Performance Evaluation of Atlas 4.0 – Technical Paper

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Abstract

The work detailed in this technical paper is the result of the extensive design and engineering development of Ruroc's latest full face motorcycle helmet, Atlas 4.0. Specifically, Atlas 4.0 has been developed with the goal of achieving the latest and most stringent motorcycle certification, ECE 22.06, as well as addressing customer concerns over acoustic and thermal comfort. Atlas 4.0 has achieved and surpassed the certification requirements of ECE 22.06, as well as drastically improving upon the acoustic and thermal performance of the helmet. The result of this is the safest and most advanced Ruroc helmet produced to date. This technical paper details the findings from in-depth analyses of aerodynamic and acoustic studies, using a state-of-the-art wind tunnel facility equipped with a high-fidelity load cell, as well as a real-world thermal analysis to assess the performance of a newly developed switchable top vent. The principal results show that Atlas 4.0 is the quietest helmet Ruroc has ever produced, with up to 30% improvement in acoustic performance over the previous model, Atlas 3.0. Results also show that the addition of a switchable top vent to Atlas 4.0 grants the end user efficient control of their thermal comfort, with an average temperature delta of 15% across the entire helmet upon actuation of the ventilation system. In order to assess Ruroc's performance within the motorcycle helmet industry, Atlas 2.0, 3.0 and 4.0 were compared against several competitor manufacturers in all areas of focus and detailed in this report.

Keywords: ECE22.06, acoustic, thermal, stability, drag, aerodynamics, analysis, performance

1. Introduction

With the introduction of Atlas 4.0 to Ruroc's line up of full-face motorcycle helmets, a comprehensive engineering development and testing phase was undertaken in order to assess and develop a product that remedies customer concerns and elevates the performance of Ruroc's helmets within the market. In combination with perceivable performance improvements such as thermal and acoustic performance, Atlas 4.0 also surpasses the latest, most stringent certification, ECE 22.06, as a result of shell and EPS (expanded polystyrene) layer refinement, the addition of reactive polymer technology developed by Rheon Labs, and an extensive redesign of the comfort liner.

This report details the aforementioned testing undertaken, providing detail about the advancements over the previous generation of Ruroc motorcycle helmets, namely the Atlas range. The aim of this report is to provide a level of clarity to the consumer on all areas of improvement over existing models. A natural byproduct of this for the end user is confidence in the design and engineering of their product, as well as a clear understanding of the performance of the product amongst competitors. The report will serve as a milestone that will be referenced in future development as Ruroc continues to pursue groundbreaking advancements in the protective helmet industry.

1.1. Targeted Areas of Design Focus

Ruroc takes great pride in the relationship it has built with its consumer base, which has evolved into a community. This community has provided Ruroc with a direct communication channel for product feedback and an infinitely valuable resource for future product development. Ruroc strive to provide customers with clarity and transparency on the development of their products in an attempt to demonstrate that all feedback is absorbed and utilised in producing continuously advancing products. As such, Ruroc recognises the importance of acting upon customer concerns swiftly and with great diligence. Atlas 4.0 aims to address the concerns that were raised and attempted to be rectified throughout the sale of Atlas 3.0, those areas of focus being:

- Acoustic comfort
- Thermal comfort
- Physical comfort

Ruroc has also identified the advancements in helmet technology and safety and as such has undertaken the due diligence in achieving and surpassing the test requirements outlined in ECE 22.06 in order to continue to provide customers with the safest helmet possible.

1.2. ECE 22.06

UN ECE (Economic Commission for Europe) 22.06 is the latest and most stringent version of the regulations covering motorcycle helmets and visors, such as those sold by Ruroc, for European and UN countries. This is the first update to these regulations for twenty years, addressing the short comings of ECE 22.05 whilst also incorporating advancements in technology over this period. The most significant changes cover impact testing with new tests added to cover a wider range of impacts. In addition to the existing impact at 7.5m/s found in 22.05, low energy impacts at 6m/s and high energy impacts at 8.2m/s have been introduced and an additional twelve impact points have also been introduced.

It is now widely regarded and documented that rotational acceleration forces experienced from glancing blows are a significant contributor to serious brain injury. Additional impacts at 8m/s against a 45° oblique anvil have been added to 22.06 to evaluate the performance of helmets in protecting the rider against injuries from glancing blows. An additional roll-off test in the reverse direction has also been introduced to assess the positional stability of the helmet during an accident.

