AERODYNAMIC PERFORMANCE OF

THE HUNT 42 LIMITLESS GRAVEL DISC WHEELSET

Luisa Grappone, Product Engineering Manager (MSc Aerospace Engineering)
Chris Colenso, Development Engineer (MEng Mechanical Engineering)
Peter Marchment, HUNT Co-Founder (MSci Natural Sciences)

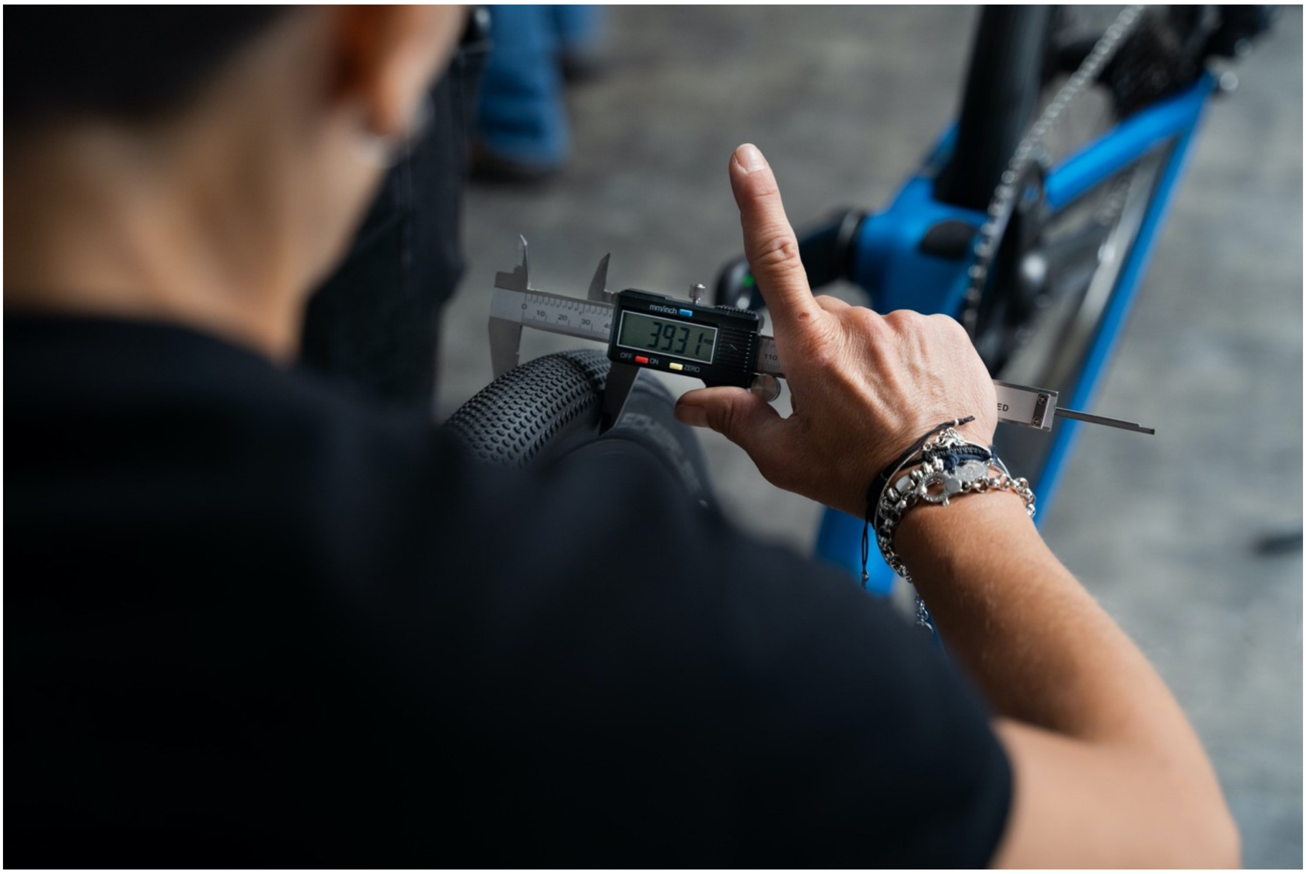
HUNT BIKE WHEELS (ITS Cycling Limited), West Sussex, United Kingdom

