PINARELLO BOLIDE HR WHITE PAPER 1.0

1. Introduction and history

Introduction

Hour Record is cycling's toughest test of strength and endurance.

Cicli Pinarello has a strong relation with the Hour Record. In the middle of the 90s, we dedicated a lot of time and resources to this kind of race and we developed specific bikes for this. Everybody remembers the beautiful Espada, which Miguel Indurain rode during his successful record attempt in September 1994.

2. Bike development

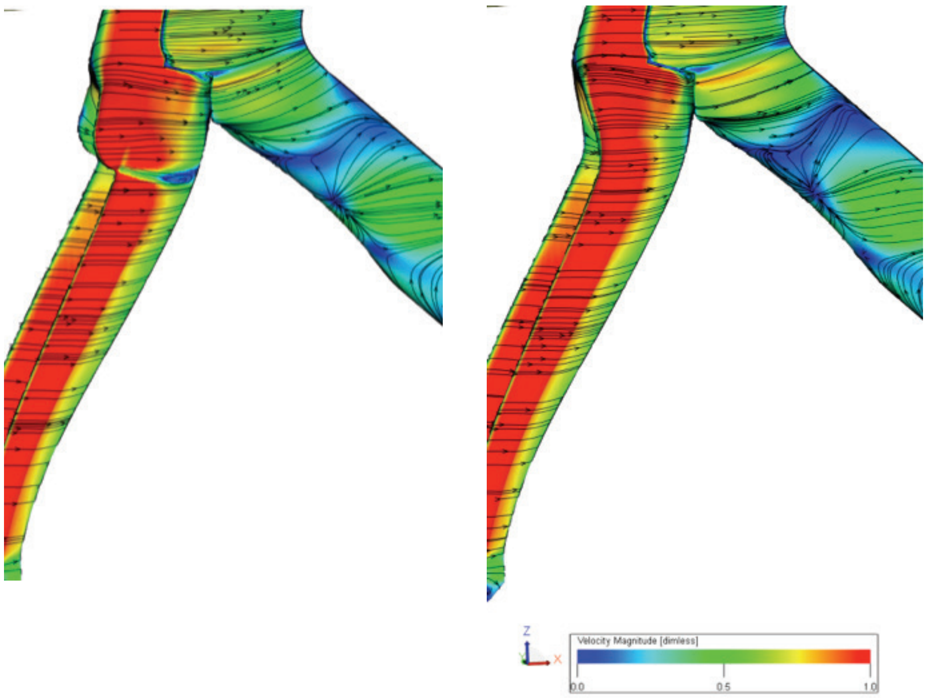
Frame design

The first step to design the bike is the analysis of the conditions during the event. The Hour Record is ridden on a track and, with the exception of the starting laps, the speed should be high and constant. Considering these conditions, the main characteristics to pursuit are the aerodynamics (which is the most important considering the high speed) and the stiffness (to transfer the riders' energy to the rear wheel). The last few years, Cicli Pinarello investigated in depth the aerodynamics of its bikes, using cutting-edge technologies such as CFD[1] analysis and Wind Tunnel testing. All this effort allowed the company to develop and realize bikes with extraordinary aero performances, proven by the results achieved by our pro riders, one for all the Time Trial World Championship in Ponferrada 2014.

With all this in mind, Pinarello began the development of the Bolide HR using the road version of the Bolide as starting point.

Track bikes are quite different from road bikes, because many parts are missing, such as brakes and derailleurs. This permitted the redesign of some parts the Bolide frame and fork, to improve the aerodynamics; this was made possible and validated using the latest CFD simulations.

