CFD comparison of Friction and Pressure Drag Between Road and Time Trial Helmets for Wheelchair Racing.

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Introduction

Computer Fluid Dynamics (CFD) has been used by sports scientists aiming to improve the athlete's performance in sprinting events. In wheelchair sprinting velocity can reach 7m/s. Sports garment such helmets may reduce aerodynamic drag by 10%. The aim of this study was to compare the friction and pressure drag between a road and time trial helmet.

Methods

Subject: A wheelchair racer (category T-52), European medallist in sprinting events and world championships finalist was recruited for this research. The subject wore a road helmet (LAS, Istron) and a time-trial model (LAS, Cronometro).

Geometry Model: The geometries were obtained by a 3D scan (Artec-L, Artec Group, Inc., USA). The scan was edited in Geomagic studio (3D Systems, USA) for hole filling and mesh smoothing.

Mathematical Model: The aerodynamic force was calculated in this study for the drag force acting parallel to the flow direction. To compute this force equation 1 was acceded.

$$D = 0.5 \cdot \rho \cdot v^2 \cdot S \cdot C_D \quad (1)$$

Where D is the drag force, ρ the air density (being 1.2041 kg/m^3 at 20º C and sea level), v the velocity, S the frontal surface area and C_D the coefficient of drag (assumed to be 0.7).

Fluent (Fluent, Inc., USA, New York) code allowed to compute numerical simulations applying a mathematical model to the fluid flow, in a created domain with discretized expressions of the Navier-Stokes equations (equations 2, 3, 4 and 5). It solves the equations with a finite volume approach. The domain, created by a 3D mesh of subdivided cells, represented the fluid flow around the head and helmets. Realizable k-epsilon turbulence model was applied. The 3D mesh had more than 6 million cells for booth helmets domains and helmets angles of attack was 0º.

$$\frac{\partial_{\mathrm{Ui}}}{\partial_{\mathrm{xi}}} = 0 \quad (2)$$

$$\frac{\partial_{Ui}}{\partial_t} \pm U_j \frac{\partial_{Ui}}{\partial_{x_j}} = -\frac{1}{\rho}\frac{\partial P}{\partial x_j} + \frac{\partial}{\partial x_j}\left(2\upsilon S_{ij} - \overline{\mu_j{}'\mu_i{}'}\right) \quad (3)$$

$$\frac{\partial_{\theta i}}{\partial_t} \pm U_j \frac{\partial_{\theta}}{\partial_{x_j}} = \frac{1}{\rho_{cp}}\frac{\partial}{\partial x_j}\left(k\frac{\partial \theta}{\partial x_j} - \overline{\mu_j{}'\theta'}\right) \quad (4)$$

$$\frac{\partial_{C}}{\partial_t} \pm U_j \frac{\partial_{C}}{\partial_{x_j}} = \frac{\partial}{\partial x_j}\left(D\frac{\partial C}{\partial x_j} - \overline{\mu_j{}'c'}\right) \quad (5)$$

Boundary Conditions: The fluid flow velocity was set in inlet portion of the dome surface at 2m/s, with increments of 1.5 m/s up to 6.5 m/s. Typically the wheelchair racer will reach these range of speeds over a short distance event (Fig. 1).

