R&D WIND TUNNEL TESTS

Carbon Ceramic Derailleur Aero

NOVA RIDE

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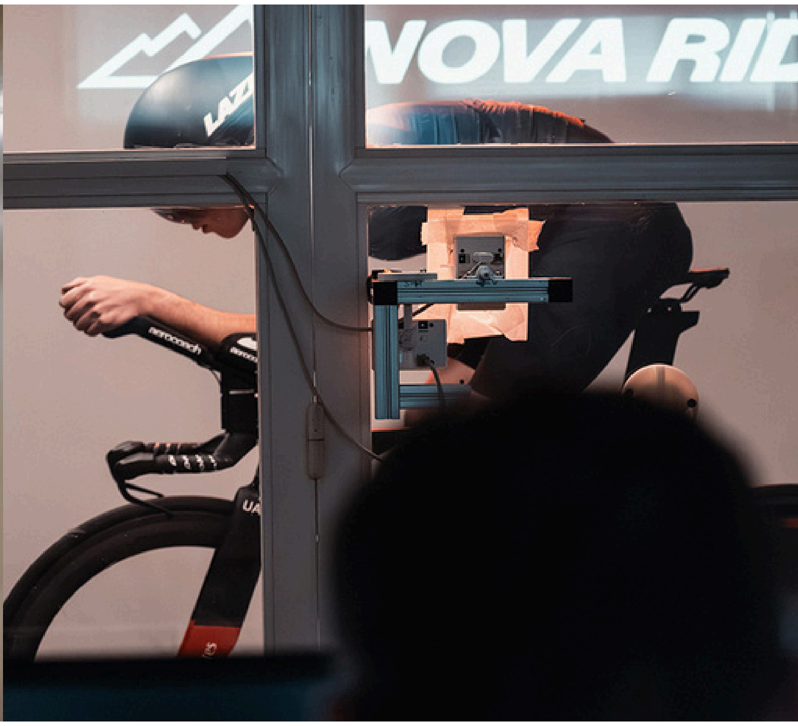

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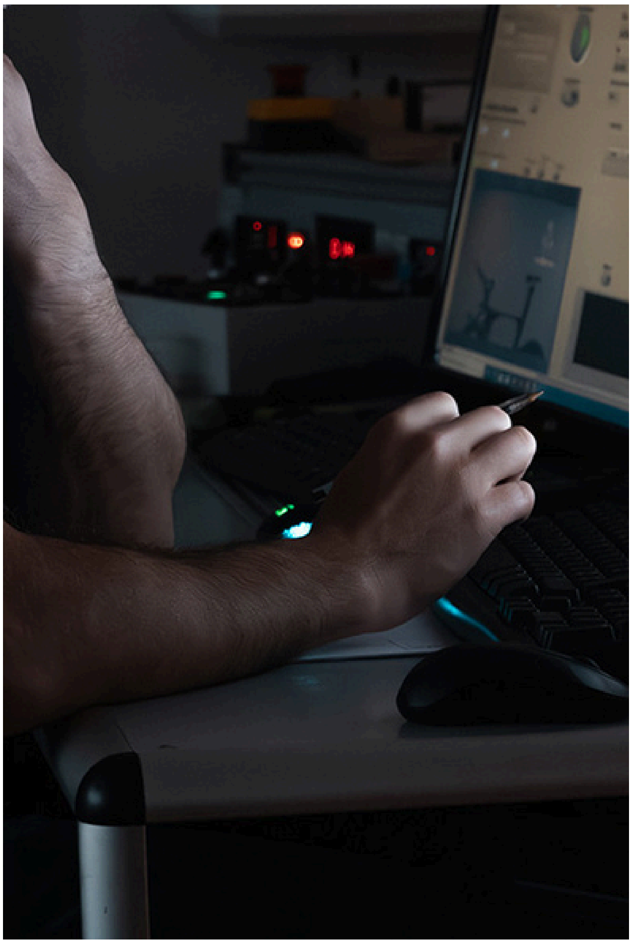
Introduction

At Nova Ride, our goal is to provide components that improve the performance of all cyclists. When we unveiled our first **Carbon Ceramic Derailleur (CCD)** cage in 2020, we wanted to enable cyclists to reduce internal friction in their drivetrains by offering oversized derailleur cages with ceramic bearings.

