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CFD helps FLO Cycling design innovative Bike Wheels at Affordable Price

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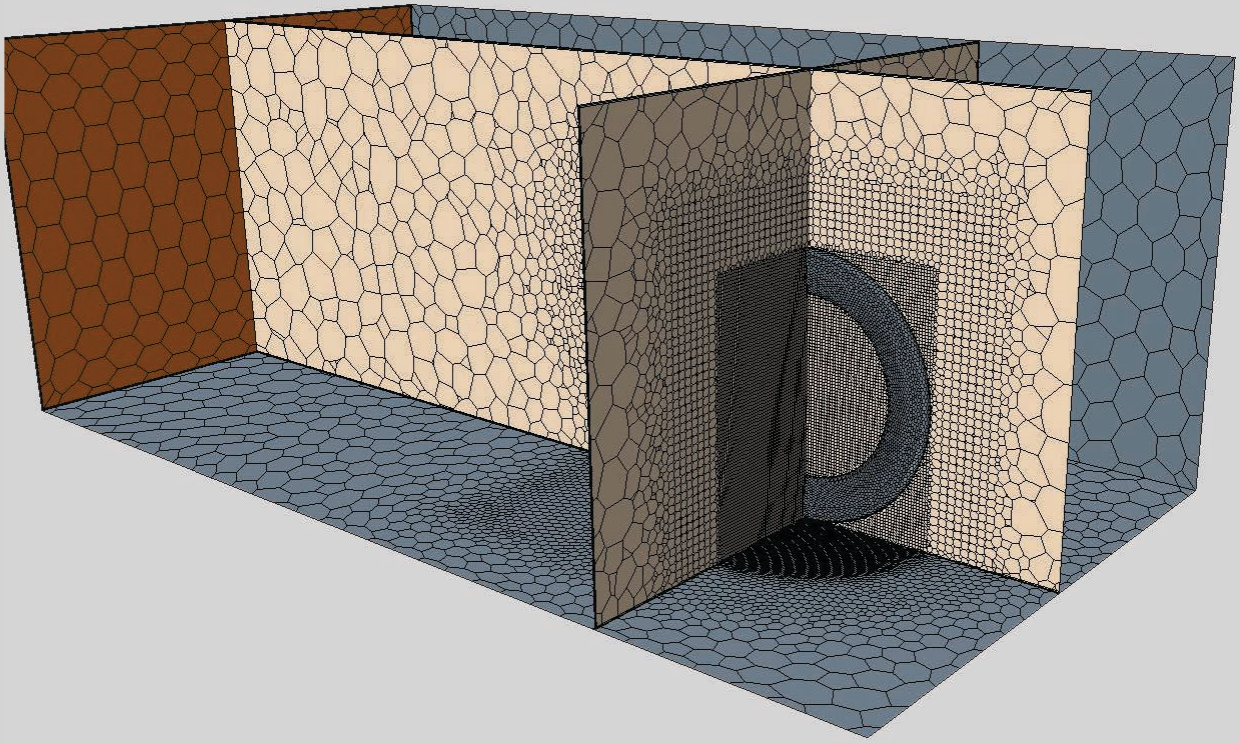
▲▼ **ABOVE & BELOW**
Flow visualization showing pressure and velocity around the wheel



▶ **RIGHT**
Polyhedral mesh

In the grand theater that is modern competitive sports, the equipment is as crucial as the competitor. The advent of cutting-edge engineering technologies has pushed the boundaries of competition far and beyond what one could have envisioned a decade ago. In this multi-billion dollar industry, to stay ahead of the competition, high-end engineering plays a critical role in improving equipment constantly.

This article focuses on FLO Cycling, who have used such advanced engineering methods, Computational Fluid Dynamics (CFD) to be specific, to bring to the market a product that was the 'mythical unicorn' of the bike racing world not so long ago - industry leading, high-performance, superior aerodynamic bike wheels at affordable pricing.

Bike wheels, especially for competitive triathletes, are a significant investment. On one end of the spectrum are the cutting-edge, highly aerodynamic, fully engineered wheels that are considerably priced. The other option are very affordable, well-manufactured but minimally engineered wheels that offer an alternative to buyers at a lower cost but reduced performance. FLO cycling's idea is simple - to bridge this gap with high-quality, high-performance race wheels that come at a fraction of the current market cost. How can the same product with the same quality come at one-third of the market cost? Is that even possible? FLO Cycling, with their innovative to-market strategy, have proved it is.

