parcours

RONDE WHEEL DEVELOPMENT – WHITE PAPER
February 2021

BACKGROUND

Following the launch of the Strade in January 2020, the move towards adopting wider (28mm) tyres, run at lower (<80psi) pressures has continued. Building on the experience of developing the Strade, as well as our ongoing #thinkwider research project with Nottingham Trent University, we wanted to broaden our product line-up and introduce a shallower rim profile, allowing for a lightweight overall wheelset.

Furthermore, with the wide (22.5mm) internal rim width, such a wheelset would also be perfectly positioned for all-road use, giving the flexibility for running a wider tyre. Based on upcoming ETRTO guidelines, this would permit the running of anything from a 25mm tyre up to the widest 700C tyres of ~50mm.

Given the cross-over with the Strade development, the initial rationale for #thinkwider is included below:

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[1]. 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 the new Continental GP5000 tyre will deliver the same rolling resistance at 81psi in a 28mm version as at 92psi in a 23mm version[2].
   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.
   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.

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

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.

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

Building on the experience of the Strade, we wanted to develop a wheel that is:

1. **Aerodynamically optimised for a 28mm tyre**
2. **Tubeless-ready**
3. **Disc brake-specific**
4. **Shallow rim profile to minimise weight**
5. **Sufficiently robust to allow all-road running**

The design benchmark would be the existing Grimpeur Disc (40mm rim depth wheelset), providing aerodynamic and weight targets for the development project.

DESIGN PROCESS OVERVIEW AND CONTRIBUTING FACTORS

Aerodynamic performance

The baseline aerodynamic performance was set such that:

- Ronde must outperform existing Grimpeur Disc wheelset when fitted with the optimal width of tyre
  - Ronde fitted with a 28mm tyre / Grimpeur Disc fitted with a 25mm tyre

Rim depth

As previously established, rim depth is one of the key drivers for aerodynamic performance. Given the project's design goal of performing in line with the Grimpeur 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.