As stated at the beginning of this technical paper, Atlas 4.0 has achieved and surpassed the ECE 22.06 test requirements. The primary contributor to the impact performance of Atlas 4.0 is the multi-layered carbon fibre shell. Upon impact, the primary goal of the shell is to absorb and dissipate energy. The shell structure experiences interlaminar and intralaminar fracture which initiate and propagate through the structure. Failures such as fibre breakage, fibre pull out, debonding or separation are all dependent on the impact scenario, but consequently aid in absorbing the kinetic energy. The re-designed shell combined with the optimised Atlas EPS work together in providing exceptional impact performance. In conjunction with these improvements, a re-designed comfort liner, later discussed in this report, features integration of a reactive polymer into the headliner, provided by leading experts in energy absorption and dissipation, Rheon Labs. This acts to provide further protection against rotational, oblique and longitudinal impact scenarios.

2. Methodology

In order to develop the aforementioned design requirements, a thorough test plan was constructed with careful consideration into the facilities and equipment required. The test plan defined objectives clearly with an emphasis on collecting accurate and reliable data.

2.1.1. Testing Facilities

With acoustic comfort a key area for improvement based on customer feedback, a significant amount of resource was invested into data collection at the Silverstone Sports Engineering Hub wind tunnel facility. This allowed for accurate assessment of acoustic, drag and stability performance using state of the art equipment. Given that multiple rounds of testing were carried out, accurately calibrated equipment was used to determine dynamic pressures and subsequently adjust the test conditions to ensure consistency of results despite varying atmospheric conditions. A number of configurations of Atlas 4.0 were tested throughout the development phase, of which the results of the final refined configuration are detailed in this report.

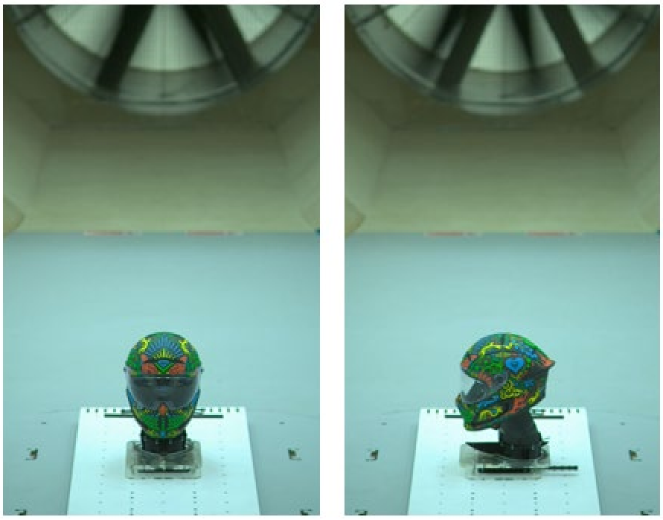

Figure 1. (a) Helmet at 0°; (b) Helmet at 90°

Ruroc recognised that specific isolated test environments were not a complete representation of those that the end user would encounter, and felt it was essential to additionally capture data in real-world scenarios. As a result, Ruroc privately hired Castle Combe racing circuit in order to further develop the thermal and acoustic performance of Atlas 4.0. Once more, accurate and reliable results were of paramount importance and so a repeatable and objective test method was followed with emphasis on replicating real-world environments.

2.1.2. Test Subjects

In order to gain an understanding of Ruroc's previous and current day performance in the motorcycle helmet market, it was crucial to fully analyse a number of key competitors. For use in referencing results later in this report, the code names of all helmets subjected to test are listed below.

