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Conference Abstract
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The effect of geometry simplifications on aerodynamic cyclist posture optimization through numerical simulations

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Abstract

Cyclist aerodynamic performance can be optimized using Virtual Skeleton Methodology, adapting the rider posture, and evaluating its performance through numerical simulations, aiming to minimize overall aerodynamic drag. The goal of the present work is to understand if the outcome of this optimization procedure relies on the presence/absence of a bike or the specific leg orientation, when changing the rider's upper body position. The Generic Cyclist Model in time-trial position is used adapting the lower arm angle. The results show that the flow downstream of the cyclist remains relatively unaltered when removing the bike. The arm position that exhibits minimum aerodynamic drag is also independent of the presence of the bike and, in addition, of the specific leg orientation. This suggests that virtual cyclist posture optimization can be conducted without a bike and considering only a single leg position, which significantly simplifies the optimization process.

Keywords

cyclist aerodynamics; posture optimization; drag minimization; CFD

1 Introduction

The interaction of a cyclist's body with the air is responsible for about 70% of the overall resistance of the ride-bike system. Hence, changing the cyclists' posture can significantly reduce the air resistance (Crouch et al. 2017) and possibly provide the rider with a competitive advantage. The quest for the most aerodynamic posture may be performed with the rider in a wind tunnel, measuring the athlete's aerodynamic drag using a force balance. Alternatively, a rider's digital twin may be used, virtually varying the position of the rider, and evaluating the aerodynamic performance through CFD simulations. Such an optimization strategy has been proposed, among others, by Giljarhus et al. (2024). These authors considered a simplified cyclist model, namely one without a

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bike and in one specific static leg position, while adapting the upper body posture. Leg position, however, can significantly affect aerodynamic drag (up to 15%, Crouch et al. 2014). The bike is generally responsible for about 20% of the total aerodynamic drag. Hence, it is currently unclear if, and how, these simplifications affect the obtained optimal cyclist posture.

The main goal of this work is to understand how these simplifications affect the variation in the aerodynamic drag when adapting the rider's upper body position.

2 Material and Methods

Computations Fluid Dynamic (CFD) simulations are conducted on the Generic Cyclist Model (GCM) in time-trial position (see Figure 1). This rider-bike geometry is freely available online (Terra et al. 2024). The GCM dataset contains wind tunnel measured aerodynamic loads and flow fields, which are used for CFD validation. The aerodynamic drag of the rider in four different positions is compared for (1) with and without a bike and (2) in two different leg positions (asymmetric and symmetric legs). The bike has been slightly adapted (handlebar and crankset removed) to cater for the rider positional variations. The lower arm angle, β is varied around the original position: $\Delta\beta = [+7\ 0\ -7\ -21]^o$ using Virtual Skeleton Methodology (Giljarhus et al. 2024) in Blender. The Blender file is freely available in the GCM database (Terra et al. 2024).

The numerical simulations are conducted in OpenFOAM, following the guidelines of Van Druenen and Blocken (2023). The RANS simulations employ the T-SST turbulence model for closure. The computational domain measures 55 × 30 × 15 m3 [x × y × z] with the cyclist positioned 15 m downstream from the domain inlet. At the inlet, a streamwise velocity $U\infty = 14$ m/s and a zero gradient for the static pressure are prescribed. A slip condition was enforced on the side walls and at the domain exit a fixed mean static pressure was set. The computational mesh, with and without the bike, consists of about 27M and 16M cells, respectively, and the average y+ value is around 2.5. The uncertainty of the obtained drag coefficient is about 1.5%.

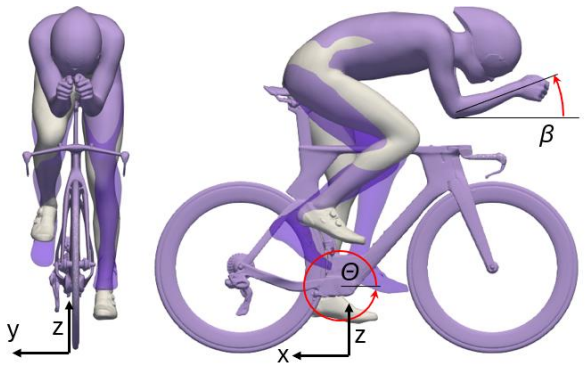


Figure 1. Bike-rider geometry in the symmetric (purple) and asymmetric leg position (grey).

