e-mobility technology international

VOL 8 | SPRING 2021

How the Pandemic is Changing Our Perception of Cleanliness Inside the Car

FIND ON PAGE: 129

AUTOMAKERS ARE NO LONGER HARDWARE MAKERS BUT ARE EVOLVING INTO TECH COMPANIES

PAGE 86

Torque show:

how YASA's high-efficiency axial-flux motors are extending EV range

PAGE 20

CONNECTED CARS:

the next cybersecurity challenge PAGE 24

MAKING FUEL CELLS MORE DURABLE – AND AFFORDABLE

PAGE 32

THE CHALLENGES FOR THE BATTERY OF THE FUTURE

– from laboratory to industrial scale PAGE 114

MARK PHILIPS

EDITOR A NOTE -

This year, 2021, started with great hopes for all of us.

To have our lives back would be so great.

But it also brings with it memories and experiences that we never thought possible. However, as often happens in the greatest crises, it has been an opportunity for big changes, an "accelerator". It forced us to think out of the box and find practical solutions to enable business to continue and change for a better future.

Numerous enterprises and start-ups have entered this industry due to the growing demand for electric vehicles. The sector is also witnessing several technological developments linked to faster charging time and more extended range.

The pandemic is accelerating the structural transformation of the sector on the road to digital and carbon-neutral mobility, which had begun back in the last decade.

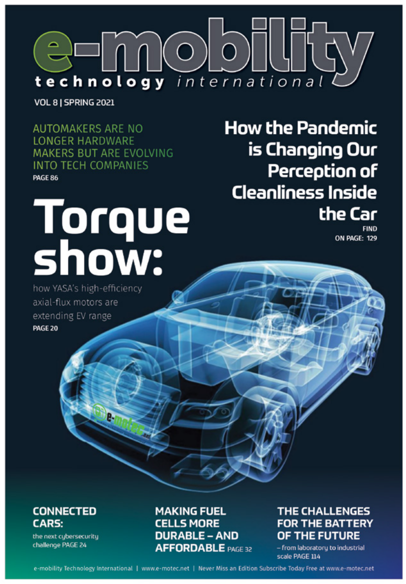
The demand for electrified vehicle is increasing and while the overall share in the market is still modest, it reached 11% in Europe in 2020, it is growing rapidly. The same applies to smart mobility and connected services. The fight for a part of the future share is, however, taking place right now.

The intensity of industry rivalry within the electric vehicle sector is growing, with rising opportunities and government interest fuelling the global demand. Moreover, leading players are investing in the market to augment their presence.

Suppliers are currently reviewing and adapting their product portfolios, with development of new technologies a priority.

We are proud to showcase some of the latest within these next pages.

To all our readers and contributors thank you for your engagement with us and your continued support.

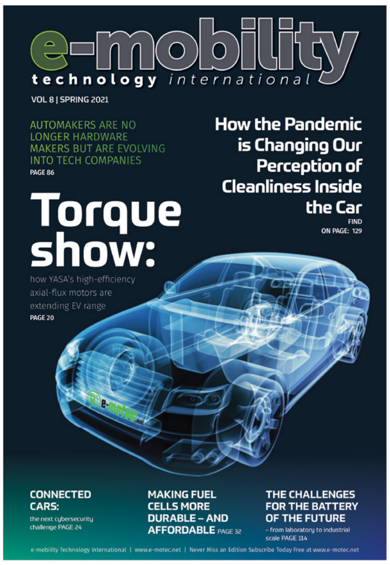


On the cover

Torque show:
how YASA's high-efficiency axial-flux motors are extending EV range

Automakers are no longer hardware makers but are evolving into tech companies

How the Pandemic is Changing Our Perception of Cleanliness Inside the Car



World Electric Vehicle Association

Editor: Mark Philips
Associate Publishers:
Rachael McGahern
Ujjol Rahman
Anthony Stewart
Client Relations: Anita Justinia
Designer: Carly Jackson

Published by:
CMCorporation Ltd
234 Whitechapel Road
London E11BJ UK
info@cmcorp.co.uk
www.e-motec.net

e-motec.net
e-mobility technology international

(ISSN) ISSN 2634-1654.

AVERE
The European Association for Electromobility

Zero-emission Mobility for All

100% ZERO-EMISSION BY 2050

The EU's e-mobility sector is key to reaching the Green Deal's decarbonisation targets, creating high- skilled jobs, and increasing the competitiveness of the European economy.

THE GOAL

- **100% new zero-emissions vehicles by 2030**
- **Fully decarbonised European road transport by 2050**
- **Making Europe a world leader in electromobility**

WHERE ARE WE

Close to **2.5 million** electric vehicles currently on European roads, with EV sales tripling since last year (2020). The EU's Green Deal and the Recovery Plan offer unique opportunities to further scale up electromobility in coming years.

WHY ELECTROMOBILITY?

We must support and accelerate the transition to zero emission mobility.

Decarbonisation potential

Electric vehicles have 3 times lower GHG footprint than Internal Combustion Engine vehicles under the current energy mix.

Clean air

Electric vehicles do not produce any tailpipe pollutants such as NOx and fine particles (PM10 and PM2.5).

A rapid decline in price and growing availability

More models are coming to the market in larger quantities while price per unit keeps reducing steadily.

Potential for zero emissions long term as renewable energy scales up

Reaching the COP21 goal of limiting temperature to 1.5°C will require a complete decarbonisation of the transport sector by 2050.

Reducing noise pollution

An electric vehicle is silent at city speeds and during acceleration.

Adapting Europe's mobility sector to future global change now

Electromobility is a global growth market, and Europe cannot afford to lag behind.

Headline Actions

- Phase out Internal Combustion Engines (ICE) by 2030
- Drastically reform CO2 emissions standards for cars and vans
- Create the conditions for a dense European charging
- infrastructure Scale up the EU's battery industry
- Boost the use of renewables in transport

OUR 2021 POLICY PRIORITIES

ACCELERATING THE UPTAKE OF ELECTRIC VEHICLES AND PHASING OUT ICE BY 2030.

We must strengthen CO2 reduction targets for cars and vans and include an ICE phase-out date by 2030 to help increase the uptake of zero emission mobility.

The upcoming revision of the Regulation setting CO2 emission standards for cars and vans should therefore

- Significantly raise the ambition compared to the current regulation
- Introduce annual intermediate reduction targets
- Reconsider the inclusion of plug-in hybrid vehicles and establish a pure zero-emissions vehicles mandate

Most importantly, AVERE calls for a **phase-out of new ICE vehicles by 2030**. This trajectory is crucial for full decarbonisation of road transport by 2050, since new cars and vans stay on EU roads for around 15 years on average.

We must also introduce legislation favourable for e-trucks, from mandated toll discounts to the relaxation of national driving bans for zero-emission vehicles.

ESTABLISHING A HARMONISED, HIGH QUALITY, DENSE EV CHARGING INFRASTRUCTURE NETWORK

The charging environment across Europe must be more consumer-friendly, seamless, interoperable, and suitable to heavy-duty vehicles

The upcoming revision of the Alternative Fuels Directive (AFID) will be crucial to support the growing amount of EVs on European roads. It should include:

- Harmonised rules for charging hardware and operations (in the form of a regulation rather than a directive)
- A clear focus on zero-emissions mobility, setting clear targets for expansion of charging infrastructure
- Improvements to quality of infrastructure and users' experience

The EU should also establish a 'right to plug' in Buildings in the upcoming revision of the European Buildings Directive (EPBD), ensuring that consumers are never denied the right to have a charging point.

WORKING TOWARDS A GREEN, INTEGRATED, SMART AND EFFICIENT ENERGY SECTOR

In order to fully reap the benefits of electromobility, legislation should support the rapid uptake of renewable energy, as well as of smart charging and vehicle to grid technology.

The upcoming revision of the Renawable Energy Directive will be a significant opportunity:

- We must increase the target for renewable energy in transport, going beyond the 24% goal set in the Climate Target Plan for 2030
- It should include a possibility for fuel suppliers to demonstrate compliance with their obligations via electricity crediting mechanisms.

We must also swiftly enhance Energy System Integration, specifically through the development of smart charging and vehicle to grid technology. EU power markets should permit EVs, as a decentralised energy resource, to provide flexibility services.

ESTABLISHING A SUSTAINABLE AND COMPETITIVE EUROPEAN BATTERY INDUSTRY

As EV sales begin to take off in Europe, the EU's ability to remain competitive with the rest of the world will be heavily dependent on domestically developing batteries at a larger scale.

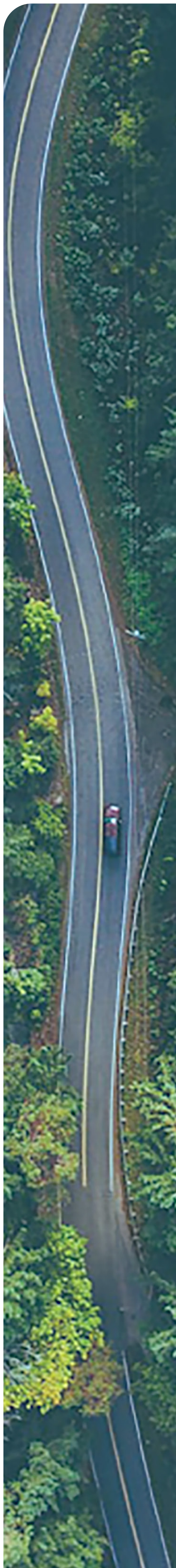
AVERE welcomes the European Commission's Battery Regulation proposal from December 2020. The new regulation should:

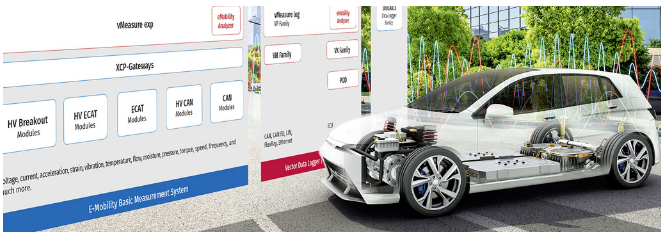
- Ensure harmonisation in the internal market
- Balance quick implementation, a robust methodology and effective enforcement
- Establish proportional and well-designed provisions to enable sustainable battery production, use, and end-of-life management

In the context of the upcoming proposal on Due Diligence, AVERE also strongly supports the introduction of rules for the responsible sourcing of raw materials for batteries.

A COMPREHENSIVE REGULATORY FRAMEWORK FOR CONNECTED AND AUTOMATED MOBILITY

EU regulation needs to be consistent and holistic , taking into account the various business models already established on the market. It should stimulate the development and uptake of innovative technologies, while keeping consumer interests at heart.





vMeasure exp
XCP-Gateways
HV Breakout Modules
HV ECAT Modules
ECAT Modules
HV CAN Modules
CAN Modules
E-Mobility Basic Measurement System

BSI Consulting Services

Ensuring connected automotive security requirements by addressing:

- Cybersecurity strategic consulting
- Security architecture and testing assurance
- Security awareness and training
- ISO/SAE 21434 compliance

"Through constant change, the automotive sector faces new challenges every day. This pace of change requires an organization to adapt quickly to sustain organizational resilience".

Mark Brown, Managing Director for Cybersecurity and Information Resilience, BSI Group

Find out more

IE/International
Call: +353 1 210 1711
Email: cyber.ie@bsigroup.com
Visit: bsigroup.com/cyber-ie

bsi.

Inspiring trust for a more resilient world.

BATTERY TECHNOLOGY

CYBER SECURITY

CONNECTIVITY

TESTING & MEASUREMENT

CHARGING TECHNOLOGY

POWER ELECTRONICS

Smart Ultrasonic Welding

Unbeaten in flexibility, reliability, and performance, the electronic industry relies on more than 15 trillion wire bonds per year. For large-area joints in EVs, this ultra-sonic process comes as Smart Welding.

Dipl.-Wirt.-Ing. Sebastian Holtkämper

The first modern battery EVs (BEV) have been on the market for more than10 years. Today, the automotive dealerships and product pipelines of the EV manufacturers present a broad range of widely accepted electric cars. EVs being available in any class of passenger cars will be the big push for an increasing EV market share. This requires scalable high-volume production that drives the related technologies to the next level.

Different concepts and designs of the battery pack its related power electronics are in the field. They are proving their ability to persist under strong competition in cost and performance.This applies also to the chosen production technologies. While the big players appear to have made their strategic decisions, many small and medium-sized projects are flexible and curious enough to keep the race between interconnection technologies open. This enables them to build up wide process know-how and gain competive advantages by choosing the technologies which best fit their technical requirements. With this mindset and the plurality of target applications, the fastest adapting equipment suppliers will be the most successful.

As a responsible engineer you visit manufacturers of laser and/or ultrasonic welders, wire bonders and you will benchmark them to known technologies like bolting or resistance welding. Each of these technologies deliver good arguments like lowest cost per joint, shortest takt time, best traceability and quality control, lowest contact resistance or ease of application [1]. In the end, decisions may feel like compromises.

Avoiding Compromises Between Joining Technologies

Smart Welding now closes such a gap for applications joining a contact element to a base structure. As an ultrasonic joining method it does not require applied heat and provides high material flexibility. Additionally, Smart Welding merges the three main strengths of ultrasonic welding and wire bonding: High power (1) for large joints of traditional ultrasonic welding with the precise control (2) and speed (3) of wire bonding. The stability and efficiency of the underlying hard- and software benefit from decades of experience from the original technologies and their features.

Wire bonders can provide ultrasonic powers up to 200 W and welding forces up to 40 N. This is sufficient for joint areas of 1-3 mm². Effective contact area can easily be increased by adding wires. Large area joints are always necessary when massive connectors are required for their electrical and also thermal performance. Contact elements like copper terminals of power modules require up to 1000 N of weld force and 1.5 kW of ultrasonic power output. Such elements are applications for Smart Welding.

Precision Is the Key to Stable Results

The placement accuracy of wire bonding equipment of below 10 µm is well appreciated in the industry. Taking also the image recognition and the operator into account, placing accuracies on good products are still below 20 µm. In any application, such good positioning, together with image recognition, does compensate the X- and Y-placing tolerance of the contact element caused by the pre-positioning. This is a great benefit for a stable weld area size. In case of batteries, the cell balancing will not be distorted by alterning resistances due to high variance of weld areas.

And there is another advantage of a very dynamic motion control and a precise control of position and force: The process control is accordingly. Profiles of force, overtravel and ultrasonic power can be tailormade for the product and its conditions. The deformation is measured with micron accuracy and, together with the oscillation feedback, it can be traced how the joint forms and how the conditions (e.g. friction, vibrations) change.

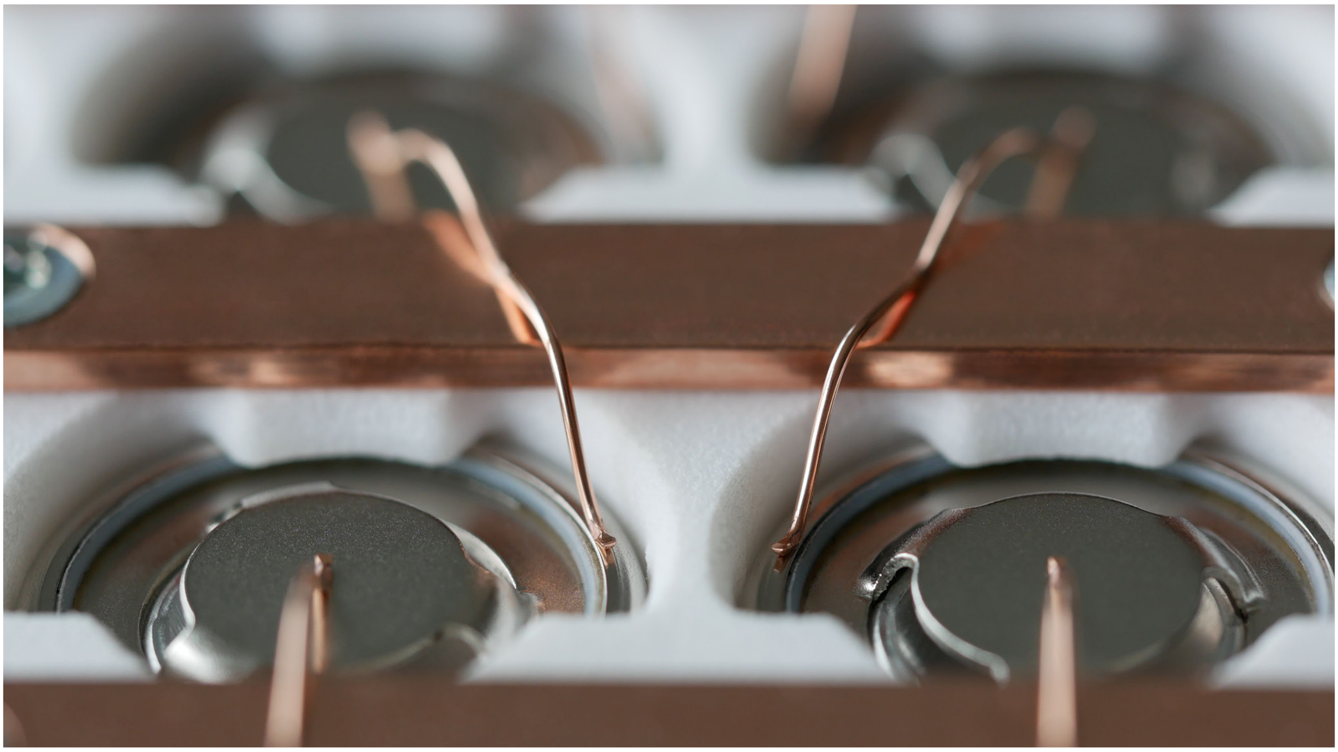


Figure 1 Contacting Battery Cells with Copper Wire Bonding

Speed Alone Is Not the Key to Low Cost of Ownership

As Smart Welding equipment has highly dynamic motion control, it enables high travel speed. However, the major share of the process time is spent welding, rather than travelling. When focusing on the process time, other technologies might appear faster at first sight.

On the one hand, the processes are well comparable as both use the same motion system. On the other hand they are not, as the wire bonder provides the connector within the same process, while Smart Welding and other technologies require a corresponding pre-process. This is not represented in process times, but matters in assessing the complexity and cost of the whole production line.

This is just one example of why process time alone provides only a limited perspective. The production and automation concept, including loading and positioning processes, is crucial for judging speed in general and total cost of ownership.

Electromobility production lines demand stable quality, flexibility and full embeddance

Tracing the process data and the equipment variables to each single weld in real-time is a requirement to track failure modes and changing conditions during production. Doing this efficiently requires monitoring and a central server station, that handles the data and the equipment management. With such a system, additional production machines can be added to existing lines by plug&play as they synchronize to already existing machines. To reduce downtime in production, operators can clear production stoppers like image recognition errors from their work place or their mobile devices.

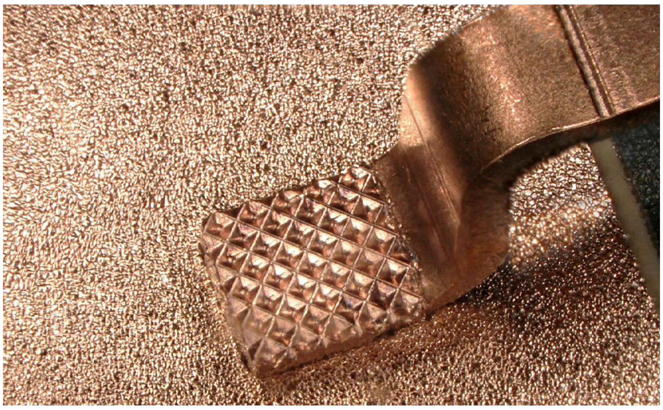


Figure 2 Smart Welded Terminal Smart Welded Terminal on Direct Bonded Copper (DBC – ceramic isolation between thick copper layers)

Figure 3 Smart Welding and Wire Bonding Production Line with Centralized Control

Understanding the Requirements of Future E-mobility Products

Both high voltage components and low voltage sensing connections are affected by an increasing degree of integration of battery packs. More and more compact designs limit space on pack and module level. Also power modules and battery management systems must be integrated properly, while still performing on the same or even higher levels. Smart Welding tool designs enable welds on the crimps of cylindrical cells or inside housings at close distances to the walls.

On the materials side, copper with its superior thermal and electrical properties is a desired joint material. In wire bonding, copper used to be a challenging process However, understanding the wear mechanisms and developing appropriate tools and processes now allows bonding tools to last for more than one million copper joints [3]. This is another benefit that wire bonding brings into Smart Welding processes – the readiness to cost-efficiently weld copper.

The Entry to Sustainable Benefits

Smart Welding is a new technology rooted in well-established and stable processes. It can provide a decisive competitive advantage to those who flexibly strive for best results and who do not accept limits set by other technologies. Developing processes in collaboration with equipment manufactures can be key to quick product launches and become the basis of fruitful partnerships.

Dipl.-Wirt.-Ing. Sebastian Holtkämper, Product Management Hesse GmbH

Further Literature

[1] Brökelmann, M; Holtkämper, S.; Hunstig, M.; Ultrasonic Bonding for Automotive Semiconductor and Battery Applications, MicroTech 2019 – Power in Packaging, 2019

[2] Hunstig, M.; Schaermann, W.; Brökelmann, M.; Holtkämper, S.; Siepe, D.; Hesse, H. J.: Smart Ultrasonic Welding in Power Electronics Packaging. CIPS 2020 – 11th International Conference on Integrated Power Electronics Systems, 2020

[3] Brökelmann, M.; Siepe, D.; Hunstig, M.; Guth, K.; Schnietz, M.: Wear optimized consumables for copper wire bonding in industrial mass production. CIPS 2016 – 9th International Conference on Integrated Power Electronics Systems, 2016

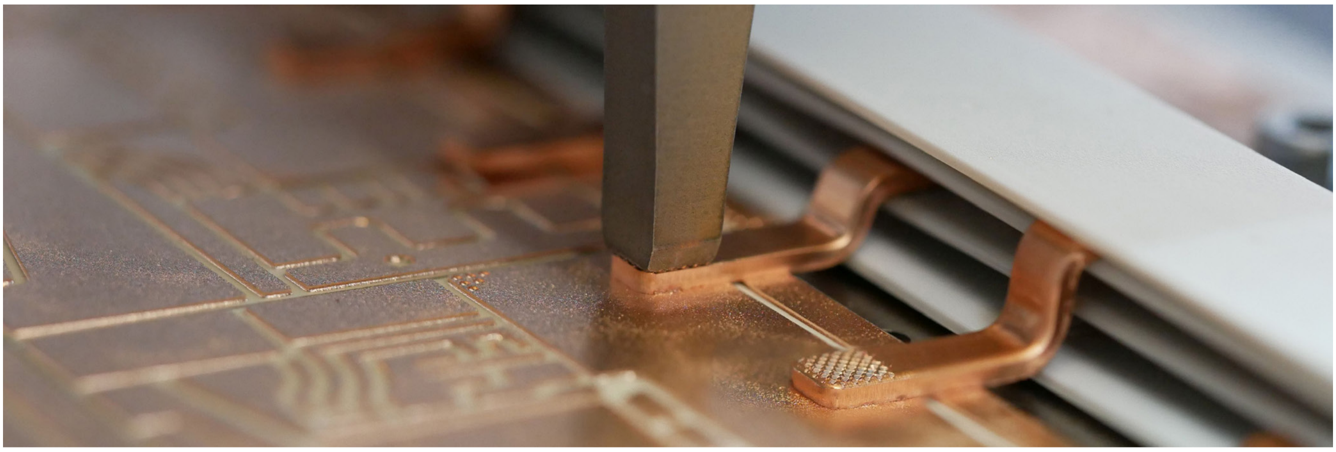


Figure 4 Smart Welding on Typical Substrate for Power Modules


AsahiKASEI
THINK HOLISTIC
BATTERY MATERIALS
SYNTHETIC RUBBER
FIBERS & TEXTILES
FOAM MATERIALS
PERFORMANCE PLASTICS
ELECTRONICS
WE MAKE FUTURE MOBILITY WORK.
asahi-kasei.eu/automotive

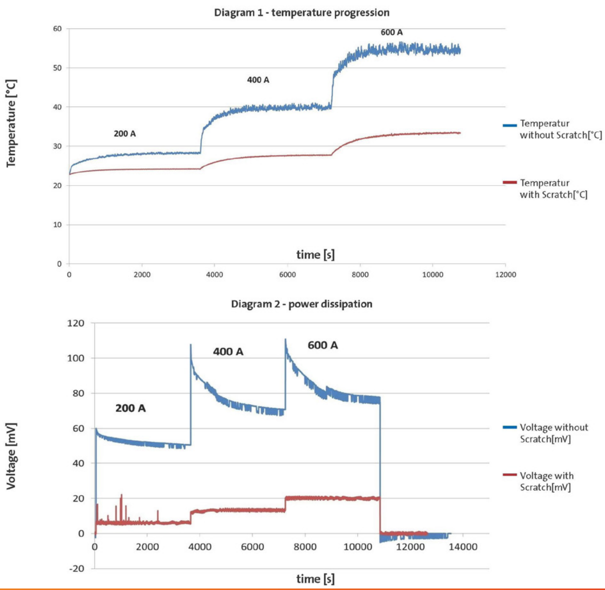
New contacting challenges in e-mobility

Lukas Hülser

E-mobility with fast charging processes at high currents and with different technologies for battery cells also creates completely new challenges for the contacting and testing technologies. Batteries, electric engines, inverters, connectors and other devices must be reliably contacted under high currents. Low contact resistances have to be realized in a small space. Smart contacting solutions also allow the detection of mechanical details, the presence of protective devices or the monitoring of temperature processes.

Challenge 1: Contacting of battery cells

In the development and production of battery cells, the challenges for contacting technology are enormous. The charging and discharging processes require very high currents, often over a long period of time. Parallel to the charging or discharging current, a voltage measurement often has to be realized. Temperature monitoring directly at the contact point is also commonly required. All these challenges demand innovative solutions (picture 1).



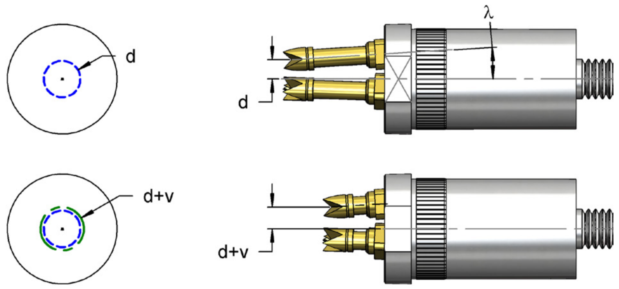
Results of the ISEA study according the benefits of scratch contacts

Scratch principle for low contact resistances

An important basis for optimum contacting at high currents is an extremely low contact resistance to the test item. This is realized by a scratch contact developed and protected by Feinmetall, which causes a defined scratching movement on the contacted surface and thereby achieves the best results, especially with dirty or oxidized surfaces. The scratch solution is especially suitable for contacting battery cells, since the typical aluminum current collector on the cathode side and the nickel-plated copper current collector on the anode side can be reliably contacted. In particular, the occurrence of a wetting current effect can be avoided. This guarantees reproducible good contacting results.

This type of scratch contacting is realized by contact blocks with slightly inclined spring loaded contact probes. If the plungers of these probes have a defined distance from a vertical mid-axis when touching the contact surface, this distance increases during the spring deflection of the contact probes by a defined offset v (image 2 next page). This offset corresponds exactly to the path of the scratching movement. In practice, usually several inclined plungers are mounted in a contact block. This way, the lateral forces on the test item compensate each other and in total a force from the inside to the outside is applied, which does not push the test item aside. The picture shows a round contact block with three plungers arranged in a circle. For higher currents and larger contact areas, however, rectangular contact blocks are also available, which allow currents of several hundred Amps.

An independent institute has validated the excellent results regarding the current carrying capacity of this scratch contact: The ISEA Institute of the RWTH Aachen, Germany, has conducted extensive research comparing the behavior of the contacting with and without scratch movement (diagram 1). It can be clearly seen that contacts with scratch movement show a lower temperature increase over time and over a gradual increase of the current load. The power dissipation over time is also significantly reduced and the contact resistances are much lower and more stable. It becomes clear that no wetting current effect is visible.



2: Feinmetall scratch contact principle √ +-

Multifunctional contacts for battery cell contacting

However, modern contact probes for e-mobility must do more than "just" carry high currents. Typical requirements are the additional possibility of voltage measurement parallel to current transmission, temperature measurement directly on the contacted surface or cooling of the contacting area. For this reason, contact probes ideally have a modular design and can optionally be equipped with sense pins or temperature sensors. This allows the user to find a perfect solution for his specific problem. Coaxially designed contact probes with a spring-loaded sense pin and a very small, spring-loaded temperature sensor inside as well as a connection for cooling by compressed air represent these state of the art contact probes. The dimensions and the exact design of these probes depend on the needed current carrying capacity and on the requirements given by the test item and the test strategy.

Challenge 2:

Contacts for testing charging interfaces with finger protection cap

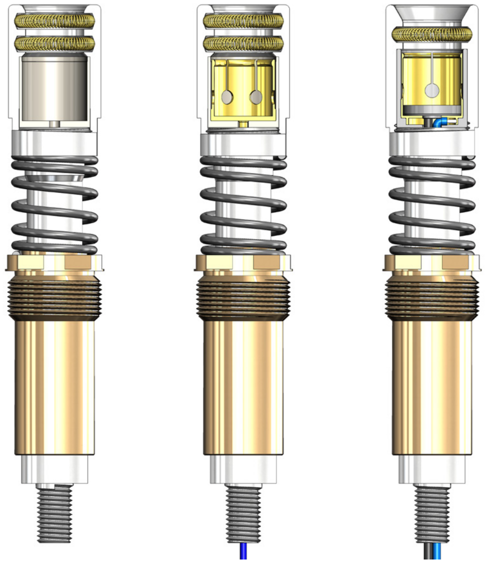
A further contacting challenge is a test of the systems that are connected to the electrical power distribution (e.g. electric engines, inverters, battery modules). First of all, connectors with round pins have to be contacted with high currents, while achieving low contact resistances and compensating certain dimensional tolerances without damaging the pins. Optionally, a simultaneous voltage measurement may also be necessary here, which can be realized by an additional sense contact. In addition, a test of other specifications, such as the presence of safety-relevant finger protection caps, can be an important feature for quality management.

High current contacting of round pins by using coil springs

Canted coil spring contacts are great for coping with different tolerance levels of round pins. The contact force is independent from the travel of the contact probe. That secures great contacting conditions at all time. The contact in this design is not very aggressive, so traces on the test item are minimized. Such solutions are able to carry very high currents, so they are the perfect contact for testing high performance systems.

Contact probes with canted coil springs in the plunger head are also ideal for contacting connectors with finger protection caps, as they contact the connector from the side and the finger protection cap therefore has no negative influence on contacting. For realizing a simultaneous voltage measurement an additional sense contact in the spring contact probe is necessary, which is realized by a cup spring that also creates a lateral contact to the test item. For an optional presence test of finger protection caps an extra function in the contact probe is necessary: an additional, electrically isolated contact element can be used to determine if the protective cap is correctly applied. Such a contact element needs to contact the test item vertically. This is just another example of multi-functional contacting solutions.

The picture below shows all three options of contact probes for round pins. The standard version only creates a low resistance high current contact to a round pin (left). The version with cup spring also provides a sense contact (middle) and the version with additional isolated vertical contact allows presence test of finger protection caps (right).

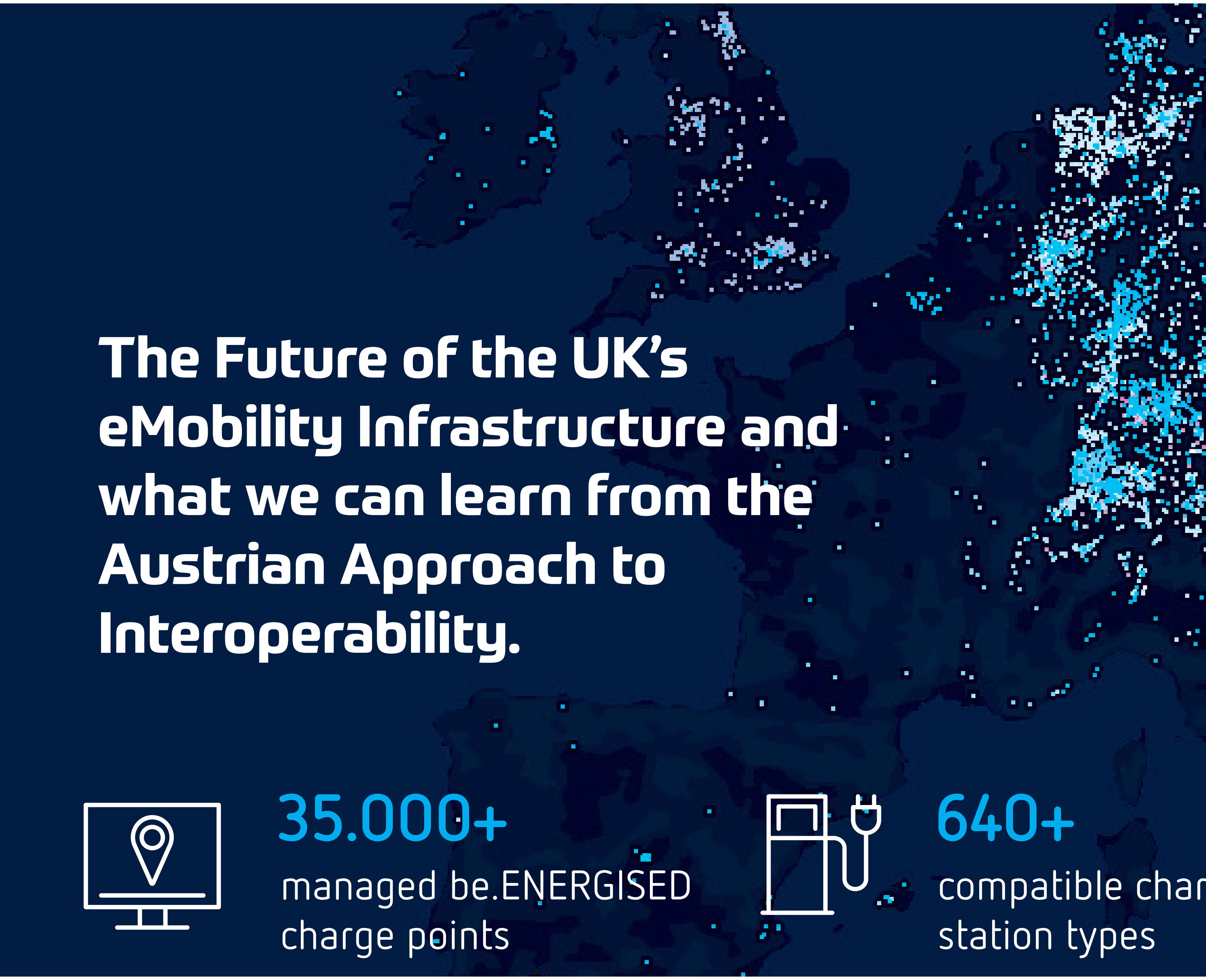


3: High current contact probe versions for contacting round pins

Conclusion

Although contacting technology is a very specific field in e-mobility, reliable testing of specific components is not possible without suitable contacting. And only reliable testing ultimately ensures reliable vehicle technology and enjoyable driving in the end. That's why Feinmetall has a strong focus on all contacting challenges in the automotive industry in general – and of course on the special high current requirements in all new e-mobility test applications.

Lukas is a product manager at Feinmetall Metal GmbH



The Future of the UK's eMobility Infrastructure and what we can learn from the Austrian Approach to Interoperability.

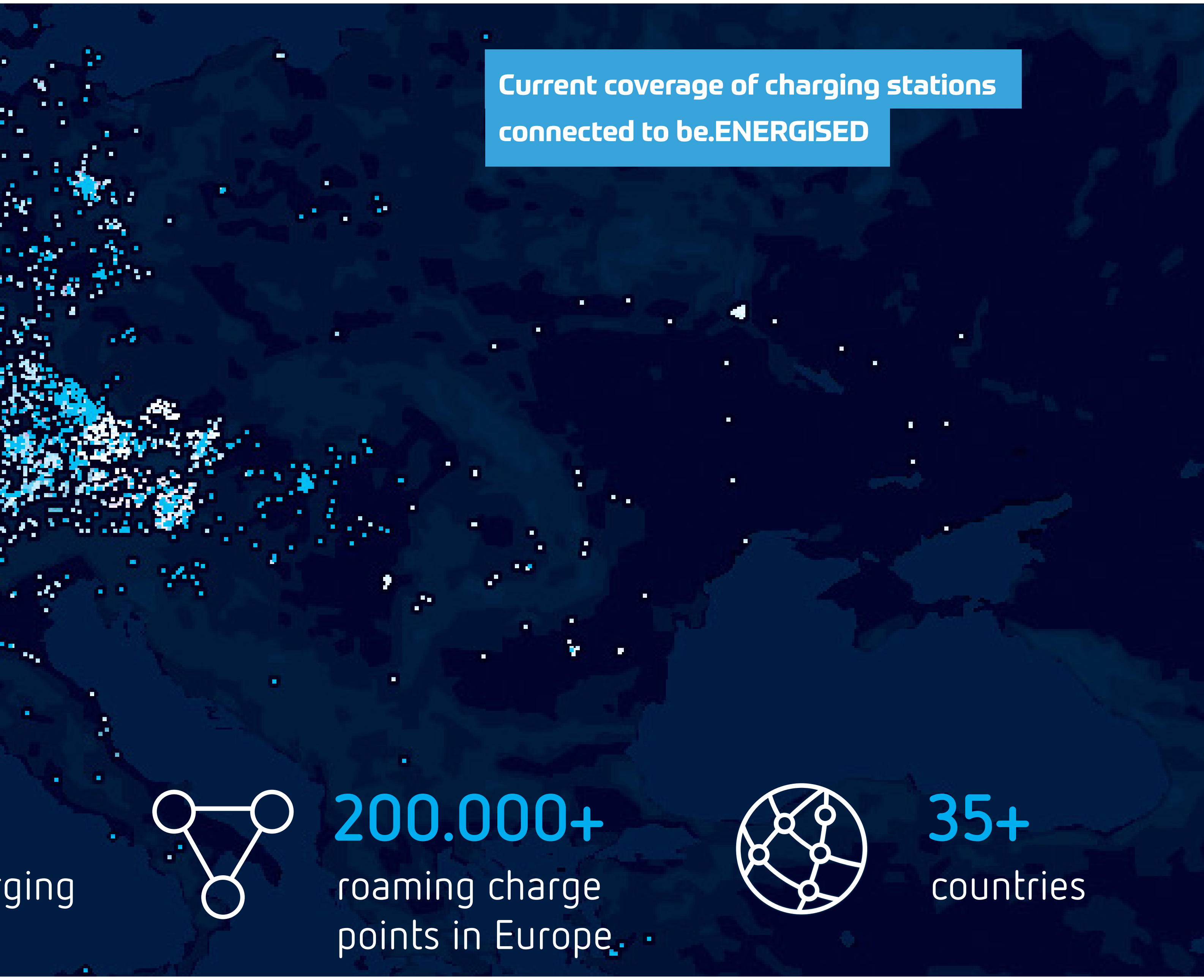
35.000+
managed be.ENERGISED charge points

640+
compatible char
station types

The UK government's ban on petrol and diesel cars and vans by 2030 has accelerated the rollout of charging infrastructure, heralding a new eMobility era for Brits. The UK currently has 24,000 publicly available charge points, but there's a long way to go to ensure there's enough infrastructure in place for the 36 million EVs set to hit the streets by 2040. The Society of Motor Manufacturers and Traders estimates Britain will need 2.8m public charge points. With such rapid growth and little standardization in place other than the sheer force of vertical market's cooperation, are we about to see the next spaghetti junction electrified with fragmented multi-supplier networks requiring multiple fobs and Apps to charge, price gouging and restricted access to some stations?

The Electric Vehicle Energy Taskforce—a lobby group of more than 350 members, including car firms and energy companies, believes Britain could take steps now that would facilitate the eMobility revolution that is underway. The top of their agenda is the need for coordinated planning, and standards that enable future proofed investments, interoperability, and data sharing. They're up against a ticking clock, technology in this area is moving at break-neck speed, and there's a pandemic and post-Brexit negotiations to contend with. Can we wait for them? Or should we dive in now and find the key issues involved and why interoperability is pivotal?

There are two central roles of infrastructure operators that we need to understand. The Charge Point Operators (CPOs), who operate charging stations and are legally responsible for compliance with the statutory and technical requirements to ensure that charging sessions are accurately recorded and tamperproof. CPOs provide direct access to EV drivers, or outsource access to Mobility Service Providers (MSPs) to facilitate access to their stations.



MSPs have a direct relationship and licence agreement with a large body of EV drivers. The advantage for CPOs to outsource to MSPs is that they can handle administration, allowing the CPO to focus on their core business. EV drivers can access a much wider network of charging stations, making it possible to extend their range and receive only one bill. Sometimes it is the same organization with two separate approaches. A great example of this in the UK is Elmtronics, who has introduced the Hubsta network, that provides drivers with a fob that allows them to load at various stations. This is particularly advantageous for fleet management systems that cannot provide credit cards to every driver to use Tap & Go or employee corporate charging that requires dynamic pricing, e.g. free charging for employees, low cost for customers, and premium rates for peak times to make a profit.

Facilitating the relationship between the CPO and MSP requires an interconnected system, so that they can communicate with each other. They can directly connect via Open Charge Point Interface protocol (OCPI) or use systems with interconnected interfaces with a peer-to-peer system or connect to a hub via a third-party roaming platform like Hubject.

MSPs generally want to connect with as many CPOs as possible to attract EV customers, and offer competitive prices. MSPs then become subject to the terms of each roaming platform and individual CPO.

Confused? Think of it like a train system—one operates the tracks (CPO) and leases it to various companies to use (MSPs). The tracks cross multiple regions/networks with different tax rates and prices to complete a journey. Simple, right? With over 640 different charging station hardware types and 356.5 billion vehicle miles driven on British roads in 2019, things get complicated fast.

Fortunately, in Britain's race to net-zero, this wheel is one of the things they don't have to invent. Almost a decade ago, Martin Klässner, Director of has·to·be gmbh, found a way to outwit a similar situation in the German-speaking market with Germany, Austria, and Switzerland. They were pioneers in envisioning the future of mobility as a service and now, using their software, be.ENERGISED, it's effortless and affordable for EV drivers to travel long distances in Central Europe, connect to a multitude of networks, and pay just one bill. Any charging station that is online capable (OCCP 1.5+), regardless of their API interfaces, can connect to their cloud-based backend and make their station available to EV drivers.

One of their greatest contributions to the future of eMobility is their work as an aggregator using one of their products, the be.Energised COMMUNITY. Rather than every CPO and MSP having individual contracts with each other and every roaming platform, they can simply connect to the COMMUNITY, which bundles them and pushes them to Hubject, creating a vast, interconnected network. Drivers can charge at any station with one affordable and easy-to-use payment method. SMEs now have their stations and services appearing on every charge map across Europe, and have all administrative tasks involved with being a CPO or MSP fully automated with has·to·be gmbh's white label services that take care of marketing, billing, taxation, legal regulations, dynamic pricing, hotline services, confidentiality data laws, fleet management, etc. For retailers, municipalities, and companies offering charging as a secondary business, this allows for generating passive income while focusing on their primary business mandates. Operators that want to be more involved can scale back on those options and receive raw data from the charge logs and administer directly to their customers.

The Austrian team took a hardware agnostic approach from the start because they foresaw OEMs flooding the market with station model types. Staying hardware neutral, they easily support every type of charging infrastructure and keep up with the latest technological developments, the next big one being ISO 15118 and the next generation of Plug & Charge vehicles. Numerous UK companies, county councils, police forces, hospitals, universities, supermarkets, and retailers are already benefiting from the be.Energised platform via the Hubsta network.

How does it work?

Charging stations transmit a real-time request triggered by the CPO's driver that connects to be.Energised, and the driver remains anonymous via a tag ID that is uniquely assigned. The software verifies the ID using a database comparison of the CPO's customer ID and authorizes them to start to charge. The information about the charging process is recorded in the software cloud. Once charging is complete, the charge point transmits a charge detail record (CDR) with the charging process data in be.Energised, allowing the options of automated white label services and tariff management, remote monitoring, and support.

Why do we need Roaming when we have Tap & Go?

Roaming is one more option that has many benefits for drivers, CPOs, and MSPs. The UK eMobility market is just getting going but it is already competitive. For SMEs, interoperable software like be.Energised allows them to step into the market with instant access to EV drivers. As more eDrivers sign up with MSPs that offer more competitive rates and customer loyalty incentives, we will see more roaming options in the UK like Hubsta, Digital Charging Solutions GmbH, and The New Motion BV, who are already using be.Energised.

Anthony Piggot, Founder & Technical Director of Elmtronics & Hubsta said:

It's already possible for EV drivers to increase range, make no upfront payment, and receive one monthly bill by signing up with Hubsta, which is a huge benefit for our customers, especially our fleet managers. Our customers also enjoy 24/7 hotline and station monitoring, so if a charger is faulty, it can be reset remotely or notify a technician immediately. That makes the end-user experience painless. We can provide this level of service because of the be.Energised platform. What I really like about be.Energised is that when we want to partner with other MSPs and CPOs, we can directly connect via OCPI or using the be.Energised Community. That level of flexibility and scalability make it easy for us to operate and expand.

We asked Martin Klässner, Director of has·to·be gmbh, his advice for British eMobility providers:

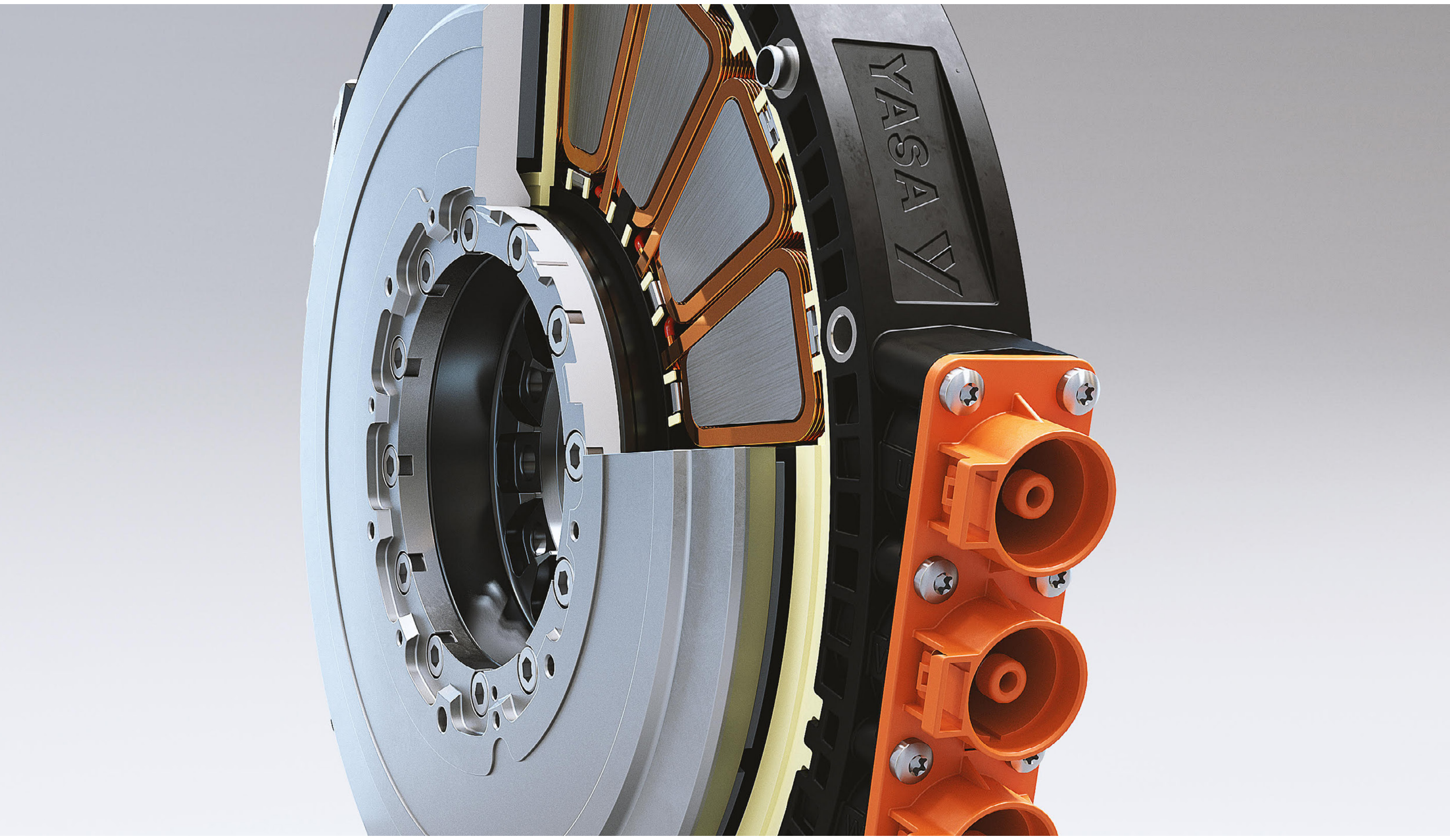
This is a very exciting time for eMobility in England and many are eager to get started. It can be tempting to go with the next-best hardware and software. But all too often, these "out of the box" solutions are very rigid systems that cannot be adjusted when your company expands or as the landscape shifts as it is sure to do in this market. My advice would be to opt for infrastructure that is open, easily scalable, and flexible enough to add features as they are developed. This way, you can be sure you are future-proofing a sustainable solution for your company and community. There are lots of start-ups that will be vying for your business now, but infrastructure decisions last for 40+ years. It is worth the time to talk to industry experts on what they advise. Our team would be happy to field your questions and think through these ideas with you without any obligations.

Afton Chemical
Passion for Solutions®

The **people** that make the **additives** that go into the **oil** that **lubricates** the **transmission** that **drives** the wheels **smoothly** in **electrified** passenger and commercial **vehicles.**

evolving™

www.aftonchemical.com



Interview...

Torque show:
how YASA's high-efficiency axial-flux motors are extending EV range

Tim Woolmer

If a tech scale-up is to be judged by the company it keeps, the Oxford-based electric motor and controller manufacturer YASA has to be a major-league company of interest for vehicle OEMs in the EV industry. The reason? YASA already numbers supercar makers like Ferrari amongst its customers for its revolutionary breed of high-power-density, highly efficient axial-flux electric motors.

But it's not all about luxury, high performance EVs: YASA, in its next growth phase, is planning a second factory. A new high volume factory to make hundreds of thousands of electric motors and inverters for the premium EV market. At the same time, the company is moving into aerospace, partnering with Rolls Royce on a record-breaking aviation electrification project as well as mainstream airframers. So how is YASA winning hearts and minds across both the automotive and aerospace industries? To find out, Paul Marks spoke to YASA's CTO and founder, Dr Tim Woolmer:

PAUL MARKS:

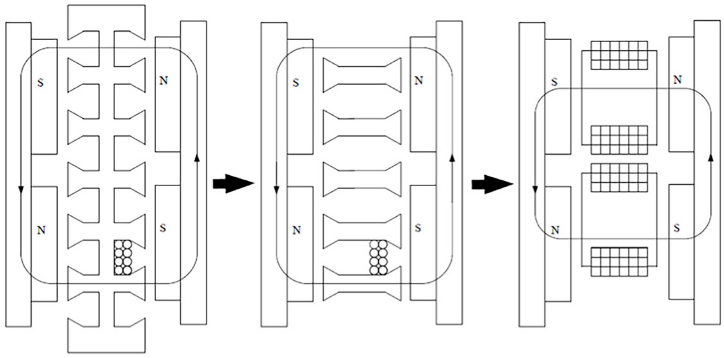
How has a relatively early-stage company like YASA, which is only a decade old, managed to acquire so many high profile manufacturers as customers? What exactly is the innovation that has attracted them?

