

THE FASTEST BICYCLE IN THE WORLD



How a team of Delft students is building a bicycle to break the world speed record

The Netherlands is a country known for its extensive use of bicycles as a means of everyday transport. However, while it has existed for about two centuries, today's bicycles only differ from those of the 19th century in relatively small details. Human Power Team Delft is building a whole new type of bicycle with the potential to break the world speed record of 133 km/h.

TEXT Gjalt Annega, Student Aerospace Engineering and team member Human Power Team Delft

In September 2010 eight students from the faculties Aerospace Engineering and Mechanical Engineering started a project with the ambitious goal of breaking the World Speed Record for Human Powered Vehicles. The current record is 133km/h or 82mph, held by the Canadian Sam Whittingham. Every September in Battle Mountain, Nevada, USA a record event is held during which many teams have a shot at the record.

BATTLE MOUNTAIN

There are multiple reasons why the event is held in a remote place like Battle Mountain. First of all a long stretch of road with no turns is necessary to have enough distance available to reach such speeds. Second of all the road needs to be nearly flat, the maximum allowed downward slope is 0.67%. Third, altitude is an advantage because of the lower air density and thus less aerodynamic drag. Battle Mountain fulfills all of these requirements. Located at an elevation between 1,400m and 1,460m

lies highway SR 305, where on a five mile stretch of road with a slope of 0.64% the event is held.

AERODYNAMICS

David Wielemaker, aerodynamicist, chief engineer and 3rd year student Aerospace Engineering tells the story of the aerodynamic design: "The trick of designing a fairing with the lowest drag, is finding the lowest product of drag coefficient and drag area, $C_d \cdot A$. An example of a shape with a very low drag coefficient is an optimized body of revolution. However, this shape is very inefficient in terms of space for the cyclist, it must be large enough to accommodate a human. On the other end of the spectrum there is a so-called body sock, a fairing that follows the body. This can be made very small, but the drag coefficient is high. The optimum is somewhere in between.

The first step was determining a suitable shape from which to start the design.

This was found in the Selig S1016, an airfoil shape specifically designed for Human Powered Vehicles, for the top view, and a NACA 7 airfoil for the side view. However, this was far from an ideal form, this is where the optimisation with CFD comes in. I used a program called VSAero for this because it delivers results quickly with reasonable accuracy for the expected flow phenomena. The CAD program SolidWorks was used for the design of the fairing. Over the course of four months I made many iterations, each time modifying the shape based on the pressure distribution of the last iteration. One of the dilemmas I came upon concerned the footbox, the imaginary rectangular area through which the feet of the cyclist travel when pedalling. The two options were to make the fairing cross-section more rectangular around the footbox or to make the fairing larger while retaining the elliptical cross section. This is a very good example of the choice between drag coefficient and frontal area. After using VSAero

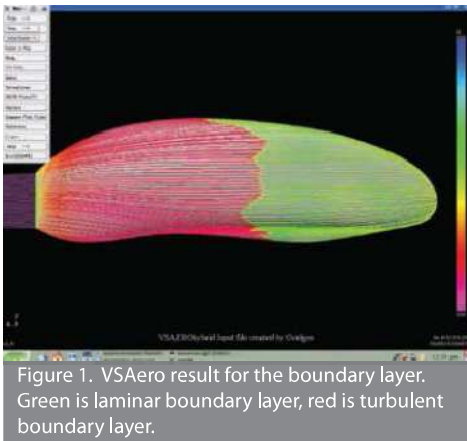


Figure 1. VSAero result for the boundary layer. Green is laminar boundary layer, red is turbulent boundary layer.

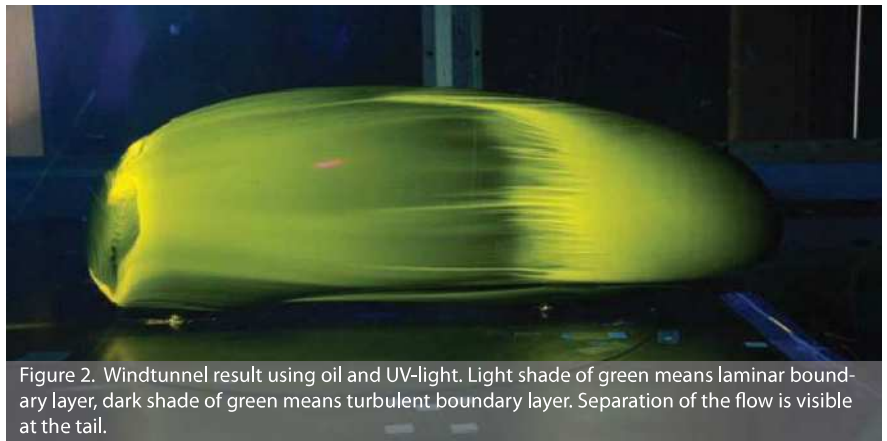


Figure 2. Windtunnel result using oil and UV-light. Light shade of green means laminar boundary layer, dark shade of green means turbulent boundary layer. Separation of the flow is visible at the tail.

