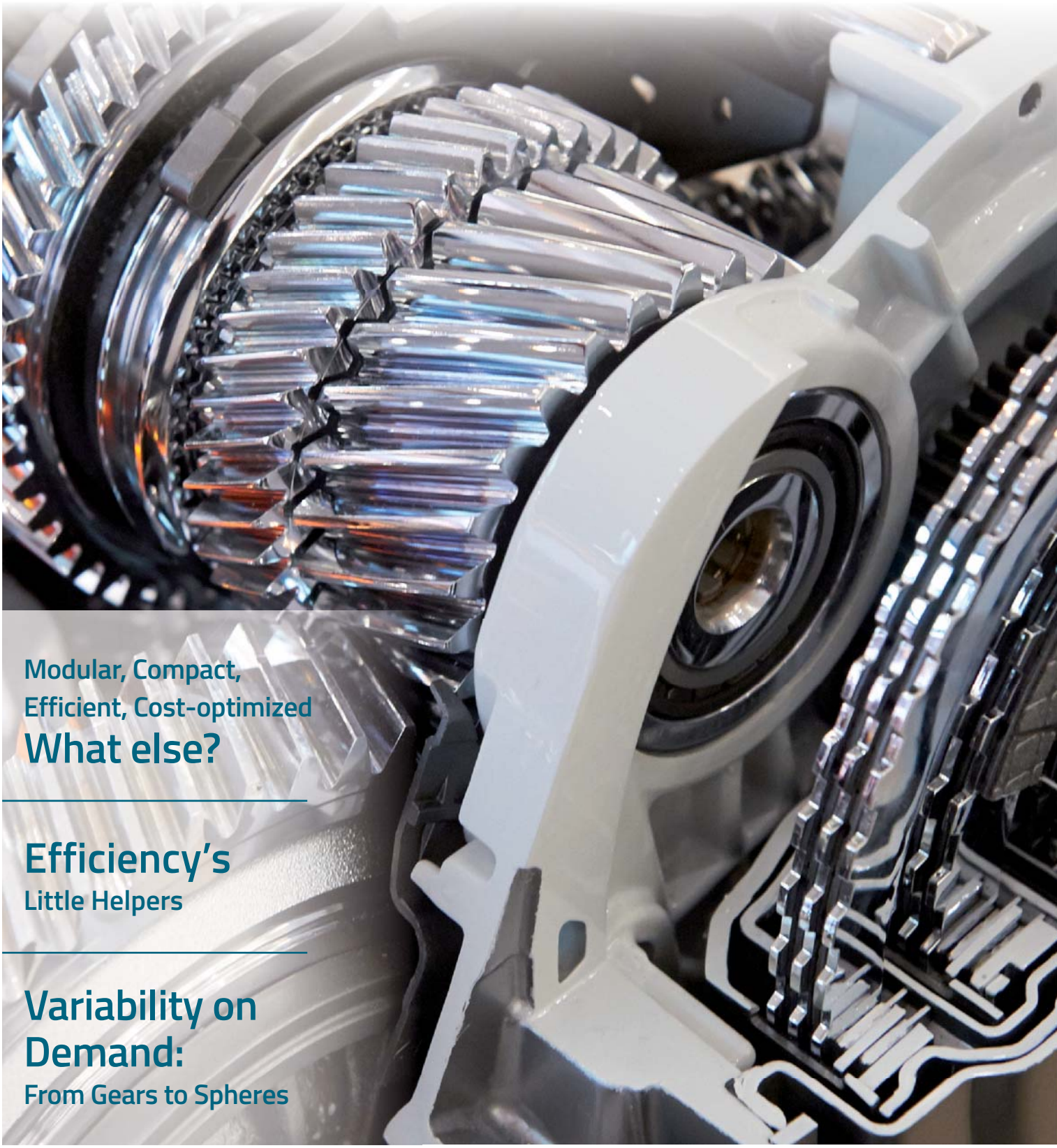
CTI MAG

The Automotive TM, HEV & EV Drives magazine by CTI

December 2014



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Efficiency's Little Helpers

Variability on Demand: From Gears to Spheres

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Dear reader,

In the rapidly-changing field of automotive drives and transmissions, manufacturers, suppliers and research institutes have to pull out all the stops. Apart from efficient development tools, they also need to deliver innovative aggregates, components and elements for drives and transmissions. In this issue of CTI Mag, some companies show just how well they are meeting this challenge. We wish you an enjoyable read!

Best wishes,

Your
CTI Mag Team

P.S.: the fourth issue of CTI Mag appears in May 2015.
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Variability on Demand: From Gears to Spheres

Once a bicycle technology, a new CVT technology is now successfully proven in a wealth of applications including automotive accessory drives.

by David Markley, VP Technology Development, Fallbrook Technologies and Jeremy Carter, VP Product Development, Fallbrook Technologies

The primary function of any multi-speed transmission is to manage the variability between what is driving and what is being driven, as best seen in automotive applications worldwide. Whether managing the power from the engine to the wheels or all of the accessory components (Figure 1), automotive transmission systems are designed to keep either the engine or accessories within a narrow speed and power band, while the speed of the vehicle is constantly changing.

In fact, it is remarkable how much technology exists in the automotive industry to accommodate the fact that the engine speed changes with vehicle speed. For example, variable valve timing, variable displacement pumping and variable A/C compression all exist to accommodate the ever-changing operation of the engine.

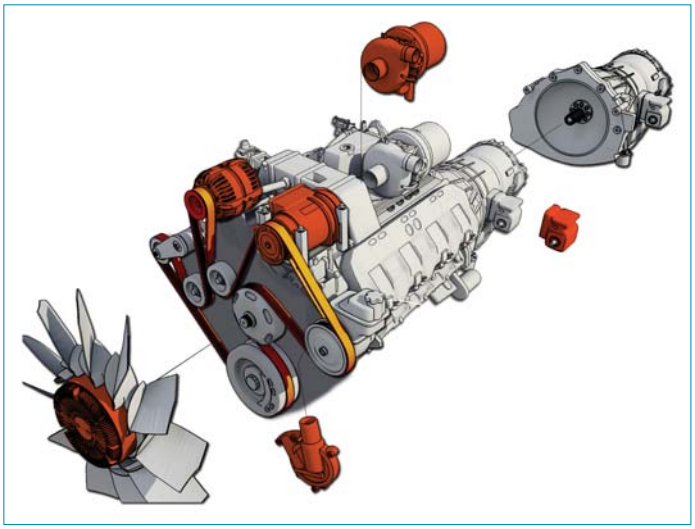

Figure 1 Automotive engines and accessories would both benefit from a narrower band of operating speeds

The ideal case is to manage the variability by either 1) holding the engine near constant speed and controlling the vehicle speed with the primary transmission, or 2) decoupling the accessories from the varying engine speed and controlling them independently. CVTs offer the opportunity to realise these benefits, but their widespread adoption has been slowed by challenges of cost, scalability, size and durability.

Old + old = new

A continuously variable planetary (CVP) technology is a transmission technology that combines the advantages and promises of traditional CVTs with the functional benefits of time-proven planetary gears and manufacturing processes similar to those of ball bearings.

In developing the CVP, American company Fallbrook Technologies has taken the basic configuration of a planetary gear system and leveraged known bearing technology, both in design and manufacturing, to achieve a unique capability for custom-geared transmission systems. The resulting CVP is a planetary gear set with spheres instead of gears (Figure 2).

Similar to a traditional planetary gear set, the CVP technology comprises:

- an input ring, driven by the power source;
- an output ring, connected to the CVP output;
- a central idler, also referred to as a 'sun', to pilot the rotating assembly;
- and a set of planets, each rotating on its own axle and fitted between the input ring, the output ring and the sun.

Merging the strengths of these established mechanical components changes the way mechanical power is transmitted to provide additional flexibility to engineers and improve the performance of primary

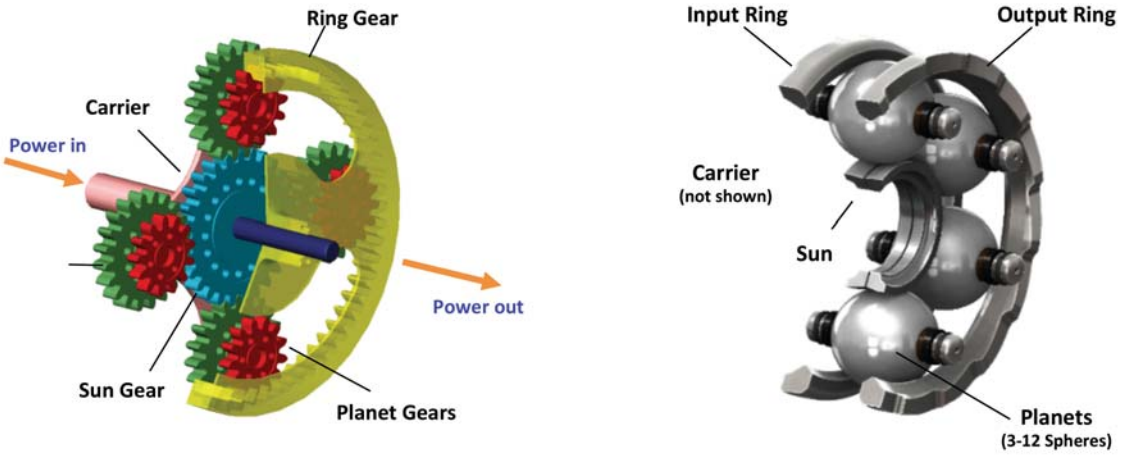

Figure 2 A CVP is a planetary gear set that uses spheres instead of gears

transmissions, automotive accessory drives and other vehicular and industrial drives.

Gear teeth no longer required

The basic function of a gear is to transmit torque by meshing teeth together. Gears transmit torque very efficiently but offer no variability in speed due to the fixed geometry of the gear teeth.

In contrast, the way power is transmitted by a CVP is similar in principle to the rolling traction of an automotive tire: flexibility, or variability on demand, is achieved using smooth surfaces for transmitting torque via traction. In the same way, power is transmitted from the input ring to the planet, and from the planet to the output ring.

