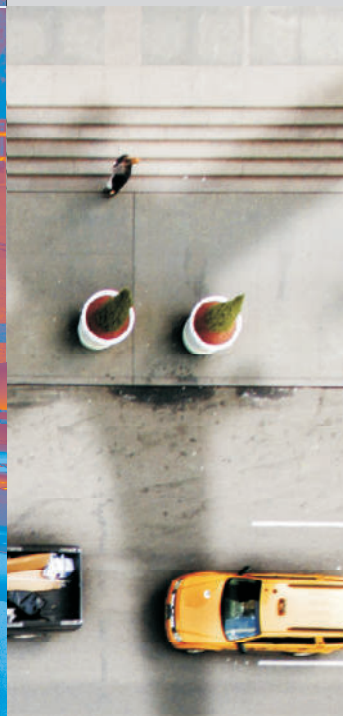
Automotive Technologie in Bavaria +e-Car

GLOBAL PARTNER



VOSSIUS & PARTNER

Special ideas require special protection.

For over 50 years, VOSSIUS & PARTNER has been providing high-end consultancy for innovative companies in all fields of patent, trademark, design and copyright law. VOSSIUS & PARTNER works in your interest: competently, reliably, precisely and creatively.

Legal areas. Patents, trademarks and brands, design rights, copyrights, know-how protection, domains, competition law, anticounterfeiting, software and IT, law on employees' inventions, licensing, food law, distribution agreements, franchise agreements, R & D agreements, media law, right of publicity, antitrust aspects in licensing, supplementary protection certificates, pharmaceutical law.

Technical areas. Mechanical & electrical engineering, IT, physics, chemistry, biotechnology, pharmacology, life sciences.

Services. IP prosecution, IP litigation, IP searches, freedom to operate, contracts, annuities, arbitration, mediation, IP portfolio management, due diligence, strategic IP consulting, IP landscaping, IP valuation services.

It is not without reason that VOSSIUS & PARTNER is among Europe's most renowned law firms in the field of intellectual property.

VOSSIUS & PARTNER · Patentanwälte Rechtsanwälte mbB · MÜNCHEN · DÜSSELDORF · BERLIN · BASEL
Main Office: Siebertstr. 3 · 81675 Munich, Germany · Tel.: +49 89 413 04-0 · info@vossiusandpartner.com · www.vossiusandpartner.com

Editorial

Mobility at the heart of society

No sector influences people's behavior as causally and effectively as the automotive industry.

New test fields are opening up, bound for the mobility of the future. The development of the automobile is being driven forward in order to maintain competitiveness.

Priority is given to autonomous and environmentally friendly systems as well as the provision of an appropriate infrastructure.

Exciting questions that need answers:

- What role do trucks play in the freight transport of the future?
- Is synthetic fuel an option on the way to a clean internal combustion engine?
- What will sustainable, environmentally friendly mobility solutions look like in the next few years?
- Can hydrogen technology be a long-term strategy in the mobility field?
- What intelligent solutions in the field of battery and charging technology are there for at home and on the go?
- Mobility & health – is this a symbiosis of increasing importance?

Find out how collaborative work can help develop useful standards and correct solutions.

Walter Fürst, Managing Director

Masthead:

Publisher:	media mind GmbH & Co. KG Hans-Bunte-Str. 5 80992 Munich/Germany Phone: +49 (0) 89 23 55 57-3 Telefax: +49 (0) 89 23 55 57-47 E-mail: mail@media-mind.info www.media-mind.info
Managing director:	Walter Fürst, Jürgen Bauernschmitt
Design + DTP:	Jürgen Bauernschmitt
Prepress:	media mind, München
Responsible editor:	Ilse Schallwegg
Published annually:	1 x annually

Dear readers,

if you read this magazine page by page, you will gain some remarkable insight into the creativity and capabilities of the automotive industry in Germany's largest state. Even on a global scale, Bavaria is a region that sets an example to others in the industry. AUDI AG as a company and, in particular, I as the member of the Board of Management responsible for Procurement know full well just what benefits are on offer thanks to the diversity that we have right on our doorstep and throughout the entire value chain. We have a lot to defend as we negotiate a phase of industrial development characterized by disruptive technologies and new competitors from all kinds of countries and industries. Audi has continued to refine its strategy so as to focus more closely on offering the best solutions to meet customer demands concerning premium mobility.

At the heart of this strategy are products that deliver distinct added value relative to the competition when it comes to electrification, digitally connected services and sustainability. Our Audi e-tron, for example, is manufactured on a completely carbon-neutral production line, which is an environmental plus without parallel anywhere in the world on an industrial scale. Audi also offers its own eco-electricity solutions for customers as well as digital updates to key vehicle functions such as drive system power components or lighting. That means real Vorsprung durch Technik for people buying our technology.

The product initiative is well under way. In 2019 alone, we launched 20 models. Many of these were entirely new and had no direct predecessors. It is particularly important to note that by the end of 2020, our line-up will boast five electric cars and seven plug-in hybrids. When it comes to fuel-cell drive systems, Audi is even acting as a competence center for the entire Volkswagen Group, with the first vehicles due to enter series production at the dawn of the next decade. That means that we will be adding to our range in this promising segment more rapidly and systematically than any of our competitors. Just six years from now, a third of new Audi vehicles will be electric. In preparation for this monumental accomplishment, we have already added considerably to our expertise and given our employees further training in electrification, digitalization and conditional automation. The pace of the transformation is building all the time.

Many other companies in the industry across Bavaria are setting themselves similar assignments. We need to work together to meet these challenges, partly for the future of our company, but also for the future of the entire state. After all, something that even critical voices in politics and society in general should keep in mind at all times is that the automotive industry accounts for 30% of industrial added value in Bavaria.

Dr. Bernd Martens

Member of the Board of Management of AUDI AG
Procurement and IT

Automobil Technikum Bayern ATB

Founded by the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology, the test laboratory is accredited according to EN 17025 and situated within the Automobilzulieferpark (= Automotive Supplier´s Park) Pole Position at Hof-Gattendorf. It performs tests and experiments in accordance with **customerspecific test instructions** and requirements. As regards concepts, the tests are supervised by competent staff. Engineering services and solutions to problems as well as constructional adjustments are offered individually.

Concerning service strength, **three Occubot seat test robots made by KUKA** are available at ATB. Using a system for changing test dummies does not only provide an automated programme process, but a continuous picture documentation as well. At the same time the test loads are constantly observed and readjusted. The area of service strength comprises as well four spring testing machines, versions „Schenck“ and „Reicherter Short and Long Stroke“.

Automobiltechnikum Bayern GmbH

The Automobiltechnikum Bayern is your independent competence center for environmental simulation, fatigue testing, measuring methods and electrical engineering.

Contact
Automobiltechnikum Bayern GmbH
Ferdinand-Porsche-Straße 10
95028 Hof/Haidt

E-Mail info@atbayern.de
Phone + 49 (0) 9281 / 850 19 - 0
Fax + 49 (0) 9281 / 850 19 - 500

Vibrations / wideband noise / harrowing: Audi VR611.4 2004-07, DIN 50100, DIN EN 60068-2-6, DIN EN 60068-2-53 **Climate tests:** BMW PR303.5, VW PV 1200, VW PV 2005, DAG A166 620 0000, DAG 7.1.1, DAG 7.1.2, DAG 7.1.3, PSA D17 1058, GM 9540P, DIN EN 60068-2-1, DIN EN 60068-2-2, DIN EN 60068-2-14, DIN EN 60068-2-30, DIN EN 60068-2-38, EN 60068-2-78, DIN EN ISO 9227, PV 2005-A, PSA-10-AF, P PV 4015, P PV PTL 8140

The servo-hydraulic testsystem with a total of **8 hydro-pulse cylinders** operates with loads of up to 40 kN and mximum strokes of 400 mm.

Two electric stroke cylinders with loads of up to 20 kN and maximum strokes of up to 350 mm can also be operated in connection with a climate chamber of 1,5 m3. Tests with lower loads may be run by using various pneumatic stroke cylinders.

The area environmental simulation disposes of **14 climate chambers with sizes ranging from 240 litres to 30 m3,** the latter being accessible by vehicles. Temperature ranges lie between -70 °C and 180 °C, the relative humidity can be programmed continuously between 10 % and 97 %.

The two **heating furnaces** with a volume of up to 720 litres allow tests up to 300 °C. The **salt spray fog chamber** with a test volume of 2 m3 complies with all established test standards, also for condensation tests.

The measuring laboratory contains a **material testing machine for tensile and pressure tests,** several digital tracers by HBM with up to 8 measuring channels per system, an **infrared camera** and a digital light optical microscope with up to twohundredfold enlargement.

Furthermore, **photogrammetric surveys** are offered, thereby using a system produced by ALCON.

The **90 kN shaker** is fitted with a Headexpander measuring 150 cm x 150 cm. The frequency range goes from 5 Hz to ca. 2000 Hz. Maximum acceleration is achieved at ca. 15 g. In addition, the control system enables tests in multisinus mode. A climate chamber of 15 m3 may be positioned over the support plates.

Author
Peter Rüpplein

Executive Director
Automobiltechnikum
Bayern GmbH

E-Mail: pru@atbayern.de

For further informations please see our website
www.atbayern.de

- **environmental simulation**
- **fatigue testing**
- **measuring laboratory**
- **electrical engineering**

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-11100-01-00

TÜVRheinland®
CERT
ISO 9001

Tensile and pressure tests: DIN EN ISO 13934-1, DIN EN ISO 527-1, DIN EN ISO 527-2, DIN EN ISO 527-3 **Electrical engineering:** LV 124 / VW 80000, LV 148
More standards: Audi VR 630.1, DAG A0010017499, VW PV 6732, VW TL 226, VW 50014, VW PV 1303, DIN 75 220, DIN 60068-2-5, EP 84.300.19, PR 080.3Ford DVM-0004-RG, Ford DVM-0035-ST, RSA D 171058, Volvo 1579605, Opel TM 422000

◀ electrodynamic shaker in action

The New Audi A1 Sportback – ideal companion for an urban lifestyle

In 2010, a brand-new Audi model line made its debut in the shape of the A1. And now the second generation of the compact success model is rolling to the starting line. Its dynamic design characterizes the new Audi A1 Sportback. It is the ideal companion in the urban environment and is also very well-suited for longer journeys. With its full-size-worthy infotainment and driver assistance systems, the A1 Sportback is firmly networked with the digital world. New trim lines provide ample opportunity for customization.

Exterior design: Striking, masculine with genes of the sporty Ur-quattro

The A1 Sportback has grown significantly in length—with an additional 56 millimeters (2.2 in), it now measures 4.03 meters (13.2 ft). At the same time, the width has remained almost the same at 1.74 meters (5.7 ft). The new-generation model is only 1.41 meters (4.6 ft) tall –including antenna, the car is 1.43 meters (4.7 ft) tall. The wide track and short overhangs provide for a taut, sporty look. The wide, low-placed Singleframe grille and the implied side air inlets dominate the distinctive front. Below the edge of the hood are three flat slits – an homage to the Sport quattro, the brand's rally icon from 1984.

The new A1 Sportback also emphasizes a resemblance to the Audi Ur-quattro and Sport quattro when viewed from the side: The wide, flat sloping C-pillar seems to push the car forward even while standing still. The roof contrast line, which is available in two dark colors, ends above the C-pillar. This gives the impression that the roof is flatter and the complete car is even lower-slung. All lines on the flanks, from the window edge to the sill, slope upward toward the rear in a wedge shape. The distinctively highlighted wheels and the low shoulder line in between give the A1 Sportback a solid stance on the road. The low line between the fender edges draws the visual focal point downward even further.

Audi A1 Sportback ■

With S line equipment, Audi has emphasized the sporty character even more through numerous features. These include larger air inlets, additional sill trims, three flat slits located centrally beneath the hood – the middle slit is larger than the two outer ones. The larger rear wing rounds off the sporty overall package. The top-of-the-line engine is also recognizable with its stricking twin tailpipes.

The distinctive daytime running light graphics of the optional full-LED lights echo the dynamic wing shapes from sailing, known as hydrofoils. The design of the trims for the main light functions also draws inspiration from sailing. The wing segments on the flanks create an impression of maximum width. A low-set, concentrated look in conjunction with the small rhombus segments in the top section of the headlights provides a sporty appearance.

The dynamic segmentation motif also features in the rear lights to reinforce the instant recognizability of the A1 light graphics. It is encased in the striking 3D geometry of the lens. The seamless light pattern of the graphics in the dark constitutes a remarkable feature of the two-part rear lights. ■

Audi A1 Sportback – Interior ■

More space and comfort: the space concept

The new A1 Sportback is much more spacious–making life much more comfortable for the driver, front passenger and rear passengers. Despite the compact exterior dimensions and the sporty roof line adults in the rear seats still enjoy plenty of head and leg room.

Luggage capacity has increased by 65 l (2.3 cu ft): Normal capacity is 335 liters (11.8 cu ft); with the rear seats folded down, this increases to 1,090 liters (38.5 cu ft). Loading sill height is a comfortably low 67 centimeters (2.2 ft). ■

Fully digital: operation and display

The new Audi A1 Sportback is fit for the digital future. Even the basic version comes standard with an all-digital instrument cluster with a high-resolution, 10.25-inch display and a multifunction steering wheel. The optional Audi virtual cockpit with an extended range of functions presents comprehensive and diverse information such as animated navigation maps and graphics of some driver assistance systems in the driver's direct field of vision. ■

Fully connected and always up to date: Infotainment and Audi connect

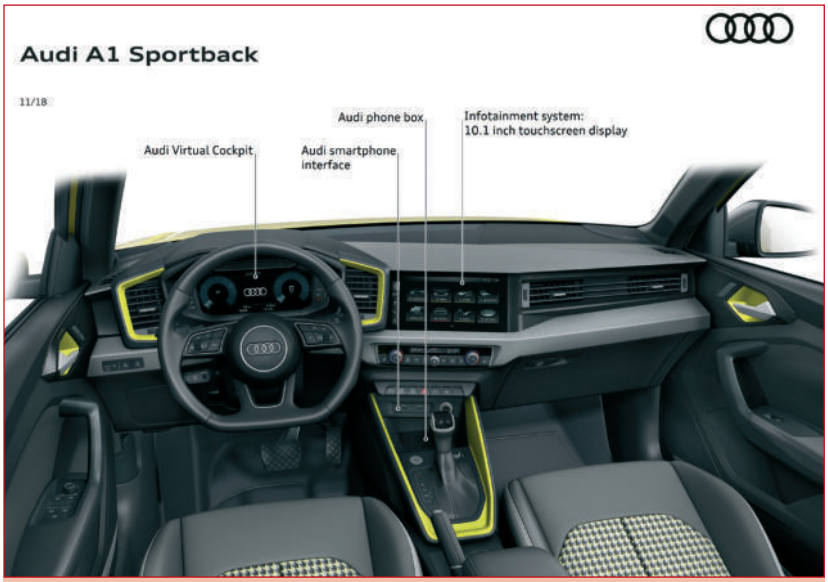
The Infotainment concept in the new A1 Sportback comes from the full-size class. The MMI radio comes as standard – it can be operated via the multifunction buttons on the steering wheel and the display in the fully digital instrument cluster. In the top configuration, MMI navigation plus offers a 10.1-inch MMI touchscreen, which blends seamlessly into the black glass look area. As with a smartphone, all commands are via touch input. The latest generation of voice control further improves the dialogue between driver and car.

In conjunction with Audi connect, MMI navigation plus offers A1 Sportback drivers functions such as hybrid route guidance – this calculates the route in the cloud, taking into account the entire traffic situation.

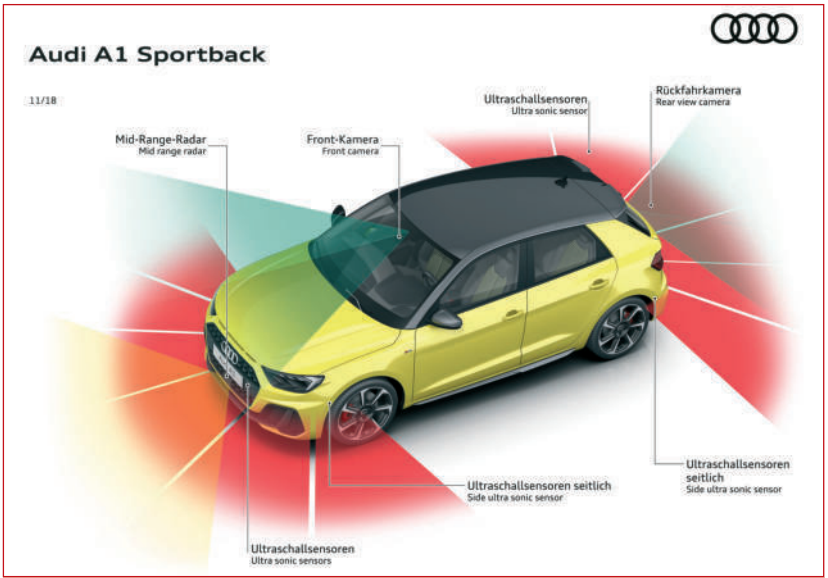
Additional highlights are the satellite map view and the new 3D city models, which offer a precise map view of many urban centers. Up to four map updates per year are automatically downloaded and installed free of charge – in addition, the customer can also use the versatile online services from Audi connect.

The Audi smartphone interface ensures you are always well connected on board the new A1 Sportback. It integrates iOS and Android smartphones using Apple CarPlay and Android Auto into an environment in the MMI programmed specifically for them and offers two USB interfaces (1x USB-A, 1x USB-C with increased charging current). Another option, the Audi phone box, in this way ensures improved reception quality with LTE support and charges the smartphone inductively via wireless charging according to the Qi standard.

