BOOK OF ABSTRACTS Open Access

Toward a robust and inexpensive method to assess the aerodynamic drag of cyclists

M Voiry, M.[1] ✉, Lemaitre, C.[1] Andre, C.[1]

Introduction

The major part of the resistive forces - between 80 % and 90 % - applied to cyclist are due to the aerodynamic drag. One of the key challenge in cycling performance lies in reducing the effective frontal Area (ACd) and thus the aerodynamic drag. Therefore, ACd needs to be adequately quantified. In this regard, different methods have been proposed [1]: wind tunnel, dynamometric measurement, deceleration, and linear regression. Recently, a new approach that couples 3D digitization and computational has been investigated [1-3]. 3D model and CFD tools interest: The approach based on 3D modeling and CFD has number of advantages. First, the operating and equipment costs of this system are lower than the one of wind tunnel or linear regression. Moreover, the measuring conditions are closer to real-world testing than the other approaches. Finally, extensive experiments can be performed with only one set of digitized data, including: (I) simulating different wind and cyclist speeds, (ii) assessing different equipments (e.g., helmet, wheel, etc.) by adding them during the simulation, and (iii) creating virtual scene in order to simulate team pursuit [2] or bunch effect. However, « 3D + CFD » methodology has some limitations. The obtained results are indeed relatively far from the ground-truth. In [1], a difference of 10.9 % with the wind tunnel and 13.1 % with linear regression on track has been observed. These results are similar to [2] which observed a difference of 10,5 % comparing to the wind tunnel. These differences can be explained through two different factors. First, the ACd of the cyclist is obtained as the difference between ACd of the solid cyclist + bike and the bike's ACd. Unfortunately, such subtraction cannot easily be done due to the heavy non-linear behavior of the aerodynamic phenomena. Secondly, the acquired data represent only one position in the pedaling revolution. We will show later in the experiments that the ACd is not constant along the pedaling revolution. Therefore, it will be beneficial to integrate data during the whole revolution cycle to obtain robust ACd values. Moreover, other elements can reduce the relevance of such ACd measurements: (i) experimental set-up is too far from real-world testing (e.g., fixed bike, no residual motions); (ii) the variability of the cyclist speed and of the wind conditions (i.e., direction and speed) are not taken into consideration. We will illustrate the influence of these two last factor in the later experiments.

Methods:

In order to address these limitations, we propose to apply the following improvements: (i) 3D digitization of the cyclist and the bike together; (ii) 3D digitization during a full pedaling cycle (i.e., 3D+t acquisition); (iii) Measurement conditions close to real-world testing (i.e., the cyclist is free to move on his bike during the process); and (iv) aggregation of a number of simulations to obtain a composite value of ACd more representative of the reality.

3D+t Scanning: To have a low cost solution and to obtain a real-time acquisition compatible with cyclist motion, we use 4 low-cost RGB-D (color and depth) sensors. This experimental set-up gives rise to many scientific problems with respect to computer vision and will be described in depth in another individual paper.

CFD simulation: The CFD simulations were performed with the OpenFoam solver. The cyclist surface was discretized using a polyhedral surface mesh. The numerical wind tunnel consisted of a box with a cross section of 3 m by 3 m and a total length of 6 m. The k-ω-SST turbulence model, due to its ability to correctly model separating flow, was used throughout the simulations.

Composite ACd computing: We propose to aggregate the results of simulations modeling from different environmental conditions (cyclist's speed, wind speed, and direction). Our methodology fully explained in the patent WO2017/012923 allows computing a composite ACd value able to summarize real racing changing conditions.

Results and conclusion

Results shown in Table 1 illustrate the sensitivity of ACd to the legs position (around 5%). Table 2 illustrates the influence of the cyclist speed on ACd (until 3 % here). Table 3 shows the positive impact of wind conditions on the measured ACd.

These results demonstrate clearly the benefit of using 3D+t scanning device and considering different conditions in a composite ACd value for modeling real racing performance.

Vertical position	0.2567
Horizontal position	0.24

Table 1: ACd vs Crankset position

15 ms^{-1}	0.2567
12.5 ms^{-1}	0.2645
10 ms^{-1}	0.2629

Table 2: ACd vs Cyclist speed

¾ back – 5ms^{-1}	0.1556
¾ front – 5ms^{-1}	0.3893

Table 3: ACd vs Wind direction (cyclist speed: 15 ms^{-1})

Figure 3: Real-life scene

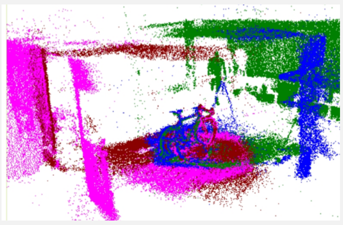

Figure 2: Point cloud from 4 RGB-D sensors

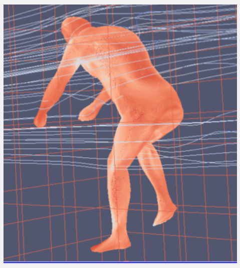

Figure 1: 3D model inside CFD software

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✉**Contact email:** m.voiry@apeira-technologies.fr (M. Voiry)

[1] *Apeira Technologies, 720 Avenue de l'Europe, 71200 Le Creusotl, France*