TIM WOOLMER:

It's actually based on a eureka moment I had about five weeks into my PhD, when I realised there was a much better way to build an electric machine called a torus axial flux motor. The insight I had was that by removing the motor's stator yoke, and splitting it into segments [see render] I could see some very significant chances to reduce the motor's weight – and yet at the same time improve its torque, power density, efficiency and manufacturability, making it potentially transformative within the then nascent electrification industry.

PM: What advantages does your axial-flux motor design offer OEMs over the incumbent radial technology?

TW: The core advantage of an axial flux motor is the spinning rotor has a larger diameter, because it's turning alongside the stator, rather than inside it. And because torque equates to force multiplied by radius, and you're working at a larger radius, you get more torque for the same force. So for the same permanent magnet and copper winding provision, you get more torque for free, essentially. This gives you a theoretical 20% benefit. However, the YASA topology also removes the stator yoke (removing 60-80% of the stator iron mass). This gives more like a 50% benefit when compared to radial-flux electric motors the like of which are used most ubiquitously in today's 1st generation mass market EV's. We are now making great progress in disrupting that.



Derivation of the YASA topology from the NS-Torus Axial Flux Motor

PM: So the YASA design improves on both radial-flux motors and conventional axial-flux motors, is that right?

TW: Exactly. Moving from radial designs to our yokeless, segmented design provides a 50% improvement. However, when we apply our direct oil cooling solution and winding technique, we generally see a three-fold improvement in power density.

PM: This power boost sounds hugely applicable to all road EVs, where range is everything. So why the headline-grabbing relationship with Ferrari?

TW: It's a peculiarity of the automotive industry: to get an innovative new product into any kind of volume, your factories need to demonstrate a huge production track record and they need to be making a product that's proven to work on quality and cost. Basically, the only way into the automotive industry is in through the top, through low-volume luxury brands.

PM: Is that why Tesla started at the sporty end?

TW: Yes. When Nissan and others tried to make a regular mass market EV, and have had limited success, Tesla realised that the only way in is through the top. So it decided to make the best electric vehicle it could, build the brand, and then build bigger factories, take costs out and get volumes up. And YASA has mirrored that journey, with high-performance OEM customers including Ferrari - and now the technology is proven, we're entering the premium car market.

PM: What aspects of your technology are you trying to improve? Is there a "Moore's Law" of sorts for axial-flux motors?

TW: We constantly nudge up the numbers on motor speed and power density, following our technology road map. Typically, our motors have run at slightly lower speeds than radial machines, but that's something we're working on: we'll soon be at 14,000rpm and 16,000rpm after that, which is very competitive with radial machines. The very first motor we made ten years ago at Oxford University had power density of about 1kW/kg, and our Ferrari motor now runs at 14kW/kg, almost three times Tesla's 5kW/kg. And our aerospace motors are reaching 20-25kW/kg levels, which is a massive improvement over the 10-to-15 year period we've been developing this.

PM: Is power density the most critical metric in this space?

TW: It's important but as OEMs move to pure EV's, it's efficiency that's becoming the most important characteristic, the figure that really drives the EV's range. And we're pushing our YASA motors up to average efficiencies between 96% and 97% over standard WLTP drive cycles, whereas competitive products struggle to get much above 90%. And that has a direct impact on range: some OEMs tell us we're giving them a 5-10% range advantage against their competitors.

PM: How does the yokeless, segmented format achieve that range boost?

TW: Material differences: we're a whole lot lighter than radial machines. The laminations in a radial flux machine, for a typical automotive motor, might incorporate 20-25kg of iron. In a YASA motor of similar rating, we'll only be using 3-4kg of iron. And it's iron losses that dominate over the WLTP cycle, because a powerful 150kW or 200kW motor is being used at very light loads. So efficiency is a fundamental unique selling point of our technology.

PM: What kind of cost savings does this technology lead to for EV makers?

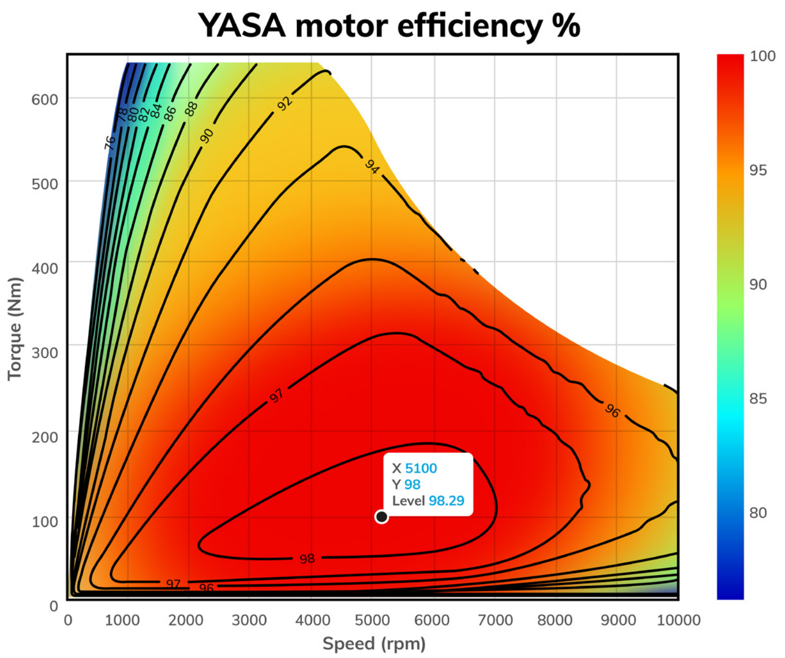
TW: There's an interesting sequence of knock-on effects here. If we can offer a 5%-10% range benefit, that could translate to a 5%-10% battery size reduction, perhaps lightening the EV by 50kg. But it actually grows to something bigger than that, because of the mass compounding effect: lightening the battery means you might end up losing another 50kg somewhere else on the vehicle, because, suddenly, you need a smaller motor because the car's got lighter, and then, just as suddenly, you need fewer electronics modules and the cooling systems all shrink too. This compounding effect has pretty much a 1:1 ratio in EVs. So if our motor is say 50kg lighter, and we save maybe another 50kg on the battery pack, that 100kg saving turns into a 200kg compound saving, which starts to get quite significant in adding further range benefit.

PM: Talking of cooling systems, why are YASA motors oil cooled? What is the advantage to OEMs of doing that?

TW: Oil is one of the reasons YASA motors' achieve higher continuous power. A 200kW peak-power radial motor, run continuously, might give 50% of peak power, say between 80 and 100kW, as a result of thermal limitations. A 200kW YASA motor will run continuously at 150kW thanks to the improved high-thermal-contact cooling oil offers. And as oil is an insulator, it's way safer than water cooling, too: even if a 1000-volt potential is attached to it, touching the coolant if it leaks does not risk electric shock. As for the OEM's, EV running costs and environmental advantages are inherent. However, as is evident from early adoption trends, consumers are also demanding more performance and fun from their EV's. An EV with a higher continuous rating, particularly in the premium vehicle segment, is going to be a highly attractive and competitive feature.

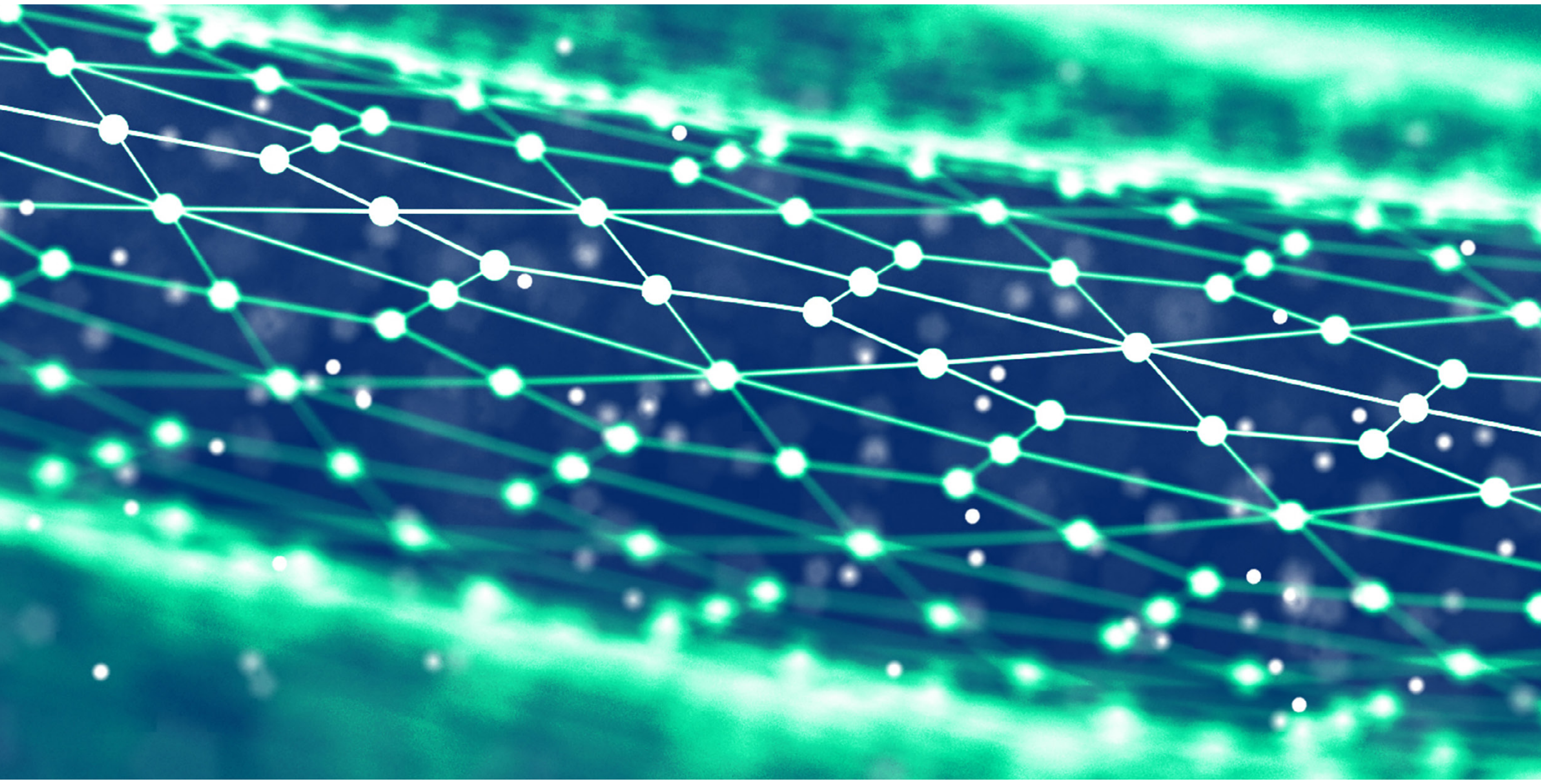
PM: Some of the most exciting research you're involved in beyond EVs is the projection of your technology into aerospace. What is YASA doing in that arena?

TW: In terms of electrification maturity, aviation is roughly where the automotive market was ten to fifteen years ago. We're working on the ACCEL project with Rolls Royce which is aiming to break the electric aircraft speed record, flying a single-motor zero-emissions plane at 300mph with a powertrain developed around a stack of YASA motors. Basically, in aviation, we're looking to effectively double the power density of our technology compared to what we are doing in automotive. Our technology scales so well we envisage there's a lot of potential for us to power this next big electrification revolution as well.



Paul is a multi-award-winning freelance journalist, writer and editor covering crunchy stories in the realms of innovation, technology, engineering, science, health, aviation and spaceflight. He has interviewed, James Dyson, Julian Assange, Elon Musk, and many others - including astronauts, cosmonauts - and new-space pioneers.


From energy
to eMotion



Connected cars: the next cybersecurity challenge

As cars become rolling computers, could hackers seize the wheel? Connectivity is one of four key trends reshaping today's automotive world. Along with autonomous driving, electrified powertrains and share mobility, connectivity is disrupting this 135-year-old industry in fundamental ways. While in-car connectivity can create tremendous value for consumers and OEMs like, the more online access a vehicle has, the greater its vulnerability to cyber-attacks.

Creating value three ways

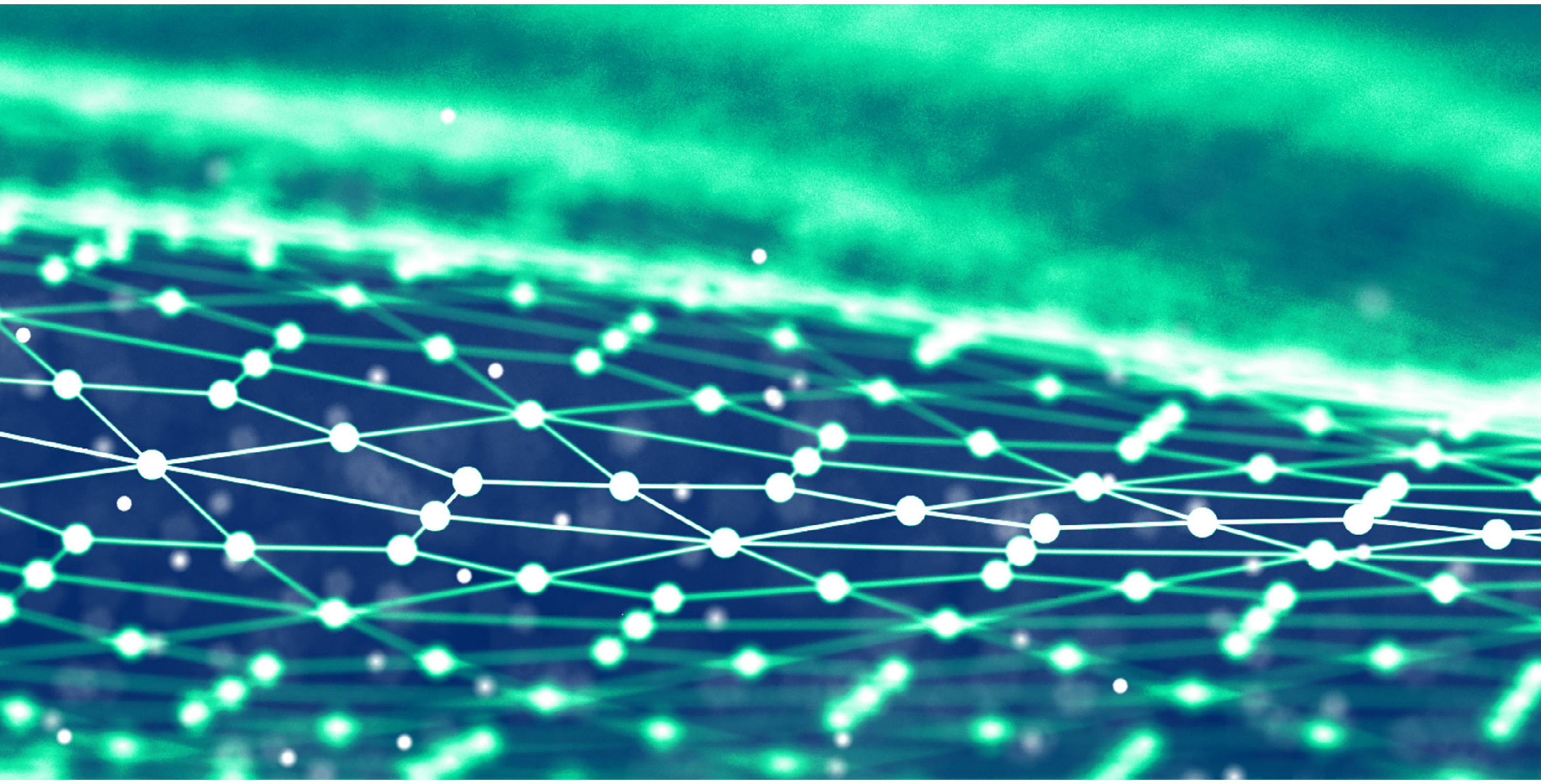
Connected cars are attractive to automakers for at least three specific reasons. First, they can generate new revenue streams through direct monetization, product sales, and the offer of updatable electronic vehicle features or services to customers. Connectivity can enable tailored advertising by using vehicle data to entice customers with individual offerings. OEMs can also sell sanitized aggregated vehicle fleet information (where legal) – collecting, analyzing, and reselling big data to third parties.

Second, connectivity can cut costs in areas like R&D and materials costs when, for example, gathering product field data for product development. It can analyze customer vehicle usage patterns to reduce repair and downtime costs, and boost customer satisfaction (thus reducing sales costs) by tailoring products and services more precisely to customer requirements.

Third, it can enhance security, cutting intervention times for OEMs to fix software issues through over-the-air software-updates and collecting and sending warnings on potential security-relevant events and attacks in real time.

Car buyers seek connectivity

Consumers naturally look for features in their cars that reflect and enhance activities in other parts of their lives. For many people, ubiquitous connectivity has become an everyday reality, and replicating that environment in their automobiles make perfect sense. In fact, according to



McKinsey research, 40% of today's drivers would willingly change vehicle brands for their next purchase in return for greater connectivity. Our research shows that regional connectivity hotspots include China and India, where car buyers consistently tout connectivity's high importance.

In fact, most automotive brands are rolling out their latest in-car connectivity functions today, with converging connectivity packages and BEV offering features on par with premium segment vehicles. (see Exhibit 1).

Connectivity packages increasingly being offered across major BEV and Premium vehicle manufactures

Non-exhaustive

○ Feature not offered ● Feature offered

		BEV OEM 1	BEV OEM 2	Premium OEM 1	Premium OEM 2	Volume OEM 1	Volume OEM 2
Traffic safety	Remote Diagnostics	●	●	●	●	●	●
	Stolen Vehicle Assistance	●	●	○	●	○	●
	Geofencing / Speed Monitoring	●	○	○	●	○	○
	Smart SOS	●	●	●	●	●	●
	Roadside Assistance	●	●	●	●	●	●
Connected infotainment	Internet Browser	●	●	●	●	○	○
	Wi-Fi Hotspot	●	●	●	●	●	●
	News Feed	●	●	●	●	○	○
	Music Stream	●	●	●	●	○	●
	Email	●	●	●	●	○	○
	Social Media	○	●	●	●	○	○
	App Store	●	●	●	●	●	○
	IFTTT	○	●	●	●	○	○
	Home connectivity (Alexa/Google Home)	●	○	○	●	○	○
	Caraoke	○	●	○	○	○	○
Traffic efficiency	Street View (Google)	●	●	○	○	○	○
	Traffic Info	●	●	●	●	●	●
	Online Route Planning	●	●	●	●	○	○
	Parking Info	●	●	●	●	●	○
	Drive recorder	○	○	●	○	○	○
Cost efficiency	Insurance Telematics (UBI)	○	○	○	●	○	○
	Driver Behavior Monitoring	●	○	●	●	○	○
	Real-time Fuel Prices	●	●	●	○	●	○
	Electric Vehicle Charging	●	●	●	●	○	○
	Predictive Maintenance	○	●	●	●	○	○
Convenience and interaction	Call Center	○	○	●	●	○	●
	Remote Services	●	●	●	●	●	●
	Remote Park-Assistant	○	●	○	●	○	○
	Car Sharing	●	○	●	●	●	○
Software updates	Over-the-air updates	○	●	●	○	○	○

Source: Web search

McKinsey & Company 1

Hacker attacks on wheels

While connectivity allows OEMs to differentiate their products with new value-adding features, it also creates a large attack surface for various cybersecurity threats. Hackers can manipulate messages received from the vehicle to, for example, scramble road traffic data to maneuver the car into dangerous areas. They can upload malicious software code during over-the-air (OTA) updates, creating a backdoor in infotainment updates to gain remote access to microphones and speakers. They could also replay remote commands sent to vehicle to unlock doors or stop the engine, or disclose sensitive data concerning the vehicle's location or the driver telematics profile.

To understand what a real automotive cyberattack might look like, those interested can examine several demonstrations from security researchers of possible hacks. For example, in 2019 a team at an annual "white hat" hacker competition was able to gain access to the infotainment system of a premium electric vehicle (EV) via a flaw in a browser and upload malicious software into the car. In 2018, an independent lab found vulnerabilities in a premium European OEM's connectivity service that allowed researchers to gain root access on the vehicle's head unit. The team also hacked the car's Bluetooth stack. Furthermore, in 2015, researchers demonstrated how they could remotely send commands to the CAN bus of a North American performance car that enabled them to control the car's braking system.

Preparing for new cybersecurity regulations

The automotive industry increasingly recognizes the new vulnerabilities connectivity brings to the vehicle platform. One example of cybersecurity's growing importance involves the new United Nations Economic Commission for Europe (UNECE) WP.29 regulation on cybersecurity, which will become type-approval relevant. Adopted in June 2020, the new regulation will become national law in over 60 member countries over the next few years. The EU has already announced it will make the regulation mandatory for all new vehicle types from July 2022. Once enforced in individual countries, vehicle manufacturers must demonstrate sound cybersecurity risk management processes and measures and track their implementation accordingly.

The new UNECE WP.29 regulation will likely cause a paradigm shift across the automotive industry's value chain in three areas.

Managing vehicle cyber risks. This involves the identification, measurement, and management of cyber risks using a systematic approach controlled through a cybersecurity management system (CSMS) that spans across the vehicle itself but also covers the related ecosystem and infrastructure such as vehicle backend systems.

Securing vehicles to mitigate risks along the value chain. This will require new ways of working among value chain players, such as adopting specific industry standards for cybersecurity. It also means automakers must design-in technical safeguards to reduce cybersecurity threats in their cars, such as encrypted communications, cryptographic key management systems, vehicle network firewalls, and vehicle intrusion detection systems.

Detecting and responding to security incidents across vehicle fleets. This involves the implementation of processes and capabilities that can detect and respond to cyberattacks in vehicles, through a security operations center for vehicles.

Three steps the industry can take now

Automotive leaders should consider taking three initial steps when it comes to mastering cybersecurity in connected vehicles.

1. Establish a clear view on relevant cyber risks. Install a cybersecurity management system (CSMS) that identifies and manages cyber risks both across the value chain and across the relevant technological ecosystems and sub-systems. The latter could include in-vehicle electronic control units (ECUs), "vehicle-to-X" (V2X) connectivity services, and vehicle backend services (e.g., data analytics).

2. Create a true digital-security-by-design culture. Attract, grow, and develop cybersecurity talent and invest in secure development practices like threat modelling or peer programming. Introduce enhanced software-testing techniques as well as new supplier-audit practices that focus on cyber risks.

3. Build capabilities to monitor the cybersecurity of cars on the road. Establish processes and technologies that proactively detect suspicious events and threats to the security and safety of vehicles on the road, making it possible to react to dangerous situations and mitigate risks through OTA software-updates as needed.

About the authors

Benjamin Klein is a specialist in McKinsey's Berlin office and Georg Doll is a Senior Expert Automotive Software at McKinsey Digital in Munich with over 20 years' experience in Automotive and embedded Software delivery and management.

White Powders for Enhanced Safety of Electric Vehicles

Yuejiang Liang, Carsten Ihmels

The automotive industry is going through a revolutionary change from combustion engines to electrical drive units. Safe rapid charging technologies and longevity are indispensable for a broad consumer acceptance of Electrical Vehicles (EV).

Probably the most important component of a modern electric vehicle is the Lithium-Ion Battery (LIB) itself. Modern separator technology based on synthetic Boehmite minerals such as **ACTILOX®** and **APYRAL® AOH** play an important role to ensure safety and long life of the battery. On top, an efficient thermal management system is a technological prerequisite for EV safety. Besides the LIB, the major components which need consideration are the electrical motor and the power electronics, mainly the inverter, converter and on-board-charger. Here specially designed Aluminium Hydroxide technology of the **APYRAL® HC** product range can play a key role for the fast adoption of new EV battery technol-ogy. This article deals with the unique characteristics of these minerals and their properties in both applications, the separators and gap fillers in Lithium-ion-Batteries.

1. LIB Separator coating

General explanation of the LIB separator coating

The heart of every electric vehicle is a powerful lithium-ion battery, which in turn consists of individual "battery packs" and cells.

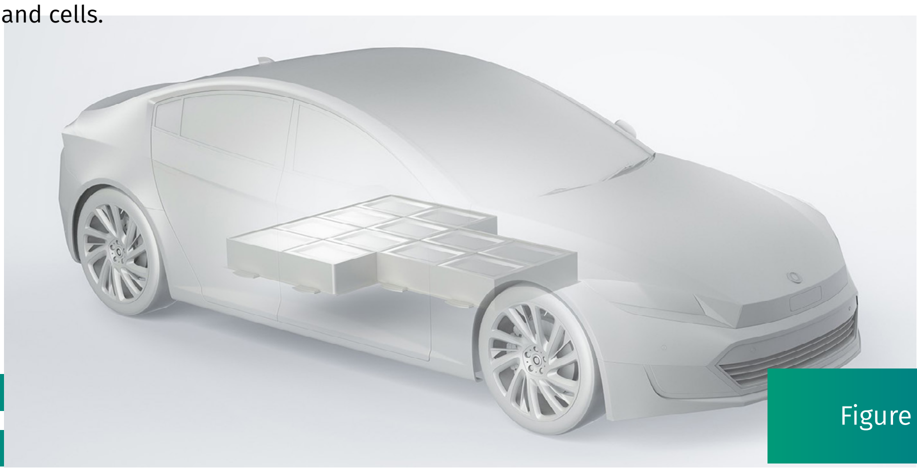


Figure 1. E-car with battery module

Each battery cell is built up in several different layers. The energy source is hidden in these layers. A porous separator acts as a separating layer between the positively charged cathode and its negative counterpart, the anode, but allows the free movement of Lithium ions.

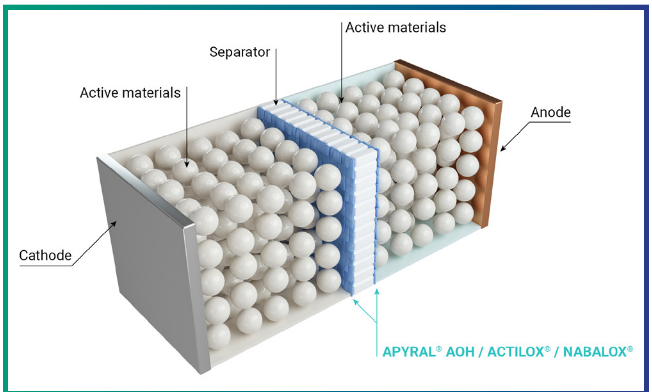


Figure 2. Three-dimensional representation of the structure of Lithium-ion-battery-cell

However, if there is an overload or an external short circuit within the system, the simple polymer based separator of former generations will shrink due to the sudden heat development. At some point there is direct contact between the cathode and the anode, resulting in an internal short circuit and thermal runaway in the battery. After which the entire system starts to burn.

To prevent this scenario, APYRAL® AOH (boehmite) and ACTILOX® (boehmite) from Nabaltec are used. The white powders are processed into a dispersion which is applied to the separator on both sides, by using of a gravure roller coating system. The separator coated in this way becomes heat resistant.

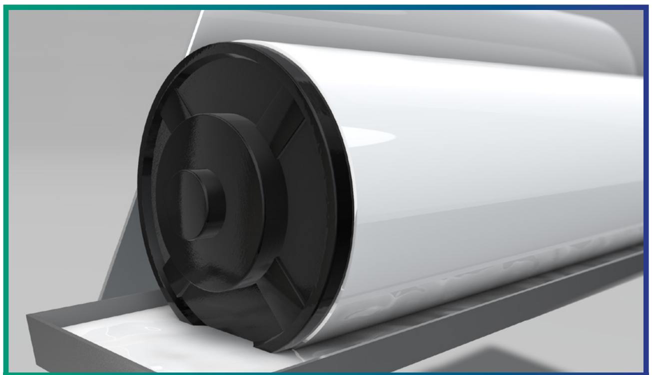


Figure. 3. A gravure roller coating system in which the dispersion is applied to the separator

It is crucial that the coating is permeable and has a high porosity. Thanks to this ceramic coating, the separator can withstand a temperature of up to 250 degrees, depending on the substrate. In compari-son, untreated separators start to shrink at around 90 °. Additionally, the coated separator is reinforced against dangerous dendrites, which may form during charge-discharge cycles, able to pierce the non-coated separator and cause short circuit when contacting the cathode.

The heat stable coating with APYRAL® AOH, ACTILOX® makes the battery much safer and more resistant to short-circuit reactions and prevents possible fires and explosion.

Advantage of boehmite over high pure alumina (HPA) and low soda aluminum ox-ide

Due to the increasing energy density of lithium-ion batteries, the use of safe separators with ceramic coatings is becoming more and more important.

High pure alumina (HPA) was developed as a first-generation commercial solution more than 10 years ago. However, HPA is on the one hand too expensive and on the other hand a ceramic coating was still a niche product at the time.

HPA was quickly replaced by the second generation of low soda aluminum oxide.

As a new coating material for the third generation, boehmite is characterized by the following advantages:

- high purity
- narrow particle size distribution
- uniform morphology
- good dispersibility
- low moisture content
- low hardness compared to low soda alumina

Materials	Mohs hardness
α Al_2O_3	9
AlOOH (AOH)	**3**

→ reduced abrasion with AOH

Products	BET (m²/g)	Na_2O (total in %)	Na^+ water-soluble (%)
Al_2O_3 typical	6.3	0.037	0.036
APYRAL AOH60	5	0.020	**0.002**

→ Reduced moisture uptake with AOH

Materials	Density g/m²
α Al_2O_3	3.9
AlOOH (AOH)	**3.0**

→ reduced total weight

Figure 4. Important powder parameters of Boehmite & low soda aluminium oxide and application benefits of APYRAL® AOH.

Based on these powder parameters the following application benefits are given:

- Reduced abrasion resistance

Aluminum oxide is one of the hardest materials with a value of around 9 on the Mohs hardness scale. In contrast, boehmite with a Mohs hardness of 3-4 is a rather soft mineral. This difference is clearly noticeable in the abrasiveness of the ceramic separators. Both the coating tool and the processing unit in cell production can thus be well preserved. Considering total cost of ownership across the whole process chain of separator coating, boehmite is more competitive compared to aluminum oxide.

With a boehmite-coated separator, the risk of secondary contamination can be minimized and thus safely incorporated into batteries.

- Reduced moisture uptake

Because of its moderate surface area according to BET when comparing with alumina of similar fine-ness, and its very low level of water-soluble soda, boehmite shows low water uptake. Consequently, separators coated with APYRAL® AOH have a very good water adsorption performance.

- Lower Density

Lastly, the lower density of APYRAL® AOH enable separators with lower specific weight and cells with higher energy density.

In summary. when using boehmite APYRAL® AOH, battery designers can improve the heat resistance and puncture resistance of the separator, increase the rate and cycle performance of the batteries, reduce the failure rate of the battery cells and reduce the self-discharge of the battery during use.

2. Gap Fillers and Adhesives in Battery Packs5

To keep the battery from overheating during fast charging, the heat has to be conducted out of the battery stacks through the battery enclosure to an external (active) cooling system. Here the adhesive attaching the stacks to the enclosure and especially the gap filler between the single stacks of the battery module (s. Figure 5) plays a key role. For gap fillers usually a thermal conductivity of 2.5 – 3 W/mK is demanded, which requires filling levels often way over 80 wt.-%

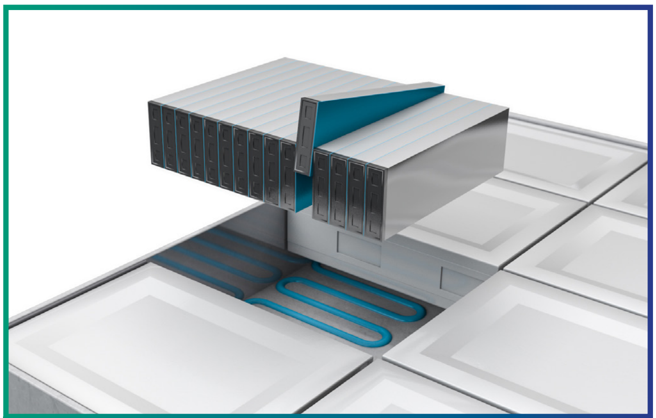


Figure 5. Adhesive and gap filler in a lithium ion battery.

While gap fillers and classic thermal interface materials (TIM) in the electronic industry are used in scale of some grams per unit, a modern LIB requires kilograms of a gap filler. In this regard easy and fast dispensing plays a critical role to enable short assembly times.

Nabaltec AG has developed high performance fillers based on aluminum-tri-hydroxide (ATH) – **APYRAL® HC**. Their optimized particle size distributions simultaneously allow high packaging densi-ties (resulting in high TC values) and extremely low viscosity levels.

When trying to improve the TC of a polymer compound a set of parameters of the compound ingredi-ents have to be considered. Figure 6 gives a simple overview on these parameters.

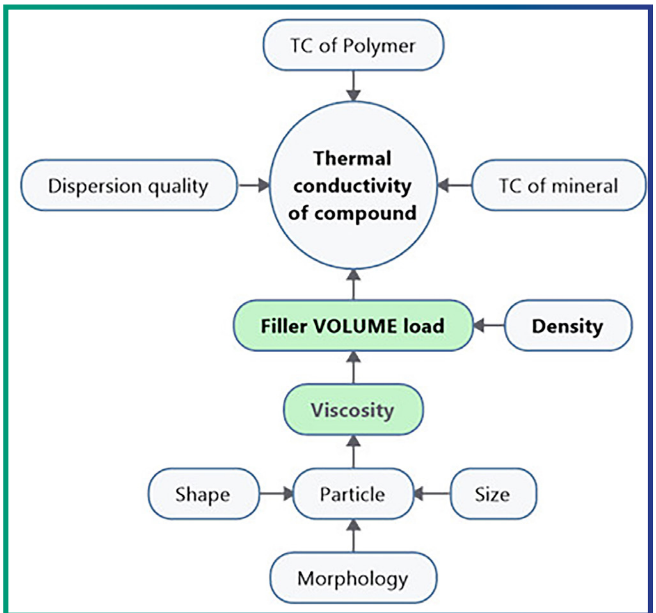


Figure 6. Important parameters to influence the thermal conductivity of a polymer compound.

Name, abbreviation	Formula	Tdecomp (°C)	TC (W/mK)	Density(g/cm³)	Mohs hardness
APYRAL® HC, Aluminum hydroxide, ATH	Al(OH)3	200	20 - 25	2.4	3
APYRAL® AOH, Boehmite, AOH	AlOOH	340	2.3	3.0	3 - 4
NABALOX® HC, Alumina, AO	Al2O3	>> polymer	20 - 40	3.9	9
Magnesium hydroxide, MDH	Mg(OH)2	320	10	2.4	3
Magnesia	MgO	>> polymer	40 - 60	3.6	6
Hexagonal Boron nitride	BN	>> polymer	15 - 400	2.2	1
Aluminium nitride	AlN	>> polymer	180 - 220	3.2	9
Silica	SiO2	>> polymer	1 - 12	2.2 - 2.6	6 - 7

Table 1. Important powder parameters of common thermal conductive fillers.

In first place one usually considers the thermal conductivity of the resin and of the mineral filler. The TC of most resins is very low, consequently TC of the mineral filler is in the focus. For an overview of selected mineral fillers for polymer applications including their TC values please compare Table 1. Naturally the formulator seeks fillers with high intrinsic TC values, like boron nitride (BN), aluminum nitride (AlN), alumina (Al2O3, AO) or magnesia (MgO). However, the most important parameter is the filler loading level. This is understandable as one tries to replace as much of the insulating polymer by the better conducting mineral. Ideally the heat conducting particles need to contact each other (perco-lation threshold level) to raise conductivity of the composite significantly. Ultimately, the formulator must gain the highest filling levels possible. Therefore, the dominating factor is the viscosity perfor-mance of the filler. Results of **APYRAL® HC** in an unsaturated Poylester resin (UP) are shown in Figure 7. The upper graph shows the influence of the filler loading to the resulting viscosity increase in comparison to other mineral fillers. Similarly, to the conductivity (lower graph), the viscosity is rising strongly with increasing filler loads. However, the rheological performance of boron nitride (BN) and alumina is lacking far behind the one of optimized **APYRAL® HC**.

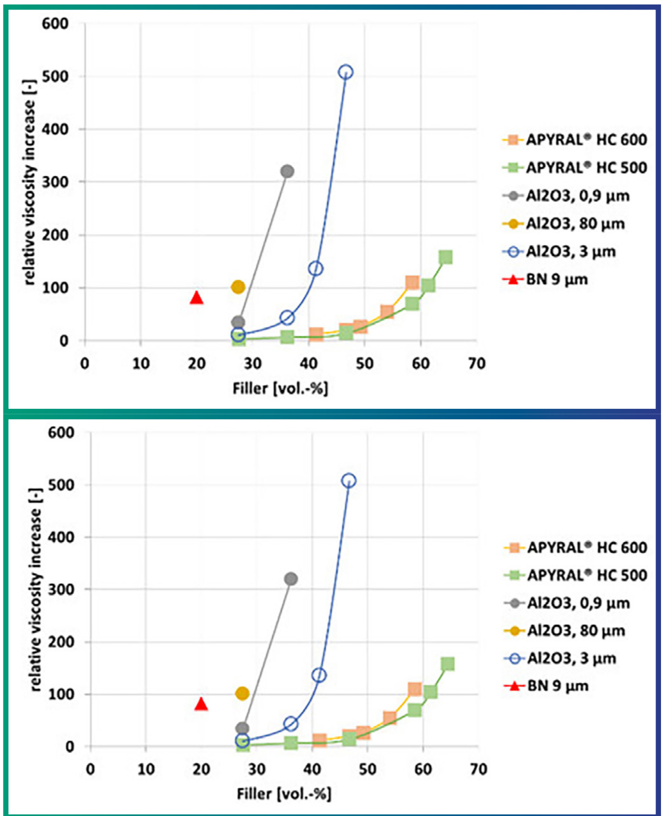


Figure 7. Relative viscosity of APYRAL® HC in comparison to calcined Al2O3, and BN in UP resin at shear rate 10-s at 22 °C (above) and the cor-responding TC values (utilizing Hot Disk method) after curing

Furthermore, the density (specific gravity) of the filler plays an important role. Low density fillers will gain a higher volume loading at the same loading level by weight. APYRAL® HC exhibits a compara-bly low density (2.4 g/ml). This is an especially important point when calculating the mass-based for-mulation cost versus the volume-based application cost, where a certain volume has to be filled.

The unique properties of APYRAL® HC 500 were demonstrated in several resins with varying viscosity and intrinsic TC levels. The results are displayed in Figure 8. Depending on the viscosity level and the mechanical properties (e.g., cross linking degree) of the resin, different loadings and TC levels close to 3 W/mK can be gained. This makes APYRAL® HC 500 and 600 ideal candidates for modern TIM and especially gap fillers for EV batteries.

Yuejiang Liang, Carsten Ihmels, Nabaltec AG

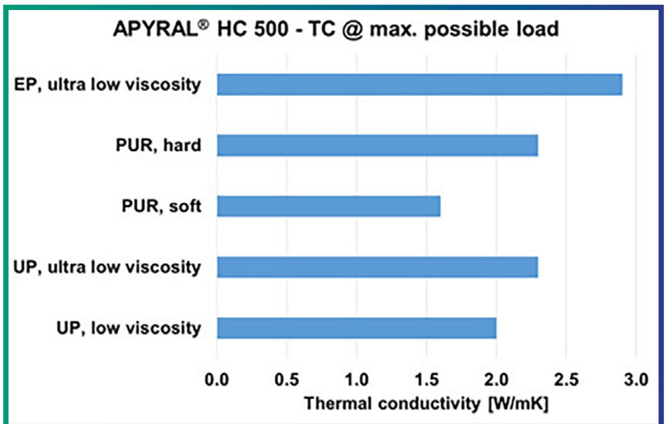


Figure 8. (oposite) Thermal conductivity of an UP resin filled with **APYRAL® 500 HC.**

Making fuel cells more durable – and affordable

Looking around us, we see more and more applications for fuel cell technology gaining traction. Examples are more than 300.000 µ-Combined Heat and Power installations in Japan, and more than 30.000 fuel cell-powered forklifts in the US. In the transportation sector, OEMs like Toyota, Honda and Hyundai have introduced fuel cell electric vehicles to the market – and the interest in applying this technology in the Heavy Duty / Commercial Vehicle segment is rising, especially where pure battery electric technology might not be able to fulfill the specific requirements of enabling long distance electric driving in combination with short fueling or charging time. As – in contrast to battery technology - fuel cells do not store, but generate electricity on-board, they enable a decoupling of vehicle weight from electric driving range which is why the heavy duty fuel cell segment sees a lot of traction.

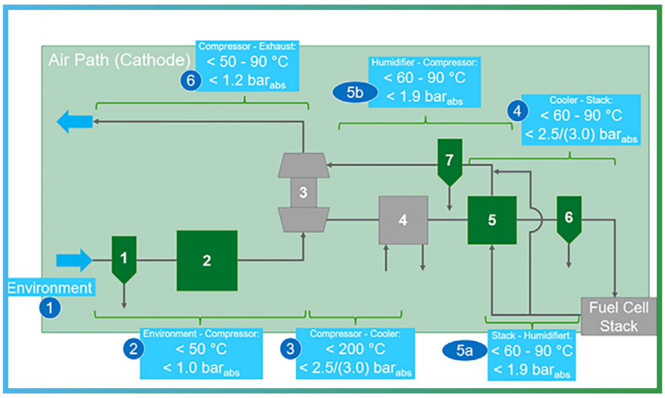
What is required to achieve market penetration of this technology? The answer is clear: system durability has to be enhanced, while cost must come down to make the technology also economically attractive.

The US Department of Energy has set targets for both to enable streamlining of development activities to achieve the ultimate goals. The table shows these targets for passenger cars and Class 8 trucks.

Realizing economies of scale and reduction of catalyst cost are major levers to achieve the cost targets. One challenge is that lower platinum loadings might make the stack more vulnerable. As the lifetime of the systems need to be enhanced in parallel, degradation rates must significantly be reduced. In addition to optimizing of operation and regeneration strategies, degradation caused by e.g. airborne contamination must be prevented. Another strategy to reduce cost is to increase the system´s energy efficiency. As approximately 10% of the gross installed power is lost to auxiliaries, mostly to the compressor, any optimization of pressure drop inside the system will help to lower parasitic losses. This opens up the opportunity to reduce the installed gross power to reach the rated net power. It will also help to reduce noises from the compressor – as no internal combustion engine will cover noises from auxiliaries which requires efficient silencers inside the system. As with pressure drop optimization, this can best be achieved not by optimizing individual components, but by considering and optimizing the system performance in a holistic approach.

Fuel cells generate electricity in a catalyzed, electrochemical reaction between hydrogen and oxygen. While hydrogen is delivered from on-board pressure tanks, oxygen is taken from compressed ambient air. As heat is also generated by the reaction, a cooling loop is also required.

Comparing the typical pressure and temperature levels in a 100 kW automotive fuel cell system, it becomes apparent that these are similar to the levels in internal combustion engine air inlets.



(1) Water separator (air filter)
(2) Cathode air filter
(3) Compressor
(4) Charge air cooler
(5) Humidifier
(6) Water separator (humidifier fresh air outlet)
(7) Water separator (humidifier exhaust outlet)

Pressure and temperature conditions:

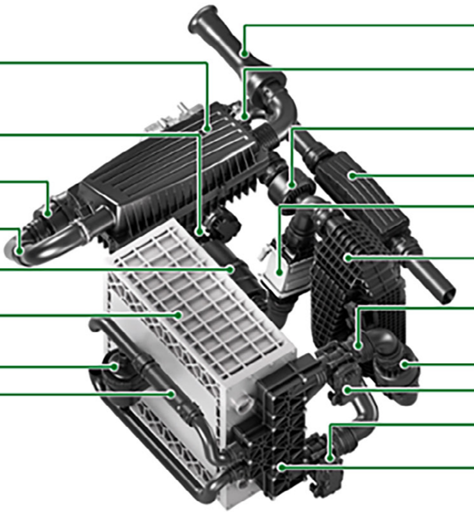
Overall system spread (approx.) -40°C - 200 °C ~0.60 - 2.5/(3.0) bar_{abs}

To reach cost efficiency, the transfer of existing technology from internal combustion engine air management to the cathode air inlet path is beneficial. Furthermore, as the fuel cell exhaust consists mostly of oxygen-depleted, hot air at high humidity, plastic technology can be applied which also offers cost- and weight-saving potentials.

Automotive / Car	2020	Ultimate
Durability [h][1]	5.000	8.000
System cost [US-$/$kW_{net}$][2,3]	40	30

Class 8 Truck	2030	Ultimate
Durability [h][4]	25.000	30.000
System cost [US-$/$kW_{net}$][3,5]	80	60

1: Criterion: drop in rated power by 10%
2: @ annual production of 500.000 systems
3: H_2 storage, battery, power electronics, electric drive excluded
4: equals 1 Mio. / 1.2 Mio. miles of operation @ 40 mph
5: @ annual production of 100.000 systems



This demonstrator model shows the cathode air inlet and exhaust system as well as components for the cooling loop built around an 85 kWnet fuel cell stack. The anode loop is not shown.

The function of the cathode inlet path is to deliver clean, humid air to the fuel cell stack at the right temperature and pressure. In a first step, airborne contamination must be removed by a filter. For efficient protection, an understanding is necessary on what are the most critical contaminants. Based on lab tests and field experience, it is commonly accepted that sulfur- and nitrogen-containing gases are critical. The degree of a partial regeneration in case of NOx contamination is higher than e.g. for Ammonia, and SO2 is acting irreversibly on the catalyst in even very low concentrations. The poisoning of the catalyst results in loss of ESCA over time. In addition, Ammonia can also react with the membrane material, increasing the membrane´s internal resistivity. Whereas particles can be separated with fibrous filter media, removal of the gases requires adsorber materials.

Standard adsorber materials are not efficient in capturing the polar target gases. Here, activated carbons with acidic or basic impregnations can be used which will capture gases exposing opposite polarity by chemisorption.

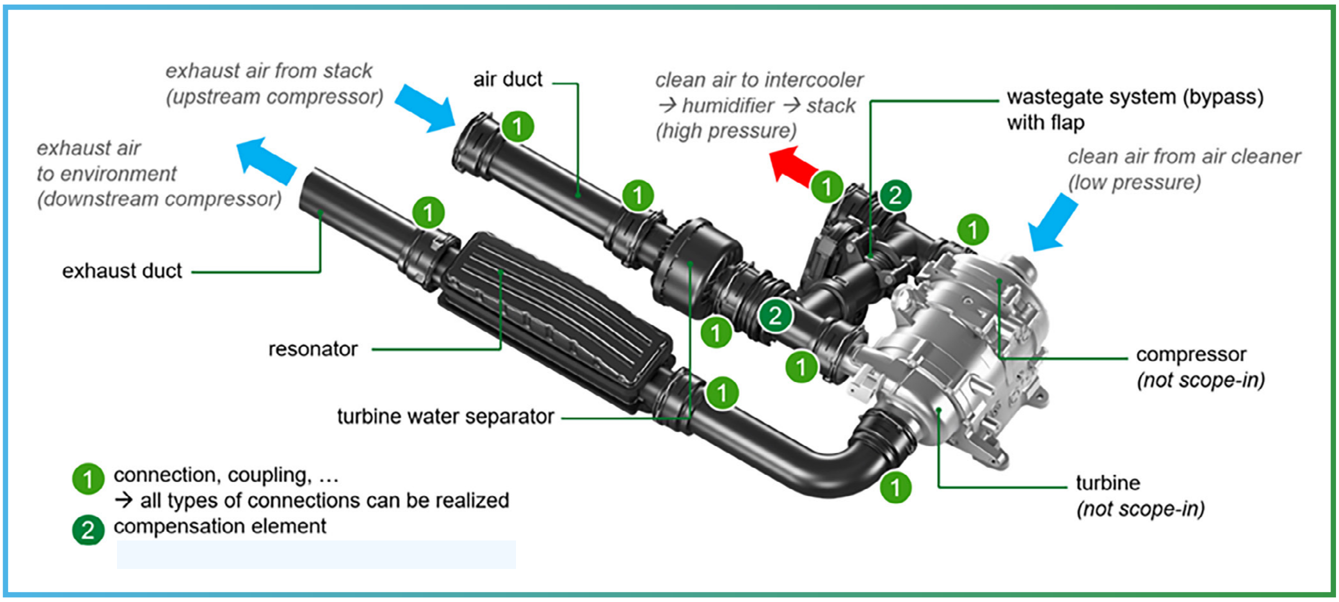
There is no adsorber material available which will capture all harmful gases alike. In consequence, different carbons must be used to achieve overall protection. This might require a multilayer-design, with a tailored sequence of carbons. As the adsorber materials all have a specific capacity for the target gases, it is essential to know their typical concentrations in real-life applications for a projected service life. Applying too much of the carbons will increase pressure drop and cost which is both contradicting the overall system design cost targets. Applying too little will lead to enhanced system degradation rates, lowering the targeted system durability. Besides averaged gas concentration levels, peak concentrations must also be dealt with by a filter solution.

While it is essential for high stack efficiency to deliver cathode air with high humidity, liquid water has to be avoided in the cathode air system. In the inlet stream, water separators might be placed in different positions, all with different functions. Axial cyclones can be applied to separate the water from the air stream. They combine sufficient separation efficiency for larger droplets with a low pressure drop. The presence of liquid water can lead to blocking the air stream through the filter, flooding of the stack, and blocking the pores inside the gas diffusion layer. All this will lead to oxygen starvation inside the stack.

While liquid air must be removed from the air stream, cathode air entering the stack must contain sufficient humidity to prevent the drying of the stack membranes as this would reduce the proton transport efficiency. Most systems use the water produced by the fuel cell reaction to humidify the cathode inlet air. While internal humidification inside the stack is possible, most systems use an external gas-to-gas humidifier. As the pressure of the “dry” cathode air in the inlet stream is higher than in the exhaust stream, the water must be transported against a macroscopic pressure gradient. This is achieved by applying membrane technology. The membranes must be gas-tight, but permeable for water, e.g. through a solution-diffusion mechanism. Either flat-sheet or hollow-fiber membranes can be used. Current research hints at a higher efficiency and thus better packaging for flat-sheet membranes.

Noises in the cathode air systems must be dampened by silencers. Here, broad band silencers can be applied which can dampen orifice noises, flow noises through ducts and humidifier, and compressor noises. When designing a silencer, the target is often set to reduce the noise by 20 dB. Reflective broad band silencers can be used, also with additional absorber foams.

On the exhaust side, one important component is the turbine water separator. The use of a turbine can reduce the energy consumption of the compressor if the remaining over-pressure inside the exhaust stream is used to drive a connected turbine. The turbine blades must be protected from impact of large water droplets or even ice crystals to prevent mechanical damage. Axial cyclone water separators can also be used here. Integration of a water reservoir and a draining mechanism is beneficial.



A waste gate system is also integrated to shut off the air stream to the turbine to prevent harmful pressure pulses in case that the stack is shutting down fast.

The ducting can be made out of Polypropylene ducts with appropriate means for movement compensation as the exhaust gas temperature typically does not exceed 100°C.

A multi-chamber broad band silencer can be used in the exhaust path as it can also operate in the presence of water.

Through the consequent transfer of experience, products and processes from air management for internal combustion engines, entering fuel cell technology becomes possible as competences and assets can be re-used. Another way to save tooling cost and to speed up (sample) supplies is the market product approach. In this, typical technological requirements are classified into a small number of requirement sets, and standard components fulfilling these are developed. These can be applied into different systems by offering flexibility in mounting. First products developed after this concept like Cathode Air Filters and Ion Exchange Filters are already used in series application, e.g. for fuel cell busses proving that the approach is what the industry needs at this stage.

