cti magazine

AUTOMOTIVE DRIVETRAINS | INTELLIGENT | ELECTRIFIED

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Dear readers,

welcome to the fourteenth issue of CTI Magazine. While the Corona crisis is restricting production at present, development work and other activities are continuing in 'home office mode'. In this issue, prominent automotive companies report on current developments in drivetrains, their aggregates and components.

In addition to modular 48 V hybrid drives, we also cover component-related topics such as position sensors, bearings and lubricants, as well as simulation and production methods. For developers, the primary goal is to cut costs and weight while simultaneously increasing efficiency and performance.

Then to complement these specialist articles, we talk to several automotive managers and experts about hybrid drives and the future of ICEs. The first two interviews are with Magna's Dr Gindele (on the new, innovative Magna DCT for the Ferrari SF 90 Stradale), and Professor Beidl of TU Darmstadt.

And to round things off, we've included a follow-up report with all the news from the recent CTI SYMPOSIUM in Berlin.

Our very special thanks to everyone who contributed to making this issue of CTI Magazine happen. Enjoy!

Best wishes,

Your CTI Magazine Team

Michael Follmann, Exhibition & Sponsoring Director CTI SYMPOSIUM
Prof. Dr Ferit Küçükay, Managing Director, Institute of Automotive Engineering, TU Braunschweig, Chairman CTI SYMPOSIUM
Sylvia Zenzinger, Conference Director CTI SYMPOSIUM

Contents

Magna's Modular and Scalable 48 V Platform eDrive Solutions

Magna uses a scalable set of building blocks to create complete powertrain systems for pure electric and hybrid electric vehicles, covering the full range of system architectures from 48 V to 800 V. Cutting edge virtual methods including artificial intelligence algorithms for predicting performance-, efficiency-, durability-, NVH-, thermal- and EMC-attributes are used in an early development phase to functionally integrate the building blocks to an application specific eDrive system meeting the local market and OEM requirements.

Due to large variations in legislation regarding CO_2 emission and fleet consumption in the US, Europe and China, many different types of electrified powertrain systems are needed in the market. In addition the end-customer expectations for pure Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) regarding performance and comfort will trigger new requirements on the electric components. It is an excellent opportunity for OEMs to provide a new level of agility and functionality using the additional degrees of freedom provided by Electric Drive (eDrive) solutions.

Based on successful eDrive serial products on the market since 2011, Magna developed eDrive platforms with cutting edge technology to meet these high expectations of future automotive applications in the range of 17 kW to 250 kW of power. The so called "building blocks" of an e-motor and inverter are re-used in a wide range of different applications providing flexibility by scaling and improving robustness as well as reducing time to market.

One important platform within this overall product strategy is the 48 V high speed platform, which was developed specifically to cover a forecasted market demand for high volume mild hybrid powertrain systems. Magna's 48 V e-motor/inverter solutions provide an integration-friendly solution with high recuperation potential as well as the customer benefit of a traction aid system and limited pure electric driving.

Magna's 48 V serial production platform consists of a scalable permanent magnet synchronous motor (PMSM) to achieve the highest power density and a modular inverter using metal oxide semi-conductor field effect transistors (MOSFETs). These two building blocks are used for several applications with a speed range of 20,000 to 35,000 rpm and a power of 17 to 25 kW peak. This e-motor/inverter platform will be mainly used in applications with very challenging packages in P1, P2.5-, P3- and P4-architectures. There will be an oil cooled version of the motor for the application in hybrid double clutch transmissions. Other applications will use a water-cooled version, and the inverter will be water-cooled in every version. The CO_2 benefit of such 25 kW systems can be as much as 21 % depending on the vehicle and system configuration.

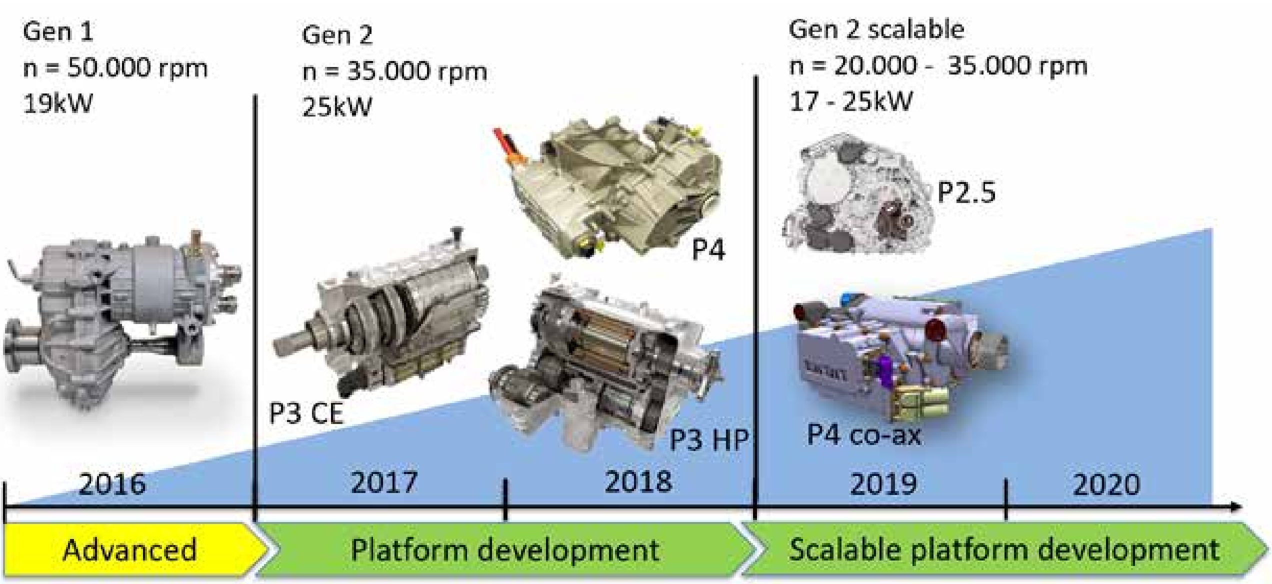


Figure 1 Evolution of the modular and scalable 48 V high speed platform

Figure 2 The 48 V high speed platform motor and inverter system is used for P1, P2.5, P3 and P4 applications from 17 to 25 kW

As an example for a typical evolution of a new technology to a set of scalable and modular building blocks for serial applications, the 48 V high speed platform had to go through three main development phases.

During an advanced engineering project in 2016, a P4 e-axle design demonstrator was built up using a high speed e-motor with a rotational speed of 50,000 rpm. The power density was twice as high as comparable motors on the market with typical speeds of approx. 18,000 rpm. The system has been tested successfully on system test benches showing an overall efficiency of up to 89 % (power electronics, motor and transmission including differential).

To enable an efficient scaling to customer requirements, Magna had to build up detailed simulation methods for performance-, efficiency-, durability-, NVH-, thermal- and EMC- optimization. All these methods have been fine-tuned and calibrated with test bench measurement results. The methods have also been enhanced during the last years of platform and serial development including influences of production methods and production tolerances having an impact on critical product attributes.

After the successful first innovation phase, the 48V platform development started in 2017. Based on the market requirements of different applications and the results of the innovation phase, it turned out that a concept with 25kW peak power and a rotational speed of 35.000 rpm was the best approach to achieve an overall optimum regarding flexibility, performance, efficiency and product costs. Also, this solution readily enables scaled solutions for other market needs, including performance down-scaling and additional package size variants.

During the platform development phase, a huge number of prototypes have been built up and tested based on multiple customer requirements. Serial production methods have been applied to get predictable results for a serial development. Finally, several demo-vehicles have been built up to test the functionality of the new systems at the vehicle level.

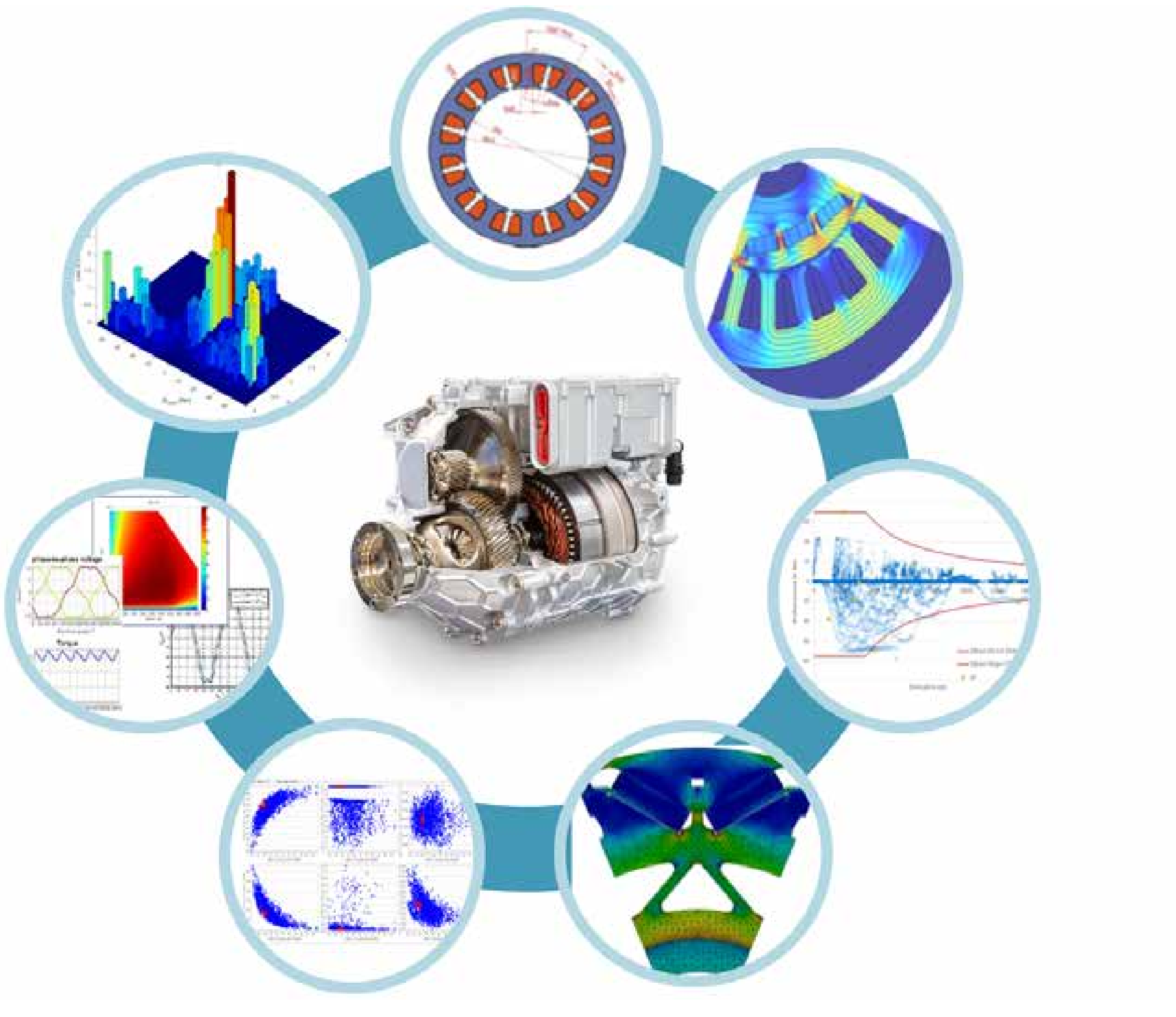


Figure 3 Simulation models and automated optimization using artificial intelligence are key for applying building blocks to new applications within short development cycles

Dr. Ing. Thomas Hackl, Director Engineering Building Blocks Electrification, Magna Powertrain

A main focus during this phase was the calibration of the simulation methods to test results including serial production process influences and serial production tolerances. The target was to get to a basis of methods and building blocks to respond to customer requirements very quickly with a very high accuracy of attribute prediction.

In 2019, the 48V high speed platform was released for serial development, enabling Magna to provide modular and scalable solutions from 17 to 25kW and a speed range of 20.000 rpm to 35.000 rpm.

Interview

"Exploring the Limits of Technology"

The new 8DCL900 is more than just a highlight in supercar transmission development. As our interview with Dr Jörg Gindele shows, taking technology to the limits can benefit large-scale production too.

Dr Jörg Gindele, Senior Director Engineering, Magna Transmission Systems

Mr Gindele, the new 8DCL900 Performance Dual Clutch Transmission you and Ferrari co-presented at CTI Berlin has a proven predecessor: the 7DCL750. Why the new development?

Performance cars have extreme torque and performance requirements. These have increased significantly in the past ten years, one reason being hybridisation. For example, the Ferrari SF 90 Stradale has an e-motor between the engine and transmission that enables overall peak torque ratings of up to 1100 Nm. We also wanted to significantly improve shift times – and direct hydraulic control has clear advantages there. On top of more performance, we also wanted even more internal efficiency. The additional eighth gear improves overall efficiency too. And finally, we wanted to get the car's centre of gravity even lower. So to achieve a lower installation position, we moved the whole hydraulic system up within the transmission.

A transmission like this is also a reference product. What insights can you transfer to series production?

That's an important point. We often ask ourselves what we can adopt from racing or high-performance applications that let you explore the limits, and demand that you do. For instance, we developed a new transmission casing with a honeycomb structure that's lighter, and improves casting quality even more. We're now adopting the new method in all series-production applications. Other examples include high-end triple carbon synchronizers, plus new materials and tooth geometries. Asymmetrical toothing is important because you can put more torque on the traction flank than on the thrust flank. We're transferring that to series production too.

You mentioned hybridisation in sports cars. How does that differ from large-series production?

Performance hybrids and consumption-oriented hybrids use fundamentally different approaches. Reducing fuel consumption is an issue in sports cars too. But in a large-scale production vehicle you might replace the 6-cylinder ICE with a smaller 4-cylinder, then add an e-motor so you still have the same overall system performance. Whereas in the Performance sector I'd probably use one or more e-motors to add power to my 8-cylinder engine. The focus is on high performance and agility, not maximum range. And for weight reasons, you'd use a battery that might not have the highest capacity, but provides power quickly through its high power density.

How is growing electrification in large-series applications changing the role of transmissions in general – not just in sports cars?

