An Analysis of Drag Force Components and Structures in the Wake of a Detailed Road Vehicle Model by Means of SPIV

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The three-dimensional flow field of a 1:4 scale road vehicle model has been investigated. Due to the model geometry including a detailed underbody, wheels/wheelhouses and mirrors, the flow field is affected by several interfering effects. Typical for a bluff body in ground effect flow separation at the rear results in the formation of a characteristic recirculation area behind the model. It is a highly turbulent dissipative field including unsteady vortex flow and breakdown. This wake has a major impact on the outer flow as well as on the total aerodynamic performance of the vehicle. To a high degree the drag of a bluff body depends on the wake structure. Analyzing the dominant flow and vortex structures of the wake and specifying their particular impact on drag was the main objective of this study. For the experiment the free stream velocity was set to U=50 m/s with a corresponding Reynolds Number of Re = 3.0 Mio.

![Fig. 1](image1.png) Wind tunnel model (scale 1:4), side view and detailed underbody

The flow field was investigated using Stereoscopic 3C2D-DPIV, force and pressure measurements, as well as oil visualization. SPIV image planes were located at X-positions 1.25x/c, 1.35x/c and 2.05x/c behind the model. The experimental data provides an important insight into the interaction of pressure induced separation and longitudinal vortices of this realistic road vehicle scale back geometry. Also secondary effects such as vortices appearing in the wake can be traced back to their geometric origin. An evaluation of the drag components is carried out. Along with the balance-measured total forces the individual drag components within the flow and at a specific x-position such as momentum loss and vortex drag are calculated by integrating the acquired SPIV field data using the control-volume approach method. The vortex drag is directly related to the in-plane flow components within the measurement plane. The base drag can be calculated with the surface pressure measurements at the base and the base area.

![Fig. 2](image2.png) Stereoscopic PIV Plane 2 at x/c=1.35 showing the x-Velocity

Behind the model two vortex cores appear on the track showing that the wake is governed by an open horse shoe vortex rather than by a closed ring vortex typical for axis symmetric bluff bodies. Also there is an overlay of different flow features like the A-pillar vortex or the separation at the wheelhouses.

The experimental results are then compared to an unsteady numerical simulation using OpenFOAM®. Since a correct numerical prediction of the integral values and the model’s flow field strongly depends on the accurate prediction of the flow separation and the three dimensional interaction between wake and outer flow the SPIV data contains valuable data to validate the simulation. Then again the numerical data of the three dimensional simulation is used to identify and trace back flow structures that appear within the two dimensional PIV planes.