Dr. Michael Harenbrock, Principal Expert Electric Mobility

"At MANN+HUMMEL, we believe that fuel cell technology will be an important contributor to decarbonization of the transport sector, especially in the Commercial Vehicle segment. Our mission is to enhance system lifetime through innovative filtration and separation systems"

NEXT LEVEL BATTERY TECHNOLOGY
– LASER-WELDING JOINING AND COOLING TECHNOLOGIES

DR. JOHANNES KAAR

Manufacturing capabilities in battery production are developing rapidly and Tesla just gave promising insights on their strategy towards cheaper and better batteries on their recent battery day. Now a less well-known but not less innovative company revealed interesting insights on laser-welding of cylindrical cells: The Austrian based company VOLTLABOR.

The connection between battery cells and the electric conducting sheet (also known as busbar) is a vital factor with positive or negative effects on the overall battery lifetime, performance, safety and stability. In the last years different methods have evolved rapidly with welding becoming a new industry standard, and within this technology laser-welding seems to win the paradigm shift.

Initially starting with bonding – which was introduced and optimized in the electronic industries starting in the 1990's – bonding has today been replaced by various forms of welding. Due to availability and stability of high-scale production facilities it was self-evident that bonding was the premier choice for transaction batteries in the beginning. However, the technology lacks vibration resistance and quality of connection in resistance and tensile forces. Disadvantages which are of less importance to electronic applications but not to e.g., e-mobility batteries. This is also the reason why welding has become more into the focus of battery manufacturers. Spot, ultrasonic and laser welding are the common system. Whereas laser-welding has initially high investment costs it is seen as the preferred option especially with pouch and prismatic cell formats. However, for a long-time laser-welding was not supposed to work with cylindrical cells. The laser-beam was not precise enough and resulted in violations of the cell-material. This technology barrier was the starting point of the company VOLTLABOR in 2008 in Austria, with a long history in laser-welding.

VOLTLABOR is a pioneer in laser welding of cylindrical cells and had managed in 2008 to laser-weld cylindrical cells on both sides with unrivalled quality at zero-failure rate. At this time the first to do so globally. This led to increasing international interest and brought the interest of top players in the field to the picturesque village in the north of Austria. Since then, the technology has increasingly developed. In recent years, the laser-technology has developed constantly with rather positive effects on laser welding, as Martin Reingruber, CTO at VOLTLABOR states: “In the last 10 years the technology has become faster and more precise.” This allows that laser-welding today outperforms other connecting technologies such as bonding or resistance welding. Together with other positive effects such as high homogeneity and high contact-forces a new standard has been set. The effects have also been scientifically investigated and proven. In various scientific papers of German and Austrian universities, which serve as development partner from VOLTLABOR, a team of engineers compared laser with spot and ultrasonic welding. Across various aspects laser-welding outperformed spot and ultrasonic welding. Contact resistance, max. tensile strength are significantly better, furthermore laser-welding allows a much higher flexibility regarding alloys and materials combinations. The following tables summarizes key insights and differences regarding the different welding methods:

As stated in the table Laser-Welding delivers best results regarding electric resistance and tensile strength. Whereas spot-welding leads to a limited temperature effect on cell pole/housing level ultrasonic welding results in the highest temperatures. This again may affect the overall cell quality and lead to negative effects in the overall production process due to negatively high process temperatures.

Similar results regarding the benefits of laser-welding versus other contacting methods have been made by the university of Uppsala (Sweden). In a thorough analysis joining methods have been compared and evaluated along different criteria. Whereas resistance welding leads to the overall worse results, laser-beam welding outperforms on average. The following table summarizes the results, with factors rated between 1-5 with 1 lowest and 5 highest:

Table 2: Evaluation of joining methods

Criteria	RSW Resis-tance Welding	UWB	LBW Laser Beam Weld-ing
Joint resistance (similar materials)	4	4	5
Joint resistance (dissimilar materials)	2	5	3
Heat transfer	3	3	4
Potential mechani-cal damage.	4	4	5
Joint current capacity	3	3	5
Joint durability	4	4	4
Potential vibration damage	5	5	5
Cycle time	4	4	5
Repeatability	3	4	4
Cost per battery connection	5	5	4
Investment	4	4	2
Easy automation	4	4	5
Flexibility	3	3	3
Safety	4	4	3

Another benefit from laser-welding results in the flexibility of the respective material mix that is possible. In contrast to spot or ultrasonic welding laser-welding allows for a myriad of different combinations of nickel/cooper/iron steel across different alloys. Thickness of the busbar has been optimized, leading to lower overall weight of the battery and minimized material costs. Depending on client wishes VOLTLABOR is able to laser-weld a broad spectrum of different materials and also cell-formats. This is especially interesting as there seems to be a clear industry shift towards bigger cell formats. With Teslas new cell-format 4680, better energy density, lower manufacturing costs and increased safety is proposed.

In the last year the company VOLTLABOR has made another big step towards professionalism becoming one of the rising stars in the industry. Through a joint-venture with established Austrian Tier-1 supplier Miba, the company has exclusive access to MIBAs FLEXcooler® Technology – a highly innovative cooling system that avoids gapfillers, reduces CO_2 footprint, weight and costs. The FLEXcooler® is a liquid cooling component and enables bottom cooling of cylindric cells. The bottom cooling is the cooling method of the future as shown by Tesla at their battery day. A single cell fuse rounds off the battery concept to a safe and reliable battery pack. This year a highly automated production line with a capacity of approx. 500 MWh per year started its production.

The trend and development definitely supports companies like VOLTLABOR a typically hidden-champion in the industry or as Stefan Gaigg, Managing Director at the Austrian battery producer, states: *“The remaining challenge lies in an automated manufacturing process, combined with outstanding product features like an innovative cooling concept. That’s where manufacturer like us still have a competitive edge over other companies.”*

Table 1: Quantitative comparison of welding technologies

	Spot	Ultrasonic	Laser
Min. electric resistance	0,167mOhm	0,167mOhm	0,130mOhm
Max. tensile strength	316,78N	661,32N	876,8N
Highest temperature on cell-poles	31,0°C	110,7°C	86,86°C
Highest temperature on cell cylindrical housing	25,0°C	55,2°C	32,5°C

Source: Larsson et al: Welding methods for electrical connections in battery systems, Uppsala Universitet, June 2019.

Advances in Quick Connectors for Thermal Management Systems in Hybrid and Electric Vehicles

Sébastien Frasse-Sombet

With the continued growth in popularity of hybrid and electric vehicles, it is now clear that E-mobility is much more than just a trend. As the transformation of how we drive and travel is completed, it will be rare to find a vehicle that is not in this category.

The effects of this transformation trickle down to affect Thermal Management system designs and integration, which creates challenges that have direct consequences on fastening and assembly. The transition towards Hybrid Electric Vehicles (HEV) and Battery Electric Vehicles (BEV) adds complexities to these systems, which are required for temperature regulation of batteries, E-motors, power electronics and other sub-systems.

Thermal regulation is indeed critical to the performance of these types of vehicles, affecting both vehicle range and battery lifespan, as well as enabling fast charging which will be key to future EV requirements. Most Thermal Management systems rely on either air or fluid circulation through pumps, valves, and several heating or cooling lines. Integrating these lines during the vehicle design phase, and enabling efficient vehicle assembly, are challenges that must be carefully considered for any EV project.

SYSTEM IMPLICATIONS

When building the latest hybrid and electric vehicles, automakers are realizing that more subsystems now must rely on thermal regulation (heating and/or cooling) than in the past in order to achieve the required performance level, and the trends make it clear that more focus must be given to Thermal Management systems when vehicles are designed and assembled.

To put it in perspective, a traditional ICE vehicle typically has between 5 and 7 cooling lines, while an HEV or BEV vehicle can have up to 30 or more, depending on how the battery pack is designed.

A key component of Thermal Management systems is Quick Connectors (QCs). QCs are a popular solution to assemble these lines during vehicle integration and help to enable both efficient and safe connections. The result is that the more lines a vehicle has, the more QCs are needed to keep it safe and effective.

By definition, more fluid lines mean more connections must be made with the large diameter Quick Connectors (QCs) that are typically used for these applications.

Now consider the installation of these QCs during vehicle assembly. The insertion effort required to achieve all these connections quickly adds up to several tons of manual pressure per day, and per operator. This creates risks of musculoskeletal disorders for workers, so improving ergonomics is paramount for QCs used in these applications.

Moreover, every cubic inch counts, as high density is required to offer the best possible vehicle performance. Higher system density indeed leaves more room for energy storage in EV battery packs, which means longer range. High complexity and density are especially critical in Hybrid cars, where all electric drive components must coexist with an ICE engine and its related components — including fuel lines, filters and fuel tank.

Fluid line connections in these complex environments can be particularly challenging to make and verify. However, reliable connections are critical, since any leakage caused by mis- assembly would generate significant safety threats, something that automakers want to avoid. The engineers know that the most efficient way to mitigate this is by paying close attention to the selecting of appropriate Quick Connectors.

NEW CONNECTOR TECHNOLOGIES SOLVING CHALLENGES

Current advances in Quick Connectors lead to enhanced safety standards, as well as an improved integration and production process.

For manufacturers, an effective way to improve working conditions and worker safety is to select optimized QC designs with reduced insertion efforts. This makes fluid line connections easier on the assembly line, which also means more reliable.

Moreover, since ensuring effective fluid line connections is critical to operational safety, today's advanced QCs also offer safety features such as assembly verifiers enabling operators or automatic systems to confirm that a proper connection has been made which mitigates risk of mis-assemblies.

This reduces non-quality costs and risks, and brings added peace of mind to the integrator, knowing that all systems were manufactured in the safest possible manner, limiting the possibility of a vehicle failure or of any costly recall.

At ARaymond, our engineers have been involved in this segment for many years, and are regularly updating our solutions to match the market demands.

Building on 10 years of experience designing and manufacturing Quick Connectors complying with the VDA standard, our latest solution is a new generation of VDA LOW PUSH Quick Connectors with an optimized design aiming to alleviate current challenges of Thermal Management Systems integration and assembly.

The design of the new QCs leads the way in terms of how the industry adapts to the vehicles of the future. These QCs have been meticulously improved to reduce the insertion effort required to achieve connection. More specifically, we estimate that the diameter NW16 VDA LOW PUSH QC reduces this insertion effort by at least 40% versus industry standards. Larger diameter QCs will display even greater benefits.

These improved figures will be critical to enhancing ergonomics and will help to facilitate the assembly of thermal management lines in complex environments.

In addition, the innovation features an optional VERIFIER tab that only becomes visible when the end piece is correctly inserted into the Quick Connector and displays a customizable QR code which can be easily detected and read. This feature enables fast and automated quality controls, boosting safety for workers and end-users, and is something that companies should be looking for as they modernize their manufacturing processes for Industry 4.0.

CUSTOMIZATION IS CRUCIAL

Auto suppliers and OEMs know that thermal line integration can be a major challenge in the complex systems offered in today's high-tech vehicles. That is why a variety of options are necessary. QCs cannot just fit one category — there needs to be a variety of diameters, angles and shapes to fit every possible scenario for every possible customer need. And so engineers must work closely with vehicle integrators when crafting the newest, most modern QCs.

Also customization opportunities via adding fluid management elements such as valves or sensors, must be available wherever needed.

This need for customizability is an essential that we take seriously and build into all our connectors This idea is foremost in the minds of our engineers as they design the next generation of Thermal Management Systems. Moreover, since most current automotive projects are deployed on a global scale, with vehicle production distributed to many assembly plants, we can deliver our latest innovations everywhere in the world with local manufacturing and engineering support.

As E-mobility continues to grow and HEV and BEV vehicles become the standard, the design and manufacturing process in relation to Quick Connectors for Thermal Management systems must continue to adapt to this new reality. The benefits to the end user will translate to longer vehicle range and more reliable vehicles. On the production side, these advances are leading to safer environments for workers by limiting the insertion effort required for QCs, which is essential since there are so many more QCs to install on hybrid and electric vehicles. New QC solutions should be customizable, easy to use, and feature cutting-edge technology that ensures vehicle safety, as there is no room for error when it comes to these critical vehicle systems.

Sébastien Frasse-Sombet
Senior Global Product Manager chez ARaymond Network

Keeping your balance

Modern lubricants work exceptionally hard to deliver the right balance of cooling, protection, efficiency and reliability for a myriad of vehicle systems. The additives in these fluids can dramatically enhance performance and be pivotal in bringing new hardware to market.

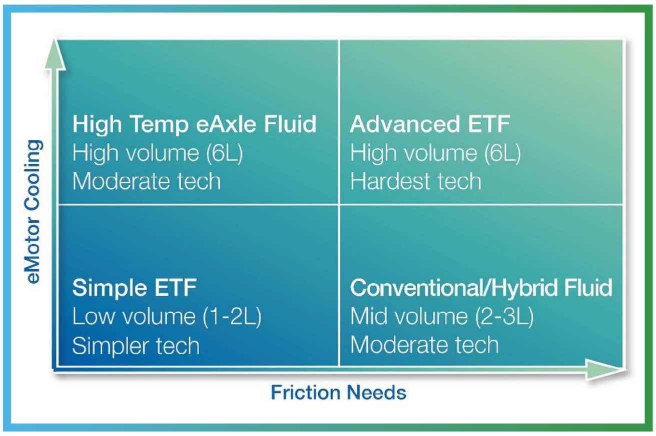
From the latest EV technology such as direct-cooled eMotors and multi-speed eAxles, to emerging technology such as immersion-cooled battery modules, all can benefit from targeted lubricant additive solutions.

Future-proofing

'Lubricant is not just an interchangeable part within a system; it makes a fundamental contribution to successful design,' explains Adam Banks, eMobility marketing manager at lubricant additive specialist Afton Chemical.

'Every lubricant contains additives that ensure it has the right balance of properties to support a given application. While additives can often make up less than ten per cent of the finished lubricant, they are responsible for much of its performance. That's why Afton works closely with OEMs and engineering firms: by identifying early the challenges brought by new materials and hardware, we can help to deliver future-proof performance gains.'

Being fit for the future means that lubricants for electrified vehicles must be ready to handle a host of new demands – particularly the ability to lubricate and cool the eMotor. Direct exposure to high speed and temperature eMotors, power electronics and sensitive electronic controls and sensors – on top of the usual gears, bearings and friction devices – places additional, and sometimes conflicting, pressures on the lubricant and its additives.



Keeping it real

'Lubricants for EV applications require robust testing to ensure that they are fit for purpose: not just at the outset, but throughout their service life,' says Dr Chris Cleveland, R&D Director at Afton. 'For electrified vehicles to be reliable for consumers, it's vital that these test results translate effectively to real world operation.'

Compared to conventional lubricants, EV fluids need to excel in three additional ways: electrical properties, thermal stability and compatibility with new materials.

Afton has developed leading test methodologies that don't just verify the laboratory properties of fresh fluid but go further, aiming to identify all the relevant factors that can affect lubricant performance over time.

Electric performance

The right fluid electrical properties don't just improve safety, they also help protect components from the potential damage caused by sudden electrical discharges.

'As a start point, any lubricant coming into contact with electrical equipment should therefore be a dielectric fluid, with low electrical conductivity and limited ability to store electrical charge,' explains Dr Cleveland.

For any lubricant, thermal breakdown is accelerated by exposure to high temperatures and eMotors generate considerable heat. Thermal breakdown increases the number of polar particles in the fluid, which increases its electrical conductivity, so thermal stability is essential to guarantee performance over the long term.

The test of time

'Standard electrical property testing is a good start for fresh fluid, but very often the changes in electrical properties that occur with age are not carefully examined,' reveals Dr Cleveland. 'Because thermal stability is crucial for EV lubricants, the in-house testing of aged fluid that we do at Afton is really important: it's what helps us to predict the behaviour and longevity of lubricants in service.'

Compatibility is the third key area. eMotor windings and power electronics both contain copper, either coated or held within a sealed unit, so fluid compatibility with the wide range of new coating and sealing materials and lacquers is essential. The lubricant must also be compatible with the copper itself, as coatings can shrink and crack over time and expose the metal to direct fluid contact.

Above and beyond

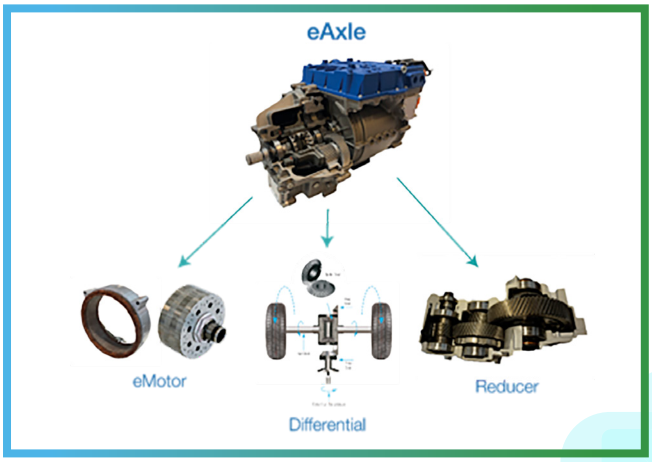
'We believe the basic copper corrosion test doesn't go far enough,' says Dr Cleveland, 'so our own testing extends the copper strip immersion time and also measures the amount of copper in the fluid at the end of the test. That gives us a much more accurate indication of metal loss, correlating better with real world performance.'

Another aspect that is overlooked by standard tests is copper compatibility when the fluid is in its vapour phase. 'Given the high temperatures created by eMotors and the increased numbers of sensors and controls, it is likely that lubricant will come into contact with copper elements while in its vapour form,' adds Dr Cleveland. 'With no industry standard test to examine the implications of this contact, Afton has developed a vapour phase copper compatibility test. This test shows that for some standard transmission fluids, copper corrosion is more severe in the gas phase than in liquid form. This challenging aspect was informed by our extensive testing and can be solved by blending a careful choice of additive chemistries.'

Unlocking new tech

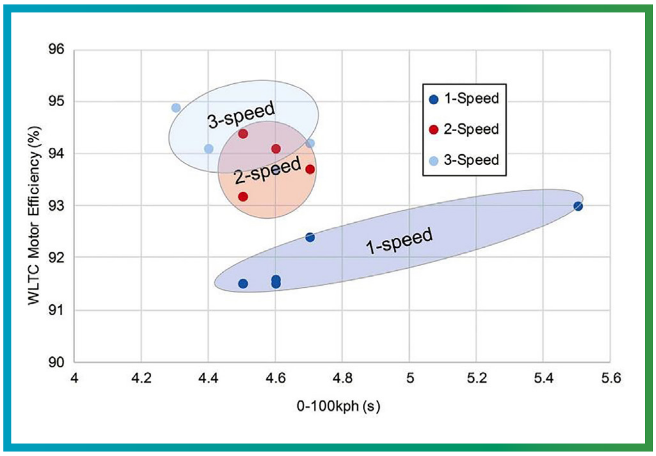
Afton's test methodologies are driving a new generation of dedicated EV lubricants. With its conventional transmission fluid chemistries already featuring in over a third of the world's cars, Afton's latest solutions now offer coverage for everything from hybrid transmission platforms – derived from step-type, DCT or CVT designs – to the latest fully electric drivetrain technology, including direct-cooled eMotors and multi-speed eAxles.

'Our HiTEC® 35701 additive package has enabled the first ETF – Electrified Transmission Fluid – to be developed specifically to meet all the requirements of direct-cooled multi-speed eAxles. This package delivers the right balance over time of cooling, wear protection, optimised friction, electrical properties and compatibility,' says Dr Harald Maelger, European OEM Relationship Manager at Afton. 'We know from our work with OEMs that efficiency, reliability and value are core concerns for engineers, so we also reached out to Ricardo for an independent assessment of the benefits of using dedicated ETF.'



Independent analysis

The Ricardo modelling identified overall efficiency improvements as high as 2-3% from direct cooling the eMotor, enabled by appropriate lubricants. Analysis also showed that further efficiency gains of 2-4%, from using 2- and 3- speed instead of single-speed transmissions, could also be realised by using lubricant with the right friction properties. 'These savings could support a valuable increase in driving range or a net reduction in eMotor and battery costs,' explains Dr Maelger.



Even for emerging technology such as battery immersion cooling, Ricardo analysis shows that direct cooling can help to support the demand for faster charging, faster power output and greater efficiency.

'While specialist battery immersion cooling technology and fluids are not yet mainstream, we're always looking well ahead to explore the value that advanced lubricants can bring to every corner and every tier of the EV market,' adds Dr Maelger.

Prototype tests

Afton's work is not only based on additive and modelling expertise, but also on practical in-house evaluation of designs that are in the commercial pipeline.

With its OEM partners, the company continues to take testing to the next level. As recently published, prototype eMotor rig testing based on pre-production OEM hardware has shown that improving the thermal conductivity of the lubricant generates measurable improvements in eMotor peak torque.

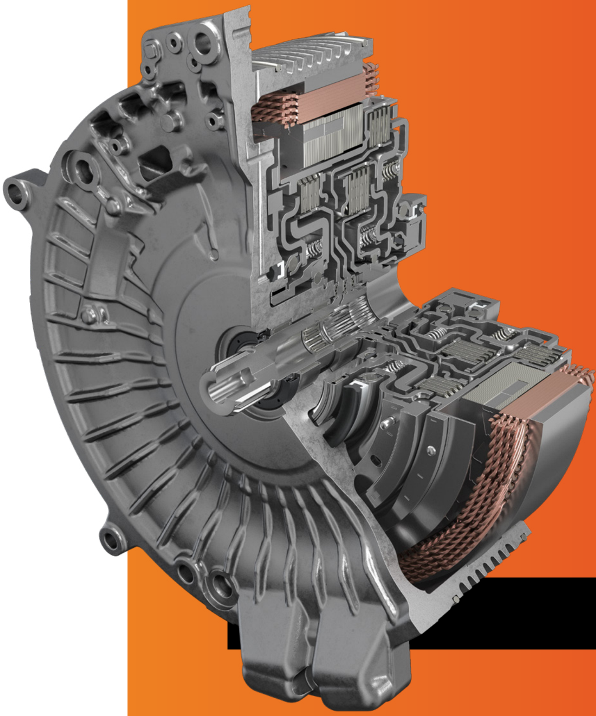
Bringing balance

Afton's value lies in its ability to unlock new technology for engineering partners through the right blend of additives.

'Successful engineering is all about balance,' concludes Adam Banks. 'This is achieved most efficiently through close and early partnerships between those providing the specialist lubricant technology and those developing the hardware.'

With so much chemistry, modelling and testing expertise at their disposal, the OEM teams at Afton Chemical continue to offer a guiding hand to help each partner find – and keep – their balance.

How to develop improved electric drivetrains



Overview

Automotive manufacturers are under growing pressure from regulations across the globe which are demanding substantial emissions reductions. Therefore, the number of passenger cars and commercial vehicles with electrified drivetrains need to be increased remarkably.

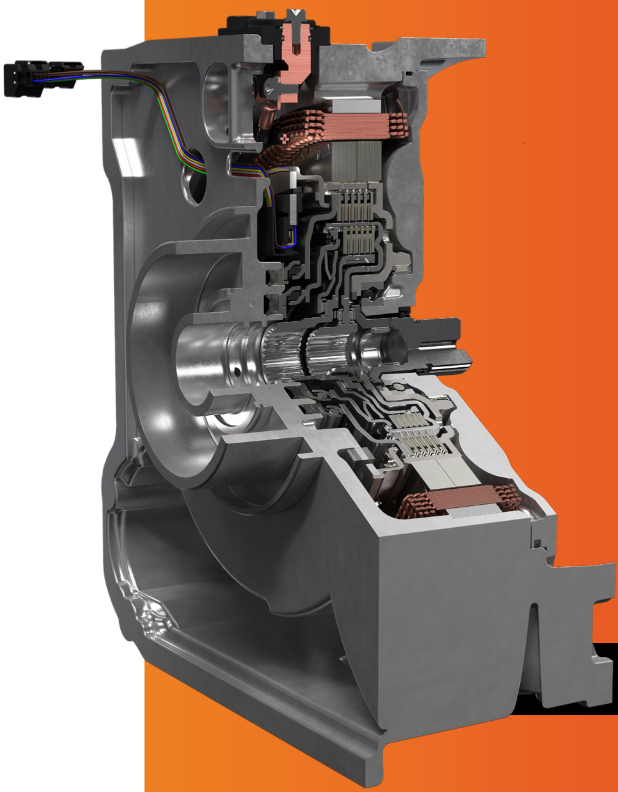
Understanding vehicle dynamics and customer needs

The process of optimizing a drivetrain according to individual client expectations needs a continuous dialogue among the engineering teams to precisely specify the OEM's requirements and to agree on all details. Developers should consider the entire vehicle system and its components to understand their impact on the drivetrain. Moreover, they must have the experience and capabilities in designing electrification solutions that conform to the Functional Safety standard ISO26262. OEMs can only comply with this standard at the overall vehicle level if the drivetrain sub-system (known as an 'item' in ISO26262) meets all of the specific requirements.

In order to define required wheel torque as well as the highest rotational speed of the wheels and to relate them to the electric drivetrain, vehicle dynamics such as top speed, desired acceleration and maximum gradient need to be understood. They are key factors in combination with vehicle mass and wheel diameter.

This also applies to the vehicle architecture: Decoupling the electric drivetrain from the combustion engine is not possible with P0 and P1 systems. P2, P3 and P4 configurations enable pure electric driving.

(Figure 1). Solutions for all architectures



(Figure 1). Solutions for all architectures

Gear ratios and transmission requirements

The design of an electric drivetrain is substantially impacted by gear ratios. Different solutions are feasible but cost, weight, package size and the required performance must be considered in advance. For example, direct drive is possible but using a single motor would be too large to package in most vehicles, while a system for providing torque to several wheels results in a more compact package that is complex and expensive. Lowest cost and highest efficiency can be achieved with a single speed transmission, but it requires an electric motor sized for maximum speed and torque. Two or more gear ratios would reduce the motor size because less torque and speed are needed. Even so, this solution will not lower the required peak power. A multi-speed transmission offers benefits but can result in a bigger package that costs more and might be less efficient due to the additional components.

Electric motor types

The most commonly used options for an automotive traction application can be seen in Figure 2: a synchronous electric motor with Interior Permanent Magnets (IPM) and an asynchronous Induction Machine (IM).

Both have advantages and disadvantages which need to be considered to define the most suitable motor type for each individual powertrain architecture: The IPM provides higher torque density for the motor which is beneficial at low speed and an efficiency advantage for city driving cycles. With the IM configuration, the motor performs better at higher speeds and low torque which is typical for highway cruising.

An IPM needs no current in the stator windings to produce rotor magnetic flux because it is provided by its high energy NdFeB magnets. At higher speeds, however, the voltage induced in the windings has to be controlled by a flux opposing that of the magnets. Additional current in the stator windings is required that can affect overall efficiency.

An IM needs current in the stator windings so that magnetic flux in the rotor is generated. The conduction losses in stator windings and rotor bars can negatively impact the efficiency of an IM at low motor speed. However, as the speed increases, the IM stator voltage can be held at the required level by reducing the magnetizing current, which is a performance advantage compared to the IPM application.

The next thing to decide on is the type of wire for the windings: Rectangular wire is the best choice for a high-powered electric motor. It offers optimum utilization of the available slot area and shows improved thermal performance. It has been used in BorgWarner High Voltage Hairpin (HVH) motors for over 15 years, along with the patented and award-winning 'S-wind' technology. In comparison, round wire is an inexpensive option, but has poor thermal properties and does not make optimal use of the available stator slot area.

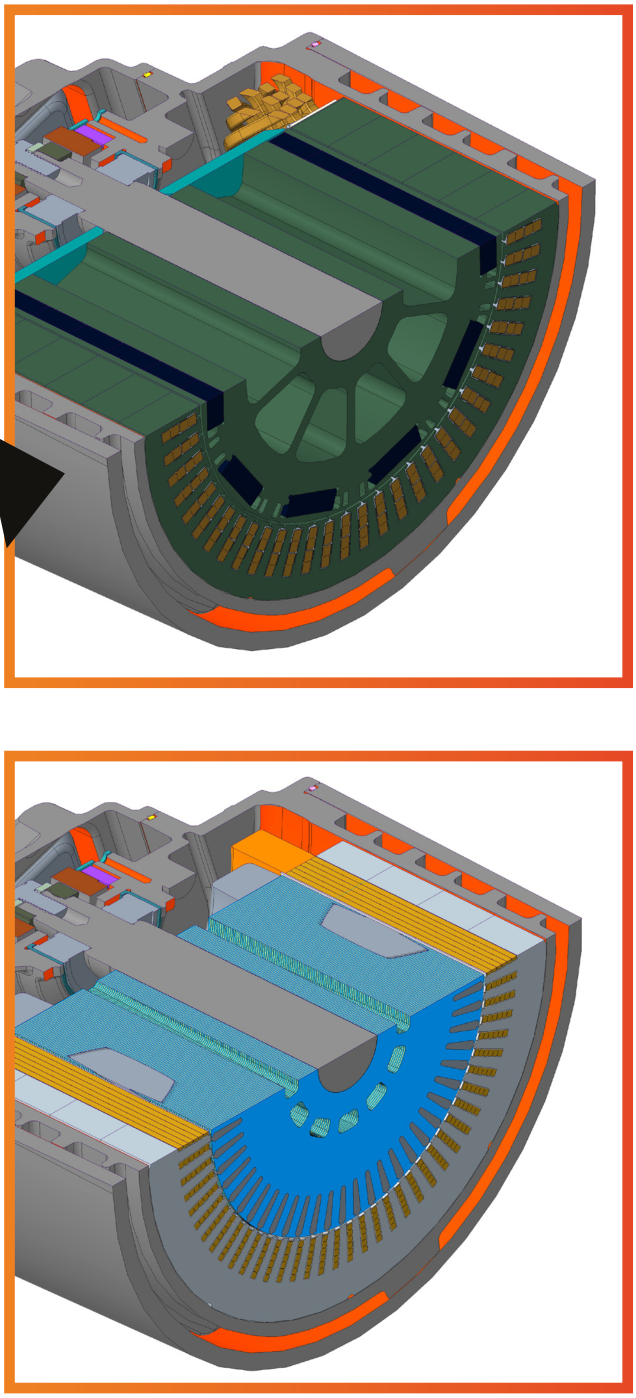


Figure 2: Sectional views of an IPM and IM

Defining power electronics design and specification

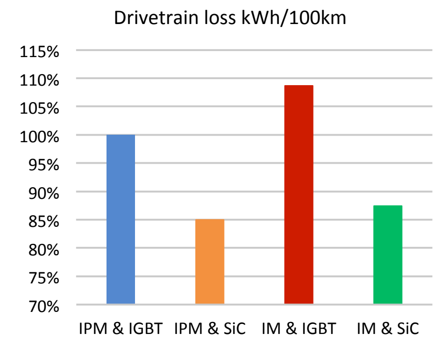
The electric motor characteristics, for example the number of magnetic poles, have various effects on the specifications for the power electronics. More poles usually mean higher torque density, but it may negatively impact the inverter and system efficiency. Inverters use the Pulse Width Modulation (PWM) technique to produce sinusoidal alternating motor current from a direct current battery. A high-fidelity current waveform requires the PWM frequency to be substantially higher than the desired current's fundamental frequency. For example, with a PWM switching frequency of 10kHz, the fundamental frequency of the motor current would maximally be around 1kHz. The rotational speed of a motor with 12 magnetic poles would be 10,000rpm at 1kHz and 15,000rpm for an 8-pole motor. Increasing the top speed of the motor to 20,000rpm would reduce size and mass, but require an increase of the inverter PWM frequency to 20kHz for a 12-pole motor design. Consequences for the power electronics would be less efficiency and increased temperature, ultimately reducing their operating life, due to doubled switching losses in the power switches. To reduce these, different modulation schemes like six-step can be applied, which also increase high speed motor torque. But this solution not only requires a significantly larger DC link capacitor, it may also result in worse NVH characteristics.

The decision between an IPM or an IM solution impacts overall system behavior and has an effect on Functional Safety. In the event of an inverter error while it is connected to an energized and spinning IM all the inverter power stage switches can be switched off, bringing the magnetic flux in the rotor down immediately. The voltage induced in the stator windings is low and no torque is produced. In an IPM configuration, however, with the magnets continuously producing flux, turning off the inverter's power stage switches at high speed can cause the electric motor to operate as an uncontrolled generator because voltage induced in the stator may be greater than the battery voltage. A substantial braking torque can act on the vehicle wheels and create critical driving conditions.

Opening a switch between battery and inverter to prevent current flow can help by removing the motor torque but the inverter's DC bus voltage can be increased considerably by the voltage that is generated in the stator windings of the electric motor. Components of the inverter or of subsystems like DCDC converter or battery charger could be damaged.

Active Short Circuit (ASC) technology offers a possible solution by short circuiting the motor terminals using the inverter power stage. This prevents regeneration into the battery and reduces voltage-related risks.

Figure 3 compares the efficiency of inverters using Silicon IGBT and Silicon Carbide MOSFETs. The linear on state characteristic and fast switching of the Silicon Carbide MOSFETs gives improved efficiency at part load which is beneficial for WLTP drive cycles and ultimately enables more mileage on each battery kWh, balancing the higher inverter cost. Positive effects of this technology also include a smaller inverter package, smaller vehicle cooling system size and improved aerodynamics due to less air flow over the radiator.



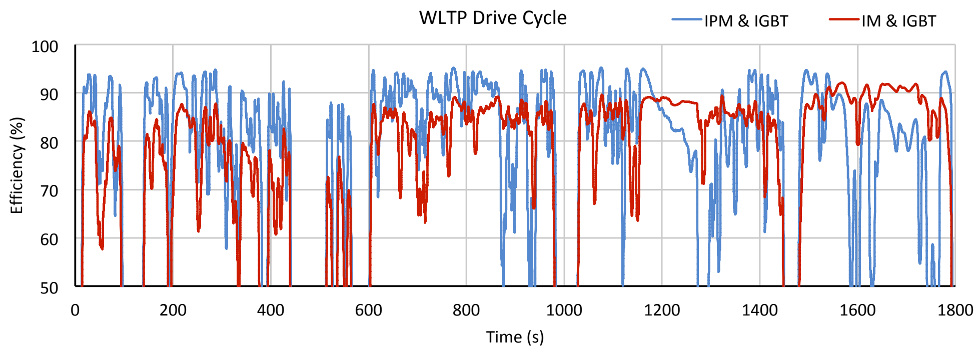


Figure 3: Efficiency comparison

Finding the optimum solution

Striving for the best possible solution often involves objectives that are mutually exclusive. Reduced weight, high mileage, peak performance, compact size and low cost cannot be achieved at the same time. For optimal results, the evaluation of a potential design must be based on several weighted criteria and restrictions placed on parameters such as package space or mass. It is impossible to improve a system on the basis of only one parameter as it will most likely result in poor performance regarding other metrics.

Figure 4 shows an optimization algorithm, which enables a choice of design options that are modular and scalable to meet different customer requirements. Vehicle specifications as well as client feedback and design parameters along with further constraints for the various sub-systems have been taken into consideration before creating potential design solutions. These are further refined with the help of Genetic Algorithms and multi-physics optimization to make sure that they ultimately meet the overall goals, both technically and financially.

Conclusion

Designing an electric drivetrain requires not only a deep understanding of the entire vehicle system and its components, engineers also have to meet their clients' wishes and needs without losing sight of technical and financial constraints

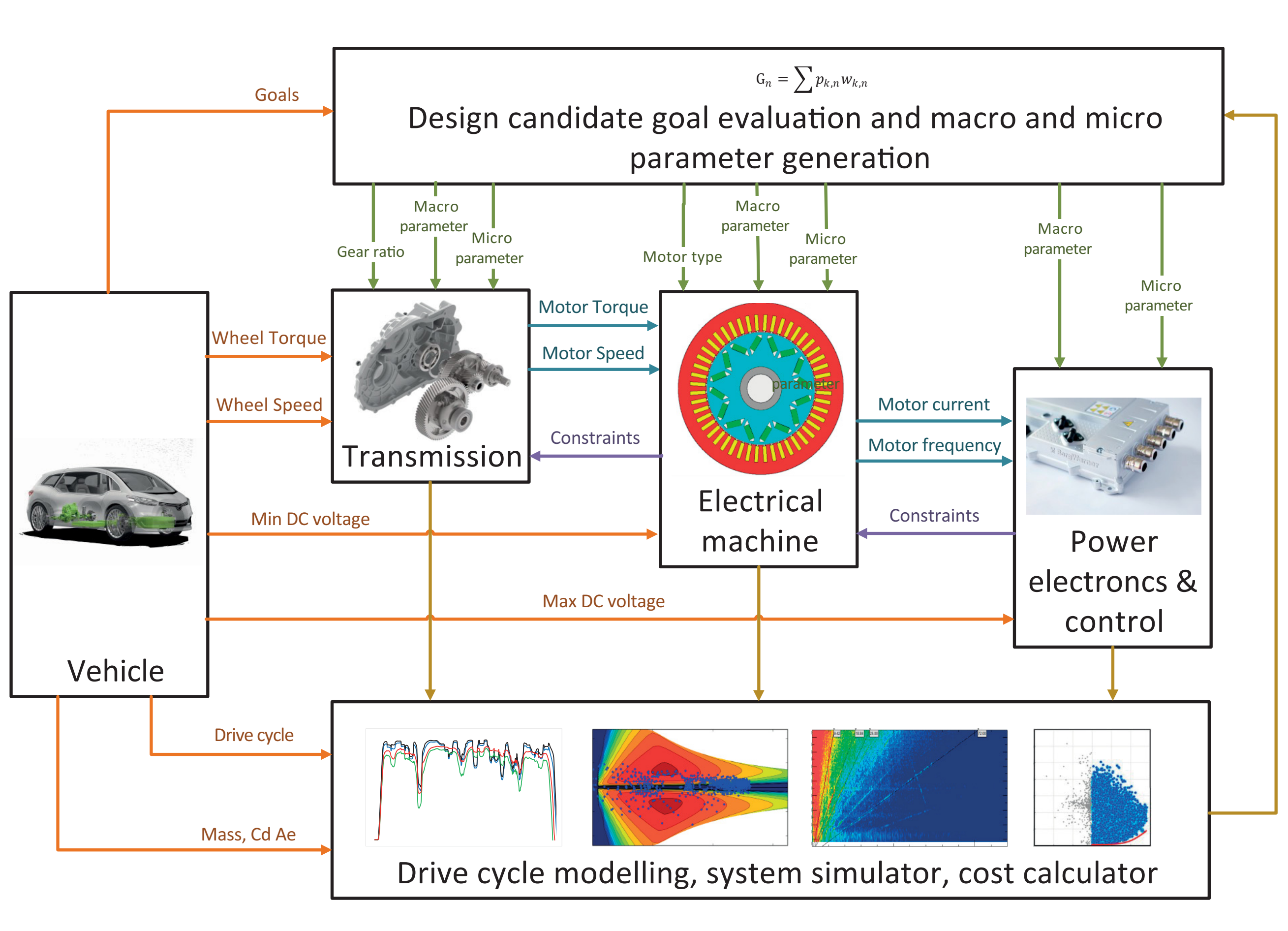


Figure 4: Optimization flow chart

Contributors

[1] Dr. Peter Barrass, Engineering Director, BorgWarner Gateshead (UK)

[2] Steve Stover, Senior Manager Product Strategy, BorgWarner Noblesville (USA)

[3] Dave Fulton, Director of Electric Innovation, BorgWarner Noblesville (USA)

Using Security to Enable Trust Through Misbehavior Detection

Omar Alshabibi

Connected mobility solutions are evolving at a rapid pace. Key areas within this space are safety and intelligent technologies, which are enabled by V2X communication – when vehicles and infrastructure communicate with one another. Sharing sensor data occurring in V2X communication allows for smarter decisions to be made, helping to predict and avoid unsafe situations.

However, while V2X provides connected vehicles with a vast amount of information for making decisions, whether automated or not, the effectiveness of the system relies on accurate and trustworthy information. Traditionally, this trust is achieved by binding information to a verifiable identity. But using this approach in V2X messaging allows each message to be tied to a specific user, creating an easy way to track and monitor participants in the network.

To avoid this and provide individual privacy, a public key infrastructure (PKI) has been proposed – the Security Credential Management System (SCMS). The system issues credentials that allow communicating devices to trust only authorized sources. Unfortunately, while SCMS is used in many pilot demonstrations and is poised to support future national deployments, a critical aspect of the system remains relatively undeveloped – misbehavior detection. Misbehavior occurs when invalid messages (e.g., location, speed, pretending to be multiple vehicles to manipulate a traffic light, incorrect information about another honest device) are sent to cause havoc or gain an advantage on the road. If a vehicle misbehaves by transmitting incorrect data, whether intentionally or due to misconfiguration or malfunction, then it must be actively removed from the network until the cause of the misbehavior is identified and addressed.

A Look at Misbehavior Detection

The SCMS is designed to facilitate message authentication and authorization without revealing the user's identity or allowing a single user's activity to be tracked. It is built on two fundamental assumptions:

1. Devices will continue to function even if they can't communicate with the SCMS for an extended period of time (up to 3 years).
2. No component should be able to compromise individual privacy in any way.

Now, let's take a look at these from a misbehavior management perspective:

1. If a misbehaving device is not actively revoked from the system, it can continue to misbehave for up to 3 years.
2. No component has enough information to add a device to a revocation list on its own.

Note the first assumption can be contradictory as it assumes vehicles are offline for long periods of time, but misbehavior detection, reporting and response require vehicles be online to forward reports and receive updates.

Misbehavior detection and response consists of a sequence of steps: Detection; Reporting; Analysis; and Decision.

Detection at the device level (vehicles or infrastructure)

Unfortunately, there is not a complete list of behaviors to monitor or report as misbehavior. However, there are some clues that can be a first step in detecting a potential offending device:

- Using expired or incorrect credentials (e.g., bad permission, geo-fence)
- Sending messages with incorrect signatures, invalid or valid fake location or data (e.g., time)
- Sending messages with bogus and unauthorized information (e.g., to get unauthorized pre-emption)

These are situations in which a device is consistently using or sending information that does not pass standard validation or is not in-line with the sensor readings of the receiver. Because these situations can be detected and reported by a single observer, they are not difficult to implement. Similarly, reports from multiple observers can be combined to provide assurance that the reports are accurate. This combination of data from multiple sources is essential, as end entities (e.g., vehicles, pedestrians, cycles, motorcycles and infrastructure units) have multiple, concurrently valid pseudonyms – to protect the user's privacy – they could use to falsely sign misbehavior reports.

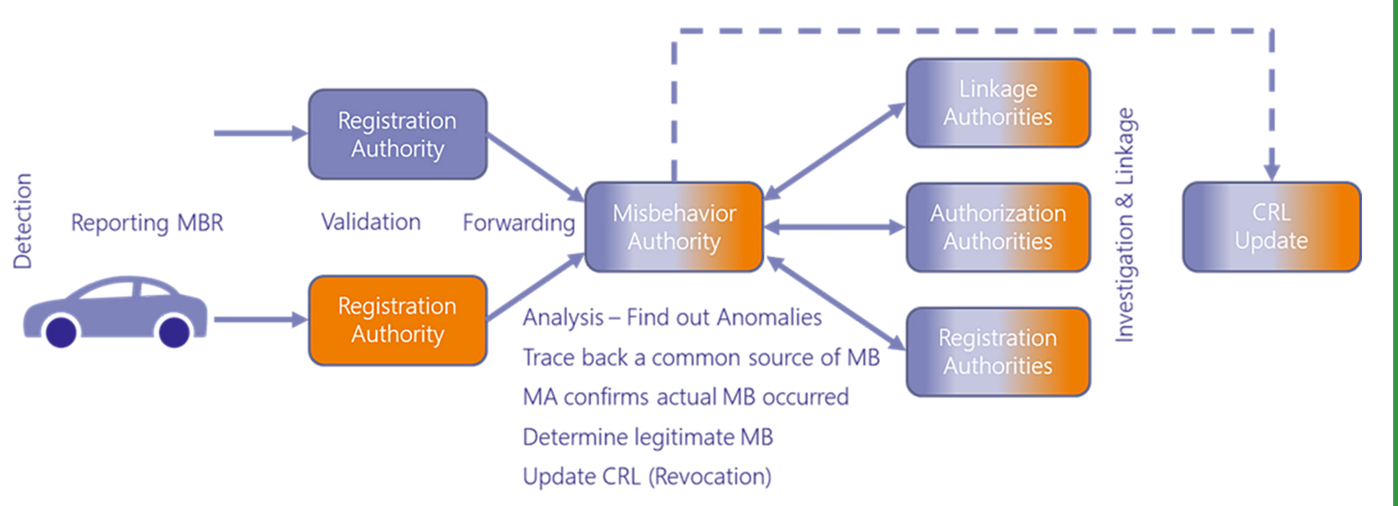
Reporting to a central entity

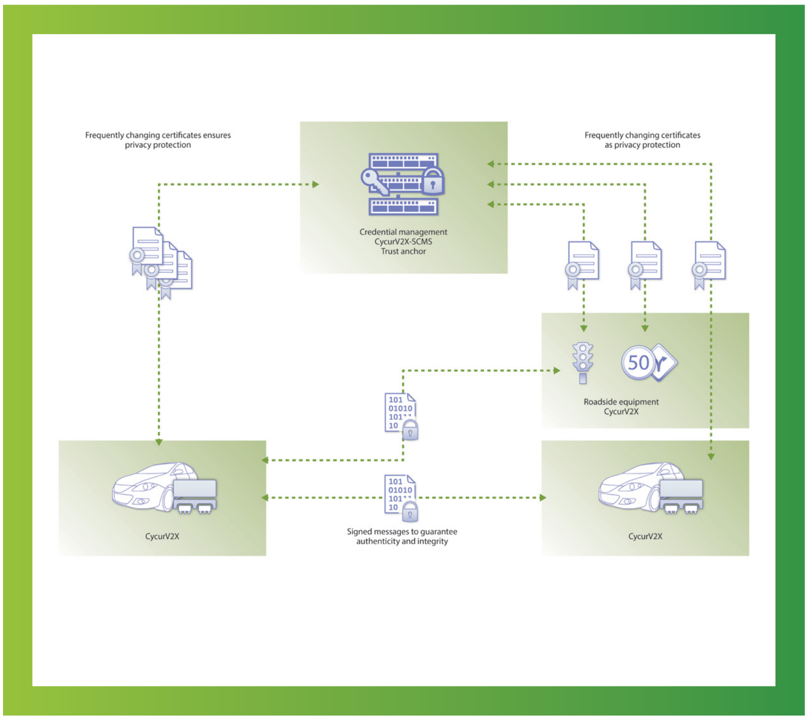
Once sufficient evidence of misbehavior has been collected by a device (e.g., vehicle or infrastructure unit), it is formatted into a misbehavior report (MBR) and forwarded to the SCMS's Misbehavior Authority (MA) via the Registration Authority (RA) for analysis. According to the Crash Avoidance Metrics Partnership (CAMP) protocols supporting vehicle pilot test sites in the U.S., misbehavior reports include:

- Version number
- Timestamp
- Current policy file used by the device
- Core misbehavior data – type of misbehavior and supporting evidence

Detection and reporting can be considered as local misbehavior (i.e. at the device level) activities.

A combination of ESCRYPT system components (purple) and third-party service providers (orange)





Analysis and correlation of reports

Currently there is no standard way or process for the MA to determine whether a set of reports constitutes misbehavior – this is an active area of research. However, the MA has a few tools at its disposal. It can correlate reports from multiple senders in similar geographic regions to determine if reports are likely to belong to the same vehicle. It also can search for distinctive features in reported messages to potentially correlate them. It is simply looking for anomalies to trace back to the common source.

Decision making

Once the MA has compiled misbehavior reports into groups likely to belong to the same vehicle, it can reach out to the Authorization Certificate Authority (ACA) and Linkage Authority (LA) within the SCMS to determine if a set of values belong to the same vehicle. With this information, the MA can refine its queries in response, or decide if the reported messages constitute misbehavior.

If the MA determines a misbehavior has occurred, the blacklisting and revocation processes are implemented. Blacklisting is the invalidation of a device's enrollment certificate, the credential used to authenticate with the RA when requesting and downloading pseudonyms. Using the linkage information from the LA, the MA provides the RA with the necessary information to determine which enrollment certificate was associated with the request for the misbehaving pseudonyms and instructs the RA to blacklist the certificate. Once blacklisted, the RA will no longer offer services to the blacklisted device, preventing the download of any previously requested pseudonyms, or requests for new pseudonyms. In short, the blacklisted vehicle is effectively unable to communicate with SCMS components

Blacklisting cannot prevent a vehicle from using pseudonyms it has already downloaded. To inform other network participants that a set of pseudonyms have been revoked, the Certificate Revocation List (CRL) must be updated with the linkage information associated with the revoked vehicle.

New applications and use cases will emerge for which current misbehavior definitions may not apply. A well-designed system should facilitate the safe deployment and integration of new technologies, not constrain it. Things will go wrong, new threats will be identified and new attacks will emerge. The V2X ecosystem must be designed and deployed with this in mind. This is especially true as sensors are used for multiple applications.

Furthermore, many V2X applications go beyond the simple sharing of data and will allow road users to proactively request changes in behavior from other road users and infrastructure (e.g., emergency vehicle signal pre-emption). This makes the understanding and implementation of misbehavior detection solutions even more important because it establishes trust in the system over time, which ensures all benefits, safety and others, remain for all stakeholders.

Omar Alshababi,

Lead Product Manager – V2X Cybersecurity ESCRYPT

Further Information

Misbehavior Authority (MA): Collects and analyzes misbehavior reports from multiple sources to determine if there is reason to do more privacy-sensitive analysis of the information.

Registration Authority (RA): Receives certificate requests from the end entity and, after expanding individual requests into thousands of requests to prevent identification, forwards to the Authorization Certificate Authority.

Linkage Authorities (LA): Generates and sends encrypted linkage values for the pseudonym certificate to the Authorization Certificate Authority.

Authorization Certificate Authority (ACA): Collects information for certificates, then signs and encrypts them, without being able to trace to a particular end entity.

Certificate Revocation List (CRL): The list of digital certificates that have been revoked by a certificate authority.

Lockdown Legacy:

Why Contactless Engineering Services are Here to Stay

Amid the multitude of challenges faced by the automotive industry during the COVID-19 pandemic, one silver lining that's emerged has been the shift towards contactless, remote engineering services.

From the use of 'secured' live data for remote testing through to virtual verification, here, Richard Adams, Head of Strategic Global Sales for Verification and Validation at HORIBA MIRA, examines the positive legacy these new ways of working could have on the industry.

Like many industries, there's no denying the coronavirus pandemic has caused unprecedented disruption and distress for the automotive sector. In April last year, British car production fell by a staggering -99.7% with just 197 vehicles leaving UK factory gates, the lowest monthly output since the Second World War, according to the Society of Motor Manufacturers and Traders1. What's more, despite the industry picking up through the year, by November as we entered a second national lockdown, the sale of petrol and diesel cars sank once again.

As the pandemic took hold at the beginning of the year, vehicle manufacturers were forced to close factories and re-evaluate new product development plans, faced with the prospect of postponing, or abandoning, critical programmes – putting at risk their viability unless new and effective working practices could be enacted quickly. Not only did the lockdown test our normal working practices, but it forced the industry to adapt and find practical solutions to ensure business could continue.

One such example is the rise of contactless engineering whereby a range of core vehicle engineering services are conducted remotely in 'real time' – a service that we at HORIBA MIRA have seen unprecedented demand for since the initial lockdown.

While many contactless engineering services have been on offer for some time, the pandemic and resulting lockdown has positioned these not only as a lifeline to keep vital vehicle development programmes running – but simply as a better way of doing things going forward. Crucially, while the decision to go remote may have initially been taken on a needs-must basis, many businesses are now realising the multiple benefits afforded by taking this approach.

