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AERODYNAMICS OF RIBBED BICYCLE HELMETS

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Abstract*- Aero-helmets in competitive cycling have been around since 1980s to enhance the winning edge. A considerable design effort has been made to improve the aerodynamic efficiency of racing bicycle helmets over the years. However, the demand for further improvement has forced helmet manufacturers and designers to introduce new design. Recently several manufacturers (LG, Giro, etc.) have introduced dimple in the helmet's outer shell mimicking the so called 'Golf-ball' dimple characteristics to reduce the helmet aerodynamic drag further. However, no independently verifiable research has been reported in the public domain about the aerodynamic and thermal performance of dimple introduced racing helmets. Hence, the primary objective of this work is to undertake an experimental aerodynamic study of three latest model aero-helmets (Lazer Tardiz 2, Lazer O2 and Giro Air Attack) and to compare their performance with similar category helmets without any dimple effects. The investigation is undertaken at a range of wind speeds, pitch and yaw angles. The experimental data indicates that there is no measurable advantage between helmets with and without dimples under varied pitch angles at un-yawed conditions.*

Keywords: Bicycle helmet, Ribbed helmets, Aerodynamic drag, Wind tunnel, Pitch angle, Yaw angle.

1. INTRODUCTION

In bicycle racing, aerodynamics play a critical part as every moment can differentiate between the winner and losers. At around 30 km/h speed, the aerodynamic resistance (drag) constitutes almost 70-80 percent of total resistance (remaining is rolling and resistances) (Alam et al. 2010, 2007, Booth 2007, Brühwiler et al. 2006, Kyle & Bourke 1984). Out of total aerodynamic drag, the rider position counts approximately 65 to 80 percent depending on body position, helmet and clothing. The remaining drag is coming from bicycle frames, wheels (mainly front wheels) and other components and add-ons (Kyle & Bourke 1984). Although, the percentage of aerodynamic drag from the helmet is approximately 2 to 8 percent depending on the aerodynamic shape of the helmets at around 30-40 km/h speeds, the use of an aerodynamically efficient helmet can play an important role by making an advantage in racing and recreational riding (Alam et al. 2010, 2007, 2006, Chowdhury et al. 2012).

Correct selection of helmet and right body position can assist a cyclist to reduce aerodynamic resistance (drag). In Tour de France, the American cyclist Greg LeMond trailed two time champion French rider Laurent Fignon by 50 seconds prior to the final stage of a 24.5 km individual time trial racing event in 1989. Although the 50 seconds gap is negligible as LeMond required riding each kilometre distance by only 2 seconds faster than his competitor Fignon. Nevertheless, LeMond using an aerodynamically efficient helmet and aerodynamically efficient normal bicycle was able to defeat Laurent Fignon by 58 seconds and subsequently won the 1989 Tour de France title by just 8 seconds. It was later revealed that the aerodynamic drag on Fignon's ponytail alone was enough to slow him down by the critical 8 seconds by which he lost the race. Although aerodynamics played an important role in time trial and road racing competitions around the world since long, the LeMond saga brought the aerodynamics to the limelight again.

Despite studies by Alam et al. 2010, 2007, Chowdhury et al 2012, Bruhwiler et al. 2006 focused on aerodynamic drag for recreational and racing bicycle helmets, little study was conducted on aerodynamics of recently introduced dimpled bicycle racing helmets. Usually time trial (so called aero) helmets possess a significantly lower aerodynamic drag (~40-50% less) than recreational helmets.

Recently, helmet companies have started incorporating dimples onto time trial helmets with a view to have less aerodynamic drag. These dimples are similar to the dimples found on golf balls. These dimples help reduce drag by delaying the separation of airflow and increasing turbulent flow regime. Dimples generally work well on a spherical shape but its effects on oval shape objects remain unknown in the public domain. Additionally, no comparative study of aerodynamic performance of time trial helmets with and without dimples has been reported in the open literature. Therefore, the primary objectives of this study are to understand the effects of dimples on helmets aerodynamic behaviour.

2. EXPERIMENTAL PROCEDURE

A total of 6 helmets (four time trial, and two road racing) have been selected for this study. Among 4 time trial helmets, two helmets (LG Vorttice and Lazer Tardiz 2) have dimples (see Figure 1) and other two helmets (Giro Advantage and LG Rocket Air) have no dimples. The road racing helmets are Lazer O2 and Giro Air Attack. The Giro Advantage has 6 air vents and mass 390 grams. The LG Air Rocket possesses 7 air vents and weighs around 429 grams. The Lazer Tardiz 2 has 6 air vents and 395 grams mass. The LG Vorttice possesses only 2 vents and mass of 426 grams. The Lazer O2 has 24 air vents and weighs around 310 grams. The Giro Air Attack has 6 air vents and weighs around 283 grams.

