Porsche Engineering
MAGAZINE

Nardò
Technical Center
40 YEARS 1975 2015

CUSTOMERS & MARKETS Special features of the Chinese automotive market
PORSCHE UP CLOSE The new Cayman GT4—Rebels, race on
ENGINEERING INSIGHTS New method for measuring component temperatures

ISSUE 1/2015

www.porsche-engineering.com

Comprehensive Vehicle Development

ENGINEERED TO THE END.

Malte Radmann and Dirk Lappe,
Managing Directors of Porsche Engineering

Dear Readers,

_____ always looking at things from a holistic perspective is in our genes. Whether it's an individual part, component, or system, we don't simply focus on the individual function, but ensure its intelligent integration in the right environment. As an engineering services provider of Porsche, we cover all areas of vehicle development, always consider individual processes comprehensively, including all preceding and subsequent steps, and also provide supporting activities. In this issue's focus theme we present in detail our comprehensive approach to vehicle development.

"Rebels, race on." is the apt slogan for the new Porsche Cayman GT4. In this article we present the new GT racer with its own unique mid-engine concept in a bit more detail. We also talk with two industry experts about the Chinese automotive market and future challenges in vehicle development.

We would like to congratulate the Nardò Technical Center on its 40th anniversary! In our special supplement "40 Years of Future-Oriented Testing," the proving ground is presented with interesting articles and fascinating photos from years gone by and today before yielding the floor to customers and friends to share their personal experiences and stories about this unique venue.

A variety of exciting topics awaits—enjoy the read!

Sincerely,
Malte Radmann and Dirk Lappe

About Porsche Engineering

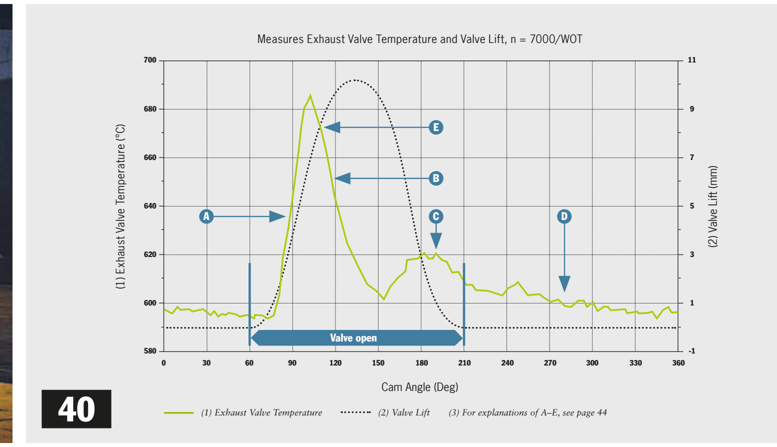
Creating forward-looking solutions was the standard set by Ferdinand Porsche when he started his design office in 1931. In doing so, he laid the foundation for today's engineering services by Porsche. We renew our commitment to that example with each new project that we carry out for our customers.

The scope of services provided by Porsche Engineering ranges from the design of individual components to the planning and execution of complete vehicle developments, and is also transferred to other sectors beyond the automotive industry.

28 SPECIAL SUPPLEMENT

40 YEARS OF FUTURE-ORIENTED TESTING IN NARDÒ

Since its founding in 1975, the Nardò Technical Center has established itself as the partner for complete testing services and high performance.



Nardò Technical Center 40 YEARS 1975 2015

CAYMAN GT4
Fuel consumption
city: 14.8 l/100 km
highway: 7.8 l/100 km
combined: 10.3 l/100 km
CO_2 emissions: 238 g/km
Efficiency class: G

News

SUCCESSFUL START

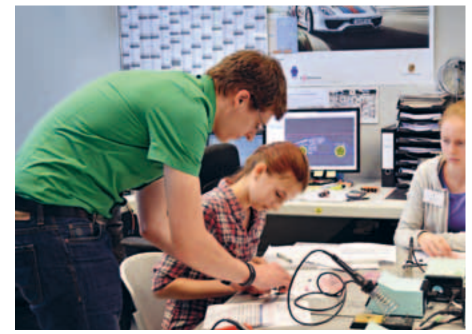
INAUGURAL CEREMONY IN SHANGHAI

___ The inaugural ceremony for Porsche Engineering (Shanghai) Co., Ltd. in December of last year turned out to be a very auspicious beginning for the new location in China. The subsidiary of Porsche Engineering Group GmbH, Weissach, invited guests from the worlds of business, science, and politics to join in the festivities. The two managing directors of Porsche Engineering, Malte Radmann and Dirk Lappe, were pleased to receive the congratulations of longtime customers and political representatives.

With regard to current and future challenges in automotive development, Dirk Lappe promised to offer sustainable concepts that would fulfill the requirements of Chinese customers. “We develop solutions for the future—a future that we‘re very much looking forward to,” said Dirk Lappe in his speech. ■

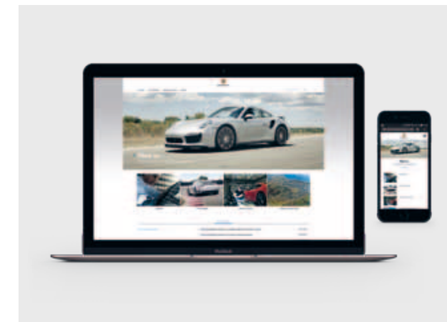
News

GIRLS’ DAY OPENS UP NEW PERSPECTIVES



___ Once again this year, interested schoolgirls had the opportunity to get a closer view of the engineering profession at Porsche Engineering as part of Germany’s nationwide “Girls’ Day 2015” campaign. The 22 girls were treated to detailed introductions to the technical departments such as electrics/electronics, body, complete vehicle, drive technology, and engines. The girls also gained practical experience in the technical environment in small groups. For example, CAD designs were created and temperature measurements taken on the thermal test bench. During a joint lunch, the girls were able to talk to the engineers about their everyday work lives as developers. ■

RELAUNCH OF THE COMPANY WEBSITE



___ Informative. Compact. Current. These are the watchwords of the new company website from Porsche Engineering. The website presents the company’s comprehensive range of services clearly structured and in detail, with impressions from the company and working world of a globally active engineering services provider. The website is optimized for mobile devices and was adapted to current internet use patterns. Thanks to a clear design language and the lean structure, relevant information is available in a clear and compact form. ■

www.porsche-engineering.com

PORSCHE TAKES OVER CLIMATIC WIND TUNNEL

___ With the acquisition of a climatic wind tunnel specially designed for the areas of air conditioning, safety and emissions from Modine Europe GmbH in Filderstadt-Bonlanden, the sports car manufacturer has further expanded its development capabilities. The facility will continue to be made available by Porsche Engineering to other vehicle manufacturers and suppliers for development tests. The proximity of the climatic wind tunnel to the Porsche development center in Weissach will further promote the efficient development of sophisticated projects. The acquisition is part of an investment package aimed at equipping Porsche’s development location for the future. The highly modern facility is suitable for all vehicle variants from sports cars to commercial vehicles. ■

COMPREHENSIVE
VEHICLE DEVELOPMENT

Less is more. These three words sum up the challenge faced by the automotive industry today and the impetus for the massive efforts to find solutions. Less consumption, lower emissions, less weight. But also more power, more variety, and more customer benefits. And all this with ever-shorter product cycles and with requirements and conflicting objectives that can only be resolved with new ideas, better technologies, and solid experience. Porsche has all of those things. As the original core and integral subsidiary of Porsche AG, Porsche Engineering puts its OEM experience at the disposal of its customers. Vehicle development is our core competence. The meticulous planning from the design and development of a new vehicle is described in the ***Product Development Process*** section on page 10. Our engineers combine their experience with the customer's core processes to create a custom project. For all of our ***engineering services***: in engine development, our specialties include the intelligent and time-saving use of modern simulation tools (page 20), which help us design even more efficient engines. A cross member (page 14) designed for the specific requirements of an electrically powered research vehicle that combines less weight with greater stiffness highlights the new paths being taken in the field of hybrid lightweight construction. Porsche Engineering also offers ***supporting services*** that allow customers to focus on their core business and leave the increasingly complex peripheral tasks to us.

PRODUCT DEVELOPMENT PROCESS

Concept & Styling ▸ Construction Design ▸ Calculation & Simulation ▸ Testing ▸ Industrialization

ENGINEERING SERVICES

- Complete vehicle
- Body
- Electrics/electronics
- Chassis
- Powertrain

SUPPORTING SERVICES

Project management, procurement and supplier management, production planning, logistics planning, launch management and series support, change management, FMEA and functional safety, sales and after-sales planning, tolerance management, weight management, information systems, legal regulations, approval management

Well Considered

The product development process

By Steffen Rudert and Jens Trumpfheller

____ The foundation for the success of a product is laid in the product development process (PDP). It includes all phases of development and describes the core processes involved in launching a product on schedule, on budget, and with the desired quality. Porsche Engineering makes its process capabilities and experience from sports car series development available for a wide variety of development projects in the automotive industry and beyond. This experience allows to take account of preceding and subsequent PDP phases in every development. Porsche Engineering can cover the entire product development process itself, work within the framework of customer-specific PDPs, enhance existing PDPs, or develop completely new ones.

The product development process (PDP) is a living construct and is always the result of continuous learning and ongoing development based on known and new challenges. The strong market orientation of automobile manufacturers (Original Equipment Manufacturers or OEMs) and the increasingly fast reaction times that this requires mean that development times are growing ever shorter. At the same time, the rising degree of individualization in combination with exacting quality demands leads to great technical complexity. Moreover, the PDP must ensure effective networking between internal and external resources from the development stage onwards and integrate development partners and system suppliers.

As a rule, each automobile manufacturer has its own specific PDP, yet there are some basic commonalities that take on different shapes according to the company's philosophy and circumstances. There might be differences in the length of the concept phases, for example, or in the placement of individual design-freeze milestones.

Fundamentally, the overall PDP process is divided into main phases with milestones known as quality gates between them. As synchronization points, these quality gates are used to check the status of predefined criteria which, once fulfilled, trigger the approval of the preceding phase and the continuation of the project. The PDP contains interfaces between development, project management, quality, procurement, production, and sales. Thus the PDP forms a detailed procedural model for mapping the simultaneous engineering process and, in terms of methodology, represents the ideal process for creating a vehicle.

Pre-PDP and product definition

The pre-PDP step precedes the actual product development process and serves to flesh out the product idea and integrate predevelopment topics in the project. The outlines are defined in a profile and work begins on a rough assessment of feasibility and the specification of requirements. In addition, the positioning of the product with respect to the competition and in the target markets is determined. Project management gets under way in this phase and establishes the project organization, rough scheduling and initial resource and budget planning.

In the product definition, the departments define their requirements of the product based on the profile. In addition to developing styling designs, this phase also includes analyses of the competition and elaborations of the concept. Ultimately, the result of this phase is a design for the overall vehicle, including the rough concept, the package, safety considerations, production technology, and aerodynamics values. Thus both technical objectives and an economic outline have been defined.

During the early phases of pre-PDP and product definition, the core processes take place under the aegis of the manufacturer. Porsche Engineering can provide technical expertise and advisory services for processes. The spectrum of services ranges from concept studies to concept evaluations and benchmark studies. Existing concepts are evaluated in terms of technical feasibility, decisions regarding producibility and production technology are made, and styling recommendations are presented. Porsche Engineering provides support in integrating long-term development trends in the concepts such as downsizing, e-mobility and lightweight construction, as well as modern assistance systems and connectivity options. Alternative concept proposals may also be developed.

In many cases, Porsche Engineering is involved in such predevelopment and research projects because the customer lacks or has limited experience with a new technology and the expertise in using it. Porsche engineers have a wide range of technological expertise in this area as well as many years of experience across the entire vehicle spectrum as well as in the non-automotive field.

