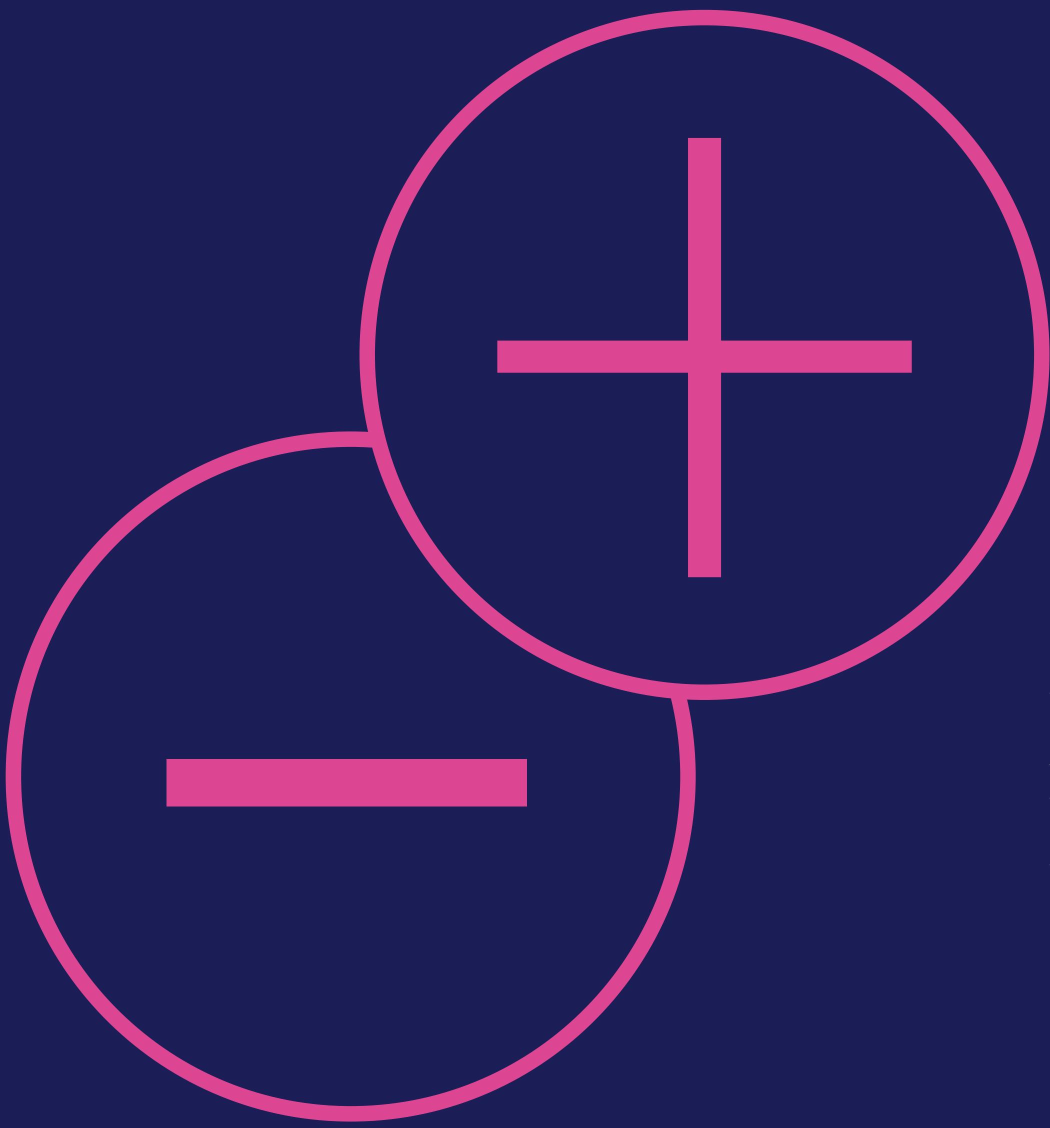
02

forward

The IAV magazine about the future of mobility



Interview
What security risks does AI pose and what does it take to trust it? One of our experts answers these questions.

Smart change for good cooling
Effective heat dissipation in the electric drive.

Skid marks in the air
New test center for brake particles.

Tension. We promise.

"We develop sustainable mobility for our customers. A mix of smart drive, vehicle and mobility concepts is needed to maximize our contribution to climate protection."

Dear Readers,

Public acceptance of e-mobility depends to a large extent on further progress in battery development, especially in terms of costs, range and charging times. At IAV, we built up in-depth expertise in the key technology for e-vehicles at an early stage and will continue to play a key role in shaping further developments in the future.

Want some examples? At our Smart Test Factory in Stollberg, we have set up a new test center where HV batteries can be tested in a cost- and energy-saving manner. Before we start developing a battery, we carry out a comprehensive life cycle analysis with precise evaluation and subsequent recommendation to the OEM (page 25).

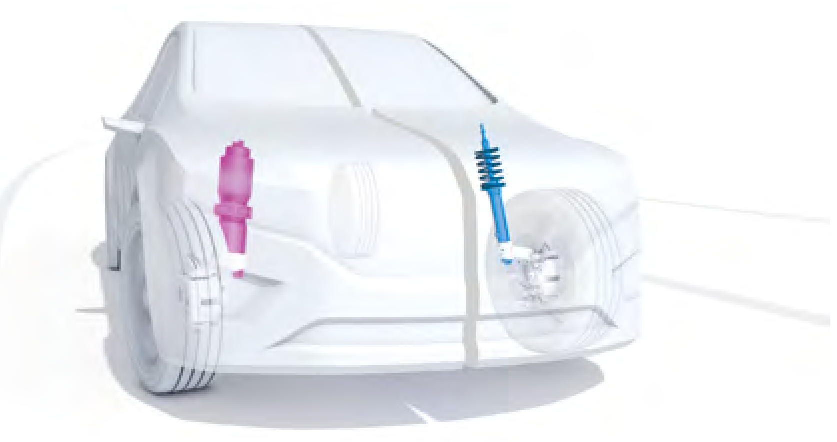
Not only the battery, but the entire drive system of an e-bike developed by IAV benefits from innovative phase-change cooling (page 30). We round off the topic of e-mobility with further interesting articles on thermal management (page 20), NVH (page 34) and a "health check" for fuel cells (page 44).

The potential of artificial intelligence is currently being evaluated and tested across all industries. At IAV, AI is now firmly established in development and customer projects. To read about the risks of AI and what it takes to trust it – see the exciting interview with one of our AI experts (page 8).

Last but not least, this issue also contains exciting articles on topics such as virtual chassis development, a new test center for brake emissions and alternative fuels.

I wish you an inspiring read!

Thomas Müller
Executive Vice President Powertrain Systems



18 Big leap in riding comfort

They are better than their reputation: together with Hyundai Motor Europe Technical Center, IAV has developed a method that optimizes jaw clutches to such an extent that gear changes are barely perceptible.

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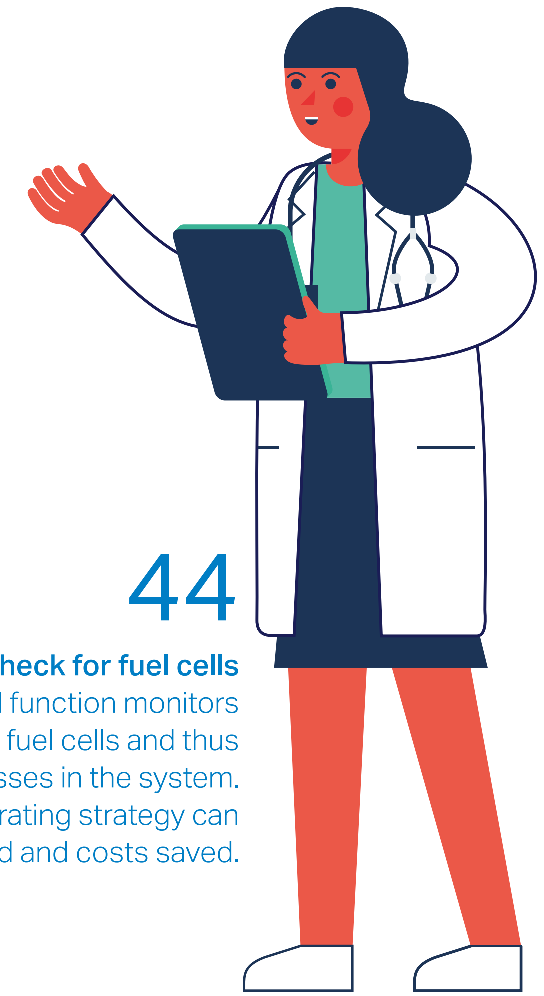
How do you bring smart concepts from science directly into the vehicle? The collaboration from IAV together with Technical University Darmstadt, a research institute and its technology consultant provides the answer - based on of two brand new chassis components.

25 This battery thinks of everything

High energy density, short charging time, low power loss in cold conditions. In addition, cheap and available raw materials, a sustainable design and a small ecological footprint. How does this work? With the “Twin Battery” concept from IAV!



44 Fitness check for fuel cells

A software-based function monitors the health status of fuel cells and thus prevents power losses in the system. As a result, the operating strategy can be improved and costs saved.

Impulses

Home straight reached

At the end of last year, the most important EU bodies agreed on the framework for the new Euro 7 emissions standard. However, the details and implementation regulations for some of the topics, such as on-board monitoring (OBM) for monitoring exhaust emissions or manipulation protection, have yet to be defined.

Nevertheless, even if much about Euro 7 is still up in the air, IAV as a development partner is prepared for all innovations. Whether OBM, upper limits for particles from tire and brake abrasion, durability of traction batteries or tamper protection for vehicle components – IAV has built up in-depth technological and methodological expertise in all relevant areas.

