A Comprehensive System Approach for Future Powertrain Electrification

Interview
Oliver Blume (CEO, Porsche)
Tomorrow’s Sports Cars

Automotive Diagnostics - Shifting from Digital to Intelligent

Including Featured Topics about Automated Driving and Digitalization
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Dear reader,

welcome to our next milestone: the 10th issue of CTI Mag! The automotive industry is currently heading for a digital transformation, with AI applications becoming more and more important in drivetrains and development processes, and automated driving set to impact on powertrains too. In this issue we cover both topics for the first time - together with numerous new developments in the transmission and drives segment.

Read for yourself what big-name manufacturers and suppliers have to say about their latest electrification concepts, as well as how they are improving the efficiency, performance, cost and weight of individual drive components. Other topics include the latest insights in lubricants, transmission sensor systems and product methods, and the challenges and legal parameters that are shaping automated driving and vehicle connectivity, Big Data and Cloud technology applications.

To round off our specialist articles, we also interview high-level automotive managers and experts on a range of fascinating topics. Dr Oliver Blume, CEO Porsche, talks about tomorrow’s sports cars and Porsche’s electrification strategy; two drive and fuel experts – Prof. Dr.-Ing. Peter Gutzmer, Schaeffler and Dr. Wolfgang Warnecke, Shell – discuss carbon neutral mobility, while drive expert Lipeng Zheng, Great Wall, describes the first DCT to be developed and manufactured in China.

Our special thanks to everyone who helped make this latest issue of CTI Mag happen. We hope you enjoy reading the results!

Best wishes,

Your CTI Mag Team
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Mr Blume, Porsche is now investing massively in pure electric drive development, as well as in growing its hybrid range. What’s the underlying strategy?

The same strategy we have been pursuing for years. Porsche was the first premium segment manufacturer to offer hybrid systems in three different series at once. That sent a signal, and that’s where we’ve continued. Over time we optimized performance and electric range, and our 918 Spyder showed what hybridization can look like in the supercar segment. On the racetrack, our 919 Hybrid has been extremely successful in the LMP-1 class. So electrification has been part of our development and product strategy for many years.

Do you expect drives to displace combustion engines long term?

Certainly the bulk of combustion engines. Political plans for reducing road traffic emissions will see to that by themselves. But the world’s regions are developing at different speeds, so we’re positioning ourselves as flexibly as possible for an interim period of about ten years. That means models with further optimized combustion engines, attractive plug-in hybrids and pure electric sports cars.

And how does Porsche’s product portfolio reflect these parallels?

Above all, our model range reflects the different wishes of our customers. We’ve divided it into four dimensions. The first is our successful ‘Base’, where we examine in which segments derivatives make sense – for example the Panamera Sport Turismo, a version of our luxury limousine with more generous luggage space. The second dimension is ‘Image’: high performance cars with racing in their DNA, such as our GT and RS models. In the ‘Lifestyle’ dimension we combine modern automobiles with popular elements from earlier generations. And the ‘Future’ dimension stands for all our plug-in hybrid and pure electric cars.

How big will this ‘Future’ dimension’s share be by the mid 2020’s?

Our hybrids are already very popular with customers. Roughly three in five Panameras sold in Europe since the market launch have a hybrid drive. In some countries the order quota was much higher – for example about 90 percent in Scandinavia. So we expect the hybrid share to remain strong in future too, with stable tendencies. Our assumption is that by 2025, roughly one quarter of all new Porsches will already have an e-motor.
So will there soon be a pure electric 911 or 718?
The mid-engined Boxster and Cayman are particularly suitable for pure electric drives, as several research prototypes since 2010 have shown. But we made the decision to develop a completely new series, starting with the first all-electric model.

When will the first e-Porsche roll off the line?
In about a year’s time. The new production unit, a factory-within-a-factory at our Zuffenhausen headquarters, is already being built. We are well on track to market the first Mission E as announced at the end of 2019. This car won't just go fast, it will charge quickly too. Thanks to its 800-volt architecture, Mission E can cover 100 kilometres on a 4-minute charge. That makes it suitable for daily use, and above all for long journeys. This car will also set new standards in terms of design, driving experience and performance.

And we’re already working on derivatives. At the Geneva Motor Show we presented a study of the Mission E Cross Turismo, our first Cross Utility Vehicle. Like the Mission E, this CUV will also be able to accelerate and brake repeatedly without power loss – all with a range of more than 500 km.

Tesla has announced a roadster for 2020 with twice that range, or 1000 km. Does that concern you? Could Mission E be too late after all?
No, Mission E is perfectly timed. We’re not shy of competition. We watch other manufacturers carefully, but we focus on our own product strategy. We don’t dazzle; we deliver.

For us, every car has to pay its way; only then can we safeguard jobs and invest in new technologies. Porsche has a long heritage, is an extremely valuable brand and stands for fascinating premium sports cars. We have a loyal customer base, particularly in the USA. And with Mission E, we are launching a car that meets our customers’ requirements perfectly.

Given the Tesla announcements, is Mission E’s performance still competitive?
The series version of Mission E will be more than competitive in terms of range, acceleration and top speed. And not just on paper – it will reproduce that performance and deliver it sustainably. The power comes from 800V technology, where Porsche is a development leader. With short charging times and ranges as long as those of combustion engine cars, this will promote customer acceptance of electromobility.

But surely charging network densities are also crucial?
I agree. To make electromobility attractive for long journeys too, we need high performance fast-charging networks. This is why Porsche co-founded the joint venture IONITY with Audi, BMW, Daimler and Ford. The goal is to rapidly build an ultra-fast high-power charging network on major European traffic arteries so EV customers can cover long distances. It’s an important step for making electromobility accessible to the mass market.

The network is based on the European Standard Combined Charging System (CCS), so it’s compatible with most current and upcoming electric vehicles. As a first step, around 400 stations are planned in Europe.

That’s a big investment for what will start as just one series …
Long term, of course, Mission E will not be the only electric series at Porsche. We’re already co-developing the ‘Premium Platform Electric’ with Audi, with two series for Audi and one for Porsche. That yields enormous synergies. We can develop faster, learn from each other and save on costs. Brand differentiation is also assured – for example through performance data, driving dynamics and acceleration.

Are more cooperation schemes part of your strategy too?
In a sense. Beyond the Volkswagen Group we’re mostly reaching out to young start-ups. That secures us access to technologies that are relevant for our company’s future, above all in Digitalization, Connectivity, Artificial Intelligence and the Internet of Things. After all, our aim is to develop Porsche into a leading provider for digital mobility solutions in the premium automotive segment.

So will tomorrow’s sports cars be digitalized through and through?
Digitalization is not an end in itself for Porsche. But wherever it enhances customer functionality or simplifies our processes, we will use it – and we will do so in typical Porsche style.
Will the Porsche of the future drive autonomously too?
Connectivity technologies are extremely important for us. That goes for production as much as for the cars. The road to autonomous automobiles will involve many assistance systems – for instance traffic satnavs, or instruments that let cars locate a space and self-park. Different levels lead up to completely autonomous driving; depending on the series, we will offer more or less functionality. We don’t need to be first in fields like autonomous driving or connectivity. Instead, we need to offer solutions that are tailor made for our customers. And even on the racetrack, autopilot can be fun when it follows the racing line and shows you the perfect point to brake going into the bend, and accelerates coming back out.

How might that look in practice?
One idea is the Mark Webber app, named after the racing driver who is our brand ambassador. With this app, your car could go round a track like Nürburgring autonomously as if Mark was driving – perfectly, in other words. First the software records the exact course he drives. Next, the autopilot in the car uses that data to replicate the lap Mark drove. Afterwards, you can take the wheel yourself and get your car to show you the racing line. So you can train and improve your driving skills using the direct feedback your car provides.

Is there a business model for an offering that like?
Absolutely. First, many of our customers like to visit the track at weekends. Second, a licence for an app that special could easily cost a four-figure sum.

Will Porsche offer Function on Demand, as some competitors already do?
Starting with Mission E, Porsche will offer a growing range of functions on demand and wireless updates too. So customers can purchase new functions at any time – even long after buying the car, or for a limited period. You could, for example, compile your own suite of autonomous driving modules. Other application fields could be more PS or a different handling setup for the racetrack – or dynamic headlights, if you’re planning a long drive at night.

So these offerings will help safeguard dividends in the future too?
Exactly. We have to invest massively now in developing these new services. So far we have mainly invested in conventional automotive development; now we’re strengthening our services development significantly. But we want to, and must, earn money with the new services. So above all we need concepts for low resource growth, where we don’t always have to own all the resources ourselves.

What will the Porsche of the future look like?
Will we still recognise it as a Porsche?
Definitely. Even if it’s a pure electric, it will absolutely drive and feel like a Porsche. We will continue to build exclusive, high performance sports cars, which for us means further optimizing our combustion drives too. In both fields, we will stay true to our traditional Porsche DNA and connect it with tomorrow’s technologies. Porsche will still be Porsche in future.

Join us at the CTI Symposium USA „Automotive Transmissions, HEV & EV Drives“
14.-17. May, Novi, Michigan
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- High integration density allows fully integration into the electric motor
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- Coolant pump for internal combustion engine, charge air cooling, electronic motor

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A Comprehensive System Approach for Future Powertrain Electrification

Electrification opens up many new opportunities, but also causes a complex interaction between the combustion engine and electric motors in hybrid vehicles. This is why new concepts and components for powertrains are in high demand. It is not enough to simply mix and match existing options. Magna Powertrain is meeting this challenge by offering a modular and scalable product range that provides vehicle manufacturers with a wide range of options.

Dr Joerg Gindele, Senior Director Core Engineering, Magna Powertrain

The automotive industry is facing its greatest revolution since the invention of the automobile at the end of the 19th century. The electric motor may be replacing the combustion engine, but this process is sure to take decades. Magna Powertrain is heavily affected by electrification as a leading manufacturer of powertrain systems, seeing as these constitute the core of our business. Quite rightly, automotive manufacturers are expecting compelling technological solutions that will allow them to effectively navigate the transformation taking place and play an active role in shaping the process.

In line with the motto ‘Magna Powertrains brings the power to the wheels,’ the company has developed a full line of products over the past years for electrifying drive trains, ranging from mild and full hybrids to battery-powered electric drives. Having many options is necessary since no single drive is able to provide all of the benefits that the individual powertrain versions offer and hence take the market by storm. Rather, a multitude of drive options will be available over the next several years, if not decades, which will address different customer interests. If the forecasts are indeed correct, then, vehicles with electrified powertrain will achieve a market share of over 66 percent by the end of 2030, while the market share for battery-powered e-vehicles will be about 13 percent (Fig. 1).

Source: Magna OEM Fleet Analysis 2017
One recurring topic in the automotive industry is costs. Because the battery is a major cost driver, and since this is not set to change in the foreseeable future, electric vehicles will be more expensive than non-hybrid vehicles with a combustion engine in the long run. While car buyers may accept somewhat higher prices in exchange for additional benefits such as local zero-emissions or quiet driving, the price gap will remain. To make electric vehicles more competitive, this gap must be kept as small as possible — and this is where powertrain manufacturers have a crucial role to play. In doing so, there are also technical challenges that contradict each other in part, such as electric output (power density), efficiency, and space. Different demands require different solutions. Ideally, a powertrain manufacturer should be able to offer a wide range of modular, scalable solutions that provide enough options for vehicle manufacturers that allow them to set themselves apart from their competitors.

The main argument behind introducing electric drives is, of course, to save fossil fuels and lower CO₂ emissions. The most basic option is a mild hybrid.

The recuperation potential in the test cycles depends mainly on two factors: the performance of the electric system and vehicle’s weight. For example, over 90 percent recovery potential could be possible for a vehicle that weights up to 2000 kg, if it is equipped with 25 kW generation power system and a sufficient energy storage capacity is available (Fig. 2). For lighter vehicles with a lower recovery target, a 15 kW system with lower battery costs is sufficient. However, with higher system performance, more additional functionalities such as boosting, e-creeping, sailing and all-wheel drive will be possible.

Although the electric drive system can be placed in the positions P2, P3, and P4 as shown in (Fig. 3), a one-size-fits-all e-drive product will not meet the needs of the market because different applications have different customer requirements, such as power, cost, and package. Therefore, a smart concept based on modularization is required in order to build a foundation for different requirements.

Furthermore, the e-motor and inverter in e-drive systems are not off-the-shelf products, even though they have been through almost 200 years of evolution. The requirements for automotive applications is completely different from the requirements for industrial motors. Therefore, there is much room for technological innovation.

What applies to electric motors also applies to the entire powertrain. You can’t just take existing components off the shelf and combine them. The key consideration in each case is what specific properties the manufacturer is looking to offer in a particular model. There are several important aspects that developers can focus on:

- Costs and value-add
- Peak performance/continuous output
- Efficiency
- Space for installation/package
- Power density and/or weight
- Modularity and scalability

Figure 2
The CO₂ saving potential of 48V MHEV System, value-add on System level

Figure 3
Package Challenge for eDrive Systems
There are a wide range of options available to meet these different requirements, which conflict with each other in certain cases. The aim is to find the best possible overall system design from amongst the many options available. What is needed is the optimal combination of the required properties. To this end, Magna models the powertrain and narrows down the options in a multi-objective optimization.

For example, a multi-target optimization on the e-drive level always started with finding the most suitable solution for the electrical components. This requires a powerful toolchain operating several iteration loops in order to find a solution to the multi-dimensional optimization problem. (Fig. 4).

The 48 V onboard power supply, in combination with a 25 kW electric motor, offers added value that goes beyond lower emissions via regenerative braking. Depending on the configuration, there are other advantages, such as boosting, e-creeping, sailing with the engine off and of course all-wheel drive in P4 architectures.