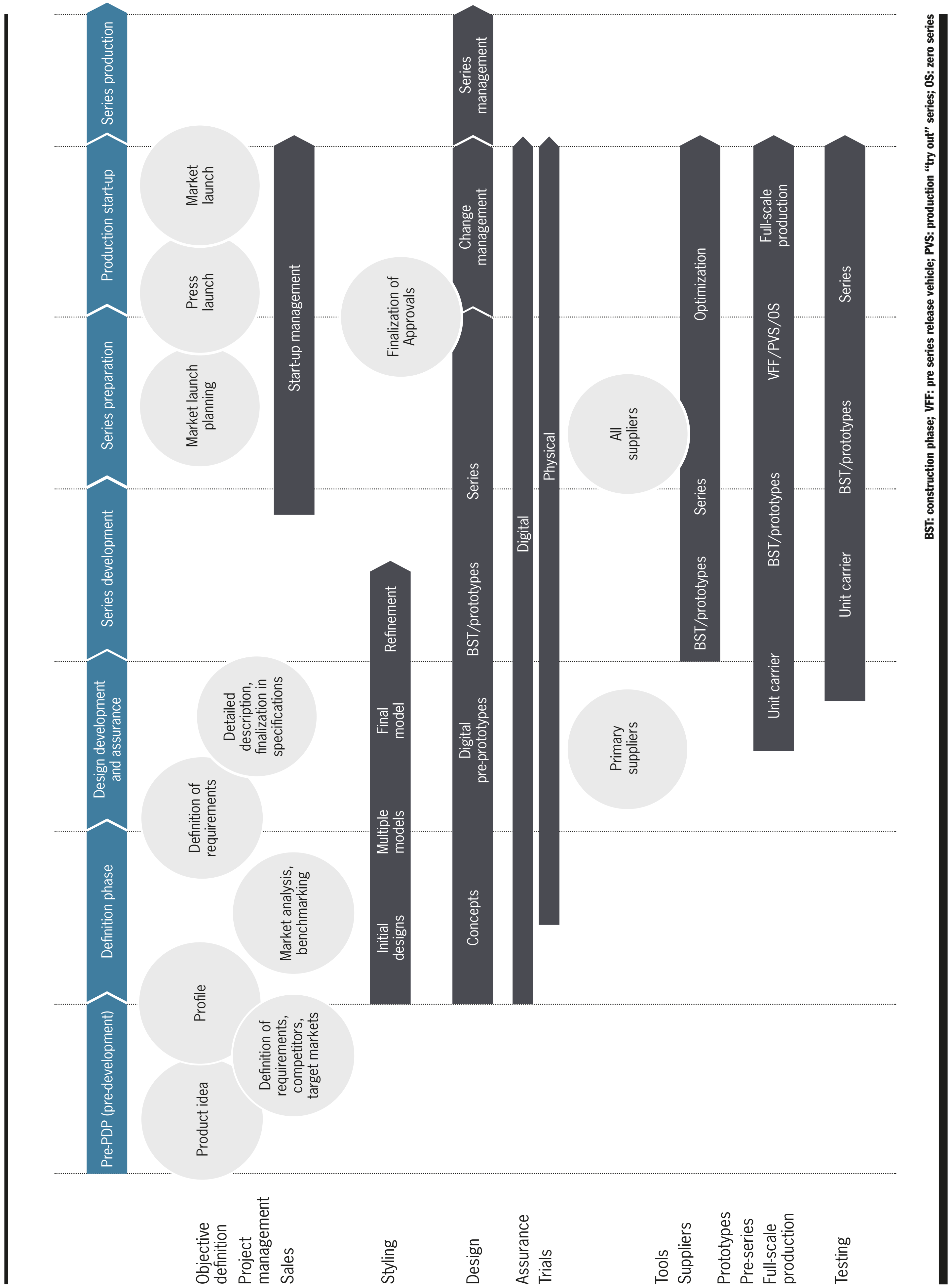
Concept development and assurance

The concept development and assurance stage involves the design and production of digital prototypes as well as detailed planning and finalization in the specifications. Beyond simulation, initial testing with unit carriers takes place. Following selection of the final styling model, refinements begin that will continue into series production of the vehicle. Typical project requests in this PDP phase, as well as in pre-development projects, concern the development and creation of a demonstrator or prototype. The starting point is rough drafts or product profiles provided by the customer. Based on them, Porsche Engineering takes over all development processes from design to calculation and trials as well as the setup, application and testing. Moreover, all development-related functions such as procurement, logistics, and quality management are handled internally and contribute massively to the successful implementation of the project. Porsche Engineering can also count on reliable partners specialized in prototypes, limited-run, and pre-series. After assembly, the prototypes can be tested on test benches.

When a prototype is being created, many of the PDP processes are conducted in a concerted manner. Porsche Engineering has developed its own processes and systems to accompany and control the creation of prototypes. This includes not only devising and maintaining the bill of materials but also a multi-level approval system and an in-house system for test plans. But this is no immutable apparatus; instead, the entire system is designed to react flexibly to customer requirements and, if needed, to work together with customer systems.

Series development

In series development, the creation of prototypes and the construction phase, the design of the series vehicles and the start of testing all occur in parallel. At the end of this phase, all suppliers have been selected and start-up management takes up its work to prepare the next phase. ›



Schematic representation of the product development process

Like in the conceptual design phase, Porsche Engineering also frequently assumes responsibility for components and modules in this phase. This involves assuming responsibility for components from the concept and sample phases through the pre-series and on into series production. Associated with this task is responsibility for all interfaces between the different development areas as well as with procurement, production, logistics, quality, and sales. Moreover, they have the requisite skills from a process and methodology perspective, such as functional safety (FuSa), FMEA (Failure Mode and Effects Analysis), and tolerance management. With their well-founded knowledge of many customer-specific processes and systems, the engineers from Porsche Engineering can easily occupy an overarching role within the customer's development organization.

Responsibility for components can cover an entire field of application—for instance the complete bodyshell—or indeed the entire vehicle. It can also be highly specific, such as the development of a high-voltage battery or the use of innovative materials (see the article "Precisely Developed: Hybrid cross member made of fiber-reinforced plastic" on page 14). When it comes to testing the construction phase as well as pre-series testing, the Porsche testing grounds in Nardò in southern Italy represent the ideal complement to the development expertise in Germany, Prague and, since late last year, the new location in Shanghai.

Series preparation and full-scale production

Series preparation involves moving closer to series production-readiness through a sequence of staggered pre-series. With the first vehicles in series and series-like facilities, the vehicle manufacturer not only stabilizes its production and logistics processes internally, but also externally as the entire process takes place throughout the supply chain as well.

When the run-up to series production is finished, the actual development activity is at an end and the work of the project organization as well as all development teams is complete. Emerging issues are handled by the series production team, which has already begun its work with the step-by-step hand-over and the finalization of approvals during the pre-series phase.

In the final two PDP phases, the development scopes are handed back and the core processes resume in greater concentration with the customer. Porsche Engineering remains active at this stage—in addition to continuing and finalizing development packages from earlier phases—in the industrialization process. The focal points are procurement and supplier management, quality management, production and logistics planning, as well as start-up management. This includes sampling inspection, checking series capability at the suppliers', FMEA workshops in the production field, developing equipment, controlling change management processes, as well as series management following the start of production.

Conclusion

Porsche Engineering is well-versed in development work across a broad range of different contexts. Detailed processes and specifications are implemented with great expertise, often directly in the customer systems. At the same time, the engineers demonstrate great flexibility and creativity in developing custom solutions, both in terms of technology and process, even where the specifications are less precise. While the focus is clearly on the technology, when needed processes can be adjusted pragmatically to bring the projects to a successful conclusion.

In addition to development work with customer-specific PDPs, Porsche Engineering can also add elements to existing PDPs or develop them from scratch. Regardless of what type of development or the phase of the PDP that engineers are currently working on, the preceding and subsequent process steps are always taken into account, or otherwise incorporated into the overall process, in order to ensure smooth integration with the customer environment.

Porsche Engineering is always enhancing its own capabilities and expertise. Its ever-growing expertise in the field of simulation is perfectly in step with the increasing digitization and virtualization of PDPs. And the use of modules and platforms is an effective way to reduce development and procurement costs by increasing the number of shared components. ■

Precisely Developed

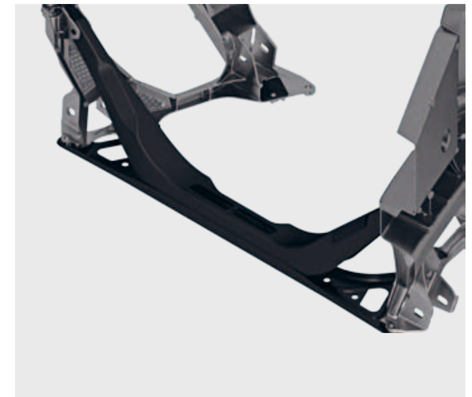
Hybrid cross member made of fiber-reinforced plastic

By Markus Hofmeister and Andreas Tegtmeier

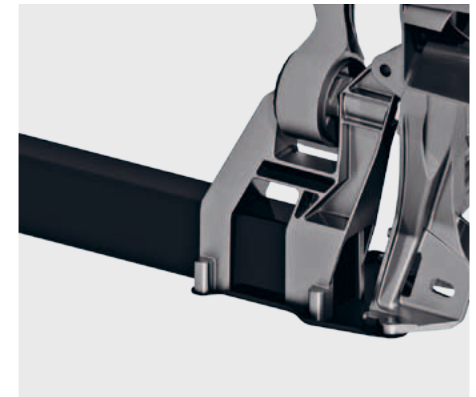
____ Lightweight construction and electrification of the drivetrain are important objectives in modern vehicle development. In combination, they present development engineers with new challenges that call for innovative solutions. Porsche Engineering employs intelligent development methods to meet those challenges. One example is the creation of a structure-stiffening suspension component with composites.

In 2012, Porsche took the lead in the e-Generation (see info box on page 16) research project with the Volkswagen Group research division as a consulting partner. In the project, leading German companies and renowned universities are developing a new generation of components for electric vehicles.

The platform for integrating these groundbreaking components was the current Porsche Boxster, whose basic structure as a mid-engine sports car makes it especially suitable for a purely electric-powered concept car. Over the course of development, nearly all of the car's combustion engine components were removed to make space for other components. Among other elements, a structure-stiffening suspension component in the area of the rear axle was developed. The task of the reference component slated for replacement was to increase the torsional rigidity of the rear as well as the connection stiffness of the rear-axle wishbone to the body. The newly developed component is also subject to other requirements. The



Reference component



Mount for the power unit carrier

developed hybrid cross member made of fiber-reinforced plastic (FRP) is also used to mount the motor of the electric drive unit and serves as torque support.

The development of this component, which was led and largely shaped by Porsche Engineering, ranged from the concept phase to design, optimization and simulation as well as production and testing.

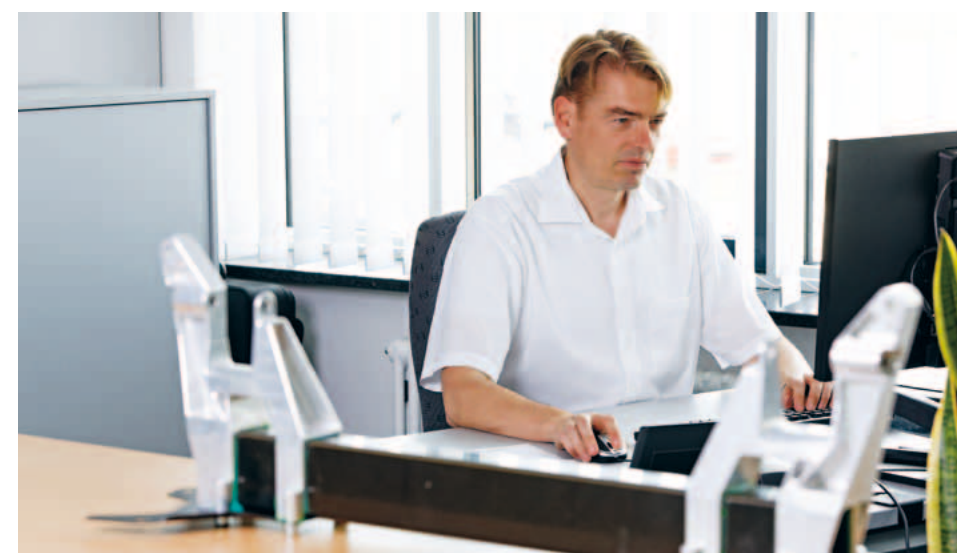
The development methods

In the development of the innovative cross member, the aim, beyond achieving the defined requirements, was to use as little material as possible. The cost angle was also a consideration from the outset with the potential for series production in mind. To achieve these objectives, the engineers at Porsche Engineering employed state-of-the-art development methods for the design and material selection processes.

By selecting the Porsche Boxster mid-engine sports car as the base vehicle, the usable construction space for the design and the defined force-transmission points in the body were pre-determined. A topology optimization in the construction space did, however, enable the creation of a new basic design optimized for the load flow.

