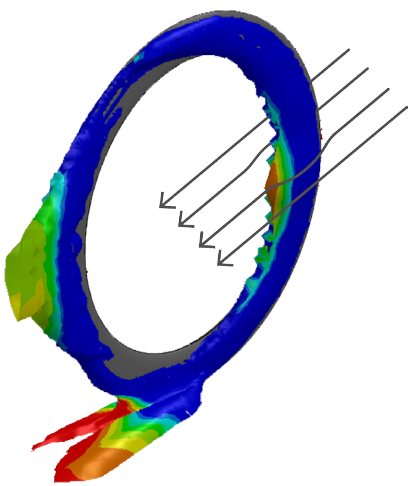
OPTIMIZED AERODYNAMICS

Optimum Balance

There are different factors that determine the aerodynamic performance of a wheel. The main factors are, however, the rim depth and the rim shape. While it is widely known that deeper rims provide better airflow, it is their specific shape that defines the aerodynamic stability and as such, how a wheel feels when being ridden.

Deeper rims are more prone to crosswinds than their shallower counterparts. A wheel with deep rims is, therefore, harder to control in crosswind situations. In order to give a rider greater confidence to choose a deep rim wheel in challenging conditions, it is important to increase its overall stability or, in other words, to find the optimal balance between low drag and crosswind influence.

For our R series wheels we've done exactly that. Together with a select group of athletes, we collected real ride wind data for more than one year. This allowed us to find out under which circumstances a wheel felt stable or unstable. We then made use of a detailed CFD analysis in partnership with the



R5c CFD analysis 15 degree angle

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TU Eindhoven and the TU Delft to define the characteristic 26mm U-shape rim profile of our R3, R4, and R5 models. As part of the process, we designed the rim shape starting from the tire to allow the latter to perfectly fit and to also create a smooth airfoil between the two of them. We then verified our findings in the wind tunnel, before validating them with our sponsored athletes.

As the result of an extensive development process, our R series wheelsets set a new benchmark for aerodynamically optimized carbon wheelsets.

Developed in collaboration with:

TU/e SCHWALBE

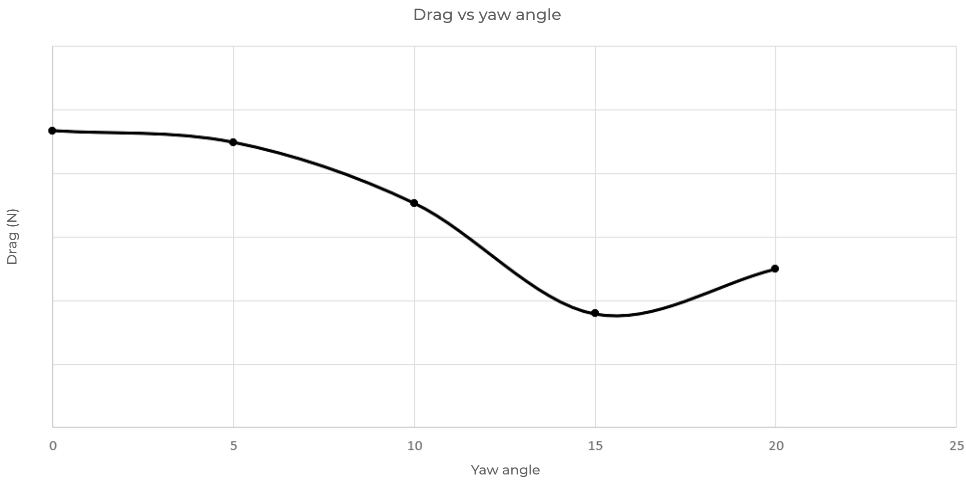
The Panel Method

CFD helped us to determine pressure drag as the main cause of resistance. It also helped us to understand that the most favorable shape for an aerodynamically optimized rim would reduce drag without adversely affecting side force. To achieve that, we needed to develop a shape that combined the positive aspects of extreme V-shape profiles with the ones of toroidal shape profiles.

There are different methods that can be helpful when developing a rim profile. One of the most popular methods at the moment seems to be the optimization of algorithms that are coupled to CFD. However, we found it insufficient to use this method and took the rather unusual choice to use the panel method to optimize the shape of our R series rims.