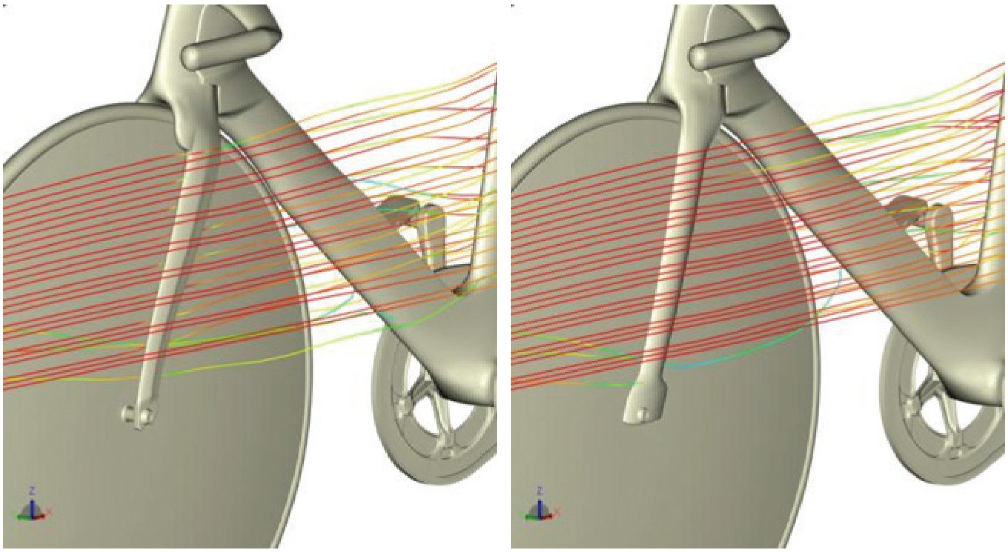
An example is shown here below. On the road version, the front part of the fork is shaped to house the front brake, and the nose of the fork is made accordingly (see image on the left); on the track version instead, since the brake is not needed, the fork surfaces area smoother (see image on the right), with a significant decrease of the aero drag.

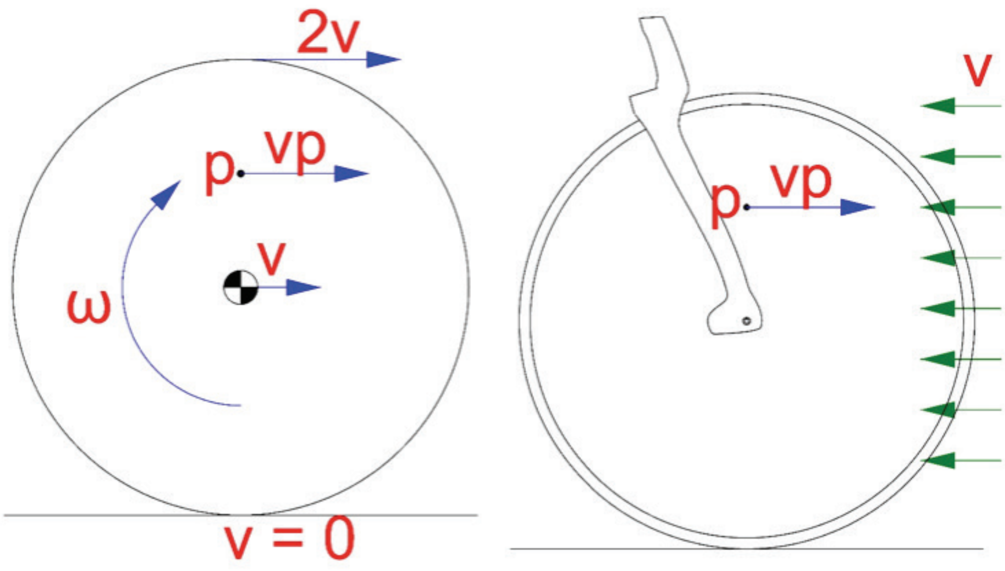


[1]Computational Fluid Dynamics (CFD for short) is a computer simulation of the forces produced when a body, such as a cyclist on a bike or a car on the road, is travelling through the air. CFD can give a very good understanding of where the drag (the force slowing the rider down) is created, as well as test very quickly new ideas on how to reduce it.