Whether it's increased efficiency or cost-savings, as we emerge from lockdowns around the world, and the automotive sector fires up for recovery, a contactless engineering approach should be embraced as a silver lining during this difficult time. Ultimately, it is a positive legacy that could change vehicle development forever.

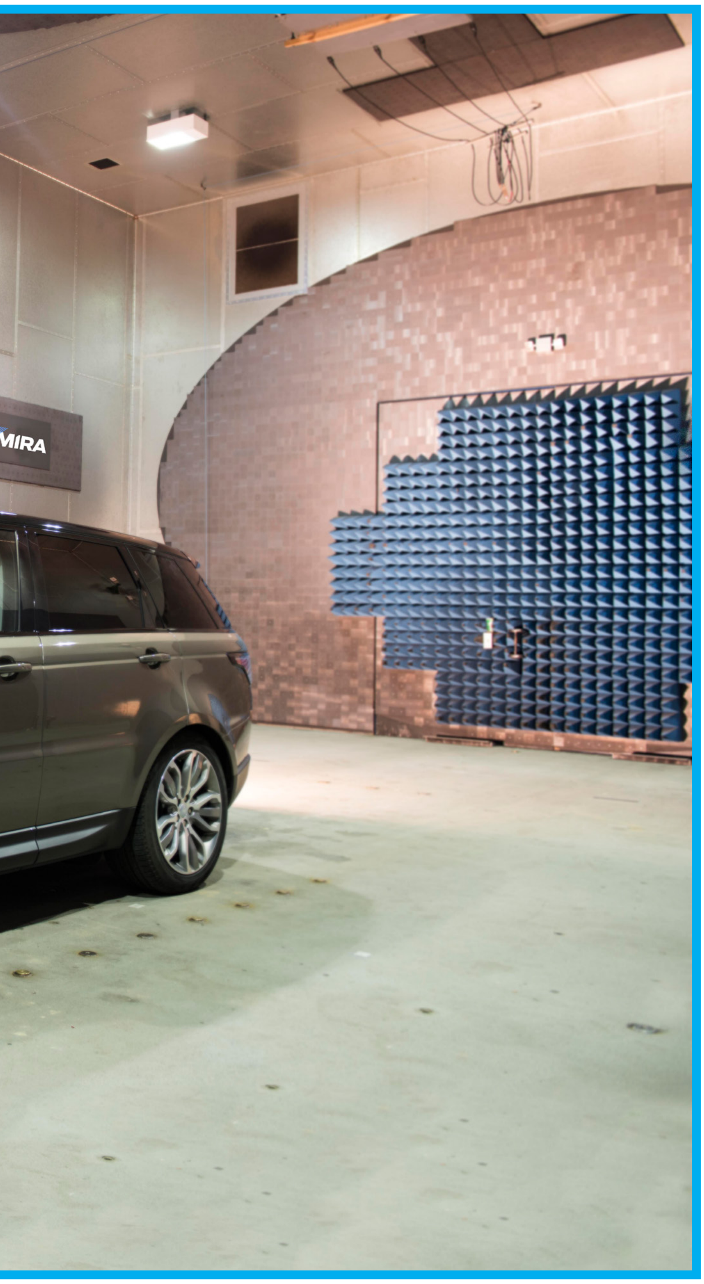
Contactless Engineering

Contactless engineering services are not a new initiative, in fact within HORIBA MIRA's EMC (electromagnetic compatibility) department we've been offering remote witnessing of vehicle engineering and test work for over a decade, but with the shift within the industry to home working and a reduction in overseas travel, 2020 saw a marked increase of contactless work, with more and more vehicle development teams from around the world choosing to dial in remotely to witness their product development.

As an early pioneer of the remote application of vehicle testing, HORIBA MIRA's end-to-end contactless services include the use of 'secured' live data, remote re-flashing, wearable cameras and CCTV in laboratory settings, which enable offsite customer teams to drive the development process in real time. We're able to turn our customers' home office into the control room and hand over the running of the project where required.

Fundamentally, a huge benefit lies in the flexibility of these services; the delivery team can be entirely resourced by our engineers, or a blend of OEM, and tier one and two stakeholders as the programme dictates at different times. This way, programme leaders, often with multiple teams operating in global locations, are able to maintain a meaningful understanding of the development status for each programme without the need to send oversized teams to witness the development process; a feat which has proved crucial amid COVID-19.

For global vehicle development programmes, many of which operate to a tight timeframe in getting their latest product to market, the benefits of this type of contactless testing are ten-fold. This approach means you can run multiple testing programmes simultaneously, for multiple locations and provide the real time data that's critical to



getting their product to market as quickly as possible. The end-result is a faster technical iteration rate at a lower cost.

And it's not just vehicles that can be developed and validated remotely, we work in this way to develop individual components too, whether it's a headlight or an internal lighting fixture, we can test it remotely and manage the whole test programme from start to finish.

The success of our remote development service has led to the roll out of remote certification services, providing vehicle makers a critical route to market throughout lockdown. Here working alongside the Vehicle Certification Agency and other European type approval authorities, key stakeholders can dial in to remotely witness and certify products. We're also now able to administer UKAS audits remotely, a request of all UK test facilities by UKAS. This approach which enables test data and live CCTV video of the product under test, along with the sharing of relevant technical documentation, has been successfully utilised during the recent ISO 17025 audit conducted by UKAS.

For us, it's clear that contactless engineering has helped to minimise disruption for the sector, whilst sparking a widespread acceleration of the adoption of next-generation development processes.

End to End Development

Going forward as an industry, adopting new ways of working will be critical to getting the automotive segment back up and thriving following months of disruption. These include contactless engineering services, coupled with consolidated on-site testing, which can provide a much more streamlined and cost-effective way for the end-to-end development of vehicles in the first place.

At HORIBA MIRA, we've been geared up for this way of doing things for years, having joined our design, attribute engineering and validation teams. Through our extensive experience of being based on the MIRA Technology Park, Europe's leading automotive R&D cluster, we've seen first-hand the benefits to be had from the maximum effective use of all prototype hardware and minimal logistics, at every stage of the V-cycle.

Lockdown Legacy

Whilst there is no doubt that there will be more change to come for the automotive sector, as we look to meet the challenge of driving forward in a post-pandemic world. The current delivery model of contactless engineering services offers the industry the opportunity to ask itself one important question - what positive legacy can we take away from the global crisis?

The answer is we can permanently reshape our working practices and retain some of the hard-won benefits and operational efficiencies achieved during lockdown, especially those provided by remote engineering services.

Author

Richard Adams, Head of Strategic Global Sales for Verification and Validation at HORIBA MIRA

Reliable and accurate power measurement technology is a keystone of e-mobility technological advancements.

Andreas Alexandrou

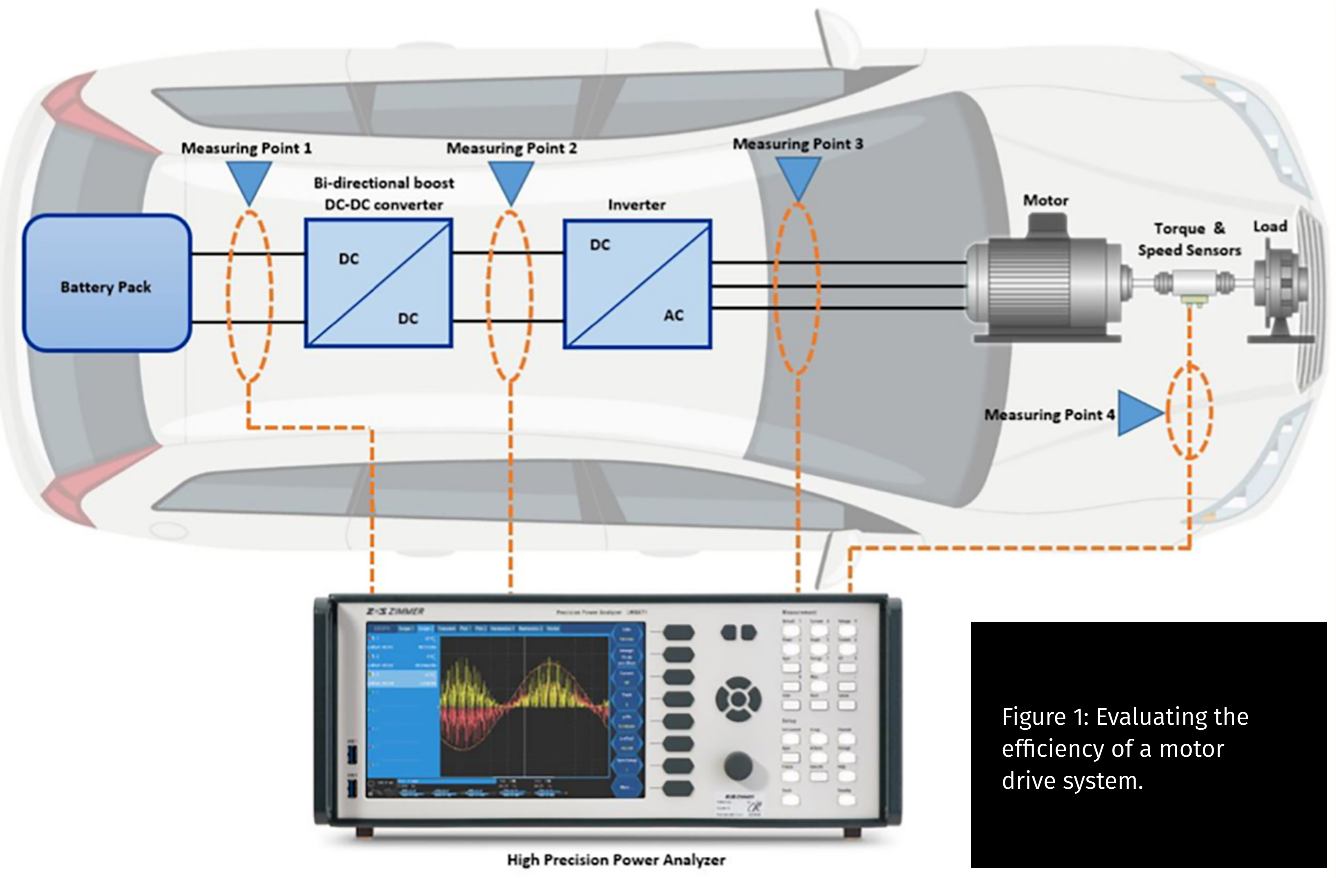


Figure 1: Evaluating the efficiency of a motor drive system.

Introduction

Recently, electro mobility has seen accelerated adoption in virtually all industrialized countries. The use of electric vehicles (EVs) has been viewed by many as a way to remarkably reduce oil dependence, operate vehicles more efficiently, and reduce carbon emissions. It is predicted that by 2040 the number of electric vehicles on the road will reach 500 million. This expected growth of the EV market poses many challenges for the R&D and test engineers, who are called to overcome them. In particular, today's high demands on the efficiency and performance of the electric vehicle powertrains and DC&AC chargers create extremely tough requirements for the measuring equipment. An old saying is very applicable here: "If you cannot measure it, you cannot control it". This is where the strengths of ZES Zimmer Electronic Systems GmbH take full effect, providing precise power measurements to satisfy every application and need.

Powertrain efficiency

The measurement of the system's overall efficiency is required for optimization. Thus, the ratio of the mechanical output power to electrical input power shall be measured to determine the efficiency map. The power analyzers from ZES Zimmer are equipped with up to 7 power channels, enabling thus not only the overall system efficiency measurement but also the efficiency measurement of the individual components such as the inverter, motor and the DC-DC converter. In Figure 1, a wiring schematic is illustrated where the battery feeds a bi-directional boost DC-DC converter. Then, the DC-DC converter is connected to the inverter, which drives the electric motor. All 6-power channels and the process signal interface (PSI), which is used for the torque and speed sensors' outputs, can perfectly be utilized simultaneously using the LMG600 series power analyzer.

High accuracy measurements are a critical precondition of evaluating the efficiency of any powertrain. If the measurements of the input and output power of the inverter contain an error component, it will massively affect the efficiency and loss values. For example, an error of 0.1% in the input power of the inverter with 99% efficiency will result in an error of 10% for the loss.

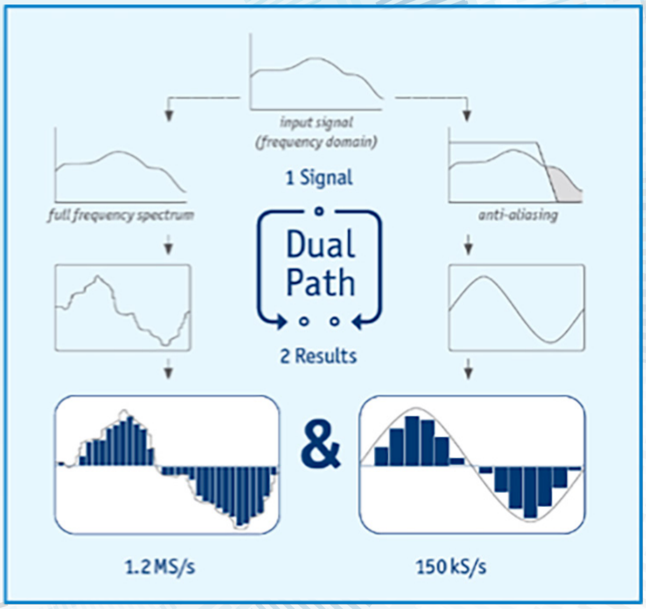


Figure 2: DualPath technology explained

The output signal of the inverter contains the torque relevant fundamental frequency of the motor plus the inverter's switching frequency, its harmonics, and other by-products. In order to allow accurate measurements on the inverter's output power, it is an imperative need to make use of a power analyzer equipped with high bandwidth and a parallel measuring ability in two bandwidths simultaneously. The LMG600 series can achieve this using the dualPath technology. The analog signal conditioning stays unchanged, but the following processing has been revolutionized: Each single voltage and current channel of the LMG600 contains two analog-digital converters (ADC). One for the wide bandwidth signal without filtering, and one for the narrow bandwidth signal with proper anti-aliasing filter. The sampling values of both ADCs are digitally processed in parallel. With this novel DualPath approach, the user has access to narrow and wide bandwidth values simultaneously without the risk of aliasing.

Battery Test Charge and Discharge

Hybrid and electric vehicles have a high voltage battery pack that comprises of individual modules and cells organized in series and parallel. Determining the basic electrical characteristics of a battery during charging and discharging mode is crucial. The LMG600 allows the implementation of a customized, versatile and powerful battery tester, providing everything necessary for detailed and accurate energy balance measurements, from charge to discharge. With an easy to use and customize GUI along with an intelligent Script Editor, important measurements of the battery characteristics such as voltage, current, energy capacity (Wh) and coulometric capacity (Ah), as well as internal resistance and Joule energy dissipation can be displayed in a single screen.

AC & DC Charging Tests

The expected growth of the EV market has to be accompanied by the development of an appropriate charging infrastructure. The grid AC power always needs to be converted to DC when charging an electric vehicle. If the power is converted before it enters the vehicle, DC charging is deployed. Conversely, with AC chargers the power gets converted inside the vehicle. Overall, DC charging allows for much faster charging compared to AC, and it is the preferred method for EV recharging, especially for long distance trips.

The ability of the LMG600 series to perform up to 7 power input measurements simultaneously makes it possible to test and evaluate the power measurements and efficiency of all different converter topologies, which are accommodated within any EV charger. A practical implementation is illustrated in Figure 3. It is, after all, our concern to facilitate the design and testing of EV chargers by enabling the access to all-important measurements efficiently and most importantly without any compromises.

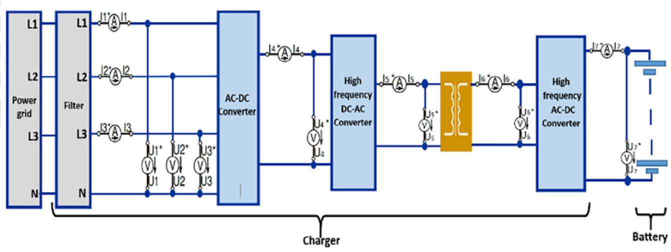


Figure 3: Logical connection of the DC charging system

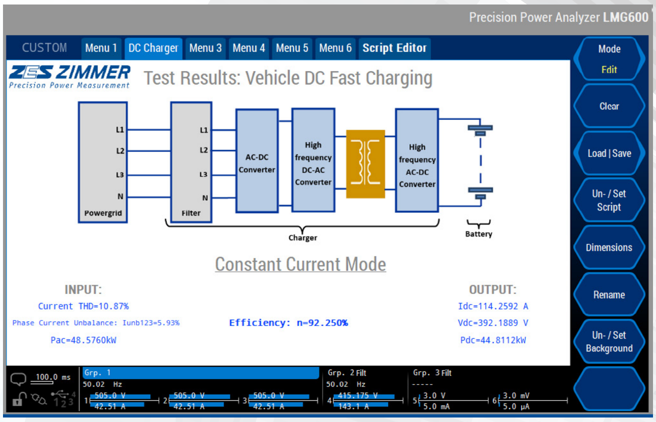


Figure 4: Fully customized menu

Finally, the LMG600 offers a convenient way to customize screens according to the demands of the application to help focus on particular results. The measurement results can be made more meaningful by adding a descriptive title and illustrating the numerical results with a schematic depiction of the setup and other graphical elements. For EV charging applications all resulting efficiencies between various inputs and outputs can be displayed in an easy and straightforward manner (Fig 4).

Powerful Interfaces

In the context of test benches, the power analyzer must often share its measurements with other existing computer and software environments. Smart interfaces shall ensure the uninterrupted data exchange, remote control and even automation of test procedure.

E-mobility applications demand high sampling rate, which in turn creates a large amount of data. Powerful **Gigabit Ethernet LAN** interface can be used to avoid any bottlenecks for the exchange of data. It is important to note here, that modern power analyzers shall offer remote control operation capabilities in an automated test setup.

In the automotive industry **CAN Bus** systems are standard, providing communication between various Electronic Control Units (ECU) for the management of a large number of vehicular functions.

In matters of power measurement, how can these

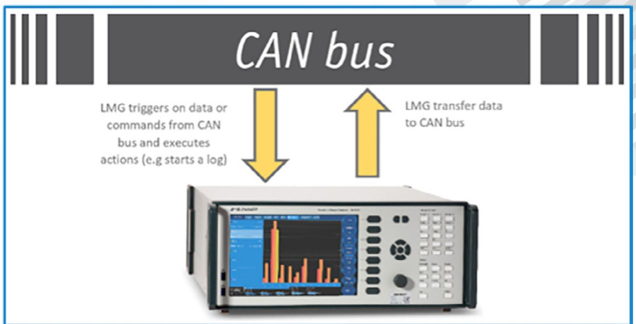


Figure 5: CAN bus bi-directional data transmission

measuring devices be integrated into the vehicles CAN network? The LMG600 series is equipped with a CAN bus interface, which enables the data communication in accordance with ISO 11898-2 High-speed CAN-Bus. The CAN bus interface supports bi-directional data transmission and trigger configuration on 256 in total slots.

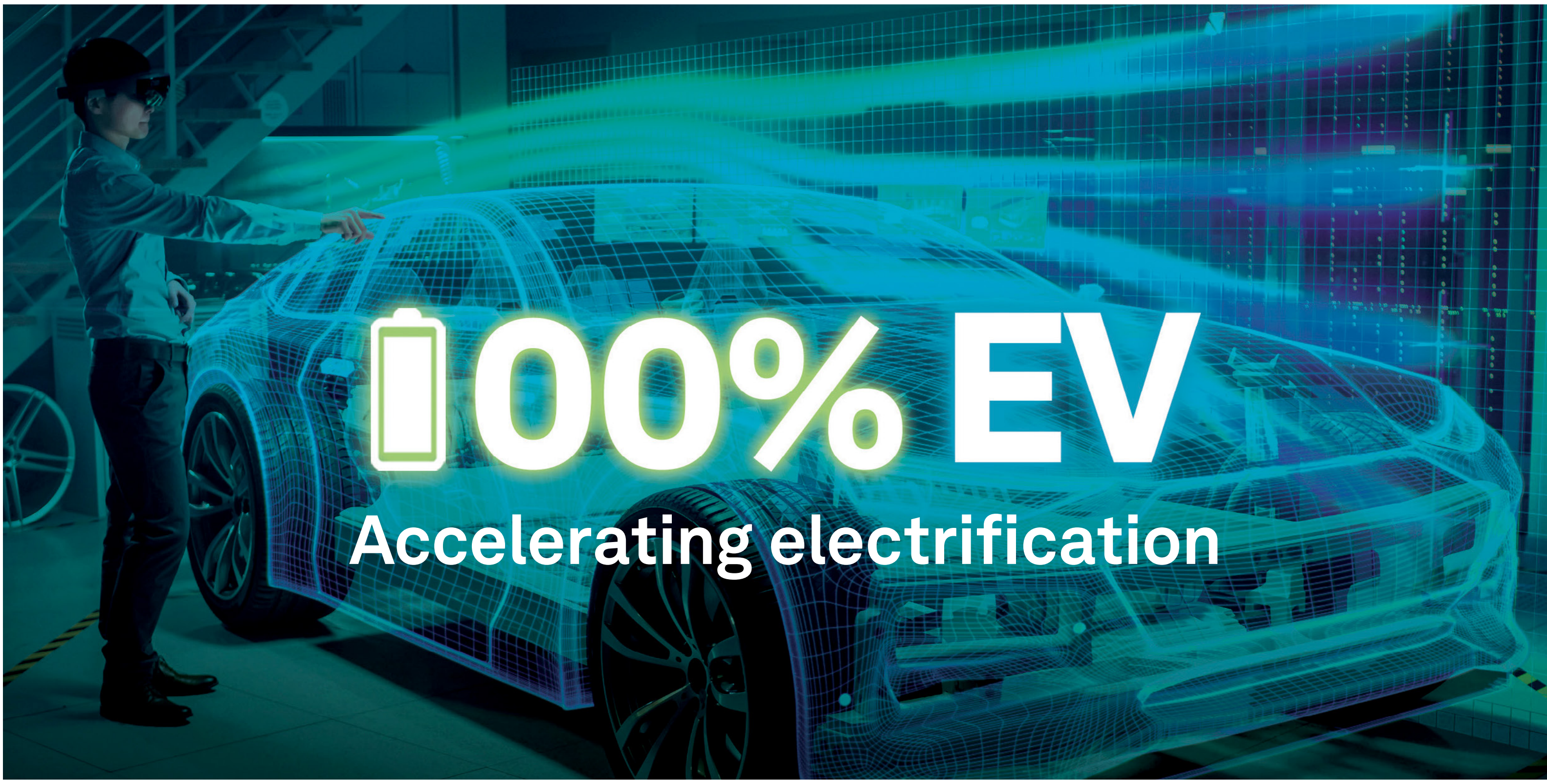
It is often necessary to take further measurements in addition to electrical parameters to be able to make a meaningful overall statement on the performance and efficiency of the device being tested. Hence, it is vital to be able to perfectly synchronize these measured values with the RMS values, in order to establish reliable timing between electrical and mechanical events. A typical application is the analysis of electrical drive systems, where torque and speed must be measured and reconciled with the electrical parameters. Furthermore, it may also be necessary for the power analyzer to output results as analogue signals for further processing, or to trigger switching operations depending on measured variables or derived values. The LMG600 series was engineered with the above requirements in mind offering a multitude of different input/output features for analogue and digital signals via the **Process Signal Interface (PSI).**

Figure 6: Process Signal Interface (PSI)

Andreas Alexandrou - Sales and Application Engineer, ZES Zimmer Electronic Systems GmbH

HEXAGON

#EVfuture



100% of vehicles in the world need to be electric

It's an ambitious goal dependent on many factors, but it's one we believe is worth working towards. This is why Hexagon has created 100%EV – to help accelerate electrification.

EVs are predicted to represent a third of the automotive market by 2025 and 51% by 2030. But we believe the automotive industry can make this shift even faster, and we want to support your efforts to do so.

We aim to offer a new set of smart manufacturing technologies for engineers, designers and OEMs, blending our experience in automotive design and engineering, production and metrology to help you make the journey toward 100%EV faster and more cost-effective.

> **The time is right to combine and commit our thinking, resource and solutions to speed up the evolution and adoption of eMobility.**
>
> Paolo Guglielmini
> President, Manufacturing Intelligence division, Hexagon

Plug in to progress

hexagonmi.com/emobility

Autonomous driving:
Cybersecurity important basis for broad acceptance

Dr. Benedikt Westermann

Approval for autonomous driving depends largely on IT security of systems and technology / Alliances for cybersecurity in autonomous vehicles as a task for the entire sector.

Beautiful new, mobile world: While the autonomously driving car glides over the streets as if by magic, the driver leans back in a relaxed manner, takes care of email correspondence using a tablet or mobile phone, watches a film or simply takes a nap. Many Germans, Americans and Chinese trust the autopilot, but there are concerns about cybersecurity. And rightly so – cyberattacks on autonomous driving vehicles could have major consequences for passengers.

An experiment of a research team demonstrated that scientists could penetrate the electronics of a Jeep and were able to accelerate and brake the car remotely, as well as disable safety and protection systems such as airbags, ABS, and door locks. To do this, they used a weak point in the software update function and hijacked the SUV via a mobile phone connection.

As representative studies by TÜV Rheinland have shown, fear of cyberattacks is particularly pronounced in autonomous driving. Although three out of four drivers in Germany can imagine being chauffeured autonomously, around 60 percent are afraid that hackers will gain control of the vehicle. The decision-making behavior of autonomous vehicles in the selection of alternatives in the event of unavoidable accidents" plays just as decisive a role for motorists as the "controllability of complex traffic situations and the safeguarding of data. For the vast majority of respondents, it is also important that independent institutions such as TÜV Rheinland test autonomous vehicles and monitor data protection and security. Vehicle tests on the reliability of automation before delivery of autonomous cars are in first place (say more than 91 percent of the respondents).

Data protection has high priority according to studies

The same applies to the important markets of the USA and China. To trust autonomous vehicles in the future, car drivers want guaranteed data protection, protection from cyberattacks on the vehicle, and the ability to decide, at any time, whether to drive independently.

Most customers like the fact that the systems of future cars will be automatically updated on a regular basis to ensure safety in road traffic and against external attacks. In China, 80 percent of respondents are in favor of over-the-air updates, while 68 percent in the USA and 64 percent in Germany also favor over-the-air updates. In addition, protection against cyberattacks is so important to consumers in all three countries that the majority of respondents (Germany 66 percent, USA 61 percent, China 60 percent) would switch car brands based on known hacker attacks.

Autonomous driving is generally well received by the respondents. Nevertheless, they are aware of problems that may affect acceptance and constitute major barriers to the deployment of autonomous vehicles. The leading framework conditions of politics and industry is the possibility for Germans to drive themselves (53 percent), followed by the clarification of the legal situation (49 percent) and the

guarantee of data protection (37 percent). Americans also give high priority (47 percent) to the possibility of taking over the tax themselves. The proof of functional safety through tests ranked second by a small margin (45 percent). Third place goes to securing the car against unauthorized access (43 percent). For the Chinese, securing personal data is particularly important (43 percent), even before guaranteeing data protection (40 percent) and securing the vehicle against unauthorized access (36 percent).

The cloud as a gateway for cyber pirates

“Interesting targets for cyber pirates are, for example, cloud services accessible from the Internet that communicate directly with vehicles, among other things. In theory, however, any externally available communication interface can be an entry point for an attacker. These can be the on-board WLAN, telematics services and infotainment, navigation and assistance systems,” says Dr. Benedikt Westermann, Lead Security Analyst at TÜV Rheinland.

The importance of cybersecurity has increased significantly in recent years. In addition, the impact of some prominent attacks shows how important the issue has become for our society and economy and highlights the vulnerability of personal data. This is also shown by the annually Cybersecurity Trend report from TÜV Rheinland. As early as April 2017, a series of hacking tools suspected of belonging to the US National Security Agency appeared via the previously anonymous group “Shadow Brokers”. In July 2017, attackers stole the data of 145 million people from the financial services provider Equifax. The Windows malware program WannaCry and the Trojan-based blackmail NotPetya followed and spread in over 150 countries. This led to ransom payments of more than two billion US dollars. The courier and logistics company FedEx attributed a loss of 300 million US dollars to the NotPetya attack alone. For some well-known automobile manufacturers, this even led to a production stop. These two infamous Ransomware attacks took advantage of the weak point leaked by Shadow Brokers. And the potential loopholes become more numerous with each interface.

It now seems easier than ever to buy blackmailer and pollutant programs on the black market or in Darknet and thus gain access to sensitive data. As businesses continue their digital transformation and users integrate “smart” devices into their daily lives, cybercrime is growing.

Growing threat to networked vehicles

As digitalization progresses, vehicles are also becoming increasingly networked. This increases the attack surface at the same time. From control panels to maintenance, repair, and operations (MRO) programs with corresponding service management software to classic GPS, cars contain a considerable number of additional functions. Like other networked products, it can be assumed in the long term that the networked vehicle will also become the target of cyberattacks. Threats range from simple unauthorized data collection to more serious crimes such as vehicle or property theft and extortion.

For the exchange of data between the vehicle and the environment, TÜV Rheinland experts developed test methods to ensure functional safety and compliance with regulations. Only this creates trust and reliability for the forward-looking technology. "We have the necessary expertise with references for the commissioning of autonomous shuttles, the application of safety concepts for test tracks for autonomous cars and the development of simulations, test scenarios and test environments for vehicles and their components". Dr. Westermann went on to say.

"We have also entered into a strategic partnership with VisualThreat to expand its services to prevent cyberattacks in vehicles and increase the safety of the next generation of vehicles. Based in California, VisualThreat is a leading provider of automotive cyber security testing and provides comprehensive vehicle security solutions for cyberattack defense. With test facilities, our experience and VisualThreat's cybersecurity technology, the automotive industry and its suppliers have access to comprehensive test services that offer their products more protection against future cyberattacks and meet industry standards for secure operation". Dr. Westermann continued.

Penetration tests for manufacturers and suppliers

VisualThreat's Auto Cybersecurity Testing Lab provides penetration testing for manufacturers and suppliers and helps the automotive industry identify and address security vulnerabilities for the next generation of vehicles. The experts test the control devices, mobile apps for Android and iOS as well as the cloud services. The company's laboratory enables an automatic cybersecurity test frame for motor vehicles. This includes more than 30 test points from the following categories: CAN bus probing, testing of individual ECUs as well as CAN communication testing for several ECUs. The tests can be performed either locally or in cloud-based modes. TÜV Rheinland's portfolio also includes safety analyses of embedded systems (e.g., control units), product testing and robustness and vulnerability scans.

TISAX ensures information security

TÜV Rheinland is one of the world's first authorized organizations to test information security according to TISAX, the Trusted Information Security Assessment Exchange. Service providers or suppliers to the automotive industry must prove at regular intervals whether they meet their customers' high information security requirements. The basis is often the requirements catalogue of the Association of the German Automotive Industry (VDA) for Information Security Assessments (ISA). At the end of 2020, a trustworthy exchange mechanism was created for the new version of VDA ISA catalogue of requirements: TISAX serves as a cross-company recognition of information security assessments and analyses in the automotive industry based on a joint testing and exchange mechanism sponsored by the ENX Association, an association of European automotive manufacturers, suppliers, and associations. Regular testing is carried out in accordance with industry-wide and internationally recognized standards and is carried out exclusively by accredited testing companies. This is intended to prevent service providers or suppliers from having to undergo identical inspections by customers at more or less short intervals.

UNECE Informal Working Group - Cybersecurity Taskforce

While manufacturers are steadily intensifying their security measures, they are working together with policymakers, industry and independent testing service providers on international cybersecurity regulations and standards for road vehicles, including in the UNECE Informal Working Group Taskforce Cybersecurity. This UN Cybersecurity regulation is set to become mandatory in the EU for new vehicle types from June 2022 and for all newly registered cars, trucks, and buses from July 2024. "This regulation is another important step for safe driving. It obliges all manufacturers to consider the issue of cybersecurity throughout a vehicle's lifecycle. In other words, from the development on the drawing board to the decommissioning of a vehicle," explains Westermann.

Holistic testing in the automotive sector

The TÜV Rheinland system is required for autonomous driving in particular. This applies in three ways: firstly, for the classic homologation - i.e., road registration of new e-mobility vehicles -, secondly for the periodic general inspection – regardless of whether they are internal combustion engines or electronically powered vehicles – and thirdly for the topics of data protection and cybersecurity. For those who drive networked or autonomously driving vehicles, their movements are recorded. At the same time, possibilities open for hacker attacks. "For more than 20 years, TÜV Rheinland has been helping companies from numerous industries as well as public authorities and institutions to use innovative technologies securely. Dr. Benedikt Westermann, Lead Security Analyst at TÜV Rheinland concluded.

Development.
Production.
Consulting.

KERAFOL® Keramische Folien GmbH & Co. KG

As a specialist in Thermal Management we are providing solutions with Thermal Interface Materials and also technical support in the field of dispensing technology.

KERAFOL® Keramische Folien GmbH & Co. KG

KERAFOL®
Keramische Folien GmbH & Co. KG
Koppe-Platz 1
D-92676 Eschenbach i.d. OPf. | Germany

www.kerafol.com

Zone computers for ADAS or autonomous driving functionality

Erich Ramschak

Recently several regions world-wide decided to enforce by law ADAS active safety functions to boost the zero-fatality mission. In Europe the new General Safety Regulation (GSR EU2019/2144) will be mandatory for new type approval from mid-2022 and for all new registrations from mid-2024. The mandatory safety functions are basic SAE Level 0 and Level 1 assistance features, but it pushes the roll-out of ADAS to the entire vehicle fleet, from small entry to large premium class cars.

In parallel, first we have the stepwise launch of the much more complex L3 (temporary automation) pilot features started with the market introduction and second, pilot fleet applications with fully automated connected features (L4) are making remarkable progress – strongly driven by operating cost savings substituting human drivers, preferred in the heavy-duty truck and logistics area.

Different level ADAS/AD features are therefore operating coexistent in several controllers disadvantaging modularity, flexibility and finally also cuts the possibility to balance electrical power consumption accordingly.

Zone computers

Traditionally, in automotive electronic networks, for each feature, the control, sensors, and actuators are treated together as a unit. Typically provided by a tier-1 supplier. For instance, brake actuators, necessary sensors, the ABS and ESP control are treated as a unit. Since there are many features in a vehicle, many such subsystems must be integrated together – also leading to a lot of control units. For ADAS and AD functions, this is currently done in a similar way. For instance, a typical ACC sensor could include the processing for object detection and the calculation of the force ramp for a smooth breaking in the same box.

Currently, an alternative approach is being discussed and first steps are being taken to implement it: Why not the separation of the sensors and actuators from the control, and then centralize the control in bigger, more powerful control units? These central units (zone computers) can replace potentially dozens of little control units. The obvious advantage of such an approach is cost, weight, and power savings because of fewer control units, boxes, and cabling. In addition, the flexibility of the OEM is increased: It is much easier to optimize e.g., sensors if they are not integrated in an all-in-one box that provides functionality of a complete feature set. A tier-1 supplier would have to adopt offerings to separate sensors, actuators, and control software. The processing power would be provided by specialized zone computer makers. Obviously, tier-1's can then concentrate on part offerings, i.e. only offering the best sensor technique, ignoring the necessary control software know-how – or vice versa.

ADAS/AD example

Let us look at how this could work for ADAS or autonomous driving functionality: We can assume that for cars the minimum requirement is to provide the GSR functions (automatic emergency braking, emergency lane keeping, and others). For this, typically a radar and a camera are used as minimum sensor configuration. Processing power demand is already significant, for object detection of camera and radar data. On the other end of the line are autonomous driving functions that can independently steer the vehicle in certain situations (like on a highway). Such level 3/4 features require many more sensors: Additional radars, cameras and lidars are potentially needed to achieve the necessary view and to add some redundancy for safety.

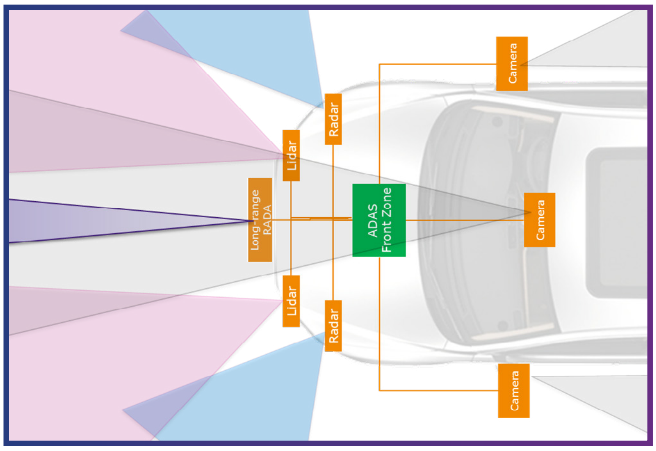


Figure 1: ADAS Front Zone computer example layout

Zone computers can be used in preparation for this range of requirements. We can summarize the requirements of such a system for the front zone like this.

Scalable interfaces

- Minimum one camera and a radar sensor
- Maximum 3-8 cameras, 3 radar sensors, 1-3 lidars

Scalable processing power

- Minimum object perception capability for one camera and one radar
- Maximum 6-12 channels of object perception capability from different input

Safety and security

- Minimum full protection against hostile access from outside.
- Minimum fail safe capability (switch off ADAS functions in case of a failure, never operate wrongly)
- Maximum fail operation capability (provide minimum operation in case of a failure in order to stop the vehicle in a safe manner)

The AVL ADAS ECU

- AVL has developed an embedded processing platform based on the above requirements. We use it here to show how a zone computer can be built to meet all the ADAS/AD challenges in an electric car.

Figure 2 shows the block diagram of the fully equipped system.

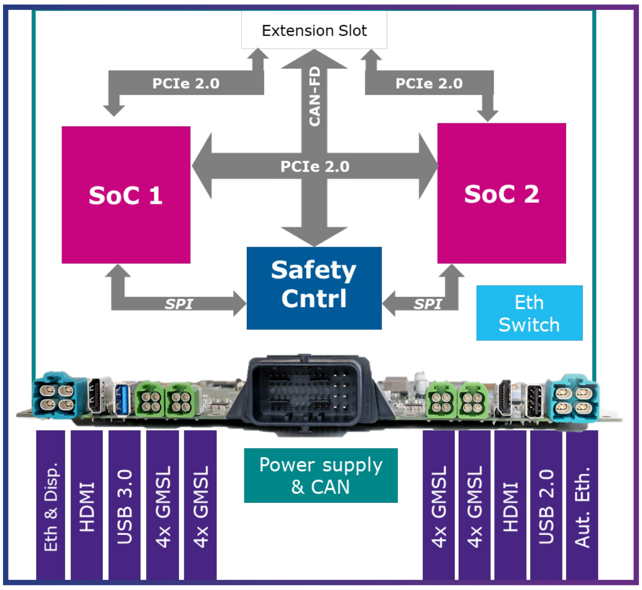


Figure 2: ADAS ECU block diagram

The system has two main sections for redundant processing (system-on-chips SoC 1 and SoC 2). The SoCs can be scaled up to a power that enables them to process 6-8 channels of object recognition, calculate several trajectories, and make decisions in each of them. Each of these sections are electrically separated, have their separate power supply and interface lines. The third controller, the "Safety Controller", is used to supervise the diagnostic state of the two separate sections. In case of a failure in one of the sections, the safety controller makes sure that the sections is closed down, a system mode change is initiated (finally to organize the safe ending of the autonomous driving function by informing the driver and/or bring the vehicle to a safe stop).

Note that Figure 2 also shows HDMI and USB interfaces. These are part of the development platform to make the ECU accessible for debugging. They will not be part of a series version.

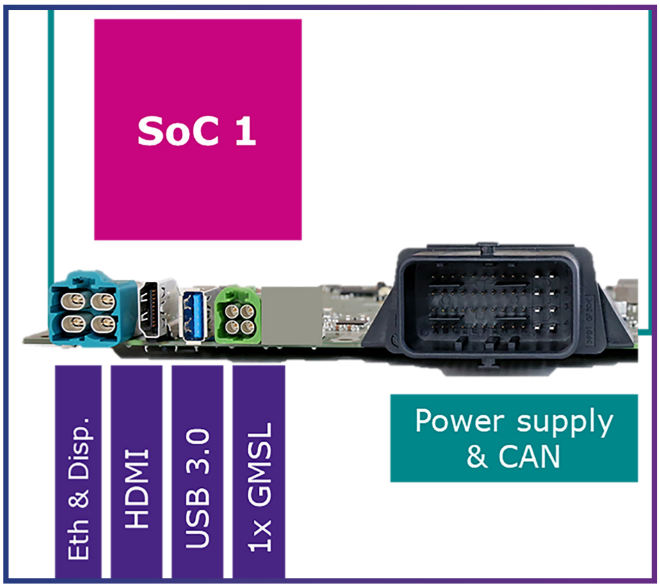


Figure 3: ADAS ECU scaled down to minimum requirements

Just by not equipping the system with all interfaces and SoCs, the same unit can be scaled down to a minimum system that only covers the mandatory GSR functions (see Figure 3, optional debugging interfaces still shown).

Summary

Zone computing can greatly increase the efficiency of ADAS and AD subsystems. Processing performance and interfaces of a zone controller needs to be sufficient to host all ADAS and AD functions. However, other requirements are also important:

- Scalability: The ADAS/AD zone computer architecture supports a range of functions (from GSR up to autonomous Level-4 driving)
- Safety: The zone computer shall have internal redundancy to provide fail operational modes to survive any kind of sensor or processor failure in a safe way
- Automotive grade power consumption and robustness

AVL provides an open development platform called Ajunic that is built up by two independent high-performance sections. It offers easy access for developers (Linux operating system, USB and HDMI interfaces), however is already made in a modular way from automotive grade parts. The design can be easily adopted to a series version just by leaving out areas that are not needed.

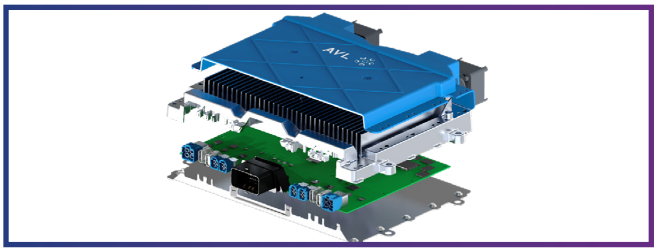


Figure 4: Ajunic, the AVL ADAS/AD development platform

Erich Ramschak Senior Product Manager AVL List GMBH

Creating Power Distribution Solutions in an Electrified World

Jim Dawson Vice President of Engineering and Technology at Royal Power Solutions, introduces two breakthrough products – High Power Lock Box (HPLB) terminals and RigiFlex™ busbar systems. These green technologies improve energy efficiency and minimize energy waste in electric and hybrid vehicles.

These two products have achieved concept approval on 22 vehicles during development in Europe and the United States. HPLB and RigiFlex have achieved concept approval in vehicles for (4) NAFTA OEMs scheduled for 2022 in addition to others in Europe.

A ground-breaking high-current, high-vibration and high-temperature terminal family for LV, HV and 48-volt applications.

High Power Lock Box (HPLB) Terminals

The High-Power Lock Box (HPLB) system is a patented multiple contact terminal system that provides ultra-energy efficiency through lower resistance. HPLB is the industry's only high current terminal system (above 150 amps continuous current) that meets USCAR2 T4 (150° C) and V4 (severe vibration) requirements while also capable of S3 standards for sealing under high pressure spray when contained in a sealed connector system.

HPLB terminals solve many problems that the hybrid and electric vehicle industry has encountered in developing applications, providing a high-current connection capable of withstand high-temperature and high-vibration mechanical stresses while delivering a full system solution.

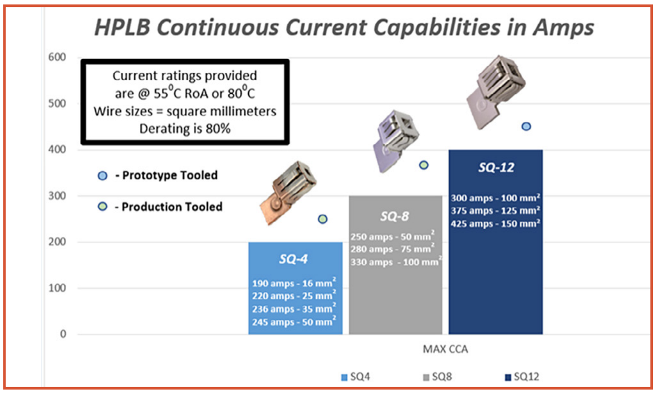
Inside HPLB terminals are stainless-steel springs, which add to structural integrity and higher current carrying capabilities, creating less resistance and heat generation, thus improving efficiency. We refer to this as an *"ultra-energy efficient connection,"* which provides almost zero energy loss, at each terminal connection point, when measured during a Dry Circuit Resistance test. HPLB terminals reduce weight and provide an assembly cost and time savings on the plant floor.

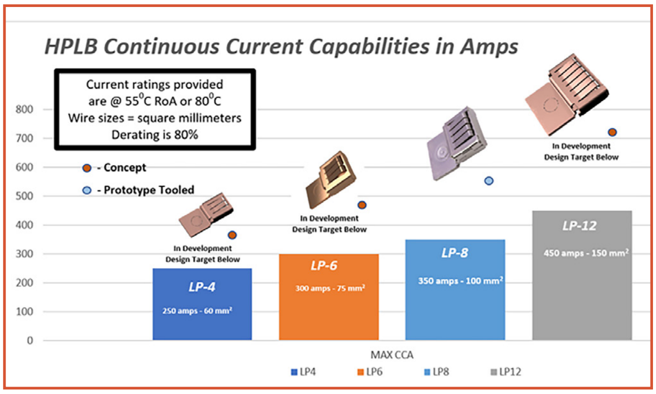
Inside HPLB terminals have been tested for use at elevated operating conditions defined by leading battery electric vehicle OEMs to further prove its robustness in application in the most challenging environments and applications.

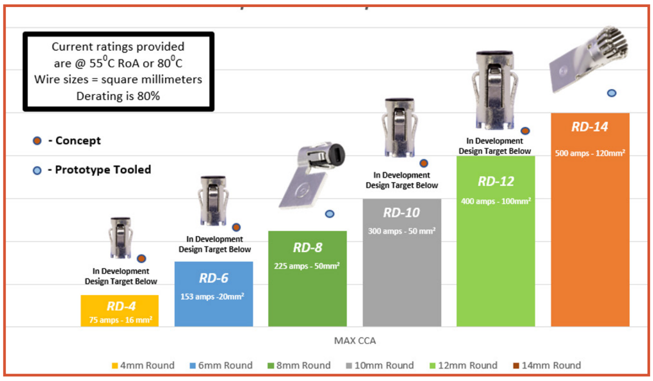
Features & Options.

- Extremely High Current Carrying Terminal System
- T4 (150° C) / V4 (Severe Vibration) Capable
- Ultra-Energy Efficient System – No Loss
- Copper (Cu) or Aluminum (Al) available
- Space Savings
- Weight Savings
- Cost Savings
- Time Savings

HPLB – CONTINUOUS CURRENT CAPABILITIES







Rigid to meet design standards and Flexible to meet design needs.

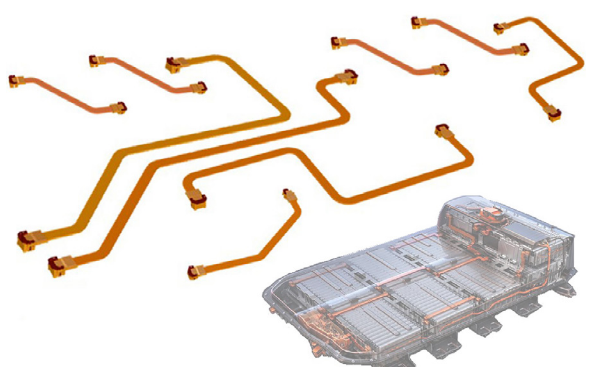
RigiFlex™ busbars

The RigiFlex™ busbar system in an ultra-efficient, durable, busbar system that is both rigid and flexible based on application requirements. The continuous, seamless conductor enables fully automated battery pack assembly. These systems utilize common conductor materials without butt or splice welds that can increase cost, resistance, and failure modes. The RigiFlex™ system is so efficient it can be "Daisy-Chained" within a module or pack design to simplify assembly and increase safety, without adding the resistance that causes energy loss due to heat generation.

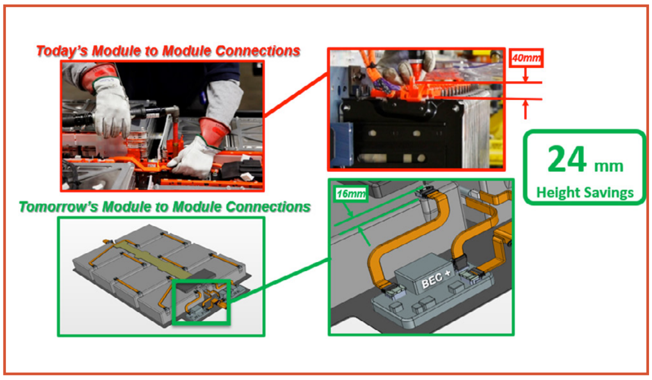
This advanced solution supports green initiatives for the market and improves the safety and handling of critical high voltage energy storage and distribution systems. RigiFlex has nearly zero development time, no Die or Mold Tooling, and Zero Engineered Scrap.

RigiFlex™ busbar systems can be combined with HPLB terminals, delivering a boltless conductor system which removes ferrous materials and inefficient welds that can create safety hazards in assembly and high resistance energy wasting hot spots.

The flexibility of this combined system overcomes stack-up tolerances and allows for more simple automation solutions at the customer manufacturing location.



RigiFlex busbar and HPLB terminal systems



With safety in mind, RigiFlex™ busbars combined with HPLB terminal systems enable automation to handle, articulate, place, and verify these busbars into modules or packs. Safety improvements are seen in production and service. In production, humans can be removed from the assembly process which alleviates possibility of shock or burn from a loose fastener causing a zero-resistance short circuit.

The push/click/pull mate solution nature of the RigiFlex connection system allows the copper contacts at the end of the busbar to be completely enclosed. This promotes safety by eliminating risks for inadvertent shock.

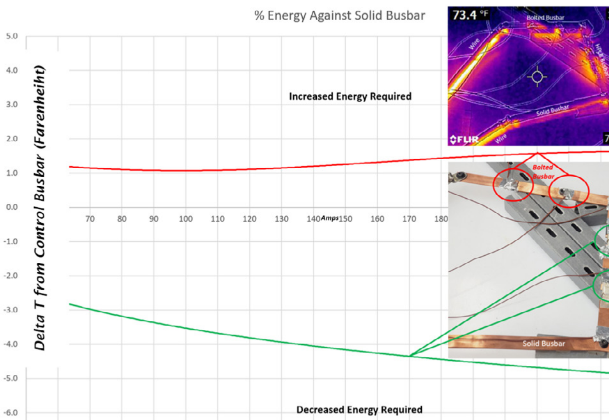
Additionally, serviceability becomes safer as the RigiFlex™ connection systems are finger-proof and easily serviceable via normal USCAR connector disengagement processes. Space constraints are another area where the RigiFlex™ connection systems out-performs typical, bolted busbars. On average, bolted busbars require 40mm of z-axis space; RigiFlex™ busbar systems only require 16mm to complete the same connection, providing 24mm of height savings in pack..