In an effort to improve our product range, we wanted to go a step further by focusing on a new parameter that is very important in cycling performance: aerodynamics.

The goal of creating this new product was to take the features that made our CCD successful and work on its aerodynamics. We were looking to produce the most efficient product in order to satisfy the most demanding cyclists, because every second counts! It is from this observation that we created the **CCD Aero**.

This report presents a study on the purely aerodynamic nature of the new product and on the gains made independently of the mechanical efficiency of the transmission.



Context

Design constraints

The development of this new product has 2 main aspects:
- Improve the aerodynamic performance of the derailleur hanger.
- Maintain our level of requirement regarding the operation of the part, without compromising on the efficiency of our existing product.

This is therefore an ultimate improvement of our CCD, specific to use in very demanding disciplines where every detail counts such as time trials or triathlons.

To do this, we have relied on our experience in the design of derailleur hangers to offer the most efficient product. During use, depending on the gear used, the derailleur hanger is in different positions to ensure chain tension.

The main design constraints were therefore as follows:
- Optimized derailleur operation and gear shifting
- Compatible with all bicycle development ranges
- Chain assembly without disassembling the cage
- Optimize the aerodynamic performance of the part over its entire angular range of use

After having fulfilled all these main functions, we worked on reducing the weight of the part as well as on the aesthetic aspect to offer a product without compromise, with which we are fully satisfied. We also sought to optimize our manufacturing process to guarantee the best possible quality for this complex part.

During the development process, we used wind tunnel tests to validate our design choices and test the efficiency of our part in real conditions in order to measure the gains made.

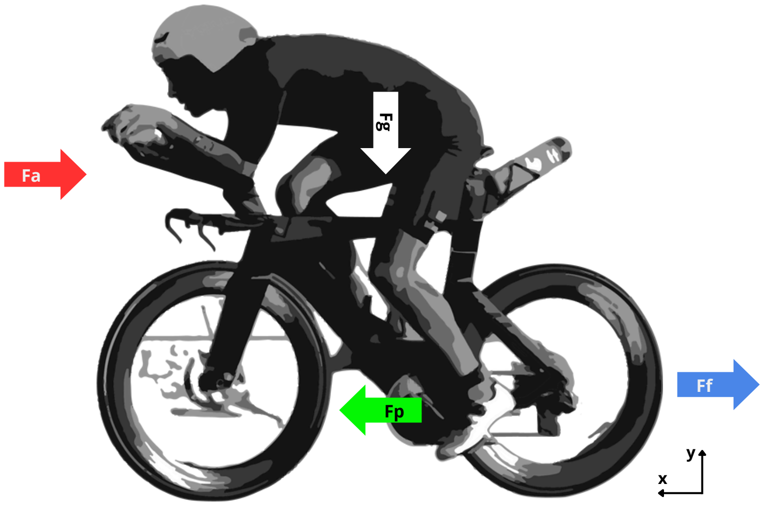
Detail of the forces applied to the cyclist

When in motion, the cyclist is subjected to several forces that condition his performance.

The equation of the forces that apply to the cyclist and define his progress is as follows:

$\Sigma F = F_p - (F_a + F_f + F_g)$

with
F_p = Propulsion force of the cyclist which allows progress.
F_a = Air resistance force.
F_f = Friction force.
F_g = Gravity force.



On x :
Si $\Sigma F > 0$, the cyclist accelerates.
Si $\Sigma F = 0$, it maintains a constant speed.
Si $\Sigma F < 0$, he slows down.

Nb: In the case of a zero slope, that is to say that the cyclist rides on the flat, the force of gravity is zero because $F_g = m.g.\sin(\theta)$, θ being the slope of the road. Therefore, if $\theta = 0$, $\sin(\theta) = 0$ and $F_g = 0$.

In the case of a cyclist moving at constant speed on a flat surface:

$\Sigma F = F_p - (F_a + F_f)$ so $F_p = F_a + F_f$
In our case, to optimize the cyclist's performance, we can play on the friction forces of the mechanical elements as well as on the air resistance force.

Our CCD component reduces the friction forces Ff by reducing the internal friction of the transmission. See Nova Ride component performance report for more details.

