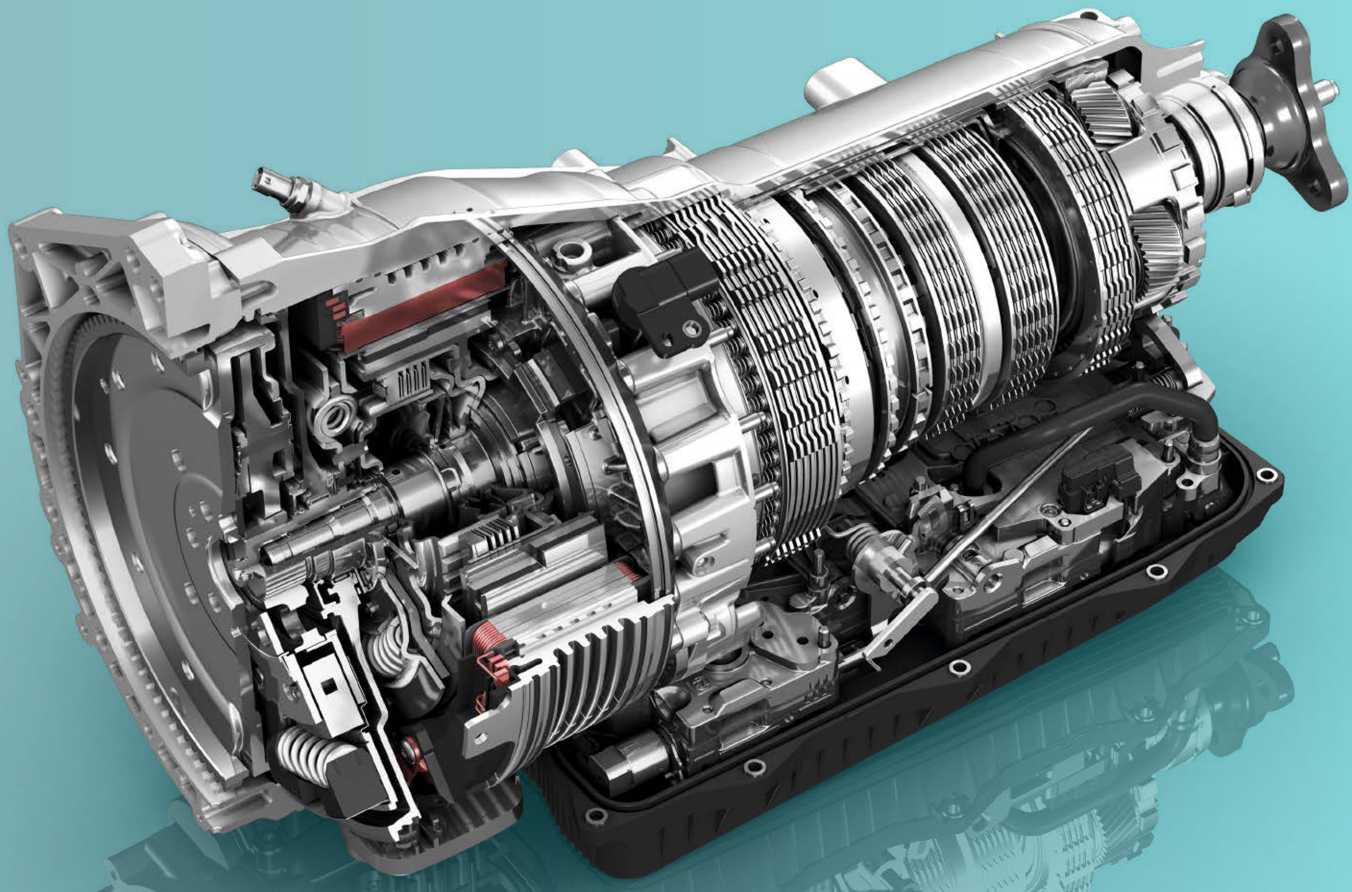
cti magazine

AUTOMOTIVE DRIVETRAINS | INTELLIGENT | ELECTRIFIED

May 2019



ZF

ZF Delivers Fuel-Sipping Innovations to Advance Mobility

INTERVIEW

Walter Sackl, Magna Powertrain

"We Can Enable Development Cycles of One Year"

Total Lubrifiants

Electric Mobility & Innovation: Total Launches a Pioneering Line of Fluids for Electric and Hybrid Vehicles

Dear reader,

welcome to the twelfth issue of CTI Magazine! The automotive industry is being confronted by new realities as it transforms and enters a new era. Particularly for drives, that means using electrification to enable low-to-zero-emissions mobility. So in this issue, big name suppliers report on their latest transmission and drive developments once again.

In addition to articles on 'building block' e-drives and transmissions, you can also read up on component-related topics such as shift elements, pumps and production methods. For developers, the focus here rests firmly on boosting efficiency and performance, while also reducing costs and weight.

To complement the articles, we also interviewed leading drive expert Walter Sackl, Magna Powertrain, on two topics: his company's 'building block' approach to drive electrification, and the Magna e2 Hybrid Demonstrator. And to round things off, our follow-up report brings you all the latest news from the recent CTI Symposium Berlin.

Our special thanks to everyone who helped put this issue of CTI Magazine on the road. Enjoy!

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cti magazine contents

ZF Delivers Fuel-Sipping Innovations to Advance Mobility

Dr Michael Ebenhoch, Senior Vice President, Car Powertrain Technology, ZF Friedrichshafen

Improving fuel economy while delivering the vehicle performance consumers demand has been a challenge that automakers have faced for years. And, today, developing zero-emission mobility has become increasingly important to meet emission regulations. Advance driveline technology is a key enabler allowing the industry to better meet the balancing act between government requirements and vehicles consumers want to drive.

For more than 100 years ZF has been developing innovative driveline, axle and powertrain products that deliver improved fuel efficiency and are fun to drive. As one of the automotive industry's leading providers of transmission technology, the company has had a profound impact on reducing fuel consumption while delivering more power with its award-winning 6- and 8-speed longitudinal transmission as well as 9-speed transverse transmission. ZF's range of transmission technology was an integral part in enabling automakers to deliver high-performance internal combustion engines (ICE). In fact, each transmission was recognized by an Automotive News PACE Award for the industry-first innovation and efficiency it brought to the market.

As the industry moves toward driveline electrification, ZF continues to be at the forefront with its premier automatic and dual clutch transmission, as well as a full range of hybrid and electric drive technologies currently being utilized by automakers. Opinions may differ in how fast the global vehicle fleet will transition from primarily ICE to fully electrified, but one thing is certain: ZF's robust e-mobility product portfolio provides the industry turnkey solutions to meet future needs.

Although ZF is primarily seen as a Tier 1 supplier providing technology directly to the automakers, the company is also advancing the industry by providing a series of in-house capabilities for automatic transmissions and subsystems to driveline suppliers. ZF's experience, knowledge and high quality products can provide automotive suppliers a competitive advantage in the marketplace.

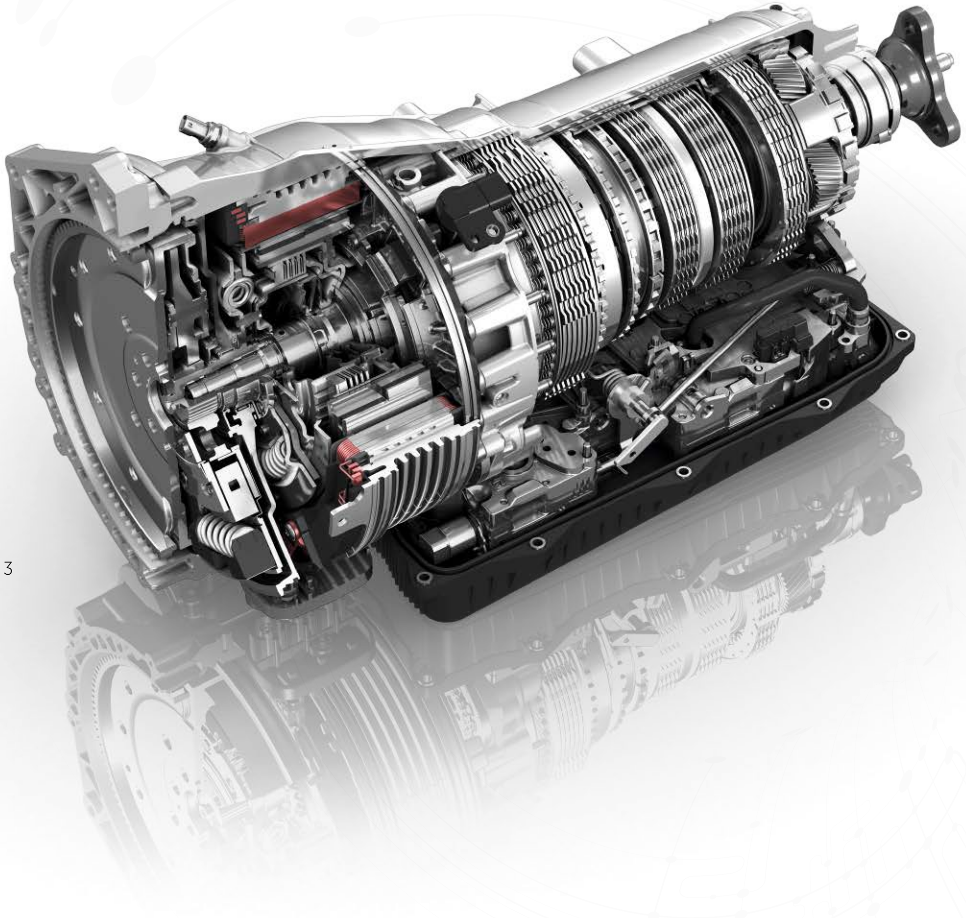


Figure 1 ZF 8 HP Gen 3

More Comfort and Less Fuel Consumption

Modern low revving/direct injected engines require innovative damping/torque converter technologies for increased fuel efficiency and improved driving comfort. ZF designs and develops a full range of launch devices and torque converters that enable automakers to achieve the increasingly stringent fuel emission regulations. In addition to torque converters and dual clutch launch devices, ZF has a full range of electric motors designed for simple adaptation to front-wheel drive and rear-wheel drive base transmissions for mild-hybrid electric, hybrid electric and plug-in hybrid electric and fully electric vehicles.

Today, increased computational power is required by modern drivelines and ZF has developed state-of-the-art transmission controllers that support future software architecture. ZF's transmission control software lowers fuel consumption while delivering more dynamics and comfort. To improve design flexibility, the controllers can be mounted externally to a transmission or inside the transmission to the valve body itself. Additionally, ZF has developed a range of shift-by-wire gear activation systems that support the industry's transition to shift-by-wire technology.

Light-weight and NVH Improvements

When developing products, ZF remains focused on delivering the highest quality while keeping function and light-weighting in the forefront. The company was one of the first transmission suppliers to introduce an in-house designed and developed plastic oil pan that incorporates the filter element. This design allows a more efficient final assembly operation in addition to weight and NVH improvements.

Extended Engine-off Range

Reducing parasitic losses has been a target for automatic transmission suppliers for years. ZF has developed a full range of modern internal vane or gear hydraulic pumps for driveline products. In addition, as engine-off driving becomes more prominent with modern hybrid vehicles, ZF's range of conventional hydraulic pumps augmented by both internal and external electrically driven pumps allows an engine-off driving range.

Validating Serial Production Quality

To ensure transmission, axle, tires and conventional or e-driveline driveline technologies meet customers' expectations and requirements, ZF offers a vast range of highly flexible research and development test benches and tailored end-of-life test stands. The customized equipment allows companies to test components separately as well as run functional tests of complete systems under realistic conditions. ZF Test Systems support efficient research and development activities by reducing time and cost, and during serial production at customer plants, ensures quality and efficiency.

Dr Michael Ebenhoch,
Senior Vice President,
Car Powertrain Technology,
ZF Friedrichshafen AG

Digitalization of the Powertrain

Digitalization is reimagining the automotive industry's business models. The digital economy joins physically and electronically connected devices with Big Data. "Powertrains were one of the first components to incorporate intelligent function, and the advancement continues in conventional as well as electrified and purely electric drivetrains to further increase efficiency, comfort and dynamics. The key factors that drive the intelligence of components are platform-based innovations and hyper connectivity. When these combine with big data analytics, unprecedented possibilities open up for serviceability like predictive maintenance features, early damage detection, service, product updates, remote access and much more," stated Dr Michael Ebenhoch, ZF Senior Vice President, Car Powertrain Technology.

As a system provider, ZF delivers solutions for the mobility of the future. Its broad and unique product portfolio allows vehicles to see, think and act in an effort to achieve a society with zero emissions and zero accidents. The company works collaboratively with customers across the automotive supply chain in an effort to help advance the industry.

Interview

"We Can Enable Development Cycles of One Year"

Magna Powertrain's e2 Technology Demonstrator vehicle uses a scalable set of building blocks to show different hybridization options, from 48V to high voltage, with front-wheel drive or AWD and torque vectoring. Walter Sackl, Director of Product Management Driveline Systems, Magna Powertrain, explains the thinking behind e2.

Walter Sackl, Director Global Product Management at Magna Powertrain

Mr Sackl, the US, Europe and China have different ideas about how much electrification passenger cars need. How would you summarize these?

Electrification levels are mainly determined by legal requirements, which differ greatly in the US, Europe and China. Countries with high mobility rates and readily available renewables will try to cut CO_2 emissions in the mobility sector with electrification; regions with potential outside the transport sector might use other levers. The countries and regions make very different decisions in that respect. Local emissions restrictions, for example in Europe and China, are a second factor, although their main focus is air quality in big cities. But now electrification, whether BEV or hybrid, is triggering new customer expectations too. In terms of performance, comfort etcetera, we are seeing new opportunities to create enthusiasm among consumers with things that only used to be possible in higher vehicle segments.

What value do these electrified drives add?

One the one hand, obviously, more dynamics and comfort. However, there are other benefits too. In North America, for example, pickups are also being electrified because that enables entirely new functionality. To a certain extent, owners see their pickup as a tool. One of the most important features being discussed right now is the ability to connect 110V power tools to the vehicle. In Japan, plug-in hybrid drives owe part of their success to their ability to power homes during temporary outages in the power grid, for example, when a tornado strikes. The US often has weather situations that impact on public infrastructures too. So using vehicle batteries to store power is not just attractive for drive electrification, it also makes life easier overall for consumers.

"You can make plug-in hybrid drives fuel-efficient at constant speeds, but only if you decouple the e-motors."

Last February you invited people to Sweden for winter tests with the e2 technology demonstrator, which can represent different levels of hybridization. What does this vehicle have to offer, particularly for North America?

Currently many markets, including North America, still define vehicle performance in terms of the combustion engine. We want to show how a system with the same ICE and differently scaled e-motors can realize completely different operating modes. In North America, for instance, efficiency over long distances at constant speed is very important. That doesn't require all that much ICE power. But American motorists also expect fast acceleration from zero up to the speed limit. The e2 drive architecture delivers very high dynamics thanks to the e-motors, plus low fuel consumption on long journeys. The modular concept is also suitable for 48V hybrid drives, but in North America, we mostly expect to see strong interest in high-performance high voltage applications and AWD systems with a rear e-axle.

What are the core elements of the building block system? Which components are shared and which are scaled?

We call the elements 'building blocks' because we re-use them in a wide range of different applications. Many stay the same in all applications; a few are scaled, for instance the e-motor. One benefit is repeatability across different customer programs, which in turn yields economies of scale in production. Another really important advantage is that we can represent innovation in individual building blocks independently of the overall product. And that means we can bring attractive solutions for current market requirements to the overall product very quickly. It's a bit like smartphone apps that add innovation and features without changing the device itself. Innovation cycles are three-to-four years for the building block hardware, and maybe six for the overall product. But at function level we can represent cycles of one year. That makes it much easier and faster to launch attractive products.

What will typical applications look like from a consumer viewpoint? You are probably not planning to implement all the possible options ...

That's right, we won't implement everything that's currently possible with the e2. What matters is having the flexibility to do so with little effort. OEMs have specific clienteles to serve. Some manufacturers have a very broad portfolio, with platforms ranging from the B segment right up to D; they use similar block structures, but serve very different customer requirements. Other OEMs still have multiple stand-alone vehicle series. The building block system is particularly useful for them: it enables them to add new vehicle series faster and more flexibly, and accelerate innovation.

You said the function level is a core element for innovation. How does that change the work of engineers?

For consumers, functionality is the only thing that really matters. So as developers, the thing we think about first is which functions we want to generate. These days, OEMs build their organization more around functions and less around physical product characteristics. Some manufacturers are very advanced in that respect. Their organizations represent functions like longitudinal dynamics, lateral dynamics or vertical dynamics, the latter means roll, tilt and so on. So solutions for function requirements could be found in the drivetrain area, but also in the chassis or in functional networking. At the end of the day, it's about defining and implementing dynamics to suit the vehicle in question. Only then do you select a solution.

Can this function-based systems view also mean outsourcing tasks to the supplier?