We are ready to play a key role in shaping the further development of these topics in the future and to develop Euro 7-compliant solutions. Please contact us if you are interested!

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SLOWED DOWN

For more safety in truck-based freight transport: IAV and TU Berlin have developed a method that allows heavy commercial vehicles to brake even more safely by evaluating weather data and existing sensors on board.

In two years of research work, both partners have developed the technical basis for a new driver assistance system as part of a research project.

This allows the transmittable force between the tire and the road to be evaluated during driving and the driver to be warned of a reduced coefficient of friction. The highlight here is that no more sensors are required than are already on board. Only weather data is brought into the vehicle and evaluated via software.

IAV and TU Berlin have built up an extensive database on a wide range of brake tests and have also considered data from over 8,000 braking maneuvers. If developed further, this method could be used in highly automated commercial vehicles.

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Healthy vehicle fleets?

Car manufacturers want to assess the condition of their car fleets in the field to be able to estimate failure risks. The advantages are manifold – maintenance can be carried out in line with demand, the stocking of spare parts can be better planned, and quality cost forecasts can be made more precisely. IAV has demonstrated in two applications how system failures can be predicted using probabilistic models.

In the first case, the course of a health indicator was predicted with a view to the remaining service life; in the second case, component failures were predicted based on observed failure data. The second application in particular enables OEMs to identify the risks of certain components and act. The core of IAV's patented process is the use of probabilistic models that combine the advantages of machine learning and statistics. Both methods have been implemented as a cloud service so that simple, scaled use is also possible for non-experts.

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How safe is artificial intelligence?

Dr. Mirko Knaak, Senior Technical Consultant for Artificial Intelligence at IAV, talks about the risks of artificial intelligence and explains what it takes to trust it.

Can artificial intelligence (AI) manipulate people and technology?

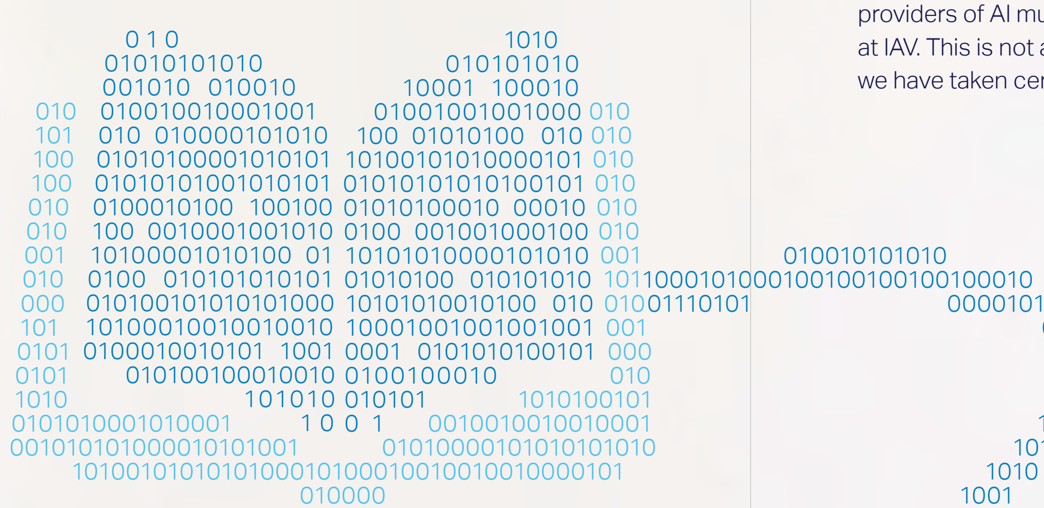
An AI has no free will. That is why it cannot manipulate humans or technology on its own. Of course, humans can use them to manipulate, but such AIs will be banned in Europe as soon as the EU Artificial Intelligence Act comes into force.

Nevertheless, the fear remains that the AI in the autonomous vehicle has been manipulated and the car will become uncontrollable. Is that realistic?

The fact that an AI can be manipulated is a well-known and now well-documented phenomenon in research. Manipulation can succeed in object recognition for autonomous driving, for example, if someone sticks specially designed stickers on road signs that humans cannot distinguish from conventional stickers. As a result, the AI can get confused and do exactly the opposite of what it is supposed to do. This is because the stickers create very specific patterns and exploit the AI's weakness. This is what happens with adversarial attacks.

In which situations is it problematic that an AI cannot read the context and reproduces a distorted image?

An AI only learns by memory what the data records contain and tries to recognize patterns in the data. This can quickly become problematic. Let's say I want to write a CV for the engineering profession and train the AI with the data of all employees of an engineering service provider. Without intending to do so, this results in a bias. The bias occurs because in many companies there are significantly more men than women working in the engineering profession. The system then learns that being male is a criterion for getting a job.



How can developers avoid the ethical bias in the example?

As an AI developer, I must always assume that such ethical issues will arise and actively counteract them. There is now research and measures that document how to work specifically and consciously against this.

How does this happen at IAV?

This is less important for IAV and our fields of activity because we use AI in many cases to assess the service life of parts. We examine the failure probabilities of various components and try to detect anomalies in the data. As a rule, no ethical bias arises in the process.

If IAV comes across data that could be discriminatory, we are naturally very attentive. For example, one of our engineers noticed that restraint systems in the vehicle are geared towards a standard man. He wanted to change this and initiated a project to achieve the safety of all occupants in the vehicle. Interior cameras and AI estimate gender and age to adapt the restraint systems accordingly.

So, can we trust the judgments of an AI?

Trust is difficult, we should not do this unconditionally. In many cases, we already trust an AI today. Who takes a map with them when a navigation system is available? However, as soon as life and limb are at stake or other risks emanate from AI - which, as we have seen above, can easily happen - we developers and the providers of AI must safeguard them. This is also a central point at IAV. This is not a sure-fire success. We can only trust an AI if we have taken certain measures.

What measures is IAV taking in this regard?

We addressed the challenges and opportunities arising from the use of AI technologies at an early stage. As early as the last AI hype in the 2010s, IAV initiated various research projects with renowned university and Fraunhofer institutes to investigate the security and explainability methods of AI systems. We were able to draw on many years of expertise in functional safety and advise companies in this field. This experience has helped us to develop a validation process and a toolbox that are consistently used in projects and are also available to customers.

What does IAV's own hedging process involve?

We start the safeguarding process as early as the requirements elicitation stage. We consider not only the requirements of the overall system, but also specific risks of the AI for specific situations. We set requirements for the data, as the AI can only do what was contained in its training data. We also set requirements for the AI itself, such as self-monitoring or the use of an emergency solution in unexpected situations. Environmental components and the use of the AI also have corresponding requirements. The IAV Toolbox enables us to check this process in a highly automated manner.

What does IAV do in terms of standardization?

We are very active in various standardization committees in Germany and are working with many employees to make AI safe. For example, there is the DIN initiative, the German AI standardization roadmap. IAV is working on various ISO standards here.

Can IAV succeed in making an AI safe all by itself?

No, nobody can do it alone. It can only be achieved by working together. That is why we have created a Safe and Secure Community to bring together the needs of stakeholders, regulators, industry and users. If we proceed in this way, we can build an AI that we can trust very well in certain use cases.

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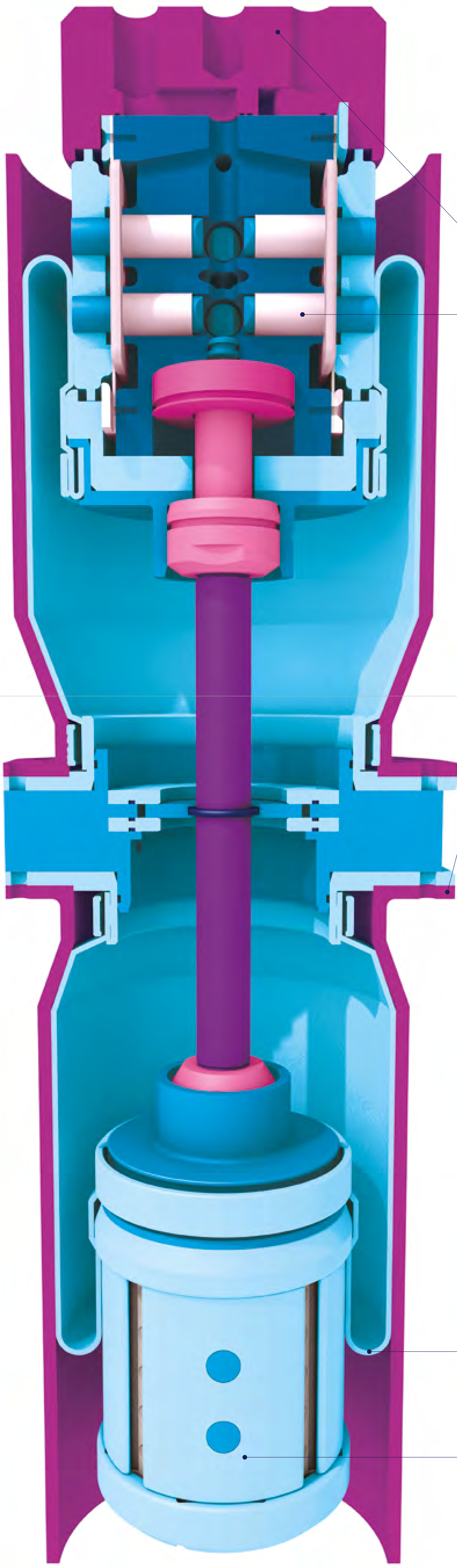
A matter of cooperation

How do you smartly combine vision with implementation? IAV's cooperation with TU Darmstadt, one of its research institutes and its technology consultant shows how innovative university concepts can be applied directly in the vehicle.



