CTI MAG

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The Automotive TM, HEV & EV Drives magazine by CTI

Expert Forum:
Will China Drive Global Powertrain Electrification?

ECU Consolidation to Dominate the new E/E Architectures for Powertrain in Hybrid and Electric Vehicles

Interview with Jake Hirsch, President, Magna Powertrain:
"Data Security will be a Key Challenge"

CTI MAG Contents

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Dear readers,

welcome to the first issue of CTI Mag in 2017! Once again, it's grown in scope and contains even more innovative, interesting articles than its predecessor.

The hot discussion topic in the Expert Forum is "How much will the strong trend towards electric mobility in China promote drive electrification in European and USA markets?"

In other articles, well-known manufacturers and suppliers talk about their latest electrification concepts and the way new developments in conventional transmissions and individual drive train components affect efficiency, performance, cost and weight. We also present the latest insights from the drive components production sector.

Michael Follmann, Exhibition & Sponsoring Director CTI Transmission Symposia, CTI

Prof. Dr Ferit Küçükay, Managing Director, Institute of Automotive Engineering, TU Braunschweig, Chairman CTI Symposium

Sylvia Zenzinger, Conference Director CTI Transmission Symposia, CTI

To round off the Expert Talks, we interviewed two automobile experts – Robert Gruszczynski (Volkswagen) and Jake Hirsch (Magna) – on the issue of onboard data security. And last but not least, there's a follow-up report on the recent CTI Symposium in Germany.

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

Your CTI Mag Team

PS: The next issue of CTI Mag will be published in December 2017.
The submission deadline for articles and adverts is 6 October 2017.
To get all the details, just send a brief email to michael.follmann@car-training-institute.com.

Expert Forum

Will China Drive Global Powertrain Electrification?

Regulatory developments and incentives are likely to push forward powertrain electrification in China to meet requirements for less CO_2 and emission-free driving in megacities. Western OEMs and suppliers will support this development with existing expertise and new technical approaches. The question is: Will this trend speed up electrification in markets like North America and Europe too?

"Increasing e-mobility in China will have an effect in Europe and USA as well"

Electric mobility is currently experiencing massive growth in China, with over 330,000 electric vehicles sold in 2016. The increased demand can mostly be attributed to state subsidiaries. To limit costs, the Chinese government raised the number of electric vehicles by obliging every producer to make 12 percent of their sold vehicles electric by 2020. The move is driven by China's specific economic and ecological framework, where steadily growing purchasing power, together with the fact that the majority of the population will likely live in megacities within the next thirty years, creates an urgent demand for mobility that can only be achieved with electric vehicles.

Satisfying the demand with fossil fuels will necessarily lead to a scarcity of resources. Hence, in the long term China depends on electric mobility for socio-political reasons. The resulting increase in volumes of electric drive systems in China will have a positive impact on production costs, and will have a lasting effect on electric mobility in Europe and the USA.

Dr Ing. Renate Vachenauer,
Vice President Transmission and Drivetrain, BMW

“Given a breakthrough in battery technology, China can be a big player”

China has released a very ambitious legislative concept to create bigger demand for electric vehicles. From 2018, car manufacturers are expected to have about 10 percent NEVs in their portfolio. These can be PHEVs, BEVs or FCEVS. The aim is to improve air quality very quickly.

With BEVs, it's important to have a range of more than 350 km. This gets you additional points that permit you to sell more cars equipped with a combustion engine. However, there are other aspects too, such as the energy mix for electric power, the supercharger infrastructure, and not least driving conditions in different countries. Most driving in China is in urban conditions, so the demand for BEVs may be higher there than in other markets. Particularly in markets with more demand for high-speed driving or extended driving ranges, a PHEV powertrain might be the better solution since it offers high driving ranges in combination with a combustion engine, and emission-free driving in cities.

Having said this, the main challenge for all NEV concepts is the development of battery technology. If there is a breakthrough in energy density, the BEV concepts will dominate the PHEVs very quickly, and China might be a very big player in this field.

Michael Schöffmann,
Head of Transmission
Development, Audi

Stephan Rebhan,
Executive Vice President
Business Unit Transmission,
Continental

“The efficiency of electric powertrains needs to be further improved”

In China, global powertrain suppliers have to offer small electric vehicles as well as SUVs and luxury cars with a high degree of first class powertrain automation. On the one hand, we expect city access restrictions will strongly drive market penetration rates of electrified vehicles. But in places with no driving restrictions, there is a trend towards bigger SUVs with traditional powertrains. Here, we expect the share of automatic transmissions to double within the next five years. That means new multispeed automatic transmissions as well as dual-clutch transmissions. Along with a trend towards transmission add-on hybrid solutions, we also foresee strong demand for e-axles and P4 hybrids to enable electric driving and all-wheel drive functionality.

In Europe we are already supporting the next generation of HEVs and EVs that is currently being developed at all major vehicle and transmission companies. Mild hybrids based on 48 V technology will become the standard within the next ten years. For PHEVs, we expect further integration of electric drives into transmission and axle units.

With BEVs, we are facing requirements for higher integration of e-drive and power electronics combined with powertrain control and actuation systems. The efficiency of electric powertrains also needs to be improved further. We are therefore investing heavily in new materials and smart actuation systems to reduce weight and energy consumption in an optimal way.

“The Chinese market will take the lead with full electric powertrains”

Powertrain electrification will change individual mobility massively in the coming decade. Essentially, this development is driven by ecological and socio-ecological parameters that are reflected in stringent regulations and incentives. However, our clients in the markets concerned are still hesitating. There are still unanswered questions in terms of appropriate technology, driving range, infrastructure and, of course, cost.

From a present-day perspective we can expect that in China, particularly after 2020, strict political decisions on the one hand, and favourable conditions in a growing market on the other, will strongly favour full-electric powertrain solutions. That would put China in the lead and make it something of a role model. We expect established Western regions such as Europe and the USA, with their challenging political requirements and legal systems, to focus on 48 V mild Hybrids in volume segments and on Plug-In Hybrid solutions combined with further optimized combustion engines. We also expect to see a growing share of battery-electric powertrains as in China, but more towards the end of the next decade.

Prof. Dr. Ing. Peter Gutzmer,
Deputy CEO and CTO, Schaeffler

“We will supply all kinds of powertrain technology from a single source”

New mobility concepts and regulations might shift customer demand from combustion engines to hybrid solutions and electric drive in the mid and long term, depending on vehicle segments and regions. At present, however, we cannot reliably forecast how quickly – and in what form – the change will come.

Bosch sees e-mobility as a crucial business area. In the future, we will supply existing and new customers with all powertrain technologies from a single source. At the same time, the Powertrain Solutions division will work very hard to further improve combustion engine technology. In addition to the 20 million new hybrids and electric vehicles on the world’s roads in 2025, there will be some 85 million new gasoline and diesel-powered vehicles. Whether with fuel or electricity, Bosch will power the powertrains of the future.

Ulrich Schrickel,
Senior Vice President Gasoline Systems, Transmission Control, Bosch

As the technology and market leader for powertrains, Bosch is playing an active role in shaping the transformation of mobility concepts. Our Powertrain Solutions division will cover a wide-ranging portfolio of technologies that will make getting from A to B more efficient and more economical for people around the world.

How Chinese trends will influence other markets is very much a matter for speculation. What is clear, however, is that the Chinese market in itself is a very important one, and that we are fully committed to being successful in China, as well as in the rest of the world.

“Competition from China will reduce the prices of e-drives”

Despite all efforts and initiatives, BEV and PHEV sales in Europe are still low. By contrast, the market shares of BEVs and PHEVs in China are increasing significantly, helped by subsidies and legislation as well as by incentives such as 'no-lottery' license plates in Shanghai. These steering measures make the sales base in China fairly safe to predict. That makes planning car volumes easier, both locally and globally, and pushes the development of EVs and PHEVs. Western OEMs might offer these products in Europe and North America as well. The minimum range of 50 km for PHEVs in China might set a standard for other markets.

The Chinese market is price sensitive, and China is demanding a higher share of localized production. The competition from Chinese companies will accelerate the price reduction in electric drives and will likewise affect Europe and North America. For example, Chinese manufacturers have been market leaders for electric city buses for some years now. In 2016, 115,000 new buses were registered. Demand for electric buses in Western cities is growing rapidly, and Chinese makers are pushing into this market, which increases the pressure for Western manufacturers.

Dr techn. Robert Fischer,
Executive Vice President, Engineering and Technology Powertrain Systems, AVL List

Generally speaking, restrictive city regulations will be a significant driving force in increasing the market share of electrified vehicles – and not just in China.

"Electrification in China will push technology know-how globally"

In China, the need for all-electric vehicles and PHEVs in megacities is strongly driven by incentives and regulations, which certainly results in a steering effect towards higher volumes. We may see restrictions in large European cities mid-term as well, but by comparison there is more demand for powertrain electrification with long-distance compatibility, for example mild-hybrid drives.

Generally, we need to consider that car customers in different global markets have specific expectations with regard to cost and performance. From a design and production viewpoint, this calls for scalable and modular products to enable scaling effects at component level, while at the same time being able to offer customer-specific products. Currently, we see solutions that have been started in Europe and the US being transferred to market-ready products in China. Associated with that, local production facilities on all levels of the supply chain will gain in importance.

We expect that electrification in China will stimulate engineering efforts further and boost the acquisition of expertise. For example, know-how acquired with plug-in-hybrid drives or electric axles may well be used for mild or full hybrid drives intended for Europe or the US. In this respect, growing electrification in China will create synergies that may speed up powertrain electrification in Western markets as well.

Dr Ing. Carsten Bünder,
Senior Manager, Product Engineering, GETRAG Magna Powertrain

Prof. Dr Ing. Tong Zhang,
Tongji University, Shanghai

"The Chinese strategy will boost electrification in all markets"

With over half a million plug-in hybrid and pure battery electric vehicles produced in 2016, China was clearly the global Number One for e-mobility.

By recognizing and acknowledging the technological advantage of some Western markets, China is pursuing a smart strategy that focuses on full electric vehicles first, whereas European and US OEMs are concentrating on sophisticated hybrid vehicles. Through systematic government strategies, strong support from regulation and incentive policies, rapid expansion of the charging infrastructure and innovative business models – for example public car rental systems – China has created a thriving electric vehicle market.

Unlike traditional hybrids, full electric and plug-in hybrid cars do not have a technology bottleneck today. For urban and suburban usage, full electric cars appear to have a clear advantage in terms of simplicity and cost.

Taking the Chinese strategy as an example, combined with strong OEMs, innovative technology and a high quality global supply chain, powertrain electrification is certain to come to the European and US markets – and sooner than most people might expect.

P3 Hybridization of Manual Transmissions

In terms of cost and fuel efficiency, manual transmissions still take a leading position. However, solutions are needed to make them compatible with future ADAS and powertrain hybridization. The GETRAG modular upgrade concept offers a scalable approach, adding automation and electrification on a common MT platform.

■ Dr Ing. Frank Casimir, Director, Product Segment Manual Transmissions, GETRAG Ford Transmissions GmbH, Magna Powertrain

Why invest into manual transmissions?

Governing bodies of all major markets are planning to continuously tighten CO_2 limits. Between 2020 and 2025, and depending on market specific limits and vehicle sizes, more and more powertrain electrification will be applied to compensate for the limits of pure internal combustion engines. At the same time, advanced driver assistance technologies will increasingly enter the market. Existing systems like pre-collision assist, adaptive cruise control and Active Park Assist will be extended to systems like Traffic Jam Assist, ACC Stop&Go and Fully Assisted Parking. In the longer run, fully autonomous systems will enter the market.

However, these advanced functions cannot be supported with a manual transmission. Therefore, GETRAG has developed a concept to upgrade manual transmissions to make them compatible with future ADAS system, while further reducing CO_2 emissions through hybridization.

The GETRAG Modular Hybrid Concept

GETRAG has long-term experience in developing hybrid designs for layshaft transmissions, which have been implemented into several market-ready products. The existing designs were initially developed for dual clutch transmissions. The transfer to manual transmission is done based on the same principles:

- Off-the-shelf components for specific hybridization and automation elements (like e-motor, inverter, e-clutch actuator, etc.), **Figure 1**. This will generate economies of scale and further cost advantages.
- Portability of concepts between transmission base architectures, e.g. from DCT to hybrid DCT (HDT) and from manual transmission type to hybrid manual transmission (HMT). This will minimize technical risks, complexity and application development cost.
- Integration of the hybrid function into the transmission. This allows for "turnkey" solutions for the affected vehicle application development, reduce the complexity of control interfaces and, simplify vehicle assembly and EOL testing by providing a fully tested unit to the line.

The upgrade of a base manual transmission based on these principles can be done in three steps. Each of them provides a functional enhancement of the base transmission. The technology upgrade options can be used selectively over time to respond to specific market needs without the risk for dead-end solutions.

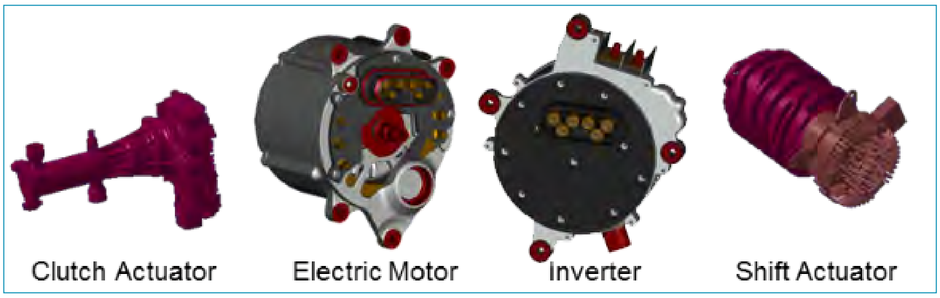


Figure 1 Hybrid component kit

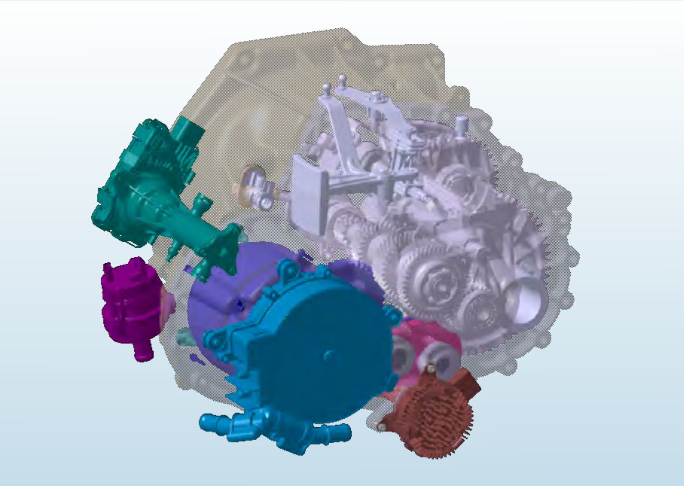


Figure 2 Step 2 – adding the e-motor

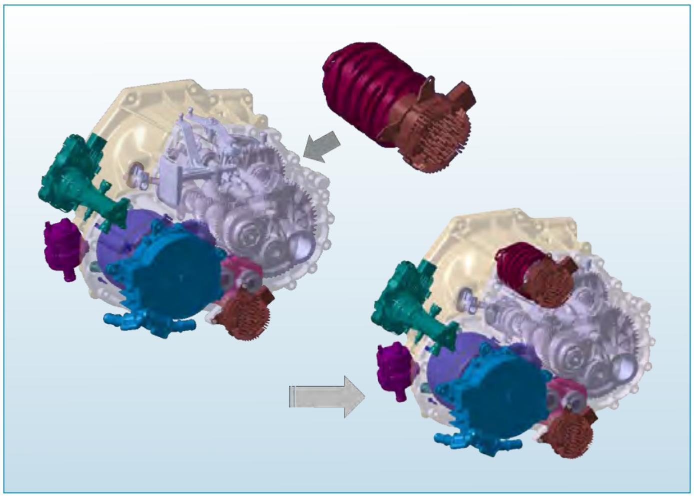


Figure 3 Step 3 – adding gear shift actuation

E-Clutch, HMT and AHT

Step 1 is the integration of an independently controllable clutch actuator (e-clutch), either through a clutch pedal override system, a clutch-by-wire system (both 3-pedal solutions) or a fully autonomous clutch actuation system (2-pedal). This step can generate moderate CO_2 benefits by enabling idle and stop/start coasting ("sailing"), and support basic parking, vehicle launch/stall prevention and emergency braking assistance function. A secondary but valuable benefit is the prevention of unintended clutch misuse, thus improving durability and reliability.

Step 2 is the integration of an e-motor and inverter into the transmission, creating a hybrid manual transmission (HMT). GETRAG went for a P3 concept, connecting the e-motor to the final drive of the transmission, **Figure 2**. The 48 V motor/inverter unit is carried over from the GETRAG HDT family (6HDT200 and 7HDT300). The e-motor integration substantially reduces CO_2 emissions. Moreover, the P3 design enables fully autonomous parking using the e-motor.

Step 3 includes the integration of an automatic gearshift unit (e.g. shift drum), thus transferring the hybrid MT into an automated hybrid transmissions (AHT), **Figure 3**. In this configuration, the P3 arrangement of the e-motor helps to fill the torque interrupts that are typical for AMTs, thus significantly improving shift comfort.

The GETRAG HMT concept

The first HMT development is based on the new 6MTT215 6-speed manual transmission, which was launched end 2016. Within its torque segment, this new transmission is benchmark in terms of torque-to-weight ratio and is intended for the B- and C-car segment.

While the hybrid versions of the GETRAG dual clutch transmission portfolio are set up in P2 configuration, for hybrid versions of manual transmissions a P3 configuration was selected. The main drivers for this decision were

- Driver-independent low speed electric manoeuvring including autonomous parking
- The ability to provide pulling force and fill torque interrupts via the e-motor during shifts.