Two features are required to enable this transfer of power: the grip between mating elements, and a mechanism that clamps the rolling elements of the system.

The grip, which is provided through an elastohydrodynamic traction fluid, is the CVP's equivalent to gear teeth. When the traction fluid enters the contact patch, it momentarily solidifies, providing the grip to transmit a tangential force. The traction fluid also separates the metal traction components to protect their lifespans by preventing destructive metal-to-metal contact, and it provides lubrication for bearings and other components.

Clamping can be likened to the spoilers on a Formula 1 race car, applying force so that the car remains on the road while the tires provide the traction at the interface between the tire and the track. The CVP's equivalent to a spoiler's wings is a simple set of passive mechanical cams.

While clamping is required in all traction CVTs, the function of the CVP cams is simplified because, unlike other CVT technologies whose traction diameter changes constantly, the diameter where the ring touches the planet never changes. The CVP cams are passive and do not require high-pressure hydraulics to manage clamping and control like most traction drives, providing the same functionality in a far smaller space.

Gearless planetary design offers enhanced flexibility

In application, the CVP's flexibility is enhanced by the planetary nature of the device, which has two main advantages: power summing with multiple inputs and outputs, and power in/out on the same axis, where both power in and power out are achieved on the same centreline.

Consider the alternatives: belts are on parallel, offset centrelines, and toroidal systems are usually on dual centrelines. In contrast, the CVP offers two options to take power in and out of the same centreline (Figure 3): a Thru Drive configuration (where power goes in on one side and out of the other), and a U Drive (where power is taken in on one side, makes a U turn and comes back out on the same side).

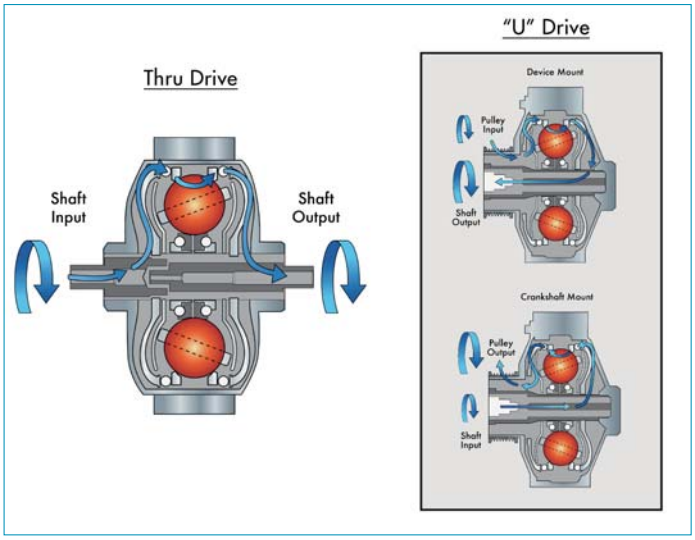

Figure 3 Examples of versatile CVP power paths

While the Thru Drive configuration is often ideal for primary transmissions, the U Drive configuration enables the CVP to be easily adapted to belt-driven applications such as automotive accessory drives, providing additional opportunities for performance improvement and packaging flexibility.

Further flexibility and potential for design optimisation is enabled because the CVP can be used as a power-splitting or power-summing device. For example, a CVP could be used as the core-summing component for a new hybrid drivetrain combining gas and electric power, which varies the ratio and enables it to maximise performance of both what is driving and what is being driven. The CVP's ability to power-sum and its numerous power path configurations are unique and applicable to a broad range of applications.

While one automotive industry trend is the introduction of 7-, 8- and 9-speed transmissions, where it is normally necessary to add another planetary or clutch, the CVP system has the ability in its core to run multiple forward speeds without any clutches, and in some applications forward and reverse can be achieved without clutching or a torque convertor. It, therefore, reduces the number of components and is the only system currently available that can achieve infinitely variable transmission (IVT) functionality without splitting power.

A fundamental shift in shifting

The CVP has a very simple shifting interface compared to alternative technologies:

- Pushbelt systems require a high-pressure hydraulic control system with active feedback and very high pressures for both clamping and control, and they have the tendency to shift to ratio extremes.
- Toroidal systems require assemblies on each power rolling element that are linked to each other through a complex and high part count mechanism, all of which requires more package space and higher cost.

In contrast, the CVP utilises drive force to shift via a passive closed-loop skew shifting system, which requires minimal actuation force and is inherently very stable. Shifting is actuated by moving one carrier relative to the other, and each planet locates its ideal angle based on this single shift input. Only about 10mm of movement is necessary, and this can be achieved by leveraging throughput power to minimise actuator force requirements. For example, approximately 100W is adequate for a system that might be transmitting as much as 20kW.

A scalable approach to transmissions

As with planetary gear sets and ball bearings, the fundamental principles of the CVP technology are scalable to different applications. The NuVinci® CVP has been sold commercially in bicycles and electric bikes since 2007 and has won industry awards for design and innovation. While bicycle products demonstrate the commercial viability of the CVP, the capability of the technology to operate at higher speeds and duty cycles directly relevant to automotive applications has been shown through numerous in-vehicle proof-of-concept demonstration programmes with a variety of partners.

Since 2004, proof-of-concept prototype designs have been demonstrated in primary drivetrains for passenger cars, two- and four-wheel electric vehicles, an agricultural tractor, a riding lawnmower, zero-turn radius mowers and a small wind turbine. The primary benefit in most vehicular applications is to enable the motor or engine to operate at its most efficient speed, providing system-level improvements in fuel efficiency. Additional benefits have included measurable improvements in towing capacity, acceleration, hill-climbing capability, range before recharge, noise reduction and shift performance.

Parallel work began in 2008 to demonstrate the potential benefits for accessory drives (Figure 4). The basic premise in these applications is to decouple the accessory drives from engine speed, enabling constant speed operation of accessories at either idle or highway speeds. Successful demonstrations have been conducted with CVPs mated to accessory drives, including alternators, air compressors, superchargers, a fan drive and a water pump.

In one programme, the CVP was mounted on the end of the engine crankshaft of a demonstration vehicle (Figure 5) to enable constant speed operation of all of the belt-driven accessories. In-vehicle test data (Figure 6) demonstrated that by maintaining near-constant operating speed, the accessories provided additional performance at lower engine speeds and improved efficiency at higher engine speeds.

Through a combination of analysis and testing supported by third parties, Fallbrook has been able to demonstrate component efficiency and performance improvements ranging from 4% to 75%, which cumulatively would have a measureable impact on BSFC. Additional im-

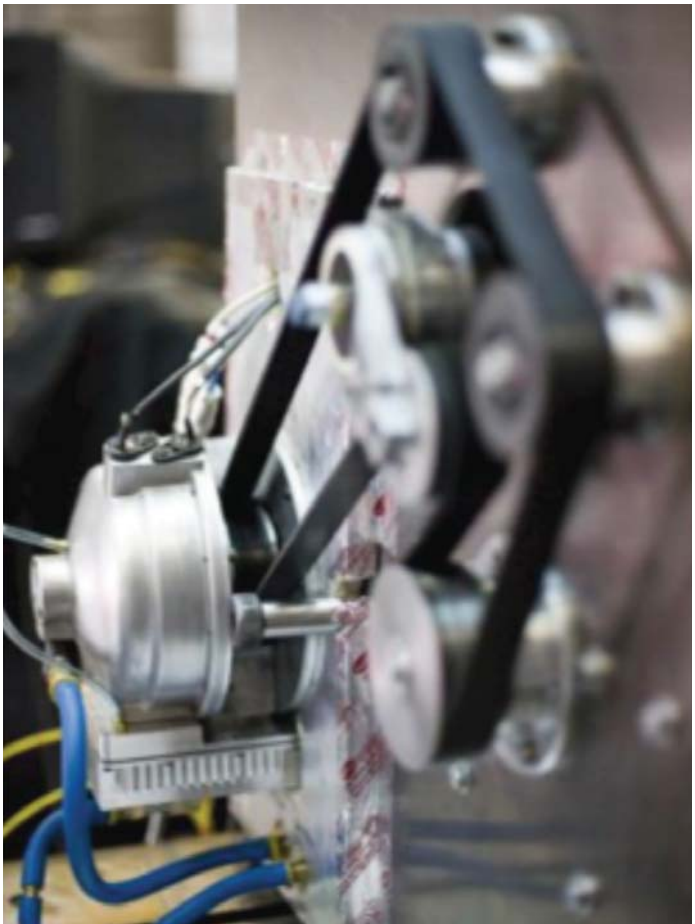

Figure 4 U Drive CVP mounted on a test stand for belt-driven accessory drives

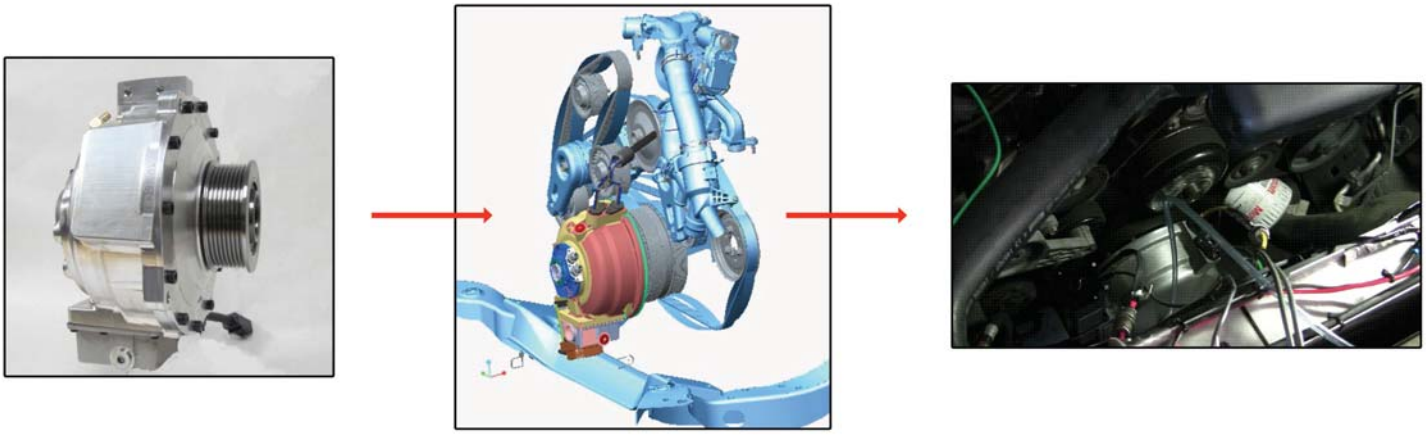

Figure 5 CVP mounted on the end of an engine crankshaft

provements in various applications include more power at idle, faster cool down and improved supercharger boost.