Fig.1: Road racing and time trial helmets used in this study

The aerodynamic study was undertaken in RMIT Industrial Wind Tunnel. Three forces (drag, side force & lift) and their corresponding moments were measured simultaneously using a six component force sensor type JR3. The force sensor measures forces and moments in all six degrees of freedom and resolves the forces and moments into the orthogonal aerodynamic co-ordinate system. The tunnel is a closed return circuit wind tunnel with a test section dimension of 3 metres wide, 2 metres high and 9 metres, making the cross sectional area of 6 square meter. The wind tunnel, powered by a DC electric motor, is capable of generating free stream wind speeds up to 140km/h, has a turbulence intensity of 1.8% and is fully equipped with wind control machines and data calibration reading machines. The air speeds were measure using the NPL ellipsoidal head Pitot-static tube located at the entrance of the test section. The Pitot-static tube is connected to a MKS Baratron pressure sensor through flexile tubing.

A purpose made mannequin was used to simulate the body position and size of a representative road cyclist (see Figure 3). The mannequin body was made by polystyrene foam. Body measurements were taken of male cyclists and the averaged results were used to shape the model. As depicted in Figure 3, the mannequin was connected to the force sensor via a “sting.” The sting is a single metal rod which transfers the generated aerodynamic forces from the mannequin to the force sensor. An adjustable neck has been incorporated into the mannequin to allow for variation in head pitch (head position). Time trial helmets are sensitive to pitch due to their elongated shape, and as such it is important to have the ability to test the effects of pitch on aerodynamics. During testing, the helmets were individually attached onto the head of the mannequin. As wind passes through the tunnel, the aerodynamic drag felt by the mannequin was measured by the JR3 force sensor.

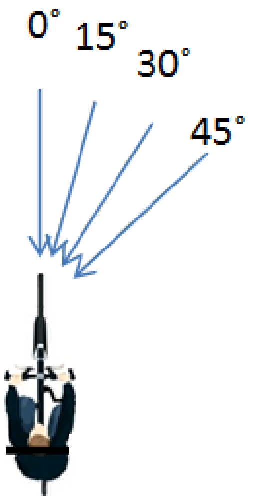


Fig.2: Yaw angles representation

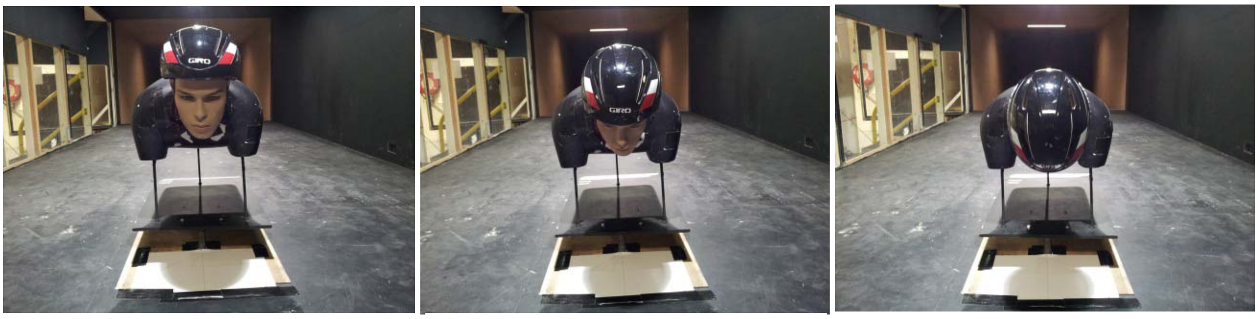
Wind speeds ranging from 20 km/h to 60 km/h with a 10 km/h increment were used for study. Yaw angles of 0º to 45º with an increment of 15º to simulate the crosswind effects as shown in Figure 2. Three pitch angles (0º, 45º & 90º) were considered for this study. The head position at each pitch angle is shown in Figure 3. The projected frontal area of each individual helmet was determined using parallel light projection method. The frontal-area data for all 6 helmets are shown in Table 1.

