AERODYNAMIC DRAG IN CYCLING PELOTONS

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In the course of 2017, a large collaborative project between four universities, two multinationals (ANSYS and Cray) and three Dutch model-building companies was conducted to investigate in detail the aerodynamic drag for every cyclist in full pelotons of 121 riders.

It is well-known that in the so-called “belly” of a cycling peloton you ride “sheltered from wind” and, therefore experience less air resistance. But how much less had not yet been thoroughly investigated. Earlier research with small groups of up to four in-line riders has shown that riders in third and fourth position encounter about 50 percent of the air resistance experienced by an isolated rider (Figure 1). Subsequently, this number has been extrapolated to the whole peloton.

Percentage reduction in aerodynamic drag for four in-line riders due to drafting.

This and similar numbers (40% to 70%) referring to air resistance in the peloton can be found in numerous books on cycling science and also in scientific publications on mathematical models for cycling break-aways. However, professional riders and coaches suggest that when you are well-embedded in the belly of a tightly-packed peloton (Figure 2), you “sometimes hardly have to pedal,” so the air resistance must actually be much lower.

The study was based on numerical simulations with computational fluid dynamics (CFD) and wind tunnel measurements of two pelotons of 121 riders (Figure 3, 4, 5, 6). After intensive validation studies, the peloton CFD simulations were performed with the RANS equations and the Langtry-Menter 4-equation Transition Shear Stress Transport (SST) k-ε model (Menter et al. 2006; Langtry and Menter 2009). This model is based on the coupling of the SST k-ε transport equations with two additional transport equations, one for the intermittency and one for the transition onset criteria, in terms of momentum thickness and Reynolds number. Very high-resolution grids were employed.
in which the laminar sublayer was resolved with wall-adjacent cell sizes down to 0.02 mm (Figure 4). This is required to accurately model boundary-layer transition, separation and reattachment. The total cell count is nearly 3 billion, which renders this a world record as the largest CFD simulation in sports. The simulations were run with ANSYS Fluent CFD software on a Cray XC-40 supercomputer requiring 49 TB of memory and 54 hours wall-clock time for every peloton, most of which was used for writing output files.

Cycling pelotons. Sources: Left: http://johnericgoff.blogspot.com; Middle: www.danpontefract.com; Right: © Cor Vos, reproduced with permission.

Cyclist model geometry in dropped position with definition and values of (1) sagittal torso angle; (2) shoulder angle; (3) elbow angle; (4) forearm angle; (5) hip angle; (6) knee angle; (7) ankle angle.

Details of computational grid on and around the cyclist geometry, the wall-adjacent grid cell is 20 micrometer.
The CFD simulations and the wind tunnel tests yielded the same conclusions. The best position is not in the belly of the peloton, but in the mid rear, where a rider has a drag that is 5 to 10% of a cyclist that is riding alone (Figure 7). That is up to 10 times less than previously assumed. This means that it is as if a rider is cycling at 12 to 15 km/h in a peloton that is speeding at 54 km/h.

This corresponds to the experience by professional cyclists and cycling experts. Tim Wade, at UK analytics firm Dimension Data, in a team car at the first day of the 2018 Tour de France, said: “You can see immediately, from the car beside the riders, that some are hardly pedaling at all”. It is also shown that the benefit for the leading rider can be up to 16% reduction in drag compared to a solo rider. This is a direct result of the subsonic upstream disturbance, in other words, the elliptical mathematical character of the governing partial different equations for subsonic flow. To some extent, a peloton resembles public transport: by riding together, everybody benefits.

One should not misinterpret these results. They do not at all imply that an amateur cyclist can ride along with a peloton of professional cyclist when he or she is well embedded in the peloton. This might be possible for a short distance and under the conditions of our study, i.e. a straight, flat road and a tightly packed peloton. But as soon as the rider take a bend, the so-called accordion effect sets in, the peloton stretches out and the resistance becomes much larger. So there is no reason whatsoever for less respect for professional cyclists and their efforts. Rather, this study indicates how difficult and impressive it is for a rider to escape, stay out of the grasp of the peloton and finally prevail.

The scientific article (open access) can be downloaded here: https://www.sciencedirect.com/science/article/pii/S0167610518303751.

The two peloton configurations.
Highlights

Aerodynamic drag in cycling pelotons

References


Drag of every cyclist in peloton A as a percentage of the drag of an isolated cyclist riding at the same speed. Background of the figures (b) and (c) are contours in a horizontal plane at 1 m height of mean wind speed (m/s) and mean pressure coefficient, respectively.

Setup of peloton configuration A in the wind tunnel at Eindhoven University of Technology.