PulsaR design: CFD comparative study of speed-record Human Powered Vehicles

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POLITECNICO DI TORINO

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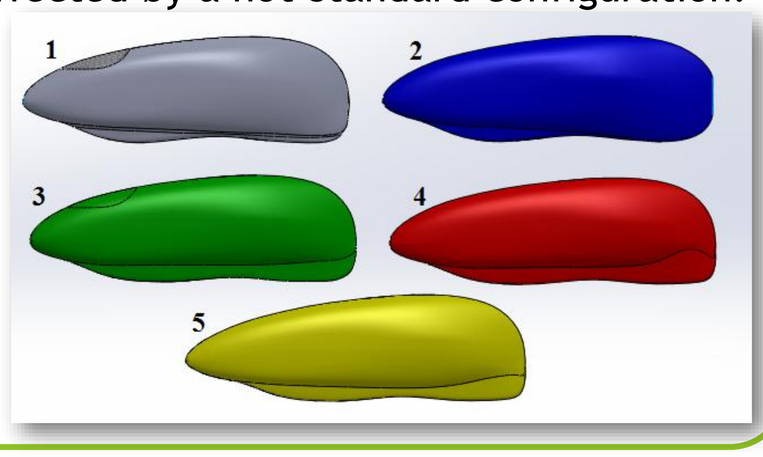
CONTEXT

High speed Human Powered Vehicles (HPVs) are specifically designed in order to race at the World Human Powered Speed Challenge (WHPSC), an event taking place in Battle Mountain, Nevada, with the purpose of pushing streamlined bike technology to the limits. The speed is measured on a -0.6% average slope road by timing the HPVs through a 200 m trap after a run-up of 5 miles (~8 km). Record-legal wind must be <6 km/h.

SHAPE VARIATION COMPARISON

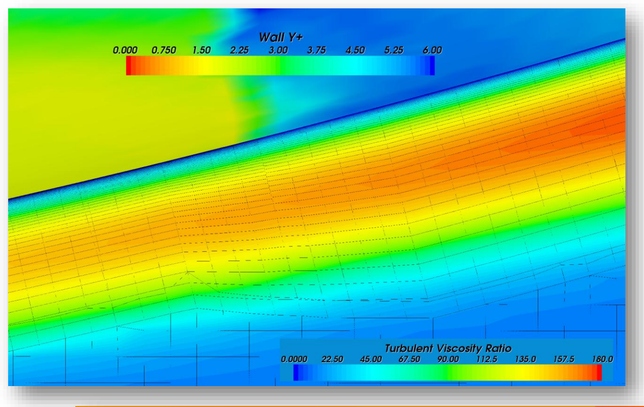
The design of PulsaR was aimed at the minimum frontal area, given the "compact" size of the rider Andrea Gallo. Crank length and Q-factor (the pedal lateral distance) were reduced after experimental confirmation that the power output was not affected by a not-standard configuration.

Given a first draft shape accounting for the main volume constraints (head and helmet, shoulders, legs and feet movement), 5 design versions were created by slight variations of length, nose, tail and wheel cover profile.

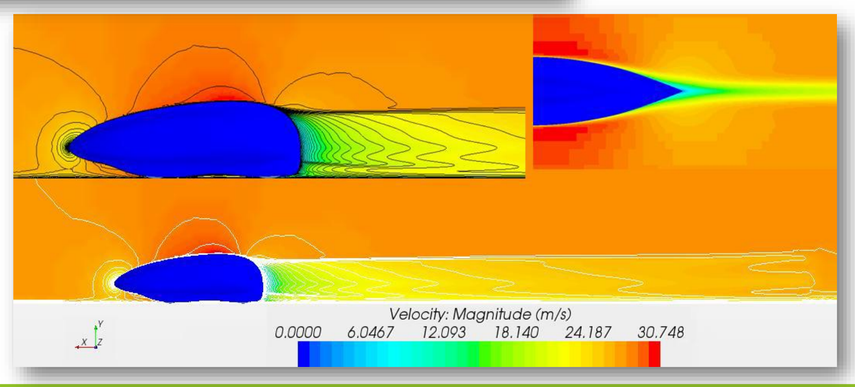


SHAPE RANKING AND SELECTION

The CFD analysis was performed with CD-Adapco StarCCM+. Particular attention was given to the mesh of the boundary layers, where laminar flow is expected. A shape ranking by drag was obtained, allowing to select the most efficient solution.