The hybrid components are integrated as shown in **Figure 4**. The e-motor is connected with the transmission final drive ring gear by a two-ratio cascade of auxiliary gears with a three way dog clutch (ratio 1 – open – ratio 2) to connect to either of the two ratios or to disconnect. The low ratio step provides sufficient torque to the wheels for low speed electric driving and parking, even on grades. The high ratio step allows to operate the e-motor connected at higher vehicle speeds, offering usable torque for coasting primarily.

Next evolutionary Step: AHT

By replacing the internal manual shift mechanism with an automated actuation (adopted from the DCT150 shift drum actuator), the HMT is converted to an AHT following the modular logic described above.

Other than with dual-clutch transmissions, torque interrupts of AMTs cannot be eliminated by means of an overlapping clutch operation. This was one reason, why GETRAG chose a P3 configuration that integrates the e-motor at the final drive. This is regarded to be a major feature to gain market acceptance. The ability to fill torque interrupts with the e-motor obviously depends on the available torque of the e-motor. However, even in a "mild" 48 V configuration, shift comfort can be significantly improved. Although an 48 V e-motor generates only moderate torque output, the ratio of the connecting gear set enables torque fill levels of 20 to 40 percent (vs. the corresponding maximum engine torque). **Figure 5** shows the available electric torque at each vehicle speed in comparison to the maximum tractive effort provided by the combustion engine.

The resulting vehicle acceleration during shifting with and without electric torque fill is shown in Figure 6. The objective assessment of the shift quality with the AVL Drive tool leads to the conclusion that the achievable shift quality rating is comparable to a good automatic transmission with the exception of the 1–2 WOT upshift which achieves a rating of 7.5 on a 1–10 scale. Therefore an AHT can be considered as a viable upgrade option to the hybrid manual transmission to make it long-term compatible to the requirements of fully autonomous driving.

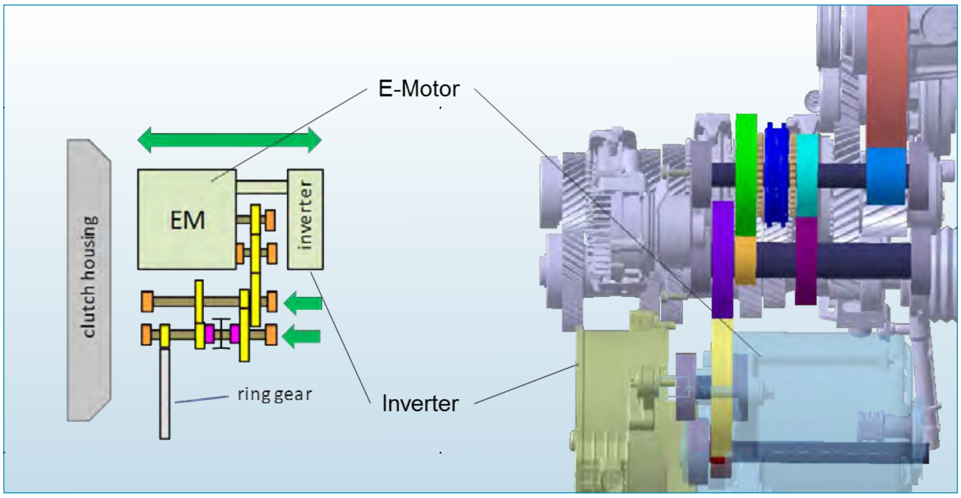


Figure 4 Integration and connection of E-Motor in GETRAG 6MTT215

As a further upgrade option, the AHT can be scaled to a plug-in hybrid. The GETRAG modular hybrid kit includes a high voltage e-motor/inverter combination where the motor fits into the same installation package as the 48 V motor. With the electric torque and power from this unit, a wider range of electric driving is possible which allows using the unit in PHEV applications. Moreover, the considerably higher torque of the e-machine can provide even higher torque fill levels, which may practically eliminate torque interrupts.

Summary and outlook

The P3 hybridization of manual transmissions is a very efficient way to combine benchmark efficiency with moderate product cost and high economies of scale, while at the same time qualifying them for future advanced driver assistance systems. Thanks to the compatible upgrade path from MT to HMT and AHT and using common parts with GETRAG hybrid dual-clutch transmissions, the HMT and AHT offer technical maturity from the outset. Compared to a P2 architecture, the P3 configuration offers a level of shift comfort that can reduce torque interrupts to a minimum in common use and enables simple autonomous functions like all-electric parking.

In terms of marketability, the P3 MT hybridization enables a straightforward hybridization of existing vehicle platforms at reasonable costs. Depending on the engine used, a CO_2 reduction of 12 to 15 percent in the WLTP can be achieved with a 48 Volt solution. The favourable combination of moderate product cost on one hand and reduced fuel consumption on the other hand can help to achieve significantly lower fleet consumption values on a global scale in the short term.

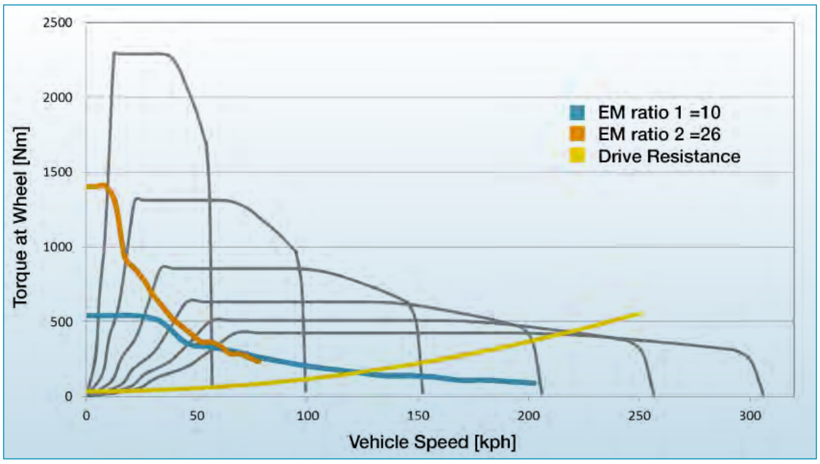


Figure 5 Hybrid MT / AHT tractive effort diagram

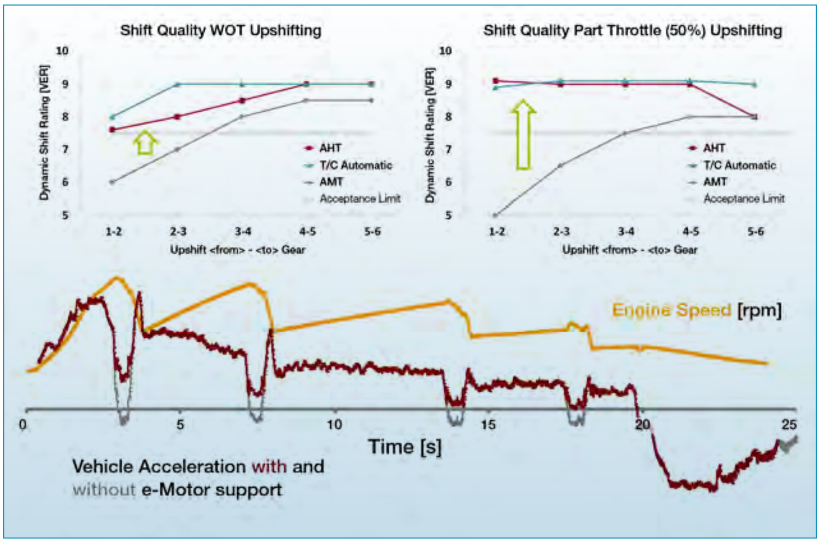


Figure 6 Shift quality improvement with partial torque fill during gear shift

Market and prospects for ECU consolidation in powertrain for hybrid and electric vehicles

ECU Consolidation to Dominate the new E/E (Electrical/Electronic) Architectures for Powertrain in Hybrid and Electric Vehicles

In this article, IHS looks at the consolidation of ECUs for the next generation E/E architectures of powertrain in hybrid and electric vehicles. This article identifies the emerging technologies within powertrain and discusses the impact of various levels of autonomous driving on the CO2 emissions.

- Dr Richard Dixon, Principal Analyst MEMS & Sensors, IHS Markit
- Ahad Buksh, Analyst Automotive Electronics, IHS Markit

Evolution of the E/E architectures

Today, a premium level car needs more that 70 ECUs, and even up to 100. With electrification, the powertrain of a hybrid and electric vehicle needs to perform certain additional functions such as AC-DC conversion for the high voltage battery, DC-DC conversion for 12 V systems, AC-DC conversion for the motor, battery monitoring, etc.

Today, most of these functions are performed by individual ECUs, but IHS Markit now sees a trend towards integration of these functions. In effect, each ECU will handle multiple functions in future.

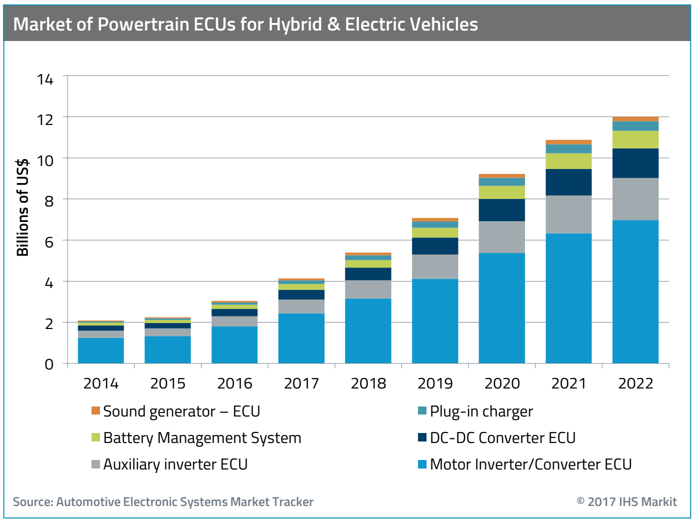
Market overview

Clearly, the number of ECUs for hybrid and electric vehicles varies with Tier-1 design philosophy, level of hybridization, regional market preferences, battery technology, and so on. A typical value for ECUs in the powertrain for electric vehicles such as a VW E-Golf could be in the range of $ 1500, even without consideration of the value of the battery pack.

Taking these factors into account, IHS Markit forecasts that the market for powertrain related ECUs will exceed $ 12 billion in 2022, up from $ 3 billion in 2016 — a CAGR of 26 %. Underpinning this growth are new ECUs for battery management systems, DC-DC conversion, plug-in charging and AC-DC conversion. Note that ECU shipment growth is around 31 % over the same period. The difference in growth rates reflects the typical 5 % annual price erosion for components in the forecast period.

Consolidation trends

The Nissan Leaf is one of the electric vehicles that has benefitted from integration. It has been re-engineered from six powertrain ECUs in its 2010 model down to five powertrain ECUs in the 2015 variant. Nissan introduced a Power Delivery Module (PDM), and ECU that performs two functions — AC-DC and DC-DC conversion.



BMW has also revisited its ECU architecture in the i3 model series. The company has introduced an Electrical Machine Electronics (EME) system that performs the DC-AC conversion for the traction motor as well as the DC-DC conversion for the battery. The main advantages for consolidation are weight and space savings in a vehicle, which has positive implications for performance and range, achieved by

- Reduced wiring harnessing (weight)
- Reduced power consumption
- Lower complexity of the module design

Apart from powertrain, ADAS, chassis & safety, infotainment and body & convenience domains will also undergo similar architectural changes.

Note that companies like Bosch, Infineon and Siemens are already proposing new sets of architectures where the functions would be clustered into domains and connected by high performance networks.

Emerging materials for Powertrain ECUs in Hybrid and Electric Vehicles

Aside from architectural developments, the industry is also working on developing the new materials for components in powertrain ECUs. The two most common materials are wide-bandgap devices based on Silicon Carbide (SiC) and Gallium Nitride (GaN).

Since 2012, Mitsubishi, Denso and Hitachi have advances with prototype motor inverters by deploying SiC devices. Suppliers like Infineon, ROHM, Wolfspeed and Exagan have partnered with research institutes like TÜV NORD and government organizations such as the US Department of Energy to provide these chips.

In 2015, Toyota began testing vehicles with SiC transistors and diodes embedded in its powertrain control units. Industry estimates show that these components can reduce the total system cost by as much as 10 % and system size by up to 50 %. Toyota expects to improve fuel efficiency by up to 10 % using SiC devices in its modules.

Recently, Mitsubishi also introduced a SiC inverter, which is claimed to be world's smallest SiC inverter for hybrid and electric vehicles.

The three main potential applications for SiC and GaN components in a HEV are:

- Motor generator inverter/converter
- DC-DC converter
- Plug-in charger

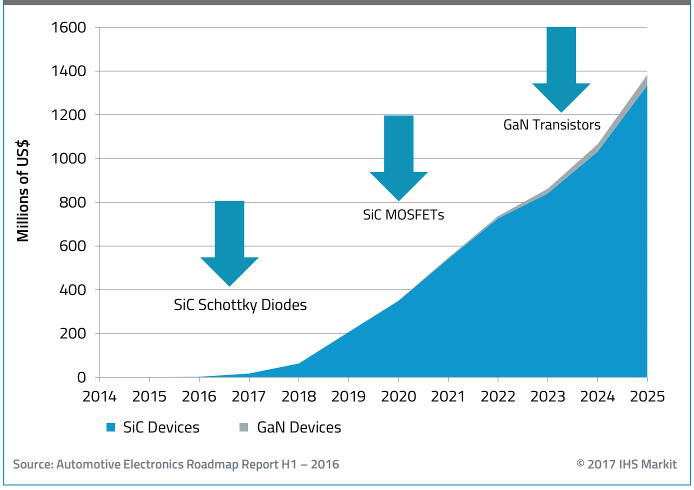
Market for wide bandgap devices

IHS Markit forecasts that SiC and GaN discrete components will be used in DC-DC converters and plug-in chargers. Motor generator inverter/converters will only deploy the SiC MOSFET power modules.

Impact of various autonomous driving levels on CO_2 emissions

The other major automotive industry trend is autonomous driving. To achieve a self-driving car, new ECUs and sensor modules are needed. Cameras, radars, LIDARs and sensor fusion ECUs are all essential to these new systems. These ECUs consume power and affect the CO_2 emission of a vehicle.

Revenue forecast for SiC and GaN in hybrid and electric vehicles



Continental has shown that bringing in new electrical components for different levels of automation also adds to CO_2 emissions. The company believes that in order to reach the L2 (partial automation) level in a C-segment vehicle, the CO_2 output increases by as much as 4.2 g/km, while attaining the L5 (highest automation) level implies further detrimental emissions behavior to the tune of + 6.7 g/km.

This counterproductive surge in emissions demands efforts in the areas of architectural optimization. One way is through the integration of ECUs as explained earlier.

Conclusion

Today, a premium level car exceeds 70 ECUs – at least one per application. While more functions will emerge in future, there is a need to consolidate multiple functions into single ECUs.

Notes: Data in this article come from the following IHS datasets and reports:

- Automotive Electronics Roadmap Report H1 - 2016
- Automotive Electronic Systems Market Tracker

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Ahad Buksh, ahad.buksh@ihsmarkit.com

Interview

"It's a Cat-and-Mouse Game"

Communication via the on-board diagnostics (OBD) port can be vulnerable to unwanted data traffic or attacks, causing security risks and even safety risks. We discussed these with **Bob Gruszczynski**, OBD communication expert at Volkswagen of America and Vice-Chairman of the SAE E/E Diagnostics Committee. Can there ever be full protection?

Bob Gruszczynski, OBD communication expert at Volkswagen of America and Vice-Chairman of the SAE E/E Diagnostics Committee

Mr. Gruszczynski, what does OBD communication have to do with cyber security?

Originally the OBD port was only there to plug in a device and make sure all emission on-board diagnostics systems work correctly. Most of the data is useless for other purposes; the only things that are useful for most people are vehicle speed, engine speed and maybe the airflow in the engine. This data can, for example, be combined with GPS in a dongle that communicates with other devices via a wireless connection. In the early days, some dongles acted irresponsibly in terms of how they requested data from the car. OBD is request-and-response, and some of them asked for data so quickly, they took the CAN bus down. Some were asking for stuff that the vehicle just rejected or did not how to deal with. That was my professional point of entry into this whole area – just misbehaving dongles, not anybody deliberately hacking the vehicle. Generally, there is the original legitimate use for on-board diagnostics, a "gray area" with aftermarket applications – and technically, there can be misuse like tuning or even attempts to manipulate vehicle systems, including powertrain components.

You mentioned the "gray area". How can OEMs persuade third parties to make sensible use of the OBD information?

We have this dichotomy between data access and data security where we draw a line, and I think this line is still somewhat blurry. For example, we just had a new update of the copyright law in the US. Previously, vehicle software was covered under copyright law and if you did something to change it in your vehicle, we could actually prosecute you in the US. That copyright law has recently been rescinded, so this area has become more open and the aftermarket certainly is trying to move into it. We have had many discussions with the aftermarket. Across the board, aftermarket suppliers want to sell telematics units, which might be vulnerable to security attacks. They want to sell tuning kits and other applications that connect to the OBD port. It is a very lucrative business, and I understand why this is such a big area. We fight battles sometimes, but so far we've always been able to work together and come to some agreement.

What influence do OEMs have on transparent data use, for example by insurance companies?

In the US, I don't think many drivers really care about the use of their data. Many people don't understand what's happening and as far as I know, there are around three-and-a-half million vehicles connected to insurance companies. When the car owners plug this device into their OBD port, they agree that the insurance company gets all that data to set their insurance rates. There is certainly a difference between OEM and third party supplier solutions. For example, when you sign up for GM's OnStar or My Ford Sync or similar OEM services, you get the chance to opt in or out of specific functions. I'm pretty sure insurance companies make the data use transparent as well, but I'm not sure about third-party aftermarket suppliers. Where their data goes, who knows?

