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COMMERCIAL VEHICLES

Automated Driving Increases Safety Levels

MILD HYBRID
with 48-V Technology for Medium- and Heavy-duty Trucks

AERODYNAMICS
of the ID.3 Electric Car from Volkswagen

DESIGN
of CFRP Structures Using Simulation

/// **INTERVIEW** Torsten Gollewski [ZF]

/// **GUEST COMMENTARY** Stephan Müller [DLR]

H_2 – a Herculean Task

Dear Reader,

Who invented it? The Swiss did! The truth of this saying was demonstrated yet again in a post on the British hydrogen website H_2-View, which reported that 1600 fuel cell trucks powered by green hydrogen would soon be in operation on Switzerland's roads. The report even reached the Asia-Pacific Hydrogen Association in Singapore, which considered the information to be so important that it was included in the association's newsletter. With their joint venture known as Hyundai Hydrogen Mobility (HHM), the Swiss are following up words with deeds. The Swiss company H_2 Energy has a coherent overall concept that it is putting into practice with the help of its partners.

By 2025 Faurecia, one of the partners of HHM, will have installed hydrogen storage systems in 1600 Hyundai H_2 Xcient trucks with 190-kW fuel cells. Faurecia will manufacture the tanks, with a capacity of 35 kg hydrogen per truck, at its center of competence in Bavans (France). A total of 1600 trucks in five years amounts to a production rate of 27 units per month, which seems like slow progress. However, Faurecia estimates that by 2030 around 350,000 new commercial vehicles will be fitted with fuel cell technology worldwide. The market is obviously flourishing.

Another player on the market is a German-Swedish alliance. Daimler Truck and the Volvo Group have begun cooperating on the development of fuel cells. This Herculean hydrogen task can only be handled by large companies that combine their forces in joint ventures. The goal is to develop, manufacture and market fuel cell systems for use in heavy-duty trucks. For this purpose, Daimler has brought together all its fuel cell activities in its Daimler Truck Fuel Cell company. At the same time, it is stopping all research and development of fuel cells for cars. The high priest of fuel cells, Christian Mohrdiek, is moving from Mercedes-Benz Fuel Cell in Nabern (Germany) to join the new joint venture as co-Managing Director.

This heralds the end of fuel cell cars at Daimler. It all began at the company in 1994 with the world's first fuel cell model, the Necar 1, which was based on the Mercedes-Benz MB 100 van. After 25 years and the production of 3000 Mercedes-Benz GLC F-Cell cars, it is all coming to an end. However, Germany has more H_2 fuel stations for cars than anywhere else in Europe. No other country can compete with the German network of 87 stations (Europe as a whole has only 177). Hopefully Daimler Truck and Volvo will make it possible for cars to be retrofitted quickly with the truck connections, but because of the different nozzles and pressure levels this is likely to prove very difficult.

Michael Reichenbach

Dipl.-Ing. Michael Reichenbach
Deputy Editor in Chief

COMMERCIAL VEHICLES

Automated Driving Increases Safety Levels

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Automated driving system functions offer major benefits especially for heavy-duty trucks. The latest assistance systems make it easier for drivers to do their day-to-day work on the highway, in the yard of the haulage company, and in the inner city. Turning assistants that protect cyclists from collisions and better vehicle dynamics control systems bring overall improvements in road safety.

© ZF


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36 48-V mild hybrid powertrains are more cost-effective and take up less space than high-voltage versions. Mahle explains the special requirements that the battery has to meet.


© Volkswagen

48 With a c_D value of 0.26, the ID.3 takes up a strong position in the competition on the electric car market. Volkswagen has achieved this result by consistently improving the model's aerodynamics.


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62 CFRP designs are often disorderly and are characterized by numerous iterations. BMW and the University of Erlangen-Nuremberg show a more efficient process.

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COVER FIGURE © MAN

Audi | **Duesmann Heads Technical Development Division**

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Markus Duesmann

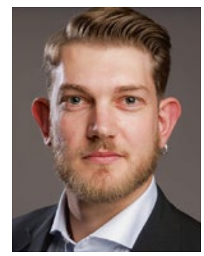
© Audi

Hans-Joachim Rothenpieler

In addition to the role of CEO, Markus Duesmann has taken on responsibility for the technical development division of Audi AG. He succeeds Hans-Joachim Rothenpieler, who is leaving the company at his own request. Duesmann will take the development division in a new direction with a particular focus on process quality. He will be supported by a chief operating officer, who will coordinate the day-to-day work of the development engineers, and a chief transition architect, who will organize the realignment of the division. In his function as Board of Management Member for Development, Duesmann is also heading a newly created division that will independently manage the product ranges, which currently consist of 65 models, as well as the Premium Platform Electric (PPE) project center. Following another strategic decision by the supervisory board, the Chairman of the Board of Management will also assume direct responsibility for the company's business in China in the future.

TÜV Nord | **Calibration Laboratory under New Leadership**

Dr. Malte Sommer, who has a doctorate in acceleration physics, is now Head of the calibration laboratory at TÜV Nord Mobilität. He joined the company at the start of 2019 and at the end of the year took over responsibility for the laboratory. Before that he spent eight years carrying out research with the Delta particle accelerator at the Technical University of Dortmund. Now he and the members of his team are providing calibration services according to DAkkS standards for exhaust gas measuring equipment for gasoline and diesel engines, brake test rigs and headlight adjustment systems. The laboratory works closely with the company's in-house testing equipment department to ensure that the devices tested in the laboratory meet all the necessary legal requirements. The range of services provided includes maintaining and repairing exhaust gas meters, tests of brake test rigs to ensure that they comply with accident prevention regulations, together with routine testing and adjustment, and routine tests of headlight adjustment test devices.



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Malte Sommer

New Motion | **Lane Appointed CEO**

© New Motion

Melanie Lane

Melanie Lane is the new CEO of New Motion, the charging solutions provider, which is a subsidiary of Shell. She succeeds Sytse Zuidema, who has held the position for the last five years. In the future, Lane will be responsible for the strategy and the further rowth of the service provider. Lane is taking on the role after over 20 years at Shell, where she has worked in various marketing, sales and business development roles. Since 2015 New Motion has grown from a start-up to a leading company in the field of electric mobility in Europe. In 2017 it became a fully owned subsidiary of Shell. "I'm looking forward to joining the team," said Lane. "Our New Motion network and public roaming network are expanding rapidly and will soon reach a new milestone with 150,000 charge points in the roaming network." Shell plans to stop producing emissions by 2025 – if possible even earlier.

ZF | **Takeover of Wabco Completed**

ZF has successfully completed the acquisition of the commercial vehicle technology supplier Wabco, having gained approval from all the regulatory authorities. Wabco shares ceased public trading with immediate effect. Following the end of the acquisition process, the integration of the company into the ZF Group will begin. The aim of the two organizations is to advance the development of commercial vehicle technologies and to expand the range of services for commercial vehicles and the operational customer business. In the future, Wabco will operate as the independent commercial vehicle control systems division of ZF, which makes it the group's tenth division. It employs around 12,000 people at 45 locations worldwide. "This acquisition represents an important milestone in the history of our company," said Wolf-Henning Scheider, CEO of ZF. The division will be headed by Fredrik Staedtler. He has long experience of the commercial vehicle industry, most recently as Head of ZF's commercial vehicle technology division. Jacques Esculier, CEO of Wabco, will leave the company.

© ZF

Wolf-Henning Scheider

© ZF

Fredrik Staedtler

Daimler | **Management changes at Mercedes-AMG**

© Daimler

Philipp Schiemer

The Mercedes-Benz high-performance subsidiary AMG has a new CEO. Philipp Schiemer, formerly Head of Mercedes-Benz do Brasil, has taken over responsibility for the company. In addition, Jochen Hermann has been appointed Chief Technical Officer and Member of the Board of AMG. He was previously Head of E-drive Development at Daimler AG. Tobias Moers, who has been Chairman of AMG since 2013, is leaving the company at his own request to become the new CEO of Aston Martin Lagonda in the UK. Philipp Schiemer has held various management positions at Daimler in Germany and Brazil since 1987, including Head of Marketing at Mercedes-Benz Cars. Hermann was previously Head of Overall Vehicle Development at AMG from 2014 to 2016, before focusing on electric drive systems and battery research as Head of E-drive Development at Daimler. He joined the Daimler Group in 1997 and has also worked in areas such as driver assistance systems and steering systems.

Seat | **Tietz Heads Research and Development**

Dr. Werner Tietz has been appointed Executive Vice President for Research and Development at Seat. His most recent role was Head of Development at Bentley. He replaces Axel Andorff, who is moving to Škoda to take over responsibility for the midsize and MEB product lines. Tietz is a graduate of RWTH Aachen University and joined the Volkswagen Group in 1994. He held several positions at Audi and was responsible for the development of all Audi interiors. In 2011 he transferred to Porsche, where he worked in the body and interior departments. From 2018 onward, he was a member of the Bentley executive committee and Head of Development, where he put in place a new development strategy and laid the foundations for the electrification of the brand. More than 1000 engineers are employed at Seat's development center.

© Seat

Werner Tietz

ATZ | Mahle | **Berger Joins the Advisory Board**

Dr. Martin Berger, Vice President Corporate Research and Advanced Engineering at Mahle International, is the newest Member of the ATZ Scientific Advisory Board. Berger has held his current position since the start of the year. He began his degree course in telematics, specializing in computer science and electronics, at the Technical University of Graz in 1993 and went on to complete his doctorate in applied computer science there in 2001. After finishing his studies, Berger held a range of management positions at an engineering service provider and then joined the Mahle Group in 2014 as Head of Mahle Powertrain.

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Martin Berger

IMPULSES

Dr. Johannes Liebl
Editor in Charge
ATZ | MTZ | ATZelectronics

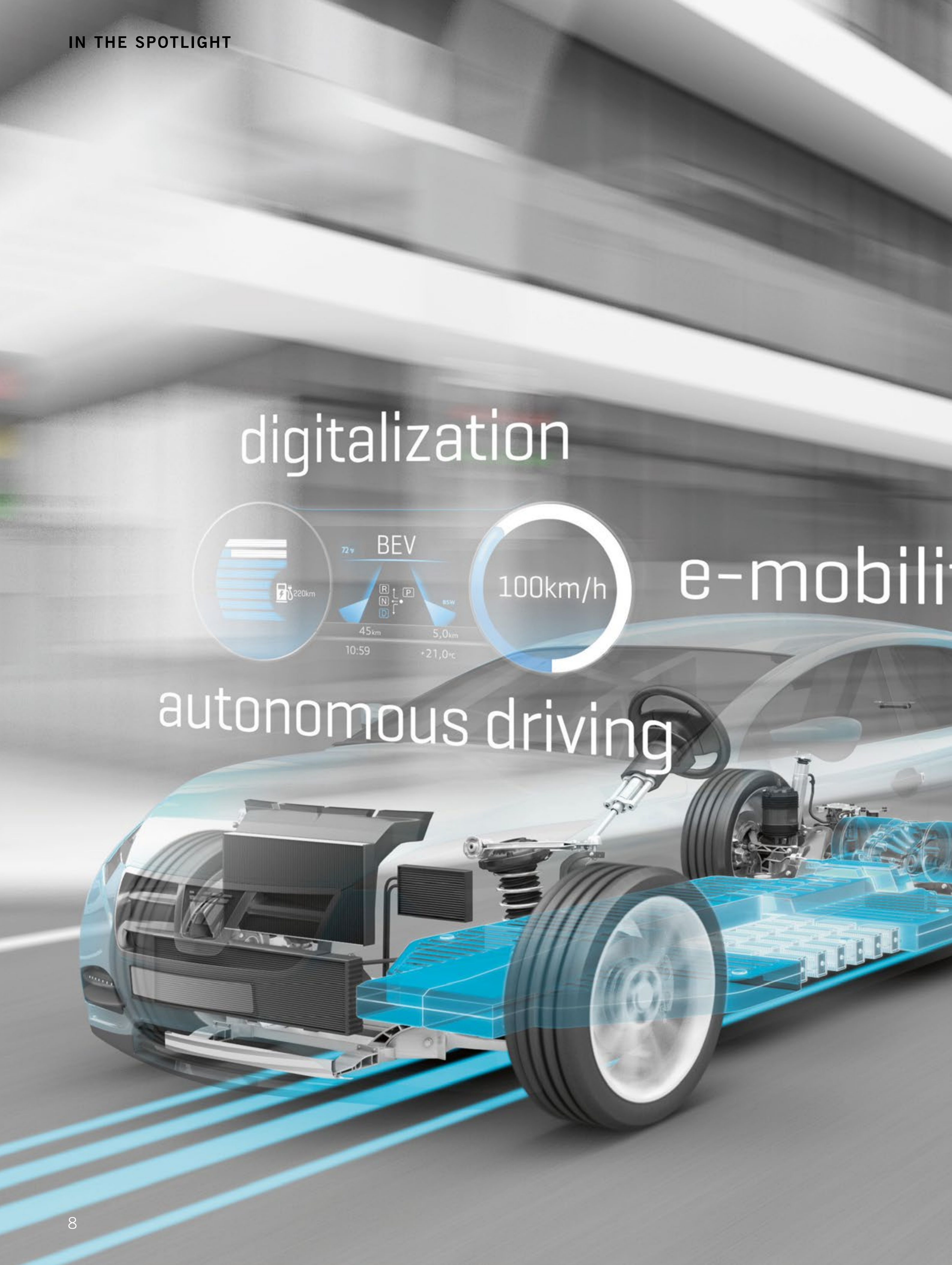
A Missed Opportunity

The transition to low-carbon mobility will only be successful if we make use of all the technologies available to us. That is a key finding of the new summary report produced by Working Group 2 of the German National Platform Future of Mobility (NPM). The German federal government was already aware of this message when it introduced its 130 billion euro economic stimulus package.

A total of 50 billion euros from the package will be used to promote the technologies of the future, with a focus on energy and climate change mitigation. One of the cornerstones is the introduction of hydrogen as a fuel. Hydrogen must now become part of the energy chain and will be used as a means of storing excess electricity generated from renewable sources.

Reconversion to electricity is not generally recommended for reasons of efficiency, but hydrogen can be transformed into mechanical energy in combustion engines and fuel cell powertrains. In addition, it can be combined with CO_2 to produce synthetic fuels. This is part of the politicians' plans for aviation and shipping, but not for cars.

Why did the government not listen to the NPM? If we are to meet our targets for 2030 using only electric vehicles, more than ten million new BEVs will need to roll off the production lines in the next ten years. After the coronavirus pandemic is over, people will have less money to spend. Many of them will postpone the purchase of a new car and when they do buy, the price will be a very important consideration. This is why the existing fleet must become part of the solution. And that is only possible with synthetic fuels that are produced using renewable energy and added to fossil fuels. Why does the economic stimulus package not incorporate this approach?


digitalization
BEV
220km
45km
5,0km
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+21,0°C
100km/h
e-mobilit
autonomous driving

© Vibracoustic

Less Complexity Through Electrification?

It is a widely held view that the electrification of vehicles will lead to less complexity and, consequently, less value creation. Upon closer examination, however, what one sees is an open field of new tasks, not only in the powertrain. How much more or less complexity are we in for?

VOLATILITY AND COMPLEXITY

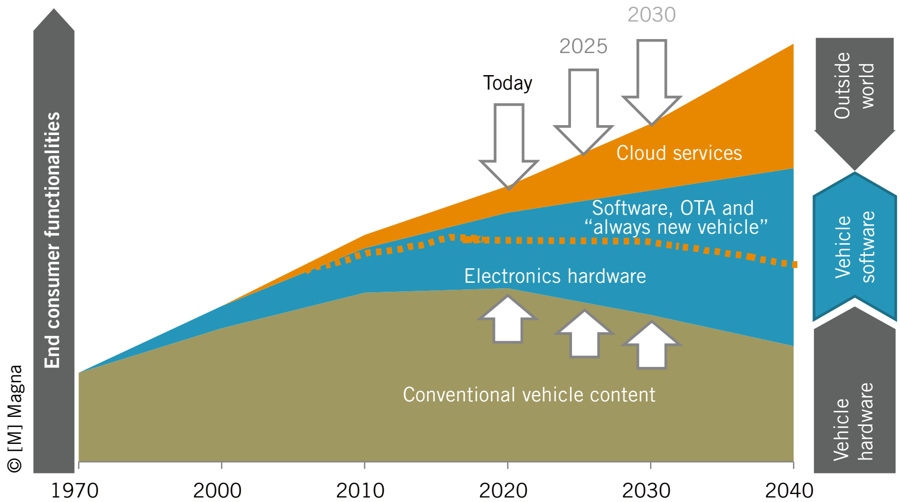
The unpredictability of external factors makes it especially difficult to anticipate long-term developments in the industry. For instance, when China decided in 2019 to cut its subsidies for Battery-electric Vehicles (BEVs) by 50 % and eliminate those for electric vehicles with ranges of less than 250 km, the market responded immediately, as new BEV registrations plummeted and those for PHEVs spiked. Similarly, the German government's decision at the beginning of June 2020 to subsidize electric vehicles was also a case of regulatory intervention some observers did not see coming.

Setting aside the issue of whether BEVs are a cure-all, let us assume in what follows that the Internal Combustion Engine (ICE) will continue to play a role in powering passenger vehicles, albeit more differentiated in its role depending on the applications. Electrification is therefore seen as encompassing all manner of Hybrid-electric Vehicles (HEVs) through to BEVs. But it is not only about the engine itself. As Prof. Hans-Christian Reuss of the Research Institute of Automotive Engineering and Vehicle Engines (FKFS) in Stuttgart (Germany) says: "Electrification is an enabler of a range of new technologies." This is the case, for example, with automated driving systems, vehicle connectivity, and novel mobility concepts.

So how much more (or less) complexity are we in for, and what opportunities will we encounter along the way? According to Anton Mayer of Magna, we need to look at system borders and timelines when assessing complexity. Moreover, in addition to traditional platforms, equal attention needs to be given to HEVs, PHEVs and EVs. And this means that we will see an initial increase in complexity until the number of different electrification variants declines. In summary, Mayer suggests that while value added will be lost in conventional areas of production, it will increase disproportionately in the area of electronics, onboard and cloud services.

POWERTRAIN DIVERSITY

Before moving on to these opportunities, let us take a look at the core of electrification – the powertrain. Magna's powertrain portfolio currently includes conventional transmissions, variously scaled engine-electric hybrids, and purely electric powertrains of the sort presented by the company in 2019 in the e4 demo vehicle. Dedicated Hybrid Transmissions (DHTs) [1] have also emerged as linchpins in powertrain systems. The expanding role of electric motors has enabled a



Although Magna projects a smaller share in the area of conventional vehicle technology by 2040, this is more than compensated for in the area of electronics and both onboard and cloud services

reduction in the number of gears in DHTs, as well as various ways of simplifying ICEs. In general, Mayer expects a gradual streamlining of the powertrain at the mechanical level.

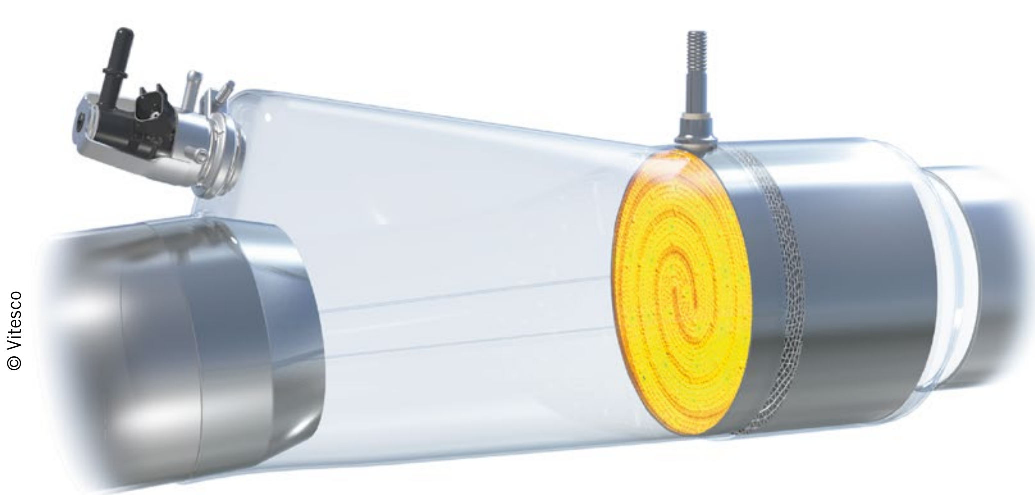
According to Prof. Michael Bargende at the University of Stuttgart's Institute of Automotive Engineering (IFS), such streamlining depends on the electric output. Bargende sees three major trends. The first is downsizing combined with charging and possibly 48-V hybridization so long as the ICE remains the dominant source of propulsion. The second is an extensively simplified engine for plug-in hybrids. Incidentally, full hybrids will regrettably lose significance in the wake of EU emissions regulations favoring plug-in hybrids in his opinion. The third trend is toward gasoline engines with extremely high efficiency rates (up to 45 % or more), as seen today especially in Japan but also in China. Success in this latter case depends on an extensive approximation of the isochoric process with high peak pressures.

A talk given at the end of 2019 by Ruiping Wang, Vice President R&D and Manufacturing, Zhejiang Geely, was especially notable in this regard [2]. She also expects that we will see a wide variety of hybrid applications, with greater electrification going hand in hand with a gradual decline in complexity and culminating in a serial-mode, two-gear DHT for parallel hybrid operation with a Dedicated Hybrid Engine (DHE) and an efficiency rate of up to 45 %. The fact that such ambitious work is being done on advanced ICEs in China – and not only at Geely – makes one think.

Looking at Europe, Stefan Demmerle of BorgWarner sees charged engines as the persisting trend, often combined with P1 and P2 architectures. As a company with a global reach, however, the aim is to cover all product and system components, ranging from charging plugs to wheels. In short, the challenge here too is in the range of options.

These developments do not really sound like simplification, but as Prof. Uwe Dieter Grebe of AVL put it in an interview [3], the internal combustion engine is modular "from the outside," which means that the effort of functional scaling is not as high as it might appear at first. Variously scaled hybrid powertrains therefore do not necessarily run counter to the trend toward streamlined engine families, also given that they continue to lose their role as components that enable emotional differentiation.

In any case, emission control is clearly growing more complex. This applies to 48-V HEVs owing to reduced exhaust temperatures and to PHEVs when the ICE takes over or is left unused for an extended period. The supplier Vitesco Technologies sees a number of new requirements emerging in the area of thermal management for exhaust systems. For instance, electrically heated catalytic converters have become relevant, as well as active-purge pumps that not only empty the tank's activated carbon filter, but can also supply an airstream or an air-fuel mixture for heating. NO_x sensors may also be enlisted to enable more precise lambda control in gasoline engines.



The Emicat by Vitesco uses the current of 48-V hybrid-systems to heat the catalytic converters of diesel engines when the exhaust temperature falls

AN IMPACT ON THE CHASSIS

The chassis is perhaps not the first thing that comes to mind in connection with electrification. According to Damian Harty, Director of Chassis and Vehicle Dynamics at Byton, the link between motor and wheel in electric powertrains is essentially a “rigid” system, in contrast to that of conventional powertrains. There are simply no components such as Dual-mass Flywheels (DMFs), clutches or torque converters that enable slippage or damping. This can make the task of controlling lateral dynamics more difficult in driving scenarios characterized by a reduced friction coefficient, for instance, when wheels need to resynchronize with the road after losing grip. Harty takes a holistic view of everything, from the motor to the surface of the road.

There are several conclusions to be drawn here. The significance of approaching the powertrain and chassis as parts of a unified system has grown: Even in the case of electric powertrains, one should not underestimate the role of clutches when it comes to controlling vehicle dynamics, given that disengaging the clutch permits axle-specific load shifting. Control quality requirements have become far more demanding. Harty sees major challenges, for instance, when it comes to computational speed, redundant monitoring systems (ASIL D), and signal transfer. CAN 2.0 is at its limits here. The newer CAN-FD is better suited, but requires new chip sets and extensive testing.

© Vibracoustic

Responding to new NVH challenges: the “Rolling Chassis” by Benteler and Bosch on a rolling test bed at Vibracoustic

A point made by Frank Esser at Ford is also interesting in this connection. Given the urgent need to lower the cost of electrification, there is a clear interest in cost-effective chassis. But at the same time, controlling high loads for precise tracking and making the chassis

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Anton Mayer
VP Corporate Engineering & R&D Core Product Group at Magna International

2 QUESTIONS FOR ...

What opportunities do you see in electrification to create value for consumers?

MAYER _ The essential value added is the reduction in carbon emissions. But other advantages include enhanced powertrain control and greater sovereignty via connectivity and the services associated with it – for instance, when it comes to avoiding traffic jams, locating parking spots, and reserving charging stations. And our e4 demonstration vehicle introduces a new level of vehicle dynamics and safety that is immediately graspable for all. It represents a whole new world of mobility.

What can be done to make sure that electrified vehicles remain affordable despite their powertrain complexity?

MAYER _ For us, it comes down to developing modular kits with core elements that permit scaling according to electric output and functionality. While there is a clear opportunity to target simplification at a mechanical level, batteries naturally remain challenging when it comes to acceptable cost. Other promising areas include robotics and Industry 4.0, as well as the shift toward software and services. We’ll definitely see a downturn in the case of hardware, but considerable value added in the case of functionality.

© Faurecia

Electrification and connectivity are also changing vehicle interiors, for instance, with the introduction of switchless, context-sensitive user interfaces

even quieter is a great challenge. While predictions about the future are always uncertain, this looks like an emerging gap between standard and premium chassis.

TESTING BECOMES A COMPLEX TASK

NVH is another area where the complexity of developmental tasks has increased. According to Dr. Jörg Böcking of Vibracoustic, we are used to the fact that the engine masks other noises. Now, all of a sudden, we hear the noise generated by auxiliary components such as pumps, compressors and switch valves, let alone the fact that electric motors introduce a need to master entirely new frequency ranges of up to many kilohertz. And in the case of engine-electric hybrids, we are confronted by the vibrations associated with both means of propulsion. Moreover, recuperation causes previously unknown longitudinal dynamic loads in tensile direction, especially in the case of powerful electric drives. This requires new damper and absorber solutions as well as considerably more testing expenses, compared to conventional powertrains. Given the many tasks at hand, Vibracoustic built a new development center in Weinheim (Germany) in 2019 [4].

According to the supplier Benteler, the additional work involved in designing and testing the vibration system including drive and chassis favors the use of standard platforms. Together with Bosch, Benteler presented the so-called Rolling Chassis in 2019, which is “ready to drive” in terms of crash management, chassis, e-axles and battery systems, as well as software and system integration. Marco Kollmeier, Head of the E-mobility division, sees a need for such a solution especially among small and young OEMs, enabling them to save several years of development time. In March of 2020, Pininfarina joined the cooperation, and is expected to provide car body expertise, particularly when it comes to defining the vehicle interfaces.

In 2019, the FKFS also expanded its testing facilities through the addition of new test beds for high-performance electric and hybrid powertrains [5]. Of the many new testing tasks, Reuss mentions the case of the thermal behavior of electric powertrains, for instance, in heavy-load and continuous-duty conditions. In addition to cooling, new operating strategies are necessary to better control derating, that is, a kind of intelligent, incremental reduction in output. After all, electric vehicle owners will naturally want to avoid sudden losses of power. According to Reuss, the significance of electric powertrain operability and the many other factors relating to operating strategies has grown significantly.

THE COMMUNICATING VEHICLE

Indeed, selecting the right operating strategy is important for the entire vehicle because software-defined functionality blurs the distinction between the vehicle domains. For the automotive supplier Continental, solutions along the path to the intelligent vehicle (for example connectivity, software, and enhanced driver-passenger experience) are a driver of growth that has already had a profound impact on the company’s corporate strategy. Signs of intelligent solutions include functional modularity, scalability, and new E/E architectures that enable update capability. Continental says that in 2019 alone it generated around 20 billion euros in sales from technologies for safe and connected mobility. Moreover, the high-performance computer segment for cockpit, body, and gateway functions has also shown significant growth.

Vehicle interiors are also being transformed in the wake of these developments as new functions require new and expanded user interfaces. The supplier Faurecia, for example, is focusing on communicative interiors. According to Marketing Director Gherardo Corsini, smart surfaces that include switchless operating elements can enable intuitive, context-specific vehicle operation. Furthermore, aiming to reduce weight, Faurecia has also turned its attention, among other things, to hybrid structural parts, natural fibers, lightweight seat structures – and, for example, to heat-radiating surfaces in order to reduce the heat output of the blower.

WHERE DO WE GO FROM HERE?

While the aforementioned examples present a limited account of the latest developments, they do make clear that as long as conventional and variously electrified powertrains coexist, complexity in the area of vehicle development will continue to increase. And even in the case of fully electric powertrains, development will be shaped by new and complex challenges relating to NVH, vehicle dynamics, automation, connectivity, cloud services, and electronic-system security.

However, electrification also presents an opportunity to better align vehicles to the wishes of consumers. In this regard, Bargende concludes: "We'll continue see variety for as long as consumers are capable of experiencing an emotional attachment to passenger vehicles." He then concludes that it is this variety that unleashes creativity and innovation among developers, and that he would only worry in the face of a trend toward uniformity. One could also put it this way: complexity that goes hand in hand with value is a competitive advantage while mere commodities are interchangeable.