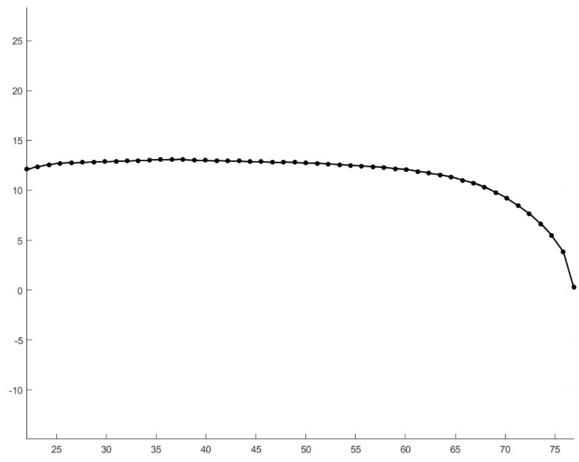
The panel method is a surface-based flow analysis technique. We used it in conjunction with an optimization routine in MATLAB, which helped us to automatically generate shapes that satisfied the constraints with the objective function of reducing drag.

Using the panel method allowed us to



exert complete control on the rim shape. For the purpose of optimization, the rim was discretized into different elements. Each element was considered to be a polynomial of the 3rd degree. This is shown in the below figure with the curve being discretized into 50 elements. Since the curve had to be continuous and smooth, constraints were placed on the curve and its derivatives. The curvature radius towards the trailing edge was also constrained, to limit an excessive formation of a V-shape.

As a result, we were able to define a rim shape that reduced drag without compromising side force behavior.



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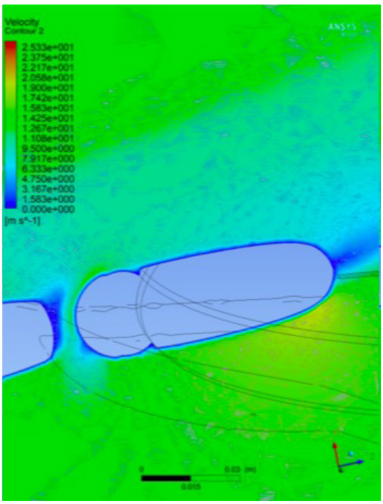
Computational Fluid Dynamics (CFD)

We used Computational Fluid Dynamics (CFD) to develop our current generation of R series wheelsets, since the method allows for a variety of test runs of different models within an efficient amount of time. Besides learning more about the airflow around our 3D modeled prototypes, this method also helped us to further improve and optimize the chosen rim shapes for the R3, R4, and R5 models. To understand the full scope of the aerodynamically relevant aspects, we looked at the performance of a complete wheel with tire, spokes, and hub, while considering variables such as wheel rotation, moving ground, wheel in ground effect, and frame interaction. In order to capture and resolve pressure drag, a computational domain of 2D, and 3D proved to be a sufficient choice. To investigate the drag force variations over a range of yaw angles ranging from 0-20 degrees, we ran steady state RANS simulations and tested different turbulence models to capture the correct flow dynamics. We used the best models for the optimization.



Top view of wheel interaction at 10 degree yaw

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CFD Validation, Prototyping and Wind Tunnel Testing

Once we defined the rim shapes for the R series wheelsets, we validated them using CFD. This allowed us to ensure that we had found the most favorable shapes for aerodynamically optimized rims and to build prototypes.

We printed 3D models of the R3, R4, and R5 rims and also build respective carbon prototypes. All prototypes were then tested in the wind tunnel to confirm our CFD findings. The wind tunnel test helped us to further understand the interaction of the optimized wheel with aspects such as rotation, fork and frame, as well as rider. It was also crucial to determine the final shape of our R-series rims.

Although our chosen optimization and validation method is somewhat similar to inverse airfoil design, it had, to date, not been applied to bicycle rims. And while our approach might seem unique inside the cycling industry, it actually brings our core values to the fore: Trying to push boundaries without any excuse.

AERODYNAMIC BENCHMARK