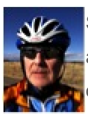
Bicycle Racing on the Computer? Modeling and Simulation for a Small Business

Intel's Bill Feiereisen, an avid bicyclist, combines his enthusiasm for the sport with his HPC credentials to take a look at the use of computational fluid dynamics (CFD) in the design of advanced racing wheels. Work by Intelligent Light, makers of FieldView, a CFD post-processing and visualization package, has uncovered aerodynamic wheel behaviors that were previously unidentified. Their work has also demonstrated how CFD can be used by small and medium-sized manufacturers.

December 9, 2011 by Bill Feiereisen

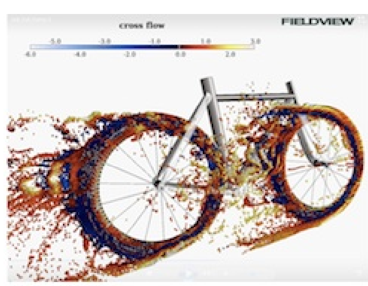


Some of my colleagues know that I love bicycling. I ride recreationally and have even raced, but my ambition has always been greater than my ability. I am almost always at the back of the pack, and often last.

Professionally, I am devoted to the development and use of high performance computing (HPC). I wouldn't ...ought that these two worlds might actually cross. Imagine my surprise after talking with Brian Kucic at R...ns, who wanted to tell me about the computational design of bicycle racing wheels that he has been ...ting.

...ent Light (Rutherford, NJ) is the maker of FieldView, a CFD (computational fluid dynamics) post-...sing and visualization software package. They have enthusiastic cyclists on their staff who have applied ...FD analysis and workflow expertise to the simulation of the airflow around a bike wheel. Their four-year ...led by FieldView Product Manager Matthew Godo, Ph.D., has brought to light aerodynamic wheel ...ors that were previously unidentified, demonstrating in the process how CFD can be used by small and medium-sized manufacturers.

Why is this important? In top-level racing, the slightest aerodynamic advantage adds up over the course of a race and can easily make the difference between first place and "also ran." If you follow racing, or maybe just tune in to a few televised stages of the Tour de France, you'll see racers riding on wheels with deep-section rims. From the side, they almost look like fat tires, but only the outer portion of the wheel is actually the thin high-pressure tire. The section inside the tire is made of carbon fiber, and its deep profile and shape are responsible for the reduction in aerodynamic drag that has made deep-section wheels appear almost universally on racing bikes. You simply must have them to win.



Massless particles follow the computer-generated flow, revealing its secrets. FieldView image courtesy of Intelligent Light.

One of the cool things about bicycle racing is that the exact same equipment used by winners of the Tour de France is immediately available for purchase by duffers like me. Those of us wannabes who have bought these wheels, in the vain hope that they will compensate for our defective abilities, also know that they can be a handling nightmare in cross winds. Gusty winds cause the bike to snake around, which is not only unnerving, but also dangerous in a tight racing pack. But gusty winds also affect professional racers, with the squirrely handling causing differences of fractions of a second among them.

Bicycle aerodynamics has been studied in wind tunnels for years. The slippery aerodynamics of deep section wheels have been proven through direct measurements, but the transient effects, those that develop over time and are presumably responsible for these handling difficulties, are very difficult to measure. Therefore, no real insight into remedies for the handling problems has been available.

Had I been asked about this problem in my day job, I would have followed my professional bias and suggested computational analysis. Simulation on the computer produces an estimate of performance by measuring pressures and drag from the mathematics of the simulated flow field. This is exactly what Godo and Intelligent Light have done.

CFD for Smaller Manufacturers

Until recently, the ability to do this type of work would have been unavailable to small and medium-sized companies for several reasons. Any useful simulation must represent the whole geometry of the bicycle and all the components that affect the airflow. This includes the frame, the rotating wheels, their spokes, and the ground surface over which the bike is traveling. The simulation must be accurate enough to capture the real airflow, from which performance can be estimated. In CFD jargon, this requires a time-dependent, high-resolution, three-dimensional simulation. Such a complex simulation usually required an expensive supercomputer, immediately placing it beyond the resources of a small company.

And while much of the necessary simulation and visualization software is now available commercially, its use has required much specialized knowledge in fluid dynamics, numerical modeling, and their implementations on supercomputers. This broad palette of knowledge has been scarce and possessed by only a few.

Things have changed. The power of a top-end supercomputer from the mid-1990s is now available on a desktop, and a small department-level server now rivals the power of the world's fastest computer of the year 2000. Software makers have been working hard to make their simulation software easier to use, and experts, like Godo of Intelligent Light, have been showing how small companies can apply it to their own manufacturing design workflow.

s a cyclist, but he is also a scientist and has turned his expertise to the simulation of racing bicycles. His lbreaking research on the aerodynamics of a rotating bike wheel in contact with the ground1 caught the on of Zipp Speed Weaponry (Indianapolis, IN), the company that invented the category of carbon aero s – the wheels that I and most all other wannabe racers lust after. One of only two remaining U.S. bike and component manufacturers, Zipp is a small, tech-oriented company with 24 design and manufacturing ers and one of the early adopters of wind tunnel testing and analysis.

eading Godo's 2009 AIAA technical paper (co-authored by David Corson, Altair, Inc.) on the wheel research, Josh Poertner, technical director at Zipp, approached Intelligent Light. In that initial paper, Zipp saw the future – to move beyond drag and focus on handling. Previous wind tunnel experience was that side force and wind-induced steering torque was purely a function of wheel surface area, but Godo's FieldView findings showed that different rim shapes had different side force distributions, which meant the center of pressure could be moved. Godo pushed the study further, publishing an updated AIAA technical paper in 20102, which helped Zipp engineers realize that the center of pressure was moving due to periodic shedding. This fluctuating center meant fluctuating torque, which is what cyclists generally call 'buffeting.'