Major advantages of the RigiFlex™ busbar system:

- Space Savings - More active material/range in EV battery packs
- Ultra-Energy Efficient – Virtually no loss due to heat loss/mitigation.
- Sustainability – Zero Engineered scrap
- Ease of Connection – With optional HPLB Push-Click-Pull Connector Terminals
- Copper (Cu) or Aluminum (Al) Available
- Simplification of Production –
  - No Die Tool for Busbar
  - No Over-mold Tool for Busbar
  - No Tool Development Timing
  - No Loose Piece Nut on Mfg, Line
  - No CANNED Gun Air Equipment on Mfg. Line
- Largest cross-sectional area in market today
- T-shapes and 90-degree forms

RigiFlex™ busbar and HPLB terminal system vs. Traditional bolted busbars – test results

In recent tests, a control (solid) busbar system in a series was compared with HPLB terminals using RigiFlex™ busbars. The ends of this series busbar are each attached to 50mm2 copper wires which are connected to power supply and ground.



The test demonstrates that as 250 continuous current amps (CCA) are applied to this system, some interesting results are evident. As the test was conducted, RPS utilized its FLIR camera to depict the hotspots of the system and strategically place thermocouples at each connection to record accurate temperature readings during the test.

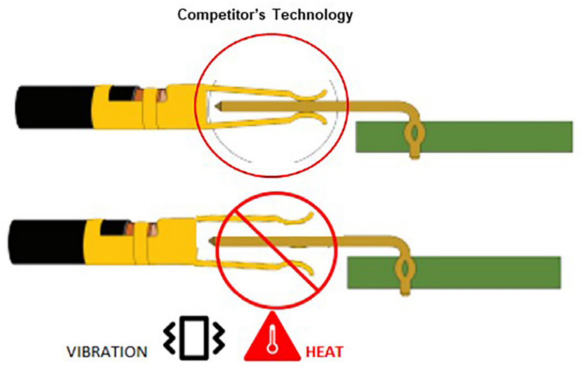
First observation:

At 250 CCA, there, is a 6° differential in operating temperature. This is a very significant operational advantage for HPLB over bolted busbars in Lithium-Ion battery packs that are cooled. The reduced resistance of current flow through the HPLB connections, compared to bolted connections, wastes less precious system energy in the form of heat. HPLB's lower operating temperature means the pack cooling system does not need to mitigate as much heat, resulting in valuable range addition.

Second observation:

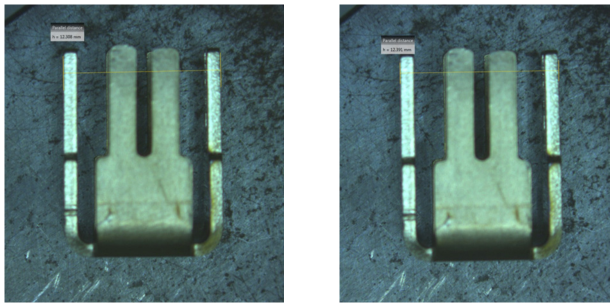
There is an inverse relationship between the bolted busbar and the RigiFlex boltless busbar in terms of heat generation. The bolted busbar continuously increases in temperature due to the constant resistance of the bolted connection. The HPLB connection decreases in resistance as the temperature increases. This is made possible because of the internal spring of this terminal's design. As the heat increases, the HPLB terminal's internal spring relaxes, increasing normal force of the connection thereby lowering the contact resistance. This phenomenon counteracts the consistent resistance/heat/temperature increases that must be endured in the bolted system.

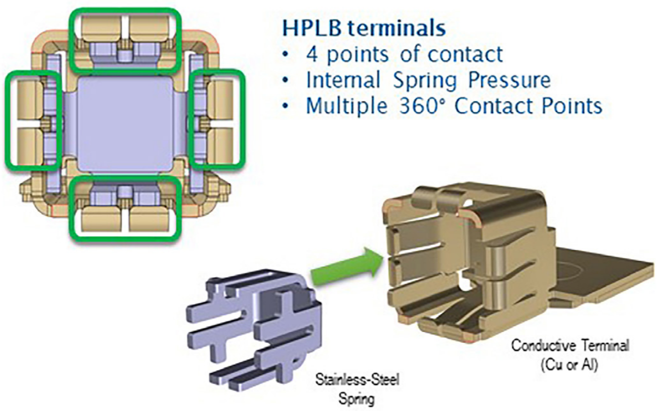
HPLB terminals and RigiFlex™ busbar connection systems allow for truly optimized energy connection systems –



Standard Box & Blade designs only provide 2 points of contact and spring squeezes blade

Room Temperature 30°C - 12.308mm   High Temperature 197°C - 12.391mm





Third Observation:

Busbars that are bolted together are not only less efficient, but they are also dangerous to assemble. Using again the example of a Lithium Ion traction battery pack, the modules are live during assembly of the pack. This means the assembly technicians must wear high voltage gloves to assemble the traditional module-to-module and module-to-device bolted connections.

HPLB terminals combined with RigiFlex busbars facilitate the possibility of automated pack assembly due to their unique flexible and rigid ability to comply with manufacturing variances and module thermal expansion and contraction. Further, the space we require to make this connection is 60% less than a bolted connection, easily serviced without special tools and HPLB is not susceptible to vibration failure.

RigiFlex™ is a US trademark owned by Royal Power Systems. High Power Lock Box and RigiFlex are patented in the US and internationally with many other patents pending worldwide.

A facility that follows the standards of a clean room environment is ideal

Braking systems:

technological advances that bring us to a standstill

Daniel Triolo, Andreas Minatti, Dr. Rudolf Randler and Dr. Jakub Kadlcak, look at the future of braking systems and how small components such as sealing solutions play an instrumental role in terms of safety, integrity and performance.

Some might be tempted to argue that braking systems have changed relatively little in the last 25 years. A combination of vacuum booster, callipers and brake fluids in place has been the standard, and therefore the requirements in terms of components have also remained consistent. Engineers were clear in the design parameters and geometries required and, although small changes have been implemented, the principles remained the same.

Today, however, the technology has evolved and will continue to do so without a doubt. The development of the electrohydraulic booster (EHB) means that not all partners along the supply chain have experience in handling the new, advanced sealing solutions that are now required. Of course, this evolution into EHB technology has largely been driven by the move towards the electrification of vehicles and the increasing amount of advanced driver assistance systems. Electric Vehicles (EVs) are projected to account for 19% of the market by 2030 – with Full and Plug-in Hybrids accounting for 11% and Internal Combustion Engine (ICE) only and Mild Hybrid Vehicles the remaining 70% - and the EHB is a natural fit, particularly given there is no internal vacuum creation in EVs that is required for the vacuum booster.

The technology is a complete departure from the traditional vacuum booster, and therefore it is essential that manufacturers and sealing solutions experts work closely together in order to bring products to market as soon as possible in terms of serial production to benefit from the advantages of the new system.

How EHB systems contribute to designing the car of the future

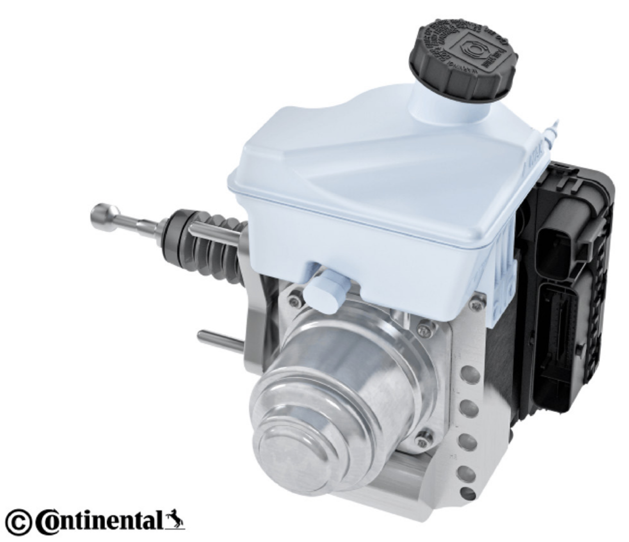
While the vacuum booster has done a stellar job of making global road users safer for decades past, there are several advantages to the move into electrohydraulic alternatives. One is that electrohydraulic boosters are smaller and lighter, which means there is more space free within the engine compartment, while in EVs there are significant advantages where recuperation is concerned – bringing energy from the braking system back into the battery. There are also advantages in operating advanced driver assistance systems, as everything is electrically controlled.

Braking power in an emergency is also much higher and generated much faster than with a standard vacuum booster system. Normally, in a vacuum booster, the brake is applied with the foot and there is a physical relationship between the brake pressure transmitted through the hydraulic system and the size of the vacuum booster. However, the calculation of the transmission force is difficult because it depends very much on the individual that applies the brake and is perceived very differently from person to person. With an electrohydraulic booster, electric actuation of the brake is achieved which in turn reacts much faster and generates much more friction power than was possible in the past with the vacuum booster. This provides a far more consistent performance and potentially shortens response times in terms of reacting to an emergency situation on the road, enhancing driver and passenger safety.

Advancements in sealing applications enabled the use of sensors for streamlined production and tracking. The traceability of parts via smart sealings - for example with embedded sensor technology – could expedite a product recall if required, minimizing the safety impact and potential reputational damage a brand could suffer. Sensors could also be used for predictive maintenance purposes in the future, along with providing solutions relating to authenticity that could combat counterfeiting and ensure parts are from the original manufacturer. Not least, sealing solutions designed and co-engineered specifically for purpose in these new applications will provide the highest levels of quality and integrity, ensuring the safe operation of the braking system throughout its lifetime.

Co-engineering helps to deliver the safest possible braking systems

Given the critical importance of reliable, effective braking systems and the fundamental impact any fault could have

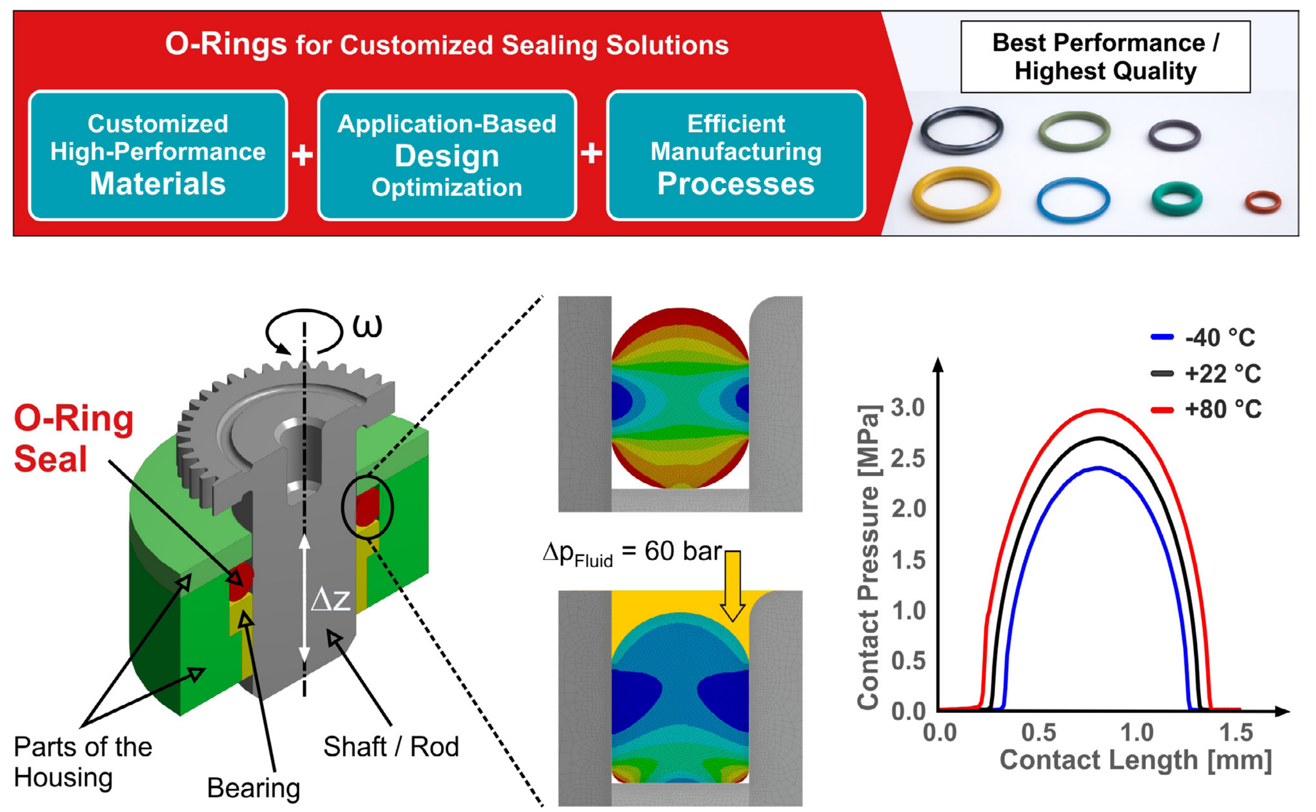


Continental's EHB MK C1, where Datwyler assists its partner with high-performance polymer components, is one of the most important electrohydraulic brake systems.

in terms of safety, a wide range of factors must be carefully considered when developing system-critical components such as seals. With the EHB, a number of special requirements are imposed, such as abrasion resistance, cleanliness categories, and the precision of sealing solutions in production. Among other things, the elastomer components in modern brake control systems must also be able to resist high-frequency, dynamic-mechanical loads under high pressure, and simultaneously guarantee safety over the lifetime of a vehicle.

To ensure these requirements are met to the highest possible standards, many companies looking to enter into advanced braking solutions are choosing to work in partnership with component suppliers at a very early stage in the development process. This partnership approach in co-engineering projects can make the difference between a good product design and a perfect one. Where system-critical sealing systems are concerned it is key to take into account all functional needs and the requirements of materials, tooling designs, and manufacturing processes.

As seen in the graph on next page, elements such as geometric design and functional performance optimization can be supported by structural mechanics simulations, while virtual molding simulations ensure best tool design, efficient production processes and top product quality. Sealing systems only achieve their optimum functionality if the designs of the sealing element and mounting space are a perfect match. Therefore successful co-engineering projects require cooperation very early in the development process, when there is still sufficient design freedom for the overall system to optimize both the sealing element and the installation space.



As an example for components specifically designed according to customer requirements, the illustration shows a customer-specific O-ring seal for use in brake systems - a design perfectly matched to the installation space and operating conditions in combination with a tailor-made material makes the difference.

Meeting new project requirements with material and design expertise

Evolving technology often requires a new approach to material development and the designs associated with the finished solution. Here it is a distinct advantage for producers of braking systems to engage with a component supplier with a demonstrable track record in this area. Often, a design or compound may only need a slight adjustment to deliver optimal performance, but if a supplier lacks the knowledge to make the necessary modifications, severe delays could be encountered.

In terms of safety, only an optimal solution will meet the required standards. Therefore, understanding the compound and the process required in its manufacture is essential – particularly when dealing with system critical parts. Primary and secondary seals, for example, fall into this category, as failure during operation compromises the entire braking system. Even if a vehicle is still able to stop, any decrease in the efficiency of that system is of severe concern and a potential hazard.

Today, with advanced simulation capabilities available, product development time can be shortened and therefore time-to-market and cost can be reduced. Through working closely with system suppliers from the outset, designs can be optimized in terms of the sealing elements to ensure there are no unforeseen issues when a product goes into full production.

This can even include the simulation of the flow behaviour of the compound - how it will behave when injected into a mold cavity, for example - and how the gating system can be designed to optimize the required tooling to ensure the most efficient production processes for manufacturing the highest quality products. Every design and processing detail can be simulated and checked ahead of time – meaning manufacturers can enter into production with the full confidence required of their sealing solutions.

As an example of a potential issue that could occur in material development, here we will look at a compound that has become sticky – rendering it ineffective. A slight adjustment is all that is needed, but the expertise required to identify and overcome this quickly has been earned over many years.

Cleanliness is key when optimising the production process

Because of the potential for particles and residual dirt to jeopardize the functionality and lifetime of the sealing system, an optimized production environment, capable of producing several million units per year, is required to ensure the highest levels of cleanliness where sealing component production is concerned. A facility that follows the standards of a clean room environment is ideal, especially when combined with lean concepts which optimize process flows and meet cleanliness standards. The ultimate aim is to maintain the highest possible quality standards with zero defects.

The monitoring of cleanliness levels accomplished by this environment should ideally be undertaken by an in-house laboratory, while highly automated production processes minimize the need for human contact wherever possible to further mitigate the risk of contamination.

A recognized method for measuring particle precipitation in the automotive industry is the so-called "Illig-value": For its calculation, all detected particles are classified according to their size and then the number of particles of each size class is weighted with graded factors and summed up. The right sealing solutions supplier will aim at optimising this value by implementing a tailored production line concept.

In addition, as the compound development process can be optimized from the outset, standards such as those set by REACH can also be factored in, allowing manufacturers to meet current requirements and to mitigate the risk of non-compliance with any pending or future requirements that may be in the pipeline.

Future-proofing braking systems through strong partnerships

As technological advances in braking systems continue to forge ahead, manufacturers must be prepared to adapt to remain competitive. Of course speed to market is a vital element when looking to offer a new technology and to achieve this while maintaining the highest levels of quality and safety required in the mobility sector can be a challenge if not approached correctly.

Things move fast, and already the industry is seeing the emergence of brake-by-wire technology. This is considered to be the next level after EHB, and the main component differences are that there are no brake fluids within the system, meaning it will be smaller still when compared to EHB. The parts and their associated components will be even more sophisticated, therefore there will be a very high focus on precision molding and a move towards automated processes.

Engaging with expert suppliers helps to expedite the development process exponentially, whichever technology is the focus, and where a co-engineering approach can be adopted, the benefits continue to mount. As braking systems continue to advance, building partnerships now can ensure suppliers to the industry will be ready for the future, ensuring the safety of road users as their highest priority.

Contributors: Daniel Triolo, Lead Key Account Manager, Andreas Minatti, Head of Business Development, Dr. Rudolf Randler, Head of Simulation and Dr. Jakub Kadlcak, Head of Materials Development and Surface Technologies Mobility at Datwyler

Preventing braking system failure before its fate is sealed

In EHB systems, failure of primary and secondary seals can cause leakage, leading to failure of the entire brake fluid cycle and a system that is, for all intents and purposes, out of control. To combat this situation, the processes involved in the manufacture of the sealing compound and its housing must be controlled and optimized.

Defining the appropriate parameters for the production of these parts is critical and should be as a result of trials to refine the process. This is undertaken for every part produced. On the supply side, a dedicated prototyping team should ideally be entirely focused on this element. As a result, every part that goes into serial production will have its own optimal production parameters. This will make the transition to serial production a smoother one, helping reduce time spent and costs associated with going from prototyping to production.

From the first stages of prototyping to serial production, production parameters such as vulcanisation time and temperature are critical to get right, particularly when producing elastomer parts. OEMs and suppliers are often unaware of some of the seemingly minor issues that can make massive differences at a later point. As an example, in the vulcanisation process a complex 3D structure is created where the polymer macromolecules are chemically linked to each other. These links, when you vulcanise for too long, can break due to the temperature. This can weaken the physical properties before the part even leaves the facility.

It is crucial to keep in mind that every single compound has its production optimum, whether it is a mixing programme or vulcanisation conditions for parts, which has to be aimed for and determined via a series of testing in the lab and in the process development department. Elements such as the molecular structure of the compound are monitored indirectly to determine this optimum, leading to a solution of the highest possible quality.

[1] Source - FEV

High-quality laser optics for hairpin welding

What is the key to mass production of traction motors for electric vehicles?

Pravin Sievi

Electric mobility in the passenger car segment is gaining ground and virtually all major manufacturers are adding electric vehicles to their fleets or completely changing over their model line-up. Integrating the right manufacturing technology is an important prerequisite for bringing these vehicles to market in the projected quantities. Hairpin welding is rapidly becoming a standard process in the production of electric motors.

China – the world's largest market for passenger cars – set a 10% quota for electric vehicles last year. And this number will increase by an additional 2% per year. In Norway, the share of electric vehicles in new car registrations already exceeds 60%. Car manufacturers are under pressure to master today's challenges in order to move forward with mass production of electric vehicles. Currently, the most important technological issues involve the batteries, charging infrastructure and a range that is practical for everyday driving. But the automotive industry is also placing high demands on electric motors. What they need is a maintenance-free unit that delivers high performance in the smallest possible installation space and can be cost-effectively produced in mass quantities.

Hairpins replace winding

The stator is one of the most complex components of an electric motor and it accounts for the lion's share of production costs. Material costs for copper are high and winding the coils is a relatively complicated process. As a result, hairpin technology is becoming more common in traction motors for electric vehicles. In place of winding, the coils consist of separate copper pins bent into the shape of a hairpin. These fill the slots of a stator more effectively and enable the motor to run more efficiently. During assembly, the hairpins are inserted into the stator laminations. Instead of mechanical crimping, the hairpin pairs are laser welded. This enables a more compact motor design and, similar to conventional winding, creates a coil that generates the necessary magnetic field.

As a material, copper places high demands on the control of the welding process – pore formation and spattering must be avoided by the optimized selection of parameters.

© Scansonic

Ensuring that the welding process is automated and extremely safe is of crucial importance. Depending on the electric motor design, 160 to 220 hairpin pairs must be welded for each stator. A single defective weld can render the entire component unusable. Laser welding is widely used in automotive production and offers numerous advantages. For instance, this process enables an extremely precise and focused energy input similar to electron beam welding. This is important to ensure that the insulation layers of the hairpins are not damaged in the welding process. Unlike electron-beam welding, however, a vacuum is not required. Laser welding is also an easily automated, flexible process that enables shorter cycle times. But copper is a material that makes laser welding highly complex – and this calls for innovative solutions.

Copper is a challenge

As a material, copper has relatively difficult properties for laser beam welding. The advantageous laser sources that are scalable in the power range are emitted in the infrared wavelength range at 1030 or 1070 nm. At these wavelengths, the absorption of laser light at room temperature is only around 5%. Shortly before the melting temperature is reached, the degree of absorption increases to around 15% and ultimately reaches nearly 100% when a vapor capillary, or keyhole, has formed.

The viscous copper melt pool results in a distinct process dynamic that can easily cause spattering of the material when the keyhole briefly closes and the vapor pressure causes molten material to be ejected. Production, however, requires a process with as little spatter as possible to ensure no ejected material enters the stator because this could cause short circuits or other defects. Spattering can be avoided if the welding speed is higher than 20m/min. However, no solution against spattering was available for the start of the process until now. It has been demonstrated that by specifically adjusting the relevant process parameters, such as laser power, speed and focus size, the keyhole can be stabilized in order to significantly reduce spattering.

Another challenge lies in the process steps required before the actual welding. The hairpins have a rectangular cross-section of only a few square millimeters. Before being inserted into the stator laminations, they are cut to length, bent, and the insulation is stripped from the ends. After insertion into the stator laminations the matching ends lie next to each other. All of these upstream production steps can influence the outcome of the welding process and have an impact on quality as a result of burrs on the cut surfaces, leftover insulation and imprecisely bent hairpins. In order to achieve an optimal weld seam, the process in the automated manufacturing process must be adjusted if, for example, the ends of the hairpins have a vertical offset or there is a gap between the two ends to be welded.

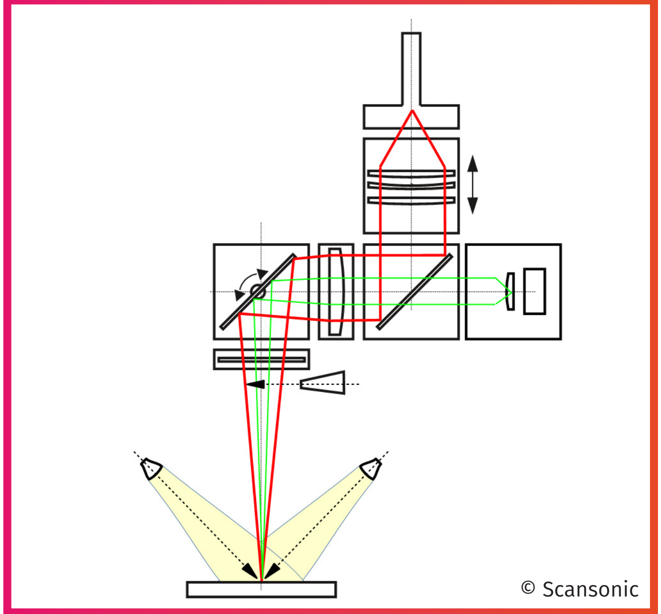
Advanced image processing

Any imprecisions in the positioning of the hairpins must be detected before the welding process begins. In laser welding, image processing is commonly used for this purpose. The Berlin-based Scansonic company is well known for its laser processing optics used in auto body construction. Scansonic has adopted a unique approach to laser welding of copper hairpins with its line of RLW-S optics. High-performance scanner drives are used to deflect the laser beam in order to maximize shape accuracy of the oscillation function, even at high frequencies. This guarantees a reproducible and highly reliable process.

Basically, two functional modules integrated into the optics work together to precisely determine the position of the hairpins.

The optics use conventional camera-based image processing. But this is challenging because the surfaces of different hairpins reflect varying degrees of light. As a result, they appear in the grayscale image with widely varying levels of brightness and may not be reliably recognized. Scansonic engineers solved this problem by illuminating the surfaces from different angles to significantly improve recognition reliability.

Nevertheless, the camera system capabilities are limited because images of the hairpin pairs are only provided from the front side. Although the position and any possible gaps are recognized, the system does not detect a vertical offset between the two ends to be welded. This offset can be detected using laser line triangulation with a sensor that projects a straight laser line onto the surface of the two hairpins. The light is reflected and measured by the receiving element in the sensor. Using an angular offset between the projection unit and the receiving element, the sensor can measure the height profile of the object. The height offset is then precisely recognized and taken into account in the subsequent welding process.



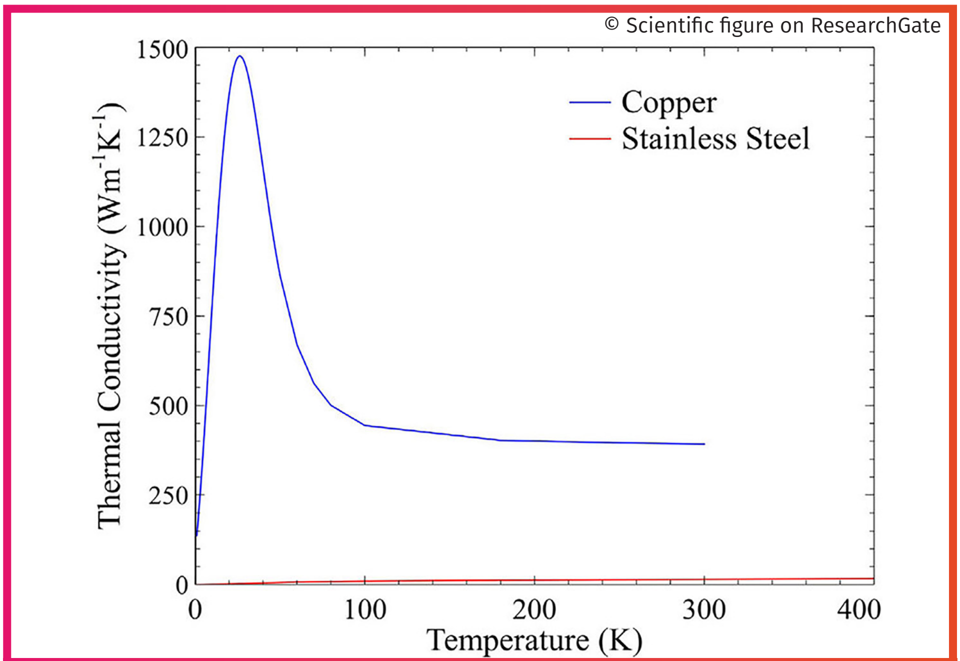
RLW-S laser optics have been successfully implemented in the production of electric motors.

Demand for short cycle times

Hairpins can be welded reliably in high quality using advanced laser optics with integrated image processing and the right controls for laser power and focusing. Using this method in high-volume production operations requires maximum processing speed and process reliability. Assuming that a vehicle is produced with a cycle time of 60 seconds, one or more motors must be completed within the same timeframe. In addition to the cycle time, the required number of production lines plays a key role, which is directly reflected in the required investment volume.

To increase speed, it would be conceivable to use a large scanning field. This would allow all hairpin pairs to be welded without moving the stator. However, experience in the first production lines has shown that quality problems can be caused by the angular offset in the various positions of the stator.

With this in mind, Scansonic focused on process quality and stability in the development of its RLW-S system. The company's engineers implemented a smaller scanning field made possible by post-objective scanning and an optimally adapted field of view of the camera. This ensures an optimal position of the laser beam processing point on the component and also applies to the position measurement of this point via the camera. In order to weld a complete stator, the unit must be rotated using a rotary axis. The desired cycle time is therefore a question of engineering and can be achieved with a powerful rotary axis. Standardized processing optics can thus take full advantage of their technological capabilities. Using this approach, Scansonic RLW-S laser processing optics have already demonstrated flawless operation on the production lines of a major car manufacturer.



Variation of thermal conductivities of copper and stainless steel with temperature

About the author

Pravin Sievi is a product owner at Scansonic MI GmbH in Berlin and is responsible for remote welding solutions.

Battery packaging in return flow systems – an eco-friendly challenge

Tor Larsson

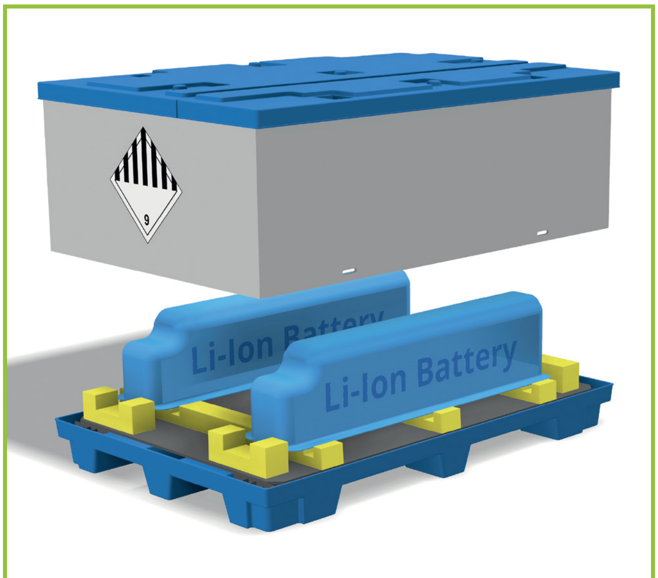
The battery industry is regulated by several governing organizations and various standards apply. There are European entities and their U.S counterparts and e.g. Japan has their own standards for testing and certification as do other part of the world. Regarding transportation, The United Nations issues recommendations for the transport of dangerous goods worldwide.

Vehicle batteries, such as Lithium-Ion batteries, are classified as dangerous goods. This means that the packaging needs to be UN-certified. The certifying process requires rigorous testing and the shipping regulations vary depending on many factors. Factors that determine the packaging is the state of the battery – if it is a prototype, a tested series battery, a waste battery packaged for disposal or recycling, or if it is a damaged or defective battery. Weight is also a factor and is often substantial. The third factor is how the battery will be transported. There are different shipping regulations whether a battery should be transported via road, by train, via sea or via air. Swedish packaging company Wellplast AB develops solutions for packing everything from small battery cells to heavy load truck-batteries and takes responsibility for the projects all the way through the certifying process.

Return flow systems for maximum efficiency

The ever-faster transition to electrification places new demands, but it also means new opportunities. "We were quick to see the potential as we could see positive synergies with our established segments", says Jonas Friberg, CEO at Wellplast AB. He continues: "With our experience in bespoke return flow systems we can use that and adapt and develop to suit battery packaging." Shipping regulations vary, not only depending on the mentioned factors, but also on which part of the battery it is. An automotive battery pack consists of individual cells, which are organized into modules. When the modules are fitted together and combined with a BMS (Battery Management System) and a cooling device, they together form a pack.

The pack is the form in how numerous battery cells are installed in an electric vehicle. The modules, and especially the packs, are heavy and the packaging needs to withstand, among other tests, drop tests from 1,2 meters height with the packaging frozen to -18°C. These demands tend to make one-way packaging solutions an expensive option. "Our main focus is developing packaging solutions for modules and packs", says Jacob Volckerts who leads the battery projects at Wellplast AB. He continues: "These are the most complex packaging projects, and this is where we gain strength from our extensive experience in creating effective return flow solutions." Packaging solutions that can be used in many return cycles provides opportunities for large savings as well as a reduced environmental impact. "We have gained a lot of knowledge through several battery packaging projects for the automotive industry", says Jacob Volckerts.



By replacing one way packaging for a single battery with a return flow container system that holds two batteries, significant savings can be made, both economically and environmentally.

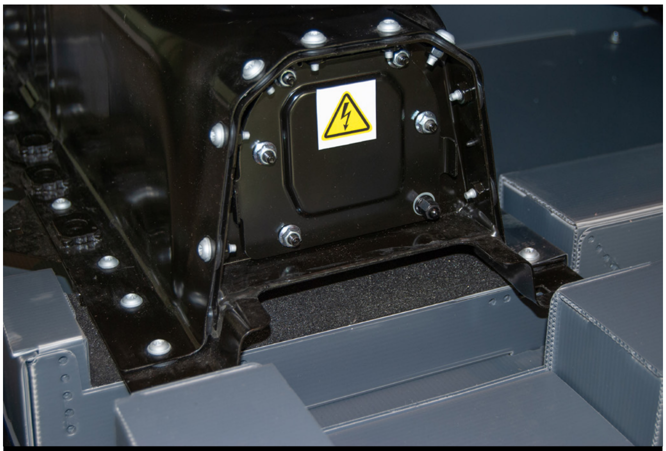
Certifying process

Under the UN-regulations, and specifically UN-3480 for Lithium Ion Batteries, must meet or exceed minimum standards of performance before it can be authorised for the carriage of dangerous goods. UN approved third party certification agencies are granted to conduct the required package testing and to provide certification that the packaging is in compliance with the requirements for the package type. Package performance is established by subjecting specimens of the packaging to the tests described in Chapter 6.1 of the UN Model Regulations. If the construction passes the tests, packaging subsequently manufactured to the same specification, may be regarded as meeting the requirements and marked with a construction-specific code that indicates e.g., year and location of the manufacturer and identification of the approval agency along with the UN symbol.

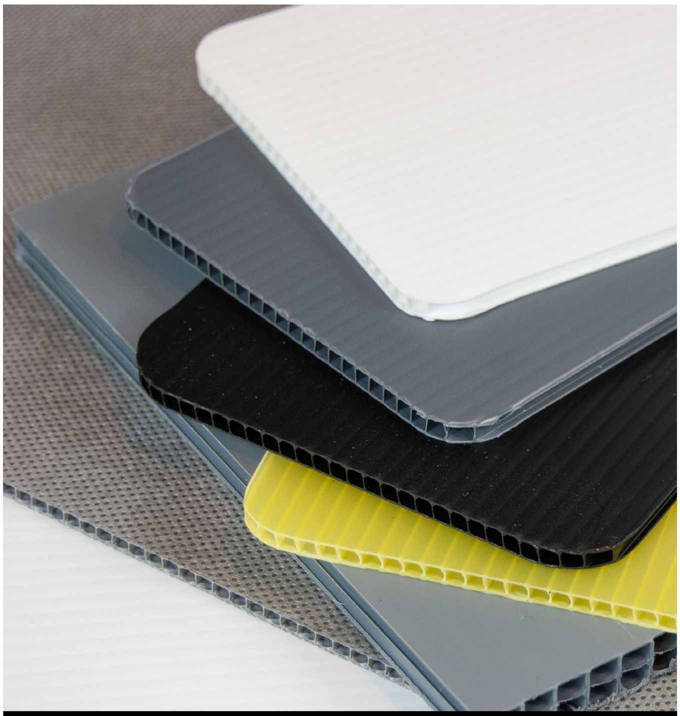
Material properties

Working with polymers such as polypropylene (PP) and polyethylene (PE) has many benefits for the use in battery packaging. The material is clean and moisture-proof, emits no particles and can, if needed, be fitted with ESD protecting properties. Optimised for demanding applications, polypropylene is also durable, lightweight, and versatile. The use of different techniques for merging, e.g., ultrasonic welding, omits the use of glue thus avoiding the contamination of the material. This is critical for the recycling purposes of used packaging.

The heavy duty load carrier is durable and used for hybrid vehicle batteries and large size batteries for trucks and buses. It is designed for return transport systems with an optimised pallet box and interior fitment adapted to the specific battery.



Wellplast consists of 100 % polypropylene, re- cyclable, clean and moisture-proof. By using the materials unique properties, the construction can be made with very few added components, thus making the recycling easier at the end-of-life.



The properties of different Wellplast® materials make it a versatile component for various packa- king solutions. Light weight, extremely strong or flexible, with additional properties as non woven surface for scratch-sensitive products, anti corro- sion or ESD.

The price for a single use transportation container for one battery is not much less than the price for a plastic container for return flow systems. Already after the second trip, the return flow container has paid off.

Recycling process

An important factor is the rapidly increasing environmental awareness and the demands for a circular use of materials. Wellplast AB is part of the Circular Plastics Alliance, a European initiative to boost the EU market for recycled plastics. In the effort to meet the goals for a circular use of materials, the company also offers a repurchase program for the recycling of used materials. By recycling polypropylene (PP) into new products and by using the plastic material as a circular asset, great savings can be made in regards of energy requirements and CO2 emissions. “The material properties give us the possibility of developing mono-material packing solutions which creates a great advantage in the recycling process. By avoiding contamination of the material, we can reuse the material to produce new packaging solutions. Instead of sending it as waste to energy recovery we can thereby decrease our use of virgin material”, says Jonas Friberg.

A significant use of padding builds great a volume of waste to recycle and take care of in the single use packaging.

The recycling of used and damaged batteries is critical for a sustainable battery industry and to be able to safely transport the batteries with minimized environmental impact is vital for the quickly evolving automotive industry. To meet the demands for electric vehicles it is important to build a sustainable supply chain, not only in the manufacturing phase, but in all parts of the battery’s life-cycle. China has invested enormous amounts in increasing recycling capacity and things are happening also on the European market. Thus, to establish reliable return flow systems for the battery production and recycling, is key with an increasing need of raw materials.

Corrugated paper, wood, plastic and metal mixed makes the single use container strong, but expensi- ve and hard to dismantle for recycling.

Tor Larsson, Head of marketing and sales Wellplast AB


It's time to change.
Replace traditional resolver technology in the electric drivetrain now!
Inductive automotive sensors for tomorrow's demands.
Get your prototype within four weeks!
For all motors, especially synchronous and reluctance
Increased performance: significantly more precise measurements
More freedom of design: smaller space requirements
Flexible mounting options: on- and off-axis
Easy integration: compatibility with almost all automotive inverter systems
Designed for mass production
Better performance at less costs
Source: Adobe Stock
Contact our experts today:
www.lenord.com info@lenord.de
LENORD +BAUER
Finding solutions. Founding trust.

Experimental and numerical research of the MM Welding® joining technology for sandwich panels

Classical fastening methods like screwing, riveting, or gluing often prove to be complicated on modern lightweight materials, as the process might require surface preparation, pre-drilling, or post-processing [1,2]. Adhesive bonding is a common alternative for traditional fasteners. However, these techniques strongly depend on the geometry of the contact surfaces and the presence of contaminants, while debonding leads to significant damage of the contact region [3,4].

To cover these emerging requirements in light-weight structural design, MultiMaterial-Welding AG invented and patented a broad portfolio of technologies and products (see Fig. 1), based on the joined application of ultrasound and pressure on at least one thermoplastic material. The other part of the assembly contains either fibrous, porosities and/or geometrical feature containing undercuts. In particular, the LiteWWeight® technology, consists of a family of thermoplastic fasteners with different geometries that provide strong intimate contact between pin and sandwich panels with honeycomb structure (see Fig. 2). The LiteWWeight family allows the fixation of functional parts (handle, hinges,) or create a solid base location for a plastic screw, and therefore unleashed design freedom to produce parcel shelves, load floors or even roof components.

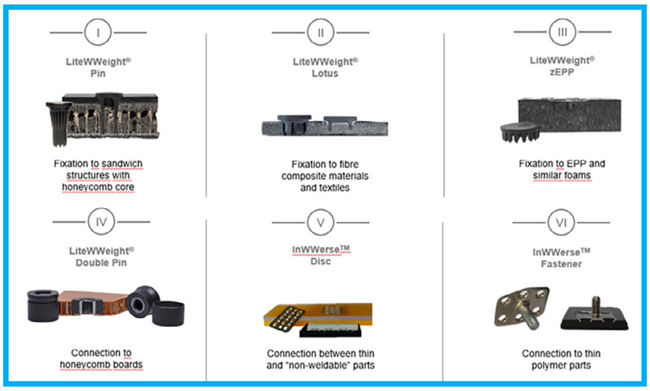
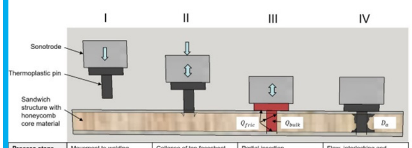


Fig. 1 Presentation of the MM-W products portfolio

Fig. 2: LiteWWeight® Pin and cross-section of joint inserted in a lightweight honeycomb structure (left). And assembly application example (right).

The ultrasonic vibrations together with pneumatic or servo-driven pressure allow the fasteners to pierce through the substrate material's top layer, and partially melt into the porous internal structure, thus creating a highly interlocked mechanical bond (see Fig. 3).



Process stage	Movement to welding position	Collapse of top facesheet	Partial insertion	Flow, interlocking and cooling
Details	-	Applying of pressure and ultrasonic excitation	Heating by friction and plastic deformations	Material flow into the "porous" structure to form an interlock with the substrate

Fig. 3: LiteWWeight® joining process

To build a deep understanding of the process, a research project was initiated in collaboration with the Fachhochschule Nordwestschweiz / Institute for Polymer Engineering, and funded by the Swiss Innovation Agency (Innosuisse, Nr 27066.1 PFIW-IW). The project deals with the experimental and numerical investigation of the joining process using the LiteWWeight® technology. For this purpose, material characterization was conducted, and an online process monitoring system was developed to capture data from multiple force and displacement sensors [5]. Experimental test series were performed to obtain time-dependent process data, including high-speed video of the process coupled with point-tracking algorithms and CT-scanning of the sandwich structure both prior to and after joining. Based on the collected data, a finite-element thermo-mechanical model of the joining process was developed in ABAQUS/Explicit.

Experimental methods

In this study, a pneumatic driven ultrasonic welding unit (Branson 2000Xc) was used to acquire data such as force, displacement, amplitude, and energy coupled with the developed Online Process Monitoring system [5].

Various experimental methods were used to characterize mechanical and thermal material properties of the pin material (a glass fibre reinforced polyamide) to identify parameters for the finite element simulation. First, differential scanning calorimetry (DSC) experiments were performed to derive heat capacities and to understand the melting behaviour of the polymer. Temperature and frequency-dependent dynamic mechanical analysis (DMA) measurements were performed to determine storage and loss moduli. Additionally, rheological, and thermogravimetric analysis (TGA) experiments were carried out. Furthermore, following mechanical tests were performed: tensile test on face sheet substrate material, compression behaviour of pins and sandwich substrate. Computer tomography (CT) scans were performed to present an inside view of the pin and to measure internal geometries of the components.

ABAQUS/Explicit FEM

Commercial software ABAQUS was used for the simulation of heat transfer, elastic and plastic deformations, and failure in pin and honeycomb structure elements. Fully coupled thermal-stress analysis was implemented due to most of the heat arising from friction and plastic deformations, and material properties being temperature dependent [6].

Three general heat sources arise in the pin and substrate during the process: heat from friction, plastic deformations, and ultrasonic energy dissipation.

ABAQUS/Explicit predicts material progressive damage and failure based on the undamaged elastic-plastic response of the material, damage initiation and damage evolution criteria. A ductile damage material model was implemented for the pin, honeycomb cells and foam elements. For the prediction of anisotropic damage in the fibre-reinforced composite face sheet, the Hashin damage model was implemented, which considers four different failure modes: fibre tension, fibre compression, matrix tension, and matrix compression [6].

The model assembly consisted of 3 parts: an ultrasonic horn, the pin, and the sandwich panel (See Fig. 4). The horn material is steel, and it is significantly stiffer than the pin. Therefore, the horn was considered as a rigid surface with the same shape as the real horn.

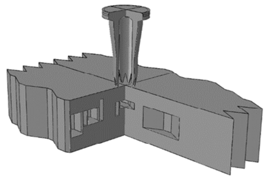


Fig. 4: Model assembly based on simplified CT data (view is cut by cross-sections)

The geometry of the sandwich was reconstructed in detail on the base of CT scans due to the high variability of the internal sandwich structure and its strong influence on the process outcome. Different material properties were defined for the honeycomb cells and the foam.

Results

Several criteria of model accuracy were considered for the validation of the proposed numerical method. These criteria are based on the horn reaction force provided by the online monitoring system, the pin's damage state depending on collapse distance, and temperature distribution measured just after the joint.

The reaction force signal measured by the Branson 2000Xc load cell is smoothed by a gaussian filter and no original raw signal data was available. Therefore, for the comparison of simulated and measured data, the simulated reaction force curve was smoothed by a similar filter. Comparison of the measured and simulated smoothed force over time, as well as raw data provided by simulation, are presented on Fig. 5.

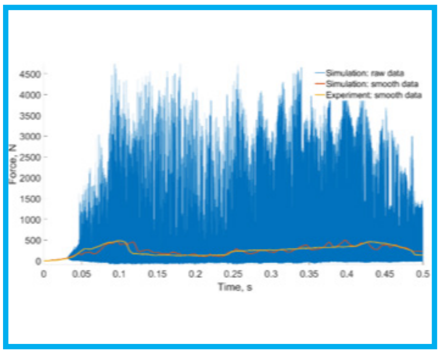


Fig. 5: Horn reaction force

The ABAQUS solution for the temperature is not presented here, but results are presented in [7]

With the mechanical damage model, the pin destruction state can be predicted, and depends on the process phase. In general, the pin teeth's damage evolution could be described in 4 steps:

- Before upper face sheet collapse (collapse distance is 0-1.5 mm): teeth are partially melted and deformed, loss of their height is about 10 %.
- After upper face sheet collapse (collapse distance is 1.5-3 mm): teeth are partially destroyed, approximate loss of height is 10-30% depending on the local stiffness under a single tooth.
- Before pin reaches the bottom face sheet (collapse distance is 3-16 mm): teeth maintain the destruction state obtained after the face sheet collapse or increase it slightly.
- After pin reaches bottom face sheet (collapse distance is 18 mm): teeth lose most of their original height and form an intimate contact with the bottom face sheet and sandwich internal structure.

A comparison between experiments and simulation for the key steps of this joining process is presented on Fig. 6.

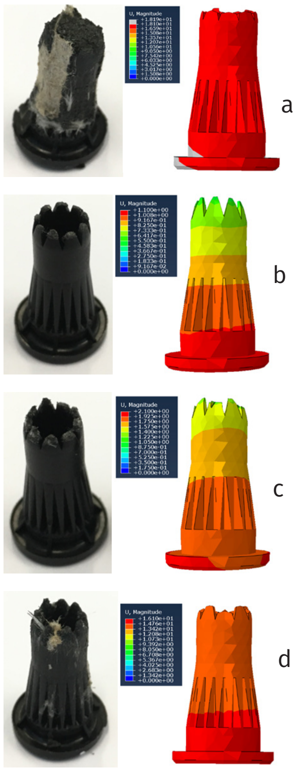


Fig.6: Observed and simulated pin damage state at the various collapse length (1, 2, 16 and 18 mm)

Conclusions

The developed FE model covers all the phases of this joining process, including face sheet collapse, partial insertion, and final consolidation phases. It can represent the interaction between the pin and the substrate and can be used for the prediction of damage, and heat generation and transfer depending on the pin's geometry, material properties, sandwich type or process setup.

The presented approach successfully represents the MM Welding® LiteWWeight® process and is a key parameter for the deep understanding necessary to the scaling of this technology to further applications in the transport sector.

References

[1] Thoppul S, Finegan J and Gibson R. Mechanics of mechanically fastened joints in polymer–matrix composite structures – a review. Compos Sci Technol 2009; 69: 301–329.

[2] Altmeyer J, dos Santos JF and Amancio-Filho ST. Effect of the friction riveting process parameters on the joint formation and performance of Ti alloy/short-fibre reinforced polyether ether ketone joints. Mater Des 2014; 60: 164–176

[3] Katnam K, Da Silva L and Young T. Bonded repair of composite aircraft structures: a review of scientific challenges and opportunities. Prog Aerosp Sci 2013; 61: 26–42.

[4] Ageorges C, Ye L and Hou M. Advances in fusion bonding techniques for joining thermoplastic matrix com-posites: a review. Compos Part A Appl Sci Manuf 2001; 32: 839–857.

[5] Christian Brauner, Lucian Zweifel, Clemens Dransfeld, Joining of multi-material assemblies by the MultiMaterial-Welding technology – Development of an online process monitoring system, Proceedings of 4th International Conference & Exhibition on Thermoplastic Composites; 2018; 82-86

[6] ABAQUS Inc., 2006, ABAQUS Analysis User´s Manual, Version 6.6

[7] C. Brauner, L. Zweifel, I. Zhilyaev, M. Rheme, G. Eckhard, V.Bersier, Experimental and numerical research of the MM Welding® joining technology for sandwich panels, Proceedings of 5th International Conference & Exhibition on Thermoplastic Composites; 2020; 211-214

The role of better, more direct communication technologies that allow the cooperation and coordination of all road users and infrastructures

5G will redefine the driving experience of all users

Maxime Flament

As we look towards the future, we should remember how connected mobility has become synonymous with automated driving, the digitalisation of transport and traffic management. 5GAA has over 130 members, all major industry players from the Telco, Auto and IT industries who are together delivering end-to-end connected mobility services for all road users. Our contribution entails the development, standardisation, testing and deployment of cellular-based communications for the automotive market and the stimulation of global implementation. Commercial market availability is also one of our major priorities.

We primarily address connected mobility by leveraging mobile network technologies such as 4G/LTE, and 5G. Thanks to multi-gigabit speed that will create new opportunities in infotainment and teleoperation use cases, 5G will redefine the driving experience of all users. Such features must be reliable, predictable and provide low-latency Quality of Service (QoS). We have already successfully shown on-road 5G tests combining safety-relevant dynamic map downloads and multi-media streaming. Should the signal be reduced, the first service is guaranteed while the video quality is reduced.

Decarbonising transport is now a core public policy theme around the world in line with the Paris climate agreement's objectives. One of the long-term aims of the European Union on CO_2 emissions is an overall reduction of 80-95% by 2050.

In this regard, mobility systems in general, and transportation in particular, are undergoing profound changes. They will likely evolve more in the next ten years than they have in the previous 50. We should brace ourselves.

Transport is a vital sector in any economy and will doubtless impact fuel modernisation while remaining a key source of employment. But modernising the economy and addressing climate change can and should go hand in hand.

C-V2X and 5G, smart sensors, artificial intelligence, big data and blockchain are examples of emerging technologies with massive potential to help in this transition.

Connected Automated Mobility will be a cornerstone to improve road transport's sustainability. This positive impact is expected to result from a host of sources, e.g., less congestion, the increase of shared mobility, and synergies with clean mobility.

Moreover, there is increased interest in the potential environmental benefits of C-V2X, or cellular vehicle-to-everything communication. The question is to what extent connected driving, with increasing levels of automation, can lead to sustainability and environmental benefits. Last year, 5GAA asked TNO to conduct a study into the ecological effects of C-V2X communications.

The emission reduction potential of C-V2X services have been shown in various real-world pilots, driving simulator studies and traffic simulation studies. In addition to the literature results, TNO carried out indicative calculations with a microscopic emission calculation tool (EnViVer), using speed pattern data from real-world pilots and microscopic traffic simulations. We used hypothetical speed patterns to illustrate the potential of future use cases where vehicles drive with minimal dynamics (enabled by coordinated movements between vehicles, for example). We also analysed how the identified C-V2X services could be deployed considering the available communication

technologies as well technologies expected for the future.