Gernot Goppelt

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Gernot Goppelt
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WHAT DO WE THINK?

"While those who have so far embraced the narrative that the traditional players in the automotive industry missed the bus on electrification will probably continue to do so, reality is telling a different story. OEMs, suppliers and engineering service providers are hard at work on all aspects of electrification. For engineers at least, work assignments have grown rather than stagnated. The biggest change is perhaps the evolution from a component-specific to a complete-system approach that includes the vehicle and beyond. While this marks an opportunity for 'new players,' they will neither be able nor want to replace the expertise of the automotive industry when it comes to mastering one of the most complex of consumer products. It seems there is no lack of new tasks."

COMMERCIAL VEHICLES

Automated Driving Increases Safety Levels


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With blaring sirens and flashing blue lights, a fire truck races along the highway. Far ahead of it, a semi-trailer truck pulls over in good time into the inside lane, freeing up the outside lane for the emergency vehicle. There is nothing apparently unusual in that, but the remarkable fact about the maneuver is that it was not carried out by the driver, but by the truck itself. Mercedes-Benz caused a sensation in 2014 with its Future Truck 2025, which had a range of automated driving functions.

Six years have passed since then and many of the systems needed for autonomous driving have already reached a high standard of maturity. This is allowing developers to focus on details. While ABS systems can be used almost unchanged in driverless vehicles, the same is not true of electronic stability control functions, for example. This is because the directional and roll stabilization functions are based on the driver's steering movements and not on the layout of the road ahead, which in the past the system knew nothing about. But nowadays it can tell what is coming.

Experts are predicting that trucks will play a pioneering role in automated driving. However, the development of heavy-duty trucks in particular differs significantly in one way from the process for cars: The model cycles are very long. A new generation of trucks is only introduced every 15 to 20 years, and facelifts of existing models take place every six to eight years. For developers to meet the requirement for a future-proof generation of trucks, they need to take a new approach to the architecture, so that tomorrow's technology can be integrated into the trucks of today.

The high standard of maturity of automated systems referred to above is already reflected in the order books of automotive industry suppliers, as Torsten Gollewski from ZF explains. There is a growing demand for systems that will allow for automated driving on levels 4 and 5 in only a few years. Radar, lidar and camera systems are ready for use, and the latest central computers can manage even complex maneuvers. However, standardized legislation and infrastructures are needed to enable these systems to be used in normal or mixed traffic.

Frank Jung

The Electrics/Electronics Architecture of the New MAN Truck Generation

The new MAN Truck Generation sets standards in terms of digitalizing the trucks of tomorrow. The future-proof, central electrics/electronics architecture is characterized by modularity, scalability, expandability and openness. It thus represents the platform for current and future technologies, such as the electrified powertrain or automated driving.

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REQUIREMENTS FOR THE TRUCK OF TOMORROW

The developments in electronics over the last 20 years show an exponential increase in complexity, which has a massive impact on the underlying methods, processes, development tools, and people, but also on the E/E architecture and the systems themselves. The demands on the truck of the future are constantly increasing.

The product development cycle in the commercial vehicle sector has some special features and differs significantly from the cycles in passenger car development. The long model cycles are particularly characteristic. For example, a new model generation is launched every 15 to 20 years and a facelift of the model reaches the market about every six to eight years. New functions and systems are developed further every year and integrated into the vehicle series over model years. A high degree of variance, driven by numerous everyday applications, continues to characterize the commercial vehicle sector. In addition to this, a commercial vehicle represents a capital good. The Total Cost of Ownership (TCO), reliability and future viability of the truck play an important role.

In order to meet the requirements of a new, future-oriented truck generation in development, a new methodical architectural approach is needed. It is necessary to create a customer-oriented approach, which in particular guarantees the temporal stability of the new E/E architecture in order to meet the requirements of long life cycles.

A NEW METHODOLOGY ENABLES THE ARCHITECTURAL APPROACH

The currently predominant image of an E/E architecture is a component-oriented representation that shows the mapping of control units and bus connections. The disadvantages of this approach are particularly apparent in the implementation of new, innovative functions in which hardware and software components interact with each other across ECUs and lead to higher-level functionality.

As early as 2003, MAN laid the foundation for today's E/E architecture and, with the help of a new meta-model, radically changed the previous approach to an architecture topology. The basic approach of requirements analysis, concept development/programming and evaluation is not changed in the process. Rather, the goal is to create a time-stable, customer-oriented approach to how the results of hardware and software development can be described.

The top level of the meta-model represents the vehicle function, **FIGURE 1**. It describes a certain behavior of the vehicle from a bird's eye view and contains the requirements for the functionality and its description. The functionality of the meta-model can be explained using Adaptive Cruise Control (ACC), a distance-regulating cruise control system. The ACC vehicle function is realized by several sub-functions that are derived from the requirements and contribute to the respective vehicle functionality.

For example, there is one function for the ACC which detects the current speed of the vehicle, another which contains the cruise control, functions which detect vehicles in the environment and measure their speed, a display function for the driver and finally the function which influences the speed and torque and thus changes the vehicle speed. The individual functions communicate with each other via signals. The sum of the vehicle functions, their sub-functions and communication interfaces form the so-called functional architecture of the vehicle.

The functional architecture currently contains around 250 vehicle functions that describe how the truck functions. A customer who has a non-functional ACC in his vehicle and visits a workshop will describe that his ACC is not working. However, the customer will never say that his radar is defective. However, this component-oriented

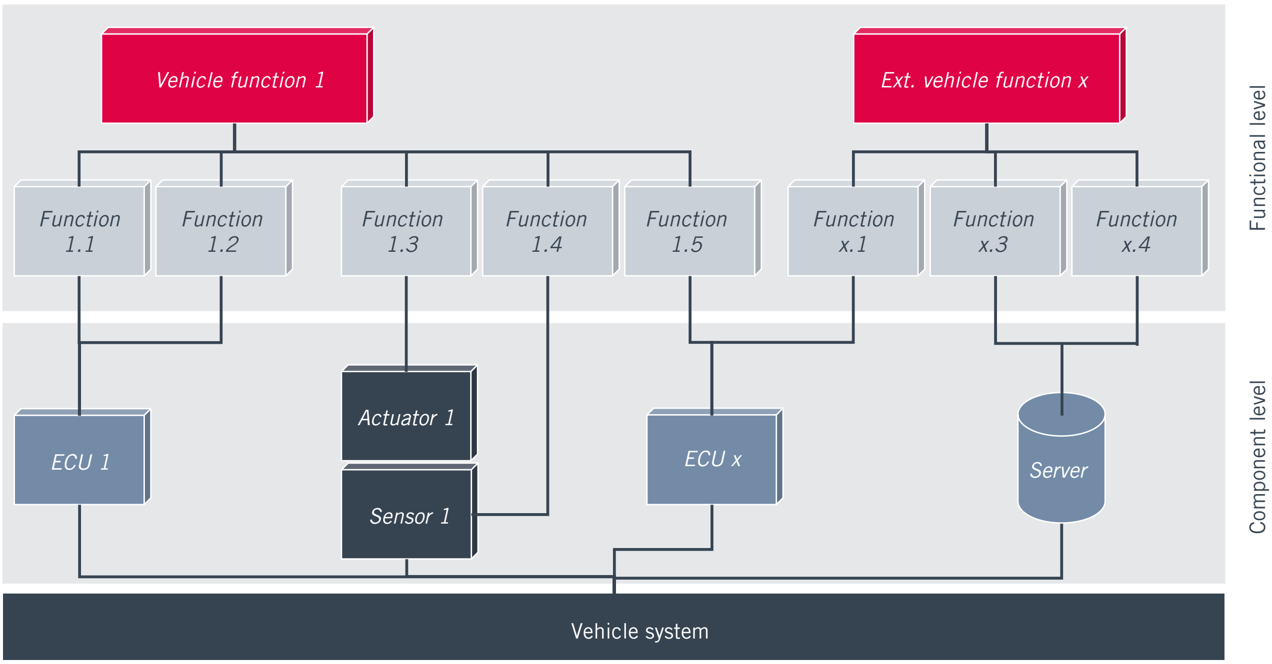

FIGURE 1 Schematic representation of the developed methodology/meta-model (© MAN)

description has been predominant in the past.

The development of vehicle functions and hardware components also shows changes: While the majority of vehicle functions remain constant, rapid changes are evident in the field of hardware technology. The vehicle light function, for example, has changed very little. However, the technology from H4, H7, xenon to LED has changed significantly.

The functional architecture is virtual, meaning the level acts independently of components (control units, sensors and actuators). Only in a second step are the functions assigned to the components of the system architecture and thus to the topology.

Since 2003, MAN has been using this approach to describe the domains of the vehicle and develop strategically important functions that satisfy the meta-model. This approach has many advantages: The functions are reusable. If a new topology is introduced within the E/E architecture, the vehicle functions and features can be reused to a high degree. A simple switch from an existing topology to a new one is made possible, as the functions are simply reassigned to the components. Potential sources of error lie exclusively in the area of functional integration. Errors in the function itself can be excluded. A high quality vehicle can be realized quickly after a switch.

THE FEATURES OF THE NEW E/E ARCHITECTURE

The new E/E architecture is characterized by a centralized approach, that means there is a central computer that contains all strategically relevant functions of all domains. The vehicle information is consistently available to the functions on an internal bus (middleware) in real time.

Due to the chosen approach, the intelligence of the vehicle is reduced to one component. But also the number of control units in the vehicle is reduced to a minimum. Remaining ECUs no longer contain strategic functionality. Consequently, the integration of new functions takes place at functional level and no longer at the level of ECU and CAN network, **FIGURE 2**.

Due to the central approach, the architecture is modular, which means a wide variety of engines, transmissions and braking systems can be supported and integrated. This can be illustrated

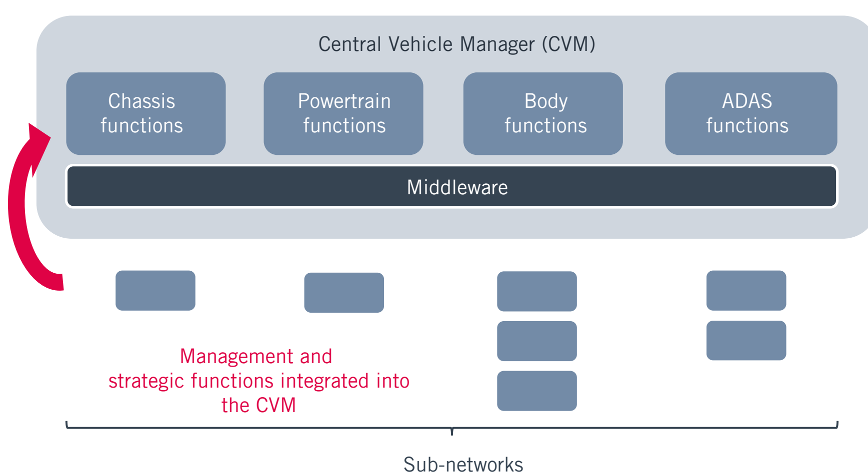

FIGURE 2 Schematic representation of the central E/E architecture approach (© MAN)

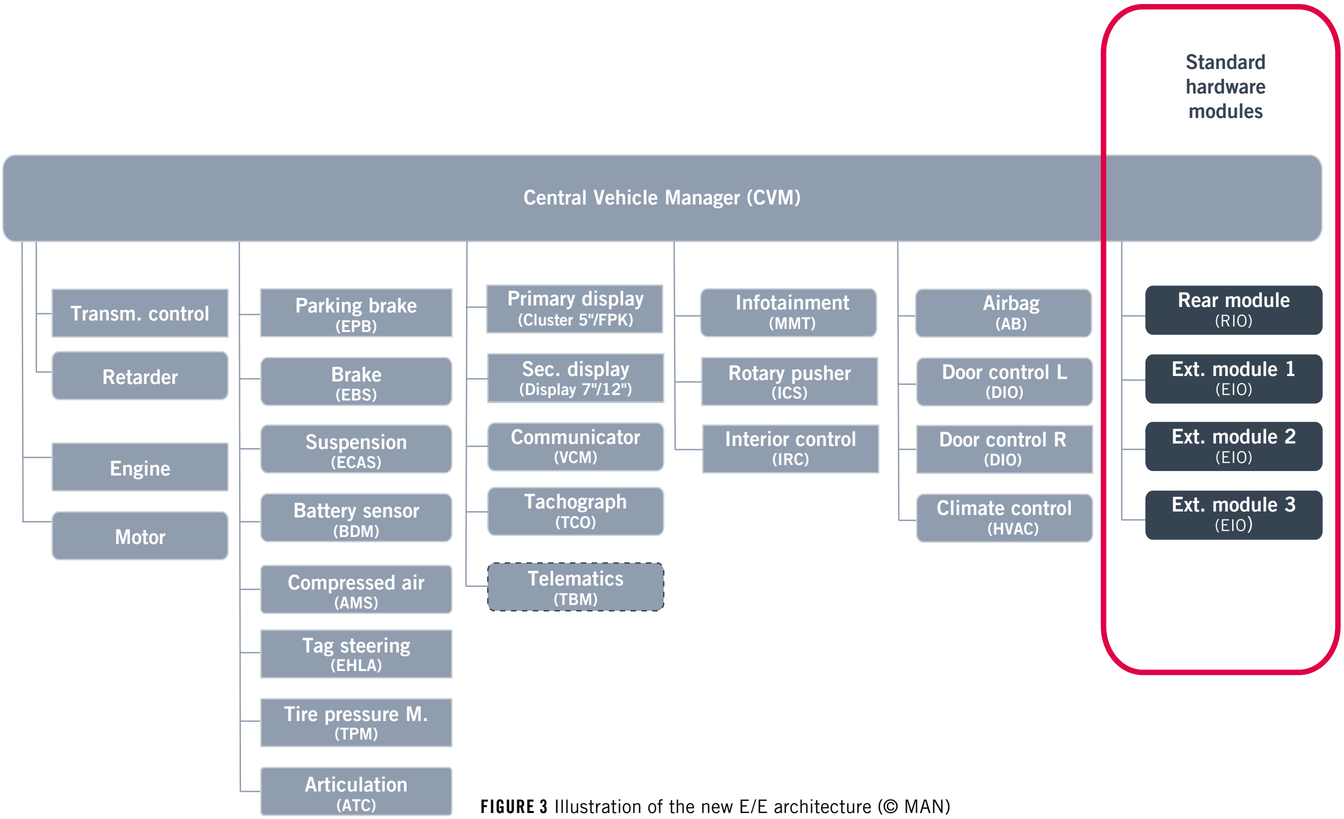

FIGURE 3 Illustration of the new E/E architecture (© MAN)

using the example of the shifting strategy: Since the entire powertrain management including the shifting strategy is located on a central computer, it remains intact when a transmission or engine is replaced. Only the new physical properties of the unit are adapted via parameters.

In addition to the central computer, standardized input/output modules (I/O modules) have been introduced into the architecture. This enables scalability. If a complex vehicle requires additional sensors, these can be installed via an additional I/O module in order to read in the sensor technology or to control an actuator system. This also results in good expandability for future vehicle functions and systems and makes the architecture future-proof, **FIGURE 3**.

Another important requirement for a new E/E architecture is the openness of the platform. A future-proof commercial vehicle must be open for logistical processes and their layout. The app framework used makes it possible to integrate third-party software into the vehicle and use the vehicle's information.

In addition to the properties of scalability, modularity, expandability and openness, the E/E architecture also fulfills technical properties. For example, it has been developed according to ISO 26262 and offers functions up to ASIL D to be integrated in the central computer.

Two 12" displays and generic operating modules such as the Smart Select (rotary pushbutton with touchpad) allow new or third-party functions to be integrated into the vehicle HMI.

The central computer is connected to the connectivity module via Ethernet. This enables broadband data transfer between the vehicle and the MAN back end, allowing rapid updates and expansion of the existing fleet. For the customer this means that their vehicle changes and develops over its life cycle like a smartphone. The role of architecture has thus become one of the most important in development.

THE E/E ARCHITECTURE CHANGES THE ORGANIZATION

The new description standard for the vehicle has been introduced throughout MAN and covers the areas of product management, the entire vehicle/production series, electrics/electronics through to service.

As already evident in the first sections, an E/E architecture is not the same as a

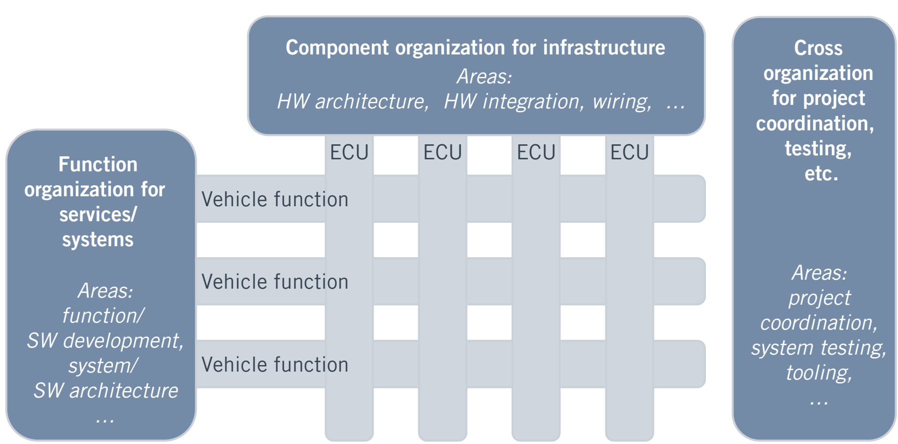

FIGURE 4 Representation of the E/E organization (© MAN)

topology. Rather, the E/E architecture represents a bracket, spanning many layers and description models, up to the processes, tools and those who use them – the employees.

The model of separation of function and component, as well as the different architecture layers, lead to the introduction of a new form of organization. MAN's E/E unit is centrally organized, which means there is an electronics unit where the complete development of all ECUs takes place, **FIGURE 4**. Within this unit there is a clear separation between functions and components, and it follows the principle of a system IT house.

While one unit is responsible for all components, the complete hardware platform including the vehicle electrical system and hardware integration, a second unit is responsible for the complete responsibility of the vehicle functions. This division integrates the applications on the hardware platform in terms of IT.

In order to maintain the dual control principle, the testing unit is provided separately and a project management unit takes care of the organization of the projects.

Within the organization, the architecture levels are also reflected. There are dedicated departments for the functional, system and hardware architecture.

New roles and responsibilities are thus created within the E/E area. For example, there are departments that deal with the implementation of functions in the software and have no responsibility for components. An essential challenge regarding the successful introduction of the E/E architecture is therefore also in the area of organization: the transformation from a classical component-oriented way of thinking to a functional one, **FIGURE 4**.

CENTRAL PROCESSES AND TOOLS

In order to master the complexity of a modern commercial vehicle, processes and tools are important elements. For this reason, MAN is also consistently developing the tool chain in parallel with the new approach, **FIGURE 5**. The focus is on the central development database eese (EE simplifying engineering) on which all developers work. The database contains the described meta-model and thus ensures that all developers work according to the same methodology.

Areas such as requirements management, architecture development, content/source code management, test management, error management, as well as data set development and administration are united in the development database.

In addition, the single source principle applies, which means that each piece of information is generated once and used consistently in each process step.

The process of function and software development is completely decoupled from the classic mechanical product development process, thus enabling a flexible and fast introduction of new functions. The processes are set up in such a way that a team-oriented, agile working method is supported.

THE ASSISTANCE SYSTEMS OF THE NEW MAN TRUCK GENERATION

The E/E architecture is designed to support future technologies already today, such as electrified powertrains or automated driving. In the case of automated driving, a second computer must be installed in parallel to the current central computer to provide redundancy for the driver. In addition, a redundant onboard network is also necessary to ensure the power supply. Both components are already conceptually available in the architecture.

The developed central architecture not only supports the developments toward automated driving, but also

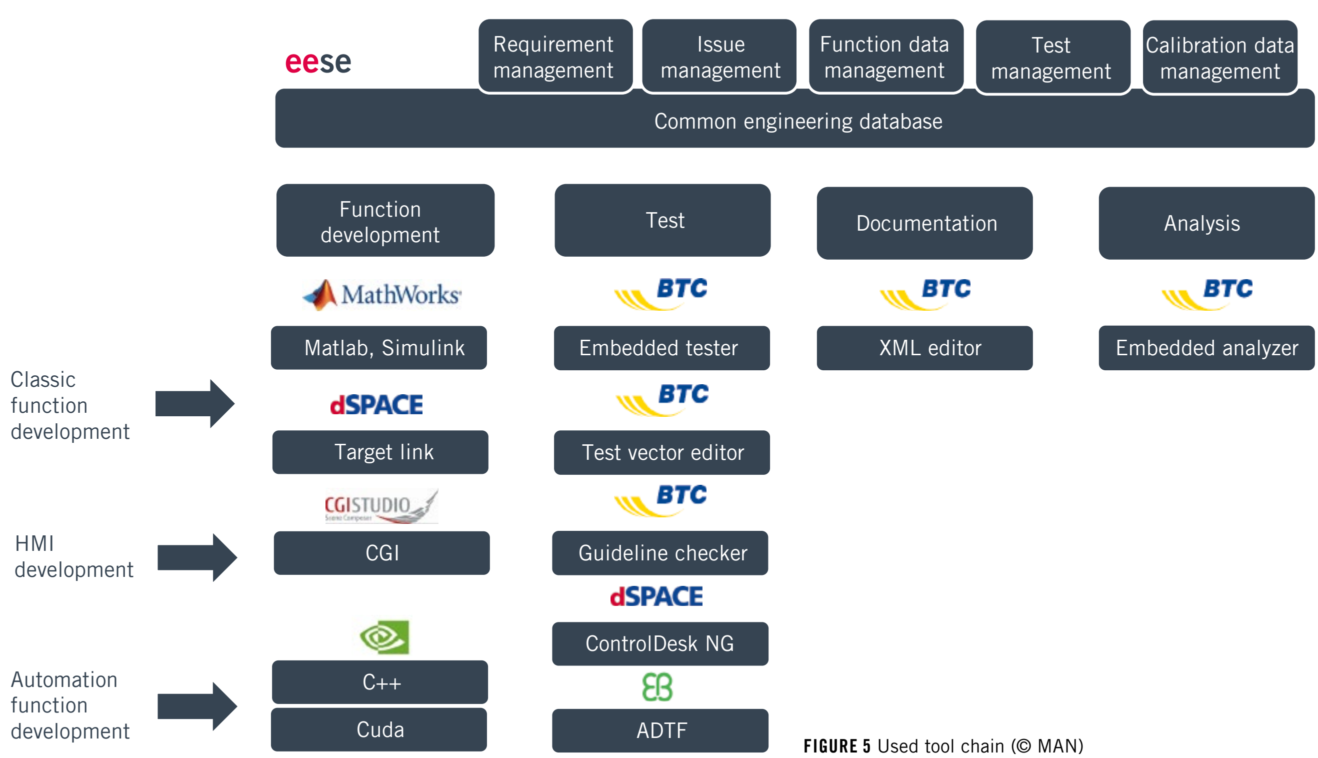

FIGURE 5 Used tool chain (© MAN)

enables the implementation of assistance systems already available in series, such as:

- the emergency brake assistant
- the lane departure warning
- the lane tracking system
- the turn-off and overtaking assistant (including the installed side radar sensors)
- the longitudinal guidance assistant (Efficient Cruise and ACC Stop & Go)
- the fatigue warning
- the high beam assistant.

Based on the new E/E architecture, all essential assistance systems have been developed and integrated with the new truck generation. The chosen holistic systemic approach allows a joint consideration of all assistance systems. They are coordinated with each other, which leads to an increase in system performance and more intuitive system behavior for the driver, **FIGURE 6**.

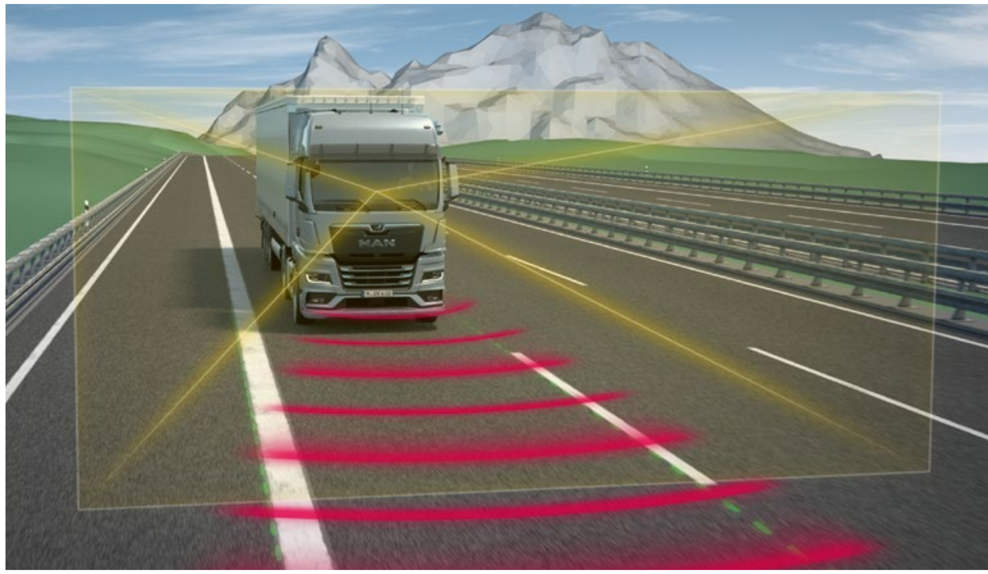

FIGURE 6 Assistance systems of the new truck generation (© MAN)

Looking into the near future of the commercial vehicle, automated functions such as the congestion assistant and the motorway pilot are within reach. The use of the new E/E architecture enables the integration of future-oriented functions. With its new truck generation, AN is technologically and organizationally equipped for this.

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"From a technical perspective, we're ready to go"

Many experts believe that automated driving systems up to and including level 5 will first become widely available in the commercial vehicle sector and in passenger transport. Torsten Gollewski, Executive Vice President Autonomous Mobility Systems at ZF, gives an insight into the company's latest developments, ranging from central computers and electric robo-taxis to shuttles that are reliable in all types of conditions.

ATZ _ Torsten Gollewski, how important is automated driving for ZF in general terms?
GOLLEWSKI _ At ZF we have an integrated vision of safe, clean mobility that is comfortable, convenient, affordable and fully automated. This next generation mobility will cover all the main areas of goods and passenger transport. In addition to climate-friendly powertrains, which we supply at production levels and continue to develop, we are also making consistent progress with automated driving systems. Automated and autonomous driving will ensure that transport is safer, more efficient and more convenient in the future. However, different types of solutions are needed depending on the application. Intelligent assistance functions on level 2+ offer the greatest initial potential for use in cars. By contrast, in commercial vehicles and urban public transport systems, we are likely to see fully automated systems on level 4 or above being introduced. This is confirmed by the orders that we have received from car and truck manufacturers.

Torsten Gollewski (born in 1969) is Executive Vice President Autonomous Mobility Systems at ZF Friedrichshafen AG and CEO of Zukunft Ventures GmbH in Friedrichshafen (Germany). He completed a degree in electrical and telecommunications engineering at Ravensburg University and then began working at DASA (now EADS) in the aerospace division. In 1993 he moved to Temic Automotive, and in 1995 he began studying at Henley Business School, where he gained an Executive MBA. He joined Audi in 2000 to become Head of Electronics Pre-development. He then went on to act as Head of Cooperations and Project Management at Audi Electronics Venture. In 2002 he took on the role of Managing Director of PMD Technologies and then in 2007 returned to Audi as Head of Electronic Systems for vehicle safety and, subsequently, as Managing Director of the Automotive Safety Technologies division. Gollewski has been working at ZF since 2016 and his first role was Head of Pre-development.

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What role do commercial vehicles in particular play?
Their role is very important because we are working on the basis that autonomous driving will become widespread in the commercial vehicle sector, first of all. In this area, we are already seeing demand for systems that will make fully automated driving at level 4 and above possible in a few years' time. Commercial vehicles can already function in fully automated mode in enclosed areas or restricted lanes. In addition, driverless operation in company yards and in urban public transport systems offers potential savings that would allow the systems to pay for themselves very quickly.

Which technical and legislative challenges need to be overcome first in order to make automated driving possible?
From a technical perspective, we are ready to go. The technologies needed, in particular radar, lidar and camera systems, are sufficiently advanced and our central computers can even manage complex maneuvers. In fact, via our subsidiary 2getthere, we have been successfully running driverless shuttles for more than 20 years. Vehicles supplied by 2getthere have covered more than 100 million km autonomously, transporting more than 14 million passengers with a system availability of over 99 %. However, all of this has taken place on restricted routes. We still do not have the standardized infrastructure and legislation that would allow the vehicles to operate in normal road traffic.