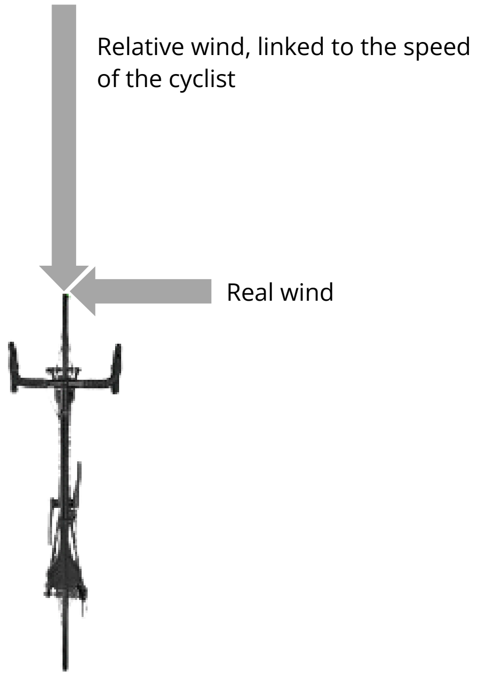
Our new CCD Aero is designed to reduce the air friction force and thus improve the bike's air penetration.

Taking wind into account

In cycling, the distinction between real wind and apparent wind is crucial to understanding the sensations and efforts felt.

Real wind is the wind as it is felt by a stationary observer, it has its own direction and speed, independent of the cyclist's movement.

Apparent wind is the wind felt by the cyclist in motion, it results from the vector combination of real wind and the cyclist's speed. In other words, it is the sum of the wind that is actually blowing and the wind created by the cyclist's own movement.



Considering the cyclist's speed, it is rare to encounter high apparent wind angles. Also, the higher the cyclist's speed, the lower the apparent wind angle values, due to the larger velocity vector component.

Calculation detail of Fa:

$$Fa = \frac{1}{2}\rho.SCx.V^2$$

ρ (kg/m^3) = air density
SCx (m^2) = frontal area * drag coefficient
V $(m.s^{-1})$ = speed

To overcome this force opposing forward motion, the cyclist must produce a power Pa (in Watts):

Pa = Fa . V

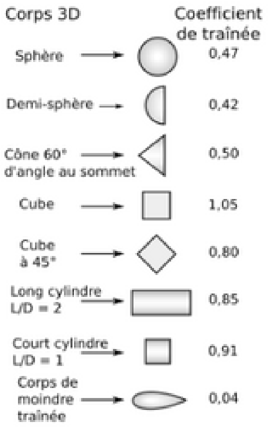
We then have: $Fa = \frac{1}{2}\rho.SCx.V^2.V = \frac{1}{2}\rho.SCx.V^3$

This necessary power Pa therefore increases proportionally to the cube of the speed, which means that a small increase in speed requires a much larger increase in power. It is therefore all the more important for the cyclist to optimize his aerodynamics when reaching high speeds.

Our component acts on the S.Cx parameter of the equation. The S.Cx is an essential aerodynamic parameter in cycling, directly influencing the cyclist's performance in the face of air resistance. It is the product of two elements:

Frontal surface (S): this is the projection of the silhouette of the cyclist and his bike on a plane perpendicular to the direction of movement (in m2).

Drag coefficient (Cx): this coefficient quantifies the aerodynamic resistance of a body moving in the air.



It is on this coefficient that we will play by defining a more optimized shape for the derailleur cage.

The product of these two values represents the equivalent drag surface. A lower S.Cx value indicates better penetration in the air, thus reducing aerodynamic resistance and improving the efficiency of the cyclist.

The interest of this S.CX parameter is that it is not dependent on the changing variables between the different test sessions.

To determine these real S.Cx values on our part, we worked with *AerOptimum* by carrying out wind tunnel tests.

The test

The wind tunnel

AerOptimum is a French test center specializing in aerodynamic testing of bicycles, located near the Nevers Magny-cours racing circuit.

Built in 1990, the *AerOptimum* wind tunnel was used until 2002 to define and optimize the aerodynamics of the Ligier team's Formula 1 cars and then those of the Prost Grand Prix team.

A closed-circuit and closed-vein wind tunnel, this extraordinary installation is presented as an enormous tube with a diameter varying between 2 and 8 meters. 40 m long and 15 m wide, it is equipped with a 9-blade fan with a diameter of 3 m developing 340 hp.
The brand new measurement system designed specifically by *AerOptimum* engineers allows for precise and rapid measurement of the aerodynamic drag of the bicycle/cyclist assembly.