The fact that measureable improvements could be made on first-generation designs that were not optimised suggests that the CVP could have an even greater impact on future automotive designs. The advantage to engineers is a level of flexibility in system design that has not been available previously. Constant speed operation of engine accessories provides an opportunity for optimisation, providing either improved performance from existing components, or future packaging and cost improvements by delivering the same level of performance from smaller drives.

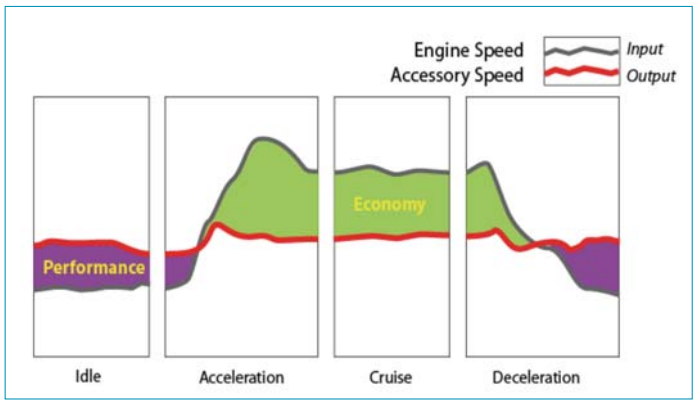

Figure 6 Vehicle test data showed that the CVP improved performance at low engine speeds and efficiencyat high engine speeds

In summary

By combining the basic functionality of a planetary gear drive and the simplicity of ball-bearing technology, the CVP offers unique flexibility to the designers of automotive drives.

The depth of scalability has been demonstrated in proof-of-concept programmes with more than 20 development partners. Application as a primary drivetrain alternative has been demonstrated in applications such as light electric vehicles, passenger cars, lawn and garden equipment, and off-highway applications. The packaging flexibility offered by the CVP has also been demonstrated across multiple accessory drive applications such as water pumps, fan drives, alternators, air compressors, superchargers and a crank-mounted application that managed the complete front-end accessory drive system. The measureable improvements in performance and efficiency could enable system-level design optimisation of existing components and downsizing in future drive systems.

Boosting hybrid vehicle display: an innovative transmission which makes all the difference

Modular, Compact, Efficient, Cost-optimized, what else?

IFP Energies nouvelles proposes an innovative transmission concept to enhance hybrid powertrain efficiency, for easy integration into small vehicles.

by Sébastien Magand, Nicolas Des Courtils, Tanja Ivanic, Misa Milosavljevic, Samy Laabidi, Thomas Valin, Stéphane Venturi, G. Zito, IFP Energies nouvelles

Market context

The international market is facing major challenges with the introduction of CO2 regulations and increasingly fierce competition from manufacturers in the emerging countries. Moreover, increasing traffic congestion and urbanization hints at a growing market share for small vehicles (segments A to C). Hybrid vehicles, which are the answer to some of these issues, should cover a large panel of powertrain architectures with various internal combustion engines, electric motors, etc. This clearly paves the way for the development of a new product in order to promote the deployment of hybrid applications and to improve overall vehicle efficiency at reasonable cost.

What is the best compromise between efficiency and cost?

Many hybrid topologies and a number of transmission designs, like eCVT, eDCT, power split, pure electric drive axle system and so on, are currently being proposed. In most cases, these concepts are adaptations and hybrid technology therefore has to comply with the constraints inherent in the existing conventional solutions. Consequently, the full potential is limited by comparison with a technology designed from scratch (around hybridization). The complexity of these future drivetrains is also a matter for the OEM; the commercial success of this technology still depends on the concerns of the end customers, such as total cost of ownership and so on. A simple solution is therefore required.

In this context IFP Energies nouvelles proposes an innovative transmission for hybrid powertrains. It consists of two planetary gears allowing 11 modes, including 2 electric drive ratios, 3 pure internal combustion engine modes, 3 hybrid parallel modes and 3 eCVT modes. All these modes can be obtained with only 3 electro-mechanical actuators and possibly with no clutch. Figure 1 gives an overview of one version of the IFPEN transmission layout. The synchronizer (A3) is used to change the electric drive ratio and has a third position (neutral)

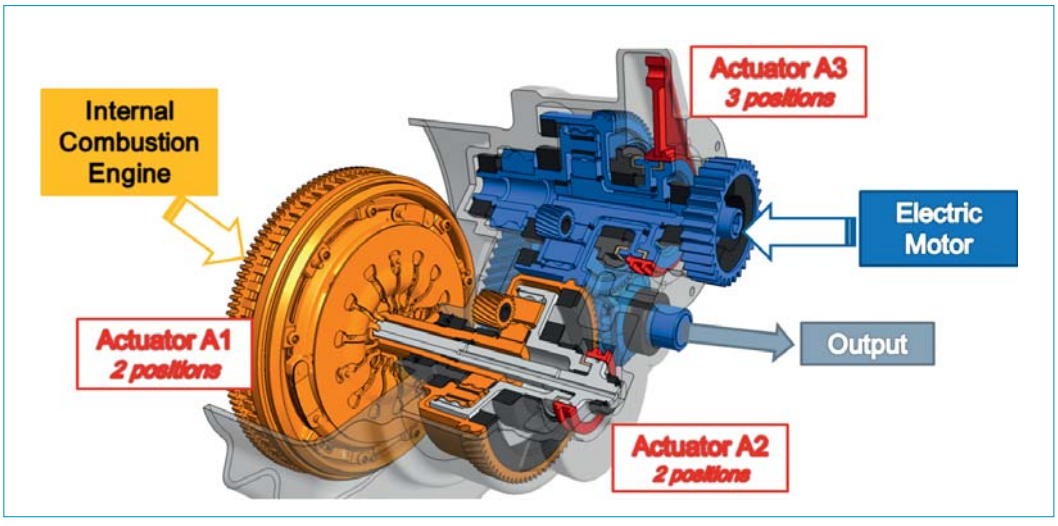

Figure 1 IFP Energies nouvelles hybrid transmission layout

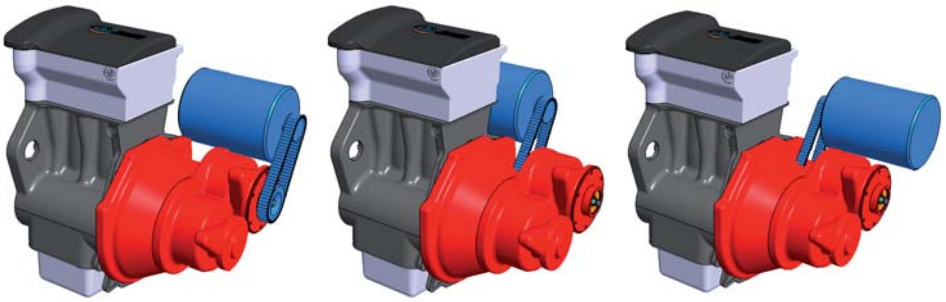

Figure 3 Electric motor integration flexibility with an innovative IFP Energies nouvelles concept

to propose a CVT-like function. The two other actuators (clutch (A1) that could be replaced by a synchronizer in another version and synchronizer (A2)) on the internal combustion engine (ICE) planetary gearset offer 3 gear reduction ratios for an ICE.

The first electric gear ratio that uses only one of the planetary gears (and thus a reduced number of mechanical contacts) to further increase global efficiency, could be used for urban conditions up to 60 km/h. The second one is suitable for extra-urban situations up to 140 km/h and offers a broad operating range in zero emissions modes. Hybrid parallel modes are the most efficient for ensuring vehicle traction and for operating the internal combustion engine (ICE) within its optimum efficiency range. eCVT modes enhance vehicle performance and drivability by increasing wheel torque for take-off or by increasing vehicle top speed for peak demand. Finally, ICE modes are useful in particular situations, for example low battery charge; it is also possible to charge the battery during standstill or traction operations and not only during decelerations. Drivability has been also taken into account, in particular during gear shifts. Electric motor torque can thus compensate for torque interruption during these phases with a minor fuel efficiency penalty. Drivability can be adapted to customer requirements by using this control feature.

After developing off-line energy management strategies, the optimization of the use of these different modes on an HEV B-segment vehicle with a 30kW electric motor (EM), leads to a fuel consumption reduction (of up to 10 %) for a certification driving cycle (NEDC, WLTC) as well as for other mission profiles, by comparison with current hybrid best-in-class applications such as the powersplit concept. In addition it is close to the figures given for high-cost future concepts such as eDCTs (Figure 2). With regard to real-life driving profiles (urban customer use for example), the gain is up to 65% compared with conventional vehicles, and 10 % compared with some hybrid solutions. Part of this gain is obtained by the use of free-wheeling in order to disconnect the ICE automatically during deceleration and thus maximize energy recovery. It is also noticed that the weight of the vehicle, and therefore of each component, is crucial in reducing energy requirements for vehicle traction; the transmission is consequently optimized to weigh less than 50 kg and thus contribute to overall vehicle efficiency optimization.

