Cycling Aerodynamics: Wind Tunnel Testing versus Track Testing

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Abstract— **This paper deals with the aerodynamics of time trial cycling, presenting a reasoned comparison between the results obtained from cyclists wind tunnel testis and track tests carried out in an indoor facility. The paper outlines the difference between the two kinds of tests and the indications that can be extracted from the results.**

Keywords— **Aerodynamics, Cycling, Wind Tunnel.**

I. INTRODUCTION

It is well known and widely documented that the most part of the resistance experienced by a time-trial cyclist is due to aerodynamics [1,2]. In facts, the aerodynamics resistance is largely dominant respect to bearings and tires losses. Namely, it can be estimated that, for a time-trial cyclist riding at 50 km/h the aerodynamic resistance is more than 90% of the total amount [3] and it can be estimated that the cyclist himself produces more than 60% of the total aerodynamic resistance[4]. Furthermore, although the clothing effects are not negligible (see, for example, the references [5] and [6]) the most of the drag is related to the body position[3]. For all these reasons, an accurate adjustment of the cyclist position is quite important to get a good aerodynamic efficiency and the wind tunnel is a quite appropriate tool for this purpose[3,4,7,8,9]. In facts, in the well defined wind tunnel flow conditions, with video recording and accurate drag measurement, a very detailed analysis of the cyclist attitude effects is possible. Nevertheless, the optimal aerodynamic position can be not so good from the ergonomic point of view. As a mater of facts, aerodynamics is a part of cyclist biomechanics because the cyclist position affects both the amount of deliverable power [11,12,13] and the power requirement due to the drag resistance. Thus it can be concluded that the cyclist performance depends on the balance of ergonomic and aerodynamic factors [7,11,13].

In other words, if the cyclist position is intrinsically stressing, the advantage that in principle could be obtained by the drag reduction could be scaled down by the effort required to remain in that position. This question is not easily investigated during the wind tunnel tests because the wind tunnel biomechanical conditions are not exactly corresponding to the real race conditions (the constrains are not exactly equivalent) and, furthermore, because usually the wind tunnel tests cannot be continued for a long time due to problems of costs. Thus the question about the real reproducibility of the results obtained during the wind tunnel test sessions becomes a fundamental point to be investigated (see, for example, the reference [10]). The present paper deal with reasoned comparisons between the results obtained in the large wind tunnel of Politecnico di Milano and the results obtained with the same cyclists by means of track testing in the new facility of Montichiari. The different measurement approach and the cyclists' behavior in the two situations are discussed to extract useful indications for the athletes and their trainers.

Six cyclists participated to the wind tunnel tests campaign and to the track activity as well. The main anthropometric data of the cyclists are listed in Table 1

Table 1 Cyclists data

Cyclist	Weight[kg]	Height [cm]
TK	68	182
AK	73	184
KD	70	182
SD	75	182
DD	65	177
KS	61	173

II. WIND TUNNEL TESTING

A. The Wind Tunnel

The wind tunnel test activity has been carried out at GVPM, a large facility of Politecnico di Milano. The GVPM test chamber section, in cycling test configuration, is 4m x 3.54m thus the solid blockage is very small and not affecting the results [14]. The effect of blockage in small wind tunnels is quite evident from the synopsis presented in the Ref.

The speed is settable up to 200km/h (that is much more than enough for cycling tests).

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B. *Experimental Setup*

The test rig consists in a strut fixed over a six-component block-balance and supporting the bicycle. The bicycle is fixed to the strut at the rear axle by an apposite fork and each wheel leans on a roller. As the two rollers are connected by a toothed belt, both the wheels are spinning when the cyclist pedals. The belt is also connected to a braked flywheel that helps to achieve a more realistic movement. The present solution has been preferred respect to a strut that constrains the front axle too [10] because the present one allows for a more natural cycling.

C. *Test Procedure*

In order to obtain a meaningful statistic [17], two thirty-seconds tests were carried out for each cyclist at 45km/h.

Before the test, the athlete has to stay motionless for 5s for the tares. Then he can start to pedal and when the wind tunnel has reached the required velocity he is asked (by radio) to reach the same velocity (looking at his speedometer) and to keep the velocity during all the acquisition.

Except for the first two tested cyclists, an acquisition has been done at the higher speed of 50km/h without to stop the tunnel between the two measurements.

Three positions have been tested for each cyclist, corresponding to three different height of the handlebars position. Figure 1 presents a cyclist during the wind tunnel tests.

Fig. 1

III. Track testing

A. *The Track*

The on-track tests have been carried out at the new indoor facility of Montichiari, in the North of Italy. This track is 250 m long and 7 m wide, with a maximum banking of 43 degrees.

B. *Experimental Setup*

The bicycles were equipped with a hub power meter wireless connected to the recording unit fixed to the frame. Figure 2 presents the cyclist TK testing at Montichiari track.