Wind tunnel operated by Ernst Pfeiffer
GST Windkanal, Immenstaad, Germany

For years safety and adventure have been the two main reasons for people who started to ride on gravel paths. Most of the time bikes for this kind of riding were just existing bikes converted, when possible, to suit the different roads' surfaces and conditions.

As gravel has continued to grow in popularity with more and more gravel events taking place all over the world the cycling industry started to produce bikes and components specifically conceived for this new discipline.

With this increase in popularity for relaxed adventure, soon after followed a proliferation of gravel races and competitive events. No longer are just comfort and versatility the key features when developing gravel specific components, but lightness and aerodynamics have become important factors in the achievement of top performances on the global stage.



1-TESTING THE THEORY

1.1 – Introduction

As well as in other disciplines, when it comes to gravel racing: aerodynamics matters. Despite the use of wider tyres (typically wider than the rim) and off-road tread patterns deeper and wider rims still bring a considerable aerodynamic advantage when compared to standard shallower rims. In February 2020 the Hunt team performed wind tunnel testing to compare the aerodynamic performance of aero gravel wheels versus non aero gravel wheels. The results showed that the drag curve for the non-aero optimised wheel displaced to a higher magnitude than the other wheels, equating to a significant power loss of 2.9 Watts.

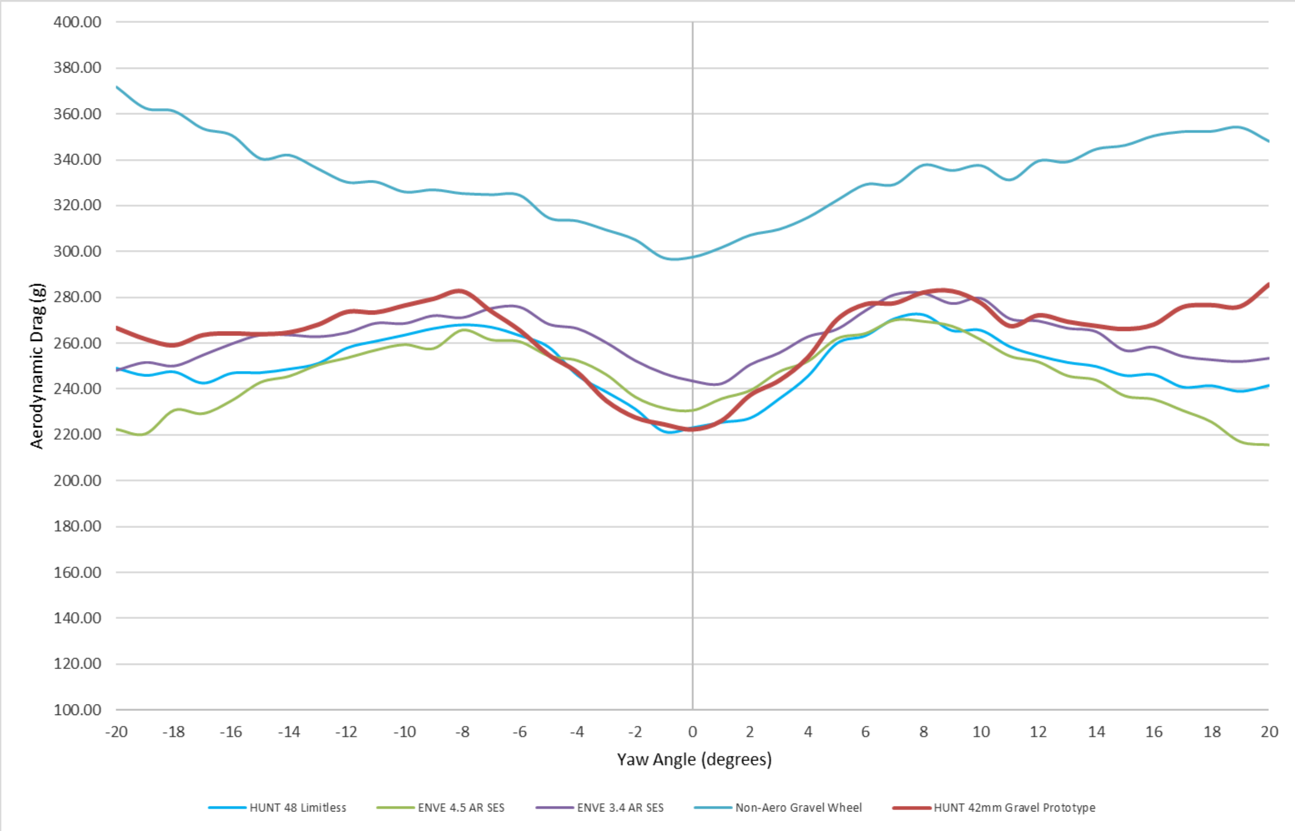


Figure 1: Drag [g] vs yaw angle [°] from wind tunnel test showing aero optimised wheels vs non aero gravel wheel

1.2 - Research Purpose

The HUNT team established a design brief for the project:

- Test two (leading) aerodynamically developed rims commonly used in gravel racing from ENVE and Zipp, and the new HUNT 42 Limitless Gravel Disc.
- Conduct the test using the Schwalbe G-One 38mm and the Teravail Cannonball 42mm tyres. These tyre widths represent the upper and lower range of widths and treads severity used by elite gravel racers.
- A simulated moving speed of 32km/h – chosen to represent the speeds achievable at events such as the DK 200-mile (322km) race (and also many others) - as well as the standard wind tunnel testing speed of 45km/h.