3 Results and Discussion

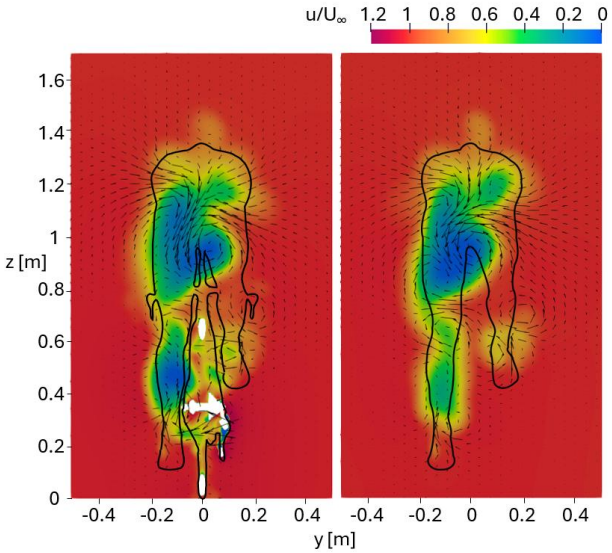


Figure 2. Streamwise velocity in yz-plane intersecting the rear wheel axle with (left) and without bike (right).

Figure 2 depicts the non-dimensional streamwise velocity downstream of the rider with (left) and without a bike (right). Differences in the flow field are observed, in particular, in the lower wake ($z < 0.7$ m); The wake of the stretched leg is clearly present in both cases, however, the interaction with the bike significantly increases the peak velocity deficit downstream of the left calf (bike: $u/U \sim 0$ vs no bike: $u/U \sim 0.3$). The upper wake remains relatively unaltered when

omitting the bike. This suggests that the bike has a limited effect on the changes in the aerodynamic drag through posture optimization of the upper body (torso/arms).

Figure 3 presents the drag area of the GCM against the changes in lower arm angle for the model in symmetric (red) and in asymmetric position (blue), with (solid line) and without the bike (dashed line). First, it is observed that the drag area of the GCM in the symmetric leg position is consistently about 8% below that of the asymmetric position and that removing the bike reduces the drag area by about 15%. The 8% difference in drag area stemming from the leg position matches well to the 5% difference measured in the wind tunnel.

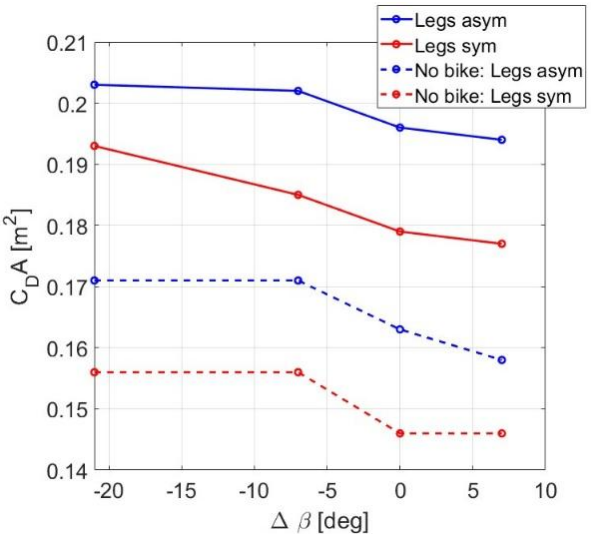


Figure 3. Drag area vs changes in lower arm angle.

Regarding the effect of the variations of the rider position, it is observed that, independent of leg positions and the presence of the bike, the drag area decreases with increasing lower arm angle. In all cases, the drag area drops at the highest rate between $-5^o < \Delta\beta < 0^o$. The variations in C_DA are less significant around the rider position with the lower arms parallel to the floor ($-20^o < \Delta\beta < -10^o$). Despite, that the trends among the four different configurations do not match exactly, the C_DA extremes are obtained around the same position of the lower arms. In this work, a limited amount of lower arm angles is considered. The author expects the present findings to remain unaltered, when the variations are further refined. Nevertheless, future results need to validate this.

The optimal posture of a cyclist's upper body seems unaffected by the presence/absence of a bike or the orientation of the riders' legs. During the conference, torso angle variations are also presented to help us understand if this can be concluded more in general. The ability to leave out the bike in the optimization process, significantly simplifies the CFD simulations.

4 Conclusions

CFD simulations are conducted for a cyclist in four different lower arm postures. It is observed that the position that exhibits minimal aerodynamic drag is unaffected by leg orientation or the presence or absence of a bike.

Conflicts of Interest: The authors declare no conflict of interest.

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