BOOK OF ABSTRACTS Open Access

The influence of the rim depth to the aerodynamic performances of a wheel: a numerical study

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Summary

The aerodynamic drag and side force of five different wheels are evaluated by means of Computational Fluid Dynamics (CFD). The wheels are identical with the exception of the depth of the rim, which varies from 20 to 100 mm (Figure 1a).

Introduction

Aerodynamic drag is responsible for about 90 % of the total resistance of a cyclist travelling at racing speeds (Kyle & Burke, 1984). The bike contribution to the total drag ranges from 28% to 36% of the total drag depending on his or her position (Defraeye et al., 2010a). Earlier research has shown that the wheels' contribution to the total drag is within 10% ‒ 15% and that an overall reduction in aerodynamic drag of 2-3% is possible solely by optimizing the wheels (Greenwell et al. 1995).

Therefore, a correct selection of the wheel can make a difference in the final result of a cycling race. In this paper the aerodynamics of spoked wheels as the most commonly used wheels in cycling races are investigated. The aerodynamic performances of spoked wheels are mainly affected by three factors: i) spoke count; ii) spoke shape and iii) rim depth. The first two parameters are kept fixed in this study while the rim depth is varied in order to better understand its effect on the aerodynamic forces generated on the wheel. To do so, an elliptical rim shape is adopted for all wheels.

Methods

3D steady Reynolds-Averaged Navier-Stokes (RANS) CFD simulations are performed to investigate the aerodynamic forces acting on five wheels with different rim depth at different yaw angles. The evaluation is based on validation with wind-tunnel measurements of Zipp Speed Weaponry, Indiana, USA, as presented in Godo et al., 2010.

The wheel considered for the validation study is the Zipp 404. Detailed characteristics of the wheel are provided in Godo et al. (2010). Subsequently, five wheels are created with elliptical rim shape of different depth.

The fluid domain is split in three regions. The first zone is built around the hub, the spokes and the internal part of the rim, and is later modelled as a moving reference frame (Figure 1b). The second zone is built externally to the wheel and has a cylindrical shape, which can be rotated to obtain different yaw angles for the wheel. The third zone is a parallelepiped representing the far-field domain.

The wheels are first drawn using the Computer-Aided Design (CAD) program PTC-Creo. The computational grid is then built using ANSYS/Fluent Meshing (Figure 1c). The volume grids consist of prismatic cells in the boundary layer region near the wheel and the ground while tetrahedral cells are employed nearby the wheel. Moreover, hexahedral cells are used in the far-field. The rotation of the wheel is imposed using a moving reference frame in the volume zone near the spokes. In the rest of the wheel, a rotational moving wall boundary condition is applied. The wheel-ground contact is modelled extruding the wheel's footprint for 7mm. The k-ω SST turbulence model is used. Note that the good performance of this turbulence model for cyclist aerodynamics has been shown in several occasions in the past, e.g. Defraeye et al., 2010b.

Results

Earlier research results (Godo et al. 2010), have shown that for spoked wheels a decrease occurs in the drag coefficient, C_D, when the yaw angle is increased up to 10 degrees. For larger yaw angles, C_D increases. The expected effect of increasing the rim depth is to decrease the aerodynamic drag of the wheel, but an increase of the side force for large yaw angles is also expect.

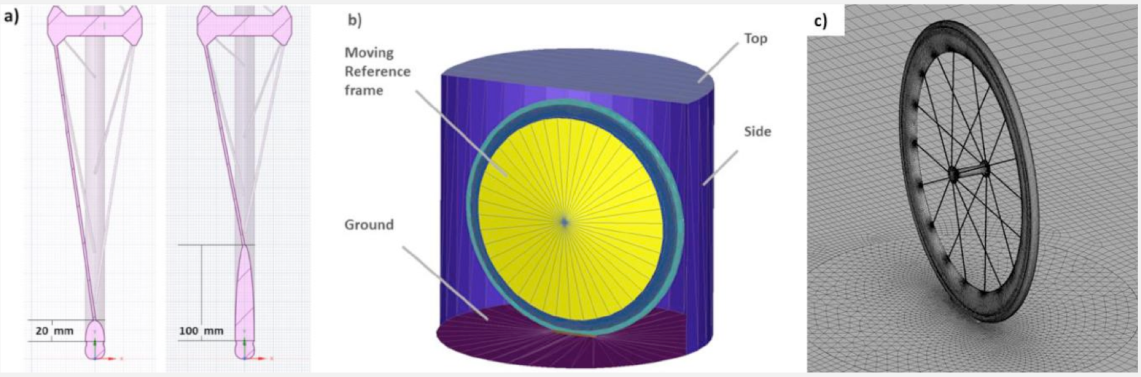

Figure 1. a) CAD modelling of two wheels having a rim depth of 20 mm and 100 mm respectively; b) CAD modelling of the moving reference zone surrounding hub, spokes and internal part of the rim; c) surface mesh of wheel and ground

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