Table 1. Test Subject Codes

Test Subject Code			
1.	RR2	2.	SHN
3.	RR3	4.	ICA
5.	RR4	6.	ARQ
7.	HJR	8.	SHR
9.	SHX	10.	XL8
11.	LGR	12.	SXA
13.	AGR	14.	SCS

2.2. Test Methodology – Wind Tunnel Testing

For all tests utilising the wind tunnel facility, a repeatable approach was taken to ensure consistency of results. This approach involved an initial baseline test with the bare Ruroc acoustic manikin. This baseline was then normalised at the start of each test day to ensure consistency between different test days was achieved. Following the baseline, each helmet was tested at both 0° and 90° to the direction of fluid flow. For continuity, all helmets were tested with visors down, vents closed and chin strap securely fastened (unless otherwise stated). A single helmet test comprised of capturing data at both angles, with wind speeds of 30, 40, 50 and 60mph respectively, each running for a period of 30 seconds. Through use of calibrated binaural microphones mounted within the Ruroc acoustic manikin's ears, sound intensity (in the form of dB readings) was captured. A high fidelity load cell mounted to the test platform provided drag forces at each wind speed. Stability performance was also assessed using accelerometers. In the stability analysis, stability was assessed at 0° only in order to avoid disrupting the aerodynamic profile of each test subject.

2.2.1. Acoustic Data Analysis Methodology (Wind Tunnel)

For each data file, the peak sound intensity for each test point through left and right headphones was extracted. These values were averaged to give an average peak sound intensity reading documented later in this report. Negative values of sound intensity are output by digital audio workstations due to the limited number of discrete values that can be assigned to the amplitude of a sound wave. As such, a calculated offset was applied to normalise the results.

2.2.2. Stability Data Analysis Methodology (Wind Tunnel)

Stability performance was assessed using an accelerometer positioned at the central rear of each helmet. As previously mentioned, this was done to mitigate disruption of the aerodynamic profile, given that the fluid flow should have separated from the helmet before reaching the accelerometer. Consistent positioning of the accelerometer also ensured that the vectors remained aligned, yielding consistent results for each test.

Each test was completed at the four wind speeds mentioned prior. The data files were then sampled in order to produce graphical plots of key results, namely accelerations and angular velocities in X, Y and Z axes, along with magnitudes.

Through use of the plots, the data was further sampled to discard unwanted data, such as the fan spooling up and spooling down. This ensured the final stability results were visualised in a consistent steady state and over a similar period. This report later details results of acceleration magnitude (how the helmet was translating in X, Y and Z), angular velocity in Z axis (how the helmet was buffeting side to side), and angular velocity magnitude (how the helmet was pitching and yawing as a whole around X, Y and Z).

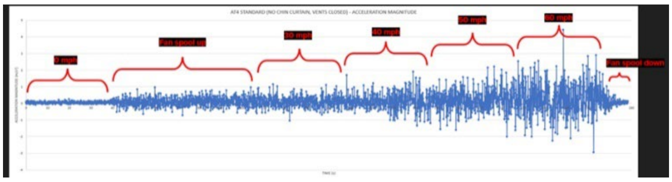

Figure 2. Stability Analysis Data Sampling

2.3. Test Methodology – Track Testing

Castle Combe Racing Circuit was privately hired, allowing for data collected in a controlled environment that is more aligned to the customer experience than the wind tunnel. Using a control motorcycle for each test, in this case a BMW S1000R fitted with an Akrapovič exhaust system, a minimum of three laps were completed with a targeted lap speed of 70mph where achievable in order to achieve a steady state condition. Acoustic data of the exhaust system was also collected and referenced in this report in order to provide a relatable reference point for sound intensity to the reader.

2.3.1. Acoustic Data Analysis Methodology (Track)

For each data file, the average sound intensity for each test point through left and right headphones was extracted. These averaged sound intensity values, documented later in this report, were combined with the previously mentioned offset to normalise the results for use in the comparison.

2.3.2. Thermal Data Analysis Methodology (Track)

Thermal data was captured using the Ruroc thermal balaclava, equipped with K-type thermocouples, and a data logger. The data from each test run was sampled and inspected in order to select a period in which the data was at steady state. In this case, a 300 second sample of steady state data was selected from each test to be used in the thermal comparison.