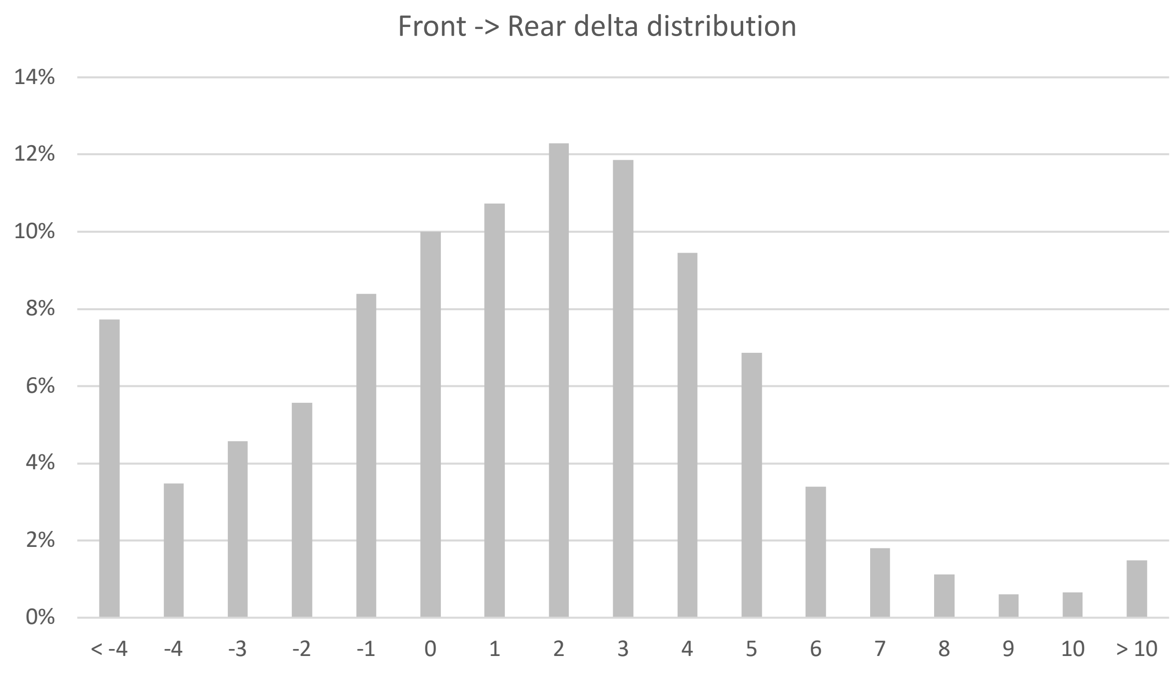

Fig.1 – front wheel to rear wheel yaw angle delta, field testing

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

Additional testing showed that the ideal ratio of c.110% for between front:rear rim depth.

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 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.

Prototyping

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

- Parcours Ronde prototype front wheel A (35.6mm depth / 32.0mm width)
- Parcours Ronde prototype rear wheel B (39.3mm depth / 30.5mm width)

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:

- Parcours Ronde prototype
- Parcours Grimpeur Disc
- Enve 3.4AR
- Zipp 303S

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

- Continental GP5000TL (25mm)
- Continental GP5000TL (28mm)
- Continental GP5000TL (32mm)
- Schwalbe Pro One TLE (28mm)
    - Note that the Schwalbe Tyre was included as both Enve & Zipp wheelsets use hookless rims and are therefore not compatible with the GP5000TL range

TEST ONE: AERODYNAMIC PERFORMANCE VS. PARCOURS BENCHMARK

Total wheelset aero drag:

