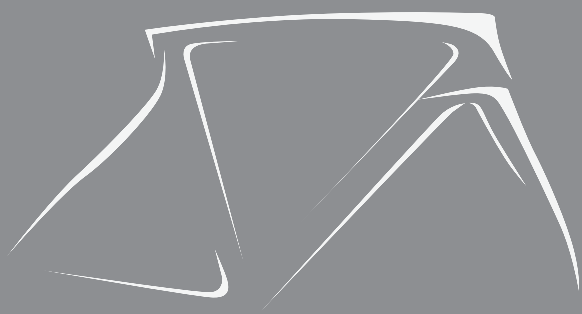


PINARELLO DOGMA F8

© Cicli Pinarello Spa - All rights reserved - April 2014

CONTENTS

3 **1. Introduction** - Background

4 Collaboration with Team Sky and Jaguar

5 Purposes and engineering method

7 **2. Structural Design** - Introduction to FEM

8 Frame asymmetry

11 Torayca T1100 1K carbon fiber

12 Pre Processing

12 Processing

15 **3. Aero design** - Introduction to CFD

17 FlatBack profiles

18 Pre Processing

19 Processing

21 Post-Processing & Results

24 **4. Final Design**

25 DOGMA F8 highlights

31 Rapid prototyping sample

32 **5. Tests Structural tests**

33 Wind Tunnel Tests

35 Road Tests

© Cicli Pinarello Spa - All rights reserved - April 2014

1. INTRODUCTION
Background

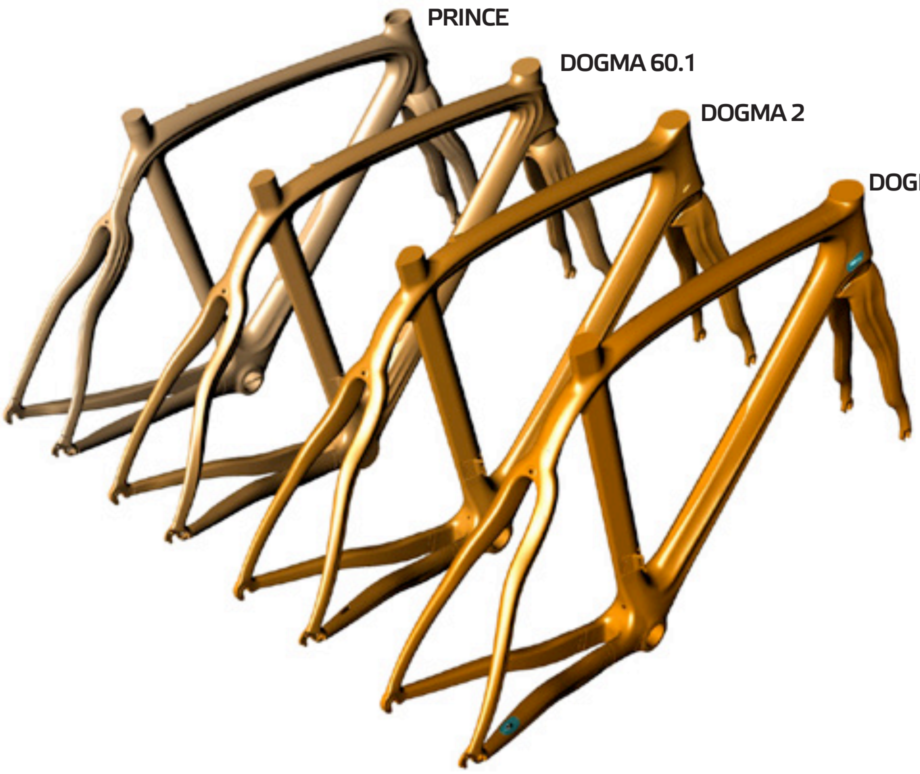
The bicycle is a land vehicle propelled by muscle power of the legs. It, during its motion, is subject to different forces, which depend on conditions and are opposite to the motion. These are the rolling resistance, the weight force and the air drag. The first depends on many factors acting on the road-wheel-powertrain system. The second, as is known, depends on the slope of the road, as well as by the weight of bike and rider. Finally, the third depends mainly on the "shape" of the frame and the position assumed by the rider, as well as the speed. It is therefore clear that the main features of a road bike frame is the following: stiffness, weight and aerodynamics.

Stiffness prevents the loss of energy generated by the rider from useless deformation of the frame, and transfer it to the rear wheel. Asymmetry, a famous characteristic of all Pinarello frames, significantly increases the overall stiffness of the frame: different sections between the left and right sides allow a more balanced response to the forces during a ride. Since 2009 Pinarello has studied and implemented this concept on its bikes, to offer each rider a bike as balanced as possible.

Weight reduction brings benefits in every moment of the ride. It is logical to think that the lower the weight of the bike, the lower the force that opposes the motion during a climb. Less intuitive, but equally important, is that a lower weight results in lower inertia and therefore less energy needed to speed up or slow down the bike. Aerodynamics is now a fundamental quality to search while developing a bike: mainly on flat courses, given the ever-increasing race speed, with averages above 40 km/h, the reduction of aerodynamic drag of the bike plays a key role in preserving energy during the race.

Prince, Dogma 60.1, Dogma 2, Dogma 65.1 Think2, are the bikes that so far have taken the path of asymmetry and aerodynamics, in a continually improving process.

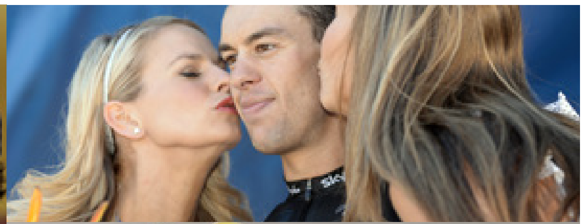
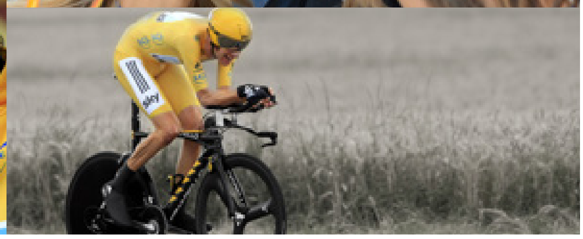
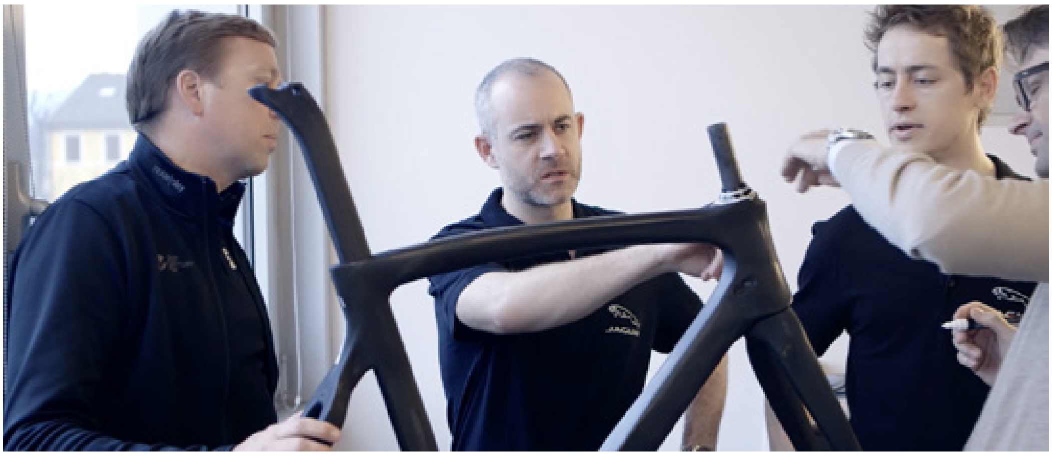
The Dogma 65.1 has won 2 Tour de France with Sir Bradley Wiggins and Chris Froome, the Road World Championship with Alberto Rui Costa and more than 130 UCI ProTour races during the two years in which has been used by the professionals. The Dogma 65.1 is also the best-selling frame in the Pinarello history since 1961, and the most imitated frame on the web, an unquestionable symptom of how it is the absolute benchmark in the cycling world.



© Cicli Pinarello Spa - All rights reserved - April 2014

Collaboration with Team Sky and Jaguar

Pinarello has supported Team Sky since its foundation in 2009, providing the team with bikes. This allowed us to test our bikes in the most important races across the world and to gather precious feedbacks to improve them. Also during the development of Dogma F8, there was an intense collaboration with the team, exchanging information and knowledge.
Furthermore, in this new project, Jaguar also joined us during the development of the bike, sharing their leading innovative design and technological testing facilities. They played an especially key role in the design process of the bike through advanced CFD and aerodynamic modeling.


© Cicli Pinarello Spa - All rights reserved - April 2014

Purposes and engineering method

There are many factors to consider when designing a new bike, especially if it must be an all-around bike. It is very important to identify which are the project's purposes, to follow them along the development and, at the end, to verify that the new bike complies with them.

Our aim was improving the structural and aero performance of the bike, maintaining our typical handling and ride feeling.

The four purposes at the beginning of this new project were:

Maintain same handling, to guarantee the same ride feeling as the Dogma 65.1. We want to allow every rider to get on board the new bike and experience the improvements, certain that it would behave as his previous Pinarello bike, agile and precise in every corner. So we used same geometries (13 sizes allow every rider to find the frame which best accommodates his body), and same tapered headset of Dogma 65.1 (top bearing 1"1/8, bottom bearing 1"1/2);

Increase powertrain stiffness and vertical compliance, to avoid any waste of energy and to have a more balanced behavior of the bike. The power transfer happens especially through the head tube, down tube, bottom bracket and chainstays: more stiffness is required in these zones to lessen energy wasting deflections and increase the power transfer between the rider and the rear wheel. Then, if the "upper part" of the frame (seatstays and seat tube) is properly designed, it can easily absorb the terrain roughness, assuring a more comfortable ride. We've used a new material and improved the asymmetry concept to reach this;

Reduce air drag, to reduce any waste of energy due to air resistance. We used new tubing sections and deeply analyzed the interaction of every component, to optimize the airflow along the bike;

Reduce the weight, to reduce the energy needed in a hilly route or climbs. Furthermore, this would also reduce the bike's inertia, allowing quicker accelerations and braking. The use of a new material, the optimization of the tubing sections and the new development of the asymmetry concept help us to reach this purpose.