Music and acoustics aficionados will be pleased to find a Digital Audio Broadcasting tuner, the Audi sound system and the Bang & Olufsen Premium Sound System. The B&O system drives eleven speakers with an output of 560 watts. Its 3D effect uses the windshield as a reflecting surface. ■



Audi A1 Sportback – Dashboard



Audi A1 Sportback – Sensors areas for environment observation ■

Safety first: the driver assistance systems

The driver assistance systems for the Audi A1 Sportback also come from the full-size class. They keep the small compact car at the right distance from the car ahead, making it easier for drivers to maintain the lane and help them with parking.

The standard lane departure warning helps the driver to keep the car in the lane from a speed of 65 km/h (40.4 mph). Also standard is the speed limiter, which reliably prevents the A1 Sportback from exceeding a selected maximum speed.

Another standard feature is Audi pre sense front. The radar sensor recognizes critical situations involving other vehicles, crossing pedestrians or cyclists ahead of the vehicle, even when visibility is poor such as in fog. The system then gives an acoustic and visual signal to warn the driver. At the same time it prepares for a possible full brake application and, if necessary, initiates automatic emergency braking in order to prevent an imminent collision or reduce its impact. If necessary, the protective measures of the optional Audi pre sense basic are initiated. The front seat belts are electrically tensioned, the windows are closed and the hazard warning lights are switched on. The adaptive cruise control also is radar-based. It keeps the Audi A1 Sportback at the desired distance from the vehicle ahead. If the vehicle is equipped with S tronic, the system covers a speed range of 0 to 200 km/h (0 to 124.3 mph); with the manual transmission, the range begins at 30 km/h (18.6 mph). In stop-and-go traffic, the A1 Sportback with S tronic transmission brakes to a standstill and gets going again under certain conditions automatically.

The new Audi A1 Sportback offers various systems to make parking easier. For the first time there is a reversing camera in addition to the parking system, rear. The front ultrasonic sensors of the parking system plus recognize objects in front of the car and emit acoustic and visual warnings. The park assist steers the A1 Sportback lengthways and sideways into parking spaces. With the new version of the assistant, the A1 Sportback also parks forward into perpendicular parking spaces, maneuvering multiple times if necessary. The system also exits parallel parking spaces. ■

Light and particularly robust: the body

The body of the new Audi A1 Sportback includes components made out of hot-formed steel that form the backbone of the passenger cell. The rigid body and exact fits ensure sporty, precise driving and prevent intrusive noise on board. With a front area of 2.07 sq m (22.3 sq ft) and a drag coefficient of 0.31, the new A1 Sportback offers very little windage. ■

Plenty of scope for customization

The new A1 Sportback is available in a choice of ten colors. The roof of the small compact model can be optionally finished in a contrasting color from the A-pillar to the roof edge spoiler. The exterior mirror housings, the side front spoiler lips and the side sills are also available in a contrasting color.

The “edition one” model, based on the S line equipment line and available from market launch, is particularly distinctive. It impressively showcases the design language of the A1 with numerous contrasts. Large 18-inch wheels – in bronze, white or black depending on the exterior finish – set powerful accents. The Audi rings in film on the side of the car are also available in the rim color. Borrowing from the legendary Audi Sport quattro, the LED headlights and LED rear lights are dark-tinted. The Audi rings in the Singleframe and the model designation at the rear are in black. ■

Freely combinable: the equipment lines

A new feature in the A1 Sportback is the modular lines structure. This provides for a particularly high degree of flexibility. For the first time, customers can combine exterior and interior lines however they like.

Depending on the equipment line-basic, advanced or S line – the attachments on the exterior are available in various configurations. The black styling package sets additional accents. By offering the lines “Interior advanced,” “Interi-

Audi A1 Sportback – Cockpit ■

or design selection" and "Interior S line," Audi is additionally affording customers numerous possibilities to select colors and materials accordingly. ■

New look: the interior design

"The sportiest interior in the compact class," that was the stated aim of the design. The interior is accordingly driver-focused, with its emotive, customizable design. The eye is drawn in particular to the sporty compact unit of air vent nozzles, hood and the digital instrument cluster. All of the controls and the optional MMI touch display are strongly driver-oriented, thus emphasizing the distinctive cockpit character.

The display and the air vent strip on the front passenger side are integrated into an area in black glass look. The optional contour and ambient lighting package brings the interior design to life in the dark, if desired, through LED light elements in 30 selectable colors. ■

Powerful and efficient: the engines

Whether running around town or going on a weekend excursion – its powerful engines in particular make driving the new Audi A1 Sportback so much fun.

There is a choice of efficient TFSI engines with outputs ranging from 70 kW (95 metric horsepower) to 147 kW (200 metric horsepower). Turbocharging, direct injection and a particle filter are standard. Audi offers four different engines for the A1 Sportback. As a three-cylinder engine with 1.0 l of engine displacement, there is the 25 TFSI (combined fuel consumption in l/100 km: 4.7-4.6) (50.0–51.1 US mpg); combined CO_2 emissions in g/km: 106–104*) (170.6–167.4 g/mi)) with 70 kW (95 metric horsepower) and the 30 TFSI (combined fuel consumption in l/100 km: 4.9-4.8*) (48-49 US mpg); combined CO_2 emissions in g/km: 111-108*) (178.6-173.8 g/mi)) with 85 kW (116 metric horsepower) of power. The A1 Sportback 35 TFSI (combined fuel consumption in l/100 km: 5.1–5.0*) (46.1-47.0 US mpg); combined CO_2 emissions in g/km: 116-115*) (186.7–185.1 g/mi)) is a 1.5-liter four-cylinder that boasts 110 kW (150 metric horsepower) and the cylinder on demand efficiency system.

The 40 TFSI (combined fuel consumption in l/100 km: 6.0*) (39.2 US mpg); combined CO_2 emissions in g/km: 137–136*) (220.5–218.9 g/mi))– also a four-cylinder – is the Audi A1's most powerful engine with 147 kW (200 metric horsepower) and 320 Nm (236.0 lb-ft).

Audi is making a manual transmission or the S tronic dual-clutch transmission available depending on the engine. The four-cylinder variants, which are equipped with the S tronic as standard, are an exception to this. ■

Sporty, poised tuning: the suspension

The axle design of the new Audi A1 Sportback delivers agile handling and a sporty, poised driving experience. The front suspension is a McPherson construction; A compact, lightweight torsion beam axle is used at the rear. Besides the basic suspension, there is an option for a tauter sport suspension.

Dynamic packages, individually configured for every engine version, bundle equipment options to give the A1 Sportback an even sportier trim. The "Basis" dynamic package for the 25 TFSI includes a sport suspension, red brake calipers and larger brake discs. Audi offers the "Performance" dynamic package for the other engine versions. This also includes red brake calipers and larger brake discs as well as a suspension with adjustable dampers, a sound actuator and Audi drive select.

The brakes of the new A1 Sportback can be precisely metered and provide a responsive, taut pedal feel. The optional hold assist enhances safety on uphill and downhill slopes by preventing the car from rolling after stopping. Wheels are available in sizes from 15 to 18 inches. ■

Four modes for an individual driving sensation: Audi drive select

The new A1 Sportback rolls off the production line with the Audi drive select dynamic handling system as an option. With it, drivers can select from four modes that influence the driving characteristics: Auto, dynamic, efficiency and individual. ■

Fuel consumption and CO_2 emission figures given in ranges depend on the tires/wheels used.

Contact:

Tobias Söllner
I/GP-P3

D-85045 Ingolstadt
Phone: +49 841 89-36188
tobias.soellner@audi.de
www.audi.com

Ready for the next level

From specialist for power seat structures to system supplier of dynamic interiors: In preparation for the next stages of autonomous driving, automotive supplier Brose is expanding its expertise in interiors. The family-owned company is doing this in part through joint ventures and research partnerships. The combination of Brose expertise in the fields of vehicle interiors and vehicle access offers special added value for customers.

With the push of a button, autopilot takes over control of the car and the steering wheel disappears into the dashboard. Now the vehicle user can decide how he or she wants to enjoy the ride. The vehicle interior is flexible: seats, screens and consoles slide and adapt to the desired use. Various modes for working, relaxing, entertaining and for entering and exiting the car offer maximum comfort and flexibility.

Brose already presented this vision of a dynamic interior at the International Motor Show (IAA) in 2017 as the mechatronics specialist's answer to one of the most interesting questions right now in the industry: How will users' demands on the interior change when cars begin driving themselves? The future-oriented "Brose Interior Experience" exhibit generated great interest from car manufacturers. Since then the automotive supplier has continued to push forward with its strategy to become the preferred development partner of OEMs for innovative vehicle interiors. ■

New adjustment systems for the interior

The most obvious step is to expand the adjustment possibilities of seats: concealed guide rails

The interior of the future adapts to changing driving situations. New kinematics and additional adjustments allow maximum flexibility. ■

From 2020, Brose will manufacture structures for moving center consoles. ■

for length adjustment, fold-out leg rests and retractable control elements in the armrest allow for new adjustment scenarios from a four-person meeting to a comfortable reclining or working position. Brose will also expand its competence in mechatronics to the entire vehicle interior – including the center console, which will be very flexible in the future. It will divide, swivel, slide forward and backward, convert into a table or integrate an adjustable screen. The company has already received the first order in this new field: from 2020 Brose will supply the structure for a moving center console to a carmaker in North America. The supplier is also responsible for the motor development and the electronic anti-trap protection. ■

Innovative sensors

The family-owned company's expertise in electronics will play a key role in dynamic interiors: dozens of adjustment systems need to be linked and securely coordinated.

Thanks to its more than 30 years of experience in the field of electronics, where it has around 600 employees and supplies over 75 million electronic systems and sensors annually, Brose can also take advantage of its expertise as a world market leader in mechatronic systems for doors and liftgates.

And to meet the special safety requirements for flexible interiors, the supplier is partnering with sensor specialist Vayyar, which makes the 3D radar image sensors that Brose embeds in the electronics environment. In addition to anti-trap protection, precise interior monitoring adds functions such as anti-theft protection and gesture control. It is also able to detect if children have been left in the vehicle, which could become a legal requirement in the very near future. Also, this eliminates previously needed components such as seat occupancy mats. Customers like this approach: several companies have already equipped test vehicles with the sensors.

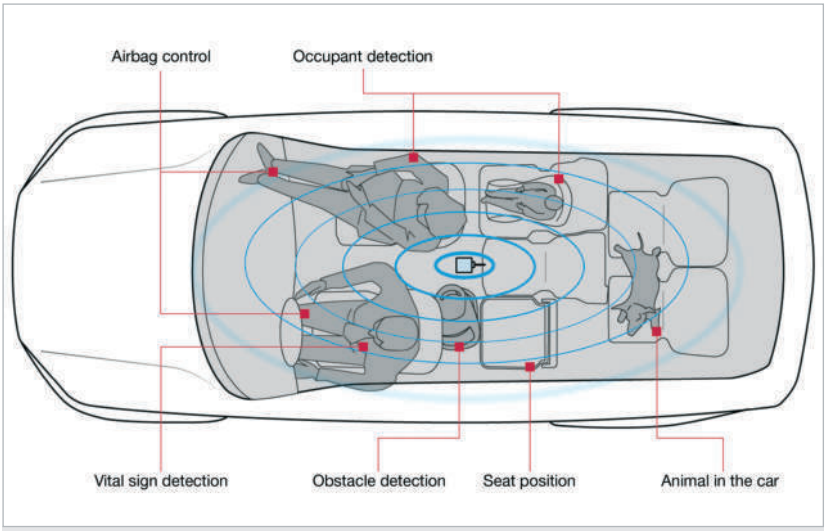
Another partnership is focused on the development and supply of completely upholstered vehicle seats through the joint venture Brose AUNDE Fahrzeugsitze.

Cooperation partner AUNDE provides its know-how in foam, upholstery and trim. The collaboration is an opportunity for both companies to grow and develop technological innovations – like seat foams with integrated massage systems, new kinds of luxury headrests or 3D printed seat covers. This leads to entirely new seat concepts. ■

Focus on cross-system customer experience

The vehicle user is always at the center of all further developments.

Brose brings together expertise in seat, door, drive and electronic systems to offer end customers a unique experience. An example of this is vehicle access, which will be more comfortable and convenient than ever before when the vehicle is able to recognize the user, open the door and move the seat into a "welcome" position automatically for easy entry. Brose supplies OEMs with the necessary technologies – perfectly coordinated and from a single source. ■



The interior sensors from Brose and Vayyar provide reliable collision protection for flexible interiors and other applications such as airbag control or theft protection. ■

brose
Excellence in Mechatronics

Author:

Sandro Scharlibbe

Executive Vice President Seat Brose Group

Brose Fahrzeugteile GmbH & Co. KG, Coburg

Max-Brose-Str. 1
D-96450 Coburg
Phone: 09561/21-0
info@brose.com
www.brose.com

Holistic Quality Assurance System for Highly Flexible Production Systems in the Body Shop of the Future

Innovative Sensor Technology and Data Evaluation Using Artificial Intelligence as an Enabler for Highly Flexible Joining Technologies

Requirements for (automotive) production systems of the future

The increasing variety of models and variants with which automobile manufacturers meet the increasing demand for customer-specific products requires production technologies that allow a flexible production of body variants within an economic framework. In addition to the increasing complexity caused by the growing number of vehicle variants, ever shorter product life cycles and an increasingly volatile sales market pose major challenges for conventional production structures. [1]

Today's production systems in body construction are rigidly interlinked and model-specific. Particularly in the field of joining technology, vehicle-specific clamping fixtures are used which allow only very little geometry flexibility. Changes to the body structure during a model or variant change therefore generally require a great deal of effort. Due to the constant increase in complexity and increasing volatility, the flexibilization of production systems is gaining strategic importance. Resistance spot welding is currently used to a large extent as one of the central technologies in body construction. Together with the typically used fixture-based clamping technology for positioning the components, this method offers only very limited

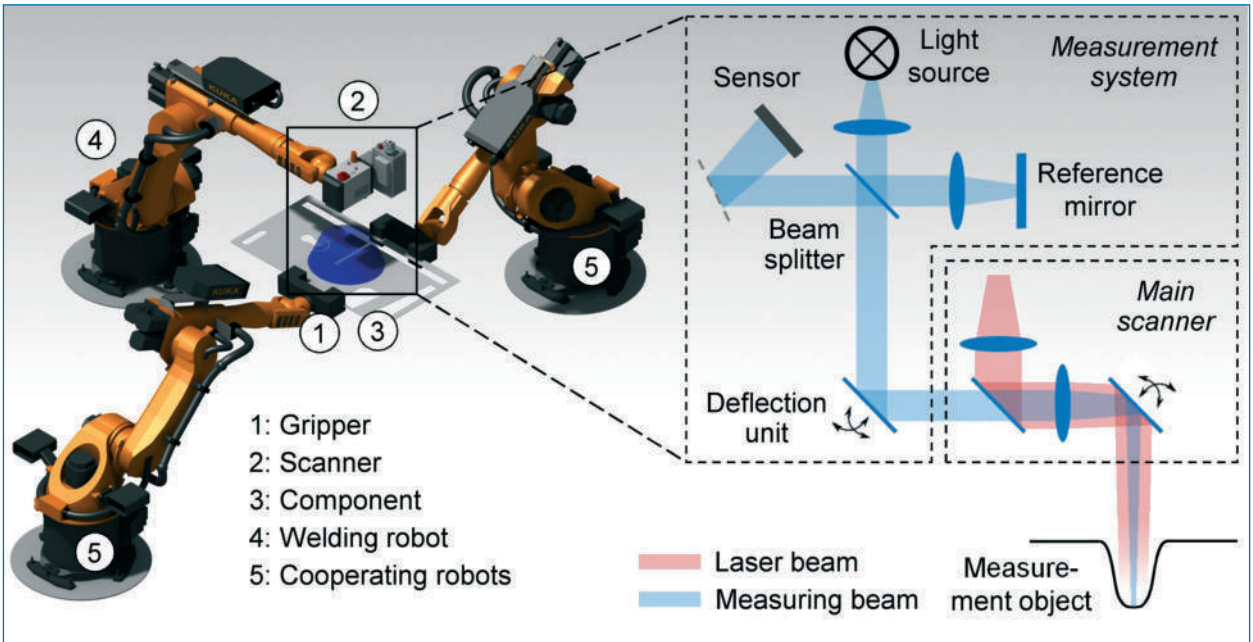


Fig. 1: *Functional demonstrator within the research project RoKtoLas for the realization of a highly flexible system based on remote laser beam welding (left) as well as a schematic sketch of short coherence interferometry (right)* ■

flexibility - both with regard to geometric changes to the body structure and with regard to changes to the production process. ■

Technological leap in automotive body construction

At the Institute for Machine Tools and Industrial Management (iwb) of the Technical University of Munich, together with partners from industry, research is being carried out to increase the flexibility of car body construction. The focus of the approach is the partial substitution of resistance spot welding by remote laser beam welding, which is particularly suitable for the realization of adaptive and networked production systems due to its highly dynamic and flexible process control. The concept of a highly flexible production cell using remote laser beam welding and the functional principle of the optical sensor unit are shown in *Figure 1*. With regard to the numerous effects of this technology substitution – from vehicle design through the entire production chain of body-in-white to subsequent production steps – a unique consortium of sensor developers, system developers and automotive OEMs has come together. Within the framework of the publicly funded RoKtoLas research project, a comprehensive plant and production concept based on the novel optical sensor unit is being researched and the industrial feasibility of this approach is being demonstrated. ■

Universal sensor concept for holistic quality assurance

For a large-area industrial use of remote laser beam welding, a comprehensive assurance of the quality of each weld seam is a mandatory prerequisite for many applications. Conventional quality assurance systems, however, either allow only an indirect assessment of the highly dynamic processes during welding and the resulting seam properties or require very complex subsequent test steps. A system based on Optical Coherence Tomography (OCT) allows for the first time a direct observation of the interaction phenomena in the process zone by recording geometrical information. The interferometric principle enables distance measurements with high temporal and spatial resolution, which are largely independent of electromagnetic process emissions and metal vapor or plasma generated during welding. By a suitable deflection of the measuring beam, topographic scans of the process zone and the surrounding areas (*see Figure 2)* can be recorded in real time during welding.