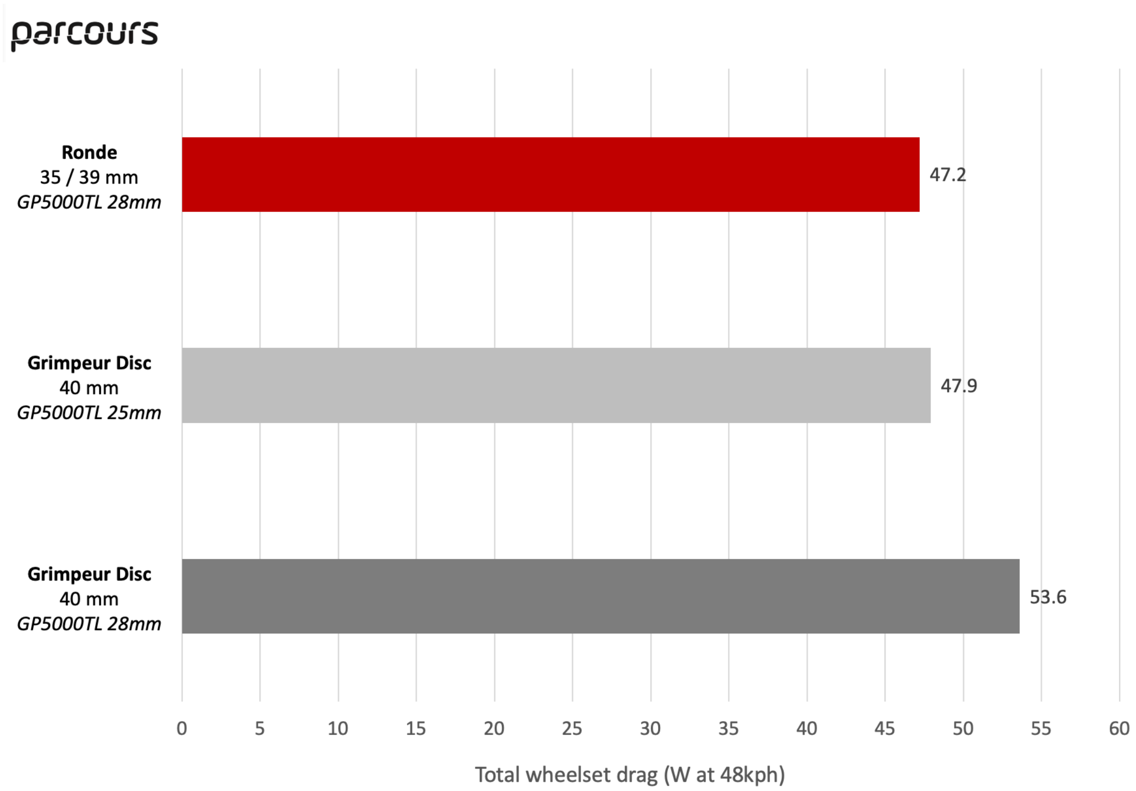

Fig.2 – total wheelset aerodynamic drag for Parcours models

Per the design brief, when fitted with a 28mm tyre the Ronde performed in line with Grimpeur Disc wheelset and a 25mm tyre. The Ronde marginally (0.5W) outperformed the older wheel, despite running a wider tyre.

Moving to a 28mm tyre from the recommended 25mm tyre on the Grimpeur Disc, there is a significant (5.7W) penalty. This represents approximately 50% of the overall aero savings taken versus the benchmark box rim wheelset used in our testing.

When combined with the improved rolling resistance of the wider tyre, the Ronde is overall a faster wheelset choice versus our prior Grimpeur Disc model.

Continental GP5000TL tyres were used for all runs in Test One.

TEST TWO: AERODYNAMIC PERFORMANCE VS. COMPETITOR WHEELSETS

Further to testing versus our existing Grimpeur Disc wheelset, we were also keen to see where the Ronde would be positioned versus competitor wheelsets. We chose two competitor models to test against:

- Enve 3.4AR (39mm front / 43mm rear): chosen as the "benchmark" aero wheelset at a similar rim depth, optimised for running with a 28mm tyre
- Zipp 303S: chosen as a competitor wheelset offered at a similar RRP (currently £985 in the UK). Also recently launched & recommended for use with a 28mm tyre

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

Front wheel testing:

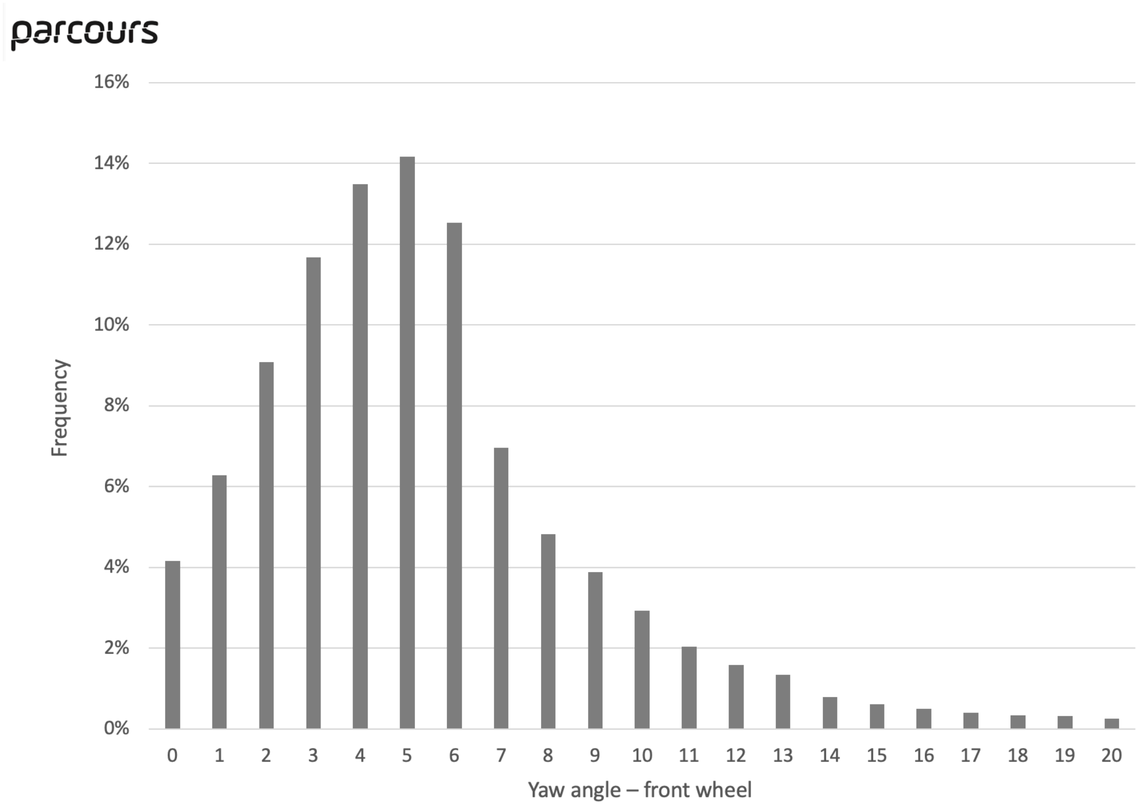

Fig.3 – observed front wheel yaw angle

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

Drag chart:

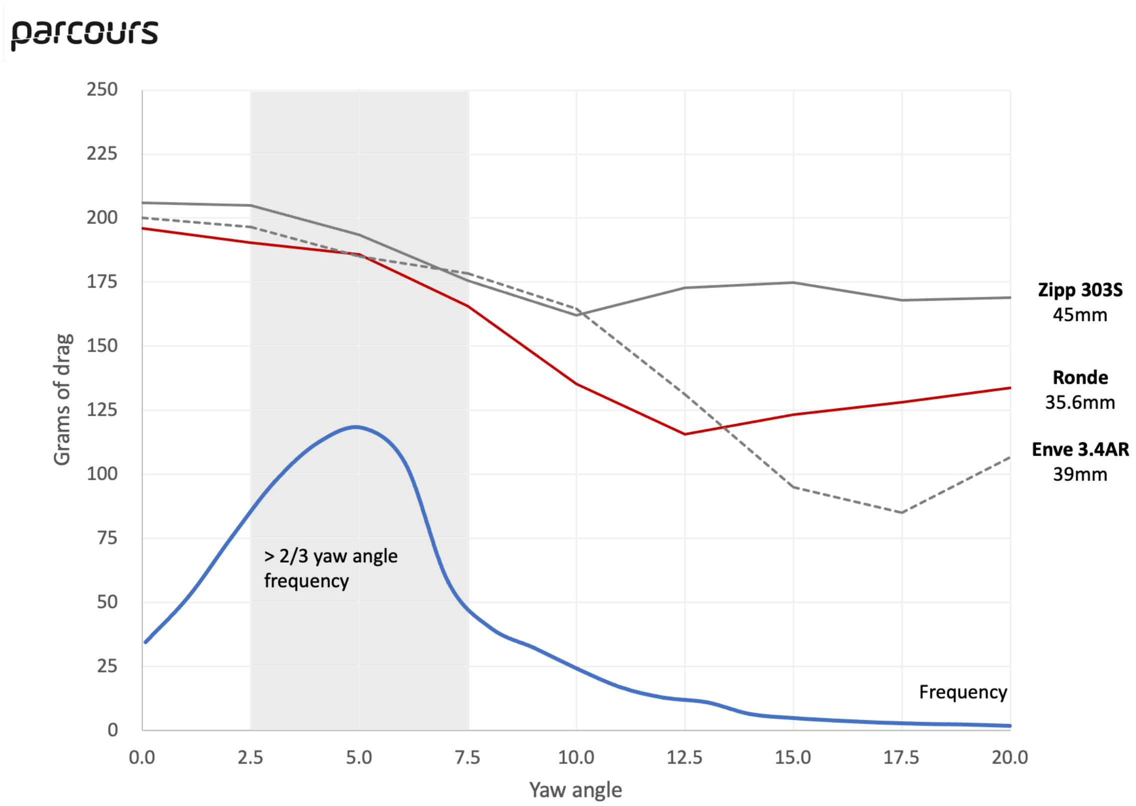

Fig.4 – aerodynamic drag at 2.5° intervals

Within the key yaw angle window of 2 - 8°, the Ronde front wheel outperforms both competitor wheels. 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 Zipp 303S hitting its stall angle at 10° of yaw, the Ronde at 12.5° of yaw and the Enve wheel not stalling until 17.5° of yaw. Stall angle is particularly relevant for high crosswind riding, as in these circumstances it is likely the key yaw angle window will shift to the right on the chart.