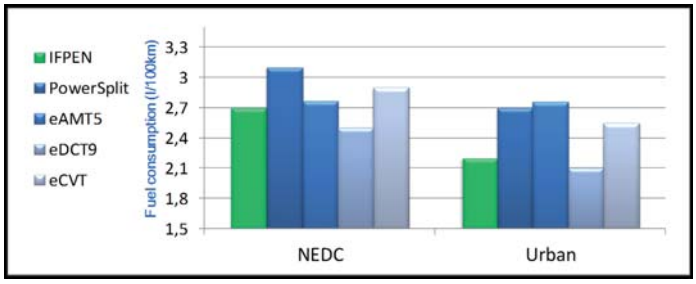

Figure 2 Fuel efficiency for different transmission concepts

Design-to-cost methodology is applied during the design process to enable the implementation of this solution in lower segment vehicles. Owing to the use of off-the-shelf components such as free-wheels or synchronizers, but also by cleverly designing the two planetary gears with the same dimensions in order to achieve economies of scale, the resulting estimated cost of this transmission approaches the cost of an automated manual transmission. Only one electric motor is required in this concept in order to help produce the most cost-efficient vehicle overall. A solution with a synchronizer instead of a clutch can be also used to reduce costs even further, with no major architecture change, while retaining the possibility of starting the vehicle with the ICE and with low SoC battery.

Versatility is the key

Modular can mean different things when talking about hybrid applications and it is a major factor in facilitating the industrialization stage of a new product for a currently growing niche market.

Offering a compact product is the first way to simplify a multi-platform adaptation from small to luxury vehicles. This innovation for instance is less than 300 mm long, the shortest ever and more than 70 mm shorter than all current and proposed hybrid transmissions. Investment in production facilities could thus be slightly offset by having a cross-product covering the entire OEM vehicle range.

Another definition of versatility concerns the powertrain components. Firstly, electric motor (EM) variety to meet mild, full and also plug-in hybrid requirements, in terms of power or torque, but also concerning component dimensions, highlights the need for transmission flexibility. Hence the integration of this component can be adjusted on demand with the IFP Energies nouvelles solution as shown in Figure 3. Furthermore, because downsizing and a reduced number of cylinders (2-cylinder or 3-cylinder) is a major trend in internal combustion engine (ICE) design, this leads to challenging NVH issues. Among the different solutions, enabling higher stiffness in transmission design means that this issue has to be taken into account by decreasing resonance frequency and thus possibly avoiding the use of dual mass flywheels in certain cases, thus reducing overall powertrain costs. With regard to NVH issues, it should also be noted that the design of this transmission leads to the absence of gear shot-blasting.

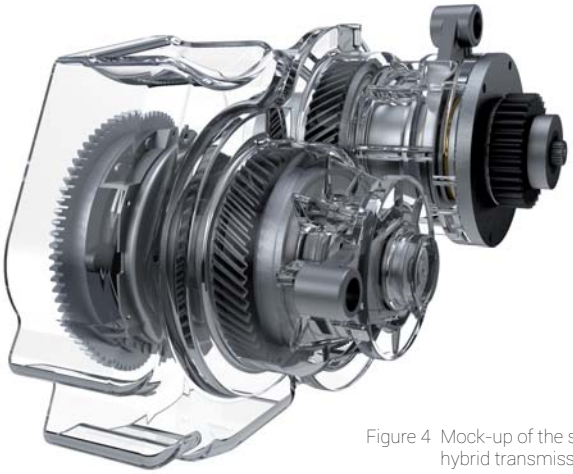

Figure 4 Mock-up of the simplified hybrid transmission

Outlook

By combining cost analysis, simulation and design skills, IFP Energies nouvelles has been able to develop an innovative, cost-efficient hybrid transmission. This patented concept manages the tricky challenge of proposing an alternative simplified transmission for a large range of hybrid applications with an interesting efficiency and cost trade-off. Finally, after a mock-up demonstration (Figure 4), the next stage, currently under investigation for this innovative concept, concerns the construction and testing of a prototype in conjunction with an industrial partner.

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About IFP Energies nouvelles

IFP Energies nouvelles is a public research and training player. It has an international scope, covering the fields of energy, transport and the environment. From research to industry, technological innovation is central to all its activities.

In the field of transport, IFP Energies nouvelles develops technologies to reduce the emissions and fuel consumption associated with road and air transport. Its research work relates to the improvement of conventional powertrain performance, assessment and validation of alternative, low-carbon fuels and vehicle electrification, in particular. It also develops technologies and processes for the production of low-carbon electricity and heat.

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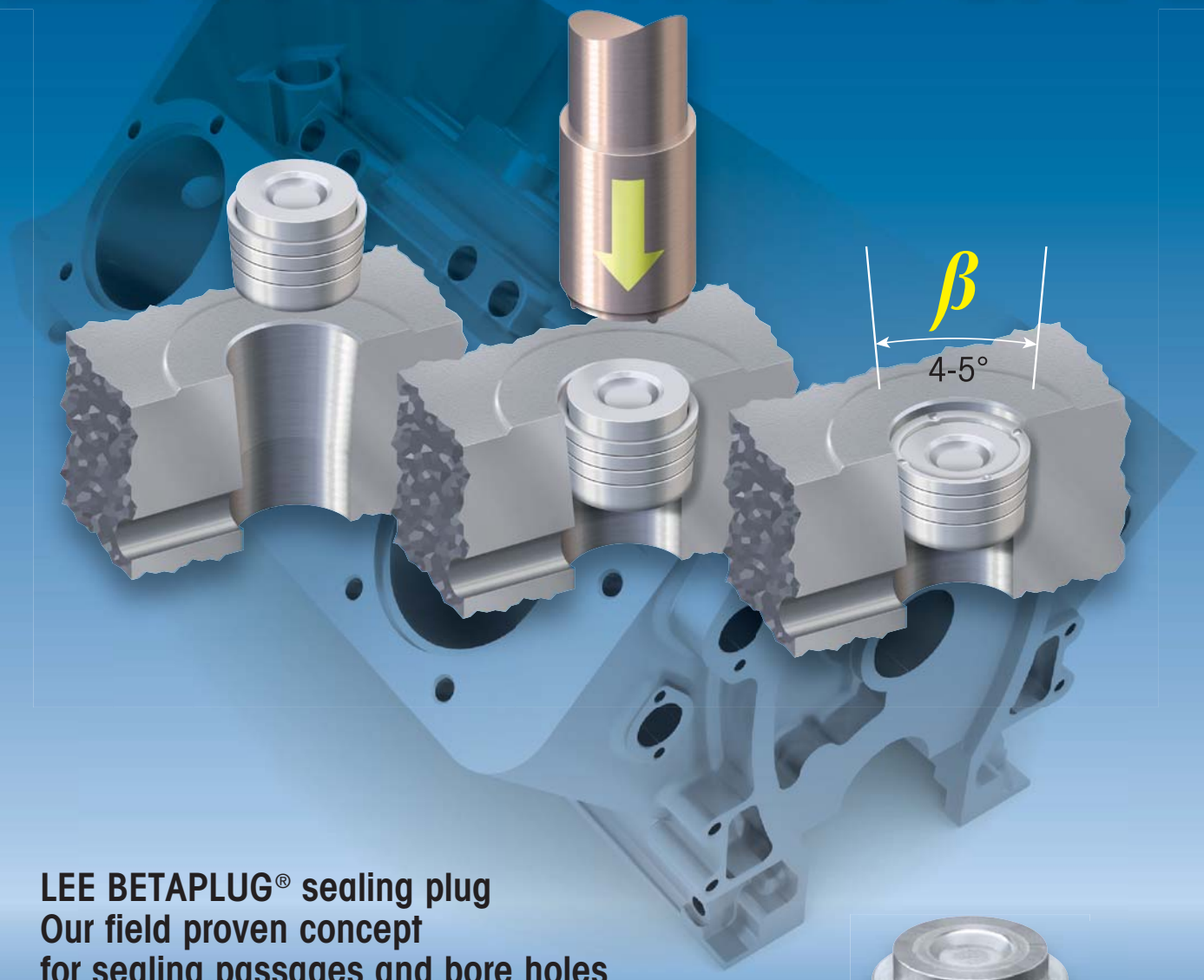

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- Prof. Dr Ferit Küçükay, TU Braunschweig, Institute of Automotive Engineering (IAE)

Introduction

The ongoing discussions regarding fuel consumption and CO_2 emissions require the consistent development of more efficient drives and resource-efficient mobility. More attention must be given on the interactions of components at the system level in order to exploit all potentials for increasing the overall efficiency. In this regard, transmissions have a key position: on the one hand the shift strategy determines the operating point of the engine and therefore the overall efficiency of the drivetrain. On the other hand each individual component of the transmission causes losses which have to be minimized.