The motorized drive of the bicycle wheels and the consideration of pedaling make it possible to get as close as possible to real conditions of use while guaranteeing high precision and repeatability of measurement.

Test parameters

Test bike: Colnago TT1 - Shimano Ultegra DI2 12s groupset - Zipp 303s Firecrest 60mm front wheel - Zipp super-9 Disc wheel rear wheel

All tests were carried out on the bike's largest gear ratio, large chainring and small sprocket, i.e. a gear ratio of 55-11 (cage in vertical position).

Tested cages:
- Shimano Ultegra Di2 R8150 12s
- CCD Nova Ride Shimano 12s
- CCD Aero Nova Ride Shimano 12s

Speeds and yaw angles tested for each configuration:
35 km/h, 45 km/h and 55 km/h at 0° yaw angle
50 km/h at yaw angles of -15°, -10°, -5°, 0, 5°, 10°, 15°

The different test speeds simulate the cyclist's forward speeds and the yaw angles simulate the angles of incidence of the apparent wind, perceived by the cyclist.

For these wind tunnel tests, we chose to carry out headwind tests at 35, 45 and 55 km/h to cover the usual speed range during time trials or long-distance triathlons. This allows the performance of components to be verified in varied scenarios and to analyze the variation in performance at higher speeds, where drag becomes dominant.

Next, we ran our series of tests at different wind angles at 50km/h, in both directions, to check the behavior of the tread under an airflow directed to the sides of the part.

The most complete measurement at different yaw angles was carried out at 50km/h to represent the performance of elite cyclists in time trials and to accurately capture the dominant aerodynamic effects at high speeds. Indeed, at 50km/h, drag represents up to 80-90% of the total resistance and testing at this speed allows us to accurately measure the aerodynamic gains of the components in conditions where they will have the most impact. Finally, it allows us to follow industry standards since this speed is often taken as a reference for this type of testing and to obtain measurable gains in competitive conditions.

These different measurements allow us to best cover all the intended ranges of use and to have consistent results to highlight. Thus, we were able to determine the gains at these speeds and verify the consistency of the results over this range of use. Each series of measurements was made twice to verify the results. The final value is the average of the 2 tests.

The results of these different measurements allowed the calculation of the aerodynamic power, which is a weighted average value perceived by the cyclist at this speed, according to the probability of encountering the different wind angles depending on the speed.

Wind tunnel tests allow for very good measurement repeatability since the tests are independent of external conditions, provided that the test configuration is identical between each measurement.

The most realistic configuration is the measurement with a cyclist pedaling in order to take into account the impact of the cyclist's position and the disturbances caused by the pedaling movement.

In our case, we expect to obtain small differences between the different test configurations and we seek to isolate the behavior of the derailleur cage as much as possible.

The behavior of the cyclist while pedaling can cause small differences in the measurements, even when paying full attention to maintaining the position. To avoid these measurement uncertainties due to the behavior of the cyclist, we chose to carry out the measurements with the different cages on the bike alone. Indeed, this allows us to have exactly the same configuration on each of the tests and to compare precisely and only the influence of the cages.

Measurement results

All values given are data averaged over a 20 second acquisition time.

Nova Ride CCD AERO Ultegra / Dura-Ace 12S

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)
0	35	0,388095	36,73661804
0	45	0,654125	80,52643342
0	55	0,98967	148,518451

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)	Average power at 50 km/h
0	50	0,821375	111,6471311	108,7
-15	50	0,76614	111,1414966	
-10	50	0,75786	105,5836168	
-5	50	0,795025	108,1111207	
0	50	0,82965	112,4399457	
5	50	0,7937	109,225164	
10	50	0,717105	101,7810434	
15	50	0,75392	112,0497369	

Nova Ride CCD Ultegra / Dura-Ace 12S

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)
0	35	0,38206	36,33543465
0	45	0,64566	79,72755669
0	55	0,980425	147,6009819

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)	Average power at 50 km/h
0	50	0,815945	110,9693704	107,5
-15	50	0,753995	109,8780875	
-10	50	0,7473	104,5842115	
-5	50	0,78127	107,1880372	
0	50	0,80985	110,53179	
5	50	0,78474	108,2144128	
10	50	0,706565	100,6061884	
15	50	0,74293	110,8213943	