However, the possibility to reduce the environmental impact while improving the overall ride quality is in direct conflict with the vehicle package. With the 7HDT300, Magna Powertrain has proven it is possible to resolve this conflict. The GETRAG seven-speed hybrid dual-clutch transmission that is supplemented with a 15 kW electric motor and an inverter has the same installation length as the original non-electrified version. In the WLTP cycle, a vehicle equipped with the 7HDT300 consumes 14 to 16 percent less fuel.

From the perspective of Magna Powertrain, the transmission in combination with a 48 V onboard power supply is an excellent solution for a mild hybrid within the vehicle described above. But there is also another version of the 7HDT300 rated at 85 kW for plug-in hybrids with an electric motor up to 400 V.

With this combination, it is possible to achieve fuel savings of between 19 and at least 68 percent in the WLTP cycle and to drive solely on electric power even on the highway. No additional space is required for the transmission in this variant. All components are fitted within the same housing as the mild hybrid version.

A high packaging density is also an advantage in fully electric drives, which can be operated on their own or in combination with a combustion engine within a P4 hybrid system. Magna currently offers highly integrated eDrives in different performance levels from 70 to 140 kW, which can be combined in all kinds of architectures with ASM and PSM motors.

**From 0 to 100 km/h in 2.5 seconds**

The potential offered by the concept could be demonstrated by the company with a Tesla Model S that was stripped of its drive and fitted with three highly integrated eDrives, each rated at 140 kW peak performance and 3,300 Nm torque (Fig. 5).
Two drive the rear wheels while one drives the front axle. The car can accelerate from zero to 100 km/h in 2.5 seconds. The improved handling is most noticeable in corners. Because the rear drives can deliver different torque to the wheels via torque vectoring, the car travels almost as if it were on rails.

These examples show what challenges can arise in powertrain electrification and how they can be resolved. A company must be able to cope with different requirements and solution options, ranging from the mild and plug-in hybrids to the fully electric drives, for all performance categories, from small cars to premium SUVs, and for different configurations, from positioning the electric motor inside of the transmission (P2a) to placing it on the axles (P4). The closer it is to the wheel, the higher the amount of energy that can be recovered and the greater the efficiency. This general rule of thumb applies even for 48 V systems.

Is it possible to manage this diversity in terms of organization, and is it economically feasible? Magna Powertrain believes the answer to these questions is ‘yes,’ and it has developed a modular, scalable platform strategy for electrical drives and hybridization that covers all areas of the aforementioned solution space (Fig. 6).

Thankfully, not every combination requires a completely different set of components (Fig. 7).
Some of them can be reused (green), while others require certain modifications (yellow). Electrification does not stop at the drive. Many components that used to be mechanically operated by the combustion engine will run electrically in the future, including pumps and cooling units. Magna Powertrain also offers such components for the 48 V onboard power supply.

Transmissions are a significant part of Magna Powertrain’s business. The fear that they may no longer be needed due to shift towards electric vehicles will not come to pass. Non-hybrid combustion engines now have up to nine gears. In mild and full hybrids it still makes sense to have seven speeds. With the new type of the dedicated hybrid drive (DHT), in which the electric motor is a substantial functional part of the transmission, it is expected that there will still be three to four gears. Battery-powered electric drives also benefit from having at least one extra gear. A two-speed gearbox increases the torque at low speeds or allows for the installation of a smaller electric motor. At high speeds the second gear shifts the load point to a more favorable efficiency range and could increase the efficiency of the system in such a way that a shifting system and a second gear are affordable. The interaction between the physical gears which would be needed for different architectures and degrees of electrification is illustrated in Fig 8.

To summarize: As the shift towards electrification gains pace, the design of powertrains will become significantly more complex. This opens up many new possibilities, from lower emissions to improved driving dynamics and greater comfort. This potential can only be tapped with modular and scalable components that serve many different requirements. Magna Powertrain has created a comprehensive product range to this end.
Great Wall’s 7DCT450 is the first dual clutch transmission to be entirely developed and built in China. We spoke to Lipeng Zheng and Gerhard Henning, both Great Wall, about the motivation and purpose of this in-house development, and specifics of the Chinese market.

Mr Zheng, Mr Henning - what are the highlights of the 7DCT450?
Henning: The 7DCT450 is a very compact, reliable design that’s suitable for nearly all our vehicle platforms and is configured for high production volumes. It has a wet clutch with hydraulic actuation and a high-performance cooling system for better control and greater reliability throughout its lifecycle. And it’s really important for us that we’re best in class for NVH too.

Why is NVH so important for you?
Zheng: NVH is a big requirement in China. We compared our own development with various automobiles from European OEMs. They were the benchmark, and our goal was to surpass them. Our Chinese customers are very sensitive about this. Furthermore, we see our clutch cooling system as a big highlight, we spent a lot of engineering and testing on it. We have some heavy SUVs. It may not be apparent at first glance, but some of them are heavier than a Mercedes GLE for example. And the topography in China is very challenging too, so we need a really robust solution for clutch cooling. Overall, the expectations of Chinese customers have risen sharply in recent years.

You use a dual pump system with one mechanical and one electric pump. What’s the advantage?
Henning: We actually have two versions of transmissions: one with just the mechanical pump, the other with the dual pump. The mechanical pump is sufficient in conjunction with the 1.5 liter engine, where towing capacity is no issue. For the 2.0 liter engine we fit the electric pump too, so we can vary the oil volume flow more flexibly. We’ll also use the electric pump for hybrid drives, to provide hydraulic functionality when the ICE is not running.
Why did you decide to develop in house?
Henning: In the past Great Wall Motors used to purchase automatic transmissions from different suppliers like Getrag, ZF and other Asian OEMs. But considering our large automatic transmission production volumes in the next years – one million per year and more – we need faster time-to-market. We need full control over production capacity, transmission technology including software and calibration, as well as engine, transmission and vehicle application – and finally quality and cost. So it was a strategic decision to develop this transmission in house. For small production volumes, for example our Haval H8 and H9, we think it still makes sense to rely on suppliers.

Which components are particularly important to develop in house, and what do you still outsource?
Henning: In the long term I think we’ll gradually develop and manufacture more components ourselves. We can save a lot of money and improve time-to-market. But as I said, that’s also a strategic management decision and requires a business case.

You can benefit from in-house economies of scale on components for manual shift and dual clutch transmissions. That’s another point in favour of DCTs. Where do you still see a need for ATs with torque converter?
Henning: We prefer AT automatic transmissions with torque converters for longitudinal applications like heavy vehicles and for higher torque and high towing capacity requirements. ATs are more convenient in that constellation, and the torque converters are less sensitive with regard to slip of the launch element; by the way, their torque multiplication is generally beneficial during start-up. In the USA for example, towing capacity is something you absolutely have to offer. People there have luxury automobiles, they own boats – ATs still have their place for applications like that.

Great Wall has a strong focus on SUVs. How do you square that with the call for significantly lower emissions, which is very strong in China too?
Zheng: We have to make a clear distinction in China too. The quota system, which requires a set share of EVs and plug-in hybrids, and CO2 are two different issues. For SUVs, first we need components that are more efficient in general, such as our new DCT. As a next step, we need to offer more electric drives. SUVs are very popular for drivers in China now. You have more space, you sit higher and they’re very practical – especially in challenging road conditions. And then, drivers just like them. It’s the same as in North America and Europe: customers want SUVs.

What’s your preferred hybrid architecture in terms of e-motor positioning?
Henning: At the moment we prefer the P4 e-motor positioning. We presented a P4 solution at IAA 2017 in our Wey P8 model and now we’re preparing the market launch. Package-wise, the P2 constellation is more challenging in our vehicles, because we do not want to have certain limitations. For high voltage hybrids we’re currently working mainly on P4 drives. But we can imagine P2 for our future vehicles platforms too.

What do you think of P2/ P4?
Henning: The functionality of this arrangement is very attractive, especially for high performance and luxury vehicles.

The quota system in China mainly promotes pure electric and plug-in hybrids. What are the chances for 48V?
Zheng: The technology is interesting, we’re working on it. We need all the different solutions. 48V hybrid is not the solution for the quota system, but it can make an important contribution to reducing CO2 emissions on a large scale. China too needs technologies that customers can afford.

Interview: Gernot Goppelt
WE KNOW WHAT DRIVES SUCCESS

Schuler – your expert in design and process technologies for the manufacture of complex stamping parts.

The powertrain is the heart of every car, which is why reliable components are essential for every engine. Especially in times of electrical and hybrid vehicles, Schuler wants to contribute the knowledge in forming technology to your future generations of powertrains for electrical and hybrid drives.

The Schuler tool and die shop helps you with its expertise in parts design, die engineering, manufacturing and tryout of dies from the very beginning to ensure the quality of your gear parts and therefore the vitality of the vehicle. Together with the tool and die shop of Aweba, we are able to offer both know-how and efficiency in the design of parts and dies for the powertrain.

We are looking forward to facing your challenges.
The Importance of Rheology and Viscosity Index Improver (VII) Selection in Passenger Car Efficiency

Boris Eisenberg, Global Product Manager, Engine Oils, Evonik Resource Efficiency

Introduction
Lubricants have always been the “lifeblood” of automotive vehicles, reducing energy losses in the battle against friction, preventing wear, and ensuring durability and longer vehicle lifetimes. For modern drive-trains, purposefully formulated lubricants are a vital design element. They enable high levels of fuel economy and powertrain efficiency in response to government mandates designed to protect the environment and limit global warming to an acceptable limit. Figure 1 shows the average fleet CO₂-emission (in g CO₂ per driven kilometer) since the year 2000 by region, normalized to the New European Driving Cycle (NEDC). If the goal for 2025 is set to 75 g/km, it would represent another improvement of 38% compared to that of 2015.

Original equipment manufacturers (OEM) have many technical options at hand to lower CO₂-emissions. They have been identified and listed by the International Energy Association (IEA) in 2012 and ranked by the cost that comes along for 1% improvement in fuel economy, as shown in Figure 2. Cost for full hybridization has been amounted to 110 Euro per 1%, while the equivalent lowering of 1% by optimized engine and drive-train lubrication accounts only for 8 Euro. The IEA stated that advanced drivetrain lubrication has the best cost/benefit ratio, when it comes to improving fuel economy.

Maintaining a good rheological profile, a term used to express the viscosity-temperature relationship of a fluid, in both the fresh and used oil, has been found crucial to improving the drivetrain efficiency and fuel economy. Oils with a good rheological profile have a high Viscosity Index (VI).

Rheology - essential to improving fuel economy
High viscosity creates a high resistance to flow of the lubricant and a significant amount of energy is spent to mechanically move it. Since...
this energy is spent on moving the lubricant, it can no longer be spent on moving a vehicle forward. However, if lubricant viscosity becomes too low, lubricating oil films on the parts surfaces become too thin. The result is high energy losses due to friction of insufficiently lubricated parts and abrasive wear, which also lowers the lifetime of the aggregate significantly. Therefore, keeping the lubricant viscosity within an acceptable range throughout a broad window of operating temperatures is an important factor in its design and development.

A recently developed class of Viscosity Index Improvers (VII): Evonik Oil Additives Comb Polymers.

The general VI-mechanism of Comb Polymers is illustrated in Figure 3. Comb Polymers’ performance characteristics are found in their two sub-elements: the backbone of the comb with its temperature triggered solubility and the side chains, which assure good overall solubility at all temperatures. Figure 4 illustrates the viscosity contribution of both a regular VII and a Comb Polymer as a result of temperature.

At low temperatures the backbone of the Comb Polymer collapses. It is only stabilized in solution by the side chains, which contribute little to thickening. As a result the contribution of the Comb Polymer to the viscosity of the oil solution is minimized. At high temperatures the backbone is solvated in oil, thickening the oil significantly. A regular VII cannot minimize its coil size as much as a Comb Polymer. If its main chain would collapse like the comb’s backbone, it would precipitate out of solution and create gel throughout the oil, deteriorating low temperature performance rather than improving it.

The VI-advantage of the Comb Polymer is shown in Figure 5. The graph shows an ASTM D341 like plot of two SAE 0W-20 formulations and that of the respective base oil. The plot shows linearized viscosity as a result of temperature. Both SAE 0W-20 formulations contain the same type and amount of performance package, have the same base oil mix and have both been adjusted to the same high temperature, high shear viscosity (HTHS150) of 2.6 mPa·s at 150 °C, differing only by the type of VII. At lower temperatures the viscosity of the Comb
Testing was conducted according to three test cycles – New European Driving Cycle (NEDC), World Harmonized Light Vehicles Test Protocol (WLTP) and the US EPA Federal Test Procedure for city driving (FTP75). Each test cycle differs significantly regarding test time, average speed, load and oil sump temperature, both on average and course of temperature over test time. It was expected that the absolute fuel economy number would differ, and that the advantage of the high-VI fluid could be demonstrated in each of the cycles.

Table 1 shows the rheological details of the tested oils. Figure 6 illustrates the low and the high temperature rheological benefit. The excellent VI-performance of the Comb Polymer can be seen by comparing specific data in table 1. The relatively high SSI of the standard VM requires formulation of the respective fluid to relatively high pre-shear viscosities, otherwise the after shear limit for viscosity at 100 °C couldn’t be met, as specified by SAE J300. Even though both candidates provide equivalent “protection”, there is an obvious rheological benefit for the Comb Polymer based fluid, with lower HTHS100, HTHS80 and KV40. These lower viscosities translate directly to minimized churning losses and higher engine efficiency.

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“reference" formulation, a fluid with exactly the same base oil mix and DI-Additive chemistry, only the VII being different. Significant fuel savings of up to 1.6% are achievable within the same viscosity grade.

**Chassis dynamometer tests on SAE 5W-30 and SAE 0W-20 formulations**

Two main goals were set: confirming the general findings of the engine bench dynamometer with a different engine on the chassis dyno, and demonstration of fuel economy benefits of the same VII-Additives in a lower viscosity grade. The same SAE 5W-30 fluids as used in the engine bench study were run on a chassis dyno test. In addition, two SAE 0W-20 oils were formulated with the same conventional VM and the same Comb Polymer that were used previously. Details on the formulation and its properties are shown in Table 2 and Figure 8.