The FLO Wide Toroidal Wheel

FLO Cycling's target groups are mainly triathlon racers and cyclists, most of whom cannot afford the high-end bike wheels that cost a few thousand dollars. The main reason for the really low cost of the FLO wheels comes from their marketing and distribution strategy of going directly to the customers. Still, like any other highly engineered product, an efficient engineering process is half the battle won in keeping the cost low. This is where CD-adapco's flagship software STAR-CCM+ comes into play. Being a start-up, keeping the design and manufacturing costs low were highly critical for FLO Cycling. The use of CFD enabled them to zero in on the most optimum fairing shape, thereby reducing the need for expensive testing of numerous prototypes by limiting the number of fairing shapes to test in the wind tunnel.

The most widely used fairing types for bike wheels are the V-notch and the Toroidal Fairing, as seen in the images next page. Both of these have been very successful for years in competitive racing but even the best designs can become better. The V-notch had low aerodynamic drag but showed instability in crosswind conditions due to the asymmetry between the front and rear half of the tire. The Toroidal Fairing showed better crosswind stability compared to the V-notch.

In headwind conditions, most wheels have very minor differences but racing is rarely done in headwind conditions. Side winds create a yaw angle at the leading edge of the wheels, resulting in side forces and more complex aerodynamics. The front of the wheel serves as the leading edge at zero yaw angles and in this state, things stay simple when it comes to aerodynamic design.

During side wind, the leading edge of the back of the wheel also affects the aerodynamics and this is where FLO Cycling's rounded-edge back wheel leading edge differs from earlier. By rounding the leading edge of the back of the wheel, a much improved crosswind stability was obtained and excellent aerodynamics were observed. →

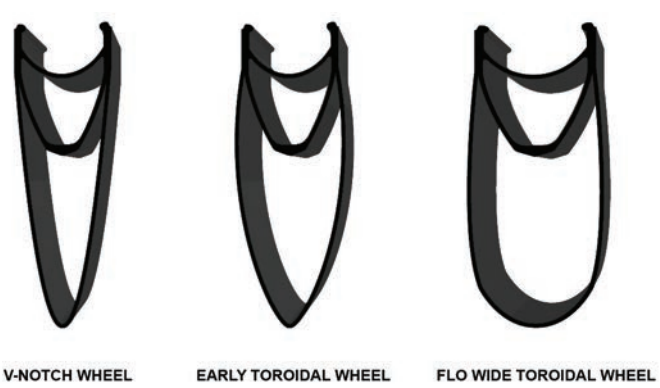
▲ **ABOVE**
Flow visualization showing pressure and velocity around the wheel

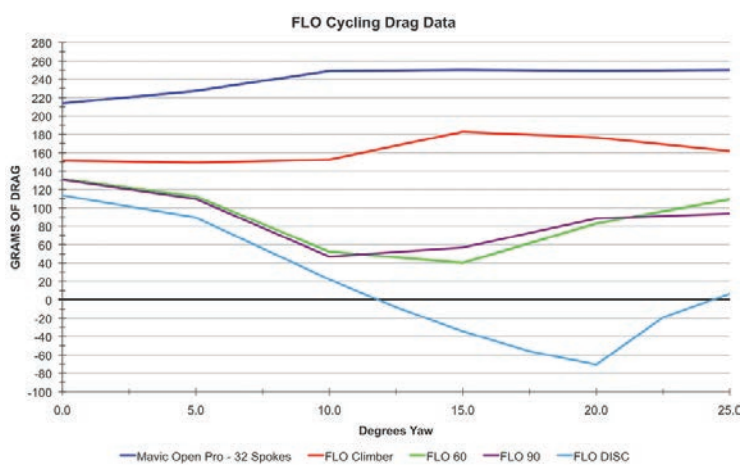
FLO Wheels
Four different wheels were designed based on this fairing shape: FLO Climber, FLO 60, FLO 90 and FLO DISC. The FLO 60 is the most versatile of the wheels with a 60 mm fairing that was designed solely using STAR-CCM+. With its reduced weight and leading edge aerodynamics, it is excellent for fast riding as well as everyday training. The FLO 90, built for fast riding, has a 90 mm fairing and is excellent for elite athletes as a front wheel or for everyday bikers as a versatile rear wheel. The FLO DISC is the fastest wheel in the line-up with a disc covering the spokes. With negative drag from 12 to 24 degrees of yaw it is the perfect wheel for time trials and triathlon. The rim shape for all the wheels were designed using CFD.

Net Low Drag Technology
Another major differentiator for the FLO wheels is their Net Low Drag Technology. Current racing wheels offer lowest drag and fastest speed at one particular yaw angle but these are not the race conditions, where the yaw angles vary from 10-20 degrees. FLO Cycling's improved methodology designs wheels with a net low drag that ensures the fastest speed at all yaw angles between 12-20 degrees, the typical yaw angle range in a race. After choosing the optimum fairing and rim shape based on CFD, the final designs were tested in a wind tunnel to calculate the net drag reduction value (NDRV) on the wheel compared to an off-the-shelf standard box section rim (results in accompanying graph). NDRV is a calculated weighted average of drag reduction between 10-20 degree angles of yaw, where 80% of the racing is done. Regardless of the wind angle, the FLO 60 wheel will save 70.1 seconds, the FLO 90 saves 68.8 seconds and the FLO DICS saves 101.5 seconds, all over a 40 km time trial.