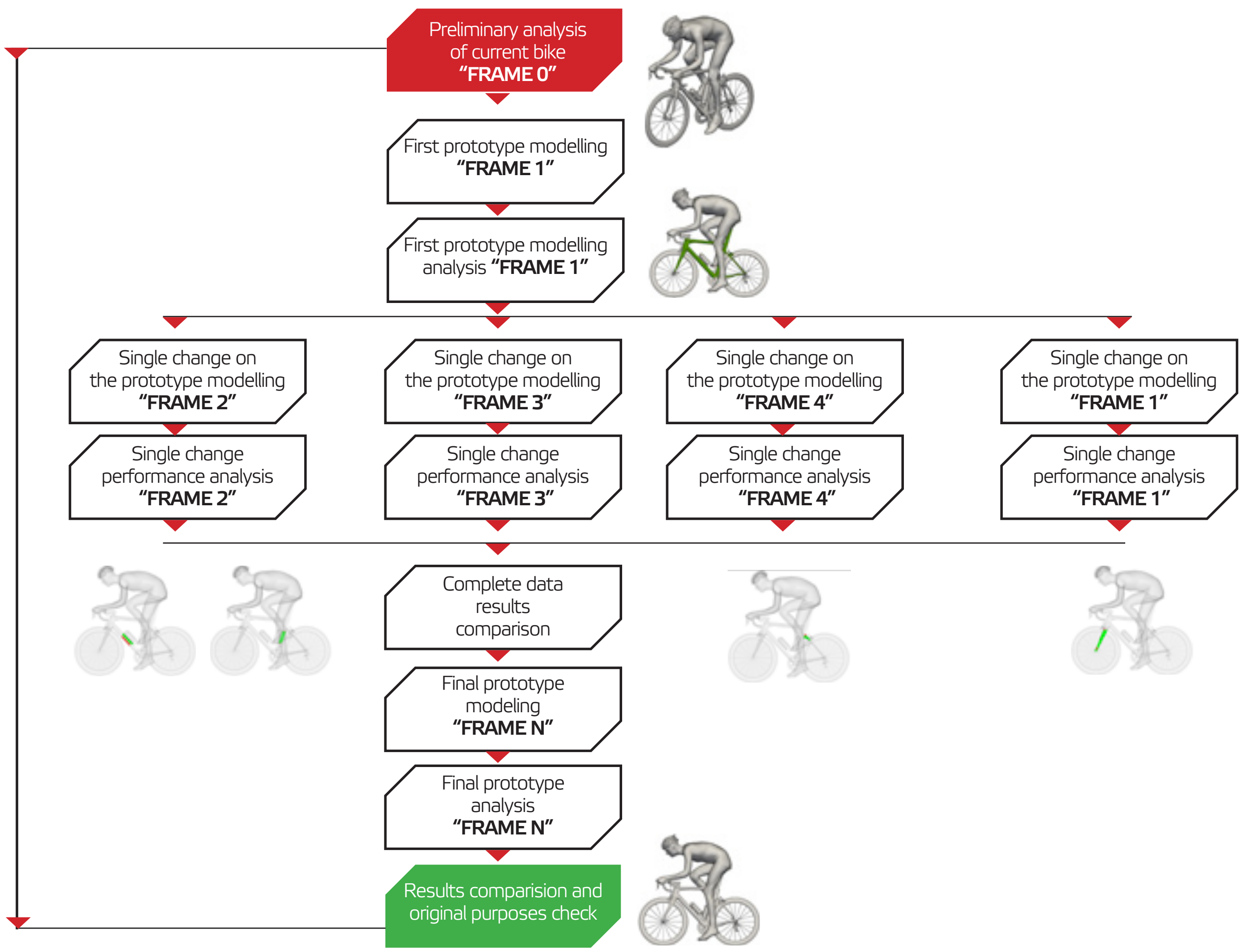
© Cicli Pinarello Spa - All rights reserved - April 2014

Purposes and engineering method

Each of the purposes listed above is a good improvement for a bike, but what we looked for was an overall improvement. Using FEM and CFD analyses and collaborating with Team Sky and Jaguar, we reached all the above purposes, ensuring the best possible solution.

The engineering method used during the design phase was intended to verify every step of the development and can be summarized with the chart below. This iterative approach had been used both for structural and aerodynamic design.

First of all we analyzed the performance of Dogma 65.1, fixing a reference point for verification (we called it “Frame 0”); this analysis also highlights the most critic zones to improve. Then we designed and analyzed a first prototype (called “Frame 1”), which yet contains new solutions. After that we modified the “Frame 1” applying every time a single change, obtaining many different frames (“Frame 2”, “Frame 3”, …, “Frame n-1”); the analysis of every single frame show us the benefits of these modifications. Finally, after we analyzed and compared the results of many different prototypes, we fixed the features that ensure the best compromise; with these features we designed the final version of the frame (“Frame n”).
At the end, we compared the performance of “Frame 0” and “Frame n”, verifying if we reached the original purposes.



© Cicli Pinarello Spa - All rights reserved - April 2014

2. STRUCTURAL DESIGN

Introduction to FEM

FEM (Finite Element Method) is a method to virtually reproduce, study and verify the behavior of a real object when subjected to some forces.
Using this technique we could:
- create and compare many different virtual prototypes;
- optimize the shapes and sections of the tubes, in relation to the performance needed;
- reduce designing time and costs, because the performances could be preliminary verified without producing real prototypes.

Structural characteristics of a frame, stiffness and weight, primarily depend on material and shape.

The material, wrongly called carbon fiber, is a composite material, as it is composed of fibers/fabrics and resin: its properties depend on the type/quality and the interaction of both. It ensures high stiffness to weight ratios, as well as the possibility to place the material according to need; for example, reinforced areas are the bottom bracket and steering, while other areas less stressed are lightened.

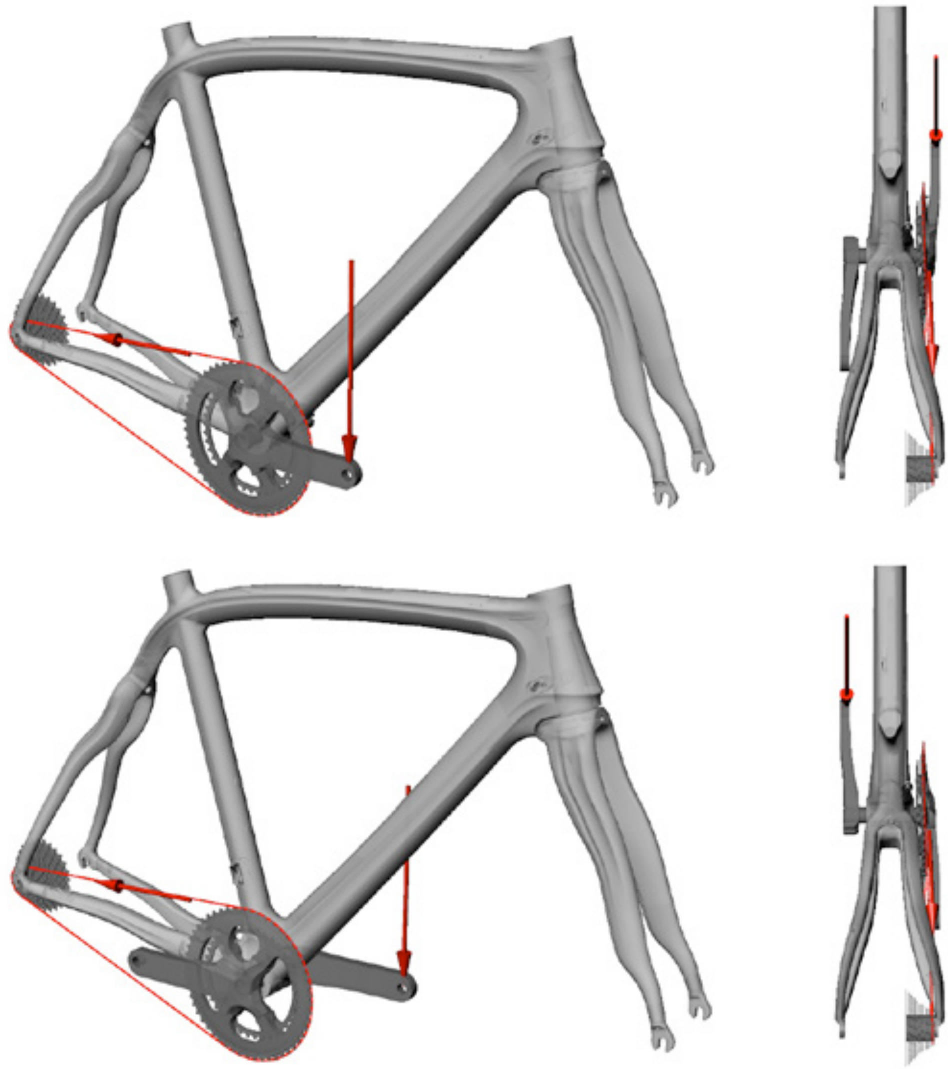
On the other hand, though often neglected, the shape of the tubes has an equally important role. It is well known that the various parts of the frame are subjected to different stresses and must ensure different responses, depending on the position in which they are located; for example:
the power transfer area (head tube, down tube, bottom bracket and chainstays) must be very stiff to minimize power wasted in useless deflection and maximize the power transfer to the rear wheel;
the area of the seat stays and seat tube, if properly designed, can absorb shocks from the ground to provide greater comfort to the rider.

FEM has allowed us to analyze different possible frame tubing, obtaining the best solution for our needs. During the analysis the real material was not simulated (analysis did not consider lay-up and real material properties), because the aim was the shape optimization.

© Cicli Pinarello Spa - All rights reserved - April 2014

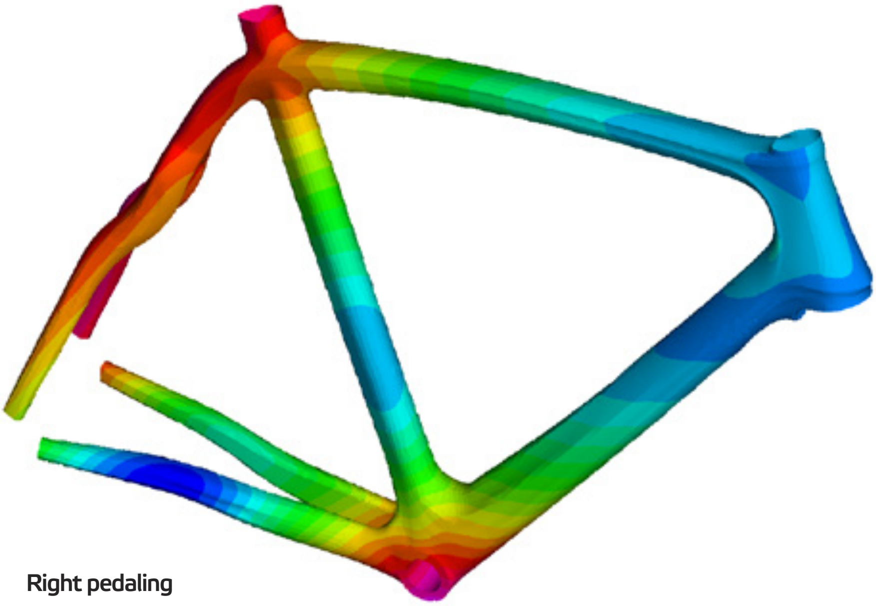
Frame asymmetry

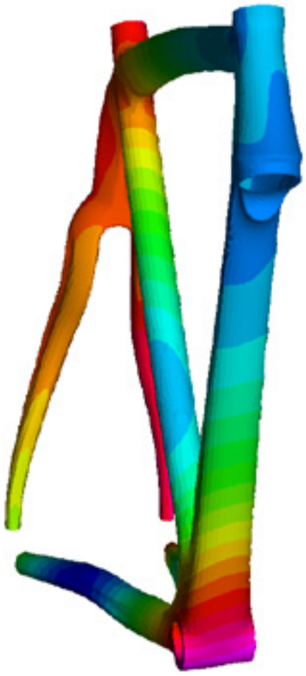
Well known in Pinarello design, the sections' asymmetry improves the symmetry (balance) in response to the stresses.
The power transmission from the rider's legs to the rear wheel hub happens through pedals and cranks, crankset, chain and sprockets. Most of these components are positioned on the right side of the bike, while the rider's force is applied on both sides of the bike.
Neglecting the physiological differences between right leg and the left thrusts, we can assume that a rider pushes on both pedals with equal force.
Considering a crank length between 170 and 175 mm, and a 53 teeth chainring, with simple formulas you can easily calculate that the force acting on the chain is about 60% greater than the force produced by the rider.
To give you an example, if the frequency is 1,5 Hz (90 pedals per minute) and the power expressed is 250 W, the force acting on the pedal is about 150 N, so, the force on the chain is about 240 N.