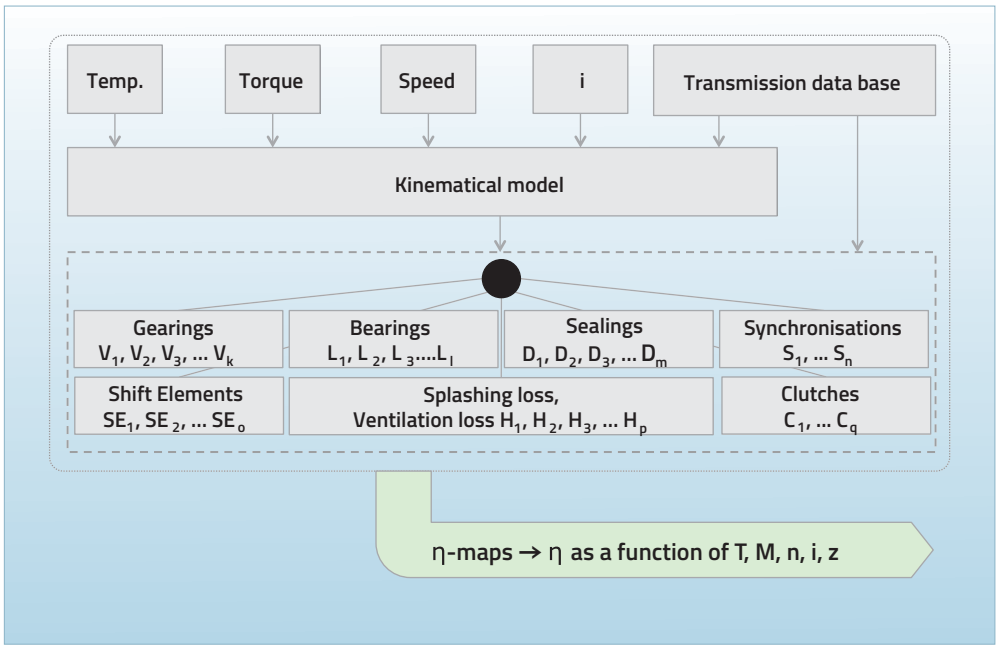

Figure 1
Transmission Power Loss Calculation Modell

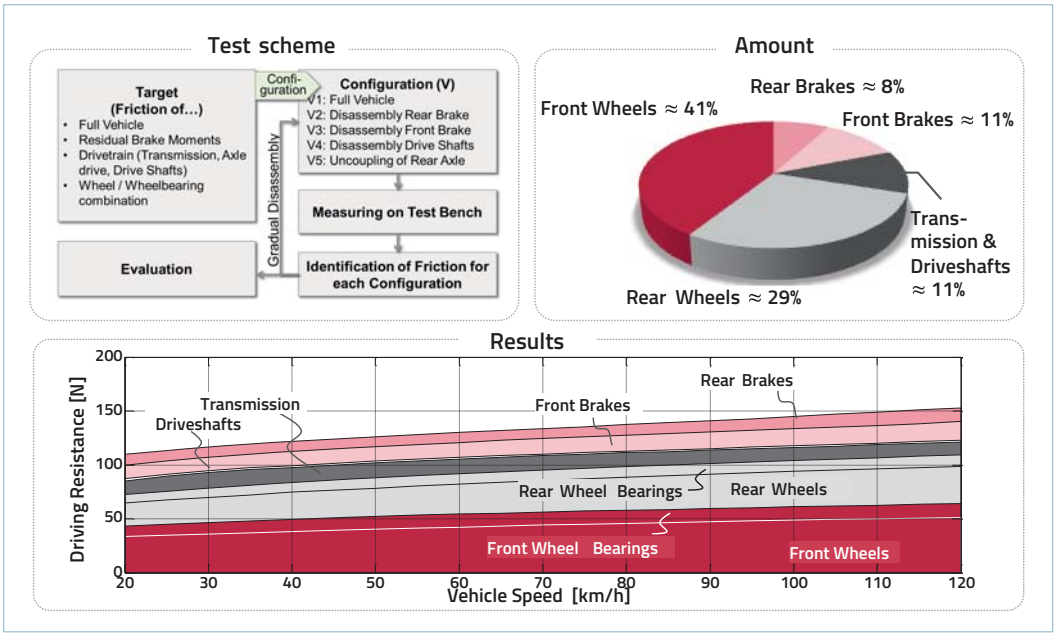

Figure 2
Results for Drivetrain Friction Losses

Transmission Losses

For a holistic evaluation of transmission component losses in the system context of the entire vehicle a tool for the calculation of losses for manual and dual clutch transmissions was developed at the Institute of Automotive Engineering (see Figure 1).

This model is based on empirical approaches and verified by measurements. It allows the calculation of the overall transmission efficiency as well as the losses of the individual components depending on various environmental parameters. This includes losses of bearings, gearings, sealings, synchronizers, switching devices, load-independent losses of the gearings and in case of dual clutch transmissions losses of the clutch. Depending on the operating point up to 80 % of the losses are caused by bearings and gearings. The transmission efficiency shows a high sensitivity to the transmission input torque. Less pronounced is the behavior with respect to the input speed.

Conversion and Transfer Losses

In order to fully reflect the demand of energy for conversion and transfer losses of the drive, all other losses (including power losses of wheel bearings and residual brake moments) are determined by measurement. The determined driving resistance is for the whole vehicle between about 100 N at 20 km/h and 150 N at 120 km/h. Due to the successive disassembling of the brakes, drive shafts and by decoupling the rear axle, the friction torque of the entire vehicle, the residual brake moments of both axes, the friction of the drivetrain and front and rear wheel bearing combinations is identified. In a next step, the share of the power losses of the wheel bearing and the losses by the drive shafts are measured on special test benches. This is necessary because the share between wheel and wheel bearings, and drive shaft and transmission is not quantifiable in the total vehicle measurements. Figure 2 gives an overview on the distribution and amount of the frictional losses of a midsized vehicle, which were obtained by measurements in the entire vehicle and on component test benches.

Full Vehicle Simulation

With the help of a full vehicle simulation the vehicle energy balances are presented. Moreover energy potentials are identified and analyzed. The consideration of system-side interactions succeeds by connecting the components (including energy conversion, transmission and other powertrain components). The analyses take place under consideration of the environmental conditions and are evaluated both in the New European Driving Cycle and in representative customer use. Therefore the 3D (Driver, Driven Vehicle, Driving Environs) methodology is used. The 3D method is an efficient tool for analyzing the field of customer use. The key element of the method is the so-called 3D parameter space, which was derived from extensive measurements and is represented in the simulation.

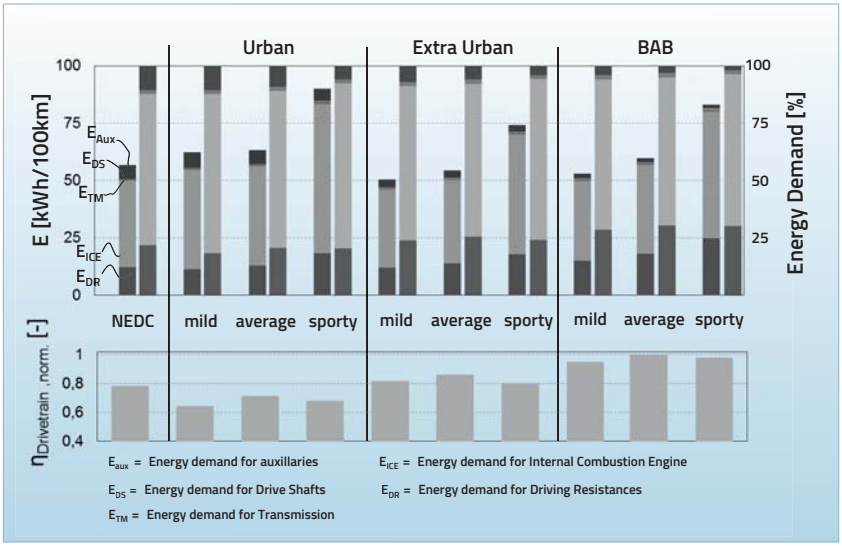

Figure 3 Results for Energy Consumption in NEDC and in Customer Use

The axes of the 3D parameter space represent three variables: Driver, Driven vehicle, and Driving environs. The "Driver" is characterized by driving style, divided into mild, average and sporty. The "Driven vehicle" is defined by the four load conditions light, average and full as well as fully loaded with trailer. The "Driving environs" is influenced by the type of road the customer chooses, which means that customer use is fully covered by taking urban, extra urban, mountain and highway roads into account [1].

To get customized energy consumption the initially definition of a problem-specific 3D-Parameter Space is need. The comparability between NEDC and the customer use is done by characteristic parameters which describe the vehicle and the usage. Examples for this are cycle based parameters like average friction coefficient or average selected gear, cycle parameters like average acceleration or deceleration, and energy related parameters like energy demand for driving resistances.

The representative customer use and the composition of the energy consumption are focused in the simulation in addition to the detailed energy balance of the vehicle to identify energy optimization potentials. The investigations for transmission and drive train efficiency are carried out for a midsized vehicle with 7-speed dual clutch transmission. The energy demand of the drivetrain including the transmission losses on component level is based on the transmission load profile. The drivetrain efficiency is improved significantly the more dynamically the driving environment and driving style is; although this causes a higher amount of losses (see Figure 3).

The optimization of the internal transmission efficiency is based on an improvement in the surface roughness of teeth [2]. The measure to enhance the outer transmission efficiency is done by changing the ratio for the axle drive to longer amounts. The results vary for different driving styles and driving environments. For the optimized tooth surface energy savings can be particularly achieved for mild and average driving style in (extra-) urban environment. The engine operating points change slightly towards lower loads due to the lower performance degradation at the transmission. However, this effect is compensated by the shift strategy. By optimizing the tooth surface, customer-type-specific energy savings of up to 12 % can be achieved. In this case, the mild urban driver has the maximum energy optimization potential at component level. But at system level, the maximum saving is only about 1%.

A longer gear ratio leads to significant system efficiency benefits due to energy-optimized operating points in urban traffic. However, this effect is not pronounced the same for all types of customers. Thus, especially in urban transport (about 5 %) maximum fuel savings can be achieved, while on highway it even has a positive effect, but not that distinct. However, the measure has disadvantages for some of the transmission component losses. One example is higher gearing losses due to poorer geometric properties.

Conclusion

Different markets and customers can require varying component optimizations. Therefore, the aim must be to define the load spectra of the application range to perform a targeted efficiency improvement. In this context, the presented tool provides a holistic approach to assess the losses of different transmission concepts at component level in the system context.

Literature

[1] Müller-Kose, J.-P.: Repräsentative Lastkollektive für Fahrzeuggetriebe, Dissertation, TU Braunschweig, Institut für Fahrzeugtechnik, 2002
[2] Inderwisch, K.; Eghtessad, M.: Influence of the component efficiency on the drivetrain energy demand, 12. International CTI-Symposium Automotive Transmissions, HEV and EV Drives, 2013, Berlin

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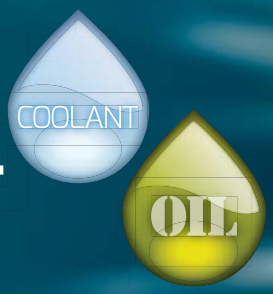

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Auxiliary electric transmission oil pumps can help to facilitate and secure ambitious efficiency goals in multiple ways.

Efficiency's Little Helpers

What happens within the transmission to vital functions like oil pressure and temperature when the combustion engine comes to a stand still? How does one safeguard the instantaneous reaction to the driver's command at any given moment of the stop-cycle?