Table 1: Helmet Projected frontal area

	Projected Frontal Area (m^2)	
	Helmet Type	Yaw 0, Pitch 0
1	Advantage	0.0686
2	Rocket	0.0748
3	Tardiz	0.0711
4	Vorttice	0.0723
5	Attack	0.0692
6	O2	0.0736

a) Head Position 1, Pitch Angle: 0 deg b) Head Position 2, Pitch Angle: 45 deg c) Head Position 3, Pitch Angle: 90 deg

Side View



a) Head Position 1, Pitch Angle: 0 deg b) Head Position 2, Pitch Angle: 45 deg c) Head Position 3, Pitch Angle: 90 deg

Front View

Fig.3: Head position under variable pitch angles

3. RESULTS AND DISCUSSION

The aerodynamic drag for all helmets along with the bare head as a function wind speeds under 3 pitch angles (0º, 45º, 90º) at 0º yaw angle (i.e., un-yawed condition) is shown in Figures 4-6. As expected, the drag force increases with an increase of wind speed. The figures indicate that the Giro Advantage and LG Rocket Air produce pretty similar amount of aerodynamic drag and can be considered the benchmark of which the newer generation aero-helmets are based upon.

At lower wind speeds (20 to 30 km/h), the drag forces for all helmets are comparably similar. The dimpled helmets: Vortices and Tardiz prove to be very comparable with the non-dimpled Giro Advantage and LG Rocket Air at 0º and 45º pitch angles (i.e., Head Position 1 and Head Position 2) as shown in Figures 4 & 5. The dimpled helmet Tardiz displayed significantly higher drag at pitch angle 90º (i.e., Head Position 3) compared to all other helmets.

The road racing helmet Giro Air Attack with 6 air vents fell in between the ranges of the time trial helmets and the road racing helmet as expected in Head Positions 1 and 2. It also generated less aerodynamic drag at Head Position 3 (i.e., pitch angle 90º) beating all time trial helmets with and without dimples. This is believed to be due to the smaller frontal area in Head Position 3.

As expected, the road racing helmet Lazer O2 with 24 air vents generates higher aerodynamic drag at all pitch angles (Head Positions 1, 2 & 3) compared to all other helmets. The vent generally increases drag as it creates local flow separation. However, the drag due to vents can be minimized by placing vents appropriately on the helmets.

No noticeable gain in aerodynamic drag reduction due to dimples was found. However, a slight gain was by the Vortices helmet. Nevertheless, this gain is within experimental error.

The dimples on a golf ball work well because of its spherical shape and the dimples were situated throughout the surface of the entire ball. This is not the case for the Vortices helmet. The Vortices has the dimples for a quarter of the helmet frontal area which is oval shaped hence the effectiveness of the dimples could not be fully materialized.

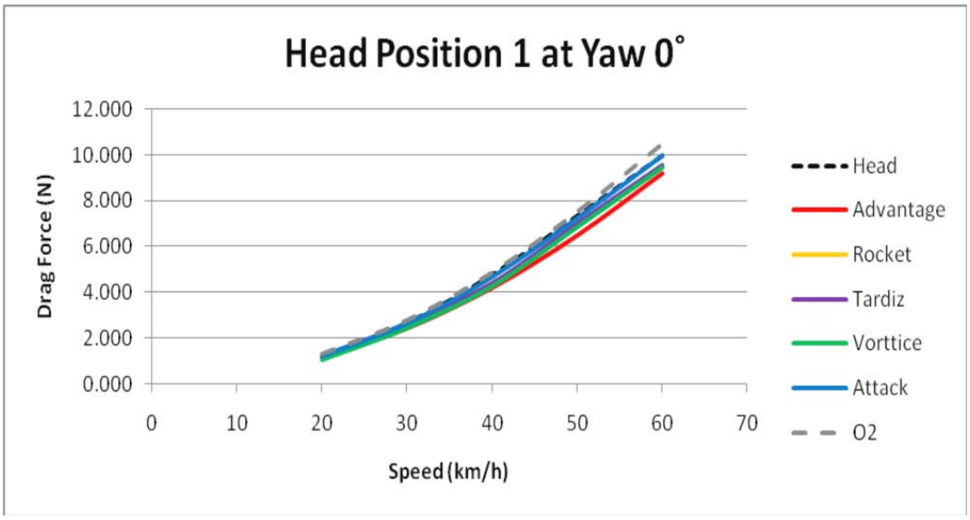


Fig.4: Aerodynamic drag variation with speeds at Head Position 1 (0º Pitch & 0º Yaw)