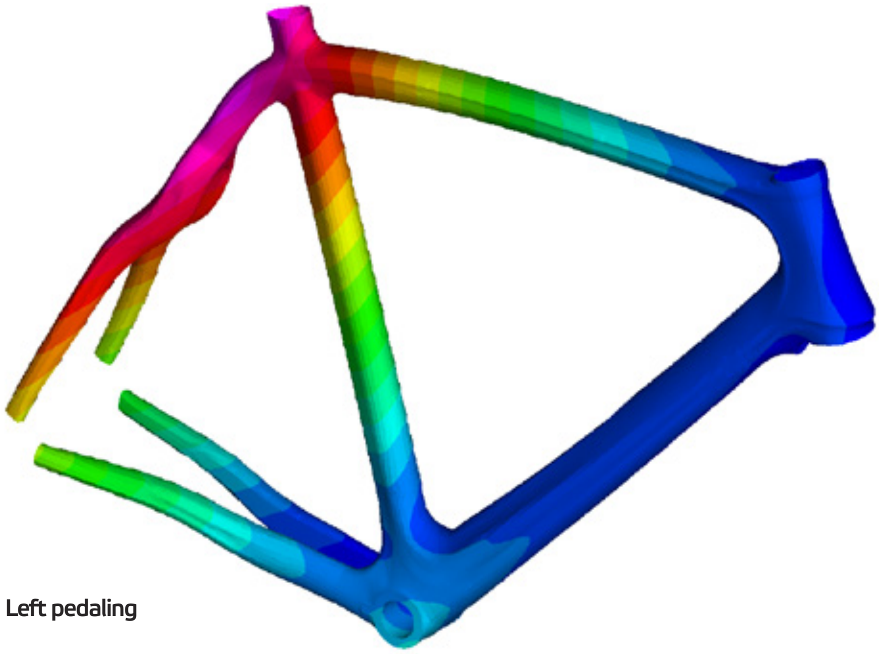
While pedaling on the right, these two forces (push on the pedal and chain pull) act concurrently on the right side: the frame twists and the bottom bracket is pushed to the left. While pedaling on the left, the two forces act in opposite manner on the two sides: the frame flexes, but in a less evident way as the forces (and the deformations too) are opposed to each other. It is now clear the asymmetric load conditions that the frame must counter. Designing and making a frame with asymmetrical shapes makes it more responsive to the stresses and provides a more balanced and symmetrical behavior, guaranteeing better performances and safer handling.
Images below show how the frame deflects while pedaling.

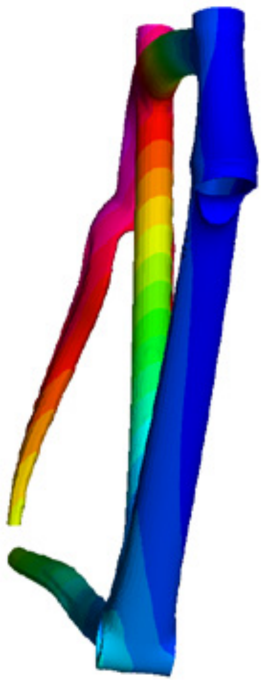
© Cicli Pinarello Spa - All rights reserved - April 2014





Right pedaling

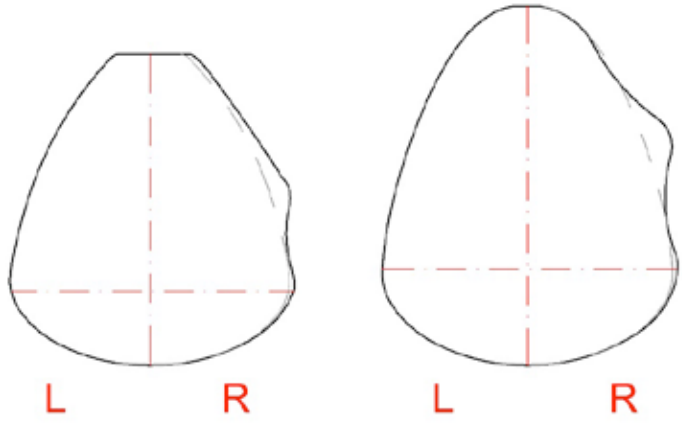




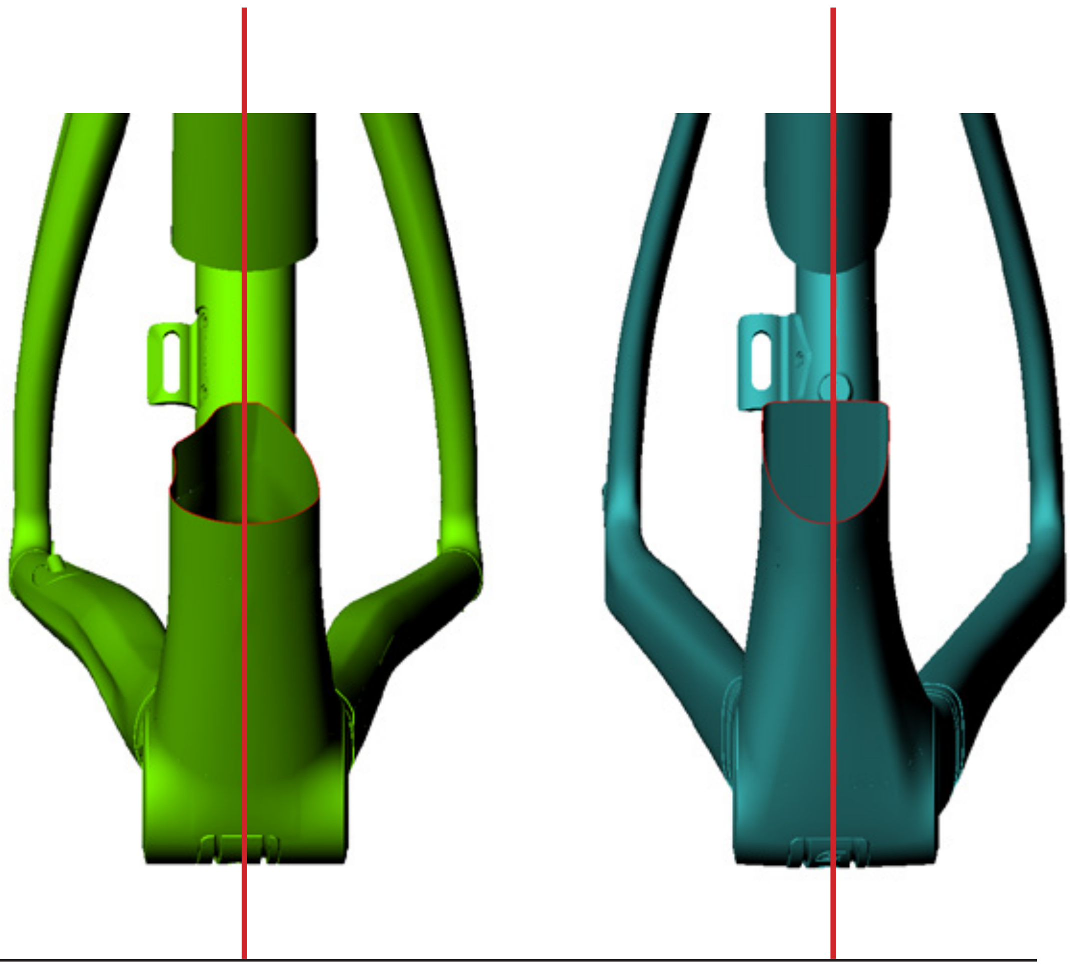
Left pedaling

The asymmetry concept has been adopted on our bikes for long time, but, while developing this frame, we re-analyzed and enhanced it. Until the Dogma 65.1, asymmetry was intended on the tubing's sections: the right half of the section was bigger than the left one. Picture below shows 2 examples of Dogma 65.1 sections of the down tube, where the right side is bigger than the left side.

© Cicli Pinarello Spa - All rights reserved - April 2014



With this new bike we enhanced this concept, not only modifying the sections, but also "moving" the tubes of the main triangle (top tube, down tube and seat tube) to the right side of the bike. FEM shows us that this solution further increases the stiffness of the frame and ensures a more balanced behavior.
Pictures below compare the down tube sections of Dogma 65.1 (left) and Dogma F8 (right): it is evident that the down tube of Dogma F8 is moved right.



© Cicli Pinarello Spa - All rights reserved - April 2014

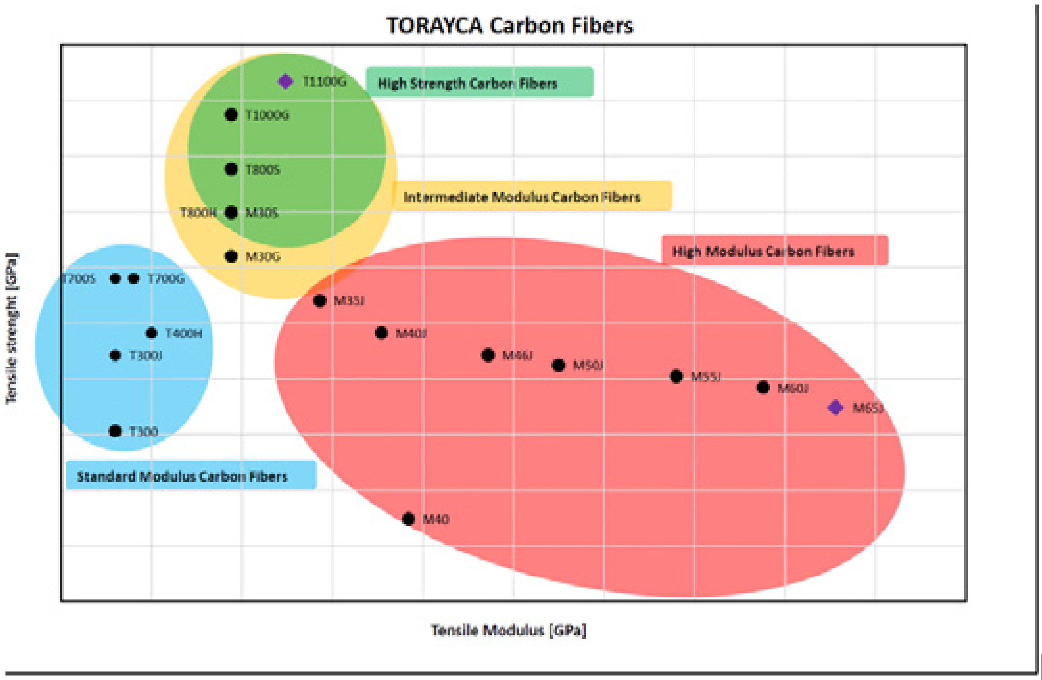
Torayca T1100 1K carbon fiber

Before discussing about the material, it is essential to clarify some concepts.
First of the name: usually everybody calls it "carbon fiber", but the proper name is "composite material". It is indeed a mixture of carbon fiber/fabrics and resin, and all its properties deeply depend on fiber properties, resin properties, lay-up and production method: if just one of these characteristics changes, the behavior of the material is definitely different.
Fibers can be used as simple bundles or interlaced into fabrics: this choice, as much as the lay-up (i.e. the direction of the fibers), influences both the production method and the performance. The main properties of the fibers are the Tensile Modulus and the Tensile Strength. Tensile Modulus, or Young's modulus, specifies the stiffness of the material: the higher this value, the stiffer the material. Tensile Strength, or Strand strength, specifies the amount of force needed to break it: the higher this value, the more resistant the material. For example, a rubber band has high strength and low tensile modulus: it is easily deformable, but difficult to break. On the other side, a matchstick is very stiff but quickly breaks if forced: this means a high tensile modulus and low strength.
Furthermore, one of the most dangerous conditions for composite material is when it is subject to an impact: the higher the strength, the better it reacts to this condition.
On the other hand, the resin assumes the fundamental role to compact the fiber, transferring the loads.
Two important features of the composite material are:
high stiffness to weight (E/ρ) and strength to weight (σ/ρ) ratios if compared to traditional materials:

	E/ρ	σ/ρ
Steel	0.0256	0.069 ÷ 0.256
Dural	0.0257	0.107 ÷ 0.178
Glass fiber + Polyester Resin	0.0233	0.518
Carbon Fiber + Epoxy Resin	0.1350	0.864

the possibility to reinforce only stressed areas, removing useless material from those zones little stressed.

