parcours

#THINKWIDER DEEP SECTION WHEEL DEVELOPMENT – WHITE PAPER
September 2022

BACKGROUND

In early 2020, Parcours launched the Strade, our first wheelset specifically designed around a 28mm tyre. The Strade introduced our #thinkwider rim technology with differential profiles for front and rear wheels. The differential design was based around our real-world yaw angle testing, conducted in partnership with Nottingham Trent University[1], which showed that wind conditions are materially different at various points on the bike.

Test results on final production wheelsets showed that the Strade delivered optimal aerodynamic performance when paired with a 28mm tyre, whilst the front rim profile also substantially reduced crosswind sideforce. As a result the 49mm depth Strade front wheel would perform better both aerodynamically and in terms of stability, in windy conditions than our existing 40mm Grimpeur Disc, regardless of whether the shallower wheel was fitted with a 25mm or 28mm tyre.

Following on from the Strade, we then applied #thinkwider to a shallower profile rim, leading to the all-road Ronde wheelset. Again, rigorous testing showed the Ronde to outperform many of its peer group of comparable wheelsets both in terms of aerodynamics and also crosswind stability.

#THINKWIDER DESIGN RATIONALE

Tyre width

It has become increasingly apparent that there are a number of advantages to running a wider tyre:

1. **Reduced rolling resistance**: a number of studies have been published that show a reduction in the coefficient of rolling resistance (CRR) as tyre width increases[2]. The wider tyre will have a shorter and wider contact patch with the road, than an equivalent narrower tyre. This in turn reduces the friction and hence energy loss.

2. **Ride comfort and traction**: as a result of (1) above, riders are able to reduce tyre pressure, whilst still maintaining a suitably low CRR. One study has shown that a Continental GP5000 tyre will deliver the same rolling resistance at 81psi in a 28mm version as at 92psi in a 23mm version[3].
   Reducing pressure improves the ride comfort, as it increases the suspension effect of the tyre. This reduces the strain placed on the rider's body, especially over rougher road surfaces. This is of particular relevance in the context of a triathlon, given after completing the bike leg, athletes will transition to the run leg. If a rider can reach the end of the bike leg in improved physical condition with reduced fatigue, there will be a subsequent positive impact on their running performance.

[1] https://www.parcours.cc/pages/thinkwider
[2] Tour Magazine, Wide tyre test (January, 2014)
[3] Bicycle Rolling Resistance: https://www.bicyclerollingresistance.com/specials/grand-prix-5000-comparison

Finally, a reduced tyre pressure will improve traction by slightly increasing the contact patch with the road. Whilst this does (as per (1) above) increase CRR, it is a worthwhile trade-off in e.g. wetter conditions where grip is key.

Tubeless tyres

The introduction and adoption of tubeless tyre technology has only furthered the benefits of a wider tyre (and hence the demand with riders). Eliminating the inner tube from the system entirely removes the risk of a pinch flat where a tube could be "pinched" between the rim edge and road when run at a lower pressure.

Disc brakes

However, whilst the benefits of a wider tyre have become established, wheel designers were still constrained in rim design. A traditional rim brake caliper would only allow up to a c.28mm rim width before the rim will no longer fit between the brake pads. This created an issue, as in order for the wheel/tyre system to maintain its aerodynamic benefits, the rim must measure out to c.105% of the tyre width. The "Rule of 105" limited tyre widths to c.25mm.

The final piece to the puzzle has been the shift to disc brakes in road cycling. Whilst the UCI have only recently approved disc brakes for racing, riders have been increasingly moving to disc brake setups over the past few years, so much so that many of the leading bike manufacturers are now releasing disc brake-only frame designs. This trend has now been mirrored in time trial and triathlon bike design, with the vast majority of frame manufacturers now focusing development on disc brake-specific frame designs.

By moving the braking force from the rim to the hub, this has allowed for far greater flexibility and innovation in rim design. Firstly the rim width is no longer constrained to the c.28mm clearance of a brake caliper. The rim edge can also be more aggressively contoured as there is no longer a requirement for a flat (or close to flat) contact area for the brake pad to exert a frictional force. Finally, as no frictional force is exerted at the rim, there is no longer a need for heat-resistant properties at the outer edge of the rim. This is a benefit as the heat-resistant resins that are used in a carbon fibre brake surface are more rigid and therefore less resistant to impact.

PROJECT GOALS

Throughout the Strade and Ronde design projects and subsequent testing, we were able to establish that applying #thinkwider rim technology to existing rim depths would improve both aerodynamic performance and handling stability.

For this project we set out to explore the relationship between the two attributes, whilst also looking to offer a range of deeper section wheels each optimised for a specific performance attribute. This would most likely appeal to time trial or triathlon usage, with a potential cross-over to road racing on flatter, faster courses.

Building on the experience of our Ronde and Strade wheelsets with #thinkwider rim technology, we wanted to develop a choice of wheels that are:

1. **Aerodynamically optimised for a 28mm tyre**
2. **Tubeless-ready**
3. **Disc brake-specific**

The design project would then be split into three strands, focusing on:

Wheelset A:

4a. **Maintaining aerodynamic performance of existing Chrono Disc wheelset (77/86mm) whilst maximising handling stability**

Wheelset B:

4b. **Maintaining handling stability of existing Chrono Disc wheelset (77/86mm) whilst maximising aerodynamic performance**

Rear wheel C:

4c. **Redesigned rear Disc wheel to be optimised for running with a 28mm tyre**

The design benchmark for Wheelset A & Wheelset B would be the existing Chrono Disc (77mm front / 86mm rear rim depth wheelset) fitted with a 25mm tyre, providing aerodynamic and weight benchmarks for the development project.

For Rear wheel C, the benchmark would be the existing Disc^2 rear disc wheel, fitted with a 25mm tyre.

DESIGN PROCESS OVERVIEW AND CONTRIBUTING FACTORS – WHEELSET A & B

Performance benchmarks

The baseline aerodynamic performance was set such that:

- Wheelset A must perform in line with, or better than, Chrono Disc wheelset when fitted with the optimal width of tyre
    - Wheelset A fitted with a 28mm tyre / Chrono Disc fitted with a 25mm tyre

Baseline handling stability was set such that:

- Wheelset B must perform in line with, or better than, Chrono Disc wheelset when fitted with the optimal width of tyre
    - Wheelset B fitted with a 28mm tyre / Chrono Disc fitted with a 25mm tyre

Rim depth

As previously established, rim depth is one of the key drivers for aerodynamic performance, as well as relative handling stability. Given the project's design goal of performing in line with the Chrono Disc, we were able to anchor the anticipated aerodynamic performance and vary the rim depth to achieve this in CFD simulations.