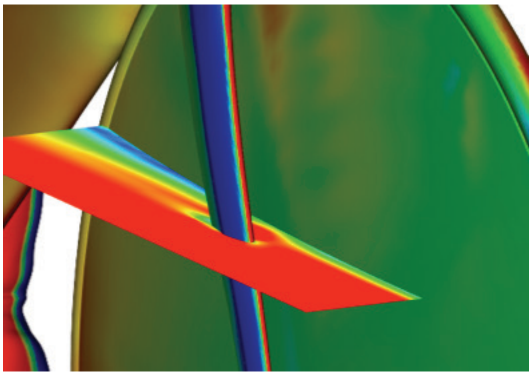
Another important consideration is compatibility with the surrounding components. On road cycling, there are different types of wheels, and the frame/fork has to be designed to fit all of them. In the case of the BOLIDE HR the selection of components was narrowed down significantly, therefore it was possible to match the different components better and extract better performance overall.

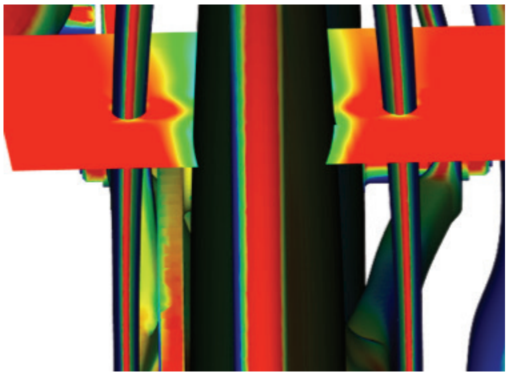
One example is the matching between the fork and the front wheel. A wheel spinning with a rotational speed ω is moving at a speed $v = \omega \cdot r$, where r is the radius of the wheel. Through simple calculations, the speed at the contact point with the ground is $vg = 0$, while the speed at the top of the wheel is $vt = 2v$; fixed the point p, which is half radius above the centre of the wheel, $vp = 3/2\ v$ (see left image). At the same time, if the bike (i.e. the wheel) is moving at a certain speed v, the air flows on the bike at the same opposite speed v. Considering the point p, the air near the disk surface is moving with a speed vp, while the air flow is moving with an opposite speed v (see right image): this condition generates extra drag and must be minimized.



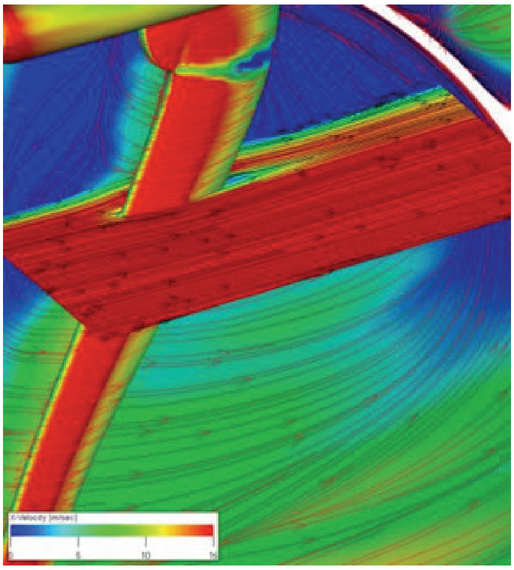


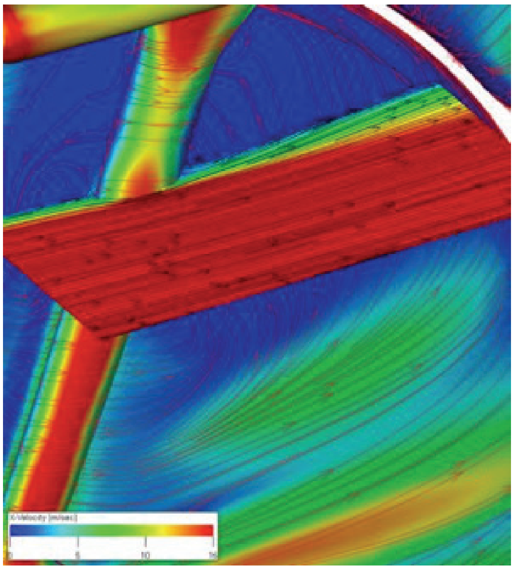
CFD clearly highlights this phenomenon in the images below.