In the last ten to fifteen years, transmissions have played an increasingly important role. More and more, they're becoming central torque coordinators in the powertrain. When you have multiple drive sources on board, the transmission is where they converge. Hybrid managers are often located near the transmission – or the functions are combined in the TCU. Actually, the engine now plays a smaller role; the TCU will usually handle its torque.

Looking further ahead, what are the prospects for dedicated transmission concepts, or DHTs?

Our assumption is that DHTs will replace 'normal' transmissions in many areas. One reason is that we're taking mechanical complexity out of the system and replacing it with electrical functions. That includes reducing the number of gears, because the e-motor compensates for the reduced spread and you can use it for driveaway etcetera. So e-motors are becoming an integral, core component of drive systems. At some point they'll probably also become the differentiating factor for performance. On the other hand, ICE spread range will become smaller. In the next generation, we'll basically build the mechanics around the electric motor. That will also enable us to produce drives like that for an acceptable price. As I see it, DHTs are the future. And for once, the rollout will start in compact cars. Cost pressures are particularly high in that sector, and you need to achieve consumption savings at an acceptable cost.

Computing power and software development have made tremendous progress. How does that improve the way transmissions work?

With the 8DCL900, advances in computing power definitely enabled new technologies and improved performance. DCT controllers contain huge amounts of logic. They can calculate gear selection behaviour or predict driver behaviour, and there are even models for calculating oil deterioration and fatigue strength during operation. By speeding up cycle times and calculating individual tasks more quickly, we boosted performance considerably. For instance, processes like pulsation during clutch actuation can occur at high frequencies. With faster computing, clutches can operate in a better creep zone, for example. That really improves driver comfort – and you can transfer advances like that straight into series production. We've just developed a function that actively addresses the clutch hydraulics to imprint a reverse-phase signal. That improves comfort – and it's pure software. Another topic is new functions that 'think' for the driver. For example, GPS-controlled shifting strategies that shift down ahead of bends are now coming on line.

How does all this change the job profiles for tomorrow's transmission developers?

Developers already need to have an understanding of mechatronic systems. Obviously we'll still need the traditional skills for configuring transmissions in terms of strength, gearing, production technology etcetera. But in future we'll be dealing with software development, control and electronics – and electric motors. So developers need to know how electric motors work, how they differ and what performance characteristics they have. Even in the past you had to know how an ICE worked too, but there were still clutches in between. Now e-machines are becoming an integral part of the transmission. For example, we're now talking about bearing wear caused by current ripples. An e-motor in the transmission can cause pulsations that impact on mechanical components and can cause damage. That in itself shows you the enormous impact e-motors have on transmission systems. And tomorrow's developers will need to know how to deal with that. ●

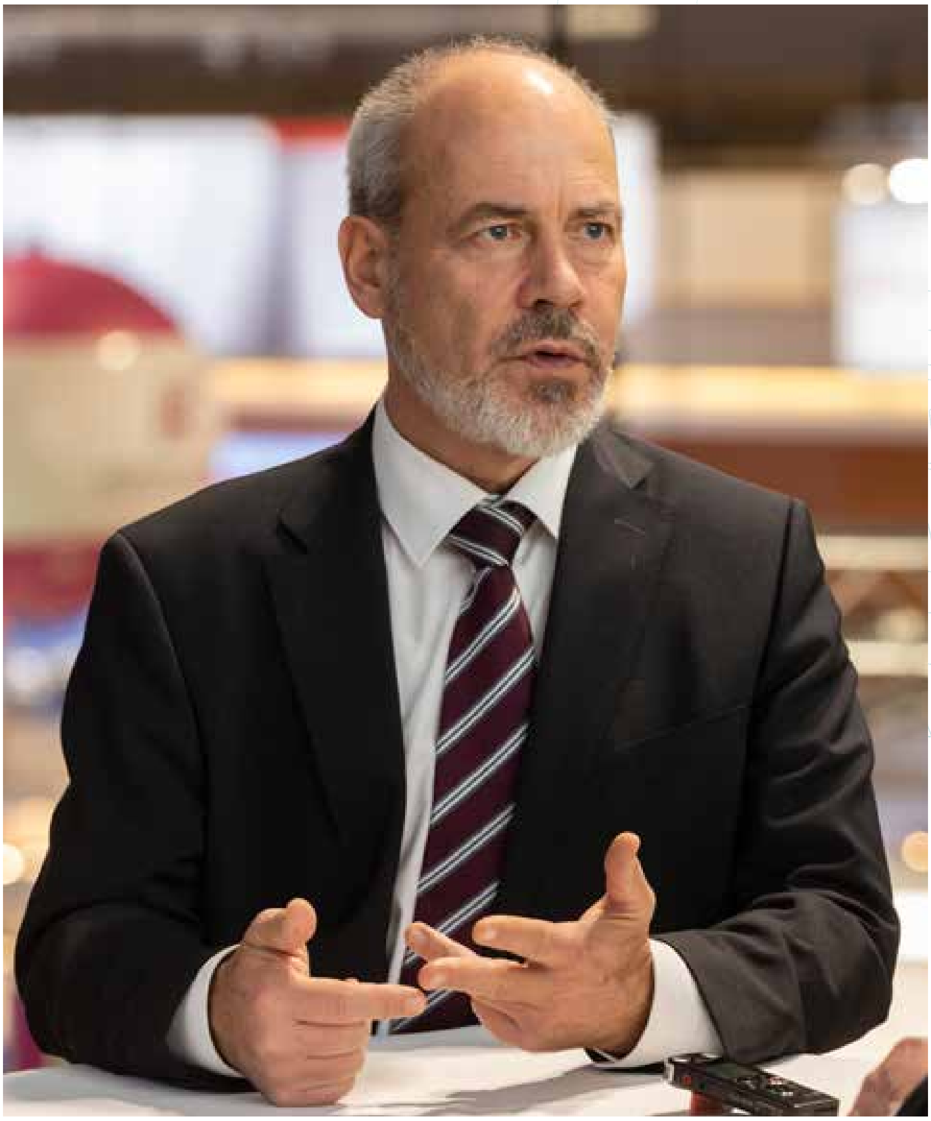
Interview: Gernot Goppelt

> E-motors are likely to become the differentiating factor for performance
>
> Dr Jörg Gindele,
> Magna Transmission Systems

Interview

"From a consumer viewpoint, hybrid drives reduce complexity."

Everyone agrees that most of tomorrow's drives will be electrified. But what will become of combustion engines? Are hybrid drives just a transition technology – and when do all- electric vehicles make sense? An interview with Professor Christian Beidl from Technical University Darmstadt, Germany.



Professor Beidl, diesel engines are in disrepute. What chances do they still have?

Diesel engines are certainly not the right choice in the small car segment, where the benefits no longer offset the outlay. But for larger vehicles and longer distances, I don't know anyone who is not happy with the utility diesels offer. They will probably remain successful in these fields. But driving bans, and the poor image diesels have, affect many ordinary people directly. The public will certainly take some convincing that emissions are not a problem for modern diesels. I am seeing some initial success on that front.

RDE has further increased the pressure on polluting emissions. What do you expect from Euro 7?

Besides reducing some emission limits, it will probably include more evaluations of specific driving events. Cold starts are an obvious example; at present, they play a secondary role because the driving cycle involves a long trip. Additional exhaust gas components could be N_2O and NH_3. In general, RDE will attempt to record as much as possible. One question will be how to detect some components at all when particle sizes are less than 23 nanometers in some cases. From a technology viewpoint, RDE alone has already led to dramatically tighter legislation effectively. But from a political viewpoint, the programme is more or less to keep reducing limit values.

How will combustion engines fare as electrification progresses?

One thing the public completely overlooks, particularly in Germany, is the ongoing wealth of interesting approaches in research and development. Sadly, many of these take place abroad, which is something that should concern us. Take Japan, for instance, or China, as the Geely lecture at CTI SYMPOSIUM Berlin demonstrated. With hybridisation, of course, you no longer need auxiliary units like belt drives. But when it comes to engines there's no reason to take out proven technologies that improve efficiency, such as turbocharging, variable valve control, VTG, Miller etcetera. Then there is the potential of new technologies like Artificial Intelligence or additive manufacturing, and all that in connection with carbon-neutral fuels. Not using research on ICEs would mean squandering a big lead in innovation.

In terms of CO_2, hybrid drives are considered to be essential. Some people say they can also help reduce raw pollutant emissions, via phlegmatization. To what extent is that a reality today?

Hybridisation is certainly extremely helpful in eliminating specific events that lead to emissions issues – not just raw emissions, but exhaust treatment too. While conventional operation will not necessarily benefit, you can address topics like cold starts or exhaust system temperature in a different way by reducing gradients that are difficult to master. The bottom line is that overall emissions control becomes better, more stable and more robust. Series applications are doing this already. But you never hear much about it because naturally, that's not something you can use in advertising.

Developers are increasingly working on multimode hybrids. Might that result in ICEs being simplified after all, and operating with a narrower fuel consumption map?

The multimode trend has to do with the fact that there are lots of smart ideas for new, simplified transmission architectures. Naturally, the possibility of partly serial operation offers a new level of freedom. You can use that in some situations, for instance for thermal management or charging the battery. The option of decoupled operation makes multimode transmissions very attractive. That said, a greatly simplified single-point motor makes no sense in real-life driving because you would lose so much efficiency. Apart from that, we are talking about engine technologies you can make very affordable due to economies of scale.

What do you think of purely serial operation? Some people say if you optimise an ICE accordingly, this can compensate for efficiency losses in the conversion chain.

With serial operation, you have to look at the system in a different way. The e-machine and ICE both need to be bigger because unlike in parallel operation, there is no torque addition. For a compact "People's Hybrid" I would envisage smaller motors that can be mass-produced. That gives me high system performance with moderately dimensioned individual components. This is a systemic advantage of parallel architectures – and depending on their configuration, of multimode architectures too. As for the overall system's efficiency chain, I am not aware of a single purely serial concept that yields efficiency benefits in practical operation.

How do you rate the respective benefits of using one or two e-machines in a DHT?

Using two e-machines has functional benefits. Providing it's done well, I would expect the costs to be broadly similar. There are two reasons: firstly, I can use smaller e-machines to achieve a specific system performance; secondly, I can take costs out of the system – for example by omitting mechanical synchronization. However, to leverage the full potential of the overall system, this calls for a consistent approach.

What will become of multispeed transmissions, as we know them today?

That depends where you are coming from. If you set up the drivetrain using existing components and powerful ICEs, a multispeed transmission will still be helpful. But if you design from scratch specifically for hybrid applications, somewhere around four gears is probably the figure you'll arrive at. That is assuming you leave out the starting clutch and start electrically. Then I can configure the whole system to cover a wide range of speeds sensibly in parallel operation too. We are going to need consistent concepts of this kind. They may not all prevail, but intelligent functional integration is definitely the key.

Plug-in hybrid drives add some complexity – but would you agree they offer highest flexibilty in terms of energy use?

One of my core beliefs is that energy systems, meaning how energy gets into the vehicle, will decide what powers us tomorrow – not drive technology. However, there is another aspect too. Initially, hybrid drives are obviously more complex than pure electric drives. But in return they give drivers more flexibility and are less complex to use in daily operation. When people are in a hurry they want their cars to just work, right there and then. So in that sense, plug-in hybrids are not complex from a consumer viewpoint. Besides, we should also remember that if there is one thing established automotive manufacturing countries do well – it is mastering complexity. Ultimately, the extra complexity is balanced out by less complexity in daily use. That is why I advocate hybrid drives.

How do you get people to actually use the charging lead they carry in their plug-in hybrid´s trunk?

Price is always the first driver, for example fuel prices. Without a price tag, all you have is environmental awareness. And when it's raining hard and you want to stay comfortable, that awareness may not always be so strong. But over time I think users will get more used to it. Part of the problem, of course, is that in many cases the requisite charging infrastructure simply is not there. Technical solutions are also conceivable – for example, targeted incentives to reward electric driving in cities. One thing I find alarming is when people decide plug-in hybrids are a bad concept per se just because some users are to convenient to charge.

Let's talk about battery electric vehicles: might the enthusiasm for BEVs wane because of practical downsides?

Nobody would deny that BEVs are great to drive. Everyone I know praises the torque and the pleasant driving experience at low speeds. Conversely, a lack of comfort in conventional drives – for instance traction gaps in automatic transmissions – is simply no longer acceptable because it no longer stands comparison with electric drives. But the real challenges lie elsewhere. BEVs are still not mainstream, yet already we are seeing hotspots in some regions where you cannot find a free charging station. I also have my doubts about how representative the experiences of small driver groups we see analysed and published actually are. What it comes down to is, at what market share for BEV does the entire system logjam? In all likelihood, that percentage is not very high. The BEV tech path is very important, and can contribute to protecting the climate in the long term. At the end of the day, this technology too will have to prove its merit in daily life.

> Not using research on ICEs would mean squandering a big lead innovation.

Prof. Christian Beidl,
Technical University Darmstadt, Germany

I sometimes wonder if electric cars really do always meet users' needs ...

We really are in a curious situation now. In terms of usage and energy, the technologies that are currently available and marketable are often inappropriate. We have big, heavy vehicles being electrified even though it makes little sense. We talk about urban traffic and BEVs in city centres, yet BEVs take up just as much space, and compete with public transport. We talk about electrified trucks, yet lugging five tonnes of battery around with you simply does not add up. One category that does work is electric cars for owners in affluent commuter belts around cities. Incidentally, I think the Volkswagen approach of offering users a choice of battery size is very wise. For many customers, a low range is all they need. At the end of the day, it is important that drive concept characteristics match user requirements. That is often not the case today, which causes a great deal of uncertainty. On the other hand, deploying the specific benefits of different drive systems in an optimal way offers great potential. Dealing with growing diversification in ways that make sense ecologically and economically is probably a central challenge in the transformation that is currently taking place. ●

Interview: Gernot Goppelt

Highly accurate inductive rotor position sensors for various electrified powertrain topologies

Sven Hoenecke, HELLA, Vice President Program Management Components NSA

Dr. Fabian Utermöhlen, HELLA, Head of Hardware and System Engineering Position Sensors

Dr. Harry Weber, HELLA, Hardware Engineer, Hardware and System Engineering Position Sensors

As the automotive industry continues to drive for electrification, so does the demand for state-of-art technology and electronics. We must continue to push the limit and enhance the overall driving experience, while being building robust, smaller, and lighter components. With technology changing at an ever-increasing pace, it is the role of the suppliers to not only provide the solutions of today but also the solutions that will drive tomorrow.