The graph below shows Torayca main fibers' properties:



© Cicli Pinarello Spa - All rights reserved - April 2014

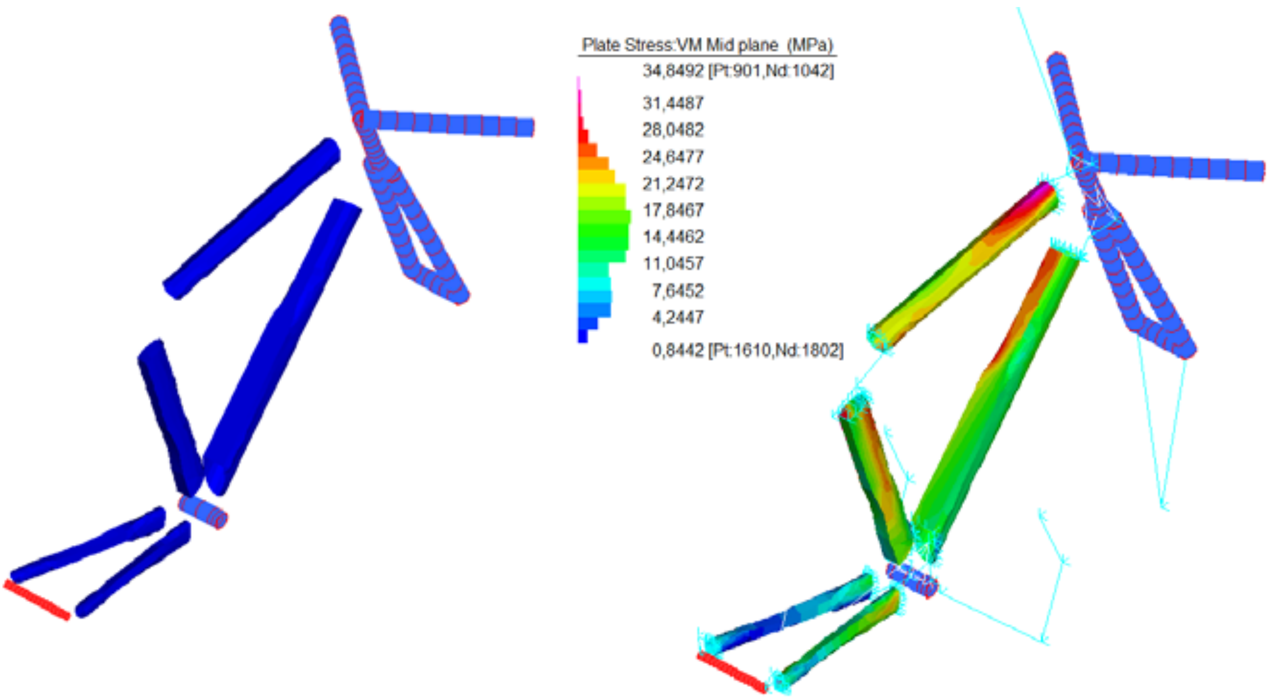
High tensile modulus carbon fibers (red area) are very stiff, but they are not as strong as the better high strength fibers. High tensile strength fibers (green area) are very resistant, but not stiff as the better high modulus fibers. So the optimal choice is using a mixture of different carbon fibers, depending on where they would be used and the performance needed.
In our Dogma F8 the best fiber used is the newly developed T1100G, which has the highest tensile strength in the world. This choice contributes to increase the impact strength, to prevent breakages. Furthermore we use T1100G prepreg with a new nanoalloy technology resin system, which also contributes to improve the impact strength.
Thanks to the highest grade of carbon fiber used (especially higher strength) we were able to get a lighter frame maintaining its strength unchanged. T1100G fibers have been used in the higher stressed areas, in order to take advantage of its incomparable strength.
The stiffness loss due to this new material has been replaced by tweaking the frame geometry (especially the new asymmetry concept) and on the lay-up; laboratory tests have confirmed.

Pre-processing

As mentioned, first analysis was made on the frame of Dogma 65.1; this provided a fixed reference point to compare the subsequent data. Then results of the following simulations were compared to this, considering the benefits that each solution was carrying in terms of stiffness and weight.
To evaluate the performance of each geometry (shape and sections of the tubes), neglecting the material variable, we supposed that frames were made with an isotropic material of constant thickness. This simplification has allowed on one hand to speed up the analyses, on the other to compare the real performance of each geometry.
Loads and constraints applied were derived from the regulation EN 14781 - Racing bicycles - Safety requirements and test methods (2005).
The load conditions represent different crank angles, and other conditions, such as a high vertical load on the saddle.
In addition, the fork has been analyzed, simulating longitudinal or lateral loads.

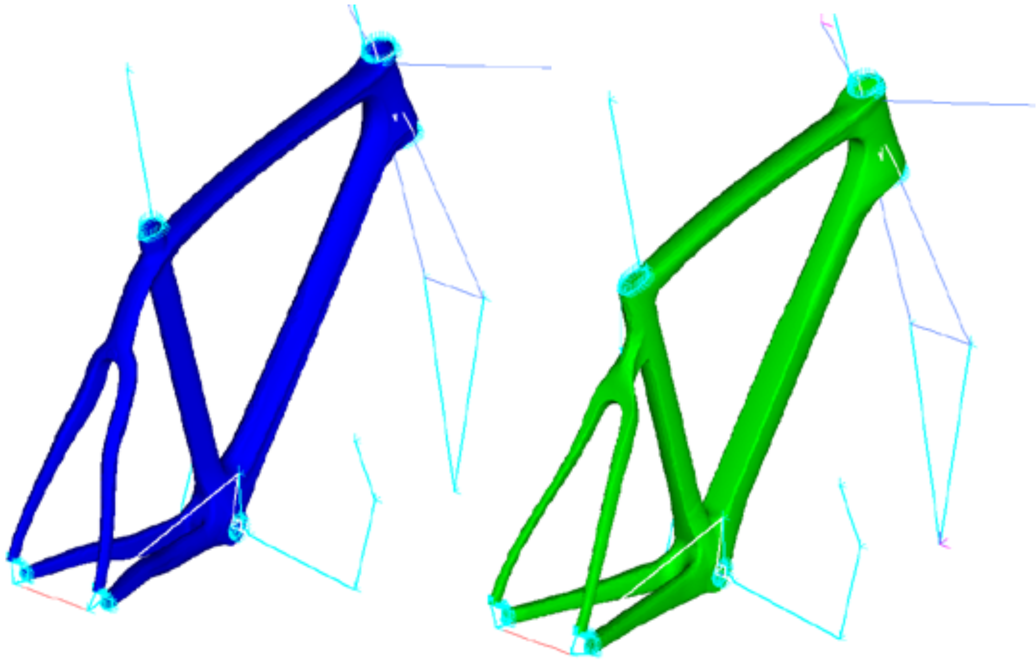
Processing

Analyses were performed in 2 phases:
preliminary analysis, in which only tubes were modeled, omitting junction areas. This analysis, albeit very simplified, enabled on one side a preliminary evaluation of the performance of different models, providing data for subsequent analysis and on the other hand to reduce the time of modeling and analyzing. This simplification also allows us to deeply analyze the influence of the asymmetry on the performances; indeed, omitting the junction area, we easily designed many different prototypes with the tubes moved to the right, comparing the performance and reaching the best compromise.



© Cicli Pinarello Spa - All rights reserved - April 2014

advanced analysis, in which the frames were completely modeled (with the exception of rear dropouts), to have a full evaluation of the performance. These analyses were performed once the main features of the bike were decided, to compare the real performance of the different frames.



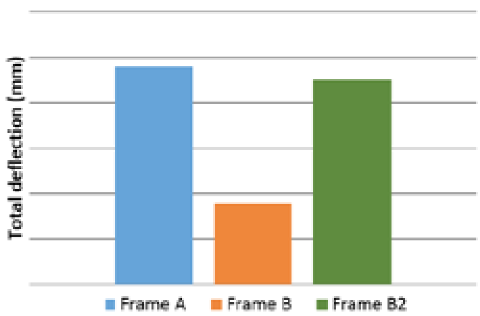
Totally we tested 35 different possible solutions, with more than 200 single FEM runs performed.

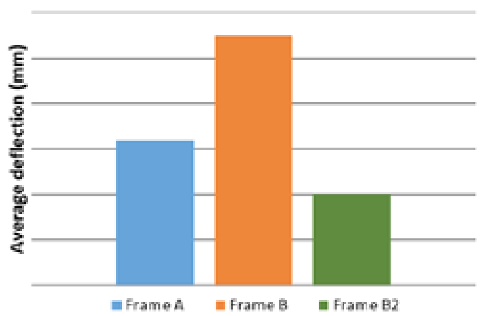
Post-processing and results

The results of every analysis have been compared to the others, evaluating the behavior in terms of stress distribution and displacement of reference points.
To compare the results, evaluating stiffness and symmetric behavior, we define two different indexes:

total deflection, intended as the sum of BB deflections for left and right pedaling. The lower this value, the greater the frame's stiffness;
average deflection, intended as the difference of BB deflections for left and right pedaling. The lower this value, the more balanced the frame is.

Example below better explains these indexes and how we used it during the design.
We consider 3 frames:
"Frame A"
"Frame B" similar to the previous one but with seat tube and down tube turned out by 5 mm near the BB and top tube turned out by 10 mm to the right
"Frame B2" same as "Frame B" with -3% wall thickness.