In essence, it is about the chassis, one of the most important areas in the vehicle, which includes all the components that connect the car to the road. This includes dampers and springs, whose job it is to keep all parameters relating to driving safety and comfort in perfect balance.

"Vertical dynamics is always about finding the optimum compromise between safety and comfort", says Dr. Mark Wielitzka, Senior Specialist in the Chassis Systems & Engineering Support department at IAV. "Both variables are in permanent conflict with each other. We developers go to great lengths to find the optimum solution for each individual vehicle."

Two brand new suspension components

The Institute of Fluid Systems Technology (FST) at TU Darmstadt has developed two completely new components with an actively controlled air spring and a passive fluid dynamic damper for different vehicle segments, each of which has a different effect on the suspension and damping of the body. The active air suspension system enables significantly greater improvements in driving safety and comfort.

With the increasing electrification of drive systems and changing mass distribution in electric vehicles, new demands are being placed on chassis tuning. In addition, the perception of the actual driving experience and the car passengers' awareness of comfort are increasing, particularly due to the elimination of engine vibrations in electric cars.

"The issue of riding comfort is certainly a driver of demand for air springs, because they decouple noise and vibrations between the wheel and the body and thus enable a comfortable ride", says Niklas Puff, research associate at the FST.

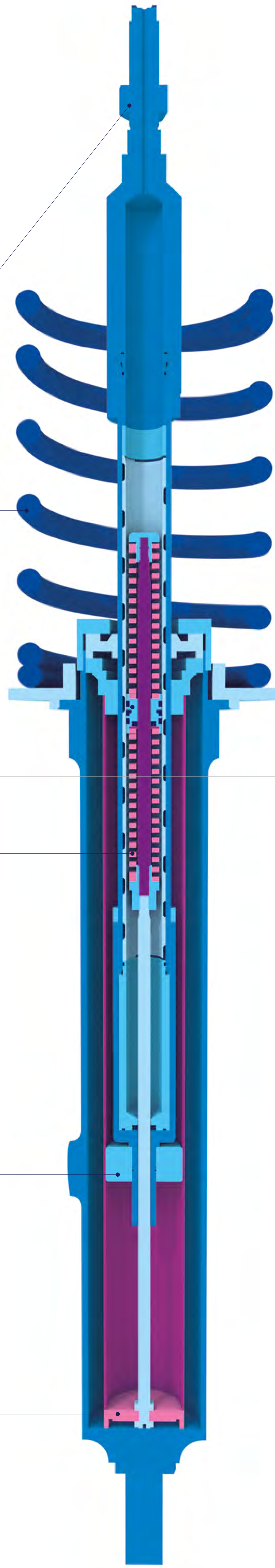
The FST founded Industrial Science GmbH to transfer its expertise, particularly on methods and technologies, to industry. IAV has been cooperating with Industrial Science for years – both have worked together on a wide variety of projects, for example on wind energy, cooling pumps for vehicles, medical technology, and project management software. IAV relies on its application expertise to make university knowledge usable for companies.

Target-oriented cooperation for all parties involved

"No company has sufficient resources or the staying power to drive forward such complex topics in depth", says Ingo Dietrich, Managing Director of Industrial Science. "That's why this cooperation is beneficial and expedient for everyone involved."

The Berlin-based tech solution provider is contributing its expertise in system integration and complete vehicles to the ongoing project. IAV has integrated the chassis components developed by FST as digital twins in a virtual complete vehicle and carried out a wide range of tests with a view to optimizing the conflicting goals of safety and comfort.

Of course, IAV also considers possible malfunctions that can occur while controlling an active air suspension system, as well as their possible effects and how they can be overcome. Essentially, the aim is to holistically examine an overall package for possible series development and to evaluate functional safety issues at an early stage.



Link between research and OEMs

"We are the link between research and industry", says Dr. Marcus Perner, Senior Specialist in the Chassis Systems & Engineering Support department at IAV. "We take concepts straight from research and test them together with the OEM. This is a kind of door opener for the components."

Already last year, there was a direct exchange with representatives of the automotive industry on the advantages of the new components when IAV and FST jointly presented the technology at the International Munich Chassis Symposium "chassis.tech plus", where it attracted a great deal of attention. IAV was also present there with a specialist lecture and its own exhibition stand.

Of particular interest to those involved was the innovative approach by which the load-bearing capacity of the air suspension is actively adjusted during operation.

Of the available options, FST and Industrial Science opted for an active change in the effective area of the air spring. "This allows the greatest forces to be applied in the least amount of time", says Dietrich. "From our point of view, this currently gives us a unique selling point."

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Big leap in riding comfort

Dog clutches have a bad reputation when it comes to driving comfort. Wrongly so, as a joint project by IAV and Hyundai Motor Europe Technical Center shows. Using a new method, they can be optimized so that gear changes are barely noticeable.

They are simple in design, lightweight and inexpensive, and can be easily synchronized with an electric motor: dog clutches. For that reason, they would be an attractive option for use in e-vehicles, but they are considered to be prejudiced regarding the driving experience.

"With every gearshift, there is a brief interruption in tractive force and often a synchronous impact, which the passengers perceive as a jerking or clicking noise", reports Felix Matthies, Team Leader Modeling & Simulation Systems at IAV. "Together with Hyundai Motor Europe Technical Center, we have therefore developed a method to optimize dog clutches in terms of drivability at an early stage of development."

The dog clutch model developed by IAV is very detailed yet can be calculated quickly – and is therefore suitable for the many millions of iterations required for optimization. It is integrated into IPG Automotive's CarMaker simulation environment so that developers can realistically simulate not only the behavior of the clutch but also that of the vehicle. "The INCA Flow TDT (Transmission Driveability Toolbox) developed by IAV is used to evaluate the riding comfort of each simulated clutch variant", explains Matthies. "It provides us with key figures by which we can objectively evaluate riding comfort."

Parallel development of hardware and software

During the methodology project with Hyundai Motor Europe Technical Center, experts from IAV simulated millions of clutch variants and continuously refined the contours of the teeth. At the same time, software and hardware were precisely coordinated. The result was a dog clutch in which the interruptions in tractive force were barely noticeable – thanks to the perfected hardware in combination with software that had also been optimized.

The dog clutch was produced as a prototype and has sufficiently proven its roadworthiness on the test bench and thus, the efficiency of the virtual development method. The best prerequisites for changing the image of dog clutches soon.

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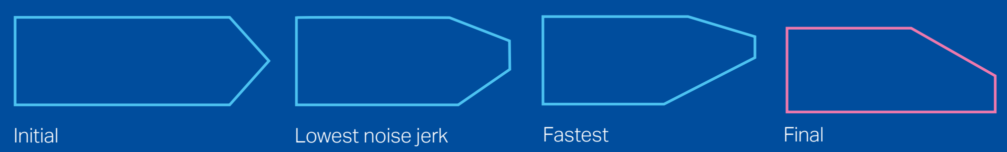
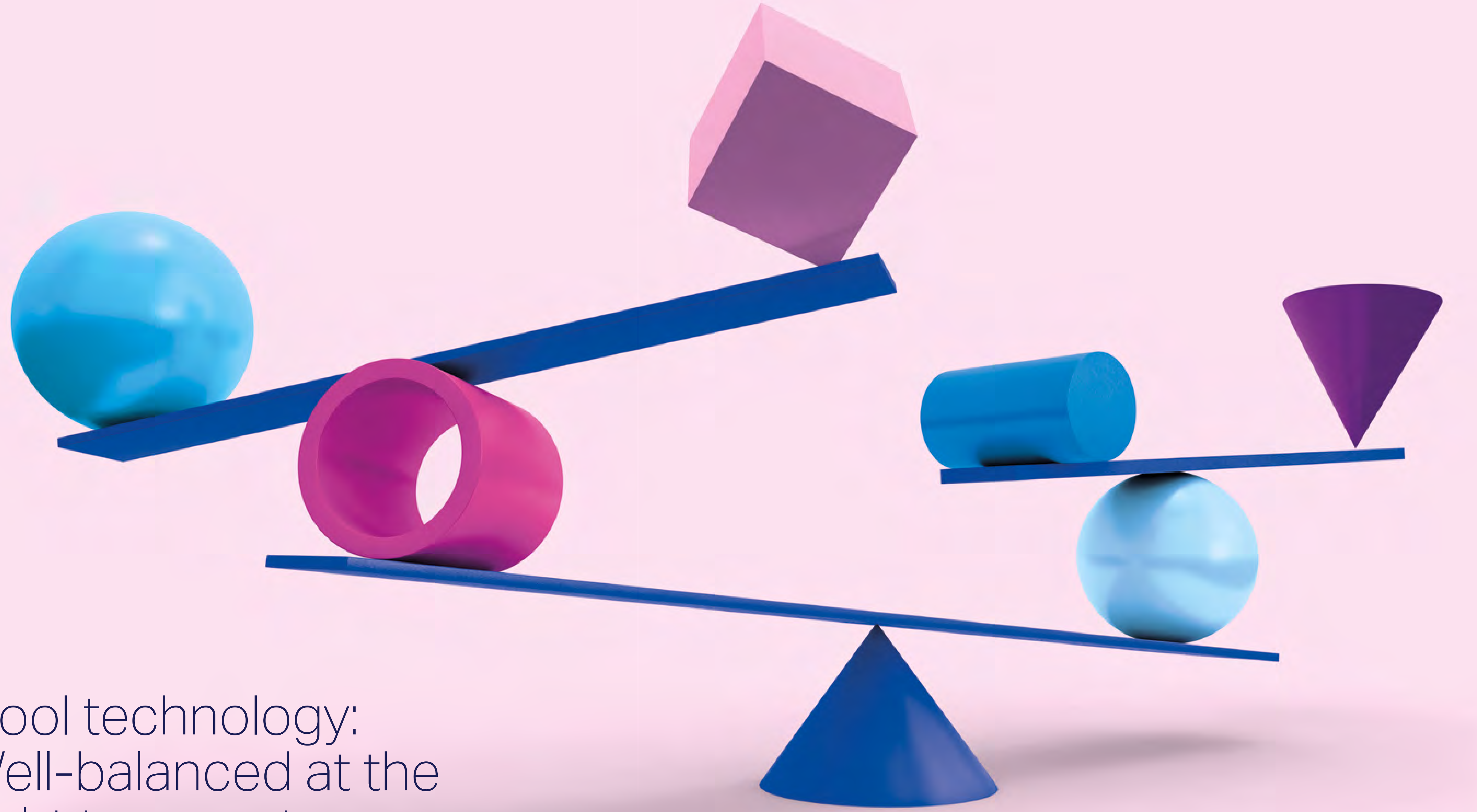
Tooth Designs