OEMs always keep the fundamental responsibility for the highest software level. That defines the vehicle's characteristics, so it's a key differentiator. Normally, a supplier never defines branding. There is a hierarchy of different software levels inside the vehicle. The function level handles control and management. We usually supply that software along with our components because it describes them. On a higher level, you have control processes that affect the entire vehicle. Take our Flex4-Disconnect system, for example: we, the supplier, are responsible for how the synchronization processes run. But above that is the hybrid controller that decides when these processes are triggered. Now that involves data from systems all over the vehicle, such as navigation, vertical and lateral dynamics, predictive assistance systems and, increasingly, autonomous functionality. Obviously, the supplier won't merge those functionalities. But our software, which is also a functional building block, does simplify that task at OEM integration level.

Coming back to drivetrain design: plug-in hybrids in particular have a reputation for poor long-distance fuel efficiency. What are the levers for changing that?

Some people put that down to the heavy battery, but that is not the case. Weight does affect vertical, longitudinal and lateral dynamics, but it has virtually no effect during constant-speed travel; actually, it is used to recuperate kinetic energy. The bottleneck lies elsewhere: Under load, the PSMs in today's plug-in hybrid drives have a high efficiency of 90 to 95 %. But when they're being dragged at constant speed, their magnets act like a brake. So one solution is to decouple the electric motor in certain scenarios, using a disconnect system that is imperceptible for the driver. That way we can use the ICE's optimal efficiency at constant speeds. Very few plug-in hybrids have implemented that so far, and just at their e-axles. But transmission-side disconnect systems are sure to come too – PSMs have a clear edge there because of the compact build size. Summing up, you can make plug-in hybrids fuel-efficient at constant speeds, but only if you decouple the e-motors. And you can only do that on P2.5, P3 and P4 – not P0, P1 or P2.

The e2 demonstrates a wide range of scalability. How would you configure your own personal, custom drive?

I'd go for the highest stage – a high-voltage plug-in hybrid with around 85 kW of electric power front and rear, a 136 kW internal combustion engine, and torque vectoring via torque distribution between the front and rear axle. Torque vectoring really benefits lateral dynamics. Subjectively you don't notice the extra weight from the battery; the vehicle is very safe to drive and agile. At that scale, the e2 is definitely a very sporty car – much more than you would think by looking at it. So personally, I'd probably style the bodywork to match …

Interview: Gernot Goppelt

The e2 Technology Demonstrator

The highly integrated hybrid drive in the e2 features a 7HDT300 hybrid transmission, an 80 kW e-machine, a P4 rear e-axle with up to 150 kW and a standard 100 kW ICE for all configurations. Traction battery capacity is 13.6 kWh. On top of full functionality with full system power, AWD and Torque Vectoring, the e2 can also simulate all other electrification modes, e.g. conventional FWD, HV and 48V AWD (traction assist). These are switched via an app to demonstrate their various benefits.

The New Building Blocks of Propulsion Systems Design

How Means has developed new tools for transmission engineers to reinvent the design of efficient and compact electrified propulsion systems

Carl Beiser, Technical Business Manager, Means
Rich Marr, Marketing Analyst, Means
Tim Hunter, Marketing Manager, Means

Thousands of solutions for a handful of critical challenges. That's one way to characterize the automotive industry in the 21st century.

Figuring out how to get a person from point A to point B as efficiently, inexpensively, and now as cleanly as possible, should be a relatively straightforward proposition these days. We've had over 100 years to figure out the best propulsion system architecture for moving a vehicle down the road, yet the spectrum of solutions remains overwhelmingly vast. Meanwhile, the cost of these systems continues to climb. And the gamut of global and regional regulations which must be adhered to? Convoluted at best, as the complexities continue to grow.

So where does one start? Many OEMs take the approach of improving on existing technology. This can be an attractive approach because current powerflows are time-tested and vetted, with billions of miles driven as validation. The problem with this approach is the fact that any future gains at this point are incremental at best, where capital is invested on marginal improvements providing only fractional MPG gains or emissions reductions.

A potentially more attractive solution is developing entirely new technology, exploring new frontiers and disrupting the entire landscape. However this can be a daunting journey to undertake for established suppliers, which must manage the risks of launching new projects that are not yet time tested and potentially cannibalize legacy business, all the while navigating the subsequent overlapping investment in the old and new.

The Journey Begins

Means first entered new space over 20 years ago by launching the Mechanical Diode (MD) One-Way Clutch, a strut-based system that mechanically locks instead of using friction. The technology was successful because it was easy to integrate, was more torque dense, able to run at higher speeds, and resulted in reduced drag torque. The MD played a key role in helping propel the 6 speed automatic transmission from a niche product to a staple of the global automotive industry.

An innovation to take this to the next level was the Controllable Mechanical Diode (CMD), a Selectable One-Way Clutch (also known as a Two-Way Clutch) that expanded the options to multi-modal controllability. This new system offered OEM transmission manufacturers a solution that would reduce system mass, improve efficiency, and offer additional packaging flexibility. Use of a CMD can result in about 100 W energy savings at freeway speeds, when compared to a Roller / Friction Pack combination. Today this technology can be found in 8, 9 and 10 speeds being produced around the world. For the GM version of the CMD that went into the 9T50 Hydramatic transmission, Means won a GM Innovation Award in 2016. Means has now shipped over 40 Million MD and CMD clutches to date.

New Age, New Answers – Electrically Actuated Clutches

But as we approach the next decade, the answers of the past simply won't be able to address the same questions anymore. While some regions will cling to ICE propulsion, others are embracing the race to electrification like never before. No one yet knows what the winning solution will ultimately be, so multiple paths must be explored to ensure viability in the new mobility landscape.

One of the new answers that Means is working on is a static, electrically actuated CMD (CMD-e) which provides the unique benefits of latching in state and not requiring a constant power supply. Because an electric motor is present in such propulsion systems, precise synchronization is achievable which minimizes the benefits of a passive overrun strut set and allows for two independent controllable locking elements to be used.

The passive overrunning strut set is replaced by a single locking element which is operated by a solenoid. A second single locking element is used to transmit torque in the opposite direction. Independent control of each solenoid allows torque transmission in the clockwise (CW) and freewheeling in the counterclockwise (CCW) direction, or visa versa. Simultaneously engaging both solenoids creates the clutch brake function (no-way clutch). See Figure 1.

Means' new static CMD-e design can improve system level efficiency in two ways. First, hydraulic control is completely eliminated, along with all of the cost and complexity associated with it. Second, power is only

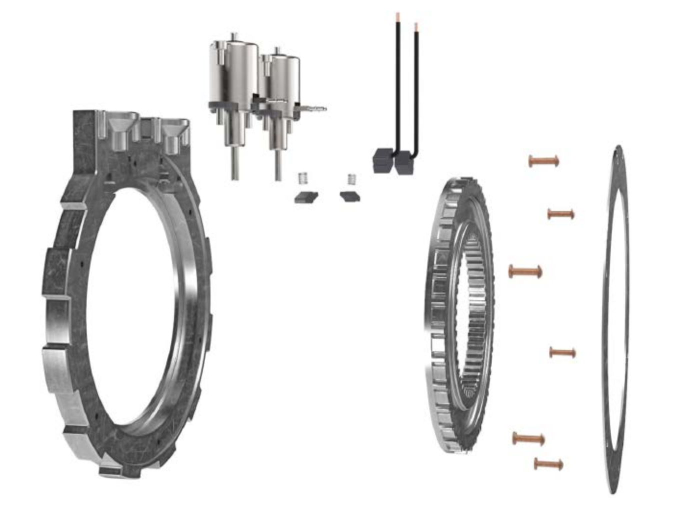


Figure 1 Static CMD-e

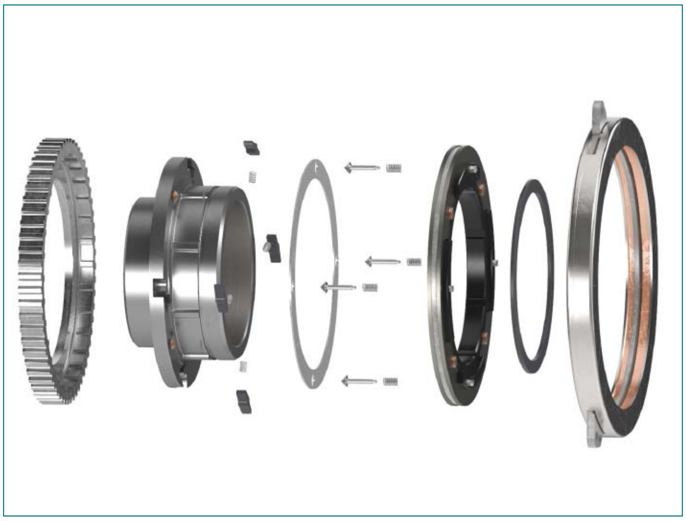


Figure 2 Dynamic Controllable Clutch (DCC)

consumed during state transition. The solenoids are bi-stable, meaning they latch in state which eliminates the constant power demand. Once the locking element engages, power is removed and magnets in the solenoid hold the plunger in place. Because the locking element is torque locked, the magnetic latch does not have to be large.

New Age, New Answers – Electro-Dynamic Clutches

However, static clutches are only half the answer. Transmissions of all kinds also need dynamic clutches, or clutches which have two rotating races. Wet friction clutch packs, dog clutches, and synchronizers are commonly used in dynamic clutch positions and have been around for decades. These solutions are suitable to electric propulsion systems, but system efficiency and packaging are compromised due to complex hydraulic systems needed to control these clutches.

Means' answer to the compromise is the new Dynamic Controllable Clutch (DCC), which packages in dynamic clutch positions and is electrically-actuated. The DCC has two rotating races, the pocket plate and notch plate. The pocket plate contains two sets of locking elements; one set for CW and the other set for CCW engagement. During engagement, the locking element simultaneously contacts the pocket and notch engagement faces which allows the clutch to transmit torque. See Figure 2

Unlike the static CMD-e clutches, the dynamic functionality does not allow for solenoids to be used to engage and disengage the locking elements. Therefore, Means uses a new type of actuation system called a linear motor, which can control the locking elements while both races are rotating.

The linear motor is comprised of two components called the stator and translator. The stator is the stationary component and is fixed to the transmission case. It consists of copper wire coils and steel plates. The two coils are wound in series with reversed polarity relative to one another (anti-series). The other component is called the translator, which is assembled to, and rotated with, the pocket plate. The translator consists of permanent magnets, steel plates, and plungers that operate the locking elements.

Figure 3 details how the linear motor controls the DCC's locking elements. The plungers within the translator assembly directly contact the locking elements and cause them to pitch up or pitch down depending on actuation direction. When the translator moves from off to on, the plunger contacts the locking element, causing it to pitch upward so it can engage into the notch plate. The clutch is able to transmit torque after the locking elements are engaged. A return spring under the lock-

Figure 3 DCC Modes (Left: Freewheel 0/0 mode and Right: Lock 1/1 mode)

ing element is compressed during the engaged state. When commanded off, the translator moves back toward the off position and plungers lose contact with the locking elements. The compressed return spring creates a force that causes the locking elements to pitch downward, or disengage. Once a torque reversal occurs, the locking element can disengage and the clutch can freewheel.

Figure 4 shows the linear motor assembly in the off and on positions. To change state from off to on, electrical current energizes the coil nearest to the translator. The energized coil produces a magnetic field, which repels the steady state field generated by the permanent magnet while the far coil produces an attractive field.

The combination of repelling and attracting from the stator coils causes the translator to move. Once the translator passes over the center stator steel, the permanent magnet attempts to fully align the leftmost steel plates of the stator. However, the mechanical off stop prevents full alignment, which results in a biasing force that holds the translator in the on position. The translator is magnetically latched in the on position.

Similar to the bi-stable solenoid, the magnetic latching allows the electric power to be removed whenever the device is not actively changing position. After 50 to 150 ms, the electrical current is turned off as change of state is achieved and is no longer needed. The magnetic latching force eliminates energy consumption during steady state conditions.

To disengage the DCC, current is applied to the coil nearest to the translator (formerly the far coil) and the linear motor moves from the on stop to the off stop in a similar manner described above. The off mechanical stop prevents full alignment of the permanent magnet and rightmost steel plate of the stator, remaining magnetically latched in the off position.

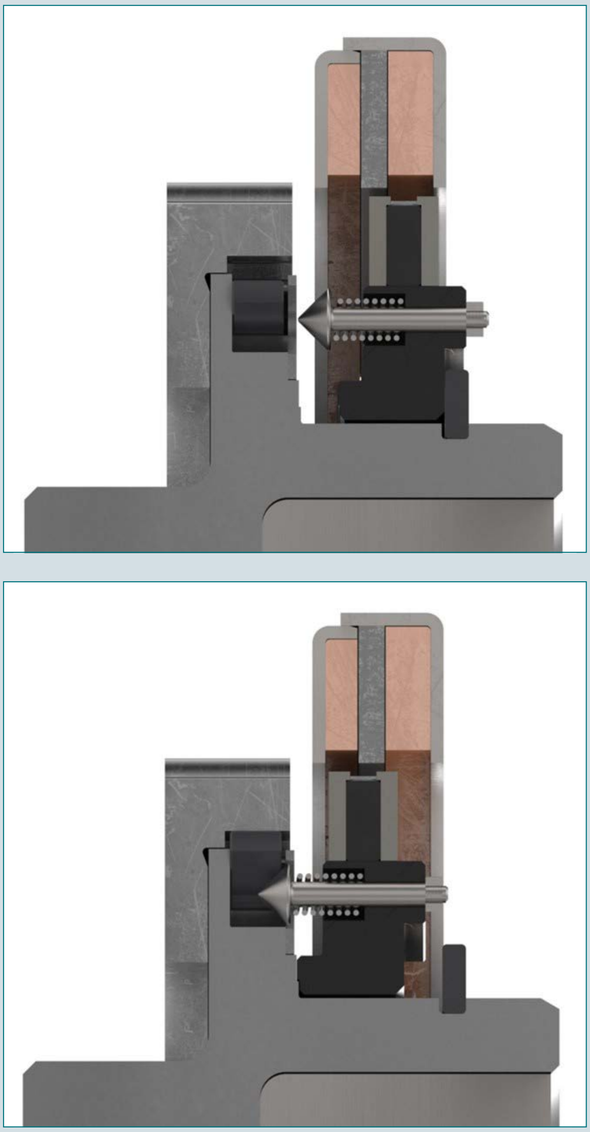


Figure 4
DCC Linear Motor Positions (Top: Translator magnetically latched in Off position, and bottom: On positon)

Bringing It All Together

The value of these two new clutch technologies reaches another level when the two systems are used together. For example, when the shifting concept is employed in a BEV architecture, the need for hydraulics is eliminated, meaning there is no more need for the pump, valve body or torque converter. The friction clutches are replaced by low spin loss mechanical clutches, and no energy is required to hold these clutches. The low energy consumption, lighter weight, and high torque capacity make this an ideal solution for the wide variety of electrified vehicle architectures expected to populate the global automotive landscape within the next decade.

The DCC can replace synchronizers within simple gearboxes such as AMTs and DCTs, and improves overall packaging by eliminating complex shift fork-based actuation systems. Shift fork actuation systems are eliminated and the linear motor actuation system packages completely inside the transmission case.

The technology really takes off when these clutches are connected to a planetary gearset, such as the proven and popular Ravigneaux gearset, or the slightly more efficient Simpson gearset. This combination allows for the creation of simple multispeed gearboxes comprised of only a gearset, input and output shafts, several electric clutches, and housing.

Putting It In Drive

Perhaps the greatest differentiator from these new technology advances is the flexibility they offer. These building blocks of electrified propulsion systems allow transmission designers to create simple solutions that add a whole new level of sophistication to the electrification of the automobile. More speeds can be added to the transmission, efficiency is markedly improved, and it's all done without needing more packaging space. The added benefits of low energy consumption, lighter weight, and high torque capacity are all gained when these clutches are used in concert.

Whether the system is used in a DCT, AMT, BEV, HEV, PHEV or DHT, the Means Static CMD-e and Dynamic Controllable Clutch provide OEMs with proven solutions to many of the fundamental challenges that the electrification revolution will pose, now and in the future.

www.meansindustries.com

Electric Mobility & Innovation: TOTAL Launches a Pioneering Line of Fluids for Electric and Hybrid Vehicles

Hakim EL BAHI, Research Engineer, Total M&S
Yanis Frikha, Product Development Manager Driveline Fluids and Coolants, Total Lubrifiants
Thomas Gillet, Transmissions Product Engineer, Total Lubrifiants

At Total Lubrifiants, we have always worked hand in hand with our customers to develop tailored solutions that meet their specific needs and guarantee optimum operation and maintenance for their vehicles and equipment.

After several months of R&D, we are very proud to have developed two new, highly innovative product ranges that meet vehicle manufacturers' requirements and will help them design increasingly efficient electric and hybrid vehicles: TOTAL QUARTZ EV FLUID and TOTAL RUBIA EV FLUID.

The Challenges of the Energy Transition

The energy transition is now clearly under way and regulatory constraints are impacting the automotive industry like never before, requiring non-stop innovation.

With the growing concern over tailpipe emissions prompting stricter standards for carbon dioxide and pollutants like nitrogen oxides, unburned hydrocarbons and particulates, hybrid and electric vehicles are no longer on the fringe. On the contrary, they represent the next big wave of automotive technology.

