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An Experimental Study of Thermal Comfort and Aerodynamic Efficiency of Recreational and Racing Bicycle Helmets

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Abstract

The thermal comfort and aerodynamic efficiency are becoming important factors in bicycle helmet design and marketing. Currently most of the manufacturers primarily focus on safety features in helmet rather than aerodynamic efficiency and/or thermal comfort. The characteristics of the bicycle helmet (position, geometry and number of vents) are extremely important features for heat dissipation and aerodynamic drag. A comprehensive research is needed to improve the design of bicycle helmets. As part of a larger study, five commercially available helmets have been studied using RMIT Industrial Wind Tunnel under a range of wind speeds, yaw and pitch angles to determine their aerodynamic and thermal performance. In order to obtain the results as realistic as possible, an instrumented mannequin was used. Thermal comfort was measured based on heat dissipation properties of each helmet as a function of wind speeds. A relative ranking of each helmet was made based on their aerodynamic and thermal properties. Modification to one of the helmets indicates that there is scope for further improvements.

Keywords: Aerodynamic drag, thermal comfort, racing bicycle helmet;

1. Introduction

The primary purpose of the use of a bicycle helmet is to provide protection to the riders from head injuries. Tens of thousands of bicycle riders are being killed each year worldwide due to the head injury sustained during the fall. In the USA alone, around 540,000 bicyclists visit emergency departments with injuries each year, of those, about 67,000 have head injuries, and 27,000 have injuries serious enough to be hospitalized [1]. The risk of injury is reduced dramatically when cyclist wears a bicycle helmet during the ride. In Australia it is mandatory to wear helmets while riding professional or for recreation purposes. Manufactures of the bicycle helmets must comply with strict safety standards for their bicycle helmets.

Despite of the potential danger of head injury, still a large number of bicycle riders do not wear helmets due to the lack of thermal comfort. A survey conducted in the US consumer product safety commission in 1999 showed

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that 18% of riders who do not wear bicycle helmets at all, and said that comfort were the main reason for not wearing the bicycle helmet [2]. Much of the hesitation professional cyclist and the general public alike have are from getting too hot while cycling especially in summer in most western countries and round the year in sub tropical countries including India and China. In fact, most people usually ride bicycles during this time.

In addition to safety, two other parameters such as aerodynamic efficiency and thermal comfort are equally important for any bicycle helmet design be it for recreational or professional use. By using appropriately designed helmet and maintaining correct body position, a cyclist can reduce aerodynamic drag significantly and the conserved energy that can be put into the pedalling at appropriate stages of the racing. It is especially important in bicycle racing where some seconds determine the winners. An aerodynamically efficient helmet can reduce the riders drag up to 8% of the total aerodynamic drag of a cyclist usually generates. This is why aerodynamics is important in time trial and road racing competitions.

Although prior studies by Alam et al. [3, 4], Bruhwiler et al. [5], Kyle & Bourke [6], and Blair & Sidelko [7] were conducted to measure the aerodynamic drag for recreational bicycle helmets and racing helmets, little study was conducted on combined aerodynamics and thermal comfort on recently available recreational and racing bicycle helmets. Despite some manufactures claim their helmets have superior aerodynamic efficiency and thermal comfort, no independent data is available to support their claims. Additionally many of these highly acclaimed racing helmets (especially time trial) helmets do not comply with the minimum safety standards for head protection as manufacturers believed that the main purpose of racing helmets is to provide better aerodynamic advantage rather safety. The aerodynamic performances of these commercially available helmets are unknown as only limited information is available in the public domain. Additionally, no comparative study of aerodynamic performance of various time trial and racing helmets has been reported in the open literature.

Therefore, the primary objectives of this research work have been to study the aerodynamic performance of five commercially top ranking helmets and one low ranking helmets that are widely used in recreational and racing in Australia. In addition, a helmet was slightly modified to explore if any opportunity exists to improve its aerodynamic quality without compromising the thermal comfort.

Nomenclature

D	Drag Force
C_D	Drag Coefficient
V	Velocity of Air
A	Projected Area

2. Experimental Procedure

2.1. 2.1 Description of Helmets

Five bicycle helmets have been selected for this study. Three helmets are sports/recreational helmets and the remaining two are time trial racing helmets. These helmets are: a) Giro Inos, b) Giro Atmos, c) Prowell F22-Raptor, d) LG Rocket Air, and e) Giro Advantage (see Figure 1). The selection ranges from the well-known expensive sports helmet to a cheaply made bicycle helmets (Prowell). From this range of selection, it was also intended to investigate whether the expensive helmet was really worth the price.