As with the optimization of the topology, the virtual assurance of the component to be developed was conducted in part with specialized finite element (FE) programs and the components were calculated by the developers together with software experts. This involved the use of software for linear predesign of the component as well as simulation of the tensions while taking into account non-linear considerations.

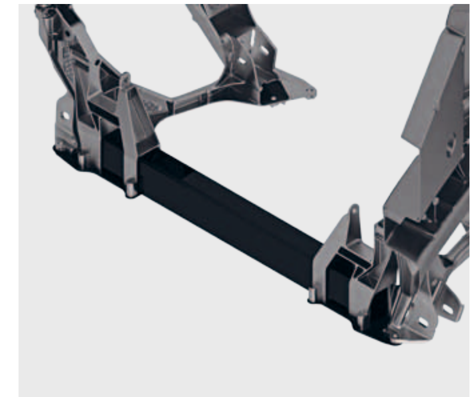
As the properties of fiber-reinforced composites strongly depend on the orientation of the fibers, they have to be aligned in a load flow-appropriate manner to exploit their full potential. Thus the orientation of the composite fibers was optimized through simulation and designed to maximize the material properties. ›



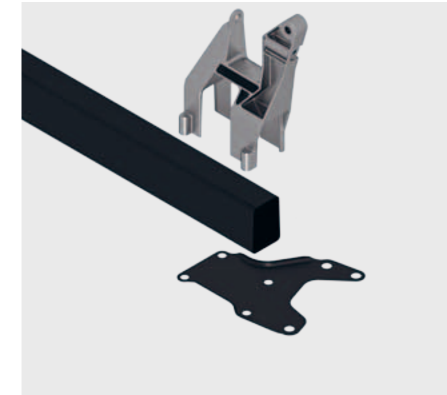
The engineers employ state-of-the-art development methods for the design and material selection.

Structure optimization of the construction space

Areas with different characteristics



FRP hybrid cross member



Individual parts of the cross member

Requirements and material selection

Over the course of initial research, it became clear that the welded sheet-metal construction used in the reference component was not ideal under the new conditions. Weight was the primary consideration in the development of a new component. Every kilogram saved enables increased range, either through decreased driving resistances or by allowing a larger battery.

Material selection is the decisive factor here. Aluminum alloys, high-strength steels and fiber-reinforced composites form a ground floor for components with this purpose in mind. It is very important, however, to select the right material as needed for the right area of application. Useful in this context is a comparison of the materials available for selection with regard to the specific stiffness, i.e. the relationship of the E-module [N/mm²] and the density [g/cm³].

The results for the future component revealed three different areas, all with rather different requirements profiles:

1. A flat area that is determined by the surrounding components; it is imperative that this part be capable of handling the major shear forces that can be expected to emanate from the wishbone.

2. A middle area with a high flexional resistance generated from the connection points with the body.

3. A section that can handle the significant forces of up to ten kilonewtons from the power unit mount.

In the first area, steel is the perfect material owing to the low available construction height of just a few millimeters. It is the best-suited material for passing on the high shear forces without buckling or warping.

For the second section, a design was selected that would enable maximum stiffness at the lowest possible weight. The choice was a profile made of carbon fiber-reinforced plastic. This was perfect for increasing the stiffness of the rear.

To best handle the loads in the third section and support surrounding components, aluminum was selected. In this application, aluminum guarantees high specific stiffness while offering great freedom to shape the material.

A two-component adhesive was used to connect these different materials optimized for their respective tasks. Thus three in themselves essentially optimal subcomponents were combined to form a single component. In short: the best of three worlds.

Characteristics and production-appropriate design

All elements of the cross member were also designed with a mind to subsequent series production. The production method therefore also influenced the design. Common processes in series production were taken into account.

The first area, also known as the closing panel, was manufactured out of ›

e-Generation

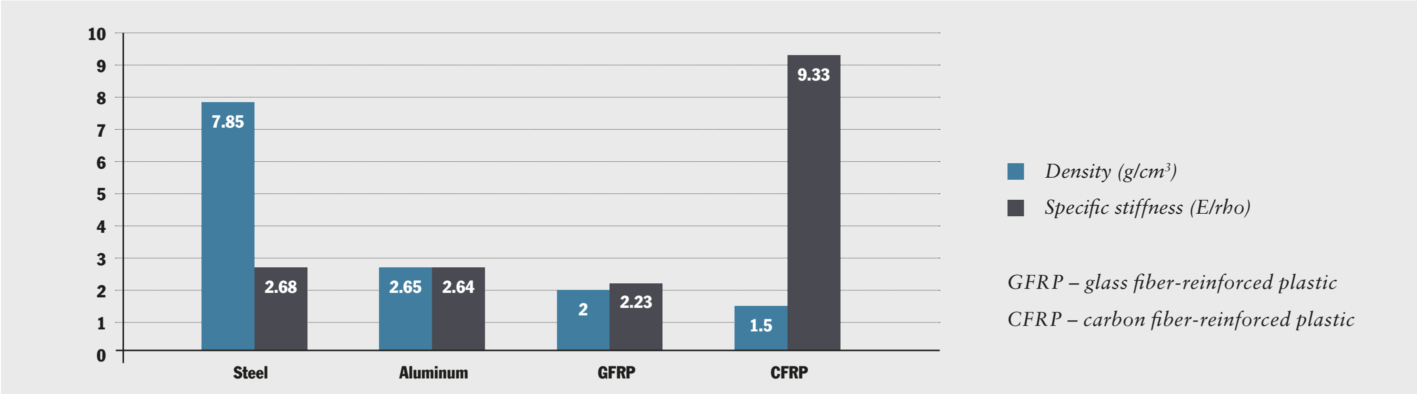
In the current environmental and climate situation, new solutions in the field of vehicle-based mobility are urgently needed. Leading German companies and renowned universities and research institutions joined together to advance the cause of e-mobility as part of the e-Generation project sponsored by the Federal Ministry of Education and Research (BMBF).

The joint project supports the goal of the federal government to establish Germany as a leading market in the field of electromobility with the aim of improving the range, cost, and day-to-day usability of the vehicles.

Electric vehicles are currently still significantly more expensive than conventional vehicles. In spite of the many innovations that electric vehicles require, potential customers expect a good and easy-to-use vehicle. To increase the market appeal of electric vehicles, the costs of the requisite e-mobility components and systems must be reduced drastically. With this in mind, the project is examining the possibility of a module for electric drivetrains.

To increase the range, the use of energy resources must be optimized. Beyond the fundamental reduction of consumption, research efforts in this area also focus on new means of vehicle air conditioning. Reducing the overall weight also contributes to increased ranges, which is why lightweight construction and efficiency-focused measures are also being examined. New generations of drive components coordinated with other components in the overall vehicle composition should result in new potential for greater efficiency as well.

The close collaboration between the vehicle manufacturers and important suppliers and universities ensures the market-relevance of the research results and thus creates the basis for rapid market implementation. The aim of the research results is also to improve the competitiveness of the automobile and supplier industry in conjunction with research institutions in Germany and thus pave the way for Germany to assume a leading role in the global marketplace.



Comparison of density and specific stiffness

cold-forming micro-alloyed high-strength steel and given a cathodic coating to protect against corrosion. A positive side-effect of this is a coated component suitable for adhesive application without further preparation.

This material and coating are frequently used in the automotive sector, which aside from having the desired characteristics, also results in low material costs.

Through two screw connection points, the closing panels form the lower interface to the body.

The consoles—i.e. the third section—are made of aluminum. Die cast molding is preferable for the manufacture of the part because this method, compared to other casting methods, allows smaller wall-thicknesses and a great deal of freedom in shaping. The material was one used in the suspension area for subframes and suspension arms. Each of the aluminum consoles has a fixed mount for the drive unit and together they form the upper interface to the body.

The heart of the cross member is a square profile that emerges as a pultrusion profile via the pullwinding method. The pultrusion method is currently the most cost-effective means of manufacturing fiber-reinforced elements in larger unit numbers. Continuous fibers running lengthwise in the profile direction are shaped through a thermosetting matrix and saturated with an epoxy resin. To incorporate fibers crosswise to the profile direction in the component as well, the continuous fibers are additionally wrapped in fibers at an angle deviating from the pultrusion direction.

This makes it possible to generate almost any fiber orientation or configuration without breaks for joints in the fibers. Thanks to this production method, the profile used in this component demonstrates greater robustness and stiffness than a comparable part made of high-strength steel—at a quarter of the weight.

The subcomponents are joined with a two-component adhesive from the bodyworks. The adhesive procedure was specially developed and tested for this cross member.

The adhesive alone is enough to ensure an absolutely adequate bond between the components. Since suspension components, as in the present case, are usually safety-relevant components, the aluminum consoles are additionally fastened to the closing panels with screws. This ensures that even in the case of a hypothetical failure of the adhesive bond, limited functionality would be assured.

Thanks to the use of modern development and production methods, the cross member that emerged from this process is twice as stiff as the reference component. It also integrates the function of the unit carrier and yet weighs five percent less than the reference component.

Assurance and production

To ensure proper functioning in the vehicle, the cross member and all joining techniques were simulated and evaluated with calculation programs. One particular challenge in this regard was validating the FRP profile and the adhesive connection.

After proving the requisite robustness and calculating the stiffness, initial prototypes of the cross member were created. This was always done with a view to potential series production: even the first components were produced and joined so as to be as similar as possible to cross members produced automatically in any later production process. The aluminum consoles were designed in a cast-compatible fashion and the closing panels were manufactured in line with the envisioned series production method. The process safety of the joining process was also subjected to continuous examination and optimization throughout the process.

Before being used for the first time in the vehicle, the FRP hybrid cross member had to prove its long-term robustness on the test bench. This involved simulating an endurance test at the Weissach testing grounds that approximates the strains of a vehicle lifetime in a very compressed format. The component went on ultimately to pass the test without any significant damage being detected.

To check the cross member after the exacting ordeal on the test bench, various methods of examination were used, including computerized tomography. After all of these assurance measures, all vehicles in the e-Generation project were outfitted with the component.

Evaluation and completion

The development of the FRP hybrid cross member shows what can be achieved with an intelligent material mix combined with new component development methods and established production procedures. This opens up an alternative to the existing more expensive and time-consuming methods such as the ones used in the motor-racing context.

The untapped potential for lightweight construction within the field of hybrid component design opens up the possibility of using innovative development approaches to build lightweight and stable components at relatively low costs. An entirely lightweight construction-oriented design of the cross member could enable additional weight savings of up to 30% without compromising in terms of the requirements. ■

To check the cross member, various means of examination were used, including computerized tomography.

Exactly Calculated

Concept and CAD-based simulation in engine development

By Matthias Penzel

____ Shortened product life cycles and thus significantly reduced development times on the one hand, highest customer expectations in terms of development quality on the other: the engine development process of Porsche Engineering proves that these demands are not necessarily mutually exclusive, thanks to the early integration of the simulation activities in the development process.

For decades, components and modules were developed on the basis of the experience and simplified calculations of the designers. Until the first prototype was tested, it remained an open question whether the theory would work in practice.

With the introduction of computer-aided engineering software, the developers have been provided with powerful tools that enable them to push the design to the limits of the physical laws and material properties. The traditional time-consuming development loops, based on the trial-and-error process, can be therefore dramatically reduced and the mechanical and durability tests can be limited to the validation of the final design.

In the early design stage, however, the simulation has to cope with a critical trade-off: on the one hand a reasonably mature design status is the prerequisite for starting the calculation activities; on the other hand, waiting until the final design is ready would lead to enormous time losses. In fact, the simulation process consists of a series of necessary sequential steps from the meshing to the calculation and finally to the post processing, each of which requires a certain amount of time. Moreover, the results of the simulation may determinate design modification; the time necessary for this activity must also be planned. Staggered component release can only mitigate the problems: in a complex mechanical system, such as a combustion engine, the components are mutually interdependent and must be developed simultaneously. The key word to solving the issue is frontloading.

Time saving through frontloading

In the near future, no major calculation-time reduction for highly sophisticated computer-based simulation, is expected. Thus, in order to optimize the efficiency of the development process, it is crucial to accurately coordinate the design and simulation activities. For years, engine development at Porsche Engineering has resolutely followed the path of frontloading, through an early integration of simulation in the development process as well as the systematic implementation of CAD-based calculation.