How exactly do these results happen? Some of the services provided by C-V2X that will help reduce emissions include-

- Assisting the driver to choose an optimal route (route optimisation based on minimising emissions, avoiding congestion to save the driver both time and fuel).
- nfluencing and/or harmonising speeds to such an extent that congestion can be avoided, decreased or resolved, thus reducing travel times and overall emissions.
- Eco-driving services for situations where the driver (or the vehicle, with higher levels of automation) can anticipate the situation ahead and is mostly free to choose an optimal and fuel-efficient speed and acceleration pattern. The technology could also potentially report back to the road user on issues ranging from when the tires need to be changed or pumped to when an oil change is required. This further adds to the technology's sustainability, as well-maintained cars can stay on the road considerably longer.

The role of better, more direct communication technologies that allow the cooperation and coordination of all road users and infrastructure could be hugely valuable, in achieving the best environmental impacts.

Connected cars in general could eliminate 400,000 tonnes of CO2 emissions and save 280 million hours of driving every year, according to automotive supplier Bosch, 2017. They may also reduce road accidents (a source of delays and, as a result, increased driving times and emissions) by up to 250,000 a year. This is an impressive range of sustainability benefits for a field of technology whose initial aims were traffic safety and efficiency and general passenger travel comfort.

Connected cars are likely to act as a catalyst for the overall green transition in transport. According to the U.S. Department of Energy (DOE), automated or semi-automated cars could reduce energy consumption rates by 90 to 200%- a dramatic impact on the overall fight against climate change and sustainability. When we couple this with the ongoing rollout of electric and hybrid vehicles and the emission reduction this implies, we can see that the road sector is poised to lead the transport sector's overall response to the green transition. This may spur our sister sectors of rail and aviation in their drives for emission reduction.

The synergies involved in these technologies, which initially focussed on improving safety, have quickly seen spin-offs into one of the most crucial areas of our time. Based on all the facts and figures presented here, we at 5GAA remain ready to continue to give strong engagement in the process of forming the green new deal.

Post green transition, the world will look very different. We currently see these changes accelerating with the recent response to the corona crisis. However, of course, it is a world that will need transport and therefore our sector must change accordingly. Connected cars in general and C-V2X, in particular, have a huge role to play, and our sector is ready to further engage in this vital process.

Maxime Flament CTO, 5GAA

Automakers are no longer hardware makers but are evolving into tech companies

Addressing the challenges of a sector in transformation and preparing to meet new cyber compliance burdens (ISO/SAE 21434)

The world of connected vehicles is no longer a farfetched utopia of self-driving cars. Fast-forward from 1996, when GM launched what would be considered as the first connected car, the world of connected automotive has changed dramatically in the last century and this is only the beginning.

Computerized systems in automotive, originally aimed at enhancing a vehicle's performance, have now expanded to areas such as personalization or AI-based autonomous vehicles. But, why has this shift been so prevalent in today's world? The answer is simple, to place the consumer first. The 'connected car' era has directed manufactures to implement and adapt to digitalization in order to deliver outstanding customer experience that builds loyalty and creates value for the consumer and their changing business. This shift has led manufacturers to focus on 4 key strategic areas:

1. **Optimizing the online and digital purchase journey:** by providing a seamless experience from initial research through to aftersales
2. **Building partnerships and collaborating** establishing strong, trusted partners that position manufacturers as leaders
3. **Creating loyalty through next generation consumer service:** a win or lose factor based on the level of trusted customer experience provided
4. **Turning car data into value:** data coming in and out of vehicles can support numerous touch points towards a positive customer experience, for example, infotainment, remote diagnostic and repair or even improved navigation

This has resulted in a drastically changed landscape where automakers are no longer hardware makers but are evolving into tech companies. Effective cybersecurity is a strategic enabler on all 4 business aims described above. Cyber branches in connect cars will undermine consumer trust and therefore inhibit successful realization of these organizational goals.

Connected automotive threat vectors

With the rise of connected vehicles, and data becoming a commodity, the automotive sector has seen an increased volume of vulnerabilities as well as new entry points for hackers to leverage.

In 2020, Tesla filed a lawsuit against a former employee after it emerged the employee made changes to company source code and exported gigabytes of proprietary data to unknown third parties. This, as with many other similar examples, illustrates a new wave of cyber-attacks where hackers can gain access to a vehicle's main information system through multiple vectors such as a car USB port, keyless entries, key fobs or mobile apps, among others.

The biggest challenge our clients see is how to stay protected against the ubiquitous threat vectors that circle a vehicle that are omnipresent and malicious in nature. According to recent research by Upstream Auto that analysed incidents since 2010, the three most common attack vectors are - servers (32.9 per cent); keyless entry systems (26.6 per cent) and mobile apps (9.9 per cent).

Man-in-the-middle (MATM) attacks, where the attacker covertly relays and possibly alters the communications between two parties who believe that they are directly communicating with each other, like eavesdropping, are also prevalent. These attacks can be resolved in numerous ways by authentication, like key-agreement protocols, tamper detection, where a normal process might take a bit longer than normally, and digital forensics. The latter is obviously by advanced means. It allows a suspected attack to be checked and monitored using incident forensics, identifying if data was comprised, where the attack happened and provides threat intelligence to remediate the situation.

Until the advent of ISO/SAE 21434, no formal connected automotive cybersecurity standard existed in the marketplace.

The ISO standard establishes "cybersecurity by design" and provides the model for developing a risk assessment system and specifies details on processes and work products. Crucially, it has been designed to support implementation of the new UNECE Automotive Cyber security regulations and may be used to demonstrate compliance with the regulations by OEMs and their supply chains.

ISO/SAE 21434 overview

ISO/SAE 21434 covers all stages of a vehicle's life cycle from design through to manufacturing, to decommissioning by the application of cybersecurity engineering. The standard applies to all electronic systems, components, and software in the vehicle, plus any external connectivity. Moreover, the standard will provide developers with an overarching approach to implementing security safeguards that span the entire supply chain and protect the life cycle of the vehicle.

The importance of the standard

is unequivocal and a first for the industry. With the increase in connectivity in vehicles, such as Wi-Fi, Bluetooth and future 5G connectivity as well as the development of autonomous cars, the risk of cyberattacks and subsequent damage also rise. To cover this type of risk and therefore new guidelines and standards needed to be established.

The intent behind the standard is to provide a structured process to ensure that cybersecurity considerations are incorporated into automotive products throughout their lifetime. Furthermore, the standard will require automotive OEMs and suppliers alike to demonstrate due diligence in the implementation of cybersecurity engineering and that cybersecurity management is applied throughout the supply chain to support it, including the all-important aftermarket.

Security by design is encouraged as part of an organizations culture so that everything is designed with security considerations in mind from the start.

BSI E2E connected automotive cybersecurity model

At BSI, we have a large team of highly experienced, industry leading consultants that support clients to ensure they have all the connected automotive security requirements they need for their organization. BSI has constructed an E2E connected automotive cybersecurity model across three key pillars:

1. Strategic consulting: through a holistic consulting model, using the team's experience, we begin by conducting a threat modelling framework with risk matrices and design. Then, we look at the security model, design the relevant roadmap, and look at areas such as trust and identity, supply chain integration, controls and assurance through product certification. We can then create an ISO/SAE 21434 aligned and compliant security architecture, operation integration, third party risk and compliance on controls and checks.

2. Security engineering and assurance: our consultants look at the life cycle of the Security Bill of Materials (Sec BoM) and analyse it through a series of security tests using purple and red teaming engagement across the vehicles full production cycle and beyond.. This includes testing with adversary and attack simulations to defence and protection techniques, as well as in the event of a data breach or vector attack, along the cycle pathway to verify that it is robust and secure, ensuring information resilience.

3. Compliance services: lastly, on the E2E model we examine the controls and methodologies used against leading standards from IACS to CC-ITSE as well as regulations like the EU GDPR on data protection and privacy management and FIPS compliance. As a final step we review them against best in class security test models such as OWASP's ASVS and embedded controls and MITRE's ATT&CK framework among others. This iterative approach is proven to simplify achieving ISO/SAE 21434 compliance.

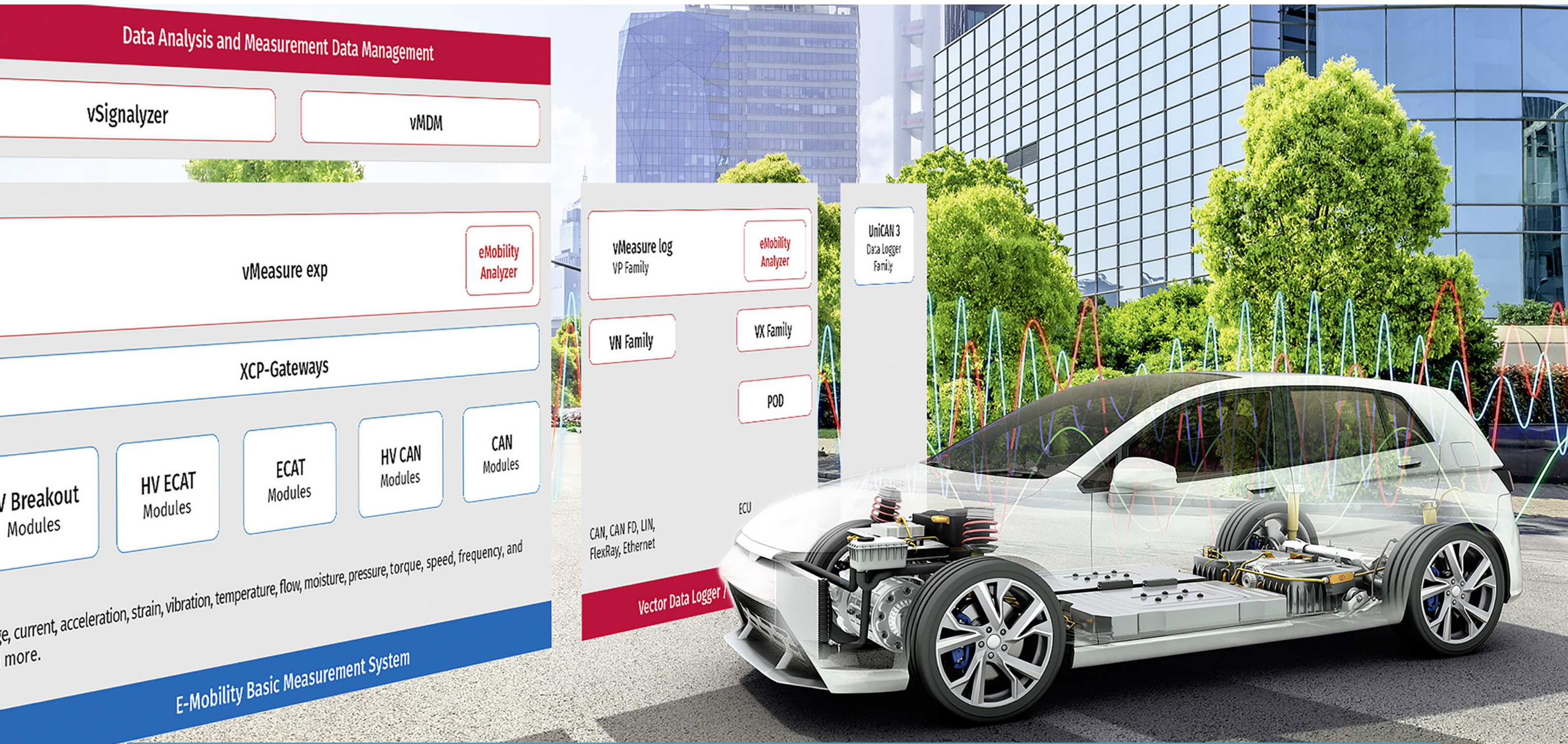
The BSI team has years of industry relevant and multi sector experience, providing cutting edge and leading consultation and insights to ensure IoT infrastructure and connected assets are secure and are information resilient all backed by leading edge innovative alliances specializing in IoT, connected systems and automotive security.

BSI is also a part of Project Endeavour, a collaborative project that will enable us to apply our expertise in Standards and Certification to help ensure and support the safe and secure trialling and development testing of automated and autonomous vehicles on our roads and on test tracks. Project Endeavour is part-funded by the Centre for Connected and Autonomous Vehicles (CCAV), delivered in partnership with Innovate UK. It is part of the government's £100 million Intelligent Mobility Fund, supporting the Future of Mobility Grand Challenge. We're committed to working together with the team and industry to help accelerate innovation whilst ensuring safety.

About the author

Mark Brown is BSI Cybersecurity and Information Resilience Global Managing Director.

Mark has more than 25 years of expertise in cybersecurity, data privacy and business resilience consultancy. He has previously held leadership roles at Wipro and Ernst & Young (EY), amongst others and brings a wealth of knowledge including extensive proficiency on the Internet of Things (IoT) and the expanding cybersecurity marketplace having worked for Fortune 10 and Fortune 500 firms as Global CISO and Global CIO/CTO respectively.



Innovative measurement solutions are needed to keep pace with the rapid development of electromobility. Tests and measurements in this area face special challenges. The new E-Mobility Measurement System from Vector and CSM was developed precisely to meet these challenges. In the following, it is explained using successful customer applications as examples of how this innovation has been deployed to increase powertrain and overall EV efficiency, and identify required changes prior to production approval.

Understanding EV performance with innovative measurement tools

Consistent e-Mobility analyses throughout the product development cycle

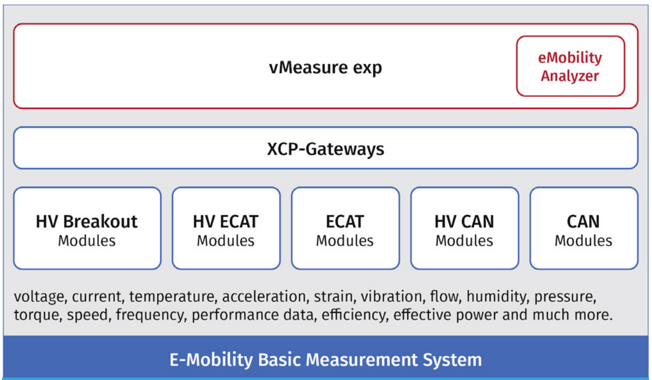
The challenges of measurement technology for electromobility

Automotive and other vehicle manufactures are working on operating systems and solutions with artificial intelligence. A few AI processors control all functions centrally. The algorithms deployed and the system components connected to them must be verified and tested for design improvements and final approvals. For this purpose, all physical parameters and vehicle characteristics should be measured and acquired synchronously in real time. One example is the investigation of high currents and voltages as well as their ripple for the verification of the high-voltage vehicle electrical system. At the same time, physical parameters such as temperatures, vibrations, and accelerations from components such as the battery, the powertrain, and other subsystems drawing energy from the main battery system must also be acquired and analyzed for both component and system optimization. During verification and for troubleshooting, it is important to synchronously acquire this physical measurement with the ECU-internal data and values communicated via the vehicle communication busses. In particular, high precision, multi-channel current, voltage and power analysis must be performed in real time to detect effects of driving maneuvers during road tests, for example to verify vehicle performance criteria or when following a standardized drive cycle for WLTP or EPA predictions. These systems involve potentially dangerous high-voltage and, therefore, safety for equipment and user must be ensured. For fleet tests, remote data logging and future-proof measurement data management are necessary.

E-Mobility Measurement System from Vector and CSM

In cooperation, Vector Informatik and CSM have developed a new E-Mobility Measurement System to meet these challenges. Applications exist in all development phases for measurements, tests and verifications for all types of electrified vehicles. The two companies' competencies for software tools, algorithms and hardware measurement technology combine for an ideal system.

The E-Mobility Basic Measurement System allows the simultaneous measurement of all physical vehicle parameters as well as the real-time calculation of variables such as performance, efficiency or energy consumption. Other analyses are also performed in real time, such as ripple, Fourier or harmonic analysis.

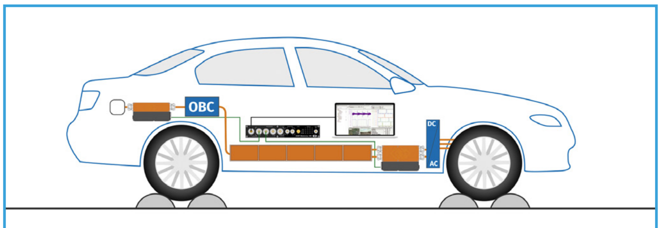


E-Mobility Basic Measurement System consisting of CSM measurement modules, XCP-Gateway and the measurement software vMeasure exp with the *eMobilityAnalyzer*.

With the various small and robust CSM measurement modules, an application-specific measurement system can be easily configured, and distributed around the vehicle to be close to the measurement sensors. Depending on the requirements of the measurement sampling rates, the measurement modules are networked via CAN and EtherCAT® (ECAT) communication busses, or a combination of both. The measurement data is transmitted to the Vector software, vMeasure exp or CANape via specialized XCP-Gateway which synchronizes all measurement data acquired better than 1 µs. This Vector software include the specially developed eMobilityAnalyzer, which is a library of functions that performs all real-time calculations of various powers, efficiency, and others.

Selection of CSM measurement modules for usage in vehicles and on test benches.

In this way, the energy consumption in a vehicle is measured with only three main measurement system components. If additional parameters are to be acquired, more measurement modules can be easily added to the measurement network.



Power analysis with three components: vMeasure exp software, receiving data from an XCP-Gateway and the HV Breakout Module taking the measurement of current and voltage directly from the high-voltage cable.

eMobilityAnalyzer and HV Breakout Modules

The measurement of high currents, voltages and powers in various locations throughout the vehicle is a fundamental requirement for electrification. The use of traditional measurement tools and approaches has proven to be inadequate for such a task: The classical power analyzers or tailored transient recorders are centralized devices, which are cumbersome to use, and are not designed to measure high voltages. The E-Mobility Measurement System allows high-voltage safe measurement with innovative HV Breakout Modules (HV BM) installed directly in the high-voltage cables. The inner high-voltage conductors are simply connected to the modules with terminal rings and the braided shield is applied to the module to assure continuity.

CSM HV Breakout Module as a ready-prepared, HV-safe plug-in system with plug and socket.

Special variants of the Breakout Modules are available for single cables, double cables, 3-phase and even to include precisely measuring shield currents.

The current and voltage sampling takes place synchronously inside the module and the sampled values are sent to the DAQ.

Several HV Breakout Modules are necessary to acquire all energy consumption data throughout the vehicle and its components. Figure 4 shows the simple setup for power and consumption measurement at a single location of a powertrain.

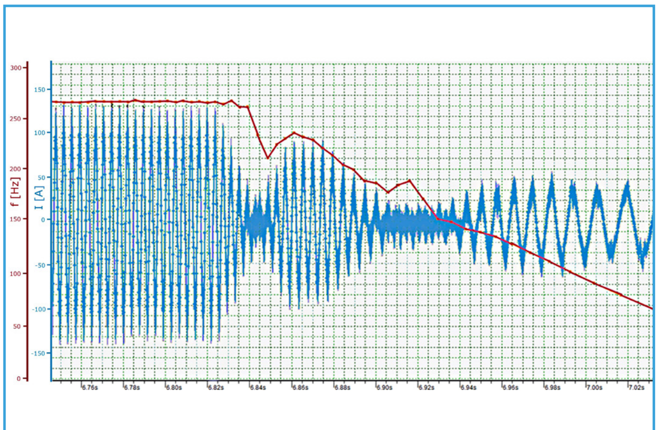
The two basic tools, a HV Breakout Module and the vMeasure exp software with eMobilityAnalyzer library, are used to measure physical values and calculate power, energy consumption or efficiency in real time. The application is very simple: The HV Breakout Modules sample synchronously current and voltage at a high rate of 1 MS/s (1 Mega Samples per second). The values are used to calculate the power consumption or efficiency in real time. From the sampled values, vMeasure exp uses the eMobilityAnalyzer function library to calculate all power parameters in real time, such as active power, apparent power, reactive power, power factor or electrical work. The individual functions are precisely optimized for the measurement task:

Application	*eMobilityAnalyzer* **Functions**
Efficiency of electric motor	Power analysis electric motor, mechanical motor power (speed, torque)
Efficiency of powertrain	DC power analysis, mechanical power axis (speed torque)
Efficiency of inverter	DC power analysis, input power electric motor
Efficiency of DC/DC converter	DC input power, DC output power
Power analysis electric motor	input power electric motor, star-delta transformation for phase currents and voltages
Energy consumption	Electrical work, ampere hours, DC power analysis
Charging efficiency, charging power, charging energy	Effective power, electrical work, efficiency
High-voltage electrical system quality	Current / voltage ripple, characteristics of signal fluctuation, DC and RMS values

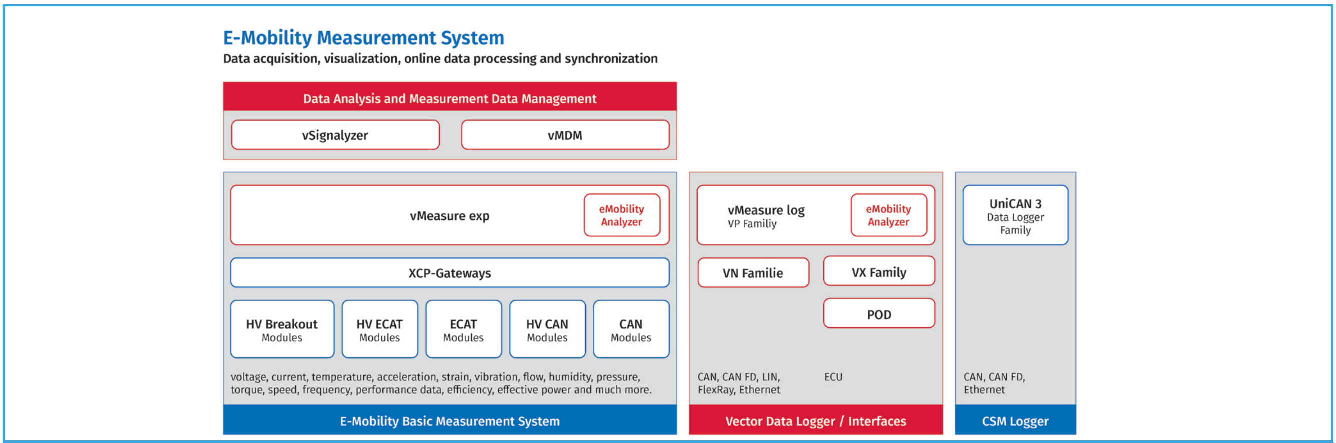
A central component of the power measurement is the determination of the electrical frequency or the speed as shown in figure 6. Simple methods for detecting the zero crossing deliver unstable results due to transients in the current signal. Therefore, integration over several periods is necessary. The model-based prediction approach implemented in vMeasure exp combines high dynamics with high stability. Thus, the active power can be calculated accurately for high velocity gradients as well as for constant velocity conditions.

Measuring acceleration, temperature and strain in high-voltage environments

The E-Mobility Basic Measurement System also includes measurement modules for the acquisition of all physical parameters such as temperature, humidity, vibration, acceleration or speed. They are also networked via EtherCAT or CAN as appropriate for the sampling rate of the sensor used. Depending on the test object or application, conventional measurement modules or high-voltage safe measurement modules are used for this purpose. For high-voltage applications, standard sensors can be used, but they are connected to high-voltage safe sensor cables and measurement modules



Measured current and calculated frequency



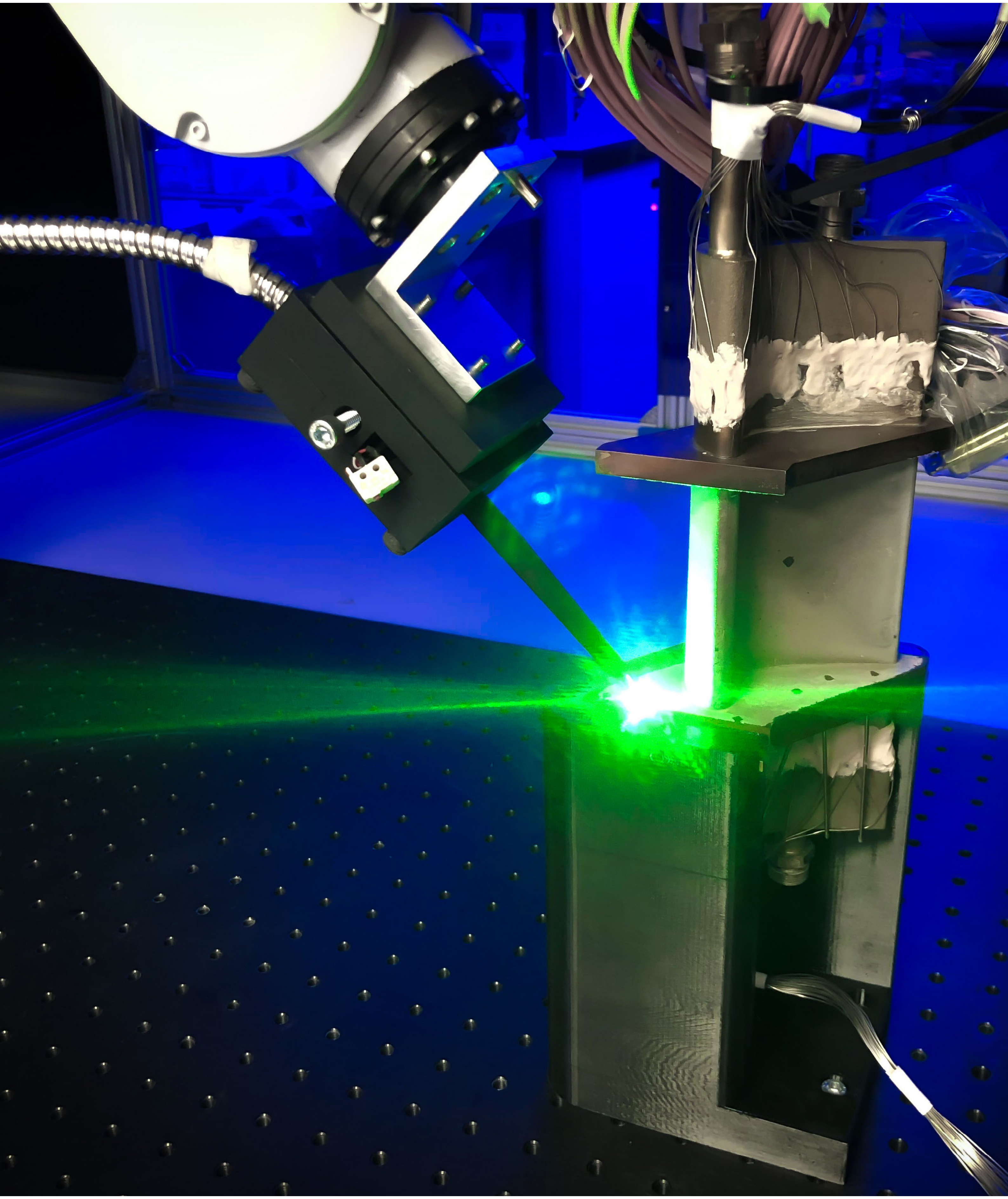
The complete E-Mobility Measurement system from Vector and CSM

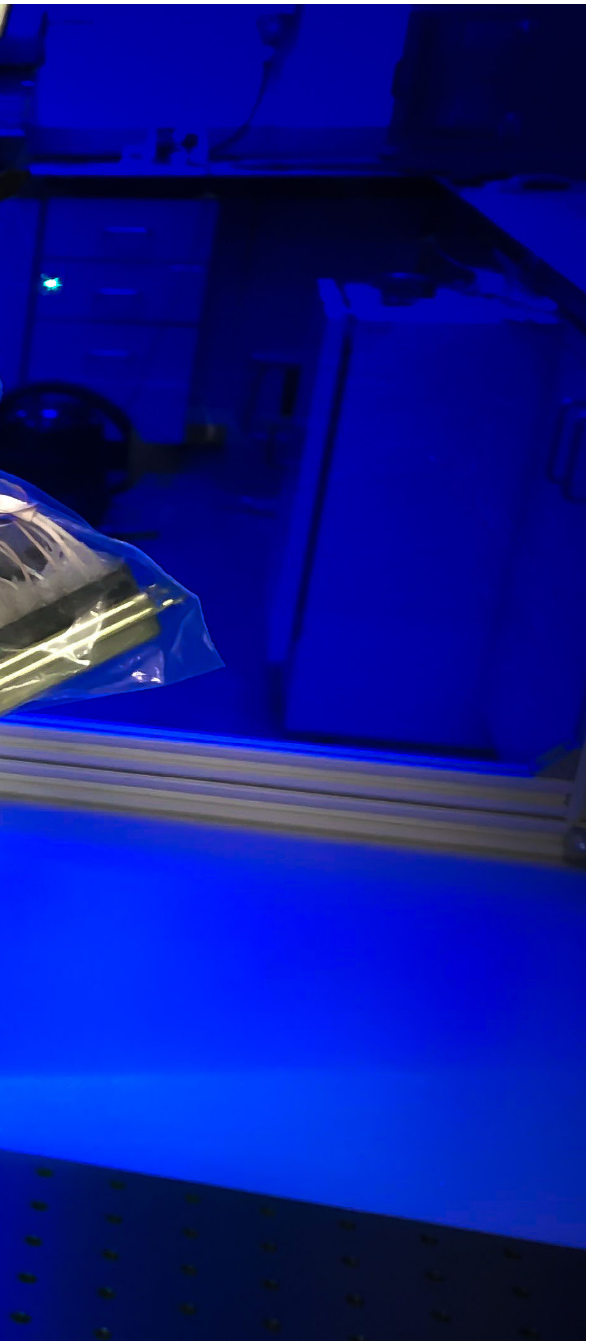
Vector CSM E-Mobility Measurement System

The E-Mobility Basic Measurement System is the heart of the complete measurement system, but not the whole system. As shown in Figure 5, other ECU interfaces, data logging, and data management components complete the entire system.

The additional data from ECUs can be acquired synchronously and recorded on data loggers for online or later analysis. This provides a finely scalable E-Mobility Measurement System that can be used in all development stages of vehicles in the test bench and in road tests. An important advantage lies not only in the immediate application of relatively simple measurements, the also in the possible expansion for complex measurement and validation tasks. This scalability offers security in adding any future innovations and protects the investment in such a system. Since Vector software tools are often used in development areas for ECU software, vehicle calibration or testing, another positive aspect is that little training time is required on the part of users. The E-Mobility Measurement System is continuously being expanded by Vector and CSM with further new application functions in cooperation with customers. Vector and CSM offer additional consulting services if required.

Johann Mathä / Manager E-Mobility

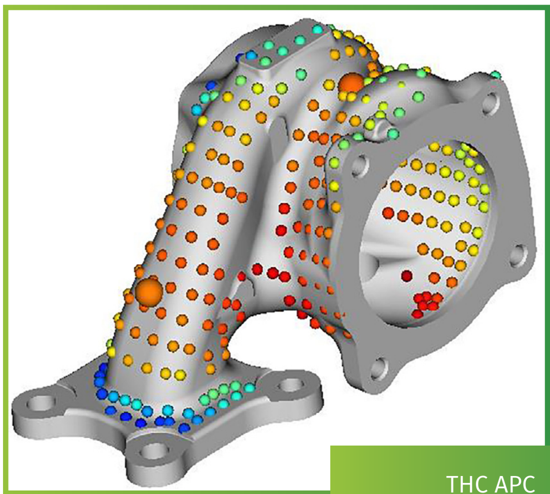




Shining a light on the thermal measurement needs for future EVs

Jörg Feist, Silvia Araguas Rodriguez, Jim Hickey, and Ahmed Zaid explain the need for accurate temperature measurements for future transportation solutions

Sophisticated temperature detection is needed in traditional combustion engines, but how can the latest thermal mapping technology drive development in cleaner automotive propulsion systems?



THC APC

High temperatures are common in combustion engines. Some automotive pistons and turbochargers operate between 400 °C – 700 °C, with some high-performance turbochargers reaching beyond 800 °C. To drive higher thermodynamic efficiencies, operating temperatures in gas turbines now approach 1600 °C. Amongst other challenges, such high temperatures can shorten component lifetime, requiring accurate and precise temperature characterisation.

Many temperature measurement technologies have been developed over time, including pyrometry, infrared cameras and thermocouples. The latest in an engineer's temperature measurement toolbox are Thermal History Coatings (THC) and Thermal History Paints (THPs).

THCs and THPs have been developed for automotive and gas turbine applications, covering temperatures between 150 °C and 1600 °C. The coating or paint can 'remember' their highest exposure temperatures. When applied to a component, these memorised temperatures can be read from the THC/THP post-operation using a bespoke laser scanning system, providing high-resolution temperature maps. The data is plotted on a CAD file, mapping hot-spots or in-built cooling effectiveness as examples.

The phosphorescence temperature sensor

Temperature, as a manifestation of thermal energy, is not directly empirically measured. Instead, engineers measure analogous parameters to deduce temperature: for mercury thermometers, this is the liquid volume; for thermocouples, the voltage between two wires. For THPs and THCs, the analogous parameter is phosphorescence, the phenomenon behind glow-in-the-dark stickers, road markings, and watch handles.

THPs are comprised of a ceramic pigment doped with a rare-earth ion. The pigment is mixed with a water-based binder. Through careful design, these materials undergo a gradual structural change when exposed to increasing temperatures. Known as the amorphous-to-crystalline transition, the THP molecules continuously rearrange towards a crystalline structure. This change is non-reversible: the partially arranged structure is memorised even when cooled. The degree of crystallinity (and hence temperature history) is monitored by measuring the changes in the phosphorescence of the rare-earth dopant ions.

To measure component temperatures practically, the THPs are deposited as a thin 30 μm functional coating on the component. During component testing (e.g., an engine or rig test), the THP locally changes with exposure temperatures. These changes are measured afterwards using SCS's bespoke optical instrumentation. A laser-pulse is delivered to a pre-determined THP location, triggering paint phosphorescence. Post-pulse, the phosphorescence signal intensity decays with time. Known as an afterglow, as seen in Fig.1 (left), the signal decays as a single exponential, with the magnitude of the decay time (τ, or lifetime decay) increasing proportionally to the degree of crystallinity, and therefore temperature. Through calibration of lifetime decay measured at known temperatures, the lifetime decay measured on the components is related to the past maximum exposure temperature (Fig. 1 (right)).

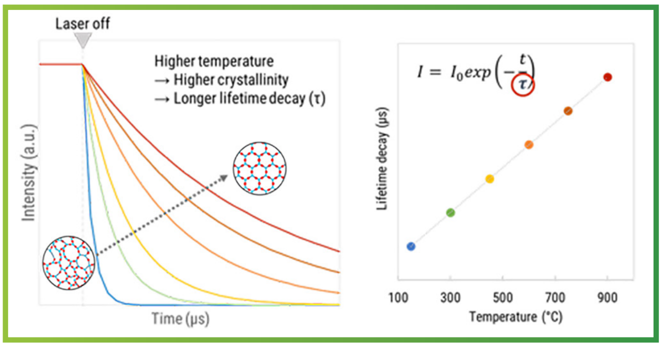


Figure 1: (left) The phosphorescence lifetime decay plots plotted against time for several exposure temperatures. Plots of lifetime decay with known temperature are used to calibrate unknown component temperatures (right).

Temperature detection needs for EV Hot Fuel-cells

Efficient, fuel-flexible and now with specific energy densities that compete with internal combustion engines, fuel-cells are promising power sources for auto-applications.

Proton Exchange Membrane Fuel-Cells (PEMFCs) and Solid Oxide Fuel-Cells (SOFCs) are the two main fuel-cell technologies used or in development for auto-applications. Momentum in fuel-cells is gathering with Hyundai, Toyota and Honda already offering passenger hydrogen-fuelled PEMFC vehicles. Hyundai, BMW, and Volvo Trucks are also renewing R&D into fuel-cells for passenger and haulage vehicles.

SOFCs will make their way into auto-applications, but challenges to their widespread adoption as a low-carbon power source remain. Carefully characterising fuel-cell operating temperatures is key to their deployment.

Today's SOFCs require impractical operating temperatures (up to 1,000 °C) for practical power outputs. Fundamentally, these temperatures are required to maintain a steady-stream of oxygen-ions across the solid electrolyte, limiting an engineer's materials palette and creating a thermal-stress headache. Slow oxygen-ion transport also means slow fuel-cell start-up times, further limiting their practical application. State-of-the-art SOFCs can operate at around 600 °C, but 350 °C is a target for auto-applications according to the UK's APC, perhaps achievable using nano-structured electrolytes to boost oxygen-ion transport.

SCS's technology has been implemented on fuel-cells, successfully mapping temperature history profiles of SOFCs operating at ~600 °C in cell areas inaccessible to other techniques like thermocouples or pyrometers. Through its application on ceramic thermal barrier coatings used on turbine components, SCS's technology has also been proven to be fully compatible with the fuel-cell materials, especially SOFCs.

Key to the good operation of a fuel-cell in a vehicle is to carefully manage its operating temperature, requiring well-engineered onboard thermal management in the form of advanced heat-exchangers, condensers, and distributed heat-sources as examples. SCS is well positioned to characterise these types of systems, with experience in applying its technology to compressor turbine wheels and heat exchangers.

Electric motors

Contrary to combustion engines, the efficiency of electric motors falls with temperature. Good motor thermal management is therefore essential since overheating not only reduces efficiency but also motor-component lifetime.

Helping to drive the auto-sector's transition to carbon-free propulsion systems, motor developers are reducing motor size, weight, and cost as well as improving torque/power control and efficiency. Trade-offs exist between these parameters however and good thermal management is a key bottleneck: pushing more current through motor windings will boost torque, but the increase in Joule heating will need to be accounted for.

Motor thermal management is complex; even reliably measuring temperatures in the inaccessible interior of an operating motor is challenging. Conventional temperature measurement tools used to this end have downsides. Pyrometers for example require optical access, therefore potentially missing hotspots. Thermocouples are sensitive to a motor's magnetic field. Thermal modelling is a credible approach, but model qualification and accuracy depend on the supplied conditions of a real experiment, such as thermal coefficients and loss distribution.

THPs and THCs are promising technologies that offer an elegant path around these limitations. THP technology has been demonstrated for temperatures between 150 °C – 900 °C, well above the highest temperatures typical in electric motors (<300 °C). Offline temperature measurement (i.e., post-operation) means component visibility is not necessary during operation, thereby allowing for different thermal management designs to be tested and their effectiveness assessed. In short, thermal surface maps with a spatial resolution of 1 mm in inaccessible interiors of a motor are possible and interference from a motor's magnetic field does not need to be accounted for.

An alternative to clean EVs: Hydrogen Internal Combustion Engines

Over 50% of the UK electricity demand is still supplied with fossil-fuels. Hence EVs will not be completely carbon neutral when getting their power through the national grid. Coupled with a projected uptick in green hydrogen production, there is therefore renewed interest in re-engineering internal combustion engines (ICEs) to combust hydrogen. ICEs still enjoy significant cost and supply-chain maturity advantages over fuel-cells. ICEs also still edge fuel-cells when it comes to power-density, meaning they could be particularly useful for vehicles requiring high-power-bursts, such as those used in mining or heavy lifting.

Technical challenges to hydrogen-fuelled ICEs remain, however. Whilst CO2 free, high-temperature, stoichiometric combustion of hydrogen with air produces NOx. Leaner fuel dramatically reduces NOx emissions and makes a hydrogen ICE run more efficiently, but this erodes ICE's power advantage over fuel-cells, meaning power-boosting technologies like turbochargers would be required. Leaner fuelling also generally increases the operating temperature of the engine. This coupled with the presence of engine hotspots and hydrogen's low autoignition temperature can lead to unplanned ignition, which can ultimately destroy an engine. Carefully characterising hydrogen ICE temperatures to identify and mitigate against hot spots would therefore aid their commercial deployment. To this end, SCS's technology has been used to measure temperatures in hard-to-access regions of ICEs, like pistons and valves. Applications in hydrogen engines would be a logical next step.

Perhaps the greatest challenge to the adoption of hydrogen ICEs however is that they are about half as efficient as fuel-cells. A significant barrier to the adoption of hydrogen in the auto-sector is its onboard storage, this means twice the volume of hydrogen would need to be carried, or half the distance could only be travelled, if a fuel-cell were swapped for a hydrogen ICE. Significant progress in hydrogen internal combustion engine efficiency is therefore required if they are to remain competitive to fuel-cells and other electrified propulsion technologies in the long-term.

Outlook

Future automotive propulsion systems will be net-zero. However, this will not be possible with electric cars alone, likely requiring complementary propulsion technologies like thermal engines. A quick change to electric propulsion or hydrogen-powered cars requires a bedrock of enabling technologies to be developed and deployed. The need to analyse and validate thermally loaded parts in this sector will not disappear, and will require existing technologies to adopt. In the future THP and THC could be 'hot' candidates to support validation and durability testing to accelerate the development of cleaner cars.

Jörg Feist, Silvia Araguas Rodriguez, Jim Hickey, and Ahmed Zaid are all from Sensor Coating Systems in the UK

Resources – fuel-cells:

https://www.apcuk.co.uk/news/behind-the-scenes-the-2020-automotive-fuel-cell-roadmap/

https://www.apcuk.co.uk/app/uploads/2020/11/Technology-Roadmap-Fuel-Cell.pdf

https://link.springer.com/article/10.1007/s41825-020-00029-8

https://www.sciencedirect.com/science/article/pii/S2451910319300651

Testing materials for lithium-ion batteries

Matthias Hahn

A battery is a can with two terminals named plus and minus, or 1 and 2. Testing this battery means that you apply either a voltage (V12) profile or a current (i12) profile across the two terminals, and measure the corresponding current or voltage response. The profile can have many different shapes such as square, triangle, sine, or some arbitrary profile. This concept applies to small and large battery cells as well as to arrays of such battery cells connected in series and/or in parallel (battery modules or packs). One could therefore think that a single battery tester is good for all those configurations. This is not true. Battery testers for R+D on battery materials must fulfill very special requirements as we will discuss in the following.

Our focus here is on R+D battery testers that are specialized on battery experiments carried out to understand and improve the chemical ingredients of the battery: anode, cathode and electrolyte. For simplicity, we only consider today's most prominent battery chemistry comprised of a lithium metal oxide as the cathode material (such as NCM) and graphite as the anode material. Both are layered materials, which can accommodate lithium ions between their layers. In the battery, the two electrodes are sandwiched with a separator in between them. The porous electrodes and separator are soaked with an electrolyte solution containing lithium cations and PF6 anions in a mixture of organic solvents. Initially, the NCM lattice is filled up with lithium ions, while the graphite lattice is empty. This is the energetically favored (lowest overall energy) configuration. The lithium ions feel good in the NCM and see no reason to leave to the opposite graphite electrode. Electrically speaking, the voltage of the battery is zero. Charging the battery means to force lithium ions from 1 (NCM) to 2 (graphite) through the electrolyte layer, and at the same time move the same number of electrons through the outside part of the circuit, again from 1 to 2. We say "charging", but this verb is misleading. In fact, we don't end up with any excess charge on the electrodes, but instead just convert electric into chemical energy. Charge separation is only at an atomic scale inside the electrode materials. The device we use to charge or discharge (to cycle) the battery is the battery tester.

By applying a current between the two electrodes, we move electrons from the NCM to the graphite backbone along the outside part of the circuit and, at the same time along the inner part of the circuit, extract the same number of lithium ions from the NCM lattice and move them through the separator into the graphite lattice. In the fully charged state, at 4.2 V cell voltage, all "easily" available Li-ions from the NCM lattice have been brought over to the graphite lattice. And during discharge, those Li-ions will then migrate back into the NCM lattice.

Equivalent circuits are often used to model what goes on in a battery and are helpful for a basic understanding. The simplest circuit (Fig. 1a) is just a resistance-less voltage source V12 in series with a resistance (or more precisely impedance) Z12. Both V12 and Z12 depend on the SOC of the battery cell, and can be determined empirically.

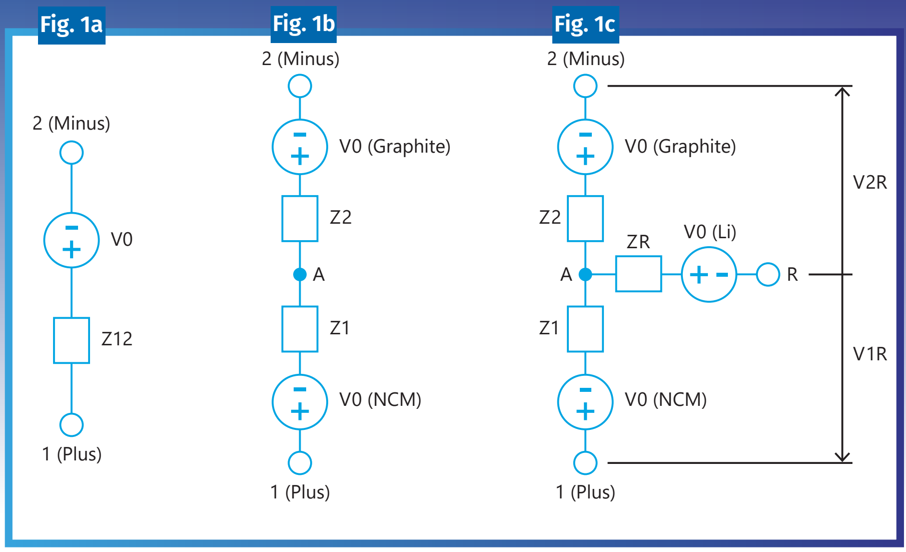
A better model takes into account that the battery cell is actually made up of two electrodes in series (Fig. 1b). Now each electrode ("half-cell") is represented by its respective voltage source and impedance. This model accounts for the capacitance matching of the two electrodes: At best, the graphite electrode can accommodate all the Li-ions released from the NCM during charge, no more, no less. Also, this model accounts for the fact that the electrodes can have quite different kinetics, i.e., impedance, for the uptake and release of Li-ions, again dependent on their SOC.

How can we find out about the individual characteristics of the two half cells? This is actually the question that lets us understand the special requirements of the R+D battery tester.

Fig. 1a: Equivalent circuit for a battery represented by an ideal voltage source V0 and impedance Z12. Both V0 and Z12 depend on the state of charge.

Fig. 1b: Two-electrode equivalent circuit showing the two electrodes NCM (1) and graphite (2). Both electrodes are described by their chemistry specific dependence of voltage and impedance on the respective SOC. We would like to know the voltages relative to point A, V1A and V2A.

Fig. 1c: Three-electrode equivalent circuit including the lithium metal reference electrode (R). Details see text.



The above two-electrode equivalent circuit (Fig. 1b) allows us to directly measure the two half-cell voltages by connecting a voltmeter between the respective battery terminal and the node A. However, node A is located inside the electrolyte and so we can't directly connect the LO test probe of our voltmeter to this point. Instead, we place here a third, so called reference electrode, for instance a lithium metal ring placed at the edge of the separator. With this 3-electrode set-up, the two half-cell voltages can now be easily measured, albeit with an unknown voltage offset V0(R) which is defined by the nature/chemistry of the given reference electrode. The half-cell voltages V1R and V2R can be easily measured; they are often named electrode potentials and must be referred to the chemistry used as the reference. In our example, the reference electrode is lithium metal and accordingly V1R and V2R are given in units of "V vs. Li/Li+". As long as R is only used as a measuring probe, with zero current across ZR, the voltage offset V0(R) is constant during the experiment.

What can we do better with a battery that has 3 rather than 2 electrodes? Well, we can now measure three rather than only one voltage. And we can control one out of these three voltages in potentiostatic test mode. In galvanostatic mode, we can direct the charge flow between electrode 1 and 2 (most common), or between R and 1, or between R and 2. We come back to these "strange" modes later on.

For now, lets focus on the results of a basic 3-electrode experiment the results of which are depicted in the graphs below (Fig. 2). The test cell used here comprises an NCM|graphite sandwich with a lithium metal ring located at the edge of the in-between separator. We charge the cell with a constant current i12 untill the cell voltage V12 reaches 4.2 V, hold the voltage for a while, then discharge back to the initial voltage of 2.5 V. With a 2-electrode battery tester, one would only see the black V12 voltage trace during the cycle. No way to observe what happens to the different electrodes. It is only thanks to the reference electrode, that we can distinguish between the individual electrode potentials, red line for NCM, blue line for graphite.

Same for the impedance. The modulation of the DC current by a sinusoidal excitation leads to a modulation of the cell voltage V12 and so of the two electrode potentials V1R and V2R. The ratio between the amplitudes of voltage and current, the impedance Z, is a measure of how easy charge carriers can move at a given frequency. And again, only with the reference electrode, we can distinguish between cathode (Z1) and anode (Z2).

For the experiment shown in Fig. 2, impedance at 0.1Hz was measured intermittently every few minutes. With this special technique all important dc and ac parameters of the battery and the individual electrodes are obtained in one single experiment.

What are the two "strange" galvanostatic modes of the R+D battery tester good for? Ideally, one electrode is the source, the other one is the sink for lithium ions, and there is no other interaction between them. In reality, the electrodes interact with each other. For example, manganese ions can be leached out from the NCM lattice in a side reaction and poison the graphite electrode. To understand how the graphite electrode would age during cycling without this side reaction, one can build a symmetric graphite (1) |graphite (2) cell with a lithium metal ring electrode (R). Then apply a current i1R to lithiate graphite (1) from the lithium ring (R). And finally run a conventional cycle test with i12 control to shuttle the lithium ions back and forth between the two graphite electrodes. To name just one of many new possibilities with a 3-electrode cell.

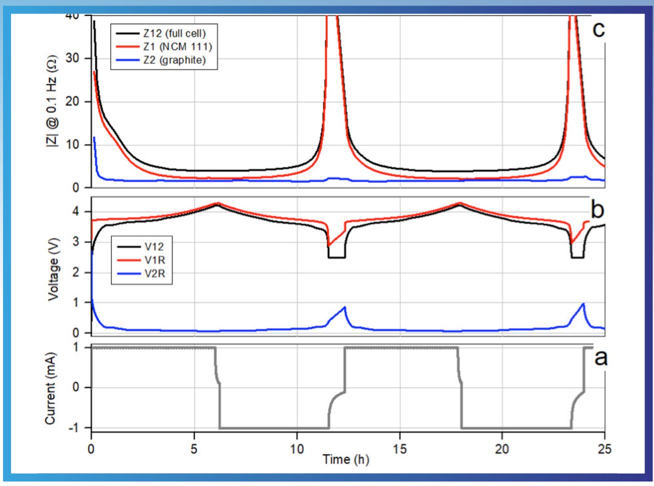
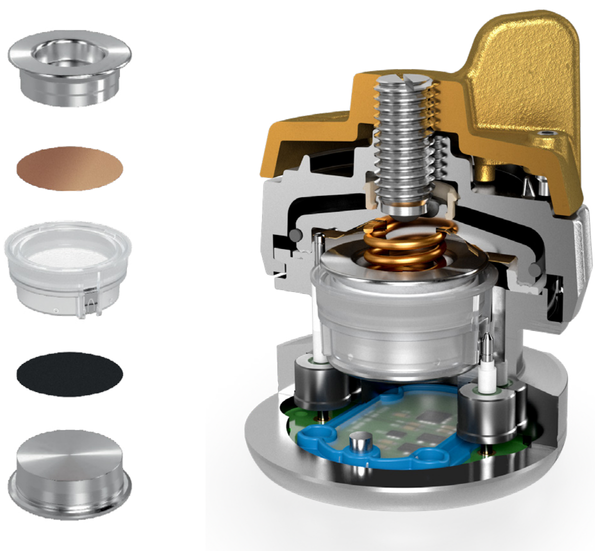


Fig. 2: Test results obtained with a PAT-Tester-i-16 and a 3-electrode PAT-Cell. For details see text.

From the above test cases, we can compile the specific requirements for an R+D battery tester as follows.