Battery costs have declined 75 % over the past five years and next-generation powertrains are delivering improved performance. The automotive industry has taken assertive action to capture the trend and is devoting virtually all of its R&D spend to electric vehicles (EVs).

There were around three million EVs on the road worldwide in 2017. According to various scenarios, EV sales are expected to account for between 10 and 50 % of the light vehicle market by 2030.

New Configurations from OEMs

In **all-electric vehicles**, there are two configurations for lubrication. In the simplest and most widely used configuration, air or ethylene glycol-based water coolant is used to cool the electric motor via an indirect cooling system with a heat exchanger. Fluid is needed only to lubricate the mechanical transmission, which in an electric vehicle is the reducer. Unlike internal combustion engines, electric motors have a very large operating range (up to 20,000 rpm) and reach peak torque almost instantly, so there is no need for a multi-speed gearbox. In the second, more complicated, configuration, fluid is used as a coolant for the electric motor – and even the power electronics and battery – as well as a lubricant for the reducer and electric motor bearings.

Since the fluid will be in direct contact with the components to be cooled, it will also serve as a coolant. As a result, a more comprehensive strategy is needed for formulating the products that will be used for these specific applications.

Hybrid vehicles combine the constraints described above with the traditional constraints of mechanical transmissions. Those include managing synchronizer friction in manual and automatic transmissions, as well as friction in all applications with clutch systems, such as dual clutch transmissions and torque converters.

TOTAL QUARTZ EV FLUID and TOTAL RUBIA EV FLUID have specific properties that allow them to withstand these technical constraints of electrification.

Dielectric Properties

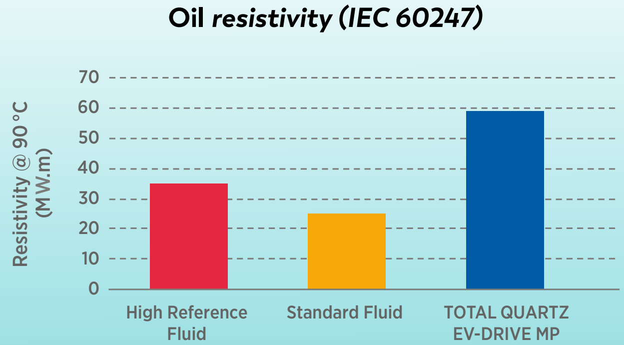
Very specific electrical properties are required when a vehicle is equipped with an electric motor and when lubricant comes into contact with the motor's components.

Four factors are taken into consideration when assessing a lubricant's dielectric properties:

- **Electrical resistance.** This measure of a material's opposition to the flow of electric current is expressed in ohm-metres (Ω.m). Insulating materials have high electrical resistance, in the megohm range. Ideally, the electrical resistance shouldn't be lower than a kiloohm, to avoid a flow of electric current, or higher than a gigaohm, to avoid electrostatic shock.
- **Dissipation factor, or loss tangent.** The loss angle (δ) measures the difference in phase between the alternating current applied across a material and the resulting alternating current passing through it. In dielectric materials, the loss angle (δ) is often small and used interchangeably with its tangent ($\tan \delta \sim \delta$), which translates the energy dissipated by the Joule effect. Temperature rise is therefore directly related to the value of δ. Typically, the loss tangent (or tan delta) of a transmission fluid is around one at room temperature. A good insulating oil should maintain a low tan delta.
- **Dielectric strength, or breakdown voltage.** Dielectric strength is the voltage that a material can withstand for a given wall thickness before electrical discharge through a material occurs. It is usually expressed in kilovolts (kV). An insulating oil typically has a dielectric strength of 50 to 100 kV at room temperature.
- **Relative permittivity, or dielectric constant,** is an expression of the ability of a substance to store electrical energy in an electric field. In mathematical terms, relative permittivity equals electric flux density divided by electric field strength. Because permittivity depends on a material's polarization, it will be higher in an oil that contains polar molecules.

These dielectric properties need to remain stable over time even though an oil may be degraded by higher temperature, oxidation, humidity or dust particles.

TOTAL QUARTZ EV-DRIVE MP (ELECTRICAL PROPERTIES)



Thermal Properties

The temperatures in electrical applications are higher than those observed in internal combustion engines. This is due, in particular, to the electrical components installed in the vehicle. Through the Joule effect, a large amount of heat can be given off in a very short time during strong acceleration or fast charging. Thanks to their thermal properties, the new fluid ranges optimize the thermal management of the various electrical modules and remain stable over time, even when subjected to very high temperatures (up to 180 °C).

The heat transfer provided by our new fluid ranges can be evaluated by the comparison criterion resulting from the following relationship:

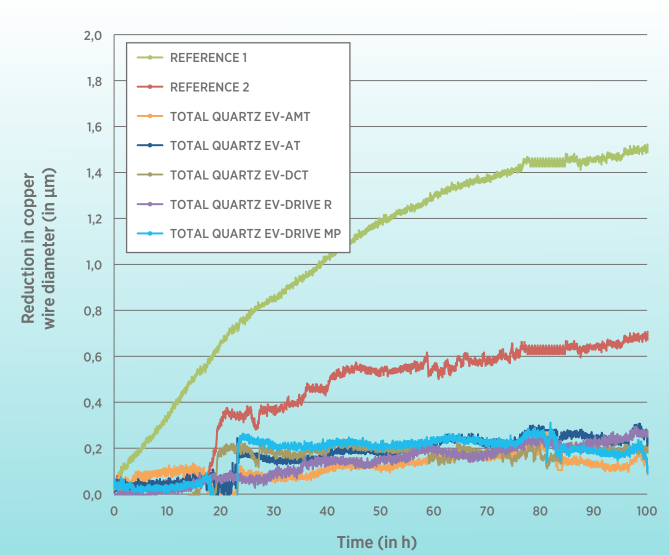
$$P = \frac{\alpha\, C_p\, \lambda}{v}$$

where P is the cooling criteria, α is the thermal expansion coefficient, C_p is the specific heat, λ, is the thermal conductivity and v is the kinematic viscosity. The higher P is, the better the heat transfer is.

Compatibility with Materials

Because the fluid comes into direct contact with the vehicle's electrical and electronic components, it also needs to be compatible with the different materials used in their coatings. Any chemical attack would compromise the electric vehicle's integrity. Copper is one of the critical materials in these applications. Due to its high electrical conductivity, copper is the main material used for wires, windings and electronic components. It is therefore crucial to design a lubricant that is highly compatible with copper and, in particular, to avoid all corrosion. Corrosion can occur in the volume of fluid itself or when the lubricant is in vapor phase. To characterize copper corrosion, we determine the loss of mass due to this phenomenon. Using a test developed in our laboratories, we are able to precisely monitor the corrosion kinetics of a copper wire. A lubricant that is highly compatible with copper will maintain the integrity of the metal's mass over time.

Analyses are also conducted to determine a lubricant's compatibility with **polymer coatings used for insulation**. Polyamide coatings, for



example, are used to insulate electric motor windings because of their good dielectric and mechanical properties. Compatibility with polymer-based materials can be evaluated in a static immersion test. The usual values for material characterization, including changes in elongation, hardness and volume, are measured after the test. We also use the dynamic Peel Test in our laboratories to evaluate compatibility. The coating is immersed in a lubricant under precise test conditions and then placed in special torsion machine that allows us to calculate the number of revolutions before the material breaks.

Standard Lubrication Functions and Friction Properties

To enable the introduction of more powerful electric vehicles, electric motors will have to operate at higher speeds (above 20,000 rpm) in the near future. This will put added stress on the rotor bearings. A new type of anti-wear/extreme pressure additive will be needed for optimal bearing lubrication at high speeds. Dedicated testing methods will also have to be rolled out to characterize the impact of these very high speeds on lubricants.

The electric motor's high speed also has an impact on the transmission, which relies on a splash lubrication system. Studies show that at high speed, **aeration** is a key factor in gear oil churning losses. The surface energy of the multitude of air bubbles created by the faster churning at high speed ends up causing greater energy loss than drag. Lubricants must therefore be formulated to meet this new constraint.

Long Service Life

TOTAL QUARTZ EV FLUID and TOTAL RUBIA EV FLUID are long lasting thanks to their heat resistance and lubrication properties. Manufacturers can be sure that the fluids will stay clean and effective throughout a vehicle's life, although they can be changed if mileage warrants.

With TOTAL QUARTZ EV FLUID and TOTAL RUBIA EV FLUID, Total Lubrifiants has developed a specific response to the growth challenges of the automotive industry and strengthened its commitment to cleaner mobility in the broader drive to protect the environment.

This program to accelerate progress was carried out in cooperation with our vehicle manufacturer partners to tailor the fluids to their specific needs and ensure a long operating life for their vehicles and components.

Efficient Synchronizer Solutions for (Dedicated) Hybrid Transmissions

Marcus Spreckels, Head of Technology, Oerlikon Friction Systems
Nils Weber, Development Engineer, Oerlikon Friction Systems

The targets of future regulations for automotive CO_2 emissions require increased engineering efforts and innovative solutions from the OEMs and their suppliers. Automotive powertrains will have to be optimised to highest possible efficiency to play their part in the future. That includes a consequent reduction or power losses and weight of automotive gearboxes. However, the emission targets can hardly be achieved by efficiency improvements of the conventional powertrain only. The preferred technology to fulfil the requirements are electric vehicles especially hybrid electric vehicles in parallel, serial or torque split configuration. Hybrid powertrains in parallel configuration require special transmissions to combine the power of the combustion engine and the electrical motor. This could be conventional dual clutch or even automated manual transmission upgraded with an electrical motor or dedicated transmissions for hybrid powertrains. Synchronizer systems will still have their place inside the future transmission to provide fast gear changes for an economical operation of the combustion engine.

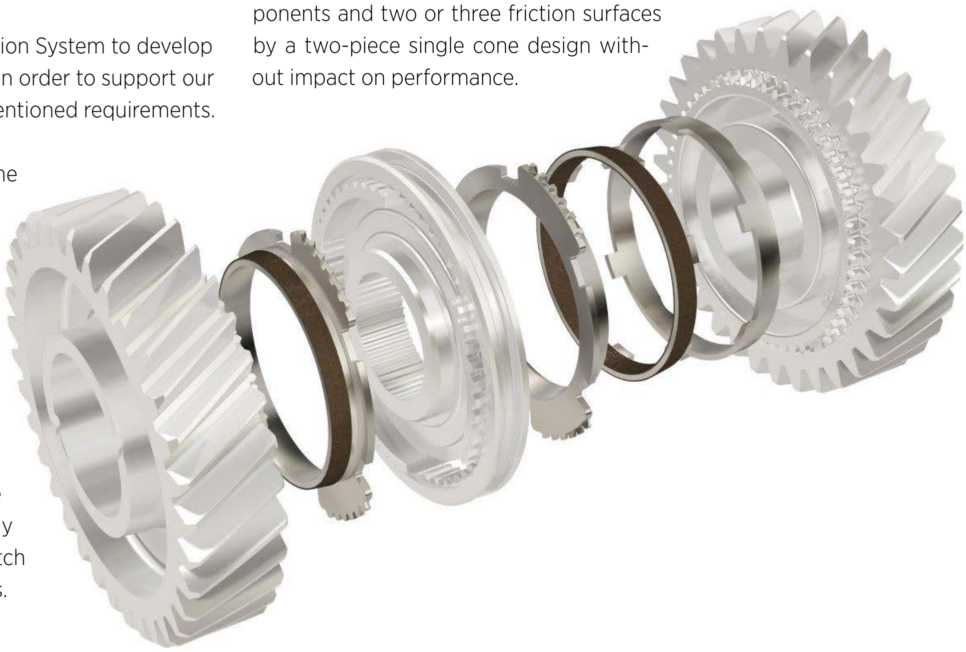
Those market challenges triggered Oerlikon Friction System to develop advanced and innovative synchronizer solutions in order to support our customers and partners to address the above-mentioned requirements.

The Segmented Synchronizer System ***S³*** with the high performance Carbon friction lining ***EF®8000*** is the ideal solution for performance and efficiency upgrades of existing conventional gearboxes. The ***S³*** concept provides the same performance like multi-cone synchronizers with less components. By reducing the weight of the transmission as well as a significant reduction of drag losses, the ***S³*** concept is the right answer for cost- and fuel saving transmissions now and in the future. The Segmented Synchronizer System can be easily integrated into existing manual (MT) or dual clutch transmissions (DCT) without major modifications.

The main requirements to synchronizer systems for hybrid transmissions are a compact design as well as high performance and efficiency. A compact design especially in axial direction is required, because additional components like the electrical motor must be integrated into the existing space of a conventional powertrain. Oerlikon Friction Systems gives the right answer to those requirements by presenting the new ***E*Sync** sychronizer family, which is designed to save as much space as possible without any limitation to the function or comfort. ***E*Sync** enables our customers and partners to develop the most efficient hybrid dual clutch (HDCT) and dedicated hybrid transmissions (DHT).

S³ – Segmented Synchronizer System

The advantage of the Segmented Synchronizer System is the reduction of weight and increase of efficiency by reducing the number of components and friction surfaces. The ***S³*** is able to replace double cone and triple cone synchronizers consisting of three components and two or three friction surfaces by a two-piece single cone design without impact on performance.



The concept of a conventional synchronizer is limited by a conflict between shift quality and torque capacity. A small cone angle reduces the shift time by increasing the torque capacity, but could also negatively influence shift quality. A larger cone angle provides good shift quality, but reduces the torque capacity and therefore increases shift time and shift force. Higher torque requirements need to be realised by multiple cone synchronizers with the consequence of increasing costs, weight and reducing efficiency.

The Segmented Synchronizer System is separating the function "synchronizing" and "releasing" by using a split friction ring with two different cone angles; the concept allows a reduction of the friction cone angle below the physical limit of conventional synchronizers. During synchronization, the blocker ring embraces the split ring and the inner small cone angle of the friction ring is providing the synchronizer torque. After synchronization, the larger outer cone angle of the friction ring allows the blocker and the friction ring to separate easily for a comfortable gear engagement. The benefits of the segmented synchronizer system are obvious:

- Reduced drag torque due to a reduced number of friction surfaces → up to 40 %
- Less weight by reduced number of parts → up to 20 %
- Space reduction in radial and axial direction → up to 13 %
- Cost saving → up to 30 %

S³ can be used as a drop-in solution for existing MT and DCT transmissions. The replacement of a multi-cone system by the Segmented Synchronizer System ***S³*** requires minimal modifications only; no changes to the hub and sleeve are required. The innovative friction ring can be combined with conventional brass or steel blocker rings.

S³ is a perfect system to upgrade existing transmission for higher efficiency, lower weight and reduced space.

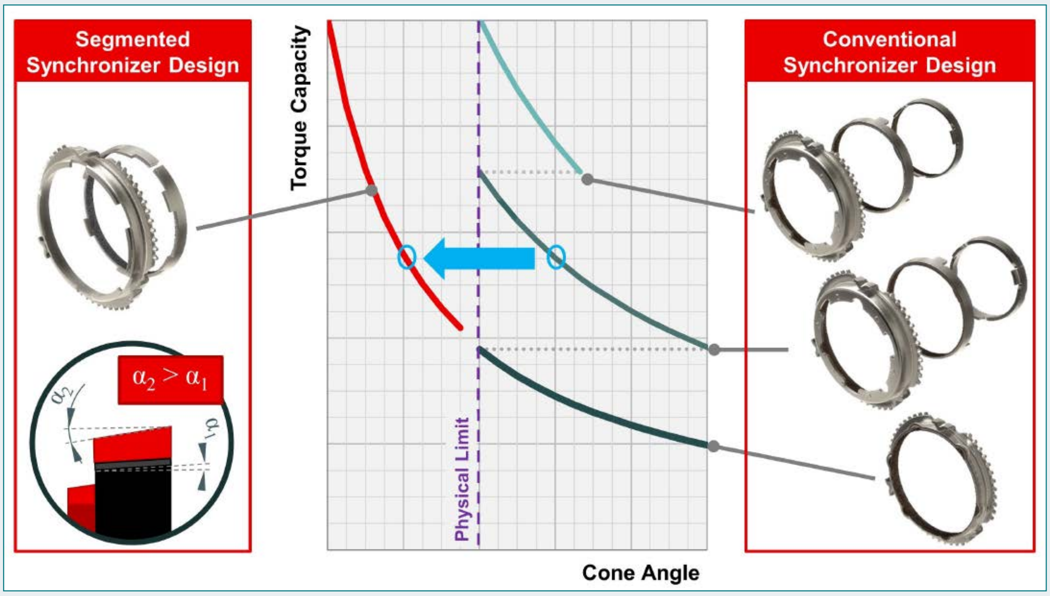


Figure 1 ***S³*** replaces multi-cone systems

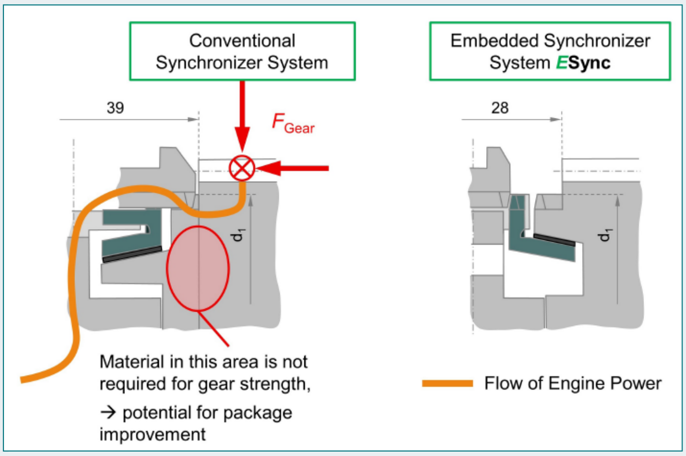


Figure 2 Redesigning the gearwheel by removing material

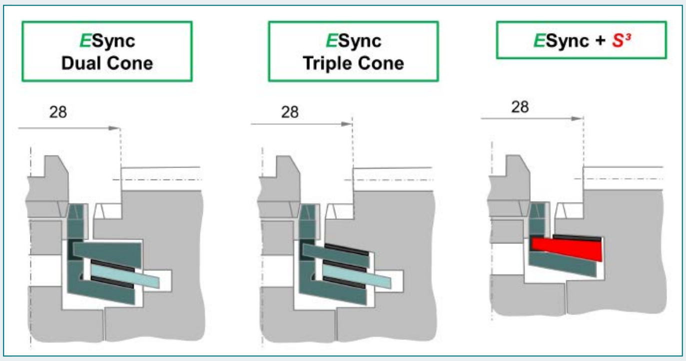


Figure 3 ***E*Sync** in different designs, multi-cone and ***S³***

*E*Sync – Space-saving design for future transmissions

To achieve future emission requirements, the number of hybrid cars will increase significantly in the next years. The largest portion will be plug-in hybrid vehicles (PHEV), which still need transmissions to connect the combustion engine and the electric motor to the drivetrain. The mechanical complexity of such transmissions is increasing, as additional components need to be integrated, for example electrical motors and actuators.