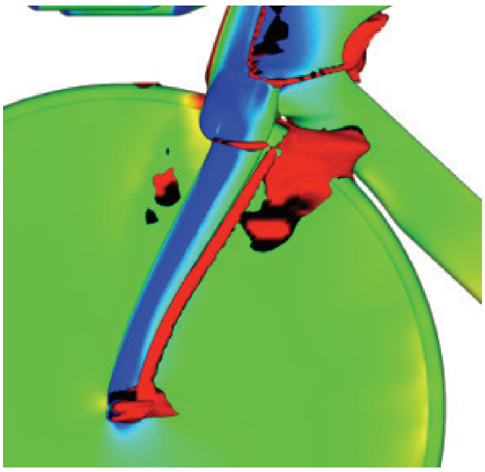


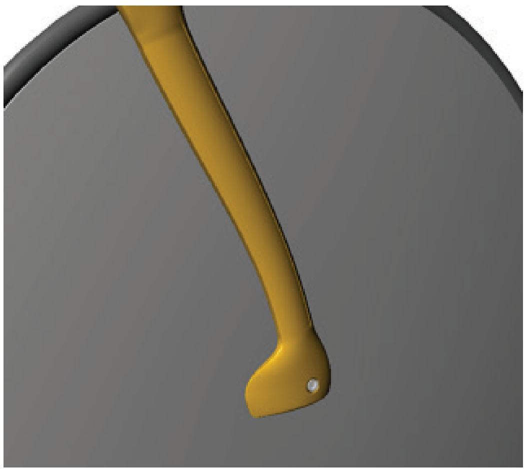
To solve this problem the solution could be widen the fork, to increase the space for the airflow, or minimize this gap within the disk boundary layer, to prevent the air to pass. We decided for the second option, shaping the legs very close to the wheel. The images below compare the initial model (with high turbulence near the fork) (left), with the final design (right), where the airflow avoids this gap.





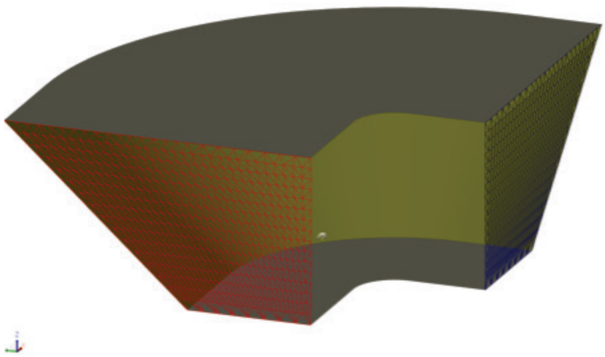
Even the front dropout highlighted a low pressure zone and, therefore, it has been modified. Image below, on the left, highlights the detachment of the airflow and high turbulence just behind the dropout; on the right, you can see how the shape has been modified to improve the airflow there.

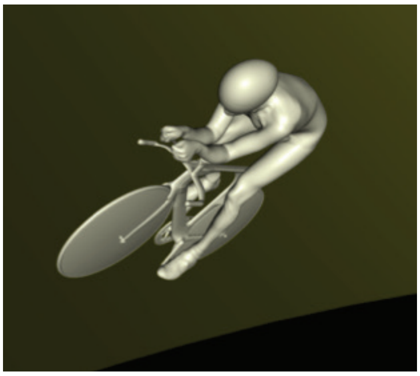


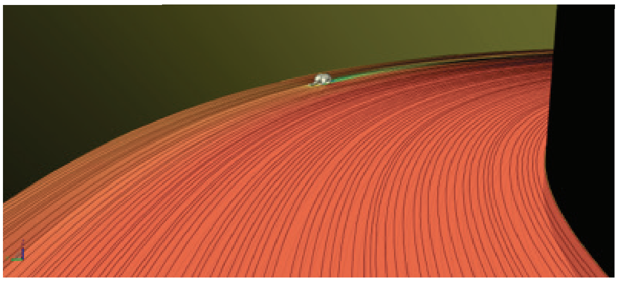


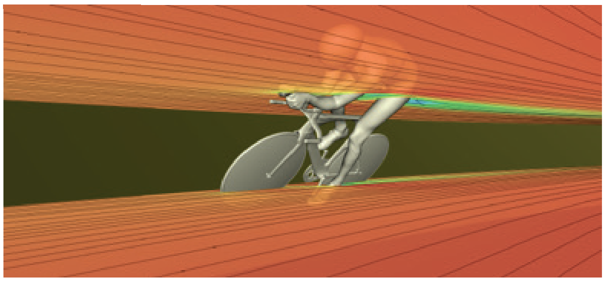
Similar considerations and analyses have been made for the other parts of the frame and components, such as the rear wheel and the handlebar.

