EARLY AND EFFICIENT

Optimization potential in the early phase of aerodynamics development

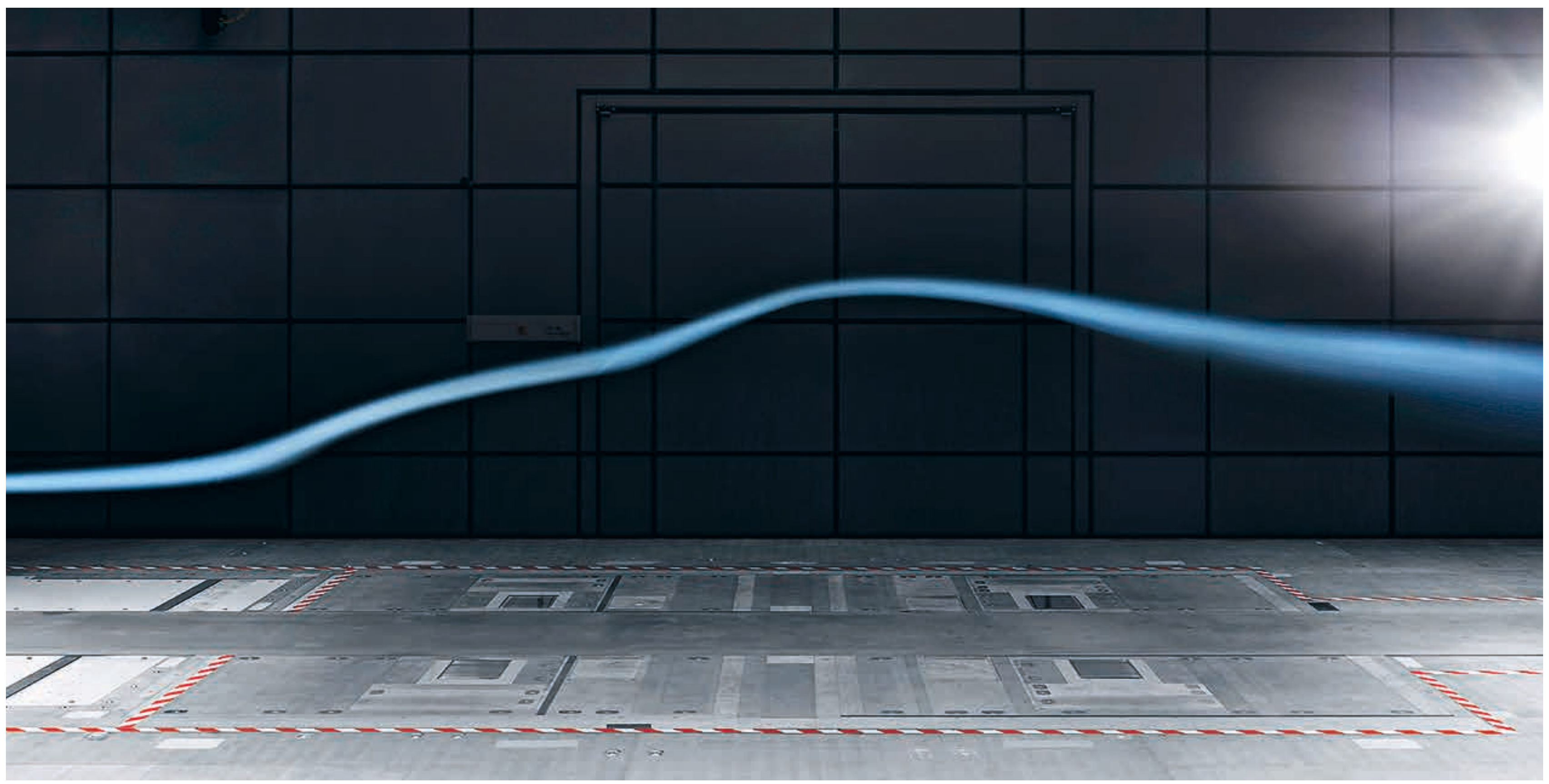
____ Aerodynamic optimization plays a central role in all Porsche sports cars—always have. Even in the very first Porsche vehicles, a great emphasis was placed on good aerodynamics. This contributed to many triumphs on the race track in vehicles presumed to be outmatched by the competition. And the engineers don't just design Porsche models using exceptional aerodynamics—they do the same for other manufacturers and industries as well. In particular the early phase of aerodynamics development offers great potential for efficiency enhancement.

By Thomas Aussem and Marcel Straub

The aerodynamic forces acting on a vehicle are enormous. They rise in relation to the square of the vehicle speed; and at a speed of approximately 250 km/h they reach a level that causes an airplane to lift off. The task of an automobile aerodynamics engineer with performance-oriented vehicles is to utilize these forces to generate downforce to enable higher cornering speeds and driving stability. At the same time, the drag is reduced to the greatest extent possible to enable low consumption, low CO_2 emissions, and high top speeds.

Aerodynamics play a major role in deciding whether the vehicle will meet the desired objectives. New test cycles, new requirements in the field of electromobility and the further tightening of legal requirements will make having low aerodynamic drag an ever more important factor in the future.