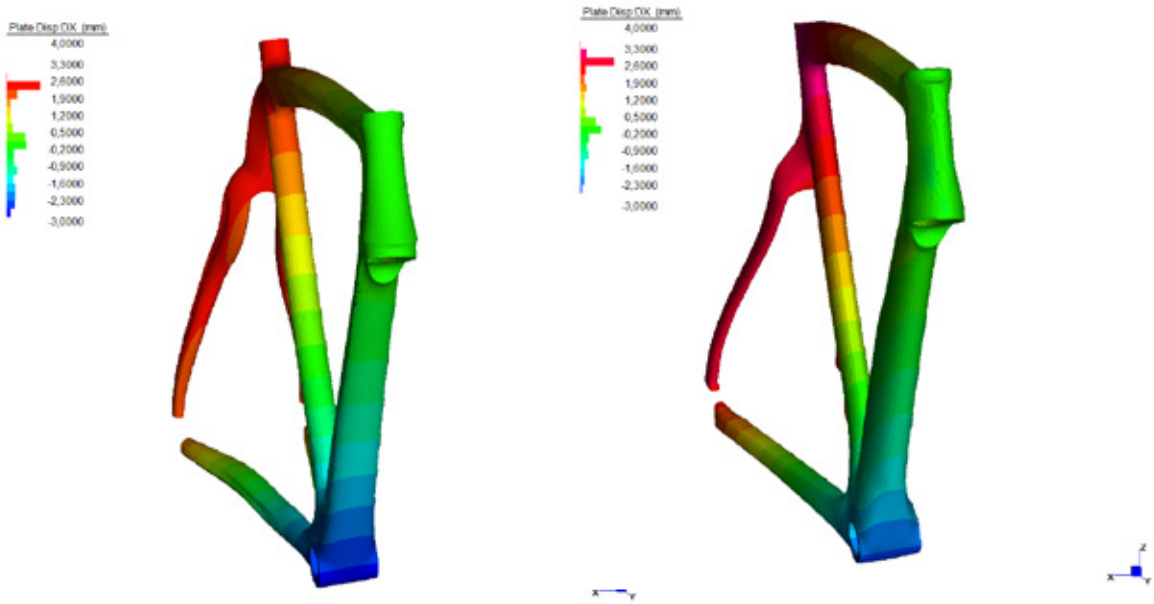




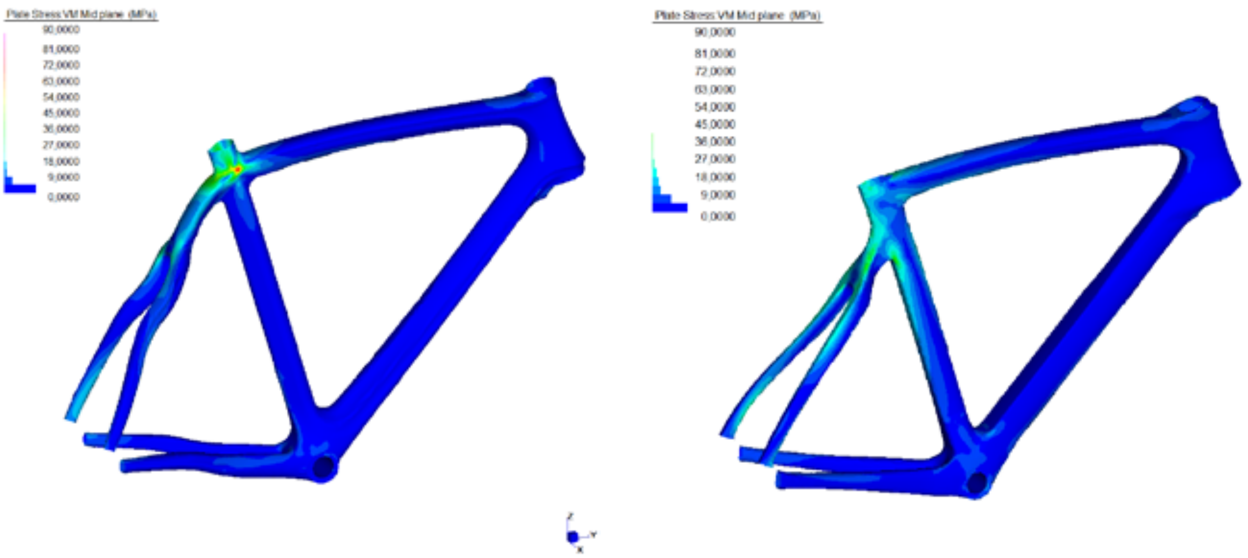
© Cicli Pinarello Spa - All rights reserved - April 2014

Previous charts show that frame B is stiffer than frame A, because it has a lower total deflection; on the contrary it has a higher average deflection, which means that it is less balanced. Frame B2 instead has a total deflection a bit lower than frame A (i.e. the stiffness is close), and a lower average deflection, which means that it is also more balanced; furthermore, since the wall thickness is 3% thinner, it is also lighter.

Beyond the numerical data, frames' performances were also compared through visualizations and animations. Below an example of displacements in right pedaling condition.



Below an example of stress distribution in vertical load condition. It is clear that the stresses are more distributed in the Dogma F8 frame and also the max value is lower.



The final comparison between Dogma 65.1 and Dogma F8 shows that Dogma F8 is 12% stiffer and 16% more balanced, without adding any material. These are the results of FEM comparison, so they only depend on the shape of the frames.
These theoretical gains were used to increase the stiffness and reduce the weight of the real bike.

© Cicli Pinarello Spa - All rights reserved - April 2014

3. Aero design

Introduction to CFD

When riding on flat routes, about 80% of the power expressed by the rider is needed to overcome the aerodynamic resistance that opposes the motion. Of this resistance, the rider affects approximately 75%, the frame and fork for around 15%, while the remaining 10% depends on the other components (wheels, handlebars, etc.). It is therefore clear that aerodynamically optimizing frame and fork would reduce the energy spent by the rider.
The aerodynamic resistance is a force, always opposite to the motion, which can be calculated through the following relation:
Fd = ρ v2 Cd A
where ρ is the air density, A the frontal area of bike and rider, Cd a coefficient that depends on the shape and the position of bike and rider. Once fixed these parameters (A and Cd depend on bike and rider), the aerodynamic drag depends on the square value of the speed. When riding on a flat route (where the weight's force is negligible), and average speeds are high, this is the main force to defeat.
A proper design of the frame allows reducing the frontal area A and the coefficient Cd, to minimize this resistant force, reducing the energy spent and improving the final performance.
Computational Fluid Dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Using CFD software during the design phase allows us to analyze the aerodynamic performance of different solutions, to highlight those zones that create the most drag and to verify the part of every single frame's zone and component (down tube, top tube, …, brakes, handlebar, etc.) on the overall drag. This achieves a bike with a lower air drag.

Weighting function

Before beginning the CFD analysis we should define a weighting function to properly compare and analyze all the results.
To define the weighting function we started collecting data about the wind. Both the wind's direction and the road traveled by the rider can be considered random. Our study focused on wind maps and data collected from 78 weather stations for 10 years. These databases contain information about the average speed of the winds at high altitudes (20 ÷ 50 m); to make these values useful were recalculated them as if they were measured at 1 m above the ground.
Once known the distribution of ground speeds, we proceeded determining the distribution of the yaw angles (i.e. we calculated the weight function). We define now some values regarding the speeds acting on the rider:
Vr is the rider's speed;
Vw is the wind speed;
Vin (inlet velocity) is the "ostensible" speed given by the sum of the previous two;
αw is the angle between the wind direction and the rider's direction;
αy is the yaw angle, between the inlet velocity and the rider's direction.

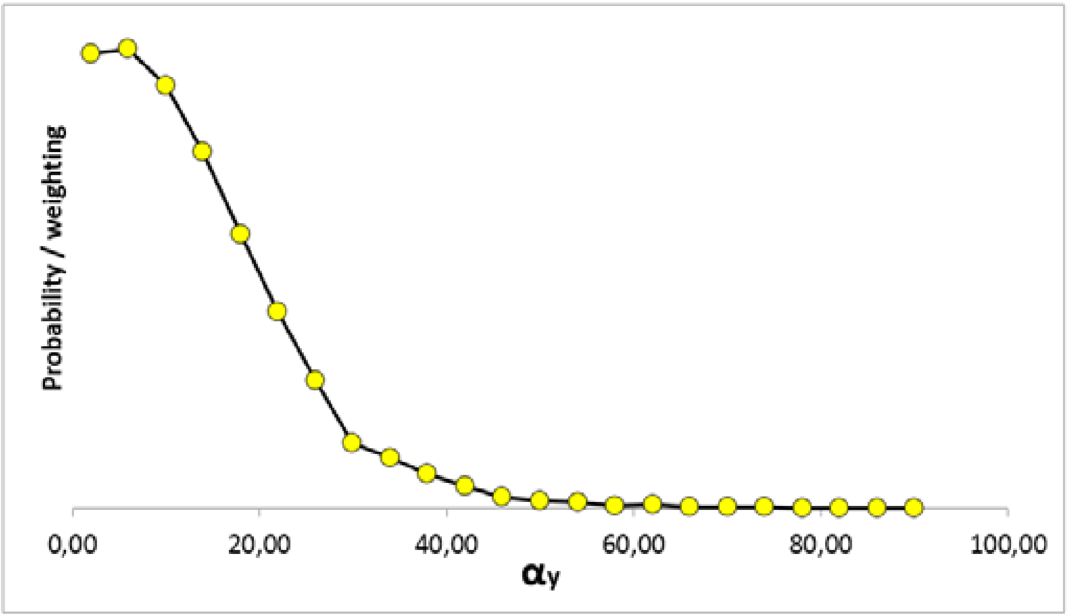
© Cicli Pinarello Spa - All rights reserved - April 2014

Using some vector relations, we obtained how αy depends by the other values. Fixed Vr = 14 m/s (50,4 km/h), we integrated the function for αw = 0º ÷ 180º and Vw = 0 ÷ 20 m/s, obtaining the distribution of yaw angle. This is not the probability that blows in a certain direction (as mentioned earlier, it is to be considered random), but the probability that, whereas rider's speed and wind speed are fixed, the rider is invested by an inlet wind of known yaw angle.

The individual values of αy relating to each speed Vw (for αw = 0 º ÷ 180 º) were multiplied by the weight/probability of the speed Vw and summed to all those of the other speeds. The values obtained are then "grouped" within specific ranges of αy angles. The percentage of the values which are in a specific range of αy (for example between 0 º and 4 º) gives the weight/probability of each yaw angle.

Previous chart shows the distribution of the yaw angles calculated.

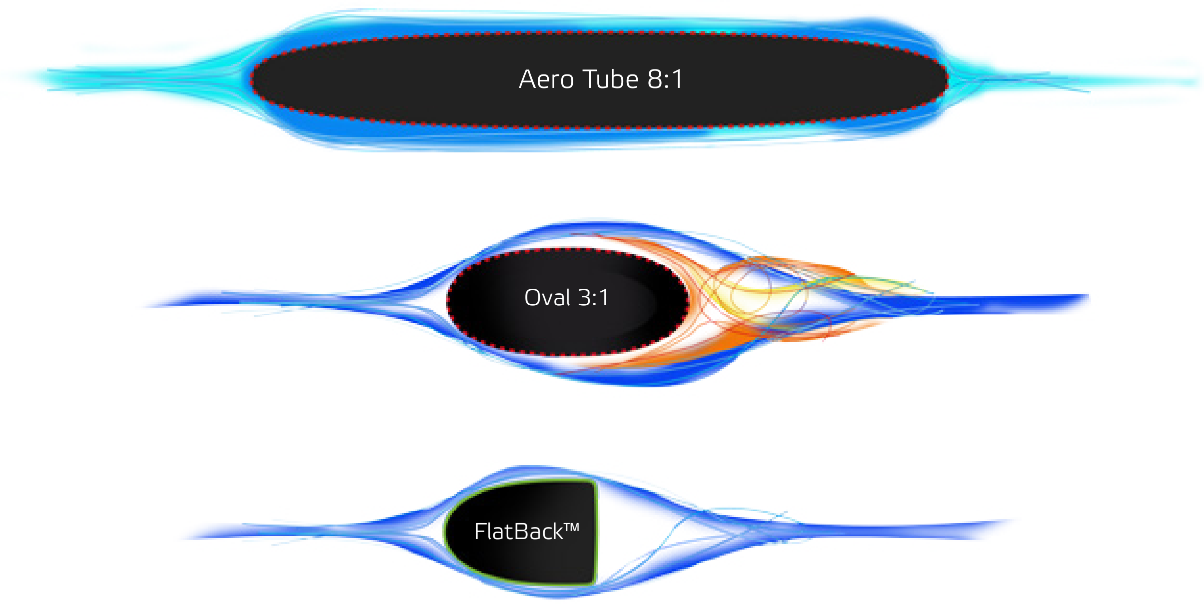
Weighting function gave us the opportunity to concentrate all performance of the bike into one number that represents the entire motion field.



© Cicli Pinarello Spa - All rights reserved - April 2014

FlatBack profiles

During the design phase of the new sections of the frame's tubing it was essential to use profiles that minimize the aerodynamic drag, while maintaining the required stiffness.
To guarantee the stiffness required the tube should have a given width L (for example, for the down tube, we can suppose close to 40 mm).
For a good airfoil (such as an airplane's wing) the ratio between its height H and the length L is at least 8 to 1; in this case, for example, the height should be at least 320 mm).
The UCI regulation, however, imposes that the maximum ratio between these two dimensions is 3 to 1.
The first hypothesis is therefore "squeezing" the profile reducing its height (the width L remains fixed to preserve the stiffness): this solution, however, completely nullifies the profile properties dramatically worsening the aerodynamics. This change would indeed make a stubby profile, causing the early detachment of the flow and a great drag.
Furthermore, beyond the 3 to 1 ratio rule, UCI also dictates that the maximum size for tubing is 80 mm.
The alternative then, instead of "squeezing" the profile, is to "cut" it at the proper length keeping only the forebody. This solution, in spite of reduced performance if compared to the original airfoil, provides much better aerodynamics than the hypothesis of "squeezed" section.