For more than a century, HELLA has been a leading automotive supplier, specializing in innovative lighting systems and vehicle electronics. As a global market-listed, family-owned company, with over 125 location in some 35 countries, we are more than a supplier, but a true partner to our customers. Our commitment to development and innovation allows us to be at the forefront of innovation. As the global market leader with more than one billion inductive sensors manufactured, HELLA continues to bring a new solution for e-mobility.

Independent from the topology of the electrified powertrain, the rotor position has to be measured for a precise and efficient control of the machine torque and the required motor phase currents. HELLA has developed a state-of-art position sensor solution that addresses the main challenges of e-mobility, with the HELLA motor position sensor (MPS). The MPS features highly accurate angular position measurements at power on as well as at a very high rotational speed. Due to the proven CIPOS® technology, the HELLA MPS is immune against electromagnetic fields and therefore the smart and efficient alternative to currently used resolvers or magnetic based rotor position sensors.

Functional principle of MPS

In Fig. 1 the functional principle of the CIPOS® technology is presented, which is used for the MPS. The sensor consists of a stator on which the transmitter and receiving coils are realized. In addition, the electronics are mounted on the PCB. In a certain distance to the PCB a rotor is applied, whose position is detected by the stator based on inductivity.

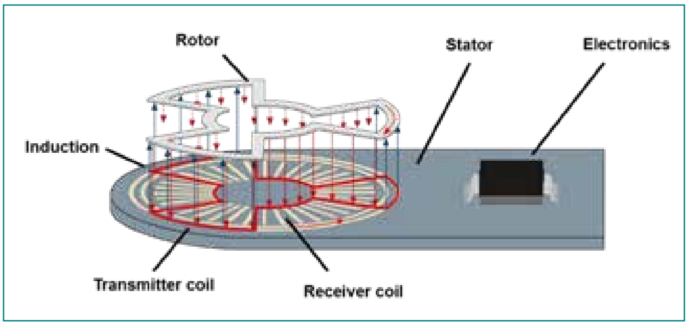


Figure 1 CIPOS® functional principle used for the MPS.

In Fig. 2 the electric model of the MPS is shown. The sensor is essentially designed by three basic parts. The capacitors C_1, C_2 and inductor L_1, which is realized on a PCB, are part of an LC-oscillator with an excitation frequency between 3 MHz to 4 MHz. Due to the time varying excitation of L_1, induction occurs. The generated fields can be considered as quasi-static fields since the frequency is low enough so that no waves occur.

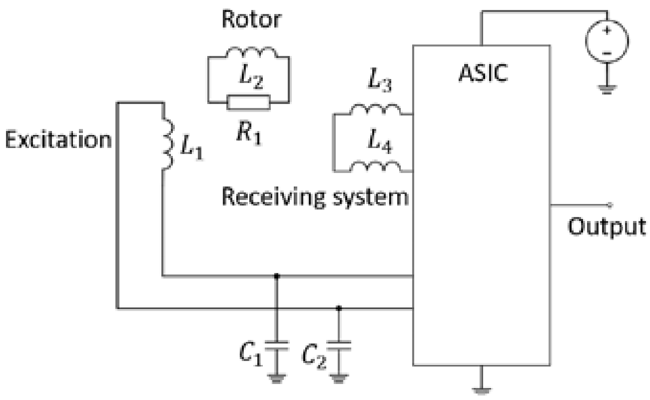


Figure 2 Electrical model of the MPS based on the CIPOS® principle

The second part is a rotor which is modelled as a shorted inductor L_2 with the resistor R_1. The induced voltage or the current in the rotor by the excitation can be calculated with the help of the mutual inductance L_{12} between L_1 and L_2. The resistor R_1 depends on the applied material, the frequency, due to the diffusion process, as well as on the cross section. The mutual inductance L_{12} changes with the relative position between L_1 and L_2. Additionally, the diffusion process has an impact on L_{12}. Since L_1 is symmetrically, a rotation of the rotor does not change L_{12}.

The receiving system is the third part formed by the inductors L_3 and L_4, which are coupled to L_1 and L_2. The coupling is described by the mutual inductance L_{13}, L_{14}, L_{23} and L_{24}. Further, a coupling between the receiving coils occurs which is described by the mutual inductance L_{34}. In contrast to L_{12}, the mutual inductances L_{23} and L_{24} changes by rotation of the rotor due to the special design of the receiving coils. Since the induced voltage in the receiving coils depends significantly on L_{23} and L_{24} and thus on the position of the rotor, the rotation angle or the position of the rotor can be determined. In dependency of the design of the coils, a robust behavior can be realized which is not sensitive to mechanical tolerances of the rotor for example.

Additionally, the coil design allows to obtain immunity against magnetic distortions, which enables an application in challenging environments. For this purpose, a simulation procedure is applied in order to achieve desired performance by an optimized design. The induced voltages in the receiving system are further processed in the ASIC. After the signal processing, the angle signal is provided at the output, whereby a digital as PSI5, SENT, etc. or analog (sine/cosine) interface can be used.

Structure and integration possibilities

An important benefit of the MPS in contrast to state-of-the-art solutions like resolver, is the variable integration possibility. The MPS provides a larger variety of integration, whereas a resolver can only be implemented around the motor shaft. In Fig. 3 the different possibilities of the integration are illustrated. Besides the through hole mounting, the MPS can be implemented on shaft and end of shaft. This variability provides more flexibility in the design of an electrical motor for example yielding a reduced size.

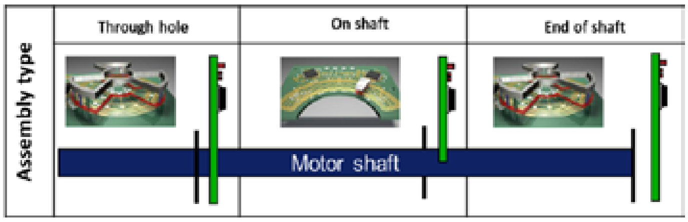


Figure 3 Different integration possibilities of CIPOS® based position sensors

Comparison to Resolver

In this section, the performance of the MPS in comparison to a resolver is presented and compared. For this purpose, a comparable MPS with similar diameter is used. In Fig. 4 (a) the measured MPS with a sensing structure of 90° and a diameter of 35 mm is shown.

The results are compared with the resolver shown in Fig. 4 (b). The resolver has a similar diameter of about 37 mm and provides also a measuring range of 90°. The MPS provides the angle information in the same fashion as a resolver by an analog output.

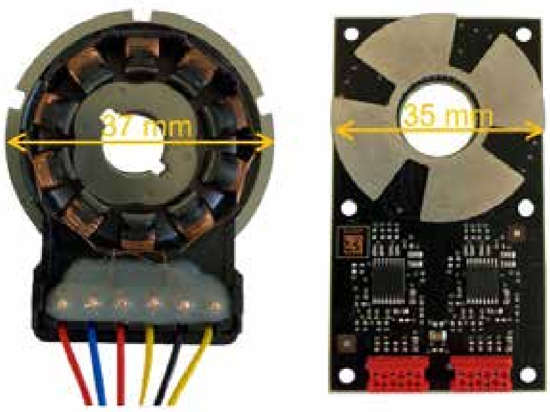


Figure 4 (a; left) Measured MPS with a sensing structure diameter of 35 mm; (b; right) Comparable resolver with a diameter of 37 mm

The raw output signals of the MPS and the resolver are shown in Fig. 5 (a) and (b). As shown, the MPS and the resolver provide the similar analog output signals with a cosine and sine shape.

In order to improve the angle calculation, the amplitude, offset and phase of the signals can be adjusted once and used for further measurements. In order to obtain the necessary information, a DFT algorithm can be applied. For both sensors the same signal processing is applied. The corrected signals are shown in Fig. 6 for the MPS (a) and the resolver (b). As presented, the amplitude is normalized to 1, the offset is compensated, and a small phase shift in comparison to Fig. 5 can be noticed.

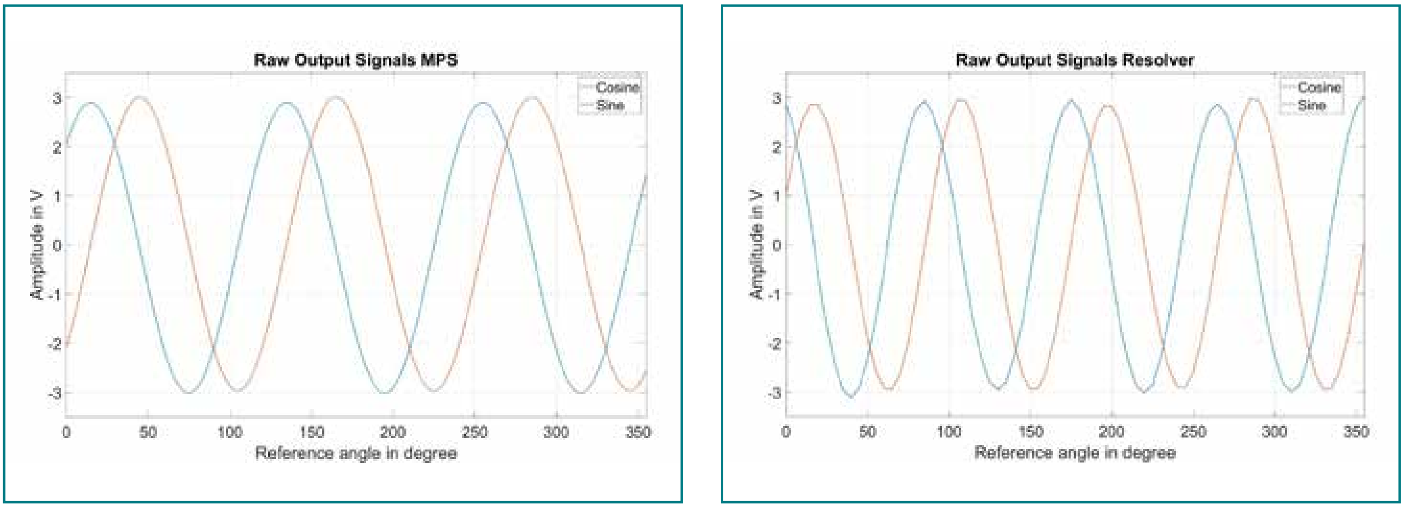


Figure 5 (a; left) Raw output signal of the measured MPS in Fig. 4 (a); (b; right) Raw output signal of the resolver in Fig. 4 (b)

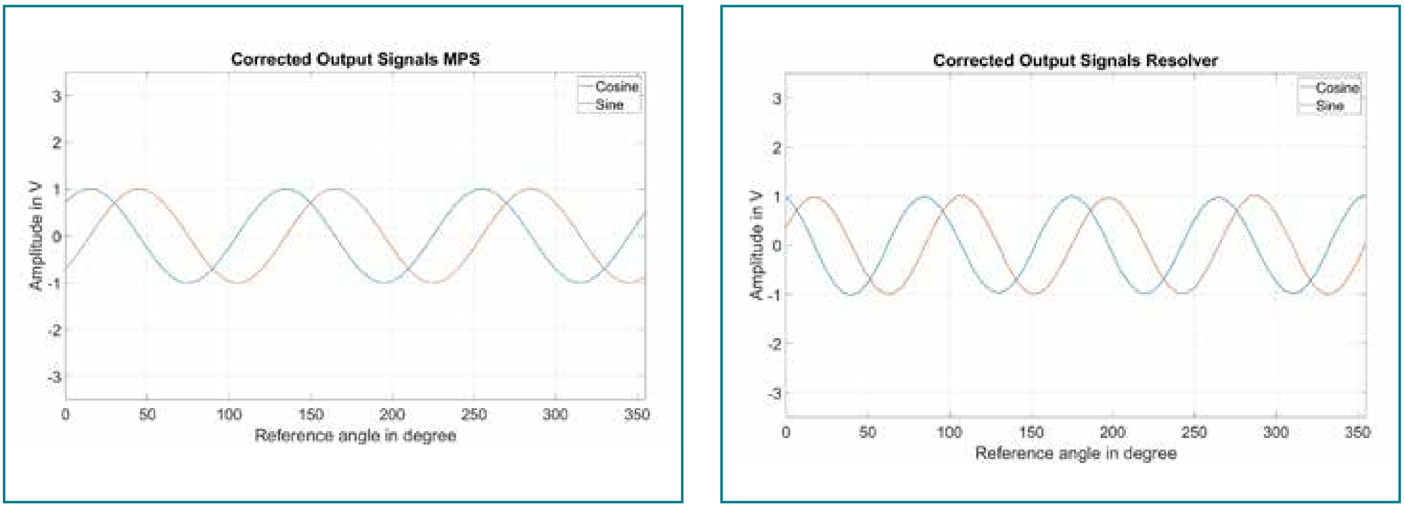


Figure 6 (a; left) Corrected output signals of the MPS; (b; right) corrected output signal of the resolver

With these corrected signals the output angle can be calculated by arctangent. In Fig. 7 the absolute error in °el of the MPS in nominal position is compared to the error of the resolver for different eccentricities (ECC) of the rotor.

As shown, the MPS provides a higher accuracy in nominal position in comparison to the resolver. Further, the error increases in the case of the resolver for a displaced rotor of about 0.25 mm in one direction. In comparison, in Fig. 8 the influence of ECC on the MPS is shown. Only a small variation of the error is noticeable. Providing a much higher accuracy over a large tolerance range.