(a) Giro Ionos (b) Giro Atmos (c) Prowell F22-Raptor

(d) LG Rocket (e) Giro Advantage (f) Modified Giro Atmos

Fig. 1. Selected helmets for study

2.2. Experimental Facilities

In order to measure the aerodynamic properties and thermal comfort, the RMIT Industrial Wind Tunnel was used. The tunnel is a closed return circuit wind tunnel with a maximum speed of approximately 150 km/h. The rectangular test section dimension is 3 m (wide) x 2 m (high) x 9 m (long), and is equipped with a turntable to yaw the suitable size model. Using a six component force sensor (type JR-3) and purpose made computer software, all three forces (drag, side and lift forces) and 3 moments (yaw, pitch and roll moments) were measured simultaneously. More details about the tunnel physical properties including turbulence intensity and physical dimensions can be found in Alam et al. [8, 9].

A purpose made mannequin was designed and manufactured to simulate the body position and size of a representative road cyclist (see Figure 2). Body measurements were taken of male cyclists and the averaged results were used to shape the model. Additionally, a separate mannequin head was also used for thermal testing.

In order to evaluate thermal comfort, the mannequin head was wrapped with a heater matt and helmet was put on the top of it. The heater matt was heated using constant power supply. Nine thermocouples were used to measure the temperature distribution within the mannequin head. The head's matt temperature can be set by adjusting the voltage of its power supply. Prior each test started, the heater matt was heated at 56°C. The airflow over the helmet carries heat away and reduces the temperature in between the helmet and heater matt. The thermocouples sense temperature drop and showed on a digital display screen. The temperature difference before and after the wind is blown into the head gives the cooling capacity in terms of thermal comfort.
The projected frontal area (A) was estimated for each helmet separately and the values were used for their respective C_D calculations.

Fig. 2. Mannequin mounted in RMIT Industrial Wind Tunnel (Left to Right: Front, Side & Top View) and Heater Matt

3. Results & Discussion

Each helmet was tested at speeds ranging from 30 km/h to 70 km/h with an increment of 10 km/h. At each speed increment the test apparatus (mannequin and helmet) was rotated between yaw angles of ±20° in an increment of 5° to simulate the crosswind effects. The head pitch was altered between 0°, +45° and +90° in increments. However, the results presented here are only for zero yaw angle and +45° pitch as these positions are most practical and widely used.

3.1. Aerodynamic Testing Results

The aerodynamic drag coefficient for all five helmets as well as mannequin is shown in Figure 4. The advantage helmet displays the lowest aerodynamic drag coefficient compared to all other helmets and the mannequin. The Giro Prowell helmet has the highest (C_D) value amongst all helmets and the mannequin. The mannequin has the 2nd highest (C_D) value which is unexpected due to the fact that it is believed to be more streamlines compared to helmets with vents.

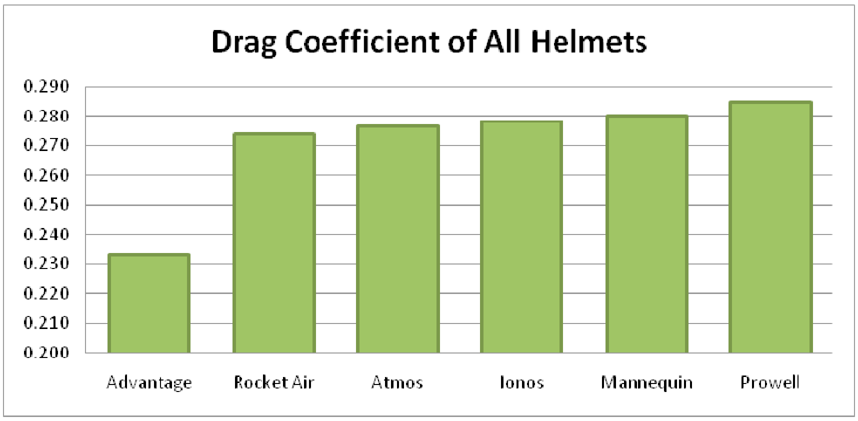

Fig. 3. Drag Coefficient (C_D) for helmets & mannequin

3.2. Thermal Testing Results

The initial average temperature of the mannequin head was set to 56°C at 0 km/h wind speed. The mannequin head without helmets was tested first and then each helmet with the mannequin was tested separately to compare the temperature variation. Nine thermo couples were used to monitor the temperature drop. The temperature drop was recorded after five minutes run of the wind tunnel. The temperature drop for all helmets and the mannequin is shown in Figure 5. The figure shows there is a decrease in temperature with the increase of wind speeds. The temperature drops sharply from 30 to 40 km/h, but when higher speeds are reached the temperature drop becomes less. Any further increase in wind speed did not cause a drop in temperature and stays relatively constant. The Giro Ionos was the best performing helmet in terms of heat dissipation compared to all other helmets. The Giro Atmos and Prowell are the 2nd best performing helmets. The LG Rockect Air and Giro Advantage are the worst performing helmets despite possessing 7 and 5 vents respectively.