Fuel Economy measurements according to the NEDC protocol were run at ISP Salzbergen on an Opel Astra Sports Tourer, with a 1.4 liter turbo charged, direct injected gasoline engine. All tests were run on the same MAHA-AIP chassis dynamometer with Horiba gas analyzers and the same operator. The same batch of EU5 reference fuel was used for all tests. A baseline oil was run before and after the candidate to assure a constant measurement. As a baseline oil, the same OEM recommended service fill SAE 5W-30 formulation was used. Repeatability of all tests was good with max 0.3% (with regard to average fuel consumption for the base line oil). Results of the chassis dynamometer study are shown in Figure 9.

Significant fuel economy advantages were demonstrated for high VI Comb Polymer formulations over conventionally formulated oils. On the chassis dynamometer test the high VI SAE 5W-30 oil performed 0.6% better with regard to fuel consumption than the comparable reference oil.

Lowering the fluid viscosity can be an effective measure as shown by the result of the SAE 0W-20 oil formulated with a conventional VM. This low viscous fluid performed 1% better in terms of fuel consumption compared to the SAE 5W-30 counterpart, formulated with the same VM. However, adopting Comb Polymer technology can boost fuel economy by another 0.8% in the same grade. The high VI SAE 0W-20 formulation performed 1.2% better than its SAE 5W-30 counterpart and 1.8% better than the SAE 5W-30 oil formulated with the conventional VM. The chassis dynamometer results compare with results obtained from the fired engine bench test, despite test method and engine type being different.

**Summary & Conclusion**

Lubricants can contribute to limiting CO2 emissions from passenger cars and help limit global warming while meeting strict government mandates. Special attention was paid to the fluid viscosity and the importance of the VI and its effects on fuel economy. Comb Polymers enable formulators to design highly fuel efficient engine oils. The potential for fuel savings was demonstrated in several fired engine bench and chassis dynamometer tests and different fuel economy test cycles. Comb Polymers can reduce the fuel consumption by 0.6 – 1.6% within the same SAE-grade of the engine oil, when comparing to standard VM technology. Therefore significant fuel savings can be achieved without lowering the lubricant viscosity grade and without compromising durability of the engine hardware.

---

<table>
<thead>
<tr>
<th>VI</th>
<th>Standard VM</th>
<th>Comb Polymer</th>
</tr>
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<tr>
<td>DI-Additive (GF-5) %wt.</td>
<td>8.9</td>
<td>8.9</td>
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<tr>
<td>Group III base oil mix %wt.</td>
<td>85.1</td>
<td>86.9</td>
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<tr>
<td>HTHS 150°C mPa·s</td>
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<td>2.61</td>
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<tr>
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<td>8.01</td>
<td>8.24</td>
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<tr>
<td>HTHS 100°C mPa·s</td>
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<td>5.25</td>
</tr>
<tr>
<td>KV100°C mm²/s</td>
<td>8.40</td>
<td>7.73</td>
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<td>248</td>
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<tr>
<td>CCS -35°C (0V) mPa·s</td>
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<td>452</td>
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<td>Noack %wt. loss</td>
<td>11.4</td>
<td>10.6</td>
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<tr>
<td>KV100°C sheared mm²/s</td>
<td>7.6</td>
<td>8.03</td>
</tr>
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</table>

Table 2: Data of tested oils.
Development of Chain CVTF

Toshiaki Iwai, Drivetrain Lubricant Team Leader, Idemitsu Kosan Co., Ltd & Masato Ogawa, Subaru

Abstract
In the area of transmissions, continuously variable transmissions (CVTs) have been adopted for cars with various engine displacements mainly in Japan and North America because of their better fuel economy and smooth shift feeling.

Continuously variable transmission fluids (CVTFs) with lower viscosity and optimal friction property for chain and pulley will be effective for improving fuel saving performance in CVT.

In this study, compared with a market chain CVTF, the developed oil had a lower viscosity, a higher metal friction coefficient, and higher clutch transmission capacity, while its anti-seizure property was better than a market chain CVTF. As to higher metal friction coefficient, small islands were observed on friction surface by Atomic Force Microscopy (AFM). It is supposed that those islands promote a shift to the boundary lubrication regime, contributing to a higher friction coefficient. The developed oil containing some additives demonstrated 10% higher variator torque capacity compared with a commercial CVTF.

1 Introduction
Recently, awareness of global environmental problem has increased. Particularly due to issues of global warming and depletion of fossil fuels, automobile manufacturers are trying to reduce emission gases such as CO₂ and increase the fuel economy of automobiles. In the area of transmissions, continuously variable transmissions (CVTs) have been adopted for cars of various displacements mainly in Japan and North America due to their higher fuel economy[1] and smooth shift feeling.

Chain CVTs as shown in Figure 1 have excellent flexibility relative to push belt CVTs. Due to their wide range of transmission gear ratios, excellent transmission efficiency (about 5% higher than that of push belt CVTs)[2], and their ability to increase torque capacity by increasing chain width, these systems have attracted attention as the next generation of CVTs and are seeing practical application. They are also believed to increase fuel economy (10% relative to that of 4 speed automatic transmission cars)[3].

Chain CVTs transmit power via contact between the chain pin and the pulley, and are characterized by having higher surface pressure than push belt CVTs. Therefore, continuously variable transmission fluid (CVTFs) is required to have high anti-seizure property and metal friction coefficient. [4][5]

This paper describes the performance of CVTFs developed exclusively for chain CVTs.

2 Properties of CVTF
In CVTFs, various kinds of additives are blended in base oil to meet required performances. For reducing viscosity of fluid, the selection of base oil and viscosity index improver (VII) is important. To higher metal friction coefficient, detergent, dispersant and extreme pressure agent will be contributable.

The general properties of chain CVTFs. Kinematic viscosity, an important physical property of CVTFs, is 7.1 mm²/s at 100 °C lower than that of market chain CVTFs (7.5 mm²/s). This would suggest some effect in terms of fuel economy effects due to the reduction in agitation loss.

3 Evaluation of various performances
3.1 Evaluation of metal friction coefficients
When examining a chain CVT, the relative sliding between the chain and pulley, which it the area that serves as the power transmission portion, gradually increases as the input torque increases. Because a chain CVT transmits power between the chain and the pin and pulleys, CVTFs is required to have a higher metal friction coefficient.
In this study, the metal friction coefficient was measured by using a block on ring tester as shown in Figure 2. This type of tester is widely used for conducting evaluations. The friction characteristics between the metals were evaluated by varying the sliding speed from 0.02 to 1.0 m/s with a load of 1112 N and a constant oil temperature (110 °C) under the conditions listed in Table 2. [6] Figure 3 shows the results. The developed oil contains a calcium detergent and a boron type dispersant to increase the coefficient beyond that of market chain CVTFs.

Figures 4 and 5 are photographs of wear scars on test pieces taken using Atomic Force Microscopy (AFM) after the block on ring test. The sample with a low friction coefficient has a smooth appearance (Figure 4), while on the sample with high friction coefficient small islands were observed. (Figure 5) It is supposed that those islands promote a shift from the fluid lubrication area to the boundary lubrication area, contributing to a higher friction coefficient. [7]

### 3.2. Evaluation of anti-seizure property

One of the primary performance requirements of Chain CVTFs is that the friction coefficient between the metals of the chain and pulley must be high. In addition, Chain CVTFs must also work with the other lubricated parts. Along with the high friction between metals, the anti-seizure property of the oil solution is also important because the chain CVTs has a single point of contact between the pulleys and the pin, and thus has higher surface pressure compared to belt CVTs, which have a linear contact. Thus, CVTFs for chain CVT is required to have high anti-seizure property.

The anti-seizure property was evaluated by using a pin-on-V block type friction tester (the FALEX tester) as shown in Figure 6. To test pieces mimicking a real machine, with the pin revolving at a constant speed (0.096 m/s), loads from 0N to 10 000 N were applied at an oil temperature of 110 °C, and the pieces were observed and judged for the presence or absence of seizing. Figure 7 shows the results of the test. The friction force was monitored while the load was being increased, and the load at which the friction force suddenly increased was deemed to be a seizure load.

The developed oil achieved high anti-seizure property because it contained a sulfur-phosphorus extreme pressure agent, which provides excellent extreme pressure properties.
When using the developed oil for the test chain CVTs, post-test surface analysis of the test pieces using. We examined the correlation of the anti-seizure property and friction surfaces by using the information about the composition inside the lubrication film, which was obtained by using analysis methods that employ beams, such as Electron Probe Micro Analysis (EPMA) showed the presence of phosphorus and sulfur all over the surface, as can be seen in Figure 8. It is supposed that formation of such a stable phosphorus and sulfur film resulted in excellent anti-seize property.

3.3 Chain box tester

For this development a “chain box tester” shown in Figure 9 was fabricated. This consisted only of the pulleys and the chain CVTs in order to measure torque capacity. It enabled us to successfully measure the torque capacity of lubricants with high precision. Figure 10 shows the torque capacity limits as measure with the device.

The developed oil was determined to have increased torque capacity (by 10% relative to the market oil).

4 Conclusions

In this study, new techniques elucidate for chain CVTF. Compared to market chain CVTF, the developed oil had lower viscosity, a higher metal friction coefficient, and higher clutch transmission capacity, while it’s anti-seize property was comparable to that of market chain CVTF. As to higher metal friction coefficient, subtle projections were observed on friction surface by Atomic Force Microscopy (AFM). It is supposed that those projections promote a shift from the fluid lubrication area to the boundary lubrication area, contributing to a higher friction coefficient. The developed oil containing multifarious additives demonstrated 10% higher torque capacity compared with a commercial CVTF.

References

Electric Oil Pumps for future mobility

Pump and actuation solutions for:

- DCT, AT, CVT, MT, BEV and DHT
- Parking lock (x-by-wire)
- Transfer case and AWD coupling
- Limited slip differential

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We look forward to seeing you at:
12th International CTI Symposium USA | Novi, MI
Diamond Center at Suburban Collection Showplace
May 16 – 17, 2018 | Booth 34
Report

Rods to Carbon Neutral Mobility

The question of which energy sources we can provide efficiently at all is as important as the respective benefits of conventional, hybrid and electric drives, if not more so. Wolfgang Warnecke, Shell and Peter Gutzmer, Schaeffler, advocate a differentiated assessment from well-to-wheel, or even beyond.

Gernot Goppelt, CTI Correspondent

An integrated view of mobility

Tomorrow’s mobility calls for an integrated view of energy and drive options. At the CTI Symposium 2017 in Berlin, that insight prompted Dr Wolfgang Warnecke (Shell) and Prof. Peter Gutzmer (Schaeffler) to deliver a shared lecture that covered different solutions’ efficiency completely from well to wheel.

Warnecke sees a historical precedent for the use of non-fossil energy sources: “A long time ago, humans lived from biomass before the use of fossil energy sources became widespread.” However, he noted that the use of renewables is already steadily growing and believes we will no longer use fossil-based energy in the 21st century – a case of ‘back to the roots’. But what does the road there look like? Given that even regional requirements vary greatly, Warnecke thinks we will need different solutions. Today, for instance, the share of transport-relevant CO2 emissions is relatively low in China and relatively high in the West, yet local emissions are far higher in China than, for example, in Germany. As a result, Warnecke says we must distinguish between urban and overland applications, and hence between locally active pollutants and CO2 emissions.

Transition to renewable energy

An interesting recent trend in Germany is that gasoline consumption has fallen due to more efficient drives, while diesel consumption is up slightly due to the trend towards bigger automobiles and higher transportation figures. Natural gas (CNG) is actually ‘the best fossil fuel’ yet still accounts for less than one percent of consumption (LPG at least manages 2 percent). But as Warnecke pointed out, an incredible transition to e-mobility with renewables is now beginning. One driver is cheaper electricity; photovoltaic power still costs around 5 dollars/kWh, but some calls for proposals are already in the region of 1 to 2 cents. So we will have lots of cheaper renewable electricity, and the question will be “How do we get this to the right place at the right time – and how do we use it for e-mobility?”

“We should think in terms of scenarios and systems and factor in political and social changes in order to shape and not be shaped”
Aside from direct use for battery electric drives, Warnecke sketched out three paths for fuel production: creating hydrogen via electrolysis, then creating methanol or liquid fuels in derivative downstream processes while capturing CO₂, mainly from the atmosphere. Warnecke believes hydrogen makes sense for trips of over 600 km due to its high energy density, saying it remains to be seen whether regional markets in California, Japan and Central Europe will accept the technology.

Energy density vs. process efficiency
Compared with batteries (ca. 2 MJ/kg) or methanol (ca. 8 MJ/kg), e-fuels have an even better fuel density of over 30 MJ/kg, Warnecke made clear. Also, drivers can refuel with methanol and e-fuels in minutes, and e-fuels are very easy to store and transport. But in a well-to-wheel assessment — which covers efficiency both during operation and when producing the energy source — that picture is basically reversed. According to Shell, battery electric then achieves 72 percent, while fuel cell automobiles score 37 percent and regenerative diesel fuel manages just 12 to 17 percent.

This sobering balance sheet instantly suggests that battery electric drives would actually be ideal if (only) we could store and transport electricity as flexibly as fuels. “Yet we see scenarios with an increased power demand, while renewables generate practically zero.” While solutions such as pump storage or smart grids cannot compensate for this sufficiently today, Peter Gutzmer foresees more flexibility in future.

He sees a second challenge if well-to-wheel assessments were even replaced with cradle-to-grave, which covers battery production and disposal too. In that case, a Tesla Model S performs little better than a comparable Audi A7 diesel. The high demand for raw materials such as lithium and cobalt, which are also energy intensive to obtain, was also a factor.