Putting it into Action

Where existing solutions such as resolvers and magnetic sensors are facing issues to serve the appropriate immunity against electric disturbances to deliver accurate signal in electrified vehicles, HELLA has introduced the MPS. With the well-established CIPOS® technology, the MPS is the smart and efficient alternative. The sensor can be applied in harsh environments with liquids and electromagnetic disturbances without loss in accuracy and reliability, while also providing a very high accuracy, even for a large tolerance range. As the industry drives electrification, HELLA continues to focus on driving the future and providing state-of-art electronic vehicle technologies. ●

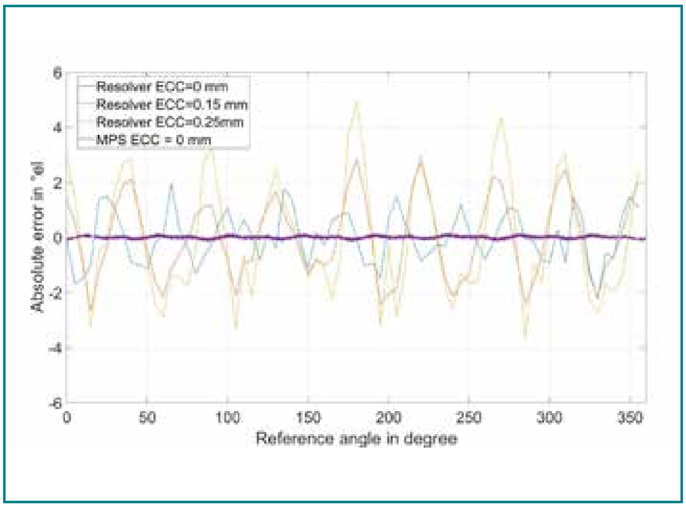


Figure 7 Comparison to the MPS with a Resolver for different eccentricities (ECC) of the rotor

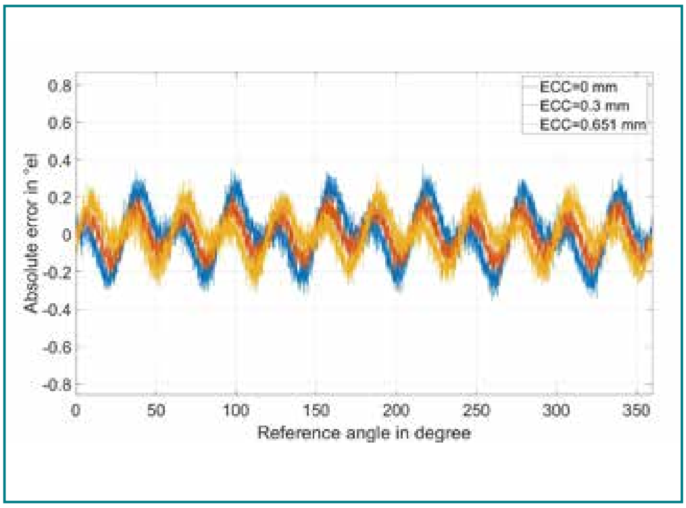
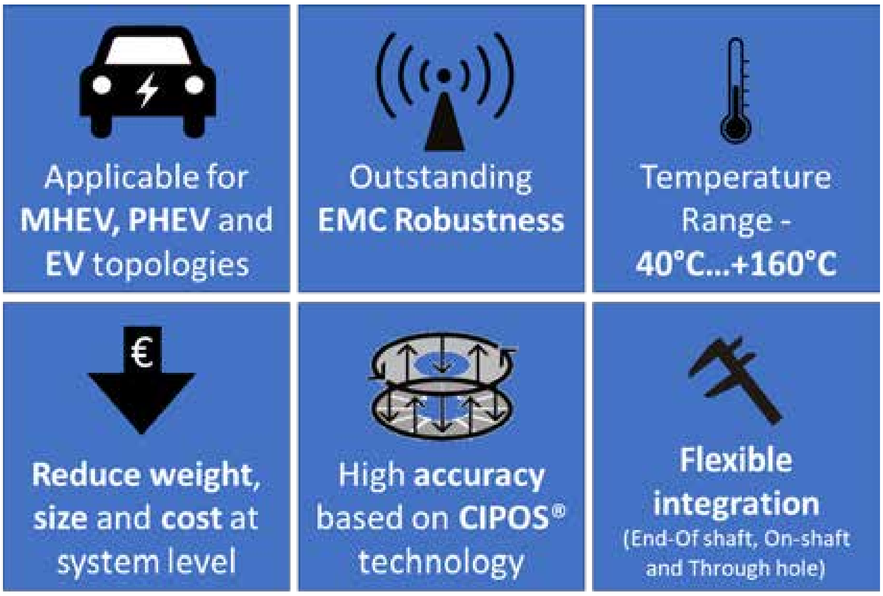


Figure 8 Error for MPS for different eccentricities (ECC) of the rotor



Newly Developed Tandem Ball Bearings for Optimal Axle Efficiency

Improving traditional axle differential efficiency through improved system understanding and bearing optimization

Al Makke, Engineering Group Leader, Schaeffler Group USA Inc.

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1 Introduction

The automotive world is undergoing a significant transition to electrification to reduce emissions and improve fuel economy. Although industry experts have different predictions on how fast the transition will happen, there is consensus that the number of hybrid and electric vehicles will continue to grow. This transition is crucial for many automotive suppliers. With most development efforts focused on electrified powertrains, electric drives, and their components, a slow transition into the electric future would mean a slow return on investment. However, existing products which subsidize the development of new technologies can still be improved with minimum effort; automotive axles are a good example. For Schaeffler, certain bearings are at the forefront of this dynamic. In the early 2000's, Tandem Ball Bearings (TBB) for passenger vehicle axle differentials became the premium solution for pinion shaft support due to their high efficiency. However, their implementation in axles was based on manufacturers' experience with Tapered Roller Bearings (TRB) which prevented TBBs from being used to their full potential. Consequently, TRB suppliers, including Schaeffler, worked on improving TRB efficiency. Eventually, the lower cost TRB became as efficient as the standard TBB in systems designed around TRB limitations. This study shows how TBBs can address these TRB-specific limitations to push axle efficiency to new heights. In addition, these improvements can help improve the efficiency of some traditional products until the electric future fully emerges.

2 Approach

The goal of this TBB friction improvement is to allow axle manufacturers and OEMs to take their system-level efficiency to unprecedented levels. This requires bearing-level and system-level improvements:

Bearing Robustness:

- Improve TBB robustness because "right-sizing" provides friction benefits.

Friction Improvements:

- Bearing-Level: Improve TBB friction by use of Schaeffler's OPTIKIT toolbox in BearinX (CAE).
- System-Level: Reduce oil churning losses by reducing axle oil fill levels, blocking excess oil with new TBB designs, optimizing oil channels in axle housings, or taking advantage of cooler running oil with TBBs (lower viscosity lubricants).

2.1 Improve TBB Robustness – Understanding Sensitivity to Axle Contamination

Aside from quality issues, bearings rarely fail due to incorrect sizing; they typically fail due to misalignment, incorrect preload, excessive contamination in the lubricant, or other unpredicted system interactions. In axle applications, TBBs are sensitive to contaminants which leads to abrasive wear and surface-initiated failures in the raceways. This leads to TBB designs with large safety factors. To fully understand the influence of these particles on bearing performance, two axles with different contamination levels were flushed and the contaminants were tabulated and classified by hardness, size, and count. This provided a sample of common axle contamination levels. An example flush result is shown in Table 1 below.

SEM (Partikel pro 100 ml Öl):													
	DMAX (um)	Total		[5.00 -	[15.00 -	[25.00 -	[50.00 -	[100.00 -	[150.00 -	[200.00 -	[400.00 -	[600.00 -	
	Class	Particles	<<<	15.00)	25.00)	50.00)	100.00)	150.00)	200.00)	400.00)	600.00)	1000.00)	>>>
soft	PTFE	33845	0	27405	4700	1400	335	5	0	0	0	0	0
	Lime	15405	0	14005	1300	100	0	0	0	0	0	0	0
	Solid lubricants	2000	0	1900	100	0	0	0	0	0	0	0	0
	Chlorine (chlorides)	300	0	300	0	0	0	0	0	0	0	0	0
	P/S/Na/Mg/K/Ca	220470	0	207340	10300	2100	655	65	0	10	0	0	0
	Others	9805	0	9200	600	0	5	0	0	0	0	0	0
	Zn/Cr coating	26510	0	22805	3000	600	105	0	0	0	0	0	0
	Zn/Mn phosphate	101075	0	96820	3800	400	55	0	0	0	0	0	0
	Titanium	11910	0	10700	1100	100	10	0	0	0	0	0	0
	Nickel	705	0	500	200	0	5	0	0	0	0	0	0
	Copper	2110	0	2000	100	0	10	0	0	0	0	0	0
	Zinc	2900	0	2600	300	0	0	0	0	0	0	0	0
	Tin	0	0	0	0	0	0	0	0	0	0	0	0
steel	Unalloyed steel	112575	0	102920	7300	1900	425	30	0	0	0	0	0
	Low-alloy steel	36995	0	34805	1600	500	90	0	0	0	0	0	0
	High-alloy steel	40355	0	36705	3000	500	140	10	0	0	0	0	0
	Contaminated steel	152480	0	140030	9400	2200	775	65	10	0	0	0	0
hard mineral	Aluminium/corundu	3930	0	3500	400	0	30	0	0	0	0	0	0
	Si-/SiAl oxide	27465	0	24805	2000	600	60	0	0	0	0	0	0
	Particles of interest	800835	0	738340	49200	10400	2700	175	10	10	0	0	0

Table 1 Example of particle count of an axle with elevated contamination levels

Various recipes were created and classified per ISO 4406, and a Taguchi L12 DOE was conducted with these recipes. The results are shown in figure 1 below.

Results show that there is no correlation between the ISO contamination classes and the B10 life of the bearings. The highest and lowest B10 bearing life results ran in ISO Class -/19/16 which renders this classification insufficient for bearing life calculations; the hardness of the contaminants is not considered in this standard. This data enables the development of a new statistical model that predicts TBB life in any application based on the contamination mixture. With a more accurate life prediction, the bearings can be right-sized for the application without unnecessarily high safety factors. This is the first step towards friction reduction.

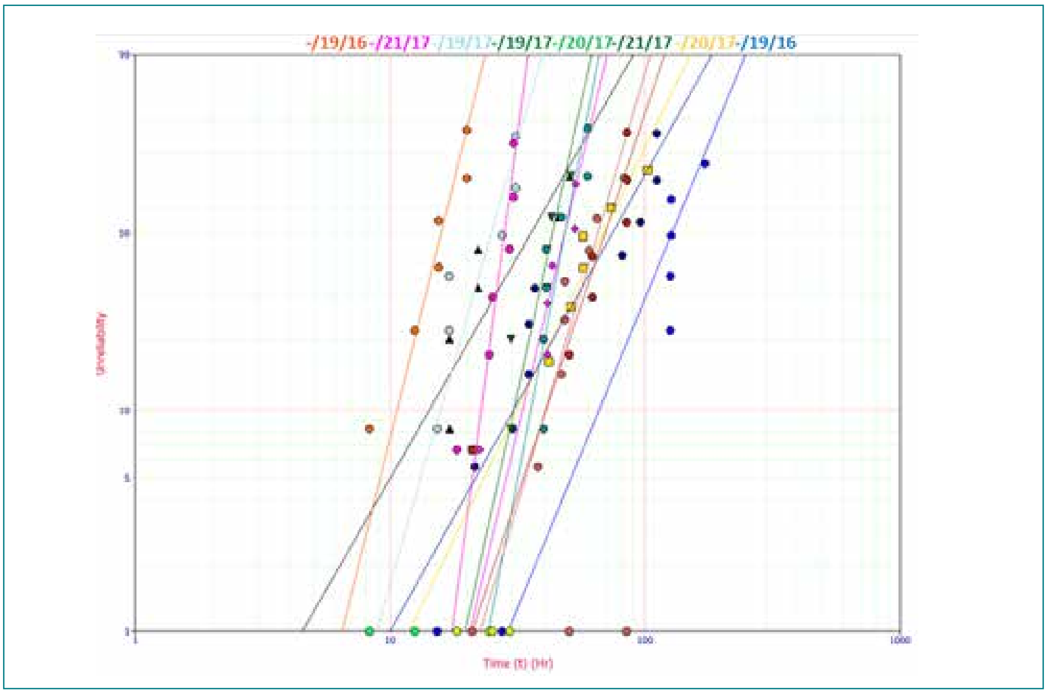


Figure 1 Weibull slopes of each of the Taguchi L12 experiments with different contamination mixtures

2.2 Friction Aspects of Tandem Ball Bearings

There are three elements of tandem ball bearing friction:

- Rolling/sliding friction at the raceway/ball contact – represented by red segments in figure 2.
- Friction at the ball-cage interface – though represented by the blue segments in figure 2, it is out of scope of this research.
- Oil churning losses which is lubricant resistance caused by excessive lubrication at higher bearing speeds – represented by the green arrows in figure 2.

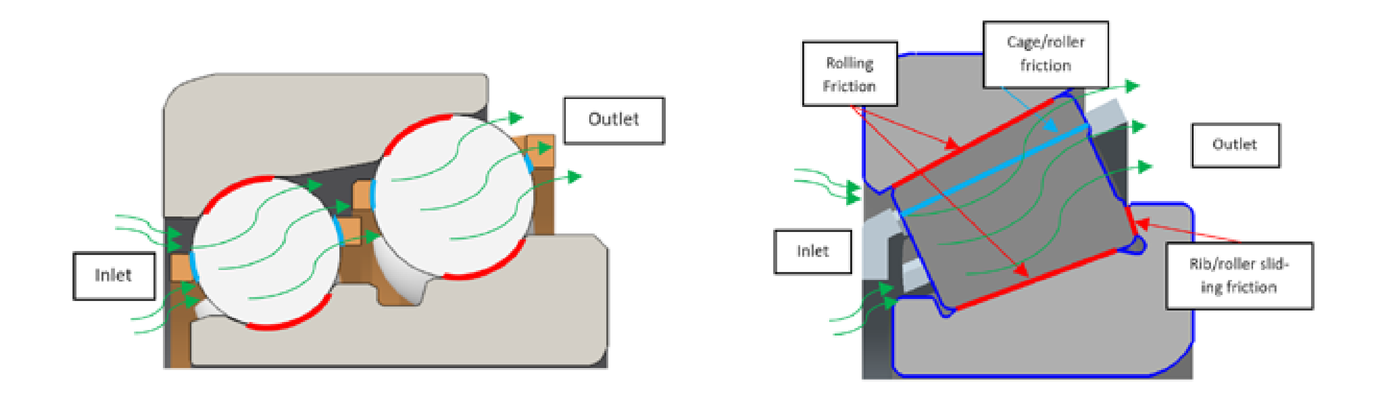


Figure 2 TBB friction elements (Left) vs. TRB friction elements (Right)

2.2.1 Bearing-Level Friction Reduction

There are various design features that influence TBB friction. Depending on the application loads, the hypoid gearset configuration and bearing positioning, TBB efficiency can be optimized accordingly. Traditionally, this optimization process is done manually by application and development engineers to achieve optimum bearing performance targets. The engineer must define the boundary conditions for the application which includes application configuration, customer target reliability, bearing design guidelines (contact angles, number of balls, pitch diameters, etc. ...), and target efficiency given by the customer. However, improvements in Schaeffler's CAE capabilities automate this process allowing for many more accurate design optimization loops in a much shorter period. Schaeffler's optimization toolbox, OPTIKIT, is integrated in the bearing calculations software BearinX. Similar to the development of Ultra Low Friction (ULF) TRBs that Schaeffler had published in the 2018 Schaeffler Symposium, TBB efficiency can also be improved.

