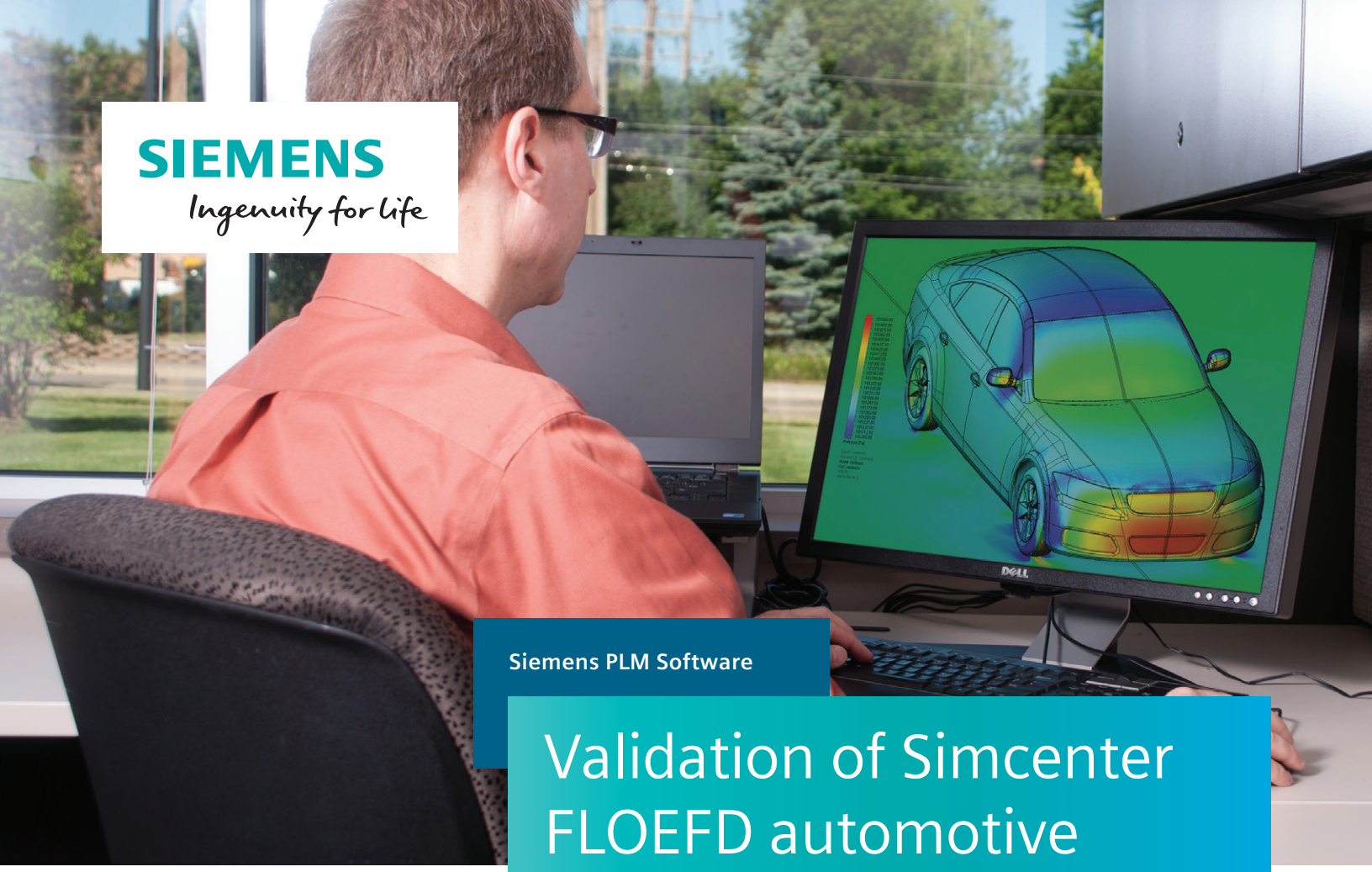

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Validation of Simcenter FLOEFD automotive aerodynamic capabilities using “DrivAer” test model

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Introduction

The aerodynamics of modern cars and trucks has a direct influence on a large number of parameters which define the technical and operating characteristics of these vehicles. Engineers must not only consider drag force reduction but also need to consider lift and lateral force magnitudes, roll pitch and yaw. It is also necessary to incorporate access for air intake via intakes, outtakes and channels for engine and brake disks cooling, and passenger compartment ventilation.