Evolution in the project: refining the tooth contours to achieve the perfect dog clutches



Cool technology: Well-balanced at the right temperature

Short charging times at the charging station and long ranges on the road: this is what advanced thermal management can do. Four thermal management experts from IAV know how the technology optimizes the temperature of the battery and ensures that the car is pleasantly warm.

Why do we need thermal management in vehicles?

Vehicles require thermal management systems in order to operate components within their optimum temperature range. If these systems did not exist, they would overheat and eventually stop working. For this reason, we need to cool and condition them. Conditioning means getting the components to their operating temperature as quickly as possible and then keeping them there.

Where exactly does thermal management take place in the car?

At low temperatures, for example, it is necessary to bring the High Voltage (HV) battery into its comfort zone. Thermal management also has the task of keeping the vehicle cabin at the right temperature. As the technology keeps the windows free of ice and fogging, it is also relevant to safety.

What are the challenges of conditioning electric vehicles?

Vehicles with classic combustion engines use the waste heat to heat the interior. The electric drivetrain cannot do this – due to its high efficiency. Electric vehicles draw their energy from the battery, which competes with the drive and range of the vehicle. Compared to combustion engines, the range of electric vehicles is generally shorter anyway, which is why it is even more important to optimize battery efficiency in order to achieve maximum performance and range. In addition to the vehicle cabin and the electric drive, the electric axle and future ADAS systems must also be conditioned in the electric vehicle. The target temperatures of the components differ significantly in some cases.

What influence does thermal management have on the range of electric vehicles?

Thermal management has a direct and indirect influence on the energy consumption of an electric vehicle. The direct influence arises, as described, through the vehicle's own consumption in competition with the drive energy. Indirectly, thermal management influences the temperature control of the components in order to improve drive efficiency. In the long term, this also minimizes battery ageing and thus the loss of range.

Thermal management is a challenge in both summer and winter. How can the battery withstand extreme temperatures?

First of all, the cost-intensive traction battery in electric vehicles requires careful treatment. In winter, too low a battery temperature can lead to reduced performance and even ageing, so fast and even temperature control is important. During fast charging in summer, the thermal management system must ensure that the heat is efficiently dissipated from the cells to the cooling medium. A sophisticated operating strategy enables heat to be absorbed and released as required so that both normal operation and extreme loads can be managed in an energy-efficient and component-friendly manner.

What does IAV offer customers in thermal management?

We develop partial or complete systems for vehicle powertrains and interiors that need to be heated or cooled. We try to design the best thermal management system for the customer's specific needs. This requires testing of the entire refrigeration and cooling system as well as the individual components to ensure efficient cooperation. We also use tools and methods to harmonize the multitude of thermal systems in a vehicle-specific manner. In the concept phase, the tool can support the design of the thermal management system by generating the optimum system using a genetic algorithm. In addition, we use physical simulation environments to evaluate the various systems.

What changes can be expected in thermal management as a result of autonomous driving?

Autonomous driving poses new challenges for thermal management, as the decelerated driving style influences the temperature control of the components. At the same time, the higher computing power of the system requires more cooling, which can be achieved through systemic or component adaptations. We can achieve further efficiency benefits through predictive control of the climate control and targeted use of interactions between the drive and thermal management. Another factor is the external sensors, which can become dirty or iced up. We are working on addressing these issues as part of a project.

Sensor cleaning, that sounds exciting. What exactly is it about?

In this project, we are developing a sensor cleaning system for lidar and radar sensors as well as for cameras in order to ensure unrestricted sensor use in an autonomous vehicle. We are also working on how to keep sensors free of dirt, ice and snow. In this way, we contribute to the functionality of the vehicle as a whole.

What challenges do you still face in the future?

It is becoming apparent that refrigerants based on perfluorinated and polyfluorinated alkyl compounds (PFAS) will be banned throughout the EU. This is a major challenge for OEMs because they will have to fall back on natural refrigerants as alternatives. In all likelihood, these will be CO_2 (R744) and propane (R290) as refrigerants. The former refrigerant circuits are characterized by a significantly higher pressure level, while the higher safety requirements for the latter lead to increasing system complexity. We have already received many inquiries and initial projects for new developments and are working on solutions ready for series production. This will be a strong focus in thermal management at IAV over the next few years.

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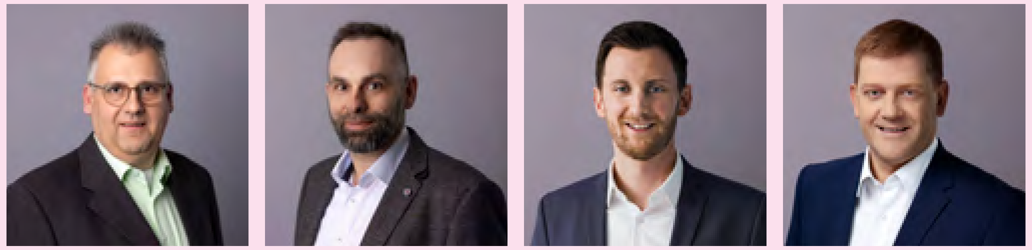

The questions were answered by:
Michael Brieskorn, Department Manager Climate System Development,
Thomas Einzinger, Department Manager Thermal System Development,
Dr. Matthias Steinsträter, Project Manager Thermal System Development, and
Ronny Mehnert, Head of Department Energy Management Powertrain.

This battery thinks of everything

Ecological and economic efficiency is a decisive factor in battery development. IAV demonstrates the implementation of a systematic life cycle analysis (LCA) as an effective tool for assessing the potential environmental impact of a new product in a structured and qualified manner right from the start.

Li

When developing new vehicle batteries, various requirements must be reconciled. Besides their performance – in other words technical parameters such as power, storage capacity or charging time – sustainability also plays a key role. Thus, IAV carries out comprehensive life cycle assessments (LCA) before the start of development work.

"For us, sustainability has two dimensions – an ecological and an economic one," says Panagiotis Grigoriadis, Team Leader Sustainable Solutions at IAV." In the ecological assessment, we examine factors such as greenhouse gas, acidification and abiotic resource depletion potential as well as toxicity for humans and the environment. In the economic assessment, we look at possible risks such as the origin of raw materials and their availability, as well as the costs of implementing sustainable solutions."

In steps to the LCA

The first step in a life cycle analysis is to define the scope of the study. Key points are the definition of the system boundary and the functional unit. The product system to be examined (HV battery system) is defined and described in more detail, followed by the life cycle inventory. Here, IAV experts collect and calculate the inputs and outputs of the system.

"Inputs are, for example, energy as well as raw and auxiliary materials for the production of batteries. Outputs include cells, the emissions generated during the manufacturing processes or complete battery systems", explains Manfred Prüger, LCA expert at IAV. "The challenge in this step is to find valid data for these inputs and outputs." For this, IAV partly uses its own databases, which rest on simulations using electro-physicochemical models of the battery cells. Other data comes from external sources.

	Lithium-Ion Battery	**Twin Battery**
Chemistry	Graphite anode / NMC811 cathode	SIB: HC anode / PBA cathode SSB: Lithium metal anode / LFP cathode
Energy density (cell level)	265 Wh / kg 800 Wh / l	220 Wh / kg 500 Wh / l
System voltage	800 V	800 V (800 V SIB and 400-V SSB with DC / DC converter)
Architecture	6 modules, 100 cells per module Uniform pack housing (~ 1.85 / 1.35 / 0.13 m)	8 SSB modules, 30 cells per module 2 SIB modules, 250 cells per module Uniform pack housing
Energy (net)	79 kWh ~ 13 kWh per module	79 kWh total ~ 29 kWh SIB and ~ 50 kWh LFP SSB
Mass	Battery: ~ 450 kg / Single cell: ~ 530 g	Battery: ~ 600 kg
Cell geometry characteristics	Cylindrical (H: 100 mm, D: 46 mm)	SIB: Cylindrical (H: 120 mm, D: 46 mm) SSB: Pouch (L: 600 mm, W: 115 mm)

This is followed by the impact assessment, for which, for example, the greenhouse gas emissions during battery production are calculated on the basis of the underlying electricity mix. The final step is an evaluation and recommendation to the OEM as to which battery technology is the optimum solution for a particular vehicle from a technical and sustainability perspective.