What are the differences between commercial vehicles and cars in terms of automated driving?
Automated driving is likely to become widespread in sectors where there is a suitable business model, in other words, transporting goods and passengers. Level 4/5 applications will be introduced in this area in the future, when the appropriate legislation is in place. In cars, we are expecting to see different versions of level 2+ systems, where the driver still has full responsibility and control. Our aim is to supply systems for cars and commercial vehicles. We are already developing systems on behalf of customers in both areas. The fact that ZF is an ideal partner for implementing automated and autonomous driving solutions is reflected in the contract we have signed with an international commercial vehicle manufacture, to develop the ZF ProAI RoboThink. This is our central computer for an automated level 4 system that will be in use in trucks from 2024/25 onward.

"Autonomous trucks will play a key role in the logistics systems of the future"

ZF is taking a multi-pronged approach to the development of people movers. Why is this?
We are a supplier which means, of course, that we want to offer our customers a portfolio of innovative products and solutions that is as wide-ranging as possible. We also supply open and scalable systems. I wouldn't call this a multi-pronged approach. Instead, I would say that we want to supply the best solution for every customer's individual requirements. This is true of ZF as a whole and does not just apply to people movers, where we are already offering two designs capable of transporting up to four or up to 22 people. For example, we have worked with our US partner TuSimple to coordinate our products with an Autonomous Driving (AD) software stack. The AD system is already in the validation phase.

In the context of automated driving, people immediately think of electric powertrains. Does the combustion engine still feature in your plans?
There is no doubt that electrified drives are the future of transport. This applies in particular to new mobility solutions such as robo-taxis. At ZF we are pushing ahead with the development of climate-

friendly powertrains and starting to produce them on a mass scale. We are focusing more closely on the systems of the future and paying less attention to improving existing technologies for vehicles with combustion engines. The transformation is our number one priority. However, particulary in the case of commercial vehicles, we need to look in detail at each individual application. For example, it currently makes no sense to develop battery electric drives for long-haul trucks because of the distances they travel each day. The heavier the vehicle, the larger the battery capacity required to achieve the same range. However, the increased weight of the traction battery comes at the cost of the payload. If the range is an important consideration, as it is for the logistics industry for example, then an inadequate charging infrastructure is also a key factor. The situation is quite different for local public transport and delivery vehicles. In this area, ZF has been supplying electric drives on a production scale for several years for use in city buses and vans, for example.

What are the next stages in the introduction of automated driving functions into production models of trucks?
We are supplying sensors, software, central computers and actuators, all of which contribute to improving safety levels in commercial vehicles. Examples of solutions that are already on the market include emergency braking and lane keeping assist systems. One of the main driving forces behind the technical development and market penetration

“Public transport systems without timetables will redefine urban mobility”

of assisted and automated driving functions is legislation. Future requirements state that trucks are fitted with turning assistants, for example. Our systems use short-range corner radar to identify cyclists in the truck’s danger zone and to alert the driver if necessary. In April of this year, we began a cooperation with the US company TuSimple, which is working with commercial vehicle manufacturers to speed up the development of autonomous trucks, in particular in the USA. It already has a fleet of more than 40 automated trucks which make 20 trips every week between Arizona and Texas for companies such as UPS. Autonomous trucks will play a key role in the logistics systems of the future.

What potential does a virtual driver offer with regard to environment detection, route planning and longitudinal and lateral control when the vehicle is stable?
Virtual drivers in trucks have the same potential as they do in cars. They improve levels of comfort, but most importantly, lead to increased safety. In emergencies, they could even save lives. For this reason, we believe that the highest priority for virtual driving systems is their reliability under all types of conditions. People will not trust assistance systems if they do not consistently perform to the same high standard or only work in fine weather. We are setting the bar high in this respect. ZF’s products are always automotive grade. This means that our customers can be certain that ZF will supply them with a fully developed, reliable product which meets all the relevant automotive and safety standards. We have seen companies in Silicon Valley, among other places, develop components which I would describe as laboratory solutions. By contrast, the ZF AD system is based only on automotive grade components. This is essential because we cannot develop a sustainable, long-term business model using non-automotive grade solutions.

What will local public transport systems look like in future?
We are currently offering two different types of shuttle via 2getthere. The larger Group Rapid Transit vehicle has space for up to 22 people and is designed for use in local public transport systems, at airports and in business parks and campuses, for example. It has an 85-kW electric motor and a battery capacity of up to 92 kWh, which enables it to reach speeds of up to 40 km/h. We also have the smaller Private Rapid Transit (PRT) vehicle in our range, for groups of up to four people. This has been in operation in Masdar City in the United Arab Emirates for several years without a safety driver. These PRTs could be linked if required. Both shuttles have radar, lidar and camera systems that they use to detect the precise features of their environment. In addition, we use a patented magnet technology for localization that functions when the roads are covered with snow, for example. This is a situation where cameras have difficulty in detecting the edges of the roads. At the same time, the magnet technology acts as a redundant solution for our HD maps, which have special features for automated driving. We believe that over the next decade autonomous shuttles of this kind will become widely used in public transport systems, including airports, park-and-ride schemes and inner cities. Autonomous shuttles will make a public transport system without timetables a possibility and will redefine urban mobility.


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Automated and autonomous driving will make the mobility solutions of the future safer, more efficient and more comfortable, says Torsten Gollewski

Torsten Gollewski, thank you for this interesting discussion.

INTERVIEW: Frank Jung

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Stability Control for Driverless Commercial Vehicles

In order to be able to use driverless commercial vehicles in all parts of the world in hot, wet and slippery conditions, ESC systems for vehicle dynamics must be improved. ZF Group Commercial Vehicle Control Systems proposes the use of a trajectory interface that regulates driving stability more precisely. It also makes it possible to prevent critical situations in advance. The integration of an active steering system further enhances the quality of long-haul transport truck stabilization.

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DRIVERLESS TRUCKS NEED A TRAJECTORY INTERFACE

Automated commercial vehicles (according to SAE levels 3 to 5) are currently being operated in areas with predominantly dry weather and low-density traffic, for example in the desert of Arizona (USA), where external factors have little impact on vehicle behavior in order to test them as an entire system. However, the weather and traffic conditions around the world are not always as favorable as in regions like Arizona, and in order to be able to use driverless vehicles in areas like Rovaniemi (Finland), which is wet and has packed snow, stability control systems are a must, **FIGURE 1**. These systems are designed to stabilize the vehicle in vehicle-dynamics-critical driving conditions, such as on slippery roads or in situations with high lateral acceleration, and could even prevent these hazardous situations from happening in the first place.

Such novel stability control systems, as they are being developed by Wabco (acquired by ZF and now part of the ZF Group) for automated driving, support a "Virtual Driver," just like contemporary Electronic Stability Control (ESC) systems help human drivers in conventional commercial vehicles. The use of a trajectory interface is required for this purpose. It controls driving stability, even preventing the onset of critical situations. However, safe automation can still benefit from additional new functions of the extended stability control: Integrating an active steering system into the actuator concept enhances the support for µ-split maneuvers and improve the fail-safe ESC fallback level will also raise stability and, as such, the safety of self-driving vehicles. Last but not least, the ability to activate individual brake interventions on the front axle wheels allows an excellent fallback level in case the active steering system fails.

SPECIAL ESC SYSTEMS FOR AUTONOMOUS COMMERCIAL VEHICLES

Contrary to Anti-lock Braking Systems (ABS), the ESC systems cannot simply be integrated into driverless commercial vehicles. That is because the ESC function, which is used in commercial vehicles for directional and rollover control

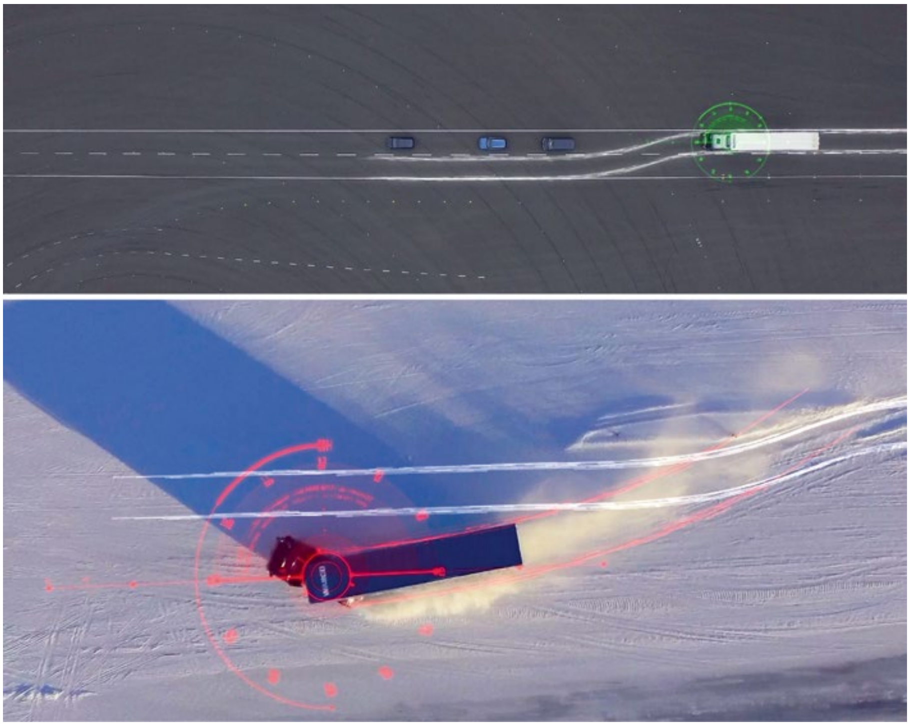


FIGURE 1 Heavy-duty commercial vehicles must remain stable in all weather conditions – both on dry surfaces on the test track in Jeversen (Germany) (top) and with snow in Rovaniemi (Finland) (bottom) (© Wabco)

(avoiding over- and under-steering and as roll-over protection), has so far been based on the driver's steering behavior – and not on the vehicle route, which was previously unknown.

In autonomous commercial vehicles, now the nominal route, which is available in the virtual driver's route planning module, can be used as an input signal for the ESC function. A usage of the trajectory interface makes safe automation easier because the virtual driver does not have to learn special skills, such as fast counter-steering or vehicle control at the limits of handling. The virtual driver can simply determine the trajectory based on the route and the current traffic situation and describe the vehicle's nominal route for a defined time window of several seconds, **FIGURE 2**. By the handover of the route, it is possible for the first time to realize a predictive vehicle stability. Here, the required travel distance is matched with the expected driving behavior in order to realize early control interventions. In this way, dangerous instabilities cannot only be mitigated but, in some cases, can even be prevented completely.

The communication with the virtual driver is very important to achieve this aim. The virtual driver will be warned in advance in the case of potential instability, so that it can adopt a defensive driving style in order to prevent losing control.

Just like in conventional ESC, in order to stabilize the vehicle in the event of unforeseen circumstances (for example an avoidance maneuver because of a pedestrian crossing the road, a collision or the tail end of a traffic jam), a graduated response is initiated by the control strategy: the combustion engine torque is limited and a yaw torque is applied to counteract over- or under-steering.

In addition to the familiar single-wheel braking, an active steering system also helps to ensure stability control in autonomous commercial vehicles. With the help of this additional actuator, the vehi-

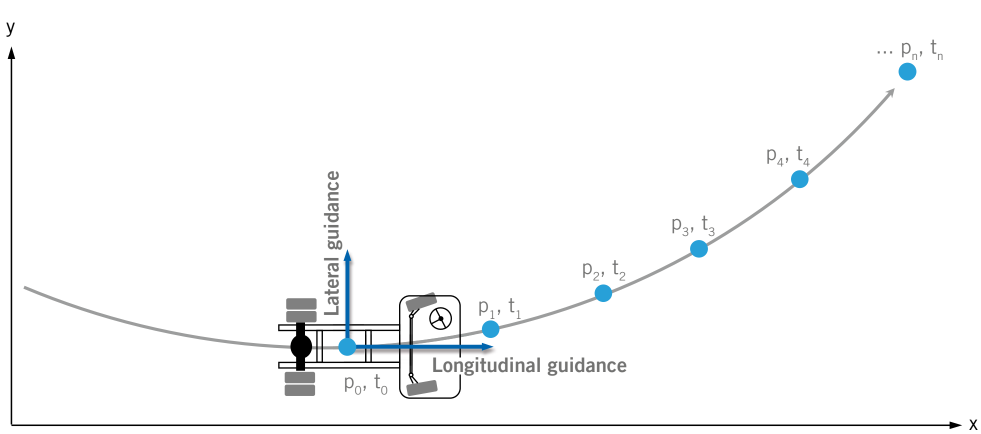
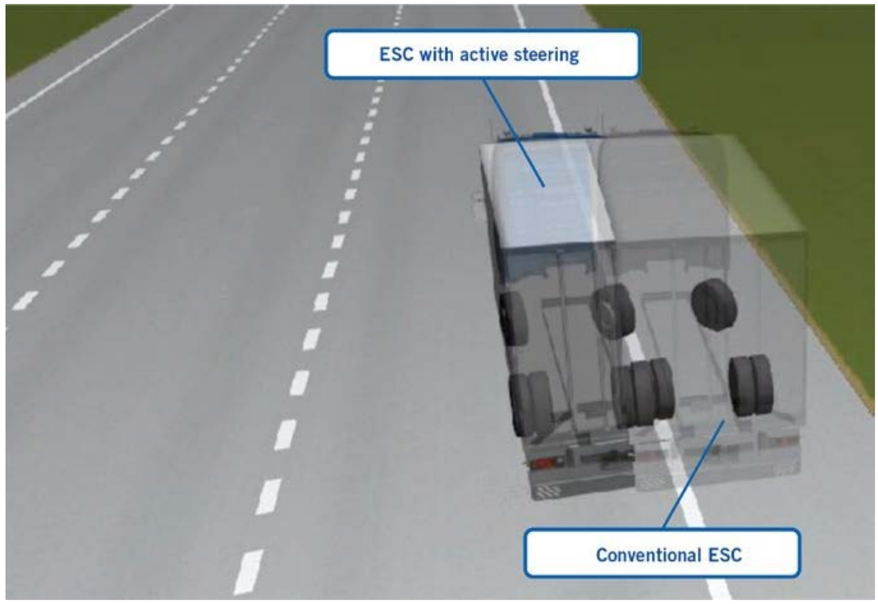


FIGURE 2 Exemplary course of the trajectory with the positions p in a time window from time t_0 to t_n (© Wabco)

FIGURE 3 Benefits of the ESC and steering proven with a certified simulation system (Simba) – the vehicle equipped with the additional active steering is not deviating from the lane (© Wabco)



cle stability can be improved and this contributes to increased safety in road transport.

Due to the scarcity of traffic space – especially for commercial vehicles – lateral guidance is generally more important than longitudinal guidance: reaching the destination at a pre-defined time is less important than safe driving. In practice, this means that the driving speed will first be reduced in order to follow the geometric trajectory in X- and Y-directions, **FIGURE 2**. A deviation from the nominal speed, which can also be defined in the trajectory, is acceptable.

The in-house simulation tool Simba, which is certified for ESC homologation, proves how steering interventions improve the performance of stability control. **FIGURE 3** compares the impact of a conventional ESC system (right) to that of an active steering intervention (left) after driving through a left-hand bend at a low coefficient of friction. While in this case of under-steering, the conventional ESC-controlled vehicle has already deviated into the lane to the right, the vehicle with additional active steering intervention clearly deviated less at the same driving speed. The vehicle without control system would also already be far to the right of the lane, on the grass (not visible in this figure).

FIGURE 4 shows schematically that the ESC system was extended with nominal route preset and sensor technology and additional actuators for new technical possibilities, like the active steering and electric wheel drives. This extension, which is called the Dynamic Motion Controller (DMC) in-house, combines various individual tools in an all-in-one platform. In this way, the DMC can also improve vehicle handling in stable conditions – for example by taking into account the self-steering gradient during stable driving by means of model-based vehicle knowledge, which helps to steer the vehicle more precisely. The trajectory interface can also enable maneuvering functionality for automation in yards or freight depots [1].

To enable this, the specified driving task has to be carried out correctly. Information must be also passed on to the virtual driver, which will then be able to control the vehicle adequately and safely, based on static and dynamic information coming from the DMC. The total combination mass detected by the Electronic Braking System (EBS), for example, is used to determine the acceleration and gradient capability and is communicated to the virtual driver via a “passability corridor.” This corridor also contains information on the maximum permissible lateral dynamics and provides dynamic data such as friction coefficients or limit ranges reached by traction control (ATC), ABS or ESC systems. This enables the virtual driver to adapt its “driving style.” In an open system such as road transport, however, it will not be possible to rule out unexpected situations where ABS and ESC are needed to ensure driving stability, for example in the event of suddenly occurring obstacles or unexpectedly slippery roads.

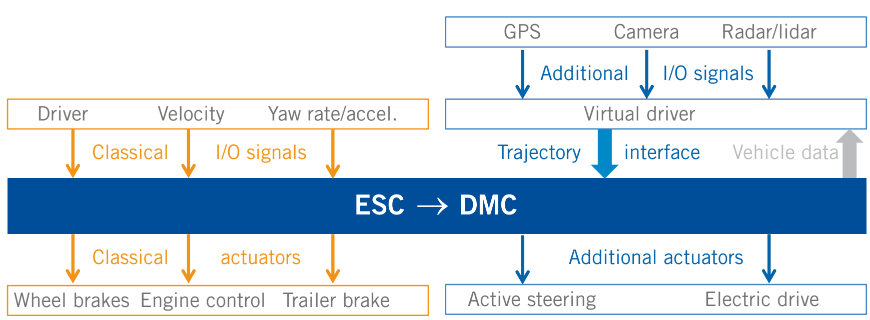


FIGURE 4 The evolution from pure ESC to the Dynamic Motion Controller (DMC) with active steering and electric wheel drives (© Wabco)

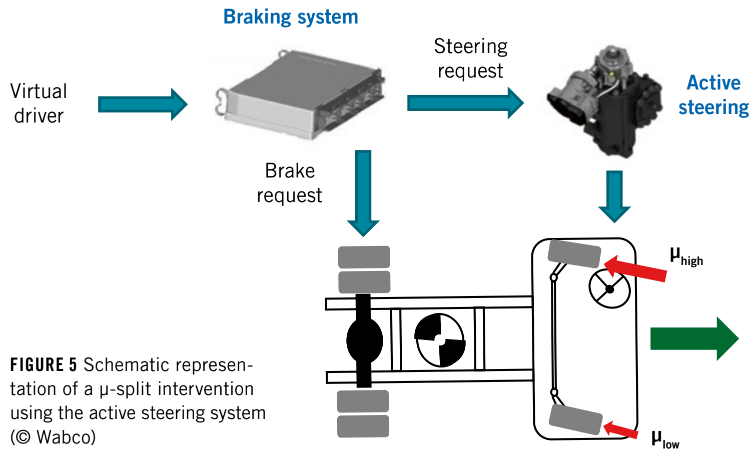


FIGURE 5 Schematic representation of a µ-split intervention using the active steering system (© Wabco)

µ-SPLIT SUPPORT

When a vehicle is braked heavily at coefficients of friction which vary greatly from side to side (µ-split) on a road, it causes a sudden breakaway of the vehicle in the direction of the higher coefficient of friction (partly reinforced by the front axle geometry). This can cause a number of critical situations for the vehicle and its surroundings. In this situation, which is difficult even for experienced drivers, decisive countersteering is needed to keep the vehicle on track. Taking into account a driver's reasonable steering forces and reaction time, current EBS limits the rate-of-pressure-change gradient of the front wheel and its rise in pressure at the front axle. As a result, braking distances are lengthened.

In the case of a self-driving vehicle, this counter-steering must be done automatically. The information about the existence of such a situation is already available in the braking system. Based on that information and the current vehicle behavior, the DMC's µ-split function, **FIGURE 5**, can immediately determine a deviation from the planned nominal route and initiate counter-steering via the active steering system. In this way, it ensures that the vehicle keeps following its nominal route and avoids swerving. In addition, the shorter reaction time and the higher available steering forces of an active steering system allow a stronger brake intervention at the front axle, which ultimately leads to a shorter braking distance.

STEER-BRAKING IN CASE OF UNSTEERABILITY

The loss of steerability, for example due to a failure of the active steering system, is a serious fault in an autonomous vehicle and must be avoided under all circumstances. In this situation, the braking system in conjunction with the DMC can provide a fallback level to perform simple maneuvers. This is called steer-braking with a Fail Operational Steering System (FOSS), **FIGURE 6**. For this purpose, the wheel-individual interventions known from the ESC system are used specifically on the front axle to set the steering angle that the virtual driver requests.

The vehicle's reaction is monitored with existing sensors (velocity, yaw rate) and the brake pressure at the front axle is controlled so that the vehicle follows the required nominal route. To avoid wear and tear, this steer-braking is, of course, only possible for a limited time, as the wheel brakes heat up considerably during such steering interventions. The intervention is just long enough for the vehicle to stop in a safe place out of traffic circulation (minimal risk maneuvers: for example changing lanes on the sides of the road, limited continuation to the next possible stop).

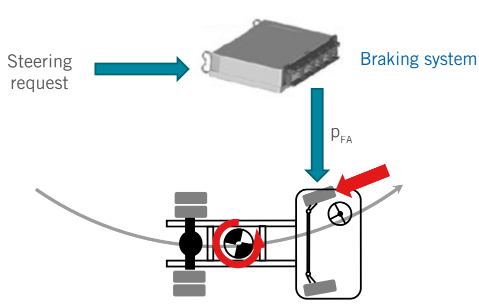


FIGURE 6 Schematic representation of steer-braking operation with the wheel-individual brake pressure p_{FA} at the front axle (© Wabco)

FALLBACK LEVEL FOR ESC

An additional functionality is required to ensure stability in case the braking system fails instead of the steering system. In a braking system that is ready for automation – like the next generation of braking systems – a second braking circuit is activated when the first one fails. This circuit not only helps the vehicle to slow down, but also includes a fallback level for the ESC function described before. In this way, it will stabilize the vehicle solely by means of active steering interventions and axle-by-axle braking, if there is no single wheel braking capability.

SUMMARY AND OUTLOOK

As shown here by Wabco, an extended ESC helps to boost the safety of autonomous commercial vehicles. If driverless trucks have to operate reliably under all environmental conditions, stabilization features are not only helpful, but indispensable to ensure product liability.

A trajectory interface incorporated in the DMC enables the virtual driver, which is usually unable to act reasonable in critical driving conditions, to operate the vehicle safely under all driving conditions. Consequently, the interface is the virtual driver's best possible driving assistant. It helps the operator of the self-driving vehicle to ensure the best possible vehicle stability under all environmental conditions – in a simple way and with the least development effort. Based on the features of the proven ESC, the DMC is a future-proof extension that takes into account the requirements of vehicle automation and electrification.

In the long run, the authors believe that this type of vehicle stabilization support via the trajectory interface is a prerequisite for the safe, widespread and worldwide use of automated commercial vehicles.

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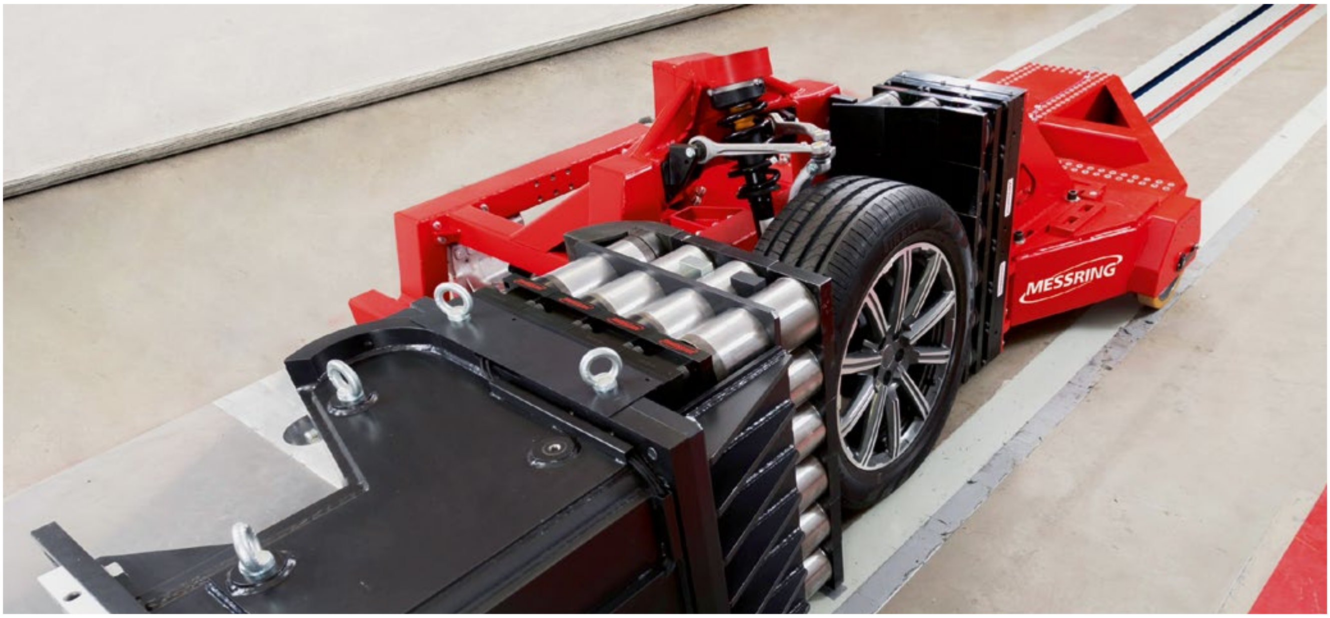
[1] Wulf, O.; Dieckmann, T.; Wolf, T.: Assistance and Automation for Commercial Vehicles at Freight Depots. In: ATZworldwide 9/2018, pp. 40-43

Messring | **Crash Slide for Component Testing**



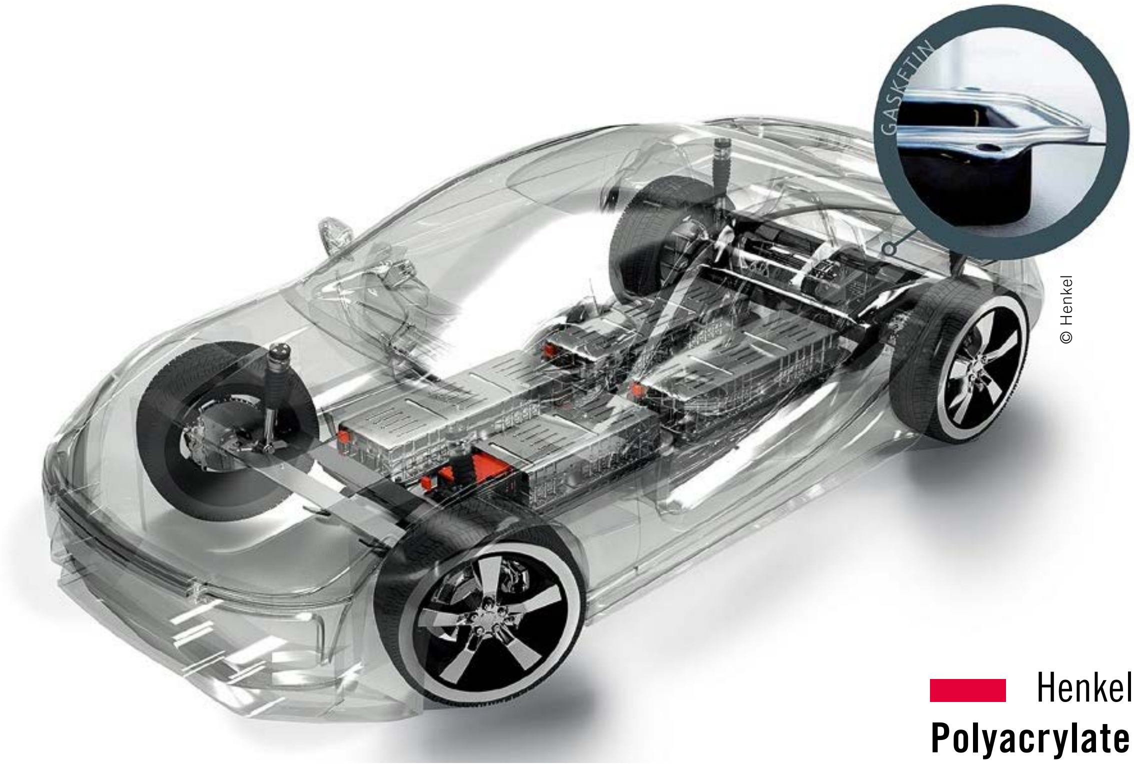
© Messring

The Small Overlap Crash Test is one of the greatest challenges to the structural strength of vehicles. One of the main assessment criteria is the penetration of tires, body and chassis parts into the passenger compartment. With the M=SLED Small Overlap from Messring, there is now the option of testing critical chassis components that could penetrate the passenger compartment without destroying an entire vehicle body. The test sled is designed for use with a hydro brake and is designed to realistically display the test scenario on the left side of the vehicle. The chassis under test runs freely rolling on the ground at up to 64 km/h against a force measuring wall, which is contoured to the small overlap barrier, and is decelerated in a controlled manner until it breaks. Thanks to the additional force measuring wall, which is based on a wheel housing shape and travels on sleds, the resulting forces and deflection of the components in the wheel housing are recorded. The sled can be adapted to different chassis mounts.