As a result, prototypes that were optimized with OPTIKIT were tested and showed ~22 % efficiency improvement compared to existing TBB designs as shown in figure 3. The tested load cases were based on the NEDC efficiency cycle.

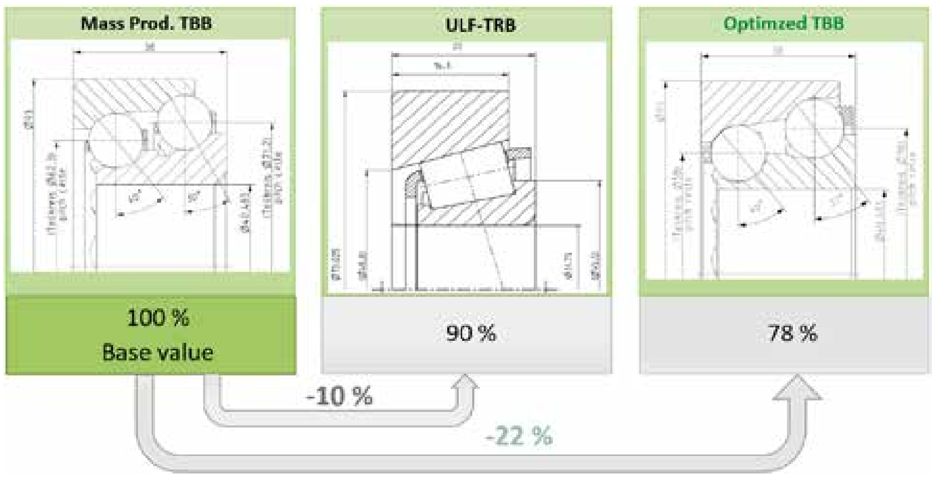


Figure 3 A comparison between standard TBB, ULF-TRB, and newly developed TBB

2.2.2 Friction Improvements – System Level – Oil churning losses

Churning/splashing losses in bearings are caused by excessive lubricant through the bearing at high speeds. In many rear axle applications, the ring gear flings the lubricant from the axle sump through an oil channel in the axle housing between the two pinion bearings (Figure 4). As mentioned in the introduction section, most axle manufacturers specify their oil fill levels to prevent seizure of TRBs in adverse conditions like high torque, cold start, or driving on a grade where the tail bearing is at risk of oil starvation. For example, some OEM's use an angular contact ball bearing or a TBB in the tail position to avoid this TRB limitation. In most cases, these TRB-based practices are unnecessarily carried over to axles with TBBs which negatively impacts overall axle efficiency. TBBs require less oil for lubrication compared to TRBs due to the rolling point contact and the absence of the sliding rib contact (Figure 2). This provides the opportunity for an axle manufacturer or OEM to reduce oil fill levels to minimize overall churning losses (including gear churning losses!). This can be achieved by reducing the sump fill levels, optimizing oil channels in the axle housing, or a combination of the two.

According to the Schaeffler Technical Publication "Lubrication of Rolling Bearings", the minimum oil fill level for bearings should supply the centerline of the lowest rolling element. Also, for TRBs, the sliding contact between the roller end-face and the inner ring large rib, additional oil supply is required to avoid overheating and seizure. Therefore, a spin loss test was conducted with two different oil fill levels, and two oil restriction configurations at the bearing inlet (no restriction, and oil restricting shims). Figure 4 shows two oil fill levels. The first one, represented by the red region, is the axle fill recommendation by the OEM for this specific axle per the Owner's Manual. The second one, represented by the green region, is the minimum oil fill level for TBBs per Schaeffler's "Lubrication of Rolling Bearings".

The test conditions are summarized below:

- Pinion speed/Preload: 1000 RPM, 2000 RPM, and 3000 RPM @ 2800 N of preload (to focus on churning losses).
- Only pinion torque is measured. Pinion gear and ring gear are decoupled, and the ring gear is driven separately at a speed that is derived from the gear ratio of this specific axle to maintain the oil flow characteristics in the axle.
- Two main axle fill levels: Per customer owner's manual (1500 mL – red fill), and minimum oil fill level required for ball bearing lubrication (500 mL – green fill).
- Oil type: 80 W-90.

The results are summarized in the graph below, and a benefit of ~25 – 30 % can be realized at pinion speeds that are associated with vehicle highway speeds.

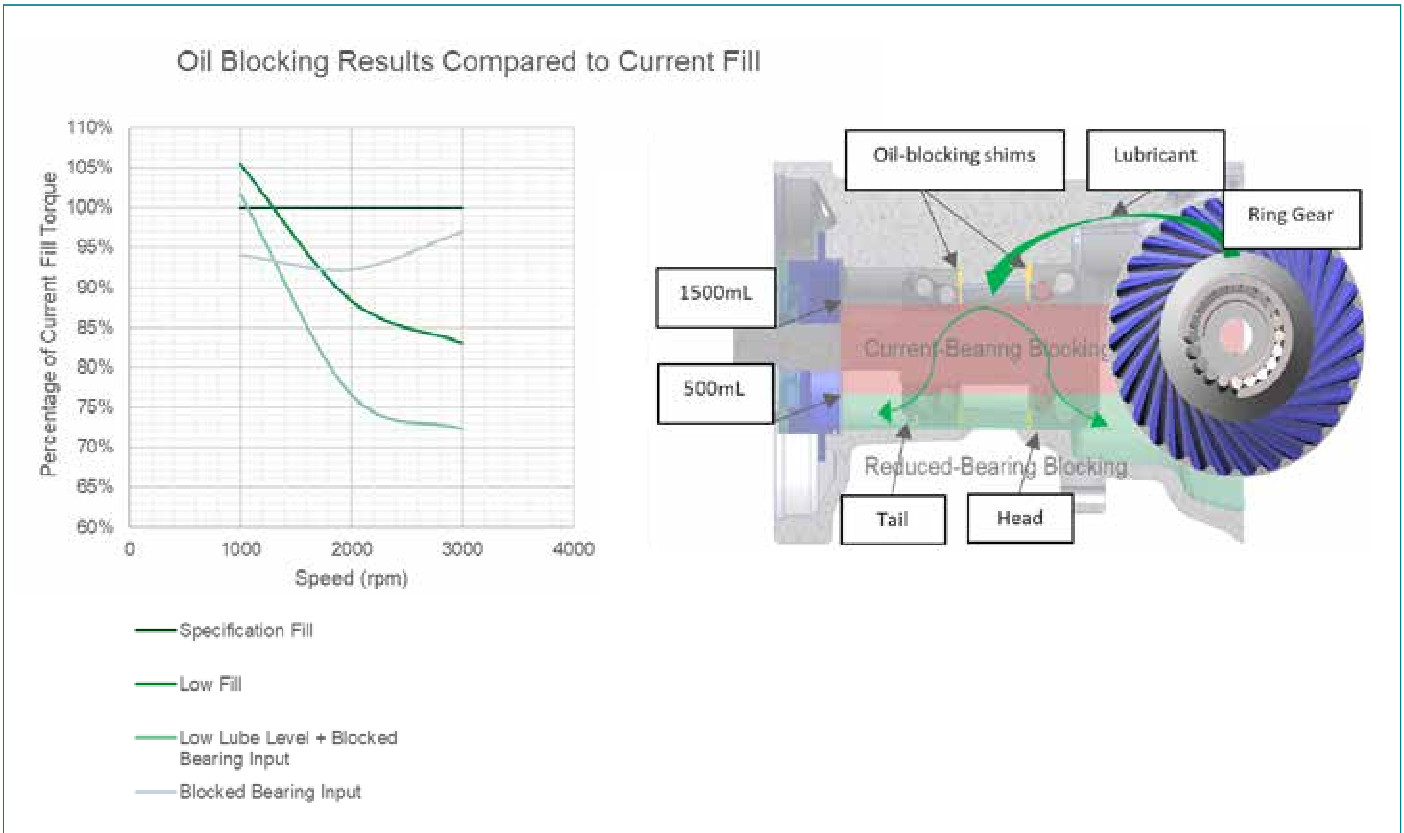


Figure 4 A schematic of the 4 tested configurations with the corresponding test results

TBBs eliminate the barriers put forth by TRB oil fill requirements and provide the opportunity for system level efficiency improvements. Reduced oil fill levels minimize churning losses by the bearings and the gearset as well. These cascaded benefits are largely ignored by many OEMs. Alternatively, TBB cage designs can be adjusted to restrict excessive oil churning losses at high speeds if reducing oil fill levels in the axle is not possible. However, cage-only design improvement is not the most favorable option for optimal efficiency.

3 Conclusion

Improving the efficiency of traditional axles is possible with Tandem Ball Bearings and requires bearing and system-level improvements. Bearing-level improvements include "right-sizing" and internal bearing geometry optimizations. Right-sizing is achieved by better understanding current axle contamination levels and, therefore, safety factors and then reducing them within acceptable margins. Optimizations using Schaeffler's CAE Tool "OPTIKIT" allow for fine-tuning Tandem Ball Bearing designs for axle applications which leads to additional efficiency benefits. Tandem Ball Bearings (TBBs) also offer system-level improvements by requiring less oil for lubrication than Tapered Roller Bearings. Lower oil fill levels in axles, lower viscosity lubricants, optimized oil channels, and new bearing cage designs are examples of how this system-level benefit can be realized.

Combining the efficiency benefits of reducing churning losses, right-sizing, and automated optimization using OPTIKIT, the newly developed TBBs can reduce pinion friction losses by ~25 % compared to the standard TBB and Schaeffler's Ultra-Low Friction TRBs. This is evaluated using the NEDC and WLTP efficiency cycles. Additionally, there are system-level benefits that axle manufacturers and OEM's can take advantage of (reduced churning losses of the gearset) that are not quantified in this study. Therefore, TBBs remain the best possible solution for efficiency for primary drive axles (RWD) disconnecting secondary axles where the pinion shaft continues to rotate even when disconnected.

Advanced e-Fluids for mobility on land, sea and in space

The world of transport is going electric and e-fluids have a vital role to play. EVs play a key part in the mobility revolution and the pathway to decarbonizing transport. Castrol's e-Fluid expertise extends across land, sea and even space.

In space, Castrol greases to help keep its $820 million NASA InSight Mars Lander working in the unforgiving conditions on the Red Planet.

At sea, Castrol e-Fluids support equipment used in the transfer of power from an engine or electric motor to a propeller or thruster.

On land, Castrol has developed a range of e-fluids to meet the needs of vehicle manufacturers. From transmission fluids, which are inside many EVs already on the road, to greases and coolants, these fluids enable electric vehicles to run smoothly, efficiently and stay cool.

Developments include Castrol's lowest viscosity e-transmission oil, designed for efficiency, durability and reliability.

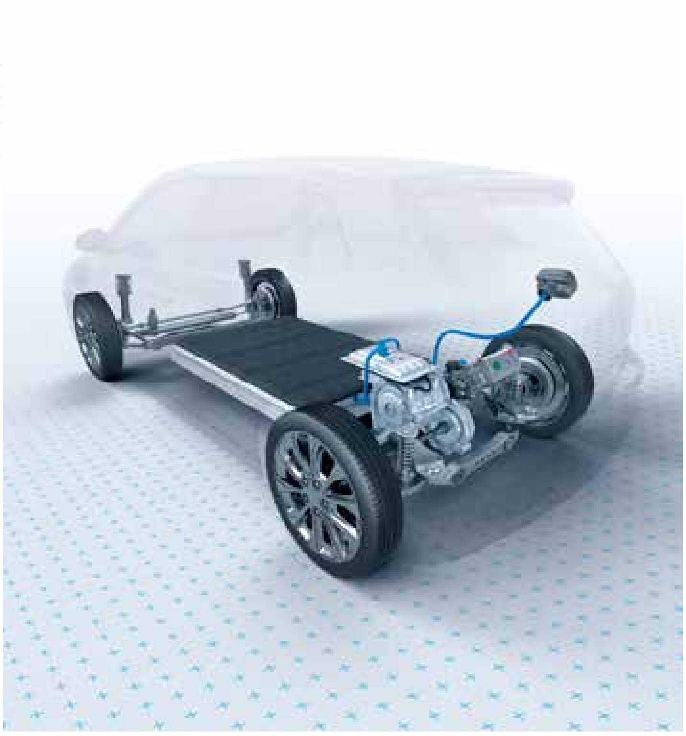
Castrol is partnering with major manufacturers to ensure its lubricants deliver what drivers want: to go further on a single charge, enable longer life of transmission and component parts, and ensure long-lasting battery health.

As EVs continue to evolve, Castrol's best brains are not only defining the fluids, but the way the fluids are defined: pioneering unique testing and monitoring methods, driving efficiency and economy going beyond the standard requirements of the fluids, taking consumer insights and engineering technical solutions; advancing technologies that will lead to breakthroughs for the transport of tomorrow.

Transmission e-fluids: the demands on e-transmissions are more severe than conventional transmissions, with maximum torques delivered at low speeds and sometimes the integration of electric motors into the transmission. Castrol develop fluid possessing appropriate dielectric properties and component compatibility to allow electronics to function correctly over lifetime.