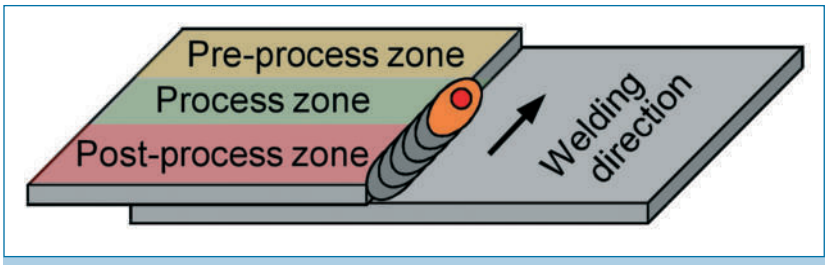


Fig. 2: *Process zones in laser beam welding* ■

The topographic recordings can be used for process observation, process control and quality assurance: The exact position of the butt edge can be determined from the height measurements in the pre-process zone, in order to compensate for any component or path tolerances *(see Figure 3)*. In the process zone, the depth of the vapor capillary can be measured as a decisive influencing factor on the resulting mechanical properties of the weld seam. In the post-processing zone, topographic scans allow an exact reconstruction of the weld surface for quality assurance purposes.

In addition to geometric information about the vapor capillary, which is one of the central influencing factors with regard to the resulting weld properties, a large number of quality criteria for the weld seam can be derived without further test steps using suitable evaluation algorithms. ■

Artificial Intelligence for real-time data evaluation and process control

Although the measuring principle allows a high-precision distance measurement with an accuracy of a few micrometers and a temporal resolution in the order of 100 kilohertz, a major challenge is to evaluate the recorded data in a suitable way to be able to use the inline measured welding depth signal for process control. The characteristics of a typical welding depth signal are shown in *Figure 4*. The challenge is the correct and universal interpretation of the signal structure under the requirement of a real-time capability. Investigations of the signal characteristics showed that the scattering in the welding depth does not only follow stochastic fluctuations of the vapor capillary, but is caused by characteristic process phenomena and can be reliably correlated with them. Conventional approaches to signal proces-

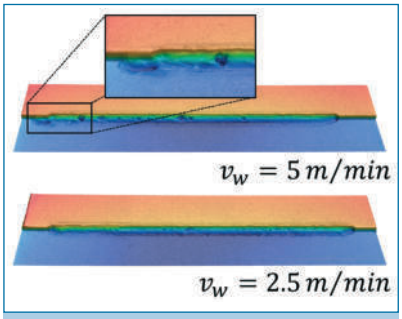


Fig. 3: *OCT-based edge tracking and topographic measurements for quality assurance (according to [2])* ■

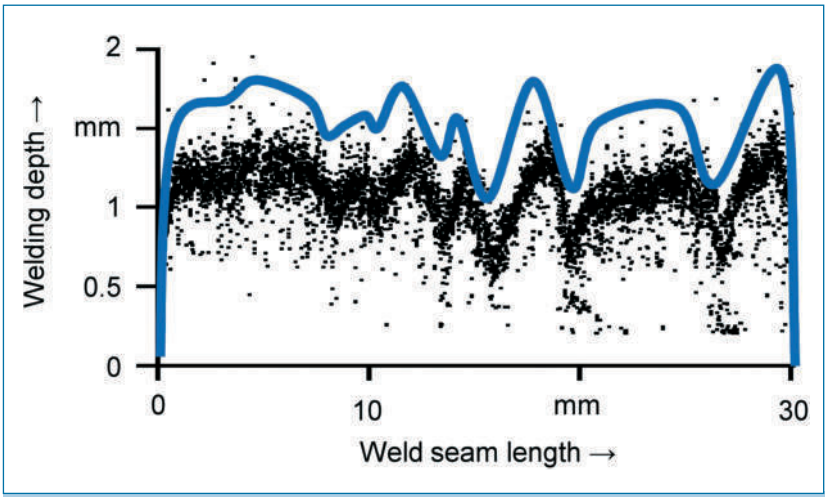


Fig. 4: *Determination of the welding depth (blue) during laser beam welding based on the OCT signal and Machine Learning methods* ■

sing and analysis can only approximate the welding depth in a very limited range with the given data structure, for which detailed investigations must be carried out in advance. For deviating process states, the signal characteristics can change considerably and require a correspondingly adapted evaluation. Also, effects whose influence on the fluctuations in the welding depth signal cannot be quantified by simple statistical parameters cannot be reliably detected. An alternative approach is the use of Machine Learning methods. Without being able to quantify the underlying signal patterns, artificial neural networks, for example, are able to reliably find correlations between signal characteristics and process effects. ■

Machine Learning as enabler for highly flexible production systems

The highly dynamic processes in laser beam welding require a high level of understanding of the exact processes to be able to validate the corresponding process data. An exact study of the processes, however, is usually limited to the individual application and can only be transferred to a very limited extent due to the complex measures for a comprehensive process observation in laser beam welding. If, for example, the material of the joining partners changes or other process parameters are applied, new comprehensive investigations are usually necessary to gain a sufficient understanding of the process (e.g. to evaluate the influence of the radiation characteristic, *see Figure 5*). In contrast, data evaluation using Machine Learning does not require a fundamental understanding of the physical interactions and phenomena within the process zone. Rather, suitable training algorithms can be used to automatically recognize dependencies and interactions and make them usable for future applications. Modern approaches in data evaluation thus enable flexible and universally applicable systems that can guarantee a valid evaluation of the highly dynamic and complex processes in laser beam welding independent of the application and without prior design attempts. ■

Remote laser beam welding for the body construction of the future

A reliable method for process monitoring is the basis for a robust process control and a valid quality assurance in laser beam welding. Optical Coherence Tomography in combination with suitable methods of Machine Learning allows a very robust and direct observation of the process. Compared to conventional approaches for quality assurance in laser material processing, the direct measurement of the pro-

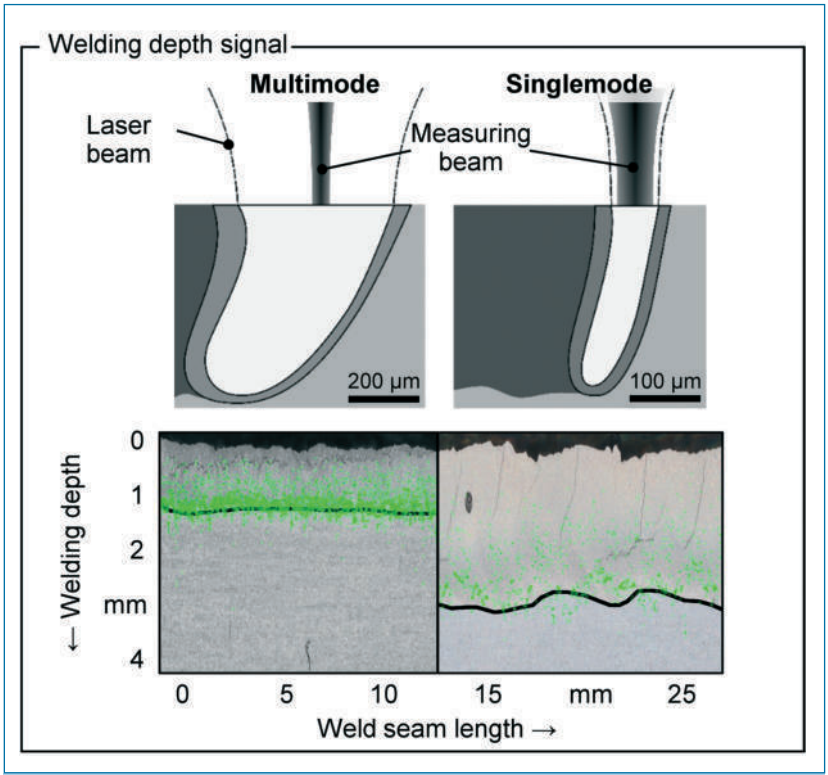


Fig. 5: *Influence of the radiation characteristic on the weld penetration depth measurement (left: multimode laser radiation, right: singlemode laser radiation (according to [3])* ■

cess zone greatly reduces interpretation errors. The extensive generation of process data also allows the evaluation of a large number of quality criteria based on the data recorded inline.
This makes it possible to obtain a valid statement immediately after the welding process regarding the compliance with process limits. The universality of the sensor concept allows a continuous and comprehensive process data recording and thus a complete traceability throughout the process chain. In addition to the evaluation of the process stability and the resulting weld seam properties, the creation of a knowledge base enables a process qualification for many applications for which extensive investigations are still required today. By qualifying the highly flexible process for the use in body construction, highly adaptive systems are possible. Within the framework of the project, a concept for the realization of intelligent joining system technology in the sense of a fully digitalized production will be demonstrated and validated on the basis of serial component assemblies. ■

Acknowledgements

The results presented were achieved within the RoKtoLas project, which is supported by the German Federal Ministry of Education and Research (BMBF) within the Photonics Research Germany funding program (contract number 13N14555) and supervised by the VDI Technology Center (VDI TZ). We would like to thank the BMBF and the VDI TZ for their support and for the effective and trusting cooperation. ■

Literatur

[1] Erler, F.: Downstream-Risiken in der automobilen Wertschöpfungskette: Instrument zur Risikobewältigung in der Kundenbeziehung von Automobilzulieferern. Dissertation. Technische Universität Chemnitz (2015).

[2] Stadter, C.; Schmoeller, M.; Zeitler, M.; Tueretkan, V.; Munzert, U.; Zaeh, M. F.: Process Control and Quality Assurance in Remote Laser Beam Welding by Optical Coherence Tomography. In: ICALEO Conference Proceedings (2018).

[3] Schmoeller, M.; Stadter, C.; Liebl, S.; Zaeh, M. F.: Inline Weld Depth Measurement for High Brilliance Laser Beam Sources Using Optical Coherence Tomography. In: ICALEO Conference Proceedings (2018). ■

Authors:

Christian Stadter
Research Field Intelligent Joining System Technology
christian.stadter@iwb.mw.tum.de
+49 89 289 15560

Maximilian Schmöller
Research Field Laser Manufacturing Technology
maximilian.schmoeller@iwb.mw.tum.de
+49 89 289 15492

Prof. Dr.-Ing. Michael F. Zäh
Head of Institute
michael.zaeh@iwb.mw.tum.de
+49 89 289 15502

Technical University of Munich
Department of Mechanical Engineering
Institute for Machine Tools and Industrial Management (iwb)
www.iwb.mw.tum.de/en/roktolas

The truck of the future

"Truck2030": Technical University of Munich presents concept for efficient cargo transport

Trucks will remain essential to cargo transport in the upcoming decades. Scientists at the Technical University of Munich (TUM) and their partners have developed a concept for the truck of the future, including Europe-wide approval for the use of LHV trucks (Longer Heavier Vehicles), diesel hybrid drives and a multifunctional driver's cab.

According to a forecast by the German Federal Ministry of Transport and Digital Infrastructure, by 2030 the volume of truck cargo transport will have risen by 39 percent compared to 2010. This means efficient and environmentally friendly transport concepts are of continuing importance when it comes to reducing road traffic and emissions such as carbon dioxide, soot particles and nitrogen oxides.

In the project „Truck2030" scientists at TUM investigated all aspects of the truck of the future. Here are the most important results in the areas of People, Transport and Logistics, Environment and Politics:

An illustration of the truck of the future. (Image: Chair of Industrial Design / TUM) ■

People

The researchers' concept is based on the assumption that the truck of the future will drive on the highway automatically. Drivers would then be able to invest the time saved in their own health. The driver's cabin presented by the team is equipped among other things with cables and pulleys which can be used for exercise, already familiar from the health club. A game-oriented aspect will be added in order to increase motivation, for example based on a virtual reward system. ■

Transport and logistics

Long trucks with a length of 25.25 meters are ideal for efficient cargo transport. Here two LHV trucks can replace three normal-length trucks. This makes it possible to save fuel, resulting in benefits to the environment and the economy. And the total number of trucks on the road will also be reduced. Apps that record cargo information using scan codes or NFC could save time and resources during loading and unloading. ■

Environment

The use of LHV trucks alone could cut CO_2 emissions by 20 percent due to lower fuel consumption with the same cargo loads.

Using diesel plug-in hybrid drives could reduce CO_2 emissions by another 10 percent, the best solution from both the environmental and economic points of view. Based

on the current state of the art, a solely electric drive train would not be feasible, since a battery capable of providing sufficient energy for the necessary range would be too large and too heavy.
Tires with optimized road resistance and improved truck aerodynamics could reduce CO_2 emissions by 10 percent. ■

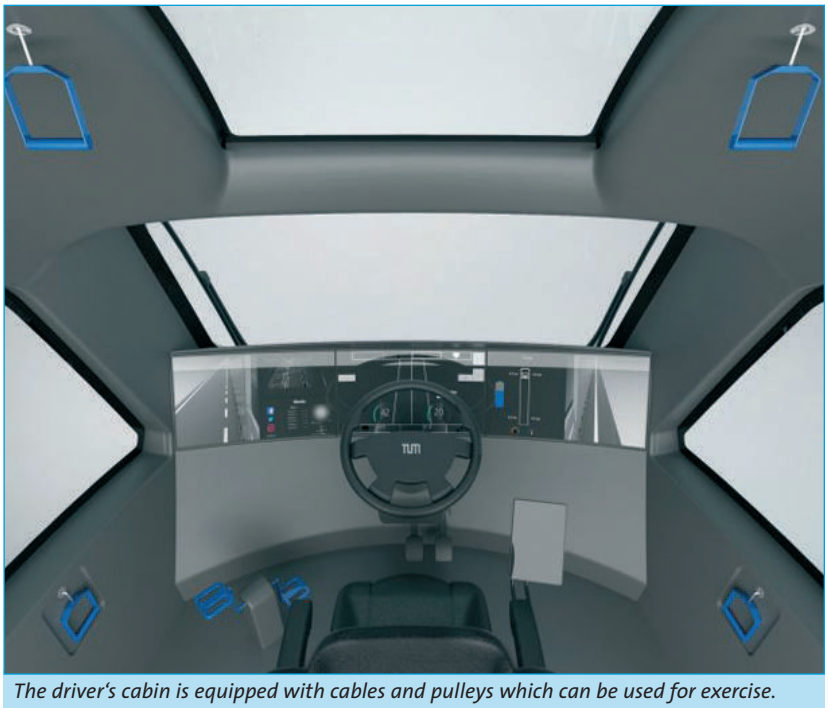
Politics

The most important prerequisite for realization of the concept is the approval of the use of LHV trucks in all of Europe. In their investigations the scientists successfully refuted counterarguments such as lower driving safety and increased road wear.
Another important point is infrastructure: Use of the diesel plug-in hybrid will require additional charging stations on highways. Electric cars will also be able to use these charging stations. ■

More information

Truck2030 is a Technical University of Munich (TUM) research project, conducted in collaboration with the OTH Regensburg (Ostbayerische Technische Hochschule) as well as five industry partners. The project receives support from the Bavarian Research Foundation. The Technical University of Munich units participating are the Chair of Automotive Technology, the Chair of Internal Combustion Engines and the Chair of Industrial Design.
https://www.truck2030.tum.de/home/ ■

The team is building a model of the driver's cabin.
(Image: A. Heddergott / TUM) ■



The driver's cabin is equipped with cables and pulleys which can be used for exercise.
(Image: Chair of Industrial Design / TUM) ■

High resolution images

mediatum.ub.tum.de/1453998 ■

Contact:

Christian Mährle
Chair for Internal Combustion Engines
Phone +49 89 289 16344
maehrle@lvk.mw.tum.de

Sebastian Wolff
Chair for Automotive Technology
Phone +49 89 289 15881
wolff@ftm.mw.tum.de

Simon Rauchbart
Chair of Industrial Design
Phone +49 89 289 28674
simon.rauchbart@tum.de

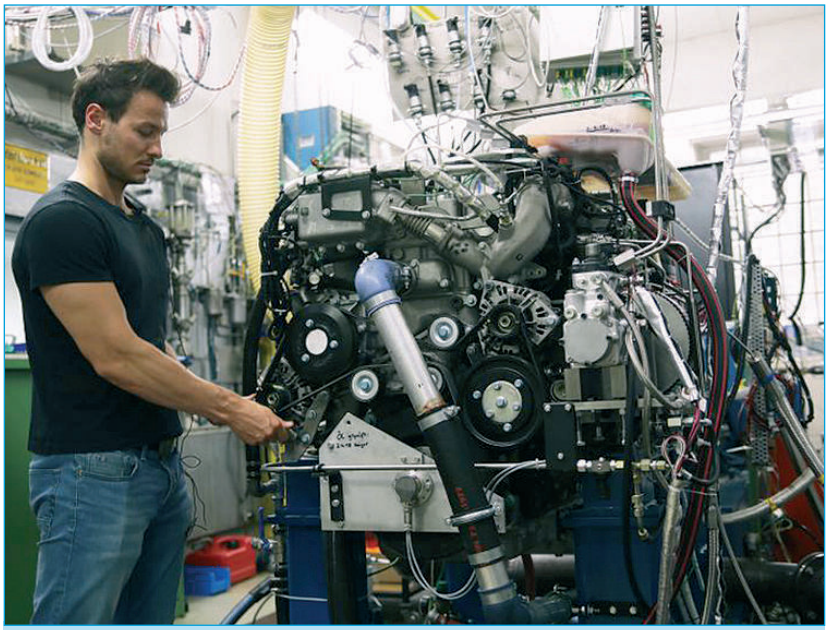
On the road to a clean combustion engine

OME: Researchers test synthetic fuel

Emissions-free combustion engine cars — synthetic fuels like oxymethylene ether are bringing the idea into the realm of the conceivable. Researchers at the Technical University of Munich (TUM) have tested how this kind of fuel behaves in engines and have developed an optimized combustion process.