With the overall purpose of offering riders detailed research and results into the aerodynamic performance of different rims.

1.3 - Gravel Tyres and Aerodynamics

Research carried out when developing the Hunt 48 Limitless Aero Disc wheelset showed that in order to achieve optimal aerodynamic performance across a range of yaw angles, the rim profile should be very wide with a truncated edge (blunted spoke bed) to help airflow stay attached. The airflow can follow the curvature of the rim profile and remain attached to the surface longer before it separates. Once the flow separates from the surface, it creates a region of low pressure in the rear, producing wake and drag force. As the separation is minimized, because it happens later, the wake region is smaller and drag force significantly reduced.

The conditions encountered in gravel riding necessitate larger volume tyres, with well-protected and knobbly treads for puncture resistance and good grip. This results in a cross-section profile with a much less ‘smooth’ (to be clear a road tyre does have tread, and this is critical to flow attachment) transition between tyre and rim. The consequence of this is the previously stated assumption that the turbulence created from the knobbles would cause early separation, adversely affecting the aerodynamic performance of the wheel and tyre working together as a global system.

The following profile characteristics are important factors when considering the purpose of the wheel, whilst trying to extract the maximum aerodynamic performance.

1.2.1 - Rim Depth

As a general rule when developing aerodynamically optimised performance road wheels; the deeper the rim, the better that rim will perform aerodynamically. This notion is also true for gravel as previous research has shown.

However, shallower rims are conventionally used more often in gravel riding for reasons of comfort/compliance, and suitability for the terrain. These additional needs of the rider must balance against aerodynamics when designing a wheel for the maximum overall performance. During gravel riding the rim is subject to greater impacts, fatigue and a harsher environment than would generally be seen road riding. Profile and depth must not become susceptible to rock strikes, nor can they be too deep which would significantly compromise the ride feel and control over the long distances of modern elite gravel races.