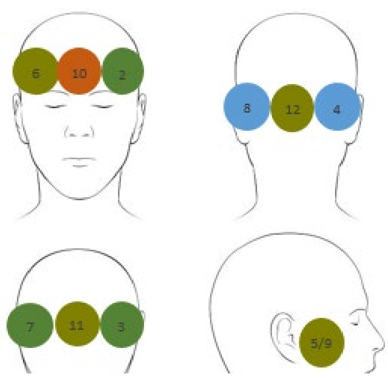

Figure 3. Ruroc Thermal Balaclava - K-Type Thermocouple Locations

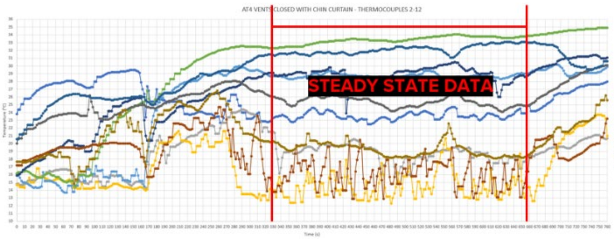

Figure 4. Thermal Analysis Data Sampling

3. Results

The interpolated rankings discussed throughout this section refer to a scale ranked 1 to 10, with 10 being the highest performance score for that particular criterion. The overall rankings have been interpolated to give context to the performance standards, allowing the reader to visualise where helmets are close in performance, or if there are clear gaps in performance. To supplement this, clear visual comparisons have been included in the appendix and referred to throughout the remaining sections of this report.

3.1. Acoustic Results – Wind Tunnel

Decibels (dB) are used to report the intensity of sound on a logarithmic scale. The logarithmic scale means that a sound increase of 10dB equates to a sound that is ten times more powerful. This scale means that a small variation of 1-2dB between helmets results in a sizeable difference to the perceived noise levels.

Sound intensity, referred to in this report in SI units to remove the logarithmic scaling, is the amount of energy flowing through an area perpendicular to the direction the sound waves are travelling, per unit time (W/m^2). This is a more objective measurement and is clearer to visualise the perceivable difference in actual noise levels experienced by the end user than simply using the dB scale.

3.1.1. Atlas Results

The Atlas 4.0 is the quietest Ruroc helmet to date, showing reduced noise levels at all wind speeds compared to Atlas 2.0 and 3.0. At 60mph, there is a 30% reduction in perceived sound intensity. This results in a markedly quieter helmet for the customer. This result has been verified by road test user trials carried out internally.

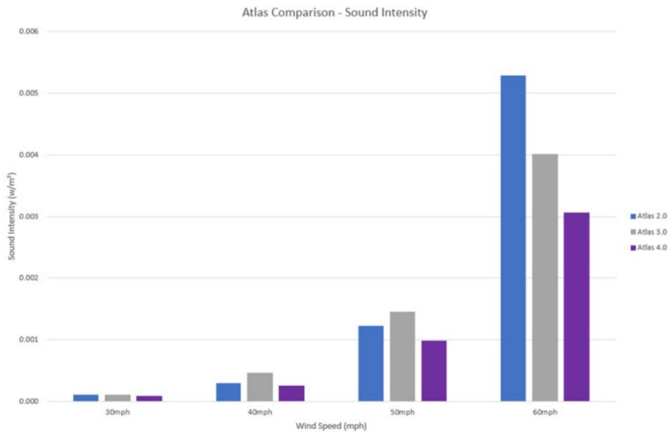

Figure 5. Atlas Sound Intensity Comparison

3.1.2. Competitor Comparison

Overall, Atlas 4.0 ranks in 4th position, out of a possible 15 positions, in the wind tunnel. This is a significant improvement over Atlas 3.0 which ranks 10th. Atlas 4.0 performance is also much more consistent across all wind speeds compared to predecessors.

Interpolated rankings against key competitors show that Atlas 4.0 performs well, surpassed only by three competitors. Figure 7 shows the recorded peak dB levels for all helmets under test, broken down by wind speed. This shows Atlas 4.0 placing very well across all speeds in comparison to competitor helmets, whilst also demonstrating the advancements in acoustic performance over previous generation Ruroc helmets.