Here, as in other industrial sectors, engineers are faced with a wide range of problems, and the solution of one problem is closely coupled with others. For example, the need for air intake for brake cooling or lift force challenges leads to an increase in head resistance. In order to investigate all factors, solve these challenges to find the best solution, one needs to make use of most effective computation tools that enable accurate estimations of all flow structures of considered vehicles.

Such tool development relies on experimental investigations which become a base for supporting validations of computational techniques and codes. As a rule, simplified car models such as the "Ahmed body" [1] and the "SAE" model [2] are used for this aim. In contrast to specific production vehicles, the simplified models offer a broad spectrum of both numerical and experimental validation data and are, accordingly, well suited for validation purposes. Generic models help to identify and analyze basic flow structures by reducing the interference effects between different areas of the vehicle. However, in the same time this is a shortcoming of such model because they fail to reproduce important parts of the flow field such as the flow in the wheelhouses in combination with rotating wheels which in turn interact with the road surface and influence on the car underbody airflow. In other words, the automotive aerodynamic model detailing level has grown considerably. One of necessary conditions to keep this trend is computational capability growth over the past years. Due to this fact it is now feasible to investigate more detailed models at low expense.

The Institute of Aerodynamics and Fluid Mechanics of the Technical University of Munich, in cooperation with Audi AG and the BMW Group, proposed a new realistic generic car model – the "DrivAer" model [3]. Two typical medium sized cars, the Audi A4 and the BMW 3 series, were chosen for the development of the "DrivAer" model. First, the CAD data from both original vehicles were smoothed and the surfaces were described through characteristic curves. These curves were then merged to generate the new CAD geometry [3].

Generally, vehicle production can be divided into three basic groups, according to the flow phenomena at their rear window: estate back vehicles, fastback vehicles and notchback vehicles. To be able to investigate the specific flow structures of the different vehicle types, the "DrivAer" model was designed as a modular concept with three interchangeable rear end forms and two different underbody geometries: a smooth underbody and a generic underbody based on the simplified underbody geometry of the Audi A4.

For Simcenter FLOEFD™ calculations the geometry with fastback rear end and smooth underbody was chosen. In addition, mirrors and wheels were added (figure 1). An oncoming airflow speed of 16 m/s was used in the calculations. This speed (57.6 km/h) represents a car average speed within a city.



Figure 1. Experimental "DrivAer" car model in wind tunnel.

The initial SmartCells™ computational mesh is rather coarse, about 300,000 Cartesian cells. It is enough for geometry resolution and provides a quick determination of general flow parameters around the car. During the calculation, automated Simcenter FLOEFD technology for "adaptive mesh refinement" for flow singularities

was used. The technology makes it possible for mesh refinement in regions with high flow parameter gradients that improve computation accuracy and reduces computational resource. The final adapted mesh consisted of around 1.5 million cells (figure 2).

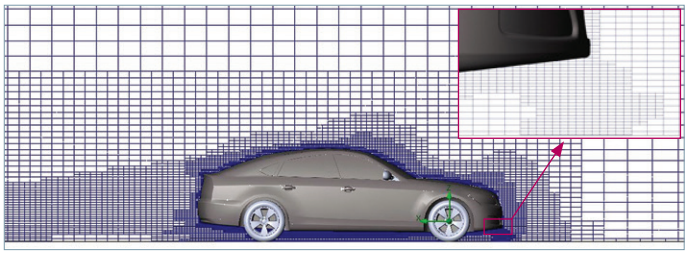


Figure 2. Computational mesh fragment.

To evaluate Simcenter FLOEFD computational accuracy, the calculation parameters were compared with experimental data taken from Heft et al [3]. The experimental value of drag coefficient is 0.243 [3].