1.2.2 - Rim Width

The challenges with rim width are much the same as rim depth; namely that a compromise must be made between the aerodynamic advantages of a wider profile rim and the suitability to the terrain and purpose. In simple terms, it’s not beneficial having the most aerodynamic rim if they’re so much wider than your tyre that a rock strike could easily end your adventure or your race.

2 - TESTING METHOD

There are three primary tools currently used for measuring aerodynamic drag when developing bicycle components:

1. Wind tunnel testing – widely accepted as the industry standard for testing completed products. It generates reproducible and reliable results and allows testing over a range of wind yaw angles.
2. GPS based track testing – Uses a GPS locator combined with power data to measure aerodynamic drag. Cannot be used to measure drag at non-zero yaw angles and relies on consistent rider position to measure component performance.
3. Computational fluid dynamics (CFD) – uses a finite element analysis to compute the airflow through a 'mesh' constructed around computer generated model of the shape. The time and cost required to develop detailed meshes for use with a complex and rotating component like a complete wheelset makes it impractical for whole wheel development. It can be relevant for improving some specific elements of rim development. Results from CFD are highly dependent on the quality of the model and mesh and need to be corroborated with other testing methods.

It was decided to test the wheels using the wind tunnel at GST in Immenstaad, Germany. GST is an open wind tunnel, constructed in 1986 for use by Airbus Defence and Space. It is now independently operated, and as a low speed tunnel it is well suited for bicycle testing. The tunnel has been used widely across the cycling industry including by Tour Magazin for their independent aerodynamic testing.

Wheelsets were tested while fitted to a Canyon Grail CF SLX Disc bike.

Two tyre models were tested representing the most popular choice of tyre widths, a Schwalbe G-One 38c and Teravail Cannonball 42c.

Before each run tyres are inflated to 45psi and aligned in the wind tunnel. The wheels are driven by rollers at 32 km/h, to represent the speeds achievable in gravel racing events such as the DK 200-mile race.

The turntable is rotated continuously through yaw angles between -20° and +20° to the oncoming airflow as measurements of the drag force are taken.

Figure 2: GST WindKanal

2.1 Aerodynamic Performance

The results obtained from the wind tunnel are processed to produce the recognised drag v yaw angle plot providing a visual representation of how the wheels perform against each other.

Using the aerodynamic force data from the wind tunnel it is also possible to calculate the average aerodynamic Power and from this to derive the time needed to cover a certain distance. In this case the authors have calculated the time loss based during a simulated 200-mile race as the same 32 km/h average speed as the 2019 male winner, Colin Strickland.

When quantifying performance, it is most relevant to consider the power loss in Watts associated with different wheelsets calculated in its simplest form, this is:

$$P = Fv \quad (1)$$

Where:

F = force acting against the forward motion v =

velocity of object

The Aerodynamic Force to overcome drag obtained from the wind tunnel being:

$$F_d = \frac{\rho * C_d * v^2 * A}{2} \quad (2)$$

Where:

p = density of fluid

C_d= coefficient of drag

A = reference Area (often frontal area)

However, the power required to maintain a rider's speed is dependent on many other forces:

$$Total\ Power = P_d\ (drag) + P_r\ (rolling\ resistance) + P_f\ (friction) + P_s\ (slope) + P_a\ (acceleration) \quad (3)$$

This is now a complicated equation which is very dependent on the conditions and not possible to solve from wind tunnel data alone.

Instead as mentioned we will only consider aerodynamic forces. The following equations detail how the authors calculated the Power and Time Loss presented in the Results section.