They generate carbon dioxide, particulate matter and nitrogen oxides: combustion engines are in the cross-hairs of public opinion and many inner cities have already imposed driving bans for certain kinds of diesel-powered vehicles. But synthetic fuels like the group of oxymethylene ethers (OMEs) might hold the answer. They burn virtually free of undesirable by-products such as soot and hydrocarbons, and thus provide an additional air-quality benefit over other long-standing designer fuels. However, they also have disadvantages: production costs are higher than those of fossil fuels and there are no production facilities available yet.

The XME Diesel project, funded by the German Federal Ministry of Economics, aims to promote the use of OMEs. Scientists from TUM's Chair of Internal Combustion Engines are also involved in the project. They investigated the behavior of OMEs in engines, the adjustments required to improve combustion efficiency and the degree to which harmful emissions can be reduced in comparison to fossil fuels. ■

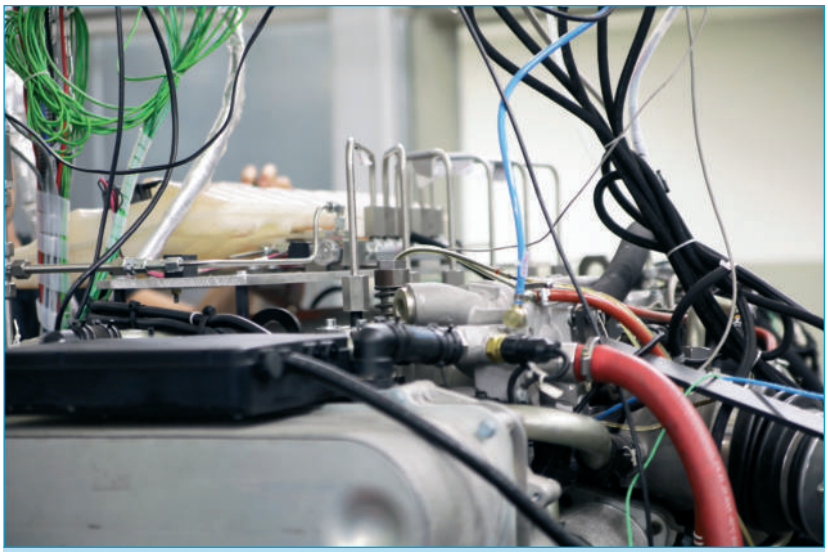


Dominik Pélerin at the full-engine testbed. (Image: Moritz Ermert / TUM) ■

From one cylinder to a full-scale engine

First, the researchers did computer simulations and experiments on a single-cylinder engine testbed. They determined the optimal parameters for efficient combustion. For example, the synthetic fuel has a lower calorific value than diesel, which means more fuel must be injected into the engine to achieve the same performance. The scientists thus adapted the injectors accordingly. Furthermore, since the synthetic fuel does not produce soot, large amounts of exhaust gas can be recirculated into the engine without contaminating the intake. This approach inhibits the formation of nitrogen oxides because the recirculated exhaust gas prevents very high temperatures during combustion.

Next, the scientists tested the parameters on a full-engine test-



Full-engine testbed in the engine laboratory of TUM's Chair of Internal Combustion Engines in Munich-Moosach. (Image: Mortiz Ermert / TUM) ■

bed comprising a six-cylinder production engine that was adapted specifically to run on synthetic fuel. The tests on the full engine confirmed the previous results. ■

Emissions can be reduced to zero

„We determined that using this fuel can significantly reduce pollutant emissions," explains Dr. Martin Härtl, who coordinates the project. „The Euro 6 level, the currently applicable limit, is easily met when using the synthetic fuel. We are also convinced that high-performance exhaust aftertreatment can even reduce emissions to almost zero." OME made from waste CO_2 – carbon dioxide generated in processes in the steel and cement industries, for example, or in coal and gas-fired plants – and electricity from renewable sources, would even be carbon neutral.

Particularly interesting is the use of OME in vehicles and systems in which internal combustion engines cannot be readily replaced by battery-powered electric drives, explains Härtl. Examples include long haul trucks, energy provision in remote areas and the aviation and shipping sectors. ■

More information:

The tests were carried out as part of the project „XME Diesel – (Bio) Methyl Ethers as Alternative Fuels in Bivalent Diesel Engines," funded by the German Federal Ministry of Economic Affairs and Energy.

Further research in the field of OMEs at the Institute of Internal Combustion Engines is part of the project „OME – Environmentally Friendly Diesel Fuel Additives" (funded by the Agency for Renewable Resources with funds of the German Federal Ministry of Food and Agriculture) and the project „Sub-Zero-Emissions Diesel Engine" (funded by the Bavarian Research Foundation). ■

Contact:

Technical University of Munich
Institute of Internal Combustion Engines

Phone: +49 89 289 24110
haertl(at)lvk.mw.tum.de

Shaping Mobility By Leveraging the Transfer Potential of Aerospace and Automotive!

At first glance, the modern aerospace industry would seem to have little in common with the automotive sector. However, metrics like development cycle time, number of employees, sales and price per aircraft/vehicle reveal major differences in some cases. Yet both industries are characterized by highly sophisticated technologies and increasingly interconnected embedded systems. At the same time, the two are increasingly converging as part of a trend toward multi-dimensionality in mobility – the mobility of the future.

Definite synergy and transfer potential

A more holistic approach to mobility is needed in order to meet the challenges arising in our increasingly networked and globalized world. It is thus key to identify the synergy and transfer potential latent in the aerospace and automotive sectors to be able to leverage these in targeted fashion for mobility overall.

Both industries deal with means of transport that to some extent involve extremely complex interfunctionalities. Realized as embedded systems involving electronics and software, these functionalities must meet incredibly high demands for real-time applications. Their respective integration into complex traffic control systems is also comparable. And from an engineering perspective, the domain structures in the bodywork & cockpit, drive and platform control systems are largely similar as well.

Of course, the specific functional requirements – and thus the eventual solutions derived – are usually fundamentally different. There is great overlap however regarding processes and the transferability of basic technology approaches and solutions.

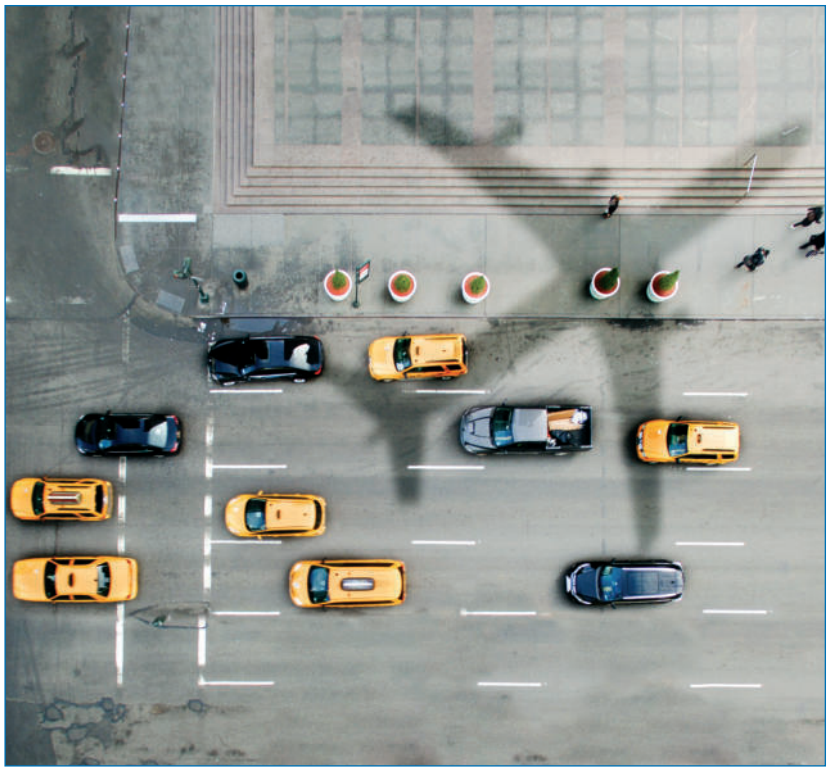
As such, the main common denominator can be found in the area of approaches to problem solving – in other words, engineering. The following are examples of this: At its core, ‚functional safety' is about how to create a functionally reliable product that meets the given requirements. And ensuring functional safety is essentially an overarching process not specific to either field. Requirements management is similar in both, for which the same standard tool can be employed. The basic solutions used are transferable, even for system architecture, which is more technical in nature. ■

Transfer processes done right

Transfer is not a simple matter due to a number of fundamental differences between the automotive and aerospace industries, such as development time, innovation speed, production quantities, costs and product service life. However, the process steps in electronics and software development are comparable in the two industries. These common features thus certainly do allow finding promising leverage points for the automotive industry.

The increasing importance of software in vehicles calls for a software development process that is efficient and robust in equal measure. An increasing number of functions now need to be realized by an increasing number of players to increasingly tight deadlines, while an increasingly confusing set of parameters must also be taken into account. This makes the processes and methods involved incredibly complex; a factor that can only be overcome by seamlessly intertwining the development steps in the networks of vehicle manufacturers, suppliers and service providers and clearly defining the division of roles in a way that is transparent to all those involved. An important step toward achieving this is the standardization of interfaces.

The aerospace industry has long been aware of the great advantages of standardizing non-differentiated technical solutions, and



has acted accordingly. Over recent years, the digitization of cars through the extensive use of electronics and software has been driven by a high innovation speed, with the result that the system complexity in a premium car with all the variants is now much higher than that of a modern commercial airplane, at least when based purely on the sheer amount of software and data involved. Standardization, as seen in the aerospace industry, is thus one way of removing part of the complexity from the development process, affording a model to be emulated by the automotive industry! ■

Technology transfer: added value through experience

The technological foundations, as we have observed, are comparable (processors, programming languages, sensors, actuators etc.). However, like-for-like, outright technology transfer is not feasible, and cannot yield any breakthroughs. Yet transferring experience does makes sense in problem-solving, with system and support functions for example, i.e. such operational functions as steering, control and system reliability, and administrator functions like support for development, production and service processes). A similar principle applies to the basic functions at the user level, such as sensor and data fusion, system status detection, environmental awareness, centralized system coordination and maneuvering support and execution. ■

Top-down architecture development requires a holistic system concept

We have more or less undergone a critical technological paradigm shift – away from traditional mechanical engineering and toward electronics, embedded systems and IT. However, drive electrification, the ever-accelerating growth in the use of software and the wealth of different new, heavily networked assistance systems – plus the elimination of system boundaries due to the advent of cyber-physical systems – are all issues that demand new, future-proof solutions.
A holistic system view in the development process is the key to and the hallmark of this change. The highly sophisticated, top-down architecture development process employed in the aerospace industry serves as an exemplary model for this. The core elements in this process are standardization, interface uniformity and abstracting upward from granular technological solutions. Key factor: Safety and security can really only be practicably realized on the architecture side. The same applies to system verification, which also benefits from a stringent architecture approach.
Attempting to do this at the subsystem and component level is a very hit-and-miss process, and extremely time-consuming to boot. Safety cannot be divided, and must therefore be 'drafted' in its entirety from the architecture. With its focus on highly reliable systems and safe functions, which is born of years of experience, the aerospace industry represents an excellent role model for this.
This can require great effort of course, but the benefits are real in terms of technology, functionality, processes ... and profits, as we firmly believe! ■

ESG MOBILITY

Author:

Jörg Ohlsen
CEO
ESG MOBILITY

ESG MOBILITY GmbH

Frankfurter Ring 211
D-80807 München
Phone: +49 89 92161-0
mobility@esg.de

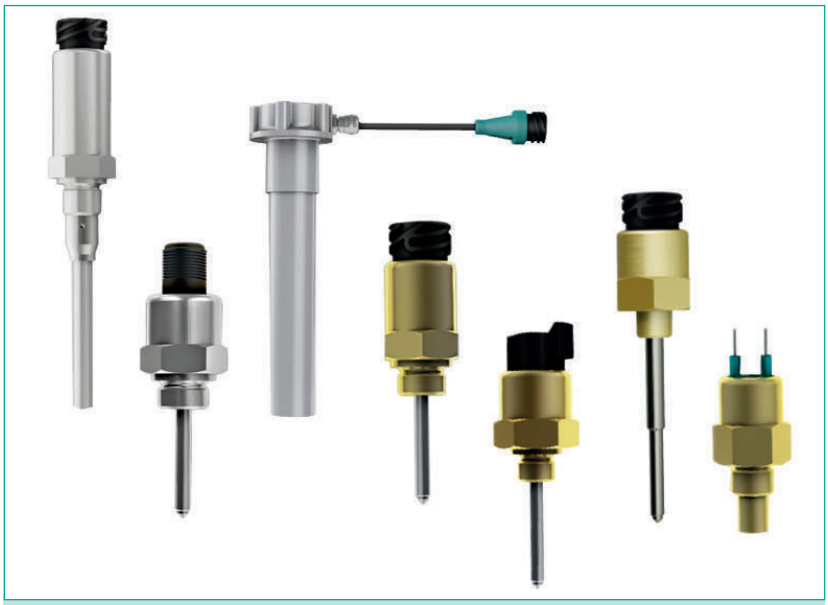
BEDIA – more than 30 years thought-out solutions at the highest level

Fill level/temperature sensors + automotive cables

Founded in 1986 in Leinburg as BEDIA Motorentechnik GmbH, BEDIA is a German medium-sized, family-run company with an international focus. In the first few years the company concentrated mainly on selling sensors, water filters and automotive cables.

Thanks to the company's innovative and far-sighted decisions, BEDIA has developed successfully through continuous and healthy growth. In 2006 the business division BEDIA Kabel GmbH & Co.KG was spun off as an independent GmbH & Co.KG. A milestone in the company's history was the relocation of the two independent companies in 2009 into the spacious company premises in the Altdorf Business Park in Unterwellitzleithen.

The company's continued growth led in 2017 to the building being expanded by an additional warehouse and parking spaces. The modern building accommodates currently over 140 – mainly long-term – employees. All company functions from development through production to shipping are located at this one site. Interesting future-oriented apprenticeships are available for the career profiles of industrial manager and warehouse logistics specialists. ■



Fill level/temperature sensors ■

BEDIA Motorentechnik GmbH & Co. KG

BEDIA Motorentechnik develops, produces and distributes well thought-out solutions in the fill level and temperature monitoring sectors.

Having focused our competencies in the areas of fill level and tem-

BEDIA head office in Altdorf near Nuremberg ■

perature monitoring under extreme operating conditions for many years, we are now able to respond to the specific requirements of our customers with customised solutions for both large-scale production and smaller production quantities. We have achieved this by combining our proven technologies with innovative product ideas. It is specifically through the development of these customised solutions that BEDIA Motorentechnik can showcase its high level of expertise and flexibility in the best possible way. BEDIA Motorentechnik has been a respected partner worldwide of numerous manufacturers of construction machines, engines, commercial vehicles, agricultural machinery, aggregates and compressors since 1986. Thanks to their robust construction, IP protection class and operating temperature ranges of -40 to +125 degrees Celsius, the monitoring sensors can be used in many different environments. The high quality standard demanded by the long-standing international customers for BEDIA Motorentechnik's products and solutions is the company's motivation for continuous improvement. In 2012 BEDIA Sensors was founded in Austin / Texas (USA) as a new sales subsidiary. BEDIA products are represented successfully in the most important markets through our worldwide distribution partners. ■

The BEDIA Reel Cart ■

BEDIA Kabel GmbH & Co. KG

As a recognised partner of numerous companies, BEDIA Kabel specialises in the purchase and resale of all types of branded cables. BEDIA Kabel supplies customers worldwide in the automotive, commercial vehicle, industry, building services, photovoltaics and solar energy sectors.
Its portfolio includes vehicle cables of all types, twisted cables, sheathed cables, ABS/EBS truck cables, H05/H07 cables, solar cables, speaker cables, welding, ignition and data cables such as FlexRAy and CAN, high-temperature and media-resistance FLR6Y, thin cross-sections with copper-magnesium alloy (FLCuMg02RY 0,13mm2) and much more.
International customers in particular value the competent inventory management with about 2,000 different cable variants and the ensuing high level of flexibility in responding to customer requirements. ■

Contact:

BEDIA Motorentechnik GmbH & Co. KG
Im Erlet 1
D-90518 Altdorf bei Nürnberg

Phone: +49 (0) 9187 9509 632
Fax: +49 (0) 9187 9509 1632
Email: bedia-sales@bedia.com

BEDIA Kabel GmbH & Co. KG
Phone: +49 (0) 9187 9509 811
Fax: +49 (0) 9187 9509 1811
E-Mail: kabel@bedia.com

Internet: www.bedia.com

Community of Practice (CoP)

Basic idea and review

In the Community of Practice (CoP), universities, research institutions, inventors, start-ups and established companies work together. The focus is on digitization projects that focus on people and their individual life situations by means of cross-sectoral digitization concepts and cross-industry approaches. The generated concepts are open to innovation and thus not yet known for changing life, work and mobility situations. The focus is on the close link between mobility and health.