To compute car aerodynamic characteristics several mesh configurations, as well as steady and transient solution modes were used. Calculated head drag coefficients and relevant error levels are presented in Table 1. It can be seen that discrepancy between Simcenter FLOEFD calculated and experimental values lies within ~4%. It is obvious that a small mesh size provides a slightly better results but further fragmentation does not lead to serious accurate improvements and slow down overall calculation time. The same error level is observed for calculated pressure coefficients and velocity distributions (figure 3-7). It should be noted that it took a couple of hours to get calculation results for the medium mesh by means of a 16 core 2 processor PC desktop.

Project Name	C_d	Error
Steady medium mesh (1600k)	0.238	2.06%
Transient coarse mesh (650k)	0.234	3.70%
Transient medium mesh (1500k)	0.237	2.47%

Table 1.

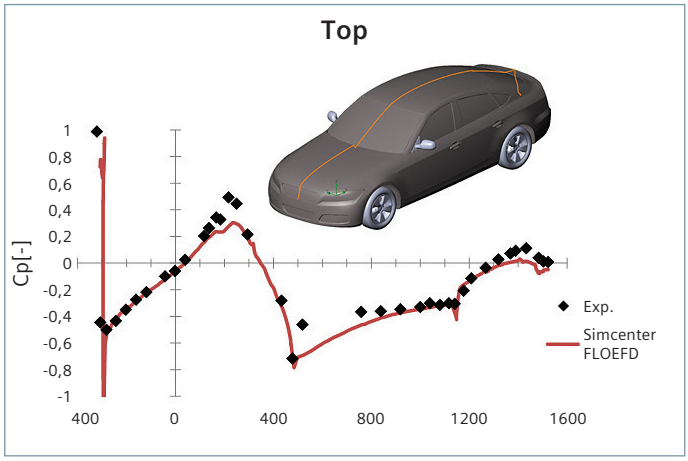


Figure 3. Distribution of pressure coefficient at top of the car at centerline.

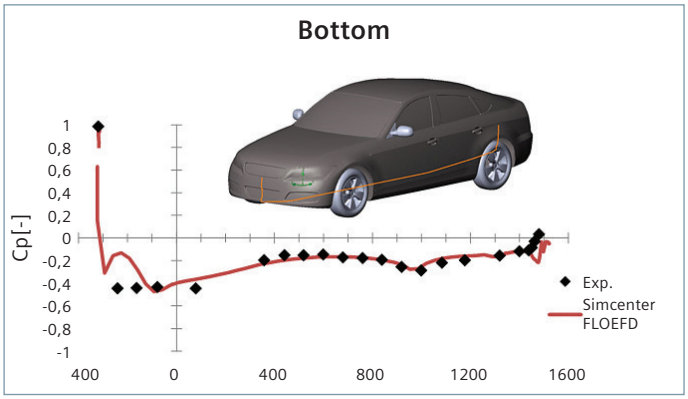


Figure 4. Distribution of pressure coefficient at bottom of the car at centerline.

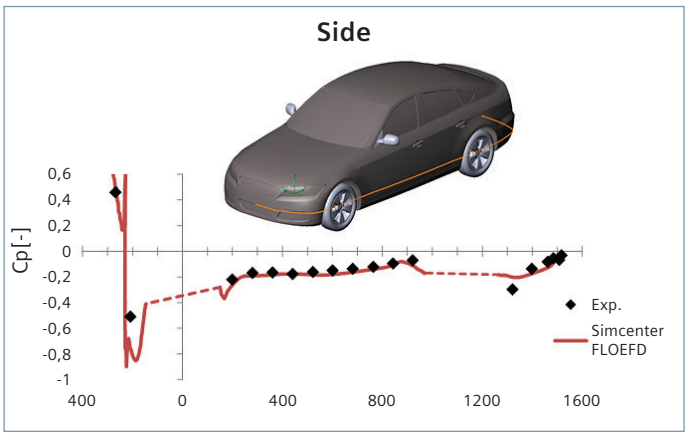


Figure 5. Distribution of pressure coefficient at side surface of the car at height 0.6 m above the ground.