Coolants e-fluids: Electric vehicle batteries work hardest when charging and discharging energy. As electric vehicles advance, batteries will face unprecedented stresses due to developments in ultra-fast charging and vehicle performance. To combat this Castrol has developed Coolant e-fluid and is working on unique technology for future battery coolants.

Greases e-fluids: for the increasing number of electric motors on board. These greases carry out a range of duties from lubricating the electric motor that drives the car, to supporting multiple electric motors supporting vehicle ancillary services.



Castrol continues to work on improving the efficiency of conventional engines and transmissions whilst also embracing the exhilarating growth of electrification. It literally is more than just oil, it is liquid engineering the future.

Dynamic simulation of gear transmission system using Multibody Dynamics

Masakazu Goto, Technical Manager, FunctionBay K.K.

Nowadays noise and vibration (NV) problem is becoming important more and more as EV and HEV are becoming popular in the automotive industry. Therefore, engineers think gear transmission simulation is an important tool for NV and are interested in it.

However, Gear transmission simulation has been done statically rather than dynamically. Because the number of EV/HEV is increasing, they are used under various driving conditions which changes significantly situation by situation. For example, engineers need to consider the behavior of shaft rotating with higher rotational speed and higher acceleration caused by electric motor instead of ICE. Thus, simulation of transient response is more important than before.

In this article, a new approach of dynamic simulation for gear transmission system using Multibody Dynamics (MBD) is introduced, which enables engineers to develop gear transmission system considering various conditions.

1. MBD for Gear Transmission System

MBD is a simulation method that calculates dynamic behavior of a mechanical system in time-domain considering applied force to each body. Vibration caused by gear contact is transmitted to a chassis via shaft/bearing/housing. Because a gear transmission system is composed by many parts and vibration is caused by force transmission between parts, MBD is suitable for this kind of mechanical system simulation.

Mesh misalignment is one of the major causes of NV problem in a gear transmission system. To simulate it precisely, the following factors must be considered in calculation. For this purpose, FunctionBay has developed a tool named RecurDyn/DriveTrain which includes new functions to consider below 4 factors for gear transmission simulation.

1. Variable mesh stiffness in gear contact

› Variable mesh stiffness by gear deformation and changing number of teeth under meshing.

2. Deformation of shaft

› Consideration of bending deformation and torsional deformation of shaft

3. Bearing stiffness considering clearance and combined load

› Consideration of bearing stiffness under combined load (axial load + radial load) applied on a bearing

4. Deformation of housing case

› Consideration of housing case deformation under applied load.

In particular, gear contact calculation with high accuracy is required in these factors because vibration is mainly excited by gear contact.

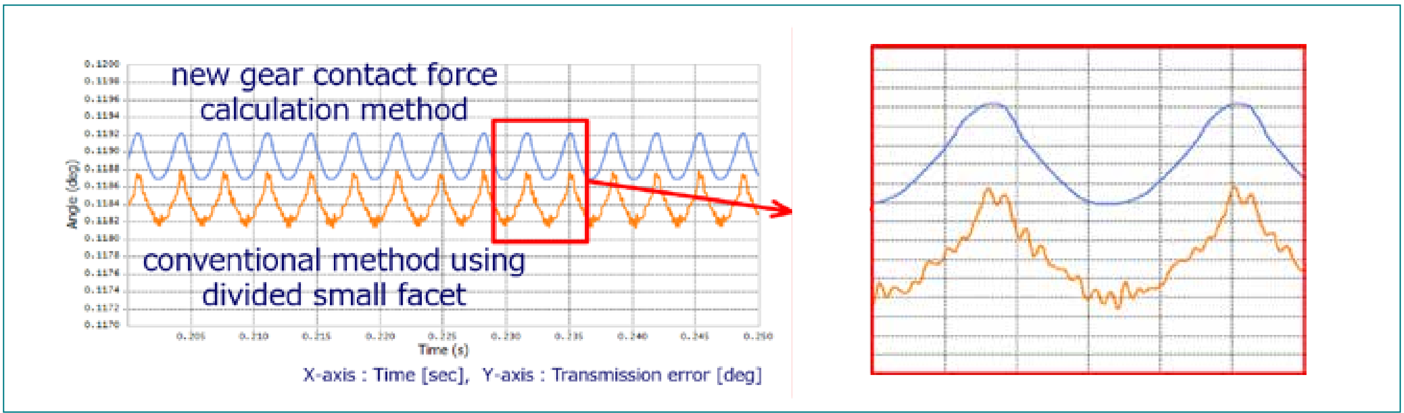


Figure 1 Simulation results comparison between general method and new method

2. Accurate Gear Contact Force Calculation

Regarding contact force calculation in general MBD, several methods are used as follows.

A) Applying reaction force between 2-points where user defines

B) Applying reaction force calculated by penetration depth between contact geometry

Although the method (A) requires less calculation cost, it is hardly used for complex geometries. On the other hand, method (B) can be used to calculate contact force between any general geometries. To achieve this, contact calculation algorithm in MBD employs tessellated small facets for contact point detection and contact force calculation instead of analytic geometry data itself. Since this method uses tessellation data (small facets), the calculated contact force is not very smooth in the case that contact is defined between curved surfaces. Because of this reason, it is not easy to calculate the accurate gear contact force with method (B) in conventional MBD.

C) New method to calculate Gear Contact Force accurately

› To calculate gear contact with high accuracy, FunctionBay has collaborated with KISSsoft to develop a new gear contact force calculation method which can consider variable mesh stiffness caused by gear deformation and changing number of teeth engaged. In this method, reaction force of gear contact is calculated using design parameters based on position and orientation between gear pair in pre-calculation stage. After then, the pre-calculated results are used for the simulation of gear transmission system. Figure 1 compares the simulation results of transmission error between the conventional method using tessellation data of surfaces and the new gear contact force calculation method. It is apparent that the result using the new method is much smoother than the result using the conventional method.

With this new method, RecurDyn now can calculate dynamic behavior of a gear transmission system more precisely.

3. Application example: Transmission Simulation

Figure 2 shows a simulation model of motorbike transmission and figure3 shows simulation results of gear contact force/bearing reaction force/reaction force measured at the fixing point of housing case. Rotational velocity of crankshaft is constant (6000 rpm) in Time-domain and Frequency-domain.

Meshing frequency is 567.6Hz and 1st~5th order frequencies can be observed in gear contact force. Also, these five orders frequencies can be observed in bearing reaction force either. In addition, these five orders frequencies can be observed in reaction force at the fixing point of housing case even though 1st order is a bit small.

From these results, it is no doubt that vibration caused by gear contact is transmitted to housing case through shafts and bearings.

Figure 4 shows the comparison of 2 results with different conditions. Rotational velocity of crank shaft is constant in one condition. In another condition, rotational velocity variance caused by combustion

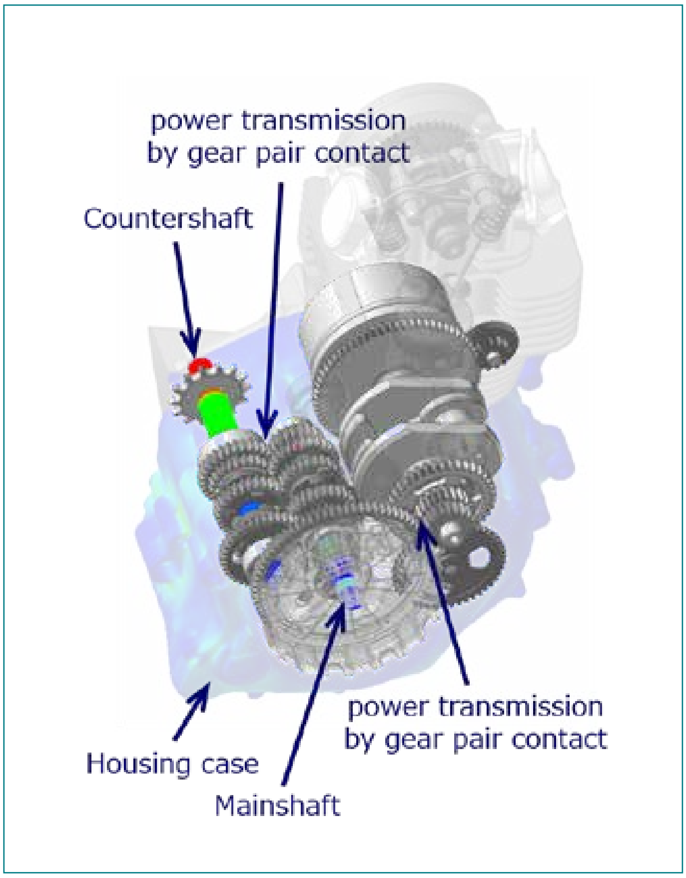


Figure 2 A simulation model of motorbike transmission

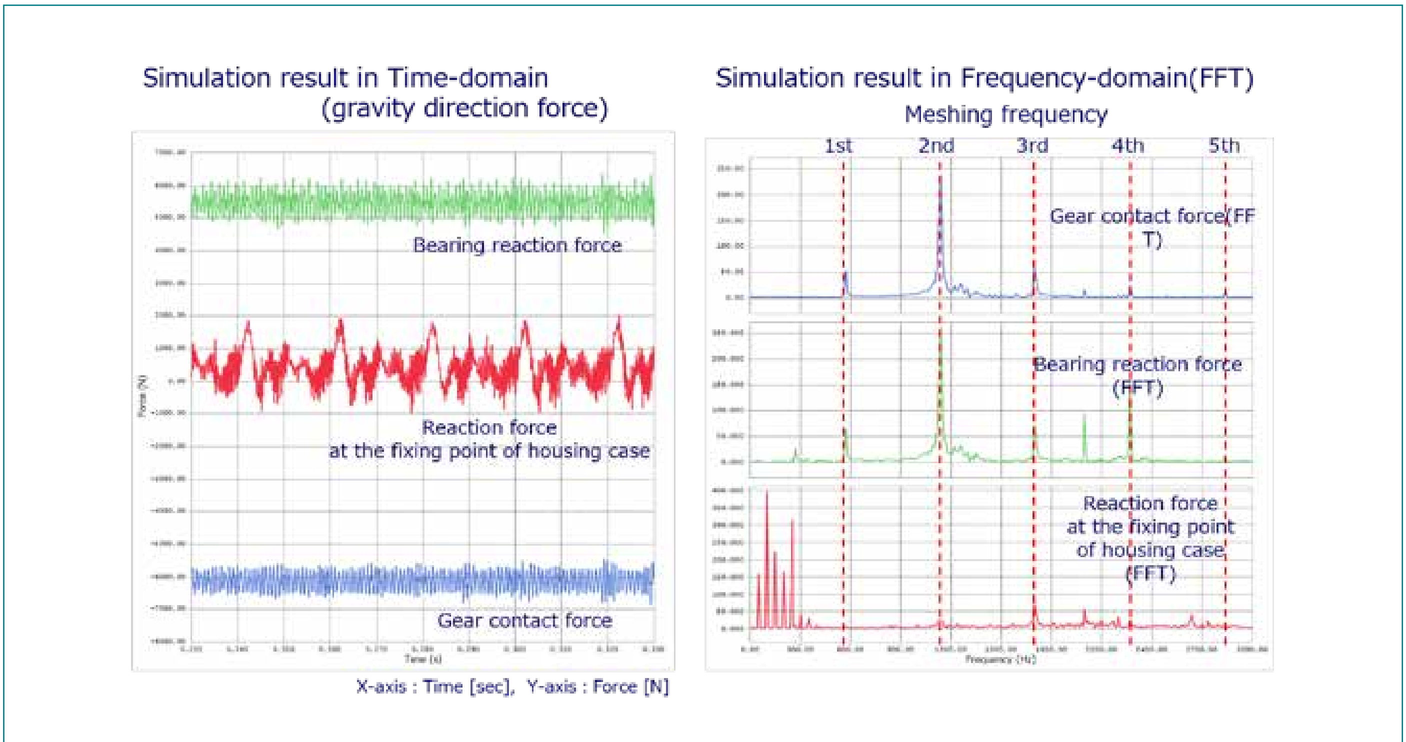


Figure 3 Simulation results (rotational velocity of crankshaft is constant: 6000 rpm)

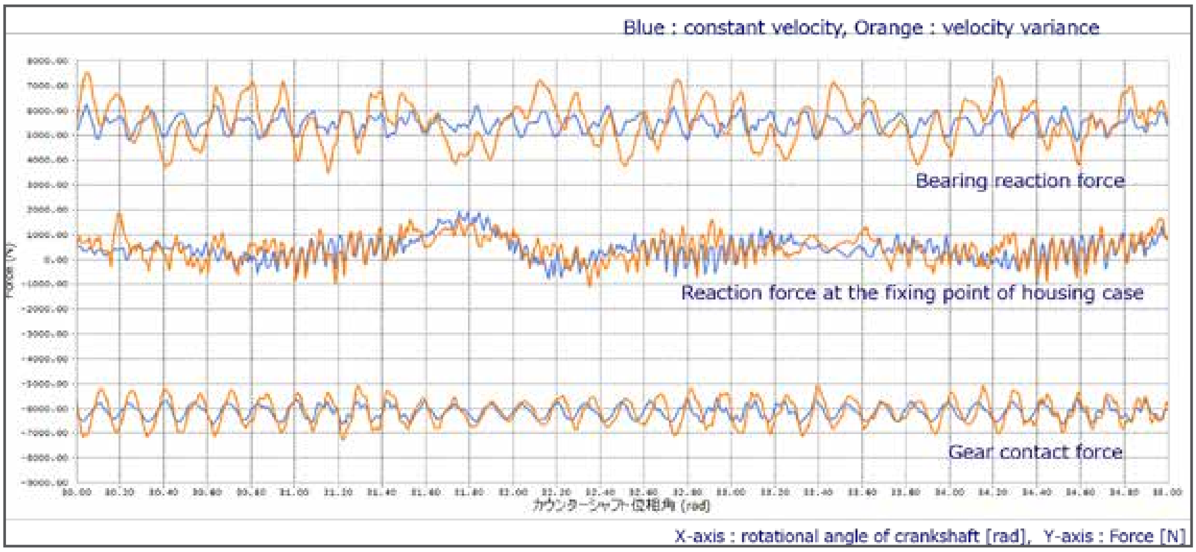


Figure 4 Comparison result of 2 conditions simulation in Time-domain (constant velocity/velocity variance in crankshaft rotational velocity)

