Implicitly coupled pressure-velocity solver for car aerodynamics

Henrik Rusche[*], Tessa Uroić[+] and Hrvoje Jasak[+]

[*] *Wikki GmbH, Braunschweig, Germany*

[+] *Faculty of Mechanical Engineering and Naval Architecture (FSB)*
University of Zagreb, Croatia

The aerodynamic design of a car is important as it plays a significant role in the behaviour of a vehicle. Investigating flow features is useful for the optimisation of the aerodynamics which results in a reduction of fuel consumption, more comfort (less noise, better ventilation) and improved driving characteristics (stability, handling).

For a racing car, it is important to achieve a large negative lift (downforce) while minimising the drag. Drag usually comes from frontal pressure when a vehicle pushes the air out of the way, and from the vacuum created at the rear when the air molecules are not able to fill the empty space left by the vehicle body. The third component is the boundary layer effect, i.e. the friction between the car and the air. Drag acts in the direction opposite to the velocity vector. Downforce (negative lift) pushes the car into the road, which increases traction. Good traction is extremely important for behaviour of the car in the corners.

There are two options for estimating the forces acting on a vehicle: wind tunnel measurements and Computational Fluid Dynamics (CFD) calculation. The financial and time aspect make CFD a better solution. The car aerodynamics components investigated in this work were the diffuser [2] and a rotating wheel [1]. Additionally, flow around a generic road car was simulated. The results of the simulations were compared to experimental data [1, 2].

Implicit formulation of the pressure-velocity system was used for these simulations. Systems of equations are dominated by inter-equation coupling terms. The conventional methods solve the system in a sequential manner, solving each equation separately, [3, 4].

Modern High-Performance Computing clusters with substantial memory resources have enabled development of coupled algorithms which rely on linearisation of cross-coupling terms and solving the system in an implicit manner. The benefits of the coupled approach are lower time-to-solution and higher stability. Performance of the coupled solver is benchmarked against the conventional segregated solver.

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