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BOOK OF ABSTRACTS

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Numerical simulations of cross wind effects on cyclist aerodynamic resistance

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Abstract

Introduction: In outdoor cycling, cross wind can affect the race strategy and the final results. Ad-hoc strategies, like echelons and Belgian tourniquet formations, are indeed adopted by cyclists to reduce wind effects and aerodynamic drag. Forces and moments generated by cross winds have been often studied for isolated wheels [1,2] and for an entire isolated cyclist [3-5]. However, to the best of our knowledge, the impact of cross wind on a couple of cyclists has not yet been investigated. In this study, Computational Fluid Dynamics (CFD) simulations are used to evaluate the effect of cross wind on the aerodynamic resistance of a couple of cyclists in two different configurations: (1) when the trailing cyclist is placed in line with the leading cyclist (Fig. 1a) and (2) when both cyclists are staggered (Fig. 1b). To compare the results, additional simulations have been performed for a single cyclist. Moreover, the impact of the upstream turbulence intensity is investigated.

CFD simulation: The cyclist geometry used in these simulations has been obtained by means of high resolution 3D laser scanning of elite cyclists. Further information is provided in Refs. (Defraeye, Blocken, Koninckx, Hespel, & Carmeliet, 2010) and (Blocken, Defraeye, Koninckx, Carmeliet, & Hespel, 2013). The computational grids consist of prismatic cells in the boundary layer region near the cyclist body while tetrahedral cells are adopted in the rest of the domain using proper growth factors. The total number of cells is about 8.3 M and 14.0 M, for the single and drafting cyclists, respectively.

The simulations are performed using the commercial CFD code ANSYS/Fluent 15.0. The 3D steady Reynolds-Averaged Navier-Stokes (RANS) equations are solved in combination with the standard k-ε turbulence model with low Reynolds number modelling based on the one-equation Wolfshtein model. This choice was made since a good agreement with wind tunnel tests was achieved in a previous validation study for the case of zero yaw angle (Blocken, Defraeye, Koninckx, Carmeliet, & Hespel, 2013). The distance from the centre point of the wall adjacent cells to the cyclist body is about 30 µm corresponding to an average y^* value of about 1. The simulations are performed for yaw angles between 0° and 45° in 5° intervals.

Results: the results show that the drag of the leading cyclist is affected by the position of the trailing cyclist only at low yaw angles ($\theta < 15$ degrees). In this case, the drag area coefficient, C_dA, is reduced by about 2.5% (not shown in the figures). The drag of the trailing cyclist however is highly influenced by his position with respect to that of the leading cyclist (Fig. 2). When the yaw angle is less than 15° the in line configuration is still advantageous while for larger angles the staggered configuration shows the best behavior both in terms of drag area coefficient and side force area coefficient, C_sA. In the case of a single cyclist, a reduction of the drag area is obtained as the yaw angle increases. Conversely the side force area coefficient is increasing almost linearly with larger yaw angles. However the dimensional drag is almost constant until an angle of around 25°, while after it slightly increases. In future studies other configurations will be analyzed and bicycles will be included in the models.

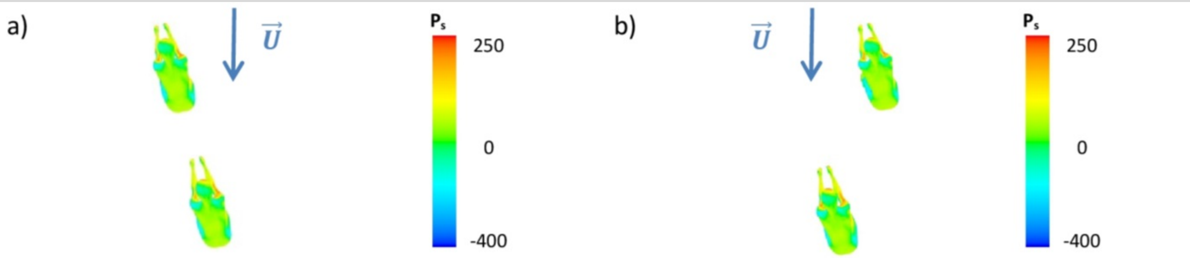

Figure 1 Top view of two cyclist configurations at θ=15°: (a) in line and (b) staggered, colored with static pressure

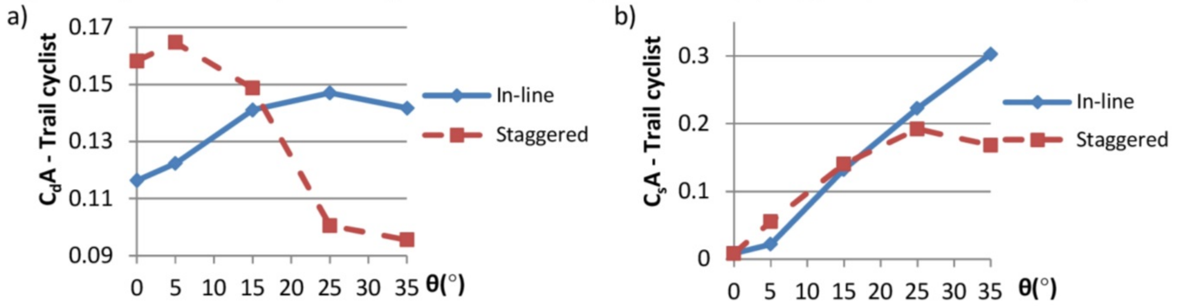

Figure 2 (a) drag area and (b) side force area at different yaw angles θ for both configurations

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