Innovative "Twin Battery"

In a contribution to the Vienna Motor Symposium 2023, IAV showed what this could look like in concrete terms. The aim was to determine the optimum battery technology for a mid-range vehicle – whereby, in addition to high energy density, short charging times and low power loss in cold conditions, the use of inexpensive and readily available raw materials, a recycling- and repair-friendly design and the smallest possible ecological footprint during production were also required.

Three technologies were compared for this purpose: lithium-ion, sodium-ion and solid-state cells. The technical investigations and life cycle analyses ultimately led to the innovative concept of a "twin battery", which combines sodium-ion and solid-state modules and can therefore combine the best of both worlds: the high energy density of solid-state batteries and the benefits of sodium-ion batteries, such as fast-charging capability and low power loss in cold conditions.

Equally innovative is the thermal management concept in question, which uses the waste heat from the sodium-ion cells to bring the solid-state cells up to operating temperature. "But the Twin Battery is also the winner in terms of environmental impact," says Alexander Fandakov, head of the Twin Battery pre-development project. "Although its greenhouse gas and abiotic resource depletion potential is slightly higher than that of lithium-ion batteries, it performs significantly better in all other categories."

According to the experts, such life cycle analyses should always be carried out at the beginning of battery development. IAV offers its customers a comprehensive service – because besides exclusive databases and in-depth battery expertise, the company can also support its customers in the development of a new battery system once an LCA has been completed.

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Smart change for good cooling

Reduce costs for electric drives and improve their eco-balance? IAV has developed an innovative cooling process that reduces the installation space and mass of the electric motor as well as the use of permanent magnets – while maintaining efficiency and performance.

E-machine concepts usually rely on a cooling jacket with water flowing through it, which surrounds the stator of the electric motor. However, due to constantly increasing motor performance, it is no longer possible to dissipate all of the machine's waste heat in this way – new cooling concepts are required.

At last year's "Aachen Colloquium Sustainable Mobility", IAV outlined what the cooling technology of the next generation of electric vehicles could look like. With the target vision of a sustainable and holistic vehicle concept, IAV presented the design for a significantly cost-reduced e-drive unit (EDU) with high efficiency and sustainability.

Phase-change cooling is key

The core of the fully tested and functional concept is the innovative application of phase-change cooling (PCC) in e-traction.

"We bring the fluid in the e-machine and in the inverter circuit to boiling point and use the evaporation energy very effectively for cooling", says Dr. Christoph Danzer, Head of E-Axle Concepts & Design at IAV. "The phase change allows us to dissipate significantly more heat than with normal liquid cooling without phase change."

Thanks to active use of the technical possibilities of the PCC, possible overheating of relevant components can be avoided, and the installed power and torque of the electric motor can be called up in full – a first for the e-drive to date.

"In this way, e-drives that are designed for continuous performance can be built more compactly for the same performance", says Danzer. "Because the drive is better utilized thermally, the electric motor can be made smaller for the same torque and the inverter also requires less power for the same performance over the long term."

Savings in costs, weight and CO_2

IAV's concept enables a cost-effective and sustainable e-drive system with high system efficiency for a mid-range SUV. The size of the electric motor can be reduced by 30 percent and its CO_2 footprint by 11 percent, resulting in cost savings of 8 to 10 percent.

For the application of PCC, IAV has investigated various technologies, for example aluminum windings and alternative magnets such as ferrites, to determine which materials harmonize best with PCC. The PCC-based process promises great potential especially for commercial vehicles and sports cars where more efficient cooling yields a decisive advantage for drives operating close to full load.

"We want to further strengthen e-mobility and contribute to making e-drives even more efficient, cost-effective and sustainable", says Danzer. "We are not only interested in applications and engineering, but also in preliminary developments for future generations of e-cars."

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Always under full load

An e-bike from IAV regularly outperforms conventionally powered machines at racing events. Part of the recipe for success is its innovative phase-change cooling system.

Thomas Arnold has been competing in motocross and Enduro races in his spare time for many years. The great thing is that the IAV Team Leader Engine Concepts & Mechanics has recently been on the podium much more often than before. Besides his riding skills, it is his bike that makes the difference: Arnold has been racing for around two years on an e-bike that regularly makes his rivals look old.

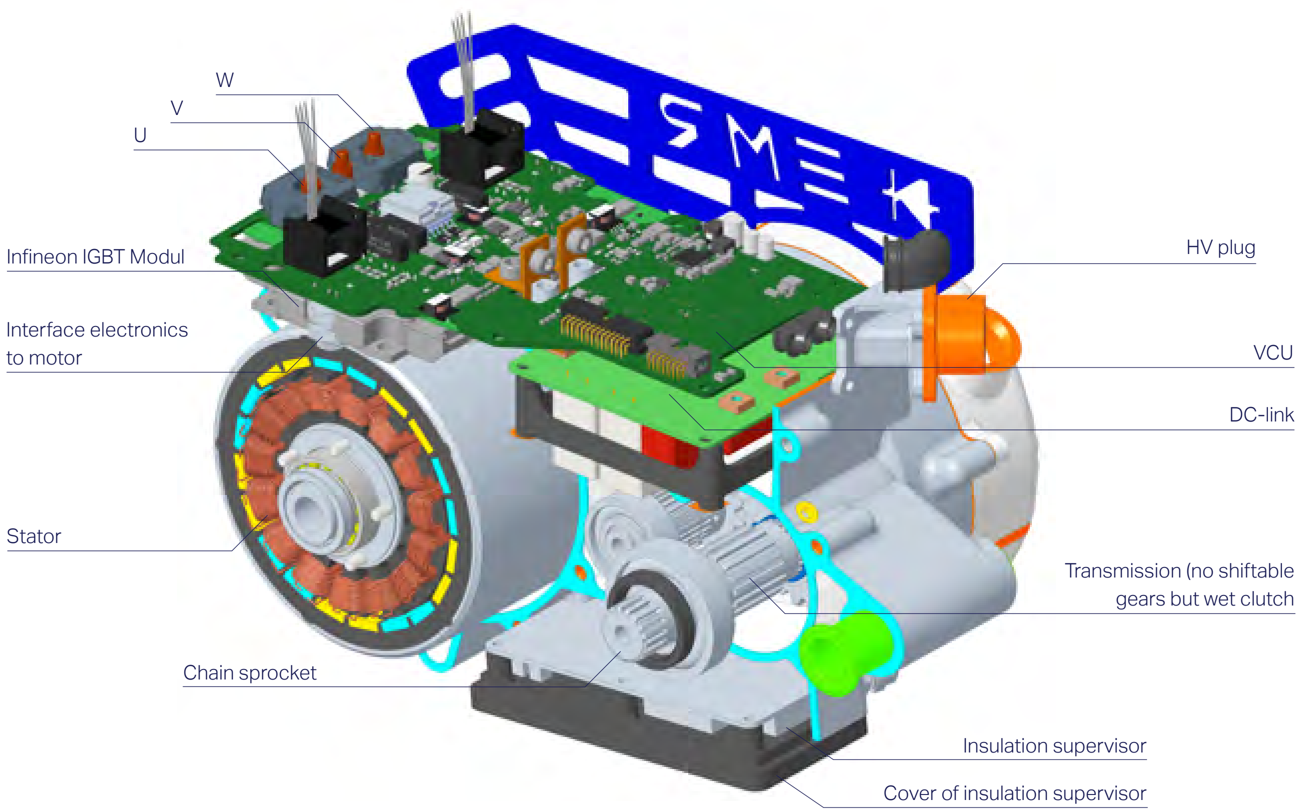
The electric motorcycle is based on a Honda chassis for which Arnold has developed a customized drive system. The high-voltage battery made from cylindrical lithium-ion cells supplies 370 volts and has a capacity of five kilowatt hours. It provides sufficient energy for short races of 30 minutes. For longer distances, the battery can be replaced with another in just a few simple steps.

The electric motor, which was also developed in-house, delivers 54 hp and a maximum torque of 55 Newton meters from 0 to 7,500 revolutions per minute. "The e-bike also has no gearbox, so there are no shifting times," explains Arnold. "Hence, there is constant tension on the chain." This is how the system engineer manages to leave even better riders behind in races time and time again.

Phase-change cooling in the electric drive

The technical highlight of the e-bike is the innovative phase-change cooling of the electric motor, power electronics and battery. The cooling medium extracts heat from the hot components through evaporation, which is then released into the environment via condensation. Due to the large temperature difference to the ambient air, the radiator could be designed smaller.

Highly integrated electric powertrain



Above all, however, Arnold can operate the electric motor continuously at full load thanks to good cooling – instead of only at around half its maximum power, as is usually the case. The concise formula for this is "peak power = continuous power". "With conventional cooling, I would have needed a 100 hp motor for the same performance," reports Arnold. "This would have significantly increased the weight and the required installation space."

The innovative e-bike is already proving itself in its second season and has around 300 hours of racing behind it. "The technology has delivered a convincing performance in real life – in other words, off-road and not just on the test bench", says Matthias Krause, Department Manager Future ICE at IAV. For him, the electric motorcycle is also a good opportunity to present innovative technologies that IAV otherwise focuses less on.

"This applies in particular to the possibilities of phase-change cooling, which we have been working on intensively over the last few years," says Krause. Thanks to Thomas Arnold's racing successes and the numerous trade fair appearances of his e-bike, their level of awareness should soon increase significantly.

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"You get to know your limits better through sport."

Three questions for Thomas Arnold, motorsport amateur and IAV team manager

How and when did you get into racing?
"I've been racing motorcycles since 1999. I got into it through my father and grandfather. We live in the Erzgebirge in a region that was already very strongly associated with enduro racing in the GDR era and still is. The MZ Zschopau motorcycle factory is only 20 minutes away from my hometown. A lot of people are involved in racing here – it's simply part of this region."