For this study, a 32 km/h (8.88 m/s in S.I. units) speed is considered and it is assumed a professional rider (Colin Strickland, 2019) produces an average power of 317W over the 200-mile (321 km in S.I. Units) DK Course. Therefore, using equation (1), the propulsive force on the pedals is:

$$P = 317\ W$$

$$F = \frac{P}{v} = \frac{317}{8.88} = 35.7\ N$$

In terms of grams of force 1g = 0.00981 N, so:

$$35.7N = 3638.96g$$

Assuming aerodynamic drag (F_d from wind tunnel results) as the only resistive force, the propulsive force (F_{tot}) to maintain the riders speed can be calculated using:

$$F_{tot} = \Delta F_d + F \quad (4)$$

The values of F and P are now known. Therefore, by manipulating equation (1) it is possible to calculate the time it would take to complete the 200-mile DK Race:

$$P = Fv = F_{tot} * \frac{s}{t}$$

$$t = \frac{F_{tot*S}}{P} \quad (5)$$

Where s = distance (m)

3 -RESULTS AND ANALYSIS

Wind tunnel testing was conducted in August 2020. The following section details the full testing results presented in the tables and charts.

All tabulated power loss data has been calculated using the industry-accepted Mavic WAD distribution law. Methods for making an absolute ranking of the aerodynamic performance of bicycle wheels are an area of debate in the industry, however it is widely accepted that the performance of wheels should be considered at a range of wind yaw angles. To do so quantitatively requires calculation of a weighted average of drag or power based on the relative time a cyclist may experience wind at a particular yaw angle while riding. This process is referred to as calculating a wind averaged power or wind averaged drag.

The Mavic WAD distribution law is shown below. The 22.5° and 25° points have been omitted in our calculation because the wind tunnel turntable allows data collection only up to 20°.

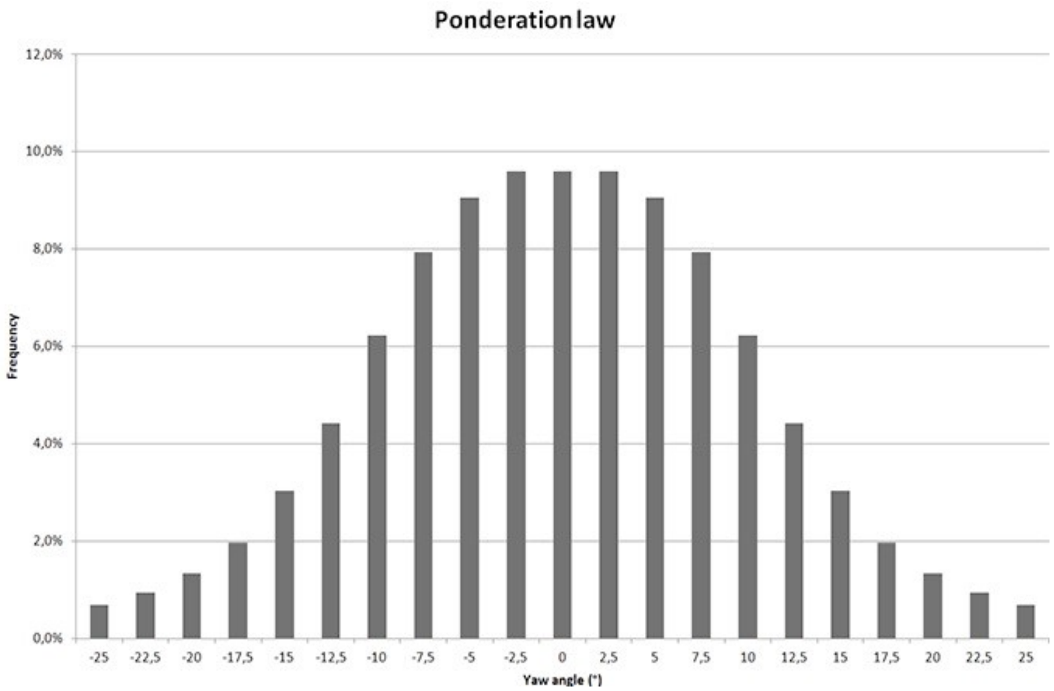


Figure 3: Yaw angle distribution proposed by Mavic, after carrying out measurements on a time trial bike with a bike mounted wind

