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Skewed Numbers

A New Angle on Manufacturer Claims About Crosswinds

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The benefit of aerodynamic equipment on the bike is a given, and research constantly reveals new ways to gain an edge against wind resistance. The last fifteen years have made wind tunnel testing and computational fluid dynamics modeling cost-effective technologies for the bike industry, accelerating product development and broadening the spectrum of research considerations. One of the more recent design aspects is crosswind performance. However, a troubling aspect of scientific research in triathlon equipment is the often aggressive nature of its use in product marketing, and in the case of crosswinds the advertisers tend to blow things out of proportion.

In case there is any confusion, here's a quick primer on crosswinds. Typically, we think of wind resistance occurring due to air hitting us directly from the front (figure 1). The total velocity of the headwind is the sum of our velocity and the wind's velocity. This is the simplest condition, though, and both the wind and cyclists are wont to frequently change directions. The other simplified condition then is a "perfect" crosswind, or one that blows in at us directly from the side (figure 2). Things get a little more complicated here. Even though the wind itself exerts no force directly against us, we still feel a headwind equal to our speed. That headwind and crosswind combine to form a new force that we call the *effective crosswind*. The important thing to understand about the effective crosswind is that it not only creates resistance, but complicated control and stability issues as well. Anyone who's ridden the bike leg at Couer d'Alene or the Queen K knows how substantial this can be. Things become exponentially more complicated once you get into angles between zero and ninety (figure 3). Several factors must be accounted for, including wind speed and angle and the cyclist's velocity. These elements influence a new factor of consideration, which is the angle between the cyclist and the effective crosswind, properly known as the *yaw angle.*

Figure 1. When the wind is directly against direction of travel, the total perceived wind velocity is the wind speed added to the bike speed.

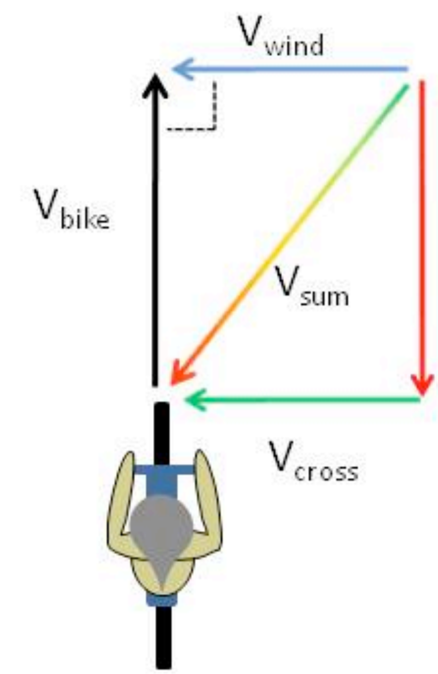

Figure 2. When wind comes in directly from the side, the crosswind is equal to the wind speed. The headwind speed is equal to the bike speed. But the perceived wind is greater than the two components, and it feels like it comes in from an angle.

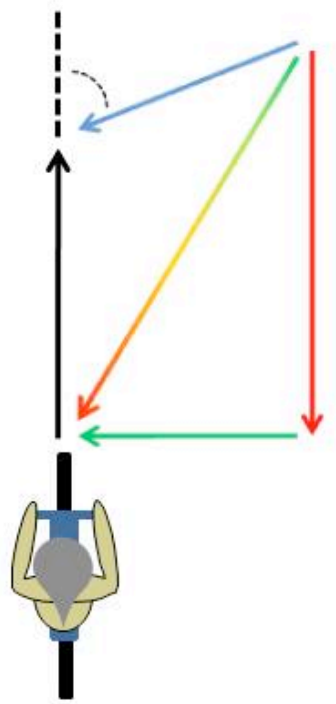

Figure 3. Wind coming in from different angles changes both the perceived wind velocity and direction.

From the bikes themselves to wheels and helmets to even water bottles, aerodynamic resilience in crosswinds is the new "it" technology. It was highlighted as a major design achievement in multiple new products from premier manufacturers at last year's Eurobike. Several high profile pitchmen lauded their product's superiority at yaw angles of ten, twenty, even thirty five degrees. But left out of the discussion was how often this advancement in design yields an advantage on the road. The response from vendors hearkened back to the original impetus for considering yaw angle winds-- you rarely pedal into a direct headwind, so being more aerodynamic in a crosswind makes sense. Fair enough. But how often do you pedal into the wind at a thirty five-degree yaw angle? According to some sales pitches, it only makes sense to be effective at the highest yaw angle possible. If you're good to go at thirty, you'll be even better at ten, right? Absolutely *not*. It's impossible to make a shape aerodynamic at all possible angles. Just turn your aero helmet sideways and you see the problem. The key to success is to design the product for the most likely range of winds you'll encounter. Again, that means figuring out the speed and angle a cyclist will see most frequently on the race course. To figure out the average speed and direction of winds in North America would take years of research and hundreds of thousands of dollars to collect data. Thankfully, someone already did the bike manufacturers' homework for them-- the automotive industry.