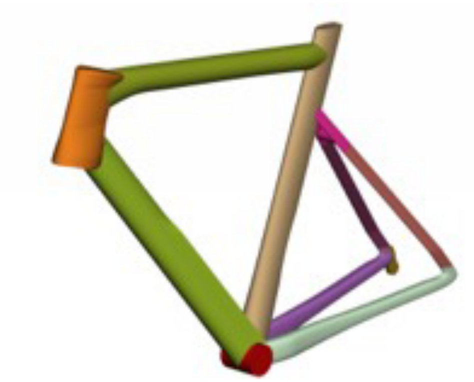


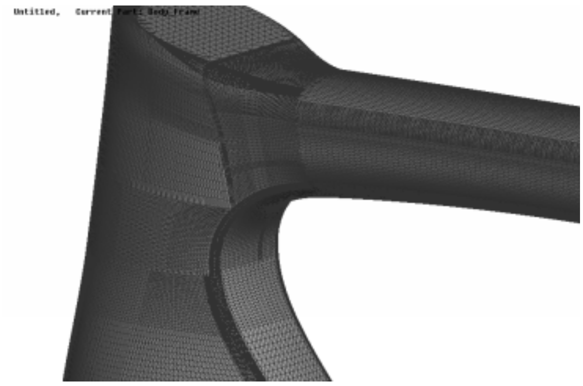
Following previous concepts, we used Flatback profiles as sections for the new tubes developed. This choice guarantees sections that, on one hand ensure the necessary stiffness (we kept the required width) and on the other hand allow good aerodynamic performance.

© Cicli Pinarello Spa - All rights reserved - April 2014

Pre-processing

Before performing CFD analyses, we arranged the models. First of all, we identified different parts of the frame, such as top tube, down tube, etc., and all the other components (brakes, handlebar, etc.). Then we applied a surface mesh at every part. Images below show respectively the different zones of the frame analyzed and an example of the mesh.





Then all components were assembled and the domain around the bike discretized with about 50 million fluid cells. The areas around the bike had an extra refinement.

© Cicli Pinarello Spa - All rights reserved - April 2014

Processing

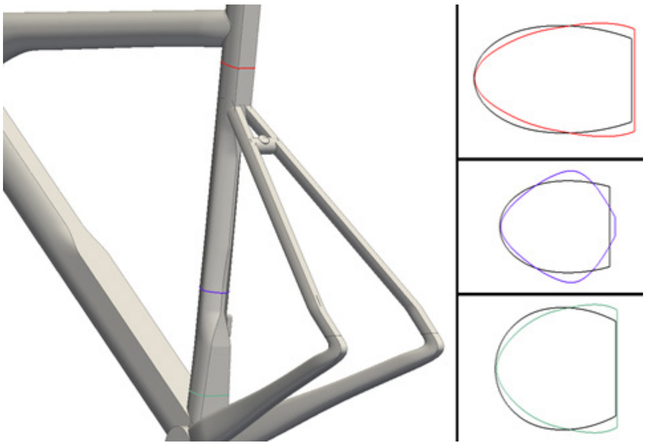
We tested several different models. The first was Dogma 65.1 model, visible below.

Then we tested a first version of the new bike, which includes some new feature.

© Cicli Pinarello Spa - All rights reserved - April 2014

We continued creating another 25 models similar, each with a single change, to distinguish the benefits that every solution involves. Below two examples of different models, one focused on the intersection between seat tube and seatstays, the other with bigger sections on the down tube to better accommodate the bottle.

These analyses allow us to evaluate the influence of every single part on the overall drag, to find the best solution possible.
In parallel, we performed an optimization process for the seat tube. Using a parametric optimizer, we fixed some parameters on the section of the tube in 3 points. The software automatically modified the sections of the tube, searching for the shape that minimizes drag. Below some images of these process.



We performed more than 300 single CFD runs in total. This generates a set of transient data, which needs to be time averaged before final post-processing.

© Cicli Pinarello Spa - All rights reserved - April 2014

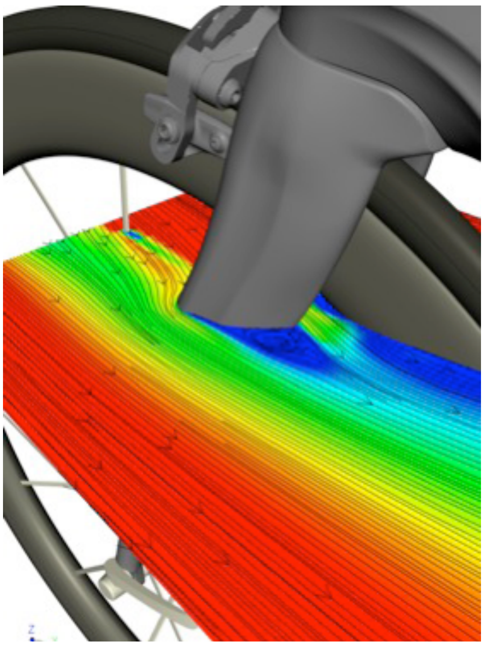
Post-Processing & Results

Result of this analysis process has been summarized in two ways: with some comparative charts and with a series of images and animations showing concretely the interaction between bike and rider and the airflow. Charts show the numerical values of drag on each component and allow to identify the "weight" of each part of the bike and the influence of each change made to the initial model. Drag values were measured both on the components of the bike (frame, fork, handlebars, etc.), and on the single parts of the frame (top tube, seat tube, down tube, etc.). Thus, we identified the most critical areas and the benefits that each solution acted on the bike. Following an example of a summary chart.

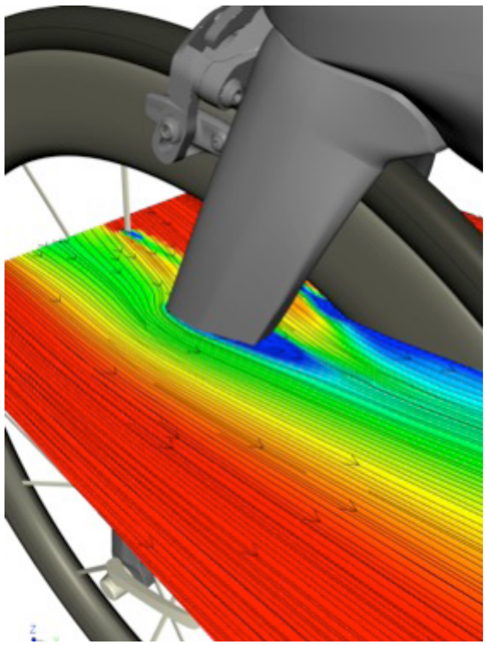
Road Bike Development				DRAG BREAKDOWN (BIKE-ALIGNED)							
Run	Yaw	Total Drag	DESCRIPTION	F & F + parts	Handle bar	Rider	Fr-wh	Rr-wh	Cables & Junction box	Total	Total no rider
	(Degrees)	(N)		(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)
PI02R003	2, 10 &18	36,03	A, m003, Baseline Bike with fr-derailleur	7,16	1,94	24,11	1,52	1,13	0,17	36,03	11,92
PI02R004	2, 10 &18	34,50	A, m003, PI02RUN003 with Air Frame and Forks	5,36	1,94	24,39	1,57	1,07	0,17	34,50	10,11
PI02R005	2, 10 &18	34,54	A, m003, PI02RUN004 with DT bottle front fairing	5,33	1,94	24,46	1,57	1,07	0,17	34,54	10,08
PI02R006	2, 10 &18	34,72	A, m003, PI02RUN004 with ST bottle back fairing	5,44	1,94	24,60	1,57	1,00	0,17	34,72	10,12
PI02R007	2, 10 &18	34,33	A, m003, PI02RUN004 with low bottles	5,14	1,94	24,39	1,57	1,11	0,17	34,33	9,93
PI02R008	2, 10 &18	34,45	A, m003, PI02RUN004 with R-Brake shield	5,30	1,94	24,40	1,57	1,07	0,17	34,45	10,05
PI02R009	2, 10 &18	34,32	A, m003, PI02RUN004 with PISA profile Fr-Fork	5,25	1,94	24,34	1,56	1,06	0,16	34,32	9,97
PI02R010	2, 10 &18	34,52	A, m003, PI02RUN004 with ST Bottle fairing V2	5,39	1,94	24,41	1,57	1,05	0,17	34,52	10,11
PI02R011	2, 10 &19	33,96	A, m003, PI02RUN004 with ST Bottle removed	4,76	1,95	24,46	1,58	1,05	0,17	33,96	9,50
PI02R012	2, 10 &20	34,09	A, m003, PI02RUN010 with ST Bottle removed	5,05	1,95	24,39	1,58	0,96	0,17	34,09	9,71
PI02R076	2, 10 &21	34,32	DT Optimisation	5,10	1,95	24,44	1,58	1,10	0,16	34,32	9,89
PI02R075	2, 10 &21	34,25	A, m003, PI02RUN007 with X aligned water bottles	5,03	1,95	24,51	1,57	1,09	0,16	34,31	9,80
PI02R081	2, 10 &21	34,42	A, m002, ST Opt Refinement005	5,19	1,95	24,48	1,57	1,07	0,16	34,42	9,93
PI02R082	2, 10 &21	34,38	A, m002, ST Opt Refinement006	5,14	1,95	24,47	1,58	1,08	0,17	34,38	9,91

In addition, we compare the results through images showing the airflow around the frames. Below some examples.

Red color shows high-pressure zones; blue color low-pressure zones, which are turbulent and create drag. The new shape of the section used in the fork generates smaller low-pressure zone, reducing the drag.



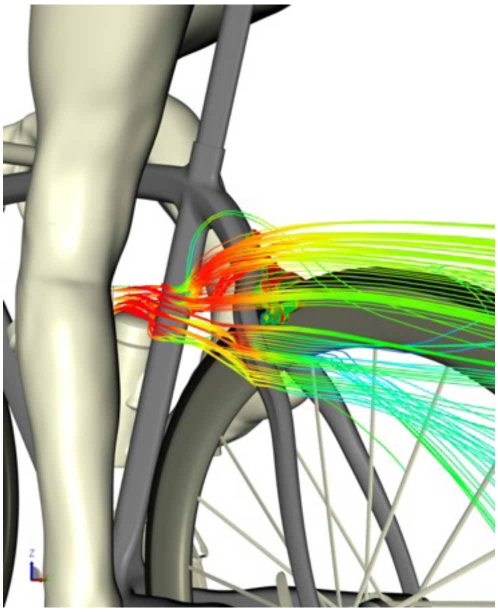
DOGMA 65.1



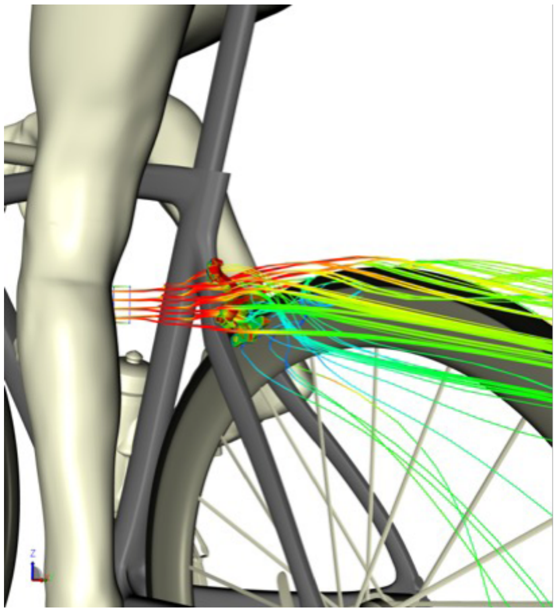
DOGMA F8

© Cicli Pinarello Spa - All rights reserved - April 2014

The same is true for the rear brake zone. The following images show how the air flows along, and if it creates vortexes and turbulences. As is visible, the intersection of seatstays and seat tube on the Dogma F8 is in a lower position: this reduces the space allowing a better airflow.