How is OBD data security being handled on a global scale?

That's an interesting point with several facets. I'm not quite sure about the Asian market, but currently there are certainly big differences between the EU and US. The EU has enacted a number of data privacy laws that are very strict. One of the items we've discussed as an industry is collecting data for our own purposes to services like OnStar and My Ford Sync etc. I think some of the functions cannot be applied anymore in the EU. On the other hand, if we build a car in Germany that has features intended for North America, can we legally sell it to the US? From the OBD side we also see big differences within the regulatory authorities. I have seen that in certain areas of the world, regulators are very knowledgeable about how vehicle systems work, and the legislation makes sense. In other areas where regulators are mostly politicians, that may not be the case. After all, there are certainly different use cases in terms of the data that insurance companies will collect in different regions.

There seems to be an ongoing race between people who push security, and people who want to prise the systems open. Can there ever be full security?

I think there is always somebody clever out there. It's a cat-and-mouse game. I don't think there will ever be an insurmountable wall. OBD dongles can use data from the port and communicate them wirelessly via WLAN, Bluetooth etc. Wireless networks can be hacked or "spoofed" and Bluetooth devices like smart phones can be infected with malware. We can filter the port communication to some extent, and in a further step we can protect communication with diagnostic systems through security keys and certificates. But we cannot control the wireless communication itself. I think some of the concepts we have been talking about in the standardization functions will come close to full security. The key will be making sure that when the mouse gets the cheese, it's not a severe failure. That's probably about as close as we're going to get.

Interview: Gernot Goppelt

OBD and Cyber Security

In a recent survey CTI asked transmissions experts "How important is cyber security for transmission and powertrain development?" In response, 54.5 percent said 'highly important', 36.1 percent said 'fairly important' and just 9.2 percent said 'low importance'. As one person pointed out, "More connectivity means more risks because electric vehicles are basically computers on wheels. We need to make sure vehicles can't be misused in cybercrimes."

What does cyber security have to do with OBD? The story begins in 1968, when Volkswagen introduced its first on-board diagnostic system. The SAE recommended a standard diagnostic system in 1988, and from 1991 on, CARB required all new vehicles to have basic OBD functionality. In 1996, the OBD II standard became obligatory for all new cars in the USA. The European equivalent – EOBD – became mandatory for cars with SI engines in 2001, and for diesel-powered cars in 2003. In China, OBD has been mandatory since 2008.

But as Bob Gruszczynski points out in this interview, OBD is request-and-response, not read access only. So while OBD was originally only intended for emission controls, the question is: Can the powertrain, or even the transmission, be manipulated via OBD? It may seem highly unlikely but the answer is 'yes, possibly'. OEMs can use dedicated pins on the OBD II interface to send data for service purposes as deep into the vehicle as the controller network permits. The risk may seem small, but protection against misuse and cybercrime seems to be a critical challenge for the future. As another survey participant put it: "Cyber security is much more important than many people think. Potentially, you could turn autonomous cars into lemmings."

Further information on the CTI Future Mobility Survey:

German | English

Jake Hirsch, President Magna Powertrain, during his speech on the 15th CTI symposium in Berlin, December 2016

Interview

"Data Security will be a Key Challenge"

Having GETRAG in the group means Magna Powertrain is now a full-range system supplier for powertrain technology at all scales of electrification. We discussed trends and challenges for future powertrains with **Jake Hirsch**, President Magna Powertrain.

Mr Hirsch, powertrain electrification seems to be gaining more and more momentum. What role does the GETRAG acquisition play?

Having the GETRAG Product Group within our organization brings us full system powertrain capability, including e-mobility products. For example, GETRAG's hybrid DCT with the torque split arrangement of the e-machine is available in mild, as well as full and plug-in configurations. It enables OEMs to offer a package-neutral hybridized transmission as an alternative to manual and conventional DCT configurations. Scaled to plug-in, these HDTs are great options that enable zero-emission operation in front-wheel-drive platforms of any size, as well as extended range operation with the base engine. GETRAG also has experience with electric axles and electric powertrains, which further strengthens the expertise we have in place already at Magna Powertrain.

"Having the GETRAG Product Group within our organization brings us full system powertrain capability, including e-mobility products"

At the Berlin CTI Symposium, you said electrification makes more than 40 additional powertrain configurations possible. Will there be a reverse trend towards fewer configurations in the longer term?

These variations exist because OEMs are seeking to leverage established products and production capacities for ICE-based powertrains while also bringing varying levels of electrification to market in order to meet CO_2 and NO_X requirements. Although the timing for a mass-market shift to fully electric systems remains an open question, we do expect all these variants or options to be replaced eventually by more standardized electric powertrains, powered either by batteries or by fuel cells. Over time, the figure of over 40 possible architectures will drop as ICE-based powertrains become less dominant. Currently, however, we expect the number of variants to remain high even beyond 2025.

Magna has long-standing experience with AWD components and systems. How can tomorrow's all-wheel drive systems contribute to CO_2 reductions?

We are starting to see powertrain electrification in place of traditional four-wheel and all-wheel drive systems in vehicles like the Volvo V60, the BMW i8 and in future, the Hyundai Wia e-4WD. These vehicles have fully electric secondary axles that replace the traditional transfer units and rear drive modules found in front and rear-wheel-drive vehicles. Firstly, these e-axles eliminate the losses and CO_2 impact of current mechanical-based 4WD and AWD systems. Secondly, they can even bring positive CO_2 benefits compared with a standard 2WD vehicle, by leveraging the e-machine in the secondary axle to reduce engine size without sacrificing performance. These systems can maintain the safety and fun-to-drive aspects of 4WDs and AWDs while significantly reducing fuel consumption and emissions.

Platform diversity, powertrain electrification, ADAS, automated driving etc. make the whole vehicle system extremely complex. How can this be handled?

One of our key objectives is to use product platforms that reflect the OEM platform requirements. We leverage our core modules like e-machines, inverters, shift actuations systems, clutches etc. to bring economies of scale to all these variants. Another key to success will come from leveraging our knowledge of powertrain integration, including the use of external inputs. We have been doing this for years in our all-wheel-drive systems, where we monitor things like ambient temperature, throttle position, steering angle, road conditions-based wiper operation etc. to optimize efficiency, performance and safety. In future, we will enhance these inputs with data from products such as cameras, radar, lidar, GPS or Car2X communication, which Magna has in its Electronics Group. We will apply our knowledge for optimum overall powertrain performance, including semi-autonomous and eventually fully autonomous operation. Finally, as data and cloud-based data exchanges increase, data security will be a key challenge too. Recently, Magna has partnered with Argus to provide secure data solutions. The more data are exchanged, the more we must ensure the security and safety of the whole system.

The e1 highlights Magna's ability to leverage e-mobility platform modules with improved handling and drivability benefits. It features three e-machines, two of them in the rear, enabling rear wheel drive, all-wheel drive and torque vectoring.

What are the crucial powertrain requirements for highly and fully automated driving?

The most important is the ability to use the vast amount of information available from multiple on-board and external sources to control the powertrain. Powertrains need to deliver a predictable, safe, comfortable and efficient driving experience to consumers under all operating conditions. This is true for all levels of driver assistance routines, and becomes more important as the level of autonomous driving features rises with time. As I said earlier, this plays well for MPT because we already have decades of experience in optimizing system performance via application-specific integration at many OEMs globally. Each OEM has unique targets for their brands in terms of performance, efficiency, etc. Our knowledge base from this experience sets us apart from our competitors when it comes to system integration and optimization of the complete powertrain.

How quickly will autonomous vehicles emerge and will we still be allowed to steer them?

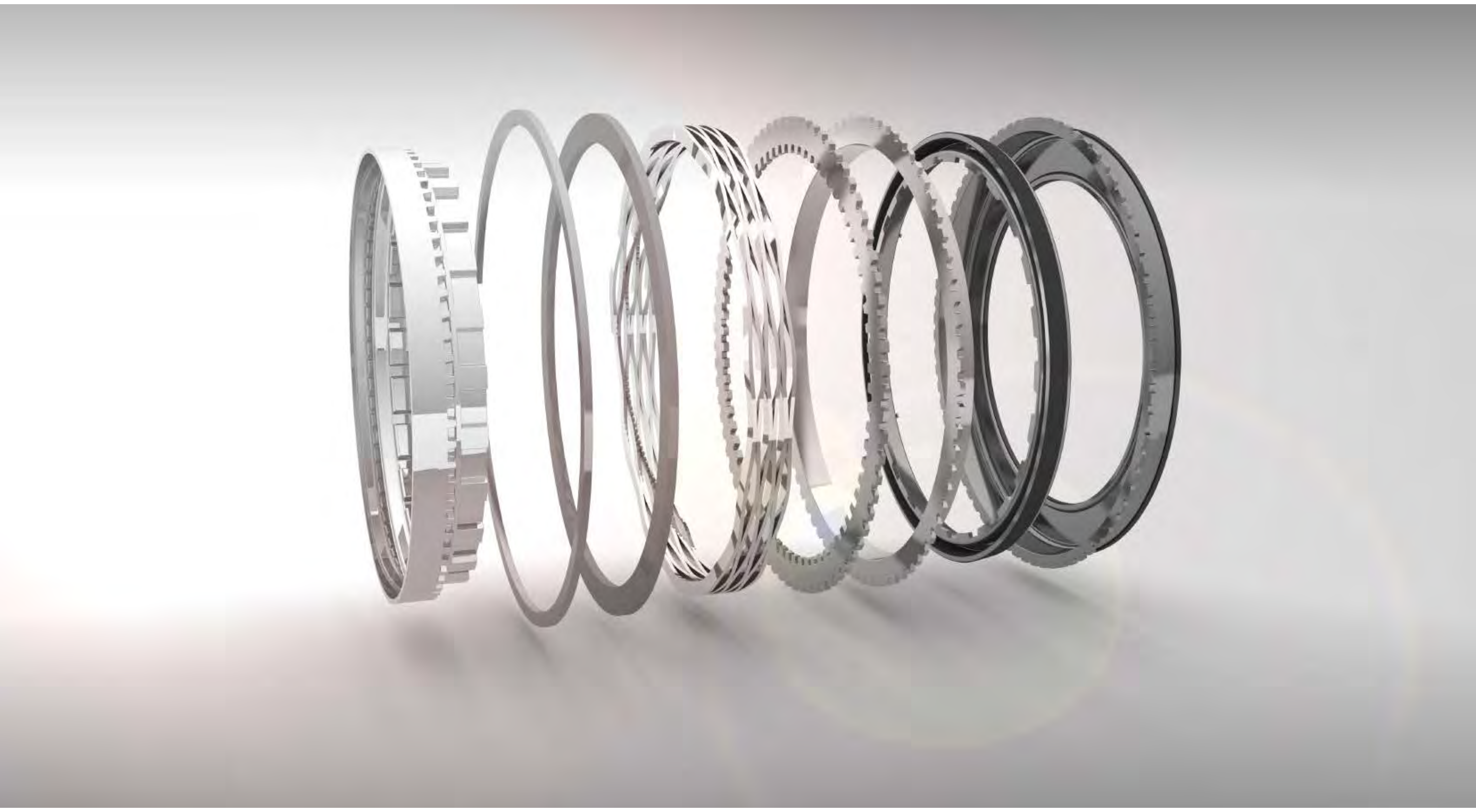
Although we will see a growing number of vehicles with autonomous driving capabilities on the roads in the next few years, there will also be a large number with lower levels of ADAS and autonomous capabilities. Even though the technology exists for cars to operate autonomously, there will be a mix of vehicles on the road operating at Levels 1 to 5. Having all vehicles on the road at Level 5 would bring maximum benefits in terms of safety, efficiency and emissions. Perhaps autonomous driving will start in inner cities, to minimize traffic congestion, enhance pedestrian and occupant safety, improve air quality, etc. It is foreseeable that occupant driving would not be appropriate in those zones longer term. But at the other end of the spectrum, there may be zones and areas where occupant driving is permitted, and we cannot reap the full benefit of autonomous driving vehicles due to the variations of simultaneous operating modes. Generally, I think it will be a long time before humans are willing to give up all opportunities to drive permanently, if they ever do at all. For me, driving is simply too much fun to disappear completely.

Interview: Gernot Goppelt

HOERBIGER Cone Clutch Design yields Fuel Savings for Automatic Transmissions

Significantly lower fuel consumption despite increased power, compact dimensions, easy handling and universal application possibilities? HOERBIGER Drive Technology has achieved what sounds like a series of irreconcilable ideal properties for automobile drive trains. TorqueLINE is a new product family of clutches and brakes for automatic transmissions which feature a revolutionary design. The most important advantage: with this innovation, HOERBIGER succeeded in intelligently combining frictional engagement and form lock.

- Dr Ansgar Damm, Head of Research and Development, HOERBIGER Antriebstechnik Holding GmbH
- Peter Echtler, Head of Advanced Engineering, HOERBIGER Antriebstechnik Holding GmbH



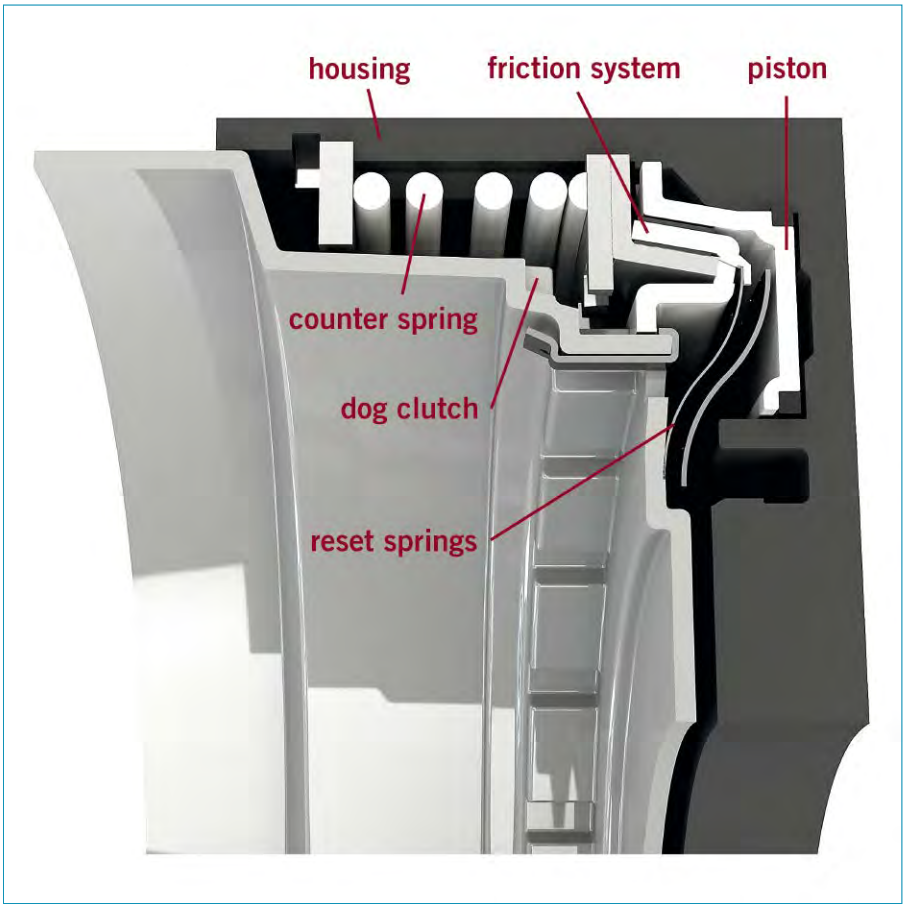


Figure 1 Composition of the HOERBIGER TorqueLINE Cone Clutch

While it may seem a given that electric drives arguably represent the only path to emission-free cars, it is also indisputable that many more years will go by before the majority of vehicles on our roads will be all-electric and help reduce fuel consumption and harmful emissions.

"With this in mind, we consider it important to make the traditional, internal combustion engine-based or hybridized drive train more fuel-efficient and environmentally friendly," says Dr Ansgar Damm, Head of Research and Development at HOERBIGER Antriebstechnik Holding GmbH.

In these efforts, the shifting system is increasingly gaining in importance: "This is also apparent from the global trend away from manually shifted systems and toward a wide variety of automatic transmissions, which improve comfort and lower fuel consumption at the same time. For these, we developed the HOERBIGER TorqueLINE family – alternative shift elements that have the potential to reduce CO_2 emissions of cars by as much as 2.5 grams per kilometer per installed unit," Damm comments.

Bye-bye discs

Designed primarily for automatic transmissions equipped with torque converters, TorqueLINE opens up the possibility of replacing common multi-disc clutches and brakes. The basic objective remains the same: to ensure the highly complex interaction between various planetary gear sets and shifting of the gears from a mechanical stand point. The crucial difference between old and new lies in the design solution – and how it affects the transmission's efficiency as a whole.

"TorqueLINE creates major advantages. The system decreases drag losses of automatic clutches when these are open, and is also able to lower the energy expenditure needed to activate these or keep them closed," explains Peter Echtler, Head of Advanced Engineering at HOERBIGER Antriebstechnik Holding GmbH.

Clever combination

The strengths of the TorqueLINE shift element stand out in comparison with conventional solutions. In regular multi-disc clutches, the contact force and the number of friction discs determine how much torque can be transmitted. This is the reason why the number of discs is so high, specifically in shift elements of automatic transmissions equipped with torque converters – generally speaking, approximately five times more friction elements than the TorqueLINE requires.

When the traditional clutch is open, the high number of discs causes significant shear losses as a result of the internal lubricant and cooling oil flow, leading to the disadvantage that power dissipation grows as the rotational speed differential increases. This typically necessitates an oversized design of the actuation system for the friction disc systems, which is consequently less fuel-efficient. This is the only way for the system to generate the necessary static holding torque.