Volvo | **Cornering Assistant**

© Volvo

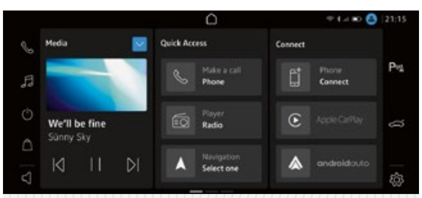
To reduce the risk of accidents, Volvo is offering a cornering assistant in its 60- and 90-series models that complements the driving functions of adaptive cruise control and pilot assist. The curve speed assist is able to automatically reduce speed before sharp bends if the set speed is considered too high. The system uses the map data of the navigation system for this purpose. After passing through the bend, the car accelerates back to the preset speed value. A comfortable set-up is set as standard; with the “Dynamic” option, the car takes the bends in a sportier manner and accelerates more when leaving the bend. The curve speed assist must be selected in the car’s navigation system in addition to adaptive cruise control or the pilot assist function. However, it can be deactivated by the driver at any time by accelerating or braking.



© Henkel

Henkel I **Polyacrylate Sealing**

The new high-performance sealant Loctite AA 5884 from Henkel is designed to improve the performance and reliability of automotive products. The polyacrylate sealing technology used ensures low gas permeability and increased oil resistance. It also enables a liquid sealant to be dosed directly onto components, which then cures within a few seconds under UV light to form a strong, seamless pressure seal. This process reduces the risk of rework and leakage. Areas of application include engine and transmission covers, electronic components and components such as expansion tanks.



© Volkswagen

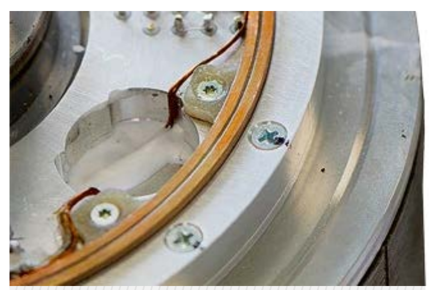
Visteon I **Infotainment for VW Nivus**

The automotive supplier Visteon is providing the infotainment platform for the VW Play system in Volkswagen's new Nivus model, which will be offered initially only on the South American market. The system is designed to improve connectivity, streaming and other services, and also includes a rear view camera. The touch panel offers a 10.1" switching display with a screen resolution of 1540 × 720 pixels and is equipped with a split-screen function to facilitate operation. The high-resolution monitor is easily visible from any angle, making the infotainment system accessible to all vehicle occupants. VW Play will be launched in Brazil and will subsequently be used in a number of models on the global markets.

© Toyota

Constellium I **Hood for Corolla**

Aluminum specialist Constellium is now supplying the body panels for the European production of the new Toyota Corolla. This is the first time that Toyota is using aluminum sheets in its European production facilities for this model series. Surfalex HS, a high-tech alloy with very good surface and roping properties as well as corrosion resistance, is used for the production of the body panels. For more and more car manufacturers, aluminum is said to be the first choice for reducing vehicle weight.



© Manner

Manner I **Mini Sensor Telemetry**

Manner has developed a miniature amplifier technology which enables single- and multi-channel dynamic component load measurements and torque measurements with a bandwidth of up to 10 kHz. The sensor signal amplifier cells can be interconnected to form multi-channel systems with any form factor. The flexible modular technology offers remote control functions (Auto Zero, gain adjustment, memory and other online health functions) as well as the possibility to perform zero and Young's modulus compensation in real time during the measurement. Exemplary applications for this new amplifier generation are couplings, pulleys, flexplates or the electric motor.

Werum | **Extended IT Platform for Testing**

© Werum

As a standardized platform of IT solutions for testing, Hyper Test of the supplier Werum has been used for years for individual solutions in the field of research and development. With Hyper Test Boost, ready-to-use modules for the different test phases are now available. These modules already provide a wide range of functions and can be individually combined and extended. The software represents a universal solution for validation and verification in the area of research and development in companies and offers comprehensive possibilities for the support and documentation of test processes in a common IT solution. All information from the commissioning of a test through preparation, planning and execution to the processing of measurement data and the final report generation is centrally recorded in one application. The testing documentation and the recording of measurement data, documents or even deviations directly in the test order increase traceability, prevent incorrect entries and produce a consistently high quality. The web-based solution Hyper Test Boost can be integrated into existing IT infrastructures.

© ITK

ITK | **Certified Toolchain**

The Continuous Integration/Continuous Delivery toolchain (CI/CD toolchain) developed by software expert ITK has been certified by TÜV Süd according to TCL1. This certificate confirms the company's safe use of the underlying CI/CD tools. In addition, it confirms that the compliant use of the toolchain at ITK is ensured by means of ready-made manuals and checklists. As a result, complex, safety-critical software can be delivered to customers in fast cycles and high quality. The toolchain covers all levels of analytical quality assurance and testing. Due to the high degree of automation, errors that can occur when manually executing the corresponding steps can be avoided.

© Volkswagen

Webasto | **Soft Top for T-Roc**

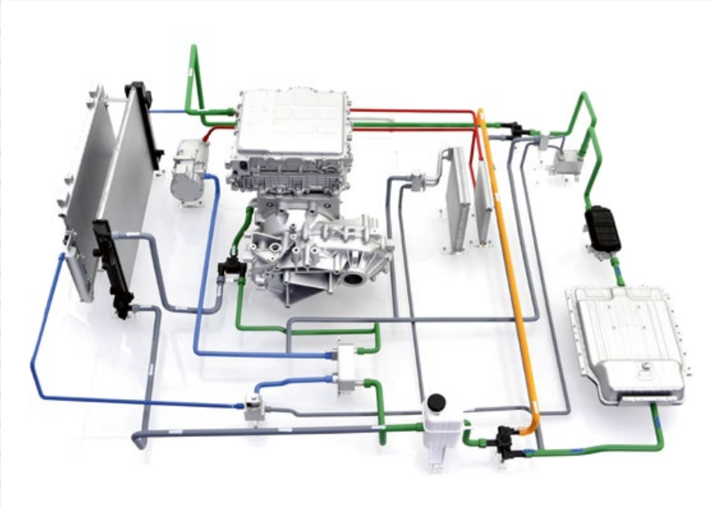
Webasto is supplying the soft top for the first CUV convertible of the Volkswagen brand. The design of the fabric soft top without bows also ensures headroom for rear passengers. The roof can be opened in 9 s at the touch of a button and closed in 11 s even while driving at speeds of up to 30 km/h. Compared to the T-Roc with a metal roof, the storage capacity of the trunk is reduced from 445 to 284 l, while loading is still possible thanks to the roof storage behind the rear seats but above the trunk. A further advantage of the soft top is that the front bow also serves as a soft top compartment lid.

© Brembo

Brembo | **High-performance Brake**

Brembo will produce the two-piece four-piston aluminum front caliper and the floating dual-cast brake disk for the Polestar 2. The front brake caliper is designed to give maximum clamping force to the 375 × 35 mm disk. The latter is made of two materials, cast iron and aluminum. It features a 15 to 20 % lower weight, improved ride comfort, less corrosion and wear, and better braking performance. During operation, the disk varies performance by operating as an integral disk at low temperatures and as a floating disk at high temperatures with minimal distortion. The low-drag design of the brake caliper prevents the pads from dragging on the discs.

Hyundai | Further Developed Heat Pumps



© Hyundai

Hyundai has further developed the heat pump system to reduce negative influences on the range of electric vehicles when using the heater. The waste heat from the electrical components is absorbed by the heat pump and used to heat the interior without significantly affecting the electrical range. Instead of conventional air cooling, the use of a water cooling system for the battery packs has a positive effect on the vehicle's range without requiring a larger battery. Since the water cooling channels take up less space than the air cooling channels, the battery cells can be packed tighter, increasing the energy density by up to 35 %. The advanced heat pump system is used in the new electric vehicles from Hyundai and Kia. It uses the heat generated by the components to evaporate liquid refrigerant. The gas is ejected from the compressor under high pressure and fed into a condenser where it is converted into a liquid state.

Edag | Award-winning Lightweight Door

© Edag

Edag was awarded the German Innovation Award 2020 by the German Design Council for its economical lightweight door for commercial vehicles called WiLeitNu. According to the jury, which is made up of independent experts, "this lightweight design concept will advance the industry through its originality, implementation and effectiveness," The lightweight door for commercial vehicles, which was developed as part of a research project sponsored by the BMWi, is distinguished by its future-oriented cabin design, which offers aerodynamic advantages and 20 % cost-neutral weight savings through special forming and joining technology. The door has a hydroformed frame profile which allows a very low concealment of the viewing angle. Pedestrians can thus be seen better. A further feature is the frame-optimized aerodynamics.


© Mahle

48-V Mild Hybrid System for Medium- and Heavy-duty Trucks

Mild hybrid drive systems on a 48-V basis offer cost and packaging advantages in comparison to high-voltage applications. Their lower voltage, however, means that the expected currents are very high. Mahle explains how the resulting increased requirements on the components battery and motor can be met.

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COMPACT AND LIGHT SYSTEMS ARE EXPECTED

A drive system as a 48-V mild hybrid can make a considerable contribution to fuel savings if energy can be stored in and retrieved from the battery in a very short time. This is particularly necessary for vehicles used for freight, commercial, and specialized applications, but also to some extent for passenger transport. For these applications, Mahle is developing a powerful mild hybrid system on a 48-V voltage basis that can significantly contribute to sustainable mobility due to its energy efficiency.

Hybridization makes it possible to recover energy that can support the vehicle electrical system or can be fed back to the powertrain under high loads. In doing so, fuel can be saved. For example, braking energy can be stored temporarily in the battery so that it is available for the next acceleration. Very high rates of charging and discharging cycles are expected during driving operation, and the mild hybrid system must be designed to guarantee this application case.

The requirements for the battery are significantly higher in terms of service life, power output, range of applications and availability as well as cycle durability in comparison to current 48-V batteries of Mild Hybrid Electric Vehicles (MHEVs) for the passenger car segment. In addition, very compact and weight-optimized systems are expected.

MODULAR SYSTEM AND AREA OF APPLICATION

The 48-V MHEV battery developed by Mahle meets the requirements described before. Along with a compact, universally deployable modular system, the high charging and discharging capability over a broad range of State of Charge (SoC) maximizes battery performance – and at reduced installation space and weight in comparison to the conventional batteries. Other increases in efficiency regarding the powertrain are achieved by significantly improving cold-cranking capability and low-temperature availability. The 48-V MHEV battery supports the combustion engine even at low ambient temperatures, helping to reduce the vehicle's fuel consumption and exhaust gas emissions, including under extreme weather conditions. Due to its high durability and the associated extended service life and higher cycle life, the battery has substantial potential for economic and environmental benefits.

The scope of application of this battery is tailor-made for use in the medium- and heavy-duty truck field and for public transport. Its chief advantage is shown in the P2 hybrid drive architecture: a mild-hybrid application with an e-machine for boost and recuperation or coasting operation and electrical system support.

OBJECTIVES AND LITHIUM-ION CELL AS SOLUTION

For the basic requirement of storing recuperation energy, the battery must have high power input and output capacity over a long service life and meet tough lifetime requirements, particularly in the commercial vehicle sector. The cyclic aging respectively the number of lifetime cycles is essential and an important design criterion.

A peak power of 20 to 24 kW over a span of 10 s and continuous power of 4 to 5 kW at up to 20,000 full cycles are the objectives of this development, along with the availability of the battery to receive and discharge power, both at temperatures as low as -30 °C and at operating temperatures ranging from 50 to 60 °C. In addition to these requirements, a cold-cranking capability at -30 °C is needed.

Fulfilling these requirements, the 48-V MHEV battery from Mahle uses a 20-Ah HP SCiB cell [1] from Toshiba, **FIGURE 1**. The lithium-ion cell with a Lithium-titanium Oxide (LTO) anode has the right advantages: increased safety from the LTO anode, high cyclic stability and long service life, high charge and discharge currents, a broad SoC range, and a temperature range in which charging and discharging are also possible at sub-zero ambient temperatures (down to -30 °C).

BASIC CONCEPT

The 48-V MHEV battery is based on a modular concept with integrated cooling, integrated Battery Management System (BMS), and optional DC/DC converter. The available SoC range for these cells used is up to 100 %, which together with high power output results in a battery whose energy content fits well in the stated range of 0.9 to 1.2 kWh.

In the development variant shown here, the so-called Cube design, **FIGURE 2**, the battery has a nominal energy content of 920 Wh and a capacity of 20 Ah. This design creates the technology carrier and the basis for the modular system approach. Variants in longitudinal or flat design supplement the cubic design. Furthermore there is the possibility to combine several cells for an optimized alignment with traction drive variants.

The efficient, active cooling, **FIGURE 3**, uses a water/glycol mixture as coolant. The active cooling further increases cycle and calendric service life and allows high power with reduction (derating). Further investigations of various scenarios – in combination with the ability to operate the cells beyond the temperature levels of other battery systems – are intended to evaluate the potential for a reduced system-side effort. Operation at higher temperatures reduces the cooling capacity on the system side and saves energy accordingly. Under the defined boundary conditions currently being investigated, it is possible to operate the thermal management only via the vehicle's low-temperature circuit. The need for a secondary circuit on the system side is therefore eliminated.

All electronics and the BMS were integrated into the battery system. The BMS is designed to ASIL C (ISO 26262 standard) for various functional safety and availability goals.

The performance objective of the battery is high power output for recuperation and boosting over a wide SoC range. This makes nearly the entire nominal capacity available as usable capacity and increases flexibility for usable and reserve capacity. In combination with very high C-rates (> 20 C), this results in a high power density, which affects installation space and costs in comparison to other technologies.

The capacity fade during the battery life cycle, from Beginning of Life (BoL) to End of Life (EoL), is much lower than in other systems, which is significantly reflected in the capacity required for end

FIGURE 1 Battery cell named SCiB from Toshiba (© Toshiba)

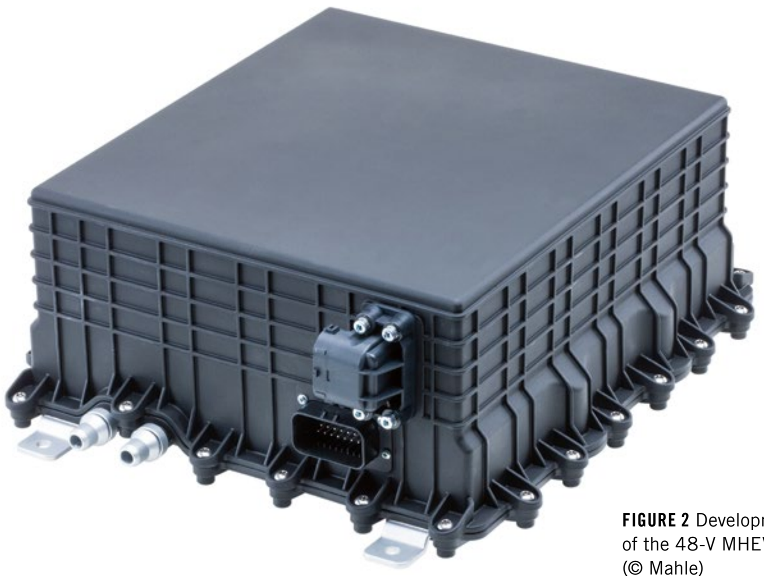

FIGURE 2 Development variant of the 48-V MHEV battery (© Mahle)

of life and the design of beginning of life capacity. This results in nearly constant availability of capacity over the entire operational life. The performance of the current concept at an operating point (50 % SoC and 25 °C) is shown as an example in **TABLE 1**. Other important properties of the system were defined for the following features:
- service life: high cycle life until EoL capacity of 80 % SoC and high calendric life – also at higher temperatures compared to other systems
- operating temperature: for charging and discharging from -30 up to +60 °C at ambient temperatures from -40 up to +70 °C and therefore a good cold-cranking capability at -30 °C
- recyclability: the structure allows the battery to be disassembled down to the cell level with minimal effort so components can be sorted for disposal.

In summary, the 48-V MHEV battery demonstrates the following advantages: high power input and output and therefore high energy turnover in a small package with low weight, combined with high expected service life and cycle durability, making battery replacement typically unnecessary, with availability over a broad temperature range.

48-V TRACTION DRIVE FOR COMMERCIAL VEHICLES

The potential for hybridization of a combustion engine is largely determined by the electrical performance of the drive system, which consists of the e-machine and its power electronics (inverter). While the recuperation potential for P2 applications in passenger cars is often reasonably exhausted at 20 to 25 kW, commercial vehicle applications still have significant recuperation potential at substantially higher power levels. The potential depends greatly on the driving cycle. The incidence of deceleration processes depend on the height profile as well as the driving strategy. A predictive driving strategy does reduce the fuel consumption of the combustion engine, but also influences the recuperation cycles of the e-machine. The required battery size depends on the electrical output and the driving cycle, especially on the maximum C-rate, which can be understood colloquially as the ratio of the charge and discharge current of a battery to its maximum capacity.

Internal testing at Mahle has shown that for a Class-5 truck (Vecto model according to [2]) weighing 40 t total, for example, a power class of 40 kW is an appropriate size for long-distance routes. In a less dynamic cycle of the Vecto modeling, higher power classes have little further potential to offer. At the same time, however, 40 kW and a reasonable battery size can still cover the majority of the theoretical recuperation potential for more dynamic driving.

In order to set up now the best possible cost/benefit ratio, Mahle is now pairing its 40-kW motor/inverter system with two battery modules. The mutually tuned sub-systems enable

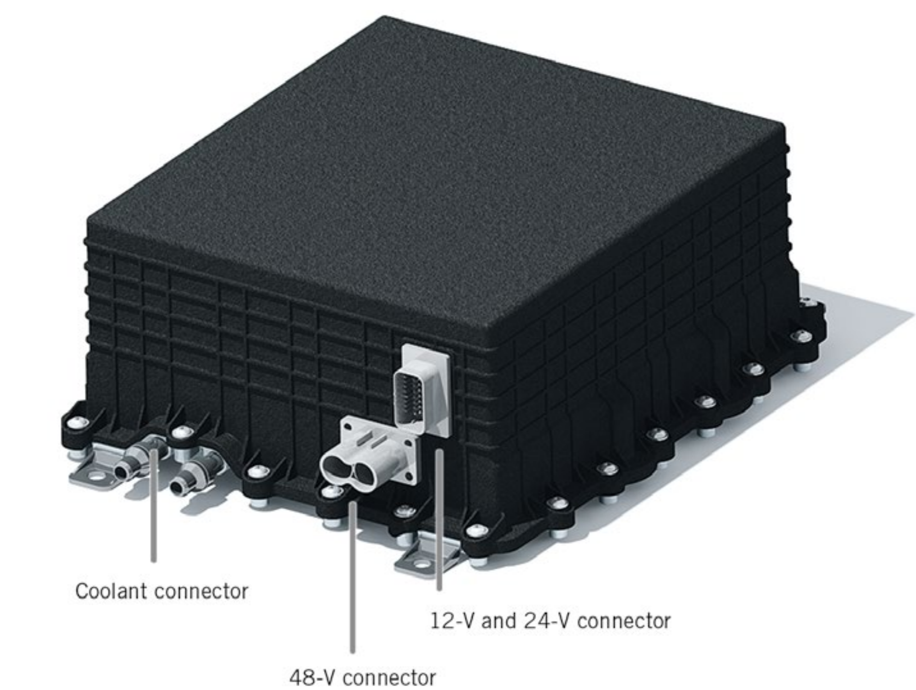

FIGURE 3 Coolant connector for the active cooling and other current connectors at the 48-V MHEV battery (concept design) (© Mahle)

Feature	Value	Unit
Capacity	20	Ah
Energy content (BoL)	920	Wh
Voltage	30 ÷ 54	V
Wiring of cells in the pack	20S1P	-
Peak power (time)	23 (10 s)	kW
Operating temperature	-30 ÷ +60	°C
Cooling	Cooling plate	-
Weight	15	kg

TABLE 1 Specifications of the current concept at an operating point (50 % SoC and 25 °C) (© Mahle)

optimal peak performance for recuperating and boosting.

In order to avoid a dual-motor solution that is difficult to integrate, and to provide such a high power output (40 kW) at a voltage level of 48 V in the smallest possible package with minimal weight, Mahle develops a motor/inverter solution comprising 2×3 phases, **FIGURE 4**. The axial integration of the inverter enables efficient routing of electrical power and coolant lines. In order to refrain from an additional oil cooling, Mahle is using a pure cooling system that is based on a water/glycol mixture and is therefore easier to integrate in the vehicle system. Furthermore an easy to integrate form factor is realized.

With the design of an Interior Permanent Magnet Synchronous Motor (IPMSM), the motor reaches a torque of 110 Nm with an outside housing diameter of 230 mm. Paired with speeds of up to 12,000 rpm, the MHEV requirements for a mild hybrid system specific to commercial vehicles are covered. The peak power in the generator mode at 52 V is greatly increased again, rising up to 48 kW instead of 30 kW continuously. **TABLE 2** summarizes the technical specifications of the MHEV system.

FIGURE 4 Traction drive of the 48-V 40-kW MHEV system with synchronous motor and axial integration of the inverter as well as with 2×3 phases (© Mahle)

Feature	Value	Unit
Topology	IPMSM, 2×3 phases, integrated inverter	-
Voltage	48	V
Power (motor mode at 48 V)	40 (peak)	kW
	25 (continuous)	kW
Power (generator mode at 52 V)	48 (peak)	kW
	30 (continuous)	kW
Torque (48 V)	110 (peak)	Nm
	50 (continuous)	Nm
Peak speed	12,000	rpm
System efficiency	95	%
Dimensions	230×290	mm
Weight	33	kg

TABLE 2 Specifications of the 48-V 40-kW MHEV system (© Mahle)

SUMMARY

With the 40-kW mild hybrid system for medium- and heavy-duty vehicle applications, Mahle provides an optimized drive on 48-V basis that meets the current and future requirements for mild-hybrid applications. The lithium-ion cell used comes with a lithium-titanium oxide anode and serves the advantages increased safety, high cyclic stability and long service life as well as high charge and discharge currents.

With a view toward Vecto legislation of the European Union in the future, Mahle combines a modular, scalable battery with high availability, high power output, and long service life with a drive system of a permanent magnet motor and power electronics including high power density, in order to maximize the energy savings potential of hybrid drives at low weight, in a small package, at low cost.

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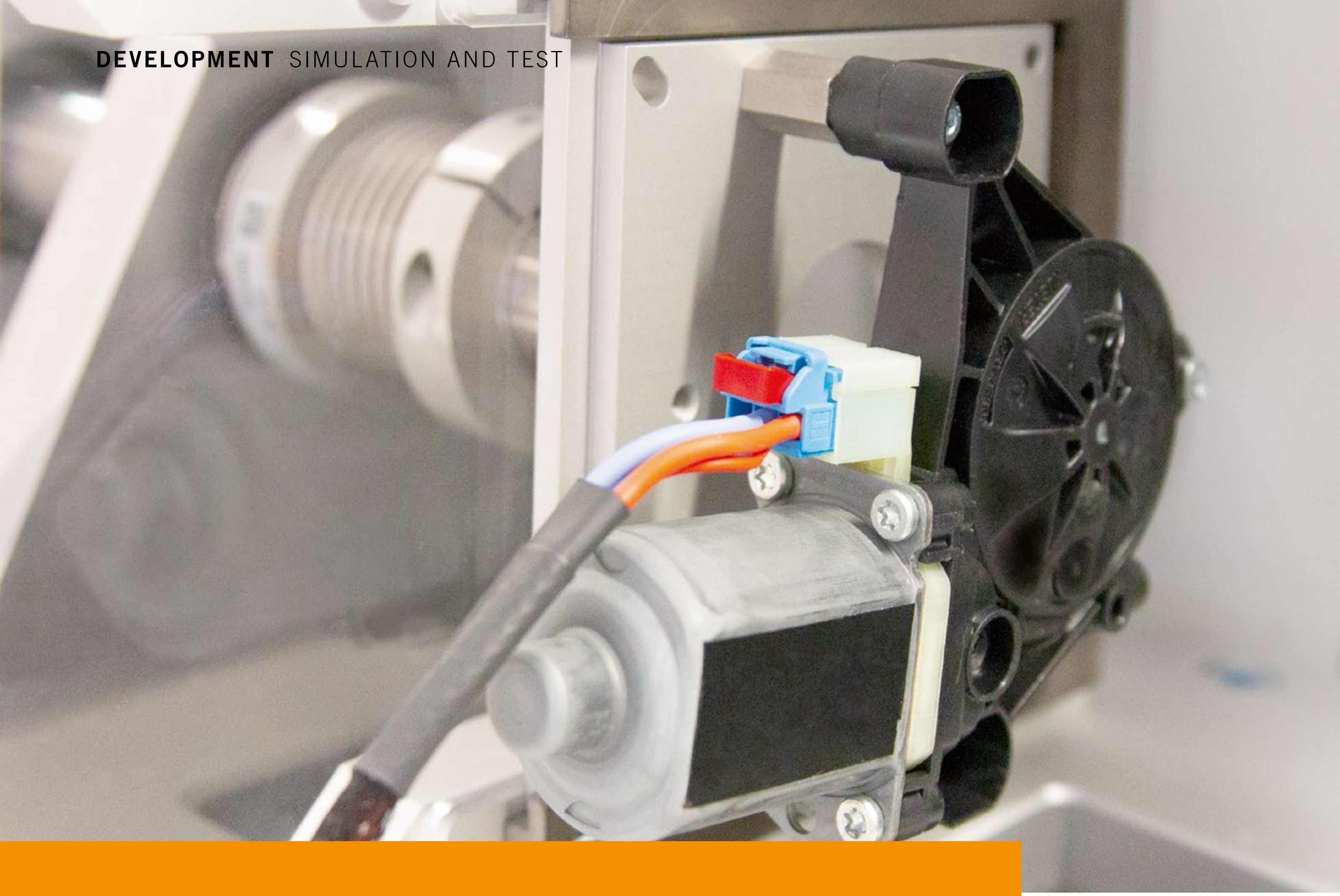

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Validation of a Window Regulator – From Prototype to Product

Power windows, automatic tailgates or electric drives for seat adjustment are installed in almost all vehicle classes. Even though they are components of the standard equipment, an enormous amount of time and money is required to test these electric drives. Göpel electronic demonstrates how safety and convenience aspects are implemented in quality checks throughout the entire cycle from the development phase to final testing.

ALMOST 100 ELECTRIC MOTORS IN ONE CAR

More and more electric drives are used in modern passenger cars to make different functions possible, in particular assistance and convenience functions. These include window regulators, tailgates and seat adjusters. Up to hundred electric motors are installed in a vehicle today. Adjusting the main headlights or positioning the exterior mirrors are other classic examples of electromotive operation.

Depending on the application area, these drives must meet completely different requirements. For example, a window regulator is operated comparatively infrequently, yet it still must provide a high force to move the window in winter despite freezing conditions. Similarly, it must resist high external force to prevent the window from being pushed down by intruders. In contrast, a cooling fan motor must be active inside a seat for an extended period of time while running efficiently and quietly at low power.

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Just as the requirements for the motors themselves are varied, the requirements are also different for the systems that help product developers improve efficiency, test long-term use during endurance testing or check the quality parameters in the main operating points in the End-of-Line (EoL) test. At the beginning of every product development is the prototype, on which extensive tests are carried out. On the one hand, developers want to gain insights into the quality of the design, and on the other hand, they want to derive initial specifications for the later production process.

QUALITY REQUIREMENTS FOR THE WINDOW REGULATOR COMPONENT

Higher standards and tighter tolerances are being applied to electromechanical components in the vehicle. These are the result of ongoing technical development and increasing requirements from vehicle manufacturers for safety aspects, durability and better convenience. Even for a "simple" product such as a window regulator, detailed specifications are defined for a supplier. Fulfillment of these specifications must be demonstrated by test procedures that are also prescribed in detail – even before a production order occurs.

The issue of safety often comes first. Fingers need to be protected from injury when the window is closed. Safety also includes resistance of the window regulator to force from the outside or very fast access to the operating point speed to close the window quickly – or, in the event of a jam, to quickly change direction and reopen the window. In terms of convenience, electric cars in particular place enormous demands on low noise generation of the e-drives. Regular true running, low coefficients of friction and avoidance of vibrations play a major role here. If speed fluctuations need to be partially rapidly adjusted, the clamping force can increase at this position. Here, incorrect reversals can result if no adjustments can be made. It depends on the correct evaluation of the irregular motion measurements within the analysis software of the Carmen development test system of Göpel electronic, **FIGURE 1**.

Energy efficiency plays a key role in the context of electric mobility. In this case, all electrical consumers in the vehicle are optimized so that as little energy as possible is needed. However, sufficient force will still be available to free a frozen window in winter, as described before.

Ultimately, the economic efficiency of the development process must be kept in mind. Consequently, developers look for options to save on sensors that determine speed, for example. A ripple component in the current signal is caused by the commutators, **FIGURE 2**. If the motor is designed in such a way that these ripples form a clean waveform, the speed can be determined by counting the periods per unit of time, and additional sensors can be omitted. Positioning is also achieved by evaluating the current ripple. This is an essential aspect, for example, in order to reduce the speed just before the window reaches its end stop.