The first focus of digitization is on mobility and travel sectors as well as health and medicine (see Figure 1). The focal points are derived from those in the following order: „Prevention“, „Accident prevention process chain“ and "Accident". Within the „Accident process chain“ priority area, accident reports via eCall and eRescuator are the main focus. The drivers/doctors of the e-rescue vehicle receive immediate access to the relevant patient data of the injured person via digital data transmission in order to be able to guarantee fast and targeted care. The focus „Prevention“ deals with preventive measures during journey or travel time. For example, it is possible that built-in sensors in passenger cars can promote a better posture by pointing out bad posture or supporting stress management with measured vital parameters. Real-time information enables drivers to be warned of potential hazards, such as traffic jams or accidents, in order to prevent further accidents. These topics have led to the development of the ongoing „personalized eCall“ funding project. Since 2018, the topics have been dealt with by MRK with the support of the Digital Health/Medicine Topic Platform of the Zentrum für Digitalisierung.Bayern (ZD.B) and Medical Valley EMN e.V.. Ideas, questions and developments regarding mobility and healthcare will be discussed during the meetings.

During the kick-off event „mobility meets health“ at the ZD.B in November 2018, the basic idea of this initiative was already implemented. Various concepts such as a mobility app for people with limited mobility were presented. Also mentioned was a sensor-supported prevention app that motivates people to move or change an unfavorable sitting posture, as well as answers to questions and suggestions. Furthermore, new approaches for the medical care of elderly people - especially in rural areas - were addressed. ■

Fraunhofer IIS

ZD.B ZENTRUM DIGITALISIERUNG. BAYERN

MEDICAL VALLEY
Europäische Metropolregion Nürnberg

MRK MANAGEMENT CONSULTANTS

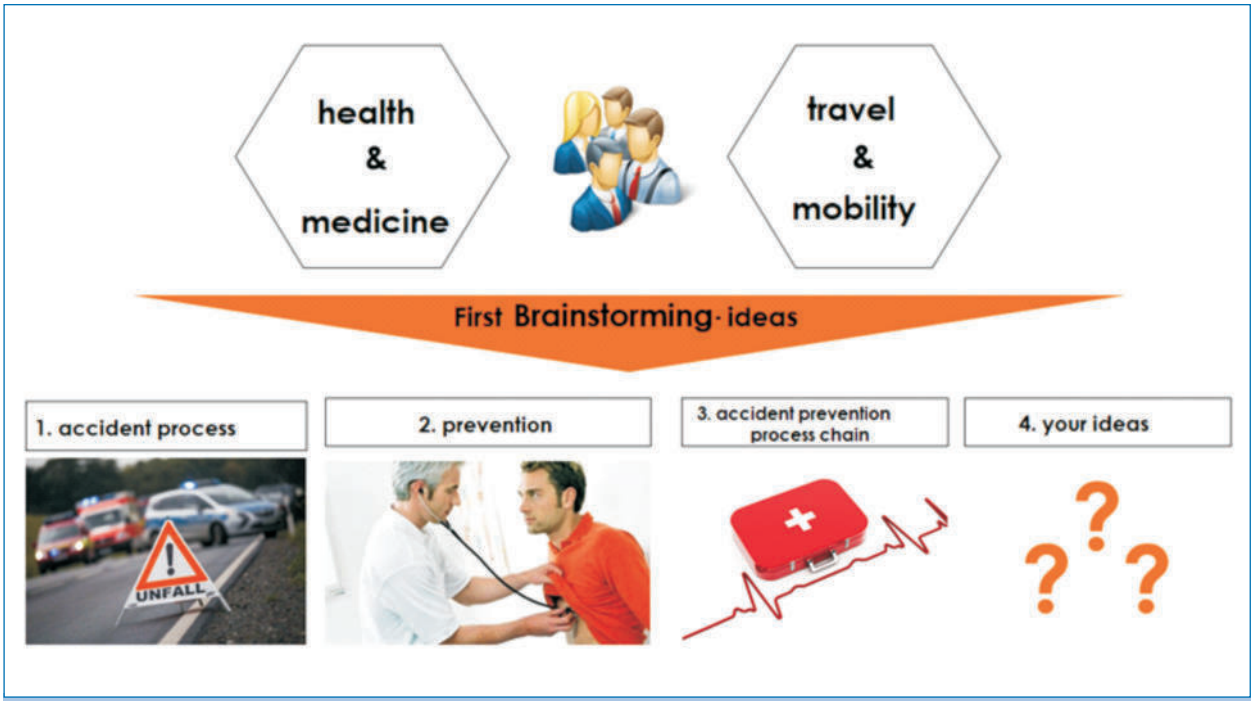


Fig. 1: *Sectors and brainstorming ideas* ■

Possible further use cases:

The CoP offers space for further use cases, which are conceivable for all modes of transport, cars, trains and aircraft.

- Acquisition of the sitting posture, stimulation and promotion of active sitting and movement stimulation.
- Non-invasive / non-contact recording of vital parameters (heart rate, heart rate variability, respiratory and movement parameters, etc.) and facial expression analysis for stress management, emotion recognition, attention recording and driver condition recognition.
- Development of a telematic infrastructure for the fusion, analysis and communication of all collected data for research purposes and for the implementation of use cases in real applications.

Invitation to automotive companies:

Especially companies from the automotive and supplier industry are invited to contribute their own ideas and ideas from their point of view.

What's the next step?

Do you also have ideas for bundling mobility and health in relation to digitization? Are you looking for partners to help you implement your ideas, or are you generally interested in the subject areas? Then we look forward to welcoming you to our next CoP meeting.
All companies, start-ups, associations, organizations, universities and research institutions active in the field of mobility & health are cordially invited to attend the CoP. For further questions please contact the speaker of the CoP Initiative Mr. Köpplinger. ■

Contact: Herbert Köpplinger | Managing Director
MRK Management Consultants GmbH
Herbert.Koepplinger@mrk.de
+49 89 21 66 67-0

Authors:

Carolin Huber
Project assistant

MRK Management Consultants GmbH
carolin.huber@mrk.de
+49 89 21 66 67-166

Hans Schell
Team leader|

MRK Media AG
hans.schell@mrk-media.de
+49 911 25 52 49-100

Matthias Struck
Group leader
Sector Smart Sensing and Electronics

Fraunhofer-Institut für Integrierte Schaltungen IIS
matthias.struck@iis.fraunhofer.de
+49 9131 776-7345

Special e-Car

munich expo

eMove 360°

eMove360° 2018

4. Internationale Fachmesse für die Mobilität 4.0
elektrisch - vernetzt - autonom

15. - 17. Oktober 2019, Messe München

PARALLEL
4
CONFERENCES

www.emove360.com

Preface

The ambitious climate targets of the United Nations of November 2015 and the decisions of the European Parliament, the European Council and the European Commission of December 2018 can be only be reached by a systematic decarbonization in the mobility sector.

It does not only make sense, but it is also absolutely necessary for most countries to focus on electromobility. But in the long run we should not neglect the hydrogen technology. The application of hydrogen technology in the sector of mobility is, without doubt, a long term strategy, going far more easily on resources than battery-based electromobility, which heavily depends on the availability of lithium.

A method of bonding the usually explosive hydrogen with an organic substance was developed at the Friedrich-Alexander-University Erlangen-Nuremberg, permitting hereby a safe storage and transportation of hydrogen and, in addition, guaranteeing the use of existing gas-station infrastructure with hardly any modification.

With the help of catalysts an organic substance named dibenzyltoluene can be hydrogenated and transported without any danger. At the destination site the hydrogen can then be separated again from the organic carrier substance.

In the national as well as in the international trade such bonded hydrogen can be transported within the existing infrastructure of container ships or on rails.

This new method has attracted enormous attention in the last few months in the scientific community and has managed to be amongst the “top three” of the “future prize of Germany‘s Bundespräsident”.

There is no doubt, that these chemical transformation processes entail losses of efficiency.

But with the increase of the renewable electricity production in the future, there will always be enough surplus electricity to be used for the production of hydrogen.

Siegfried Balleis

Honorarprofessor an der Friedrich-Alexander-Universität Erlangen-Nürnberg

Electrifyingly fun to drive: the Audi e-tron

The brand with the four rings presents its first fully electric series-production model, the Audi e-tron. The full-size SUV combines sportiness and everyday usability. Its two electric motors together with electric all-wheel drive provide for awesome performance and agile handling. The large high-voltage battery lays the foundation for a range of more than 400 kilometers (248.5 mi) in the WLTP driving cycle. In combination with a comprehensive range of charging options for home and on the move, customers can enjoy fully electric driving without having to compromise.

The Audi e-tron is an electric SUV for sport, family and leisure. It is 4,901 millimeters (16.1 ft) long, 1,935 millimeters (6.3 ft) wide and 1,616 millimeters (5.3 ft) high. It offers the spaciousness and comfort of one of the brand's typical full-size models. With a wheelbase of 2,928 millimeters (9.6 ft), the Audi e-tron has ample space for five occupants along with their bags. The total luggage capacity is 660 liters (23.3 cu ft), equipping the electric SUV for major tours. ■

Audi e-tron – Front view ■

Powerful performance on any terrain: drive and dynamic handling system

Efficiency, performance and quiet tranquility – the Audi e-tron exemplifies the driving experience of a new technological era. Two electric motors drive the electric SUV powerfully, free of emissions, and almost silently, with a system output of up to 300 kW and 664 Nm (489.7 lb-ft) of torque.

The maximum drive torque is available within fractions of a second and provides enormous pulling power. The Audi e-tron completes the standard sprint in 5.7 seconds. Top speed is an electronically-limited 200 km/h (124.3 mph).

A new quattro generation – electric all-wheel drive – provides for superlative traction and handling on any terrain and in any weather conditions. It ensures the continuous and fully variable regulation of the ideal distribution of drive torque between the two axles – within a fraction of a second. In most cases, the electric SUV tends to use its rear electric motor to achieve the highest efficiency. If the driver demands more power than it can supply, the electric all-wheel drive redistributes torque as required to the front axle. This also happens predictively even before slip occurs in icy conditions or when cornering fast, or if the car understeers or oversteers. The dynamic talents of the Audi e-tron are especially apparent at low coefficients of friction, such as on snow.

A key factor for the sporty character and outstanding transverse dynamics is the low and central position at which the drive components are installed. The battery system is optimally matched to the dimensions of the Audi e-tron and is located between the axles in the form of a flat, broad block beneath the passenger compartment. The

Audi e-tron – Interior ■

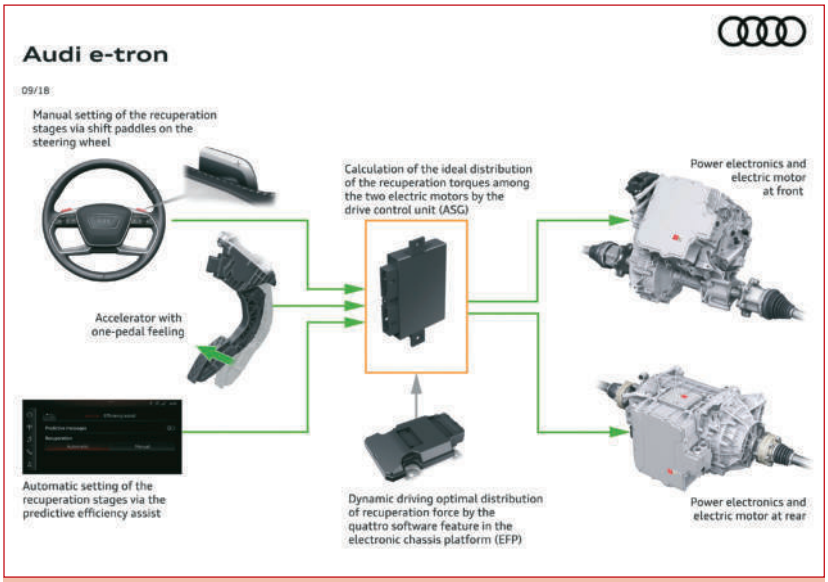
center of gravity of the Audi e-tron is thus on a level similar to that of a sedan. Axle load distribution is perfectly balanced at almost 50:50.

With Audi drive select, the driver can vary the characteristics of the Audi e-tron between seven profiles depending on the driving situation, road conditions or personal preferences. The system also influences the standard air suspension with adaptive dampers. As a result, there is a vast difference between smooth rolling comfort and sporty, stable handling. The air springs adjust individually to the road conditions depending on the speed and the driver's preferences, varying the ride height by as much as 76 millimeters (3.0 in). Especially on long journeys, a lower ride height improves aerodynamics, thus increasing the range. ■

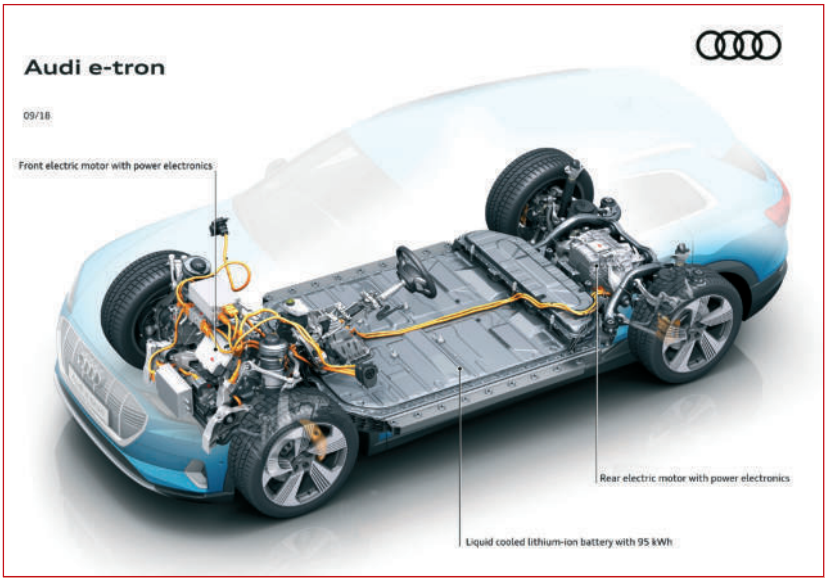
High efficiency: recuperation, aerodynamics and thermal management

The Audi e-tron covers more than 400 kilometers (248.5 mi) on a single charge in the WLTP test cycle. This value is due primarily to the innovative recuperation system, which accounts for up to 30 percent of the electric SUV's range. The electric SUV can recover energy in two ways: by means of coasting recuperation when the driver releases the accelerator, or by means of braking recuperation when the brake pedal is depressed. In both cases, the electric motors function as a generator and convert the kinetic energy of the Audi e-tron into electric energy. At up to 0.3 g of deceleration, the electric SUV recuperates solely via the electric motors. This is the case well over 90 percent of the time. The wheel brakes are involved only when the driver decelerates by more than 0.3 g using the brake pedal. They respond extremely quickly, thanks to a new electrohydraulic actuation concept. Audi is the first manufacturer worldwide to use this concept in a series production vehicle with electric drive. When braking from 100 km/h (62.1 mph), for example, the Audi e-tron can recuperate electric power with a maximum of 300 Nm (221.3 lb-ft) and 220 kW. That corresponds to more than 70 percent of its operating energy input. No other series production model can achieve such a value. The electrohydraulically integrated brake control system decides as a function of the driving situation whether the SUV uses the electric motor, wheel brake or a combination of the two for recuperation – with this taking place individually at each axle. The transition between electric and hydraulic braking is smooth and homogeneous, so the driver does not even notice it. Brake forces remain constant.