Herwig Moser, Director Product Segment Powertrain, Bühler Motor GmbH

A family of electric oil pumps addresses not only these challenges accompanying almost all transmission-side energy saving strategies but it helps even to fuel new ideas for further efficiency gains.

Splashing, coasting and hybrid driving

Start/stop operation, "coasting" with the engine switched off or in the electrical phase of hybrid driving: All these conditions have in common that you must maintain pressure, lubrication and temperature control without the help of the combustion engine.

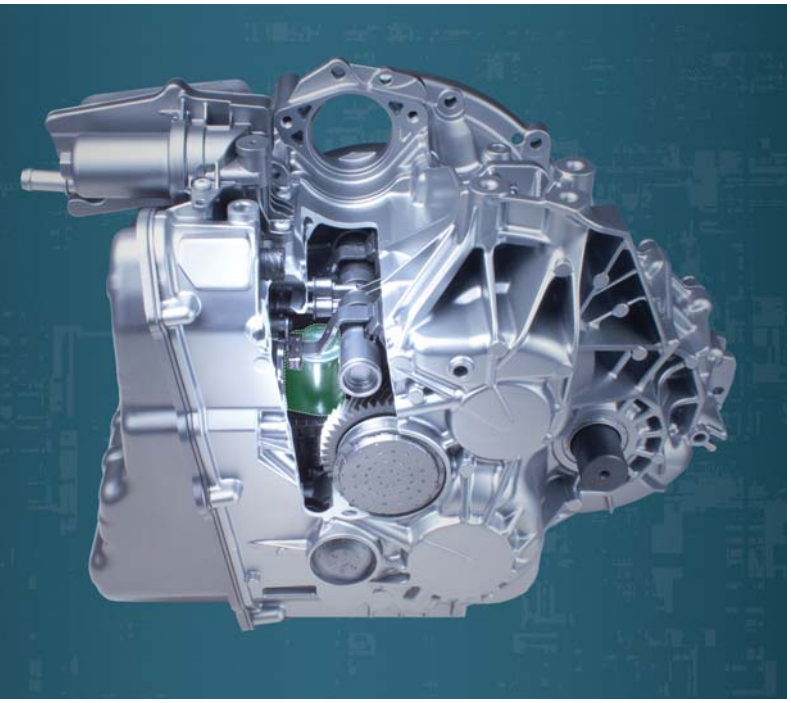


Figure 1 Electric auxiliary oil pumps can improve transmission efficiency

Electric auxiliary oil pumps are the answer. They ensure optimum lubrication and make sure that operating pressure is always safely maintained within the transmission. They are small, highly efficient, location-independent, and even integrable into most existing systems.

Coping with performance peaks

Furthermore electric high-pressure transmission oil pumps can also provide what is called a "boost function" and thus cope with performance peaks, when towing a trailer at crawl speed, for example. This means that it is possible to make the mechanical main pump much more streamlined and improve efficiency even further through this "downsizing".

Reducing splashing losses

In addition, the level of efficiency of the transmission can be improved by reducing "splashing losses". Here, an additional low-pressure transmission oil pump is used, which allows the gearwheel sets to be lubricated specifically and as required.

"Because there are as yet no generally accepted standards for auxiliary oil pumps we had to cover an extremely wide range of applications and operational conditions."

Smooth and easy, but some questions persist

The concepts the different OEMs employ are as varied as the possibilities offered by the transmission designers. In contrast to the electric auxiliary water pumps, in which only the mechanical and electric interfaces generally have to be modified, there are as yet no generally accepted standards for auxiliary oil pumps. There are too many differ-

Figure 2 The bFlow O30, O100 and O300 auxiliary transmission oil pumps

ences between the transmission concepts, experiences and philosophies of the OEMs. The assessment of the use of petrol-saving technologies for new or upgraded transmission at international level is also difficult to predict.

A family designed to tackle all challenges

The Bühler Motor family of auxiliary transmission oil pumps is correspondingly wide-ranging and adaptable. Basically, the family builds on three basic types which cover the various performance ranges.

The bFlow O 30 offers a low-pressure solution in the power range from 10 to 60 W and is particularly suitable for ensuring specific and demand-based lubrication, such as supplying a dry sump lubrication.

With a power of 80 to 150 W, the bFlow O 100 is able to provide a pressure of up to 15 bar and covers both stop/start functions and mild hybrid requirements.

Finally, the bFlow O 300 is available in versions from 160 to 400 W and provides a pressure of up to 25 bar. It is therefore the first choice for full hybrid use and can easily fulfill further functions in addition to this.

Outside or inside? It's your's to choose

The bFlow O 100 and bFlow O 300 can be used both in versions outside and inside the transmission. The charm of the external layout is the relative ease of integration in existing transmissions so that further functions can be added. Sealing against ambient conditions such as spray water, wave water or steam jet use and creating a reliable divide between the oil and the dry area must be taken into consideration.

These points no longer need to be considered with installation inside the transmission. Here oil flows around all the parts. There is therefore no need for a special sealing concept for the pump and the electrical motor, but care must be taken to ensure that all components are compatible with the transmission oil, with all its additives.

"Finally we came up with a platform that enables tailor-fit solutions in less time and at lower cost."

Command and conquer

Also the question of controlling concepts arises for all pump types. Should the transmission control unit take over the complete function? Does it need the position signals for commuting, e.g. Hall sensors? Or should the pump, as a "powerpack", provide the complete intelligence with integrated controller to communicate with the vehicle via LIN or CAN bus? And here too, there are various possibilities: Does the pump receive information from outside, such as the current temperature, and then adjust automatically, or does it follow the instructions of the transmission control device?

Comfortably building on a flexible platform

Basically, therefore, the full bandwidth is available: from the simple on/off switch through sensors for simple functions such as defining and monitoring a certain speed of rotation through to an analysis of the ambient conditions with highly dynamic control.

The scope of functions, designed space or control strategy: With its wide range of variants, adaptability and scalability, the bFlow O family of auxiliary transmission oil pumps provides outstanding solutions for all kind of applications. It has been designed with a wide scope of operational conditions in mind and allows one to reach a viable tailor-fit solution in less time and at lower cost than as yet thought possible.

Blocker Ring Basic made by HOERBIGER

New Solution for Single-Cone Synchronizers

The traditional single-cone synchronizer based on the Borg-Warner principle certainly leaves room for improvements and innovations, as HOERBIGER has proven with an attractive portfolio of synchronizer rings that cover every need. The Blocker Ring Basic (BRB) serves as the basis, requiring no additional friction linings and featuring a cost-effective steel construction.

Ottmar Back, Product Manager, HOERBIGER Antriebstechnik GmbH

According to data from IHS Global Insight, today more than half of all passenger cars worldwide are equipped with manual transmissions, double-clutch transmissions and automated transmissions – with manual transmissions representing the lion's share. This high percentage is forecast to remain unchanged in the future. A wide ratio spread is sensible even with manual transmissions because automobile manufacturers are under pressure to lower emissions and strive to improve fuel efficiency. As a result, the number of gears increases as well, and along with this the number of synchronizers necessary for every gear shift. This trend tends to drive up the weight and costs for cars with a large number of gears. However, the performance capability of a synchronizer varies based on gear and engine power. This opens up a broad market for cost-efficient synchronizer solutions, for which HOERBIGER has unveiled innovative solutions over the past few years. In addition to the entirely newly developed CompactLINE, a new synchronization technology for small and mid-sized cars, HOERBIGER has also given the traditional single-cone synchronizer a makeover. With the Blocker Ring Basic (BRB), HOERBIGER is presenting a single-cone synchronizer made of steel, in which special microgrooves perform the function of a friction lining. HOERBIGER complements this cost-effective basic solution with synchronizers that also feature newly developed sintered friction linings as well as top-quality carbon linings.

Synchronizer rings: materials and friction coefficients

The cone surface is of central importance for the performance capability of synchronizers since this is where the greatest forces act during shifting. During synchronization, the rotational speed of the transmission shaft is matched to that of the particular gear wheel. This is done by deceleration or acceleration between the conical ring and the counter cone on the engagement wheel. To increase the performance capability of traditional Borg-Warner synchronizers, there are two factors that can be modified: the size of the friction surface and the durability of the friction lining. The first option is pursued with multicone synchronizers, in which additional conical rings are available for transmitting force – thereby increasing the design complexity, and consequently also costs. The second approach addresses different friction linings for the cone surfaces, and thus the material and processing of the conical rings. This aspect will be the focus below.

Traditional synchronizer rings, even today, are frequently made of brass. This copper alloy has self-lubricating properties and is therefore also suitable as a friction material. Brass, however, also has drawbacks. For example, it is not possible to implement certain finished geometries by way of cold forming when using brass – a comparatively inexpensive manufacturing process. A second step then becomes necessary, which involves secondary machining. In addition, brass has only limited wear resistance since it is a relatively soft material, which is noticeable in the cone and in the area of the teeth.

Steel, in contrast, is a better material when it comes to durability. Moreover, steel offers many possibilities today in cold forming, making efficient production methods available when this material is used to produce synchronizer rings. The material lacks the self-lubri-

Figure 1 Blocker Ring Basic (BRB) with microGROOVE

About HOERBIGER

HOERBIGER Drive Technology is a Strategic Business Unit of HOERBIGER Holding AG in Zug, Switzerland. HOERBIGER is active throughout the world as a leading player in the fields of compression technology, drive technology and automation technology. In 2013, its 6,400 employees achieved sales of approximately 1.05 billion euros. The HOERBIGER brand is synonymous with performance-defining components in compressors, industrial engines and turbines, automobile transmissions, and multifaceted mechanical engineering applications. Innovations in attractive technological market niches are the basis for components and services that offer unique selling propositions and long-term benefits for the customer. We set standards.

cating properties that brass has to offer though, which typically requires steel synchronizer rings to be provided with a special friction lining – making the production process complex again, and driving up costs as well.