As the available space in a vehicle is limited, the additional components require a consequent space optimised design of all components. That means for the synchronizer components a significant reduction in axial package length.

The package length of the conventional system has been reduced incrementally in the past by:

- Using smaller spline module / Reduced chamfer angles
- Stronger hub design due to smaller struts
- Indexing without lugs
- Smaller friction surface by using high performance carbon
- Higher strength materials and production method for the hub

The typical package length of a conventional synchronizer is 40 mm from dog plate to dog plate. A package length of 34 mm is feasible by consequently pushing the design to the limits of material and production tolerances.

With the new revolutionary design, ***E*Sync** even shorter package length of up to 28 mm can be achieved for single cone as well as multiple cone synchronizers.

Looking inside the buildup of a conventional single or multi-cone synchronizer it can be seen, that in shifted condition the flow of engine power goes directly from the hub via the sleeve to the teeth of the gearwheel. Overthinking the major challenges for a transmission designer, like weight- and space-saving, this material is not required.

Removing the unused material creates a weight benefit up to 20 % compared with a conventional system. ***E*Sync** is integrated inside the gearwheel, filling the free space with single or multi-cone synchronizer system or even with ***S³***.

In combination with a new design of the hub, the dimension of the sleeve could be reduced and saves additional space between both gearwheels. By using the ***E*Sync** concept with a new hub and sleeve design that package length is reduced to less than 30 mm.

The benefits of such a design are:

- Less weight → up to 20 %
- Space reduction in axial direction → up to 30 %

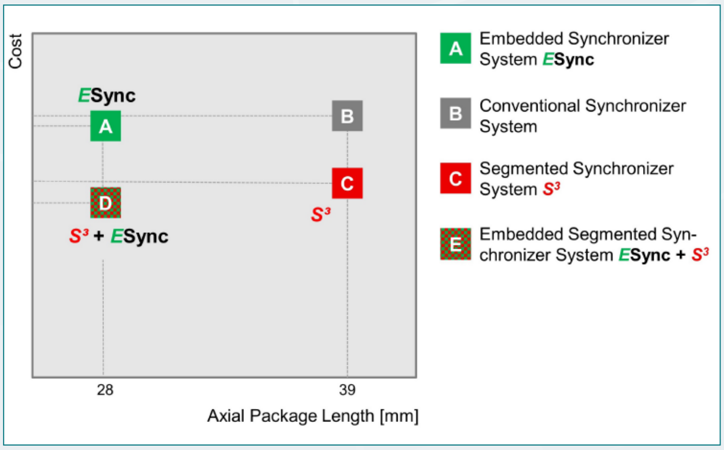


Figure 4 **ESync** and S^3 provides new possibilities for cost- and space saving

In addition, a combination of the Segmented Synchronizer System S^3 with the **ESync** concept is possible taking advantages of both systems. This combination offers reduced space in combination with a cost- and fuel-efficient design for innovative hybrid transmissions.

Conclusion

By introducing **ESync** and S^3, Oerlikon Friction Systems is offering a synchronizer system that gives new opportunities for the design of future transmissions. Both systems are not limited to automated transmission like DCT and DHT; they are also available for manual transmissions. Oerlikon Friction Systems redesigned the conventional system concept in a consequent way. Oerlikon Friction Systems is offering a revolutionary system which provides opportunities for cost- and fuel-saving and is the perfect solution for the design of advanced transmissions.

- S^3 increases the efficiency and reduces the cost and weight of a synchronizer system as a drop-in solution without compromising on the synchronizer torque capacity. By replacing multi-cone systems with S^3, existing transmissions could be upgraded and get more cost- and fuel-efficient.
- **ESync** is a complete new approach to reduce the package length compared to a conventional single or multi-cone system.
- Due the outstanding performance of S^3 and **ESync**, a high-performance carbon friction material is needed. Oerlikon Friction Systems offer this friction material with ***EF®8000***. As a global benchmark in friction characteristics and shift comfort, ***EF®8000*** is also the perfect solution for overload capacity. With a thickness of 0,45mm it is also a space-saving option which is suitable for all kinds of transmissions for passenger cars, light, medium and heavy-duty trucks.

Depending on the customer request and application, Oerlikon offers a wide range of innovative products to save costs, weight and package length. All synchronizer systems can be used as an upgrade for existing transmissions or offers new possibilities in the design.

Marzocchi's Elika Leads a "Silent" Revolution in the Automotive Sector

Marzocchi Pompe has been for the past 50 years a leader supplier of Gear Pumps in the industrial and off-highway mobile applications. Maybe not everybody knows that it is also a key player in the on-highway Automotive Sector.

Danilo Persici, R&D Dept., Marzocchi Pompe

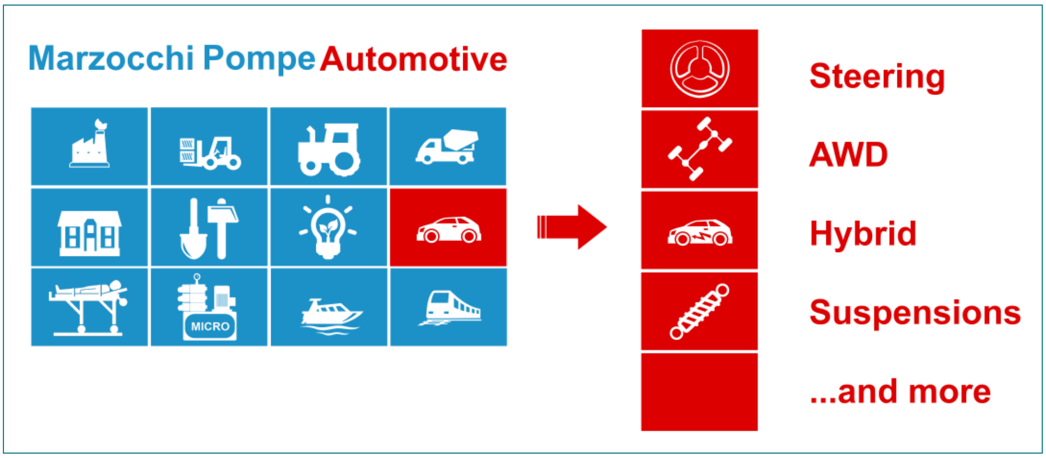


Figure 1
Applications of E05 Pumps family

Gear pumps are volumetric machines widely used in hydraulic system design since a long time mainly because of their unbeatable cost/efficiencies ratio and for their simple **construction** and **compactness**.

Marzocchi Pompe is the manufacturer with the **broadest range of displacement** reaching as low as 0,12 cc/rev and up to 200 cc/rev.

The top characteristics of quality, reliability of the **Marzocchi** products allowed the Company to gain an interesting share in the **Automotive Market**, where the most suitable range of displacement goes from 0,12 cc/rev and up to 8 cc/rev which is widely appreciated in all those applications where a **mini powerpack** is required.

The pumps are designed specifically to be part of the **electro-hydraulic system** to generate a flow of pressurized oil in a controlled manner to drive the "actuators" required in most of the above-mentioned systems.

Standard application of **Marzocchi Pompe** products are easily requiring up to 300 bars while the limited operating pressure of the automotive application, generally up to 80–100 bars, has allowed design and process engineers to introduce several design and process **optimization** with the goal on one side to maintain and even enhance very high performances specifically in terms of **efficiencies and noise and reducing** overall sizes as well, and on the other side decreasing the manufacturing costs also with the adequate level of automatization of the production and assembly of the units.

Figure 2 Evolution of E05 Pumps family

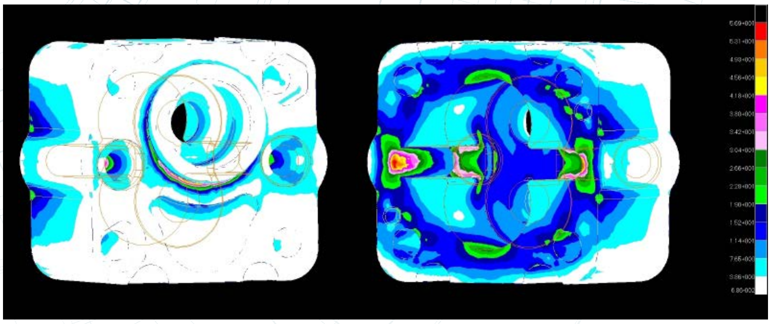


Figure 3 Structural Analysis of E05 body pump

The automotive family of **E05 Pumps** has been specifically designed to be integrated into assemblies of **automatic transmissions**, **semi-automatic clutches**, **electro-hydraulic power steering**, **AWD systems**, **assistance in hybrid-type of propulsion, suspensions' systems, trucks rear-steering etc**. The main parts of the pump, before being physically built, have been subjected to structural verification through **FEA simulations**, in order to check in advance, the structure of the pump subject to the stresses of work and also to verify the behavior during the most critical stages of the manufacturing process.

Despite their small size, **E05 Pumps**, depending on the application characteristics, can be internally **mono or bi-compensated**, the compensation system must always maintain the compensation plates in contact with the gears ensuring in all operating conditions, a **drastic reduction of internal leakage**, adequate lubrication of the moving parts and excellent volumetric and mechanical efficiency. Synthetic oils used in the automotive industry generally have a low viscosity, as it must maintain adequate fluidity even at low temperatures, down to even −40 °C. The low viscosity of the oil has imposed a fine tuning of the compensation system. The **compensation system** has been designed to **reduce the inevitable friction components increasing the mechanical efficiency of the system**. High mechanical efficiency has a direct effect to lower consumption and enable a reduction of the size of the other components, such as a reduction in the size of the electric motor required to move the micropump.

A reduction of internal friction also entails a reduction of the heat input in the hydraulic circuit. Reducing the volumetric losses is also possible to reduce the size of other components such as the radiators: lower the internal leakage of the pump means lower heat that should be then taken away through oil cooling.

Because of everything said before, **Marzocchi** can definitely provide the right answer to the specification that **TIER1 or TIER2** engineers are looking for:

- High efficiencies to cope with limited current and voltages requirement
- Low noise in order to reduce NVH (noise, vibration, harshness).
- Limited overall dimensions in order to cope with packaging restraints
- Competitive pricing versus standard pump solutions

A completely new automotive-dedicated Production Plant

Starting from 2016, the automotive pumps had been produced in a new plant completely focused on the Automotive Pumps. In the new factory of more than 9,000 m², located in Zola Predosa, just 5 kilometers from the headquarters of the **Marzocchi Pompe**, 80 people work. The pumps are produced on semi-automatic assembly and testing lines able to guarantee the high quality and contamination standards that the automotive sector requires. The Plant's **ISO IATF 16949 Certificate** has been updated until May of 2021.

The best for last – The ELIKA Family of Silent Pumps becomes larger

Thanks to the birth of the **ELIKA1P**, the range of available displacements of the **ELIKA** family is once again increasing. This time the development concerns smaller displacements with a standard range **from 2.1 up to 8.1 cm³/rev**. This family is particularly suitable for automotive solutions, where the producers are increasingly required to produce silent mini hydraulic power units for **lifting systems**, **large hydro guides** or **rear steering systems** for transport vehicles and others. Like all automotive solutions, **Marzocchi** is widely available to collaborate on customized solutions for shapes and sizes.

Figure 4 Helical Gears of ELIKA1P

Figure 5 New ELIKA ELIK1P

ELIKA itself is a **highly efficient**, **low-noise** and **low-ripple Gear Pump**, designed and manufactured by **Marzocchi Pompe.** Its realization is a result of a close cooperation with the Engineering Faculty of the University of Bologna and its development brought to many patents and trademarks registered by Marzocchi.

Just recently (09 November) at **EIMA 2018** in Bologna its Multiple Version was awarded a **Technical Innovation Prize** with the following quote by the commission:

> "Elika is a Solution for external gear pumps that allows the same design of gears previously reserved for individual pumps to be used in modular architectures, to reduce vibrations and noise."

ELIKA's **Helical Gear Technology** is the perfect choice for all low-noise level applications. The **ELIKA** gears reduce the **noise level** by an average of **15 dBA** compared with a conventional external gear pump.

The specific design of its helical gears ensures the continuity of the motion despite the low number of teeth. The low number of teeth reduces the fundamental frequencies of the pump noise, producing a **more pleasant sound**. The shape of the **ELIKA Profile**, **patented by Marzocchi Pompe**, eliminates the encapsulation phenomenon typical of standard gear pumps by thus eliminating the main source of noise and vibrations. **ELIKA** tooth profile, without encapsulation, **significantly reduces pressure-oscillations and vibrations** produced by the pump and transmitted to the other components, reducing the noise of the Hydraulic System.

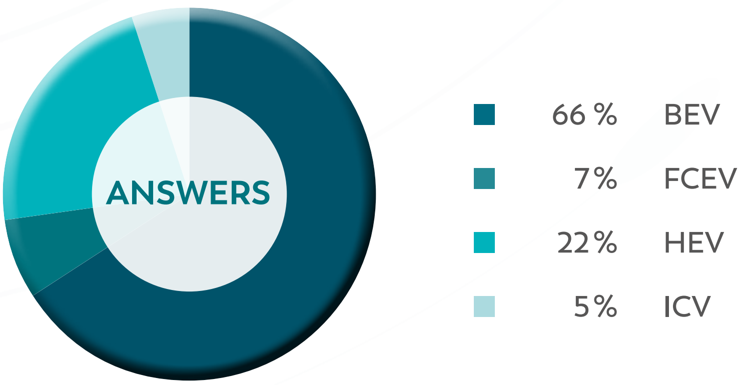
The **particularly low level of noise** produced by the **ELIKA** pump makes it particularly suitable for applications which currently employ much more expensive technologies such as screw pumps, vane pumps, or internal gear pumps. **ELIKA**, with its characteristics, is the **ideal solution** regarding a wide range of specifications such as rotation speed, operating pressure and viscosity. The structure of the **ELIKA** pump minimizes leaks and maximizes volumetric efficiency in all conditions. **ELIKA** is therefore particularly suited for applications, which use **inverters** or variable-speed drives to regulate the speed of the actuators.

For further information on Marzocchi Pumps:
marketing@marzocchipompe.com

CTI Trend Barometer

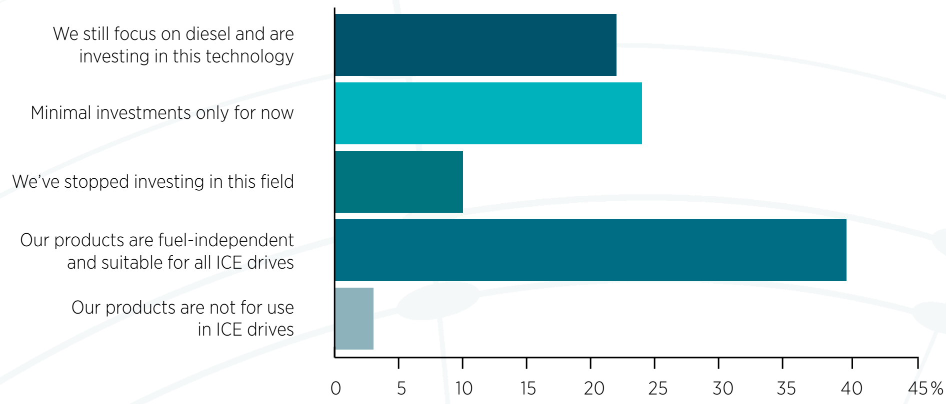
During the CTI Symposium in Berlin (Dec. 2018), we asked 1300 experts in drive technology about their predictions for the industry developments. The CTI Trend Barometer points out the results.