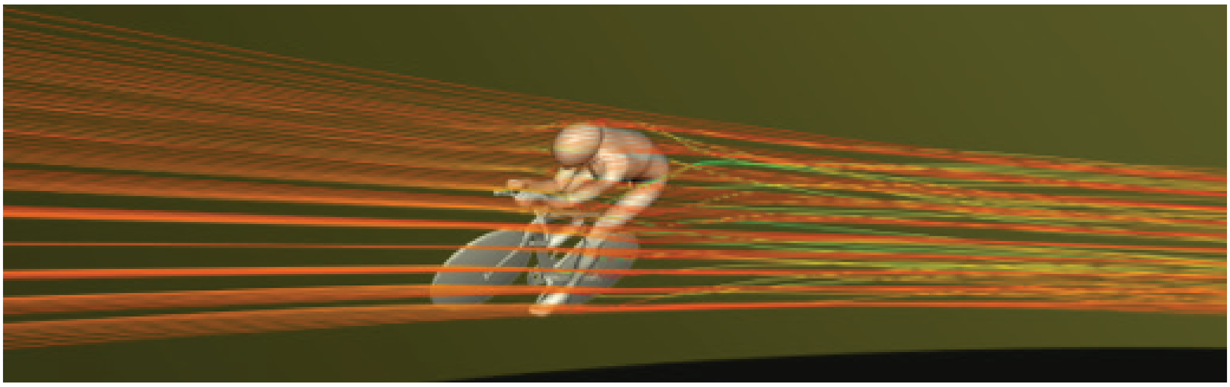
A further analysis was performed to check the aero performance considering the track characteristics (most velodromes today are 250 m long and the maximum banking is about 42º). The rider will spend almost half of the time on the curves, so the airflow will have also a lateral component, which is calculable. Again, using CFD, this condition was analyzed and measured the effect on the performance of the bike.





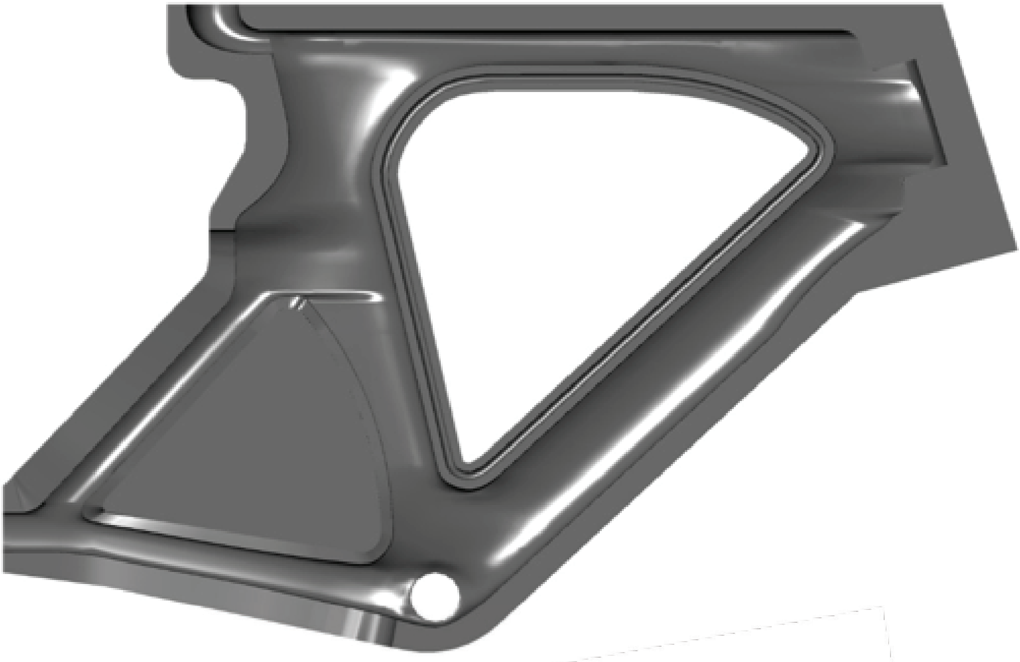






In parallel, similar attention has been dedicated to the stiffness of the frame, which is of equal importance to the aerodynamics. Increased stiffness indeed allows better power transfer to the rear wheel, without wasting energy by flexing the frame and therefore pulling the wheels out of alignment in every pedal stroke.