The frontloading strategy is based on four pillars. The first stage consists of simple math-based programs for the preliminary component dimensioning. At Porsche Engineering, these programs are often developed during an internship or a master's thesis and they offer the students the possibility of coupling the theoretical knowledge to the practical application.

The second pillar is represented by the CAE tools—finite-element (FE) methods or computational fluid dynamics (CFD)—that are embedded in the CAD environment and operated directly by the designer. This minimizes the effort and the risks of the model conversions. Furthermore, it facilitates the work load distribution between the simulation and design groups, enabling the team to handle larger projects without additional support. Here again, the aim is to reduce development loops, limiting the time and cost intensive fully-fledged simulation to the final design. The relatively simple-to-operate CAD-based simulation tools have been intensively validated by Porsche Engineering through calculation comparisons and component tests; they can be reliably used for preliminary calculation up to a certain degree of accuracy.

The third pillar consists of fully fledged simulations that are executed in a dedicated software environment and run on powerful computers. Yet, again using such high sophisticated software, there is potential for project schedule tightening. In particular, for structural questions, for example the cylinder head and block system, an early FE calculation can help identify critical areas and provide additional information for the cylinder head gasket design. Since, at this stage, the maturity of the design is typically low, a great deal of experience is required to interpret the calculation results properly and derive the right conclusions. For this task, the engine department is supported by a vast database of similar projects that have already been calculated with the same methodology. Even if a wide range of fully-fledged CAE tools is methodically employed, the backbone of a development strategy is not represented by the software capabilities, but rather by the expertise of the engineers who continuously question the output of artificial intelligence and systematically proof the plausibility of the simulation results.

Structural optimization of components and assemblies

The last pillar is structural optimization. This practice is particularly effective at the very beginning of the development process, in the concept phase. Especially for innovative components, with no comparable predecessors, the structural optimization makes it possible to design solutions that lie in close proximity to the theoretical optimum from the beginning. ›

Using CAE tools minimizes the effort required for and the risks of the model conversions.

The conceptual design of completely new components and systems is both the most rewarding, and the most challenging, task for an engineer. Assuming a certain set of expected loads, the task is to find the best possible material distribution within a given design space. Recalculations of older designs proved that very experienced engineers can achieve impressive results even without CAE support. The die-cast crankcase of the original 911, for example, represents a perfect example of harmonious design and homogeneous stress distribution. But, even if stiffness and deformation behavior can be correctly imagined by experienced designers, more complex topics, such as the acoustic behavior of complex structures, lie beyond the limits of intuition. Using simulation-based structural optimization, it was also possible to lighten the old 911 block by several hundred grams, without compromising the functional characteristics and acoustics.

Structural optimizations generally impact component design significantly. With reference to the initial design, a weight reduction of 10 to 20 percent can be typically achieved or, alternatively, the stiffness of the component can be improved by the same factor. However, the related drastic design changes are only possible in the early concept phase. Later design changes generate major additional costs and increase development risks: test results from previous design stages are, often, no longer relevant to the improved design. This is the most important argument in favor of the use of structural optimization right at the beginning of the development process.

Structural optimization can also be useful in the context of further development of existing products. New vehicle generation or periodical updates usually aim towards vehicle mass reduction, each area having to provide its contribution. For engine and transmission, structural components frequently offer optimization possibilities, which are particularly interesting when the parts can be considered as closed systems and when the mounting points remain unchanged.

In the context of structural optimization, it is crucial to perform the simulations in a systematic and standardized fashion. At Porsche Engineering, at the beginning of each engine development project, the potential components for structural optimization are identified and scheduled for calculation. The systematic use of this method makes it possible to perform a structural optimization within a single work day, if the boundary conditions are defined and available. This makes it possible to work on unplanned components on short notice, if necessary. At best the simulation is run overnight, so that the next morning the results can be directly implemented in the design.

The term structural optimization refers to and summarizes different techniques such as

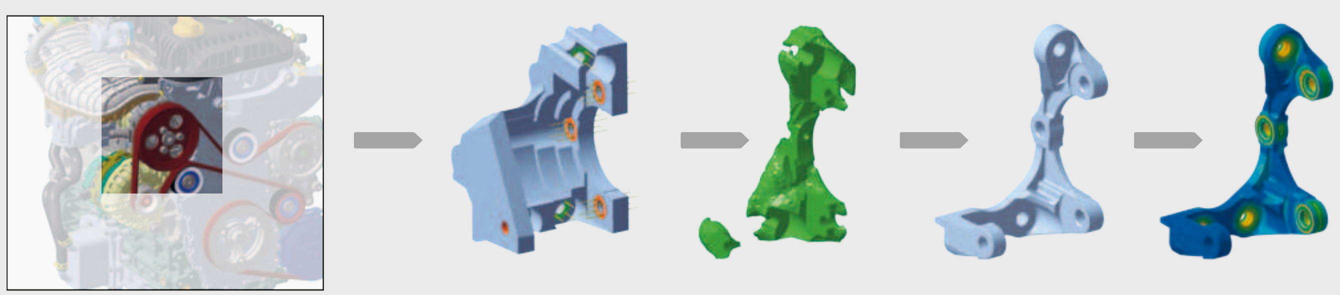
– topology optimization, which focuses on achieving the maximum stiffness with the minimum use of material, in a given design space,

– form optimization, which is particularly appropriate for high-stress component details,

– cross-sectional optimization, which represents a valuable support for the surface design (such as tailored blanks).

CAD-based simulation

Lightweight design through structural optimization



Various application options in engine development

The applications of structural optimization in engine development at Porsche Engineering are usually related to the improvement of component mass and/or stiffness as well as the NVH behavior, targeting specifically defined component eigen-frequencies. The dedicated software allows production-related issues such as ensuring a defined minimum wall thicknesses and avoiding undercut for cast and forged components to be taken into account.

The concrete application options for structural optimization in engine development are extremely varied. The typical examples are load-bearing components such as engine mountings and brackets, but also geometrical details such as oil return passages, connection of the main bearing walls to the block structure and camshaft bearing cap designs are systematically optimized. Beyond the actual technical improvements of the components, an additional side-effect has been noticed: through the constant practice with structural simulations and results analyses, the designers develop an improved sensibility to estimate load cases and predict structural behaviors. These experiences produce, therefore, a beneficial effect in completely different components and applications and, in particular, they help the engineers to quickly identify critical areas and recognize structural weaknesses.

But even with all this, the uses are far from exhausted: in a recent example, during the concept definition of an engine family with a high degree of comonality, structural optimization was used for a DOE (design of experiments) cascade focused on concept-related questions. To put that in more detail, the effects of the bore-to-stroke ratio on engine overall dimensions, engine weight, and crankshaft stiffness have been evaluated and the results have been compared against comparable existing engines.

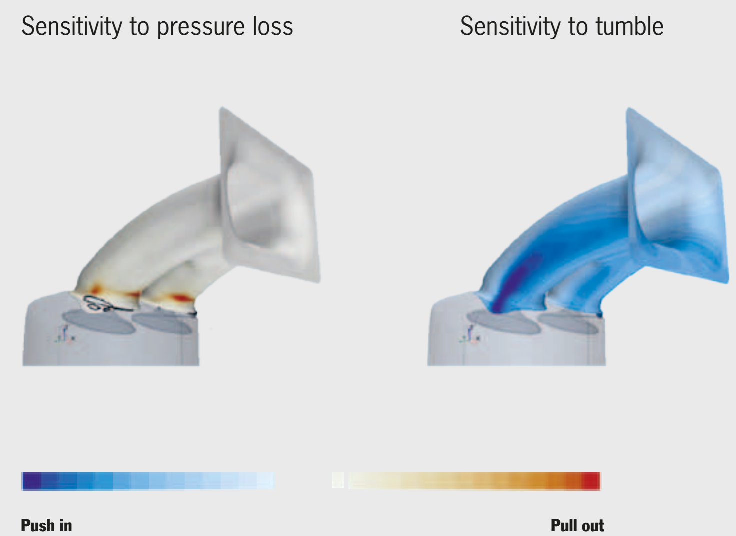
Enormous development potential

At Porsche Engineering, simulation and design methodologies are continuously updated in coordination with each other. New methodologies, such as the recently developed adjoint-based intake port morphing, show great potential to further shorten development times, while improving, at the same time, the quality of the development process.

The time and quality benefits of the early integration of CAE simulations in engine development—and not only there—are plain to see. To fully exploit this potential, the users are required to have a great deal of experience in order to properly assess and interpret simulation results based on early, and therefore not fully mature, component design. ■

Intake port optimization

The optimization tool is used to evaluate the sensitivity of the intake port geometry with reference to pressure loss and tumble.



By pulling out the red areas and pressing in the blue regions, the pressure loss in the port can be reduced while increasing the tumble.

Optimally Supported

Supporting services

By Peter Weidenhammer

____ The spectrum of expertise offered by Porsche Engineering covers the entire product development process. But the know-how of the engineers is increasingly in demand for supporting services as well. The reason is that dealing with the constantly growing complexity of such tasks sometimes requires additional capacities. In such cases, Porsche Engineering assumes the role of a partner that maintains an overview of activities in the respective field of supporting services, provides the requisite expertise and performs the task in its entirety.

Porsche Engineering not only performs pure engineering work but also takes on additional tasks and qualifies the respective component or product according to the applicable requirements. The customer can therefore focus on the core development work that is its actual area of expertise. Farming out supporting tasks makes the customer's job easier. Porsche Engineering also offers these types of services to industries outside of the automotive sector and is flexible in providing the services—development and qualification work is done according to the required standards.

The portfolio of supporting services is divided into various thematic areas ranging from project and supplier management to various planning activities and assessing compliance with legal regulations.

In the project management area, the engineers support the planning and execution of tasks. They concentrate not only on the development of new technologies, but also pay close attention to the frameworks in which the projects take place. Together with clients, they draw up detailed plans and reliably monitor and optimize factors such as cost, quality, and milestones. Implementation is closely tied to the customer's product development process.

With regard to procurement and supplier management, the engineering services provider can draw on its many years of experience in Porsche series production; Porsche Engineering knows what it takes to secure a robust supply chain. Porsche Engineering identifies, selects, and audits suppliers and provides expertise if problems arise. It also includes the planning and execution of projects to improve supplier performance and quality assurance for purchased parts. The customer can therefore count on finding the best partners and suppliers for the manufacture of their products.

With years of experience as a series manufacturer of sports cars under our belt, Porsche Engineering is well acquainted with the challenges in production planning as well as production processes and methods. Over the years, the company has always developed successful solutions by creating innovations and making continuous improvements. This knowledge is brought into the design of assembly lines. Beyond the reduction of production times and costs, the focus is also on increasing process security and identifying the potential for improvements.

Having the right materials at the right place at the right time is the key function of logistics. The basis for smooth series production is detailed logistics planning covering all steps of the product development process. Porsche Engineering supports customers in the concept, evaluation and implementation of all logistics processes and thus guarantees a smooth integration process for new developments.

There's a lot of ground to cover before a new development has reached production maturity and production is stable. With regard to launch management and series support, valuable experience from series production can be applied to the customer's processes and establish long-term improvements. Supplier management and cross-departmental quality control, but also tool tracking and work instructions, help ensure a smooth start for a new product in series production.

Adjustments are frequently necessary to achieve perfectly designed products. That's why it's important to establish internal processes for change management which clearly define when a modification can take place and how it must be documented. Customers are supported and advised in this process. To reduce costs and keep delays to a minimum, cross-model collaboration is a fundamental component and one of the goals of optimization.

Failure Mode and Effects Analysis (FMEA) is an established instrument in the product development process for identifying and correcting errors or potential sources of errors at an early stage in the design of products and the associated manufacturing and assembly processes. Due to the distinction between system, design, and process FMEA, Porsche Engineering takes all potential error sources into account. With regard to functional safety (FuSa), the risks associated with the function to be implemented are determined, thus further reducing potential dangers.

In vehicle development, dimensional management is used as a preventive quality assurance method to ensure fulfillment of visual and functional requirements. This also makes it possible to avoid potential problems before they occur. The overriding objective of dimensional management is to achieve high product quality without rework. Together with a reference point system (RPS), this is achieved through precise specifications on functional dimensions and the joint plan. This is then rounded out by tolerance calculations and a › three-dimensional tolerance simulation (see also *Porsche Engineering Magazine* 1/2013: "Dimensional Management in Vehicle Development").