Porsche Engineering offers customers in the field of aerodynamics the possibility to transfer knowledge gained in sports car development to their own projects. The range of vehicles that can benefit from this is not restricted to sports cars. From compact sedans to SUVs, all vehicle classes can profit from the engineers' many years of experience. Customers can expect a development process tailored to their specific needs including access to the entire aerodynamics testing facilities at the Development Center in Weissach.



This visualized air flow reveals the form of a familiar silhouette.

The project scopes range from consulting to measurement support to taking on complete responsibility for aerodynamics development.

Aerodynamics is more than just the C_D value

The drag is the central unit in modern automotive aerodynamics development and at speeds over 80 km/h represents the dominant factor in overall driving resistance. As a dimensionless coefficient, the C_D value is a means of quantifying the aerodynamic quality of the shape of a vehicle and enables direct comparison of different vehicle sizes and classes.

Another aerodynamic spec is the lift coefficient C_L, which is distributed among the front and rear axles. This coefficient expresses the lift and downforces generated by the flow around the vehicle contour. But it's not just these absolute values that are critical. One significant factor for driving dynamics is aerodynamic balance, i.e. the distribution of the forces on the front and rear axles, in order to ensure outstanding driving stability, especially at high speeds.

These traditional disciplines have led to the development of new fields of activity in which aerodynamics have a direct influence on the development process (see the illustration on the next page). The close link between aerodynamics and thermodynamics is particularly noteworthy. All of the air flows for the purposes of cooling and ventilation have a direct effect on the overall aerodynamic performance of the vehicle. In most cases, these secondary flows are associated with losses. Thus the principle: as much as necessary, as little as possible.

As the challenges of aerodynamics development have risen continuously, the development tools have kept pace and can handle any task in modern aerodynamics development. Porsche, therefore, has remarkable aerodynamics testing facilities at its disposal. The latest addition is an aerodynamics and acoustics wind tunnel for 1:1-scale vehicles, which also enables road simulation (see the article "Precise and Flexible" from page 16). The new wind tunnel has been in series production use since early 2015 and is helping master the challenges of tomorrow. The Weissach Development Center also has a 1:1-scale vehicle wind tunnel without road simulation capabilities, as well as a wind tunnel for 1:3-scale aerodynamics models. External customers can also make use of these resources through Porsche Engineering. The range of development tools is nicely rounded out by the use of computational fluid dynamics (CFD). This involves creating, calculating, and evaluating digital aerodynamics models with a high degree of detail and millions of cells. Thanks to modern computer clusters, accurate results are available overnight.

Aerodynamics in the early project phase

The early phase of a vehicle project is especially relevant for aerodynamics development. At this stage, it is possible to extensively influence the vehicle shape together with the styling department in order to achieve aerodynamics objectives. Within a defined set of limitations, there is still a great degree of freedom in terms of optimizing the basic shape, and changes to the vehicle shell generally remain cost-neutral. To fully exploit the aerodynamic potential of a project and achieve the desired objectives, it is essential to react quickly, flexibly, and cost-effectively to the various changes in the project. Porsche Engineering applies an integrated aerodynamics process comprised of measurements and optimizations in the 1:3-scale model wind tunnel and virtual CFD simulations. This enables the optimal combination of the complementary advantages of both methods.

The 1:3-scale aerodynamics model makes it possible to model optimizing shape modifications and evaluate their effect in the wind tunnel in a very short amount of time. ›

THE DIVERSITY OF AERODYNAMICS: CHALLENGES AND OBJECTIVES

- Drag
- Lift balance
- Engine cooling
- Engine ventilation
- Soiling
- Component forces
- Draft stop
- Aeroacoustics

This allows not only for the evaluation of the effect on the aerodynamic coefficients, but above all also the impact on the appearance of the vehicle, together with the stylist. Like this, up to 30 different model configurations can be examined on a single day. The use of a scale model has two advantages: First, it is significantly cheaper both in terms of build costs and wind tunnel costs compared to a 1:1-scale model; and second, the wind tunnel time can be used much more effectively with the 1:3-scale model because changes can be implemented more quickly.

In the early phase of a project, multiple styling variants are usually created in parallel. The creation of a large number of wind tunnel models for each of the designs would be very expensive and the reaction times between the data release and evaluation would be too long—this is where CFD simulation shows its advantages. On the prepared digital platform data-set, the styling designs can be quickly swapped out and thus efficiently evaluated. This makes it possible to assess the aero-dynamic potential of the various styling variants at a very early stage in the project.