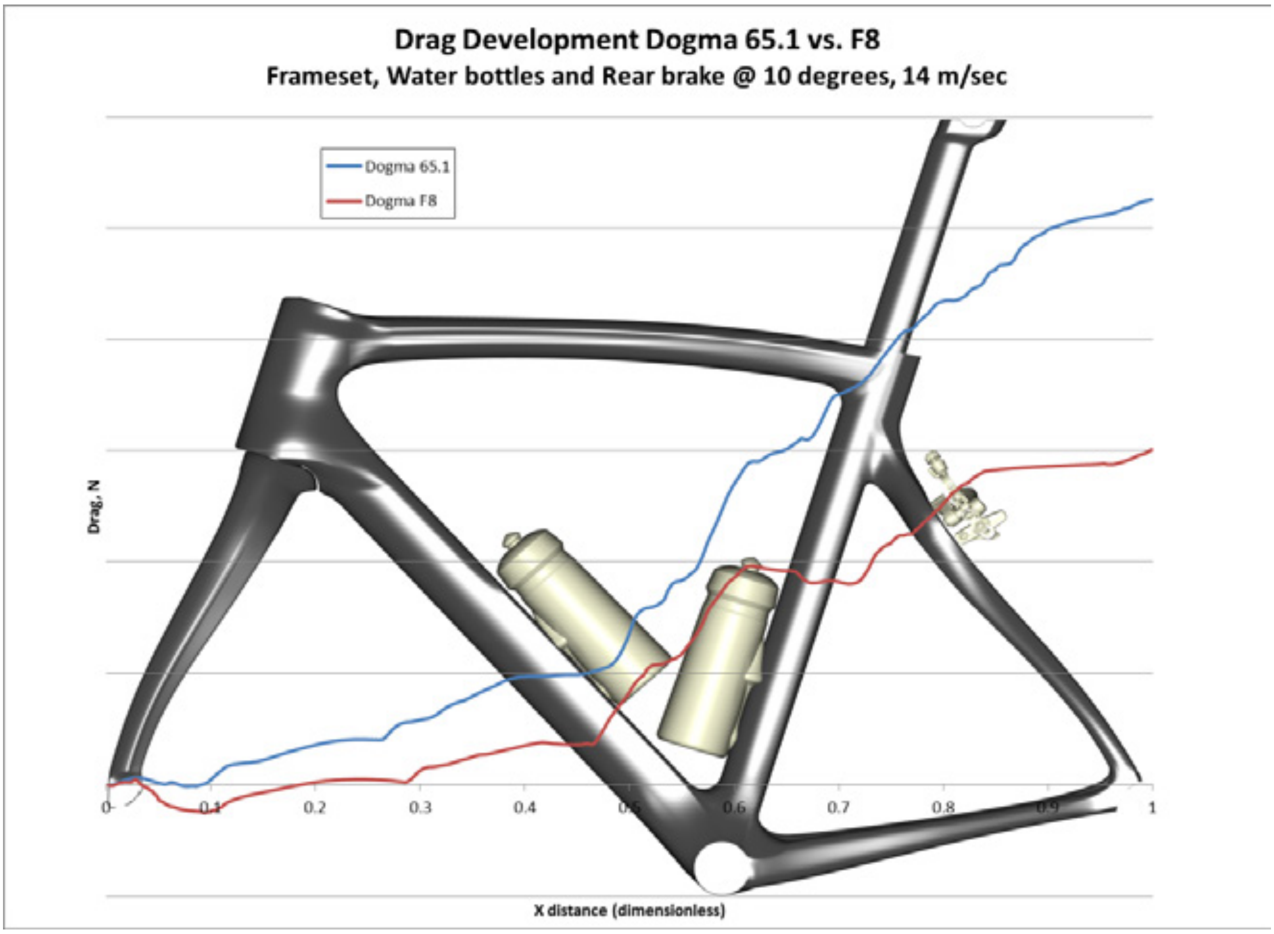


DOGMA 65.1



DOGMA F8

General results can be summarized with the following graph that clearly compares Dogma 65.1 (blue line) and Dogma F8 (red line): it shows the drag development along the frame.



© Cicli Pinarello Spa - All rights reserved - April 2014

When riding a bike, incoming air first interacts with the forks. Looking at the graph, by halfway along the fork legs, the original Dogma 65.1 sees absolutely no air resistance.

The Dogma F8 goes one step further: with unique aerodynamic leg sections influenced by the Bolide, the F8 fork acts like sails that actually pull the bike forwards in windy conditions. This effect is magnified when riding in stronger winds. For centuries, wind has been an inescapable resistance that increases rider fatigue and hinders performance. Partnered with the Dogma F8, cyclists will now be able to exploit it.

Then, it is not until the air has travelled halfway along the F8 frame that it begins to see any resistance. Air resistance increases around the water bottles for both frames, however where the drag of the Dogma 65.1 continues to surge upwards from this point, resistance decreases when the air hits the seat tube of the F8, as a result of its aero-engineered cross sections.

After travelling over the brakes, the flat shape of the graph shows that the Dogma F8 provides no additional impedance to the air flow in that area. This shows that the rear sections of the seat stays and chain stays are effectively invisible to drag.

The aerodynamic prowess of the F8 can only be fully appreciated when comparing it with the Dogma 65.1, an already two-time Tour de France winning bike and professional favorite.

Finally, we compared the aero performance of Dogma 65.1 and Dogma F8, to verify if the initial purposes were complied.

WHAT	DOGMA F8 change (N)	DOGMA F8 change (%)
Bike only	-2.09	-17.5%
Bike and Rider	-1.77	-4.9%
Frame	-1.24	-45%
Fork	-0.45	-54%
Frame & Fork	-1.69	-47%

CFD results show a reduction of the air drag of 17,5% on the bike and close to 5% considering bike and rider. Just looking on frame and fork, the new Dogma F8 is about 47% more aerodynamic than Dogma 65.1.

© Cicli Pinarello Spa - All rights reserved - April 2014

4. Final Design

All around solution

All results obtained during the analyses highlight many possible features that would improve the bike's performance. Before proceeding with the final design, we should find the best compromise between different opportunities, considering the initial purposes for this project. For example, some solutions would definitely improve the aerodynamics but, at the same time, would increase weight.
The main aim of the project was creating a bike that improves all the important aspects, obtaining an overall solution. This to offer every rider the best bike possible in every condition and every route he will ride.

Made4you

Every rider is different and unique, because of his body: someone is taller, someone else shorter, someone has long legs, etc. For this reason, we produce 13 different sizes, to properly accommodate every rider on his bike. On the other hand, Pinarello wants to guarantee every rider that the bike maintains the same performances, independently from the size.

For this reason, as done also on the previous bikes, we applied the "Made4you" concept on the new Dogma F8.
Every single size of the frame is designed and produced on its own: the bigger sizes are reinforced and shaped in order to bear higher stresses; the smaller sizes can be made using less material, saving weight.

This allows every rider to ride his Pinarello with same feelings and performances.

New features

Previous reasoning brings us to define the final and innovative feature implemented on Dogma F8.
First, from a structural point of view, the asymmetry concept has been pushed forward: we did not just increase the right side of tube sections as done for previous bikes, we also turned the main tubes to the right, with great improvement of stiffness and balanced response.

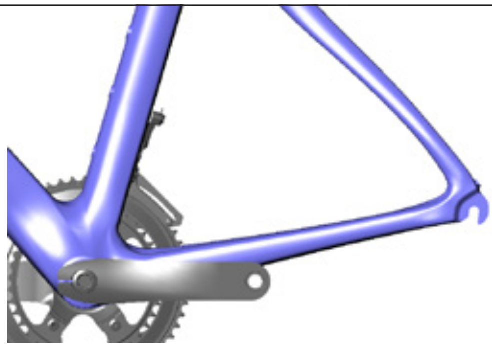
Then, regarding the aerodynamics, the optimization of tube sections and the interaction between all components has become essential to take advantage of side wind, considerably reducing the total air drag.
The previous are the main important concepts implemented, but many innovative features characterize Dogma F8.

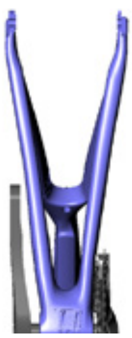
© Cicli Pinarello Spa - All rights reserved - April 2014

DOGMA F8 highlights

Seat tube and down tube are deeply asymmetric, both for section and position, to give a stiffer and more balanced bike.

Asymmetric top tube.





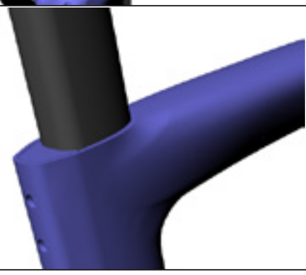
Asymmetric rear triangle to increase the lateral stiffness.

New "ONDA F8" outlines, evolution of Onda2, to increase the shock absorption and the comfort.

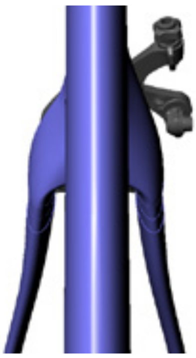
© Cicli Pinarello Spa - All rights reserved - April 2014

DOGMA F8 highlights

Curved seatstay to increase the vertical compliance.



TwinForce integrated seat clamp improves the aerodynamics and reduces weight, while assuring great clamping capabilities.



Rear brake hidden from the airflow thanks to the seatstays shape: since the brake is asymmetric, thus the seatstays are asymmetric.

Fork is designed to mirror to the front brake shape, so to protect it from the airflow.

New aero optimized profiles used on the fork, very close to those used for the Bolide.

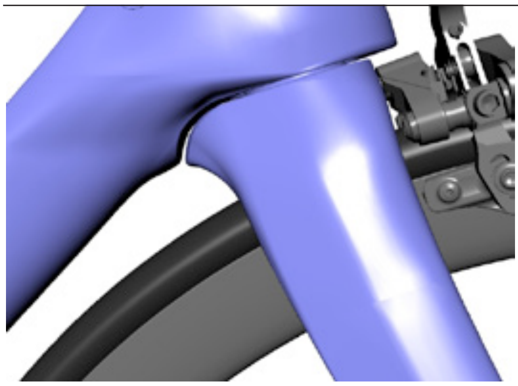
© Cicli Pinarello Spa - All rights reserved - April 2014

DOGMA F8 highlights

Flatback profiles that ensure the best compromise between aerodynamics and stiffness.

New seatpost, with lower air drag and weight

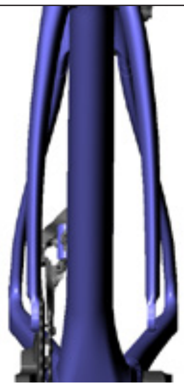
Very narrow head tube, that definitely improves aero performance.



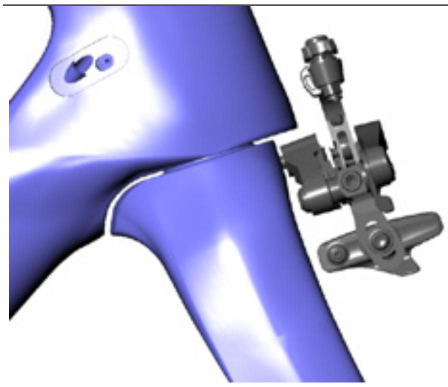
Fork crown is completely integrated into the frame to reduce the turbulence.

© Cicli Pinarello Spa - All rights reserved - April 2014

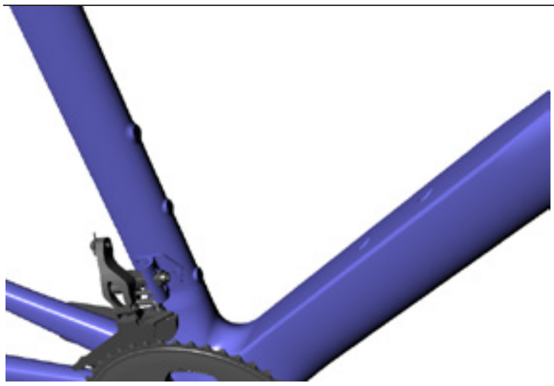
DOGMA F8 highlights



Down tube shaped to hide the water bottle from the airflow.