Front / rear rim design

The #thinkwider project, part of our technical partnership with the Sports Engineering department at Nottingham Trent University, has demonstrated the enormous benefit of differential front/rear rim design. The study has found that wind conditions (yaw angle and wind velocity) vary between front & rear wheels. The yaw angle at the front wheel is, on average, 1.5 degrees higher than at the rear wheel. As a result, we use a more "blunt" U-shaped rim to optimise for higher yaw on the front wheel, while using a "sharper" V-shaped rim for the lower yaw conditions on the rear wheel.

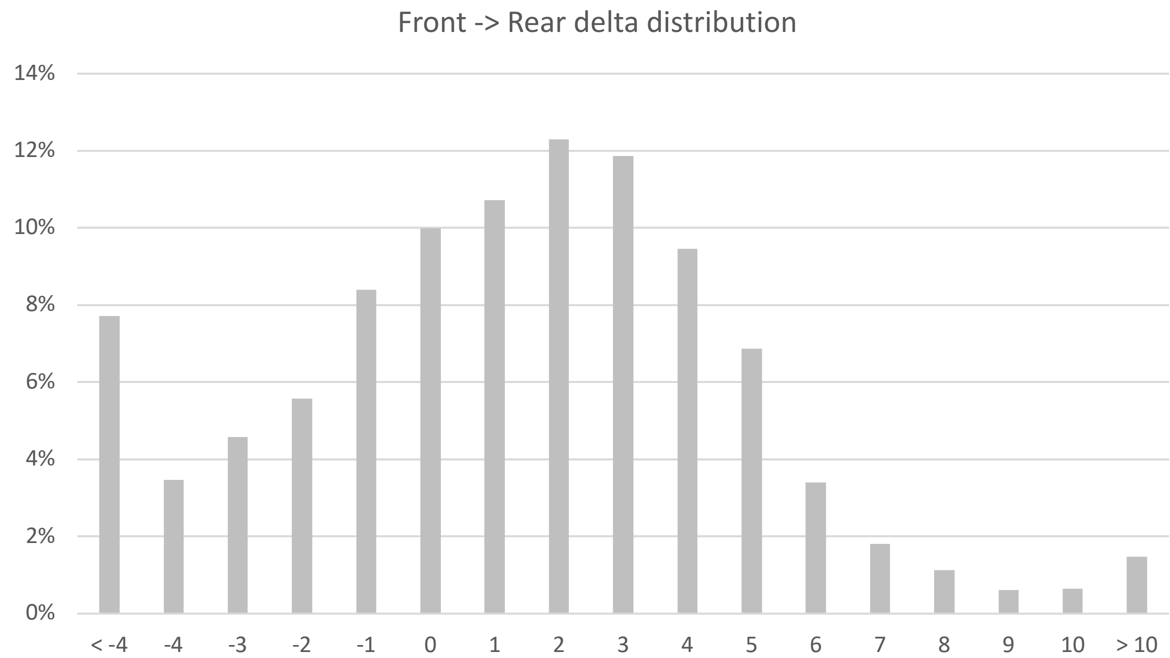

Fig.1 – front wheel to rear wheel yaw angle delta, field testing

In addition, the rear wheel has significantly reduced impact on bike handling as it is not free to move on its axis for steering. The front wheel has a much more substantial impact on stability. This allows for a deeper rear rim profile to be paired with a shallower front rim profile, whilst maintaining handling stability.

Additional testing & prior design experience has showed that an ideal ratio of c.1:1.1 between front:rear rim depth.

Impact of a rear Disc wheel on front wheel handling stability

Running in parallel with the wheel development project, we are conducting a study in partnership with Nottingham Trent University, looking at the impact of running a rear disc wheel on overall handling stability.

Early results from this study indicate that a rear disc does improve handling stability, allowing athletes to run a deeper front wheel. However, this impact was not taken into consideration when modelling handling performance benchmarks for front wheel rim profiles.

CFD design iteration

Each stage and iteration of the design process began as a 2D profile cut-out, which was then modelled in 3D CAD (Solidworks).

A 3D rendering of a 28mm diameter tyre was then fitted to the rim profile for the purposes of the following analysis.

The 3D rim shapes were then run through CFD simulations (SimScale) at a range of yaw angles (0 to 20 degrees, at 5 degree increments) under simplified conditions. These indicative results allowed us to narrow the design down to two prototype profiles for each of the front and rear wheel, one for each of the benchmarking conditions.

One key finding from the CFD analysis was that the front wheel for Wheelset B could be substantially deeper than the existing 77mm Chrono front wheel. When applying the c.110% front:rear rim depth ratio per our #thinkwider methodology, this would result in a >90mm rear rim depth. At this depth, analysis suggested that we should focus our attention on pairing this front wheel with the Disc wheel only. The weight of such a deep rim would put it close to a Disc wheel, meaning the reduction in rotational drag from a solid rear wheel would deliver superior aerodynamic performance for comparatively little penalty. Ultimately the design group could not conceive of a situation where running such a deep rear wheel would be the optimal setup, beyond very unique circumstances e.g. Ironman World Championship race in Kona, Hawaii where rear disc wheels are banned.

Prototyping

Following CFD testing, prototype rims (front & rear) were moulded, for final testing and validation in the wind tunnel:

- Parcours Chrono prototype front wheel A (68.6mm depth / 32.0mm width)
- Parcours Chrono prototype rear wheel A (75.7mm depth / 30.5mm width)
- Parcours Chrono Max prototype front wheel B (83.6mm depth / 32.0mm width)

DESIGN PROCESS OVERVIEW AND CONTRIBUTING FACTORS – REAR WHEEL C

Performance benchmarks

The baseline aerodynamic performance was set such that:

- Rear wheel C must perform in line with, or better than, Disc^2 wheel when fitted with the optimal width of tyre
    - Rear wheel C fitted with a 28mm tyre / Disc^2 fitted with a 25mm tyre

Internal rim width

As frame design & rider preference has moved towards wider tyres, so too has wheel design. In order to provide an optimal tyre profile, the internal rim width of a wheel has grown from c.18-20mm for a 23-25mm tyre, to > 22mm for 28mm+ tyres.

Our #thinkwider spoked wheel rims (e.g. Ronde & Strade) use a 22.5mm internal rim width paired with a 28mm tyre. Prior testing has shown this to offer a good degree of compatibility, with ETRTO guidelines allowing use of tyre sizes ranging from a nominal 25mm upwards. This compatibility is crucial in particular for a rear wheel, as some framesets will not have been designed with clearance for a larger tyre.