Blocker Ring Basic: Microgrooves make the difference

This is where the HOERBIGER Strategic Business Unit Drive Technology comes in with the newly developed Blocker Ring Basic (BRB). The component made of sheet steel dispenses with additional friction linings thanks to the innovative microGROOVE feature. "We assigned ourselves the complex task of developing a synchronizer ring in the entry-level price segment which has the advantages of brass rings, yet is wear resistant and cost-effective to produce in large volume," Ottmar Back from HOERBIGER Antriebstechnik GmbH commented. Thanks to the perfected production process and wear-mitigating heat treatment in the nitriding furnace, all the functional features, final dimensions and the microGROOVE of the BRB are generated in the forming tool, making subsequent machining not necessary. HOERBIGER is thus able to guarantee not only reliable manufacturing quality, but also an optimal cost structure in high-volume production. The latter is also due in no small part to the fact that steel – unlike brass – has a more stable material base price. Still, the merits of the steel ring over brass rings can also be backed with other figures. "The new BRB attained outstanding values in fatigue strength testing," Back added. "Compared to brass rings, we have reduced axial wear by around 90 percent and set a new standard in terms of robustness in this price segment." Thanks to steel's lower thermal expansion, clearances can also be optimized, which positively impacts the space constraints encountered in particular in subcompact cars and vehicles in the compact class. This is precisely the segment targeted by the HOERBIGER BRB, which is about to be launched in series production: it offers an economical alternative to brass rings for subcompact and compact cars that are equipped with moderate engines and produced in high volumes.

Solutions for all vehicle classes

At the same time, HOERBIGER offers innovations of the traditional single-cone synchronizer for applications where higher demands are placed on the synchronizer. The Blocker Ring Evo (BRE), for example, complements the portfolio in the mid-range segment. This approach sinters a friction lining onto a stamped ring even before the forming operation. A synchronizer ring is then produced over multiple steps

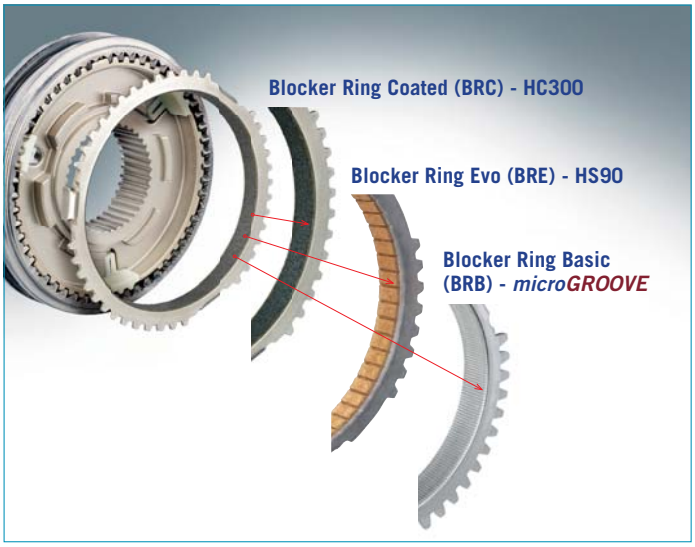


Figure 2 HOERBIGER Single Cone Solutions

using cold forming, its cone being formed together with the friction lining. The advantage of this method is that the friction lining does not have to be subsequently applied (bonded) to the synchronizer ring, and it is given added strength as a result of the production method. The sintered BRE synchronizer ring has a favorable price-performance ratio.

HOERBIGER offers its Blocker Ring Coated (BRC) for applications where particularly high synchronizing forces are encountered or where high-additive transmission fluids present an especially tough environment for the frictional characteristics of the conical rings. Here, a carbon lining that has extremely robust frictional characteristics is applied to a steel synchronizer ring. The outstanding performance, which exceeds that of the other two approaches, makes the complex production method worthwhile.

For particularly high shifting action, HOERBIGER also offers multicone solutions based on BRE and BRC technology. The company has a comprehensive product portfolio for synchronizers in place and an excellent presence in a market that has always placed particular emphasis on customized solutions that are flexible in regard to costs and the performance spectrum.

From metal to plastics in transmissions and driveline

Vespel® parts: Low Friction, Lightweight and Durable Metal Replacement

Talk to almost any automotive engineer involved in transmission and driveline development and they'll be looking for answers to these questions:

- How do I save weight without compromising part performance?
- How do I improve performance while reducing fuel consumption?
- How do I minimize friction losses between moving parts?
- How do I reduce cost?

For many applications, the answer is to replace metals with high performance plastics and composites.

CTI Mag interviewed **J. Ruterbusch, Global Transportation Segment Manager for Vespel® and Kalrez® Parts business at DuPont Performance Polymers,** to find out how the company is collaborating with auto engineers to provide solutions to the latest materials challenges in transmission and driveline.

Vespel® seal rings and thrust washers (in yellow in the picture) excel in driveline applications such as automatic and continuously variable transmissions (CVT), transfer cases and torque converters. Image: Copyright® DuPont.

Vespel® thrust washers and seal rings for driveline applications such as automatic and continuously variable (CVT) transmissions, transfer cases and torque converters. Images: DuPont.

CTI Mag: What trends do you see in automotive drivelines?

J. Ruterbusch: For several years now there has been a tremendous push in the industry to reduce vehicle weight and this trend continues. OEMs are equating dollars to every kilogram of weight shaved off the vehicle, and they talk in terms of taking 10 % off the chassis, 15 % off the engine, and a very significant 20 % off transmission and driveline. So if you are an automotive design engineer working on a big weight reduction program, the best way to achieve that is to replace metals by plastics and composites.

Much of the transition from metals to plastics has already taken place in engines via intake manifolds, cam covers and other significant parts. But when we look between the engine and the wheels we still see a lot of metal and few composites. That has been the drive for DuPont to work with OEMs to develop components that replace metals and provide cost – and most importantly – weight savings. We are turning the corner in this area. With the use of computer simulation and the evidence from commercial successes we have demonstrated how well polymers work in many applications where metal was heavily involved.

A key mega-trend we are seeing is the shift away from purely manual transmissions to automated transmissions. This includes affordable, low cost, lightweight continuously variable transmissions (CVTs) as well as multi-speed dual clutch designs.

In addition, regardless of transmission design, engineers want to improve efficiency by reducing friction – that's another mega-trend. Globally we're seeing significant effort and funding for projects where reducing friction and frictional losses are now a key objective.

Low friction DuPont™ Vespel® material performs reliably with or without lubrication in conditions that can cause severe wear to metals, and destroy many other plastics. It is at the top of the polymer pyramid with its high load and high-speed capabilities (high PV limits). Vespel® parts enable new design solutions such as higher shaft speeds and loads. They can replace metal thrust bearings to reduce overall size and weight, or enable the use of lighter weight metals. For example, due to its excellent wear properties against aluminum, using a Vespel® part may eliminate the need for heavier steel inserts or sleeves.

CTI Mag: Can you give examples of applications where plastics can provide advantages over metals?

J. Ruterbusch: One of our customers, looking for a material with excellent wear resistance for a transmission fork application, was convinced that only a move from aluminum to bronze would give the wear and friction characteristics needed. But bronze is very heavy. We provided the solution using Zytel® HTN high performance polyamide with two Vespel® wear pads which have proven to be significantly more resistant to wear than bronze.

Almost any new transmission design project can be an opportunity to replace metal. For example, a major Asian transmission producer replaced metal needle bearings in a CVT transmission with Vespel® thrust washers. These are significantly thinner than the metal needle bearings and one-third the weight, allowing the Tier supplier to reduce the overall size and weight of the CVT unit.

A European transmission producer also gained weight and space-savings, as well as maintenance-free advantages by designing with Vespel® parts. The company installed highly abrasion-resistant low friction Vespel® SP sealing rings in its CVT.

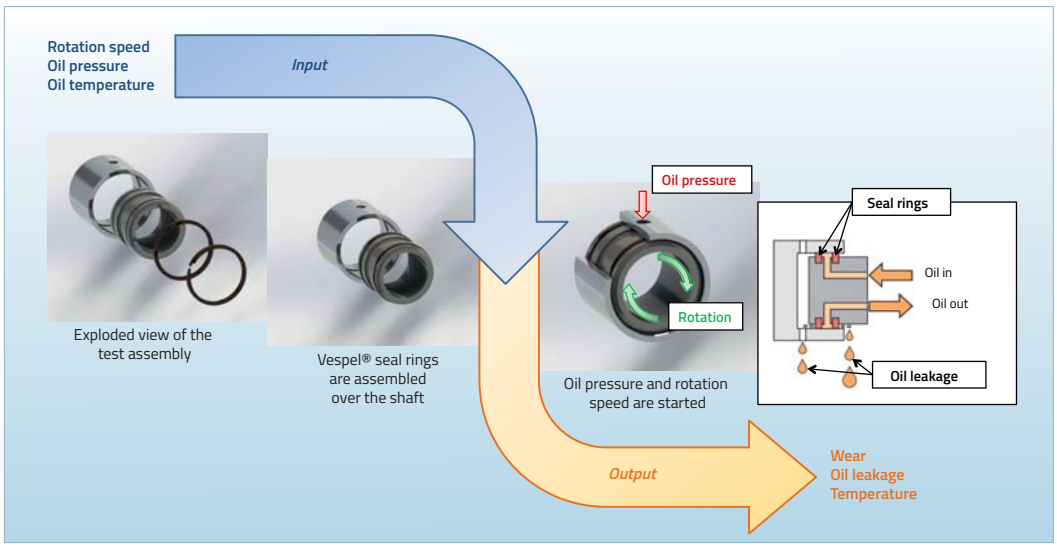
In the engine section, Vespel® valve bushings have replaced metal components in an exhaust gas recirculation (EGR) system used in four and six cylinder stratified-charged petrol engines, thanks to the advantages of Vespel®: stiffness, tensile strength, and resistance to friction, wear and hot exhaust gases at temperatures up to 220 °C. The bushings position and guide the cylindrical operating rods of EGR slip-in valves, supporting their smooth operation during millions of openings and closings. And a leading global supplier of innovative turbocharging systems chose Vespel® bushings to improve the reliability and durability of its pneumatic actuators used in turbocharger applications.

CTI Mag: Where do you see the greatest contribution of plastics?