Approaches that implemented individual brakes and clutches for planetary gears as dog clutches instead of disc clutches have emerged in the past. These transmit the power by way of form fit instead of friction. However, they are only suitable for use at very particular shifting points. They also place great demands on the transmission control unit and, in practical experience, tend to offer less comfort and functionality. "Put in highly simplified terms, we picked out the benefits of discs and dogs – while largely eliminating their inherent design shortcomings – and combined them for the HOERBIGER TorqueLINE," Damm points out.

Two steps and the first efficiency target was met

Similarly to a synchronizer, the TorqueLINE shift element consequently achieves torque transmission and engagement both frictionally and by way of form lock.

It uses a combination of a double cone and dogs to do so. During the first phase of the gear shift, the cone assumes the function of a multi-disc friction clutch: an actuating piston pushes the respective outer and inner friction surfaces – of which there are now only two in total – into one another, causing torque to build. Depending on the cone angle, the torque is approximately five times greater than in the case of discs at the same activation pressure. This is also the reason why the number of friction surfaces can be reduced by the same factor.

To limit the load on the TorqueLINE components despite the decreased friction surfaces, the friction elements are designed to transmit a slightly lower maximum torque. The second coupling phase commences indiscernibly as soon as the defined transmission force of the friction system is exceeded.

The dog shift elements, which the TorqueLINE system has already moved mechanically into the engagement position, now mesh firmly with one another, ensuring a form-locked connection that effortlessly handles even maximum torque. Application-dependent options are available to use actuators with a reduced size compared to disc systems, or to operate at a lower piston pressure to save energy.

75 percent decrease in loss

As soon as the transmission control unit lowers the contact force again for disengagement, a compression spring integrated in the system carries out the automatic separation of the dog engagement. Additional spring elements move all the remaining moving parts in a defined position, whereby the friction surfaces are completely separated in the open state.

"The bottom line is that, thanks to HOERBIGER TorqueLINE, drag loss decreases by as much as 75 percent per shift element. From a purely mathematical stand point, this equates to a potential CO_2 reduction of up to 2.5 grams per kilometer. The decreased number of friction elements consequently unleashes the greatest advantage exactly when the friction elements are not needed," Echtler explains. "This makes HOERBIGER TorqueLINE particularly well-suited as an efficiency-boosting replacement for multi-disc clutches and brakes in automatic transmissions equipped with torque converters, which are operated in the open state the majority of the time during the vehicle's operation, i.e., in the higher gears."

To ensure that the innovation, which is ready for production, will be able to capitalize on its strengths as quickly and easily as possible in practice, HOERBIGER design engineers secured that only detail adjustments are needed to existing transmissions. If necessary, it is even possible to keep the entire actuation system of the multi-disc clutches. Optimal efficiency will nonetheless not be achieved until future generations of automatic transmissions, which are designed from the very start to optimally utilize the potential gained with the HOERBIGER TorqueLINE product family.

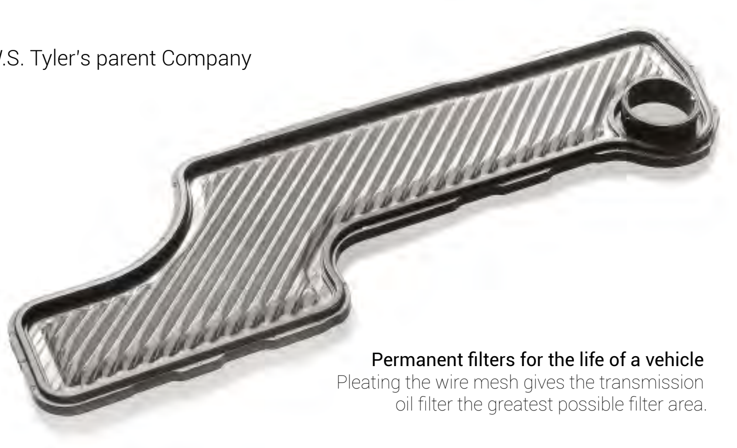
Today and for a (Vehicle's) Lifetime

W.S. Tyler, along with parent company Haver & Boecker, are leading manufacturers of metal woven wire cloth used in the automotive industry. Certified in accordance with ISO TS 16949, our wire weaving divisions produce filtration materials responsible in the suction filter of a dual clutch transmission for retaining particles. This ensures the smooth operation of the transmission – over a vehicle's lifetime.

■ Klaus Sklorz, head of the automotive business unit at Haver & Boecker, W.S. Tyler's parent Company

What properties are required to optimize filter performance from all contaminants in transmission oil, and continue to achieve this even after 100,000 miles of use? W.S. Tyler continue to answer these questions and provide the highest quality filters for the many uses of wire mesh. From the flow regulator of a faucet to the precision filter element in a spacecraft, metal wire mesh filters and moulded parts perform a wide range of tasks. The customer's wishes and requirements form the basis for producing such customizable products. Even the production line developed for transmission oil filters is based on the client's specifications. We check their feasibility and take on the design of the corresponding tools, equipment, and specialist machines.

We produce metal wire mesh on weaving machines that are designed and developed in house. The planning of the specifications (mesh size, wire thickness etc.) and the implementation are based on our many years of experience. High production and storage capacity ensure a continual supply for the process chain. We heat treating the mesh before it is fed into the production line to manufacture the oil filter. The sintering process prevents loose wires from the surrounding edges. In addition, the mesh can be manipulated into any size and shape. All our mesh products are produced in accordance with ISO TS 16949. Transmission oil filters receive the greatest possible filter surface area by pleating and pressing the fabric. In addition to standard plastics PA66 and its related products, W.S. Tyler can handle unique plastics such as heat-resistant PEEK and LCP plastics.



Permanent filters for the life of a vehicle
Pleating the wire mesh gives the transmission oil filter the greatest possible filter area.

To meet the filter's technical cleanliness requirements, transmission oil filters are cleaned under air pressure. On top of this they undergo 100 % camera inspection. The 'HAVER Vision System' developed in house is used to visually inspect and monitor mass-produced products, and is continually developed in line with growing quality requirements. Supported by manual interim and downstream visual inspections, W.S. Tyler pursue a zero-error strategy, even beyond the automotive area.

For more information, contact our office in:

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Figure 1 Continuous generating gear grinding

Modification of Surface Structure and Geometry on Gears

■ Walter Graf, Reishauer AG, Switzerland

Demands placed on today's automotive transmissions include, among others, low gear noise levels (NHV), weight reduction, fuel economy, increased longevity and high power density. Modifying the surface structures and flank geometry can lead to higher transmission performance in line with these demands. Continuous generating grinding can contribute to higher transmission performance in several ways. This paper touches on three relevant features that generating grinding contributes to ground gears, and by extension, to the entire transmission. Two of these features, Low Noise Shifting (LNS) and Polish Grinding positively alter the surface structure, and the third, Twist Control Grinding (TCG) adds control over the gear flank geometry and the surface bearing ratios.

- Low Noise Shifting (LNS)
- Polish Grinding
- Twist Control Grinding (TCG)

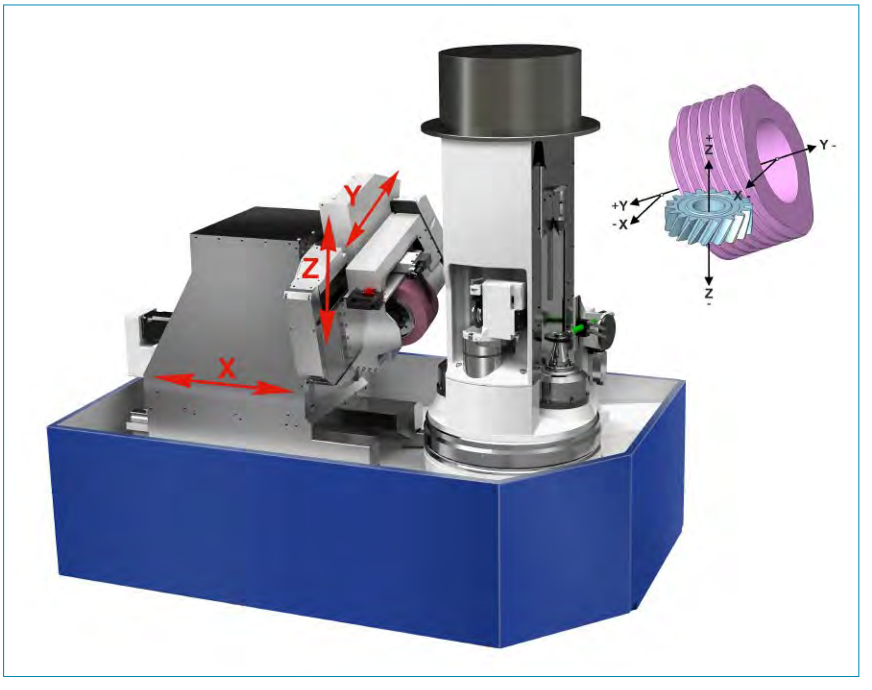

Figure 2 Continuous generating machine

Low Noise Shifting (LNS)

LNS is an additional machining movement within the grinding kinematics of continuous generating grinding. As LNS runs unobtrusively in the background of the grinding process, most users are unaware of the existence of this feature. The machine's software automatically defines and sets LNS parameters. In principle, the kinematics of continuous generating grinding can be understood as a worm drive with additional abrasive machining properties (see Fig. 2). This process consists of an infeed X to set the depth of cut, a vertical feed-rate Z, and the lateral shifting motion Y. This lateral motion ensures that the abrasive worm shifts continuously sideways by a small amount for each mm of vertical feed-rate. In this manner, the grinding always takes place with fresh, unused abrasive grits.

The operator defined shifting motion Y is used for the roughing stroke, whereas the LNS shifting motion is calculated and defined by the machine and applied in the finishing stroke. Continuous generating grinding creates grinding traces of a uniform axial waveform across the gear flank in the direction of the lead (see Fig. 3, chart top right). Since the orientation of these waveforms is at right angles to the plane of rotation, this may cause high-frequency excitation during gear meshing, which vehicle occupants may perceive as unpleasant. To put simply, the effect of LNS is to shorten and to reduce axial waveforms. LNS results in irregular surface structures (see Fig. 3, chart bottom right) that prevent the generation of tonal excitations and allows the pairing of sets of ground gears.

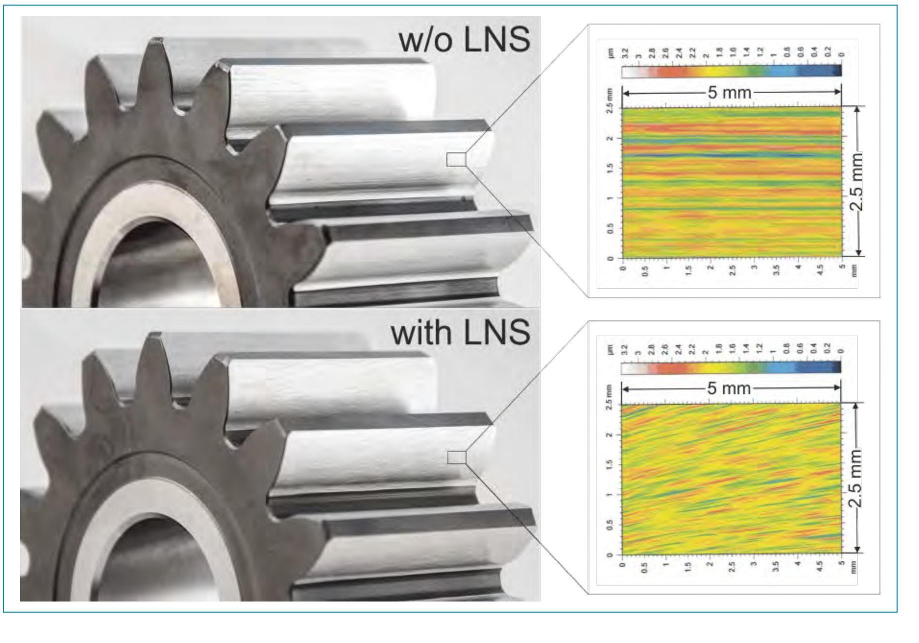

Figure 3 Surface structure w/o and with LNS

Polish Grinding

As emissions and fuel efficiency are becoming more stringent in all major markets, automotive companies are facing huge technological and economic challenges to comply. These requirements can only be met by improvements in all aspects of motor vehicles, and specifically to the powertrain, i.e., the engine and the transmission. Polish grinding reduces the friction of meshing gears and increases the bearing ratio of gear flanks. For these reasons, transmissions can be made more energy efficient. The established continuous generating method is the

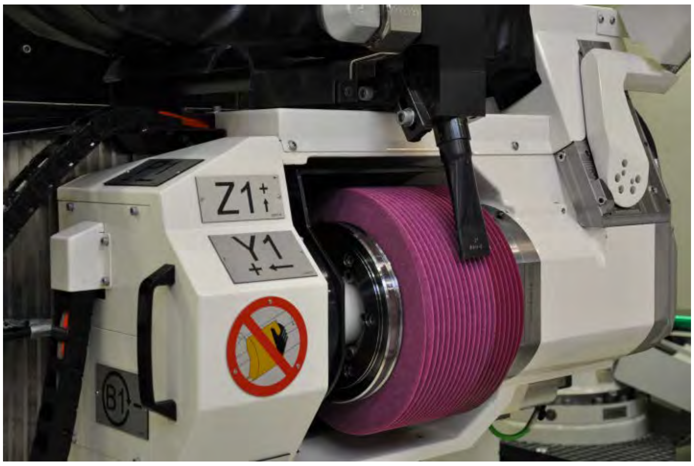

Figure 4 Two-zone grinding worm (Grinding & Polishing)

base technology for the polish grinding process. Without interrupting the gear grinding cycle, polish grinding is performed as a final machining sequence on the manufacturer's existing continuous generating gear grinding machines while the workpiece remains clamped on the part holder during both grinding and polish grinding. Polish grinding, as a general rule, consists of one polish grinding pass with the resin-bonded section integrated into the end section of the 2-zone grinding worm which performs the grinding operation (Fig. 4).

During polish grinding, only the roughness peaks are removed, reducing the roughness profile height and, therefore, this method increases the contact bearing area of the gear flanks while the geometrical accuracy of the gear flanks is not affected. The polish grinding process delivers surface qualities with mean roughness values of Ra 0.15 µm compared with the standard values of Ra 0.4 µm used in industry on continuous generating grinding machines. It is important to note that Ra surface values are only of limited utility and that the reduced peak height (Rpk) for example, is a more useful indicator of a surface's functionality. Often, there is a misunderstanding that polishing should produce mirror finishes. However, for engineering purposes, polish grinding should only remove the surface roughness peaks and must leave intact the valley surface roughness such that oil films can adhere to the polish ground surface. With the roughness profile height removed, the contact area of the gear flanks is increased. Consequently, the augmented surface contact area allows transmission designers to increase the power density of transmissions.

Twist Control Grinding

Weight reduction can contribute a major share of the total fuel consumption reduction. Hence, modifying the flank twist, also know as bias, by Twist Control Grinding (TCG) allows modification to the contact pattern of gear teeth, thus leading to higher power density and allowing a reduction in the overall weight of gears, and by extension, a weight reduction of the transmission itself. Furthermore, TCG ground

Figure 5 Ground and polished gear flanks

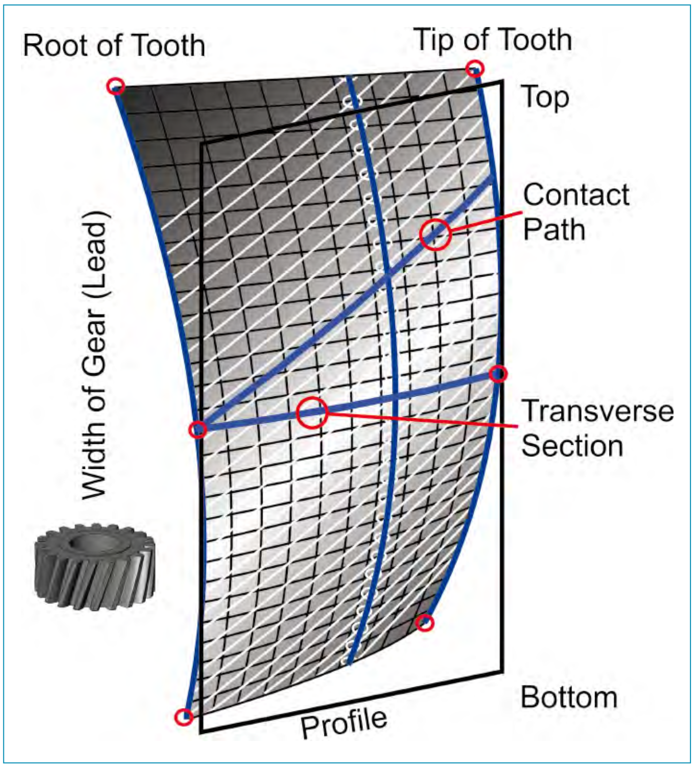

Figure 6 Twist on individual gear flank

gears have shown noise reductions in transmissions of 2 to 3 decibel (dB). Flank twist occurs as a matter of course when machining helical gears that feature lead modifications such as crowning.

This phenomenon is brought about by the geometries and kinematics inherent in the continuous generating grinding of helical gears. Simply put, the purpose of TCG is to either eliminate twist, to deliberately introduce a counter-twist, or to add a specific twist to counteract the deformation of gears under load. More often than not, twist has some negative connotations attached. However, with TCG grinding, the word twist should be seen in a positive light as it allows gear designers to use this phenomenon to fine-tune the gear geometry. By controlling twist, the contact bearing patterns of meshing gear sets can be fully controlled, and therefore, the forces acting on the bearing surfaces can be ideally distributed, which leads to higher power density, more efficient transmission of power and an increased longevity of gears. The TCG method gives gear design engineers a high degree of freedom to design gear flank geometries to match the demands made on automotive gears and to translate desired design features into an economical manufacturing process.