With legal regulations and market demands calling for vehicles with ever lower consumption and emissions, the importance of effective weight management has never been greater. With the intelligent lightweight construction of the current generation of sports cars, Porsche is once again the reference point. An optimal weight assessment depends on recording and evaluating vehicle mass and center of gravity data. The key is to balance opportunities and risks and continually check whether weight objectives are being achieved through the development process.

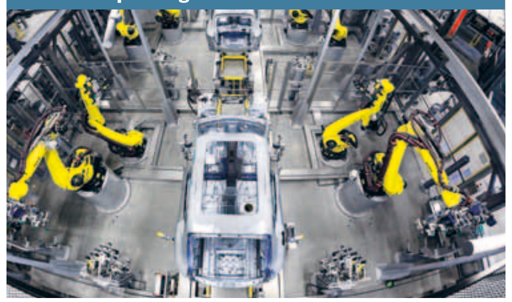
With the growing diversity of variants and derivative models in vehicle development, the demands on information systems are growing as well. The engineers are familiar with these requirements from a variety of assembly and module developments and approach them with innovative and lean solutions for tasks such as product data management, BOM systems and approval management.

Developments do not simply need to fulfill technical requirements and functional demands, but also comply with additional legal regulations. Porsche Engineering provides not only the expertise to ensure that the products are compliant both in their manufacture and characteristics, but also covers proprietary and patent rights for the developments.

Drawing on its series production experience, Porsche Engineering also handles approval management. Regardless of which stage of development the product is in, this encompasses approval management and tracking and thus comprehensive control of the approval process for components and milestones.

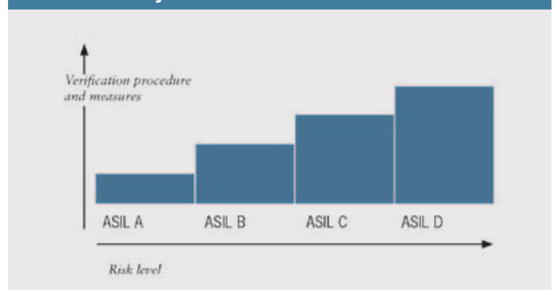
Porsche customers expect not only premium quality, but also exceptional service. The brand is thus an exacting standard for sales and after-sales planning. What that means is that in every development, service concepts are taken into account from the very outset. This ensures that the client's customers will be satisfied with developments even when servicing is required. ■

Production planning



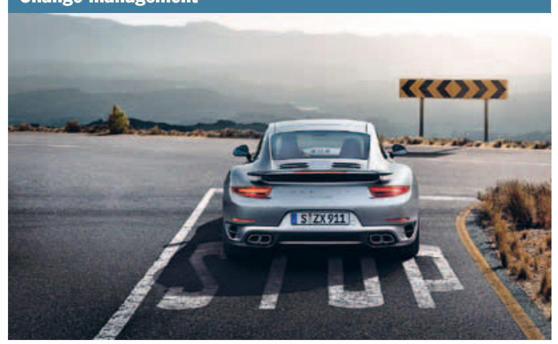
Logistics planning

Functional safety



Procurement and supplier management

Change management



Project management

Sales and after-sales planning

Information systems

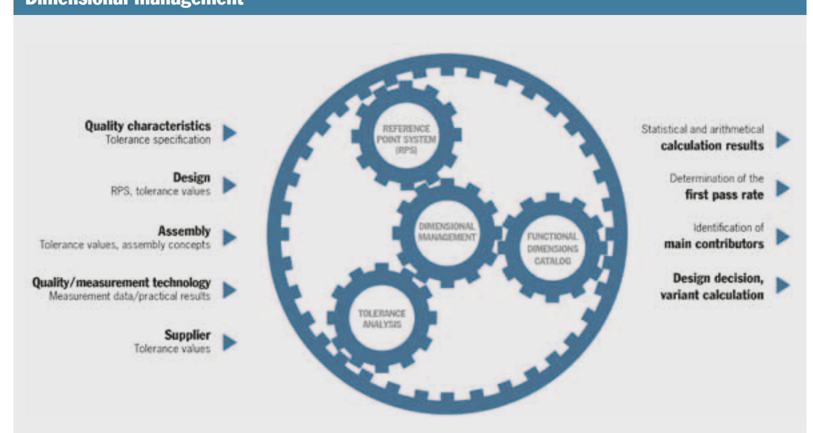
Launch and series management

Approval management

Legal regulations

Weight management

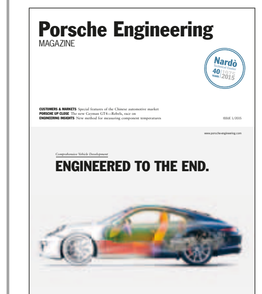
Dimensional management



IMPRINT

Porsche Engineering
MAGAZINE

ISSUE 1/2015



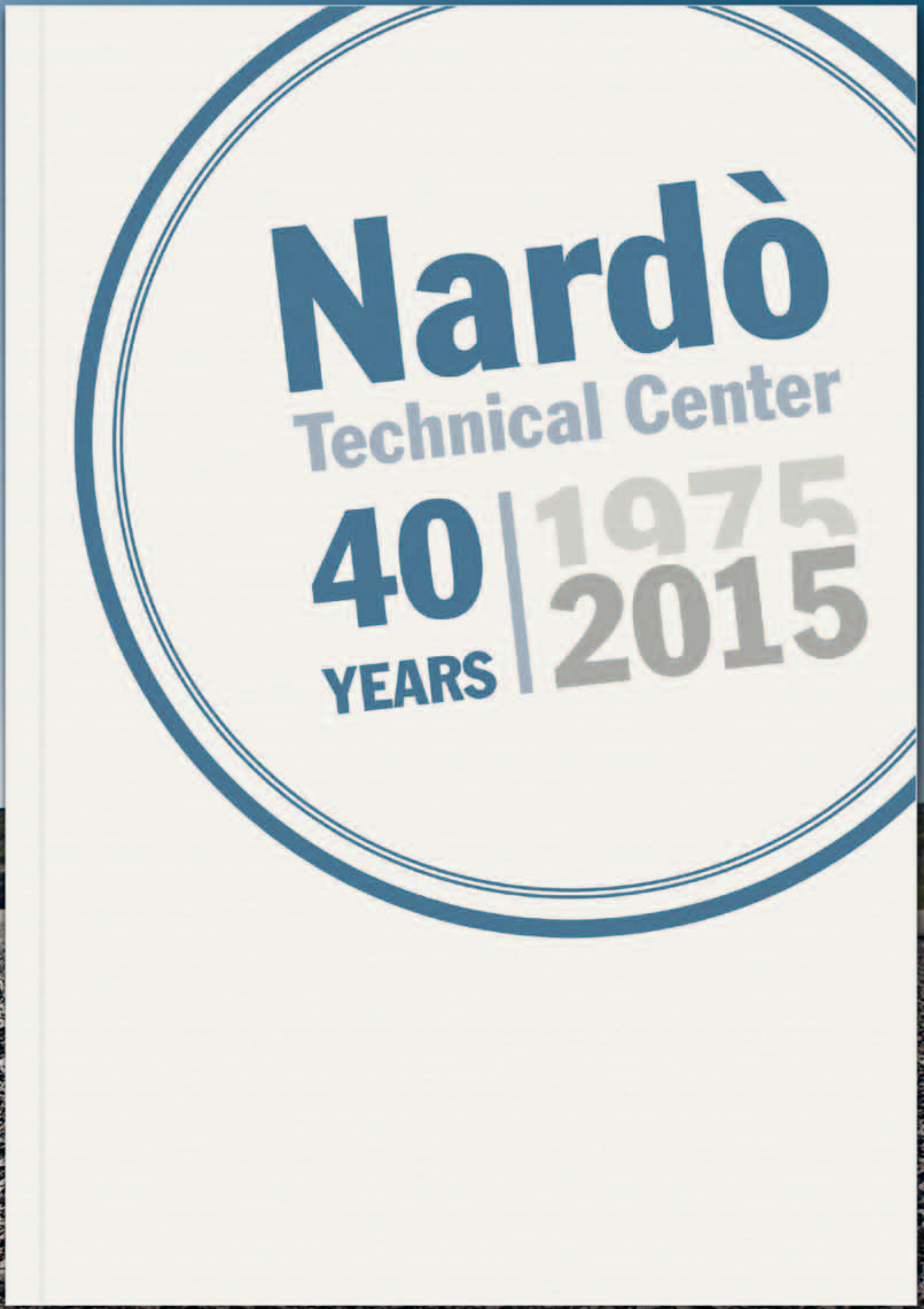
PUBLISHER
Porsche Engineering Group GmbH
Porschestrasse 911
71287 Weissach
Germany
Tel. +49 711 911 0
Fax +49 711 911 8 89 99
Internet: www.porsche-engineering.com

EDITOR-IN-CHIEF
Frederic Damköhler
EDITING | COORDINATION
Nadine Guhl
ADVERTISEMENT
Frederic Damköhler
DESIGN
VISCHER&BERNET, Stuttgart
TRANSLATION
RWS Group Deutschland GmbH, Berlin
PRINTING
Kraft Druck GmbH
76275 Ettlingen

40 Years of Future-Oriented Testing

____ The Nardò Technical Center perfectly unites tradition and the future like no other proving ground. Without losing its original character, from the very outset Nardò has planned ahead and left room for innovation. This is where testing for top performances takes place. For the entire automotive industry. Innovative and ready for the future.

Come and join us in the south of Italy!



Individual, Networked, Efficient

Future trends on the Chinese automotive market

____ China represents one of the largest and most interesting markets for the automobile industry. Thorough knowledge of this market, the ability to innovate, and new technologies are all of great importance in meeting the demands and requirements of Chinese customers. Porsche Engineering has been working with Chinese customers for more than 20 years now, and has recently strengthened its activities yet further in the country by founding a subsidiary in Shanghai. We spoke with Professor Zhuoping Yu, an automotive expert at the city's Tongji University, and Jianying Wang, the director of Porsche Engineering Shanghai, about trends and technologies on the Chinese market.

Interview: Frederic Damköhler and Nadine Guhl

Professor Zhuoping Yu

In addition to serving as assistant president of Shanghai's Tongji University and dean of its automotive department, Professor Yu is director of the Shanghai Automotive Industry Corporation (SAIC). He is also the chairman of the Collaborative Innovation Center of Intelligent New Energy Vehicle at Tongji University.

Jianying Wang

After studying automotive engineering at Tongji University, Jianying Wang started her career in the Chinese automobile industry. In 1995 she joined Porsche and since then she was managing Porsche Engineering's sales activities with Chinese customers. She was appointed director of the newly founded site of Porsche Engineering (Shanghai) Co., Ltd. in January of 2015.

What will Chinese customers expect from mobility in the future?

Prof. Dr. Zhuoping Yu Just like in Europe and the USA, individual mobility has become ever more important for Chinese people. The number of motor vehicles per 1,000 in the country currently stands at around 100. But this figure will increase approximately threefold over the next several years. This enormous rise in the number of cars will require the right kind of infrastructure. Given the well-known problems related to emissions and space, this will not just be a matter of building new roads and parking lots. Intelligent traffic systems or new ways of organizing traffic will be needed. Ideas on how to limit the use of cars are currently being considered—such as allowing only certain license plates to drive on certain days—as are different models of car sharing.

Jianying Wang I think that Chinese customers have especially high expectations with respect to safety and comfort, while low emissions and affordable prices continue to be very important as well. To achieve these aims, promising solutions might be found in ways of combining individual mobility with public transportation.

What technologies will have an especially strong influence on the automobile industry over the coming years?

Yu In my view, electromobility, lightweight construction, and intelligent driver assistance systems will be important topics in the future. Mobility is not yet a given in our country. More and more people have the means to buy their own cars these days, and want to do so because of the new type of flexibility and freedom they offer. But this development poses new challenges in terms of traffic and the environment. In order to reduce energy consumption and pollution, it's crucial to pursue further development on alternative drive concepts. As for traffic safety, ever greater significance is being attached to intelligent technologies such as driver assistance systems.

Wang Lightweight construction will play an even more important role in the future, especially when it comes to reducing fuel consumption and for electric vehicles. The challenges we're facing here have to do with high production costs as well as vehicle safety. A number of technologies and systems have to be developed further if we want to be able to combine different materials safely in cars. We at Porsche Engineering are working on various ways of doing this. ›

Lightweight construction will play an even more important role in the future, especially for reducing fuel consumption and for electric vehicles.

Jianying Wang

What will be key for development processes in the future?