With Zipp's extensive expertise in what works – and what doesn't – they recognized in the technical paper some flow features that could be affecting the handling of their wheels in cross winds. Godo worked with Poertner to perform a series of simulations on alternative designs, and the result was Zipp's 2010 new wheel profile, the Firecrest.3 By moving the center of pressure – the focal point of side forces on the rim – to its optimal location near the steering axis, Firecrest offers stable, predictable handling at every wind angle. Better yet, in addressing the periodic shedding phenomenon, Zipp realized dramatic reductions in drag with Firecrest, as the energy previously wasted on shedding was now recaptured

The rest is now history! Firecrest wheels won Ironman Kona 2010, were on several of the bikes that won stages of this year's Tour de France, and were also on the winning bike in the 2010 International Road Championships. TOUR Magazine (Germany) said of their wind tunnel test of the 808 Firecrest: "Sensational: the fastest spoked aero wheel of all time. Aerodynamically a revelation and always ahead at every speed. Despite the big surface, still easy to handle in strong winds." In 2011, the Firecrest won a 'TOUR Milestone' award for technological innovation, one of the most prestigious tech awards in the industry.

Along These Lines

Orchestrating Simulations on a Formula 1 CFD Cluster with Grid Engine

Leveraging HPC Hardware to Run Next-generation Molecular Imaging Analysis

Intel-BMW and Nvidia-Mercedes Vie for Driverless Car Spotlight at CES

LUG 2016 Wrap-up: Intel's Lustre Line Gains Traction

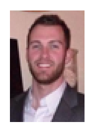
CONTRIBUTORS

Doug Black
Managing Editor

John Russell
Editorial Director

George Leopold
Senior Editor

Tiffany Trader
Senior Editor



Thomas Ayres
Contributing Editor

Alex Woodie
Contributing Editor

Steve Conway
IDC

UPCOMING EVENTS

Business Intelligence, Analytics & Information Management Summit 2017

February 20 - February 21

Industry of Things World USA 2017

February 20 - February 21

Container World

February 21 - February 23

Though the costs of developing the Firecrest were higher than usual due to additional physical prototypes and wind tunnel runs, and took longer because of the time required to develop new measurement techniques, Poertner says it was "totally worth it. Unlike our competitors who are copying the look of our rim, we actually understand the reasons it works, and that is priceless. The wind tunnel will tell us 'what' but not 'why' – CFD helps us understand the 'why,' which we can validate with wind tunnel data."

A New Gold Standard

Zipp has reset the bar for competition wheels with excellent aerodynamics and handling, and the knowledge they've gained in the process will inform all of their future product development. Best of all, these wheels are available to my wannabe colleagues and me. This is the kind of thing that makes enthusiastic amateurs sit up and take notice. We march right out and buy these things. Talk about return on investment!

Godo has used both Altair Engineering's CFD solver code AcuSim and STAR-CCM+ from CD-adapco to model the physics, then post-processed the results and produced the accompanying visualizations with Intelligent Light's FieldView package. His original simulations ran on a modern desktop computer, but as the simulation complexity increased, he was limited by its power. That's when Brian Kucic of R Systems, a commercial scientific data center in Illinois, stepped in with Dell/Intel parallel servers and provided the necessary boost in horsepower for Godo's simulations.

Such groundbreaking work requires a team, each bringing their unique expertise to the problem. Zipp knows wheels and why they work. Intelligent Light combined their domain expertise in CFD simulation and visualization with a personal passion for the problem. R Systems knows HPC and how to integrate the software and hardware into a usable package. And – what can I say? – Dell and Intel provide a stellar product upon which all of this work runs.

Rarely does one find a place where personal and professional lives cross, but this is an inspirational example . I have a passion for bringing technical computing to a wider audience, and Zipp's Firecrest wheel pment is an example of how it can be done. I hope small manufacturing companies will recognize the of computational modeling and the advantages it can have for product design. It certainly has provided a ompetitive tool for Zipp. Watch this space and see what they do next. I certainly will – and I'll have my ook ready.

nces

AA-2009-0322. An Aerodynamic Study of Bicycle Wheel Performance using CFD. Matthew N. Godo, Corson, Steve M. Legensky. (link- free registration required for papers)
2. AIAA-2011-1237. A Practical Analysis of Unsteady Flow around a Bicycle Wheel, Fork and Partial Frame using CFD. Matthew N. Godo, David Corson, Steve M. Legensky (link- free registration required for papers)
3. http://www.zipp.com/technologies/aerodynamics/firecrest.php

-----

Bill Feiereisen can be reached at: william.j.feiereisen@intel.com or wfeiereisen@cs.unm.edu

Related

Designing Bicycle Wheels in the Cloud
July 19, 2011
In "Manufacturing"

CFD For the Rest of Us
January 10, 2013
In "Manufacturing"

Capturing the Unicorn: The Lure of Affordable High Tech Bike Racing Wheels
January 18, 2013
In "Manufacturing"

Categories: Manufacturing
TAGS: aerodynamic wheel behavior, Altair, bicycling, bike racing, cd-adapco, CFD, Dell, fieldview, Intel, intelligent light, Matthew Godo, R Systems, Tour de France, Zipp Speed Weaponry

Add a Comment

Name *

Email *

Website

Your Comments

Add comment

Notify me of follow-up comments by email.

About EnterpriseTech | Contacts | Back to Top