3.1

- 32 km/h - Tests conducted with Schwalbe G-One 38mm tyre

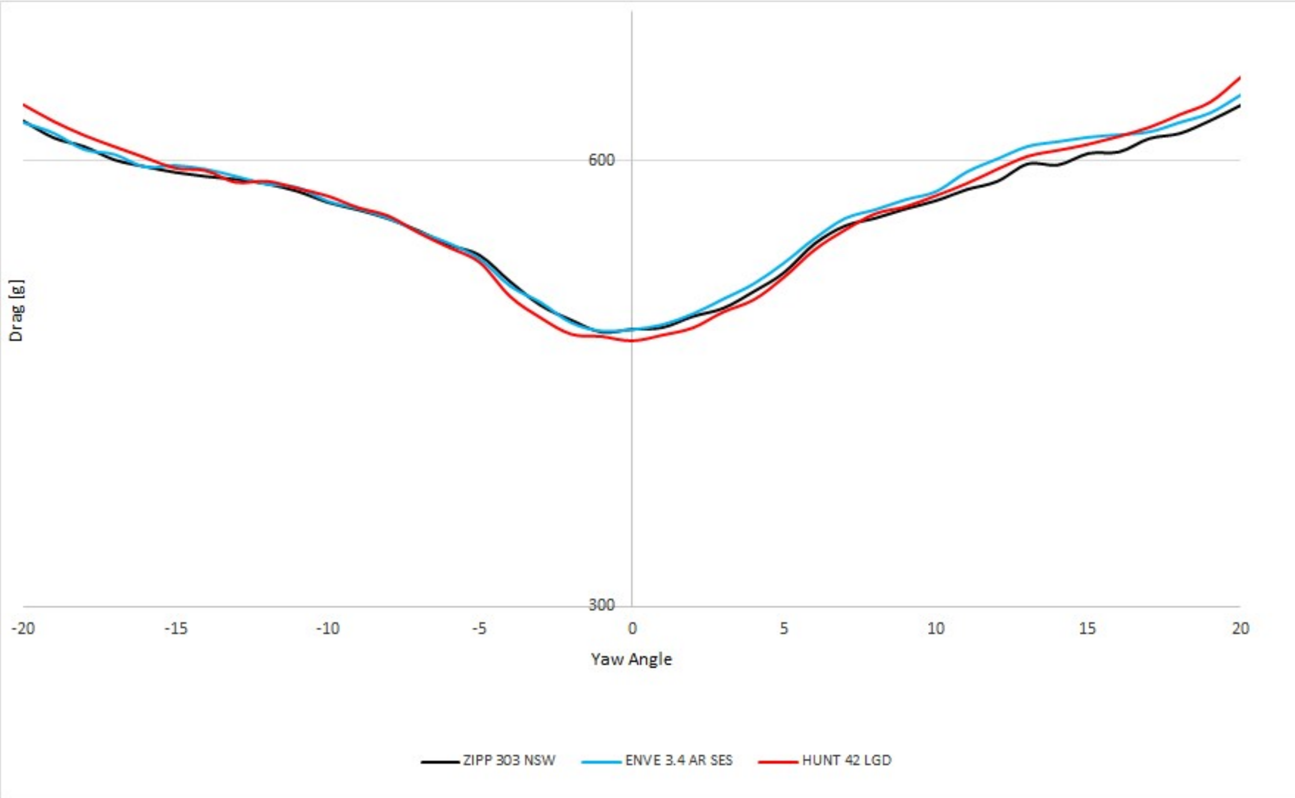


Figure 4: Drag [g] vs yaw angle [°] from wind tunnel test showing HUNT 42 LIMITLESS GRAVEL DISC against competitors, using a Schwalbe G-One 38mm tyre at 32km/h

at 32km/h with Schwalbe G-One 38	Average Pwr	ΔP tot or power loss	Average Drag force	ΔF tot or Drag loss	*Required force to overcome the Drag Force	Total time [s] required to cover 321km at 32 km/h	Time loss [s]
HUNT 42 LGD	15.15	0.00	173.87	0.00	3638.96	36161.70	0.00
ZIPP 303 NSW	15.20	0.05	174.43	0.56	3639.52	36167.27	5.57
ENVE 3.4 AR SES	15.26	0.11	175.19	1.32	3640.28	36174.78	13.07