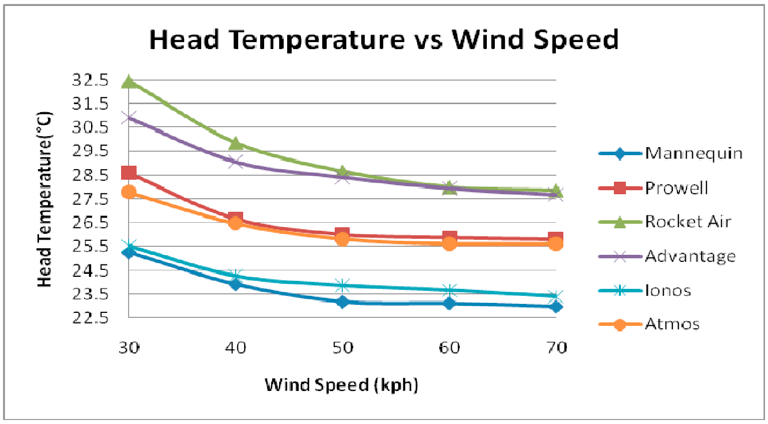

Fig. 4. Temperature drop versus wind speeds

3.3. Results of Modified Helmet

The Giro Atmos helmet was selected and modified to see if the drag coefficient can be further reduced without compromising its thermal comfort. The helmet was modified by covering some of the front and side vents with tape. The aerodynamic performance and thermal comfort of the modified Atmos was tested under the same test conditions. The modification of the helmet is shown in Figure 1f. The C_D and temperature drop for the standard Giro Atmos and modified helmet are shown in Figures 6 and 7 respectively.

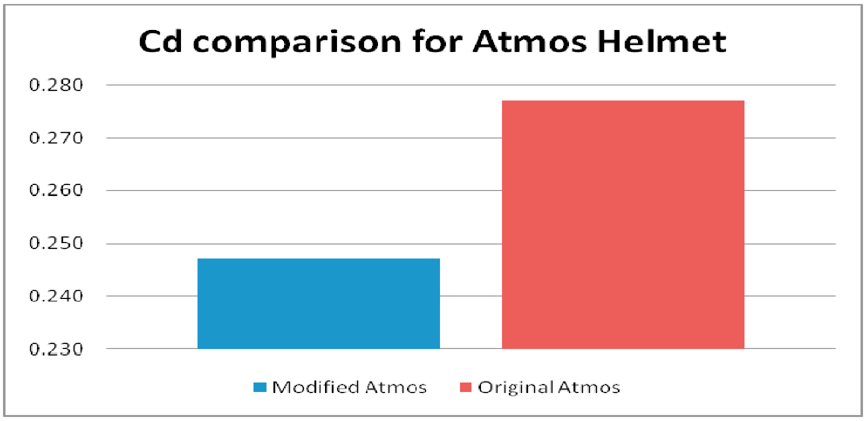

Fig. 5. Drag coefficient comparison for standard and modified Atmos helmet

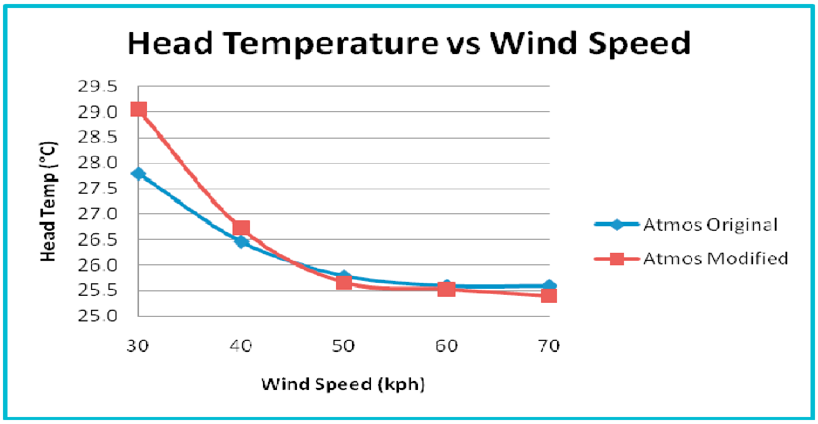

Fig. 6. Comparison for temperature drop of a standard and a modified Atmos helmet

Figure 6 indicates that the modification has significant impact as it reduces the drag coefficient for the modified helmet over 12%. In contrast, no deterioration in thermal performance was noted at speeds over 40 km/h. The modification allowed the front portion of the helmet to be more streamlined thus reducing the drag. The vent in the middle of the helmet allows air to pass and carry away the heat. Thus keeps the helmet cool.

4. Conclusion

The following conclusions were made from this work:

- Giro Advantage is by far the most aerodynamically efficient helmet and Prowell was the worst performing helmet.
- Giro Ionos is the most optimal helmet in terms of thermal comfort and aerodynamic efficiency.
- The design and venting position need to be selected based on aerodynamic and heat dissipation characteristics as modified helmet clearly indicates that the position of the vent can increase aerodynamic efficiency while keeping thermal comfort intact.

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