Which drives will most autonomous vehicles use from 2030 on?

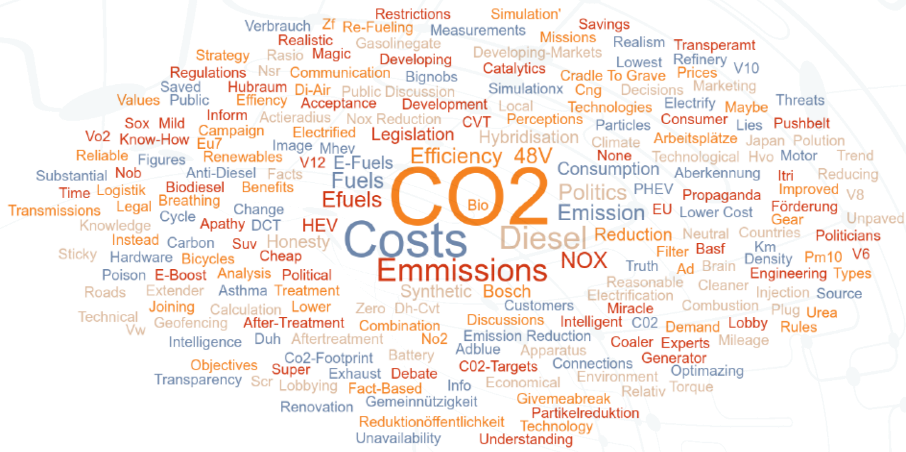


What's stopping you from buying a BEV?

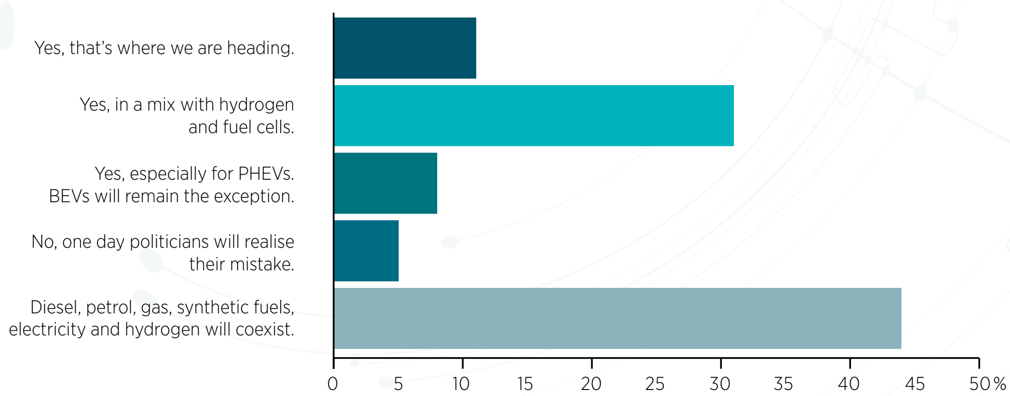
What role do diesels play in your corporate strategy?



What could save diesel as technology for passenger cars?



Is electricity the fuel of the future?



iLok™ Nut – An Innovative Fastener that Solves a 30 Year old Problem for Rear Axle Hub Assemblies

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Abstract

Truck and bus manufacturers have been constantly facing an issue to disassemble the rear axle shaft from the hub when transporting the truck from the factory to the dealership. In addition to that, the dealerships have the very same problem every time they have to replace the brake pads in some truck models, which leads to excessive service time, extra costs and aftermarket complaints. The current problematic fastening system is composed by a lock nut, a flat washer and a coned slotted bushing. The concept of this 30 year old design involves the coned slotted bushing being pressed against a tapered hole on the shaft's flange. After tightening the lock nut, the bushing clamps towards the stud and it gets stuck in between the shaft and the stud generating the problem described above. This paper shows the R&D process that Tekfor used to come up with the solution named iLok™ nut that replaces the problematic 3-piece fastening system. The methodology involved (a) Innovation process; (b) CAD modeling; (c) Finite Element Analysis; (d) Forging simulations; (e) Forging trials; (f) Prototypes manufacturing; (g) Torque and tension tests; (h) Junker vibration tests; (i) Proof load test; (j) Salt spray test; (k) Fit and function test, etc. The iLok™ nut showed superior performance in all these tests and its usage brings multiple benefits to OEMs, Tiers 1 suppliers, Dealerships and end users. This is the most important innovation of a nut for the automotive industry since the advent of the wheel nut in 1972.

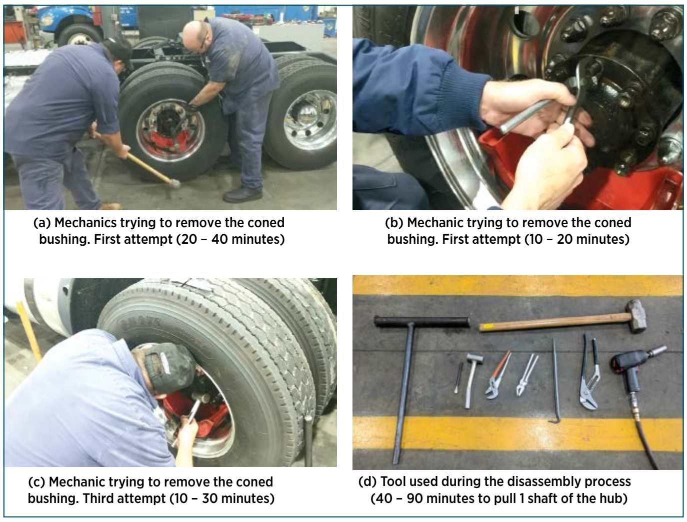
Introduction

For more than 30 years, OEMs, Tier 1 suppliers, dealerships, truck fleet owners, and end users have been facing issues with a problematic 3-piece fastening system that connects the rear axle shaft on the hub of most class 6, 7, and 8 trucks across the globe [1]. The 3-piece system is composed by a lock nut, a flat washer and a coned bushing that can be slotted or not as shown on Figure 1. Depending on the truck model, the flat washer is not used and the system is reduced to a 2-piece configuration commonly found in European trucks. In spite of that, both 2-piece and 3-piece systems present the same issue of the coned bushing getting stuck in between the flange and the stud when the shaft has to be pulled off the hub during the truck's transportation from the assembly line to the dealership, or during maintenance to replace brake pads in some truck models. This issue causes OEMs, Tier 1, and Dealerships to waste a considerable amount of time and money to disassemble the rear axle shaft from the hub. Moreover, the struggle faced during the disassembly process often results in some sort of re-work or re-paint on the shaft, or other components, due to scratches, dings, and nicks, which generates more and more costs that are cascaded through the entire supply chain. In addition to that, another issue caused by the 3-piece or 2-piece system is when the press fit between the locking feature of the

Figure 1 3-piece and 2-piece fastening systems used on rear axle hub assemblies.

nut and studs gets too tight. This issue leads to the removal of the phosphate coating from the stud threads, which causes premature corrosion of the fasteners in the field. All these extra costs caused by inefficiencies and re-work are transferred to the end user who buys the trucks.

Figure 2 shows two mechanics struggling to pull the shaft off the hub as well as the tools commonly used during service. This is the same struggle that shop floor operators face to pull the shaft off the hub at the end of the assembly line in preparation to transport the truck from the factory to the dealership. The disassembly time varies from unit to unit, but usually it is a time consuming process. For instance, it took two mechanics, nine tools, and approximately ninety minutes to disassemble the rear axle hub shown on Figure 2 in order to replace the brake pads.



(a) Mechanics trying to remove the coned bushing. First attempt (20 – 40 minutes)

(b) Mechanic trying to remove the coned bushing. First attempt (10 – 20 minutes)

(c) Mechanic trying to remove the coned bushing. Third attempt (10 – 30 minutes)

(d) Tool used during the disassembly process (40 – 90 minutes to pull 1 shaft of the hub)

Figure 2 Struggle faced by mechanics and shopfloor operators to pull the shaft off the hub

This paper shows the research and development process used to come up with a 1-piece solution that replaces the problematic 3-piece and 2-piece fastening systems.

Analysis of the 3-piece fastening system

The initial step for designing a new fastener is to understand how much clamping force the joint needs in order to secure a proper and reliable fastening system. This information is rarely available because OEMs often specify torque and rotational speed as the installation parameters rather than clamping force. In other words, OEMs and Tier 1 suppliers often have a good understanding of the required installation torque and speed for a given joint, but they rarely know how much clamping force is actually needed to secure that joint. With that being said, the actual clamping force at the rear axle hub assembly joint can either be measured with an ultrasound equipment, or it can be calculated through a torque and tension test based on the installation parameters used at the assembly line. Figure 3 shows the assembly process of the 3-piece fastening system often used by North American trucks. The installation torque and speed are respectively 150 ±15 Nm and 130 rpm. For this particular truck manufacturer, the assembly process of the 3-piece system is the bottleneck operation of the assembly line. A 1-piece system is highly desirable because it would eliminate the bottleneck operation, which would increase the overall efficiency of the entire assembly line.

Once the engineering drawings, specifications, and installation parameters were available, the 3-piece system was modeled in the virtual environment with the aid of CAE software. Figure 4 shows the boundary conditions used for the structural analysis. The stud, nut, washer, cone bushing, and shaft are made from steel and present a Young's modulus of 206 GPa and a poisson coefficient of 0.3. The hub can be made of either cast iron or aluminum depending on the truck model. This finite element analysis considered a hub made from aluminum with a Young's modulus of 69 GPa and a poisson coefficient of 0.33. The clamping force

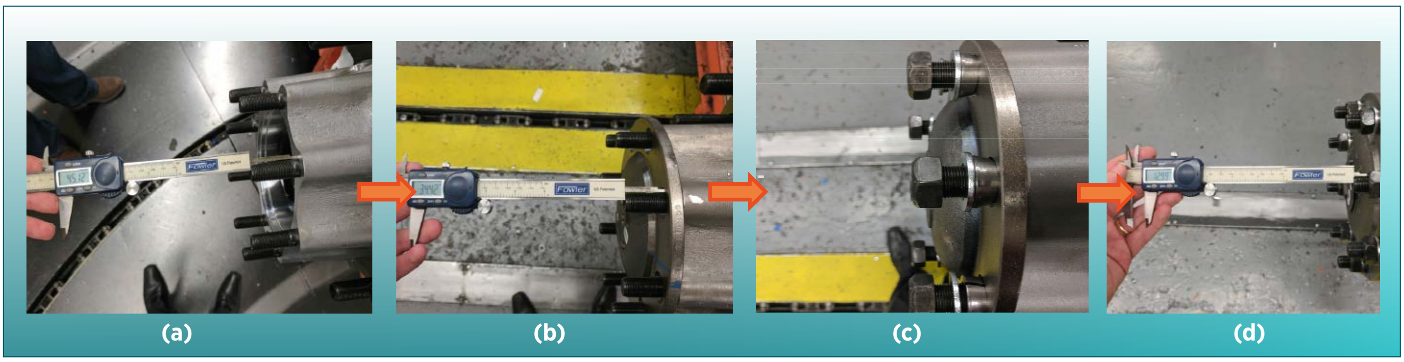


Figure 3 Installation process of the problematic 3-piece system. (a) Hub as received at the assembly line, (b) installation of axle shaft, (c) installation of the 3-piece fastening system – coned bushing, flat washer and lock nut, (d) tightening of nut

(FM) was calculated according to VDI 2230 [2] as demonstrated through equation 1. In this formula, P is the pitch diameter, d2 is the flank diameter, µG is the coefficient of friction on the threads, Dkm is the effective friction diameter, and µk is the coefficient of friction at the interface between nut and washer. The installation torque was 150 Nm as the assembly line, and the coefficient of friction µG and µk were pulled from a database of previous torque and tension tests performed for similar fasteners tested under similar conditions.

$$F_{M}=\frac{Torque}{\left(0.159\times P+0.578\times d_2\times \mu_G+\frac{D_{km}}{2}\times \mu_k\right)} \quad (1)$$

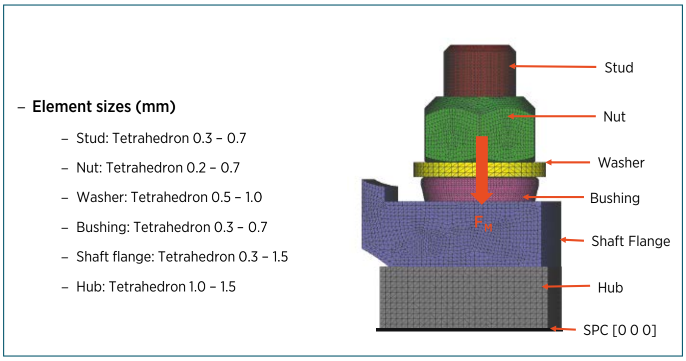


Figure 4 Boundary conditions for the structural analysis

The goal of the Finite Element Analysis (F.E.A.) was to understand how the parts interact with each other during the assembly process and identify high contact pressure areas. Figure 5 compares the calculated contact area versus the actual contact area. The virtual model showed good correlation with the real life system.

Based on the F.E.A. results, it was possible to understand that the coned bushing acts as a spring lock mechanism to prevent the stud from rotating against the hub when the lock nut is removed. Moreover, the contact between the conned bushing and the stud takes place only on the on threaded outside diameter (OD) of the stud. This contact pattern eliminates the risk of damaging the threads during the assembly process. More than likely, this is the reason why the stud presents a non threaded OD instead of being completely threaded.

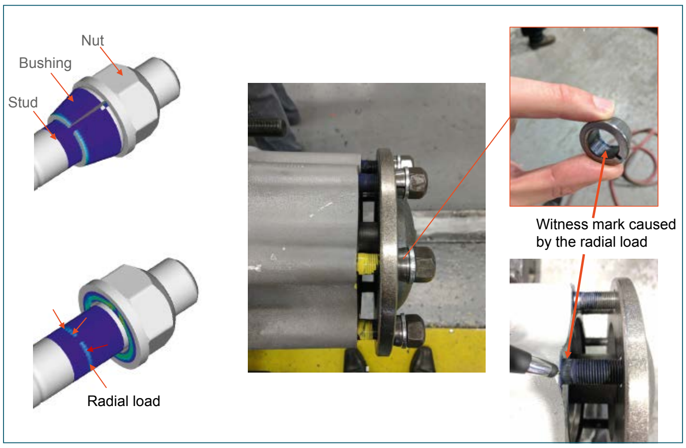


Figure 5 Calculated contact area versus actual contact area

Once the function of each individual component was understood, the analysis of the 3-piece system advanced with experimental testing in order to establish design parameters for the 1-piece system. Figure 6 shows the torque and tension test bench (DTT), which measured how much clamping force was generated for a given torque. The test was conducted according to ISO 2320 part 8.3 [3], with the same 150 Nm of torque used in the assembly line at 20 rpm. In order to reproduce the same friction conditions of the actual joint, the flange of the axle shaft was sectioned in order to fit in the standard load cell of the DTT machine. A double strain gage cell was used in order to measure how much clamping force was actually being transferred to the hub and how much force was being transferred though the axle shaft.

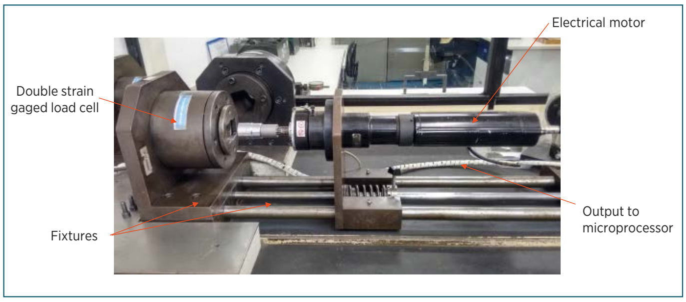


Figure 6 Torque and Tension test bench (DTT)

Five sets of the 3-piece system were tested three times each. Figure 7 presents the results of the torque and tension test for the first installation of the first set of fasteners. Note that the installation torque of 150 Nm generated a clamping force of 46.6 kN. After fifteen installations, the clamping force generated by the 3-piece system ranged from 40 to 50 kN for the same installation torque of 150 Nm. This typical variation is explained by a difference in the coefficient of friction (µges) between the rotating components for each individual set of fasteners.