70 percent hybrid drives in 2030
Summing up, Gutzmer said “We have no solutions today for totally CO₂-free mobility.” Because of this he expects combustion engines to play a big role for the next 10 to 15 years at least, even though Schaeffler’s calculations were based on an ‘accelerated scenario’ that assumes rapid electrification growth. Under this model, around 70 percent of new automobiles would still have an ICE in 2030 (40 percent of them hybrids, including plug-in hybrids), while battery electric automobiles would account for around 30 percent. Requirements would vary strongly, however — for example with more local emissions-free drives in cities due to legislation, and non- or less electrified drives in rural regions.

Hence, the majority of solutions would involve hybrid drives, and “we need to optimize this configuration”. Europe and China, and later the USA, would be the market drivers. Due to the broad range of requirements, Gutzmer believes we should think more strongly in terms of scenarios and systems and factor in political and social changes “in order to shape and not be shaped.” He said the first steps for ICEs involve topics such as variable compression and cylinder deactivation, as well as improved thermal management particularly with hybrids. In hybridization, Schaeffler expects strong growth in 48V solutions first (up to 2025), and plug-in drive solutions for local emissions-free mobility later. He also noted that we ‘could and should’ include manual transmissions with an e-clutch in the electrification chain as a highly affordable hybridization option.

Modular system for parallel ecosystems
Schaeffler supports a modular kit system for the various requirements of electrification. In addition to widespread P2 solutions, he said this should still include hub motors, which are better for ‘people movers’ because they need no space for axle constructions or central power units. In the long term, Gutzmer believes fuel cells are a good solution for long distance applications, explicitly including trucks. However, he sees the different solutions as members of a team, not competitors, saying the solutions we pick will depend on factors such as legal requirements, costs and application scenarios.

Summing up, the speakers agreed that no single solution has clear priority; we can achieve CO₂-neutral mobility either with battery electric automobiles, or with hydrogen or e-fuels. Hence, Gutzmer sees three ‘parallel ecosystems’ for industry to work towards, accompanied by ‚intensive discussion between society, automobile manufacturers, industry and of course politics.‘ Gutzmer would like politicians to measure success in terms of CO₂ footprint along the entire chain, not just tank-to-wheel results from a single technology.
Electrified Powertrains Demand New Test Methodologies for Advanced Materials

Polymer Selection Considerations for High-Temperature Electronics

E-Mobility is challenging engineers to identify more accurate test methods to ensure materials and components perform reliably at operating temperatures.

Global automotive OEMs are deploying a wide range of e-mobility technologies to ensure their next generation of passenger vehicles will be more fuel efficient and compliant with emerging CO2 emissions standards. Encompassing stop-start and 48 Volt electrical systems, traction motors, inverters and advanced batteries, these technologies have all prompted automotive engineers to seek advanced polymers able to meet more stringent design requirements imposed by increasing voltages, component miniaturization and tighter packaging spaces. Compounding the challenge for designers is the need to contain overall vehicle costs, while ensuring new polymer technologies can deliver reliable performance over the lifetime of new e-mobility systems.

In order to surmount these challenges, design engineers require a cost-effective test methodology to help them identify optimal polymeric materials for their electronic components, while taking into account key design criteria like operating temperature, chemical resistance and long-term heat exposure.

**Design considerations for polymeric material selection**

There are many factors that can affect the durability and service life of polymers used in automotive applications, including temperature extremes, electrical performance (e.g. dielectric strength and volume resistivity) and the chemical environment. Degradation caused by one or more of these factors can contribute to catastrophic failures and, consequently, must be accounted for when selecting the optimal insulating polymer for electronic components, such as sensors, connectors, terminals, bobbins, or magnet wire insulation.

Historically, polymer material suppliers have tested electronic properties like dielectric strength and volume resistivity at room temperature. OEM and Tiers usually request that the material supplier first condition polymer test coupons at their design’s targeted elevated operating temperature. After the coupon cools down, the sample is tested at room temperature; however, there are disadvantages to this approach. For example, it does not provide a clear understanding of how actual application operating temperatures influence a polymeric material’s electric performance. The outcome is that engineers need to extrapolate expected electric performance at their desired elevated temperature, which makes it difficult to predict the expected life of electronic components in the operating environment of the finished application.

Through work with an industry-leading automotive OEM, Solvay Specialty Polymers has defined test methods wherein dielectric strength and volume resistivity can be measured at elevated rather than room temperatures. The test methods developed are consistent with the International Electrotechnical Commission’s (IEC) global standards. The key objective was to align the electrical testing protocol with the anticipated operating environment of the electronic component, thereby producing a more reliable predictor of long-term component performance.

Solvay tested a range of its specialty polymer materials including: Amodel® polyphthalamide (PPA), Ryton® polyphenylene sulfide (PPS), KetaSpire® polyetheretherketone (PEEK) and Veradel® polyethersulfone (PESU) at temperatures ranging from 100 to 250 °C, depending on the material. Solvay tested each material’s exposure to automatic
transmission fluid (ATF) at 150 °C for duration of 1,000 hours. By aligning more closely with the operating requirements of finished designs, this newly established test protocol provides engineers with a more accurate method to understand how polymer electrical insulation will perform in their applications.

### 48 Volt: Selecting the optimal material for ISBG rectifiers and voltage regulators

A key enabler for hybrid vehicles is the use of 48 Volt technologies, including electrically driven superchargers, integrated belt starter generators (ISBG) and electronic brake boosters. The use of ISBGs, for example, increases engine performance while reducing both fuel consumption and CO2 emissions. ISBG components typically fabricated from polymer include rectifier bridges and voltage regulators.

Ryton® PPS is a strong candidate for these components depending on their thermal, electronic and dimensional stability requirements. PPS provides long-term temperature performance up to 200 °C, as well as best-in-class dimensional stability for parts with tight tolerances and complex geometries. Additionally, PPS is inherently flame retardant with a 94 V-0 flammability rating from Underwriters Laboratories (UL).

Figures 1 and 2 show the exceptional dielectric strength and volume resistivity of 40 percent glass-filled Ryton® R-4-200 PPS which, even when fluid aged can perform at temperatures up to 200 °C.

### Traction Motors: Selecting the optimal material for magnet wire insulation & electronic components

Traction motors, or e-machines, play a critical role in the deployment of e-mobility strategies. OEMs and Tiers are both designing next-generation e-machines to power hybrids, plug-in hybrids, battery electric vehicles and fuel cell vehicles of the future. Designers are challenged with reducing the weight and packaging space of these components, while increasing their power and torque.

Another key challenge is to identify material solutions to insulate the magnet wires of traction motors at temperatures higher than what previous generations endured. Voltage requirements are starting to exceed 650 V, which requires polymeric solutions that can withstand operating temperature above 220 °C while maintaining electrical property performance. Additionally, the polymer must be robust enough to withstand harsh bending operations in manufacturing and provide chemical resistance to cooling fluids such as ATF.

KetaSpire® PEEK allows for the use of extrusion technology versus the traditional process of using a solvent-based insulating layer like enamel, which is dip coated. Extrusion also provides the added benefit of being a more efficient manufacturing process versus solvent-based dip coating. Extrusion enables motor designers to optimize the thickness of the insulation layer, thereby increasing the slot fill. Slot fill optimization can result in increased torque and power as well as the potential to down-size the motor, reducing its weight and volume.
The data in Figure 3 reveals the outstanding dielectric strength of KetaSpire® KT-880 PEEK, with the ability to perform up to 250 °C whether or not it has it is fluid aged.

The data in Figure 4 highlights the robust dielectric strength of KetaSpire® KT-880 PEEK, with the ability to perform up to 250 °C with and without ATF exposure.

Depending on the design of the traction motor, there are other polymeric electronic components that need to be considered as well, such as connectors, bus-bars, terminals, sensors, and solenoids.

Amodel® PPA provides engineers with a suitable material option, depending on their design’s temperature and electronic requirements. PPA offers improvements in comparative tracking index (CTI), as well as thermal shock resistance. Solvay has recently developed a portfolio of Amodel® AE electrical friendly PPA grades that can be considered for e-machine electronics. These grades are organically stabilized, halogen free and extremely resistant to the galvanic corrosion of imbedded metallic terminals.

The table in Figure 5 compares two grades of PPA. Amodel® AE-4133 PPA (33 percent glass fiber-reinforced) is an electrical friendly, hot water moldable grade that delivers faster cycle times and excellent soldering assembly capabilities. Amodel® AE-8935 PPA (35 percent glass fiber-reinforced) is a hot oil moldable grade that offers robust mechanical strength and lower moisture uptake. Both grades provide excellent performance for thermal shock environments.

Like Ryton® R-4-200 PPS and KetaSpire® KT-880 NT PEEK, Amodel® PPA was tested and the results of dielectric strength and resistivity at temperature are shown in Figures 7 and 8.

![Figure 3 KetaSpire® KT-880 NT PEEK dielectric strength at temperature (V/mm)](image)

![Figure 4 KetaSpire® KT-880 NT PEEK volume resistivity at temperature (Ω-cm)](image)

![Figure 6 PPA thermal shock comparison](image)
Advanced batteries: Selecting the optimal polymer sensor material

The use and deployment of Li-ion batteries is essential to the success of hybrid and electrical vehicles. One of the key challenges engineers confront is how to design cost-effective systems to cool the batteries. Temperature sensors are necessary to monitor the effectiveness of battery cooling. But, unlike other types of sensors, the devices for batteries may operate in a dry environment at operating temperatures that far exceed the glass transition temperature (Tg) of semi-crystalline polymers like PPA and PPS that are used for sensors.

Amorphous polymers, like Veradel® PESU, are best suited in this case. With a Tg of 225 °C, Veradel® PESU can maintain mechanical and electrical properties up to 200 °C. This polymer also offers excellent dimensional stability, which is critical to maintain the sealing performance of the O-ring seal used in the sensor.

The data in Figures 9 and 10 show the exceptional dielectric strength and volume resistivity of 30 percent glass filled Veradel® AG-330 PESU, with the ability to perform up to 200 °C with ATF fluid aging and without ATF exposure.

Conclusion

With the emergence of e-mobility technologies, engineers are actively seeking solutions to address their new design challenges. Solvay Specialty Polymers collaborated with an industry-leading automotive OEM to define a test method allowing measurement of dielectric strength and volume resistivity at a range of elevated temperatures instead of room temperature. This data enables engineers to better account for the performance and life expectancy of their components. Additionally, by offering a wide portfolio of polymer solutions, including Amodel® PPA, Ryton® PPS, KetaSpire® PEEK and Veradel® PESU, Solvay provides engineers with the ability to optimize their material selection to their specific design criteria.

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CTI Trend Barometer

Artificial intelligence, electrification, fuel cells and many more: industry is driven by technology trends and developments - the main results of a survey during the CTI Symposium.

**Does a further invest in optimizing combustion engines pay off, or does it make more sense to focus on electric drives?**

- 18.6% Yes
- 14.0% No
- 67.4% Both

**What kind of drive system will probably be in your car in 15 years?**

- Conventional drive (incl. 48V) 13%
- Hybrid drive (excl. 48V) 34%
- Pure battery electric drive 30%
- Fuel cell drive 9%
- I will not own a car anymore 14%

**Will OEMs transform to mobility providers and abandon part of the hardware business to suppliers?**

- 30.2% Yes
- 18.6% No
- 51.2% Mobility concepts will be additional
The automotive ever since. These are Berlin (Dec. 2017).

**Are (climate-neutral) E-fuels a realistic option on large scale?**

- **23.5%** Yes
- **16.5%** No
- **60.0%** For certain use cases

**Artificial intelligence (AI), increased by cloud computing, is entering cars. Are you working on that in your company and planning series applications?**

- **22.1%** Yes
- **17.4%** We partner with specialized firms
- **60.5%** No

**What kind of transmission will have disappeared from the global market in 15 years?**

- **Manual Transmission**: 29%
- **Automated Manual Transmission**: 19%
- **Dual Clutch Transmission**: 3%
- **Automatic Transmission**: 4%
- **Dedicated Hybrid Transmission**: 3%
- **Continuously Variable Transmission**: 10%
- **None of the above**: 33%
Torque Sensors for High Volume Production Applications

Methode Electronics’ achievements in magnetoelastic sensor technology enable torque measurements in previously unfeasible serial production applications.

- Julius Beck, Engineering Manager MST, Methode Electronics International
- Johannes Gießibl, Senior Magnetoelastic Project Manager, Methode Electronics International

Misconception in the Market

One common misconception still held by most people in the automotive industry is that measuring torque accurately and reliably is too expensive for high volume production applications. This misconception originates largely from the most commonly used technology in the automotive industry to measure torque – strain gauges. Strain gauge type sensors require extensive manual labour during application, fault susceptible telemetries and recalibration due to aging effects, making them expensive and difficult to integrate. Consequently, the strain gauge type sensors are more suitable for use in test benches and prototype vehicles, rather than high volume production applications. In many applications, direct torque measurements essential for closed loop control systems (e.g. transmissions) have been replaced by complex and often inaccurate mathematical models, which only estimate the true torque value.

Advanced magnetoelastic torque sensors eliminate these inherent drawbacks of the strain gauge technology, while matching or exceeding it in performance characteristics, such as accuracy, repeatability, linearity, bandwidth and long-term stability. The combination of a highly automated assembly process and large scale production facilities of these magnetoelastic sensors, allows for a low-cost torque measurement solution ideal for high volume automotive applications. These include many applications where it was previously uneconomical to measure torque directly and thereby giving up many potential application specific optimisations. Methode’s torque sensing technology is enabling manufacturers for the first time to realise these optimisations in high volume applications.

Technology Description

Magnetoelastic torque sensors make use of a physical phenomenon called the Villari effect, discovered in 1865 by Italian physicist Emilio Villari (1836–1904), which states that a ferromagnetic material will change its magnetic properties when subjected to a mechanical stress (e.g. due to an applied torque), creating a magnetic anisotropy. Ways to exploit this effect to measure torque have been researched for more than 30 years. One way is to magnetise a region of a shaft with two circumferential bands as shown in Figure 1.

