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Drafting effect in cycling: investigation by wind tunnel tests

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Abstract

Cyclists travelling in groups experience a significant reduction in the wind resistance and those behind consume less energy due to the shielding effect of the front cyclist. We investigated drafting effects by wind tunnel tests realizing a test set-up with two cyclists pedalling at different longitudinal distance. Drag reduction effects on both the leading and the trailing cyclist are confirmed. The presence of lateral wind is also investigated showing a significant reduction of the drafting effect also for light winds.

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Keywords: Cycling aerodynamics; drafting; lateral wind; wind tunnel tests

1. Introduction

It is well established that wind resistance is responsible for most of the metabolic cost of cycling in level ground. Aerodynamic drag is about 80% of the total resistive force in road racing at 30 km/h and up to 94% in time trial competitions at 50 km/h, so that it becomes important to reduce it to improve cycling performance [1–4]. During races with multiple cyclists there is the opportunity to draft one another. Drafting is the practice by which individuals follow closely behind one or more other to limit the aerodynamic resistive force [5]. Drafting has also a significant application in team pursuit events [6]. Drafting effects have been less investigated with respect to the isolated rider aerodynamic optimization, although the magnitude of drafting can be impressive. Kyle[7] investigated the drag reduction in groups by coasting down tests and found a drag reduction in the trailing cyclist up to 44% while no effects have been measured on the leading cyclist. He observed, as expected, that the more closely one cyclist follows another the greater the drag reduction. Kyle investigated also the effect of alignment and showed a decrease of wind resistance from 0 to 30%, depending upon the amount of overlap and side spacing, compared to the 44% for the case of perfect alignment. Edwards and Byrnes[5] carried out field test with power meters installed on the bikes on individual and drafting cyclists with different leading and drafter athlete showing a pronounced variability of these data. In Edwards and Byrnes paper drafting effect ranges between 35 and 50%, depending on the leader characteristics and they measured also a minimal pushing effect on the leader that showed an average reduction of 1.63%. Blocken et al.[8] performed CFD simulations of the drafting effects as a function of the rider position and distance between bikes: Blocken et al.

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found a maximum reduction of 27.1% on the trailing cyclist and of 2.6% for the leading. 2-D numerical simulations performed by A Ìñiguez-de-la Torre[9] showed a possible benefit to the front cyclist of about 5%. In a recent paper Barry et al.[10] investigated the variation in aerodynamic drag for cyclists in both drafting and overtaking two rider formations. Different techniques are used nowadays to evaluate aerodynamic drag in cycling:on one side track testing allows a natural athlete's behaviour while, on the other side, wind tunnel testing is the most accurate and reliable technique [3,11]. In case of wind tunnel testing, particular attention should be given to the simulation of the pedalling with an adequate resistance, since significant differences are found between static and *in effort* tests [3]. In Broker et al.[12] the authors performed both wind tunnel and field tests on competitive team pursuiters finding out that the athlete in second position requires 70.8% of the power needed by the leader. Wind tunnel results showed a good agreement (67.7%), considering also that the rolling resistance was not included in this last value. In the present paper we investigate drafting effects by wind tunnel tests on two drafting cyclists, using a test set-up that allows the athlete to pedal with both wheels spinning. Particular attention is given to the effects of a small magnitude lateral wind.

Nomenclature

C_DA	drag area
D	drag force
d	distance between the bikes
U	wind speed
V	bike speed
V_r	wind speed relative to the bike
α	yaw angle
ρ	air density

2. Wind tunnel tests set-up

Tests have been performed in the Politecnico di Milano Wind Tunnel; the facility is a low speed and boundary layer wind tunnel located in the Politecnico di Milano technical university. To allow the positioning of two drafting cyclists the large test section of the facility has been used. The dimensions are 14 m wide and 4m hight; considering the typical frontal area of a cyclist of about $0.4\,m^2$ the blockage is very low (< 1%). The maximum wind velocity is $16\,m/s - 57\,km/h$ and the turbulence intensity is equal to $I_u = 2\%$. The velocity profile is uniform except for the presence of boundary layers close to the walls and floor: in order to put the bikes outside the boundary layer a ground-board with height equal to $350\,mm$ was installed. Two racing bicycles with traditional wheels have been used as seen in Figure 1 where the layout of the test is also presented. Each bike is mounted on a supporting frame that has two vertical arms that fix the rear wheel axis. The wheels are placed over rollers so that the cyclist can pedal with an adjustable resistance. The two rollers are linked using a belt so when the athlete pedals the rear wheel moves and the belt transmits motion to the front wheel. In this way it is possible to test having both the wheels spinning at the same velocity. The main part of the support frame is located under the ground-board and it is connected to a 6-component force balance (RUAG strain-gauge balance model 192, X-f) and it is shielded to the wind. The two bikes are mounted on two different frames and the trailing bike one can be moved in order to adjust the distance between the bikes, having always the two bikes aligned with the hypothetical travelling direction. The distance, hereafter named *d*, is defined as the gap between the rear wheel of the leading bike and the front wheel of the trailing one as highlighted in Figure 1. Each bike is mounted on a force balance allowing us to have the simultaneous measurement of the drag on both bikes. The data were sampled at 500 Hz for 20 s: mean value is used in the analysis. During the tests videos are taken to identify and control the biker position.
The leading cyclist weights 77 kg and is 186 cm height while the trailing cyclist weights 70 kg and is 180 cm height. The biker position has obviously a significant influence on the drag value and it is often an important issue in the aerodynamic optimization: in this research we use the *brake hoods* position as reference and the athletes were asked to maintain the same position in all the tests. Tests were performed at $50\,km/h$ ($13.9\,m/s$) having a cadence of $100\,rpm$.