Another key factor for the high efficiency of the Audi e-tron is the sophisticated aerodynamics. One highlight of this concept are the optional virtual exterior mirrors – a worldwide first in a series production model. Integrated into each of the mirror supports is a small camera, whose images are displayed on high-contrast OLED displays inside the vehicle. Other aerodynamic solutions go about



Audi e-tron – Manual and automatic coasting recuperation ■



Audi e-tron – Electric drivetrain ■

their business hidden from view, such as the air suspension and the fully lined underbody with the aluminum plate to protect the high-voltage battery. These reduce drag, as does the adjustable cooling air intake. It includes channels for cooling the front brakes and serves as a switching point for the complex thermal management system with the standard heat pump. Benefits of the thermal management system include unwavering high performance even under high load, long battery life and fast DC recharging. With the virtual exterior mirrors, the Audi e-tron achieves a drag coefficient of 0.27 – a top mark in the SUV segment. With a typical use profile, this value provides for a range advantage of approximately 35 kilometers (21.7 mi) per battery charge versus a comparable, conventionally powered vehicle. ■

Intelligent solutions for home and on the move: the charging concepts

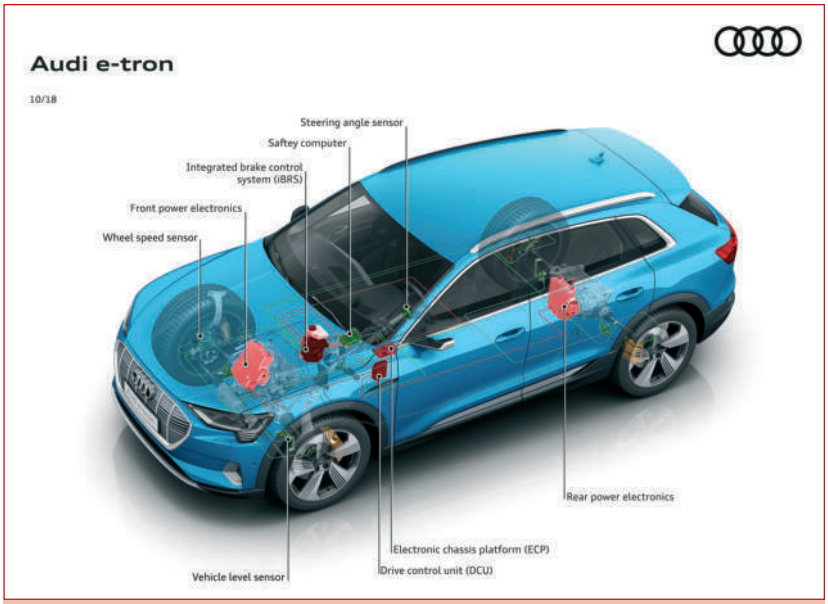
The large high-voltage battery in the Audi e-tron can store up to 95 kWh of energy and is thus the foundation for the long range. There is generally no need to stop at charging stations during everyday driving. On long trips, such as when going on vacation, customers can use fast charging stations to charge with direct current (DC) at up to 150 kW – a first for series-production automobiles. This means that the Audi e-tron is all set for the next long-distance stretch of a journey in approximately half an hour. The electric SUV can also be recharged with alternating current (AC) at up to 11 kW; recharging with 22 kW is available as an option. A proprietary Audi charging service provides e-tron customers with easy access to roughly 80 percent of the public charging stations in Europe. Whether AC or DC, 11 kW or 150 kW – a single card is all customers need to start the process. The procedure will become even more convenient with the function Plug & Charge, which will follow in 2019: The car self-authorizes at the charging station and activates it.

Audi offers various solutions for charging in the garage at home: The standard mobile charging system can be used with either a 230 volt household outlet or a 400 volt three-phase outlet. The optional "connect" charging system doubles the charging power to as much as 22 kW. In conjunction with a home energy management system, it offers intelligent functions such as charging when electricity is less expensive or with solar power if there is a photovoltaic system on the roof. Audi customers can control all charging processes as well as pre-entry climate control via their smartphone with the myAudi app. ■

Electrification visualized: exterior and interior

The Audi e-tron reflects the fundamental formal idiom of Audi design – translated into the electric age by new, stylistically defining details. Typically for one of the brand's SUV models, the Audi e-tron bears the octagonal-design Singleframe grille with vertical

Audi e-tron – Charging point ■



Audi e-tron – Network of the quattro drive control system ■

struts. Its corpus is largely enclosed and presented in platinum gray – identifying it as a fully electric model. At the lower edge of the Matrix LED headlights, four horizontal struts create the e-tron-specific signature in the daytime running lights. For the first time this is integrated directly into the headlights. The expressive design of the sill area with the black inserts visualizes the location of the battery and thus the energy center of the Audi e-tron. At the rear, slats in the wide diffuser call attention to the omission of exhaust pipes. The e-tron logo on the charging flap and optionally the brake calipers stand out in the high-voltage signal color orange.

Colorful accents such as these are also available for the spacious, airy interior, whose design embodies performance, intelligence and lightness. The large arc, into which the optional virtual exterior mirrors are harmoniously integrated, stretches across the expansive instrument panel to the sculpted door trims, taking in-car digitalization to a whole new level. The center tunnel console rests on open sidewalls. Seeming to float above it is the hand rest with integrated shifter, which the driver operates with thumb and forefinger. Lightness and performance are fused into one.

The entire driver's area has a driver bias, and the two large MMI touch response displays are angled in the driver's direction. They replace nearly every conventional switch and control. Many functions can also be controlled via the natural voice control system as well as the Amazon voice-activated assistant Alexa. With the standard Audi virtual cockpit, the driver can choose between two views that clearly present all information in the form of sharp, high-resolution graphics. The optional Audi virtual cockpit plus offers a third screen that highlights the electric drive system. The comprehensive comfort features paired with high-quality materials and fine workmanship make electric mobility a premium experience. ■

Top-caliber connectivity: infotainment and assist systems

In the German market, the Audi e-tron comes standard with the high-end media center MMI navigation plus. It supports the LTE Advanced data transmission standard with integrated Wi-Fi hotspot for the passengers' mobile devices. The navigation system makes intelligent destination suggestions based on previous routes, ideally supplemented by the e-tron route planner. This displays the suitable route with the required charging points. Besides the traffic situation, the computation also considers the battery's charge level. The projected arrival time includes any required charging time.

Numerous assist systems make the drive even more relaxing, including the standard efficiency assist. With predictive tips in the Audi virtual cockpit and automatic recuperation, it helps the driver to drive economically. The system uses radar sensors, camera images, navigation data and Car-to-X information to detect the traffic environment and the route. In combination with the adaptive cruise assist, the efficiency assist can also brake and accelerate the electric SUV predictively. Backing the assist systems is the central driver assistance controller, which continuously computes an exact model of the environment. The required data is obtained – depending on the selected options – from up to five radar sensors, six cameras, twelve ultrasound sensors and the laser scanner.

The Audi e-tron will be the brand's first model to allow customers to add certain functions online whenever the need for them arises. This will be possible from mid-2019 onwards. For example, the LED headlights can be upgraded to matrix LED headlights with intelligently controlled high beams, and assist systems or infotainment extras such as DAB+ digital radio and the Audi smartphone interface can be added. ■

ContactElectrifyingly fun to drive: the Audi e-tron

Tanja Lehner-Ilsanker
I/GP-P3

D-85045 Ingolstadt
Phone: +49 841 89-34105
tanja.lehner@audi.de
www.audi.com

Defined operational reliability due to predominantly closed-cell PUR foam seals

E-mobility benefits from knowledge transfer from a wide range of applications

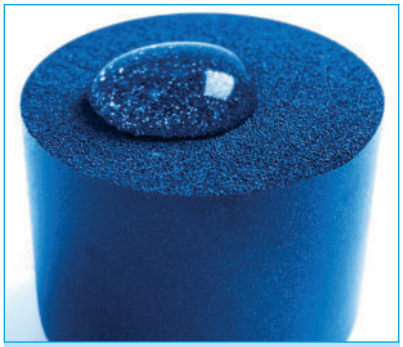
Weikersheim, 4th April 2019. As a central component of the energy revolution, the future of mobility will be electric. For the automotive industry and its suppliers, this means an unprecedented paradigm shift that requires the extremely rapid development of highly qualified expert knowledge in many details. In future, PUR foam sealing gaskets will play a decisive role in two of the central challenges – sealing of electrical connections and vibration-free (noise) insulation.

Not only the specific design of the PUR foam seals, for example in terms of density and load-bearing capacity, but also the height and the required deformability can be adapted to the respective product, in this case an electronic housing. © CeraCon GmbH ■

These predominantly closed-cell, soft sealing gaskets combine basic technical requirements for use in e-mobility applications - such as high tensile strength / fatigue strength and special tightness requirements even with considerable over- and underpressure - with the economic manufacturing and processing advantages of polyurethane (PUR) while maintaining closest tolerances, even in large-scale production.

Expertise in development

To ensure that the material and thus the foam seals can show all their advantages in applications such as battery covers, plug seals or seals for covers or housings of all kinds, it is important to involve the development supplier at an early stage in the design phase, especially in projects in the field of e-mobility: the expertise gained on decisive parameters - such as space-saving dimensioning, necessary tightness (protection against dirt / moisture / noise transmission), expected degree of deformation, seal heights, installation details (i.e. minimum installation forces), etc. – does not only have a significant influence on the long-term performance of the entire unit, but also on the costs of installation, subsequent maintenance or possible replacement. ■



The predominantly closed-cell CeraPUR® foam remains tight even if the surface of the gasket is damaged. © CeraCon GmbH ■

Expertise in material combinations

As one of the leading manufacturers of 1K-PUR foam seals including the necessary experience in the entire value chain, CeraCon is your qualified partner.

In the field of e-mobility, PUR foam gaskets will in future become both functional and economical problem solvers in a wide variety of applications. © CeraCon GmbH ■

From the needs-based selection of the specific sealing material and support in the process-optimized design of the components to be sealed to the development of prototypes / pre-series and series production in contract gasketing plants in Germany and abroad. Thus, in addition to the original task, such as tightness against dirt / moisture or noise insulation, the specific characteristics of the materials with which the foam sealing gaskets should be combined can be included in the development right from the beginning. For example, due to intensified use of lightweight constructions, a clear trend can currently be observed from the familiar cast or aluminium housings to particularly filigree metal lightweight construction or plastic solutions to which the predominantly closed-cell PUR foam seals from CeraCon Sealing systems are already adapted. ■

PUR foam gasket, here in a cover made of die-cast aluminium. © CeraCon GmbH ■

Information about CeraCon

The German mechanical engineering company CeraCon GmbH was founded in 2000 and has got its head office in Weikersheim/ Baden-Württemberg. Currently, CeraCon has got about 200 employees in different business areas working in Germany and abroad.

The core business of CeraCon is selling, designing and manufacturing of standardized and customer-specific machines. The division "Sealing systems" is responsible for processing and applying foam gaskets directly to the components to be sealed as well as for developing and producing the corresponding adhesives and sealing compounds. The division "Thermal systems" comprises the heat treatment and buffering of components in horizontal and vertical design.

Furthermore, CeraCon offers contract gasketing service and is able to apply foam to customer components in large or small series.

Target industries are the automotive sector, the respective suppliers, the electrical and electronics industry as well as the white goods sector. More than 70 % of the company turnover is achieved abroad. ■

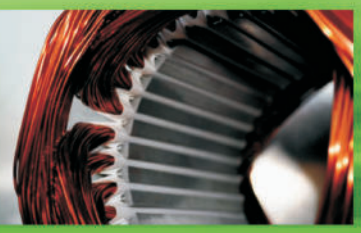
Author:

Dr. Frank Kukla

Managing director, Head of Technology and Development „Sealing systems"

CeraCon GmbH

Talstr. 2
97990 Weikersheim/Germany
Phone: 0049-7934-9928-621
Fax: 0049-7934-9928-600
E-mail: frank.kukla@ceracon.com
www.ceracon.com



Innovations for the electric motor production of tomorrow

From new process technologies, automation solutions through to Industry 4.0 approaches

Research Sector Electromechanical Engineering

New requirements for electric motor production

The spread of electric mobility will fundamentally change the automotive industry. Apart from high-performance batteries, efficient drives must be developed that meet the strict requirements of the automotive industry in terms of costs, quality, reliability and operational safety. Regarding electric motors, the reduction of installation space, weight and noise emissions is of particular importance. Further objectives include increasing power density, optimizing cooling concepts and improving controllability.

This results in a need for research not only for the development of electric motors but especially for their production. Since industrial motors in higher power classes have only been manufactured in small quantities so far, their production is largely manual. However, for an economical and series-flexible production of electric traction drives, efficient and highly automated manufacturing processes are indispensable. Therefore, far-reaching new developments are necessary to enable existing production technologies of electromechanical engineering for the automotive industry. The cost and quality goals of the automotive industry can only be achieved by a close combination of functional and process optimization measures. ■

Electromechanical engineering at the FAPS institute

In order to meet these new challenges, researchers at the Friedrich-Alexander University Erlangen-Nuremberg (FAU) are working, among other things, on the series-flexible automation of the electric motor production. In the research sector Electromechanical Engineering of the Institute for Factory Automation and Production Systems (FAPS), innovative manufacturing technologies are being researched with the aim of transferring the knowledge gained to industrial practice *(Fig. 1)*. Aside from production-oriented design, the main focus is set on the development and optimization of production processes for components and systems of electric drive technology, particularly for electric mobility and hybrid electric aircrafts. In addition, processes for manufacturing inductive charging systems are being researched.

Electric motors and inductive charging systems represent important components of future forms of mobility. However, they must always be considered in con-

Fig. 1: *View of the demonstration plants for different winding technologies in the laboratory of the research sector Electromechanical Engineering of the FAPS institute* ■

junction with other central components such as energy storage, wiring systems or power electronics. Therefore, the research activities in the field of electromechanical engineering are supplemented by the complementary work of the institute‘s adjacent research sectors Electronics Production, Wiring Systems and Efficient Systems. In total, the FAPS institute employs around 100 people, spread over its two sites in Erlangen and Nuremberg. ■

Research laboratory with extensive plant equipment

Due to the high application relevance of the FAPS institute‘s research, numerous demonstration plants have been set up and optimized in practical test series within the scope of past projects. Sufficient space is provided by the laboratory and office facilities on the former AEG site, on which the research sector Electromechanical Engineering has been located since mid-2011. The large laboratory hall comprehensively covers the various technologies of electric motor production *(Fig. 2)*.

The extensive plant equipment is not only used for the work on research and industrial projects but also for the practical training of FAU students. ■

Research projects along the entire process chain

The numerous past and current research and development projects are distributed along the entire process chain of electric motor production. Thus, the following descriptions are only a small excerpt of the research activities of the research sector Electromechanical Engineering.

As a complementary alternative in the processing of electrical steel, the continuous process of rotary cutting is investigated *(Fig. 3)*. Flexible laser cutting, on the other hand, is used for rapid prototype production. In order to increase the motor's efficiency, a further aim is to minimize the hysteresis losses of laminated cores. For this purpose, the materials used and the respective packetizing processes are being optimized in a current project.

In order to minimize product-specific tool costs, various robot-based winding and pull-in techniques are being tested. Robot-based winding techniques for high-frequency litz wires also enable the production of complex coil geometries for inductive charging systems. In addition, an innovative universal winding machine is being developed, which can be used to produce various winding patterns with varying wire geometries *(Fig. 4)*. A CAD/CAM chain allows a fast and flexible offline programming of the machine.

The next generations of electric traction drives will increasingly use semi-open form coils, so-called hairpins. While hairpins are easier to handle in an automated way, they go along with a high number of contact points. Thus, a central challenge of hairpin technology is the contacting. Here, a promising approach is laser welding, which is being holistically researched and further developed in the research sector Electromechanical Engineering *(Fig. 5)*. Additionally, other projects investigate hot-crimping and innovative ultrasonic welding for contacting enameled copper wires. In the same context, various methods for the removal of insulation from flat copper wires are qualified. Moreover, new concepts for the assembly and twisting of hairpins are examined.

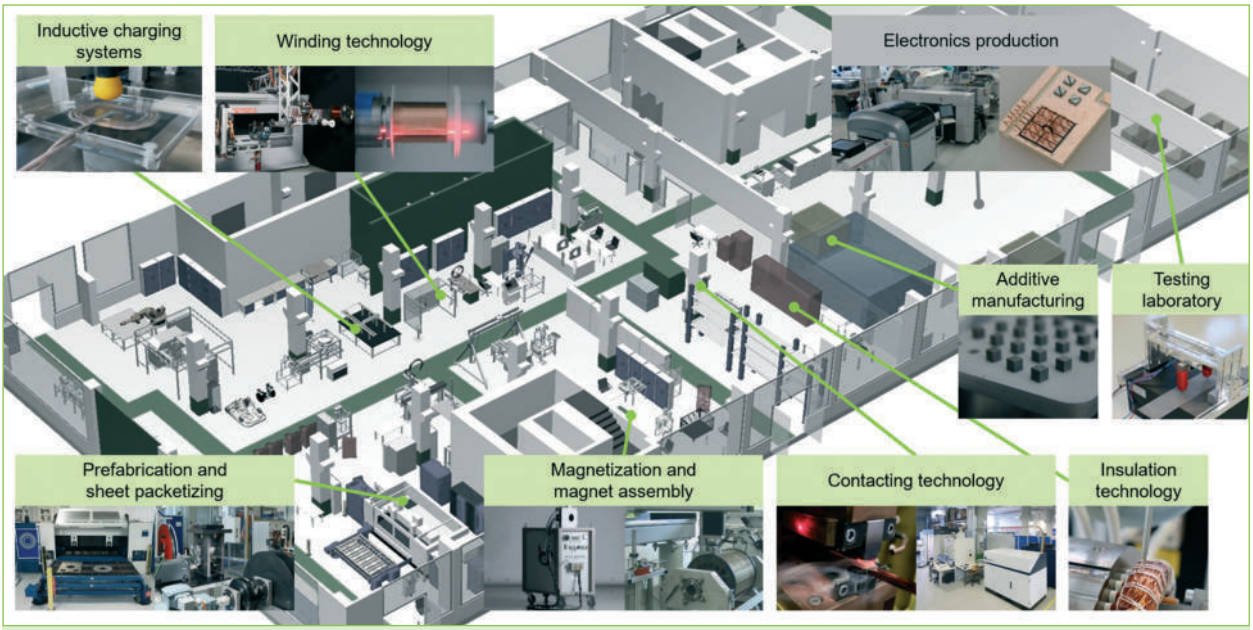


Fig. 2: *Overview of the laboratory hall of the FAPS institute at the site in Nuremberg with numerous demonstration plants on innovative technologies in the field of electromechanical engineering* ■