This magnetic encoding takes place only once during production and remains inside the shaft for the lifetime of the sensor. In the stationary secondary part of the sensor, highly sensitive sensor coils are placed in close proximity of the magnetic bands around the shaft. These sensor coils pick up changes in the magnetic field emitted by the encoded shaft caused by an applied torque, creating the sensor signal. The relationship between applied torque and signal received by the sensor coils is linear, making any signal linearization unnecessary.

A sensor that consists only of a magnetised shaft and a stationary housing containing sensor coils and an electronics PCB creates a truly contactless torque sensor with unique benefits compared to other competing technologies:

- Non-contact: There is nothing attached to the shaft and no other modifications are necessary. In contrast to strain gauges, magnetoelastic sensors do not require any fault susceptible telemetry or adhesives that cause long-term instabilities and have a limited lifetime.
**Durability**: The sensor can be completely encapsulated and is suitable for harsh operating environments. It can be submerged in caustic liquids, exposed to high temperatures (up to 210 °C) and withstand continuous and strong vibrations. It is insensitive to dirt.

**Performance**: Accuracy, repeatability and linearity are comparable to strain gauge sensors. The magnetoelastic sensors have an outstanding dynamic response in comparison to any other known torque or force sensing technology. This extremely high signal bandwidth enables detection of engine cylinder misfiring (see Figure 2) and accurately resolves any other high frequency signal.

**Minimal Packaging Requirements**: Small packaging and a flexible design that can be optimised for axial or radial space constraints makes it easy to integrate the sensor.

**Certification**: ISO 26262 ASIL levels are achievable and have been in production for several years.

**No Cross-coupling**: In magnetoelastic sensors the torque/force measurements are completely decoupled, so that, for example, a torque sensor is not influenced by shear forces on the shaft.

**Long-term Stability**: The magnetisation is permanent and the calibration will remain constant over the lifetime of the vehicle. Using a gearbox mounted magnetoelastic torque sensor, a long-term stability of 480,000 miles was demonstrated. The sensor operated without fault or change in performance characteristics. The test was only stopped due to the wearing out of gear teeth in the gearbox and torque could no longer be transferred. Shown in Figure 3 are the test results regarding the deviation in sensitivity (± 0.5 %), offset (± 0.05 %) and hysteresis (± 0.1 %).

**Recent Advancements**

Through steady investments in R&D, Methode continues to make advancements in the magnetoelastic sensor technology, pushing the boundaries of sensor performance and robustness, further reinforcing its position as the technology leader.

One such achievement is the Dual-Dual sensor, which uses three instead of two circumferential magnetisation bands. The two sensor coil...
pairs share the central magnetisation band but each uses one of the outer bands, effectively creating two independent sensors. Achieving this redundancy is particularly relevant for safety critical applications.

The magnetic immunity (i.e. the rejection of external magnetic fields such as the earth’s magnetic field or application specific external magnetic fields) is critical in some applications and is already excellent in Methode’s sensors. However, enhancements in the production process of key components of the sensor, combined with up-to-date sensor electronics, improve the characteristic of magnetic immunity to external fields even further.

Innovations such as the Dual-Dual sensor, improvements in the production process and continuing R&D efforts have allowed Methode to overcome challenges of the technology and bring it to a maturity that competitors have failed to do.

**Industrial Scale Production**

The key element that has allowed Methode to make magnetoelastic sensors a serious competitor for strain gauge sensors is the industrialisation of the technology. The industrialisation of a product that used to be assembled in largely manual fashion has allowed Methode to produce in high quantities and at very competitive prices. The technology allows for a level of automation not possible with strain gauge sensors. Current production facilities are located in Malta, Belgium, China, USA, Canada and Mexico, having a combined capacity of over three million sensors per year, equating to more than 10,000 sensors per working day.

Figure 3  Long-term stability of sensor sensitivity, offset and hysteresis

Figure 4  Methode’s Production Locations
Current Application Examples
Albeit still being lesser known than strain gauges, the magnetoelastic sensor technology is already an established technology that has been proven in numerous high volume applications with millions of sensor out in the field today.

The magnetoelastic torque sensor technology is used in Electronic Power Steering (EPS) products with a total of several million units produced since 2009. Methode’s proprietary Dual-Dual-Band technology provides the necessary redundancy in this safety critical application. Additionally, high overload requirements make this a very difficult application for any sensing solution and magnetoelastic is the only one known to provide a solution for a non-compliant sensor setup removing mechanical complexity and thereby providing a much more direct steering performance and improved driving experience.

Another safety critical application where the magnetoelastic sensor technology has proven itself is ebikes and pedelecs. The direct and absolute measurement of the torque applied to the bottom-bracket by the rider, results in optimized motor control and smooth riding experience. Methode is exclusive supplier of torque sensors for the current market leader and a large number of other eBike motor and system suppliers.

Methode has also worked together with a major German supplier for the automotive and mechanical engineering industry supporting the design of an electromechanical anti roll stability control system. This system is designed to reduce the roll angle of large passenger vehicles at high cornering speeds, improving driving comfort whilst simultaneously increasing vehicle dynamics and safety. The system is mounted between the left and right half of the stabilising bars and can either stiffen or decouple the system depending on the driving conditions. The magnetoelastic torque sensor is the underlying sensor technology that updates the system’s control unit with real-time torque values within milliseconds. The system is used primarily in larger vehicles such as SUVs, with a total of about 100,000 vehicles on the road produced since 2015 and a maximum production capacity of 140k per year.

Further Applications
With the advent of autonomous driving more requirements where torque has to be measured are created. Electronic Power Steering systems that include a torque sensor (such as the previously mentioned system) will become ubiquitous as more and more cars are featuring some form of a lane keeping assist system or even more advanced autonomous features. As the human driver is taking on a more passive role, an important feedback loop is removed. To compensate this, the state of the vehicle has to be precisely monitored. For example, knowing the torque at each individual wheel can lead to advanced stabilising systems and prevent dangerous situations due to wheel slip. The competitive cost, robustness and small packaging requirements make the magnetoelastic sensor technology ideally suitable for such applications.

A calibration stable for the lifetime of the sensor and an accuracy that is high enough to allow detection of even the smallest changes in behaviour that would indicate a possible malfunction make magnetoelastic torque sensors an excellent choice when it comes to condition monitoring and predictive maintenance applications. A cost/performance chart comparing the magnetoelastic to other technologies is shown in Figure 6.

A unique and specialised application that Methode is developing involves the measurement of the forces exerted on a tow bar when pulling a trailer behind a vehicle. In this application, instead of measuring torque, the magnetoelastic technology is used to measure the vertical, horizontal and lateral forces the trailer exerts on the towing vehicle. These measured forces are used to calculate whether safe towing conditions are met and constitute a critical component of future stability control systems.

Conclusion
Due to their superior performance and competitive cost, magnetoelastic torque sensors represent the first viable high volume torque sensor product solution. Summarising the magnetoelastic sensor technology:

- **High Performance:** Meets or exceeds strain gauge performance characteristics
- **Low Cost:** Highly automated manufacturing brings cost down
- **Proven:** multiple high volume automotive applications in the field today
- **Easy Integration:** Small packaging requirements and no telemetry make integration easy

More Information
Do have a challenging application where you need to measure torque or other forces? Contact us today or visit us at Booth #08 to see how we can assist you! www.methode.com or email to johannes.giessibl@methodegermany.com
“The CTI Symposium is a Great Opportunity” for W.S. Tyler

What leads you to exhibit at the CTI Symposium USA?
W.S. Tyler is a leading manufacturer of woven wire mesh. Our products cover a wide range of industries including architecture, Oil & Gas, Mining and Automotive. In 2017, W.S. Tyler decided that they would like to find a way to better serve the automotive industry with our high quality customizable filtration products. W.S. Tyler’s parent company, Haver & Boecker, is located in Germany and has been successful in the automotive industry in Europe. We at W.S. Tyler wanted to mimic that success in North America. During the planning stages for this industry, Haver & Boecker shared their experience and success at CTI in Europe. It was from this information that W.S. Tyler decided to attend the show here in North America, hoping to have similar successes. The CTI Symposium is a great opportunity for W.S. Tyler to connect with key players in the automotive industry while positioning ourselves as a supplier of automotive filtration.

What did you do before to find a solution for these challenges?
W.S. Tyler’s first real push to enter the automotive market was in early 2017. Prior to that our focus had always been on other products and industries separate from automotive. We attended trade shows for those other industries as well as coordinating our marketing efforts (advertising in industry magazines, email blasts to targeted audiences, etc.).

How did the partnership with CTI start and how does it work in the following?
Once we determined that the CTI Symposium would be a good opportunity for our company and filtration products, our parent company helped us get our foot in the door with the CTI Symposium team. Haver & Boecker had built a relationship with the team through their own experience which helped W.S. Tyler to get set up for success at the 2017 show ourselves.

Were your expectations fulfilled during the exhibition?
We went into the show with two goals in mind, to get exposure in the automotive market and to make connections/contacts with leading companies and potential business opportunities. Our expectations were certainly fulfilled. Many great connections were made and compelling conversations were had. Our attendance at the show led to opportunities and relationships that are still being developed and cultivated months later. The CTI Symposium absolutely helped us make a strong entrance into the automotive industry.

How would you describe the CTI Mag as a marketing tool?
The CTI Magazine allows W.S. Tyler to display our capabilities and drive potential clients to our booth. This leads to constructive conversations, development of relationships, and business opportunities that can be carried out long after the show itself ends.

www.transmission-symposium.com
Global to Local

Feintool’s Worldwide Resources Deliver the Unique Manufacturing Solutions Customers Need

Lars Reich, Executive Vice President Sales & Marketing, Feintool US Operations, Inc.

With production facilities all over the world, it’s easy to break down big challenges into smaller, more digestible parts. That’s what happened when a U.S. gearbox manufacturer approached Feintool Tennessee with a request for a disc carrier.

To manufacture the automotive transmission part at high volumes, however, Feintool first needed to add forming press capacity. And to meet the customer’s requirements, Feintool would have just eight months to design, build, install and test the tooling, and then launch production. To make all of that happen on schedule, a team from Feintool Tennessee near Nashville collaborated with forming-tools specialists in Feintool's Obertshausen, Germany, location. Their shared project: Design and build a 12-station disc carrier in-tool roller transfer tool for a state-of-the-art, 1,600-ton direct servo transfer press.

Collaborating on In-Tool Roller Technology

Given the timeline and complex part design, Feintool leveraged the knowledge and skills of the forming specialists in its Obertshausen facility to design and build the 12-station disc carrier transfer tool, which forms all features inside the press. At the heart of the advanced tooling technology are three in-tool rolling stations for the pre-roll, roll and finish roll of the formed wall sections of the disc carrier.

To achieve the customer’s volume requirements, Feintool’s in-tool roller technology forms a net-shape disc carrier for automatic transmission or clutch modules in disconnecting all-wheel drive (AWD) systems in every press stroke. To complete other features, the Feintool teams designed and built nine additional tooling stations that form and coin, stamp oil holes, form the snap ring groove and size the component to length.

Direct Servo Transfer Press Technology

The direct drive servo press – custom-built for Feintool Tennessee – represents the latest technology available for net-shape component manufacturing and includes a number of unique features:

- Direct servo drive precisely adjusts slide motion profiles.
- Adjustable forming speeds guarantee a continuous production process with optimal forming capability.
- 18-foot (6-meter) press table accommodates multiple operations and increases volume.
- Bolster moves for quick die changes.
- High-speed, 3-axis CNC parts transfer system increases capacity.
- Additional hydraulic stations integrate fineblanking operations into transfer tools.
- High flexibility is designed for complex part geometries.

In every press stroke, Feintool’s in-tool roller technology forms a net-shape disc carrier for automatic transmission or clutch modules in disconnecting all-wheel drive (AWD) systems.
The commercial advantages of the in-tool rolling technology – compared to traditional “out of tool” secondary forming processes such as flow forming – are a clear game-changer when annual volume exceeds 100,000 pieces a year. The flexibility of the cold forming process enables Feintool to form and finish transmission components, among other parts, in a single press run. No secondary processing is required.

Solving Local Manufacturing Challenges with Global Expertise

Achieving such speed and efficiency is not easy. Among the design challenges the Obertshausen team faced are the differences between European and American specifications. For example, Feintool’s employees in its Germany plant are accustomed to working with tool progressions of 13.78 inches (350 mm), but the progressions had to be 19.69 inches (500 mm) to meet the U.S. customer’s requirements. To accommodate the larger progressions, Feintool redesigned the 12-station disc carrier transfer tool.

Feintool’s employees in Germany and the United States faced another challenge – the sheer size of the 1,600-ton press. At the same time the 12-station disc carrier transfer tool was being built in its Obertshausen facility, Feintool launched production of other parts on the new servo press in Nashville. Feintool’s intercontinental team had to familiarize themselves with the servo press and learn its specifications and capabilities on the fly. Slide adjustment possibilities, connections to the coolant system and the 3-axis CNC transfer system were all new.

Feintool also faced the customer’s condensed timeline. To meet agreed-upon deadlines, Feintool had to manufacture and evaluate prototypes at the same time that the 12-station disc carrier transfer tool was being built.

“We worked together very intensively,” says Rick Garner, director of engineering at Feintool Tennessee. “It’s also important to note that, although there were some minor language barriers, it was very easy to have technical discussions, since Feintool both in Germany and the United States works with customers in the auto industry.”

About a month before the scheduled start of production, the team from Obertshausen that designed and built the 12-station disc carrier transfer tool met with the specialists from Feintool Tennessee in Nashville for the first on-site test on the 1,600-ton direct servo transfer press. They successfully produced prototypes, which the customer accepted. Series production began on schedule and meets all the customer’s requirements.
Technology and Production Locations Around the World

Feintool has strategically supplemented its core competence in fineblanking with the associated process of cold forming as well as expanded the company’s geographic footprint. Completing a significant round of investment in forming operations in Nashville – including two new 1,600-ton direct servo transfer presses – is part of this expansion.