C. *Test Procedure*

The cyclists adopted the same positions of wind tunnel tests. For each position, each cyclist ran at different increasing velocities, from 10 to 50km/h, keeping each velocity constant for 1.5minute. At the end of each test the recorded data were downloaded on a PC. At the same time, just after the test, the confort of adopted position was evaluated on the base of cyclist feeling (it was asked to the cyclist his feeling in a scale from 0 t0 5).

Figure 2 and Figure 3 show the testing activity in the cycling track.

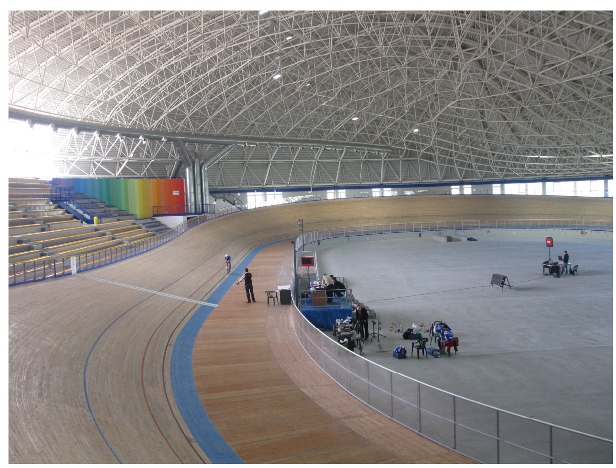

Fig. 2

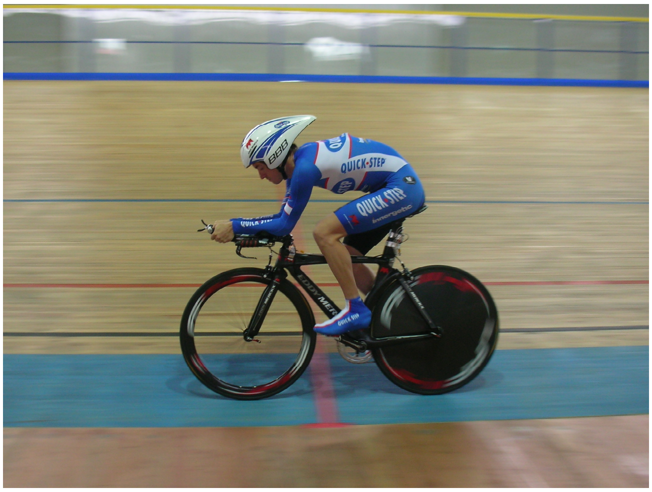

Fig. 3

IV. Results and discussion

Generally speaking the truck tests confirmed, with respect to the wind tunnel tests, the ranking of the different positions in terms of aerodynamic efficiency although, of course, the data were less regular and repeatable than wind tunnel results. On the other hand, the track tests allowed for a more clear feeling of the position comfort.

The Table 2 presents the ranking of the different tested positions for each cyclist, in terms of aerodynamics and comfort, where the mark scale is: A=best, B=intermediate, C=worse.

Table 2 Positions ranking

	Highest position		Intermediate position		Lowest position	
Cyclist	aerodin.	comfort	aerodin.	comfort	aerodin.	comfort
TK	C	A	B	B	A	C
AK	C	A	B	B	A	C
KD	C	A	B	B	A	C
SD	C	A	A	B	B	C
DD	B	A	A	B	C	C
KS	C	A	B	B	A	C

It can be seen from the table that the highest position is the most comfortable for all the cyclists while the lowest one is the less comfortable. But, on the other hand, the lowest one is the most aerodynamic for the most of the cyclists (although not for all). Thus, the choose of the best position depends on several factors and can be different for different race length: a position very efficient from the aerodynamic point of view but too uncomfortable can be inadvisable for a long race while can be the right choose for a short distance.

A collateral result obtained with the present activity is the confirmation that the overshoe produces an over-drag: test repeated with the overshoes on gave a not negligible increment in the aerodynamic resistance, according to the results obtained by Gibertini et al. [5] by means of shoes wind tunnel tests. As a matter of fact this effect can produce valuable effect on the race time as outlined in the Ref. [5].

V. Conclusions

Several wind tunnel tests carried out on a group of six cyclists allowed each of them to find his more aerodynamic position.

Further tests carried out on a cycling track confirmed the wind tunnel measurements and allowed for a better identification of the comfort level associated to each position.

Generally speaking, it can be concluded that the wind tunnel tests are irreplaceable for an accurate evaluation of the aerodynamic drag but, on the other hand, track tests allow for a real evaluation of the biomechanical efficiency.

All the data acquired in the present study will be used for further in deep analysis, taking into account the global physiology of the athletes.

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