Auto makers got interested in aerodynamics in the early 1970's out of a desire to make more fuel efficient vehicles. That interest led to a flurry of studies on how different designs behaved in wind conditions. After the general solutions to most problems were found, much of the data was set aside and other areas of improvement received attention. But in 2003 Kevin Cooper, an aerodynamicist at the National Research Council of Canada, presented a paper on the aerodynamics of large trucks and buses to the Society of Automotive Engineers. His study developed a mathematical equation for assessing the drag on large vehicles across a spectrum of yaw angles. To refine his method, he resurrected a lot of the old data on wind conditions on the North American continent and determined a model of statistical probability for crosswind component based on vehicular speed. What he found knocks the whole crosswind discussion sideways.

The odds you'll face winds at a yaw angle greater than ten degrees over the course of a ride? Just twenty eight percent. Fifteen degrees? Twelve percent. More than twenty degrees? Five percent. The biggest factor in determining these percentages is the speed of the vehicle itself (figure 4). Because Cooper's work focused predominately on trucks moving at 70mph, his research needed refining before anything substantive could be said regarding cycling. Len Brownlie, an aerodynamicist whose research has helped design high speed gear for Alberto Contador and Lance Armstrong, followed Cooper's research by adapting the vehicular numbers for bicycle use. His adjustments indicate that the vast majority of effective crosswinds occur between five and twenty degrees.

While there's cause for concern over how many consumer dollars pay for this level of "over-engineering" for the most unlikely wind conditions, more problematic is the increase in difficulty of selecting the best product. The truth can be confused with information, as Len Brownlie and co-author Peter Ostafichuk of the University of British Columbia's Department of Mechanical Engineering found when they applied Cooper's data to aero helmets.

Brownlie took Cooper's model and evaluated the performance of several helmets at speeds and angles appropriate to cyclists. There were two notable results in terms of consumer considerations. First, in tests on multiple helmets designed in the early 90's, before major crosswind-inspired designs came onto the market, every model produced less drag in every crosswind condition. It can be concluded that, even before the advent of computer-modeled aero research, helmets were doing okay in crosswinds. More important though was what happened when Brownlie interpolated the data. He weighted the drag values according to the probability that the helmets would experience the corresponding yaw angles. The result was a different rank order of the helmets' overall aerodynamic performance. Simply taking the raw average of the drag measurements would have resulted in choosing an inferior product. To further complicate matters, different manufacturers have different standards of measurement, and depending on the size and performance characteristics of the wind tunnel used for testing, data values for similar products could be totally incomparable.

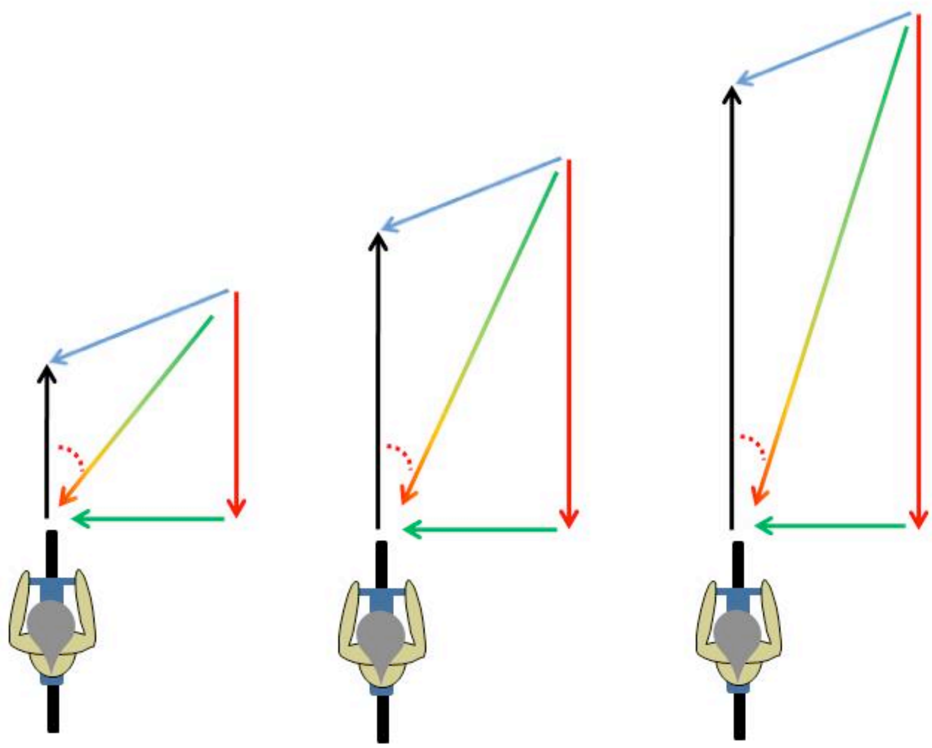

Figure 4. As rider speed increases, the headwind velocity component increases and the apparent yaw angle decreases.

This raises all kinds of issues, ranging from how well manufacturers are doing their homework to how little connection there is between the engineering and the marketing departments. Numbers don't lie, and generally speaking neither do manufacturers. To err is human, though. In their rush to keep up with the competition, some companies are getting ahead of themselves. It's therefore important to go into your next aerodynamics-based equipment purchase with pencil, paper and a bit of research. Don't sacrifice performance in headwinds for too wide a range of yaw angle and be careful of aggregate measurements. Try to obtain comparable sets of data for your competing product choices. If published measurements are radically different, then ask both the manufacturer and yourself why two brands of the same thing have unique metrics for performance. There's a small gamble involved any time you lay cash down based on advertised science, but you increase your chances of a winning hand if you play the odds right.

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