Feintool employees leverage their skills and capabilities with the best ideas from coworkers in any or all of the company’s 13 locations to meet customers’ requirements. With fineblanking and forming facilities in five countries that produce complex 3D components at high volumes for the automotive industry and others as well, Feintool indeed is a worldwide enterprise. But its proximity to its customers the world over is what enables Feintool engineers and teams to provide just-in-time delivery of innovative manufacturing solutions on a local level.

With its combination of fineblanking and cold forming, Feintool is the only full-service provider for the efficient production of complex precision components in large quantities.

GLOBAL COMPETITIVENESS

Technology and production locations around the world

Figure 5
With locations in China, Europe, Japan and the United States, Feintool is located near customers in the most important automotive markets in the world.
Wearable HMI Applications in a Flexible Vehicle Production

Efficient Worker Integration in Industry 4.0 and IIoT-focused Production Systems

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Abstract
Industry 4.0 and Industrial Internet of Things (IIoT) promise to revolutionize the way that data, machines and workers interact to bring transparency and increased productivity. A key component is the degree of integration of workers into highly dynamic and flexible production processes.

In the process of digitalization, the type and the quality of the applied Human-Machine-Interfaces (HMI) will contribute as a key component in process performance, worker acceptance and work safety. DSA has been exploring and evaluating HMI alternatives using wearable HMI devices and their use cases in automotive production with the goal of selecting the right solution for each case and increasing user adoption through better ergonomics.

This paper presents some key findings.

1 Introduction and Background
Today’s automotive industry faces an increasing number of challenges. The complexity of modern vehicle construction, in combination with a growing rate of vehicle design changes, trigger frequent changes in production requirements. Furthermore, the ever-increasing customer demand for customization requires highly flexible production processes.

Workers along the assembly line require not only additional technical knowledge but must also be able to handle the multiple variations on parts and steps for vehicle construction with increasing time pressure. Thus, they must be supplied with all relevant information at the right point of time — and ideally in the most unobtrusive way possible.

New technologies provide several possible alternatives for the digitalization of workers concerning visualization and interaction as well as process execution and documentation.

- **Visualization**: provides information to the assembly worker on their ongoing and next tasks (e.g. assembly guidance), possible alerts (quality management), status information, etc.
- **Control**: allows the operator to provide feedback and give input into the system, e.g. to confirm operations or to input required data
- **Execution Engine**: keeps track of the vehicle state and the required tasks for the correct vehicle assembly and the related testing procedures

Figure 1 Selection of Technological Alternatives for Worker Digitalization
1.1 Challenges in Today’s Production

Only 30% of today’s manufacturing plants have access to real-time visibility of the status of all products. Furthermore, more than 33% of quality issues can be attributed to the inexperience of assembly workers (Ubisense, 2014).

Traditional assembly support systems such as pick-to-light, printed assembly instructions, paper-based checklists and even computer-based fixed information stations are no longer sufficient to achieve peak efficiency and minimize errors. Fully automatic systems and robots can reduce the error rate, but they cannot be allocated flexibly enough to many of the highly individual tasks.

Furthermore, the disparity of systems required to control the production (manufacturing execution, end of line diagnostics, logistics etc.) create information silos that prevent the holistic assessment of product and quality information.

2 Wearable Technology

Wearable technology can be used to provide any type of required information for a line worker in a production plant. The information presented can be filtered specifically to the configuration and results can be transmitted automatically to a central data hub.

However, a digital information overlay can overload the user with information. To select the right device, balancing of operation time with the minimum amount of necessary information to perform the job is required.

Figure 2 shows the amount of conveyable information against the required speed of worker operation (number of tasks that must be completed per unit of time).

The following categories of wearable technology have been evaluated by DSA in several studies and demonstration projects against the background of applicability in different types and different tasks in vehicle (car, truck, special machinery) production:

- Head-Mounted Displays
  Heads-up Display, Assisted Reality, Augmented Reality, Virtual Reality
- Arm-Mounted Devices
  Smart Watches, Smart Bands, Armband Display
- Accessories
  Ring Scanners, Control Packs

3 Solution Requirements and Challenges

The integration of wearable HMI in the production process has many advantages – the proper assessment of new capabilities included the evaluation of the following aspects:

- Modularity, including the availability of proper abstraction layers to easily port to new hardware
- Flexibility, especially concerning the ability to support different types of devices and accessories
- Real Time Data Transmission and analysis capabilities
- Real Time Feedback, meaning all operators and supervisors receive real-time, up-to-date information including quality information and alerts
- Scalability – adding new users and systems must be straightforward
- Adaptability and Accessibility: Information presented to the operators must be adapted to their experience levels, capabilities and attention span

Several challenges for the large-scale implementation of wearable HMI are still to be overcome, including legal aspects of positional
user tracking (Ajunwa, Crawford, & Schultz, 2017), user acceptance (Schuster, 2014) and cost-performance concerns. However, the relentless advance of wearable HMI technology indicates that the general challenges will be overcome quickly.

(Gartner, 2017) expects that by 2021 head-mounted displays will reach mainstream adoption.

4 Use Case: End-of-Line / Test Bench HMI

The End-of-Line / Test Bench HMI use case will be described within the scope of this paper to illustrate the applicability of wearable HMI in automotive production.

Purpose: Adding flexibility to the operators during test executions at test benches

Target: Operator of test stations

Once vehicles are out of the production line, they are submitted to several test benches where further tests are executed. During this process, the concerned technicians require several types of instructions to perform the tests.

4.1 Specific Requirements

Display and input devices suited best for this type of operations are wearable devices that can act as user interface as well as basic control units. The information shown in the wearable device must be brief and clear, so the technician receives information only when necessary. He must be able to work hands free and control the tester remotely and can interact with the vehicle or the test bench installation in a highly efficient way.

User interface visualization restrictions include changes on illumination level in the production line, background movement, visual acuity of the users and security considerations. An ideal user interface solution contains:

- High contrast between text, graphical elements and background
- Little to no text to reduce the time required to look at the screen
- Large graphical elements with symbols chosen or specifically designed for the domain
- No obstructions to the field of vision of the user
- Comfortable to wear for extended periods of time
- Battery life exceeding a full shift

The ideal input solution has a limited number of buttons with the following additional characteristics:

- Easily accessed from different postures (standing, sitting, bending over, looking under the car etc.), without interfering or restricting movement
- Tactile feedback when pressed, that can be correctly transmitted to the body even when using heavy gloves or clothes
- Button orientation can be determined by touch only, with no need to look at the device

4.2 Example: Roll Test Bench

The Roll Test Bench usually carries out a dynamic driving test as well as a control unit parameter set-up, and front, rear and four-wheel-drive cars in the end of line production segment. The following wearable HMI screen example demonstrates the design of a screen targeted to drivers running a vehicle dynamic test.

![Wearable HMI Screen Design Example and Principles](image)

Figure 3  Wearable HMI Screen Design Example and Principles
The screen is divided between a “Target State”, which displays the values that the driver must reach, and a “Current State”, which displays the measurements from the vehicle or roll bench.

The volume of text is minimized to speed up the recognition of the desired state and displayed prominently. Two additional icons represent the desired gear position and the desired state of the steering wheel. On the left side, a large graphical bar shows the current speed in relation with the desired target, together with a large numeric representation. The actual limits are shown as reference only. It is expected that the user does not require reading the limits, as the speed increase will immediately be reflected. The current gear position is also shown.

As the main test of a roll test bench is “acceleration and speed”, the graphic bar is shown in an orientation that suggests movement forward.

The image above shows a hands-free operation at a roll test bench with a wearable HMI.

The worker is dynamically supplied with all required information and work instructions. The wearable HMI (here: Google Glass) is connected to and receives information via the DSA PRODIS.Server Backend as well as to the vehicle through a headless (no display) high-performance Vehicle Communication Interface (VCI) – a DSA smartMDI, which is plugged into the vehicles’ OBD port.

5 Conclusions
The usage of smart wearable HMI devices in automotive production plants can significantly contribute to improve flexibility, performance, quality as well as workplace comfort and safety aspects by seamlessly “digitalizing” and integrating workers into flexible production processes. Some of the major advantages include:

- Cost reduction
  - Reduced retooling of the line in case of product changes
  - Reduce overhead on technician tasks
- Increased measurement and control
  - Quick reaction for problems in the production line
- Collected data can be processed to provide statistical information
- Improved communication
  - Provides real time information
  - Direct communication between areas
  - Centralized documentation & analysis
  - Automated notification process

Further information can be found in the DSA Whitepaper “Smart Wearable HMI Devices for a Flexible Vehicle Production”, which is distributed upon request via E-Mail to sales@dsa.de.

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Automotive Companies are Tragically Wrong about their Approach to Data (or: the 7 Steps to AI Epiphany)

The advancements in vehicle technology in past decades have put a significant strain on the effectiveness of quality control tools (even Statistical Process Control and six sigma tools), which still rely heavily on manual analysis. Looking at the recall rates and the costs of warranty claims over the past few years, it is evident that with the growing system complexity, engineers don’t have the right tools to meet the ever-increasing quality and safety standards. This is where AI comes in. By now, AI has affected almost every industry. Journalists and experts have largely hailed it as “the next step in the information age”, marketers are using it to reach ever-more-specific target audiences, pharma companies are using it as a new tool for drug development and studying the human genome, and investors are throwing their money at it. Clearly, AI is revolutionizing various industries, providing never-before-seen capabilities to automate complex processes using large amounts of data. In order to overcome the challenges they face with current processes, automotive companies must take advantage of this technology, and introduce AI into their manufacturing facilities.

More often than not, as part of our process at Acerta, we encounter clients who seek to implement AI capabilities but do not have the rigorous data capture infrastructure in place to allow for it. This is surprisingly common, as many of them do not realize how important data is for proper implementation of AI capabilities; from its quality, quantity, and even down to its very structure. This prompted us to develop a procedure by which we support our clients in creating the right process and architecture for data collection and storage, including a practical and tailored benchmark. While in many cases it is possible to deliver some value with existing infrastructure, only after achieving this crucial milestone does it become feasible to harness the full power of AI.

So, what should the first steps be for companies looking to benefit from the power of AI?

1. Get a Data Champion.

Creating an infrastructure for data collection and maintenance is an arduous process. Too often the structure, content, and nature of a company’s data is spread amongst a huge number of groups and minds throughout the organization. No-one speaks on behalf of the data, on behalf of its quality, fidelity, or organization. Give your data a champion, a person responsible for managing what is sure to be a crucial resource, for understanding the diverse needs of each data-consuming group in the company, from marketing to engineering, and ensuring that these needs are met. Give this champion an important title (like, say, Chief Data Officer – CDO) to truly emphasize their importance to your organization.
2 Store Data on the Cloud.
Many companies have a Bob or an Alice – that person, typically from IT or engineering, who happens to have data from different sources stored locally on their workstation and might just have what you’re looking for, or know where to find it. People from various departments then manually request the data they need from Alice, and hope that that data was stored, and not simply deleted to make space. To avoid these data silos, store all the collected data from all sources in a centralized location on the cloud. Since cloud storage is very cheap, even companies that maintain a large local data center (and diligently store all types of data in it) will see significant cost savings and redundancy advantages on their data storage when moving to the cloud. Lastly, since cloud storage is also extremely secure if done properly (subtle nod to your CDO here), there is absolutely no excuse to not use the cloud to store everything you can get your hands on.

3 Make Sure the Database is Properly Structured.
A key component of data collection is to define a cold storage architecture that maximizes data and information capture across sources over time while minimizing cost. The database must be highly standardized with very rigorous structure, in order to reduce data duplication, improve data consistency, integrity, and reliability, and allow for quick and efficient queries. The infrastructure should support integration of historical and new data sources, including necessary handling of data inconsistencies (which is quite common when aggregating data from different collection systems). Data scientists spend a significant portion of their time “cleaning up” data and getting it ready for “machine consumption”, so this step will not only make data more discoverable but will also save an enormous amount of time and significantly accelerate automation.

To explain the importance of this step, consider this as your “compartmentalized” attic — everything you collect over time you simply shove in there even if you’re not sure what you’re going to do with it yet. The only twist here (hence “compartmentalized”) is that you make sure that everything is labeled and put into a proper compartment. The idea is that when the kids are older and you recall you once shoveled something in the attic, you’ll know what’s in each compartment and where it came from. And to bring it back to a case in point, when you are ready to implement AI capabilities, you’ll recall that time when you collected a heap of data that will now give you a significant advantage.

It’s simple; no data, no AI. Get as much data as possible, from as many sources as possible, and make sure it is all labeled properly. If bandwidth is limited, prioritize the data needed most frequently by the majority of data consumers. The data you are collecting will be used to train artificial neural networks, so make sure you collect a variety of examples; normal system behavior, deteriorating performance, systems with abnormal behaviors such as various failure modes, and any other relevant cases (don’t forget to label them!).
5 Make the Data Easily Accessible.
Make this data accessible to every department in your company that may benefit from it. Whether it’s engineering, marketing, manufacturing, or customer service, data discovery should be made as simple as possible by breaking silos and eliminating the bottleneck that is the human element. Even without AI in sight, there is still so much to be gained just by implementing this simple step. No more data silos!

6 Create a Hot Storage.
The number 1 objective of hot storage architecture is to support quick querying of data. This is an extremely critical step for implementing any type of AI, which allows scientists to train models properly and in a reasonable amount of time. Where cold storage prioritizes a high degree of data structure normalization, hot storage does the opposite. Hot storage prioritizes the use of highly specialized data structures and should readily trade space for computation time. The hot storage architecture must define how data should be transferred from cold storage to the myriad of different structures inevitably needed by the different data consumers in a large organization, including AI. If you haven’t yet done so in the previous steps, it is recommended that you contract an AI solution provider (preferably one that specializes in solutions for automotive) to help you take care of the subtleties of this step.