The OEMs define the appropriate testing procedures for all these requirements. Using suitable test systems, the suppliers are therefore obligated to provide evidence at the prototype stage that the eventual product will very likely be able to meet the required parameters. Once the first hurdle of successful tests or verification for the prototypes is cleared, the test specimens must be subjected to realistically replicated load cycles in endurance and service life tests.

TEST METHODS TAILORED TO OEM SPECIFICATIONS

In the laboratory, the prescribed test procedures are repeated to ensure that the quality parameters do not deteriorate significantly even after prolonged use. The suitability of the materials used for gearboxes or electronic components must be tested here, among other things.

After a supplier has completed the validation of the prototypes with sub-

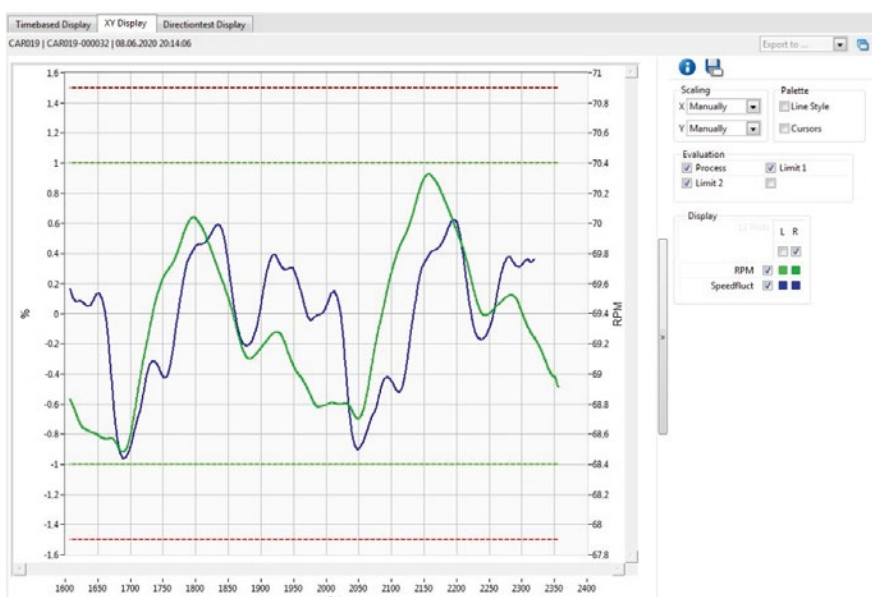

FIGURE 1 Screenshot of the analysis software of Carmen – irregular motion on a percentage basis (amplitude in %) with respect to the rotational angle phi (two revolutions correspond with 720°) of the motor rotor for a window regulator (© Göpel electronic)

sequent presentation of the results to the OEM, approval will still be pending for use in vehicle production. For this purpose, most vehicle manufacturers also carry out intensive tests using standardized procedures.

PREVENTING THE DELIVERY OF FAULTY COMPONENTS

Recalls are expensive. That is why it is determined at an early stage how the inspection should take place at the end of the production line (EoL approach) in order to prevent the delivery of faulty components. Furthermore, pilot series are used in order to optimize production processes, to identify weak points and to check whether the required parameters do not exceed a maximum distribution of the quality parameters, even when many test specimens are compared.

This means that the test cycle from the prototype to a product that is ready for series production is not yet complete. Even if a window regulator has reliably operated in the vehicle for several years, specimens are retrieved from the field and subjected to intensive tests again. By standardizing test sequences and unambiguously assigning test parameters and results to part numbers, it is also possible to investigate after several years how the quality-determining parameters have changed. As a result, knowledge can be acquired for future new generations of vehicles.

The requirements during testing are manifold: External strain on a geared motor or realistic load cycles from idling to blocking should be replicated. To achieve this, it is necessary to employ an active load by using a highly dynamically adjustable drive in combination with a precise torque measurement.

DEVELOPMENT TEST SYSTEM AS THE RIGHT TOOL

With the Carmen development test system, Göpel electronic has developed an examination system that controls electronic test specimens via bus systems and offers a measuring section adapted to performance parameters for each application. Up to three measurement sections can be integrated into the system. These have active load machines in different performance classes with high torques up to 100 Nm and robust mechanics as well as high speeds and low torques below 0.5 Nm with intricate mechanics. In this way, a test system can cover the entire product range from powerful motors, for example for tailgates, to small motors for adjusting ventilation flaps, **FIGURE 3**.

A powerful software system is the basis for the functionality. This system offers a variety of test methods, analysis tools, and parameter and data management functions. They allow product developers to identify weak points and assign measurement data and parameters to different types of test specimens.

POWERFUL PRODUCT ANALYSES POSSIBLE

The development test system Carmen allows the user to overlap the motor characteristics of up to fifty prototypes of the same type and determine the distribution. By comparing this with an idealized efficiency curve, the most efficient operating point can be determined and an assessment can be made as to whether systematic faults are present in the real measured characteristic curves at this operating point.

In this way, irregularities detected in the torque curve allow conclusions to be drawn about the quality of the gear-

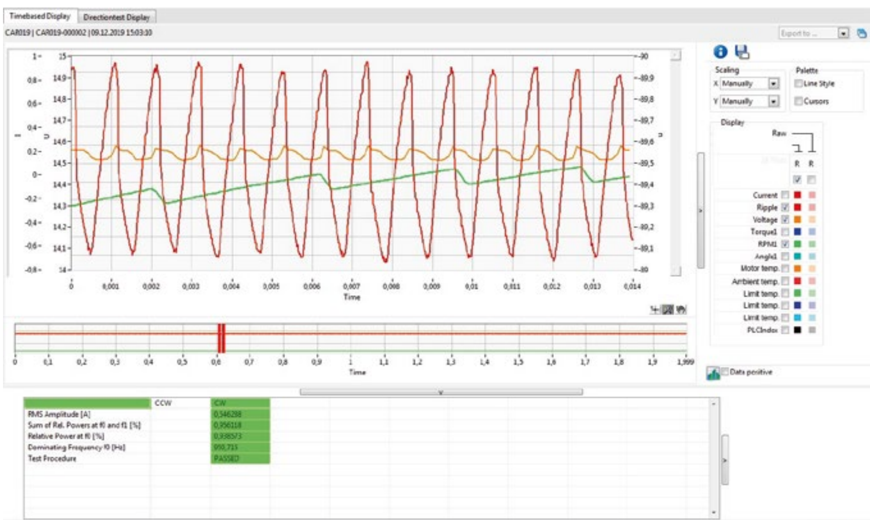

FIGURE 2 Screenshot of the analysis software of Carmen – illustration of the current and voltage ripple component I and U (top) as well as evaluation of the signal shape (bottom) (© Göpel electronic)

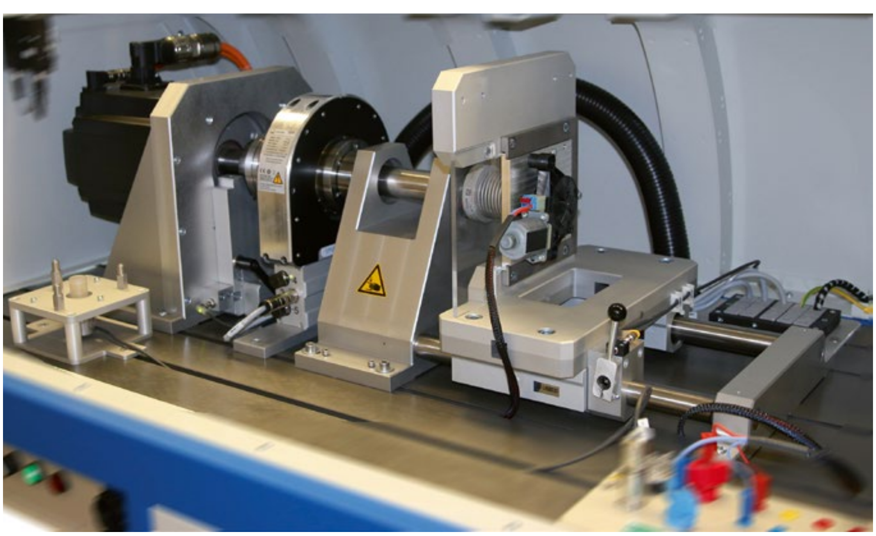

FIGURE 3 Measuring section for geared motors up to 100 Nm load with precise torque measurement and replaceable adapter for test specimen contact (© Göpel electronic)

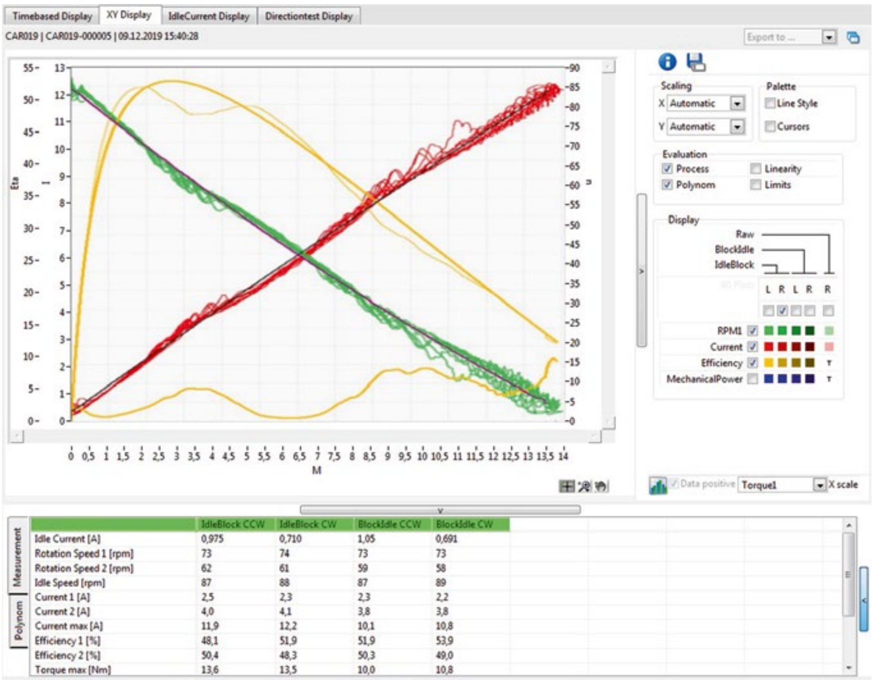

FIGURE 4 Screenshot of the analysis software of Carmen – collective curve display of ten characteristic motor curve measurements showing speed, current and efficiency above torque (© Göpel electronic)

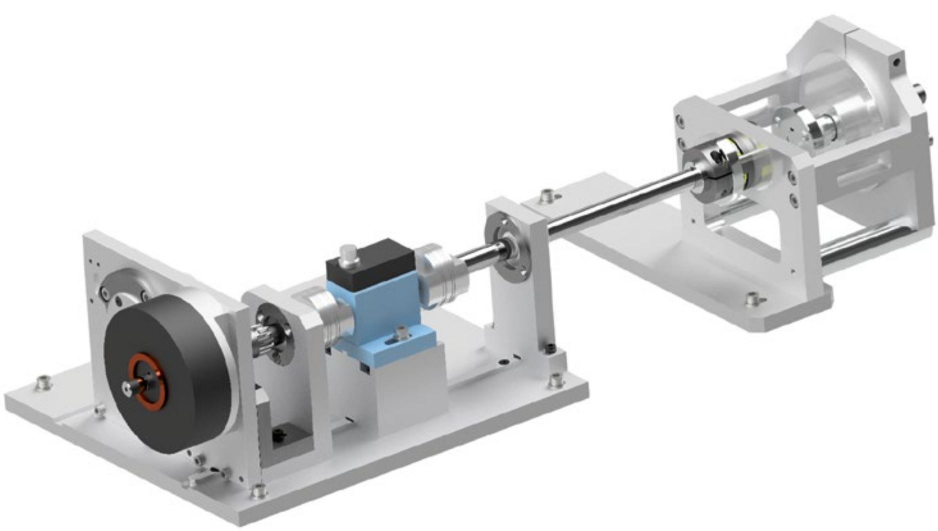

FIGURE 5 Measuring section for an endurance test system for parallel testing of four test specimens with passive load unit (black) (© Göpel electronic)

boxes or the character of the motor rotor. If a permissible distribution has been determined over a large number of measurements, this can provide insight into whether the actual nominal range is also statistically maintained. In this way, limits can be defined that can then be parameterized using a limit curve editor. The limit curves or even linearity limits are now part of a test parametrization, which is assigned to the type of test specimen and can be used for a passed/failed evaluation, **FIGURE 4**.

The example of the frozen window shows the window regulator test specimen being driven against a stationary load. Only when a minimum torque is applied by the test specimen, does the load machine take over guidance, allowing a rotational movement and reducing the load up to the normal

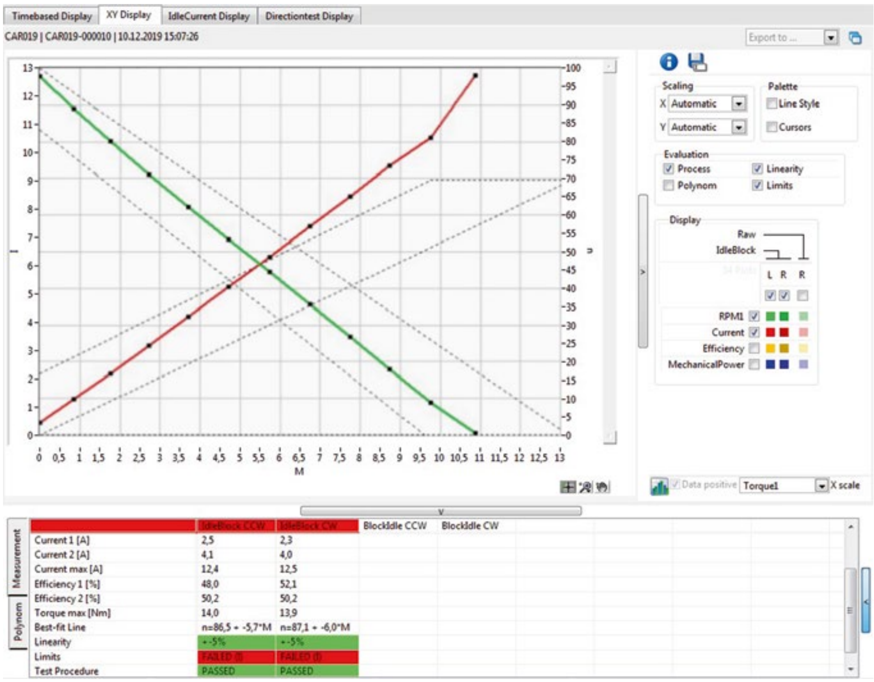

FIGURE 6 Screenshot of the analysis software of Carmen – measurement of the motor characteristic curve showing current and speed above torque at specific operating points in order to shorten cycle times (© Göpel electronic)

operating point. Within a short period of time, the test specimen must reach its operating point speed while complying with the specified performance parameters.

If product developers find problems, they can program their own load scenarios via a free sequence editor, run them and record their individual selection of available measurement data. For example, the user could expose a test specimen to a certain load, measure the resulting speed and specify it to the load machine as a new target value. In this way, a comparison can be made of how the speed of the test specimen fluctuates under constant load or how its torque behaves when forced to a constant speed. If these measurement results are now related to one revolution of the test specimen, potential problems can be identified in the windings of the rotor or increased friction in gearbox components that have not been optimally manufactured.

CHECKING THE RESULTS IN AN ENDURANCE TEST

Once the correct test parameter settings, suitable load scenarios, specific operating points and limit parameters have been determined on the development test system, these can be managed via a central database, assigned to the type of test specimen and applied across systems.

The endurance test system can now repeatedly run such load scenarios – also under climatic conditions – over a very long period of time, while monitoring the parameterized limits. Since several test specimens are usually tested at the same time during the endurance test for reasons of time, **FIGURE 5**, several measurement sections can be controlled in parallel and the results recorded or logged.

In the endurance test, unlike in the development test, all work areas from idling to a block are usually dynamically controlled, which is why hysteresis brakes or systems without a load unit can also be implemented here. If sufficient information on quality-determining parameters of the production has now been collected on the prototype through development tests and endurance tests and the production process has been optimized, the products must be subjected to an EoL quality control or functional test.

SHORT CYCLE TIMES IN END-OF-LINE TEST

The EoL test focuses on short cycle times and a consistent sequence of the tests. The user can quickly and precisely run the important operating points identified on the development test system or special load points via the software, **FIGURE 6**, and use the limit parameters for the type of respective test specimen from the central database in order to carry out a passed/failed assessment.

All test results of the test specimen are managed under a serial number in the central database. For example, a window regulator that has been tested in the EoL test as "passed" can be subjected to more intensive tests on the development test system, then subjected to an endurance test under climatic conditions and finally re-evaluated on the test system. The results of all test scenarios of this test specimen can then be conveniently compared and analyzed with the desktop version of the system software.

CONCLUSION

Requirements to research and development as well as quality assurance for window regulator motors are complex. At every stage of the product creation process, there are different general conditions, all of which have the goal of ensuring safety and convenience at all times. With the Carmen development test system, Göpel electronic offers a test platform with a software system for all test scenarios. The user can monitor the testing of the complete drive development process – from product development of the prototype with detailed investigations to validation with endurance tests to end-of-line testing with cycle-time optimized tests.

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The Aerodynamics of the VW ID.3 Electric Car

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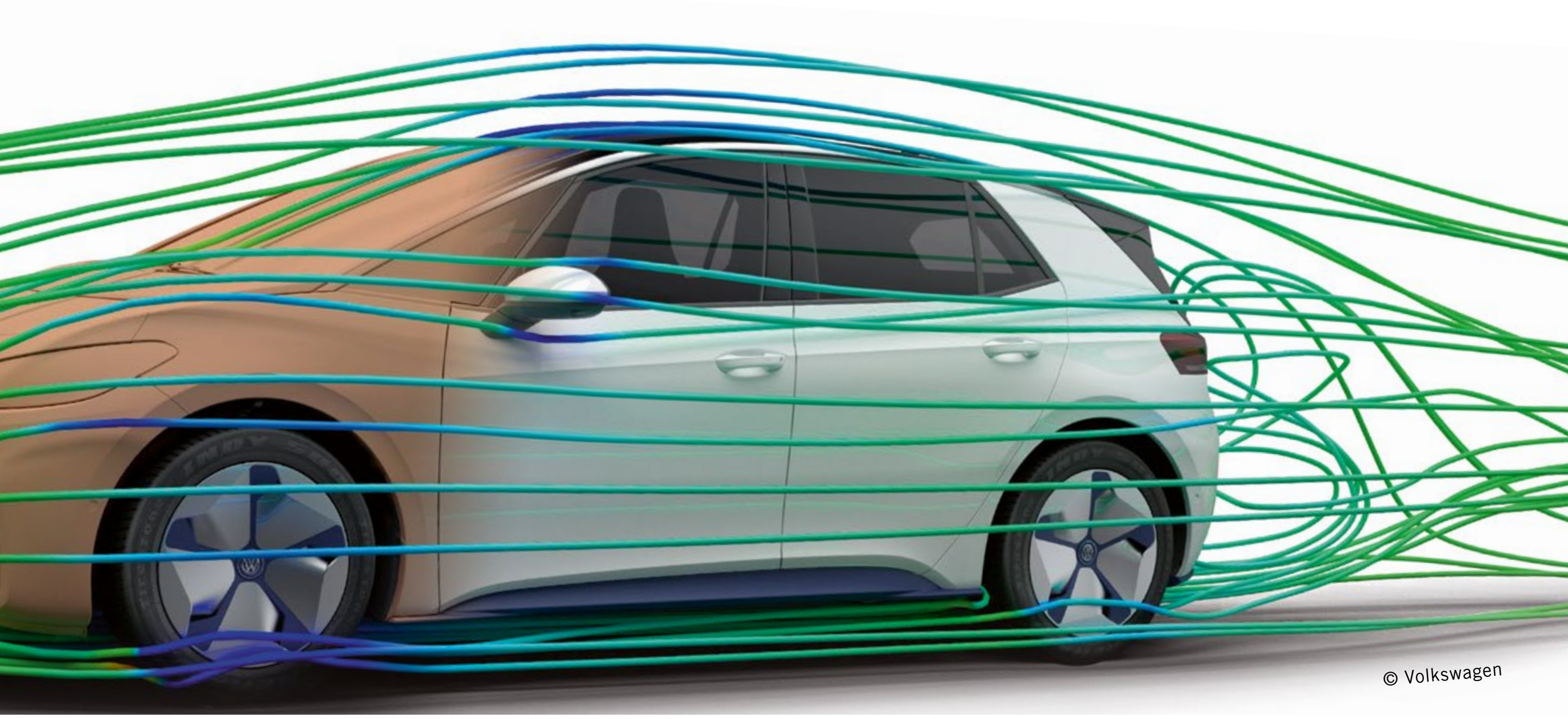
With a drag coefficient of 0.26, the VW ID.3 leads the pack when it comes to the battery electric vehicle class for hatchback vehicles. Accordingly, aerodynamics make a crucial contribution to achieving the ambitious electric range targets of up to 550 km in the WLTP. Volkswagen reached this target by using a consistent aerodynamic optimization approach for the vehicle that went from the new modular electric drive assembly matrix all the way to the base body design, the wheels and the add-on parts such as the exterior mirrors.

PROPERTIES AND DEVELOPMENT PREMISES

As a trailblazing response to the Paris Agreement targets and the stricter CO_2 emission limits that go with them, Volkswagen is starting a vehicle strategy with more than 20 models that have a purely electric drive. The leading pioneer is the ID.3, which has the characteristics of a compact vehicle. Customers have a variety of battery sizes, with the corresponding ranges of 330 to 550 km as per the WLTP, available to them. The delivered range depends not only on the battery variant, but also on the vehicle's road load. A decisive part of this – and the most important one after a speed of approximately 60 km/h – is drag, which is the product of drag coefficient c_D and cross-sectional area (A). As described in [1], the acceleration resistance, which is a function of vehicle weight, is less important in Battery-electric Vehicles (BEVs) than in conventional powertrains, since regenerative braking can be used to convert part of the braking energy back into electrical energy. Since this is not the case with drag, special attention was paid to the aerodynamic quality of the base vehicle body when developing the ID.3. Improving the c_D value by 0.010 results in a range increase of approximately 6 km in WLTP, which highlights the need for low drag. Within this context, one particular challenge was to take the conditions for the new modular electric drive matrix (MEB) and the relevant styling and dimensional design specifications and develop an aerodynamically optimized whole vehicle based on them. In particular, it is worth pointing out the following essential vehicle properties, which had to be observed in the course of the aerodynamic development process in order to achieve the ambitious range targets:



- very short overhangs with a long wheelbase
- large ground clearance for large wheels (D = 705 mm) and battery protection
- generous interior space
- innovative styling message in tune with the new ID model family.

DEVELOPMENT EMPHASES AND TOOLS

FIGURE 1 shows the main areas of focus for aerodynamic development, which were introduced in a staggered manner but ultimately ran simultaneously for the most part, and the development tools used within this context. The first step was developing the MEB platform, with the main emphasis being on an cooling air solution that would meet all relevant needs and a "smooth" underbody. Optimizing the base body under consideration of the relevant vehicle premises (overhangs, headrooms, etc.) in close consultation with Design started a bit later. This, in turn, provided the basis that made it possible to carry out the final step of designing all styling details and aerodynamically relevant add-on parts, such as the exterior mirrors and rims. The integral aerodynamic optimization of the vehicle was possible only after all three areas of focus were combined.

Two different tools were used during the development process. On the one hand, a large number of numeric Computational Fluid Dynamics (CFD) simulations based on a highly detailed computational model were run, with these simulations making it possible to optimize not only the basic styling shape, but also the add-on parts and rims, with a consistent approach during the early development phase. On the other hand, there were two detailed wind tunnel models (1:3 and 1:1) available for the experimental work. These models were made as modifiable clay models with a simulated MEB platform and were used predominantly in order to optimize details. In the end, a variety of styling and technical measure made it possible to lower the c_D value for the ID.3 all the way down to 0.26 and achieve the crucial range increase as a result.

MEB PLATFORM DEVELOPMENT

The aerodynamic losses in the underbody, in the wheel housings, and in the engine compartment are, as per [2], between 20 and 50 % of the total flow loss. Accordingly, one crucial area of focus for the new MEB platform development consisted of the cooling air solution and the underbody design.

As **FIGURE 2** shows, the so-called "cooling air drag" is reduced with two interacting solutions. The cooling air flows within a self-contained air deflector with virtually zero leaks from the cooling air opening in the bumper to the radiator assembly. There, for the first time ever in

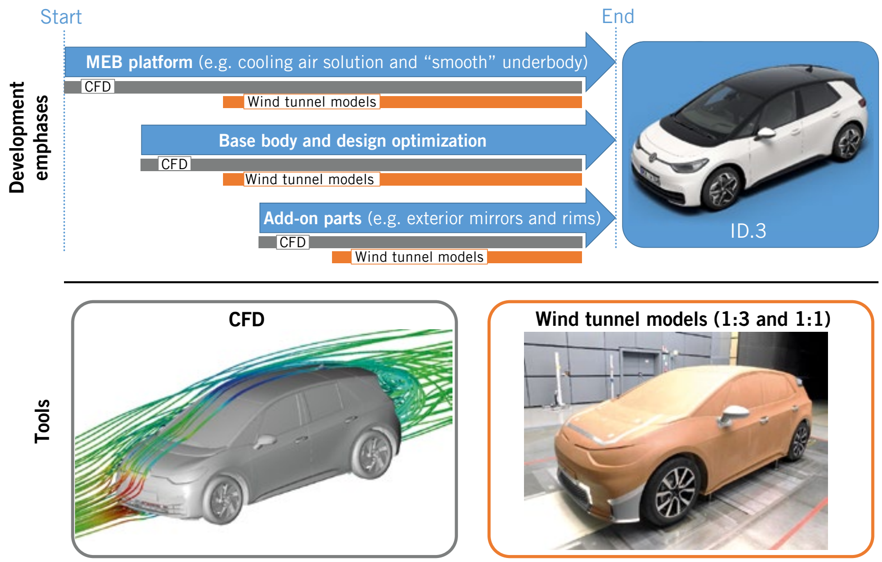


FIGURE 1 Aerodynamic development emphases and tools (© Volkswagen)

production vehicles, a radiator blind is integrated between the radiator and the condenser. The cooling air flow can be adjusted as necessary by opening this blind accordingly. This technical solution is being used for all MEB vehicles Group-wide and reduces drag by about 0.010, increasing range by approximately 6 km as a result.

With regard to the underbody design, the special characteristic of the MEB platform solution is that an integral solution that covers the whole area, has no steps, and is simultaneously modular was developed. As shown in **FIGURE 3**, the cladding for the front and rear ends, which are primarily intended to shield the packaging spaces underneath the axles, branch off from the “battery,” “sill,” and “center” underbody cladding in the center. Depending on the battery size and body shape, these platform parts are combined with variable connection elements into a single closed underbody. The steering knuckles themselves are equipped with additional cladding that guides the underbody airflow optimally regardless of jounce. In addition, due to the relatively undisturbed underbody airflow through the shielded underbody, it was important to fine-tune the rear-end downstream flow in the underbody with a diffuser so as to make it ideal for the body shape. In comparison to a conventional internal-combustion-engine underbody, a total c_D value improvement of 0.010 to 0.025 was achieved with the MEB underbody cladding, resulting in a range increase of 6 to 15 km.