Wang Individual development cycles are becoming shorter, which means that development processes as a whole are also becoming shorter and that everything is moving much faster. It's more important than ever to keep a constant eye on the market, but it's becoming harder to do so at the same time. What is innovative today will be obsolete tomorrow. And this gives rise to new organizational requirements. New tools or front-loading mechanisms are constantly being set up in order to keep pace here.

Yu Development processes will be influenced all the more by supplier industries and other sectors. Car makers will be concentrating more exclusively on the core process of development. Wheel-hub drives for electric vehicles and batteries, for example, are not part of the core business for car makers. Development processes will be split up to a greater extent, and parts of these processes will be delegated to service providers. Sales, or sales systems, will also change. Car use no longer necessarily means car ownership. These approaches will require well thought-out systems of use and information technology, which in turn will influence the development process and need to be taken into account right from the start. Successful integration of systems partners, which means joint projects and communications, will lay the foundation for the successful completion of development processes.

Non-automotive companies, particularly technology companies like Google and Apple, have entered the automobile market. What effect will that have on how the sector develops?

Wang A new competitive environment is arising. Joint ventures with these types of technology companies could be helpful in the future, and enable all partners to benefit in the best possible ways from their respective experience and developments.

Yu The way I see it, the roles will be reassigned. Google will become a major supplier and partner in the future. Car makers will have to master a lot of challenges or lose their favorable market positions to these ambitious tech companies.

Professor Yu, to what extent does the demand for sustainable mobility influence your work at the university?

Yu Our university, or rather our courses and programs, are being further developed to address the demands associated with sustainable mobility. In 2010 we formed a working group on e-mobility with members from Tongji University and the Technische Universität München as well as from two additional Chinese universities and the Shanghai Automotive Industry Corporation (SAIC). This in turn led to the launch of a cooperation and integration center for electric vehicles. The goal is to advance the preliminary development of innovations in this area. We need to incorporate the topic of sustainability into the educational system. In connection with electromobility, another major topic that the university will need to address is intelligent traffic control.

How does Tongji University differ from other universities?

Yu Compared to other Chinese universities, Tongji maintains intensive relations with leading German universities and companies. Ever since it was founded in 1907, it has been in close contact with the medical and mechanical or civil engineering departments of German universities. We started offering a degree program in automotive engineering at the end of the 1980s. Our courses and programs are very practice-based and future-oriented. Tongji has studied industrial developments in China from the very beginning and has continually adapted its programs to meet the needs of industry. Internships are also required—as is often the case in Germany—in order for students to start gaining practical experience. An ever increasing number of students and the feedback we get from companies confirm that we're on the right track with this approach.

Wang Those are the reasons why we work with Tongji University too, and especially why we support the automotive engineering department. Experienced employees from Porsche Engineering hold guest lectures at the university and also propose topics for students to work on.

And now to conclude with a very different question, Professor Yu: assuming you could take a test drive as part of series development work at Porsche, which model would you choose?

Yu A Porsche Cayenne S E-Hybrid! When can we start? ■

Car makers will have to master a lot of challenges or lose their favorable market positions to these ambitious tech companies.

Prof. Dr. Zhuoping Yu

CAYENNE S E-HYBRID – Fuel consumption (combined): 3.4 l/100 km, CO_2 emissions: 79 g/km, Power consumption: 20.8 kWh/100 km, Efficiency class: A+

CAYMAN GT4
Fuel consumption
city: 14.8 l/100 km
highway: 7.8 l/100 km
combined: 10.3 l/100 km
CO_2 emissions: 238 g/km
Efficiency class: G

Rebels, Race On.

The new Cayman GT4: Maximum driving dynamics combined with day-to-day usability

A new member of the GT family—the Porsche Cayman GT4—celebrated its world première in March of this year at the Geneva Motor Show. This marked Porsche's first GT sports car based on the Cayman that bears components of the 911 GT3. The engine and suspension, brakes and aerodynamics are trimmed for maximum driving dynamics; yet the top model retains the typical versatility and day-to-day usability of the two-seater Porsche Coupé.

The design: an aerodynamics package

Every element of the exterior has a function. Thus the GT4 impresses not only with its design, but also puts in an exceptional performance on the track as well: With a lap time of 7 minutes and 40 seconds on the Nürburgring's famed North Loop, the GT4 took its place at the front end of the pack.

The sleekness of the front is as effective aerodynamically as it is attractive to look at. The pronounced front spoiler lip extends across the entire width of the front end and the additional spoiler flows in front of the wheel wells generate aerodynamic downforce on the front axle. The large air intakes enable excellent ventilation of the water coolers. The central air intake also directs the air flow upwards through the exhaust opening in front of the luggage compartment lid and thus protects the aerodynamic downforce against rocks. The traditionally wide Porsche wing encompasses the bi-xenon headlights with their black interior design.

Cayman GT4: the aerodynamics

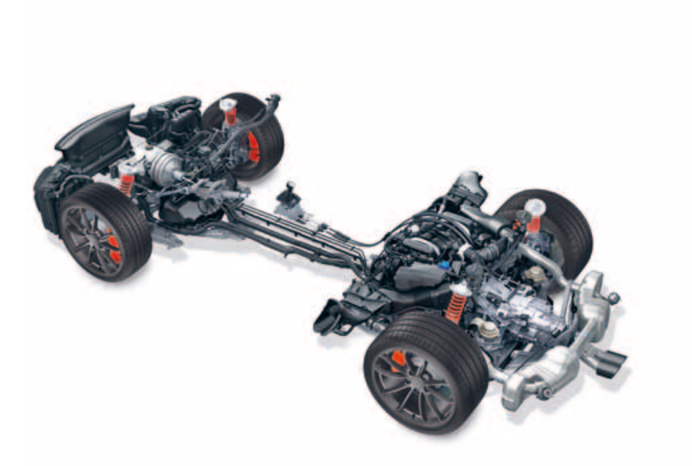
The side inlets behind the doors are also a prime example of performance-oriented design: Sideblades with the “GT4” logo generate additional dynamic pressure. The result is better air intake and more efficient cooling of the engine. The body sits 30 millimeters lower than that of the Cayman, bringing the Cayman GT4 even closer to the asphalt. The benefit: a lower center of gravity for even sportier driving behavior. Optimal contact with the road is ensured by the 20-inch, platinum-colored alloy wheels. They sit well on the outside and with their large dimensions nearly completely fill the wheel wells. In combination with the standard sport tires, the wheels improve traction and cornering performance. The V-shaped design of the spokes is also taken up by the standard SportDesign exterior mirror.

The origins of the new Cayman GT4 are most evident in the rear. The fixed wing with aluminum supports stands for pure motor racing culture. In combination with the integrated rear spoiler beneath it, it generates unmistakable downforce on the rear axle. The sideplates of the wing are designed for optimal aerodynamics: Yet more proof that every detail is designed to harmonize perfectly with the whole. The powerful conclusion is the black rear apron in diffusor look with two centrally positioned tailpipes, also in black. The sound charges ahead forcefully—thanks to the standard sports exhaust system.

Engine and transmission united to form a drive unit

In the new Cayman GT4, the typical Porsche GT performance meets the exceptional agility and cornering dynamics of a compelling mid-engine concept. Its drive unit is a flat-six engine derived from the 911 Carrera S engine. Its power transmission is handled by a six-speed manual gearbox with dynamic gearbox mounts. With its specially tuned gear ratios, the precise-handling and strikingly light manual transmission puts the engine's outstanding power on the pavement. The engine features direct fuel injection (DFI), VarioCam Plus and integrated dry-sump lubrication. In addition, a variable resonance intake system keeps the engine well-ventilated. For its part, the engine draws a stately 283 kW (385 hp) at 7400 rpm from 3.8 liters of displacement. The maximum torque of 420 Nm is available over a range from 4,750 to 6,000 rpm. Together with a low power-to-weight ratio of 4.7 kg/kW (3.5 kg/hp), the result is a veritable explosion of power, and a 0-to-100 km/h time of just 4.4 seconds. The car posts a top speed of 295 km/h.

The GT4 impresses with its water-cooled flat-six engine.



The suspension is designed for uncompromising performance.

The suspension: for optimal agility, stability and precise tracking

The entire suspension is designed to meet the rigorous requirements of oval track racing. To achieve agility, stability and precise tracking, the front axle is equipped with a reinforced MacPherson spring strut axle with oval track-tested kinematics as well as individually mounted wheels on the longitudinal and track control arms. The rear axle is also adapted to the sporty high-performance of the new Cayman GT4 with additional reinforcements and specific wheel carriers. Individual ball joints on both axles also create an especially stiff bond with the body and thus enable even more precise wheel control. The height, camber and track, as well as the stabilizers of the chassis, can be tuned individually for track use, where every millimeter makes a difference for shaving hundredths of seconds off a lap time. And more adrenaline in the blood.

The Cayman GT4 has dynamic gearbox mounts. The electronically controlled system minimizes vibrations throughout the entire drivetrain, and particularly the engine; on the other hand, however, it also adapts the damper force and stiffness to the driving style and road surface. This makes it possible to enjoy the benefits of a hard as well as a soft engine suspension. With load changes and in fast corners, the driving behavior becomes notably more stable and precise. At the same time, the vertical vibrations of the engine while accelerating at full throttle are reduced. The result is a more uniform and greater propulsion force on the rear axle, higher traction and better acceleration. And with a moderate driving style, the driving comfort is enhanced thanks to a softer configuration of the dynamic engine suspension.

Furthermore, the standard Porsche Torque Vectoring (PTV) including rear-axle differential lock also improves the driving dynamics of the GT4 additionally. The rear-axle differential lock enables greater traction as well as significantly improved lateral dynamics and driving stability during load changes in corners and when changing lanes. Moreover, with a dynamic driving style, targeted braking interventions on the inside rear wheel are initiated as soon as the car starts to steer into the corner—this generates an additional turning impulse in the turning direction.

PSM and PCCB for optimal braking performance

Porsche Stability Management (PSM) is an automatic control system for stabilization when driving at the limits of the car’s driving dynamics. In addition to the anti-lock brake system (ABS), it includes the Electronic Stability Control (ESC) and › the Traction Control (TC) systems. Sensors continually determine the driving direction, driving and yaw velocity as well as lateral acceleration. PSM uses that data to determine the actual direction of movement. If it deviates from the desired lane, it initiates targeted braking interventions on individual wheels. The special thing about PSM in the new Cayman GT4 is the sporty tuning with exceptionally sensitive and precisely dosed control interventions. The systems can also be completely deactivated in two steps.

The Cayman GT4 embodies the highly emotional connection between daily life and the race track.

With its especially large brake disc diameters of 410 millimeters in the front and 390 in the rear, the optional ceramic brake system offers even greater brake performance. The decisive advantage of the Porsche Ceramic Composite Brake (PCCB) is its extremely low weight. The brake discs are some 50 percent lighter than gray cast iron discs of a similar build and size. That makes a noticeable difference not only in terms of driving performance and consumption, but also reduces the unsprung and rotating masses, which provides better grip as well as enhanced driving and ride comfort, particularly on uneven road surfaces.

Conclusion

The new Cayman GT4 was not made to stand still; it was made to go all out. The aerodynamics are downforce-oriented, the engine performance enhanced. The chassis and brakes are designed for uncompromising performance. As a GT sports car from Porsche, the Cayman GT4 embodies the highly emotional connection between daily life and the race track and thus the sporting core of the brand: Intelligent Performance. ■

Optical Measurement of the Valve Temperature

____ Modern engine development demands ever more flexible and dynamic processes. The core aspects are the speed and precision of the measuring methods. Porsche Engineering has developed a method for contactless transient online measurement of component temperatures that can be used directly on the engine test bench or in the vehicle. This new tool provides a substantial foundation for further increases both in specific engine power as well as future CO_2 and consumption optimizations.

By Johannes Wüst and Maximilian Fischer

Legal regulations and customer demands for lower-consumption vehicles have led to major changes in the engines of new vehicle generations in recent years. Three primary tendencies have shaped the technological development: first, the introduction of direct fuel injection, which is meanwhile practically universal in Europe. Now developers are faced with the question of implementing the future Euro 6 emissions limits with the lowest possible additional production costs. Second, naturally aspirated engines have been replaced by turbocharged engines with a smaller displacement, a shift referred to as downsizing. Third, further optimizations such as thermal management, start-stop functions, hybridization and friction reduction have come into play.