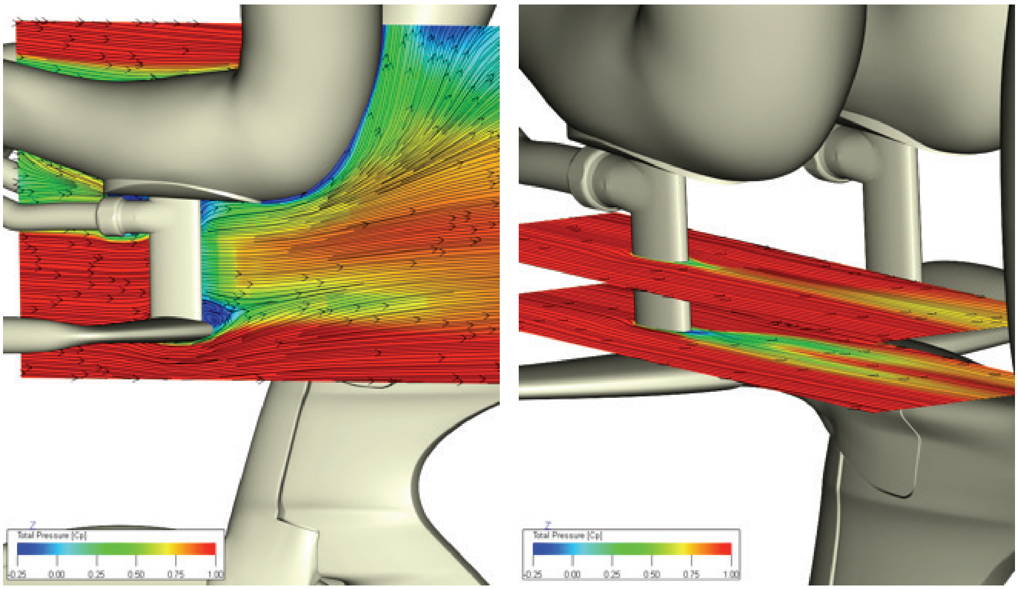
Composite materials allow the production of very stiff frames, with a low weight; at the same time, a proper design and production technique could further increase the performance. Traditional frames, for cost and time reasons, are usually produced is 2 or more parts, then bonded together, because this method allows quicker and cheaper production. At the same time, the bonding areas require more material (to allow the overlapping of the parts), which means more weight and creates zone of possible stress concentration. To solve all these problems the frame is made as a one piece composite with no bonded parts after curing; this resulted in a light and stiff frame. Below a rendering of a part of the mold for the frame, and a picture of a sample after the curing.