- The battery tester needs to support 3-electrode cells. That is, the tester needs at least 3 leads. These leads are typically labeled working, counter and reference electrode (WE, CE and RE) rather than plus and minus. And often two additional leads are provided named WE-Sense and CE Sense.
- The tester must be capable to record both half-cell voltages simultaneously. It is not enough to record just the voltage under control.
- 3-electrode test cells are small and tests are only on single cells. Thus, the requirements on the maximum current and voltage are modest, say 100 mA and 5V. Importantly, the voltage range must be bipolar, at least +/-5V, in order to support the different reference electrodes. Many battery testers only have a unipolar voltage range.
- High accuracy and resolution for both current and voltage are needed for precise determination of Coulomb (cycle) efficiency. Latest technology works with 24-bit ADCs and 18-bit DACs and on-going calibration against built-in standards. Here the limits are defined by the test cell and not by the electronics.
- To switch between the different potentiostatic and galvanostatic control modes, the user normally has to change the wiring between the tester channel and the test cell. Much more comfortable is a software-controlled switchover.
- Indispensable test techniques are constant current (CC), constant voltage (CC) and impedance (both PEIS and GEIS) up to at least 10 kHz.
- Battery tests are time consuming and so high-throughput requires multi-channel test devices. The more channels, the better.
- Compact cableless test solutions with integrated temperature control are available and save valuable laboratory resources compared to discrete solutions with separate temperature chamber and cable harness.
- Battery tests generate large amounts of data. A modern software solution with a powerful database and LAN connectivity as well as open interfaces for seamless integration with third-party software is a must.
- Finally, for the moment at least test data can't be better than the 3-electrode test cell used. Different commercial and custom cell designs are available and need careful consideration.



About the author

Matthias Hahn is co-founder and head of R+D of EL-Cell GmbH.

After finishing his PhD in 1998, he gained extensive research experience as an electrochemist over 15 years working for Honeywell, Daimler and the Paul-Scherrer-Institute. Among other things, he has worked on supercapacitors for automotive applications and electrolytes for Li-ion batteries. Matthias is author and co-author of 15 peer-reviewed publications.

A Circular Economy:
Mono-material and modular design concepts

Jochen Hardt

The responsible use of resources is at the heart of a Sustainable & Circular Economy, making the CO2 footprint as small as possible. Polycarbonates, application design and optimization utilizing engineering thermoplastics can also make a significant contribution to a Circular Economy (CE). One impactful example is the visionary use of polycarbonate in automotive forward lighting. The Application Development team at PCS has recently developed a "Mono-material" Headlamp design which propagates "Less is more"-principle and incorporates a Circular Economy focus.

In their mindset, our Application Development engineers consider a technical development as accomplished not when major performance requirements are fulfilled in an efficient and resource-saving way, but only when a clear and feasible concept for recycling is proposed. Polycarbonate, due to its high and unique property profiles offers possibilities for a "designed for sustainability" & circular economy concept, because it allows for integration of variety of functionalities, consolidation of manufacturing steps, high level of performance and longevity – all underlining the "less is more"-principle. Mono-material and modular design concepts will at the same time facilitate recycling that can be applied in Mobility, Electro & Electronics, HealthCare.

To create a highly sustainable application, an approach incorporating compatible materials and an innovative toolbox needs to be developed as a first step. Our Applications Development engineers used traditional headlamp technology as a basis for creating an innovative CE "all" PC design. Initial teardowns focused on determining the functionality, performance requirements and potential substitution of various metal and non-PC components in a traditional headlamp assembly. This exercise resulted in a starting point for determining what could truly be replaced by special Makrolon® and Bayblend® grades (including thermal conductive TC grades) in the application. After vigorous concept development, technical design, and detailed computer aided analysis (structural, rheological, thermal), a feasible "mono-material" design was generated (cf. figure 1).

DESIGN FOR SUSTAINABILITY – HEADLAMP ASSEMBLY

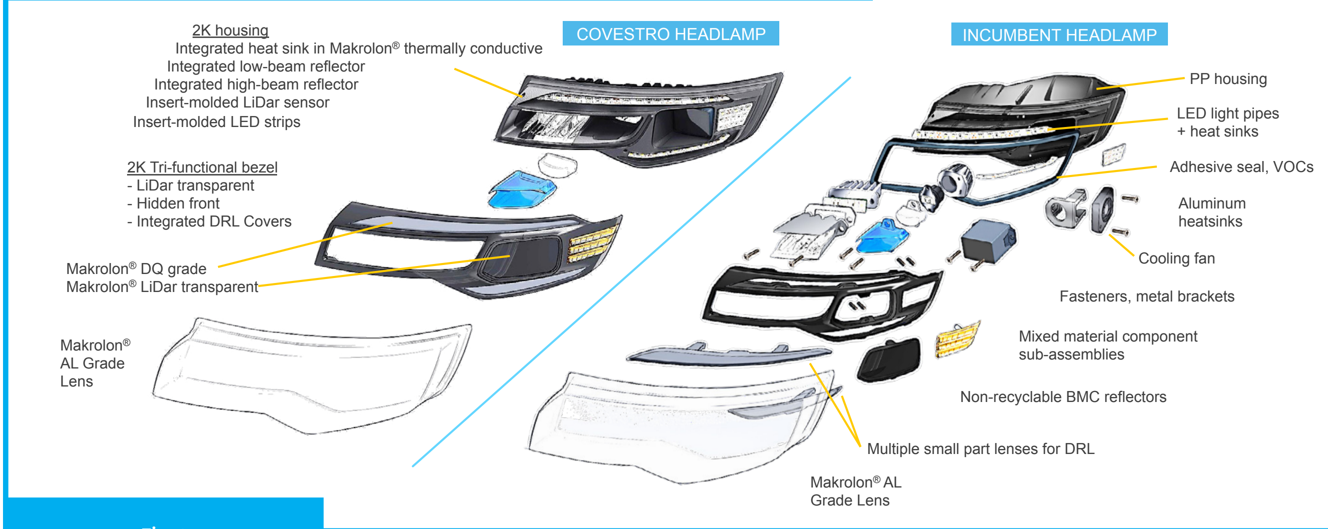


Fig 1

Thanks to the unique properties of Makrolon® and Bayblend® - and the use of advanced injection molding techniques such as two-shot injection molding, electronics insert molding and laser welding, the complex traditional design (having over 40 components) can be reduced to three or four unique integrated PC-based parts. Computer-aided engineering tools helped our engineers optimize these PC-based components to fall in line with automotive performance requirements. The highly integrated rear housing, multi-functional bezel, and transparent outer lens cover forms over 95% of the total assembly (with easily dis-assembled electronics, hard coating and metallization being the only non-PC elements). Some key integration features include:

- Fully consolidated heat sink as part of the housing utilizing Makrolon-TC
- Low/high beam reflector of Makrolon DS into the housing
- LED modules plus LED light strips in-mold assembled into the housing
- LiDAR IR transparent Makrolon-ST for the bezel hiding the LiDAR sensor from view
- Diffusion grade Makrolon LED providing DRL covers for the bezel
- 2K integrated Bayblend weld bead in the housing enabling laser welded attachment of the outer lens cover

Figure 2 illustrates the significant weight reduction of the assembly (over 40%), by taking full advantage of the durability, strength, and transparency properties of Makrolon®.

WEIGHT REDUCTION

Fig 2

This extensive use of PC-based materials allows for greatly simplified dis-assembly and easier recyclability. The resulting Circular Economy benefits are:

- Fewer parts requiring less material, tooling, and processing ("less-is-more")
- Reduced part weight aiding reduced vehicle energy consumption
- Significantly reduced material types used, allowing reduced separation complexity and simpler recycling streams
- Laser welding enabling elimination of assembly steps and adhesives resulting in reduced manufacturing operations and energy in manufacturing

The magnitude of these advantages can be clearly seen in a simplified life cycle breakdown considering component manufacture, assembly, and direct recycling. The simplified "balance sheet" (Figure 3) highlights the opportunity available from an innovative sustainable approach using a limited number of high performance (compatible) resins. One of the keys to the "Mono-material Headlamp" design is how easily the primary components can be separated and either segregated into either an "optical" bucket, or an "opaque/translucent" bucket, or a completely "blended" recyclate bucket. The resulting segregation can determine the types of components the resulting recycled materials can be utilized in their next life.

SIMPLIFIED LIFE CYCLE PERSPECTIVE

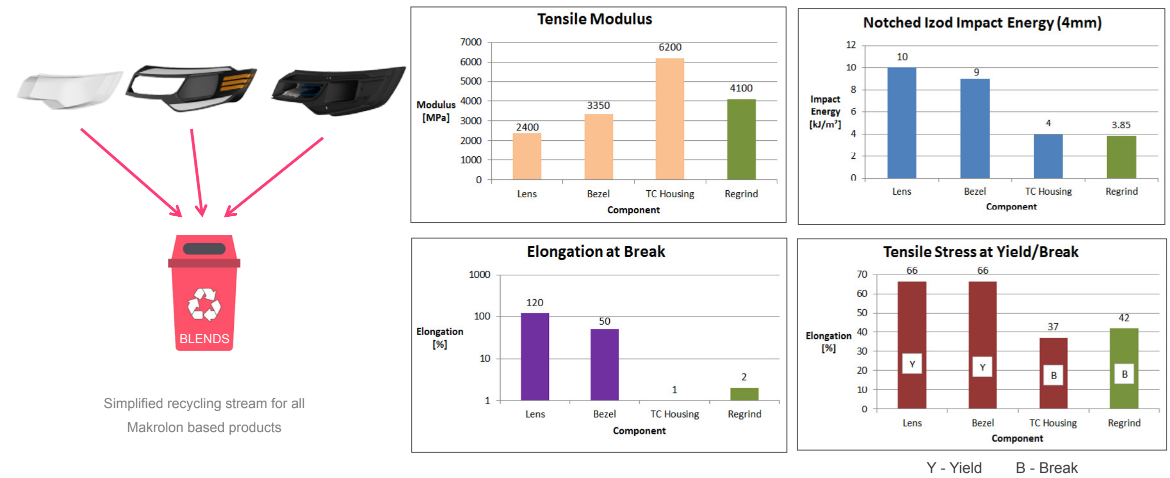
		COVESTRO HEADLIGHT	INCUMBENT HEADLIGHT
MANUFACTURING	Materials	4	7
	Unique Components	3	13
	Injection Molds	3	10
	Metal Stamping	0	1 +
	Casting Processes	0	1 +
ASSEMBLY	Adhesives	0	1
	Fasteners & Screws	Localized to sub-components	20 +
	Secondary Operations	2	4+
RECYCLING	Collection & Storage	Space saving	Bulky
	Part Separation Steps	5	15
	Adhesive Removal	0	1
	Material Sorting	Minimal	Intensive

Fig 3

The property retention of the "Mono-material Headlamp" after recycling is critical to enable a resulting high value/performance "grade" to put back into the next generation of headlamp assemblies, or into different applications. A significant advantage of our PC-based grades used in the headlamp assembly, is their high compatibility with one another, which results in properties which are sufficient for many next generation applications utilizing the new "blended" recyclate. Figure 4 provides an overview of obtainable properties.

MECHANICAL RECYCLING - PROPERTY RETENTION STUDY

Fig 4



In case of chemical recycling strategies after 10 to 15 years of service life, the mono-material headlamp design provides a module for efficient recovery of aromatic feedstocks for the production of phenol – the major building block for PC. Although efficient chemical recycling technologies based on polycarbonate streams still need to be developed to an industrial scale, Covestro already now steps into recycled phenol-based mass production of polycarbonate. The optical and mechanical quality of the final grades is identical to all Makrolon types based on classical petrochemical raw materials.

Solving the problem of generating a high-performance assembly with a sustainable after-life presents a significant challenge for the product engineer. Our patented "Mono-material Headlamp" design coupled with the highly engineered Makrolon® and Bayblend® grades provides our customers a clear path to a sustainable solution, while contributing to a truly Circular Economy.

In summary, the Covestro mono-material headlamp solution, delivers a multi-dimensional value proposition beyond recycling and sustainability to our customers with > $4 lower cost (each category per lamp), 1.8 kg weight saving, 69 fewer parts, 19 fewer steps in production and assembly and 3 cm reduction of critical packaging space.

Jochen Hardt, Global Marketing Mobility Polycarbonates, Covestro Deutschland AG

Public charging networks
– the metrics that really matter

Matteo de Renzi, CEO of bp pulse, explains why the debate over the suitability and progress of electric vehicle charging networks needs to be re-framed.

Data from Zap-Map shows that there are currently close to 40,000 charging 'connectors' in the UK, stationed at more than 14,000 different locations. Some commentators argue that we simply need to increase these numbers, and that this alone is the best measure of network quality. However, such a crude analysis doesn't account for what really matters when it comes to making EV ownership as easy and seamless as possible for all UK motorists.

Using network size as the only barometer for progress, or as the main basis for comparison between service providers, is an outmoded and overly simplistic approach. We need to re-frame the narrative and start looking at the metrics that really matter.

When considering the UK public charging network, we need to look at its suitability to the user. This means considering the location and geographical spread of charging points, as well as examining the power supply and operational support available across the network.

After all, having 100 under utilised 3kW slow chargers within a one-mile radius of one another in a borough of London might bolster a network's headline numbers, but what is the true value compared to two or three strategically positioned 150kW ultra-fast chargers that get used virtually all day, every day?

There are two important points. The first is the significance of location and geographical coverage. Our research tells us that the type of charger you need depends on the situation. If I need to quickly charge my car then an ultra-fast 150kW charger (UFC) on one of our retail sites is incredibly useful. But if I'm going to the cinema, I don't need to charge that fast the car will be charged before the adverts have finished. Here, a 7kW charge point could add 60 or so miles of range during the movie. Overnight charging on the street can be slower still. What we really need are *different speeds for different needs*.

If we want nationwide EV adoption, we must also ensure that certain areas of the UK are not left behind. According to Zap-Map data, there are more charge points in Greater London than in Scotland, Wales, Northern Ireland, the North East of England and Yorkshire and the Humber combined. At the moment, this correlates with levels of EV ownership in each region, but as we move towards 2030, levels of EV uptake will ramp up across the country. Therefore, we're investing nationwide and partnering with local authorities the length and breadth of the country.

A decade has passed since the first public chargers were installed, and technology has evolved. This means that a there is a significant amount of legacy infrastructure in the UK that is no longer fit for purpose – either because it no longer works, or it doesn't meet the needs of today's EV driver. Clearly, a poorly functioning charge point is no better than no charge point at all, which is why bp pulse is making £2 million available to help local authorities upgrade legacy infrastructure with vastly superior equipment.

Of course, when the first public charging units were installed, nobody knew how and when the EV market or charging technology would evolve. However, with a decade of experience on our side, we now know what motorists need from public EV infrastructure. Local authorities now face a challenge – to shift the approach to one where the size of your network is less important than what it can do. At bp pulse, we're collaborating closely with the public sector partners who understand that public EV charging infrastructure is much more than just a numbers game.

Noise reduction was yesterday – Sound creation makes its claim for the future

Electrical mobility changes the world of acoustical engineering. The development of a new vehicle generation is unveiling immense progress in technologies for test bench, and measurement systems.

Udo Wagner

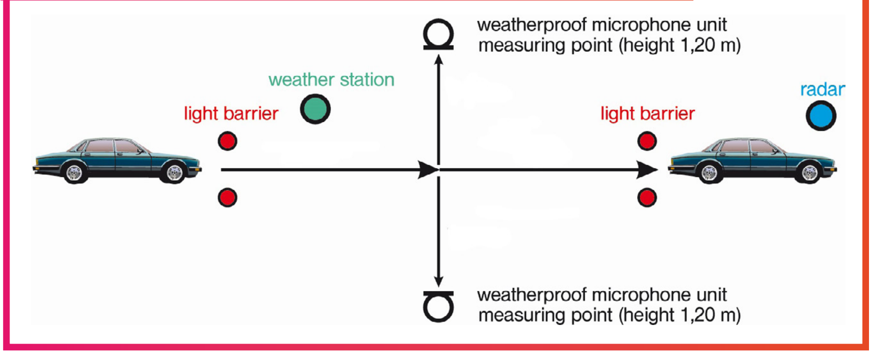
Acousticians should be excited. After many years of investigation, and preparation now we are living in the century of electrical mobility. Noise emission is low which was never possible in the time of combustion engines, both gas and diesel.

But low noise emission is dangerous, especially for pedestrians. Legislators in most countries demand a minimum noise in the speed-range up to 20km/h and in reverse mode (European directive no.540/2014). These systems are called AVAS (Acoustic Vehicle Alerting Systems) and are obligatory since 1st of July 2019 in electrical, hybrid-electrical and fuel cell cars.

Creativity of sound-engineers is not limited. Prof. Stefan Sentpali says “People have a given expectation, of how an object should sound. The sound must be high-grade, must not creak or grind ... people are familiar with vehicle sounds used in science fiction movies. They will quickly familiarise themselves with the sounds of electrical vehicles. Sounding up to two octaves higher, high frequency like a quiet pleasant whistle...” [1].

There are tools and equipment for sound-engineers, who develop the noise of the electrical vehicles. Pass-By measurement conform to DIN ISO 362-1:2017-10 is a standard method for all approved vehicles, but the same installed test benches are suitable for the creation of electrical vehicle sound (image #1).

image #1 – Test facility for pass by measurement



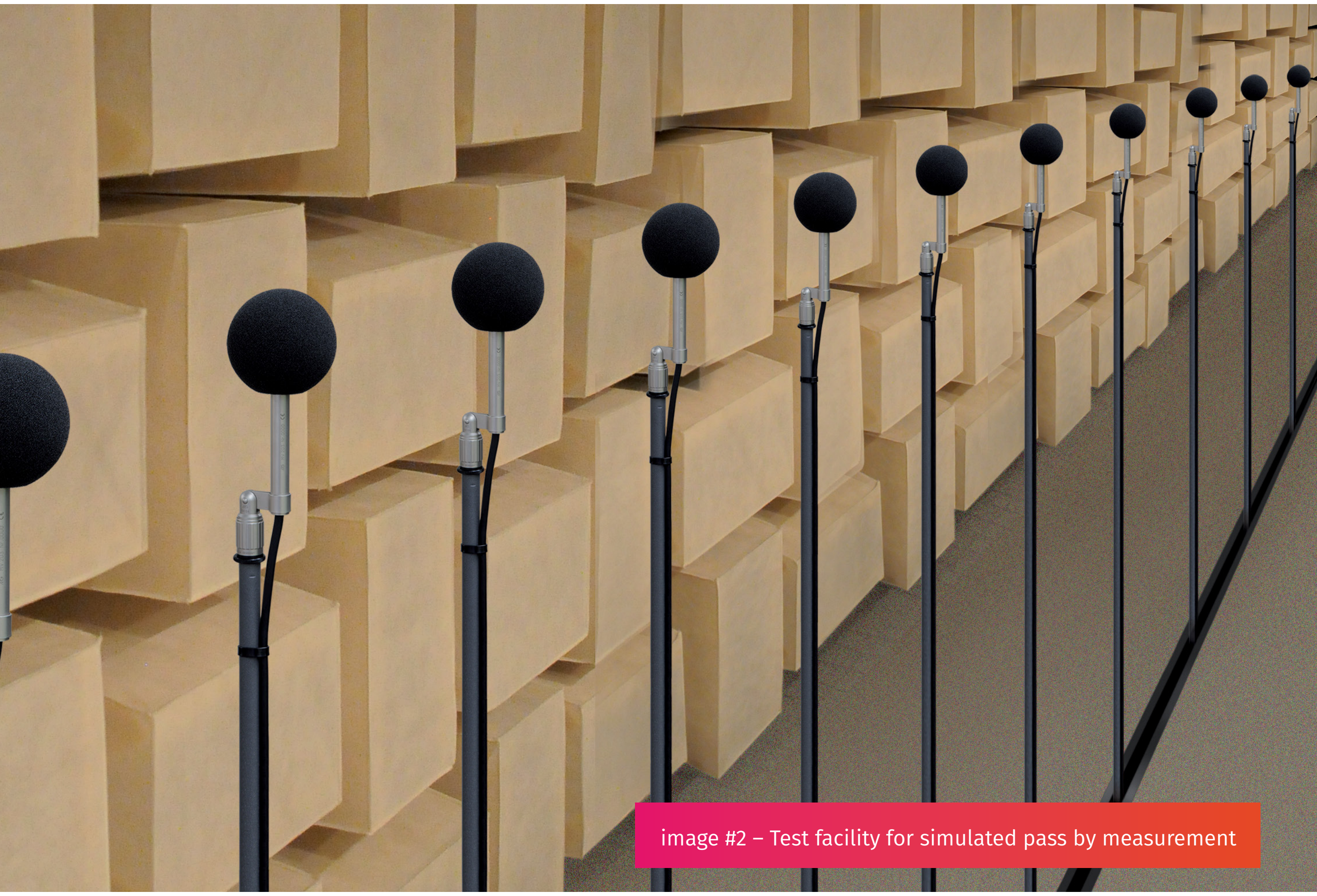


image #2 – Test facility for simulated pass by measurement

There are real pass-by test benches in weatherproof outdoor installations with two obligatory measurement microphones on one hand and on the other hand there are simulation pass-by test stands with up to 64 microphone channels in large indoor facilities with acoustic elements. (image #2).

It's difficult to imagine, but there are room-acoustic installations, which allow a measuring limit, covering a range from 40Hz to 20kHz and more. That requirement for the low frequency limit came from combustion engines, but it's usable also for developments in the electrical-mobility-sound-world.

Our human ears are sensitive in a frequency range between 16 Hz and 20 kHz, while the loudness sensation extends from 0dB, which is a sound pressure from 20µPa, to 130dB. The lowest limit is called hearing threshold, the upper limit is called pain threshold. Frequency- and loudness sensation in nature is anything but linear and that fact is important, when we want to create a sound, which is "Music to my ears" [2].

The opposite to our human ear, a measurement microphone is a sensor with a very linear frequency response. Only with filtering, for example conventional A-weighting, or psychoacoustic evaluation in software systems, do the analysed signals come anywhere close to our human sensation. Now through the use of the microphone the changing world becomes noticeable. While traditional combustions engines exhibit their spectral noise dues in the frequency range lower than 3kHz, electrical drive systems are audible in the 6kHz-, 8kHz- or 10kHz range. Up to 3kHz almost all high standard microphones, which are sound pressure receivers by their physical characteristics, have a very linear amplitude response. Within the upper 3kHz it's especially important to choose the right type of frequency-response-type for a microphone – free-field or random field type. Also, the influence of the foam-windshields, which should lower the acoustical disturbances of wind turbulences around the microphone body, are important. With windshields, which don't conform to microphone manufacturer specification, the microphones fall out of the sound-level-meter or microphone tolerance-field at the lower limit.

The microphone as a sound pressure receiver without a directional sensitivity for sound waves should have an exact omnidirectional characteristic. This is not completely true in the acoustical frequency range in the upper 5kHz, because the wavelength has the same dimension as the microphone itself. This fact causes a difference in sound-level measurement results, for example in a pass-by measurement, if microphones of a special type, like free-field with an exact linear amplitude response on axis, are installed vertical or horizontal in respect of their own axis. In other words, the important question is, if the membrane looks to the heaven or to the moving vehicle. That fact is not described exactly in the pass by standard ISO 362… in its current version from 2017.

Measurement equipment manufacturers like Microtech Gefell utilise the same effect, by installing microphones for pass-by measurement in a vertical position with simultaneous use of random (diffuse) field microphones. This type of installation should usually ensure, that a microphone gets a linear frequency response in an echoing environment, because there is less reflection and pressure build up effects in that kind of sound-field. Such a microphone type exhibits an exact linear class 1 response in 90 degree off-axis during application in free-field conditions. So, it is an ideal instrument to do pass-by measurements, because one the one hand it is a vertical microphone optimally protected against rain, humidity, and wind and on the other hand, the acoustical pattern is exactly circular around its axis, which means, the position of the car while driving by is not causing a wrong measured noise level value because of the polar pattern effect and the angular position.

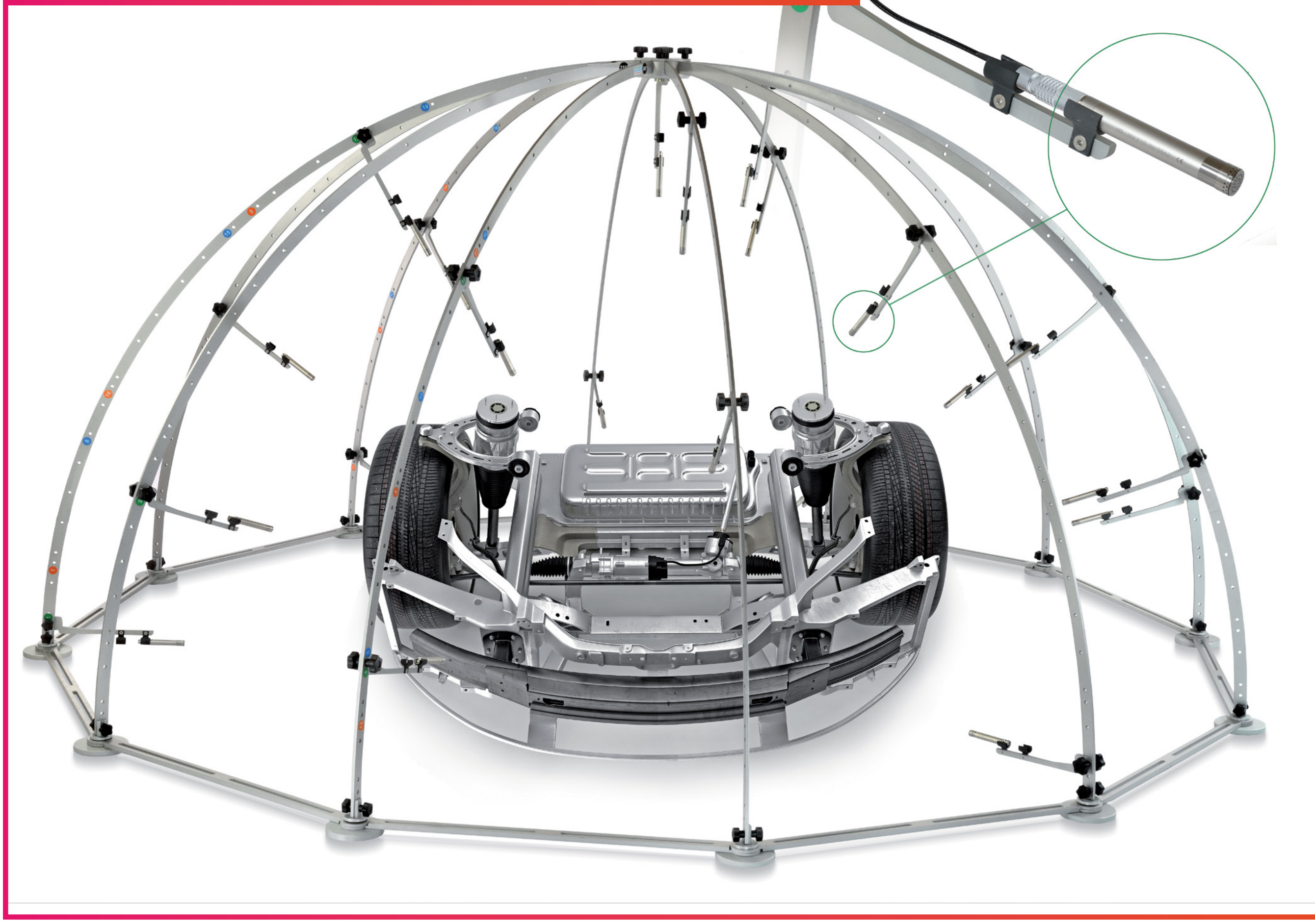
The newest product, which is developed by Microtech Gefell GmbH, is called WME 980 CN (community noise) includes exactly these acoustical and practical contexts and is a perfect tool for standard conform measurements as well as modern sound design (image #3). With its frequency response and polar pattern, it is approved for use with a sound-level-meter class 1 conforming to DIN IEC 61672.

To achieve a perfect acoustical result, more development tools in the background are needed. Sound-power is the metrological base of noise reduction investigation. But the same equipment can be used for sound creation of objects. The traditional way is measuring the noise radiation through an envelope surface. Therefore, the standards DIN EN ISO 3744 for non-directional wideband sources and DIN EN ISO 3745 are used and additionally the "universal case", which means, directional sound sources can be treated.

Microtech Gefell has developed a new product SLH (Schallleistungshemisphere) (image 4), which allows sound-power measurements using the standards 3744 and 3745. It is a hemispherical microphone arrangement with a 2m or 4m diameter, which can be installed with 6 or 12 bars and which allows the use of 10 or 20 pieces of high standard measurement microphones conforming to the standard DIN IEC 61094-4.

image #3 – WME 980 CN

image 4 – sound power measurement conforming to standards 3744 and 3745



The same microphone arrangement can be used in a perfect application to record the sound of components of electrical vehicles. We remember at the beginning of this explanation, that their sound is one or two octaves higher and according to physics, such soundwaves are much more directional. These and more facts are playing a significant role, indeed even BMW have enlisted the help of the famous sound-designer Renzo Vitale who worked with composer Hans Zimmer on sound design for the Vision M Next concept car…" [2], to develop their exclusive sound experience.

Another application for sound investigation of acoustical components through use of hemispherical microphone arrangements is the measurement of tire noise. While engine and gearbox noise have been important parts in the "combustion era", tire noise is more and more important with electrical cars and motorbikes. That part of noise emission was covered by the higher noise of the traditional elements. There are existing special tire noise test benches, where moving tires are installed on a separately driving roller dynamometer, surrounded by a microphone-hemisphere.

In addition to a hemispherical microphone arrangement there are sound-intensity probes, which are two-microphone arrangements with exact selected phase responses. These instruments are used for sound-power measurements and conform to standard DIN EN IEC 61043.

Likewise sound-intensity probes can be used for location of partial components of sound emission. It goes without saying, that Microtech Gefell's SIS 190 double, which covers the complete sound frequency range from 40Hz to 12kHz, is another professional tool for the sound designer.

Fact

All this bring us to the conclusion that the future sound development in the time of electric mobility comes closer to the composition of music. The high professional Microtech Gefell microphones are bringing together our experiences in technical acoustics and recording. What is visible is also audible in the wide range of its studio microphones: "We in Gefell are measuring, what you are hearing AND are hearing, what you are measuring".

Udo Wagner is a Director at MIcrotech Gefell

Sources

[1] Ostthüringer Zeitung, Freitag 25th of December 2020 issue (DPA), „Zwischen ´Star Trek´ und Stille: Sounddesign bei E-Autos".

[2] Automotive testing technology international, November 2020 issue, page 062ff, "Music to my ears".

30kW Liquid Cooling System High Speed & High Efficiency Technology

Why Liquid Cooling?

Jim Chen

Electric vehicles (EVs) are now gradually eroding the market share of traditional fuel vehicles, but are they fully accepted by the market and rapidly popularized? In addition to solving the problem of mileage anxiety, the real key is whether the charging time can be shortened to the equivalent of traditional gasoline vehicles.

Due to electric vehicles are hindered by the material problems of the battery and the charging gun capacity, the recharging time for a traditional gasoline-fueled vehicle is about 5 minutes, whereas that for EVs nowadays is 20 minutes or more. To speed up the charging time, the questions we faced are "What capacity does a charging system require?" and how much heat loss will be produced?

Based on different battery capacities of EVs, to travel 500 kilometers, the battery capacity required would be at least 100kW. Ideally, for the battery to be fully charged within 10 minutes, a 600kWh system would be required (certainly, we still face technical constraints such as batteries performance and EV chargers power capacities.) At present, the conversion efficiency of EV chargers is about 95%, which means there is 5% energy loss. A charging system of 600kWh would result in 30kW energy loss all the time. To solve the heat dissipation problem, the traditional method is used the fans to dissipate the heat. With such high amount of heat, a larger fan or an increase in the fan speed would be deployed to solve the heat dissipation issue, which consequently would lead to noise problems and reduced reliability. Therefore, the optimum heat dissipation solution for charging systems of 300kW or above should be liquid cooling technology which will maintain temperature stability, reduce noise, and improve product reliability.

The Proof of The Concept:

Phihong Technology's 30kW liquid cooling power module try to prove that the temperature of the electrical components will not exceed its standard limit. Figure 1 is exposure views of 30KW liquid cooling module. Figure 2 is water flow of cold plate. It is an explanation of the temperature simulation of this liquid cooling module right.

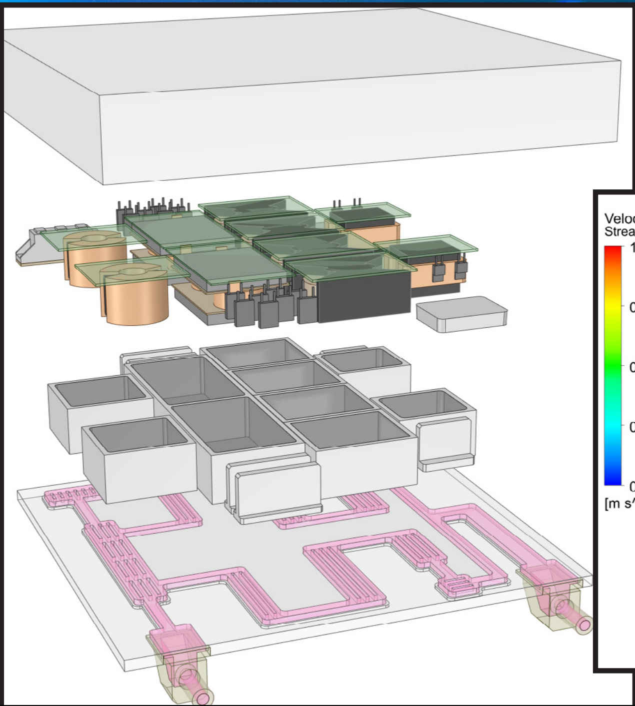


Fig.1: 30kW Liquid Cooling Module Design

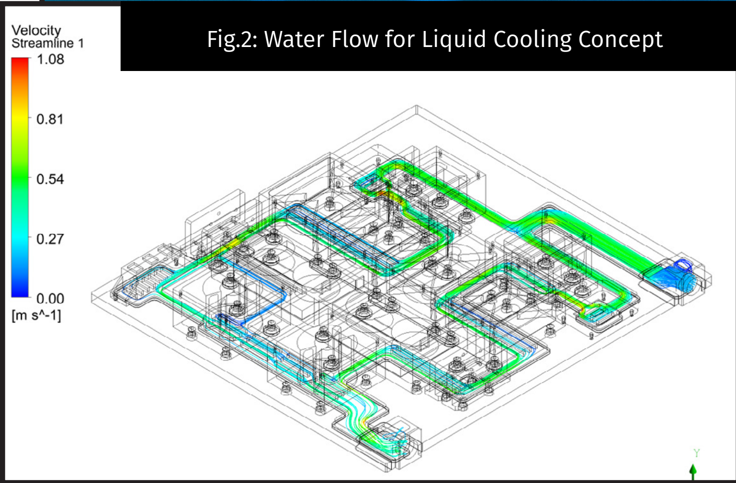


Fig.2: Water Flow for Liquid Cooling Concept

Set up Model of Thermal Simulation:

This heat dissipation module is designed with a combination of liquid antifreeze and an aluminum alloy thermal module.

- Inductive components are placed in the aluminum alloy area. We use high thermal conductivity potting as thermal fill.
- Setting at 60 degrees temperature for the inlet, the ambient temperature is also set to 60 degrees. Observe the overall cooling effect of various flow rates through the inlet.

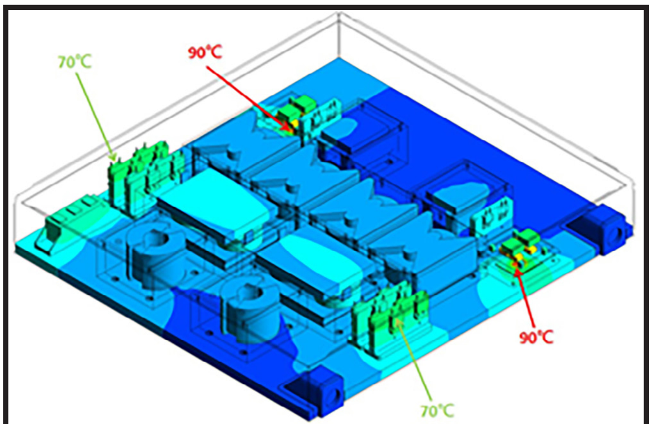


Fig.3: Thermal Profile

According to the simulation result as shown in Fig.3, to remain the temperature of the SiC MOSFET and Choke below the safety limit, the diameter of the water passage shall be 10mm and the inlet flow rate of cooling liquid needs to be kept higher than 2.0L/min.

Applications of The Liquid Cooling Charging System:

The 30kW DC power module can be Integrated with AC/DC liquid cooling PFC modules to build up a DC quick charging system. For example, Phihong Technology takes 12pcs of 30kW modules to assemble into a 360kW liquid-cooled charging system within which a water tank and a pump are used to form a cycle of water flow in the water passage. (Refer to Fig. 4 and Fig. 5.) Pumping cold water into the power modules, the water absorbing heat and then drains out. Meanwhile, the radiator cools the hot water and pump into the water tank for storage after then. In this way, the water circulation can also guide the hot water to a distance away, such as a rooftop or other places where the water can be cooled and avoid noise at the same time.

The 30kW DC liquid cooling power module can also be used for Energy Storage System after adding bi-direction functions, which can charge with battery system or discharge energy to the electrical grid. Subsequently, the bi-direction charging system can be charged for EVs or feedback the energy to grid tie.

Liquid Cooling Technology-The Critical Step to High Speed & High Efficiency Technology

- Liquid cooling technology is used widely in many applications such as charging system, data center, 5G infrastructure, gaming power or mineral digger. We could expect that liquid cooling technology will help charger increase its power rating significantly, which must be the real key to heat dissipation challenge we have suffered for a long time.
- Increasing the IP level and reliability: we can leave out fan for heat dissipation if we adopt the liquid cooling technology. It enables our cabinet design to meet IP66 requirement and extend product life of charging station at the same time.
- A big leap to improve the noise issue: in the past, the fans are noisy when they are dissipating the heat, especially in the night. With liquid cooling technology, the water circulation can also guide the hot water to a distance away, such as a rooftop or other places where the water can be cooled and avoid noise at the same time.
- Excepting the advantages mentioned above: The 30kW DC liquid cooling power module can also be used for energy storage system after adding bi-direction functions, which can charge with battery system or discharge energy to the electrical grid. Subsequently, the bi-direction charging system can be charged for EVs or feedback the energy to grid tie.

Jim Chen Electric vehicle BU R&D VP, Phihong Technology

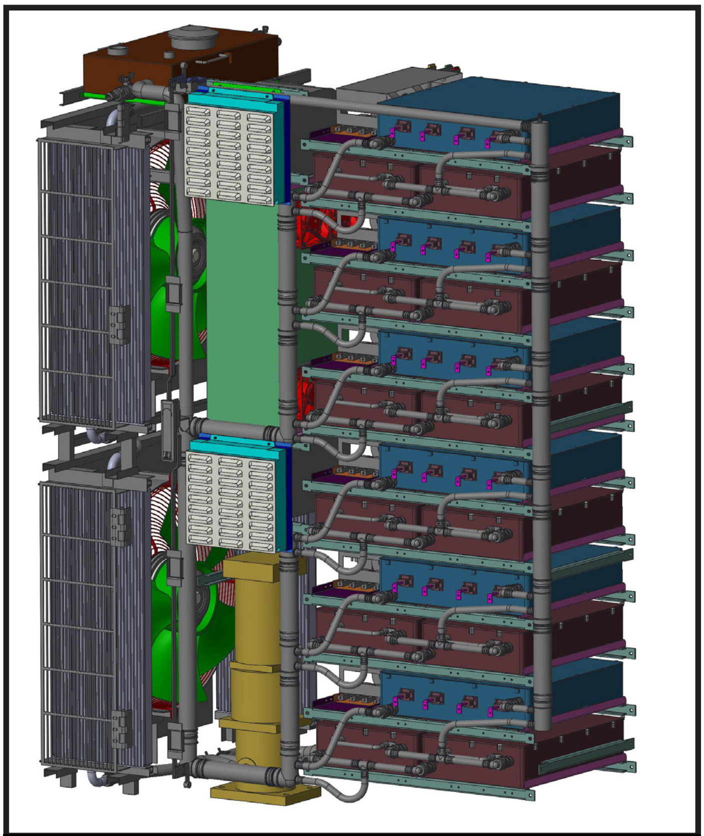


Fig.4: The Main Power Cabinet

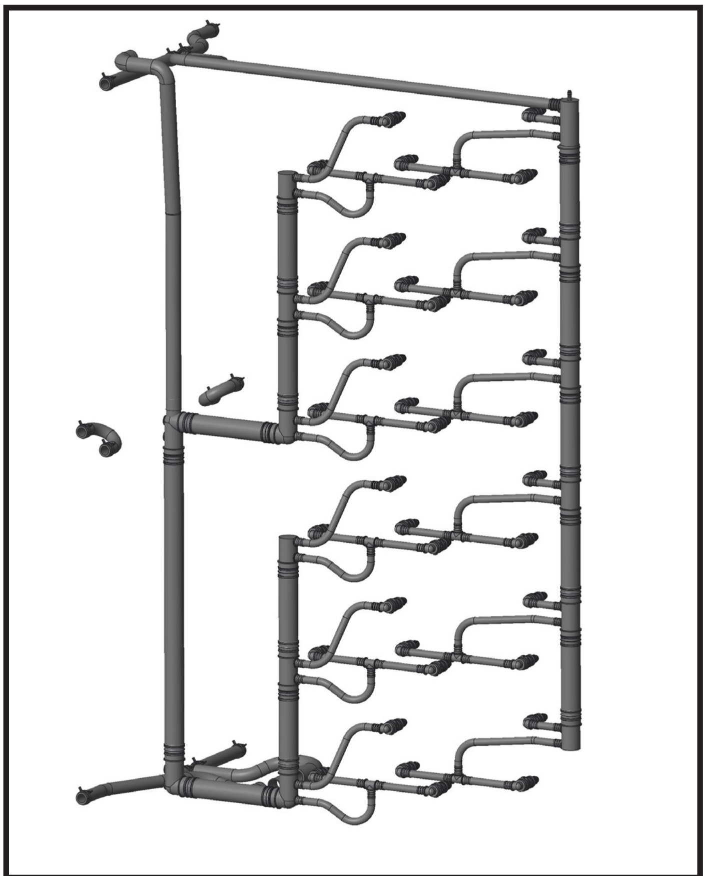
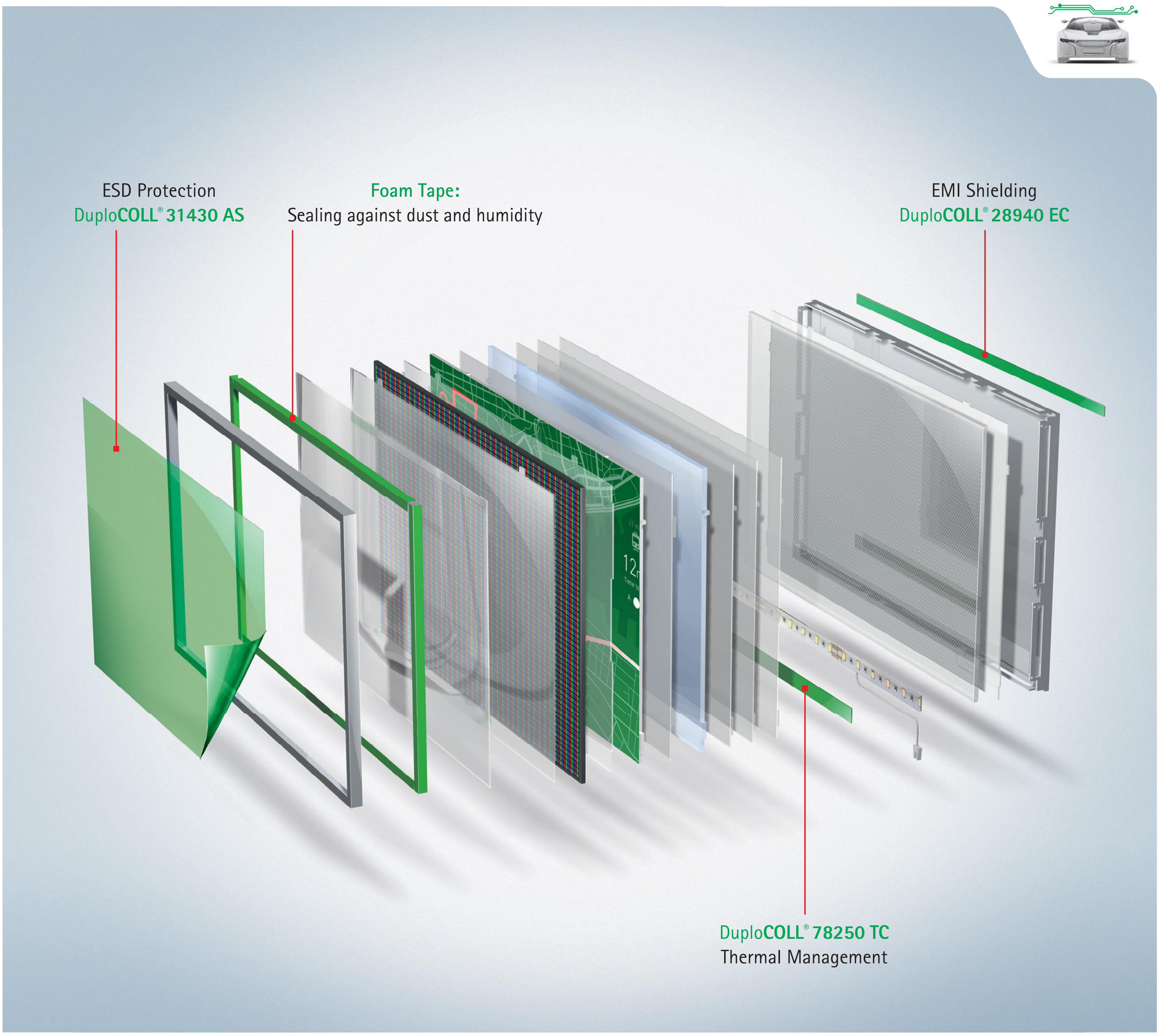


Fig.5: Water Flow in Cabinet



Motor for your success

Lohmann's bonding solutions – the all-rounders for the automotive industry.

The requirements for joints in the automotive industry are constantly increasing. Quality, design and comfort meet new materials, manufacturing technologies and more efficient processes. Thanks to their enormous flexibility, adhesive bonds adapt perfectly to a wide variation of designs and materials, thus ensuring reliable fixing. Because of that Lohmann's adhesive tapes do more than just bond – they fulfill a variety of functions for vehicles' exterior and interior. Focusing on the four main segments Automotive Electronics, Structural Bonding, Noise Vibration Harshness and Design & Function, our bonding solutions compensate tolerances, cushion, form air and water tight seals, are electrically or thermally conductive, removable, low-fogging or environmentally friendly. At Lohmann, you receive every product from a single source. We develop, manufacture and die-cut each and every tape. This is called: Smart Bonding Approach.

Get in touch with our experts and find the perfect solution for your bonding challenge!

transportation@lohmann-tapes.com
www.lohmann-tapes.com

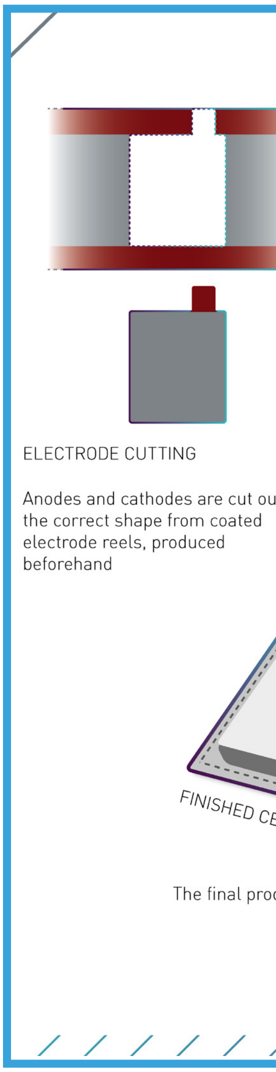
Lohmann
The Bonding Engineers

The Challenges for the battery of the future – from laboratory to industrial scale

Bringing the European battery of the future one step closer to reality.

Dr. Marcus Jahn

Scientists and engineers around the world are working currently on the cutting edge of challenges in energy storage systems. These have ever growing demands especially in the area of automotive applications in the xEV space: longevity, fast charging capability, high energy densities, i.e. long range, whilst maintaining a high level of passenger safety and increasing eco-friendly use of materials and production methods as well as recycling capability. In order to fulfil the need for an electrified transport future, the manufacturing of cells and modules has become a focus topic. Especially in the EU, where manufacturing is now on the political agenda, there is still a lot of potential for battery systems in the coming years and of course decades. Europe itself has a large innovation potential, but is still struggling to provide the European battery of the future.

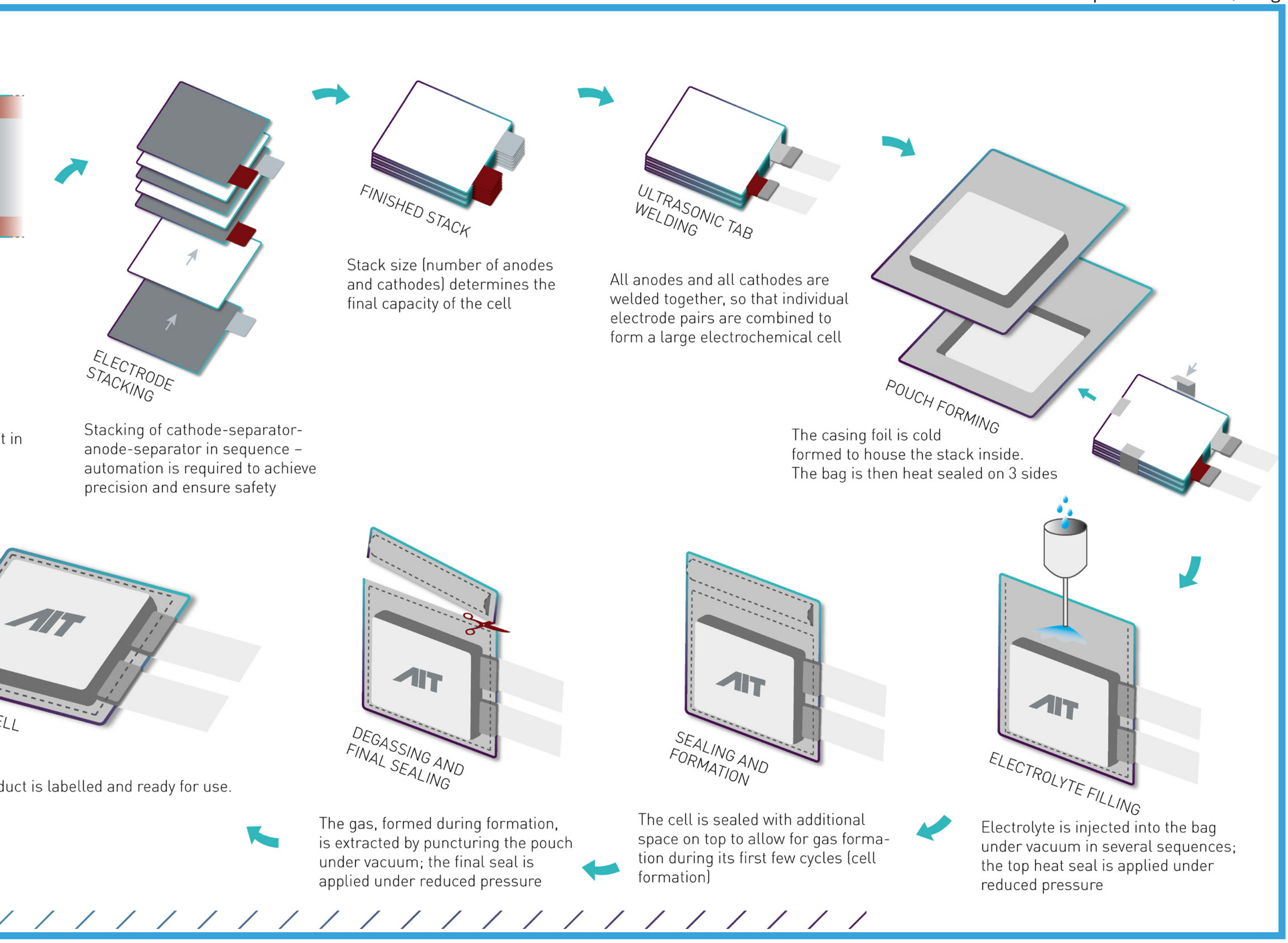


New discoveries in battery technology are made almost every day. The new breakthrough technology that satisfies all the needs of modern EVs and other modes of electrified transport, is announced more and more often. Most intriguingly many of these discoveries do not find their way to the market – but why? There are economic or business decisions to some of them, but often the main challenge lies within the scale up of the technology to an industrially relevant technology readiness level (TRL). This is one of the main reasons why research focus has been put increasingly on manufacturing technology in order to fill the gap between fundamental research and industrial fabrication.