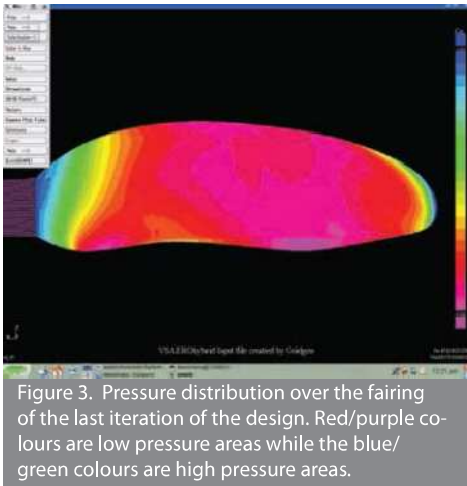


Figure 3. Pressure distribution over the fairing of the last iteration of the design. Red/purple colours are low pressure areas while the blue/green colours are high pressure areas.



Figure 4. Design of the frame and all systems inside the fairing. Notice the two-stage driveline and the difference in size of the wheels.

on the options, making the cross section more rectangular appeared to be the best choice."

WIND TUNNEL

Of course the results of VSAero are very useful, but they still differ from the real world. To check the results without building a full-scale bike and fairing, wind tunnel testing was necessary. Because the scale model was one-third of the size of the real bike, the necessary wind speeds also needed to be three times larger; around 400 km/h. Low turbulence was also preferred, to make the test more realistic. The Low Turbulence Wind Tunnel met these requirements very well, with a maximum speed of ~430km/h, a test section that can easily accommodate the model and very low turbulence. After a full day of testing at different speeds and angles, it turned out that the VSAero results deviated a lot from the wind tunnel results. Instead of the predicted laminar boundary layer over 70% of the length (see Figure 1) the boundary layer was only laminar over 30% of the length (see Figure 2). The cause was found in an empirical boundary layer stability value in VSAero, which needed to be higher than expected. This knowledge was applied in the last iterations. The pressure distribution of the last iteration can be seen in Figure 3. Sadly it was not possible to do another test with

the improved shape, the record event will have to prove the quality of the design.

INSIDE THE FAIRING

Because the aerodynamics are the most important aspect in making the VeloX fast, all other parts and systems of the bike are dictated by the space available inside the fairing. For example, during the initial design the VeloX was fitted with a single stage front-wheel driveline. However, during tests with a mock-up of the inside of the fairing it turned out that the cyclist's leg would scrape the derailleur, which is very detrimental to performance. Therefore the driveline was changed to a two-stage front-wheel type. This also eliminated the problem of insufficient stiffness and thus bending of the chain-wheel.

Another example of this were the wheels. Tires with a larger diameter have a lower rolling resistance. The largest commercially available bicycle tires (28") are also the most used tires and thus biggest selection is available. The fairing is large enough for a 28" front wheel, but not for a 28" rear wheel. This is why a smaller 24" wheel and tire were chosen, although the selection of tires in this category is very small.

The final design of the frame and systems can be seen in Figure 4.

BUILDING THE BIKE

"One of things that makes the project so much fun, is that we actually build the product ourselves" says Gjalt Annega, wheel and tire engineer and one of the media communicators of the project. "In my study (Aerospace Engineering) there is much focus on the theoretical side and the general outline of the production, but less on the details of making a product. In a project like this you get the opportunity to learn such things and you also experience practical problems such as uncertainties in the design and imperfect materials. In the end I think projects like this make for better, all-round engineers."

FUTURE

At this moment the team is producing all the parts of the bicycle. The assembly should be finished halfway through May, at which time a roll-out ceremony will be held. The first event we will go to is an event at the DEKRA test circuit in Germany to try and break the hour record, which currently stands at 90 km/h. In September 2011 the team will go to Battle Mountain to have a shot at the World Speed Record. With any luck, next years' team will also start with a new design. At this moment we are still looking for team members for next years' project. If you are interested, you can have a look at the website (www.hptdelft.nl) or send us an email. ✉