One-Button Twist-free Grinding

Up to very recently, when users wanted to grind twist-free, the machine maker had to calculate the process parameters and to design a gear specific dressing tool. This process was not only expensive but also inflexible with dependence on the machine tool builder. For this reason, a customer-friendly solution was required and recently brought to market. "One-Button Twist Control" means what it says. The user simply pushes the button "Twist-free," and the machine will do the rest; calculate and implement all necessary geometric and process calculations. Furthermore, the diamond dressing tools remain the same as for many existing conventional processes. Also, the Twist-free process requires no additional operator training if the operators already have experience with standard continuous generating grinding. Today, regarding grinding times, Twist-free grinding is on par with the standard continuous generating grinding which is well established in the industry. The benefits gained from controlling twist justify the small software investment and the influence of additional wheel dressing time. Following intensive research work and several years of industry application, Twist Control Grinding technology has proven itself in the marketplace and has, in many cases, eliminated gear honing, often thought to be the only method for large-scale twist-free, or defined twist hard finishing of gears. High volume TCG production of twist-free gears, or gears with a defined twist, is now standard production practice. The minimal additional process costs over conventional gear grinding are far outweighed by the benefits of the reduction in torque loss, the increase in bearing capacity of TCG-ground gears, and higher resulting power density in transmissions.

Ease-of-Operation for Deliberate Twist

The same ease-of-operation and economy of process as for twist-free grinding apply now also to the grinding of any specific twist. Again, with standard tooling, the customer will be empowered to simply define the desired twist with few data points on the gear flank via the machine's graphic interface, click one button, and the machine will generate a program to grind the gear's geometry accordingly. Trials have been successfully concluded, and rollout is imminent.

Conclusion

With the three features of continuous generating gear grinding outlined in this paper, the users have powerful und simple to use tools at their disposal to fully exploit required changes in geometry and surface structure to address the transmission issues of NHV, higher power density, and fuel savings.

Use of Engineered Plastics in Transmissions

Engineered Plastics Thrust Bearings for Transmission Applications

This work summarizes advances in engineered plastics and their design, as applied to thrust washers used in transmissions and torque converters.

■ Dr Sai Sundararaman, Scientist Specialist, Global Fluid Power Division, Freudenberg-NOK Sealing Technologies

Background

With advances in automotive transmission technology and regulations on emissions/fuel economy, there is a need for reducing both weight and axial space in transmissions. Engineered plastics are increasingly becoming popular for use in automotive transmissions due to their inherent design flexibility and reduced weight. Typical transmission applications include inserts, spacers, bushings, seal rings and thrust washers. However, limiting factors for use of plastics are primarily related to their inadequate tribological properties and non-optimal designs.

The present work demonstrates how a thrust bearing from an engineered plastic material with optimized geometry/material can significantly improve performance. Optimized geometry results in reduced friction coefficient while operating in the hydrodynamic lubrication regime. Material innovations significantly lower wear and friction coefficient while operating in boundary/mixed lubrication regimes. These novel materials and designs also offer additional benefits including reduced weight/axial thickness, ability to function over a range of roughness/hardness of mating components, improved robustness to misalignments and improved acoustic damping.

Basics – The Stribeck Curve

A Stribeck curve is a plot of friction coefficient as a function of duty parameter (also known as bearing number of Gumbel number) and is typically used to characterize the friction behavior between two surfaces undergoing relative motion, usually in the presence of a lubricant. The Stribeck curve is schematically represented in Figure 1 [1] and can be sub-divided into three regions. The first region corresponds to "boundary lubrication" where load is primarily supported by asperity contact and is typically characterized by high friction coefficient (and wear). The second region corresponds to "mixed lubrication regime" where the load is supported both by asperity contact and fluid film, and is characterized by a decrease in friction coefficient with increasing duty parameter. The third region corresponds to the "hydrodynamic regime" where the load is primarily supported by the fluid film. The hydrodynamic regime is characterized by an increase in friction coefficient with duty parameter (and reduced wear). Several factors affect this friction behavior including materials, loads, speeds, temperature, roughness parameters of mating surfaces, fluid viscosity and geometry.

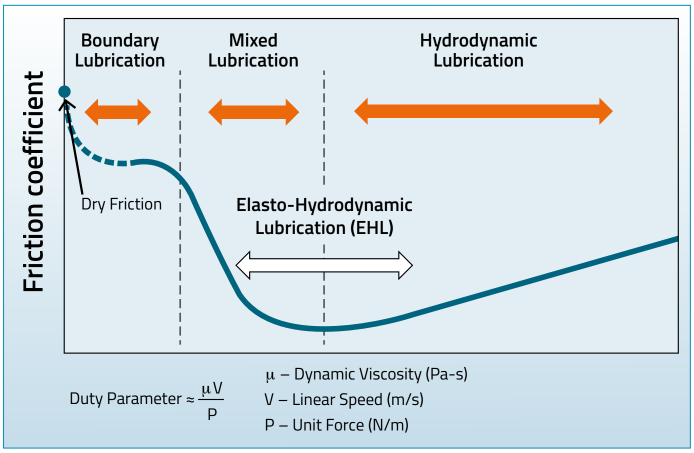

Figure 1 Stribeck Curve

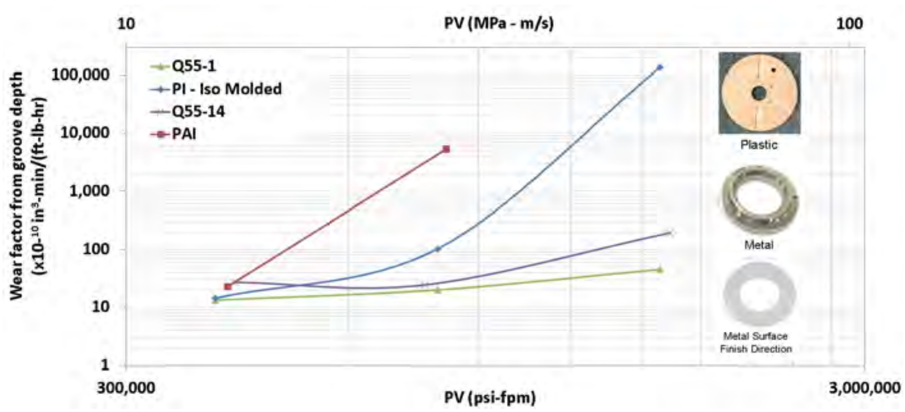

Figure 2 Comparison of lubricated wear performance of some engineering plastics

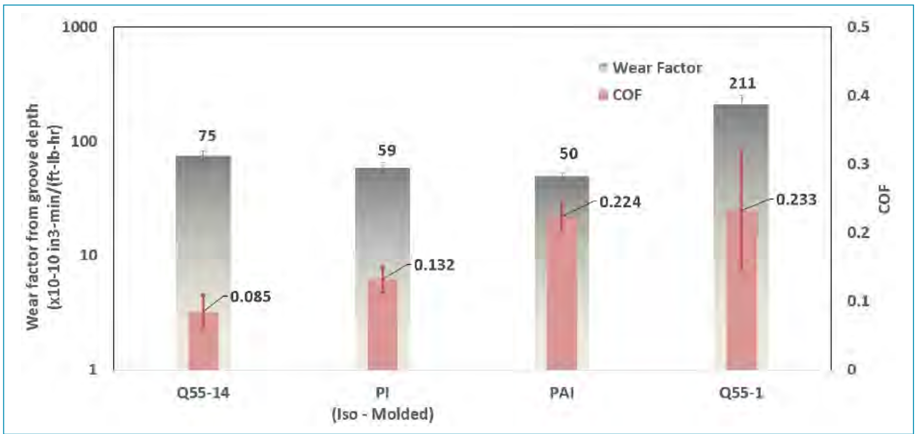

Figure 3 Comparison of dry wear performance of some engineering plastics

Materials

Mechanical and tribological performance of engineering plastics are significantly influenced by filled systems and the base polymer used. While temperature dependent mechanical properties such as modulus, strength, glass transition temperatures etc. for thermoplastics/ thermosets are determinable using standardized tests, wear/friction behavior are typically poorly understood as tribology is more of a system response than a material property and is influenced by a host of parameters. A reasonable tribological test for plastics should (1) be repeatable (2) ensure that failure mode is accurate (wear as opposed to creep or melting) (3) be sensitive enough to compare and rate materials and (4) not be influenced by the geometry of the mating surfaces. It should be noted that the purpose of a tribological test is not necessarily to replicate application conditions (as part geometry has a significant influence on tribological performance), but more so, to be able to understand and compare performance of materials under a set of controlled conditions thus providing the designer valuable insight into appropriate choice of material for a given application condition.

Freudenberg-NOK has developed lubricated and dry tribological test methods [2] to rate and compare materials while adhering to the above listed consideration. Figure 2 shows results of a set of lubricated tests on four different materials at multiple pressure-velocity (PV) combinations. The geometry of the sample, counter-surface and orientation of surface roughness are also shown in Figure 2. Recalling that geometry influences the lubrication regime under a given set of conditions, the parameters (load, speed, temperature and roughness) used for the tests were chosen such that the mating surfaces would run in the boundary lubrication regime. The counter surface is machined from D2 steel with Ra of 1.2 µm (and an Rz of ~ 7 µm) and has a hardness of HRC 23 (Rockwell 'C' scale). Temperature close to the interface was maintained at 150 °C. The Quantix®55-1 and Quantix®55-14 are Freudenberg-NOK materials while the PAI and PI are commercially available high performance engineering plastics. It can be concluded that both Quantix®55-1 and Quantix®55-14 exhibit very low wear factors over the tested range of PV (12 MPa-m/s to 55 MPa-m/s).

Figure 3 compares wear and friction behavior for the same set of materials in a dry test condition for a PV of ~ 2 MPa m/s (57,000 psi – fpm) against a counter surface with a hardness of HRC 23, an Ra of 0.4 µm (and Rz of ~ 1.5 µm) and interface temperature of 150 °C. While The Quantix®55-14, PAI and PI materials seem to demonstrate similar wear factors in the dry test, the lubricated test under more aggressive conditions show dramatic differences in their wear performance. Unfortunately, a standardized wear test such as an ASTM 3702 [3] only call for a dry test under mild PV conditions and do not necessarily reveal differences in performance that are very relevant to the application conditions. It should also be noted that the Quantix®55-1 shows significantly improved performance in the lubricated test because this material was specifically designed for operation in lubricated environments.

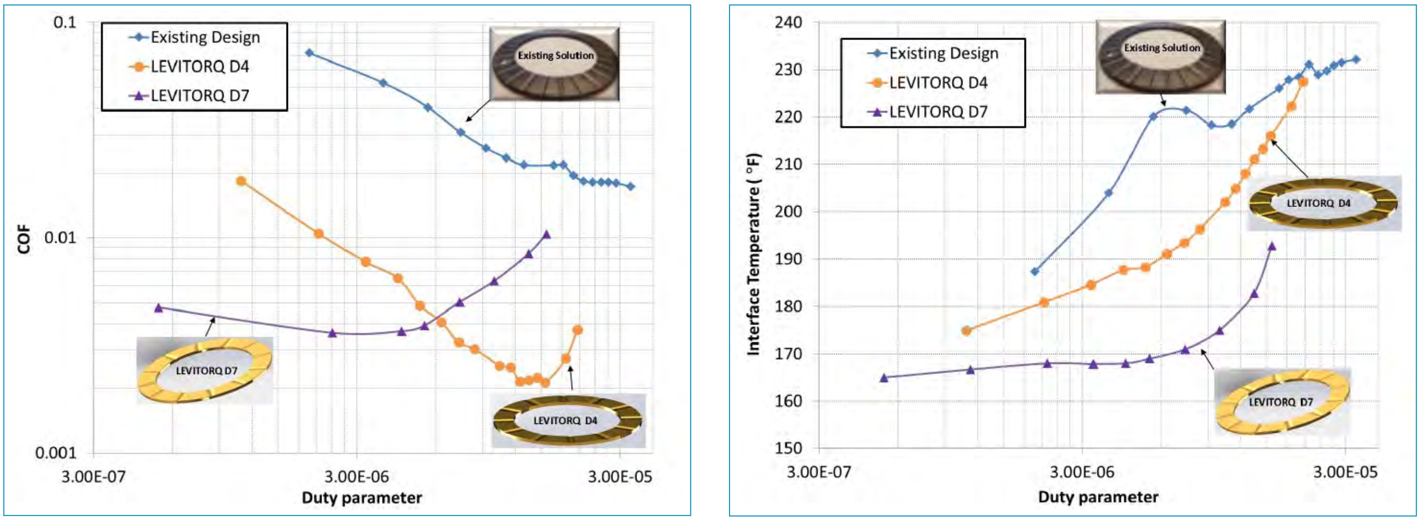

Figure 4 Comparison of friction and interface temperature for a torque converter application

Case Study I – Torque Converter Thrust Washer (hydrodynamic lubrication)

The objective of this work was to quantify the effect of using an optimized thrust washer geometry to improve hydrodynamic operation, and compare performance to an existing solution for a torque converter application. The test conditions were: Pressure = 1 MPa to 3 MPa (150 to 450 psi); Velocity = 2 m/s to 35 m/s (500 rpm to 10,000 rpm, 390 fpm to 6,890 fpm); Flow Rate = 3.78 L/min (1 GPM); Inlet Temperature of ATF = 75 °C (160 °F).

Figure 4 compares temperature close to the running surface and friction coefficient for a current solution to two Freudenberg-NOK designs (LEVITORQ D4 and LEVITORQ D7, patent pending) with optimized geometry (prototyped from the same material as the current solution). Both designs LEVITORQ D4 and LEVITORQ D7 show significantly lower interface temperatures and friction coefficients (about a factor of 7 reduction in friction) over the range of duty parameters tested. The optimized groove design also resulted in reducing the foot print of the thrust washer saving the customer both space and cost.

Case Study II – Pinion Thrust Washer (boundary lubrication)

This case study was for a pinion gear thrust washer where lubrication is minimal, application pressures are high and velocities are low, resulting in operation predominantly in the boundary lubrication regime. The test condition were as follows: Pressure = 17 MPa (2500 psi); V = 0.7 m/s (750 rpm, 150 fpm,); Flow rate = 0.076 L/min (0.02 GPM); Inlet Temperature of ATF = 75 °C (160 °F). Thrust washers with the same geometry were tested in two materials (1) Iso statically molded PI and (2) Quantix®72-4. The resulting wear of the thrust washers are compared in Figure 5. Although the friction coefficients for both the thrust washers were identical during the test (COF = 0.085), significant differences are clear from a wear perspective. The PI material had a total wear of over 0.5 mm resulting in the groove being completely worn away while the Quantix®72-4 material had less than 0.09 mm of total wear (wear rates plotted in Figure 5).

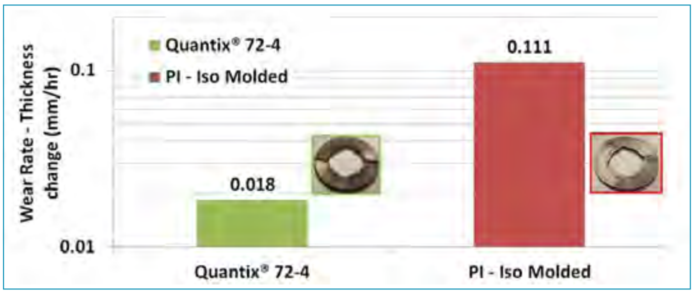

Figure 5 Comparison of wear performance of pinion thrust washers

Summary

Both geometry and materials contribute significantly to performance in an application. A thorough understanding of design, materials and application conditions is essential to be able to leverage use of advanced engineering plastics in transmission applications. Under the correct set of conditions, it is possible to use thrust washers as replacements for metallic needle roller bearings offering weight and space savings without compromising performance. The knowledge gained from this work is applicable to other components in the transmission where engineering plastics can be used.

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Electrified Powertrains Create New Packaging Challenges

Polymeric Thrust Bearings Offer Innovative Approach to Light-weight Transmissions & Packaging Flexibility

Electrification of the powertrain, which includes the addition of a traction motor, challenges automotive engineers to package an electric machine inside an envelope that already includes an engine, launch device, and high speed transmission.

■ Brian Baleno and Brian Stern, Solvay Specialty Polymers

Trends in the Electrified Powertrain

The electrified powertrain is one of several technology enablers that give car manufacturers a pathway to meet upcoming CO_2 emissions standards. Automotive engineers are challenged with designing cost-effective, electrified powertrains that also reduce fuel consumption and provide the driver with the desired performance. The demand to identify packaging savings has never been greater as powertrain engineers are now confronted with the challenge of integrating a traction motor (e-machine) into an already crowded packaging envelope. This article provides design engineers with a cost effective approach to reducing the size and weight of their transmission and launch devices while achieving highly desired space savings to better fit the given packaging envelope.

Benefits of Using Polymeric Thrust Bearings

- Save space for easier packaging
- Reduce size and weight of aluminum housings
- Improve lubrication and cooling with molded-in oil flow channels
- Snap-fit design for ease of installation

Designing Polymeric Transmission & Launch Device Components

High-performance plastics such as KetaSpire® polyetheretherketone (PEEK) and Torlon® polyamide-imide (PAI) have been widely adopted over the past ten years in automatic transmissions (AT) and dual clutch transmission (DCT) seal rings. Over time KetaSpire® PEEK and Torlon® PAI have replaced incumbent materials such as polytetrafluoroethylene (PTFE). There are several reasons why PAI and PEEK have replaced PTFE. One of the largest drivers is that the increase in the number of gears in AT and DCT has led to increasing pressure (P) and velocity (V) requirements. Another factor was that higher temperatures are generated as a result of the frictional heat. They key benefit of materials like PAI or PEEK is that these materials have a high Tg (glass transition temperature), which allows them to operate at elevated temperatures and withstand a high PV (Pressure + Velocity) environment. As a result of the recent down-speeding trends, Torlon® PAI is used in more than 90 % of the seal rings for dual-clutch transmissions.