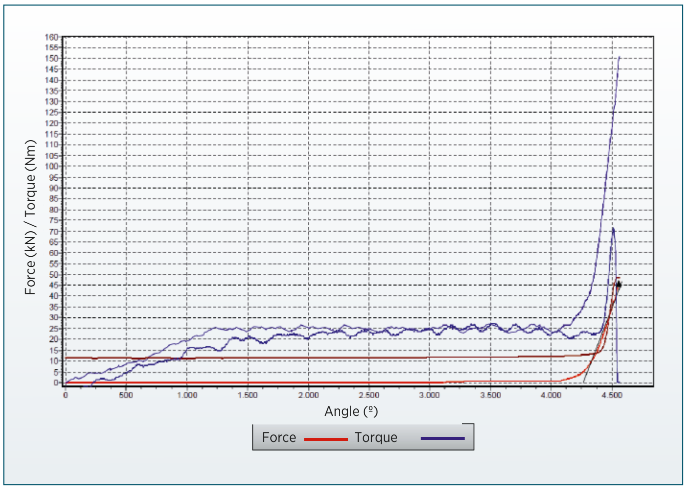


Figure 7 Torque and tension test result for the 3-pc system – First installation

As well as identifying how much clamping force was generated at the joint, the torque and tension test was also able to reproduce the problems created by the 3-piece fastening system. Figure 8 shows how the coned bushing got stuck in between the axle flange and stud, which required a considerable effort to disassemble the first set of fasteners in preparation for the next test. In addition to that, one can see that the phosphate coating was removed from the threads of the stud due to the locking mechanism of the lock nut. This condition leads to premature corrosion in the field. OEMs, Tier 1 suppliers, and dealerships face these same problems with the 3-piece and 2-piece systems.

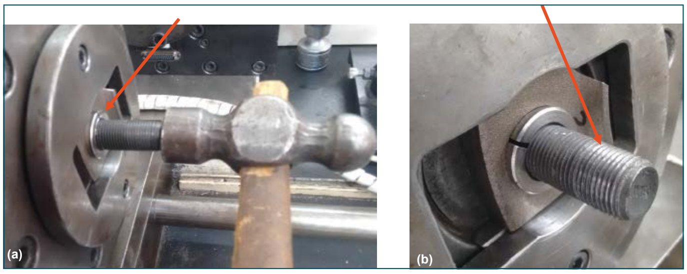


Figure 8 (a) Conical bushing got stuck in-between the flange and stud; (b) Phosphate coating removed by the lock nut

One of the concerns when replacing the 3-piece fastening system by a 1-piece system is the difference in the kinematics of the joint. While the lock nut spins against smooth surfaces such as the face of the flat washer in the 3-piece system (Ra~0.4 µm), or against the face of the coned bushing in a 2-piece system (Ra~0.5 µm), a 1-piece solution spins against the tapered hole of the flange, which presents a rough surface (Ra~ 2.9 µm). The high contact pressure created on the rougher surface leads to higher losses due to friction. That means the 1-piece solution requires higher installation torques in order to reach the same clamping force created by the 3-piece or 2-piece systems. The difference in the kinematics created by the 1-piece solution leads to a risk of spinning the stud against the hub when the lock nut is removed. In order to address that risk and establish design parameters for the 1-piece solution, breakaway torque tests were conducted on all six studs of an OEM rear axle hub assembly. This test showed that the studs start rotating against the hub when a torque of 86 Nm is reached.

Table 1 summarizes the results of the torque and tension and breakaway torque tests of the problematic 3-piece fastening system, as well as the design objectives established for the 1-piece solution. The clamping force has to be in the 40 to 50 kN range in order to secure a reliable fastening joint. The installation torque can go up to 372 Nm, as this is the upper limit of most DC multi nut runners available in the assembly lines of OEMs and Tier 1 suppliers. Obviously, the 1-piece solution not only has to reach the torque and tension values that secure a safe and reliable joint, but also it has to eliminate the failure modes created by the problematic 3-piece fastening system. That is, the new fastener cannot get stuck in-between the axle flange and the stud, it must allow a quick and smooth disassembly process, and cannot remove the phosphate coating from the treads of the stud.

Based on the design parameters shown on Table 1, the next section explains the development process that resulted in the 1-piece solution named "iLok™ nut".

The 1-piece solution: iLok™ nut

The innovation process that resulted in the iLok™ nut is shown on Figure 9. The innovation loop considered the fastener concept patented by Duraforce, the OEM requirements, and Tekfor's experience with fastener designs and manufacturing process know- how. The challenge was to find a low cost solution, without changing the adjacent components (stud, hub, shaft flange), while maintaining or exceeding the performance of the 3-piece system and making the disassembly process faster and less complicated. Multiple ideas with different geometries were generated at the early stages of the project. As the product development advanced, only one solution was proved to work effectively and was presented to the automotive market.

More than forty different geometries were evaluated in the concept phase. With the aid of CAD and CAE software, it was possible to understand how the radial stiffness of the spring lock mechanism could be tweaked by changing the outer diameter (OD), inner diameter (ID), angle (∝), slot width (w), slot length (l), and number of slots (n). The stiffness of the spring lock mechanism is directly related with the torque

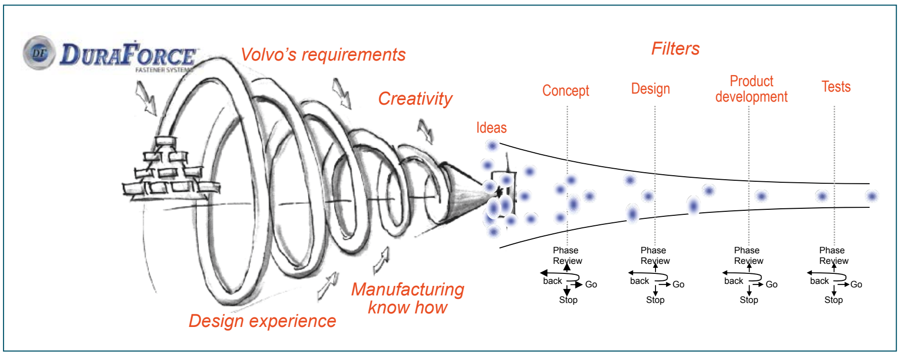


Figure 9 Innovation process

Test no	Installation torque (Nm)	Clamping force (kN)	Disassembly torque (Nm)	Bushing gets stuck into the flange?	Coating removal on the thread?	Disassembly time (minutes)
1 (3-piece system)	150	46.6	40	Yes	Yes	42
2 (3-piece system)	150	40.5	38	Yes	Yes	38
3 (3-piece system)	150	50	41	Yes	Yes	51
4 (3-piece system)	150	48	39	Yes	Yes	26
5 (3-piece system)	150	42	38	Yes	Yes	47
1-piece solution target	150 – 372	40 – 50	< 86	No	No	<1

Table 1 Summary of the torque and tension test of the problematic 3-piece fastening system and design objectives for the 1-piece solution

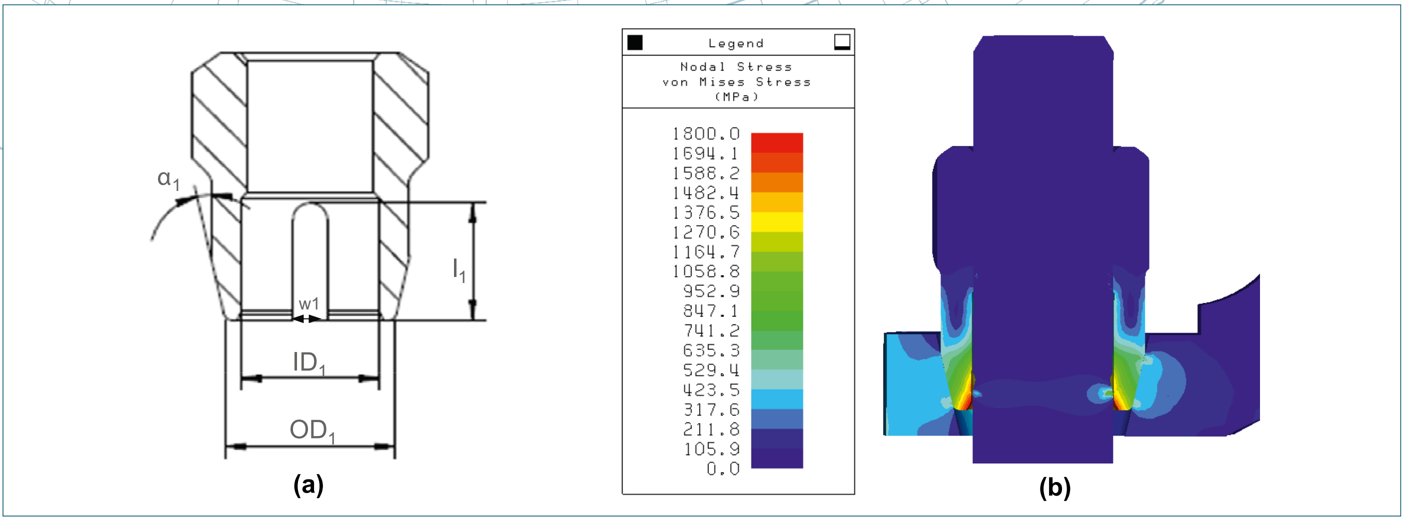


Figure 10 (a) Dimensions changed during the design phase; (b) von Mises stress result for that geometry

and tension behavior of the iLok™ nut, as well as with the amount of elastic energy that can be stored at the assembled joint. That stored energy combined with the mechanical contact between the tip of the iLok™ nut and the stud eliminates side sliding at the joint and generates its vibration-proof characteristic. Figure 10 shows the dimensions that were changed at the spring lock area during the design phase of the iLok™ nut and the von Mises stress for that particular geometry. The stress of 1800 MPa suggests that plastic deformation will occur at the tip of the nut, even for a fastener class 10.9 hardened at 32 HRC. This stress level at the contact area is similar to stress calculated for the coned bushing of the 3-piece system. Furthermore, the tip of the iLok™ nut is under compressive stresses generated by the pressure applied against the tapper hole of the shaft flange, which mitigate crack nucleation.

After the best iLok™ geometry was determined through multiple loops of FEA, five hundred prototypes were cold formed, threaded, hardened, and coated with two different types of surface treatment. Figure 11 shows the finished conditions of the iLok™ nut prototypes. The silver colored parts were coated with zinc and the black ones were coated with phosphate.

Figure 11 iLok™ nut – Finished conditions of the prototypes

Five samples of each coating type were submitted to the torque and tension test five times each. The goal was to determine what is the installation torque required to achieve clamping forces between 40 and 50 kN. The test was conducted according to ISO 2320 part 8.3 at 20 rpm. Figures 12 and 13 show the test results for the first and fifth installations of the iLok™ nut coated with phosphate. Figures 14 and 15 show the test results for the first and fifth installations of the iLok™ nut coated with zinc. The installation torque required to reach a clamping force of approximate 46 kN ranged from 251 Nm to 257 Nm for the iLok™ nut coated with phosphate, and from 277 Nm to 328 Nm for the iLok™ nut coated with zinc. These torque ranges are within the torque capabilities for typical DC multi nut runners available in the assembly lines of OEMs and Tier 1 suppliers. One can see that the assembly torque curves present a nonlinear shape on the first installation (Figures 12 and 14). This nonlinear behavior is caused by a local plastic deformation at the tip of the nut that occurs during the first installation only. This small plastic deformation was expected by the FEA results and does not jeopardize the performance of the product. The second, third, fourth, and fifth installations did not lead to any extra plastic deformation of the iLok™ nut.

Table 2 shows the summary of the torque and tension test. Not only does the iLok™ nut satisfy all application requirements relative to torque and tensioning, but also it does not get stuck into the flange nor does it remove the coating from the stud's thread. On the other hand, the installation torque has to be increased due to the higher coefficient of friction inherent to the iLok™ concept of rotational movement against the flange of the shaft.

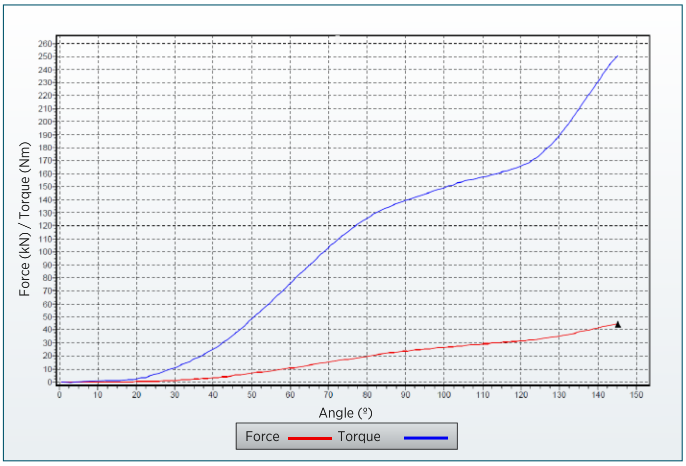


Figure 12 iLok™ nut, phosphate coated – First installation

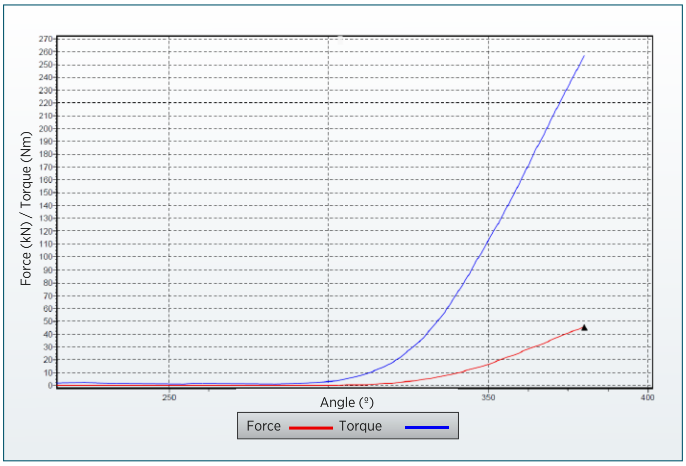


Figure 13 iLok™ nut, phosphate coated – Fifth installation

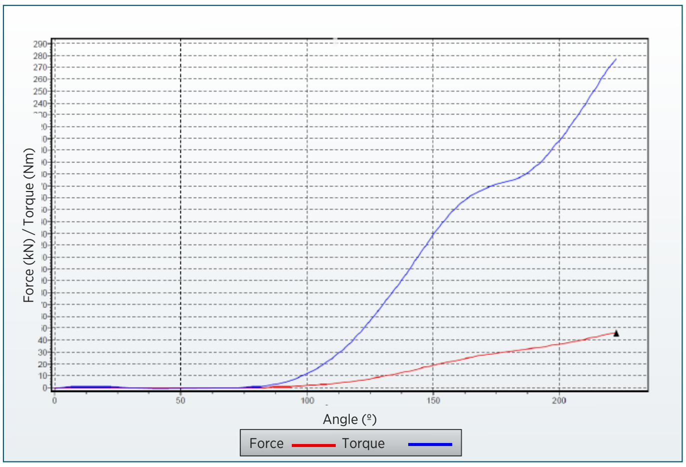


Figure 14 iLok™ nut, zinc coated – First installation

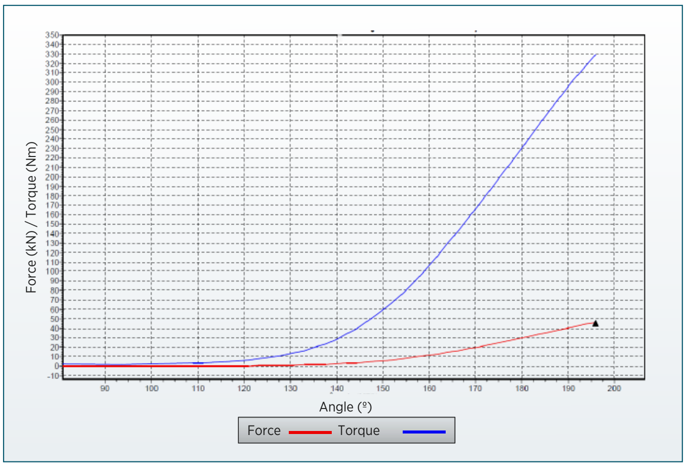


Figure 15 iLok™ nut, zinc coated – Fifth installation

Test no	Installation torque (Nm)	Clamping force (kN)	Disassembly torque (Nm)	Bushing gets stuck into the flange?	Coating removal on the thread?	Disassembly time (minutes)
1 (3-piece system)	150	46.6	40	Yes	Yes	42
2 (3-piece system)	150	40.5	38	Yes	Yes	38
3 (3-piece system)	150	50	41	Yes	Yes	51
4 (3-piece system)	150	48	39	Yes	Yes	26
5 (3-piece system)	150	42	38	Yes	Yes	47
1st iLok nut zinc	277	46.5	32	No	No	< 1
2nd iLok nut zinc	305	45.2	31	No	No	< 1
3rd iLok nut zinc	273	47.1	35	No	No	< 1
4th iLok nut zinc	304	45.5	30	No	No	< 1
5th iLok nut zinc	328	46.2	32	No	No	< 1
1st iLok nut phosphate	251	46.5	47	No	No	< 1
2nd iLok nut phosphate	243	45.2	47	No	No	< 1
3rd iLok nut phosphate	250	47.1	43	No	No	< 1
4th iLok nut phosphate	239	45.5	39	No	No	< 1
5th iLok nut phosphate	257	46.2	39	No	No	< 1
iLok™ nut target	150 – 372	40 – 50	< 86	No	No	< 1

Table 2 Summary of the torque and tension test

Once the iLok™ nut was approved in the torque and tension test, the vibration resistance of the product was extensively tested through multiple Junker vibration tests as presented on Figure 16. In this test, the unbalanced rotor generates lateral forces and induces side sliding between nut and bolt. The load cell monitors the clamping force variation per cycle. The test was conducted according to DIN 65151 [4], with a frequency of 12.5 Hz and amplitude of 10 % of the bolt diameter. The initial clamping force was set to 45 kN.