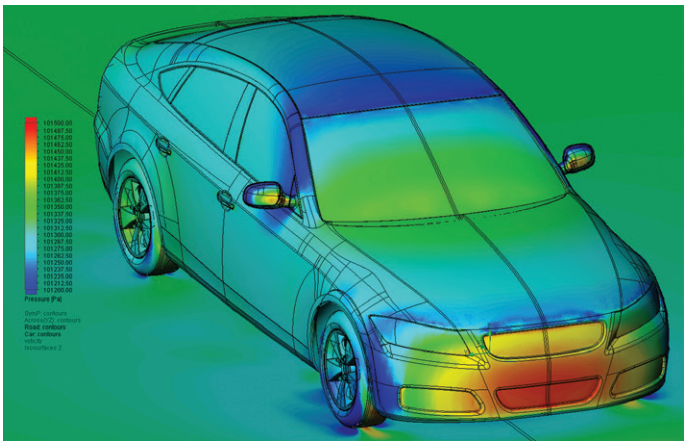


Figure 6. Computed pressure distribution at the car and road surfaces.

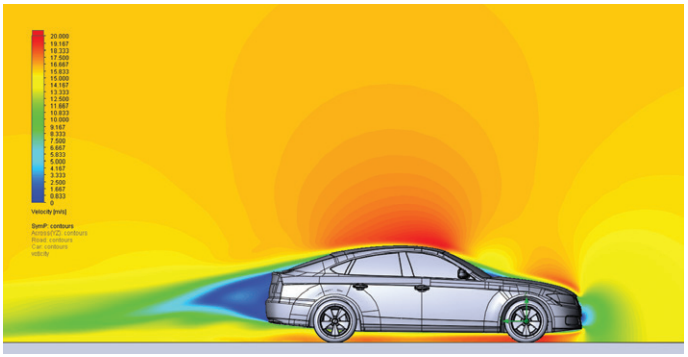


Figure 7. Computed velocity distribution at symmetry plane.

The transient calculations, enable us to observe and analyse serpentine vortexes in wake. It should be noted good resolution of the circulation zone behind the rear end of the car and complex and lengthy vortex structures into the car's wake (figure 7-9) which have an important effect on its aerodynamic drag.

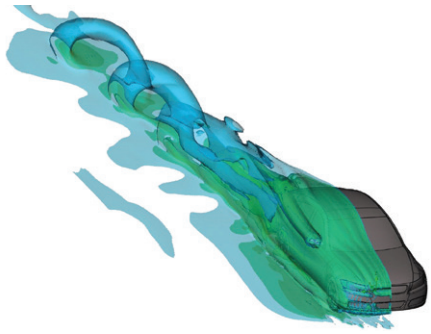
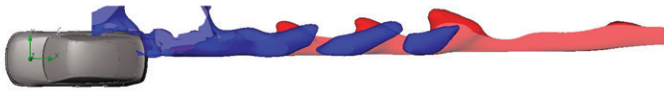


Figure 8. Q-criteria isosurfaces after transient calculation.

A – Direction – blue (positive) / red (negative)



B – Colored by its value

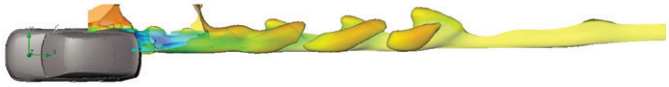


Figure 9. Computed lateral velocity (Y-component).

In general, obtained results are evidence of the efficiency of mathematical models and computational procedures used in Simcenter FLOEFD, especially when coarse mesh is employed. It can be stated, that Simcenter FLOEFD is able to estimate main car aerodynamic characteristics quickly and efficiently as well as determine general flow structures around the vehicle and take concept decisions. These capacities make Simcenter FLOEFD one of the key CFD tools in vehicle design processes.

References

1. Lienhart, H., Stoots, C. and Becker, S. "Flow and turbulence structures in the wake of a simplified car model (Ahmed model)", DGLR Fach Symp. der AG STAB, Stuttgart University, 2000.
2. Cogotti, A. "Parametric study on the ground effect of a simplified car model", SAE Paper (980031), 1998.
3. Heft, Angelina I., Indinger, Thomas, Adams, Nikolaus A.. "Experimental and numerical investigation of the DrivAer Model", Proceedings of the ASME 2012 Fluids Engineering Summer Meeting, FEDSM2012, July 8-12, Rio Grande, Puerto Rico, 2012.

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