Design Approach for Polymeric Thrust Bearings

The success of KetaSpire® PEEK and Torlon® PAI in seal rings has led to evolution of these materials as metal substitutes for thrust washers and even axial needle roller bearings. The following factors should to be taken into account when designing a polymer bearing:

- Temperature
- Pressure & Velocity
- Counter surface material and roughness
- Lubrication type
- Flow Rate of the lubricant

These design considerations establish a base line that will be further explored in the case study. Temperature is an important consideration because there are two different temperature considerations that need to be accounted for. The first is the operating temperature of the system and the second is the localized heat generated from friction. The DMA graph in Figure 1 highlights the differences in modulus between PEEK and PAI over a broad temperature range. The DMA data reveals that either PEEK or PAI offer acceptable modulus up to 150 °C which is approaching the Tg of PEEK. PAI is the preferred material when temperatures exceed 150 °C. PAI retains its modulus up to 285 °C, at which point the Tg of PAI is reached.

Aside from temperature itself, the stress/strain behavior and compressive loading should be accounted for. The stress-strain data in Figure 2 further illustrates the impact of temperature by comparing the stress-stain properties of PAI and PEEK at room temperature to those at an elevated temperature of 150 °C.

Because most bearings operate under compression, the compressive modulus of a material at temperature is a key design consideration. As shown below in Figure 3, the compressive modulus of a material is greatly impacted by the T_g of the material. The data shows that PAI is better suited when operating temperatures exceed 150 °C.

After taking into account the operating temperature environment of the thrust washer or bearing, the next step is to calculate the feasibility of replacing metal by evaluating the tribological environment. The elements of friction and wear that need to be evaluated include pressure, velocity, counter surface, and lubrication (dry or wet). A starting point is to compute the PV of a given bearing. Polymer thrust bearings can be considered up to 45 MPa-m/sec.

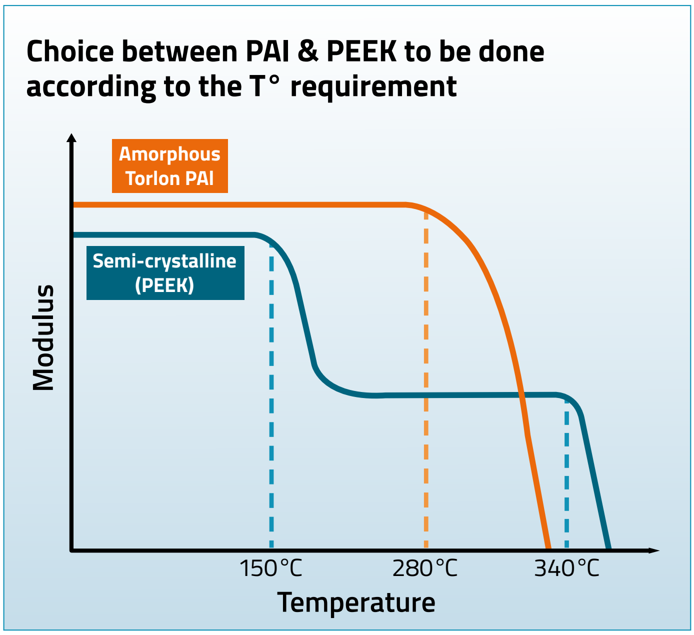


Figure 1 DMA comparison of T_g and T_m of PAI and PEEK

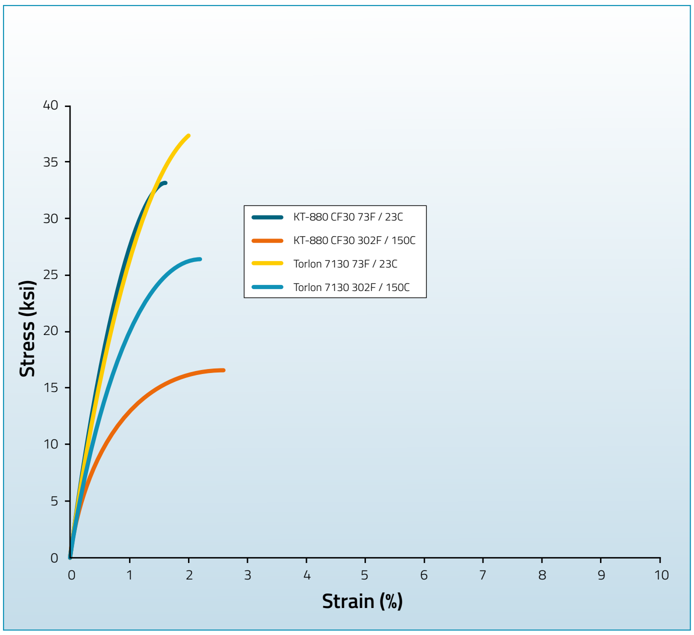


Figure 2 Stress-Strain Data comparing PAI and PEEK at 23 °C and 150 °C

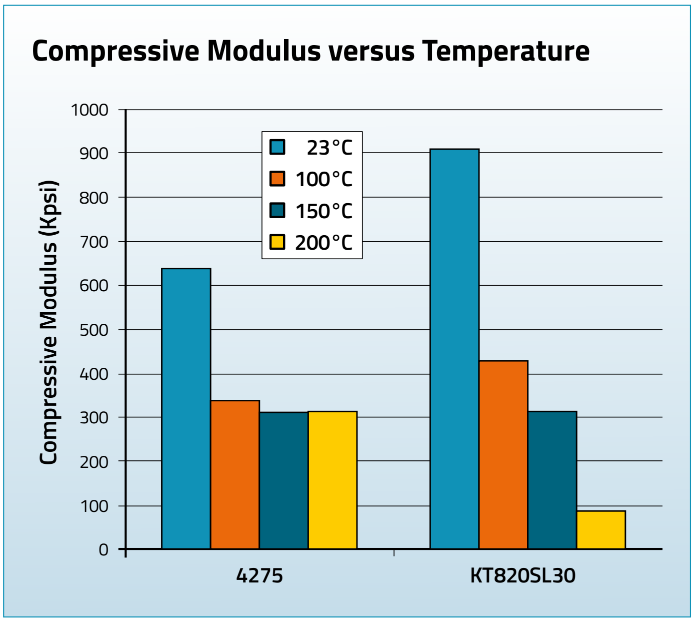


Figure 3 Compressive modulus (kpsi) of PAI and PEEK at temperature

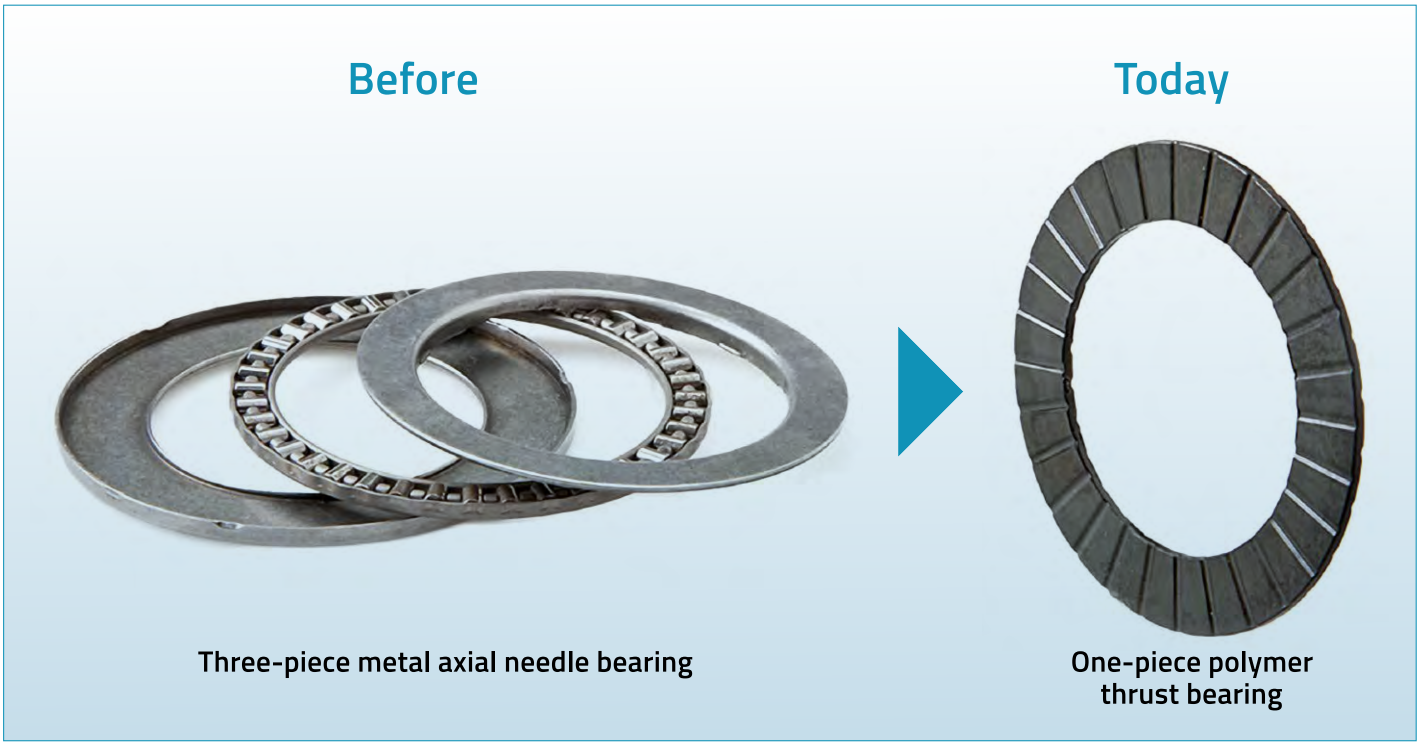
An example of that calculation is shown below:

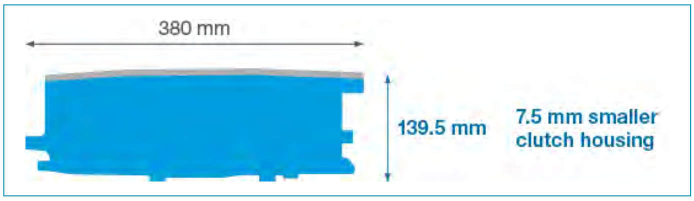
Pressure = 9 MPa
Velocity = 5 meters/second
PV = 9 MPa x 5 meters/second = 45 MPA-m/sec

Axial Needle Bearing Replacement Case Study: Potentially save 2 mm per needle bearing replaced

Polymer thrust bearings can be designed to significantly reduce design space, which can result in an average 2-mm space savings per needle bearing.

This axial needle roller bearing innovation provides transmission designers with the opportunity to reduce the size of the aluminum casting which solves two key challenges. First, the space savings allows for the reduction or down-sizing the aluminum die cast housing. The mass reduction leads to CO_2 decrease. Additionally, if the aluminum housing footprint can be down-sized or reduced, space savings can be achieved which enables greater packaging freedom.





Step 1: Review requirements the start with PV calculations at each gear ratio/position. The PV ranged from 0 to 7 MPa-meters/second

Axial needle roller bearing dimensions:

- outer diameter = 44 mm, inside diameter = 30 mm, thickness = 8 mm
- Pressure = 0.5 MPa
- Velocity = 15 meters/second
- PV = 7.5
- PV was determined to be in acceptable range below 45.

Step 2: Create prototype polymeric thrust bearings to demonstrate on dynamometer. This step can be completed by machining the thrust bearing from a stock shape.

Step 3: Dyno testing of prototype including: gear tilt, gear ratio cycling, torque, temperature, and visual analysis of the samples

Step 4: Define fit for future transmission or launch device axial roller needle bearing where target is to enable space savings by metal replacement (average savings is 2 mm per bearing replaced)

Step 5: Optimize design by including flow channels which allows for greater lubrication, incorporate snap fit capabilities which enables easier assembly and installation

Conclusion

Replacing axial needle roller bearings with polymeric thrust bearing provides numerous advantages, including the ability to achieve space saving versus standard metal needle bearings. This innovation also provides the added benefit of light-weighting and down-sizing aluminum housings which reduces CO_2 emissions.

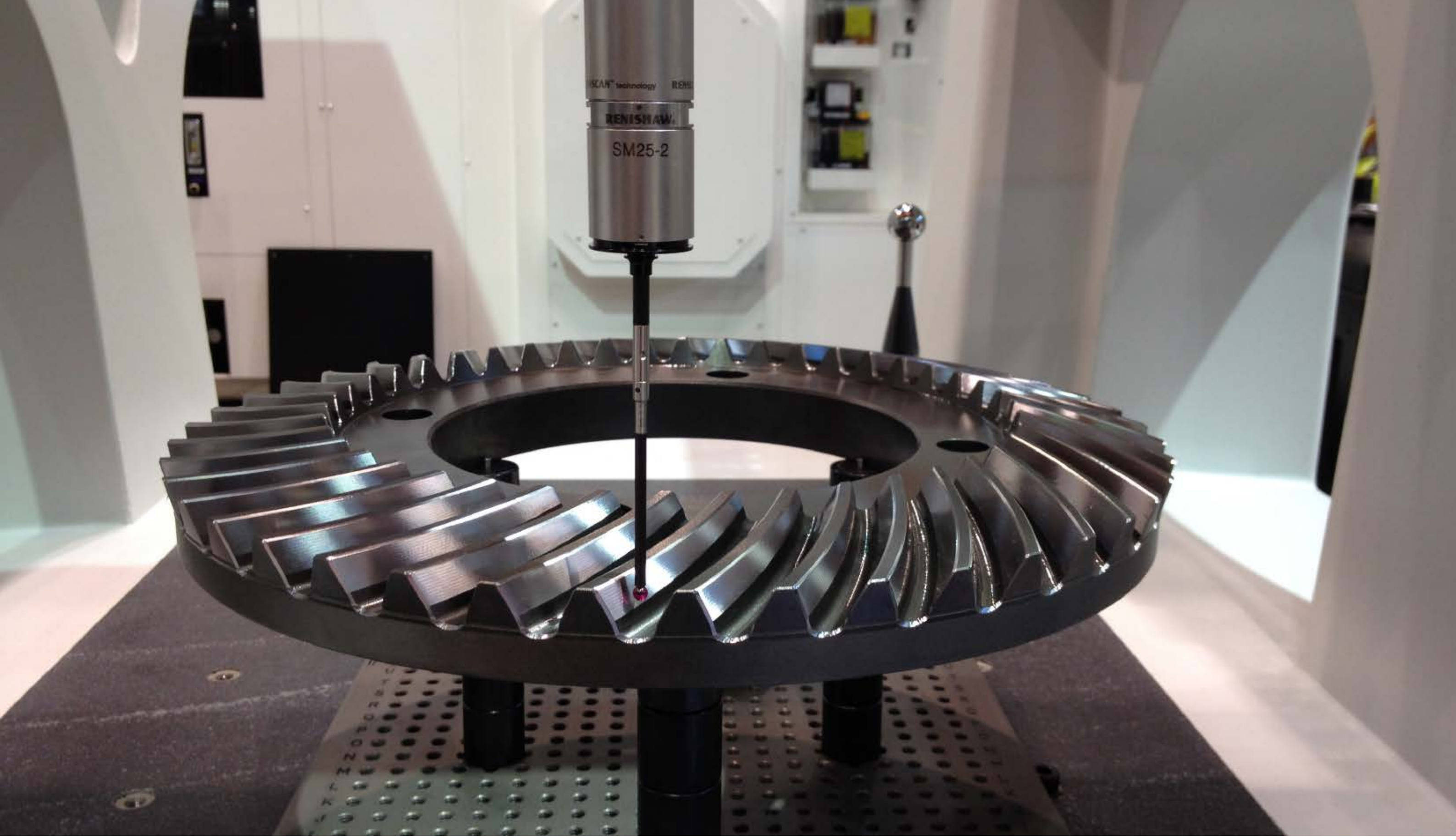


Figure 1 Surface Data Collection of Hardened Spiral Bevel Tooth Flanks on CMM

Past gear manufacture was expensive utilizing dedicated equipment. CLGM is a new way to make gears and control gear production.

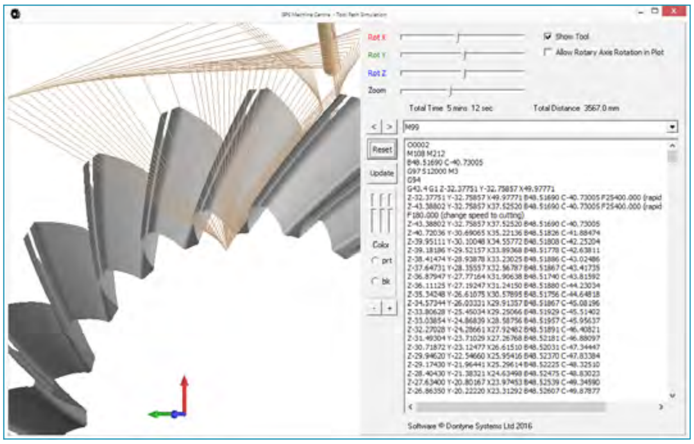
Closed Loop Gear Machining (CLGM) – 5 Axis CNC Gear Process

Most gears require dedicated machines and tools for design, manufacture and inspection. Improvements in modeling and CNC machining accuracy eliminate this requirement, increasing flexibility and reducing cost.