	30mph	40mph	50mph	60mph	Average	Ranking
HJR	**9.6**	**9.6**	**10.0**	**10.0**	**9.8**	**1**
ARQ	**10.0**	**10.0**	**8.7**	**8.4**	**9.3**	**2**
SHX	5.9	6.4	4.8	6.3	5.8	3
RR4	**5.4**	**7.7**	**4.5**	**5.8**	**5.8**	**4**
LGR	5.3	7.6	4.7	5.4	5.8	5
SHN	**5.5**	**5.5**	**4.1**	**4.2**	**4.8**	**6**
SXA	5.1	6.8	3.0	3.8	4.7	7
AGR	4.4	4.8	4.4	4.9	4.6	8
XLS	2.5	6.9	4.5	4.0	4.5	9
RR3	**3.3**	**3.0**	**2.1**	**3.9**	**3.1**	**10**
SHR	1.9	2.5	1.1	3.9	2.4	11
SCS	1.7	1.5	0.2	1.7	1.3	12
ICA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**13**

Figure 6. Interpolated Acoustic Performance Rankings

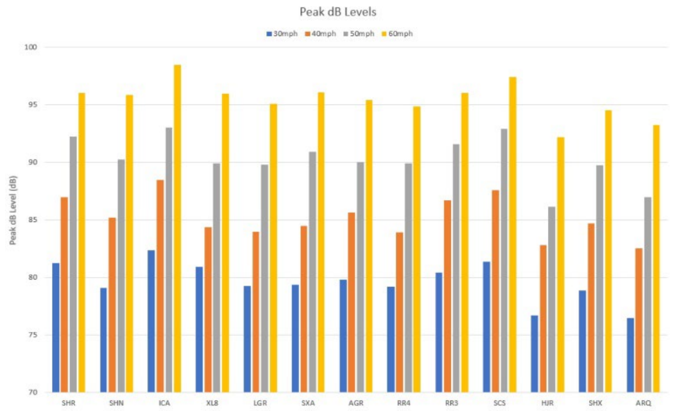

Figure 7. Peak dB Levels for all Test Subjects Across all Wind Speeds

3.2. Acoustic Results – Track Testing

Track testing results concur that Atlas 4.0 is the quietest Ruroc helmet to date, showing significant improvement of the perceivable noise level of the Atlas 4.0 compared to 3.0. This reduction in sound intensity was calculated to be 43%, which the feedback from the test riders supported.

Figure 10, included in the Appendix section, shows a clear visual representation of the acoustic performance of Atlas in comparison to competitors.

3.3. Thermal Results – Track Testing

3.3.1. Atlas 4.0 Thermal Analysis

The average steady state temperature delta across Atlas 4.0 is 15% when the vents are actuated, with a maximum steady state temperature delta of 30%. These deltas are found to be around the cheekbones, top of the head and behind the ears, which is strong evidence that the ventilation system is functioning as desired, and the airflow is travelling as intended.

Further analysis shows that thermocouple 10, located in the middle of the forehead shown by Figure 3, exhibits a temperature increase despite the chin vent being closed. This result is due to the R.A.I.D system in the chin vent, which acts to direct a small amount of air towards the visor and forehead area when the chin vent is closed to assist with de-fogging. This result has been replicated in Atlas 3.0, which is equipped with the same chin vent mechanism.

3.3.2. Atlas 3.0 Thermal Analysis

Analysis of the Atlas 3.0 results show that overall, the single chin vent demonstrated limited control over the temperature of the rider's head. The majority of the thermocouples show that the temperature deltas are close to zero, thus indicating that the chin vent is not a significant contributor in controlling the thermal condition of the helmet. As previously stated, thermocouple 10 exhibited a similar increase in temperature to Atlas 4.0 as a result of the R.A.I.D system.

3.4. Drag Analysis – Wind Tunnel

Drag force data was captured by Silverstone Engineering Hub using a high-fidelity load cell mounted within the load platform. These results were then averaged over the 30 second run at each test speed.

3.4.1. Atlas Drag Results

Over each wind speed tested, Atlas 4.0 exhibited a slightly higher drag force than Atlas 3.0. This was deemed to be a result of the new switchable top vent for Atlas 4.0, in which the vent switch disrupts the airflow, causing higher drag forces. This small increase in drag force is not found to affect rider stability and has been deemed acceptable due to being drastically outweighed by the benefits of having an effective switchable ventilation system.

3.4.2. Competitor Drag Comparison

Results show that all helmets tested were comparable in performance, due to all being full-faced road motorcycle helmets with a similar aerodynamic profile. To put this into context, across all of the helmets tested, the range in drag force was 3.6N at 60mph.

3.5. Stability Analysis – Wind Tunnel

3.5.1. Atlas Stability Comparison

Given the Atlas models share the same shell geometry, and therefore have a common aerodynamic profile, each Atlas model (2.0, 3.0 and 4.0) was compared back-to-back to inspect consistency of data.