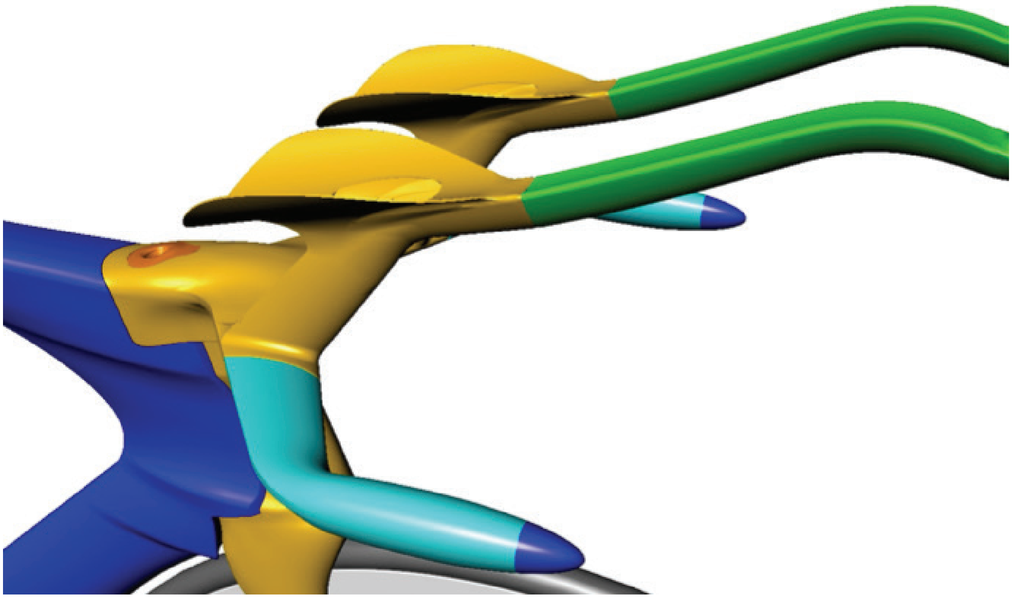
Component design

Similar considerations have been made for the components. The handlebar is placed in the front of the bike and, considering all its parts (bar, arm rests, grips, etc.), deeply influences the aero performance of the whole bike. Using CFD different possible configurations were analyzed, and improved the shape of the parts while keeping within the UCI limits of 3:1[2]

For example, behind the spacers for the arm rests, a low pressure zone is generated, because of the transition between the parts. A proper design of this zone helps to reduce this, and consequently the drag.



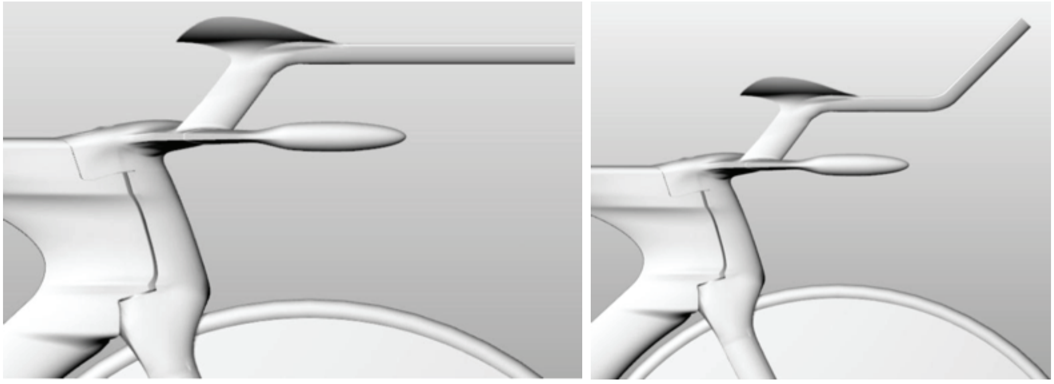
The handlebar has been deeply reshaped, and this resulted in a very innovative and particular design.