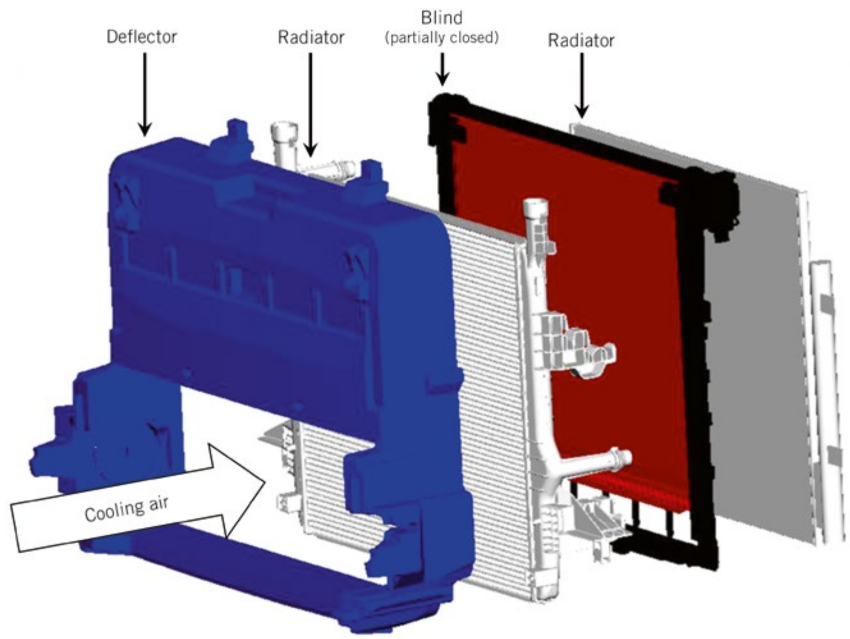


FIGURE 2 Cooling air solution consisting of air deflector and radiator blind (© Volkswagen)

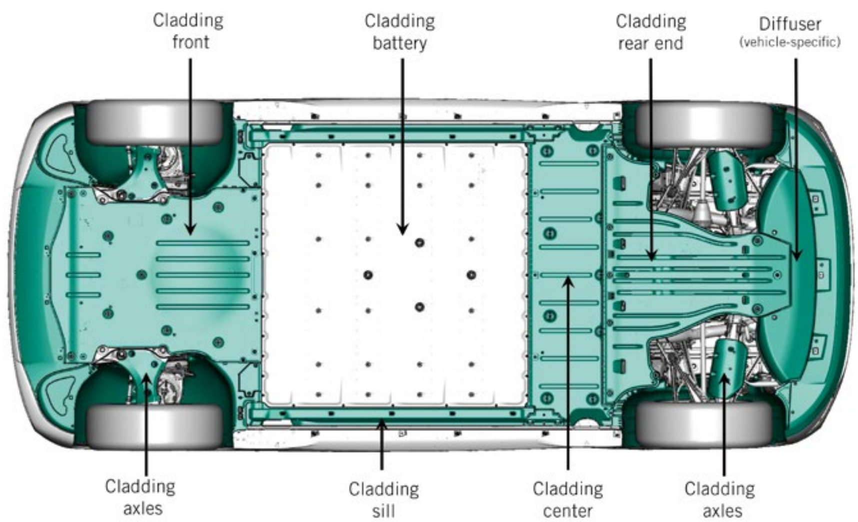


FIGURE 3 Underbody view of ID.3 with the designations for the cladding components (© Volkswagen)

BASE BODY AND STYLING OPTIMIZATION

Building on the platform development, the base body’s design took on an essential aerodynamic role. Within this context, the primary decision was the extent to which the vehicle’s drag can be developed. The main goal was to avoid flow separation as much as possible and produce a smooth airflow pattern such as the one that can be observed for an airfoil as an ideal case. The challenge was to achieve this despite the vehicle-specific requirements for the ID.3, such as extremely short overhangs and comfortable interior space conditions for a compact class that would be on a par with a VW Golf. Against this backdrop of conflicting aerodynamic and vehicle-specific requirements, consistent teamwork between Design and Aerodynamics in the early development phase made it possible, together with the use of numerous CFD simulations, to create a base body that met the overall targets.

As **FIGURE 4** shows, the lateral view in particular makes it easy to see how the basic aerodynamic principles were implemented. The flow is guided along the mostly round shape of the vehicle’s front end, over the low windshield, and all the way to the highest roof point. Then, from there, it can follow the downward contour of the roof in order to finally be brought to separation in a targeted manner that approximates that of a fastback as a result of the particularly pronounced roof and side spoilers at the rear end. The separation area produced behind the vehicle is particularly small and, as a result of it being fine-tuned optimally with the underbody airflow, it is oriented in such a way that the c_D value decrease caused by rear-end separation was kept as small as possible.

The positive base body properties were complemented with targeted design details, such as the aerodynamically

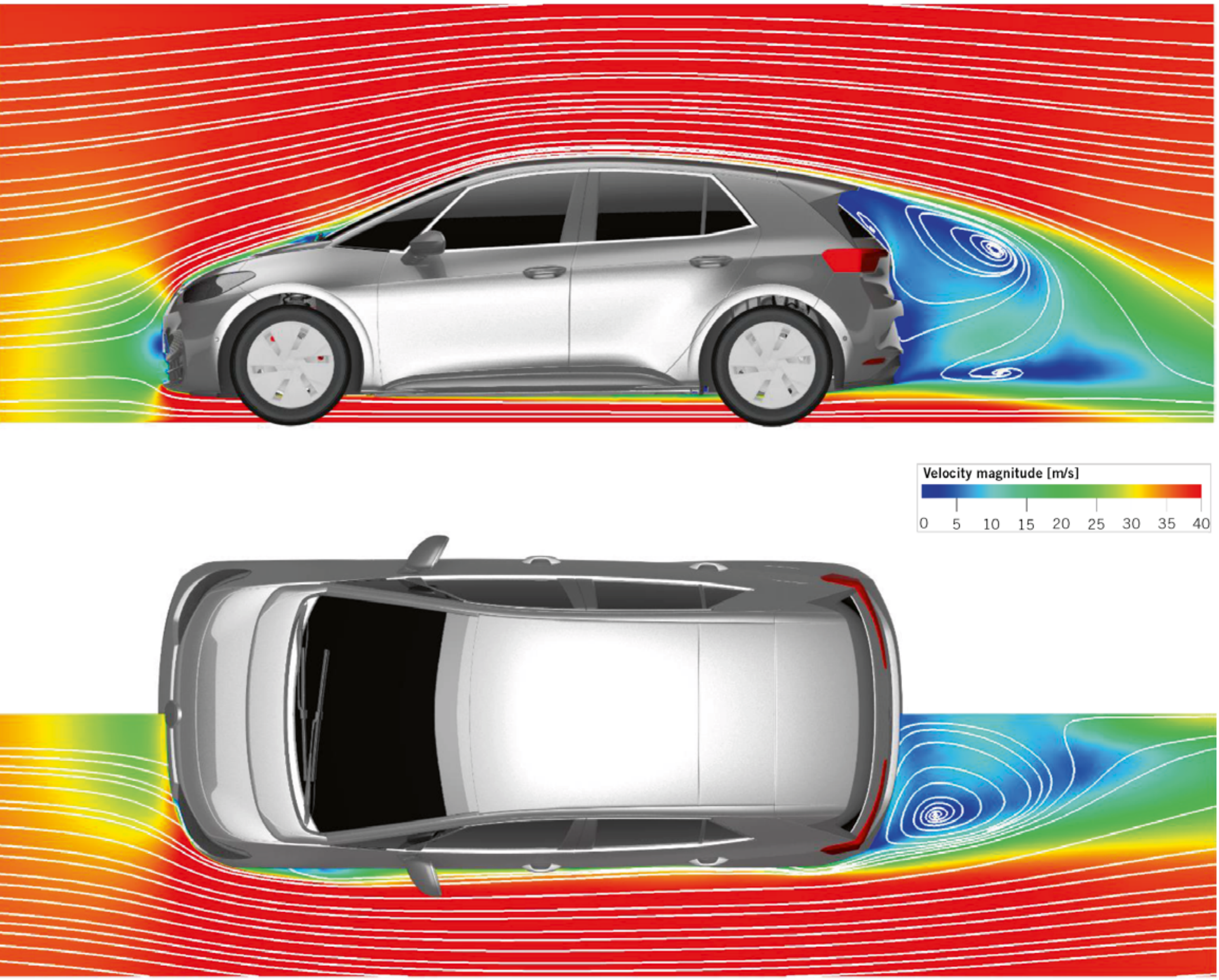


FIGURE 4 Schematic diagram of the optimization process in the early project phase and contour plot of flow velocity with flow lines in the final vehicle's Y-cross section (© Volkswagen)

designed A-pillar in combination with the water deflector strip connected to it and the systematically designed lateral separation edge in the rear end, starting at the side spoilers and ending at the lower bumper.

EXTERIOR MIRRORS

The ID.3 exterior mirrors shown in **FIGURE 5** made it possible to complete the next step in mirror evolution. They are characterized by significantly reduced drag and noise emissions that are lower by 2 dBA in the vehicle interior in comparison to previous developments. This makes them the best exterior mirrors of the Volkswagen brand to date when considering aerodynamics and aeroacoustics in combination. For the aerodynamic and aeroacoustic design of the exterior mirrors, approximately 100 h were spent in the wind tunnel (1:1 scale) for detail optimization purposes as a complement to numerous CFD simulations. In addition to measuring the c_D value as an optimization target variable and analyzing the mirror's local noise emissions with an "acoustic array," the flow on the mirror surface was analyzed with flow simulations and surface oil flow visualization in order to detect even the tiniest separations.

The inclined orientation of the mirror base toward the front results in the separation of large-scale longitudinal vortices behind the mirror base. These vortices increase drag and are undesirable as an acoustic source when it comes to interior acoustics. In this specific case, vortex generators installed on the mirror base correct the problem. These vortex generators produce small-scale longitudinal vortices that curb the development of undesirable large-scale longitudinal vortices

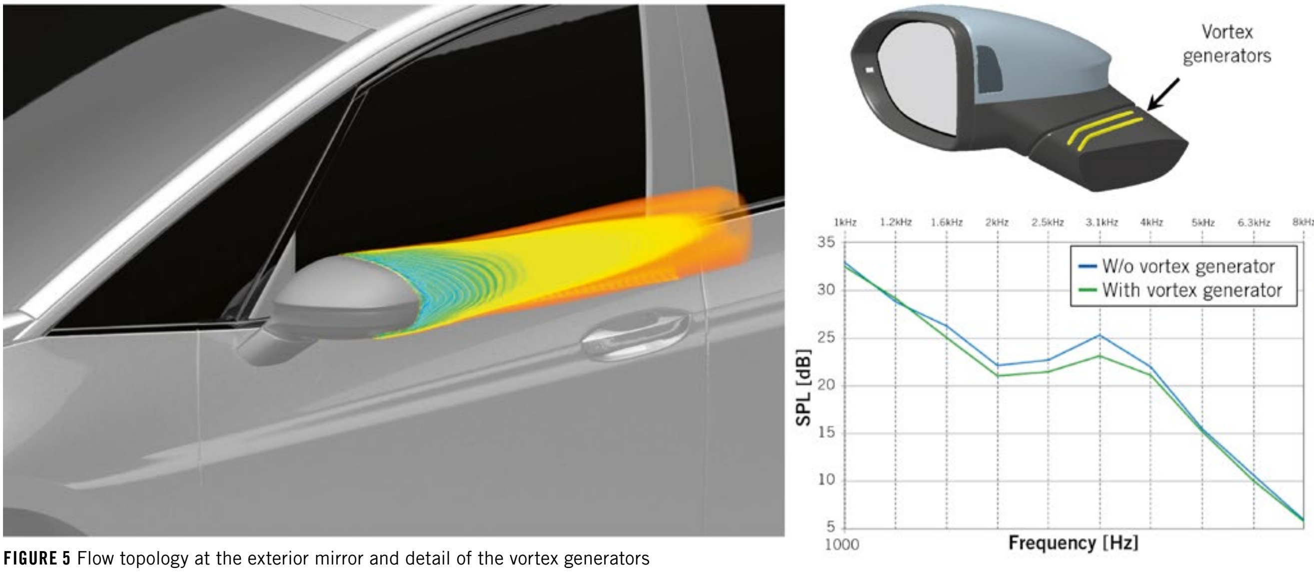


FIGURE 5 Flow topology at the exterior mirror and detail of the vortex generators on the mirror base and their acoustic contribution (© Volkswagen)

and accordingly reduce drag and the acoustic emissions at the mirror base. In addition, systematic shape optimization made it possible to create a mirror housing free of undesirable pressure-induced separation areas and accordingly reduce the mirror's drag and noise emissions.

RIM DESIGN

As per [3], the wheels make up a significant percentage of the total flow losses at 33 %. As a result, there was a special focus on the aerodynamic design of the ID.3 rims. The essential challenge within this context was to meet the aerodynamic requirements with regard to having the biggest possible rim closure and keeping the design as two-dimensional as possible while also meeting the need for an attractive and sporty design and keeping the rims as lightweight as possible. For the rims' aerodynamic development, which was based exclusively on CFD, a simplified reference case – a completely closed and flat rim disk – was used. This case was used as a reference for the aerodynamic quality of the rim options in the discussions with Design. Depending on their dimensions, conventional aluminum rims have a Δc_D value of approximately 0.020. The development goal for the ID.3 was to limit the influence of the rim design on the c_D value to less than 0.010 in comparison to the closed disk rim.

FIGURE 6 shows the results for the ID.3 rim options, consisting of an 18" steel rim, an 18" aluminum rim, a 19" aluminum rim, and a 20" aluminum rim. The results show that all the rims meet the development goal. In comparison to the closed rim disk, Δc_D values of 0.005 to 0.008 are achieved, with the steel rim with the aerodynamically optimized decorative trim being the best one and for which the c_D delta increases slightly the larger the rim dimensions are.

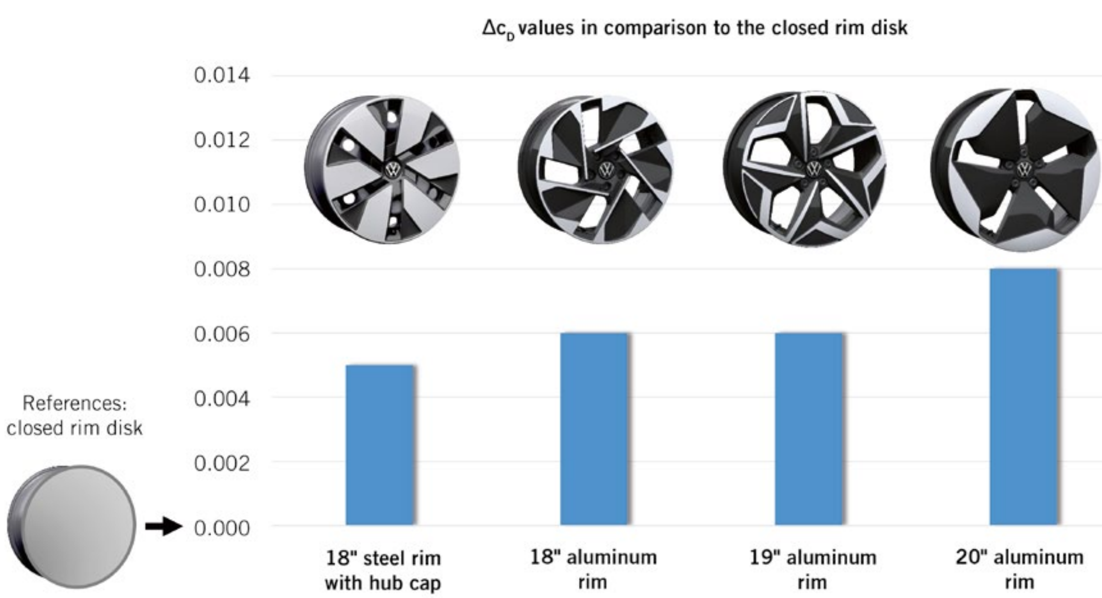


FIGURE 6 c_D deltas for the ID.3 rim options relative to the completely closed disk rim (© Volkswagen)

Finally, it is important to note that, as described in [4], the tire contour also has a decisive influence on drag and that corresponding design specifications for the tire manufacturers were required in order to get a wheel that has been optimized as a whole.

CONCLUSION

The ID.3 is the first model in a new, comprehensive battery-electric-vehicle model range by Volkswagen. The spacious interior conditions and the design prerequisites concerning short overhangs and large wheels were important challenges in the vehicle's aerodynamic development. By using flow simulations in a systematic manner already during the early development phase, the platform and the vehicle base body were optimized effectively. With the further detailed optimization in the wind tunnel, the ID.3 achieves a peak c_D value of 0.26, which makes an important contribution to meeting an electric range target of up to 550 km.

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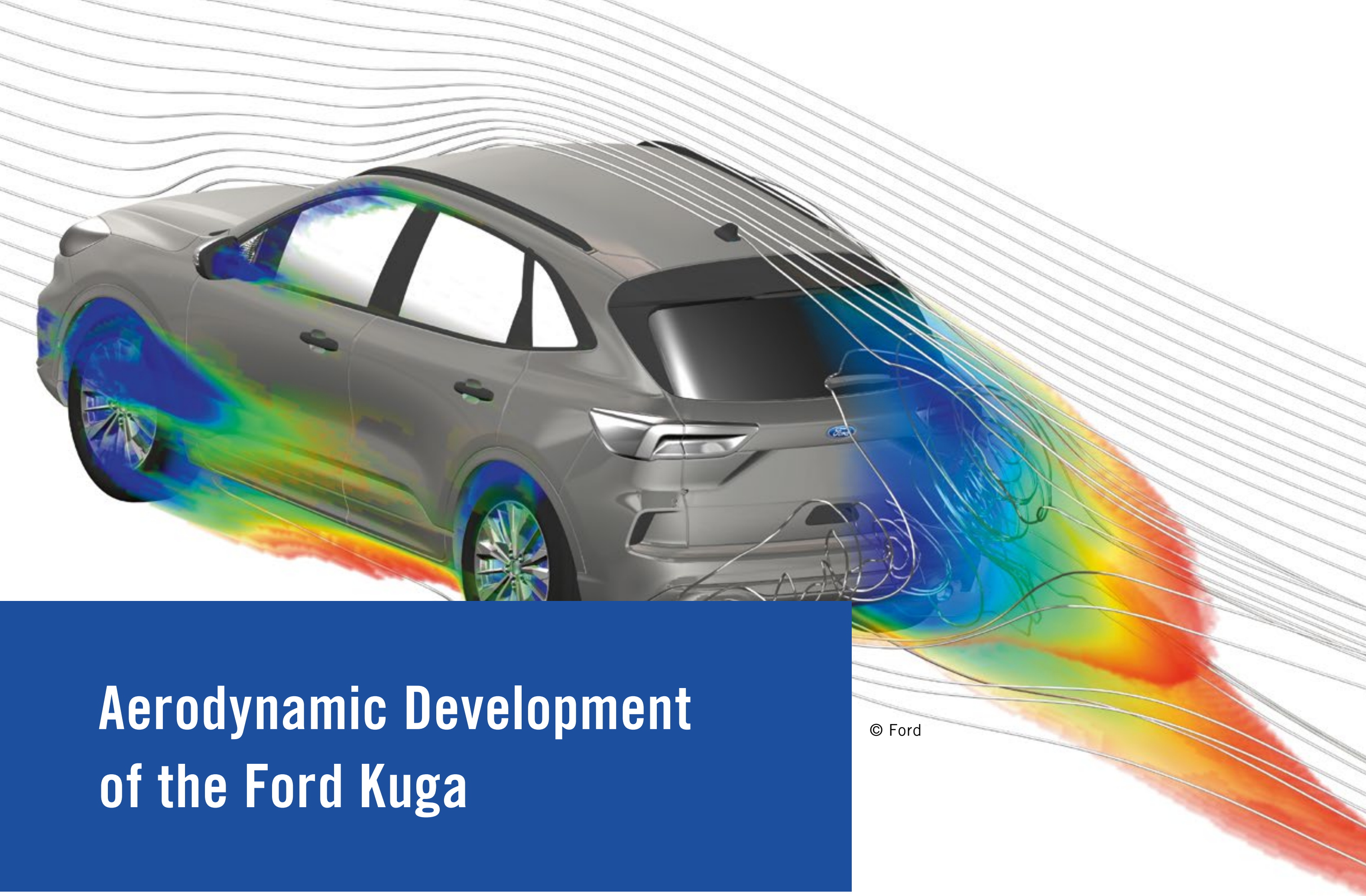

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Aerodynamic Development of the Ford Kuga

The importance of vehicle aerodynamics is ever increasing due to its positive contribution to fleet fuel economy and high range in electric driving mode. The aerodynamic development of the Ford Kuga is a good example of how modern processes and technologies can deliver on high expectations. The c_D values of the entire product palette were significantly reduced compared to its predecessor.

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TARGET SETTING FOR PRODUCT DEVELOPMENT

It was clear from the early stages of the project that optimized aerodynamics would play an important role in delivering the desired product qualities. Good c_D values should not be reserved only for a special version, the so-called Aero Leader, but be achieved by all variants. **FIGURE 1** shows the principle used to set targets during the early phases of the project. The data show the progressive development with time of the c_D values of SUVs and off-road vehicles from global manufacturers. The diagram also shows a trend line for vehicles with Kuga-like silhouettes and similar aerodynamically relevant content. The values for the predecessors and most important competitors are marked out. In general, both the trend and the variance are reducing as time goes on. Good aerodynamics has also become highly valued due to the strong increase in oil prices starting in 2000 as well as globally tougher emissions standards from about 2010. To arrive at a c_D target, the intended fuel economy and performance, the requirements of the package team as regards for example interior measurements, and the technology level improvements indicated by the trend line were weighed up against one nother. At the end of the process, a drag coefficient target of $c_D < 0.33$ was decided for the majority of the global Kuga fleet. Specific variants with special off-road requirements (increased ride height, special underbody protection, off-road tires) were allowed to reach a maximum value of $c_D = 0.35$.

The components needed to reach the aerodynamic target, for example cooling airflow management by means of an active grill shutter, underbody panels and wheel spoilers, as well as the associated financial implications were defined and decided upon.

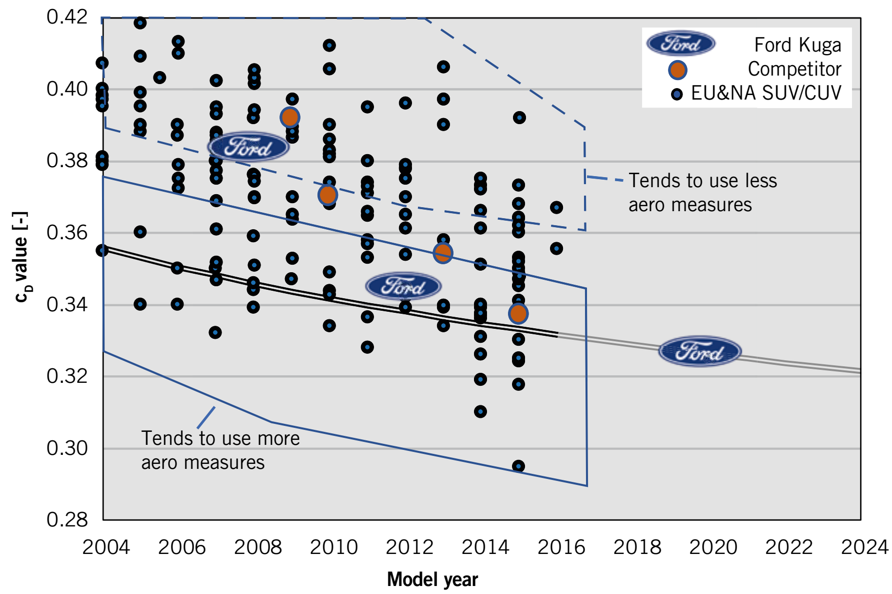


FIGURE 1 Industry trend of the c_D value for SUVs (EU and USA) and target definition before project start 2015 (© Ford)

DEVELOPMENT PROCESS

The basic principles of the aerodynamic development process shown in **FIGURE 2** are well understood [1]. The most important is a closely integrated development process involving designers, body engineers and aerodynamicists to arrive at an attractive and aerodynamic product. The ever-increasing number of variations and shorter development times require however that processes are continuously developed to give faster feedback loops. Modern digital tools help the various teams with agile design development, efficient data exchange and the use of virtual rooms where teams can meet independently of their physical locations.

To allow global trends and customer desires to flow into the design of the new Kuga, a design competition took place with the participation of all the Ford Design Studios worldwide. The aerodynamics team concentrated on concept evaluation and delivered suggestions for optimization. In the first phase of development the focus was on using the virtual wind tunnel to find the most efficient proportions. In the second half, it shifted toward the optimization of technical details. With the help of prototypes or preproduction vehicles the final optimization and approval for series production as well as certification for homologation was conducted in a WLTP-certified wind tunnel.

DEVELOPMENT OF THE BASIC SHAPE

Air flows can be principally grouped into attached and detached flow [2]. For road vehicle airflow the highly dissipative

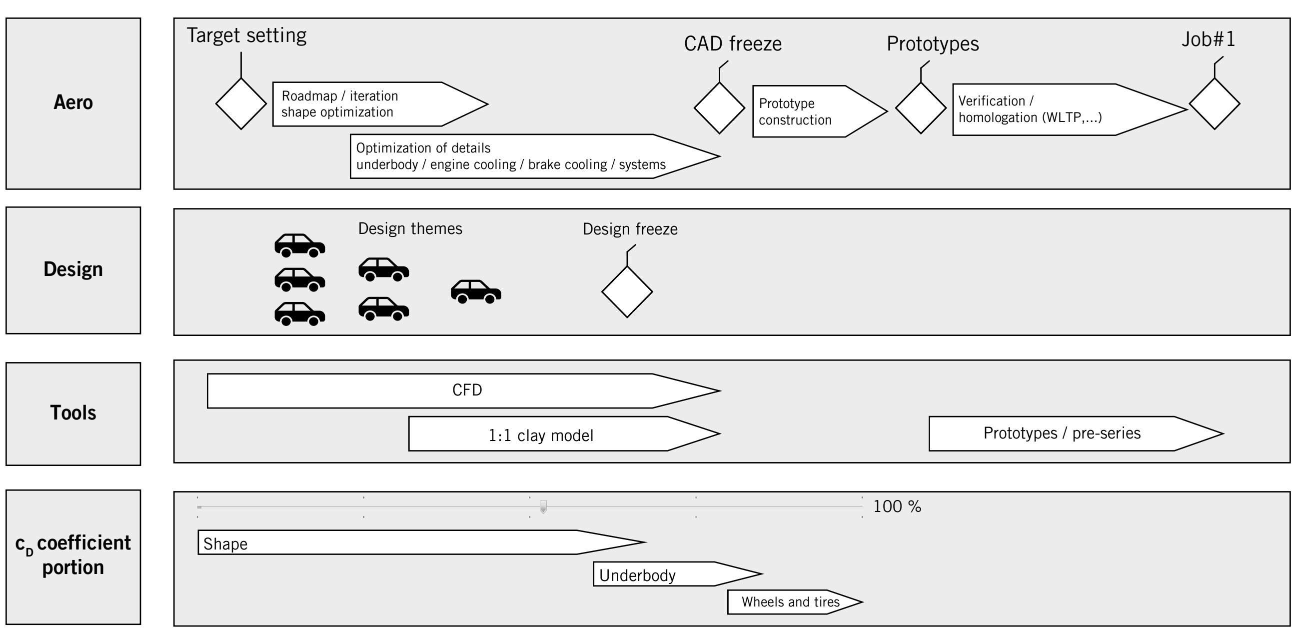


FIGURE 2 Aerodynamic development process (© Ford)

vortices in the separated regions and the associated shear layers are responsible for the majority of the pressure differences and more than 80 % of the aerodynamic drag. The reduction of this vortex dissipation is therefore the focus of the development of the basic shape. SUVs and crossover vehicles are especially demanding on aerodynamicists. In comparison to lower sedan and sports vehicles they appear "blunt" and have bigger wheels and higher ground clearance.

FIGURE 3 shows the development of the c_D value over time, from the first Kuga proportion model to the final homologation test with a pre-production vehicle. In the first phase the designers and aerodynamicists make use of a higher degree of freedom to optimize the exterior shape without adding cost. The aerodynamic properties are calculated only via the use of CFD until one design has been chosen. Models at 1:2.5 scale as used in the past are no longer part of the Ford development process.

The first design studies at $c_D = 0.36$ to 0.393 were up to 20 % above the target of $c_D < 0.33$. The evolution of the c_D value demonstrates the hand-in-hand progression of the design and aerodynamic optimization processes. By the time the final design was chosen approximately 50 % of the gap in the c_D value had already been closed. The following measures were implemented by the team: firstly the wheelbase, increased by 20 mm, was used to optimize the silhouette. Further important design and aerodynamic elements included a low stretched hood, reduced windscreen angle and optimized A pillar to minimize the induced vortices. The roofline was kept low and curving downward toward the rear. To minimize the separation in the rear as much as possible the bodysides and D pillars were pulled in at the rear. The shape of the D pillars were also optimized in regard to the important package requirements regarding the width and height of the storage compartment.

FINE TUNING AND DETAILED OPTIMIZATION

Once the proportions were decided and the design theme settled, the fine tuning and detailed optimization could take place in the aerodynamic wind tunnel. For the Kuga a classical 1:1 clay model was built with a representative underbody, engine and cooling airflow. CFD analyses conducted in parallel supported the detailed analysis of critical areas. This helped to plan wind tunnel studies efficiently. In addition, ideas generated by CAE studies were able to be realized as physical test parts by means of rapid prototyping. With a simple replacement of parts the predicted effects were able to be quickly verified in the wind tunnel. An example for the use of prototype parts was the development of the front bumper. The aim was to give an aerodynamically neutral effect to the intended design elements (surfaces, sharp edges, position and shape of the fog lights) and generate an as much as possible parallel onset flow to the front wheels. Via these design optimizations the team was able to get closer to the target by around $\Delta c_D = 0.005$.

