pinnacle of motorsport racing, with the fastest single seater race cars there are on the planet. Other single seater categories one could be familiar with are Indycar, Formula 2, Formula 3 and so on. In the last two years I have worked in an other category much less known, Formula Student in Lund, Sweden.

Formula Student is an engineering competition, groups of students from universities across the world spend a whole year designing and manufacturing a single seater race car in order to compete during the summer. These competitions take place in mythic venues such as the Red Bull Ring, the Hungaroring or Silverstone. During those competitions, each car is first investigated to ensure it is legal in regards to a long set of technical regulations before being allowed to drive. Each team will score points based on their design process, their technical choices and the car performances on track.

As designing a race car with little knowledge is challenging, the design workload is divided into various substeams ranging from monocoque, vehicle dynamics, powertrains, administration among others. I have spent my two years in Lund Formula Student as a member of the Aerodynamic subteam. As aerodynamicist our target is to design a package, mainly a front wing, a rear wing and sidepods, that will generate downforce while minimising drag. The downforce generated will allows for faster cornering speed while low drag reduces energy consumption and enables higher straight line speed.

For my master thesis, I have worked on developing Aerodynamic correlation methods for our formula student team. These methods allow our team to produce more accurate CFD (Computal Fluid Dynamics) simulations and provide a better understanding of how the airflow behaves around our aerodynamic components. The first step in this work has been to design a scaled model of our car with a scale of 1:10. The model has then been 3d printed in several parts and assembled.

Using a windtunnel I had access to in Ljungbyhed, I made force measurements (drag and downforce) on both the model and a 3d printed airfoil shape of specific dimensions. I then ran batches of computer simulations using different parameters, mainly the turbulence model and the boundary layer meshing density. I then compared the result of the simulations with the experimental data to decide which CFD parameters were best for accurate results in a computing efficient manner.

Apart from the development of correlation methods, the scaled model also proved useful to test different concepts in a time efficient manner. While a 3d printed parts at a 1:10 scale takes at most 10 hours to be printed, building the same component in a real size out of carbon fiber requires weeks of work and we could not afford to have spare parts. I designed several iterations of our rear wing with various angle of attack (AoA) for our secondary airfoils and the target was to minimise drag. Thanks to the measurements, I found that the least amount of drag was produced for an AoA of 0° with the scaled model, and the same rear wing configuration was later used for the real car at competitions.

Lastly, I tried to conduct a Particle Image Velocimetry (PIV) experiment. This consists having seeded particles (in this case small smoke droplets) flow in a wind tunnel test chamber . And through the use of synchronized lasers and cameras, one can average the path of smoke particles around an object over a period of time of several minutes. As the smoke particles are very light, we consider that the path of the droplets corresponds exactly to the airflow. Unfortunately, the experiments did not succeed, as the windtunnel used created a circulation of air in the lab room, it started to fill the room with smoke creating a fog. That lead to poor camera measurements that did not provide any significant data that could be used.

Overall, the aerodynamic correlation methods confirmed to Lund Formula Student that their CFD simulation parameters were appropriate for accurate results. Although one could look into refining the mesh of the wake behind the car to better compute the drag generated. And the scaled model proves to be a great tool to evaluate similar performing concepts in a time and budget efficient manner through the use of 3d printing.