7 It’s AI Time.
If you implemented the previous steps properly, you should by now be ready to finally implement AI capabilities in your company’s process. You have enough data, it is properly stored, structured and labeled, and is easily accessible for fast querying by a machine.

Following these steps might take some time and effort, but it’s necessary. The growing complexity of vehicle systems, along with tools that have reached their peak capabilities, creates a product quality gap. Large amount of complex data poses a serious challenge for current methods such as SPC, which rely heavily on manual analysis both for fault detection and for root cause analysis.

AI algorithms, on the other hand thrive on such abundance, and typically perform exponentially better as data volume increases. With proper data-management practices, these algorithms can churn through massive amounts of data in search of insight in a way that is simply impossible for humans to do, providing engineers with never-before-seen tools to obtain invaluable insight. But for this to be achievable, companies must have enough data in a rigorously defined structure to allow for any sort of machine intelligence application. Putting this infrastructure in place will enable you to capture the value of your data using machine intelligence, which is without a doubt crucial to remaining relevant in this extremely competitive industry.
Elephant in the Connected Room

Glenn Atkinson, Vice President of Product Safety, Geotab

Our brave new connected IoT world touts the promise of infusing “smarts” into logistics and functionality of commercial and personal mobility. The promise of efficiencies, convenience, and economies with a shared and smart mobility are all around us. Electric heavy duty trucks, integrated shared personal mobility, smart city services, zero tailpipe emissions, and vastly improved safety. It is exciting and evolving and 20 years from now, will appear to have occurred almost overnight but it will have evolved over many years and only after a massive and collaborative effort. In the meantime, there are a billion “legacy” vehicles on our planet, each with an average life of more than 10 years for light vehicles, and 15 or more years for heavy vehicles/trucks and as of today, still populating the planet at about 100 million vehicles per year. This is the massive elephant in the “connected” room.

Legacy vehicles will be connected because they can be – therefore, the real question is “how.” Researchers have demonstrated that existing CAN bus architecture on virtually all legacy vehicles is vulnerable to an unsecured connected OBD device and when exploited, depending on vehicle design, can provide an attacker access to the internal vehicles communication network. In this scenario, remote control of some vehicle functionality while the vehicle is underway can occur – a prospect that has caught the attention of many over the past several years. Geotab is one alongside many stakeholders (SAE, IEEE, Auto-ISAC, ISO, Government, Vehicle Manufacturers, Universities, fleet owners) across the connected mobility eco-system that is working to address this issue. This article describes the why and how behind the tireless and ongoing effort among stakeholders to turn lemon into lemonade – “vulnerable” into “connected and smart” – elephant style.

Neutral Vehicle is a concept advocating an “open and secure” connected architecture for existing legacy vehicles, and future smart, connected, and eventually autonomous vehicles. This view is focused on consumer “choice” and “competition” being key drivers of continuous improvement and efficiency. “Open” refers to an architecture that creates interoperability – “Security” refers to the ability to withstand efforts to attack and penetrate the connected vehicle architecture to nefarious ends.

News flash! – we don’t have to wait for the smart connected vehicle (or fleet) – the elephant sized fleet of legacy vehicles can be securely connected and become “smart” – in fact, in the commercial space the connected “smart” vehicle has been a reality for over 15 years! If vehicles currently have life spans of over a decade, and technology has a half-life of 18 months (derivative of Moore’s law), it seems reasonable that for now, and the foreseeable future, a smart transportation model must incorporate the ability to upgrade technology over the life of the vehicle. Navigation maps illustrate a prime example of this need. Neutral Vehicle presents a model that has provision for this ability to upgrade and improve, open source. First, consider the security part of the “open and secure.”
When a door has been secured – it is considered hard to open, has been fastened, or locked. It could be concluded that after a break and enter the door had not been properly secured. The standard for “security” of the door is measured against industry best practice and the value of the contents behind the door. When designing security architecture for the connected vehicle – it is not only the property (vehicle) that is at risk, so is personal safety, commercial businesses operation, cargo, reputation, and soon operations of cities. Considering what is at stake, a serious, collaborative, transparent effort to security is required, and it can’t simply be purchased and bolted on. A more thorough review of the collaborative “all hands on deck” effort currently underway to advance IoT and in particular connected vehicles is more than can be covered in this article. Suffice here to say it involves all the connected vehicle eco-system stakeholders mentioned earlier in a broad, collaborative, transparent and sharing spirit on a journey of continuous security improvement. Geotab as an example, is among the leading (and “enlightened”) participants in this effort. Secured, connected vehicles (by definition legacy) have been validated by USA DOT and DHS for their fleet vehicles, and currently in use throughout the continuum from large fortune 500 companies to a small municipality fleet of salt spreaders. Security is a journey, hard work, and resource intensive, and is one essential part as we build the connected vehicle fleet of the future and that includes existing vehicles. Neutral Vehicle concept is an invitation across the smart connected mobility ecosystem to participate in shaping the future as driven by consumer choice and free competition.

Security is only one part of what is required to capture the full benefit of the connected vehicle. The other is “open”.

An analogy is the “open” VCR format, versus the closed “Betamax” format several decades into history. The open format leads broad adoption and soon eliminated the restricted offerings of the “closed” Betamax format. This broad adoption created scores of spin off endeavors from Hollywood to community convenience stores. Soon SVHS arguably closed technical gaps. Although the VCR technology is now history – the “open” underlying architecture continues – with PVR’s (the digital equivalent of the VCR) and now “over the top” content provided via the internet. More choice, lower prices via competition, ultimately, a larger more diverse set of business opportunities for all that embrace and advance an “open” architecture. Neutral Vehicle is a connected, smart mobility concept rooted in this belief.

Could it really be possible to convert a legacy vehicle or fleet to a secured, connected, smart vehicle? Of course it can, millions of legacy vehicles already are. And as smart cities and infrastructure are developed, an open and secure connected vehicle technology can evolve too, in almost real time because once you have secured and open connectivity – new intelligence can be upgraded to large fleets and integrated into the smart city/community. The possibilities are mind blowing. There is no need to burden landfills with a billion vehicles, many can be made smart and live.

A secured, connected vehicle using an open and secure approach as advanced with Neutral Vehicle is not only possible – it is a reality for millions of vehicles, and fleets. What about the case where an unsecured telematics device connects via the OBD vehicle port? Since most legacy vehicles were designed to operate as discrete, independent vehicles the OBD port used to connect to the vehicle data communication does not have intrinsic security capabilities. Although it is demonstrated that millions of legacy vehicles are securely connected what is being done to ensure only “secured” means are used to connect legacy vehicles? Much is. That is the topic for another article.
Automotive Diagnostics – Shifting from Digital to Intelligent

How interactive and intelligent automotive diagnostics should be. How digital information in the automotive industry can become profitable.

Rainer Terlutter, Director Professional Services, Empolis Information Management

Everyone, who drives the newest generation of cars, knows: Automotive digitization has come a long way (e.g. Audi Connect, BMW Connected Drive or Mercedes Benz’ Digital Car Key). Drivers naturally use these services for their own comfort and safety.

It goes without saying that drivers also expect automotive repair shops to conduct standard service and repair processes, as well as unexpected troubleshooting, in a professional, competent and efficient manner.

The dynamics of vehicle development and digital services have led repair shops to require more service and diagnostics support from OEMs.

Therefore, every OEM must address the critical question of whether it is sufficient to simply supply digital diagnostic and service information – e.g. PDF files, HTML documents or XML formats – to meet the demands of repair shops and customers.

In other words: Is digital information enough to enable intelligent diagnostics?

**What does “Intelligent Automotive Diagnostics” mean?**

In traditional processes, service technicians and shop mechanics are accustomed to easily accessible digital diagnostics and repair information. In specific cases, a connection to appropriate, context-relevant information must be made to choose appropriate repair process.
With growing numbers and complexity of installed electronic components, service technicians are facing enormous amounts of error codes (e.g. Diagnostic Trouble Codes), to differentiate between causes and effects to carry out the correct repair processes.

However, IT-supported analysis with appropriate repair recommendations presupposes that existing documents, structures and information should be expanded by software to be applied situation- and context-relevant manners.

Conventional, structured documentation, which were originally utilized for diagnostics and repair manuals cannot accomplish this.

**Interaction between Diagnostic Documentation and Vehicles**

Existing diagnostic documentation generally provide service technicians with step-by-step instructions for diagnostics and subsequent repairs – actually, just like intelligent diagnostics – yet, with the considerable difference that with intelligent diagnostics, documentation and vehicles interact.

Thus, intelligent diagnostics is much more than just a digital version of previously analogous diagnostic documentation it represents a semi-automatic process in which many previously manually performed test steps are conducted via dialog of tester software and vehicle without intervention of service technicians.

Ideally, fully automated repairs can be conducted – i.e. when software can correct an existing error after connecting to the vehicle by correctly configuring a previously incorrectly set ECU, or by "flashing" an ECU (installation of a new, de-bugged software on ECU).

At minimum, semi-automated diagnostics provide service technicians with clear instructions on how they must conduct repairs in accordance with diagnostics. After completed repair processes, intelligent diagnostics ensure for their success.

**There isn't just one way of doing it.**

The big question is on how content, metadata and additional information can be supplied in an intelligent, situation-appropriate manner that can be utilized by software systems?

There are basically two different strategies:

- Completely re-creating information and content needed for intelligent diagnostics only (with continued use of traditional documentation, as before).

- The adoption, conversion and enhancement of traditional documentation for intelligent diagnostics.

These considerations should focus, not only on creation or transfer of information, but also on entire processes. This includes information modularization, publication, real-time use, closed-loop reporting and system integration into an existing landscape.

**How to create intelligent information with decision trees. What needs to be considered?**

As already mentioned, there are two ideal ways of transforming existing knowledge into digitally-applicable formats – i.e. for machine interpretation.

First, creation of new diagnostic procedures by an editorial team, i.e. creation of decision trees in a corresponding authoring environment. Existing diagnostic information can be used as the basis. In the end, their transformation into decision trees is carried out by experts' "translation".

This also accommodates interaction with vehicles in decision trees, i.e. query of ECU information, as well as query of individual parameters, which are necessary to be able to conduct error analysis, even for recommendations to service technicians or "fully automated repair".

Second, an editorial process is an extremely high-quality procedure due to expert knowledge incorporated into the creation of ideal troubleshooting trees. Considerable results can be achieved by automatically converting existing diagnostic information documents into troubleshooting trees. Generally, these documents are previously structured (e.g. in XML format, in part with DITA standards), so that individual elements, such as instructions, tasks or tests can be extracted and reused.

Unfortunately, this is rarely entirely possible, since context information is required by machines for automated, intelligent diagnostics, which is commonly derived through direct error detection by service technicians. Manual processing is thus required in this case.

When information is edited for intelligent diagnostic purposes, each decision tree initially must be handled by editorial teams to describe the technical process needed. However, over time, more and more decision tree elements become reusable for other, similar areas or in new product versions. Additionally, the involved editorial work becomes even more valuable since.

Creating new decision trees in other IT systems poses the risk of redundant information storage. The risk of duplications also increases for corrections and enhancements. Also, the risk of data inconsistences, longer diagnostic and repair periods and in a worst-case scenario, incorrect diagnoses and unnecessary repair processes.
Implementation requires resources
Regardless of the strategy applied, resources are needed for the respective implementation.

When incorporating legacy data from a leading system, focus is on migration and integration efforts, while most of the effort is to be expected on the editorial side for new entries.

Both strategies require a high degree of technical competence to define “intelligence” (namely the model, metadata and usage data), to enable machine processing.

Modularization of Decision Trees
With each additional product and variant, focus is placed on reusable decision trees which are suitable for modularization. This results in separation of decision tree elements into modules, which can be utilized in other trees. This simplifies the process for editors in making the right choice: use existing, using existing modules unaltered, slightly modified or a newly created variant.

Procedures for automated or editorial conversion of existing information may differ, however the possibilities for achievable optimization are identical.

Publishing (Provision of Information and Data)
Selection, connection and provision of information and data are understood when it comes to publishing. Various criteria can be applied for publishing (vehicle type, variant, series, etc.) and form the basis for machine use for diagnostics and troubleshooting.

Real-time Use of Decision Trees
Partially automated real-time troubleshooting enables service technicians to immediately evaluate the results of a troubleshooting process. For example, when changing vehicle settings, the diagnostic process can be restarted and instant problem solving of a previous problem can be confirmed, with an actuator’s positive reading, the correct sensor return value or via a no longer existent error message from an ECU.

Closed-loop Reporting for Warranties
Particularly interesting are control and subsequent reporting options for warranty claims in semi-automated repair processes. While editors establish decision trees to designate the most cost-effective spare parts and least time-consuming repair steps, reporting ensures that technicians work process-compliant – and keep costs low.

Conversely, in the premium segment, it is editorially ensured the full scope of measures are carried out to sustainably eliminate a problem. Compliance with guidelines can be supported and monitored by means of appropriate reporting, as well.

Simultaneously, permanent and detailed protocols of all processes allow for comprehensive reporting and can be used for continuous process and information optimization. Several options are conceivable: recommendation of optimization measures within scope of documentation creation and in regard to Machine Learning, using logging data for automated action recommendation.

System Integration for Intelligent Diagnostic Applications - Eliminate Data Silos!
In addition to vehicle connection to the testers, other systems must be integrated, i.e. development systems that facilitate editorial creation of decision trees (system data results which restrict possible system states).

The number of possible interfaces is unlimited. Only real usage and economic aspects limit editors’ possibilities in optimizing the systems.

Decisive success factors for intelligent diagnostic applications are their openness and the elimination of conventional data silos. Moreover, respective information and content must be connected and made available to service technicians to support their daily operations. Redundant, new data silos for intelligent diagnostics would be counterproductive for the entire process.