Results show good consistency between the Atlas models, with similar amplitudes for the respective windspeeds. The results also show a small decline in angular stability performance for Atlas 4.0, supporting the slight regression in drag performance.

Analysis of the data shows that the regression in stability performance for Atlas 4.0 at 50mph and 60mph was 5% and 17% respectively in comparison to previous Atlas models.

3.5.2. Stability Competitor Comparison

The stability performance of Atlas 4.0 was compared against a number of key competitors, many of whom have extensive experience developing and manufacturing aerodynamically efficient helmets.

The results show that some helmets performed better than others in certain vectors, with no commanding correlation between variables. However, given that all three vectors (X, Y and Z) contribute to the magnitude, the magnitudes have been selected to be used in the performance rankings. The acceleration magnitude in this case describes how the helmet translates in X, Y and Z vectors, whilst the angular velocity magnitude describes how the helmet pitches and yaws around the X, Y and Z axes.

Atlas 4.0 ranks as the best performer for acceleration magnitude, whilst the Atlas 3.0 ranks as the best performer for angular velocity magnitude. The regression in angular stability between Atlas 4.0 and 3.0 is attributed to the addition of the top vent switch which, due to being slightly off centre, induces a moment around the Z axis.

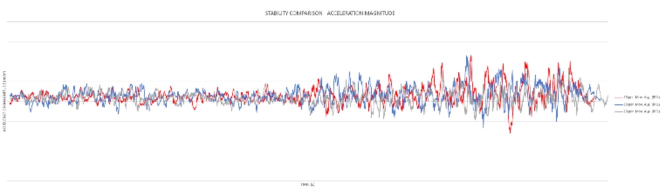

Figure 8. Atlas Stability Comparison - Acceleration Magnitude

As discussed in section 3.4.2, the stability performance of each helmet was comparable due to the typical aerodynamic profile associated with motorcycle helmets. As such, the percentage spread of the combined stability criterion between the top six highest performing helmets was 8%, shown by the close clustering illustrated on the visual comparison of Figure 11.

3.6. Comfort Assessment

Atlas 4.0 comfort liner has been re-designed from the ground up with the aim of passing the ECE 22.06 reverse roll off test requirement. A large focus was also placed on drastically improving the comfort and quality of the comfort liner over predecessors. In order to subjectively quantify this, Atlas 4.0 was tested against predecessors and competitors to determine an overall comfort ranking. Specifically, the test involved measuring against ingress (putting on the helmet), egress (removal of the helmet) and steady state conditions (wearing the helmet for a period of 15 minutes), which were ranked on an internally developed scale between 1 and 5, with 5 being the highest score attainable in each metric.

Each helmet was tested for the three stated metrics on a range of people to incorporate the natural variance of head shapes into the results. The scores were then averaged and ordered in terms of rank.

The results show that Atlas 4.0 holds a drastic improvement over Atlas 3.0. The comfort of Atlas 3.0 was highlighted as a customer concern, and so the results support that this concern has been addressed with the re-design of Atlas 4.0. Figure 12, included in the Appendix section, shows a clear visual representation of how Atlas 4.0 compares in terms of comfort against the competition and emphasises the improvements over predecessors.

Atlas 4.0 scores respectably in terms of ingress and even better in steady state, however performs less favourably for egress, which brings the overall score down. A possible cause of this is a result of Atlas 4.0 using common shell geometry to Atlas 3.0, which was known for pinching at the temples causing discomfort during removal. For future product development, Ruroc recognises the importance of re-designing this area of the shell and has begun the due diligence in improving this area of the helmet design.