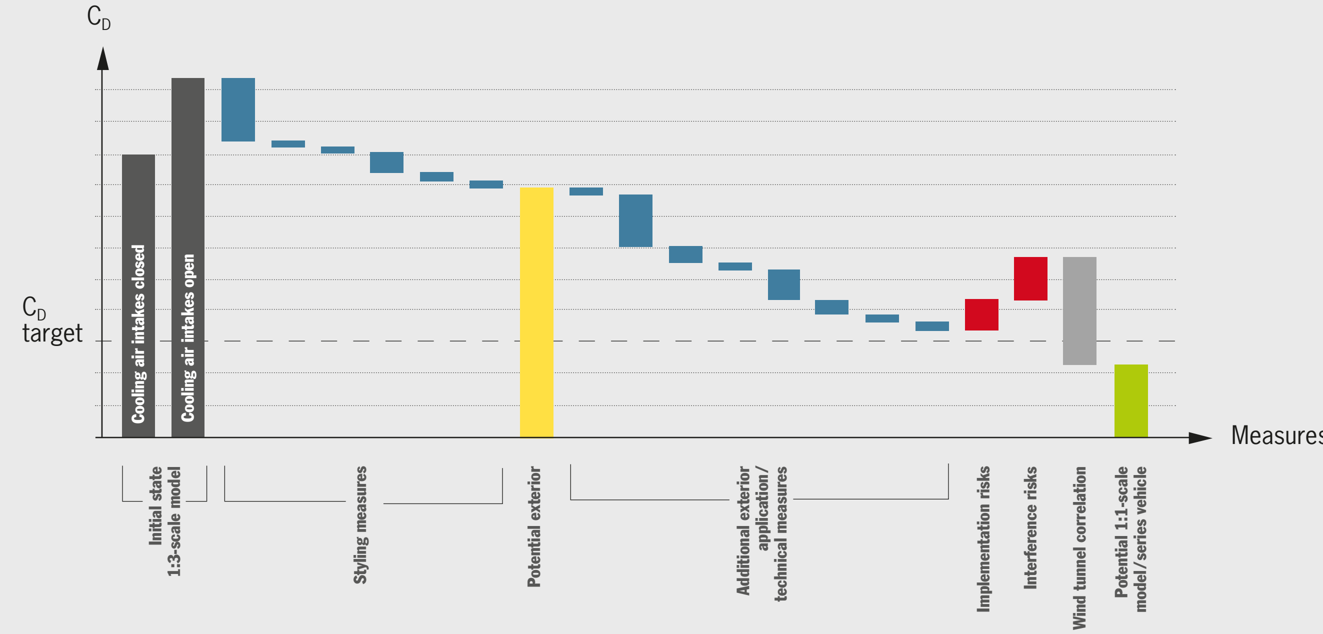
Optimization with the wind tunnel model

In model design, the primary consideration is the cost-benefit ratio, with the degree of detail of the models being the decisive factor. Porsche model design runs the gamut from simple foam bodies to complex flow-through bodies (DSK) with clay exteriors for modeling shape optimizations, as well as model radiators outfitted with pressure sensors, the mapping of engine compartment flows and a precisely detailed under-body. Based on the customer's objectives, a model mix is developed which achieves the optimal aerodynamic result in view of the specified budget framework.

The greatest advantages of development with scale models are in the flexibility and degree of freedom in the wind tunnel. A shape change can be defined and transferred to the aero-dynamics model by an experienced modeler within just a few minutes. Wind-tunnel feedback is immediate. The coefficient changes can be evaluated online and incorporated into the next configuration change. And it's not only possible to achieve optimizations through the addition or removal of clay—the effect of add-on parts such as spoilers or wings can be determined on the spot as well. It is therefore possible to assess the aerodynamic efficiency of different measures and support concept decisions at an early stage.

The results of CFD simulations also support work in the wind tunnel here, too. The virtual development method manifests its huge advantages in terms of flow visualization. Flow separa-tions, vortex structures, and pressure and velocity distributions can be analyzed with great precision from nearly every conceiv-

TARGET VALUE SCALE (SCHEMATIC ILLUSTRATION)



able viewing position and sectional viewpoint. A morphing tool also enables rapid sensitivity analyses of factors such as rear end lengths, rear end heights, or windshield and rear window angles. The insights thus gained can then be applied to the 1:3-scale wind tunnel model for targeted optimization. The result is an aerodynamically optimized vehicle model. The measures can now be discussed with stylists or deve-lopment engineers in the presence of the model. Additionally, the model is scanned, for example with a 3D laser scanner, so that it can be made available in a digital format to the styling and technical departments. Based on the diverse potentials for optimization, a forecast of the target for the later series production vehicle is determined (see also the illus-tration above). Elements such as the underbody covers and radiator grill shutters that will later be developed in detail in the 1:1-scale wind tunnel vehicle are already taken into account at this point.

The target of optimization in the wind tunnel and CFD simula-tion is to implement enhancements in the project. In many cases, new solutions must be worked out with other technical depart-ments and the styling department. This is also a part of the scope of services offered by Porsche Engineering. Porsche engineers, with many years of experience, support customers on-site with their process knowledge in representing proposals before decision-making bodies as well as in the implementation of the defined measures in order to achieve the best overall package.

Conclusion

The importance of aerodynamics will continue to rise in the future. The objective will be a further reduction of CO_2 emissions and consumption by reducing drag while also generating downforce for optimal driving characteristics and comfort. The aerodynamics engineers at Porsche Engineering approach this challenge with the intelligent combination of computational fluid dynamics and real measurements—and not least, with the experience gained through the development of sports cars. ■