And Now What? Which Strategy Should be Selected?
The preferred strategy depends on the probability of occurrence. Very frequently occurring cases (e.g. with current product lines, core business products) support the editorial approach. For rare cases (e.g. for discontinued product lines or niche products), automated conversion is recommended. More often, it is useful to approach both strategies. Strategies are determined by the way digital service information is utilized in an intelligent and interactive way.

More information: www.empolis.com
E-Mobility Design Considerations for LiDAR

High Performance Optical Coatings for Autonomous Technology

Optical coatings for the LiDAR systems powering autonomous vehicles must offer a range of key performance properties to ensure passengers are as reliably safe or safer than those riding in human controlled vehicles.

- Brian Baleno, Global Automotive Business Development Manager, Solvay Specialty Polymers

Autonomous driving promises to revolutionize the automotive and transportation industries – if the enabling technologies are proven to be as reliably safe or safer than human controlled vehicles. Much of the technology’s success rides on the ability of light detection and ranging (LiDAR) systems to provide consistently accurate data under all environmental conditions that vehicles routinely encounter.

Advanced optical coatings will play an instrumental role toward this end, both by optimizing optical transmission of scanning laser beams through the lens, and by protecting the lens against chemicals, temperatures and ultraviolet radiation. As a result, coating formulators have an increasing interest in perfluoropolymers, which have been shown to enhance these properties when incorporated into optical coating formulations.

The role of optical coatings in autonomous driving

LiDAR works by measuring the time of flight for a beam of light emitted by lasers scanning across the system’s field of view. Photons that encounter objects in that field are reflected back to an optical sensor linked to a computer that calculates their time of flight to create a three-dimensional map of what’s on the road ahead.

In order for the LiDAR system to perform accurately, it needs to project light out of an optically clear housing. Consequently, the optical clarity and transmissivity of this housing is critical to ensure that accurate measurements return from the reflecting object.

In addition, most LiDAR sensors used today are external, and therefore operate in outdoor environments where ultraviolet (UV) exposure can potentially degrade the performance of some materials. The external exposure of automotive LiDAR systems also requires the use of anti-reflective (AR) coatings to ensure ambient light does not adversely influence the system’s performance.

Lastly, because automotive LiDAR must be able to perform reliably in all outdoor environments, it is beneficial to treat the surface of the optical housing with hydrophobic and oleophobic coatings that quickly wick away moisture and other ambient fluids.

For all of these reasons, optical coatings – and their components – play a significant role in the performance, reliability and lifetime of LiDAR systems.

Hyflon® AD: Optical Coating Enhancer

Hyflon® AD is an amorphous perfluoropolymer used in optical coating formulations. It exhibits high thermal and chemical resistance, excellent hydrophobicity and oleophobicity, very low surface energy and a low dielectric constant. The material also provides outstanding...
ing UV-VIS transmittance, a low refractive index and good solubility in fluorinated solvents.

As shown in Figure 1, Hyflon® AD provides excellent transmittance in the spectral range between 200 and 800 nm (Fig. 1), where its absorption coefficient is below 0.3 cm⁻¹. When applied as a coating with a thickness of 10 microns, the material absorbs less than 0.01 percent of the light within that spectral range.

Figure 2 shows the interference pattern produced by a self-standing film of low molecular weight Hyflon® AD 40L perfluoropolymer with a thickness of 0.8 microns. The pattern can be fitted with a curve taking into account only the thickness and refractive index of Hyflon® AD.

Another important feature of Hyflon® AD is its solubility in fluorinated solvents, including Solvay’s Galden® perfluoropolyethers (PFPE) and 3M’s Fluorinert™, which are both typically used in optical coating formulations. Standard Hyflon® AD solutions are produced using Galden® D02TS PFPE, which has a boiling point of 165 °C. Solution viscosity shows the expected dependence on temperature (Figure 3) and concentration (Figure 4).

**Hyflon® AD Coating Methods**

There are several considerations when applying Hyflon® AD perfluoropolymer and optical coating formulations in which it is used. But, for optimal performance and lifetime, the ability of the coating to adhere to the glass or polymer substrate is critical.
Whether alone or in formulation, Hyflon® AD perfluoropolymer can be processed using a range of methods, including split, casting and spray coating. More importantly, the material is compatible with dip and spin coating methods, both of which are commonly used for LiDAR and other autonomous driving components.

Optical coatings with submicron thicknesses can be achieved with Hyflon® AD using spin coating technology. Since the material is soluble in fluorinated solvents, the processing or coating method will not interfere with already deposited layers. Figure 5 shows the varying film thicknesses with spin coating speed.

**Conclusion**

Hyflon® AD is a potentially key enabler of high-performance optical coatings for automotive LiDAR systems for autonomous vehicles. It offers a wide range of required performance properties for these applications, such as hydrophobicity, low surface energy, outstanding transmissivity in the visible and ultraviolet range, and a low refractive index. In addition, Hyflon® AD can be applied using a broad range of coating technologies, including spin and dip coating methods frequently used for LiDAR applications.

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The German Act on Automated Driving - Approach and Liability Consequences for Domestic/Foreign Car Manufacturers and Suppliers

In June 2017, the German Road Traffic Act was amended, legalizing highly and fully automated vehicles. The Act now (somewhat) defines the technical requirements and addresses the rights and duties of the driver when activating the automated driving mode. It also provides for a mandatory black box to identify whether the driver or the system had control at the time of an accident. This black box will impact the liability within the supply chain and likely lead to an increase in recourse claims by the involved insurers. In view of the new legal framework, car manufacturers and suppliers should carefully review their roles in the supply chain and reassess contractual agreements as needed to minimize risk.

- Bijal Vakil, Partner, Silicon Valley, White & Case LLP
- Christian M. Theissen, Local Partner, Frankfurt, White & Case LLP
The amendments to the German Road Traffic Act

In January 2017, the German government introduced a bill to amend the German Road Traffic Act and legalize highly and fully automated driving. The bill was heavily criticized, among other things for being too vague and not establishing direct liability of the car manufacturer. Nevertheless, the slightly amended bill passed through both houses of the German Parliament with lightning speed and entered into force on June 21, 2017.

Its main provisions are the following:

- Highly and fully automated vehicles are defined. The system must fully comply with traffic regulations, recognize when the driver needs to resume control and inform him/her with sufficient lead time, as well as at any time permit the driver to manually override or deactivate the automated driving mode. Notably, the definition does not cover “autonomous” vehicles, i.e. vehicles that do not require a driver.

- The use of automated vehicles is permitted within the limits of the intended use (as will be defined by the individual car manufacturers). The system must inform the driver if that is not the case regarding the current use (e.g., leaving the driver’s seat when in automated mode).

- The driver may avert his/her attention from traffic. However, the driver must remain aware in order to resume control of the vehicle without undue delay either when prompted by the system or when the driver recognizes (or must recognize) that the preconditions for the automated driving mode are no longer fulfilled.

- A 100% increase in the maximum liability limits under the Road Traffic Act (i.e., now with regard to the same incident: a maximum of EUR 10 million for death or injury and a maximum of EUR 2 million for damage to property).

- The vehicles must be equipped with a black box. In the event of an accident, the black box identifies whether the driver or the system had control of the vehicle and therefore clarifies whether liability lies with the driver or potentially with the manufacturer.

Key point for car manufacturers and suppliers: What is defined for each vehicle type as “intended use”? According to the Act, automated driving is permitted within the limits of the “intended use”. And such “intended use” will be defined by the individual car manufacturer. This will very likely be one of the key differentiating factors between car manufacturers in the next decade—particularly in Germany, where no constant speed limit on highways exists. Car manufacturers who are further advanced might define the “intended use” as being e.g. up to 160 kilometers per hour, whereas others only allow up to 130 kilometers per hour. That is only one (simple) example of where the “intended use” might differ. Other major differentiators could be driving in heavy rain or in challenging traffic scenarios. Since these are common scenarios for commuters or people who often drive long distances, these customers will likely prefer the brand which (safely) offers the widest “intended use”.

While many people say that automated driving will erase the differences between car manufacturers: That might be true (to a certain extent) when we reach the full “autonomous” driving, but until we get there, automated driving will be one of the biggest opportunities for car manufacturers and suppliers to distinguish themselves from their peers through quality and engineering.
What is the “driver” entitled to do while the system is in automated mode?

Due to the received heavy criticism, the Act now explicitly states that the driver may avert his/her attention and must be given an “adequate time reserve” before having to resume control. While it is clear that the driver will not be entitled to sleep, it remains unclear what the lawmaker considers “adequate”. During the legal debate, time delays of two to five seconds were referenced. However, one must bear in mind that this provision will apply to both city traffic at low speed and driving on a highway. What constitutes adequate in these two scenarios may be very different (because of e.g. the necessary muscle tone to take over the steering wheel at full speed on the highway and the distance driven at different speeds). The German courts will have to interpret the requirement with the assistance of scientific experts.

Should the “driver” remain in the liability loop?

Consumer protection organizations had demanded that instead of the non-driving driver, the car manufacturer be directly liable for damage caused by automated vehicles. The German lawmakers, however, did not make this fundamental change in the German liability law. Therefore, both the driver and the “owner” (Halter) remain liable even if the vehicle is in automated driving mode. But the black box will give them an opportunity to avoid liability (see next section).

In reply to the demand that the non-driving driver be taken out of the liability loop, the German lawmakers underlined that, at this stage of technological development, they do not consider it adequate or necessary to change the current liability rules. They added that this might be different once the final stage of automation is reached (i.e., autonomous self-driving vehicles without a driver able to resume control).

The black box - liability consequences for the entire supply chain and the involved insurance companies

While drivers will generally remain liable, they can avoid liability if the automated driving mode was lawfully used. If accidents are caused by the system and the drivers observed their statutory duty of care, they will be able to show that they did not act negligently. Consequently, they are not liable under the fault-based driver’s liability provisions of the German Road Traffic Act and the German Civil Code. The mandatory black box will help drivers prove they had (rightfully) only been passengers at the time of an accident.

Vehicle owners will also benefit from the black box because it will (in certain scenarios) help prove that the system failed. As a consequence, the relevance of German product liability rules is likely to increase. So far, the German Product Liability Act has been largely sidelined for exactly this reason: It was usually not possible to prove that a given accident (being a very complex and dynamic occurrence) had been caused by a manufacturing or development defect of the vehicle. The black box will change this in many cases. For example, if the vehicle did not stop at an intersection and the black box proves that (i) the system was in control and (ii) had not prompted the driver to resume control, the driver/owner will likely be able to show that the system failed (assuming that the vehicle was used within the limits of its intended use and the preconditions for the automated driving mode were fulfilled – which might e.g. exclude scenarios of heavy snow or hail).

As a result, it is expected that vehicle insurance companies will become increasingly involved. Since it is usually not possible to prove that the vehicle had a product defect, today, vehicle insurance companies rarely try to recover payments from the respective car manufacturer. This is likely to change for two reasons: First, more and more
vehicles involved in accidents will be equipped with a black box. Second, even though the number of accidents will decrease, the damage per accident will increase due to the complex additional technology installed in automated vehicles. This will render the pursuit of claims by vehicle insurance companies more attractive. In light of this, the importance of product liability and product monitoring will increase. And the further technology progresses, the more difficult it will become for car manufacturers to be exempt under the state-of-the-art defense in the Product Liability Act.

Consequently, if the car manufacturers will increasingly be held liable, they will more often seek recourse from the suppliers of the sensors, software etc. Looking at the high levels of cooperation between car manufacturers and suppliers in the past years, it will be increasingly difficult for suppliers to rely on the “supplier defense” (i.e., the defense that they only supplied in accordance with a received blueprint).

**Consequences for foreign companies doing business in Germany**

In view of the June 2017 amendments, foreign companies supplying automated vehicles or components thereof for the German market must take proper steps to understand and minimize their potential liability, in both product liability and contract law. Although non-driving drivers remain in the liability loop, manufacturers and suppliers will face increasing liability when the mandatory black box shows that the system was in control at the time of an accident. Risk management is essential, particularly due to the complex web of suppliers and manufacturers involved.

To benefit from the “supplier defense” for design defects, a supplier must purely follow specifications provided by another party. Thus, suppliers at every level of the supply chain must be cognizant of their involvement in any part of the development process for semiconductor chips, software, or other components. Even a small contribution, such as providing basic design building blocks, can lead to liability. If a supplier chooses to contribute in any way to the development process, liability for design defects should be mitigated by contract with the downstream entities in the supply chain.

Car manufacturers and component suppliers must also grapple with setting the limits of “intended use,” which is defined by the car manufacturer. Because “intended use” defines the bounds of potential liability for the entire supply chain, there is a fine balance to be struck between providing for the broadest possible use of an automated system and avoiding liability for accidents in high-risk driving conditions. Although component suppliers do not directly set these limits, they can still face strict product liability for defects that make a component unsafe under the official “intended use”. Accordingly, component suppliers should ensure that the required conditions for safe use of components, as determined by analyses and tests, are clearly communicated to downstream entities in the supply chain. Moreover, suppliers should contractually mitigate their liability arising from any disparity between the supplier’s safe use conditions and the car manufacturer’s official “intended use.”

**Conclusion**

The recent amendments to the German Road Traffic Act provide a much-needed update to the statutory scheme to address highly and fully automated vehicles (notably, according to the German lawmakers, this does not include “autonomous” vehicles that do not require a driver). The mandate for black boxes, which record whether the driver or the system is in control, introduces heightened potential liability for car manufacturers and suppliers. Meanwhile, vehicle insurers will find it easier to pursue claims against car manufacturers for product defects. Foreign companies can understand and minimize their potential liability in the German market by balancing the risks and benefits of a broad “intended use”, closely scrutinizing their involvement in design versus manufacturing of components, and, if necessary, contracting around the statutory product liability rules.

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