The aerodynamicists and aeroacoustic engineers worked together in the wind tunnel to optimize the exterior mirrors. The mirror housing was designed to be aerodynamically shaped in advance and

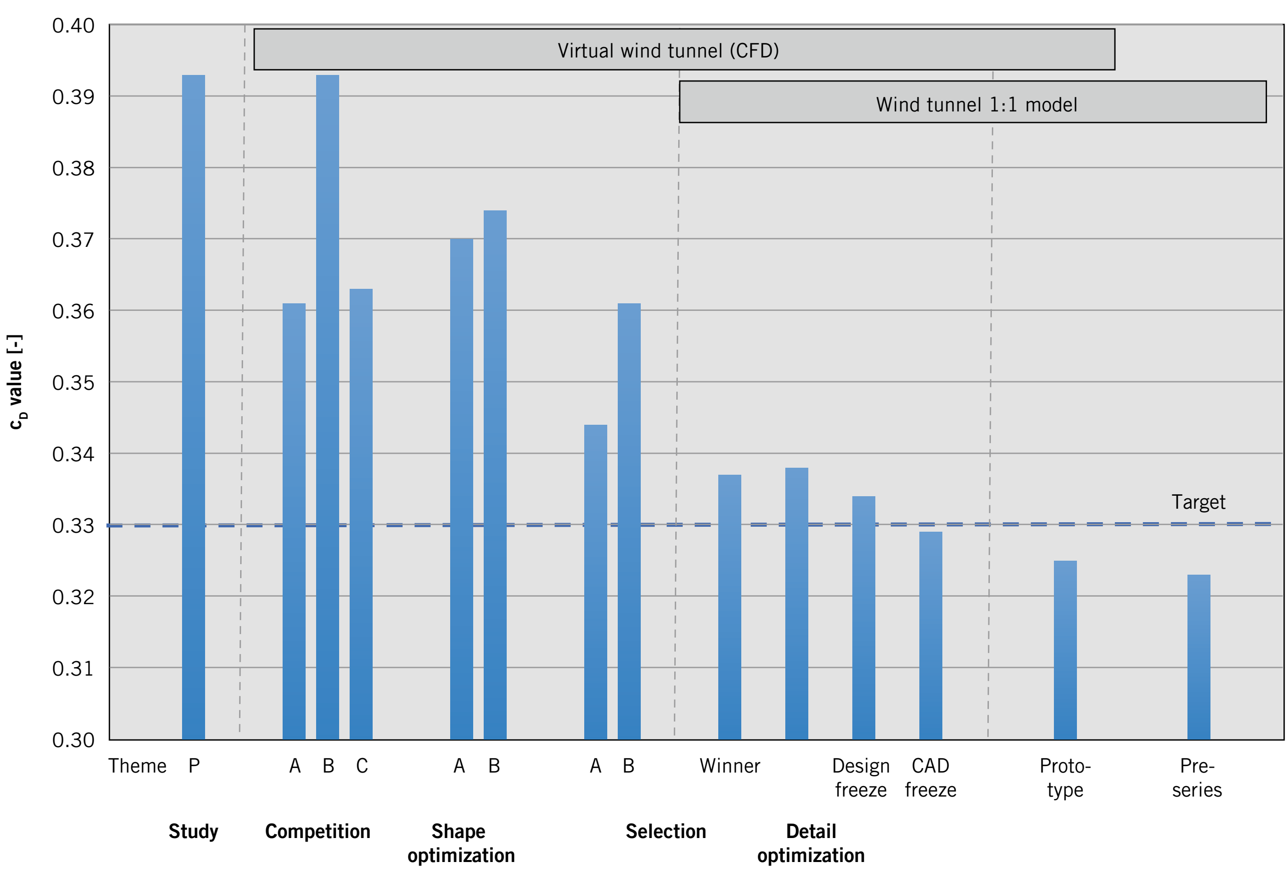


FIGURE 3 Chronological development of the c_D value (© Ford)

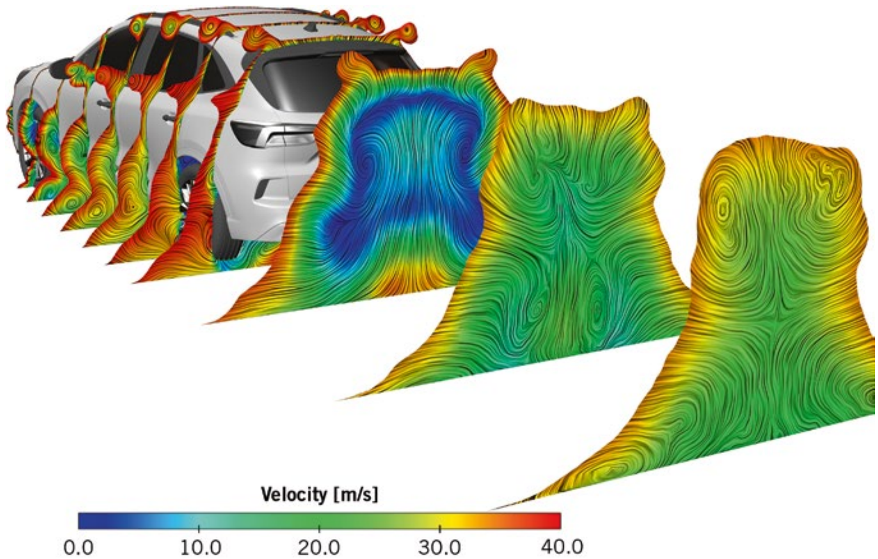


FIGURE 4 Calculated velocity distributions in visualized slices for the ST-Line variant (© Ford)

then optimized on the clay model. To minimize interactions with the body the mirror is attached to the window triangle with flattened arms. The mirror housing on the side of the A pillar is shaped like a diffusor, which controls and slows down the airflow. **FIGURE 4** shows the results via visualized slices of the airflow. The time-averaged results show that the wake of the mirror and therefore also the noise generation is kept away from the side windows and the interior. The mirror contributes less than 4 % of the aerodynamic drag of the complete vehicle.

The changes to the rear of the vehicle had the aim to define and aerodynamically optimize the location of flow separation. The spoiler, optimized in length and angle, served to gracefully extend the roof line; its corners were then extended downward as side spoilers. The shape of the spoiler had to be optimized together with the separation edges of the taillights and the rear bumper with its integrated diffusor. Thanks to the resulting reduction in vortex structure and increase of the so-called base pressure on the rear of the vehicle, an improvement of approximately $\Delta c_D = 0.013$ could be achieved.

By the point of design freeze, the target of $c_D = 0.33$ had been accomplished. The following tasks concentrated on the optimization of the non-visible components as regards aerodynamic and economic efficiency.

The flat and up to 80 % closed underbody is an important part of the Kuga's

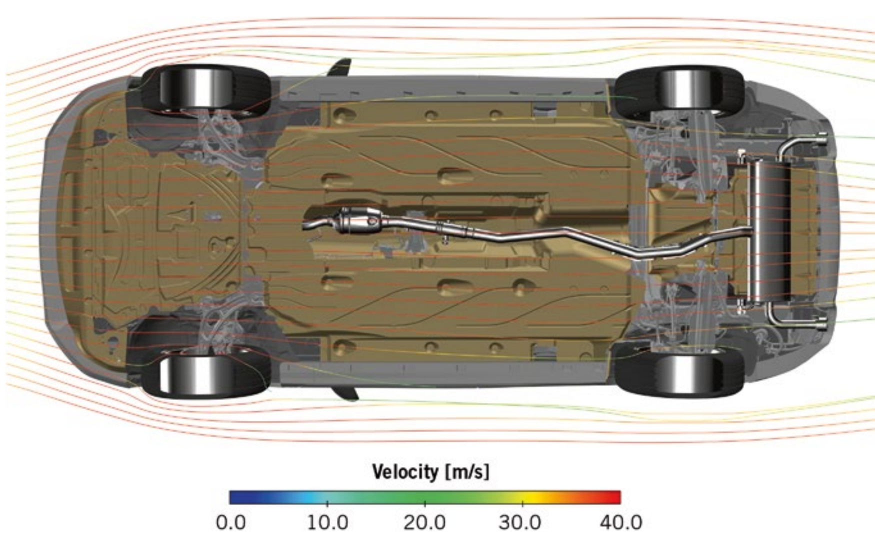


FIGURE 5 Underbody shielding with representation of the streamlines (© Ford)

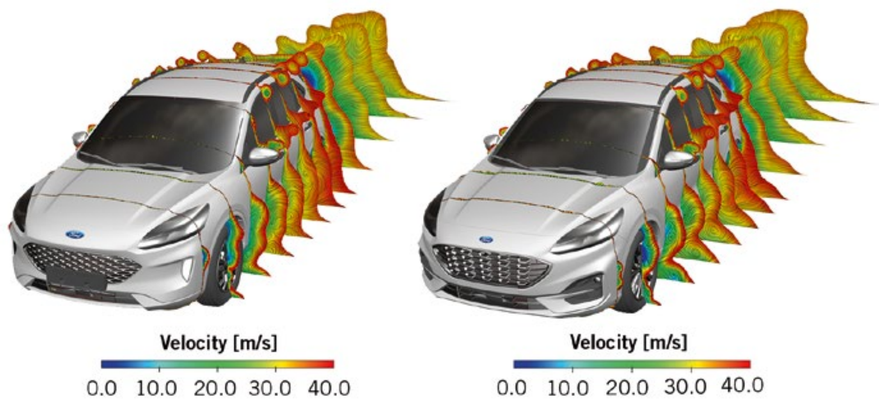
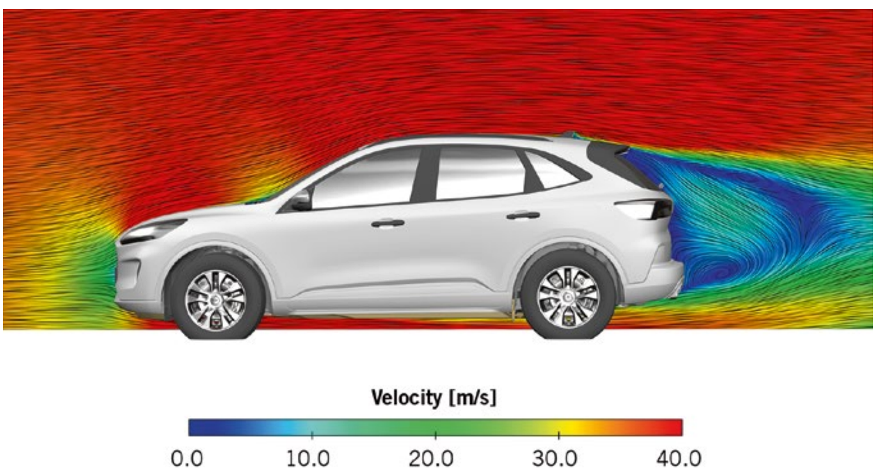


FIGURE 6 Comparison of flow topologies (cross-sections) for the variants Titanium (left) and ST-Line (right) (© Ford)



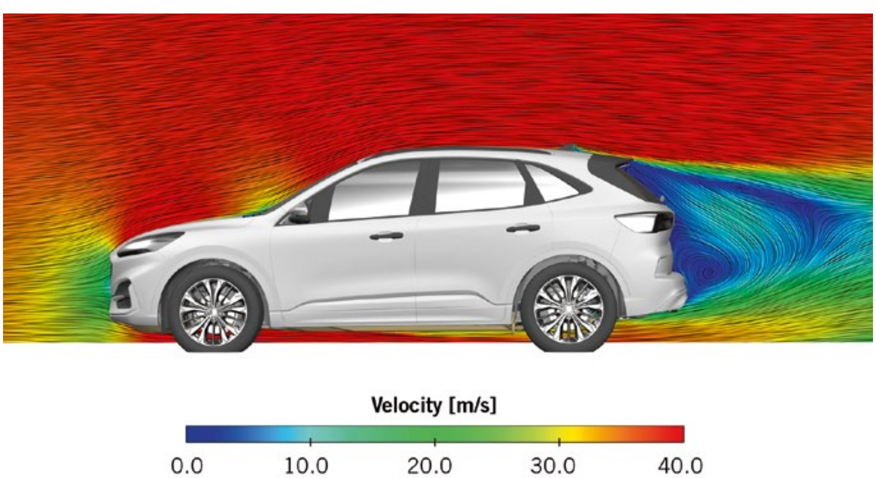


FIGURE 7 Comparison of flow topologies (center-section) for the variants Titanium (top) and ST-Line (bottom) (© Ford)

aerodynamic concept. The layout also supports the energy management of the powertrain and the brakes. The underbody of the Ford Kuga was optimized for each engine and gearbox combination individually. "Existing" parts, like the rear muffler or the flat battery of the Kuga PHEV, were integrated into the system and designed to be aerodynamically beneficial. **FIGURE 5** shows as an example the underbody for a gasoline engine with front wheel drive. The engine compartment cover, drivetrain cover with integrated heat protection for directing the engine compartment airflow, center deflector on the rear axle and rear heat-shield are shown. All the covers are designed for a flush connection to the bumpers and side skirts. The covers on the rear axle swing arms constructed in the early phases of development are found not to be cost effective for the Kuga and were not considered for series production. Fine tuning of the underbody delivered a further reduction of Δc_D = 0.005. If all the aerodynamic underbody parts were removed, the drag coefficient would increase by more than 10 %.

RESULTS

In wind tunnel tests with pre-production vehicles a drag coefficient of c_D = 0.323 could be demonstrated. The majority of the other variants also fulfill the target of c_D < 0.33. Higher values are driven by optional equipment such as bigger wheels. This very good overall result is proof of the successful optimization process for all variants.

FIGURE 6 and **FIGURE 7** present how the different parts and wheels influence the calculated airflow around a Kuga with front wheel drive and automatic gearbox. The Titanium version has 17" steel wheels with wheel trims, and the ST-Line model has open 19" wheels and a sporty rear spoiler.

FIGURE 6 shows slices through the airflow topology. Along the lower bodyside and near the ground by the Kuga ST-Line more air is pushed out to the side. Further analysis of the data shows that the ST-Line front bumper directs more air under the vehicle, and at the same time the 19" wheel ventilates more air out of the wheel arches and engine compartment, and to the side. This also reduces the lift on the front axle, with the ST-Line delivering a value of only c_{LF} = -0.003. At the same time the airflow onto the front wheels is slightly more angled than on the 17" wheel of the base version. The CFD data indicates that a higher c_D value is to be expected in the ST-Line configuration with 19" wheels, **FIGURE 8**.

The center-sections, **FIGURE 7**, show two phenomena. On the lower part of the vehicle, from around the B-pillar onward, the ST-Line shows lower velocities. This is mainly caused by the previously mentioned sideways movement of the air. In the rear it can be seen that the rear spoiler and diffusor lead the air back to the shear layers as desired and the airflow does not separate prema-

Features	Total number	Aerodynamically relevant
Trim level	4	3
Rear spoiler	2	2
Engine-gearbox combination	10	3
Wheels	9	9
Active grill shutter	1	1
Suspension	2	2
Trailer tow	2	2
Permutation	2880	648
Buildable combinations	871	291

TABLE 1 Aerodynamically relevant variants and optional equipment (© Ford)

turely. The lower airflow angle at the diffusor is angled more upward for the ST-Line compared to the Titanium. This is an indication that the lift on the ST-Line's rear axle is lower. The wind tunnel confirms the suspicion. The ST-Line has a rear lift coefficient c_{LR} = -0.049, compared to the Titanium at c_{LR} = 0.017. This slight downforce on the Ford Kuga ST-Line underlines the dynamic design of this variant.

VARIANT MANAGEMENT AND HOMOLOGATION

The parallel optimization of all the variants and the time-consuming homologation according to WLTP are especially challenging for aerodynamicists. The differences between the variants have to be sorted out as to their aerodynamic relevance, and each variant has to be aerodynamically optimized. The first sensitivity analysis is primarily done by means of CFD simulation. Selected variants and special effects are verified in the full-scale wind tunnel. Rapid prototyping offers efficient use of wind tunnel time, especially in making and exchanging various underbody and add-on parts.

FIGURE 8 shows the influence of variants and optional equipment on the c_D value in percent. It became apparent that the variation between powertrains was very small, and the sensitivity was driven by the main factors of engine and gearbox type. There were effectively three groups of powertrains:

- Group 1 (diesel engine with automatic transmission)
- Group 2 (diesel engine with manual transmission and gasoline engine with automatic transmission)
- Group 3 (gasoline engine with manual transmission and PHEV).

The difference in c_D value between the groups was only 0.5 %. This minimal variation is the result of similar cooling configuration and the optimization of the underbody for each specific variant.

The Kuga Titanium has the most advantageous c_D value. The Kuga ST-Line's is, despite its rear lift reducing spoiler (Δc_{LR} = -0.040), only about 0.8 % higher (Δc_D = 0.003). The wheels have the largest impact on aerodynamics. The range is between 0 % for the reference 17" steel wheel and 3.3 % for the 19" aluminum wheel in 5×2 spoke design. For the 17, 18 and 19" tires with their common dimension of 225/** R** (* = placeholder) the main difference is in the trend for higher resistance due to the increased rim diameter and more open rim design. That this cannot be generalized is shown by the 20" wheel with its wider 245/45 R20 tire which normally increases the aerodynamic drag [3]. The 20" wheel is however only 0.7 % worse than the reference wheel. The 20" wheel has a more closed design compared to the aluminum wheels with higher c_D values. The 245/45 low profile tires have less bulge in the shape of the side wall than the 225/** tires.

For homologation in the NEDC it was enough to test a base model to get type approval. The introduction of WLTP (2018) changed this. For the certification the aerodynamic properties of every variant and every option has to be demonstrated. According to **TABLE 1**, there are 871 buildable combinations of Kuga. It is neither sensible nor timely or economically possible to test all 871 variants. The identification of significant factors allows the number of combinations to be reduced to 291. By use of virtual methods, efficient planning and wind tunnel tests it was thus possible to provide the necessary evidence on time.

SUMMARY AND OUTLOOK

The aerodynamic development of the Ford Kuga shows how by the consistent application of a continually improved development process, ever more chal-

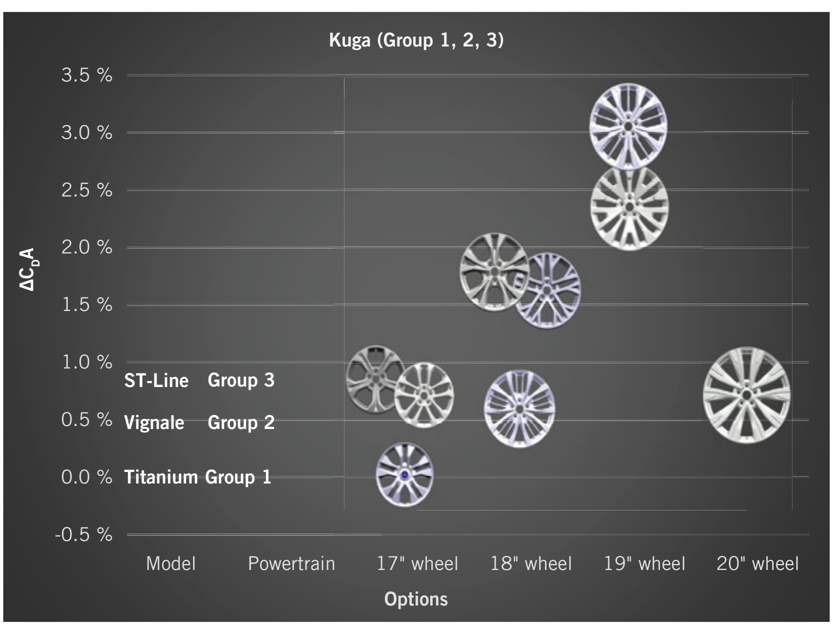


FIGURE 8 Aerodynamically relevant variants and optional equipment (© Ford)

lenging requirements can be met. The aerodynamic targets were achieved. Each variant contributes with its optimized c_D value to the efficient reduction of CO_2 emissions. Homologation according to WLTP demands of the aerodynamicist a deeper understanding of the legislation and increased testing at the end of the development project.

Ever stricter fleet emissions limits and high customer expectations for long range in electric driving mode will drive further improvements in aerodynamic drag in the future. Every part of the vehicle has its part to play in achieving an optimal result [4]. One example is wheel aerodynamics. Electric vehicles put additional pressure on aerodynamics. The aerodynamic drag plays a greater role than for a vehicle with a combustion engine [5]. Ground-up electric vehicle platforms also allow new proportions, which are made use of by the designers and must be aerodynamically optimized. Aerodynamicists are excited about the future and the advantages of electric platforms as, for example, flat, centrally positioned batteries replace the bumpy underbody with hot exhaust systems – a good starting point for an aerodynamically perfect underbody structure.

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Heavy-Duty, On- and Off-Highway Engines 2020 Highlights Combustion Engines and Alternative Solutions

The 15th MTZ conference "Heavy-Duty, On- and Off-Highway Engines" is taking place on November 10 and 11 in Mannheim. The event is the only one of its kind in Europe and promotes knowledge sharing across the industry. It gives developers and designers of engines for commercial vehicles, mobile machines and marine and stationary applications the opportunity to find out about the latest developments in the field. The conference is accompanied by a factory tour at the Daimler Truck AG plant.

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Manufacturers of large engines and engine components are facing mounting pressure as a result of legislation aimed at reducing pollution levels. Heavy-duty engines have to comply with strict exhaust emissions standards across the entire engine map and their fuel consumption must be reduced. Electrification alone will not make it possible to achieve the Paris 2050 targets, particularly in the field of commercial vehicles and large engines. For this reason, it is absolutely crucial for synthetic fuels and second-generation biofuels to be introduced onto the market as quickly as possible. Only this and a well-to-wheel analysis of fuel consumption will enable us to meet the requirements of Euro VII.

The key themes of this year's conference are new diesel, gas and dual-fuel engines and the reduction of pollution and CO_2 emissions. How much potential for improvement do exhaust gas treatment systems, heating systems and partial electrification offer? Or will the choice of fuel determine the future of large engines?

"We need to take a holistic approach. The role of biogenic and synthetic fuels and their sustainable use must be evaluated as part of an integrated energy system," emphasizes Prof. Peter Eilts from the Technical University of Braunschweig, the scientific director of this year's conference. He is setting the bar high for technical solutions and industrial strategies in the context of international market developments. The MTZ conference is characterized by varied perspectives and a combination of scientific and practical solutions and management strategies that can provide valuable guidance for specialist engineers.

Heavy-Duty, On- and Off-Highway Engines – The 15th international MTZ conference on heavy-duty engines

Date:	November 10 and 11, 2020
Venue:	Congress Center Rosengarten, Mannheim (Germany)
Networking night:	November 10, 2020 at the Bootshaus Mannheim
Scientific director:	Prof. Peter Eilts, Technical University of Braunschweig
Themes:	Alternative Concepts: Batteries, hybrids and fuel cells
	CO_2 and Pollutant Emissions: Legal requirements and solutions
	New Diesel, Gas and Dual-fuel Engines: Development trends and new components
Partners:	KST Motorenversuch, Ricardo
Participation fee:	€ 1395.00 plus VAT.
Booking:	https://www.atzlive.de/en/events/heavy-duty-on-and-off-highway-engines/

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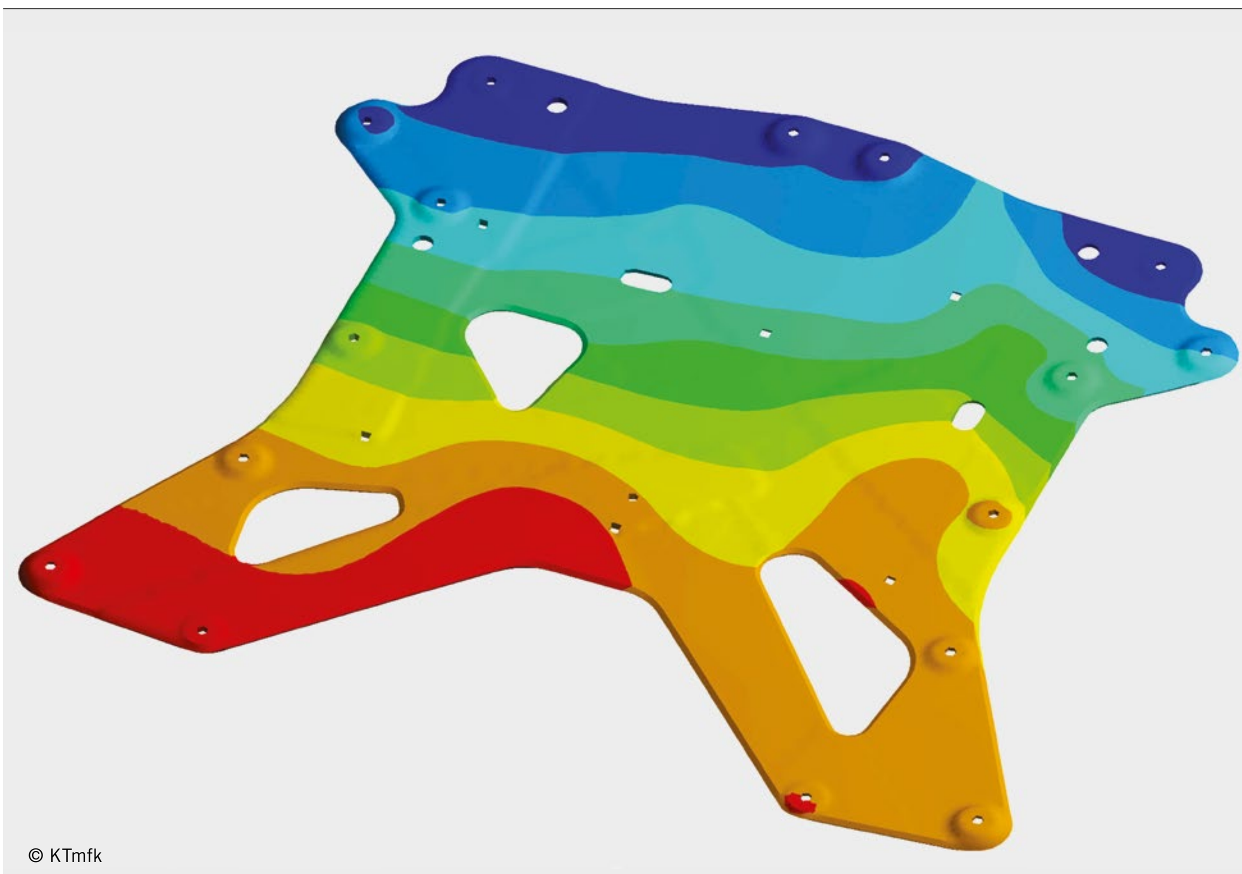
Design of a CFRP Thrust Field Using a Simulation-based Approach

The design process of structures of carbon fiber reinforced plastics is often insufficiently organized, characterized by numerous iterations and therefore very time-consuming. A newly developed simulation-based approach can help to make the design process more efficient through its structured procedure. In a joint project of the BMW Group and the Chair of Engineering Design at the Friedrich-Alexander-University Erlangen-Nuremberg (FAU), this approach was applied and evaluated using a thrust field as demonstrator part.



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1 MOTIVATION

The design of carbon fiber composite structures remains a special challenge for product developers. In addition to the highly anisotropic material properties, numerous additional design parameters, such as layer thickness or fiber orientation, are to be determined [1]. Even with the aid of various design tools, this often leads to an insufficiently structured design process with numerous iterations, and lightweight potential is often not fully utilized.

For this reason, a procedure to numerically generate composite designs has been developed at the Chair of Engineering Design of the Friedrich-Alexander-University Erlangen-Nuremberg [2, 3]. With this structured process favorable mechanical properties can be exploited more efficiently.

2 INTRODUCTION

The procedure was applied in a pre-development project using a practical example and the results were evaluated in a comparison. A so-called thrust field served as demonstrator part, which is located in the front area of the BMW i8 in order to stiffen the body structure. Five different load cases characterized the main loads as design prerequisite for the thrust field, **FIGURE 1** (a). These contain locally applied forces at screw joints. The resulting design should have minimal mass (objective) while at the same time not exceeding local deformations of an aluminum reference shear field (restrictions).

3 CALCULATION OF THE FORCE FLOWS

The design approach begins with the creation of a Finite Element (FE) model for each of the load cases. This allows carrying out a modified Computer Aided Internal Optimization (CAIO), which is an extension of the CAIO algorithm developed by Reuschel and Mattheck in the 1990s [4, 5]. With the help of this algorithm the fibers are to be aligned according to the principal stress directions in an iterative process similar to the growth of wood fibers. After solving a first FE model, principal stress directions are calculated, fiber orientations realigned and the model is solved again. This process continues until there is no significant change in the model (measured by the shear stresses in the fiber coordinate system) and the algorithm for the respective load case converges.