Direct fuel injection and downsizing in particular have resulted in rising specific engine power. Values between 90 and 100 kW/l are now the state of the art and, in view of continuous enhancements in the turbocharger field, injection technology and combustion process development, will continue to rise in the near future.

These performance optimizations lead directly to a significant increase in the specific heat energy, which in turn increases the thermal load for many engine components. It primarily affects the pistons, gas exchange valves, cylinder heads, the exhaust manifold and the turbocharger. The most common remedial measures are to modify the engine cooling, design means such as an integrated exhaust manifold, piston cooling or higher-quality materials. As a rule, however, this results in additional costs.

In any engine development process, one must continuously take account of the conflict between technical objectives such as reduced consumption and the marketability of a vehicle, i.e. cost thresholds. A typical example is the fuel selection and the design of exhaust valves: One option is to limit the exhaust-gas temperatures in the upper load range through mixture enrichment and thus also reduce the component temperatures of the exhaust valves. This makes it possible to use cheaper materials for the exhaust valves, albeit with higher fuel consumption in these load ranges. On the other hand one can use higher-quality materials, e.g. replacing a common steel alloy such as X50 with Nimonic, or using sodium-filled valves. Both options lead to a significant increase in part prices. In general, however, the focus is on completely exhausting the thermomechanical potential of the material and the design.

State of the art for measuring the valve temperatures

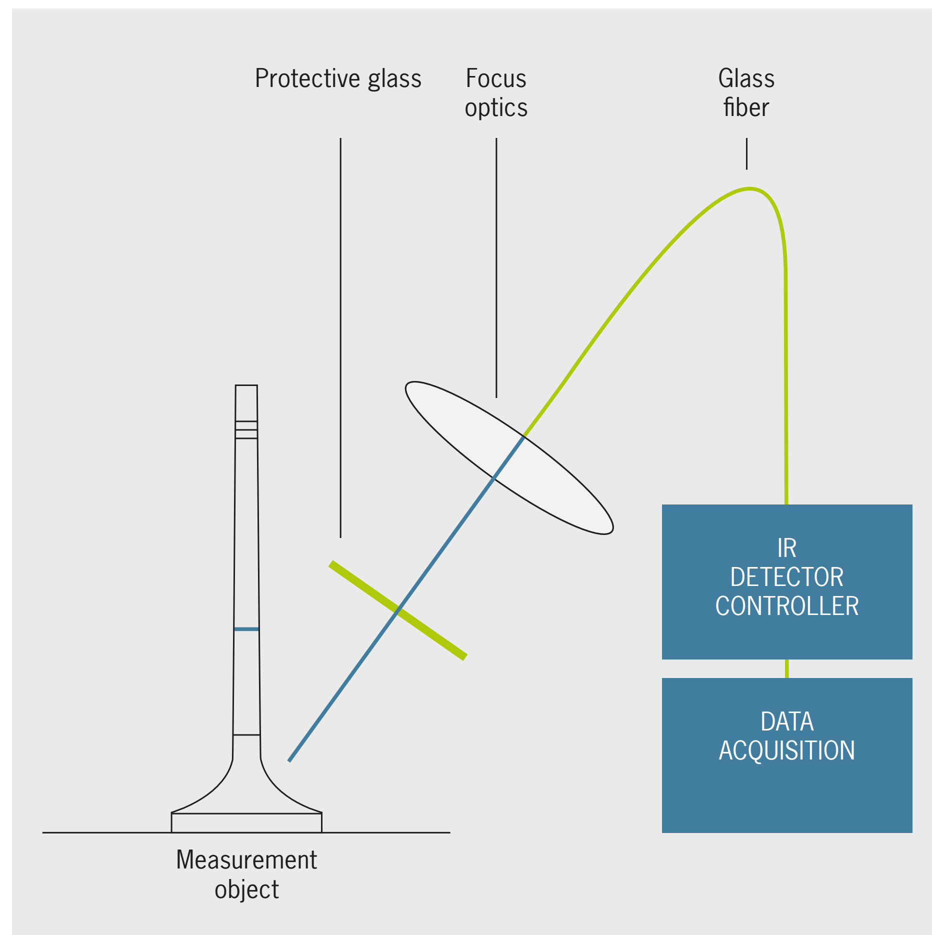
To determine the valve temperatures, thermometric valves have been used for many years from which the valve temperature can be deduced from changes in the material hardness. This procedure is well established, but the measurement values are only available much later: The engine must first be dismantled and the valves analyzed in the lab, which from a time perspective is difficult to incorporate into today's dynamic development processes. It is still only possible to use certain materials, which means that the measurement valves may not reflect the actual state. Furthermore, the results only indicate the maximum temperature reached with the applied application state in a measured operating point. Information regarding the valve temperature in other load points or with other applications cannot be attained in a single measurement.

In special cases, thermocouples are also integrated in the valves and monitored through telemetric signal transmission. This procedure is expensive and critical in terms of reliability and has therefore not established itself as a standard.

Requirements and motivation

The focus of the development by Porsche Engineering was the generation of a measurement signal that could be made available to the test engineers in real time at the test bench or in the vehicle. This would make it possible to significantly increase the efficiency of the development process both in terms of the mechanics and the application. The specifications defined:

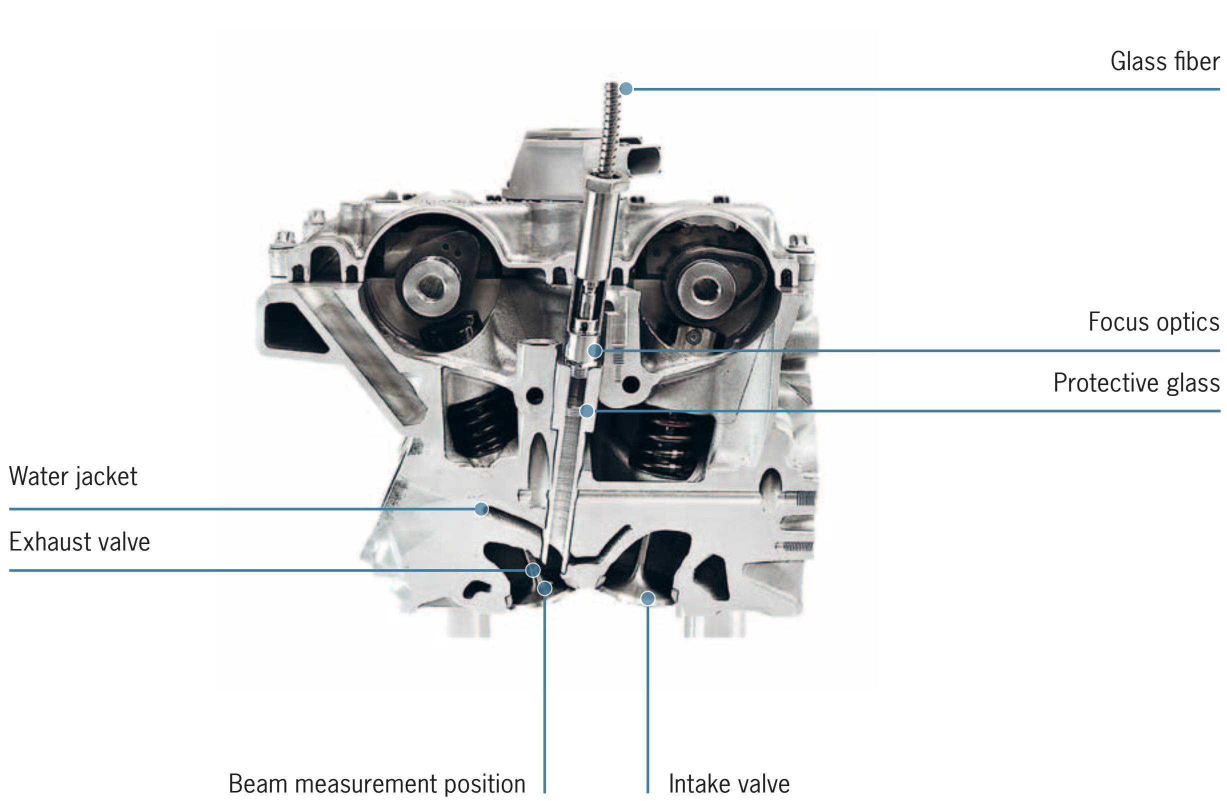
> Measurement range of up to approx. 500 degrees Celsius for intake valves and approx. 900 degrees for exhaust valves, with a sensor ambient temperature of max. 125 degrees Celsius.
> Measurement accuracy comparable to or better than thermometric valves (<10 kelvins)
> High dynamic range of the signal and availability of the measurement signal in real time
> Resistant to reflections and slight soiling
> Small size



Technical setup

From initial deliberations to market launch in 2013, the project went through multiple development cycles. Since that time, the measuring method has been successfully used in some customer projects. It was used, for example, to examine the causes of valve damage and excessive wear on valve-seat rings. Other uses included a comparison of different valve designs with and without sodium filling as well as different engine applications in order to select the most cost-effective valve material for every application variant.

The development tool is currently in use at Porsche Engineering in its 4th stage of evolution. ›



Sensor integration in cylinder head of a Porsche 911 engine

The measuring system

The central component in valve temperature measurement is a pyrometric infrared sensor. In pre-trials, appropriate sensor types were selected on the basis of their suitability for the application.

The measurement chain consists of the infrared sensor, a controller and a measurement PC. The sensor is protected against the high exhaust-gas temperatures and exhaust backpressure with sapphire glass. The measurement signal can easily be integrated into the conventional systems in engine test benches. If the measurement is to be conducted in the vehicle, the signal can alternatively be recorded in the application computer to detect direct reactions to the application status.

The construction design must be tested individually for each engine type. The purpose and reason for the measurement can impact the placement of the sensor.

One challenge of this design—assuming that it cannot be included in the cast part in prototype cylinder heads—is creating the sensor access through the oil chamber, the cooling water jacket and into the outlet port. One problematic issue was that the sealing of the sleeve against the cooling water causes significant difficulties here, which was resolved using an elaborate welding procedure. This enables the procedure to be used on already developed cylinder heads.

In the current stage of evolution, another sensor type is in use that can be mounted completely separately from the engine via a fiber-optic cable. In addition to even greater dynamics, this design is even more resistant to thermal loads, soiling and mechanical sensor loads. Possible optical reflections are avoided by means of black matte coatings and an optimal incidence angle of the "measurement beam."