- Dr Mike Fish, Director and Rich Easley, US Business Manager, Dontyne Systems
- Mike Finn, Applications Development Engineer, Mazak Corporation

Historical Gear Manufacturing Processes

In the past a gear development and manufacture process was, in many ways, considered "black magic". Only a select few gear engineers, working with highly specialized and expensive software and equipment, could develop the processes necessary to produce gears with certainty. Nearly every phase of the process required specialized equipment and/or software: the initial design, cutting of teeth, part finishing and final part inspection. This equipment is generally expensive, inflexible and leaves the manufacturer dependent on outside sources for much of the tooling and overall process development. In addition many of the processes need to be completely re-developed, taking many months and significant expense, when a new or different part is manufactured.



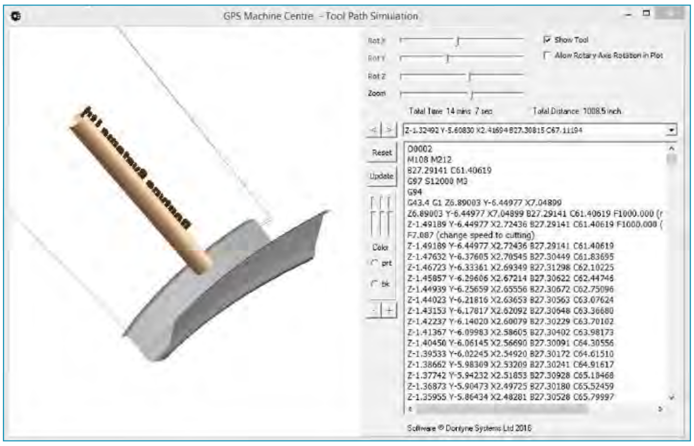
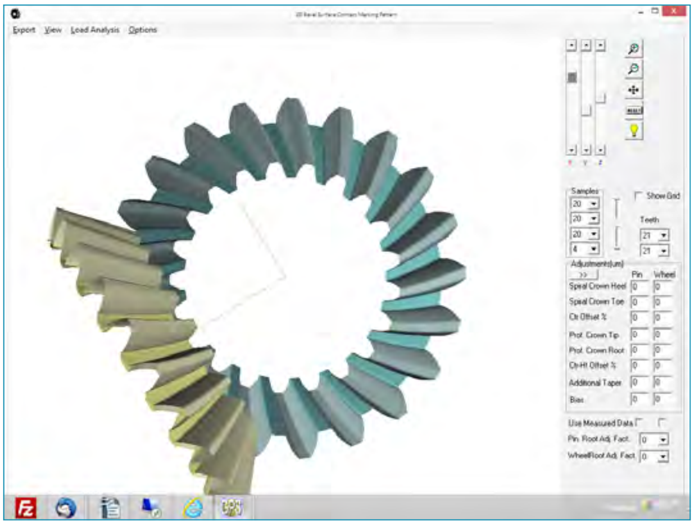


Figure 2 Toolpath Simulation of Spiral Bevel Gear



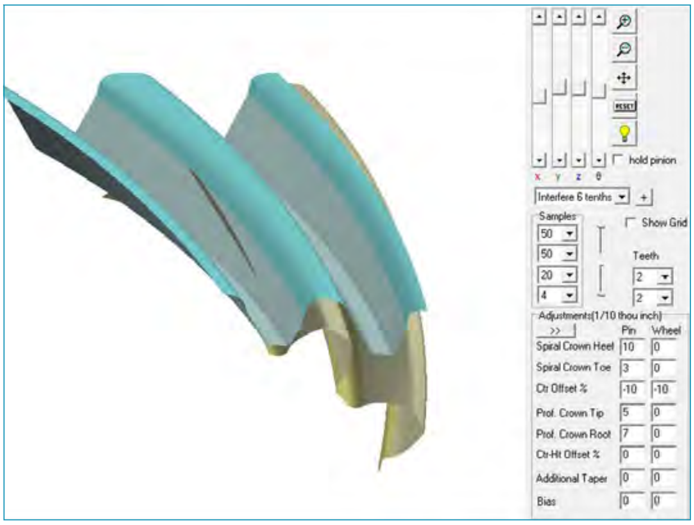


Figure 3 Spiral Bevel Miter Gear Set

Figure 4 Tooth Contact Simulation

Over time, many gear manufacturers have looked to increase their manufacturing flexibility by better simulating part operation in the development phase, utilizing multi-task machines to minimize part movement and processes, implement standard end mill tooling and feedback part inspection data for comparison to the simulated initial design. The closed loop gear machining process (CLGM) developed by Mazak and Dontyne Systems enables gear manufacturers to design, manufacture and inspect gears to these expectations.

What Is CLGM?

The CLGM solution enables clients to use 5 axis multi-tasking CNC machine tools to accurately cut gears. The upfront software functions include integrated graphics and industry standard (AGMA) engineering reports that enable a gear manufacturer to simulate how gear sets make contact, or conjugate, for different real life applications. Of particular interest to gear designers and manufacturing engineers is the contact marking pattern- the real life application of the gear set conjugation.

With CLGM the gear is designed and set conjugation evaluated and optimized in the software, the G-Code is created and the gear is then cut on a 5 axis CNC machine, the part is measured on an accurate CMM, the measured data is then compared to the original design and evaluated for acceptable conjugation. If the part is deemed to be within acceptable tolerance, the part is complete and production moves forward. If the part is deemed out of tolerance, due to tool deflection or other small manufacturing variation, corrections to the manufacturing model are made, the G-Code is re-calculated and the part recut to design.

Currently the software products sit offline of the CNC. All design, analysis, simulation and marking pattern definitions are made prior to the G-Code being posted on the machine. Inspection data is collected, imported back to the software for manufactured versus design part test/evaluation and the G-Code is then updated and reposted to the machine, if required, based on the inspection data results. Dontyne Systems expertise in modelling gear systems means that factors other than geometric accuracy can deem if the part is acceptable such as surface stress or transmission error level.

Design Phase

In the design phase the engineer can quickly design a new gear – or recreate a design to a gear that is currently in production. To recreate a gear the designer would import inspection data from a master part and check the mathematical model being used to generate the 3D gear surface. This is important to verify that any corrective settings give the desired effects. This creates the gear design including the definition of geometry and the rating of gears to ISO and AGMA standards, including tolerancing.

After the design is complete a load analysis is done to add surface modifications and to check that the design is correct under load. This also models deflections for examining performance with manufacturing or alignment errors. The evaluation uses measured data to assess whether the current surface condition is suitable under load.

The final design step is to calculate the cutting path for the CNC machine (machine and tool database), based on the design data. The result is G-Code to post on the CNC machine for a single gear tooth which can be looped to cut all of the gear teeth.

Figure 5 Hardmilling of Spiral Bevel Gear Carburized to 55 HRc on MazakVC500 5X

Part Manufacture

In most cases, with the use of a 5-axis Multi-Tasking CNC machine, the gear can be machined complete from the raw material using standard tools such as end mills and ball mills. The gear tooth cutting toolpath is combined with the cutting codes required for part manufacture. The benefits of machining the part complete on a single platform are reduction of setup time, reduction of work holding and improved accuracy.

Because all machining takes place on a single setup, the datums (bores, back faces and bearing diameters) and the gear pitch circle/cone have minimal runout with each other thus improving quality. Dontyne software gives control of the G-Code toolpath allowing the precise amount of stock on the flanks for hard-milling up to HRc62 after heat treatment.

Trials on Mazak Multi-Tasking machines have shown flank surface lead, profile and pitch accuracy to be Grade 10-12 per AGMA-A88 directly from the Dontyne export G-Code.

Tooth cutting cycle time on multi-axis machines is often stated as a major drawback. However, this is offset by including the entire machining process from turning the gear blank, to drilling bolt hole patterns and milling slots. This dramatically increases the break-even batch size relating to time up to 500 pairs with the added benefit of complete flexibility in design change.

Unlike dedicated gear cutting machinery, the tooth geometry is not limited by the cutting tool. Using common end mills and ball mills along with 5-axis motion, various types of gear teeth can be cut on a single Multi-Tasking machine ranging from spiral bevel and double helical to spur and straight splines. This flexibility is useful in a R&D and prototype environments.

Part Inspection, Feedback and Correction

Upon completion of the part machining, it is inspected on an accurate CMM machine. This inspection data can be compared to the measured data from the master part, as well as fed back to the inspection center module of the software. This link of the measuring system data to the design data provides 3D surface deviation reports and standard reporting to ISO and AMGA standards profile/lead/pitch/run-out. This 3D surface model data is then further evaluated by comparing the measured data of the actual finished part to the theoretical design part. The comparison data is then used to edit and update the original 5 axis paths for the gears and tools to improved accuracy if necessary. This corrected data is then output in G-code back to the machine to recut the corrected part- essentially closing the loop. A final inspection is then done to verify that the part is manufactured as designed.

Conclusion

Recent improvements in precision machine tool performance, computer simulation and modeling capabilities have enabled Dontyne and Mazak to develop a CLGM process for innovative gear manufacture. The CLGM process is currently being evaluated by several aerospace, automotive and other gear manufacturers to increase their manufacturing flexibility. The process has been used for both new and existing gear part manufacture.

CLGM helps satisfy increasing gear market trends demanding greater flexibility, rapid changeover speed, less special tooling, affordability and accuracy, which can now be achieved by performing all cutting operations on a single machine. Mass production requirements to feed dedicated gear equipment is no longer viable for many manufacturers. The utilization of realistic load simulation, flexible machining and accurate inspection feedback gives gear manufacturers new options to maximize the efficiency of their production machinery and processes.

More Information:

www.dontynesystems.com/
www.mazakusa.com/news-events/white-papers/closed-loop-gear-machining/

Expanding the collection of unique servo press technology in North America

Improve Precision and Production. Eliminate Weight and Costs.

Feintool adds a unique Fineblanking and Forming System (FFS™) to meet demand for lighter automotive transmission components

■ Lars Reich, Executive Vice President of Sales and Marketing, Feintool US Operations Inc.

Economically manufacturing in a single press run

Near Nashville, Tenn., Feintool has invested nearly $ 80 million in innovative fineblanking and forming technologies, building a production facility to meet demand for lighter and stronger powertrain and other automotive components in North America and globally for years to come.

The heart of the Feintool-developed Fineblanking & Forming System (FFS™) is a 1,600-ton direct servo transfer press with an 18-foot (6-meter) press table. The system includes a hydraulic power unit adapted from a 700-ton fineblanking press, located in the foundation of the transfer press.

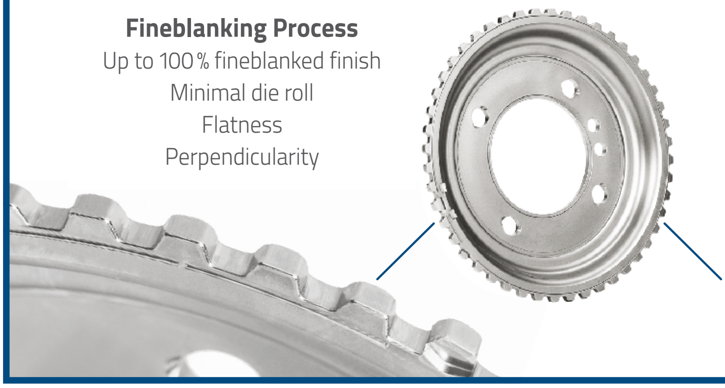
The FFS configuration eliminates the usual limitations of the fineblanking press with a relatively small bed size. The 18-foot press table accepts up to 12 individual tooling stations that enable total freedom in part design. The 700-ton fineblanking hydraulic power unit delivers high volumes of oil at precisely controlled ram positions and pressures to fully integrate multiple fineblanking operations at any stations of the forming tools.

The results are three-dimensional formed, lightweight components with fineblanked part features in critical areas to achieve precision and finishing results possible only with an FFS configuration. Disc carriers, pistons, gear spiders, driveplates and adaptive dampening components can be formed, fineblanked, in-tool rolled and finished in a single transfer press run.

With the addition of a second 1,600-ton press, Feintool now has three large tonnage presses in its Nashville production facility that uniquely combine cold-forming and fineblanking operations.

The Combination Makes the Difference

Fineblanking Process
Up to 100 % fineblanked finish
Minimal die roll
Flatness
Perpendicularity



Direct Servo Transfer Press
Large 18-foot press table
Free, programmable slide motion
Up to 12 tooling stations
Integrated 700-ton fineblanking hydraulic power unit

Unleashed productivity

All the presses are equipped with three-axis CNC controlled transfer systems that guarantee a quick transfer of components through all tooling stations. Positional accuracy and speed of the transfer system are key in unleashing the stroke rate capabilities of the direct drive servo technology.

The moving bolster is another key feature of the press systems that enables die changes of all 12 stations at the same time within 20 to 30 minutes. The direct servo presses are equipped with two moving bolsters that alternate in moving to the front or the back of the press. The entire tool can be set-up outside of the press on the spare moving bolster including the transfer arm and all sensors for parts detection. When it comes to an actual tool change, the moving bolster can simply be swapped and the machine is ready and back in production with minimal interruption.

In Nashville, Feintool collaborated with the press manufacturer to develop the following innovative technology in the new, $15 million press that also includes:

- 1,600-ton press force with direct servo-powered, fully adjustable ram movement
- Separate servo slide for automated processing of blanks
- A zig-zag feed for the most cost-efficient material usage of coil stock

The unique combination of capabilities provides Feintool with the tools it needs to cost-effectively produce components for automotive manufacturers and other customers.

"Feintool's innovative technology helps save weight and space by forming thinner, high-strength parts in high-volume, serial production," said Christoph Trachsler, CEO of Feintool US Operations Inc. "Under intense pressure to meet requirements to reduce fuel consumption and emissions, the automakers are turning to eight-, nine- and 10-speed transmissions with designs that call for increasingly complex formed 3-D components. Cars and transmissions are not getting bigger, so the added gears need to fit into the same space. That means an entirely new class of transmission components is required. These parts must become smaller, lighter and meet the tight tolerances with repeatability."

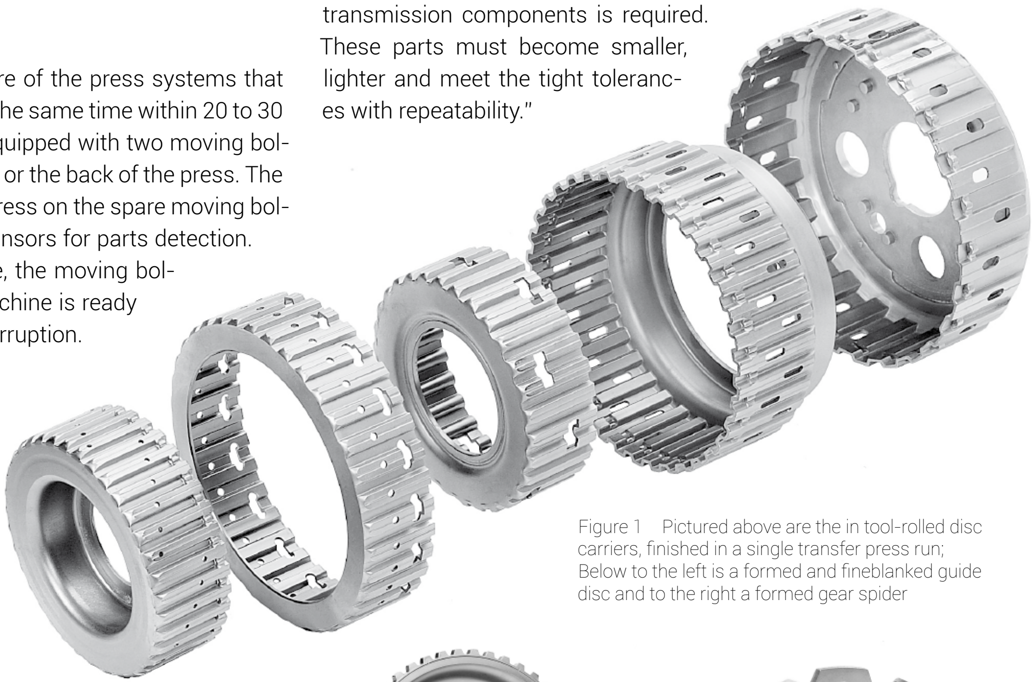


Figure 1 Pictured above are the in tool-rolled disc carriers, finished in a single transfer press run; Below to the left is a formed and fineblanked guide disc and to the right a formed gear spider

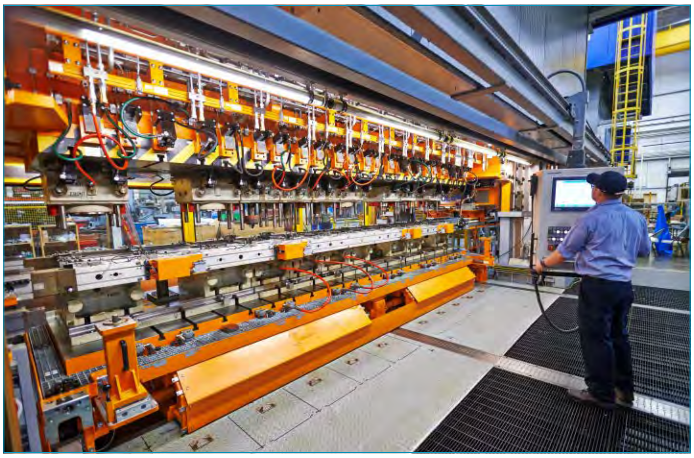


Figure 2 On a large 18-foot press table with moving bolster, components can be finished in up to 12 tooling stations in a single transfer run.

Figure 3 Feintool Nashville has three large transfer press lines with the newest 1,600 direct servo press in the front.

Leading the automotive transformation

The installation of the third large press marks the successful conclusion of the latest phase in Feintool's investment to expand in Nashville and continue to grow with the transformation of the global automotive industry.