How do you incorporate your racing experience into your work at IAV?
"As an ambitious amateur athlete with a healthy attitude to challenges and self-reflection, you can also achieve a lot in your job. Through sport, you get to know your personal limits much better and find out what you can't do. In competition, it ultimately comes down to you – you can't blame anyone else for your mistakes. Things like self-reflection and planning are trained over the years – which of course also helps enormously in working life."

What other goals do you have in racing?
"This year I want to become German cross-country champion on my motorcycle. This is a series of races throughout Germany. I took part in two of these races last year and was right at the front. That would be a nice addition to my past activities. In 2009, I took part in the "Six Days" in Portugal for Team Germany, plus four or five times in Romania at the biggest and longest "Hard Enduro Rally" in the world, twice at the "Erzbergrodeo" and at many other events, for example in Italy and the Czech Republic."

Sound of Silence

E-drives lack masking engine noise, so the transmission in particular comes to the fore acoustically. To minimize noise and vibration problems, IAV uses state-of-the-art simulation methods for NVH – and thus saves valuable time and money.

Whether it is the smallest parts, such as the gear teeth of an electric axle, the acoustics of an electric machine or the bearings and mountings of electric motors - there are numerous sources of noise and vibration problems (NVH) in electric drives that have a greater or lesser impact on the driving experience and the perception of quality.

To solve these problems, IAV links production and development processes using simulation tools with the aim of minimizing the effort involved in troubleshooting before the start of production and thus shortening a product's time to market.

"We want to offer genuine service solutions by incorporating production-relevant information into development and thus accelerating the relevant processes", says Marcus Morgenstern, System Simulation Engineer in the NVH Powertrain Integration team at IAV.

Significant cost and time savings

In an investigation of test gears for a transmission for electric vehicles, for example, IAV synthetically generated a wide variety of toothing surfaces and successively calculated the data in a specially developed simulation tool to draw conclusions about the influence of manufacturing tolerances on transmission noise.

"Our methods are highly precise in their implementation", says Ronny Mehnert, Head of Powertrain & E-Traction Simulation at IAV. "They can significantly reduce future development costs and at the same time effectively address the issues of sustainability and availability of prototypes."

According to Morgenstern, it takes between six and eight weeks from the time a decision is made to produce prototypes of components to their manufacture and use, which can be completely saved by using simulation. In virtual development, only the parameters are changed until a desired configuration is found.

No trial and error

"This is not trial and error, but a targeted and sustainable way of saving prototypes and reducing development costs", says Mehnert. "At the same time, reliable test results are available on the same evening."

Whatever passengers expect from the background noise in an electric car depends heavily on the vehicle class and the target group. IAV is actively contributing its NVH expertise to customer projects with demand currently stemming primarily from the premium segment, according to Mehnert.

However, integrated NVH and acoustic solutions are not only offered by IAV, but also by the competition. What sets IAV apart from rivals, however, is the fact that the Berlin-based tech solution provider takes a holistic approach to NVH development i. e., it covers all relevant areas from conception to structural design and virtual validation through to special tests.

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Together with Poppe + Potthoff, IAV has developed a High-Pressure Regulation Unit (HPRU) for hydrogen engines and fuel cells. In this interview, Christian Willem (Head of Strategy and Innovation at Poppe + Potthoff) and Steven Schulz (Project Manager Fuel Systems at IAV) look back on the collaboration.

“Our approach was absolutely right”

Why did Poppe + Potthoff decide to develop a new HPRU together with IAV?

Christian Willem: The starting point for our considerations was the megatrend of “decarbonization”. It was clear to us that the business with components for diesel engines would decline in the future. In our search for new markets, we asked ourselves: What innovative products can we offer with our expertise and existing production facilities? That’s how we came up with the High-Pressure Regulation Unit – because it bridges the gap between two systems: the hydrogen engine or fuel cell on the one hand and the high-pressure hydrogen tank on the other. The HPRU reduces the pressure of 700 bar in the tank depending on the current requirements of the hydrogen engine or fuel cell. Thus, it is crucial for the performance of the overall system. Thanks to our extensive expertise in common rail injection systems for diesel engines, we were confident that we could tackle the issue successfully and take a leap in innovation in this area.

How did the collaboration with IAV come about?

Steven Schulz: With this project, you always have to bear in mind that the HPRU is not an entirely trivial component. Although Poppe + Potthoff did indeed contribute a great deal of expertise from the diesel sector to our collaboration, handling hydrogen requires special knowledge, which we were able to contribute. IAV has been working with gas systems for more than 20 years, and we have been transferring our know-how from the development of diesel injection systems to this area for a long time. This makes so much sense because diesel injection systems have always operated at the limits of what is technically feasible and have used the best materials available. We were able to use this experience in the development of the HPRU to overcome the hydrogen-specific challenges.use this experience in the development of the HPRU to overcome the hydrogen-specific challenges.

Willem: At the beginning, there was an orientation phase during which we discussed our assessments of market developments. From this, we derived ideas for promising products. We came to the conclusion that the market for HPRUs is thin on the ground and that we could take the lead with an innovative product.

What exactly is the innovation in the HPRU?

Schulz: We have developed a completely new class of HPRUs for the hydrogen sector - moving away from an electromechanical and towards an electronically controlled solution. The starting point was the realization that the existing pressure regulators were not powerful enough for use in the hydrogen sector. Our aim with the new HPRU was to be able to satisfy not only current but also future market requirements. We have achieved this: the new HPRU can be used universally and is easy to adapt to most future applications.

Willem: It is important that the HPRU has a high control quality in both static and dynamic cases and therefore always provides the hydrogen combustion engine or fuel cell with the optimum pressure - even if the load requirements change and the tank empties over time. This is because, in contrast to the familiar mechanically operated pressure regulators, we can actively regulate to the respective load case. However, a distinction must be made between two cases here: The fuel cell prefers a constant pressure. A hydrogen combustion engine with intake manifold injection, on the other hand, requires between 3 and 15 bar, depending on the load case, and the variant with direct injection even requires between 25 and 40 bar. However, the new HPRU could also supply even higher pressures and is therefore also prepared for future developments.

How do you achieve the high dynamic control quality of the HPRU?

Schulz: By recognizing a step on the accelerator pedal and then immediately implementing a pilot control. We then know that a load demand is about to occur and can therefore increase the pressure quickly. This allows us to adapt very precisely to the engine’s requirements. A passive pressure regulator cannot do this - it has to wait until the pressure on the motor side drops before it can react. It therefore regulates afterwards, while we are able to act with foresight. In addition, the reaction of the HPRU is independent of the current pressure in the tank, which is why the control quality remains constantly high while driving.

What is the current status? And what is your conclusion of the project?

Schulz: We are currently investigating the A-pattern. The concept works as we expected. Our next step is to build the B-pattern, which will bring us one step closer to series production.

Willem: Our collaboration is not over yet. But as an interim conclusion, we can say that after two and a half years, we have achieved our goals and have been able to establish that our approach was absolutely right – as shown by the many customer inquiries for the HPRU from various sectors such as commercial vehicles or stationary applications. The market obviously wants a pressure control unit that works precisely and quickly. This is exactly what we can offer now. The always collegial and transparent cooperation between IAV and Poppe + Potthoff has made a decisive contribution to this success.

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Large engines almost emission-free?

Alternative fuels are also becoming increasingly important in shipping and industry to reduce CO_2 emissions from large engines and promote climate protection. IAV is working intensively on solutions for the use of sustainable fuels – also for non-automotive applications – with a focus on methanol.

The focus is on large engines for propulsion solutions in maritime and inland shipping as well as related industrial engines. Methanol is a practical and sustainable fuel solution for these areas of application, both in terms of production and use.

"Compared to bio-diesel fuels, methanol can be produced using a much wider range of manufacturing processes based on both biomass and green electricity", says Prof. Dr. Wolfram Gottschalk, Senior Technical Consultant in the Powertrain Calibration and Technology department at IAV. "At the same time, methanol enables largely particle-free combustion and offers a high nitrogen oxide reduction potential."

Automotive know-how

Because the use of methanol in the three application areas results in local CO_2 emissions, the overall climate-neutral balance of the energy source is particularly important.

"That's why IAV is also working on energy technology methods and the production side of methanol and hydrogen, for example", says Gottschalk. "This closes the circle between production and use."

IAV not only works for engine manufacturers and ship operators, but also deals with retrofit-in-service for marine and industrial engines. IAV has directly and successfully transferred its many years of method and process expertise from the automotive sector to new fields of activity.

Numerous projects with OEMs

The projects are diverse. For example, IAV is currently working with the Australian company Gane Energy to develop a monofuel methanol diesel combustion process suitable for on-and-off-highway engines. In another case, a 1.8 MW maritime medium-speed engine is being developed, where IAV is taking on a wide range of topics for the customer, from systems engineering to type approval, such as complete development responsibility and management of the partner network.

Or a pre-development project that IAV carried out for an Asian manufacturer of maritime high-speed and medium-speed vessels, in which it analyzed the strengths and weaknesses of the methanol dual-fuel process for a concept decision.

Mechanics as a lever for sustainability

Whether for maritime or industrial applications – as a mechatronic system, a large engine must complete the start-up phase, including the run-up, absolutely smoothly and offer optimum performance in terms of both thermodynamics and mechanics.

"At IAV, we carry out this development work with engine manufacturers even under extreme conditions", says Ronny Mehnert, head of the Powertrain & E-Traction Simulation department at IAV. "We also support the topics of emissions and oil consumption and develop new ideas to make engine starting processes more stable."