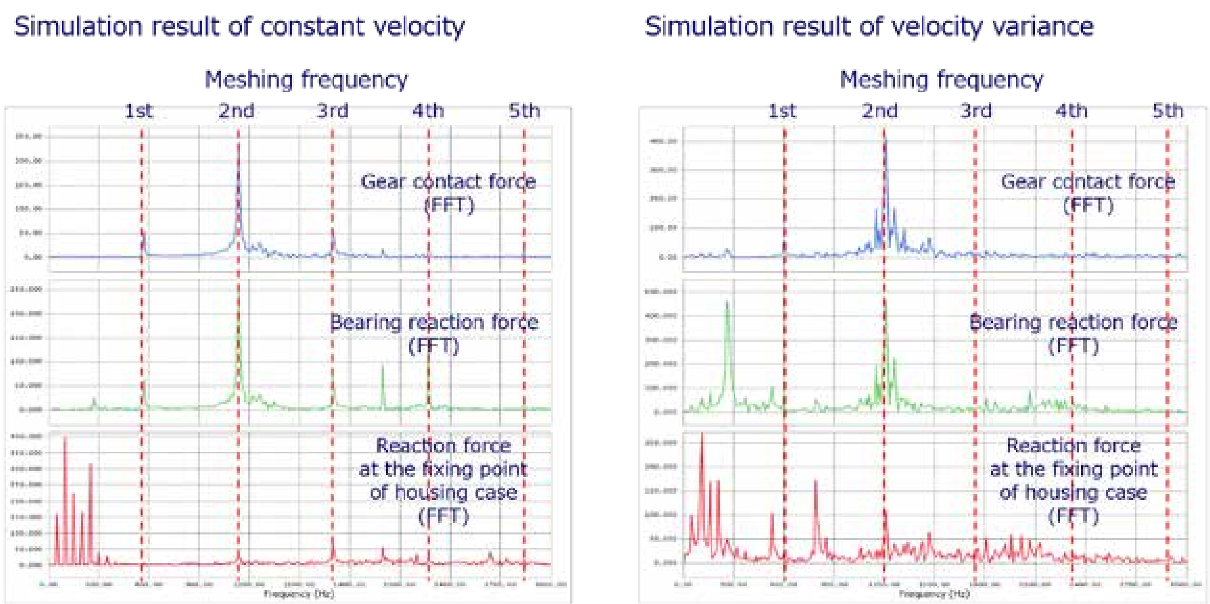


Figure 5 Comparison result of 2 conditions simulation in Frequency-domain (constant velocity/velocity variance in crankshaft rotational velocity)

load defined on the piston is considered. (Blue: constant velocity, Orange: velocity variance)

When Comparing the results, the force amplitude of the velocity variance case is larger than that of constant velocity case and is varying in a random order. In addition, FFT results show that meshing frequencies are different and frequency components around meshing frequency exist in velocity variance condition. (Figure 5)

In the case of a real mechanical system, driving conditions like rotational velocity are not constant. Dynamic analysis employing

Drive/Driven Gear Specification	Gear Type	Helical
	Number of Teeth	52
	Normal Module	2.03
	Normal Pressure Angle	18 [deg]
	Helix Angle	28.5 [deg]
	Face Width	20 [mm]
Center Distance		120 [mm]
Rotational Velocity		50 [rpm]
Misalignment	Tilt	-99.5 [μrad]
	Twist	-48.9 [μrad]

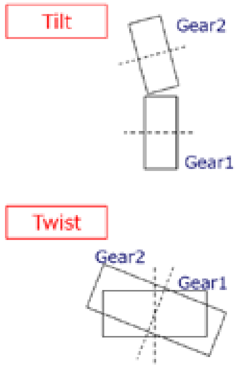


Table 1 Specification of gear pair and measurement condition

MBD can simulate gear transmission system with this kind of complex conditions, while static analysis cannot consider these kinds of realistic conditions.

4. Verification of Gear Contact Calculation

In this section, the comparison between measured results and simulation results is introduced to verify the feasibility of the gear contact calculation. Transmission error amplitude/waveform of simulation results are compared with the measured results which are showed on [1]. Table 1 shows the specification of drive/driven gears and measured data of misalignment.

In Figure 6, the simulation results and measured ones are compared. (Blue: simulation results, Black: measured results) This figure is based on the reference from Yoshikawa et al. (1997) [1]. The simulation result which doesn't consider misalignment is also showed in this Figure 6. When the misalignment is not considered in simulation, the amplitude and waveform of transmission error is completely different. However, when misalignment is considered in simulation, the tendency that the triangle-shaped waveform varies with increasing torque can be observed. In addition, although the amplitude of the simulation results is slightly smaller than the measured results, the amplitude does not vary even if loaded torque is increased. Therefore, the tendency of this simulation result coincides with the description "the amplitude of transmission error is less subject to loaded torque in the case of involute tooth surface" which is reported by Yoshikawa et al. (1997) in [1] (p. 373).

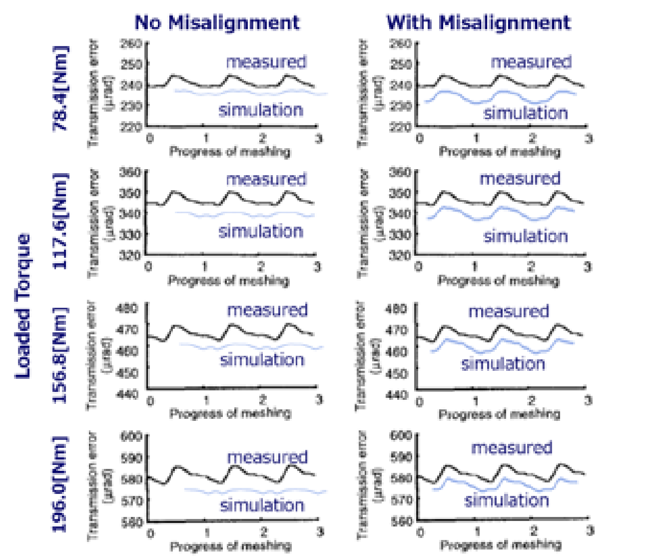


Figure 6 Comparison of transmission error (measured and simulation results)

5. Conclusion

As a prediction method of dynamic behavior of gear transmission system, MBD approach which can include stiffness variation of gear contact is introduced in this article together with its verification results. The conclusions are as follows.

- New approach for gear contact calculation can consider mesh stiffness variation by gear deformation and changing number of teeth engaged.
- Vibration caused by gear contact is transmitted to housing case through shafts and bearings. Therefore, vibration propagation from gear contact to housing case can be evaluated.
- Dynamic behavior of gear transmission system can be calculated considering transient condition.

References

[1] Yoshikawa K, Tani H, Tarutani I, Suzuki A, Maki H and Ueda Y (1997) "Measurement of Helical Gear Transmission Error and Improvement of Analytical Method". Transactions of the Japan Society of Mechanical Engineers, Series C (in Japanese) Vol. 63, No.609 (1997)

Acknowledgements

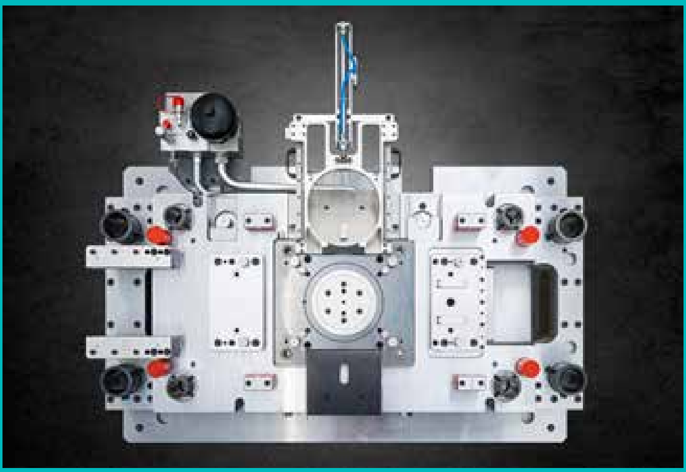
The author sincerely appreciates Dr. Aihara of Hosei University for his helpful suggestions and considerable support.

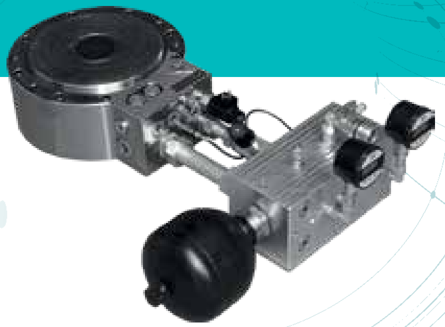
Fine-blanking for Powertrain Parts

Until recently, if you wanted to fine blank components, you would often come up against dimentional limitations. Webo GmbH, known as a leader in roller tool technology, has developed a system that provides precise smooth cuts – even without using a common fine-blanking press. The fine-blanking pad, which can be integrated into any press.

Any metalworker worthy of the name understands that not all stamping is the same. In order to achieve a high degree of precision, which often goes hand-in-hand with almost 100 % smooth edges, you have to turn to the fine-blanking process.

It's not enough here just to separate the material. Quality is measured by the cut edge which should be burr-free. Special technologies are used to achieve this high degree of precision. Classical fine-blanking presses ensure a smooth cut, but these presses are true high technology and expensive investments. A range of accessories such as pumps, control units and specially designed kinematics makes it possible to achieve cut areas with up to 99 % smooth edges. The way this type of press works, however, is very much different from the way in which an eccentric press works. The biggest problem: fine-blanking presses currently available on the market have a maximum table length of 1.5 m and – they are expensive. WEBO GmbH has developed a very competitive system to tackle this problem. The tools and systems produced by Webo are larger than the common fine-blanking presses currently available on the market can handle. And the best thing is: The customers can use the WEBO fine-blanking system on any existing hydraulical or mechanical press available at site.





Fine-blanking research by WEBO GmbH

The team developed a new solution using a gas pressure spring which they built themselves, a void filled with nitrogen pressurized to 150 bar. “One big advantage that this solution has over the disc spring is that we can vary the pressure with gas.

Fine-blanking with the WEBO pad means the intelligent separation of oil and gas. The seals developed in-house must be perfectly fitted to the system. Throttle control: precise, intuitive control is required when throttling up the counterpunch. Correct timing: since the system (upper pad and counterpunch) is closed, the component and waste must be retrieved/removed in a planned fashion. If you want to learn more about WEBO fine-blanking technology see the animation on https://www.webo.de.com/en/products bottom of the page. Due to safety and certification rules, the fine-blanking pads are entirely made by Webo where they are also filled with gas and then delivered ready for installation. In autumn 2016 the product was market ready and the patent was registered. In the meanwhile the WEBO technology was globally rolled out.

Utilizing the power of the press

The pad works like a perpetual motion machine and is only set in motion by the movement of the press. No hydraulic connection, no electrical connection, no ejector is required. The pad works as soon as the press moves up and down. Where does Webo use the fine-blanking pad? “The classic case for us is the central hole in a disc carrier or rotatory parts, i.e. a pad is built into a transfer tool with up to 15 stages.” But WEBO realizes also fine–blanking tools for parts that are not rotationally symmetrical. Sheet thicknesses between 1,5 and 10 mm are realized. Stroke rates up to 70/min are reachable without problem for the pad. It is available in four sizes for counterforce ranges from 42 up to 100 ton. WEBO provides comprehensive advice before any purchase. Joachim Prinz is the expert who analyzes feasibility and determines the correct pad size based on application, press data, ram speed, stroke rate and other technical information. When using the pad it saves often an additional work step on other presses. Modular design allows the multipurpose of one pad for different tools or parts. WEBO customizes for those cases the whole tool and die design. For example, a customer for powertrain parts uses one basic fine-blanking frame for more than 5 different tools (different fine-blanking parts).

The fine-blanking pads do not require intensive maintenance. “The system is designed for one year or one million strokes with no maintenance. After this time, we recommend maintenance which Webo can undertake on request or the customer can do it by himself after training by WEBO. Joachim Prinz: “If we undertake the maintenance, we also carry out a technical safety inspection including seal test.“ The fine-blanking pad is already in use by several automobile suppliers around the world, including US, Canada, South Korea and China. Most recently it was produced for use with a tool for a German TIR 1 as part of the electrical Porsche Taycan project.

www.webo.de.com

1600-ton direct servo press with moving bolster and automated slug loader.

Disc Carriers - Formed to Perfection in 12 Steps with In-tool Roller Technology

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

Automotive transmission technology plays a crucial role in vehicle performance, fuel economy, and passenger comfort. The introduction of eight-, nine- and ten-speed transmissions has spurred the need for more complex metal-formed sheet metal parts that meet the automotive industry's standards of quality, precision, and cost.

Feintool's Nashville, Tenn. plant is meeting this need head-on. The plant has made significant investments, boosting its capabilities in metal forming and combining large tonnage, extended table direct-drive servo technology on its forming presses with state-of-the-art in-tool roller tool technology.

These investments give Feintool the ability to form high-quality components in a single tool run and at lower costs compared to other machining processes.

Advantages of In-tool Rolling

The commercial advantages of in-tool rolling technology, compared to traditional "out of tool" secondary forming processes, such as flow forming, are significant when volume exceeds 100,000 pieces a year.

The flexibility of the cold forming process enables Feintool to form and finish transmission components, as well as other parts, in a single press run. Since no secondary processing is required, Feintool can produce the components quicker and at a lower cost.

In-tool rolled components also offer technical advantages compared to secondary forming processes. The forming rolls surround the components, and all of the material is formed at the same time. Using up to three rolling stations, Feintool can form and calibrate the components resulting in tight run-out and profile tolerances.