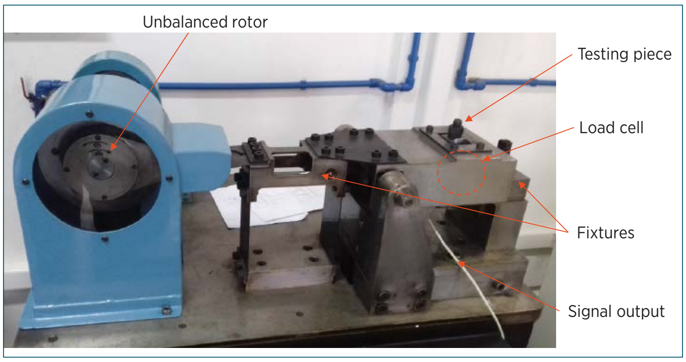


Figure 16 Junker vibration test bench

Five samples of the 3-piece system and five samples of the iLok™ nut were tested three times each. Figure 17 compares the vibration resistance between the 3-piece system (red line) and the iLok™ nut (green line). The iLok™ nut presented a reduction up to 5 % on the clamping force versus 14 % of the problematic 3-piece system. In other words, the iLok™ nut performed better than the 3-piece system on the vibration test. Moreover, the bushing of the 3-piece system got stuck into the flange, which is the same problem reported in the field as well as in the torque and tension test.

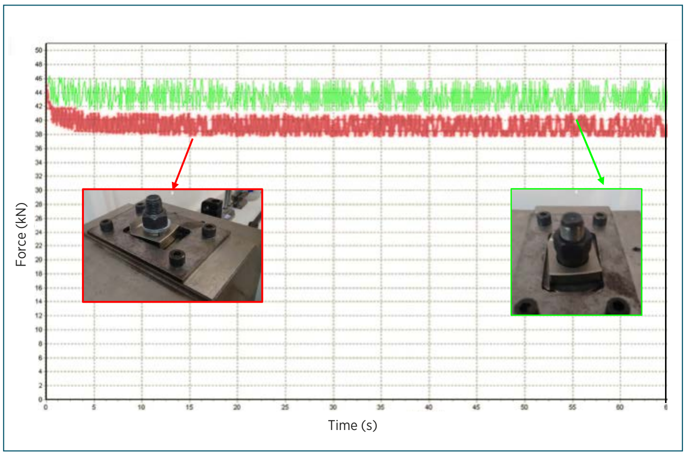


Figure 17 Vibration test summary – iLok™ nut (green line) versus 3-piece system (red line)

After the approval in the Junker vibration test, the iLok™ nut was submitted to a proof load test. This test consists in applying a specific compressive load on the nut and detect if its threads present plastic deformation. The test was conducted per IFI 100/107 for a 5/8″nut grade C with a compressive force of 17,395 kgf [5]. Figure 18 shows the universal tensile test machine and the proof load test results. The linear behavior of the load versus displacement curve indicates that the threads remained under the elastic limit for a load of 17,395 kgf. This result was expected because the tested iLok™ presented the same number of threads, same thread geometry, same material and same hardness of the lock nut from the 3-piece system. Nonetheless, the iLok™ nut can bring a considerable advantage when it comes to load capacity. Due to its physical dimension, it is possible to add one or even two extra threads to its body. This possibility brings a benefit to applications where higher torques and higher clamping forces are required.

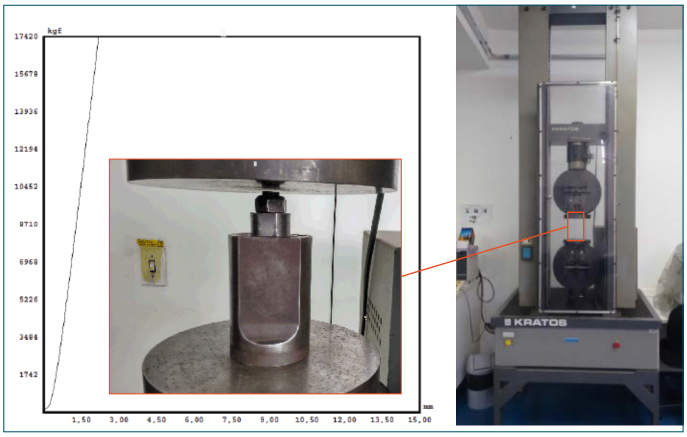


Figure 18 Universal tensile test machine and proof load test results

The last laboratory test prior to approving the iLok™ nut to be used in the field was the salt spray test. In this test, the test samples are placed inside a chamber with a highly saline environment in order to evaluate its corrosion resistance. Figure 19 shows the aspect of the 3-piece system (a) as well as of the iLok™ nut coated with zinc (b) and phosphate (c) after 72 hours of test. As expected, the samples coated with phosphate presented multiple areas with corrosion while the sample coated with zinc did not rust at all. Usually corrosion is expected to take place after 144 hours of salt spray test for parts coated with this type of zinc. The salt spray test also revealed that the iLok™ nut protects the stud's threads from corrosion due to the press fit created in the interface between the shaft's flange and the tip of the nut. This is a considerable advantage compared to the 3-piece system for applications in rear axle hubs. First, because the rusted components make the conical bushing even harder to remove from the shaft's flange and second, because the rusted threads may lead to field failure due to the lower number of threads engaged.

Figure 19 Parts after 72 hours of salt spray: (a) 3-piece system, (b) iLok™ nut zinc coated, and (c) iLok™ nut phosphate coated

Once the iLok™ nut was approved in all laboratory tests, 32 pieces were installed in a 2011 model truck with 630,000 miles on it for field testing. Another 16 pieces were installed in a test truck of a major North American OEM. The parts were marked with a witness line before the tests started in order to verify if there was any loosening due to vibration or cyclic loads. Both trucks were submitted to severe track conditions, in order to evaluate the product's performance in real life situations. Moreover, the OEM truck was testing a new suspension, which means that the iLok™ nut travelled across the many events on the track for data acquisition exercises. After 100 miles of test, there was no movement of the nuts as the witness lines were still aligned as shown on Figure 20. The nuts are still installed on the OEM test truck for further testing as this paper is being written.

Figure 20 iLok™ nut installed on both trucks after the tests. (a) P hosphate coated parts installed on a 2011 model truck, (b) zinc coated parts installed on an OEM test truck

The disassembly process of the joints fastened with iLok™ nuts was faster and easier when compared to the joints fastened with the 3-piece system. This number one complaint from OEMs, Tier 1 suppliers, and Dealerships, was solved with the 1-piece solution. Figure 21 shows a mechanic removing the iLok™ nuts after the tests. Only one person and one tool were needed to remove all eight nuts per hub in less than five minutes. The ergonomics were also improved as the operator can disassemble the nuts in a sitting position and with no effort. The above mentioned advantages bring a considerable cost savings to OEMs, Tier 1 suppliers, dealerships and freight carrier companies, as the disassembly process of the 3-piece system often requires two mechanics, nine tools, and over an hour to pull the shaft of the hub.

Figure 21 Mechanic removing the iLok™ nut. One tool used and less than five minutes needed to remove all eight nuts and pull the shaft off the hub.

Conclusions

The iLok™ nut compared to the 3-piece or 2-piece fastening systems offers:

1. Faster installation;
2. Faster and easier disassembly process;
3. Lower service and maintenance cost;
4. Elimination of re-work and re-paint of the components;
5. Superior vibration performance;
6. Protection to the stud threads against corrosion;
7. Reduction in the number of components;
8. Minimizes the risk of improper assembly;
9. Same or higher proof load capacity;

Therefore, not only does the iLok™ nut fulfill all application requirements, but also it outperforms the problematic 3-piece or 2-piece fastening systems. This innovative fastener is expected be the new industry standard for fastening of rear axle hub assemblies of class 6, 7, and 8 trucks on the upcoming years [6].

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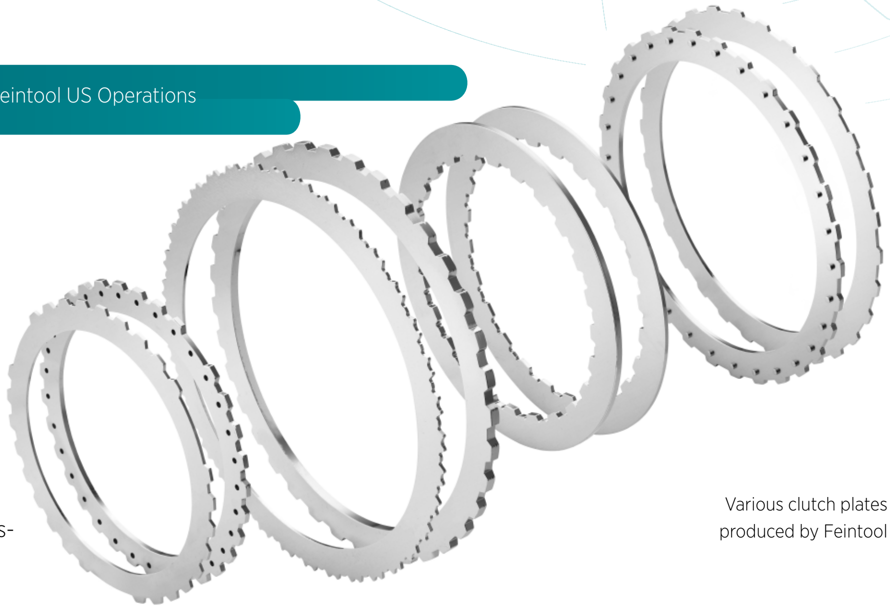
Feintool Introduces New Integrated Clutch Plate Production System

FeinClutch delivers the quality of fineblanking at the speed and cost of a conventional process.

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



Various clutch plates produced by Feintool

In the highly competitive automotive manufacturing industry, fractions of a second can mean the difference between winning and losing a lucrative multi-year contract. Feintool maintains its competitive edge by continuously refining its manufacturing processes to be as efficient and cost-effective as possible.

Some original equipment manufacturers (OEMs) and Tier 1 suppliers still believe fineblanking is expensive and slow compared to traditional blanking processes. To meet automotive manufacturers growing need for lightweight and ready-to-install drivetrain components, Feintool has developed FeinClutch, a high-speed fineblanking system, that's a real game-changer for the production of clutch/separator plates.

FeinClutch enables the company to manufacture clutch plates at the speed of a conventional process but with the quality of a fineblanking part. Using the new production system, Feintool can produce high-precision clutch plates at a speed of 40 to 60 strokes, or up to 120 parts per minute, which is almost double the previous production rate. FeinClutch generates significant savings on the individual component cost compared to a regular fineblanking process, due to the increased output.

Fineblanking offers a more Repeatable and Robust Process

Fineblanking produces higher-quality parts compared to conventional stamping; the finebanking process is a hybrid way to form metal by combining stamping and cold extrusion technologies. Fineblanked parts are manufactured using three forces instead of one, as in a conventional stamping press. This triple action, which uses specially designed tooling, results in clutch/separator plates with unique features, including:

- Improved overall part flatness by the hydraulic clamping process. The clutch plates are fully supported by the counter punch during the entire fineblanking process, and parts are checked for 100% flatness before packaging.
- Improved perpendicularity resulting in straight walls provided by the tight cutting clearance between the punch and die plate.
- Up to a 100% cleanly sheared fineblanked finish on the part edges through the fineblanking extrusion process.
- Consistent surface finish through the advanced double-sided planetary brush deburring/surface preparation process.

Improving an Already Lean Process

Over the years, the automotive manufacturing market has pressed for lower prices on high-volume, high-precision parts, including clutch plates, which has encouraged manufacturers to find new ways to increase efficiencies.

Clutch plate manufacturing at Feintool is already a very efficient process, but the company considered how it could make an already efficient op-

FineClutch fineblanking tool installed in a 880 ton Feintool Fineblanking Line

eration faster and more cost-effective. The answer was in getting the part out of the tool as quickly as possible.

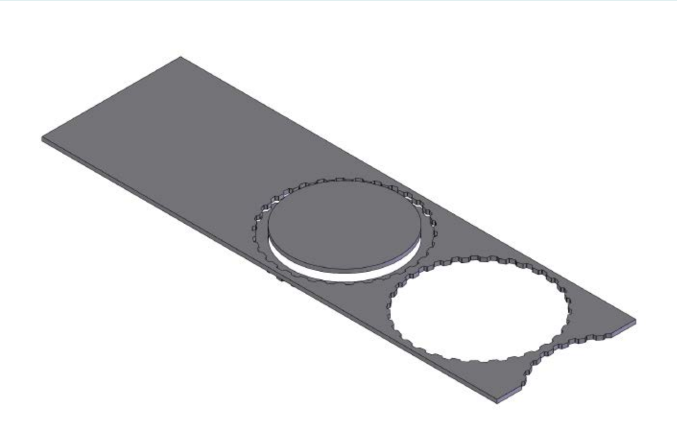
The FeinClutch engineering team had several requirements for a new removal system. Not only did it have to be fast, but it also had to be maintenance friendly, robust, simple, and cost effective.

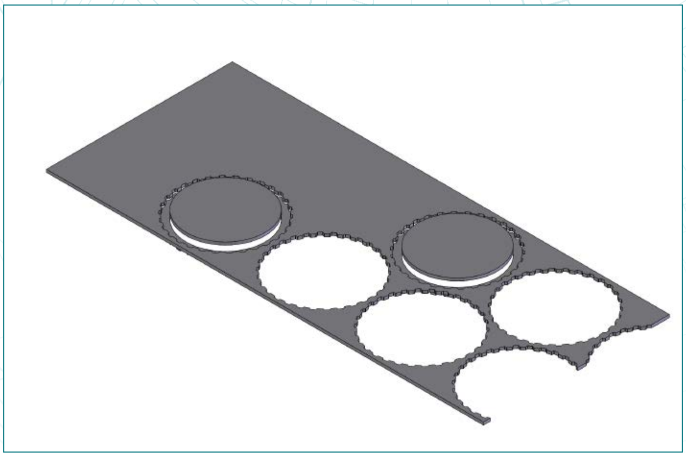
The team worked to develop a solution at the Feintool Technology Center in Cincinnati, Ohio. At the heart of the project was finding a way to optimize part removal speed. The team built a prototype and explored a variety of different configurations for how the removal arm entered the tool, grabbed the part, and exited the press. The team also had to find a way to synchronize the arm's path with the tool and fineblanking press' internal sensors; they had to get the removal arm's movements precisely right because the press wouldn't run the next cycle until the removal arm had cleared the tool.

A Simple and Robust Solution

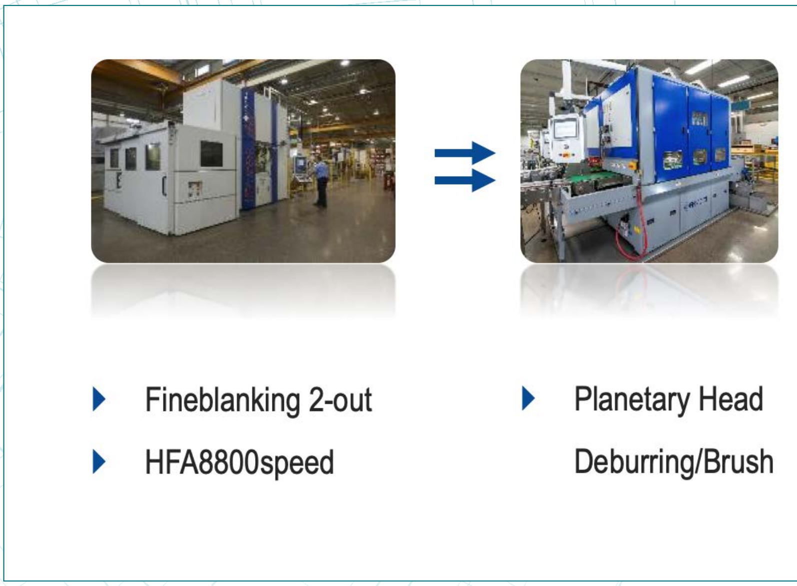
After 18 months of designing, building, testing, tinkering, and testing again – which even included using slow-motion video and simulation software to evaluate part ejection – the team delivered a solution that not only enhanced part production but shattered all expectations.

