Aerodynamics and Thermal Management

Interaction in the context of vehicle development

____ The constantly rising pressure on carmakers' development departments to reduce fuel consumption and exhaust emissions while maintaining current comfort and quality standards has led to intense development activity in the fields of aerodynamics and thermal management.

By Patrik Gisch

New wind tunnel in Weissach

In addition to simulation and calculation methods, test facilities such as wind tunnels, climatic wind tunnels, and test tracks remain important for development engineers in their work. As part of the ongoing expansion, a new wind tunnel—where engineers can test vehicles at wind speeds of up to 300 kilometers per hour—is being built at the Porsche Development Centre in Weissach. This state-of-the-art wind tunnel will meet future requirements for vehicle development, in which energy efficiency will play an increasingly important role. The new facility will help developers sharpen Porsche's already formidable expertise in the fields of aerodynamics and design.

Exceptional design combined with optimal aerodynamic efficiency have been classic Porsche hallmarks from the very beginning. As the wind tunnel will not be open solely for internal Porsche designs but also available for external customer projects, the facility has direct access to the adjacent design studio and separate entrances for discreet work on development projects.

A broad range of activities

One typical and widely known field of application for vehicle wind tunnels is optimization of the aerodynamic drag coefficient value (Cd value) of a vehicle as an important contribution to reducing consumption and improving performance. But aerodynamic drag coefficient is not the only focus in aerodynamics development. Engineers also concentrate on a range of other factors that at first glance may not be apparent as traditional aerodynamics issues. Other issues include improving a vehicle's driving stability through precisely balanced aerodynamic lift forces on the front and rear axles, directional stability, and crosswind behavior. These factors contribute to driving safety as well as enhancing performance, for example during use on the racetrack.

A Porsche 911 in the wind tunnel: a typical scene in the field of aerodynamics development

Aerodynamics and styling define the classic brand design

As aerodynamic development work necessarily also influences the shape of the vehicle, the aerodynamics and styling disciplines work together in a symbiotic relationship. For example, aerodynamics measures and components must have not only a technical function but also, by being visible or invisible, support the classic design language of the brand in the vehicle's design.

Aerodynamic measures on the vehicle's underbody and wheel well areas, or the reduction of flow through losses at radiators, represent the greatest potential for "design-neutral" aerodynamic optimization, thus allowing the vehicle stylists greater freedom in designing the outer shell.

More comfort through optimal aerodynamics

Beyond efficiency factors, performance objectives, and safety requirements, in modern vehicles comfort aspects are an increasingly important part of the quality equation and thus impact the decision to buy as well as customer satisfaction. Draft avoidance in convertibles or vehicles with mobile roofs, keeping side windows and exterior mirrors free of soiling, and reducing wind noise are examples of requirements that aerodynamics engineers have to examine closely and optimize from a comfort standpoint, because comfort is a top priority.

The most promising optimization approaches determined digitally (without test prototypes) in the early stages of a vehicle's development using calculation and simulation tools ›

Aerodynamic forces are analyzed in minute detail in the wind tunnel using state-of-the-art visualization and measurement technology.

are tested extensively in later stages of the development process in wind tunnels and optimized further to achieve objectives. Moreover, component forces caused by air flowing around and through the vehicle are analyzed and reduced as necessary in the wind tunnel. Using state-of-the-art visualization and measurement technology, the aerodynamic forces on doors, hoods, windows, sunroof, rear view mirror glass, and the expansion lids of convertible roofs can be measured, visualized, and modified.

The aerodynamics engineers from Porsche Engineering also regularly put their experience and methodology to use in developing or optimizing products from other industrial sectors: for example, designing a small wind power plant (wind turbine), working on trains, or paint shops.

Interaction of aerodynamics and thermal management

One of the core tasks for aerodynamics engineers is securing cooling and ventilation functions by providing for an adequate and homogeneous flow of cooling air. By achieving a flow-optimized overall cooling air path, the cooling air resistance—in other words, the proportion of the overall air resistance caused by cooling air flow—can be reduced to a minimum. Here, aerodynamics and thermal management interact directly.

In particular the efficient design and determination of the size and position of the cooling air intakes, the design of supply and exhaust air ducts, and not least the appropriate radiator through which the air flows deliver discernible contributions to reducing wind resistance. These components and systems are designed and optimized by aerodynamics engineers using 3D computational fluid dynamics (CFD) flow calculation simulation tools. Thus in addition to traditional engine cooling, aerodynamics can also be used to cool brakes, power units, fluids, and charge air.

Diverse thermal management solutions

At Porsche Engineering, the field of thermal management extends from traditional cooling system design for combustion engines to control of all heat flows in the vehicle, assisting the reduction of fuel consumption, thermal management of alternative drive concepts, and thermal interior comfort.

Beyond computer-aided heat management simulations in early stages of development for designing and dimensioning cooling systems, prototypes and pre-series vehicles are used to test and assure the cooling function, particularly in the Porsche climatic wind tunnel or appropriate test courses.

Efficient cooling air flow reduces the overall air resistance.

Precise routing of air around and through the vehicle for optimum aerodynamics and targeted cooling and ventilation

Thermal management on the test track

To test cooling functions, the 2.9 km course at the Porsche proving grounds in Weissach is set up like a racetrack with long straightaways, fast curves, inclines, and switchbacks. It is also very well suited for testing component and coolant temperatures under the influence of extreme acceleration phases (positive as well as negative acceleration).

With its 12.6 km circular high-speed track, the proving ground at the Nardò Technical Center in southern Italy, which Porsche Engineering took over in May 2012, offer the opportunity to determine component and fluid temperatures at high speeds and sustained top speeds. These conditions enable testing of the transmission oil cooling, among other factors. The track is approved for speeds of up to 330 km/h, and the outermost lane allows speeds of up to 240 km/h without centrifugal forces.

Direction: future

Future technologies present new challenges for thermal management. In particular, projects in the field of alternative drive concepts require exceptional development acumen with regard to thermal management. The task for thermal management specialists lies in developing new solution approaches for thermal management of hybrid components, electric drives, electrical components such as power electronics, and naturally traction batteries as well.

But it is not only the cooling function that demands new developments and innovations. The heating of components and the vehicle's interior in cold ambient temperatures must also be resolved efficiently. The exhaust heat previously provided for "free" by the combustion engine is not available in purely electrically driven vehicles and must be provided by other means. The efficiency of these measures has a direct impact on the range of the electrically driven vehicle. Using the thermodynamic test bench developed by Porsche Engineering (featured in Porsche Engineering Magazine 2/2012) in combination with a 300-kW source-sink high-voltage test bench, these development tasks are implemented for components, systems, and complete vehicles for customers worldwide.

Further expansion of the Porsche infrastructure as well as the many years and diversity of experience of the engineers in the field of aerodynamics and thermal management will enable Porsche Engineering to keep pace with rising customer expectations and legal requirements. ■