The challenges in the application of new fuels are manifold, for example their incorporation into materials with a direct influence on mechanics, lubrication and heat transfer behavior or valve control. IAV cooperates with large engine manufacturers in the development of valve train systems to ensure an optimum thermodynamic process while at the same time guaranteeing the functional safety of the mechanical systems.

"A functioning mechanism also ensures that components can be removed and recycled in the interests of sustainability," says Mehnert.

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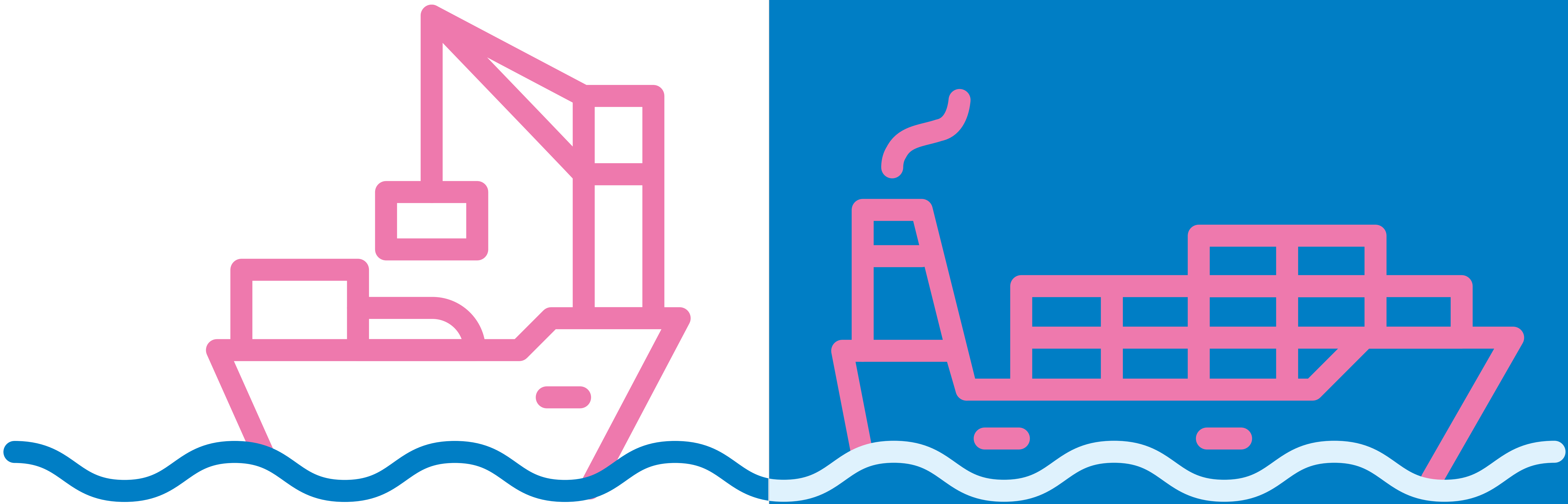
True beauty comes from within

Climate-neutral fuels such as hydrogen, methanol or ammonia make combustion engines more environmentally friendly. IAV translates the relevant combustion processes into its own models to design the units at an early stage and assess their performance promptly.



This may involve commercial vehicles such as heavy-duty transporters, ships or industrial applications such as forklift trucks, where alternative fuels such as methanol (CH_3OH), ammonia (NH_3) or hydrogen (H_2) are used in combustion engines. IAV supports its customers in the development of these engines, with the modeling of combustion processes in the cylinder at the very beginning of the development process.

"We use our own, very efficient 1D models for this. They are characterized by short computing times, but still reproduce the chemical processes precisely", says Michael Riess, Team Leader Hybrid ICE & Low Carbon Fuels at IAV. "They serve as a basis for the design and development of the engines."

Timely insights into engine characteristics

Among other things, the models developed by IAV calculate the laminar flame speed and can thus predict the propagation of the primary flame front for a wide range of fuels and boundary conditions. They also provide information on ignition delay times and thus on knocking. "With the results of our combustion models, we can determine the engine characteristics at a very early stage," says Riess. "For example, they provide us with information on combustion duration, knocking tendency, performance and, in some cases, emissions."

About five years ago, IAV began working with models developed in-house because commercially available tools for calculating combustion processes sometimes delivered implausible results. "Our first object of investigation was hydrogen. Validation on the test bench showed that our models come very close to reality", reports Riess.

Modeling of dual fuel engines

His team is currently investigating the combustion of methanol using the same approach. The modeling of ammonia combustion has recently been started. In the next step, the experts want to tackle a much more complex process: dual fuel combustion. "So far, we have only modeled the combustion of a single fuel in petrol engines," explains Riess. "However, engines in which, for example, hydrogen is ignited by pilot injection of diesel or DME are also interesting." For this, however, the combustion of both fuels must be simulated in a single model.

For IAV customers, this means that regardless of whether they want to develop an engine with mono-fuel and gasoline combustion or a dual-fuel engine with compression ignition, IAV models can be used to reliably determine the key engine characteristics at an early stage of development. Following on from this, IAV experts can also use 3D CFD simulations to calculate spatial combustion phenomena such as homogenization and mixture formation to obtain information on emissions or efficiency, for example.

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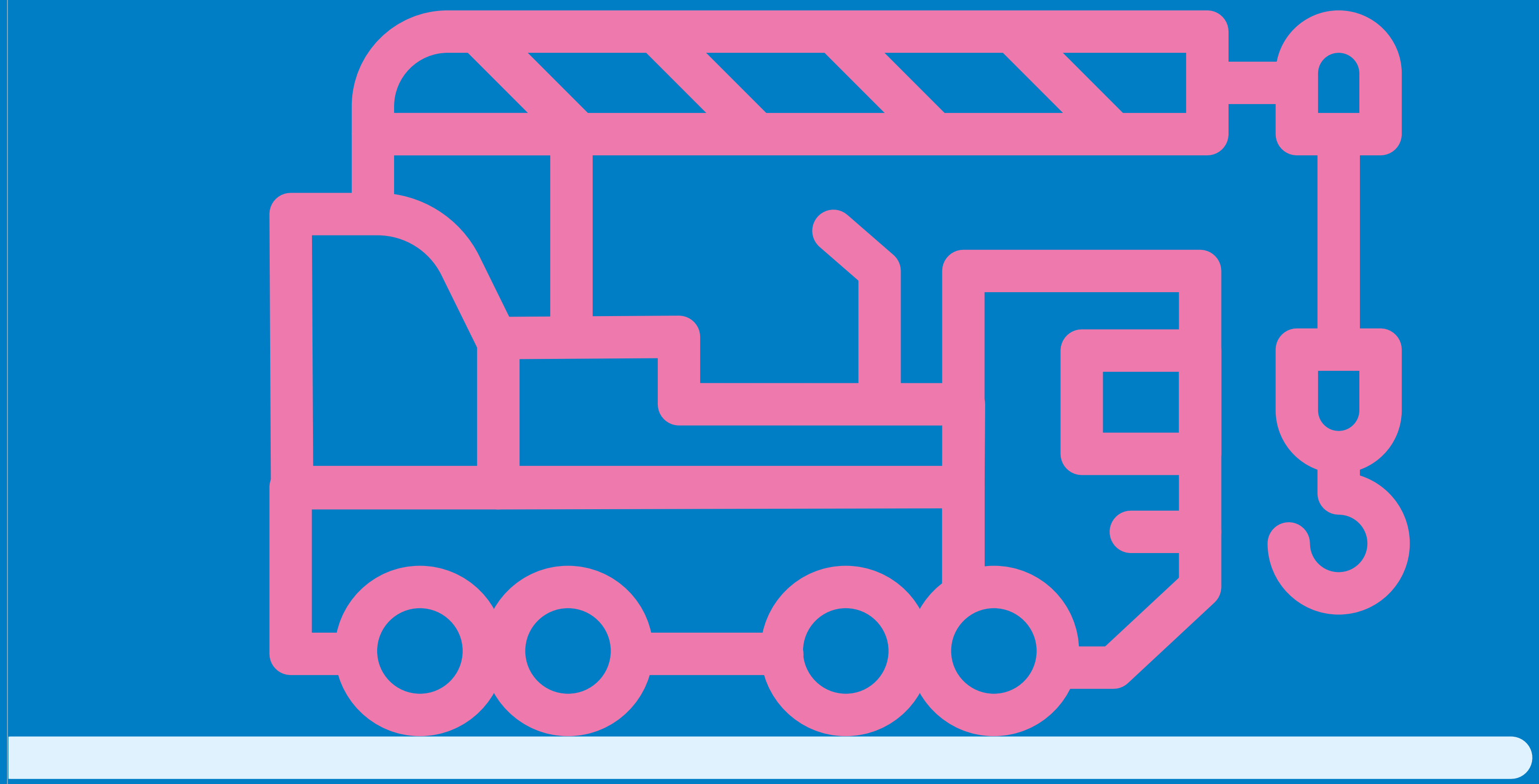