Soiling of the optics and solutions to this problem

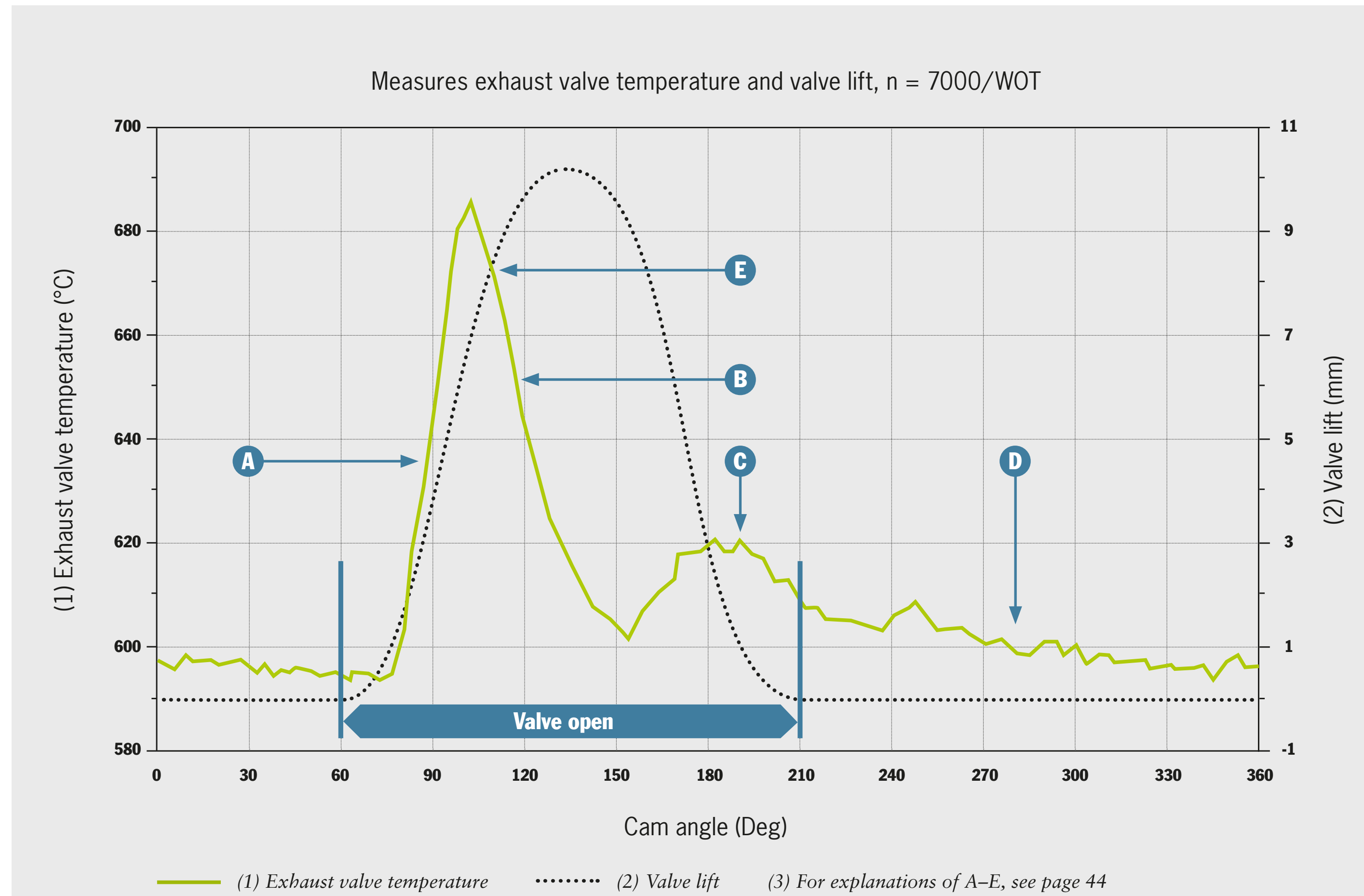
One neuralgic issue is the soiling of the protective glass by soot from the exhaust gas. In particular where valve temperature measurements are to be carried out over lengthy testing periods, the deposits of certain fuels in different countries can substantially shorten the potential measuring period. To resolve this issue, the engineers developed two different measures: a design that enables fast cleaning of the protective glass and a two-color pyrometer.

The principle of two-color pyrometry is based on the use of two infrared detectors that measure in different wavelength ranges. The fiber optics still receive the signal and direct it in the sensor housing to the two sensors through a prism. The specific signal intensity of each wavelength analogous to the temperature makes it possible to compare the signals in the controller by deriving coefficients. This increases the precision of the measurement and any signal attenuation is compensated for. This also makes it possible to determine the intensity loss and thus also the degree of soiling. Specifying a maximum permissible signal attenuation value causes the controller to switch off the sensor when the threshold value is reached; the optics must then be cleaned. This procedure ensures the uniform quality of the measurements.

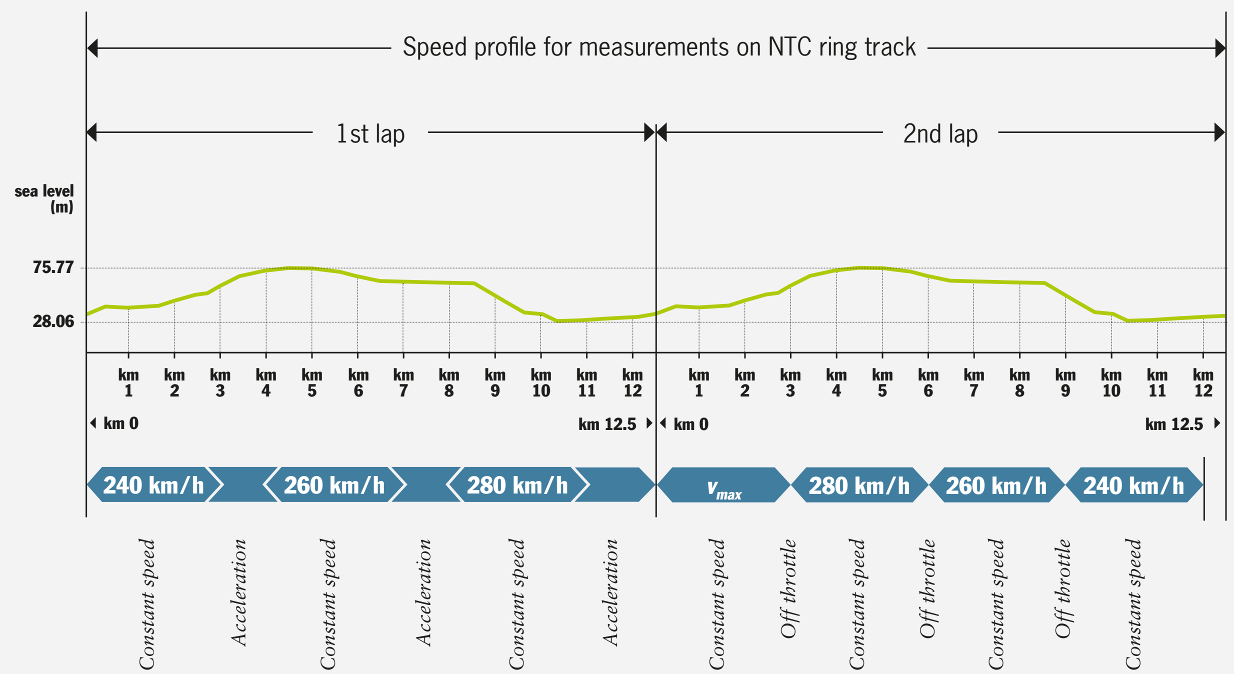
Concept validation

To demonstrate the capabilities of the system, in early 2014 an extensive internal series of tests was conducted with two test vehicles in Nardò, Italy. Both vehicles withstood the two-day, 1,600 km outbound trip as well as the return on their own steam to demonstrate the robustness of the measuring system through long-term data logging.

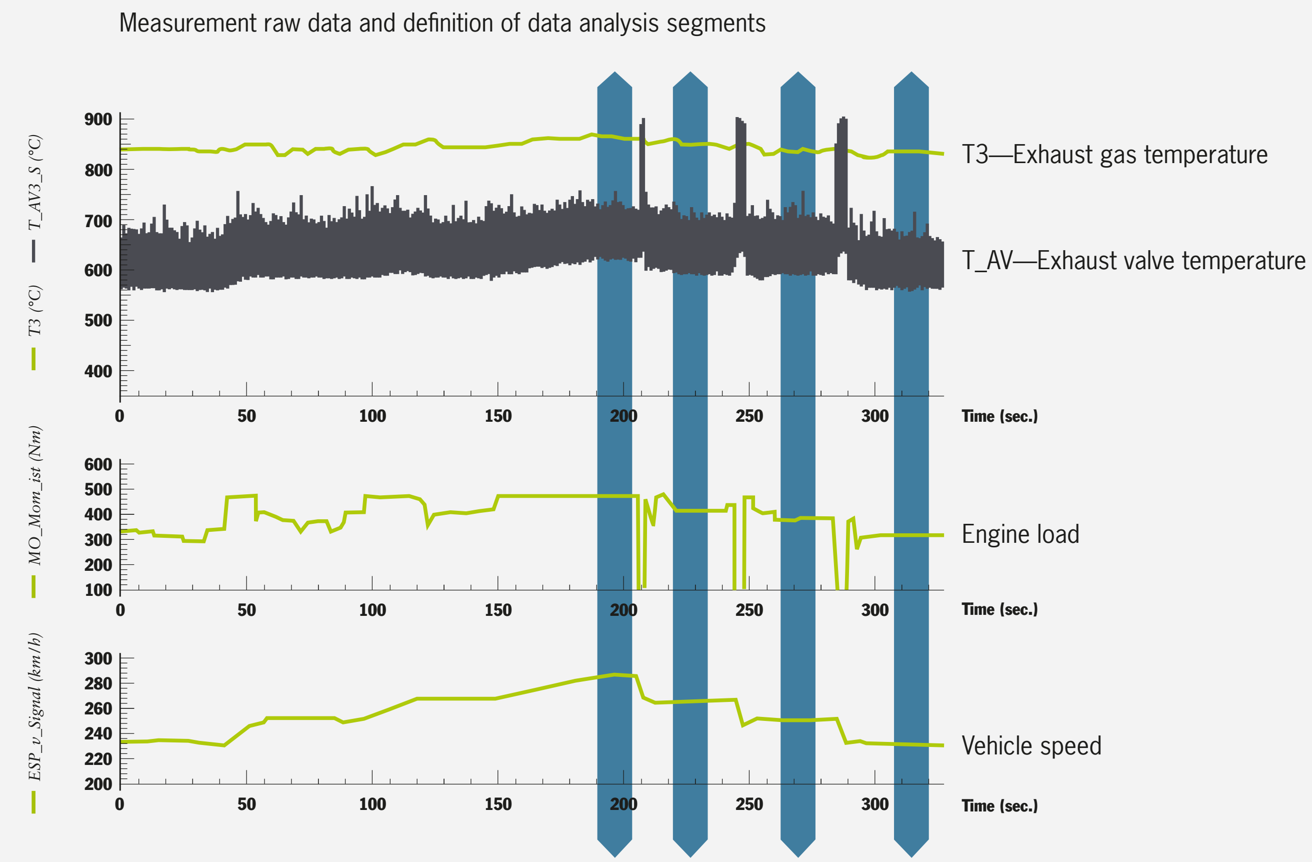
The measurements at Porsche Engineering's Nardò Technical Center were conducted as part of an extensive testing program. Both test vehicles were equipped with direct-fuel-injection, flat-six naturally aspirated engines in two different performance classes. ›



Valve lift and valve temperature at 7,000 rpm and full load



Vehicle speed profile on the circular track in Nardò



Individual measurement and definition of the static evaluation ranges, taking a 1 km journey as a reference

The exhaust valves to be tested were sodium-filled, hollow-shaft valves.

Testing included varying fuel types, driving profiles and sensors as well as alternating application values for ignition angle, oxygen value, exhaust backpressure and coolant temperature. The scope of the test matrix alone shows the data acquisition potential of this measuring technology.

Results

Even a small sampling of the results underscores the capabilities of the measuring system. One example is the high-resolution temperature signal. The figure on page 43 shows a load point at 7,000 rpm under a full load but not yet steady conditions. In addition to the temperature, it also shows the valve lift.

We see extremely high temperature gradients that are only visible with massless measuring methods. The interpretation of these temperature gradients is not easy, however. The curve of the locally measured valve temperature is interpreted as an interaction of at least four different effects:

- Heating by means of exhaust escaping at high pressure from the combustion chamber (in the figure on page 43, item A),
- Apparent cooling due to movement of the measurement position towards the colder valve shaft (B),
- Expansion effects and gas-pressure oscillation in the exhaust channel (C),
- Cooling due to heat transfer from the surface to the inside of the valve, the valve seat and the valve guide (D).

Another effect may be a rise and fall in temperature due to passing over the hottest point on the valve (E).

To evaluate the test matrix, the entire dataset was highly compressed through statistical analyses of average and maximum values. A uniform driving profile (top figure) ensured directly comparable results. For the statistical evaluations, in each case the engineers looked at a one-kilometer section of the second measurement lap (figure to right).

Under a load, the highest exhaust valve temperature (T_AV) measured in this test series was 805.6 °C. This was reached while using the poor-quality fuel in conjunction with a slight application modification. The highest recorded exhaust-gas temperature T3 of 893.8 °C was determined using a conventional thermocouple while using Super Plus 100 in conjunction with only a slight application modification—a lean adjustment in the composition of the mixture. The highest exhaust valve temperatures overall were recorded in the fired thrust. Here the new non-inertial measuring system was able to record temperatures of over 900 degrees Celsius, the upper temperature limit of the sensor calibration selected for this test series.

Conclusion

With this new measuring methodology, Porsche Engineering has created a valuable tool for the development of engines that are more efficient, lighter and yet more powerful and robust. The measurement results are directly available during the test and the effect of remedial measures can be represented in a direct comparison of "before and after" values. This significantly shortens development and testing times. Another advantage of the contactless measuring method is that it offers additional means of CO_2 and fuel savings by better exploiting the thermomechanical limits of the valves.

The robustness and reliability of the measuring system has already proven itself over a total deployment duration of over 25,000 defect-free kilometers. In early 2014, the procedure was successfully used for the first time for temperature measurement on the turbine wheel of a VTG turbocharger. As an enhancement, a water-cooled infrared sensor was used. ■