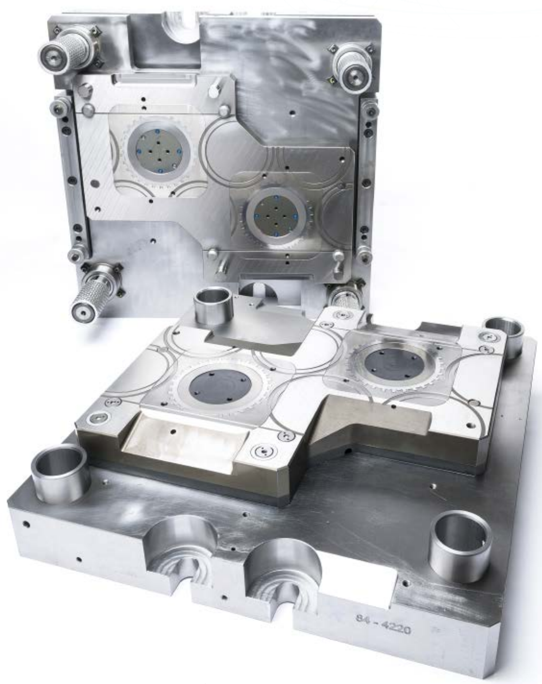
100 % sheared finish





Improved strip layout delivers 7.9% material savings. (Part example: O.D. is 145mm thickness is 4.2mm, 1-out usage 1.723 lbs/part, 2-out usage 1.587 lbs/part)





FineClutch 2-out clutch plate fineblanking tool

Born in a tool room in Cincinnati, FeinClutch is currently cranking out clutch plates at record speeds at the company's Nashville facility.

"The advantage of the FeinClutch system is that the removal arm travels a shorter distance and can separate the scrap and grab the part simultaneously, shaving off even more time," said Beat Andres, Operations Manager-Toolroom & Production Tooling.

"We're saving valuable seconds by minimizing the time the tool is open," added Jens-Uwe Karl, Vice President Engineering. "As soon as the press raises, we move the arm in, knock the slug out the back, and pull the part out, so the press can hit the next stroke a split second faster than before."

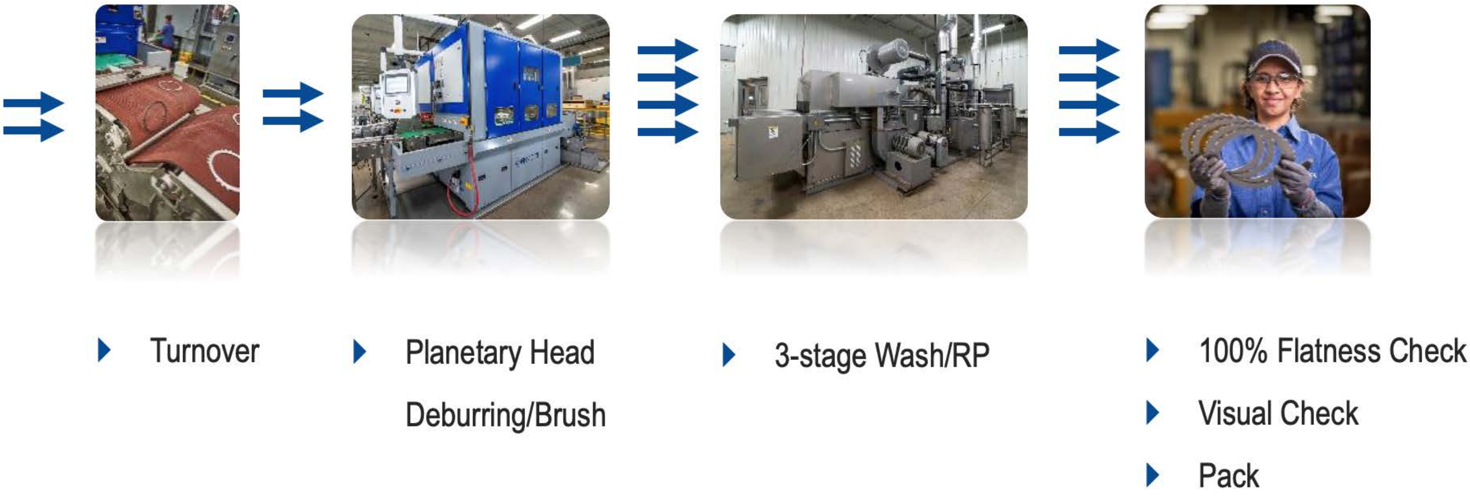
FeinClutch isn't just fast; it is also versatile.

"The basic components of the removal system are standard so that we can use it on tools manufacturing the same parts family," said Andres. "If the part is thicker, we can make a few minor adjustments. And, because FeinClutch is made from aluminum, it's easy to move from tool to tool."

This simple installation means the system can be shipped to a production facility and easily installed without extensive training. This adaptability also decreases costly downtime. Should a FeinClutch system go down, the operator can quickly swap out another unit to keep production moving.

Part of an Integrated Clutch Plate Production System

The new FeinClutch parts removal technology is only one part of an integrated clutch plate production system at Feintool.



The process begins with a precision leveling system for the coil material before the fineblanking process. Feintool uses 21 roll precision levelers with closely spaced 50mm (2-inch) diameter straightening rolls to ensure flatness of the material and the finished component.

"It's unique technology that competitors do not have," says Steven Childers, Manufacturing Engineer at Feintool Tennessee. "The process works the coil material very closely. We use small-diameter straightening rollers because they're spaced close together. This is really critical to achieve consistently flat material, resulting in an extremely flat final clutch plate."

The FeinClutch fineblanking tooling system can operate in a two-cavity tooling layout for clutch plates up to approximately 220mm (8.66-inch) outer diameter. The two-cavity configuration optimizes the strip layout and minimizes scrap and saves an average of 8%–12% of raw material compared to a one-out fineblanking tool.

After the FeinClutch removal system removes the parts from the tooling area in the fineblanking press, the parts are automatically transferred to the back of the press to a stacking station.

FeinClutch production system process flow

Then, the parts are loaded to a high-tech deburring line equipped with planetary deburring/brush heads. An automated parts flipping station ensures a controlled and repeatable surface finish on both sides of the clutch plates. A 3-stage, 21-foot wash/rust protection line is connected to the deburring line. The ability to go from a fineblanked clutch plate to a finished product on one continuous operation without any manual labor speeds up production and reduces labor costs.

Specially trained employees perform the final inspection because the human eye is still the best way to evaluate every part. These individuals check 100% for flatness and visually inspect each clutch plate for surface quality before packaging and shipment to customers.

It is this drive for efficiency and continuous improvement that led to the FeinClutch production system. Feintool has a strong reputation as a clutch plate manufacturer globally.

The company has already won quality awards and has been awarded additional contracts based on the production levels and cost savings that FeinClutch can deliver.

Automated planetary brush deburring/surface preparation process

Follow-up Report, 17th International CTI SYMPOSIUM “Automotive Drivetrains, Intelligent, Electrified” · 3–6 December 2018, Berlin, Germany

Intelligent Drive Diversity

In December 2018, conference chair Professor Ferit Küçükay greeted participants in Berlin with the words: “Welcome to the 17th International CTI SYMPOSIUM on Intelligent, Electrified Drivetrains“. The symposium’s new name reflects the big changes drive developers face; increasingly, they need to think in terms of systems that transcend the borders of drives and vehicles. Twenty years ago, electronics were the biggest growth driver in automobiles; today it’s digitalisation, connectivity and, increasingly, AI. Our automobiles are becoming electrified, intelligent, communicating systems.

The China Challenge

Particularly in these new fields, Professor Küçükay said, developments in China presented a challenge – despite the current dip in growth rates. For instance, China already had 487 EV manufacturers, supported by enormous state subsidies. Professor Tong Zhang, Tongji University Shanghai, contributed his own insights on the Chinese market. He believes ICEs will lose market share dramatically from as early as 2020, saying market forces would soon help battery electric vehicles (BEVs) to assert themselves too. He explained that the infrastructure was much more advanced than in the West, with three charging points per EV already in place. The total figure in October 2018 was 285,000, with 7,500 more being added every month. He said Chinese manufacturers already manufactured most of their electric drives and batteries in-house.

Nevertheless conventional drives are still popular in China too. Besides e-drives, for example, the Great Wall subsidiary Haval is also very active in the SUV segment, which the Chinese love like buyers elsewhere do. The company equips them with conventional powertrains, and also P2/P4 configuration plug-in hybrid drives (PHEVs) with a DCT. For Nikolai Ardey, Head of Drive Development at Audi, PHEV is more than just an interim technology. In cradle-to-grave assessments using regenerative energy sources, he said their CO_2 performance roughly matched that of pure BEVs, with fuel cell and conventional drives not far behind. So depending on the application, all drive concepts had their advantages.

Flexible energy sources

But how do unsatisfactory efficiency levels in e-fuel production fit into that line of thought? At the CTI SYMPOSIUM in 2017, Wolfgang Warnecke, Shell, had rated the efficiency of diesel, petrol and methane at between 12 and 17 percent, while hydrogen scored 37 percent. This year, VDA CEO Dr Joachim Damasky explained why he thinks we need a mix of energy sources. He said e-fuels (which are compatible with fossil fuels) could be added to conventional fuels; and besides, the issue was not so much energy carriers themselves as how we produce them. However, he said the EU Commission would not cooperate in subsidising e-fuels because in their view that could encourage the automotive industry to cling to 'old technology'.

The available energy sources were also a hot topic in the podium discussion traditionally held on Day One of the symposium. If the EU requires 35 to 38 percent less CO_2 by 2030, yet diesels are excluded and e-fuels are held back, "We can't do it.", said Damasky Prof. Michael Bargende, FKFS Stuttgart, said we would need both diesel and e-fuels in future, remarking that e-fuels might not be sexy, but were pragmatic. Incidentally, a combination of plug-in hybrid and diesel delivered outstanding real-life consumption figures.

Volatile Electricity

Pure BEVs still have too many downsides – and not just the familiar costs and range issues either. Damasky said while around 80 percent of charging currently happens at home, the grid was only built for 2 kW per household. "If three people in the street want 11 kW, the lights go out." At the evening event on Day One, Professor Konrad Kleinknecht – a physicist who has studied the risks of Germany's *Energiewende* for years – gave an in-depth assessment of electricity as a power source. If Germany converts to 100 percent regeneratives, he said, it would need ten times the current number of pump storage systems to cover a single day without wind or sunshine. And of the 5,900 km of power lines planned for 2011, just 150 km had been installed so far. Without sufficient storage capacity, volatile energy sources like wind and solar could not replace fossil fuels. With regard to adequate powertrain solutions that meant BEV alone was insufficient.

Scalable drives

Once again, this shows we need flexible, scalable energy sources. But how, asked Dr Anton Mayer, Magna Powertrain, do we master the growing diversity of drivetrain architectures that leads to? He said more than almost any other industry, the automotive industry had to reconcile evolutionary technology with disruptive technologies such as Cloud Computing, Connectivity, AI and Automated Driving. In response, Magna Powertrain had developed a scalable, modular 'building block' system where e-motors played the main role in

scaling performance, efficiency and brand character. Mayer said twelve standardised building blocks were all it took to create more 30 architectures and provide sufficient agility for a fast, flexible response to market requirements.

Thierry Kalanquin, Valeo, thinks in 2030 around 30 percent of new vehicles will be 48V hybrids, 24 percent BEVs and 25 percent conventionally powered. He predicted a 'transmission revolution' characterised by electrification, autonomous driving and digitalisation. Kalanquin coined an attractive new term for developers who will need to be at home in these new technology fields too: 'Transmissionists'. He also shared a memorable motto on hybrid transmissions: "The closer to the wheel an e-motor is, the more efficiently it recuperates." That would nominally favour P3 and P4 architectures and, in general, moving the e-motor as far to the drive side as possible in transmissions.

Digital future

Besides scalability, 'intelligent' drives also demand new thought processes in development. "In the past, R&D and IT often took place behind closed doors", said Mamatha Chamarthi, Chief Digital Officer, ZF. Today, she continued, we are seeing a 'marriage' between traditional and disruptive technologies, including cross-discipline collaborations at companies. Chamarthi said by 2035, nearly 25 percent of new cars would be autonomous and we needed to embrace change in that direction. By 2035 at the latest, she thinks 'laggard incumbents' will no longer be able to keep up. Chamarthi cited e-vehicles, batteries and connectivity as three examples of strong new 'profit pools', adding that the biggest growth driver of all would be on-demand mobility services. ZF was already enabling over-the-air updates, predictive maintenance, Cloud connectivity and more besides.

On top of this, Mark Münzer, Infineon, sees a need for a new understanding of in-vehicle electronic architectures, saying the domains 'drive', 'comfort' and 'digitalisation' increasingly overlapped and used a shared gateway to communicate with the Cloud. To safeguard data security, he said we need standardisation, agility, a hierarchical E/E architecture, and hardware-encapsulated functionality. Chamarthi floated another idea: using blockchain technology to replace centralised databases with sort of encoded, chained data modules that remained the property of individual drivers.

Agile development

As even this brief overview from the 17th CTI SYMPOSIUM shows, it's clear which way the wind is blowing. While "cars will always be mechanical too" (Chamarthi), they will increasingly also be highly complex technical cogs in a connected infrastructure. We're going to need agility in many different fields: in digitalisation; to develop intelligent, adaptable drives; and also in energy. Until we manage to store volatile, regenerative energy sources for long periods, a diverse mix of solutions is probably the smarter way to go.

Gernot Goppelt

cti magazine

AUTOMOTIVE DRIVETRAINS | INTELLIGENT | ELECTRIFIED

Publisher/ Business Address:
Car Training Institute (CTI)
A division of Euroforum Deutschland GmbH
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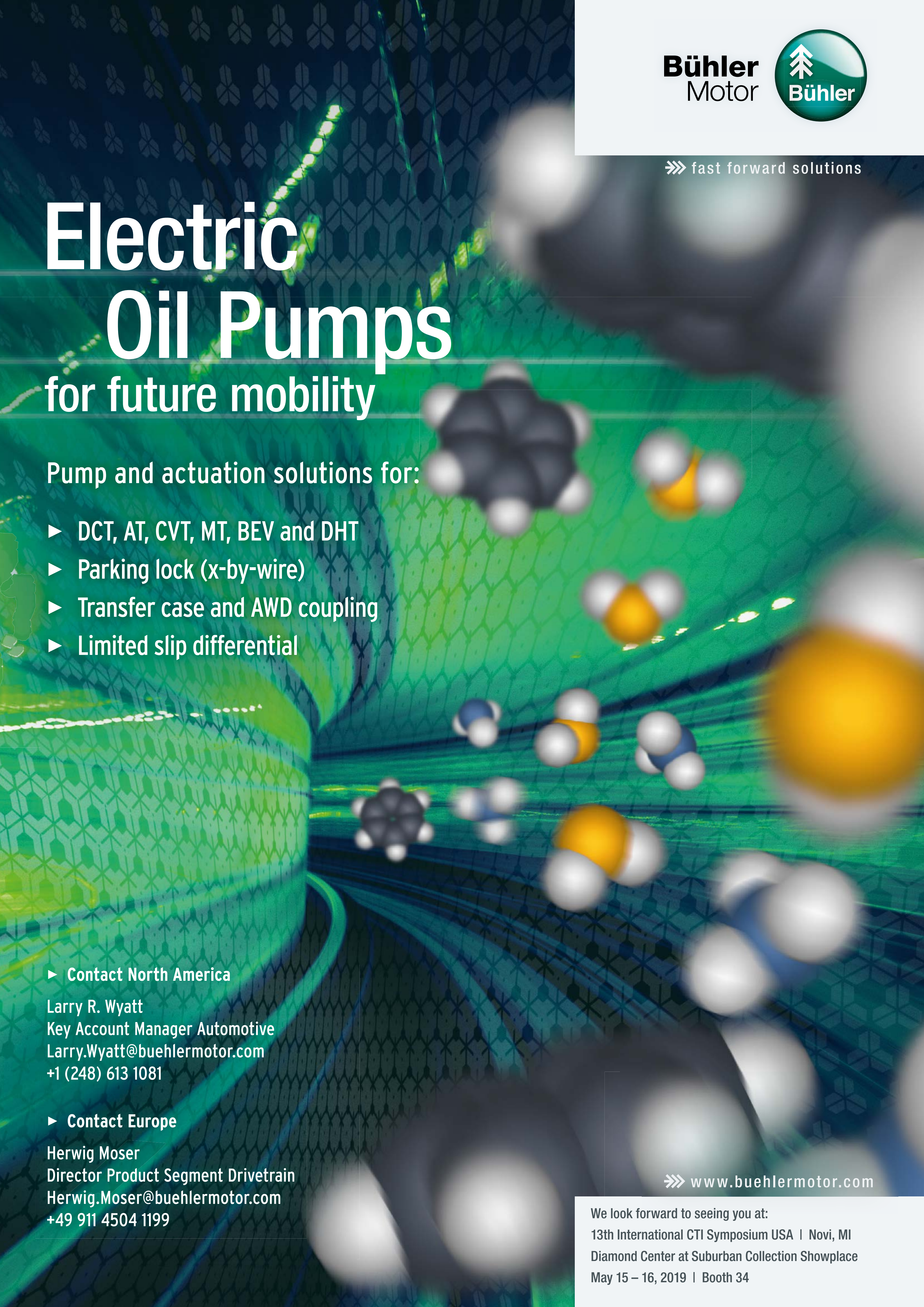
Tel.: +49 (0)211.88743-3000
www.drivetrain-symposium.world
E-Mail: info@car-training-institute.com

Do you want to showcase your expertise in drive technology or place an advert? Contact *dominik.sprenkelder@car-training-institute.com*

Print: Printnology, Inc.
Cover photo: ZF 8 HP Gen 3
Layout: Hanno Elbert, rheinsatz, Cologne
Print run: 800 copies | **Digital distribution:** 15,000 copies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