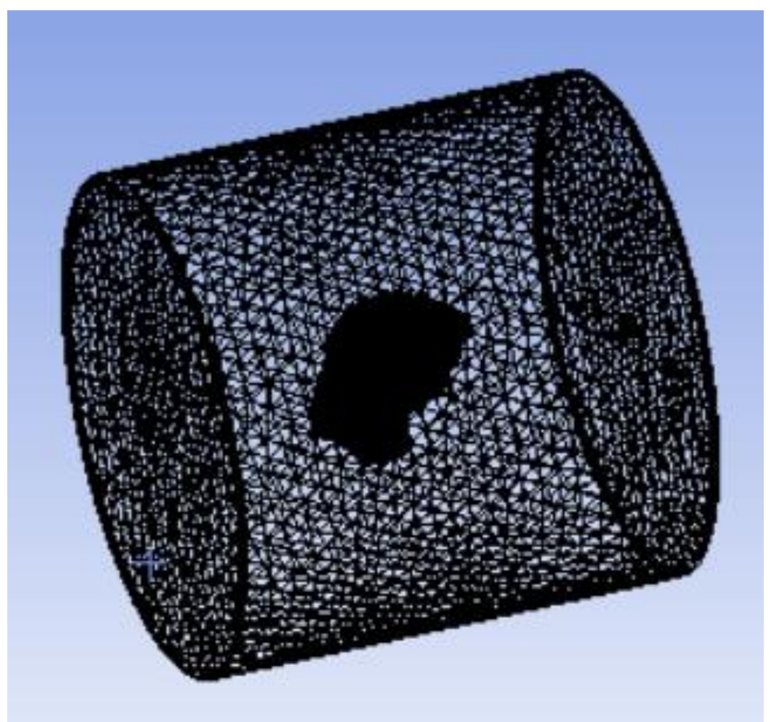
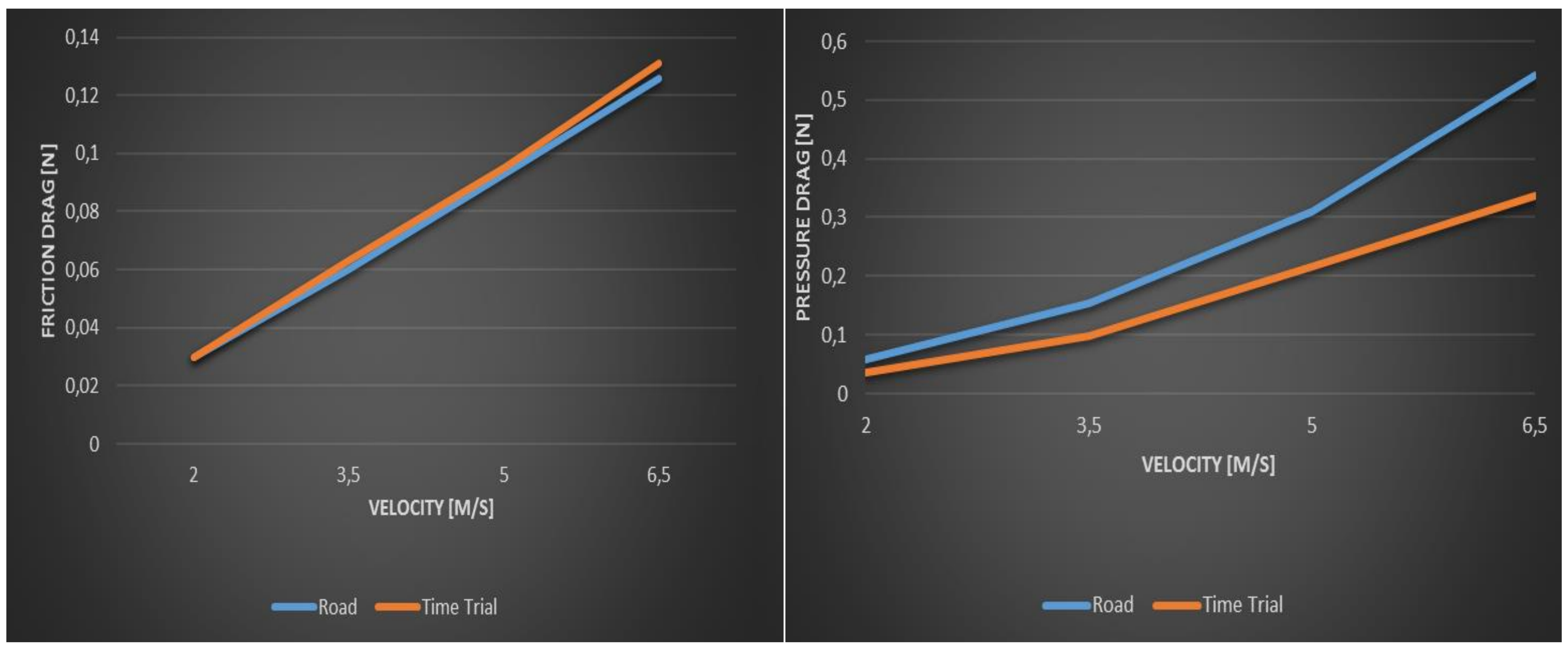


Figure 1: Head with road helmet position (90º) inside 3D domain. The whole domain was meshed with 6600000 elements.

Results

Pressure and friction drag increased with velocity (Fig. 2). Pressure drag ranged from 0.059 N to 0.542 N and 0.036 N to 0.336 N, for road and time trial helmets respectively. Pressure drag was lower wearing the time trial helmet than the road one at all selected velocities. As far as friction drag is concern, it ranged between 0.03 N and 0.126 N, 0.03 N and 0.131 N, for road and time trial helmets respectively.



(a) (b)

Figure 2: Friction (a) and Pressure (b) drag for road (dash line) and time trial (solid line) helmets at different speeds.

Conclusion

Aerodynamic drag increases with velocity. The road helmet presented a lower friction drag and the time trial a lower pressure drag. The pressure drag was the main contributor to total drag, inducing a time trial helmet usage.

References

1. S. Sidelko. "Benchmark of aerodynamic cycling helmets using a refined wind tunnel test protocol for helmet drag research" Doctoral dissertation, Massachusetts Institute of Technology, 2007.