Disc brake specific design

Time trial and triathlon bikes have only moved to disc brake-specific designs over the past couple of years, with disc wheel design arguably lagging behind. Many disc wheels, including the previous generation of Parcours Disc^2 were based on proven designs taken from rim brake-specific models, in some cases (such as the Disc^2) incorporating small design adjustments to maximise benefit from the removal of the braking surface.

For this design project, we wanted to design for a disc brake system from the start, beyond just the available increase in internal rim width. The drive side maintains the flatter profile of the existing Disc^2 to allow maximum clearance for the drivetrain, whilst the non-drive side's lenticular profile has now been redesigned to account for the presence of a brake rotor. By modelling the presence of the rotor from the outset, we wanted to ensure the non-drive side shaping would recapture as much airflow as possible, especially at higher yaw angles.

Finally, the outer rim profile at the rim extremities was based on our existing #thinkwider profile to maintain optimal airflow management at the rim/tyre interface.

CFD design iteration

Each disc wheel profile was modelled in 3D CAD (Solidworks).

A 3D rendering of a 28mm diameter tyre was then fitted to the rim profile for the purposes of the following analysis. A simplified 3D rendering of a brake rotor (160mm diameter) was also fitted to the hub to allow simulation of airflow interaction between wheel structure and rotor.

The 3D rim shapes were then run through CFD simulations (SimScale) at a range of yaw angles (0 to 20 degrees, at 5 degree increments) under simplified conditions. Indicative results validated the proposed redesign of the non-drive side to manage airflow from the rotor.

Prototyping

Following CFD testing, a prototype wheel was moulded, for final testing and validation in the wind tunnel.

WIND TUNNEL TEST RESULTS

Once the prototype designs were finalised, we took a range of wheels to the A2 Wind Tunnel in North Carolina to test. The wheels tested included:

- New Parcours Chrono prototype **(A)**
  - Front (68.6mm)
  - Rear (75.7mm)
- New Parcours Chrono Max prototype **(B)**
  - Front (83.6mm)
- New Parcours Disc^2 prototype **(C)**
  - Rear
- Parcours Chrono (MY21) existing model wheelset
  - Front (77.0mm)
  - Rear (86.0mm)
- Parcours Disc^2 (MY21) existing model wheel
  - Rear

In addition, we had a range of tyres available for testing:

- Continental GP5000TL (28mm)
- Continental GP5000TR (28mm)
- Continental GP5000TR (30mm)

Initial test runs on multiple wheels were conducted to confirm that there was no discernible difference between the TL and TR variants of the GP5000 tyre. Subsequent testing was then conducted using the TR variant and is regarded as comparable to previous test sessions conducted using the older TL variant.

TEST ONE: AERODYNAMIC PERFORMANCE VS. EXISTING PARCOURS BENCHMARK

Total wheelset aero drag:

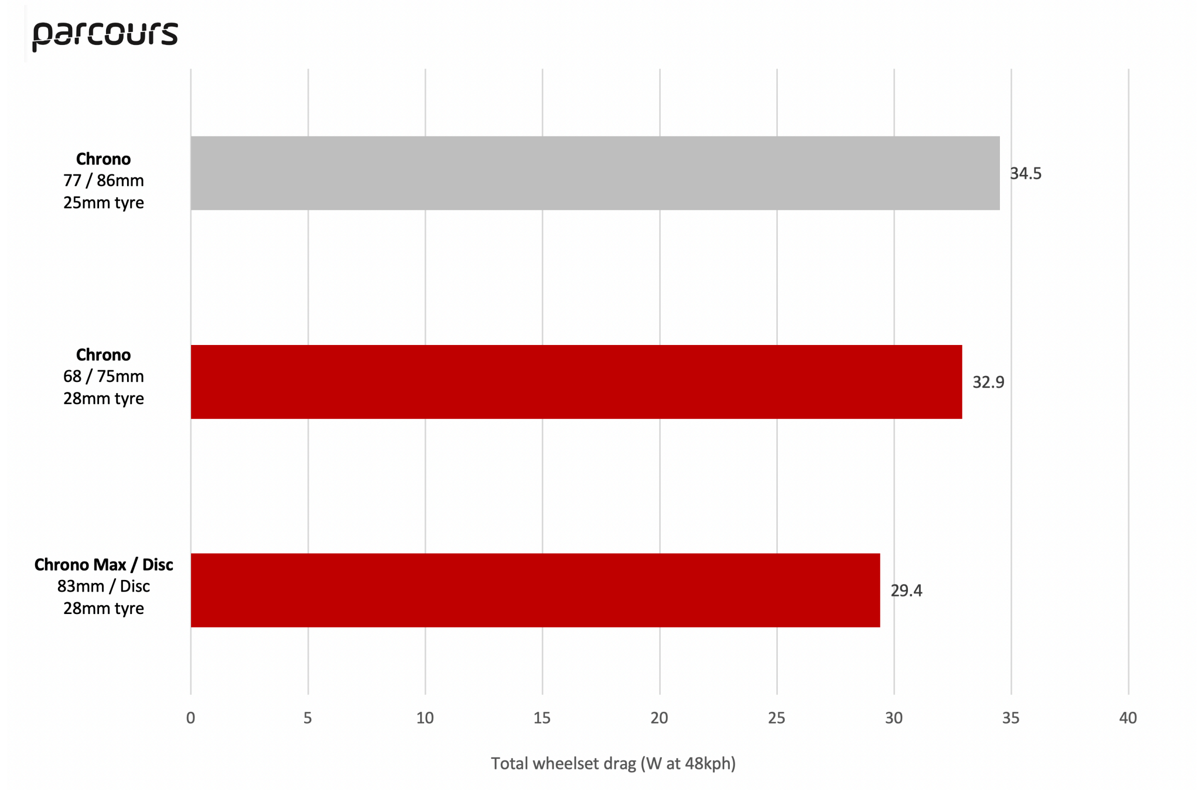

Fig.2 – total wheelset aerodynamic drag for Parcours models

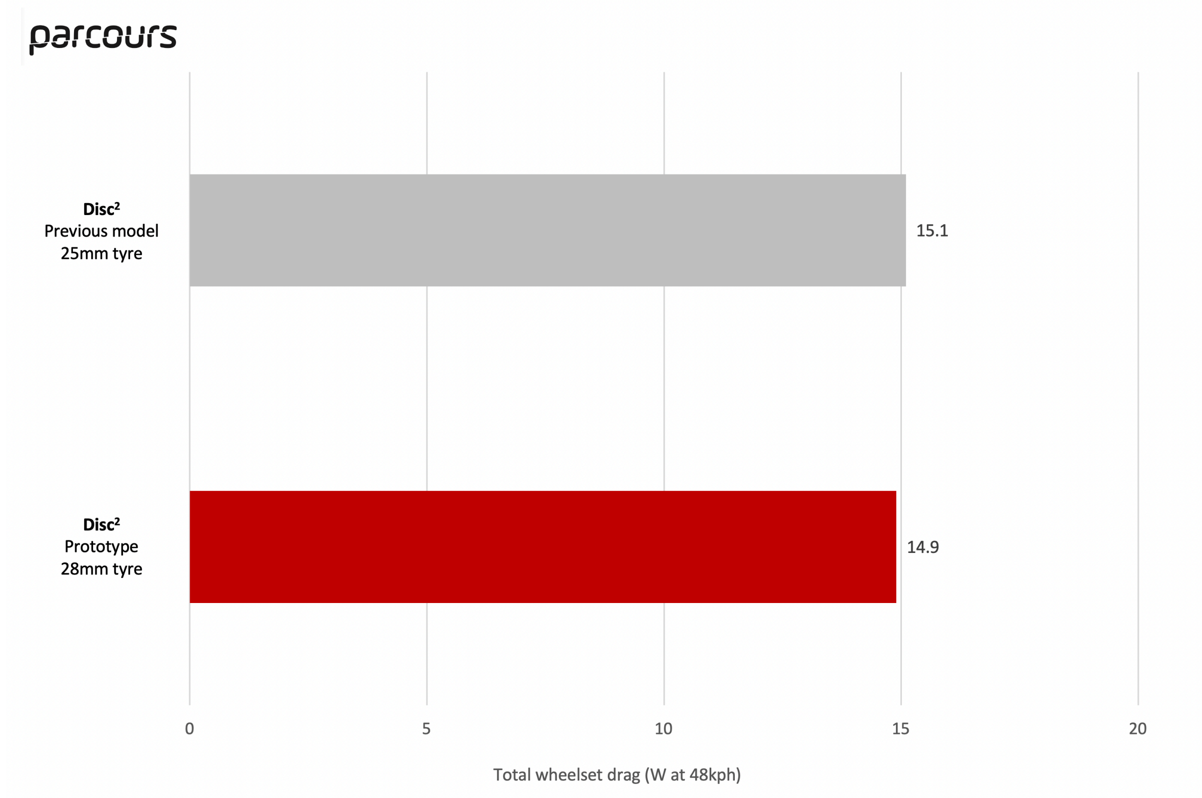

Fig.3 – rear wheel aerodynamic drag for Parcours models

The prototype Chrono wheelset (A) exceeded the design brief, outperforming the existing Chrono wheelset by 1.6W on a weighted average yaw basis. The majority of this difference occurred at lower yaw angles (<7.5 degrees), reflecting the enhanced understanding of real world yaw from our study with Nottingham Trent University.

As expected, the deeper prototype Chrono Max front wheel (B) and Disc^2 rear (C) delivered further aerodynamic benefits, outperforming the existing Chrono front / Disc^2 setup by over 2W. Notably, the majority of this saving was from the Chrono Max front wheel as testing showed the Disc^2 prototype (C) performed very similarly to the existing Disc^2 wheel.

However, when the existing wheelsets were tested with 28mm tyres, the savings grew substantially by almost 5W in both cases as the older wheelsets were penalised for their narrower rim widths. Of note is that the existing Chrono wheelset performed almost in line with the Strade (49/54mm) wheelset when fitted with a wider 28mm tyre.

When combined with the improved rolling resistance of a wider tyre, the new wheelsets deliver a substantial performance benefit when compared to our existing wheel options.

Continental GP5000TR tyres were used for all runs in Test One.

When testing wheelsets, we applied our real world yaw angle data sets, specific to the front and rear wheels.

Front wheel testing:

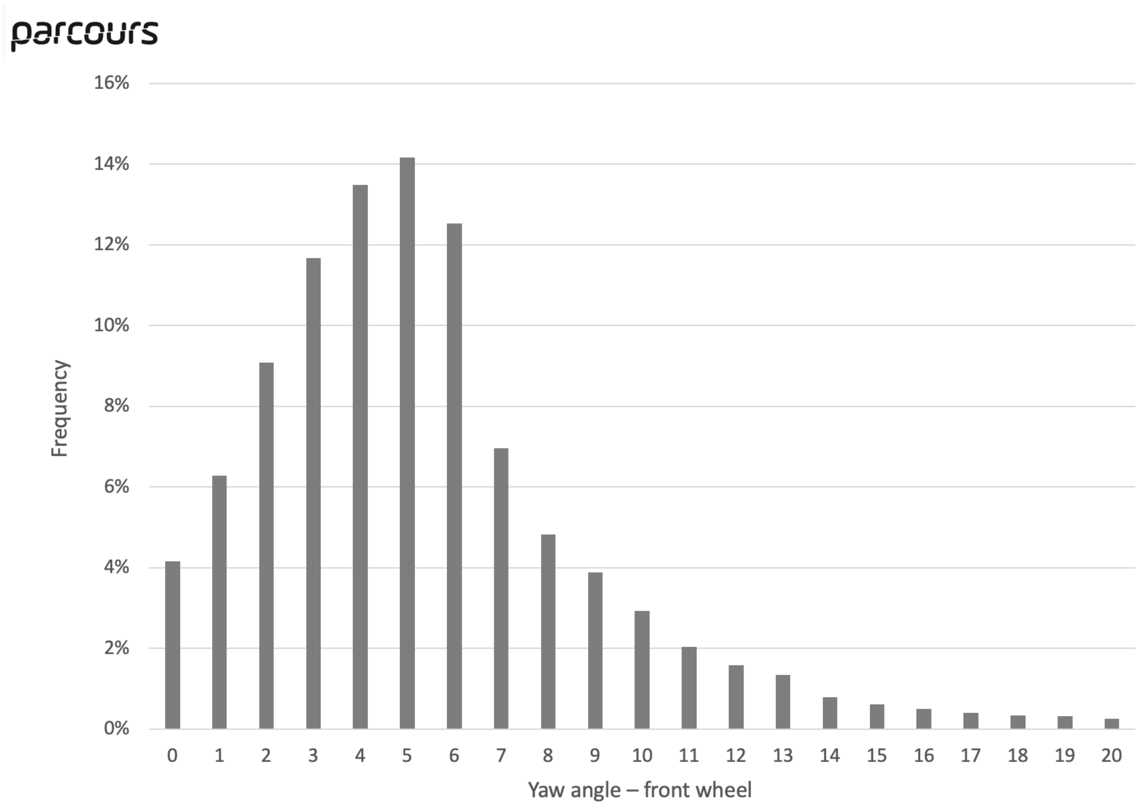

Fig.4 – observed front wheel yaw angle

The most commonly observed yaw angles for the front wheel are between 2 - 8°, accounting for over 2/3 of total frequency.