Table 1 - Calculated Power and Time Loss data at 32 km/h based on WAD

The data suggests that the HUNT 42 Limitless Gravel Disc is the most aerodynamic gravel wheelset with a small power gain of 0.05W, which turns into almost 6 seconds of advantage, when compared to the Zipp 303NSW.

3.2

- 32 km/h - Tests conducted with Schwalbe Teravail Cannonball 42mm tyre

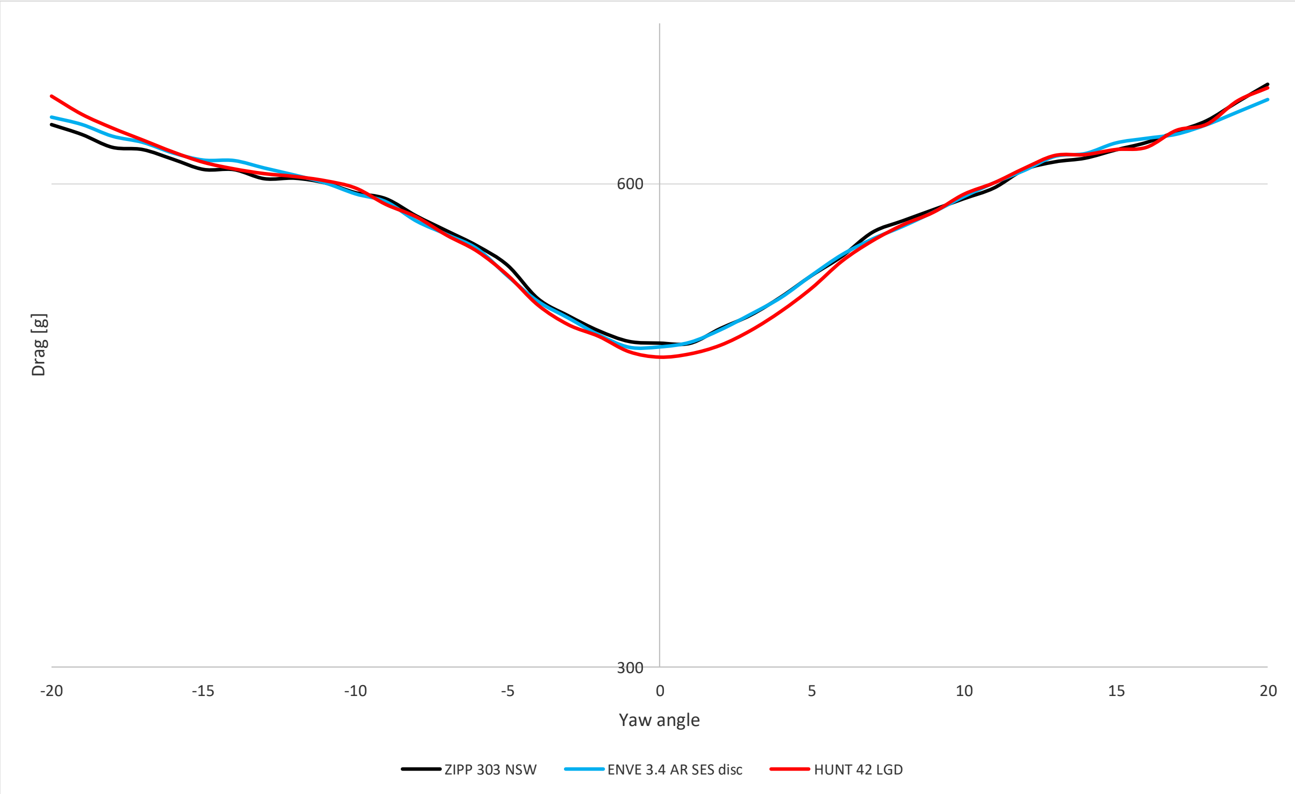


Figure 5: Drag [g] vs yaw angle [°] from wind tunnel test showing HUNT 42 LIMITLESS GRAVEL DISC against competitors, using a Teravail Cannonball 42mm tyre at 32km/h