Feintool's operation in Nashville began in 1999, supplying the domestic automotive market with fineblanked and formed components. The Tennessee plant manufactures clutch plates, disc carriers, planetary carriers, pistons, drive plates and guide discs for a variety of customers. In 2012, Feintool began upgrading its capabilities at its North American plant. First came a long-table 2,000-ton press that produces complex transmission components from sheet metal. A 1,600-ton servo press was installed in 2014; and the third large press arrived in early 2017, marking the latest phase in Feintool's investment. The flexibility of the combined cold forming and fineblanking processes enables Feintool to form and finish transmission components among other parts, in one single press run. No secondary processing is required.

"Feintool now has the youngest and most advanced fleet of forming presses in North America."

Christoph Trachsler,
CEO of Feintool US Operations Inc.

"That's what makes our newest press so powerful and a North American first," Trachsler said.

Competing globally by investing locally

With the third large servo press, Feintool can use flexible manufacturing models to avoid disruptions of component supplies to its customers. All the tooling is interchangeable, so work can be shifted to any of the large presses to avoid downtime. Feintool produced nearly 80 million parts in Nashville last year, and expects to grow that volume because of the additional press capacity.

In addition to the investment in large presses, Feintool expanded its Nashville tool room with more square footage and new high-speed machining centers, upgraded the quality lab with metallurgical testing equipment and updated the cleanliness test lab. As the Nashville operation has grown with the company's automotive customers, Feintool has increased its workforce, which now totals approximately 250 employees.

Follow-up report on the 15th International CTI Symposium – Automotive Transmissions, HEV and EV Drives, 5 – 8 December 2016, Berlin, Germany

Transmission Development on the Road to an Electrified Future

15 years of CTI Symposium Berlin stand for major progress in transmissions and powertrains. Powertrains are being more and more electrified; their control becomes increasingly complex, just like vehicle networking and automation. Future Transmission developers are facing a wide range of interesting challenges.

■ Gernot Goppelt

Fifteen years ago, the first CTI Symposium in Offenbach was a relatively modest affair with 250 participants, three exhibitors and two parallel lecture sessions. In 2016 it was a major convention with 1350 participants, 135 exhibitors from 20 countries and over 90 lectures in 16 parallel sessions. In his welcome address in Berlin, Professor Ferit Küçükay recalled the 'legendary presentation' by Pierre Lepelletier in Offenbach, as well as the many milestones in the years that followed. From the outset these included new hybrid concepts – and most recently, the Dedicated Hybrid Drive (DHT) in late 2015. This development will progress rapidly, and electrification and networked powertrain connectivity will increasingly make their mark on the transmissions symposium. For 2025, Professor Küçükay foresees a 15 to 25 percent market share for highly electrified automobiles, boosted by battery prices that could fall below $ 100 per kWh by as early as 2022. But what does this growing electrification mean for transmission developers?

Solutions for diversified electric mobility

The first lecture was "Volkswagen on the path to electrification – diversity in the drive train" by Dr Ulrich Eichhorn, CTO, Volkswagen Group. Dr Eichhorn said future emission regulations could only be met by "adding a share of electric automobiles to the mix", with modular kits for all electrification stages from mild hybrid up to all-out BEVs. The price of batteries, however, would develop more favourably than expected – and so would their energy density. From 2010 to around 2025, Dr Eichhorn predicted this would grow from around 260 to 650 Wh/l; with new battery technology, 700 Wh/l and more were possible. By 2020, Dr Eichhorn expects ranges of 500 km as standard; from around 2024 he predicts at least 700 km thanks to new battery technology. He noted that the charging infrastructure was still a critical factor, but then again "If an inventor turned up today with an internal combustion engine he'd have a problem with a lack of filling stations too". In this context, Dr Eichhorn referred to the joint venture announced last November under which Daimler, BMW, Volkswagen and Ford plan to improve the network of fast charging points. Eichhorn's predictions for 2020: 48V hybrid technology will have reached small automobile segments, plug-in hybrids will be more important, and electric automobiles are definitely coming – to the extent that the infrastructure permits.

"Transmission development has never been more exciting than today"

Dr Renate Vachenauer, Vice President Transmission, Drive Train, BMW Group, talked about the "Complexity of transmission development – trends, challenges, solutions". BMW is not a transmission manufacturer, but covers a wide range of applications. Dr Vachenauer says there are growing numbers of derivatives, and hence growing demands on how these can be assured. Drive management has more and more input parameters to cope with; hybrid drives require the coordination of two or more torques, and there are many variants in different applications. Dr Vachenauer sees a need for even more virtual development work in order to cut costs and boost robustness. She spoke of the need for modular software development systems that can map the diversity of drives, adding that this already applies for 48V and even more so for plug-in hybrids. As long as we relied on P2 transmission kits including conventional transmissions, complexity would moderately rise; using DHTs however, it would grow exponentially. Only all-electric powertrains could "sustainably save" us in this respect. The second big trend according to Vachenauer is automated driving. As a "passenger", the car driver would only have three requirements on transmissions: "comfort, comfort and comfort". However, as vehicles would not drive fully automated at first, both modes would have to be implemented.


Dr Ulrich Eichhorn, CTO, Volkswagen Group


Dr Renate Vachenauer, Vice President Transmission, Drive Train, BMW Group

Jörg Grotendorst, Head of E-Mobility, ZF Friedrichshafen AG


Toshihiro Hirai, Alliance Global Director, Corporate Vice President Powertrain Engineering Division, Nissan Motor Co


Michael Funk, Project Manager Dual Clutch Transmission, Dr. Ing. h. c. F. Porsche AG


Dr Fritz Indra, Honorary Professor and Advisor

"At that point we have reached the top level of complexity." This trend would only be reversed, as soon as we drive fully electrically and autonomously.

Fresh thinking for the charging infrastructure

In his lecture "Drives are changing and change drives us" Jörg Grotendorst, Head of E-Mobility, ZF Friedrichshafen AG, said Germany produced 647 TWh of energy in 2015, around 12 percent of it regenerative. Of that, less than 600 TWh was needed for the domestic market. What does that mean for e-mobility? Mr Grotendorst pointed out that Germany currently has around 44 million passenger cars on the road with an average annual mileage of 15,000 km. Assuming the same number of all-electric automobiles would consume 20 kWh per 100 km, the energy requirement would be 133 TWh a year, "which could already be supplied today". And if last year's energy consumption reduction of two percent could be extrapolated, we could easily run all electric automobiles in future just from the savings alone. So there was no lack of electricity, Mr Grotendorst noted – but what about the infrastructure? Here, the speaker drew parallels to other new technologies such as smart phones, where users top up at every opportunity instead of waiting for the battery to go flat. In a similar way, he argued, what electric vehicles need most of all is a tightly woven web of low-power charging stations so people can recharge whenever they wish. Mr Grotendorst is convinced the future is electric, and reminded listeners that with hindsight, we often find technologies take hold faster than expected.

Hybridization boosts CVT efficiency

Toshihiro Hirai, Alliance Global Director, Corporate Vice President Powertrain Engineering Division, Nissan Motor Co. addressed the question "What is the future key function and value of transmissions?" Mr Hirai sees ongoing powertrain development as a series of 'rational' adaptations. These include the insight that liquid fuels are at least ten times better than batteries in the longer term, especially for long trips. Hirai says a sensible hybrid drive for the immediate future would be a combination of a turbocharged downsized engine with 'light' electrification, and a broad powerband transmission with a relatively high number of ratios, or a CVT. He argued that downsizing shifts the high efficiency band to regions with low load. So conversely, the electric motor has to support it less and the transmission needs to ensure the ICE can always operate in favourable load ranges. As a longer-term step in powertrain evolution, Mr Hirai described an interesting serial hybrid concept: an ICE optimized for quasi-stationary operation with an efficiency of 45 percent powers a generator up to 60 km/h, and uses a CVT up to 180 km/h. Since this CVT would only need a ratio spread of 3.0, its mechanical efficiency could match that of gear wheel transmissions while providing significantly more comfort, something Mr Hirai too sees as a key requirement in future as well.

More complexity – more efficient development – less weight

Part two of the plenary session was defined by sporty applications. Michael Funk, Project Manager Dual Clutch Transmission, Dr. Ing. h. c .F. Porsche AG, began by presenting the second-generation Porsche PDK, a DCT with eight ratios. The remarkable spread of 11.17 covers a high speed range and permits a very short launch gear. Porsche opted for a gear set architecture with one fixed gear each for ratios 5/7 and 6/8. This permits a more compact build and enables P2 hybridization with

Dr Harald Kraus, Graz University of Technology, Institute of Automotive Engineering; Dr Markus Bachinger, University of Technology, Graz; Dr Marco Denk, University of Bayreuth (from left to right)

the same installation length. Mr Funk said Porsche has made significant progress in reducing losses, particularly in hydraulics, synchronization and wheelset friction, despite the four-shaft design. Overall, Porsche puts the improvement at 28 percent. For Mr Funk, reversing the 'weight spiral' is a key challenge for electromobility. One solution could be to use even more structurally-optimized construction elements. As an interesting individual aspect, he explained how growing torque ratings under hybridization are a burden for sporty applications. In ten years' time Mr Funk expects to see significantly more PHEVs and EVs, but fewer ATs and even PDKs (DCTs) in their present form.

The most efficient engineers are the ones who can work creatively

"Is Formula One with hybrid technology a wrong turn?" asked Professor Dr Fritz Indra, Honorary Professor and Advisor, and gave a very clear answer. Mr Indra said Formula One showcases itself as the ultimate arena for high tech and sport, an arena that hybridization has entered in stages (most recently with 1.6-litre engines combined with ERS-H and ERS-K, meaning thermal energy recuperation (H=Heat) and generator-based recuperation (K=Kinetic). In reality, Indra believes hybrid is mostly at a disadvantage compared to conventional drives. He said complexity was now so high that just three engine manufacturers – above all Mercedes – could compete. The Li-Ion batteries cost at least € 60,000, and only lasted two race weekends. ERS-H and ERS-K had driven car weights up to 722 kg, compared with 640 kg with KERS and 500 to 605 kg for conventional racing cars built between 1966 and 2009. The results were slower lap times and a higher overall energy footprint. Weighing up, Dr Indra considered whether instead of making hybrid technology mandatory, the organizers should set a maximum energy quotient per lap and let the engineers decide how they use it. Aside from his clear criticism of hybrid technology in auto racing, Fritz Indra's talk was also fascinating for the insights he provided on how drives and their hybrid components are constructed in Formula One.

Serving a successful European automobile industry

The plenary session on Day Two of the CTI Symposium was opened by Andrea Gerini, Centro Ricerce Fiat and Berlin representative of the European Council for Automotive R&D, EUCAR with his talk "EUCAR's research priorities for sustainable propulsion". He said the organization's mission was to make European auto manufacturers more competitive via strategic cooperation schemes in research and development. Mr Gerini identified the core challenges as optimizing ICE drives for lower emissions, and providing affordable electric automobiles, together with a suitable infrastructure. Mr Gerini assumes ICEs will still be with us in the near future, which is why EUCAR also addresses power-to-gas and bio fuels to reduce their CO_2 footprint. Long term, on-the-move charging concepts for electric automobiles were also interesting; EUCAR is examining the feasibility of the technologies involved. Mr Gerini said that beyond its day-to-day operations, EUCAR's general goal is to seek and initiate solutions that will be workable in the distant future, meaning in ten to twenty years.

Ways to electrified delivery services

Professor Harald Ludanek, Member of the Board, Volkswagen Commercial Vehicles, focussed on the challenges for light commercial vehicles in his lecture "Future powertrain concepts in light commercial vehicles for delivery services". He cited the growing significance of B2C trading, driven by online orders, as one example of the way demands are changing. From around one billion Euros in 1999 and 15 billion in 2006, annual turnover was now 44 billion Euros in Germany alone. On the other hand, emissions requirements for these vehicles were increasing to as low as zero for city centres. Like passenger cars – but not heavy trucks – Prof. Ludanek foresees a trend among LCVs towards broad powerband efficiency ICEs, and transmissions with six to eight ratios in the form of MTs, DCTs and ATs. He expects one or two ratios for all-electric delivery vehicles. Professor Ludanek presented an e-Crafter as an example of a series-production application. The e-Crafter Transporter has a 100 kW power rating, 290 Nm of torque and a 43 kWh battery capacity for ranges of 208 km. Professor Ludanek noted that costs were still a challenge, and that BEVs were more expensive although they incur no CO_2 penalties and save on maintenance and running costs. What will become of ICEs? "We'll still see them in many sectors – but we'll need to exploit the potential of exhaust gas recovery consequently".

Powertrains in a connected world

Jake Hirsch, President, Magna Powertrain, talked about the "Powertrain of the future" from the viewpoint of a company that operates as a systems provider for the entire powertrain. But Mr Hirsch went further still by presenting powertrains as part of an overall system that also includes aspects such as ADAS, Car2X or automated driving. Despite rising complexity, the challenge was to find highly integrated standards for products and systems. As an impressive example, Mr Hirsch named 48 different powertrain architectures that would be possible in 2025 due to electrification, as compared with just six architectures for ICE-only drives. However, the trend towards standardization was heading in the opposite direction: 54 percent of all passenger cars with production volumes over one million would be based on just 26 platforms, compared with 39 today. By 2025, Mr Hirsch also expects there will already be 600,000 autonomous automobiles driving on Levels 4 or 5. This adds context to Magna's acquisition of Argus Cyber Security, a specialist for networked automobile security. For Jake Hirsch, the powertrain of the future is an integral part of a complex overall system, so controlling that system as a supplier and system provider made more sense than ever.

DHTs and electric drives are picking up speed

In an interview in the December 2016 issue of CTI Mag Larry T. Nitz, Executive Director Global Transmissions and Electrification, General Motors, talks about the second generation Voltec DHT. In his Berlin lecture "Transformation of Mobility" he touched briefly on the electric car Opel Ampera (alias Chevrolet Bolt), which achieves ranges of 500 km (NEFZ) and 239 miles (EPA). Mr Nitz says GM market research indicates that ranges of over 200 miles mark a tipping point for the widespread adoption of electric cars, providing they are affordable. He says GM has already taken the step from "Bolt EV" to "Bolt AV", meaning the autonomous electric car. Given the trend towards increasingly autonomous driving, Mr Nitz expects a shift from driver orientation towards service-orientated automobiles, with a growing emphasis on comfort and networked communication. What does that mean for the transmissions business? Mr Nitz believes all-electric drives will be more important, but so will DHTs. By contrast, he sees add-on solutions based on AT or DCT on the back foot and believes manual shifts will gradually phase-out.

Plenary discussion and Young Drive Experts Award

There was a new format for the traditional plenary discussion on the 15th anniversary of the CTI Symposium in Berlin. Professor Peter Gutzmer, Schaeffler, Jörg Grotendorst, ZF, and Dr Renate Vachenauer, BMW, teamed up with three discussion partners who are just beginning their careers: Stefan Trommer from DLR Berlin, Dr Kerstin Schmidt, TU Braunschweig and Ruben König, TU Darmstadt. The main discussion topic was "What will the powertrain of the future look like, and to what extent has the attitude of the coming generation towards it already changed?" To touch on just one point in the discussion, the answer to that was "less than you might think". Ruben König said people would still have an emotional relationship with their automobile because as places for everyday personal objects, we live in them too. Kerstin Schmidt added that cars are also 'safe places'. Stefan Trommer thought that living on the big city outskirts as he did, he would find it hard without a car. With a view to autonomous driving, Renate Vachenauer concluded that we will need solutions that enable us to still experience cars as personal living spaces in future. 88 percent of the audience felt people would still want to own their own cars in future. Professor Gutzmer predicts that change will be driven from a different side and that increasingly, regulators would determine the framework for personal mobility as they do already in China. He ended on a positive note: "The things engineers do well always have to do with emotions".

For the first time, the 8th Young Drive Experts Award used the 'Pecha Kucha' format. The three presenters Marco Denk, Harald Kraus and Markus Bachinger, held their presentations using ten slides with each 20 seconds, an impressive feat that was greeted with loud applause. The overall winner was the candidate who received the loudest applause: Dr Marco Denk of Bayreuth University. Dr Denk talked about his doctorate thesis "In Situ Monitoring of IGBT Performance Semiconductor Modules using Real-Time Rectifier Temperature Readings". Markus Bachinger presented an approach for the generic modelling of transmission topologies with multiple coupled friction elements, while Harald Kraus outlined an operating strategy for plug-in hybrid automobiles.

Challenges in the next 15 years will be even more diverse

Over the lifetime of the CTI Symposium, transmissions have outgrown their traditional functional limitations. The build types are still there, but are increasingly becoming an integral part of an electrified powertrain system. In the next step, they will become part of a networked environment comprising vehicles with varying degrees of automation. The talks and discussions at the 15th International CTI Symposium reflected this development: thanks to progress in battery technology, there are signs that electrification for everyday use is becoming a reality. For specific applications, however – particularly long-distance travel – ICEs still seem to have the advantage due to the higher density of liquid energy sources. 'Rational' decisions can lead to very different solutions, whether conventional powertrains with a diesel engine, mild hybrids with add-on transmissions, a DHT or an all-electric automobile. Before fully automatic driving becomes a reality, the challenges for transmissions and their developers will diversify even more. This is both a challenge and an exciting opportunity. Transmissions are now a key strategic component in an overall system that extends from the powertrain to the whole vehicle and into a networked mobile world. This trend seems set to remain with us for the next 15 years.

More information: www.transmission-symposium.com/en

Andrea Gerini, Centro Ricerce Fiat and Berlin representative of the European Council for Automotive R&D, EUCAR

Professor Harald Ludanek, Member of the Board, Volkswagen Commercial Vehicles

Prof. Dr Ferit Küçükay, Director, Institute of Automotive Engineering, Technical University of Braunschweig

Jake Hirsch, President, Magna Powertrain

Larry T. Nitz, Executive Director Global Transmissions and Electrification, General Motors