The results can be explained using load case 1 as an example **FIGURE 1** (a). **FIGURE 1** (b) and (c) show the principal stress trajectories in the component after convergence in detail, which are often colloquially referred to as "force flows." It becomes obvious that these trajectories are headed from the connection points

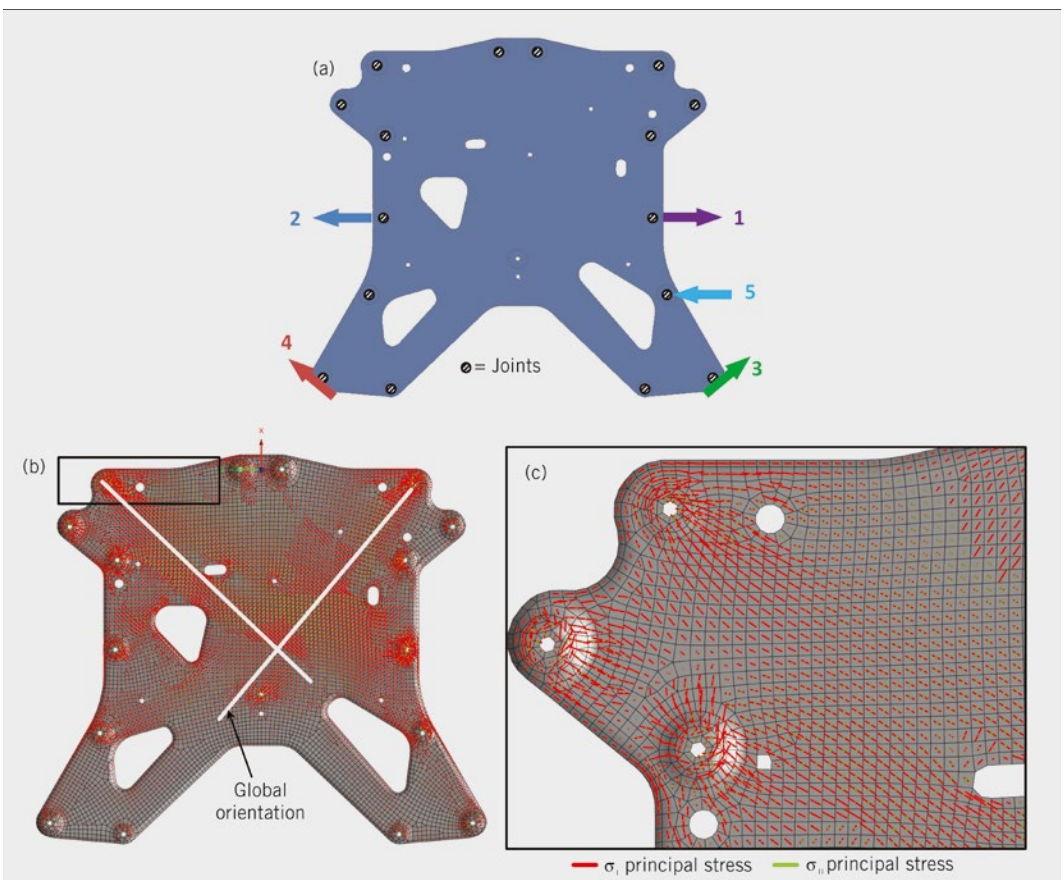

FIGURE 1 Structure of the model with load cases 1 to 5 (a), according to force flow calculation (CAIO) for load case 1 (b), detailed view of the principal stress (c) (© KTmfk)

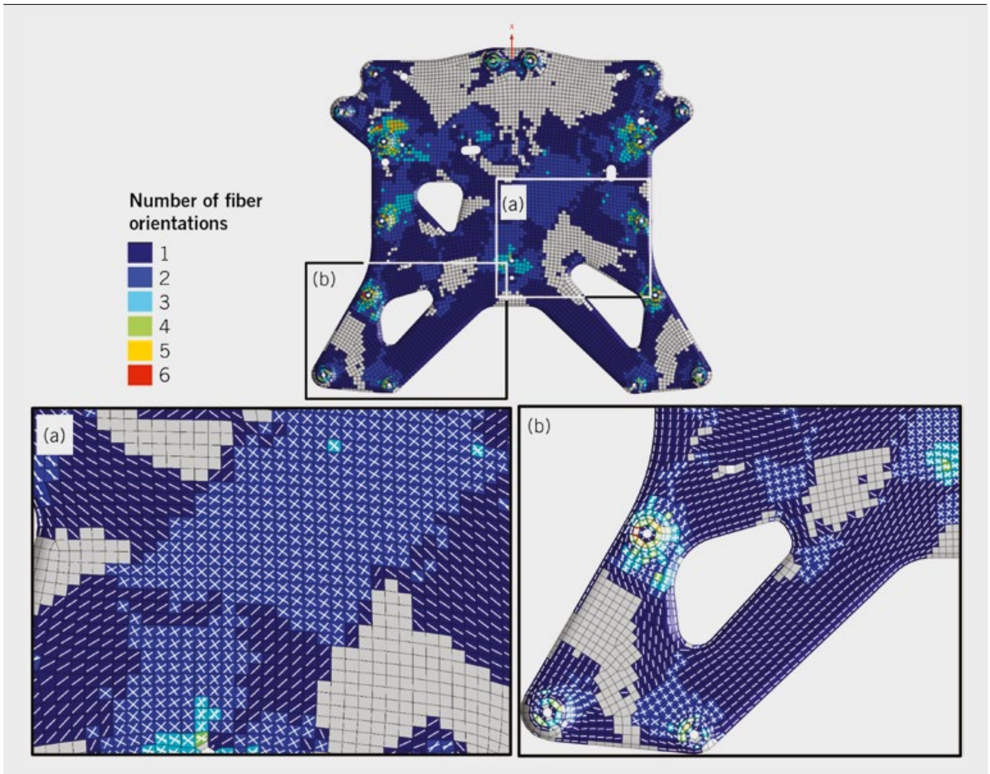

FIGURE 2 Design-relevant fiber orientations for the thrust field (© KTmfk)

towards the center of the component and thus create a cross-like pattern, which is indicated by the global orientation direction. A similar pattern occurs for the other load cases, which is characteristic for this component. Based on these principal stress trajectories from the different load cases, it is now possible to calculate the fiber directions relevant for load bearing.

4 DETERMINATION OF OPTIMIZED FIBER DIRECTIONS

If all the calculated principal stress trajectories from individual load cases are superimposed, experience shows that two recurring patterns show up in many components. On the one hand, real components usually show areas of different stress states, meaning that the calculated principal stresses are very small in some areas. If, as in the case of the thrust field, a base laminate is used, it can be assumed that these can be absorbed by the base laminate and therefore do not have to be considered for the further design. On the other hand, it could be observed in numerous components that, despite different load cases, very similar orientations of the principal stress trajectories occur in the respective component. Thus, it is possible to minimize the number of design-relevant principal stress trajectories by combining those with similar orientation into a single resulting fiber orientation. If the algorithm for reducing the principal stress trajectories is applied to the shear field and thus small principal stresses are deleted and similar orientations combined, only the fiber orientations relevant for load-adaptive design remain, **FIGURE 2**.

Despite different load cases, the principal stress trajectories can be reduced to one or two fiber orientations in large areas. Only in the area of the connection points, especially in an area where multi-axial stress states often occur, more than two fiber orientations remain even after the reduction. From these remaining fiber orientations, the next step is to define a laminate structure, which on the one hand covers these optimized fiber orientations as precisely as possible and, on the other hand, is also easy to produce.

5 LAMINATE DESIGN

The previous result contains continuous, non-linear courses of the material trajectories, as often expected from the concept of force flow analogous to fluid mechanics. In addition, the individual finite elements can have a different number of fiber orientations, **FIGURE 2**. A manual definition of where to place Carbon Fiber Reinforced Plastics (CFRP) patches with which main material axis direction is therefore usually difficult and time-consuming. In principle, it is crucial that the fiber orientation is covered as accurately as possible, especially in areas of high tension.

A cluster algorithm developed within the framework of this research helps to find areas in the previously calculated fiber orientations where the directions do not or only slightly change. Unidirectional (UD) patches, such as preimpregnated fibers (so-called prepregs), can be placed here. **FIGURE 3** shows an example of two such clusters emerging from clustering.

These clusters already give the product developer a very good indication of the geometry, fiber orientation and placement of blanks in the final laminate. However, direct use of the cluster geometries is usually not possible. Instead, the geometries have to be adapted to the selected production process and the available semi-finished products. This process can be semi-automated within the new approach to keep the time required to produce the finished laminate components to a minimum. At the end of this step, the final indi-

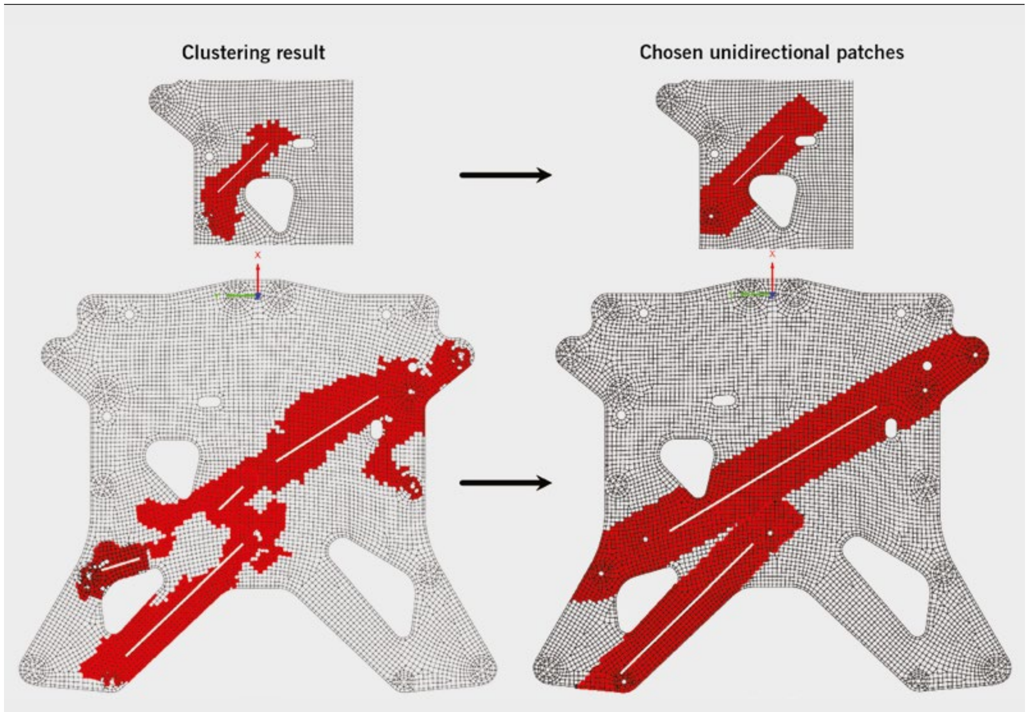

FIGURE 3 Example clusters (left) and the selected UD cuts (right) (© KTmfk)

vidual layer geometries for the component are defined. **FIGURE 4** presents the resulting laminate structure selected for the thrust field.

Due to the multi-axial stress conditions, **FIGURE 2**, it was not possible to achieve such a strong reduction to only one or two fiber orientations in the area of the connection points as in the rest of the component. In order to cover the calculated fiber orientations as effectively as possible, woven fabric patches were provided in this area. Due to the relatively homogeneous fiber orientation, it was possible to use UD tapes for the remaining areas, which also overlap in some regions. As **FIGURE 5** shows, the resulting laminate geometry covers calculated fiber orientations accurately. The previously calculated skeleton-like force flow is also reflected in the reinforcement layer structure. For the basic structure of the thrust field, an established aircraft laminate (symmetric stacking sequence $(0/\pm45/90)_s$) was used, which serves as the basis for the reinforcement layers, which are laminated on and fully covered with a woven fabric layer on top.

6 RESULT AFTER OPTIMIZATION

After defining the individual patches, the stacking order of the individual fiber patches is to be determined, as well as how many individual layers of a single direction are to be used. An evolutionary algorithm allows for the determination of these remaining parameters, carrying out a stacking and thickness (size) optimization. The main advantage compared to previous approaches based on optimization algorithms is that numerous parameters, such as fiber orientations, have already been defined in the preceding steps and only layer sequence and thickness remain. Especially for the thrust field, there is also the possibility to strongly limit the

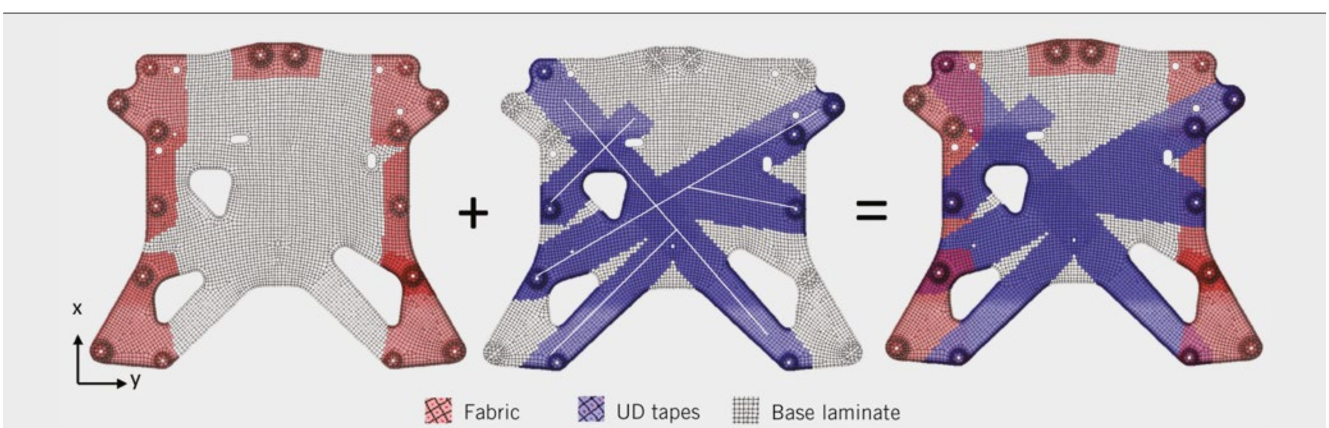

FIGURE 4 Structure of the reinforcing layers (© KTmfk)

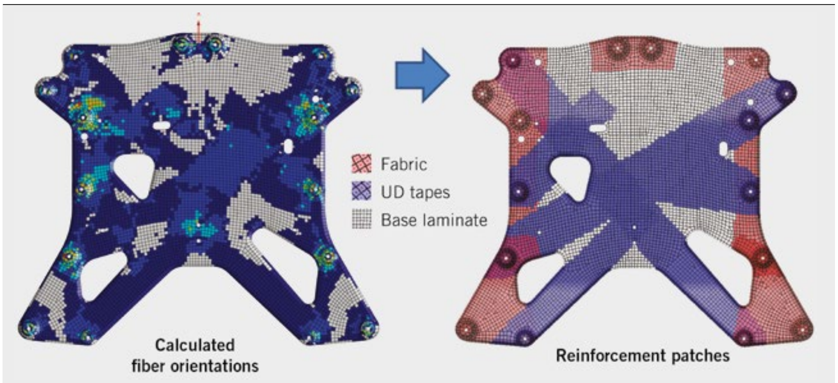

FIGURE 5 Comparison: calculated design-relevant fiber orientations (left) and selected reinforcement layers (right) (© KTmfk)

number of possible layer sequences, since it is required that the reinforcing layers are laminated onto a base layer. The stiffness of the aluminum reference component must be achieved by maintaining the strength limits of the composite material while reducing its mass.

FIGURE 6 shows the masses of different CFRP components as well as the original aluminum component, which can fully meet the requirements and which has a mass of 3.48 kg. As a basis for comparison, an initial optimization was conducted with a CFRP component consisting solely of the full-surface base laminate with fiber orientations of 0°, 90° and ±45°. This allows an initial weight saving of 200 g, which corresponds to a reduction of approximately 6 % against the aluminum benchmark. The new design, the base layer and the reinforcements determined by the optimization approach described here, **FIGURE 4**, allows a mass reduction of approximately 34 % to only 2.28 kg. With the structured, automated process of this approach, product developers can design a mechanically optimal laminate structure while clearly utilizing lightweight design potential.

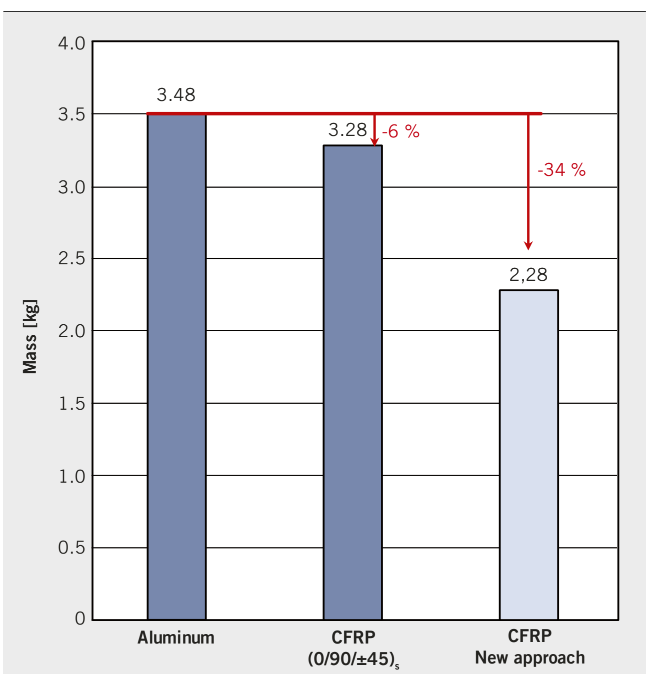

FIGURE 6 Comparison of the masses of the component made of aluminum, of a full-surface base laminate and of the base laminate with optimized reinforcing layers (© KTmfk)

7 SUMMARY

The essential steps of the presented simulation-based design approach for fiber composite structures are as follows: the force flows are calculated on the basis of FE models of the individual load cases; subsequently, the design-relevant fiber orientations are combined so that a force flow reduction can take place; the developed cluster algorithm assists in the design of the single layer geometries so that subsequently a favorable laminate structure is possible. The product developer is thus offered a structured, automated procedure that allows significantly fewer necessary iterations. Ensuring during development that the algorithms used are computationally efficient, the overall development time is significantly shorter when compared to many conventional design methods.

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The Virtual Chassis – 11th chassis.tech plus 2020

chassis.tech plus, more formally known as the International Munich Chassis Symposium, was held not in Bavaria but online for the first time this year. More than 200 participants were able to put together their own program to suit their individual preferences from the four strands of the virtual event. Q&A sessions and chat forums gave the attendees the opportunity to interact live with one another.

MORE THAN 200 ONLINE PARTICIPANTS

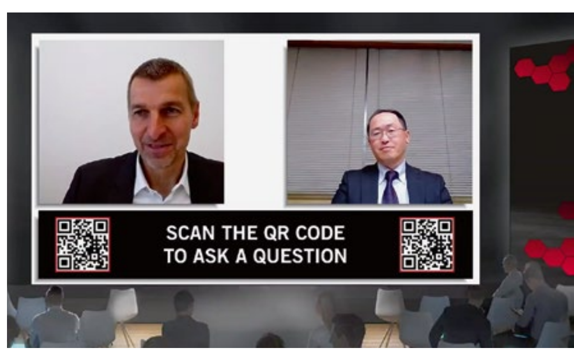
The event was a complete success. The first virtual chassis.tech plus held in 2020 had more than 200 attendees. As a result of the Covid-19 pandemic, the eleventh staging of the event (June 23 and 24, 2020) had to be relocated from the Hotel Bayerischer Hof to the worldwide web. The keynote speeches and the more than 42 presentations started after a slight delay and a few wobbly pictures of the kind that everyone is familiar with from video conferences.

The Scientific Director of the symposium, Prof. Peter E. Pfeffer from Munich University of Applied Sciences, and Dr. Alexander Heintzel, Editor in Chief of the ATZ-MTZ Group, welcomed all the international participants live online. ATZlive and its partner TÜV Süd organized chassis.tech plus together again. In the seven keynote speeches Schaeffler, Volkswagen, Showa and Toyota, together with Kempten University of Applied Sciences, TÜV Süd and Ford R&A Europe, presented the latest developments in the field of chassis engineering.

EXPERIENCES FROM DISABILITY VEHICLES

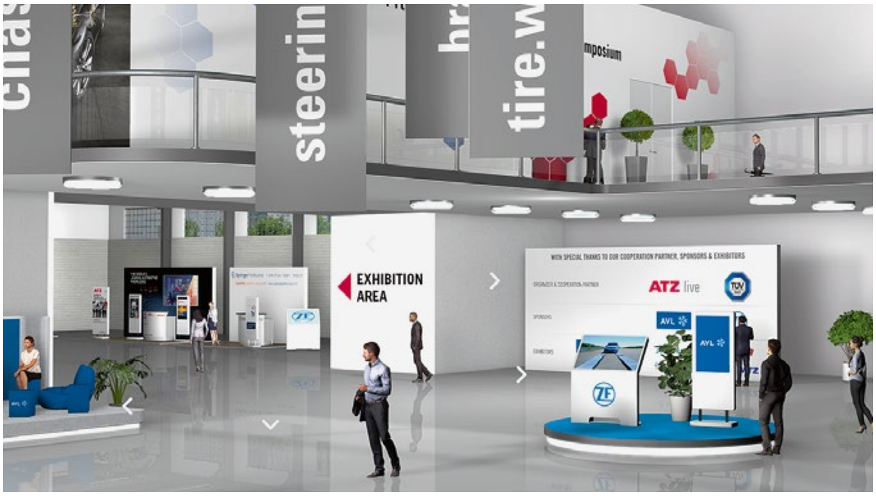
In his plenary lecture, Dr. Keiwan Kashi from Schaeffler Technologies discussed x-by-wire systems for Intelligent Connected Vehicles (ICVs), which include people movers, robo-taxis, city buses and shuttles and also goods delivery vehicles. In the future, there will be highly automated versions of all of these vehicles on SAE levels 4 and 5 traveling on our city streets. The central problems involved in automating ICVs are currently the poor reliability of the sensors,

The online exhibition with stands from AVL, Dassault Systèmes, Showa, Springer Professional, TÜV Süd and UACJ and an information feature from ZF complemented the virtual event, participants could provide themselves with a lot of information



One of the seven keynotes: Masato Fujiyama (right) from Toyota during the Q&A with conference leader Pfeffer after his speech about the chassis of the Yaris

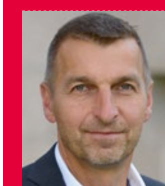
The 200 participants had the opportunity to ask the ATZlive team questions at the information desk in the virtual reception area



QUOTES

Keiwan Kashi, Schaeffler Technologies: "Our Space Drive system is the drive-by-wire construction kit for all people movers and robo-taxis."

Stefan Resch, TÜV Süd: "Fine-tuning the orchestra of chassis actuators is becoming an increasingly important factor."



Peter E. Pfeffer: "Our cars start up much more quickly than the computers in our virtual conference."

the lack of test data and the limited decision-making performance of the control units. For this reason, it makes sense to take advantage of the technologies developed for disability vehicles and this is an area where Schaeffler Paravan has 15 years' experience. The cars have covered one billion km in everyday use and therefore plenty of measurement data is available. The SpaceDrive II is a solution designed for people with disabilities that is already available and that can make the process of implementing automated driving functions easier.

AVOID DISAPPOINTING CUSTOMERS OVER AUTOMATED DRIVING

During short interviews that were broadcast live and recorded for later viewing, Pfeffer put the initial enthusiasm about the trend for automated driving into perspective. It has since become clear, including partly in engineering circles, that a lot of work is still needed on the AD functions in areas such as type approval and testing processes. More realistic estimates are needed in order to avoid disappointing customers.

The discussion with Stefan Resch from the symposium partner TÜV Süd covered the subject of functional integration. The behavior of electric cars is the result of a variety of systems. For example, although the cars are equipped with conventional friction brakes, these are not used as often because the drive system generally slows the car down by means of regenerative braking. However, the friction brakes must remain fully functional for use in emergencies.

Prof. Bernhard Schick from Kempten University of Applied Sciences spoke about the subject of motion control in vehicles. This is a factor that will become more and more important as the level of automation increases because the occurrence of phenomena, such as travel sickness, will need to be prevented. During a benchmark test with a level-2 car it became clear that the best candidates were sports cars which have precise steering and very good stabilization concerning travel sickness. All three experts were interviewed by Dr. Alexander Heintzel, Editor in Chief of the ATZ-MTZ Group.

DESIGNING CARS DIFFERENTLY FOR MEN AND WOMEN

Yousuke Sekino, the COO of the Japanese automotive industry supplier Showa, sees the chassis as a key element in the design of cars in the future. "Without the chassis you have no grip and so the chassis will continue to be important," he explained to the symposium participants in his keynote speech live from Japan.

However, Sekino believes that autonomous cars will be designed very differently. As cars have until now mainly been developed by men, "the seat position, angle of vision, steering wheel size and operating forces are all ideal for men." However, these factors are currently changing in favor of women. "Ergonomics, driver assistance systems and control elements have all reached levels where the physiognomy of the adult person driving the car is irrelevant." This trend is likely to continue.

Despite the fact that this virtual event proved to be such a success, as explained at the start of this article, many of the speakers, interviewees and participants expressed a strong wish to be able to meet in person again next year in Munich and to enjoy German beer and pretzels at the 12th chassis.tech plus on June 29 and 30, 2021 in Bayerischer Hof.

Michael Reichenbach

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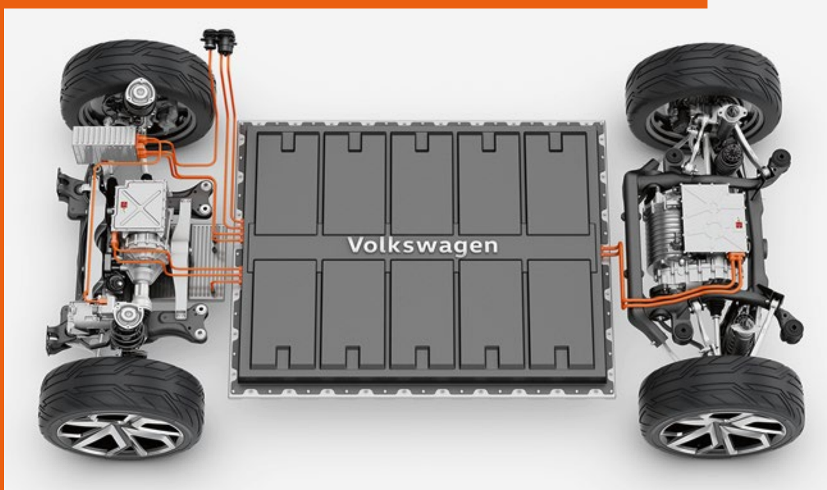
COVER STORY

Electric Mobility – Hybridization and All-wheel Drive Bring Benefits



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Electric vehicles present new challenges for developers, because many new processes and test methods are needed to determine the correct design of the electrified powertrain, and these do not allow the engineers to make use of their many years of experience of developing conventional vehicles with combustion engines. It is also important to be able to make full use of the benefits of hybridization for the powertrain, chassis and driving dynamics. Volkswagen and the Technical University of Braunschweig are working on a method that saves both time and money and involves transferring measurements made close to the driver in a car with a combustion engine to the electric powertrain of a VW e-Golf in virtual form. As part of their AWD2020 project, GKN and RWTH Aachen University aim to reduce the cost and the CO_2 emissions of all-wheel drive systems. They have developed an all-wheel drive powertrain for the growing market segment of front-engine hybrid cars. In the interview with two powertrain experts from Ford, Michael Geaney and Matthias Tonn, ATZ investigates the company's electrification strategy for mild hybrids, plug-in hybrids and electric cars and assesses the driving dynamics of the Mustang Mach-E electric sports car.

DEVELOPMENT

Testing of Safety-critical ADAS Functions with Mobile HiL Platforms

Virtualization of Approvals for Brake Control Systems

Vacuum-based Brake Booster for the Next Decade of Mobility

Virtualization of Approvals for Brake Control Systems

Aluminum Battery Housings and Their Further Metallurgical and Design Development

RESEARCH

Using Electric Drives for Active Noise Generation

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Dr.-Ing. Stephan Müller
Research Associate of the Institute of Transport Research at the German Aerospace Center (DLR)

Driverless Trucks in Ten Years – What the Logistics Industry Needs

With regard to automated and connected driving in the truck market, vehicle manufacturers have concentrated on developing trucks for two areas of application in the past: firstly, platooning (convoy driving or electronic tiller), where it is possible to drive safely at a significantly reduced distance one after another, and secondly, the mobile office, where the driver can carry out other activities such as scheduling appointments or talking to customers while the vehicle takes over the driving task.

However, our research at DLR in the ATLaS project shows that this orientation of technology development is of less relevance to customers in the logistics industry. The reasons for this are manifold and range from "We cannot buy expensive technology to make it more comfortable for the driver at work" to "Our customer's need the ordered quantity on time and not three truckloads bundled in a convoy driving up to the ramp."

Nevertheless, the possibility of automated and connected driving is generally meeting with enormous interest in the logistics industry. It is expected that the technology can provide an answer to two key challenges facing the industry: the growing shortage of driver counts and increasing cost pressure with low margins. On the demand side, this results in a very concrete technology requirement: According to our research results, driverless semitrailers are needed. And these would have to be available and reliable in ten years. This is because a solution to the before-mentioned challenges must be developed within this period. The main area of application for driverless semitrailers is in general cargo, for example night-time transport. "The more standardized the logistics process, the more likely it is that driverless trucks can be applied," was how a top manager from one of the logistics companies we surveyed summed it up.

The good news for vehicle manufacturers is therefore: With the right technology, they can tap into an enormous market potential. To achieve this, the current introduction strategy of the technology little by little in the truck market must be abstained. This means that small steps from SAE level 2+ do not help. The necessary strategy here is rather to make a direct technological leap to driverless trucks. Rather, the necessary strategy here lies in the direct technological leap to driverless trucks. OEMs must therefore weigh up promptly whether the associated high investment in research and development in the relatively short time window of ten years is feasible and promising.