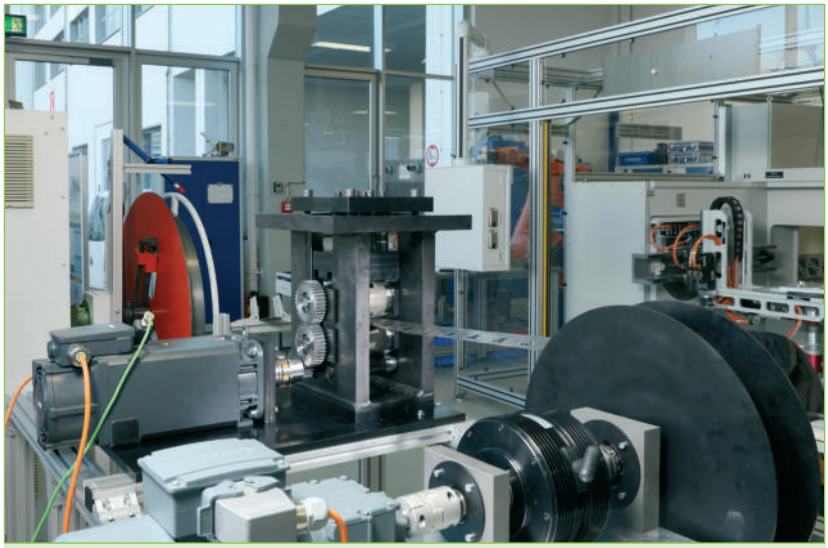


Fig. 3: *Prototype plant for rotary cutting of electrical steel as a complementary alternative to conventional punching* ■

Further optimization potential lies in the manufacturing of the insulation in electric motors. Compared to conventional slot liners, powder coating can significantly improve the copper filling factor of rotors and stators. In addition, the inductive curing of insulation resins is investigated as a resource-efficient alternative to furnace processes. For this purpose, different approaches for effective temperature control and monitoring have been developed.
A further focus of the research sector Electromechanical Engineering is the handling and assembly of permanent magnets already magnetized. Besides feeding devices, precise positioning systems and gluing processes are investigated. In addition, inline measuring systems for rotor testing and a magnet intralogistics system for selective magnet assembly are currently being developed.
Apart from that, automated process chains for the manufacturing and balancing of rotor-shaft connections are investigated. Hereby, a new concept for the combination of packetizing and magnet assembly has been established.
Due to the increased quality requirements for traction drives, it is necessary to develop efficient inline testing methods. As a result, new testing techniques are applied and further developed to enhance product understanding and defect detection. Hence, the magnetic field measuring laboratory of the research sector Electromechanical Engineering provides various magnetic field probes and measuring systems for the characterization of hard magnetic materials, electrical steel sheets or other ferromagnetic components. In addition, various high-voltage testing devices allow the qualification of primary insulation and insulation systems in accordance with standards.
Furthermore, specially developed methods enable the detection of insulation weaknesses caused by manufacturing processes.
Due to the limited availability and the high value of many materials used in electric motors (especially rare earths, non-ferrous and heavy metals), procedures for recycling as well as processes for minimizing the material consumption have also been developed.
The trend topics additive manufacturing and Industry 4.0 are also increasingly being addressed in the production of electric drives. For the additive manufacturing of permanent magnets, for example, the processing of rare-earth magnetic material by laser beam melting in a powder bed is being researched. Furthermore, computer-aided methods of the digital factory are used for the simulation of production systems and virtual process validation. In the context of Industry 4.0, data-driven approaches using machine learning methods offer great potential. In ultrasonic welding, for example, the connection quality represented by the electrical contact resistance could be predicted solely on the basis of sound emissions and images of

Fig. 4: *Innovative universal winding machine for the flexible production of different winding patterns with varying wire geometries* ■

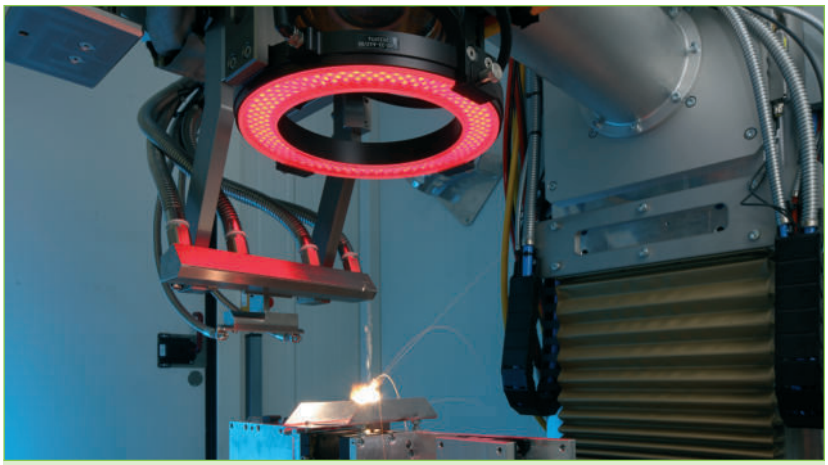


Fig. 5: *Experimental cell for laser welding in order to investigate laser-based processes for joining copper materials* ■

the burnup. Further applications for machine learning methods are currently being investigated in close cooperation with industry. ■

Forms of cooperation and technology transfer

With its research on innovative production technologies for tomorrow's electric drives, the research sector Electromechanical Engineering fits perfectly into the Bavarian cluster initiatives for mechatronics and automation, automotive as well as environmental technology. Since the foundation of the research sector Electromechanical Engineering in May 2010, a high number of research and industrial projects have already been completed. In the course of the E|Drive Center, the Bavarian Technology Center for Electrical Drive Technology funded by the Free State of Bavaria, the cooperation with partners from industry and science has been sustainably strengthened. In doing so, the FAPS institute has been established as a recognized teaching and research institution in the field of electromechanical engineering.

In addition to several invention disclosures, numerous technical seminars, lecture series and conferences were organized. Within the WGP seminar „Production of Electric Drives", scientists from the research sector Electromechanical Engineering invite you once a year to an intensive transfer of knowledge involving lectures, expert discussions and demonstrations in the research laboratory. The seminar program also offers the opportunity to discuss individual problems in electric motor production.

With the E|DPC, the International Electric Drives Production Conference, the research sector also organizes an internationally unique scientific congress *(Fig. 6)*. This year's E|DPC in Esslingen from December 3 to 4 will be the ninth time in a row that a unique platform for an intensive experience exchange on the production of electric drives between science and practice will be offered. ■

Fig. 6: *Annual international conference and accompanying exhibition on electric drives production* ■

E|Drive-Center
Bayerisches Technologiezentrum für elektrische Antriebstechnik

FAPS Institute for Factory Automation and Production Systems
Prof. Dr.-Ing. Jörg Franke

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Authors:

Andreas Mayr, M.Sc., M.Sc.
Research Assistant

Dipl.-Ing. Michael Masuch
Research Assistant

Dr.-Ing. Alexander Kühl
Head of Research Sector

Research Sector Electromechanical Engineering
Institute for Factory Automation and Production Systems (FAPS)

Prof. Dr.-Ing. Jörg Franke
Friedrich-Alexander University Erlangen-Nuremberg

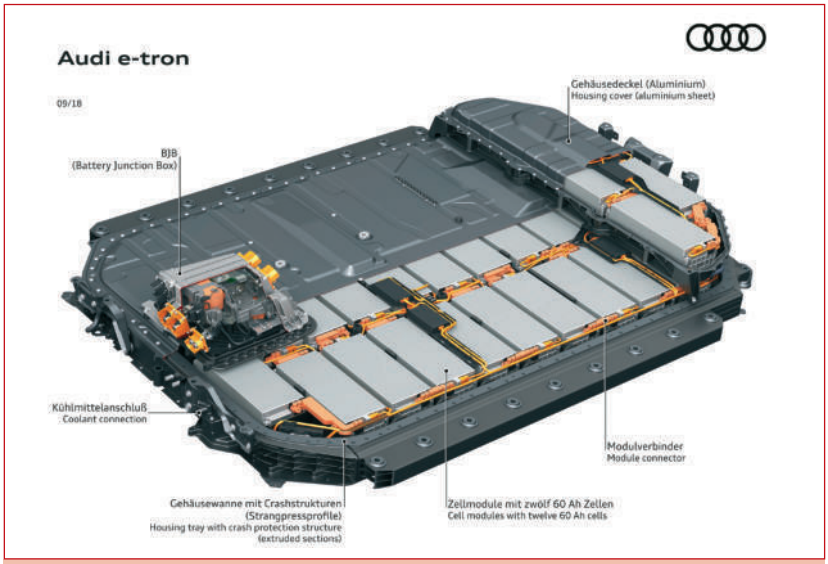
Fürther Str. 246b
D-90429 Nuremberg
Tel.: +49.911.5302.9066
Fax: +49.911.5302.9070
E-Mail: alexander.kuehl@faps.fau.de
www.faps.fau.de

Audi e-tron: Battery and charging technology

With its first fully electric series production model, Audi has transformed from a classic automobile manufacturer to a system supplier for mobility. Thanks to a comprehensive range of charging options with intelligent solutions for home and on the move, customers can enjoy fully electric driving without having to compromise.

95 kWh of energy: the high-voltage battery system

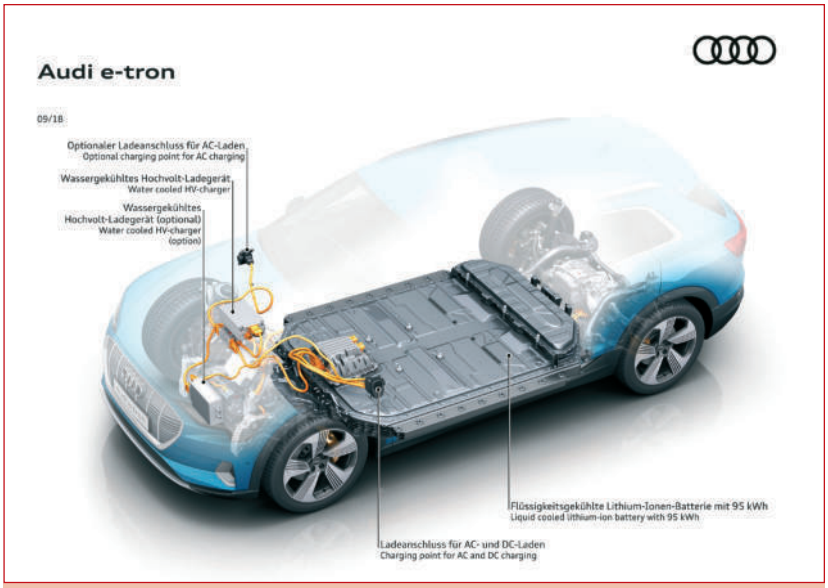
The powerful lithium-ion battery in the Audi e-tron provides for a range of more than 400 kilometers (248.5 mi) in the WLTP driving cycle. The battery operates with a nominal voltage of 396 volts and stores 95 kWh of energy. The battery system in the Audi e-tron is located beneath the cabin and is 2.28 meters (7.5 ft) long, 1.63 meters (5.3 ft) wide and 34 centimeters (13.4 in) high. It comprises a total of 36 cell modules in square aluminum housings, each of which is roughly the size of a shoe box. They are arranged on two levels, known as "floors" – a longer lower floor and a shorter upper one. The cell modules in the Audi e-tron can reproducibly discharge and charge electricity over a broad temperature and charge status window. They can be densely packed to achieve a very high output and energy density in the volume available. At market launch, each module is equipped with twelve pouch cells having a flexible outer skin of aluminum-coated polymer. In the future, Audi will use both technically equivalent prismatic cells in its modular concept, also in terms of a multiple supplier strategy.



Audi e-tron: Lithium ion battery ■

An indirect cooling system distinct from the cell space ensures the high-performance operation of the battery over the long term. It is made of flat, extruded aluminum sections uniformly divided into tiny chambers. Heat is exchanged between the cells and the cooling system beneath them via a thermally conductive gel pressed beneath each cell module. In what is a particularly efficient solution, the gel evenly transfers the waste heat to the coolant via the battery housing.

The battery and all key parameters, such as charge status, power output and thermal management, are managed by the external battery management controller (BMC). This is located in the occupant cell on the right A-pillar of the Audi e-tron. The BMC communicates with both the controllers of the electric motors and the cell module controllers (CMC), each of which monitors the currents, voltage and temperature of the modules. The battery junction box (BJB), into which the high-voltage relays and fuses are integrated, is the electrical interface



Audi e-tron: Liquid cooled lithium-ion battery with two charging points ■

to the vehicle. Enclosed in a die-cast aluminum housing, it is located in the front section of the battery system. Data exchange between the BMC, the CMCs and the BJB is via a separate bus system. ■

Standard with 11 kW, optionally with 22 kW: charging at home

The Audi e-tron will typically be recharged most often at home. And each charging cycle costs the owner just a few seconds of time, i.e. the time required to connect and disconnect the charging cable. In most cases, the electric SUV is charged overnight and then sets off the next morning with a fully charged battery and a range of more than 400 kilometers (248.5 mi) according to the WLTP test cycle.

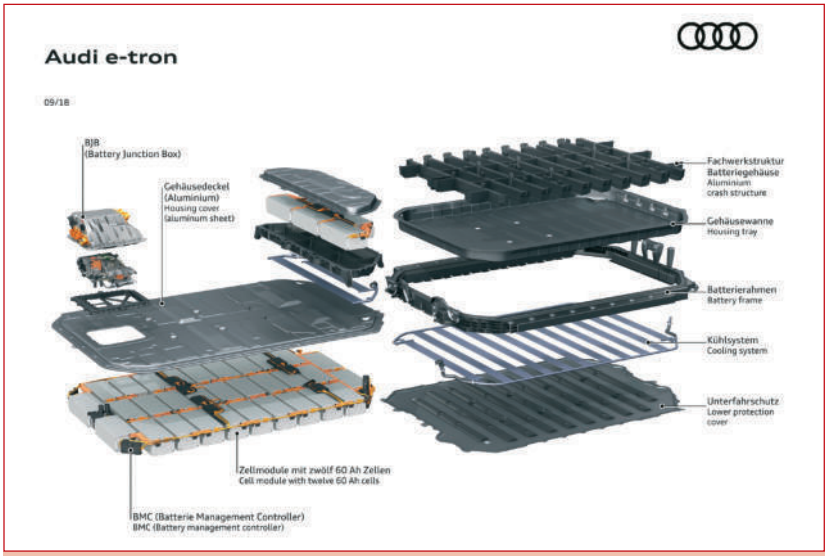
Audi offers various solutions for charging at home. If desired, an electrician referred by the local Audi dealer will check the power supply in the garage and install the suitable technology. The standard compact mobile charging system can be used in two ways – with a charging power of up to 2.3 kW when connected to a 230 volt household outlet, and with up to 11 kW when connected to a 400 volt three-phase outlet. In the latter case, the battery can be fully recharged in roughly eight and a half hours. The optional connect charging system doubles the charging power to as much as 22 kW. This requires a second charger on board the Audi e-tron, which will be available from 2019. The connect system comprises a control unit with a 5-inch touch display and a wall mount. It enables customers to view their individual charging statistics and charging progress in the myAudi portal and the myAudi app.

Together with a home energy management system, the connect charging system offers intelligent functions. In this case, the Audi e-tron can be charged with the maximum power available with consideration of other consumers in the household to avoid overloading the electrical system. Customers can also define their own personal priorities, such as charging when electricity is less expensive. If the home is equipped with a photovoltaic system, the car can be charged preferentially using the electricity generated by the system, and charging even considers forecast phases of sunshine. ■

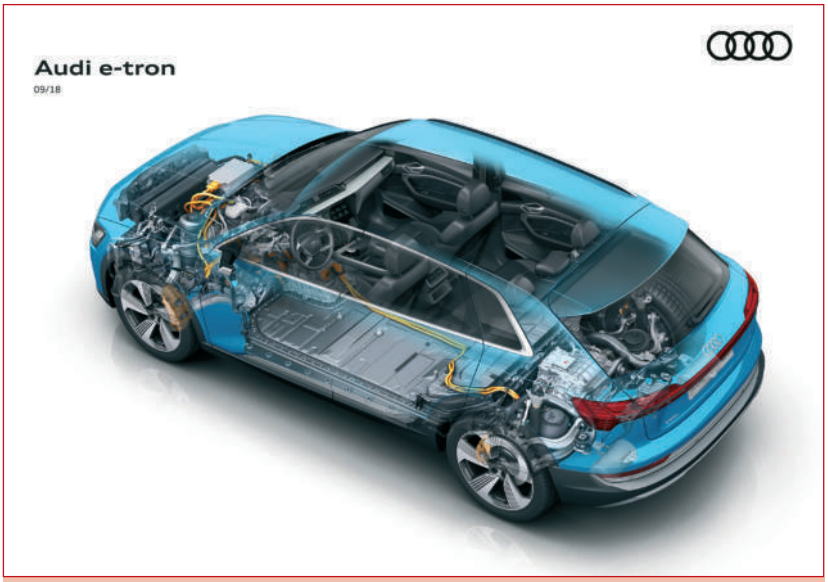
Remote control via app: charging and heating/cooling

The myAudi app provides for convenient operation with smartphone from the couch. With it, customers can also plan, remotely control and monitor charging processes and the pre-entry climate control of the Audi e-tron. They can set a departure time, for example, so that the electric SUV is charged and/or heated/cooled at the desired time.