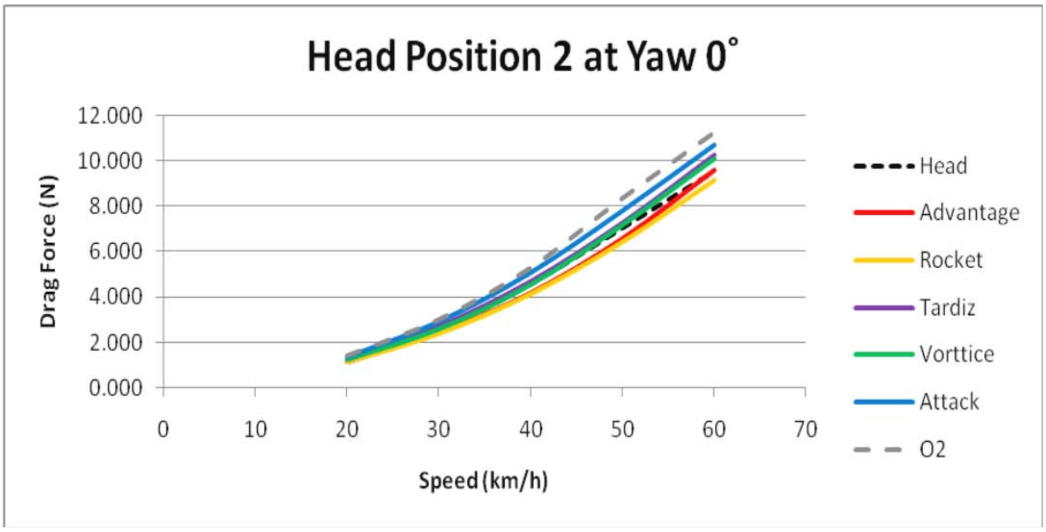


Fig.5: Aerodynamic drag variation with speeds at Head Position 2 (45º Pitch & 0º Yaw)

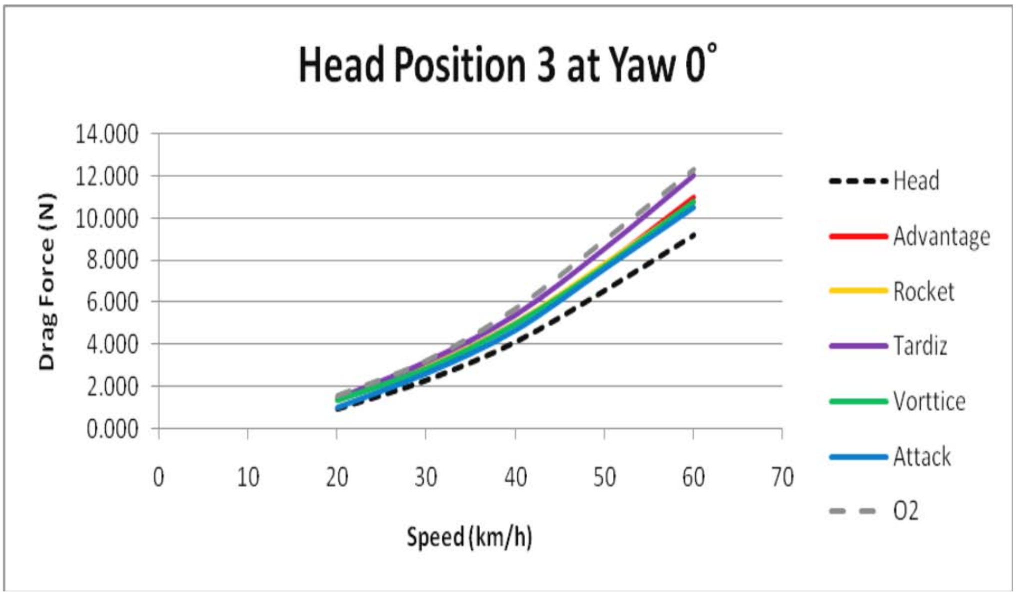


Fig.6: Aerodynamic drag variation with speeds at Head Position 3 (90º Pitch & 0º Yaw)

4. CONCLUSIONS

The following conclusions have been drawn from the work presented here:

- There were no significant signs of improvements in the helmet design when incorporating the dimples.
- The dimples may provide a marginal improvement to the aerodynamic performance, but this improvement does not offset the drag generated due to the larger frontal area that the Vortices helmet does have.
- The Giro Air Attack helmet performed better at high pitch angles due to its lower frontal area. The helmet generates overwhelmingly the form or pressure drag. Hence, the frontal area plays a critical role. Attention skin friction drag should be minimal.

5. RECOMMENDATIONS FOR FUTURE WORK

- Thermal comfort is an important criteria for all racing and recreational helmets. In addition to aerodynamic drag study, thermal efficiency investigations need to be undertaken.
- It would be worthwhile to visualise the airflow and heat signature around the helmets to understand the venting characteristics better.
- For initial optimisation of venting, the Computational Fluid Dynamics (CFD) modelling can be employed.

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