Drag chart:

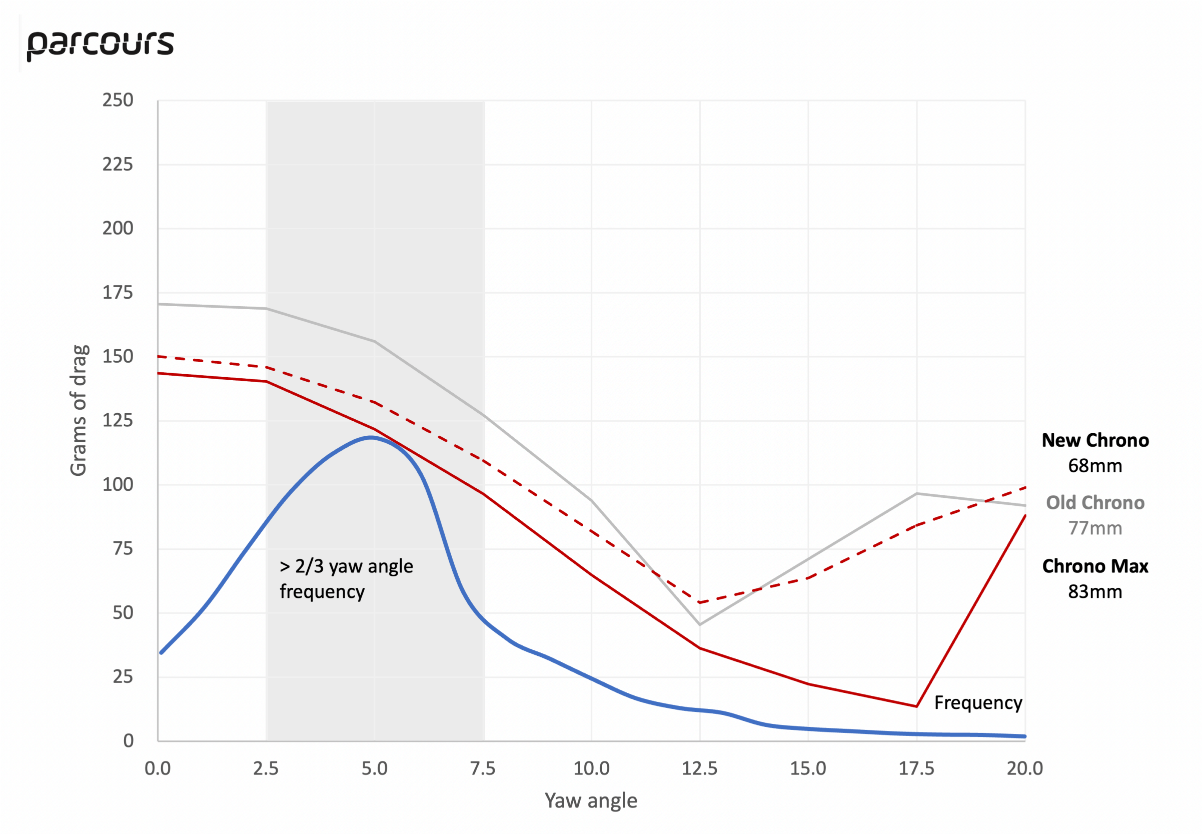

Fig.5 – aerodynamic drag at 2.5° intervals

Within the key yaw angle window of 2 - 8°, both the New Chrono (A) and Chrono Max (B) front wheels outperform the existing Chrono front wheel. Whilst the differences are comparatively small at lower yaw angles, it is here that they are magnified when looking at overall results on a weighted average basis.

The aerodynamic stall angle varies between designs, with the New Chrono (A) matching the existing Chrono front wheel in hitting its stall angle at 12.5° of yaw, albeit the New Chrono (A) shows a slower drop-off in performance as the yaw angle increases. However, the Chrono Max (B) maintains performance up to 17.5° of yaw. This follows patterns previously observed in our testing, whereby (on average) a deeper wheel will reach its stall angle at higher yaw than a shallower equivalent.

Rear wheel testing:

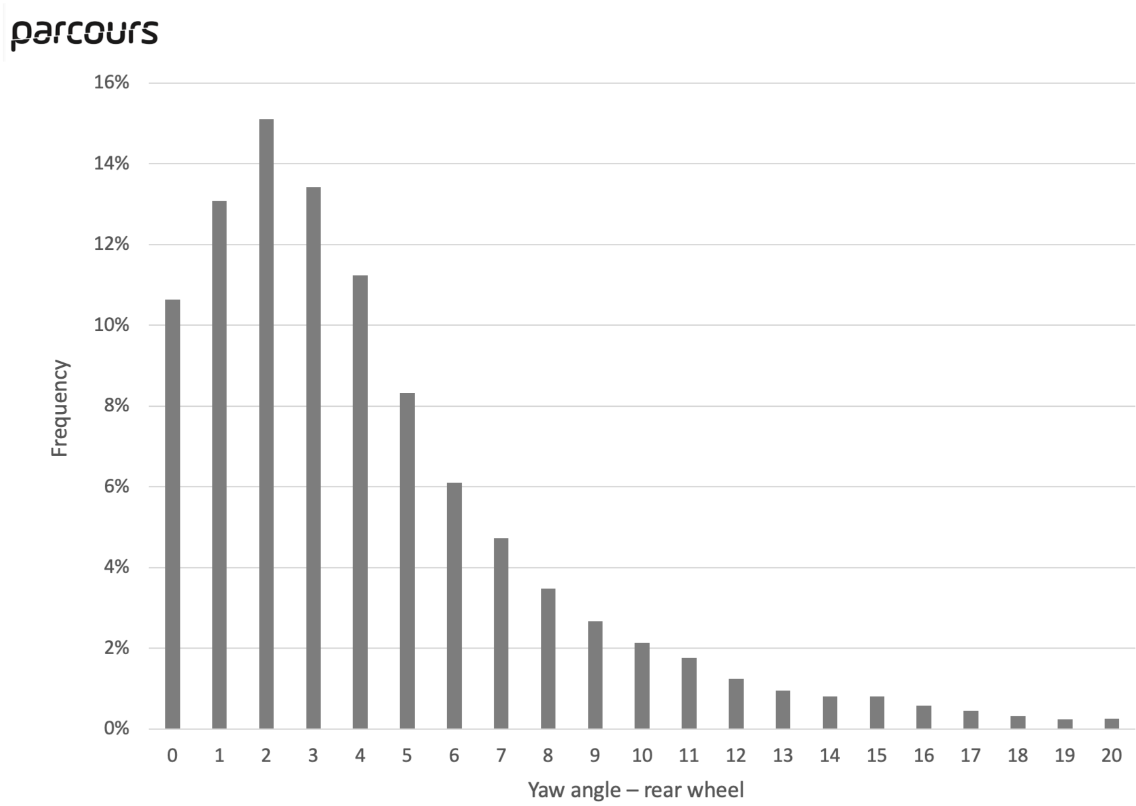

Fig.6 – observed rear wheel yaw angle

The most commonly observed yaw angles for the rear wheel are between 0 - 5°, again accounting for over 2/3 of total frequency. This is substantially lower than the front wheel, indicating low yaw performance is a higher priority.