Rear wheel testing:

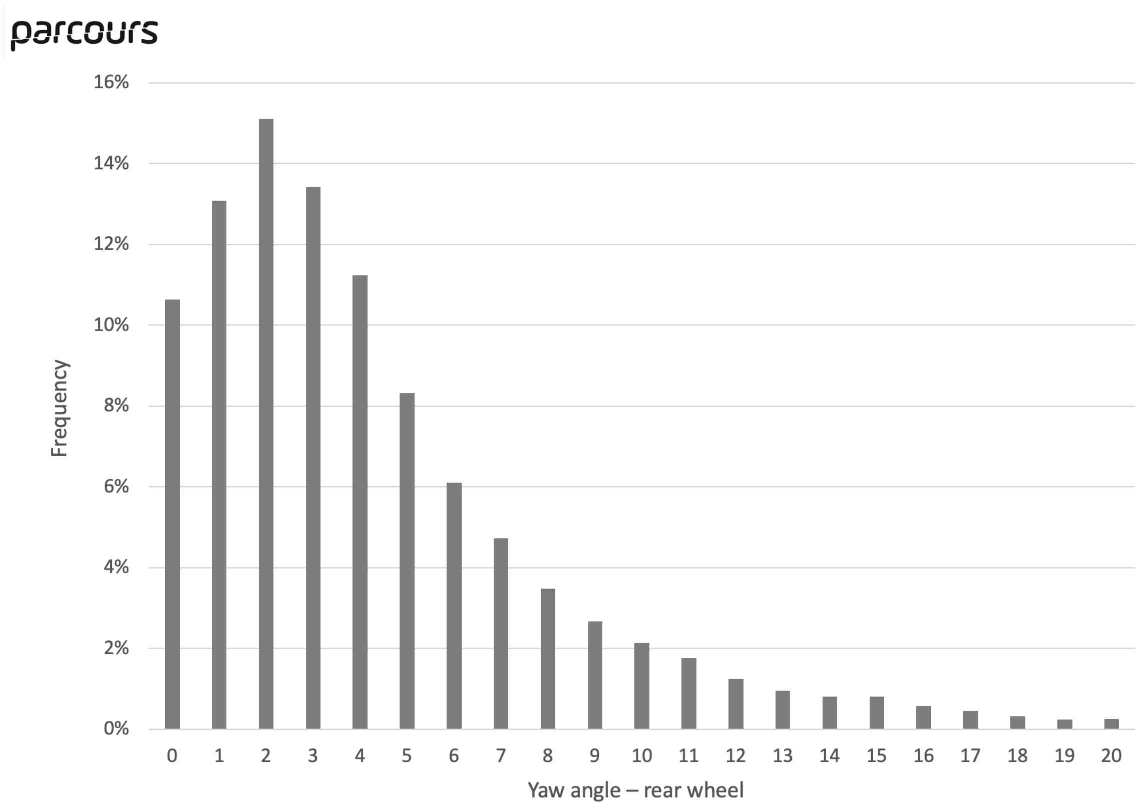

Fig.3 – observed rear wheel yaw angle

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:

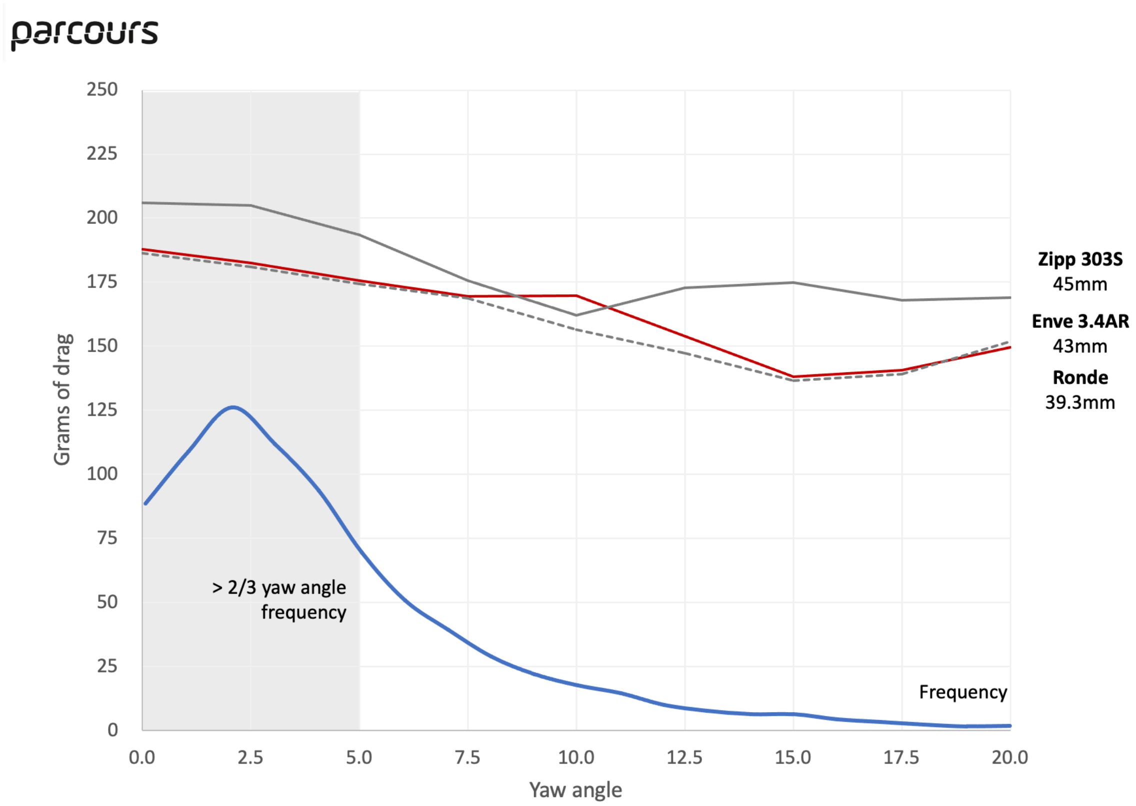

Fig.4 – aerodynamic drag at 2.5° intervals

Within the key yaw angle window of 0 - 5°, both the Ronde rear wheel and Enve rear wheel outperform the Zipp rear wheel. Up to 7.5° of yaw, the performance of the Ronde and Enve rear wheels is almost identical (Enve is c.1% lower drag). Over 85% of observed yaw angle data points on the rear wheel are at 7.5° or lower.

Aerodynamic stall angle is harder to determine for the Ronde rear wheel, as there are two turning points on the chart, at 7.5° and again at 15°. 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.

Total wheelset aero drag:

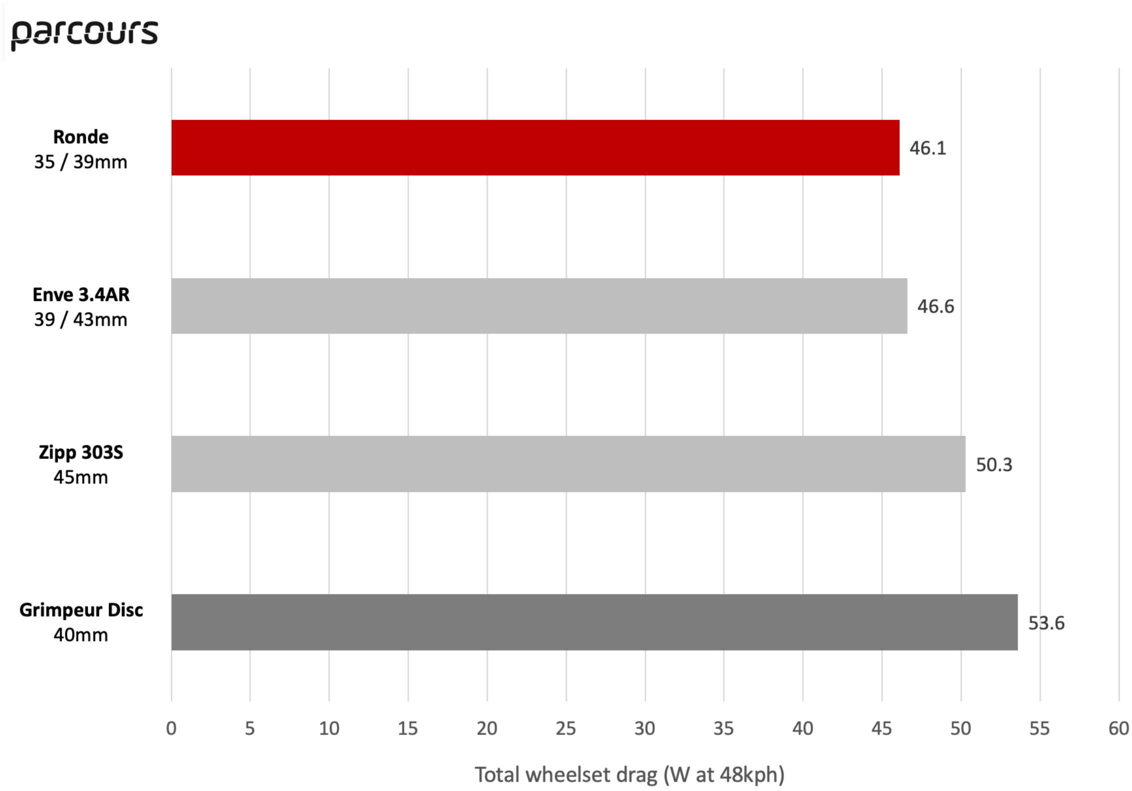

Fig.6 – total wheelset aerodynamic drag for Parcours and competitor models

Using the observed yaw angle data, we applied a weighted average yaw distribution to the wind tunnel data for both front and rear wheels. Combining the aero drag for each wheelset shows that the Ronde is marginally (0.5W) faster than the Enve 3.4AR and outperforms the Zipp 303S by 4.2W.

Given all three wheelsets were designed for use with 28mm tyres, it is no surprise to see that they all outperform the Grimpeur Disc wheelset with the same tyre.

Note that both Enve and Zipp wheelsets use hookless rim designs, which are not compatible with our default Continental GP5000TL test tyre. As a result, we used a Schwalbe Pro One TLE tyre (28mm) for this test.

TEST THREE: AERODYNAMIC PERFORMANCE WITH A RANGE OF TYRE WIDTHS

Whilst the Ronde was designed to be aerodynamically optimised for use with a 28mm tyre, we know that many of our riders will choose to run a wider tyre. Whether specifically for use on mixed terrain or more generally for everyday riding, we wanted to investigate the impact on aerodynamics.

Total wheelset aero drag:

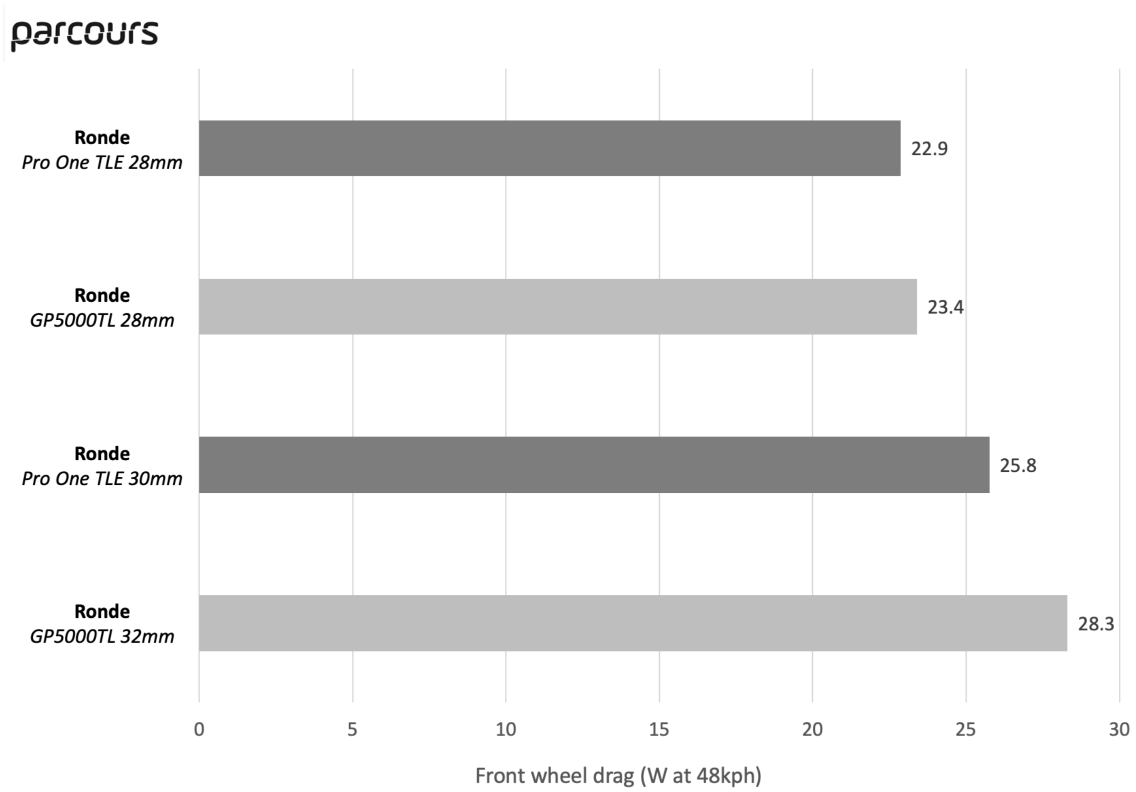

Fig.7 – front wheel aerodynamic drag for Parcours Ronde with varying tyre widths

The results show that the aerodynamic performance remains 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%".

To recap, the Ronde front wheel has a maximum rim width of 32.0mm. Based on the "Rule of 105%", this implies a maximum (measured) tyre width of 30.5mm to preserve aerodynamic performance. The Pro One TLE 30mm test tyre exceeds this (measured at 31.8mm) as did the GP5000TL 32mm test tyre (measured at 33.6mm).

It is clear, however, that the reduction in aerodynamic performance is not 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 shows that any aerodynamic benefit versus our benchmark wheel (Fulcrum Racing 5) will disappear with a tyre measuring ~34.5mm, suggesting a stated width of ~33mm. Note that this comparison assumes the benchmark wheel continues to run a 25mm tyre. Further testing would be required to establish aerodynamic benefit when both wheelsets are fitted with wider tyres.

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 80psi

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 Ronde wheelset has been shown to outperform the existing Grimpeur Disc in all aspects. It is faster aerodynamically when fitted with a wider tyre and further testing has shown a reduction in crosswind sideforce of c.17%.

Wind tunnel data shows that the Ronde wheelset, fitted with a 28mm tyre represents the new benchmark for an all-road disc brake wheelset. This setup has been shown to be marginally (0.5W) faster than an Enve 3.4AR wheelset, as well as outperforming a Zipp 303S wheelset by a wider margin (4.2W). The Ronde also maintains additional versatility by using a hooked rim design, allowing riders a wider choice of tyre.

The Ronde does remain relatively sensitive to choice of tyre width, however, with data suggesting that when fitted with a tyre of ~33mm (stated) width or wider, it will no longer be faster than a standard box rim wheelset, fitted with a 25mm tyre.

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.