COMFORT					
Test Subject Code	Average Ingress	Average Egress	Average Steady State	Overall Comfort	Comfort Rank
AQA	5	5	4.75	4.9	1
SHN	4	4	4	4.0	2
HJR	4.25	4.25	3.5	4.0	2
LGR	4.25	4.25	2.75	3.8	4
SHX	3.5	3.5	3.75	3.6	5
RR4	3.75	2.5	4.25	3.5	6
XL8	3.5	3.375	3.5	3.5	7
SXA	3.5	3	3.5	3.3	8
SRP	3.5	2.875	2.875	3.1	9
ICA	3	2.75	2.5	2.8	10
RR3	3.25	2.25	2.75	2.8	10
AGR	3	2	2.25	2.4	12

Figure 9. Comfort Assessment Rankings

4. Conclusion

Atlas 4.0 is the quietest Atlas in production, as demonstrated in both the controlled wind tunnel environment and on track. In terms of sound intensity, the wind tunnel testing showed that Atlas 4.0 was 30% quieter than Atlas 3.0 at 60mph, delivering significant perceivable difference to the end user. In addition to this, Atlas 4.0 performed much more consistently across all wind speeds compared to previous Atlas helmets, resulting in increased acoustic comfort across a broad range of speeds. To support this, track testing results showed that sound intensity was reduced by 43% of Atlas 3.0.

Results show that Atlas 4.0 is the leading performer in linear acceleration performance, not only against predecessors but also the competition. Despite Atlas having limited track pedigree, Atlas outperforms several heavily track developed helmets in this area.

Over each wind speed tested, Atlas 4.0 exhibited a slight increase in drag force than Atlas 3.0. This outcome has been shown to be a result of the addition of the switchable top vent, which disrupts the fluid flow causing slightly higher drag forces. The benefits felt by the end user having effective controllable ventilation will substantially outweigh the negligible drag force they will experience, and as such this outcome has been accepted as satisfactory.

A strong emphasis was placed on the development of Atlas 4.0 physical comfort in combination with achieving a pass for ECE 22.06 reverse roll off test. Market and consumer feedback has pointed towards Atlas 3.0 soft goods being underdeveloped and of an unsatisfactory quality for the price point of the helmet, and as such Atlas 4.0 was designed to remedy this issue. Results support that Atlas 4.0 has taken a quantum leap in certification results, quality and physical comfort compared to predecessors. Despite the improvement to Atlas 4.0, the comfort is still limited by the shell geometry associated with the Atlas range due to a pinch point around the temples during ingress and egress. This combined with the rigidity of the carbon fibre shell results in a less than desirable ingress and egress. This has been a key finding in the development of Atlas 4.0 and will be built upon for Ruroc's next generation of full-face motorcycle helmet.

This technical paper has been constructed to demonstrate the work undertaken by the Design and Engineering team throughout the development of Atlas 4.0. A byproduct of this work is determination of Ruroc's position amongst key competitors. This paper shows that Atlas 4.0 is a considerable improvement over predecessors, with performances in key attributes close to and even surpassing many reputable competitors. Using these key findings, along with continuously advancing test methods, this strong foundation will be built upon. Ruroc will continue to strive to be a market leader in helmet design and manufacture.

Acknowledgements

Ruroc recognises the importance of its consumers and as such would like to express deep gratitude to all customers, past and present, for their support in Ruroc's journey to become market leaders in protective helmet design and manufacture. The Ruroc community is one that is unmatched in all sectors applicable. Specifically, in this paper, the motorcycle community have been invaluable in providing consistent, detailed feedback to Ruroc, allowing us to develop at a pace unmatched in the industry. Ruroc will continue to hold its customers at the centre of its core values and look forward to delivering the next breakthrough in protective helmet technology.