at 32km/h with Teravail Cannonball 42	Average Pwr	**ΔP tot or power loss**	Average Drag force	ΔF tot or Drag loss	*Required force to overcome the Drag Force	Total time [s] required to cover 321km at 32 km/h	**Time loss [s]**
HUNT 42 LGD	15.57	**0.00**	178.71	0.00	3638.96	36161.70	**0.00**
ENVE 3.4 AR SES	15.62	**0.05**	179.32	0.61	3639.57	36167.78	**6.07**
ZIPP 303 NSW	15.66	**0.10**	179.82	1.11	3640.07	36172.76	**11.05**

Table 2 - Calculated Power and Time Loss data at 32 km/h based on WAD

The data suggests that the HUNT 42 Limitless Gravel Disc is the most aerodynamic gravel wheelset with a small power gain of 0.05W, which turns into 6 seconds of advantage, when compared to the Enve 3.4 AR SES.

3.3

– and Wheel stability

As previously presented in the research paper [1] there are significant performance gains to be made by utilising an aerodynamically developed gravel rim profile when compared to a shallow, non-aerodynamic profile. Further the authors have been able to design a superior performing rim when considering aerodynamic drag in the 42 Limitless Gravel Disc.

However aerodynamic drag is only a component part of the overall aerodynamic performance of a wheel. The stability of deeper section wheels for road riding is of significant importance to ensure stable and predictable handling at high speed. In Hunt's opinion, the appreciation of steering moment and therefore wheel stability is arguably more important in situations that arise in gravel riding. When descending at high speeds on loose, unpredictable surfaces, it is very important to have complete confidence in the handling attributed by the effect of wind on the wheels.

The aforementioned steering moment is commonly known as side force and is a component of aerodynamic force, acting perpendicular to the direction of travel. Side force represents the force of the wind trying to push wheel on the side. The magnitude of the side force gives an indication of the stability of the wheel in a crosswind and therefore of the comfort of the ride. The accepted negative of a deeper profile rim is greater side forces due to the increased surface area, therefore when developing the 42 Limitless Gravel Disc to be paired with a large tyre it was extremely important to minimise crosswind instability. During initial wind tunnel testing it was noted that the deeper profile competitors had less than impressive crosswind stability when compared to a non-aero profile.

The 42 Limitless Gravel Disc profile was developed with the aerodynamic knowledge gained from the previous 48 Limitless Project [2], being that stability can be improved for deeper section wheels by ensuring some design details including a wider profile. Applied to this gravel rim, the results from the wind tunnel confirm the 42 Limitless Gravel Disc exhibits improved stability in crosswinds than the similarly deep competitors tested in this white paper.

ACKNOWLEDGEMENTS

The authors would like to thank Ernst Pfeiffer at GST for all of his patience, hard work and good humour on this project and over the years working together.

Thank you to all the staff at HUNT The Rider Firm, every one of whom contribute hugely daily so that we can keep serving our riders with exceptional products.

And finally thank you to all those HUNT riders who believe in what HUNT are trying to achieve, who are constantly providing invaluable feedback and support and who ultimately are the purpose in researching and developing highly competitive wheels.

References

[1] 07.04.20 https://www.huntbikewheels.com/blogs/news/hunt-engineering-paper-graveldoes-aero-matter

[2] https://cdn.shopify.com/s/files/1/0686/6341/files/The_HUNT_LIMITLESS_48_AERO_DISC.pdf