Part of a Complete System

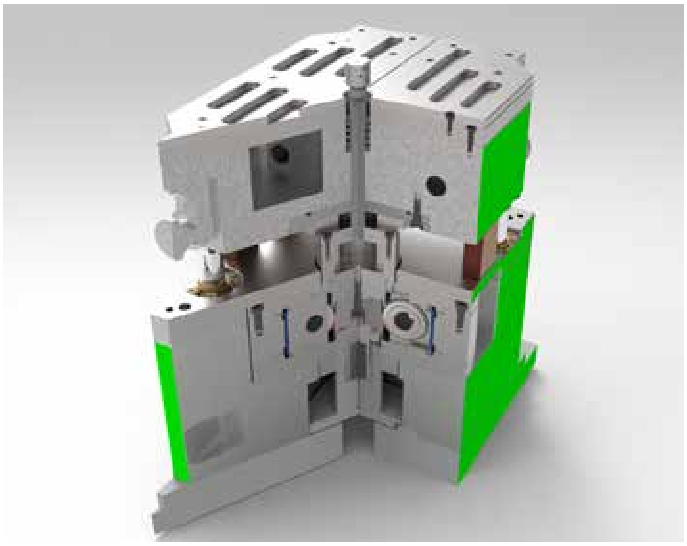
The roller tool technology is at the heart of a system developed by Feintool to produce ready-to-assemble components in a single press run.

Advanced direct-drive servo press technology with a large 18-foot press table gives component designers a lot of flexibility. The press can accommodate up to 12 tooling stations in a single run. Simultaneous operations, including deep draw, rolling of the tooth geometry, snap ring grooves, oil holes, and cutting to length, leads to lower component costs.

A 3-axis CNC-controlled transfer system guarantees a quick transfer of the components through all tooling stations. Positional accuracy and speed of the transfer system is the key for unleashing the stroke rate capabilities of the direct-drive servo press.

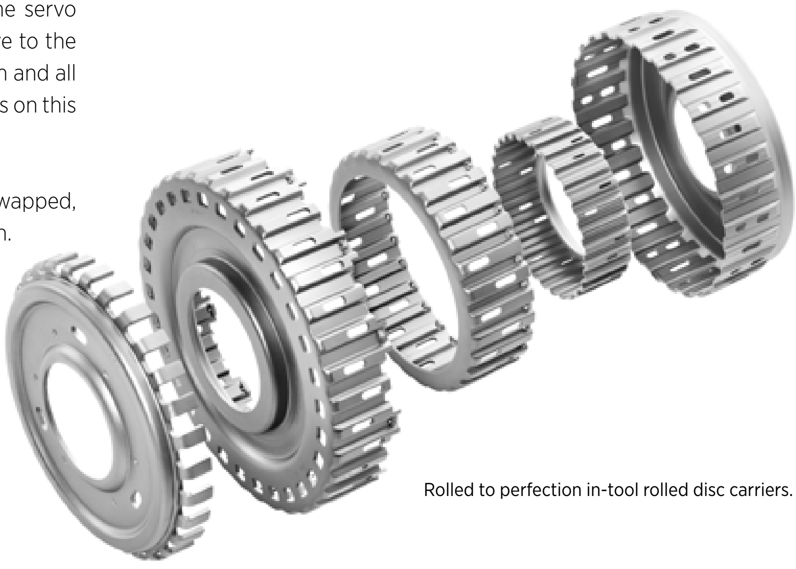
The moving bolster, which allows quick die changes within 20 to 30 minutes, is another important feature of the press system. The servo press is equipped with two moving bolsters that alternate move to the front or back of the press. The entire tool, including transfer arm and all the sensors for parts detection, can be set up outside of the press on this spare moving bolster.

When a tool change is required, the moving bolster can be swapped, and the machine is back in production with minimal interruption.



The cross-section shows one of the crucial in-tool roller stations. This is part of the 12-station disc carrier transfer tool Feintool designed and built to produce a complex transmission component for a U.S. gearbox manufacturer.

Roller die - at the core of the technology are forming rolls - arranged in pie-shaped cassettes encapsulating a part 360 degrees.



Rolled to perfection in-tool rolled disc carriers.

About Feintool

Feintool is a global technology and market leader for fineblanking, forming and electro sheet stamping products. As an innovation driver, Feintool offers complete high-volume production and automated secondary processes. We consistently expand the boundaries of these technologies and develop smart solutions to meet and exceed our customers' requirements.

Feintool is a project and development partner in the field of lightweight construction/sustainability, module variations/platforms including ICE, hybrid and electric drives.

The company, founded in 1959 and headquartered in Lyss, Switzerland, has 16 production plants and technology centers in the United States, Europe, China and Japan, ensuring close proximity to its customers. Over 2,900 employees and 80 apprentices work globally to develop new solutions and create key advantages for Feintool customers.

Feintool believes in strong partnerships that help your company succeed.

Learn more at **www.feintool.us/power**

In-tool roller technology forms complicated disk carriers in a single press run, resulting in higher quality and low-cost components.

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

Impressions from the CTI SYMPOSIUM 'Automotive Drivetrains – Intelligent – Electrified'
9 – 12 December 2019, Berlin, Germany

A balancing act between legislation and customer benefit

When the EU's CO_2 fleet target of 95 g/km takes effect in 2020, it will mark the dawn of a new era. At first, the target will only apply to 95 % of each vehicle manufacturer's fleet; in 2021 it will cover all new vehicle sales. In future, every excess gram will cost 95 € per vehicle sold. Unless something changes, only tailpipe emissions will count. Hence, OEMs must electrify their vehicles on a massive scale, with PHEVs and BEVs accounting for a significant share.

But as Prof Ferit Küçükay explained in his welcoming speech, the automotive industry is facing other challenges too. Adapting to topics such as digitalisation, artificial intelligence, networking, automation and mobility services involved significant investments. At the same time, the industry was currently dealing with reduced global production volumes, particularly in China. In other words, it had to invest heavily and cut costs simultaneously. Küçükay cited two trends that reflect this situation: cooperation schemes between automotive companies, and outsourcing more scope to suppliers.

Flexible electrification

The plenary lectures in Berlin reflected the diverse nature of these requirements. Ms Ruiping Wang, Vice President at Geely, gave detailed insights into market conditions in China. In mid-2019, China halved incentives for BEVs and eliminated them for vehicles with ranges below 250 km – yet the country still increases the mandatory share of NEVs (New Energy Vehicles) every year. Wang expects significant growth in HEVs and PHEVs by 2030, and envisages a 40 % market share by 2040. She said transmissions would tend to have fewer ratios, and would take the form of a DHT (Dedicated Hybrid Transmission) with a DHE (Dedicated Hybrid Engine).

Wang's insights into China's driving cycles were equally interesting. While the CLTC (China Light-Duty Test Cycle, due in 2025) involved an average driving speed of just 29 km/h, it resembled WLTC in terms of driving dynamics. This, she noted, reflected the high proportion of urban driving that is typical for China.

For Hakan Yilmaz, CTO at BorgWarner, the right degree of electrification depends on the end consumer's individual 'mission'. Since this required a broad range, including a wide selection of hybrid architectures, BorgWarner was backing a complete portfolio of P0 to P4 architectures. Yilmaz said the question of whether consumers chose BEV or PHEV would depend to a large extent on how regulations evolve.

Like other speakers, Yilmaz believes ICEs will retain their significance and foresees a trend towards a combination of DHT and DHE. He said BorgWarner would continue to back a broad portfolio of systems for ICEs, including e-booster and e-turbo systems as a supplement for, or an alternative to, 48 V hybridisation.

Modular range

Volkswagen is currently backing BEVs all out on a large scale. Frank Bekemeier, CTO e-Mobility Volkswagen, presented the Group's modular drive system (MEB) in Berlin, taking the VW ID.3 as his example. His colleague Holger Manz, Head of Energy Management and High Voltage Systems Electric/Electronic Development, went into more detail about the battery system.

The ID.3 is a fully dedicated new build, as a look at the battery architecture makes impressively clear. It's a central, modular element of the vehicle platform. Using up to twelve cell modules, range can be scaled between 330 km and 420 or 550 km. Each cell module is controlled with <60 V, which is well below the low voltage threshold for service technicians. Cells can be configured in either prism or 'pouch' form. Even if cell modules need to be exchanged during a vehicle's lifecycle, Manz said functional compatibility was assured – even with later-generation replacements.

The issue of 'appropriate range' also featured in the panel discussion with Prof Arno Kwade (TU Braunschweig), Uwe Wagner (Schaeffler), Christian Levin (Traton), Bernd Vahlensieck (ZF) and Prof Christian Beidl (TU Darmstadt). Beidl said the big issue for BEV users was availability, not range. Kwade pointed out that in cities of all places, charging point availability remained a major challenge. While lamppost charging points and inductive charging were possible, both were very costly. Levin saw similar challenges for commercial vehicles: "You have be able to charge vehicles where they're needed."

Vahlensieck said charging solution availability was more important than range in terms of costs too. This was particularly true for private buyers, who saw purchase prices as a critical criterion. As an approach to squaring the circle between infrastructure, availability and costs, Uwe Wagner advocated plug-in hybrids with ICEs tailored to their specific needs.

BEV variants

Coming back to the plenary lectures, three very different applications for BEVs were discussed. Jörg Sommer, former CEO of Streetscooter, explained the company's consistent focus on inner-city delivery traffic. On the one hand, he said, this affected vehicle design in terms of factors such as space utilisation, all-round visibility or robustness. On the other hand, Streetscooter also wanted to be a 'one-stop shop' for the last mile by supplying the charging infrastructure and services too. Due to this sharp focus on this last mile, he said, the concept worked in a similar way in Europe, North America and China.

The Taycan, presented in detail by Porsche CEO Oliver Blume, is more about the 'fastest mile' than the 'last mile'. This is the manufacturer's first all-electric sports car. The 800 V technology, used here for the first time, permits charging at up to 270 kW. By the end of 2020, Porsche aims to offer around 400 suitable charging stations in Europe. The two-speed transmission for the rear axle is also new; like the front axle, it's powered by a PSM. The vehicle electronics are also innovative, with fewer control units and three electronic levels – the sensors and actuators, an overlying computer or software level, and a 'backend' level that includes consumer device (e.g., smartphone) integration and communication with the infrastructure beyond the vehicle.

Christian Levin, COO at Traton, talked about battery electrical applications from the viewpoint of a commercial vehicle manufacturer. For buses and heavy trucks, he said, fuel (45 %) and drivers (30 %) were bigger cost factors than the purchase price, which together with servicing and maintenance accounted for the remaining 25 %. Levin believes in battery-electric solutions for these applications too. He predicted that even 40-tonne trucks would be electrified within ten years; the key was installing the charging infrastructure in the right places.

Battery potentials

As Prof Martin Winter from Forschungszentrum Jülich explained, battery technology plays a key role in determining where the 'tipping points' in favour of BEV lie. He predicted that Li-Ion battery pack prices would fall from today's $ 200 to $ 110, with cells costing around $ 80. Winter also went into detail about the technical potential he sees, including solid-state batteries, which many people think will boost energy density significantly. Winter said that while energy density was higher for lithium sulphur or lithium metal in theory, Li-Ion was still the best solution when costs, safety, sustainability, durability and performance were factored in – and there was still room for improvement.

Batteries also featured strongly in the panel discussion. Prof Kwade believes the energy density of Li-Ion can grow by another 20 – 30 %. In terms of volumetric energy density, he said solid-state batteries offered a further 20 – 30 % of potential. However, fast charging was more important, and in terms of cell structure and materials there were still many opportunities to exploit.

The panel also discussed the issue of who will be making money with batteries in future. Prof Kwade, Wagner and Vahlensieck all agreed that in terms of technology, Germany and Europe could keep up with Asia. But for Wagner, manufacturing in Germany makes little sense due to a lack of regenerative energy. As Vahlensieck noted, however, Germany could definitely adopt a leading role in development and in a 'system context'.

Networked mobility

Stephan Rebhan came to Berlin for the first time as a representative of Vitesco, which emerged from Continental's Powertrain division. He addressed another trend that is set to shape the automotive industry. In 2030, he said, 80 % of new vehicles would feature extended driver assistance systems (ADAS) capable of at least Level 1 automated driving. While not expecting to see many Level 4 or 5 vehicles by then, Rebhan did predict major changes in HMI and data transmission standards. Even 5G offered data rates of 10 GB/s, and 6G would increase the potential for Car2X further still.

Rebhan predicted that multiple distributed ECUs would be replaced by in-car vehicle servers. These would communicate on a higher software level with standardized sensors and actuators. He also introduced a fairly new term from the IT world: 'fog computing'. In addition to cloud computing, the speaker explained, fog computing would establish a 'local level' between the distant cloud and the vehicle itself. By communicating locally relevant information within a limited radius only, fog computing could ease the load on cloud communication. Ultimately, this would reduce data volumes, accelerate transfer rates and save energy.

High-end transmission

As the lecture by Jörg Gindele from Magna Transmission Systems showed, advances in computing power and software also benefit classic transmission applications. His subject was the new 8DCL900, which features in the new Ferrari SF90 Stradale and elsewhere. The 8DCL900 is designed for input torques of up to 900 Nm, and has a torque density of 6.4 Nm/kg.

Impressive features include the oil management system, in which oil effectively circulates around the gear set. It flows through the gearshift and clutch actuation modules above the transmission, then through the clutch itself, then back into the upper oil chamber with virtually no splashing loss. This system minimises oil loss and makes oil levels insensitive to lateral acceleration.

Francesco Strati, who co-authored the talk, was the project head at Ferrari. He contributed how the sports car manufacturer revised the TCU in-house and improved computing power by a factor of 10 compared to the previous transmission. This enabled significantly faster shift response times, as well as faster modulation of hydraulic pressure for the dual clutch.

Gindele also pointed out that many individual solutions – for example an optimized manufacturing process for the honeycomb-structure housing – were already being adopted for mass production transmissions.

A shift in focus

It's clear that the share of HEVs, PHEVs and BEVs in new registrations will grow significantly this year, as no other outcome is conceivable under current emissions legislation. In the words of Prof Ferit Küçükay, it's now a matter of finding application-specific, legally compliant solutions and following the path to automotive digitalisation. He said the challenge would be maintaining profitability, especially for electric vehicles.

Given the costs and the fact that infrastructure challenges are nowhere near being resolved, ICEs will likely be with us for a long time yet. But Küçükay said their production could shift to suppliers. If so, drivetrain differentiators would be the engine-transmission calibration and how well its interfaces were optimised for the vehicle. In other words, ICEs will still be around, but the development focus is shifting to digitalisation and electrification.

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