Appendix

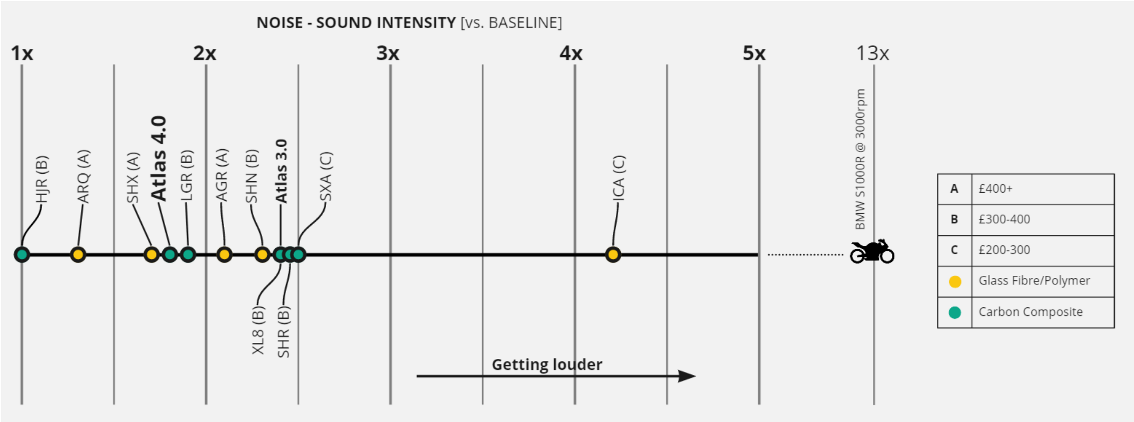

Figure 10. Sound Intensity Visual Comparison

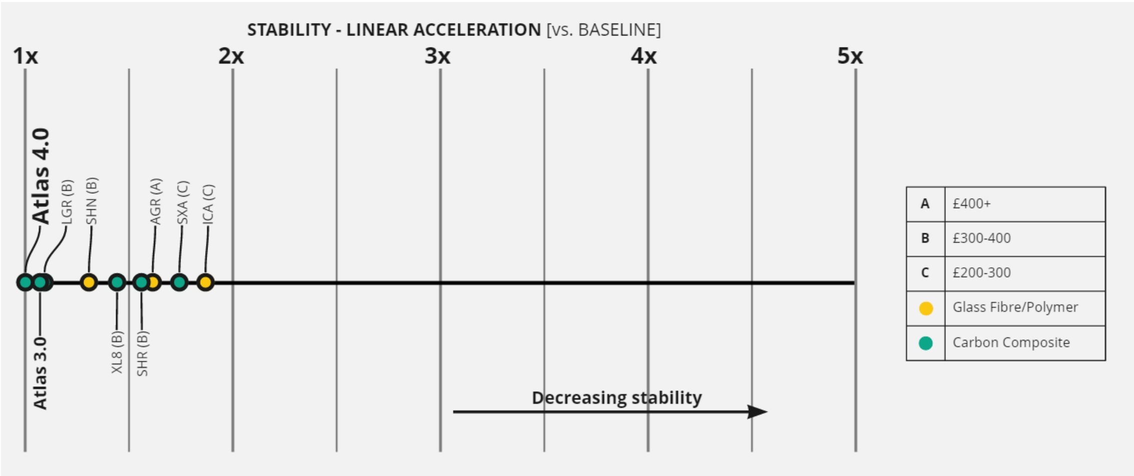

Figure 11. Stability Visual Comparison

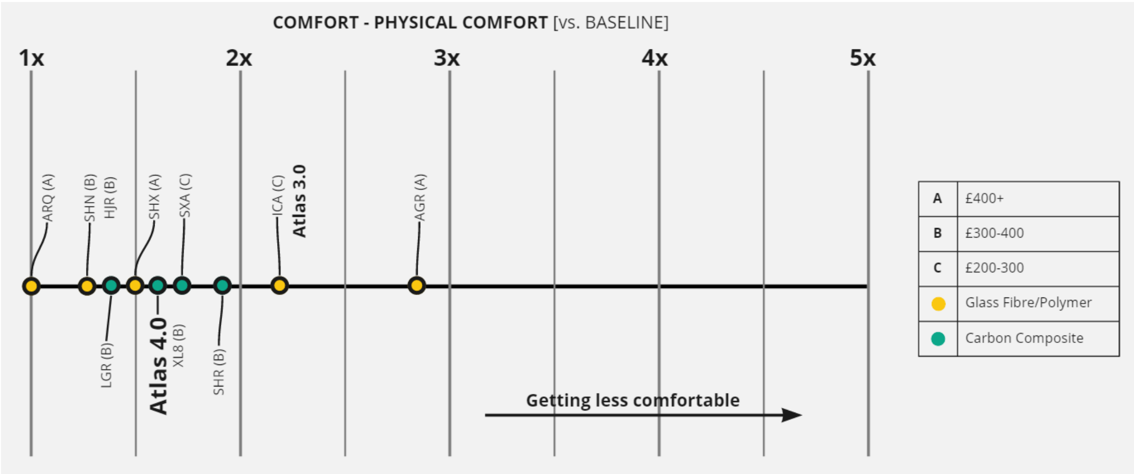

Figure 12. Physical Comfort Visual Comparison