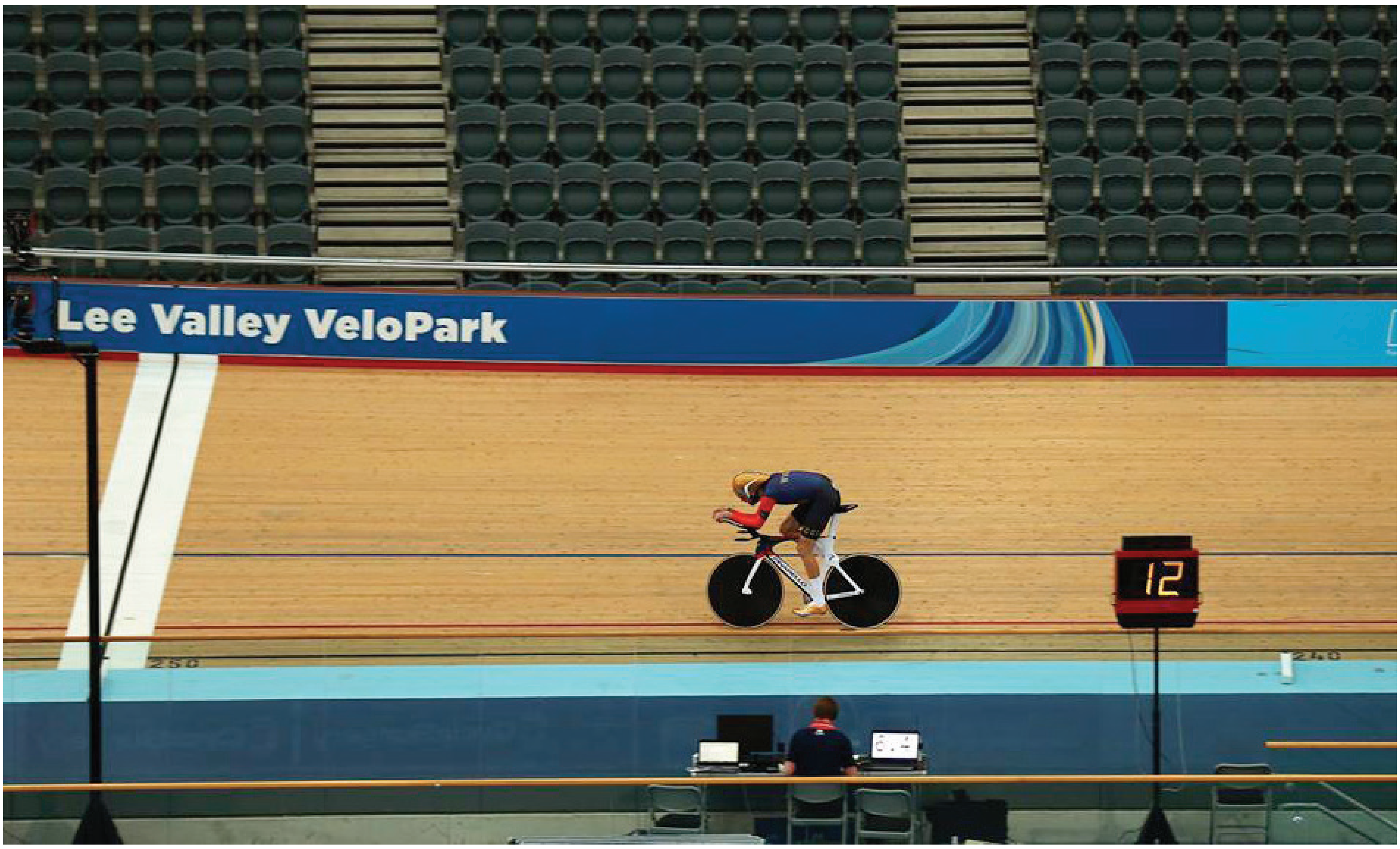
Standard technologies, such as CNC or carbon molding, would be excessively long and expensive to produce this particular shape, so we used an Additive Manufacturing method (also known as 3D Prining) to manufacture a titanium handlebar. In the additive manufacturing technique a high enertgy source locally melts the powdered material (typically metal), as defined by a 3D model, binding the material together to create a solid structure. 3D Printing is a relatively new technology that so far has mainly been used for rapid prototyping and for low-volume production of component parts.

The capabilities of this technology allowed to produce a small batch of handlebars, everyone different from the other, for example for the shape of the extensions. This method will now be used to provide a similar service to Pinarello customers via the MOST parts brand.

[2]The UCI regulations require that the maximum length of a section is no more than 3 times its maximum thickness.



Once all the components were defined and developed, the next step was to test the bike in the velodrome, to veridy the parts and finalize the setting. Below an example of the bike testing.



3. Final Design

The whole analyses performed and development allowed Pinarello to define the final shape of the bike, which minimize the overall drag.

The main characteristics of this bike are:

- Similar tubing sections of the Bolide
- Same geometry of the Bolide
- Aero-optimized fork and seatstays, which are very close to the wheel's profile
- Aero-optimized front dropout
- 3D Printed titanium handlebar
- UCI approved

BOLIDE

HR

Cicli Pinarello SpA
Viale della Repubblica 12
31020 Villorba (TV) Italy
tel. +39 0422 420877 fax +39 0422 421816
infobike@pinarello.com
www.pinarello.com