Head tube moved forward to allow a more aerodynamic shape and integration.

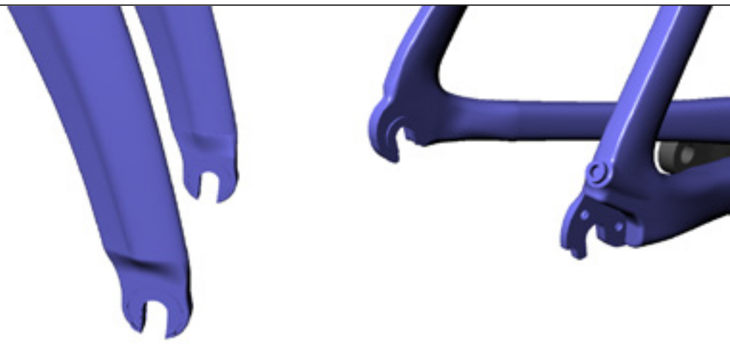


2 bottle cages positions on the seat tube: the lower improves the aerodynamics, the higher improves accessibility and comfort.

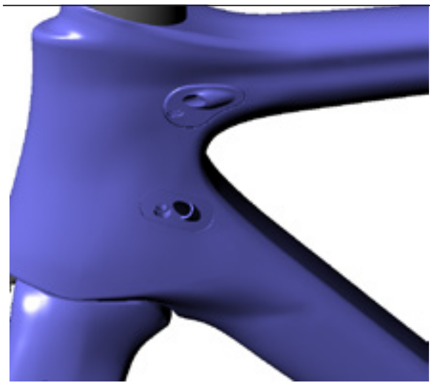
Rear derailleur cable exit behind the dropout, to improve aerodynamics and aesthetics.

© Cicli Pinarello Spa - All rights reserved - April 2014

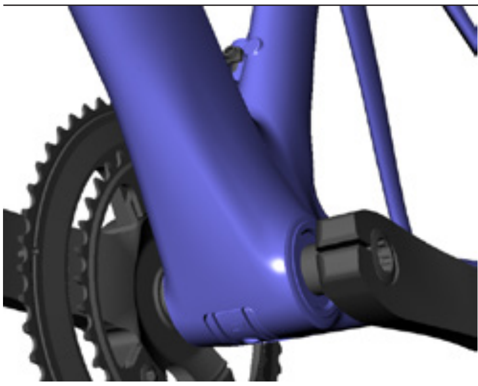
DOGMA F8 highlights



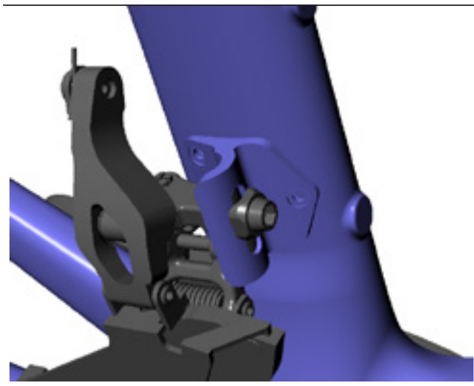
*Carbon dropout,
for both fork and frame,
to reduce weight.*



*Think2 technology to allow quick change
of mechanical and electronic groupsets.*



*Italian threaded bottom bracket,
synonymous of stiffness and long
lasting performance.*

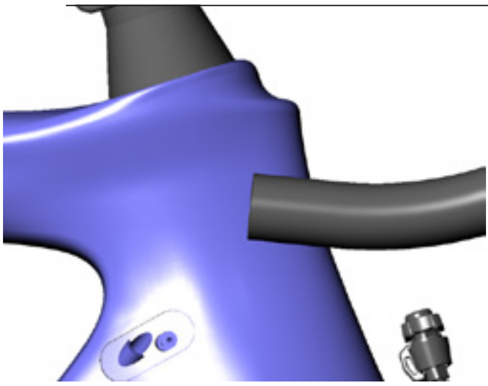


*Removable front derailleur hanger,
for ease of maintenance
and reduced weight in a flat route.*

© Cicli Pinarello Spa - All rights reserved - April 2014

DOGMA F8 highlights

Electronic batteries stored inside seattube and seatpost, respectively for Campagnolo and Shimano.



The tip of the head tube allows the necessary space for electronic groupsets' controller.

© Cicli Pinarello Spa - All rights reserved - April 2014

Rapid prototyping sample

Once the main features of the CAD model were defined, before proceeding with the production of the molds, we produced a Rapid Prototyping model.

Rapid Prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using 3D CAD data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.

We realized a full-scale sample. This allows us, on one side, to evaluate the real dimensions, the quality of the surfaces and the aesthetics of the frame, on the other side, to verify the complete assembly of bike and components.

Finally, using this RP sample, we could easily define some details, otherwise difficult to verify while designing, such as the position of the holes for the internal cable routing.

© Cicli Pinarello Spa - All rights reserved - April 2014

5. Tests

Structural tests

Once the first samples were produced, we tested them in our laboratory in order to evaluate the real performance and verify the results obtained during the design phase.
We performed many different tests reproducing conditions similar to a real-world ride.
Weight: we weighted both frames and forks, to verify the improvement given by the material and shape;
Stiffness: we performed static and fatigue tests, simulating the load conditions that usually come across while riding. Every one of the fatigue test performed loads the frame for more than 100000 cycles, simulating pedaling, braking, vertical loading, etc.;
Resistance: we tested if frames and forks could stand up to impacts without any damage. In particular we tested them with a "falling mass" (22,5 kg mass that falls down on fork and frame) and with a "falling frame" (frame and fork, loaded with 70 kg on the seat tube and fixed on the rear hub, rotate and impact the ground on the front hub).

Frame Only *Dogma F8 compared to Dogma 65.1*

Weight (gr.)	-80	-9,1%
total deflection (mm)	-1.34	-28,1%
average deflection (mm)	-1.98	-47,3%

These tests, on one side numerically quantify the performance of the new bike, to compare it with the previous, on the other side they verify the bike's safety.
Test results were also compared with FEM results, to verify and validate them.
Comparing Dogma F8 and Dogma 65.1 the results show great improvements in every condition; the chart below confirms some of these.

Above results are relative to size 54. Total deflection and average deflection are the same indexes used to evaluate the FEM results: the first distinguishes the stiffness, the second how balanced the frame is.
The Dogma F8 frame is 9% lighter, 28% stiffer and 47% more balanced than Dogma 65.1 frame; these gains are the results of the new material and new shape adopted.
If compared to FEM results, they are slightly different: these are indeed real test results, so they depends on the shape and the material. Anyway, both FEM and laboratory test results show a similar trend and great improvement.

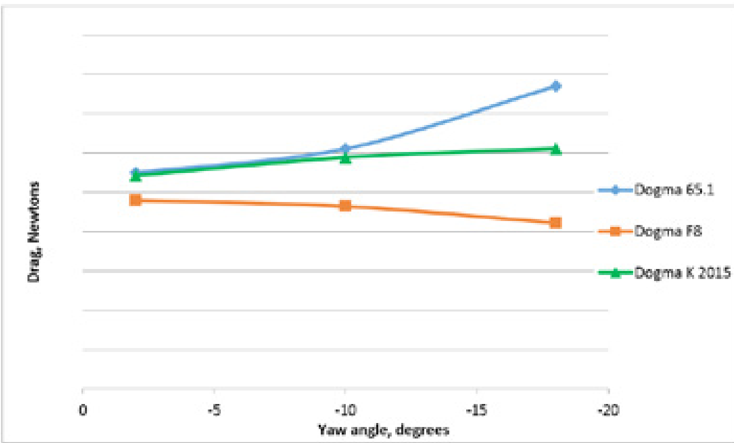
© Cicli Pinarello Spa - All rights reserved - April 2014

Wind Tunnel Test

We also tested the aero performance of the real bike through wind tunnel tests. This allows us to validate the CFD results and to compare different bikes.
To compare accurately these results with the CFD, all bikes tested had same components of the one modeled for the CFD. Furthermore we tested using both a 3D mannequin as the one used for CFD and a real rider.
We performed tests at 2º, 10º and 18º yaw angles, measuring the drag generated by bike and mannequin/rider; then, results were recalculated through the weighting function.
We tested 3 different bikes and results are resumed below:

Yaw Angle	DOGMA 65.1	DOGMA K 2015
-2º	-12,9%	-11,6%
-10º	-24,1%	-21,1%
-18º	-45,2%	-30,8%
Weigh.Avg.	-26,1%	-20,0%

The previous chart lists the percentage variation of the drag generated by Dogma F8 if compared with other Pinarello bikes (these results are relative to "bike only" condition). Considering the averaged value, obtained through the weighting function, the new Dogma F8 is 26% more aerodynamic than Dogma 65.1 and 20% more aerodynamic than Dogma K 2015.



The previous graph, which shows the drag at different yaw angles, highlights an interesting phenomenon: for both Dogma 65.1 and Dogma K 2015, as the yaw angle increases, so the drag increases; this is what happens usually with every bike. With the new Dogma F8 instead, as the angle increases, the drag decreases: it means that during side wind conditions the frame takes advantage of the wind rather than suffering it. This is a further validation of the CFD results.

© Cicli Pinarello Spa - All rights reserved - April 2014

Percentage changes between Dogma 65.1 and Dogma F8

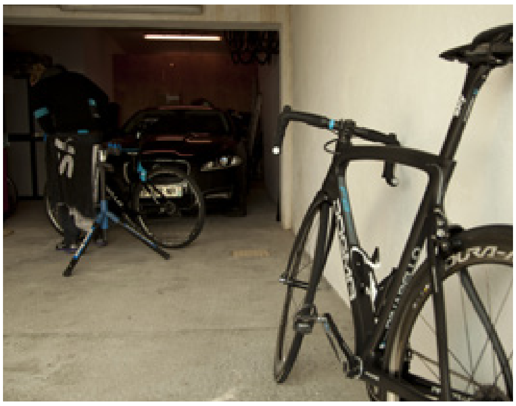
	Complete Bike only		*Complete Bike and mannequin*	
Yaw Angle	**CFD**	**WIND TUNNEL**	**CFD**	**WIND TUNNEL**
-2º	**-12,3%**	**-12,9%**	**-4,6%**	**-4,2%**
-10º	**-19,8%**	**-24,1%**	**-6,6%**	**-7,1%**
-18º	**-19,4%**	**-45,2%**	**-6,5%**	**-8,9%**
Weigh.Avg.	**-17,5%**	**-26,1%**	**-4,9%**	**-6,4%**

The previous chart compares the percentage changes between Dogma 65.1 and Dogma F8 obtained through CFD and wind tunnel tests. It appears that the results between these two tests are different: this depends on the conceptual difference between the tests. CFD is indeed a good development tools; it allows the designer to verify step by step how the project proceeds. Wind tunnel is much closer to the reality and allows a check as to how the bike would work in the real world. A pure comparison of the number is wrong because the tests are deeply different: the main thing is that results show a similar trend, assuring great improvements, as it is.

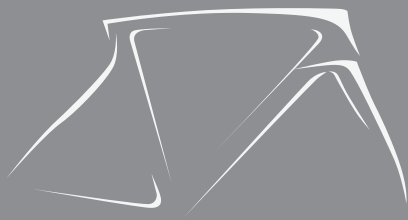
© Cicli Pinarello Spa - All rights reserved - April 2014

Road Test

At the same time, we performed the most important and sincere tests possible: road tests.
These tests verify the bike's performance in real conditions, assuring sincere results.
Professional riders, such as Chris Froome, tested the bike reporting excellent feelings and feedbacks.



© Cicli Pinarello Spa - All rights reserved - April 2014



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

© Cicli Pinarello Spa - All rights reserved - April 2014