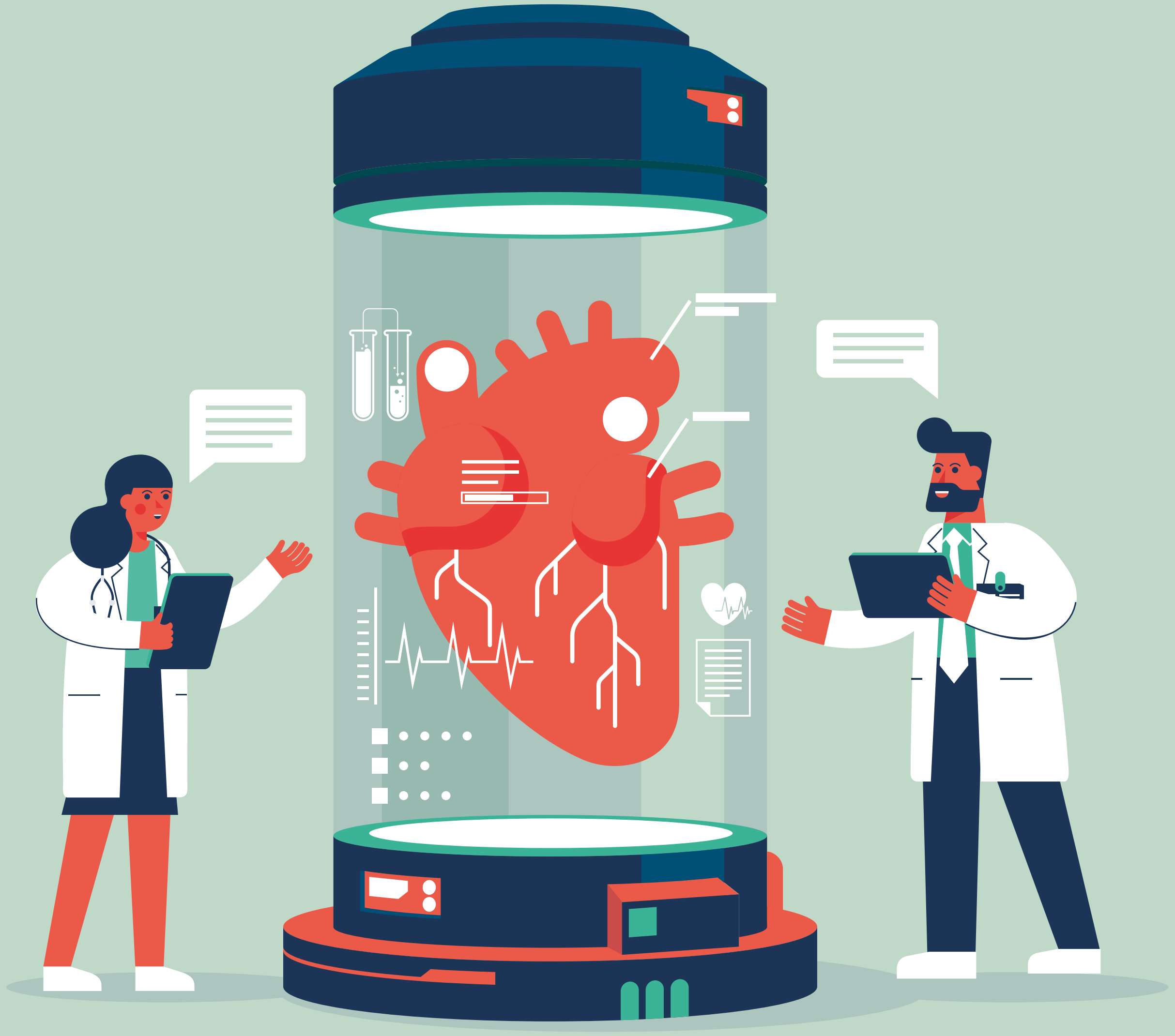

Fitness check for fuel cells

Preventing the ageing of fuel cells with permanent monitoring: a software-based function developed by IAV prevents power losses in the fuel cell system and thus enables valuable cost savings.

Electric drives with fuel cells are a particularly promising option for commercial vehicles – after all, the hydrogen required as fuel can be refilled quickly and long ranges be achieved. "That's why many manufacturers are currently looking at fuel cells", says Ralf Wascheck, Director Fuel Cell & Hydrogen in the Powertrain Calibration & Technology department at IAV. "However, ageing is still a problem: a car has around 8,000 operating hours, while a truck has around 30,000 hours. Despite high mileage, the fuel cell in a commercial vehicle must not age too much. The aim is to achieve a power loss of around ten percent at the end of the service life. Today we are seeing figures of 15 to 20 percent."

A significant ageing effect is platinum degradation of the cathode. It reduces the surface area available for electrochemical processes and thus leads to a continuous drop in system performance as well as a deterioration in efficiency. As a countermeasure, fuel cell systems are often oversized, but this again results in higher costs and challenges for the package in the vehicle. Other ageing effects such as corrosion of the carbon carrier, hydrogen depletion at the anode and thinning of the membrane must also be considered.

Aligning operating strategy with health status

Ageing can be counteracted by using an electronic control system to permanently monitor the state of health (SoH) of the fuel cell. This provides a parameter that can be used to optimize the operating strategy. "One possibility is to shift more of the dynamics from the fuel cell to the battery", says Wascheck. "Because this causes the battery to age more quickly, you have to find an optimum for the overall system."

To extend the service life of fuel cells, IAV has developed the A0 model of a function that monitors the fuel cell and calculates its SoH parameter. A physicochemical model of the fuel cell system was used for this purpose, which calculates the ageing on the basis of corresponding load profiles and was implemented as a SoH function on the "IAV Dragoon" control unit platform. This is suitable for prototypes and small series.

"IAV has implemented the Matlab-based model in a real-time-capable function using our function development process for series solutions", explains Sebastian Elgeti, head of the Commercial Vehicle Electronics department at IAV.

"Using the hardware-in-the-loop approach, we optimized the function and ultimately achieved a result that is already very close to series production", says Daniel Volquard, Head of Software Powertrain at IAV. "For use by the customer, we would only have to adapt our solution to the desired target hardware."

IAV Dragoon is also ideal for this: "The control unit is slightly larger than a pack of cigarettes, has CE certification and can be used in projects relevant to functional safety and security", says Stephan Baumgarten, Head of Vehicle Software Solutions at IAV. "The SoH function can be based directly on this. IAV Dragoon is the perfect solution for a small series."

At the start of customer development, IAV experts must measure the cells used in the fuel cell on the test bench or the customer must provide the necessary data. Series development could then start immediately based on the A0 sample.

Varied expertise

The know-how on electrochemistry, fuel cells and ageing processes that IAV has acquired in numerous internal projects in recent years has been incorporated into the development. For example, the underlying models have been adapted to the respective fuel cell systems through measurements on the company's own cell test bench. However, other domains such as function and software development also contributed to the development of the A0 model.

„The development of this function is just one facet of our wide-ranging expertise in fuel cell drives", says Wascheck. „For example, we can also develop subsystems such as the hydrogen tank system and balance-of-plant components as well as integrate fuel cell systems into the overall vehicle. With the A0 prototype of the SoH function, we want to help ensure that the climate-friendly fuel cell will soon be used in series production, especially in commercial vehicles."

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Skid marks in the air

In future, harmful substances such as particulate matter produced by brakes are to be regulated in the EU. IAV is meeting the growing need for testing with a hybrid development approach comprising a test bench and virtual development – and with a new test center.

At the Gifhorn site, the number, mass, and size of fine dust particles can be precisely evaluated. In addition to measuring and investigating the emissions of the friction partners, IAV also uses CFD analyses and experiments to evaluate particle dispersion at the new test center for brakes.

The range of services also includes leveraging the potential to reduce and avoid non-exhaust emissions, for example by using alternative materials for brake discs and pads as well as innovative brake concepts – and in the future also issuing approval certificates for OEMs.

Euro 7 as a driver

"We have a lot to offer here, both in terms of testing and virtually – it's about a holistic hybrid approach to calculations and test runs", says Ronny Mehnert, head of the Powertrain Simulation department at IAV. "We use our broad expertise in the field of thermal and fluid mechanics as well as in the generation, separation and transport of particulate emissions."

The background to this is the legislation on the planned "Euro 7" emissions standard, which provides for limit values for brake emissions. In the context of passenger cars and light commercial vehicles, this involves particle mass limits of 3 mg/km for battery-only vehicles and 7 mg/km for all other drive types.

In future, vehicle manufacturers will have to carry out a large number of tests to verify brake dust emissions for each model variant. To limit costs and time in view of the variety of models and tests, IAV is increasingly relying on simulative approaches. IAV is in dialog with OEMs and is building up qualified methodological expertise together with customers, for example on projections of crack formation or wear of brake discs and other components.

New fields of activity for IAV

"This is where new fields of activity are emerging for IAV, but also new challenges for customers because they have to make more and more inroads into development, forecasting and data storage", says Dr. Toni Feißel, Systems Engineer in the Foundation Brake team at IAV.

"In a few years' time, we will be able to dispense with real tests altogether", says Mirko Leesch, Head of Powertrain Systems at IAV. "From the amount of test results that will be available by then, we will be able to derive simulation models that are a good representation of reality."

IAV's simulation models already achieve accuracy values of over 70 percent compared to results from real tests. This applies to relevant topics such as flow simulation (CFD) for evaluating particle injection and for the dispersion and separation of particles.

IAV is also developing a digital Twin, where real driving data and emissions measured on a test bench basis are combined with physical models. With the Trinity approach, IAV aims to make development sustainable and shorten development cycles.

Challenge for e-vehicles

Regulating non-exhaust emissions is particularly challenging for electric vehicles. Because of the battery, electric cars are heavier than combustion engine vehicles, cause more tire abrasion and produce more particulate emissions. In contrast, battery electric vehicles perform better in terms of brake particles because they achieve a large part of their deceleration via regenerative braking (recuperation).

IAV is adapting its capacities in Gifhorn in line with the growing demand for testing. Three test benches for brake particles are already available there and IAV's largest development center offers further opportunities to carry out measurements and investigations of so-called "non-exhaust emissions".

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“We are experts in all key future fields. And the customer decides which technology he needs. So no matter what the decision is made - we are prepared.”

Thomas Müller, Executive Vice President Powertrain Systems