CFD Analysis of FLO Cycling Wheels
The following section will detail the CFD analysis carried out by the designers to arrive at the final fairing design. A variety of fairing shapes, based on the FLO wide Toroidal wheel were created in a CAD environment. Only the tire, rim and the wheel were modeled and the spokes and hub were omitted. The simplistic design did not really warrant a CFD analysis of the complete wheel to arrive at the best possible design. A variety of unique fairing shapes were analyzed using STAR-CCM+. Both wheels were tested for a wide variety of race conditions, with wind speeds ranging from 5-30 mph and yaw angle from 0-20 degrees.

A polyhedral mesh as shown was created with 1.5 million cells for the analysis, including a prism layer mesh to capture the boundary layer flow on the wheel. The volumetric refinement feature of STAR-CCM+ was used to create local refinement zones around the wheel to capture the wake off the wheel. A steady state analysis was run and the turbulence of the flow was modeled using the k-epsilon turbulence model.





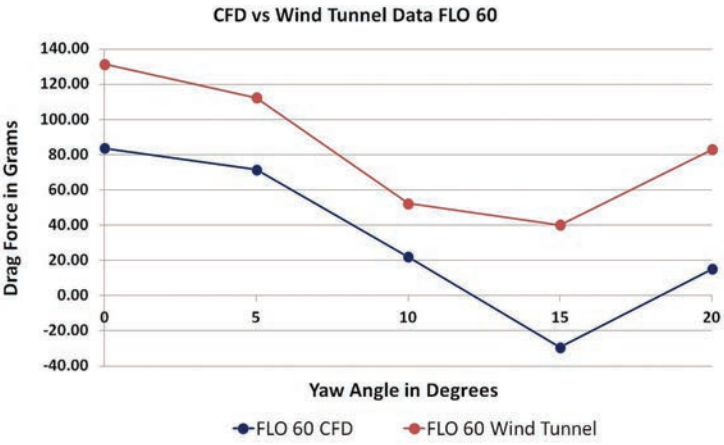
▲ **ABOVE**
Comparison of drag data from FLO Cycling wheels

The wind speed and wheel yaw angles were changed for every case and simulations were run on a single core for a total of 28 days for all cases. The most notable aspect is the high-end, cutting-edge design of FLO Cycling wheels using just a single processor. In this era of supercomputers, more computing power would only make the process faster.

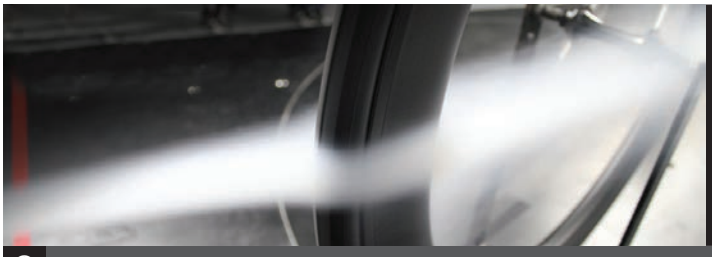
The chart on the right shows the comparison of the drag force from CFD simulation and wind tunnel for the FLO 60, the final prototype. The wind tunnel model included the spokes and hubs and hence has a higher drag force value compared to the numerical results. The numerical results gave FLO Cycling excellent insight into the trends and behavior of the FLO 60 wheel even before testing a single prototype, which was the real benefit of CFD in the design process. The visualization of the numerical results as seen in the accompanying images helped to identify the flow patterns around the wheel and the results were used in deciding the final prototype design.

Conclusion

The final prototype identified from the CFD runs was tested in a wind tunnel and the performance of the wheel was as expected. The wheels are already out in the market and FLO Cycling has by now completed a successful pre-order for them. CFD has helped FLO Cycling to successfully design their innovative wheels through the use of engineering simulation, while reducing the engineering time and cost associated with bringing these wheels to the market. ■



▲ **ABOVE**
Comparison of drag force (grams) between CFD and wind tunnel for FLO 60 wheel
(Note: The wind tunnel test included hubs and spokes, resulting in the higher drag.)



FLO CYCLING

FLO Cycling offers engineered, aerodynamic carbon fiber cycling wheels for triathletes and cyclists. We sell directly to our customers, which allows us to offer affordable prices and not skip on quality components. For each set of ceramic wheels we sell, we donate a bike and a helmet to a less fortunate child through our Bike for a Kid Program. The numerical simulations were done by JSC Engineers. JSC Engineers is a consulting company, based in Lee's Summit, MO and specialize in buildings, power plants and refineries.

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