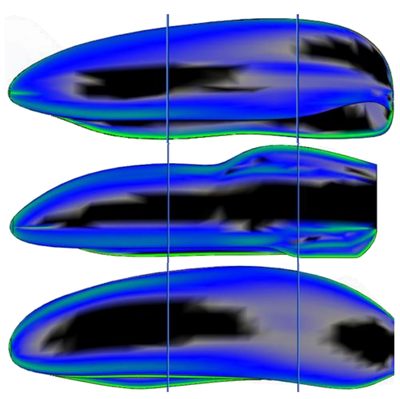
CD-adapco

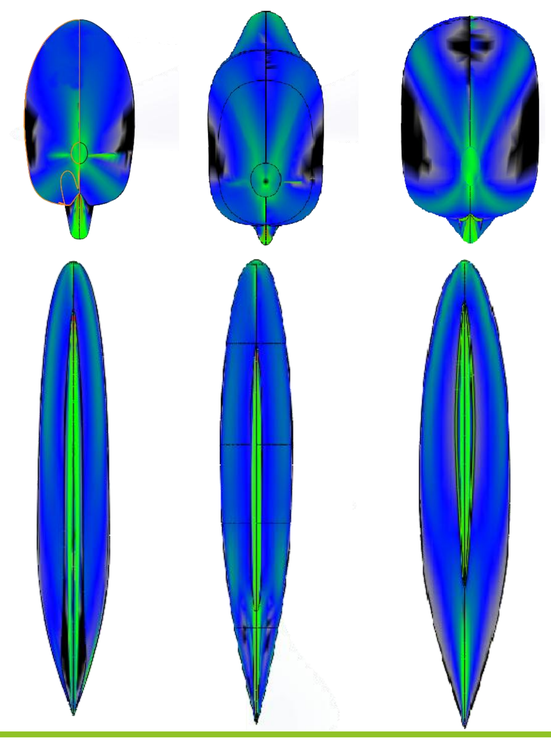


COMPARATIVE ASSESSMENT: PulsaR vs. Varna vs. VeloX I

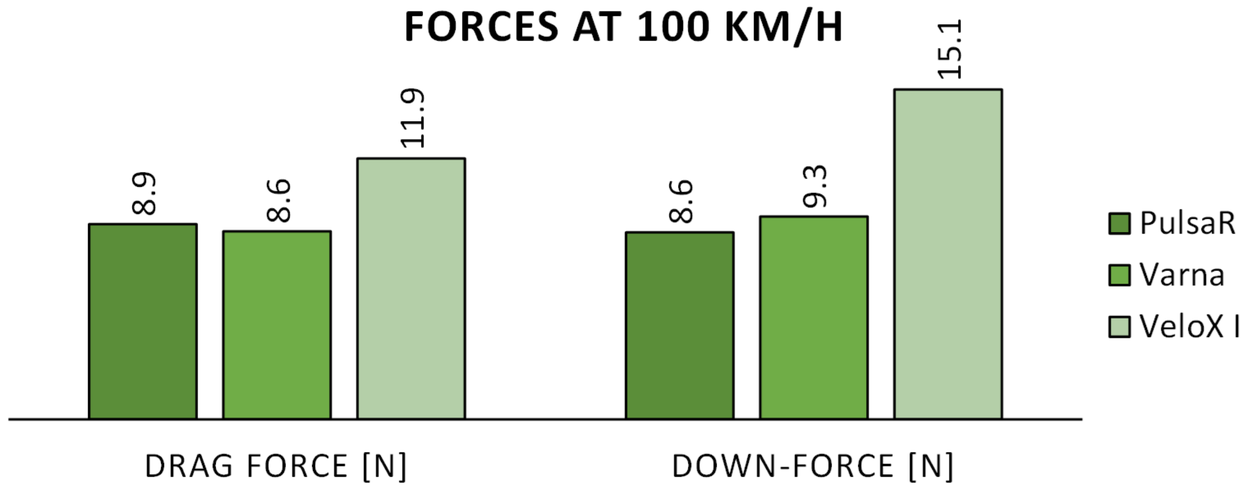
The same CFD analysis was repeated on two historical reference HPVs in order to assess the overall drag.
Left→Right / Top→Down:

- PulsaR
- Varna Tempest
  121.8 km/h (woman record)
- VeloX I
  129.6 km/h (man)





The selected design solution resulted competitive with these reference prototypes in terms of drag and, as a consequence, in terms of power required to travel at a given speed.
Also lift forces were compared showing a reduced down-force for PulsaR, lowering the effect of tire load increase with speed and resulting in less overall rolling resistance.



RESULTS

The prototype was built in the 1st semester of 2015 and raced at the WHPSC in September after about 850 km of testing. Andrea Gallo achieved the Italian Speed Record at 116.19 km/h (with a peak of 118.4 km/h at the end of the 200 m trap), becoming the 24th fastest rider in the history of this discipline.

FURTHER DEVELOPMENTS

The Team will continue to improve PulsaR to approach 120-125 km/h in 2016. In parallel, a new prototype design is being developed aiming at the world speed record in 2017-2018 (now 139.45 km/h).
Higher aerodynamic efficiency can be obtained by solving some manufacturing critical aspects: a better thermoforming procedure for the front window plexiglass and a smoother window-fairing connection.
Moreover, while the pressure profile was used to choose air inlet and outlet areas, a CFD analysis including internal ventilation is needed as far as a sensitivity analysis to lateral wind. Wind tunnel and on-road experimental validation are also needed.
For the new design to be manufactured in 2017, the use of CFD analysis combined with shape optimization tools is considered as a promising approach in order to achieve a stable laminar flow and a reduced drag.