Analysis of the effect of helmet shape and head position on performance during time-trial cycling

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1. Introduction

Cycling science has undergone a great revolution in recent years. During individual time-trials, racing events in which cyclists race against the clock are not permitted to ride behind other cyclists where they gain advantage by drafting, understanding aerodynamics and the forces acting on the bicycle can lead to substantial gains in performance and lead to victory. In time-trial competition, the cyclist’s position on the bike has been widely studied and an optimized position reduces wind resistance and improves performance (Grappe 2009, Blocken et al. 2013). The cyclist’s position alone represents about 65–80% of the total aerodynamic drag. One means of optimizing performance is to modify the shape of helmets used in time-trials (referred to as ‘aero helmets’).

An alternative approach to investigating aerodynamics in sports sciences is the numerical one. Indeed, in recent years, Computational Fluid Dynamics (CFD) has been used and shown to be a powerful and efficient tool for simulating complex fluid flows. Defraeye et al. (2010) evaluated the aerodynamic performance of different cyclist positions by means of CFD simulations and wind tunnel measurements. Sims and Jenkins (2011) used the CFD method to improve aerodynamic design of the bicycle helmet.

The aim of the present study is to gain greater insight into the aerodynamics of time-trial helmets in real-world conditions using CFD. Three time-trial helmets of different brands and shapes have been considered. In order to reflect accurately real racing conditions, the following head positions have been tested:

- Head-up position (horizontal gaze)
- Head-down position (vertical gaze)

Simulations were performed for a velocity of 15 m/s corresponding to the average velocity during a flat route time-trial competition for an international class cyclist.

2. Methods

2.1. Geometry and computational grid

The resolution of a computational fluid dynamics problem requires several steps: the first being to define the geometry and the computational domain. For this, the numerical model of the cyclist’s body was obtained by scanning a world-class cyclist sitting on a bicycle in time-trial position without helmet on. Secondly, the three time-trial helmets were scanned using a 3D scanner (ARTEC\textsuperscript{®}). Lastly, the helmets were fitted to the cyclist’s head, using CAD software (Figure 1).

The three-dimensional grid was generated using the ANSYS Workbench Meshing\textsuperscript{®} software and consists of a non-structured mesh composed of approximately $1.6 \times 10^6$ tetrahedral and hexahedral elements.

2.2. Boundary conditions

A uniform constant horizontal velocity (15 m/s) was imposed at the inlet of the fluid domain (Figure 2). At the outlet, a pressure outlet condition with ambient static pressure was imposed. A symmetry condition was imposed on the upper and side surfaces of the fluid domain. On the surface of the cyclist model, the no-slip wall boundary condition was considered.
Helmet 1 offers an optimal trade-off with the lowest drag in the head-up position and a drag equivalent to that of helmet 3 in the head-down position. However, these findings were deduced from calculations performed with a specific and super-low head position and the results should be examined in that context.

4. Conclusions

The primary goal of this study was to evaluate the aerodynamic drag of three different helmets by quantifying both the influence of external geometry and head position. In the head-up position, the three helmets present nearly equal performance. However, significant differences were deducted depending on the head position. In the head-down position, Helmets 1 and 3 exhibit the best aerodynamic performance. Due to its circular shape, helmet 3 offers similar performances whatever the head’s position.

Overall, given the small differences in drag forces in head-up position among the three helmets, and relatively greater differences in drag forces in the head-down position among the three helmets, helmet 1 offers the greatest advantage.

References

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