Shimano Ultegra 12S original cage

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)
0	35	0,38209	36,36761982
0	45	0,644495	79,86240936
0	55	0,976375	147,7943452

Angle (°)	Speed (km/h)	SCx(m²)	Aero power (w)	Average power at 50 km/h
0	50	0,802965	110,5077667	107,7
-15	50	0,74919	110,6372173	
-10	50	0,742795	105,0449096	
-5	50	0,77168	106,9634388	
0	50	0,80581	111,2894132	
5	50	0,772665	108,1597128	
10	50	0,70078	101,0654381	
15	50	0,72953	110,331914	

The calculation of the weighted aerodynamic power allows to take into account all the wind angles according to their probability and therefore to express a comparable gain in real conditions of use.

The principle of the CCD Nova Ride is based on an oversized derailleur cage: larger pulleys and a longer carbon cage. The increased frontal surface of our derailleur cage is therefore a brake to have an optimized S.Cx. The aerodynamic performances are negligible at lower speeds (less than 35 km/h) and the gains made on the mechanical efficiency bring a real advantage compared to the original configuration.

The CCD Aero takes the same parameters as the CCD; oversized 14T - 17T pulleys, identical center distance, same thickness. However, we have completely redesigned the external shape of the cage to create a body of less drag and improve its Cx. This translates into a significant gain of 1.2 W at 50 km/h compared to the CCD Nova Ride. In our case, the S.Cx of the complete bike is improved by 1.5% at 50 km/h compared to the configuration with CCD Nova Ride.

The CCD Aero Nova Ride also allows a slight gain compared to the original configuration with Shimano Ultegra 12s derailleur cage, even with a larger frontal surface. The drag coefficient of the cage is therefore significantly improved, which reduces the resistance to the cyclist's progress.

Obviously, these tests only take into account the aerodynamic parameter of the bike and therefore only influence the air resistance force (Fa). However, we know that our CCD, without being particularly optimized from an aerodynamic point of view, already allowed a significant gain in the cyclist's power by playing on the friction forces Ff.
The Aero CCD therefore allows an additional gain that adds to the results of our previous studies.

During our wind tunnel tests, we also carried out measurements with a cyclist positioned on the bike. This allowed us to measure the proportion of aerodynamic power caused by the bike and by the cyclist.

In our test configuration, the cyclist represented 68% of the aerodynamic power and the bike represented 32%. These values are only valid in our bike + cyclist test configuration and may vary depending on the bike, the cyclist's morphology and their position. However, this allows us to establish a point of comparison on the bike/cyclist distribution in the aerodynamic power equation.
Thus, in our test configuration, the Aero Nova Ride CCD allows a 1.5% reduction in the S.Cx of the complete bike and allows a gain of 1.2 Watts at 50 km/h compared to the Nova Ride CCD.

It is difficult to estimate the impact on the derailleur alone because it is positioned on the rear of the bike and therefore undergoes the airflow around the bike. It would be inconsistent to do a test on the derailleur or the cage alone because the flow would be very different from reality.

Gain CCD Aero compared to CCD Nova Ride: 1.2 Watts at 50 km/h
Gain CCD Aero compared to Shimano Ultegra Di2 12s cage: 0.2 Watts at 50 km/h

Conclusion

Until now, Nova Ride offered with the CDD a product to optimize the transmission of the bike and reduce internal friction, with the aim of improving the overall performance of the cyclist.

A new step has been taken with the development of a new version of our flagship product: the CCD Aero. The goal was simple: **to offer a product that is still as efficient but even more optimized with work on aerodynamics.** Indeed, we had already been able to test the effectiveness of the CCD which acts only on the mechanical friction of the transmission. However, air resistance is a major force that opposes the progress of a cyclist and its influence increases considerably with speed.

With this report, we were able to demonstrate the gains brought by the new CCD Aero, only on the aerodynamic aspect. **On this aspect, this product, although oversized, already allows to be more efficient than the original components.** This is thanks to work on a profiled shape to minimize air resistance and make the most of the gains made on mechanical efficiency. We were also able to estimate the gains made by the complete system in real competition conditions. In conclusion, **this new product makes a difference thanks to its mechanical and aerodynamic performance.**

The CCD Aero is our most advanced product and is the ultimate improvement for demanding and performance-conscious cyclists, especially in disciplines such as time trials or triathlon and Ironman, where aerodynamics are essential.

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