Customers can even choose for the first time to heat or cool certain zones in the car. On cold winter days, for example, they can turn on the seat heating, heated steering wheel or the heated rear window using their



Audi e-tron: Components of the lithium ion battery ■



Audi e-tron: Electric drivetrain ■

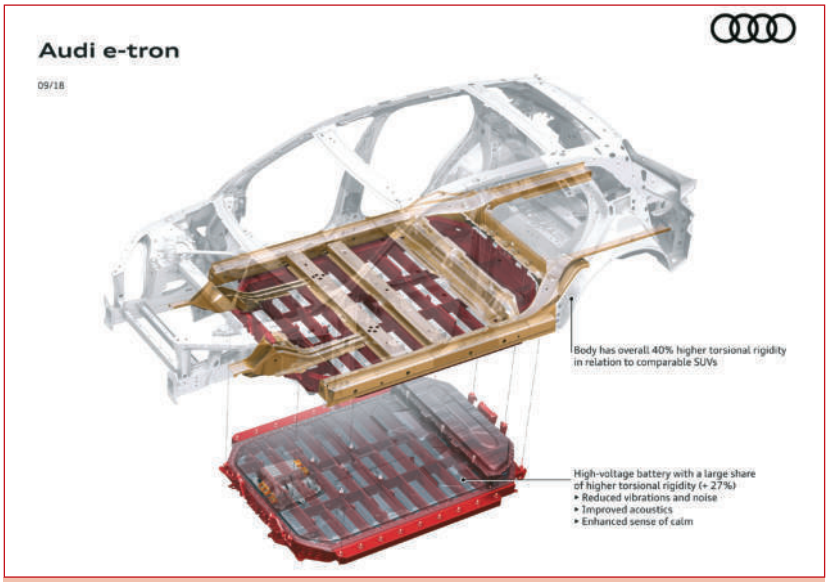
smartphone. The app also displays charging and driving data. Communication with the car is via the integrated LTE module, which is standard equipment in the Audi e-tron. ■

At up to 150 kW: charging on the move

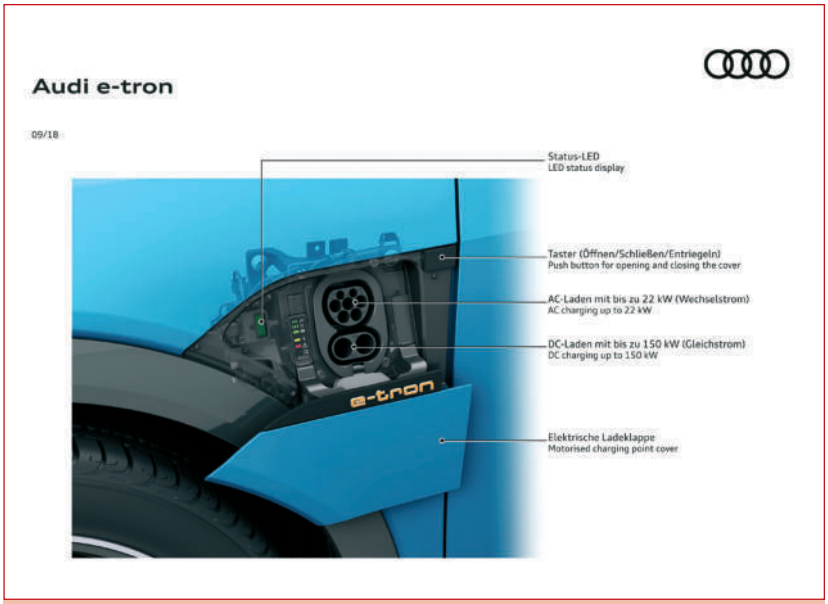
Thanks to the long range of more than 400 kilometers (248.5 mi), there generally is no need to stop at a charging station during everyday driving. This is not the case for longer trips, however, such as when going on vacation. In these situations, the Audi e-tron can recharge with up to 150 kW DC at fast charging stations meeting the European Combined Charging System (CCS) standard – a first for a series-production automobile. This means that the electric SUV is all set for the next long-distance stretch of a journey in approximately half an hour. It is all made possible by the sophisticated thermal management of the lithium-ion battery, which allows charging at up to 150 kW. Plans call for the Ionity network to include 400 such high-power charging (HPC) stations installed at 120-kilometer (74.6 mi) intervals along European highways and main transportation corridors by 2020. The Volkswagen Group including Audi and Porsche, the BMW Group, Daimler AG and the Ford Motor Company are jointly promoting the expansion of the HPC network. Additional compatible HPC charging points are also being installed in Europe outside of this joint venture.

In addition to direct current, the electric SUV can also be charged on the move with alternating current at AC chargers, with up to 11 kW as standard and at 22 kW with the optional second onboard charger. The car is connected to the charging station using the standard mode 3 charging cable. Roughly 95 percent of all existing charging points in Europe currently conform to this standard.

From market launch Audi will offer a proprietary charging service for its customers – the Audi e-tron Charging Service. It provides convenient access to roughly 80 percent of all charging stations in Europe, corresponding to well over 70,000 public charging points in 16 EU countries. Whether AC or DC charging, 11 kW or 150 kW – a single card is all customers need to start the charging process. Data transfer is based on RFID (Radio Frequency Identification) radio technology. Many charging stations can also be activated by scanning a QR code with a smartphone. To use the service, customers have to register one time on the myAudi portal and conclude a contract. Billing is automatic via the user account. No physical means of payment is used. Customers can use the myAudi portal to view their current charging history at any time, review their latest bills and manage their contract. Independent of this, customers can also use charging stations that are not included in the e-tron Charging Service portfolio. In these cases the



Audi e-tron: Integration of the high-voltage battery ■



Audi e-tron: Charging point ■

customers settle directly with the respective provider.

From 2019 onward, charging will be even more convenient for Audi customers. This is when the Plug & Charge function will be introduced. It enables the Audi e-tron to authenticate itself at charging stations via state-of-the-art cryptographic procedures, after which it is authorized – the card will no longer be necessary. This requires a valid charging contract with the e-tron Charging Service. All Audi e-tron models rolling off the assembly line from mid 2019 will support this function as standard. ■

In the spotlight: the charging process

Each Audi e-tron charging process begins with a little show: At the push of a button, the motorized charging flap in the driver-side fender opens toward the front to reveal the connector illuminated by a white LED. Next to it is a second LED that indicates the status. A pulsing green light, for example, means charging is active; a steady green light means charging is complete.

When the plug is disconnected, the charging flap closes automatically within five seconds. Together with the optional second charger, Audi provides an additional connector on the passenger side for AC charging. ■

Important performance factor: thermal management

The effective thermal management system in the Audi e-tron guarantees fast DC charging with up to 150 kW, long battery life and reproducible road performance even under heavy load. For the customer, this means high performance at all times.

The thermal management system of the Audi e-tron comprises four circuits that can be connected in various ways as required. It cools the electric motors including their rotors, the power electronics and the charger. It also cools and warms both the interior and the highvoltage battery. The rotors, which reach up to 13,300 revolutions per minute during real vehicle operation, consist of magnetically conductive electrical sheets and lightweight, high-purity aluminum. Coolant flows through the inside of the shafts to ensure that the temperature does not exceed 180 degrees Celsius. The stators and end shields of the electric motors are also water-cooled. The gearboxes mounted on the end shields benefit indirectly from this solution. Effective cooling posed new challenges for the developers, particularly with the coaxially arranged electric motor at the rear axle. The solution is to supply the coolant via a double-wall pipe and its ceramic seal on the electric motor rotor.

22 liters (5.8 US gal) of coolant circulate around the 40 meters (131.2 ft) of cooling pipes in the Audi e-tron. Being the hottest components in the powertrain, the electric motors provide the thermal management system with a large quantity of heat. The standard heat pump uses their waste heat – up to 3 kW of actual power losses are efficiently used for heating and air conditioning the interior. Depending on the outside temperature, that can boost the Audi etron‘s range by up to ten percent in customer operation.

The thermal management system also ensures that the battery is kept within its optimal efficiency range of 25 to 35 degrees Celsius in all situations, from a cold start in winter to fast highway driving on hot summer days. This also contributes to the long service life. During DC charging with 150 kW, which is possible for the first time ever in a series production automobile with the Audi e-tron, cold coolant dissipates the heat produced as a result of electrical resistance. If the battery is still cold when charging in winter, it is heated with warm coolant. ■

Contact:

Tanja Lehner-Ilsanker
I/GP-P3

D-85045 Ingolstadt
Phone: +49 841 89-34105
tanja.lehner@audi.de
www.audi.com

Safe Electromobility

Research and development for an emerging form of mobility

The technology of lithium-ion energy storages is well established. While already while being used in cell phones, smartphones, notebooks and tablets today, the automotive sector is an increasingly important scope of application. In line with the current energy revolution and thereof resulting challenges, a global growth of environmental con-sciousness as well as an increasing electrification in mobility and further technical areas, the safe storage of energy is gaining importance.

Hence, the research group "Safe Electromobility" under the direction of Prof. Dr. Hans-Georg Schweiger including a post-doc, ten PhD students and two test/laboratory engineers is researching energy storage systems. Together with small and medium-sized companies, industry partners and universities, battery systems and their safety as well as electrochemical measurement systems are being investigated. Different scenarios and the effects of various battery conditions can be visualized and tested in a safe energy storage laboratory. An external test site allows to perform abuse tests on electrochemical energy storages, especially on LIB (experiments at cell, module and system level). The focus lies on experiments for research purposes such as the further development of test procedures and the research on new battery safety concepts. ■

Teaching

Practical exercises in physical chemistry, electrochemistry and electrochemical energy storages are offered in the laboratory for electrical energy storages. This lab primarily serves for teaching at the Technische Hochschule Ingolstadt (THI).

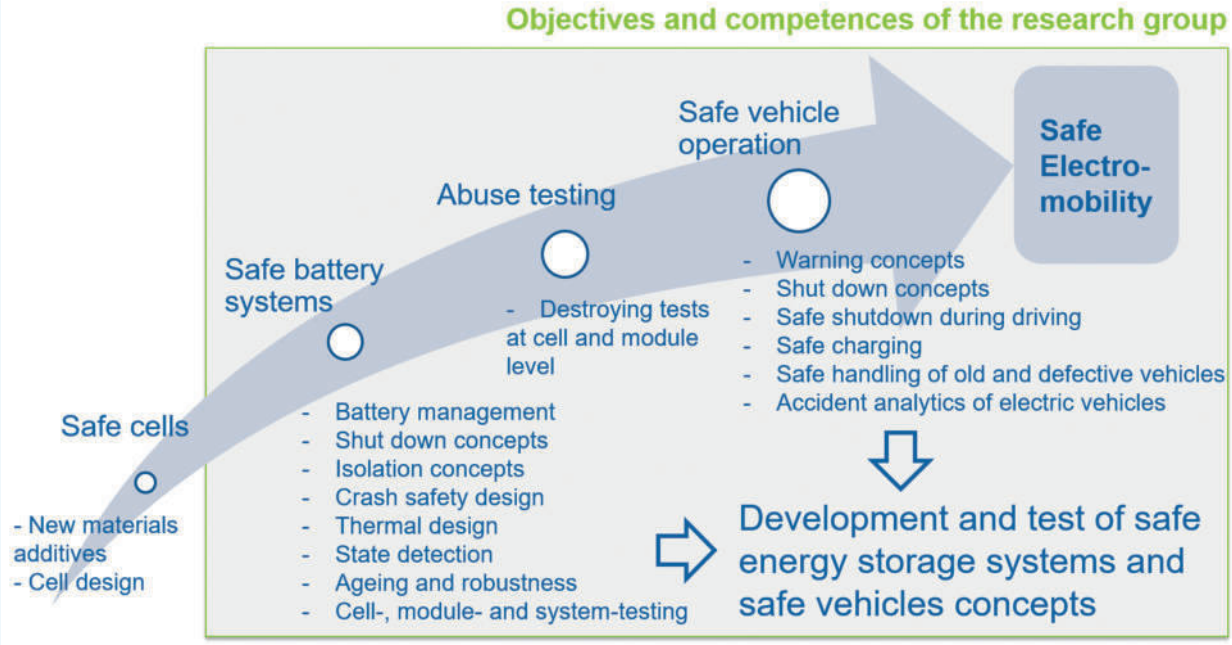


Fig. 1: *Fields of activity aimed at a safe electromobility* ■

Fig. 2: *Battery module developed in the E-Falke project at the Technische Hochschule Ingolstadt* ■

In addition, semester projects are being carried out, in which students develop battery systems, battery management electronics and battery measurement technology within the framework of teaching.
In a different lab, the Electric Mobility Laboratory, the focus is on software development for battery management systems, battery measurement technology and the simulation of battery systems (thermal, electrical and mechanical) as well as on the operation of a driving simulator for an electrified racing car. ■

Safe battery systems

The accelerated development of electric mobility significantly increases the importance of battery systems. In order to ensure the safety of the more complex and efficient battery systems, the individual components have to be considered first. By intensive research on components like battery management systems (BMS), shutdown elements, insulation monitoring and -concepts, crash-proof design, thermal design and state recognition of energy storages, the aim of ensuring their safety is pursued. Research and teaching are closely interlinked at the Technische Hochschule Ingolstadt. Thus, research results are practically applied in student projects such as the E-Falke project *(see Fig. 2)*, where the battery concept as well as the battery modules were developed. ■

Safe vehicle operation

In addition to the battery system as the central single component of hybrid and electric vehicles, the vehicle as an overall concept is considered. In order to ensure safe vehicle operation, investigations are performed considering the entire operation including the end of life of the vehicle. This includes warning concepts, shutdown strategies in all operating modes, safe shutdown while driving, safe charging and ultimately the safe disposal of the vehicles at their end of life. ■

Fig. 3: *Overcharged battery pack* ■

Behavior under extreme conditions

For a safe and reliable operation of energy storages in all application areas, it is important to know the behavior under extreme loads. In order to picture this, characteristic parameters of energy storages such as capacity, performance, energy content, internal resistance and power delivery of lithium-ion cells are examined when exceeding the normal working range. The aim is to increase the efficiency as well as the safety level during the design phase of energy storages. At the external test site mentioned earlier, abuse tests are performed with the energy storages. Abuse tests are necessary for the approval of battery systems. Performing destructive tests and the knowledge gained from them can improve the crash safety of electric vehicles and therefore lead to a significant contribution to safe electric mobility. ■

SENSE BAY - Safe Electric Energy Storage Systems Bavaria

Networking of science and industry

Powerful and safe electrochemical energy storage systems play a key role in the energy revolution and electromobility. In order to promote especially small and medium-sized companies in this dynamic market, the project „SENSE BAY - Safe Electric Energy Storage Systems Bavaria“ supports the establishment of a leading bavarian position in research and technological development in the field of electrochemical energy storages.
An adaptation of THI's test and battery measurement technology and an increase in technology transfer make it possible to establish a competence region for electrochemical energy storages in a central location in Bavaria. Thanks to a focused networking of actors in the subject area and the open, professional exchange of science and industry, innovative business models and services in the field of the development of safe energy storages are generated. Examples are the optimization of test procedures in the development phase or the realization of reliable security concepts. ■

Vision

The optimization of existing technologies, the development of innovative concepts and emerging business models lead to a high dynamic market, which is a big

Fig. 4: *Meeting with SENSE-BAY project partners* ■

challenge for companies as well as an opportunity to open up new business fields. However, the steadily increasing energy densities of the systems pose risks in production, storage and operation, which lead to a great need for innovations in the field of safety that is not easy to cope with especially for small and medium-sized companies. In addition to necessary investments in modern experimental and battery measurement technology, the cooperation of companies from various disciplines is required.

This is where the project „SENSE BAY - Save Electric Energy Storage Systems Bavaria“ comes in. An adaptation of the battery testing options targeted at specific groups at the Technische Hochschule Ingolstadt (THI) on one hand and the promotion of networking of science and industry on the other hand allows the development of cooperations to generate new business ideas and thus the development of a leading bavarian position in research and technological development in the field of electrochemical energy storages. ■

Project implementation and goals

The following measures allow the establishment of a competence region for safe energy storages:

The high demand for battery-testing options for the development of safe and powerful energy storages is addressed by strengthening the research field „Safe Electromobility“ at THI. The possibilities of advanced, modern test and battery measurement technology, such as test stands, equipment for test recording and ion chromatography for analyzing emerging pollutants, including appropriate staff will especially stimulate the development activities of SME partners and other stakeholders together with increased technology transfer between science and industry. Battery tests at cell or system level that increase the safety of electrochemical energy storages and their components are performed with the aim of developing innovative products and services in the project-funded region.

At a higher level, a network of cooperation partners is set up to provide SMEs with an exciting platform for exchange. SMEs covering a wide range of electrochemical energy storage sectors are involved, such as development service providers, manufacturers of electrochemical workstations, engineering offices, providers of power supply systems, research service providers and recycling management consultants.

The cooperation of all partners in „SENSE BAY“ takes place via semi-annual, open network meetings. These meetings will be expanded to a congress “KONSENSE – Safe Electric Energy Storages Systems Bavaria” at the halfway point and end of the project, that will provide information via lectures, exhibitions and thematic workshops to the general public. Moreover, participation in events (expert conferences, publications, lectures) is planned as well as a comprehensive digital appearance together with print media. ■

For efficient cooperation, innovation clusters were formed on the following topics:

- Battery development
- Testing
- Measurement Technology
- Application/Recycling

The project “SENSE BAY - Safe Electric Energy Storage Systems Bavaria” is funded by:

EFRE BAYERN 2014–2020

European Regional Development Fund

Authors:

Christoph Nebl
Technical Head of the technology field „Safe Electromobility“
Christoph.Nebl@carissma.eu
+49 841 9348 1491

Daniel Koch
Research Associate
Daniel.Koch@carissma.eu
+ 49 841 9348 6504

Dr. Katja Brade
Lecturer
Katja.Brade@thi.de

Prof. Dr. Hans-Georg Schweiger
Head of the technology field „Safe Electromobility“
Hans-Georg.Schweiger@thi.de
+49 841 9348 4500

Electric has gone Audi.

The all-electric Audi e-tron is here.

Audi Vorsprung durch Technik