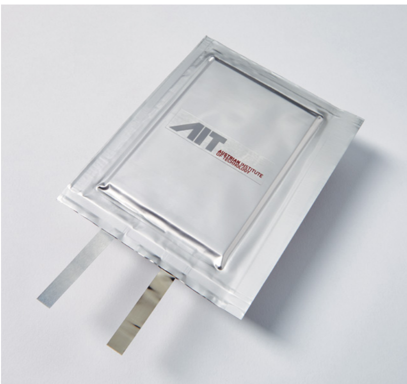
A matter of scale

When introducing a new potential material to the market, the first challenge lies within synthesizing not only milligrams of it (academic scale), but rather several hundred grams at least to start with, with the potential to scale up to kilograms and later on tons (industrial scale). This is the first hurdle for the potential breakthrough material – production needs to be scalable and economically viable. Especially when particular caution has to be taken in the synthesis process, e.g. to protect the material from oxidation or unwanted side reactions – here homogeneity on a larger scale is of great importance.

photo credit: AIT/Lang



Even with that first step conquered, a major challenge remains to bring a new material or component from a laboratory scale to the market: the move from a coin cell in a lab, to a viable large format cell such as a pouch. It is often underestimated, how many materials fail in the stage of a scaled coating process or during handling in a dry room environment instead of a protected



Argon atmosphere. Therefore, the first step here is to achieve the right mix of slurry – that is, a homogenous blend of active and passive materials that is close to the composition expected in an industrial cell. Usually active material content in an electrode coating reaches up to 96 weight percent – a typical research composition works commonly with 80 weight percent only. The mixing process itself needs to be transferred from a magnetic overnight stirring approach to an industrial setting with planetary and high shear mixers for only a few hours in total, achieving the right viscosity and completing a repeatable mixing cycle. Only then, a coating can be carried out. Many materials fail in this process to access their full potential: Coating loadings tend to go up to 4 mAh/cm2 (and even beyond for state of the art high energy cells), whereas in a laboratory setting, the loading does often not exceed 1 mAh/cm2. This has a large impact on the performance of the material and its viability for batteries in future EV applications.

Using the right tools

The proof of concept within a commercial prototype cells, such as a pouch or cylindrical format cell is nowadays vital to bring a new material or component from a concept phase to the market. In order to achieve reproducible results with such cells however, it takes prototype machinery to assemble them with a consistent quality. However, such equipment, which ideally wants to be placed within a dry room with a relative humidity of less than 1% as industry standard, is capital intensive and requires human resources to actually master their use. Specialised staff and large infrastructure investment are often not the feasibly reality for most

innovators, whether they are part of an academic institution or a start-up company. Thus, innovation is often hindered in this hurdle and remains within a high impact publication or somewhere as an unused patent.

This is where applied research labs can assist and add value to the currently present innovation landscape. In laboratories, such as the ones at AIT (https://www.ait.ac.at/en/research-topics/battery-technologies/laboratories/) , pouch cells can be produced on a prototype level including all industrially relevant steps – from mixing, over coating to the final assembly and testing. The reproducibility is one of the most important factors of such research projects, because in the end the subject matter that needs proofing is the new breakthrough material and not the manufacturer's capability to produce a cell. Hence, in order to bridge the gap between academic research and industrial relevance, the support structure of an applied research facility, such as the AIT, can be the first stepping stone to bring a new component for the future battery closer to the market. This is true for current Li-ion technology, but also applies to next generation batteries, such as all-solid-state and multivalent ion batteries, e.g. Mg.As there is a vital interest to accelerate this research and support the innovation potential on an EU level,they have recently clustered up to drive innovation with better focus in the EU. Under the EU project LiPlanet (https://liplanet.eu/), several innovation stakeholders have formed a consortium with the aim to formulate a framework and standardisation conditions for pilot line operators and research facilities, to share knowledge and to bring the European battery of the future one step closer to reality.

The AIT Research Team

The AIT Battery Technologies Team

(https://www.ait.ac.at/en/research-topics/battery-technologies/) is researching the current and next generation of batteries, with the aim of increasing the energy content of the batteries, reducing costs and manufacturing the batteries in an environmentally friendly way. The research area Propulsion Technologies (https://www.ait.ac.at/en/research-topics/propulsion-technologies/) covers power electronics including electric motor control, thermal management including comfort, driving dynamics, as well as icing and vehicle integration issues. Both areas belong to the Competence Unit Electric Drive Technologies in the AIT Center for Low-Emission Transport (www.ait.ac.at/en/let). Everything there revolves around electrification in vehicles and aircraft. 55 researchers are working on improving electrical energy storage systems and the electric drive train.

The AIT Austrian Institute of Technology is Austria's largest research and technology organisation and a specialist in the key infrastructure issues of the future.

Dr. Marcus Jahn, Thematic Coordinator, "Battery Technologies" at AIT.


Battery Systems
safe.reliable.clean.
Efficient storage of renewable energy is one of the biggest challenges of the future. Therefore at VOLTLABOR, we deal with robust and safe technologically sophisticated solutions based on sound technical fundamentals.
www.voltlabor.com
NEW platform conform to:
UN38.3, ECE R 100 / R10,
ISO 26262

Resolving NEV testing challenges with a high degree of accuracy, efficiency, and agility

Geert Jans - Kristof Marcelis – Pepijn Peeters

In automotive, with its ever-increasing pace of innovation and electrification, time is of the essence!

Gaspar Gascon

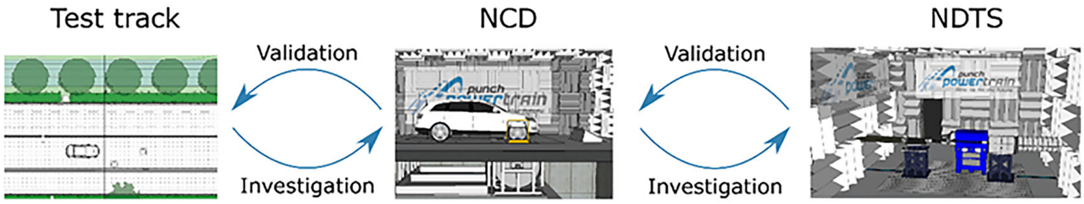
Time-to-market and rationalization in the development of automotive powertrains results in an ever-increasing focus on efficient product validation in terms of cost, lead time and environmental footprint. Additionally, **more and more e-drives** will be part of, or be the only, power unit in the drivetrain architecture of passenger cars, rendering new **specific NVH aspects** as gear whine and electromagnetic whine from e-machines and inverters increasingly important towards total product performance and end-customer satisfaction. Highly controlled conditions and elimination of masking sounds therefore are critical for the successful testing of EV and hybrid powertrains.

"Highly efficient and affordable electric propulsion systems are essential for the mass adoption of electric vehicles at any level of electrification, including a battery electric vehicle, plug-in hybrid vehicle or fuel cell vehicle. Modularity, while preserving compactness, is of the essence to combine customization towards specific OEM needs with scale." Punch Powertrain CTO Gaspar Gascon explained.

This article describes 3 approaches to increase agility of the testing process, which allow higher efficiency, more reliable results, shorter time to market – while at the same time saving expert's time, energy and decreasing harmful exhaust gasses. Notably: universal ICE emulation, the NVH chassis dynamometer (NCD) and NVH Driveline Test System (NDTS). The latter 2 offer complimentary solutions to a test track, allowing to zoom in on a specific – to be investigated - aspect of NVH, on either vehicle or transmission level with high efficiency and speed. After the aspect under investigation is resolved, validation can happen in the other direction.

Universal ICE emulation, allowing infinite simulations

The challenge: When performing durability or functional tests on a transmission system level, whether a conventional or a hybridized one, at some point in time will require the availability of the internal combustion engine (ICE) which has to be matched with the transmission. With ICEs in the development phase this results in a few risks and disadvantages: availability of prototype engines can cause delays in lead time or deviating technical specifications from the final engine, maintenance, or even technical problems during durability testing with prototype engines results in longer downtimes. In addition, bigger spreads on dimensional and performance parameters might increase the system test measurement inaccuracy and in addition the fuel consumed increases the environmental footprint.



Measurement	Test track	NCD	NDTS
Accuracy:	Low	Medium	High
Repeatability:	Low	Medium	High
Availability	Low	High	High
Build-over time:	High	High	Low
Simulated components:	-	Road Load	Road Load, ICE

Measurement	Test track		NCD		NDTS	
Accuracy	Low	Environmental parameters (weather, road conditions, ambient noise.) Variation in vehicle or ICE specs.	Medium	Test track parameters are controlled. Still variation in vehicle or ICE specs.	High	Perfectly controlled environment; only variation in parameters of DUT (Device Under Test)
Repeatability	Low	Variation from test driver, changing parameters mentioned above. Variation in specs between vehicles or ICE's.	Medium	Drive robot to eliminate test driver variation. Variation in specs between vehicles or ICE's.	High	No variation from vehicle or ICE.
Availability	Low	Depending on availability of test track, test driver, environmental parameters, and ambient noise	High	24/7 operation is possible.	High	24/7 operation is possible.
Build-over time	High	Swapping a transmission requires full build-over on vehicle, including alignment of the wheels, brake test, … (4-8h work)	High	Idem test track.	Low	No vehicle involved, change over on test rig is less complex (1-2h work)
Simulated components	-	Pure physical testing	Road Load	Simulated by the test rig through the rollers	Road Load, ICE	Road load simulated by the test rig through the output motors + Emulated combustion engine model on the input motor

The solution: At Punch Powertrain a highly agile and modular methodology and test setup has been developed to overcome these challenges. A super low-inertia servomotor (rotor inertia close to 0.1 $kg.m^2$) is used as an input motor to the transmission, which is closed-loop controlled with an advanced ICE simulator model. The model can be either based on a measured engine characteristic or on a scaled generic ICE model, tailored to the needs of the OEM. Even the typical torque oscillations, inherent to ICEs can be simulated up to 600Hz, with an 8kHz closed-loop control, resulting in highly accurate torque measurements. This requires a super low inertia and highly accurate torque measurement, and the set-up is equipped with a data acquisition system, capable of processing the real-time data.

Some of the highly specific features that can be included in the simulation are air and ignition path first order dynamics, engine mount dynamics, inertia compensation emulation for the difference in inertia between ICE and input motor on the test rig, speed lift up requests, configurable starter motor behavior for start-stop functionality and engine stalling behavior.

The result: Gaining accuracy, speed and sustainability

This progressive set-up brings myriad of advantages to the development process. Firstly, it allows perfect repeatability with no variation between different engines. Secondly, the typical time-to-market can be reduced by several weeks or several months as there is no need for a prototype engine to start the system level tests for the transmission. The motor development can be planned separately from the transmission development. The third important benefit is sustainability, with an energy consumption that is reduced by as much as factor 4, compared to testing with ICEs. In the described set-up the input power of the electromotor is almost completely recovered through the load motors, connected to the output driveshafts of the transmission and acting as the road load, being used in generator mode, and consequently only consuming the internal transmission losses. Additionally, it removes the need for a fuel supply system in the test cell or the need to dispose of exhaust gasses, dissipate waste heat from the ICE or deal with the risks of fuel leaks and vapor.

NVH Chassis Dynamometer (NCD)

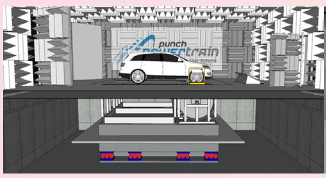
The challenge: Subjective noise evaluation (SNE) test on the test track is influenced by background noise and road surface quality, rendering it difficult to make good acoustic measurements and to exactly quantify issues. Moreover, weather conditions and test track availability may hamper additional tests to solve the issue quickly. To tackle these challenges, a NCD can be used. While making use of this installation, further features can be considered to offer an even higher degree of of accuracy, replicability, and reliability – as existing set-up – described below.

The solution: To assess the NVH performance of the entire powertrain inside the vehicle, a 270kW, 75" chassis dynamometer for 2WD vehicles is installed in a hemi-anechoic environment. With vehicle speeds up to 270km/h, a vehicle mass between 700 kg and 3700 kg (2500kg per axle) a wide range of vehicles and tests can be covered with the setup. The test vehicles are equipped with multiple arrays of vibration sensors and microphones inside the engine bay and cabin to measure the acoustic performance, signature vehicle measurements, transfer path analysis, acoustic camera measurements and Operational Deflection Shape (ODS) analysis in all conditions. The chassis dynamometer is currently equipped for FWD vehicles; however, it has the flexibility for AWD installation with minimal efforts.

To eliminate external noise pollution a **box-in-box** principle is applied, where the full concrete chamber of >140m² is fully decoupled from the building and its surroundings by metal springs, connecting it to a concrete foundation block, with a mass of 150ton and complying with ISO3744:2010. This allows to bring the background noise level in the room below 20dB(A) with a cut-off frequency below 80Hz (ISO10534).

A remote-controlled vehicle cooling fan, with wind speeds up to 100 km/h is present to realistically simulates the engine cool down during road driving. The set-up of the ventilation system is carefully tuned, to minimize the operation sound impact on measuring results to insignificant proportions. **A drive robot** (providing pedal input) is applied, allowing very precise input, eliminating operator fatigue or slight inaccuracies.

The result: This combination of highly controlled, highly realistic environment, in combination with full control over the input, allows for a very precise definition of testing conditions, as well as their perfect replicability. This allows for quick and accurate iterations to solve specific NVH-related issues.



NVH Driveline Test System (NDTS)

The challenge: detailed analysis and adjustments are further required on the transmission level. This step is highly important in the development of hybrid and fully electric drives: allowing the elimination of masking sounds, while precisely controlling the inputs of any driving situation simulation. To tackle this challenge a unique set-up was developed in close collaboration with AVL, including proprietary processes and software. Throughout the development of the NDTS special attention went to highly relevant parameters, such as: reaching a rotational inertia as low as an ICE for the input motor to be able to simulate the highly dynamic behavior and torque oscillations up to 700Nm and 300 Hz of the ICE; as well as a hemi-anechoic chamber setup to reach ISO 3744:2010 standards, resulting in - for example - a background noise level inside the test room of less than 20dB(A) and a cut-off frequency at 80Hz (ISO10534).

The solution: with the help of above-mentioned emulation software, an electric input motor (700 Nm, 10 000 rpm and 400 kW) that simulates the ICE is located inside the hemi-anechoic test cell. The 2 output motors (3232 Nm, 3000 rpm and 220 kW each), which represent the wheel loads, are positioned outside the test cell, connected with custom built carbon fiber shafts of >2,8m in length to the output shafts of the transmission.

This setup can be used with conventional and hybridized transmissions for signature NVH measurements, sound power measurements, torsional vibration measurements, endurance degradation measurements etc. from an early development phase onwards, allowing quick anticipation and design iterations to improve the NVH performance of the transmission. To run tests with the e-machines of MHEV or PHEV applications, a sophisticated DC source is available which allows the use of battery models to simulate parameters as state of charge (SoC), battery degradation, … in a very repeatable and safe way and can be finetuned to specific customer applications or technologies for battery packs. With a little re-build, the set-up can be expanded to EV testing.

The results: taking the transmission out of the vehicle and placing it on the highly controlled NDTS environment, enables replication of any scenario encountered in the vehicle (test track or chassis dyno) on a transmission level, further increasing flexibility and agility. In addition to NCD readings, in this set-up any masking noises from the car are eliminated and the same inputs (throttle, brake, gear lever position) can be used to perfectly replicate any driver action. Solution iteration speed is greatly improved as build-over times are reduced from 4-8 hours on a vehicle to only 1-2 hours on the NDTS. Finally, as the driver inputs are parametrized, it is possible to perform test scenarios more accurately than with a test driver (e.g., take-off with throttle at a constant 30 %).

At Punch Powertrain a 1100 square meters state-of-the-art new Test Center has been developed and installed in 2019 in line with its ambition to deliver this extensive expertise in testing as an added value and support for our customers and the move towards e-mobility. In this process, the company forges partnerships with testing experts, as well as welcoming customers and partners for the use of its facilities.

At Punch Powertrain we have intensively invested over the course of past years to launch pioneering approaches to bring agile and scalable solutions to the market, in everything we do: our products, our industrialization process and our testing. Specifically, today, we will focus on our testing practices, which lift the bar of automotive benchmarks. *"Many innovations are born from our passion to deliver the best result we can envisage, helping the customer in solving their challenge."* Punch Powertrain CTO Gaspar Gascon concluded.

Geert Jans - Corporate Test Center Leader, Kristof Marcelis – Testing Hardware & Software Development Leader, Pepijn Peeters – Test Rig Engineer all from Punch Powertrain contributed to this presentation.

Electric Vehicles and Autonomy: A Powerful Combination for Greater Safety

Dieter Gabriel takes a closer look at lidar in ADAS solutions

The automotive industry is rapidly changing. The increasing use of electric vehicles (EV) is also driving vehicle digitization. When switching to an electric vehicle, customers may naturally expect a higher level of digital convenience, including commerce and entertainments services. The push for technological innovation may further increase the demand for connectivity and shared mobility solutions. Additionally, this endeavor could act as a demand accelerator for more security functions and increase expectations for more Advanced Driver Assistance Systems (ADAS) functions in general.

From this point of view, it could be assumed that advancing electrification can lead to increasing synergies in the further development of ADAS technology. Both EVs and ADAS bring major efficiency and sustainability advantages.

According to a paper released in the MDPI Energies Journal, EV drivetrains are far more efficient than the internal combustion engines used in the vast majority of cars and trucks today. The paper also states that electric power generation and delivery is more efficient than oil extraction, production and delivery needed to fuel gasoline-powered vehicles. This decreases greenhouse gas emissions and pollutants at every level.

As market acceptance of electric vehicles increases, it may be likely that enhanced ADAS solutions will receive more attention from consumers. That's because ADAS can contribute to more safety for all road users.

A critical component to ADAS and autonomous solutions on all vehicles, including EVs, is lidar technology. In our last article here (vol. 7/ winter 2020), we discussed lidar and ADAS, noting:

"Lidar sensors have the potential to enable automakers to create superior ADAS, addressing edge-cases for current approaches, including winding roads, potholes, on/off ramps and roadways with unclear lane markings. This functionality can be realized in a compact form factor; for example, directional lidar sensors can be situated behind the vehicle's windshield for streamlined integration, allowing vehicles to maintain their aerodynamic design...

Lidar-powered ADAS is happening now, delivering next level capabilities to protect road users, assist drivers and save lives."

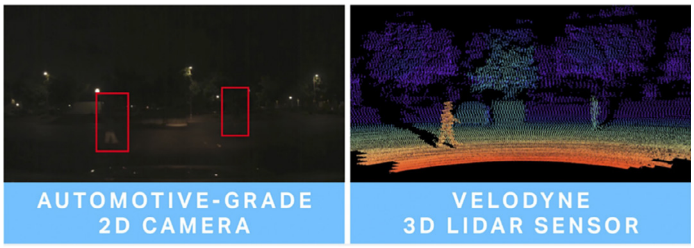
Let's take a closer look at lidar in ADAS solutions and how these, including in conjunction with smart roadside lidar, contribute to enhanced safety for all road users.

Lidar sensors are on the path to potentially become a key component of ADAS, helping to enable safer mobility. These sensors can capture high-definition, three-dimensional information, providing vehicles with a more detailed view of their surroundings to maximize roadway safety.

Improving Pedestrian Safety

The majority of pedestrian and bicycle injuries and fatalities occur between dusk and dawn, according to a U.S. Governors Highway Safety Association (GHSA) report. Additionally, during the global pandemic, the U.S. pedestrian fatality rate rose an estimated 20 percent in the first six months of 2020, noted another GHSA report.

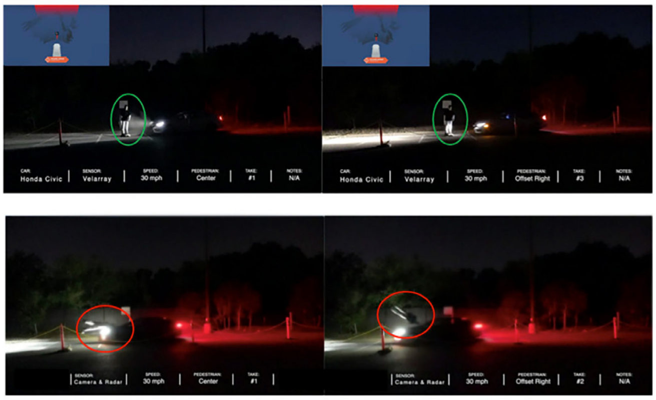
Advanced 3D lidar, which can be considered becoming the "eyes" of a vehicle, is capable of performing in a wide variety of lighting conditions. In contrast, cameras may suffer in low lighting and in the dark. For example, whereas cameras may struggle to see beyond a vehicle's headlights, lidar has the ability to detect a pedestrian or bicyclist at night should either of them enter the roadway. This capability gives the vehicle's system time to react and avoid a collision. Therefore, it is possible to prevent many deaths and injuries, day and night, by employing autonomous solutions and ADAS that use lidar for perception and object avoidance.



Side by side comparison of images produced by automotive camera and a solid state lidar (in dark conditions with streetlights and low beam headlights)

Pedestrian Automated Emergency Braking (PAEB) systems – an ADAS solution – can be significantly improved by adding lidar. Lidar-enhanced PAEB systems can interpret lidar data to avoid and mitigate crashes with moving and static objects. Through predictive collision monitoring, they can compare a vehicle's trajectory with other road users and objects to identify and avoid imminent crash scenarios.

PAEB performance in nighttime conditions is examined in a recently published Velodyne white paper, "Improving Pedestrian Automatic Emergency Braking (PAEB) in Dark, Nighttime Conditions." The white paper includes the results of nighttime PAEB tests conducted by Velodyne. The tests evaluated a highly-rated PAEB system using camera and radar-based technology and Velodyne's lidar-based PAEB system. In these nighttime conditions, the camera and radar-based PAEB system failed in all six scenarios while the lidar-based system avoided a crash in every situation tested. These results and can be also viewed in the video "Pedestrian Automated Emergency Braking."



Images show vehicle with lidar-based emergency braking stopping before adult target @ 50% overlap (above) and vehicle with camera and radar-based solution only crashing into adult target (below)

Powering Intelligent Traffic Infrastructure

Looking beyond vehicles, lidar is emerging as an important capability in making transportation infrastructure more efficient, sustainable and safe. For example, in the United States, at University of Nevada, Reno's Nevada Center for Applied Research project deployed lidar sensors with traffic signals in real-world test environments. The initiative leveraged the data captured with lidar sensors to help improve traffic analytics, congestion management and pedestrian safety. To learn more about this project, please read the white paper "Roadside Lidar Helping to Build Smart and Safe Transportation Infrastructure."

The project validated the feasibility of using roadside lidar sensors to provide high-accuracy, multimodal traffic trajectories by testing with different sensors, deployment methods and traffic scenarios. It demonstrated that roadside lidar data can support connected-and-autonomous vehicles (CAV), enhance traffic mobility and safety analysis and integrate with existing traffic infrastructure for automatic pedestrian/wildlife warning.

Lidar Advancing Safety

Deploying lidar in vehicles and transportation infrastructure has the potential to significantly advance safety. Lidar can enable vehicles to have precise, reliable navigation in real time to detect objects, vehicles and people that might pose a collision threat. EVs with ADAS features or with full autonomy deliver powerful solutions to assist drivers, protect pedestrians, save lives and advance sustainability. Lidar can also impact transportation planning and systems, and prepare roadways for the future.

The synergy between EVs and ADAS aligns well with Velodyne's vision of enabling universal mobility and improved public safety to achieve healthy and thriving communities for all.

Dieter Gabriel | Marketing Manager - EMEA

Velodyne Europe GmbH

Worried about foreign state actors hacking your car?

Maybe you should worry more about your neighbours…

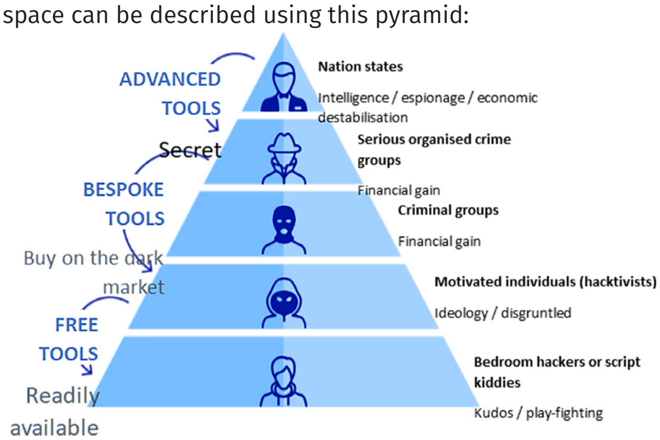
Vic Harkness

Hacking cars is a very sexy subject; the movie 'Fast & Furious 8' showed us how compromised vehicles could hypothetically be used to cause chaos and disruption. Whilst most people can understand that the scene was a dramatisation of how cars can be hacked, it's based in a real problem. Although cars can't completely drive themselves yet, we're rapidly approaching that point. Perhaps in 10 years vehicles will be entirely autonomous. If we don't secure our future vehicles, then bad people with way too many computer screens will be able to control them.

To assist car manufacturers in reaching higher levels of vehicle autonomy, various EU bodies have released documents describing how future Connected/Autonomous Vehicles (CAVs) should communicate with each other. These proposals also detail future intelligent roadways which will be able to share useful information with the vehicles which drive upon them. F-Secure conducted a study examining the security of these high-level proposals to assess where the security gaps are likely to lie.

We identified numerous potential vulnerabilities in these future systems, concentrating on flaws in the ways in which vehicles will communicate. And, based upon the current proposals, the future visions of highly interconnected vehicles are not viable. Attackers will be presented with near endless opportunities to deny vehicles access to the network, meaning the cars would be forced to make decisions on their own. As such, one of the key recommendations of the study is that all future vehicles should be able to operate safely, even if they lose access to overarching data sharing mechanisms.

To look at future threats to CAV infrastructure, or any network, we need to assess what type of attacker is likely to be targeting it. In general terms, threat actors seen in cyber space can be described using this pyramid:



At the higher levels of the pyramid, we have the big scary groups seen in Fast & Furious 8. Thankfully, there are very few of these groups. They tend to be very well-resourced, as they are backed by nation states or even high-level crime organisations with access to top-tier hackers who can create highly bespoke tooling and attacks.

Moving down the pyramid, the numbers become greater, but the resource levels lessen. The most common type of hacker, known colloquially as the script kiddie, is generally not very well resourced. Our script kiddie has probably heard about the Low Orbit Ion Cannon online and might try to run it against his school's website. On the one hand, he doesn't really understand what he's doing. On the other, he is one of thousands. An attacker only needs to get lucky once, but the defender needs to successfully fend off thousands of attacks.

For the study, F-Secure examined the types of goals that these varying levels of threat actors may have, and how these goals could be aligned with their skillsets. This knowledge was combined with the results of our security review to create hypothetical attack paths which an attacker could use to gain access to the future CAV networks and reach their goals.

As an example, I would like to introduce my favourite neighbourhood threat actor: Bob the Grumpy Guy.

Bob lives in a small village, which has a section of smart roadway running through it. He is upset by the speed at which the cars travel through the village and wants to slow them down. He has read online that the roadside units (RSUs) placed every 500m along the roadside control the speed at which cars drive, and so he decides to target them.

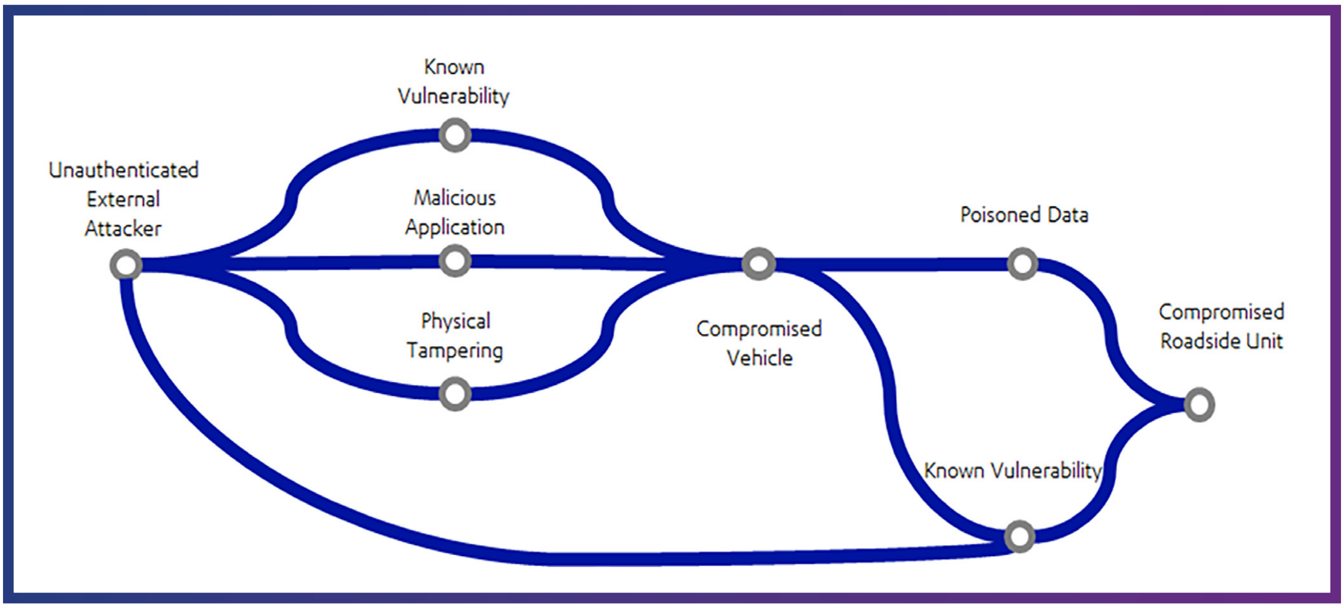
Bob spends some time learning about hardware security online. One night he takes his laptop and a crowbar to an RSU, which is hidden behind some trees. The RSU is in a locked cabinet, but Bob manages to lever it open with the crowbar. The physical tamper detection system of the RSU detects the unexpected opening of the door and sounds an alarm. An alert is sent to the CAV network requesting investigation. The loud alarm startles Bob, and he returns home.

Based on his experience with the RSU, Bob decides to try and use other devices to get to the RSU. His neighbour has a new intelligent vehicle, which connects to the RSUs. Bob does some research on his neighbour's new car, and discovers the car broadcasts a hotspot which drivers can connect their phones to. Bob reads a web forum and finds unofficial reports saying the technology used for this hotspot has an abusable authentication vulnerability.

As Bob is within the hotspot's range, he can exploit the vulnerability to connect to the car from his bedroom. Using his knowledge of network security, he can pivot through the car's internal networks until he finds the service which allows it to interface with the RSU. After some trial and error, he learns how to send status update messages to the nearby RSU. Bob uses these to send the RSU many reports that the road is covered in black ice. The RSU collates these reports and does not correctly identify that they have all come from a single vehicle. The RSU updates its model with the presence of black ice and decides that the speed limit for that area should be lowered.

The dynamically updated road signs along the village now display half the previous speed limit. Autonomous vehicles automatically adhere to them, as do most manually driven cars. Bob is happy once again.

Bob's attack path can be described as thus:



Based on this diagram, we can we see numerous opportunities to stop Bob. If only the vehicle didn't have unpatched vulnerabilities. If only the RSU didn't trust data coming from the vehicle.

Scenes like the ones in movies do not come from a single point of failure. They come from multiple system weaknesses being stacked together until a full chain compromise is reached.

Fortunately, there is still time to anticipate these weaknesses and prevent their exploitation by Bob and threat actors of all kinds. Beyond our recommendation that representative CAV testbeds be created to test for, and address, the vulnerabilities we identified prior to any safety-critical deployments, we identified an immediate need for overarching guidance on CAV and ITS security.

A consortium should be formed that includes government, vendors, and the security industry. This group would aim to establish and maintain ITS security standards that would need to meet before any device is deployed on the intelligent roadway infrastructure. Likewise, security consultancies would need to be accredited before providing auditing services.

Finally, the need for thorough detection and logging capabilities within ITS networks is of extremely high importance. Whilst solid security standards will help to prevent lower-grade attackers from compromising the networks, it is inevitable that a breach by a high-grade threat actor will occur at some point. Complex automated detection and logging will help to identify when such a breach has occurred, so that remedial actions quickly to keep the roads safe and open.

Vic Harkness, Security Consultant, F-Secure

For more information, please read our full report at:

https://www.f-secure.com/gb-en/consulting/our-thinking/future-threats-to-its-networks-and-cav-infrastructure

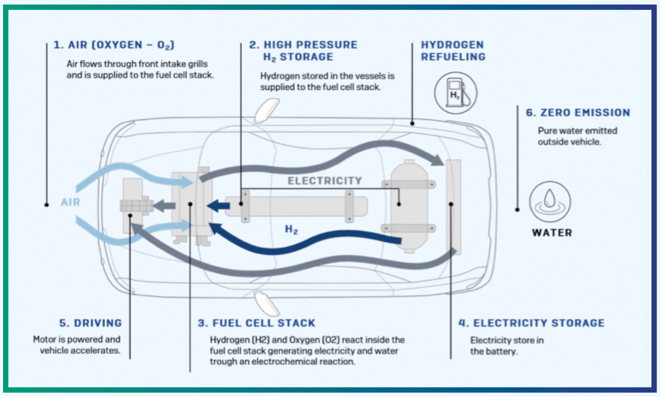
Development and large-scale production of fuel cell stacks for CO2-neutral mobility

Stack platforms as success factors

Armin Diez

The official launch date was March 1, 2021. EKPO Fuel Cell Technologies (EKPO), a leading joint venture in the field of development and large-scale production of fuel cell stacks for CO2-neutral mobility, began operations. The company's goal is clearly defined: the development and large-scale production of high-performance fuel cell stacks aimed at driving forward CO2-neutral mobility – whether on the road, rail, water, or off-highway.

The core of the portfolio is undoubtedly the PEMFC (Proton Exchange Membrane Fuel Cell) stacks that are based on patented designs for metallic bipolar plates as well as end modules and media modules, providing many benefits for integration into fuel cell systems. "Our fuel cell stacks have excellent power and durability characteristics and can be used for a very wide variety of vehicle categories", says Armin Diez, CTO and COO of EKPO. Due to a chemical reaction between oxygen and hydrogen, electrical energy is generated which, depending on system design, can directly supply an electric motor or charge battery modules in the vehicle. A distinction is made between different stack platforms, which differ because of various parameters.



Established processes and experience in production technology have given the company decisive advantages for series development and production in the field of fuel cells. "These include automated, high-precision and interlinked production of metallic bipolar plates as well as the series-compatible development and manufacturing of end plates and media modules made of plastic. Lastly there is the flexible, fully automated assembly line as well as an end of line testing for stacks", Armin Diez summarizes the core competencies.

The question remains as to how far the developments have come. "The "NM5-EVO" stack platform will be delivered for the first time for a commercial vehicle small series at the end of 2021. The "NM12 single and twin" platform will be available in series production standard end of 2022. For the second half of this decade, we then also expect series orders for commercial vehicles with significantly higher volumes", says Diez.

While the two platforms are built on the same technology, they differ in several parameters:

NM5-EVO	NM12 SINGLE
• Customer-specific stack solutions	• Customer-specific stack solutions
• with power levels up to 76 kWel	• with power levels up to 123 kWel
• Hydrogen-air operation	• Hydrogen-air operation
• Liquid-cooled	• Liquid-cooled
• Pressurized operation up to 2.5 bar_a	• Pressurized operation up to 2.5 bar_a
• IP (6KX, X6K, X7) housing with EMC shielding	• IP (6KX, X6K, X7) housing with EMC shielding
• Compact integrated cell voltage monitoring (CVM)	• Compact integrated cell voltage monitoring (CVM)
• Integrated media control, water separators andmedia monitoring	• Integrated media control, water separators and media monitoring
• Robust sensors and actuators acc. to automotive	• Robust sensors and actuators acc. to automotive standards
• standards	• Stack module validated acc. to IEC 62282 and GB/T 33978
• Stack module validated acc. to IEC 62282 and GB/T 33978	

The stacks are characterized by various key elements. They both have a compact stack design and offer high power density. "Furthermore, they have a high dynamic response in power provisioning, a robust component and stack design suitable for mass production, with long service life and minimal degradation. Another feature is the proven cold-start performance and durability", Diez describes. System simplification by integration of functions into the media supply assembly of the stack (sensors, actuators, and valves) and metallic bipolar plates in patented designs round off the whole thing.

Hydrogen will play a major role in the sustainable mobility of tomorrow and not only there since hydrogen brings huge advantages in respect to the ability by coupling different sectors. "In the mobility world a new generation is dawning. And we will play a decisive role in shaping it", summarizes Diez.

	NM5-EVO	NM5-EVO
Cell Count	335	359
Rated stack power	76 kW	123 kW
Power density stack1,2	4.6 kW/l	6.2 kW/l
Rated stack voltage	201 V	215 V
Rated current3	380 A [2.0 A/cm²]	570 A [2.28 A/cm²]
Max current		625 A [2.50 A/cm²]
Rated operation pressure	2.5 bar_a	2.5 bar_a
Active area	190 cm²	250 cm2
Cell pitch	1.34 mm	1.27 mm
Orientation	Cells vertical	Cells vertical
Dimension incl housing [mm]	329x225x687 mm	402x287x700 mm

[1] value refers to cell row assembly without end plates.

[2] preliminary data, detailed design not finalized

[3] current at 0.6 V cell voltage

Armin Diez, is the CTO and COO of EKPO

YASA electric motors are suitable for many applications across the electric automotive market.

Why did YASA start working with luxury OEMs rather than go straight into the mass market opportunity?

Ajay Lukha

With any new technology for automotive, you start with low volumes and of course the unit cost is much higher. So, you need to start working with high-end, relatively low volume opportunities where performance and weight are critical and as your supply chain matures and costs decrease, percolate down into the premium opportunities and ultimately the mass market. That's exactly what we've done over the past eight years, working with OEMs in the high-performance luxury sector and now premium and mass market also.

YASA offers axial-flux electric motors but most of the industry still relies on legacy radial technology. How has that shaped your go-to market strategy?

The supply chains for radial motors are fully mature, the technology has been around for more than 50 years, and more importantly, radial technology is legacy with almost no further opportunity for efficiency gains, but vehicle manufacturers still have radial motors baked into their thinking – their vehicle models and sub-systems are in many cases designed around it. So, we knew when we started that our market was challenging and we needed to drive a change in thinking, but we also knew our advantages in efficiency, performance, size, and weight would ultimately overcome those barriers. So, for us the ideal place to engage has really been pre-concept, and the job for me and my team is to seek out and engage with those concept engineers and product specialists within OEMs who are looking to do something different and interesting – something that's going to help them carve out a competitive edge.

YASA works with OEM customers to customize the product. What's that process like?

We take them through our advantages and then formalise it through a feasibility study. The study effectively allows the customer to make a direct and accurate comparison between what might be a typical radio motor solution for that particular requirement and our axial-flux solution. This process reveals the whole powertrain efficiency, cost trade-off, performance trade-off etc. and I don't think we've gone through a feasibility study where we didn't convince the customer. So, then there's typically a fair bit of work that goes into calibrating with the OEM's purchasing function. Once we've proven that we yield a significant technology advantage at a competitive price point, we work iteratively with the customer around their powertrain concept to configure and productionise our solution.

What's the biggest challenge that OEMs face today?

Well, the biggest challenge is figuring out the right trade-off between efficiency, price, and performance. We do a lot of simulation work to help our OEM customers navigate those decisions using our genetic algorithms for electric powertrains. We call them genetic because it effectively allows us to do calculations with millions of potential variables really quickly, running often very small changes variations to design, suppliers etc. to see the playoff of cost versus efficiency versus size versus performance.

Can you talk through the buy or build decision for OEMs when it comes to electric powertrain solutions?

It's interesting because if you're a premium OEM, you probably produce somewhere between two and three million vehicles a year. For 80% of your vehicle range, you're probably going to try and standardise around a motor solution so the majority of your fleet sales can be serviced by one electric motor that's manufactured out of what likely used to be your old combustion engine manufacturing facility, which simultaneously allows you to maintain your current workforce. But you're also going to need a solution for your top-of-the-range performance vehicles, the 20% with the highest consumer pricing and which set the brand reputation for innovation and performance. You, the OEM, want more bespoke technology with greater competitive edge around which you can differentiate. And that's where buying in a custom electric powertrain solution or working through some other future commercial model makes sense over the build decision.

What, what kind of mindset do you look for when it comes to customers?

I'll give you an example. We started talking to one of our OEM customers – a premium automotive OEM – in 2016. And at the start, we were working with very sceptical engineers. But working together over time, you kind of chip away at that initial scepticism with data, evidence, hands-on testing until they see the light, because ultimately, they're in the premium space and need to maintain their reputation for world-class innovation.

One of the things OEMs appreciate is that we're willing to work in partnership. And what we care about is that our solution delivers the maximum value to the OEM in the battery electric vehicle market, which I would say is additional range at a lower cost. That's driving OEMs right now to socialise the idea internally of 'let's take the leap – let's use axial-flux motors in our next vehicle, not radial.'

Ajay Lukha, Chief Commercial Officer, YASA

How the Pandemic is Changing Our Perception of Cleanliness Inside the Car

Sebastian Schmidt

The COVID-19 pandemic has changed mobility. It has also changed the car user's perception of safety and comfort inside the automotive. As a result, the global car user's willingness to invest into solutions against invisible germs on interior surfaces and the in-cabin air is growing. This development is one of the key findings of the second Asahi Kasei Europe Automotive Interior Survey conducted in December 2020.

The ongoing COVID-19 pandemic is having a severe impact on mobility. Recent surveys show that the use of public transport and ride sharing services has declined severely. In contrast, the popularity of the private car as a safe space with a low infection risk is increasing. The pandemic will have a lasting effect on existing and future mobility concepts – and on the materials and technologies used inside the automotive.

As the main interface between the user and the car, surface materials are defining how the driver and the passengers perceive the automotive interior and more important: the driving experience itself. In the past the materials needed to be comfortable, attractive to the eye and smooth to the skin. The COVID-19 pandemic is adding a new dimension to this topic, clearly raising the needs towards the overall cleanliness and safety against invisible threats inside the car.

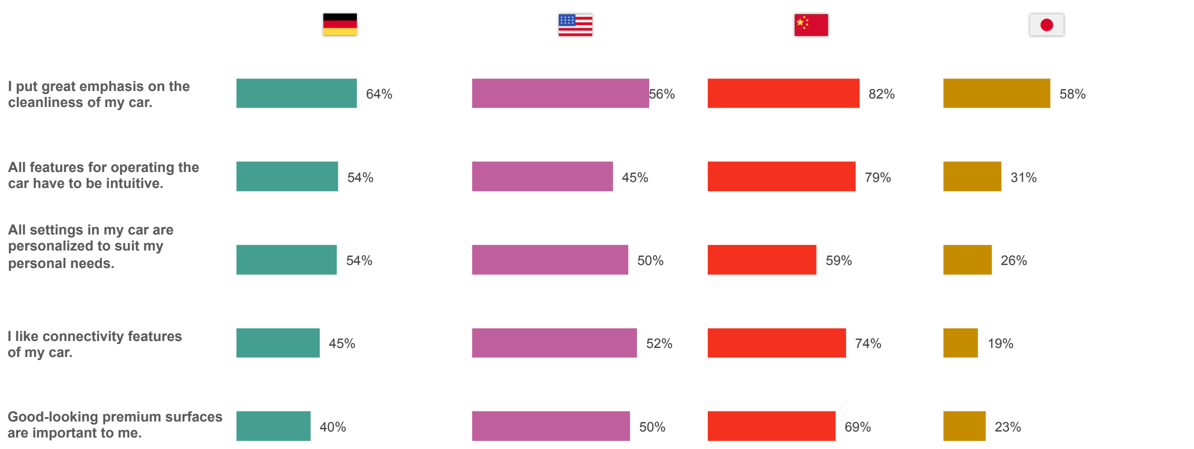
This development was another development confirmed by the second representative "Asahi Kasei Europe Automotive Interior Survey" conducted in December 2020 by Asahi Kasei Europe and the Cologne-based market research institute SKOPOS. 500 vehicle users in each of the global automotive core markets Germany, USA, China and Japan were asked about their preferences in regard to the future automotive interior.

Global car users see benefit in easy-to-maintain surfaces and air filtration systems

One key finding of the survey was the importance of cleanliness inside the car. In Germany, 64% of the car users are putting a great emphasis on this topic, valuing it even higher than connectivity, the intuitive operation or the personalization of the car. The same results can be observed in the other markets: Four out of five car users in China consider cleanliness inside the car as important **(see fig. 1)**.

The perception of cleanliness is subjective, but this topic is clearly moving the car users around the world. Premium and lasting interior looks generally climb in importance: Asked about features they would consider beneficial in

Fig. 1 - Rising Importance Of Cleanliness Inside The Car



their next car, 75% of the car users in Germany pointed out "surface and seating materials that are easy to wash", 66% in "water and dirt repellent surfaces" **(see fig. 2)**. The same features are also of high interest for the car users in the USA and China.

The current pandemic is adding another layer to the car user's understanding of cleanliness, as it clearly raised the people's awareness towards the surfaces they touch and the air they breathe – especially in a confined space like a car.

The results of the survey confirm this development: 69% of the German car users see a clear benefit in having an "advanced air filtration system filtering the OUTSIDE AIR entering the vehicle".

The topic of "clean air" is especially moving the car users in China, with 87% seeing a benefit also in an "advanced air filtration system filtering the AIR WITHIN the vehicle".

In addition, every second German car user thinks of "Surfaces with materials that can eliminate viruses and bacteria in places you touch the most" as beneficial. In the other three countries this share is even higher.

Heiko Rother, General Manager Business Development Automotive at Asahi Kasei Europe, commented on this development: "The automotive manufacturers are facing the new challenge of taking away the end user's concerns about invisible threats, making him and her feel safe and comfortable again inside their vehicle. This goes specifically for private cars, but also for all future mobility concepts."

Willingness to pay for hygienic features

The car user's accelerating needs towards hygienic features is also reflected in the readiness to pay for solutions for safe surfaces and air inside the car. Every third German car user planning to purchase a new car would be willing to pay an additional 1,000 Euro for a hypothetical, optional "Surface Protect" Package.

In the USA, every second car user agreed to pay 1,000 USD, every fourth even 1,500 USD.

70% of the car users in China would pay 5,000 CNY, every third would be inclined to pay 7,000 CNY, showing a strong acceptance on the Chinese market for additional features that contribute to hygienic surfaces.

A similar trend can be seen in regard to features that contribute to air safety. When purchasing a new car, every third car user in Germany would be inclined to pay 1,000 Euro for a hypothetical, optional "Cabin Protect" * package, ensuring safe air inside the passenger compartment. The same development can be observed in the USA, where about every second car user agrees with paying 1,000 USD, and every fifth even willing to pay 2,000 USD. In China, the demand is clearly higher, with 71% of the car users willing to pay 5,000 CNY, 40% even 7,000 CNY.

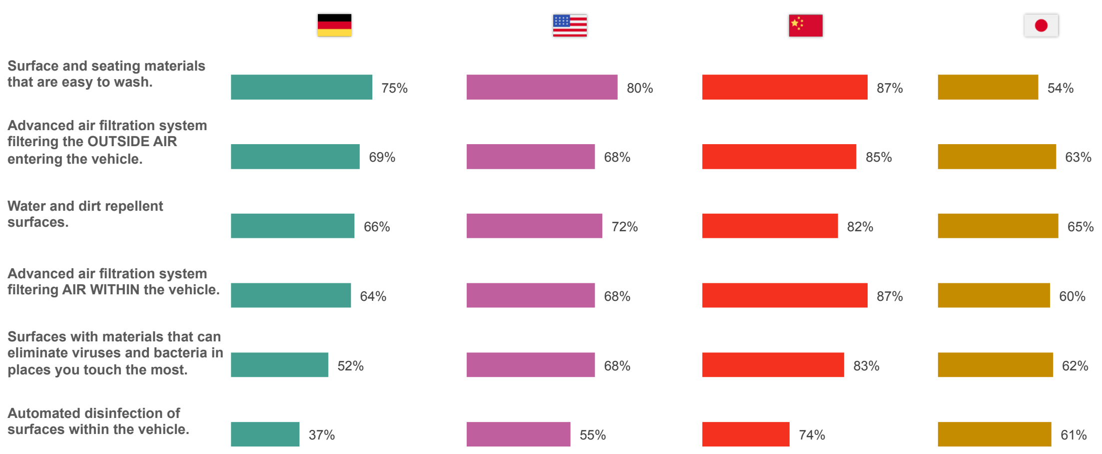
Heiko Rother concludes: "The results of the survey show that new solutions against invisible threats are in high demand. With anti-microbial seat covers and plastics, as well as innovative UVC-LED solutions for in-car air filtration, Asahi Kasei is already at the forefront of this development. We are eager to drive this further and continue our effort of teaming up with the industry in contributing to a safer mobility."

*Cabin Protect Package: A hypothetical, optional package including an automated ventilation system that eliminates microbes and pathogens in cabin air, monitors CO_2 levels to reduce drowsiness and provides active occupant sensing for child/pet left behind.

*Surface Protect Package: A hypothetical, optional package with interior materials that provide anti-viral/ anti-microbial properties, stain and odour resistance and improved weathering and scratch resistance.

Sebastian Schmidt, Asahi Kasei Europe

Fig. 2 - Global Car Users See Benefit In Hygienic Interior Features



PHIHONG

Scan for more information

REDEFINE CHARGING

• ISO15118 • OCPP1.6/2.0 JSON • RFID card reader • Customization available

AC Chargers

DC Chargers

AW Series
Wall Mount Charger
32A

AH Series
Wall Mount Charger
32A

DW Series
Wall Mount Fast Charger
30kW

DM Series
Moveable Fast Charger
30kW

AP Series
Pedestal Charger
32/63A

DO Series
Fast Charger
360kW

DS Series
Fast Charger
60/90/120/150/180kW

AX Series - Flexibility & Efficiency (3P 32A/1P 48A) Coming Soon

PHIHONG

As a top-notch manufacturer in the power supply field nearly 50 years, Phihong has successfully developed a family of highly-efficient EV charging products: charging modules, portable, wall mount, moveable and free standing chargers. We also offers EV charging software solutions which include both the front end and back end platforms. Phihong Technology provides high quality and cost-effective hardware/software products based on specific customer needs.


To serve
and protect