Drag chart:

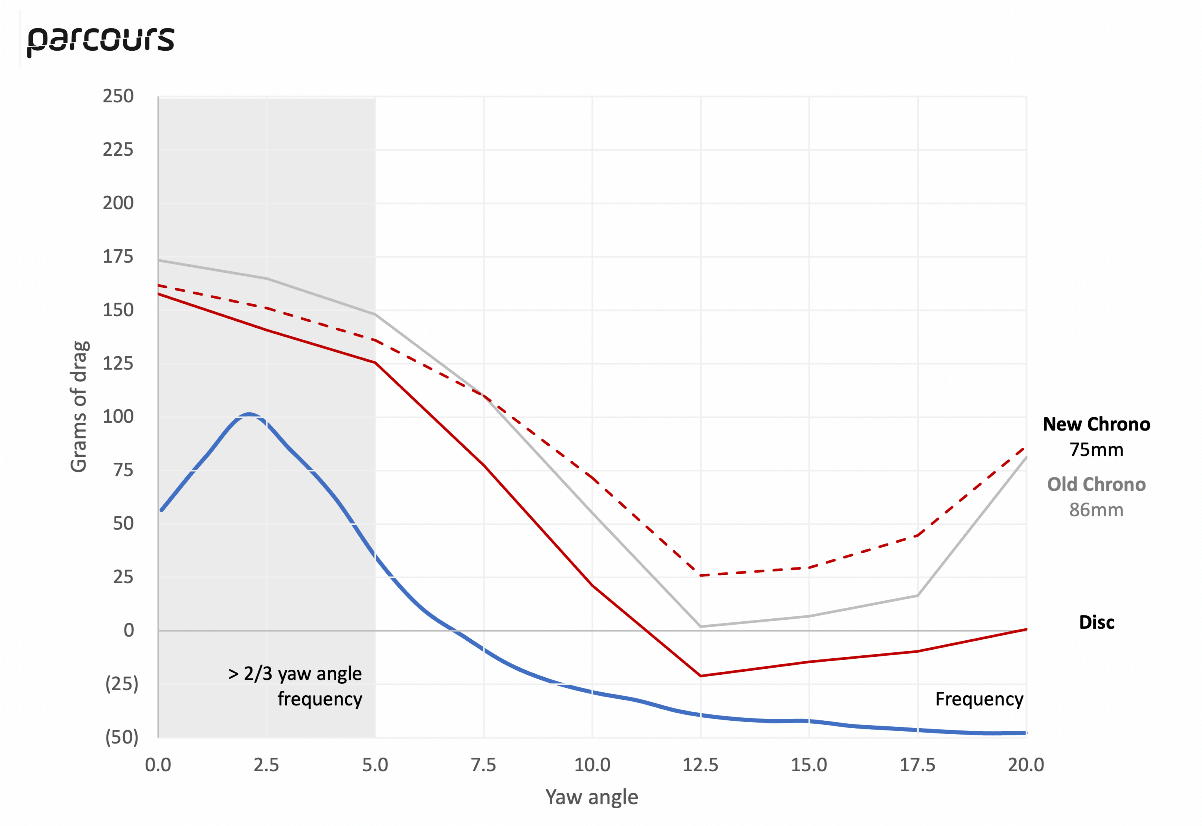

Fig.7 – aerodynamic drag at 2.5° intervals

Within the key yaw angle window of 0 - 5°, the New Chrono (A) rear wheel outperforms the existing Chrono rear wheel. This continues up to 7.5° of yaw, at which point the deeper existing rear wheel begins to outperform the prototype design. However, over 85% of observed yaw angle data points on the rear wheel are at 7.5° or lower.

Despite this crossover in performance, aerodynamic stall angle is similar for both wheels, occurring at approximately 12.5° in our testing. Given the greater frequency of low yaw angles for the rear wheel, stall angle is likely to have a lower impact on overall aerodynamic performance, even in higher wind speed conditions.

TEST TWO: AERODYNAMIC PERFORMANCE WITH A RANGE OF TYRE WIDTHS

Whilst the #thinkwider rim profiles have been designed to be aerodynamically optimised for use with a 28mm tyre, we know from experience with our Ronde and Strade wheelsets that many of our riders will choose to run a wider tyre. We wanted to investigate the impact of this potential choice on aerodynamics.

Aero drag:

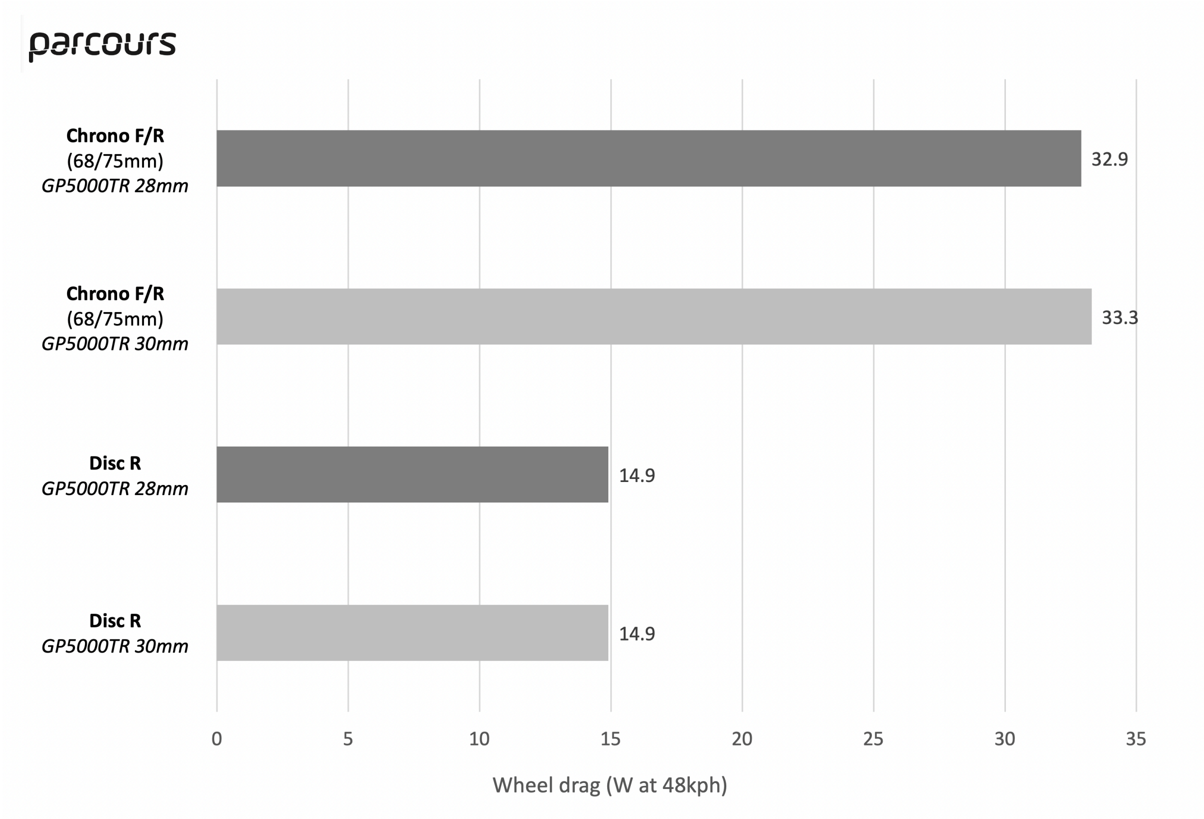

Fig.8 –aerodynamic drag for Parcours models with varying tyre widths

The results show that the aerodynamic performance remains, to some extent sensitive to tyre width. As tyre width increases, aero drag also increases, as the tyre width exceeds the limit set by the "Rule of 105%". This implies that for optimal aerodynamic performance on a rim width of 32.0mm, a tyre should measure no wider than 30.5mm.

On the 22.5mm internal rim width wheels tested, measured versus stated tyre width was as follows:

- Continental GP5000TR 28mm stated / 29.2mm measured (at 75psi)
- Continental GP5000TR 30mm stated / 30.4mm measured (at 75psi)

Note that per ETRTO standards, a 28mm (stated width) tyre will be tested on a 19mm internal rim width, whilst a 30mm (stated width) tyre is tested on a 21mm internal rim width. This is the principal driver for the difference, or lack thereof, between stated & measured widths on Parcours' 22.5mm internal rim width.

Whilst the 30mm tyre still measured within the 105% tolerance, there is a slight (0.4W) drop off in aerodynamic performance on the New Chrono (A) wheelset. However, with the prototype Disc (C) wheel, there was no drop off in aerodynamic performance when the wider tyre was fitted, indicating that it is agnostic to tyre width up to at least 30mm. This is particularly relevant for a Disc wheel as the monocoque structure can deliver a harsher ride. If fitted with a wider tyre, there is greater scope for a rider to run at a lower tyre pressure, improving ride comfort. We intend to investigate this benefit further, especially in relation to running a rear Disc.

We know from previous testing with the Ronde wheelset that any reduction in aerodynamic performance as tyre size increases does not occur as a cliff edge and reduces in close to a linear relationship. It is difficult to make extrapolations based on so few data points, but this test implies that 30mm is likely the widest stated tyre that can be fitted to the New Chrono (A) wheelset without a more significant impact on aerodynamic performance. The maximum tyre width suitable for use on the Disc (C) is at least 30mm and it is not clear from this test whether it can accommodate a wider tyre without a performance impact. However, we do not believe this will be relevant for the vast majority of riders as few, if any, time trial or triathlon bikes will have clearance for this tyre size.

Unfortunately, due to time constraints, we were not able to complete testing of the Chrono Max (B) front wheel when fitted with a wider tyre. However, both the test results from the New Chrono (A) wheelset and previous testing with the Ronde wheelset suggests that the impact on aerodynamic performance will be very limited when running a 30mm tyre.

TEST THREE: HANDLING PERFORMANCE OF FRONT WHEELS

Side force chart:

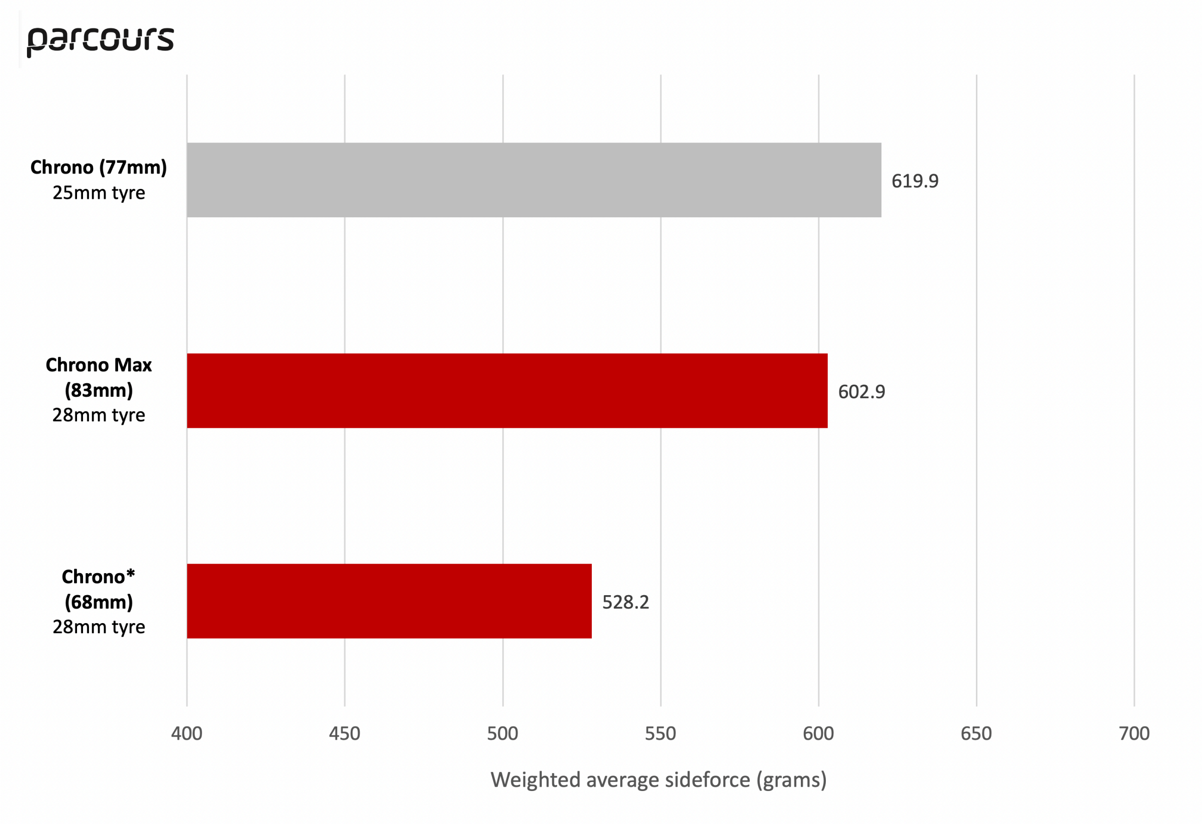

Fig.9 – front wheel sideforce for Parcours models

A key design benchmark was to ensure that the Chrono Max (B) front wheel at least maintained the handling stability of the existing Chrono front wheel, whilst for the New Chrono (A) front wheel, the aim was to reduce the crosswind sideforce to the lowest value possible, whilst maintaining aerodynamic performance.

When viewed on a weighted average yaw angle basis, the Chrono Max (B) shows a 2.7% improvement in handling stability versus the existing model. Note that this comparison is with the original wheel fitted with a 25mm tyre. If the existing model is fitted with a 28mm tyre, the difference grows to a 6.3% improvement.

Meanwhile, the New Chrono (A) prototype front wheel significantly reduces crosswind sideforce, with a 14.8% improvement versus the existing wheel model. Notable is that the reduction in surface area of a 68.6mm rim versus a 77mm rim is only 11%, indicating that the revised #thinkwider rim profile offers an additional handling benefit. If identical 28mm tyres are fitted, the improvement in handling performance grows to almost 18%, offering a substantially more stable ride.

The New Chrono (A) prototype actually generates marginally (1.3%) less sideforce than our previous generation Passista Disc wheelset with a 56mm rim depth and is within 7% of the Grimpeur Disc wheelset with a 40mm rim depth.

Test protocol:

- Front wheel and rear wheels were tested
- Each wheel was tested from 0-20 degrees of yaw, at 2.5 degree increments
- Positive yaw angles cover non-drive side (i.e. brake rotor, where relevant, exposed to the wind)
- Each test sweep was conducted twice, with results averaged
- Test wind velocity at 30mph
- The same tyre was used throughout each test, inflated to 75psi

Note: we did not remove tare (i.e. subtract the drag from the wheel clamp) for two reasons:

1. In real-world riding, the wheel will have the fork supporting it
2. As the wheel is rotated into the wind at higher yaw angles, one of the clamp posts will become increasingly "hidden" from the wind. Subtracting a simple tare value could therefore be misleading at higher yaw angles

Note: when measuring time savings versus a benchmark wheelset, we use a Fulcrum Racing 5 wheelset, which has the same spoke count as the more aero wheels, rather than a commonly-used box rim with a 32 spoke count. We believe this is more representative of the real-world benefits you will see from an upgrade.

CONCLUSION

The original design brief has been met, with all key performance targets met for the new wheelsets:

New Chrono (A) 68mm front/ 75mm rear:

- 1.6W reduction in aero drag vs. existing Chrono wheelset with 25mm tyres
    - 5.9W reduction when existing Chrono fitted with 28mm tyres
- 14.8% reduction in crosswind sideforce vs. existing Chrono wheelset fitted with 25mm tyres
    - 17.9% reduction when existing Chrono fitted with 28mm tyres
- 70g weight reduction vs. existing Chrono wheelset

Chrono Max (B) 83mm front:

- 2.1W reduction in aero drag vs. existing Chrono front wheel fitted with a 25mm tyre
    - 4.1W reduction when existing Chrono front wheel fitted with a 28mm tyre
- 2.7% reduction in crosswind sideforce vs. existing Chrono front wheel fitted with a 25mm tyre
    - 6.3% reduction when existing Chrono front wheel fitted with a 28mm tyre

New Disc^2 (C) rear:

- Performs in line aerodynamically with existing Disc wheel fitted with a 25mm tyre, however the difference grows to 2.3W when existing Disc wheel is fitted with a 28mm tyre or 4.6W with a 30mm tyre
- 140g weight reduction vs. existing Disc wheel

The introduction of our new #thinkwider time trial and triathlon wheelset line-up offers riders the option of running a modern, wider tyre without compromising on aerodynamic performance. All new wheels are truly optimised for a 28mm tyre and all outperform our previous generation class-leading wheelset.

Riders can choose between the Chrono wheelset which will significantly enhance ride handling and stability and the Chrono Max / Disc^2 combination which will further reduce aerodynamic drag.

We strongly believe that the new Disc^2 rear wheel is the first disc wheel that is designed from the ground up to be fitted with a 28mm tyre and is likely to be the only disc wheel that shows no aerodynamic penalty up to a 30mm tyre size. The 22.5mm internal rim width makes it the widest disc wheel currently available.

In the near future, we intend to publish further research findings that demonstrate the reduction in handling instability from running a rear disc wheel, as well as conducting additional research to investigate quantifying the benefits of wider tyres and lower tyre pressures.

APPENDIX

INTERPRETING A DRAG CHART

YAW ANGLE

When riding a bike, the wind you feel can be split into two main components:

- Wind resistance from your forward motion. As you ride forwards, you (and the bike) are moving through the air in front of you, creating drag. Rather than riding forwards, this is simulated in a wind tunnel
- Impact of the wind that is blowing that day (i.e. the weather). Clearly this can act upon a rider from any direction, depending on the conditions

The two components combine to give the effective wind that a rider will encounter. To model it in the wind tunnel, we need to understand both how strong the wind is, and from what direction it is felt – the yaw angle. Given that most riders will be travelling significantly faster than the wind is blowing, the wind resistance makes up the larger share of the effective wind. It also concentrates the yaw angles seen when riding into a small arc in front of the rider. As a result, wheels are tested between 0 and 20 degrees of yaw angle, reflecting the yaw angles seen in the real world.

GRAMS OF DRAG

In order to quantify wind resistance resulting from a wheel, we measure the drag force it exerts when exposed to wind. The wind tunnel measures the force on the wind axis (i.e. based on the direction the effective wind is travelling), which is then converted to the body axis (i.e. based on the direction the rider is travelling.

The drag chart shows the drag force exerted against the direction of travel for the rider. This is the component of the drag force that slows you down whilst riding. The higher the drag force, the more energy is needed to overcome it and move you forward. When reading a drag chart, this means that the lower the line, the more aerodynamic the wheel is. You should bear in mind though, when comparing wheels, a wheel may show a lower drag at one yaw angle, but higher at another.