J. Ruterbusch: There is enormous potential for polymers in automatic transmissions and drivelines. Wherever engineers need to take out weight and cost and reduce component size while sealing fluids, resisting wear, friction and loads, and withstanding chemical attack at low and high temperatures – DuPont have the products to do that.

For example, Vespel® material has a density ranging from 1.35 to 1.77, depending on grade, compared with steel at about 8.0, making weight reductions of up to 80 %, and cost savings of 30 – 50 % possible. It also has a much lower coefficient of friction, enabling unlubricated operation, downsizing, low friction, a wider operating window, plus high electrical and thermal insulation, unlike metals. As a result, DuPont already has many commercial and developmental applications across the driveline sector.

As loads, fluid pressures and shaft speeds increase, high performance polymers can help provide new levels of vehicle performance – more power from smaller, lighter components. Vespel® parts excel in auto-



Dedicated application testing equipment at the DuPont Wear and Friction Center of Excellence in Switzerland measures the performance of seal rings and thrust washers in automatic transmission fluid. Images: DuPont

matic and continuously variable transmissions, transfer cases and torque converters because they can help make new designs and concepts possible.

CTI Mag: How do you convince engineers of the long-term reliability of Vespel®?

J. Ruterbusch: Since its introduction, Vespel® has been the subject of continual development and improvement. Millions of Vespel® transmission and driveline seals, bearings, thrust washers, bushings and wear pads have been performing well for over 50 years, proving the long-term reliability of the material, not only in automotive, but in applications across all industries.

In automotive, Vespel® thrust washers that replaced metal needle bearings in CVT transmissions manufactured by a major transmission supplier to a big five auto maker became standard equipment some years ago. The significantly thinner and lighter thrust washers enabled the OEM to reduce the overall size and weight of the CVT unit. That's a standout reliability case history that convinces engineers and designers today of the long-term reliability of Vespel® parts.

For our Vespel® business, giving our customers 'peace of mind' is really where the 'Science of Sealing, Wear and Friction' provides its value. First, we have the historical material science capabilities of DuPont backing our resin development and selection process. Second, since we are the supplier of Vespel® parts, we have part testing capability in all three regions: Europe, Asia and the Americas. It's very typical for us to confirm part performance in DuPont laboratories under actual end use conditions as specified by the customer. These test facilities also allow us to optimize design and material selection before the parts are installed in the actual components.

Global testing facilities and competencies on lubricated wear and friction product and applications include the DuPont European Technical Center (ETC) in Meyrin, Geneva, Switzerland, with strengthened cross-regional and cross-functional networks.

Friction performance of seal rings and thrust washers in automatic transmission fluid (ATF) is characterized using dedicated application testing equipment. DuPont tests specific evaluations agreed with customers, and also generates data to help understand and anticipate the behaviour of the materials used in environments that evolve with market needs.

We continuously undertake studies to understand the wear and friction behaviour of polymeric seal rings, used in new generation automatic transmissions, especially to compare wear performance during initial actuation of the transmission, and long term performance.

This type of information is much appreciated by automotive customers who benefit from the DuPont capabilities and experience in evaluating technical solutions to wear and friction challenges in automatic transmissions, and from the comparisons and conclusions drawn from their own in-house or field testing. It also provides evidence supporting the long-term viability of Vespel® polyimide parts in replacement of metals.

Finally we have production capability in all three regions as well. All facilities operate to global quality standards as required by our customers.

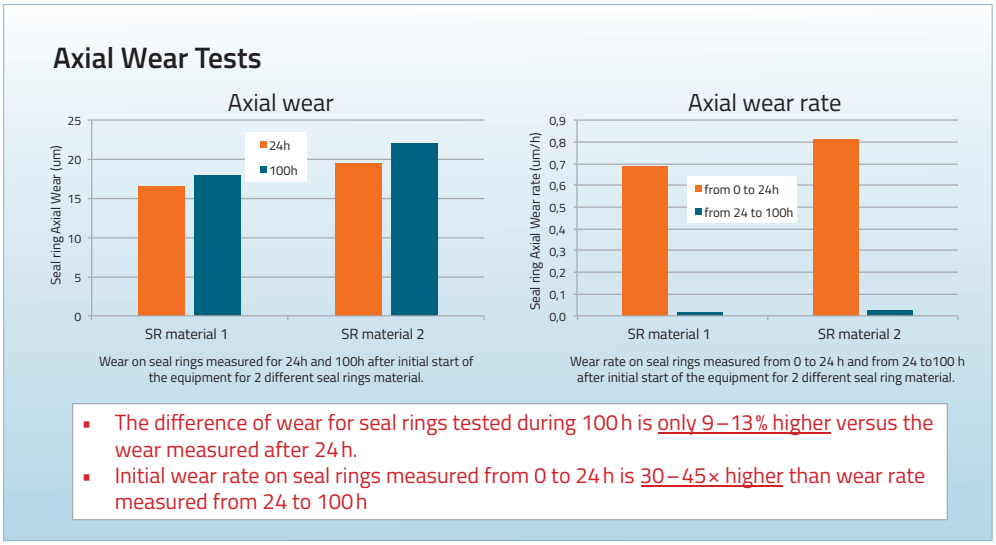
CTI Mag: Can you comment on some product capability highlights of Vespel®?

J. Ruterbusch: I'd highlight the ability of Vespel® parts to operate continuously in temperatures from -196 °C to 349 °C and above, while offering low wear and low friction at high loads and velocities in lubricated or unlubricated environments. Vespel® S parts do not have a melting point and can survive temperature excursions as high as 482 °C. Special Vespel® SCP heat resistant grades can withstand temperature excursions to 650 °C.

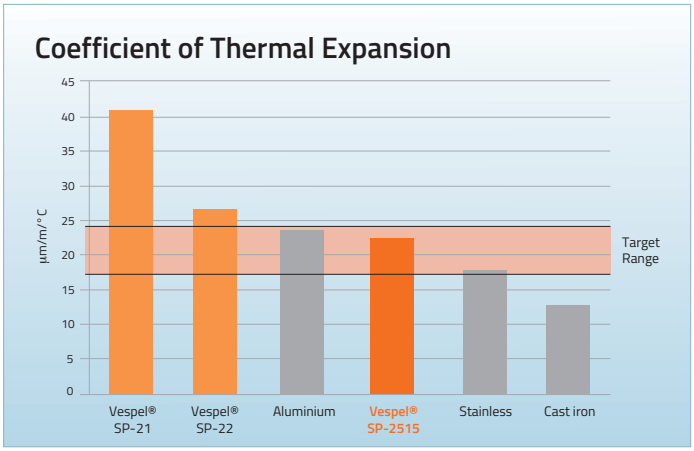
The latest Vespel® S grade, for example, exhibits a low coefficient of friction and excellent wear against aluminum. DuPont tests have demonstrated that those Vespel® S parts can

- provide significant improvement in measured torque loss on a transmission shaft
- reduce seal ring leak rates, lowering the parasitic losses associated with the transmission oil pump
- contribute to weight reduction compared to metal.

Vespel® S is commercialized in transmission seal rings offering very low friction, tolerance control over a broad temperature range, and long life.



The charts show that during the first 24 hours, the wear rate (amount of wear by time unit) of the seal ring measured in the axial direction is much higher than that observed from 24 to 100 hours. This phenomenon, often seen in friction applications, enables a better understanding of the relevance of long term testing in evaluating the wear performance of friction parts.
Charts: DuPont.



Coefficient of thermal expansion of different materials in comparison. Chart: DuPont

milliseconds, to meet government crash worthiness requirements, for example.

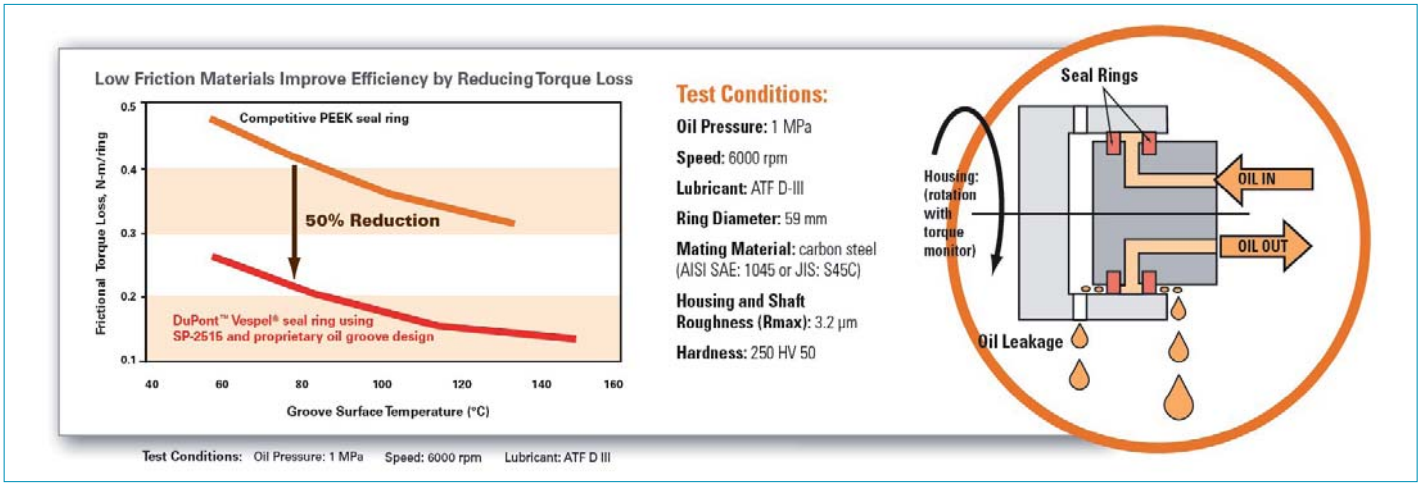
And I believe it really centers on 'peace of mind'. As mentioned earlier, we apply our science all the way from material selection to end-use testing. And because we are a global company, we can rely on our global network to support our customers anywhere they need us.

DuPont offers the industry's broadest range of polymer composites, engineering polymers and elastomers. The automotive industry already uses these products extensively. They include Crastin® PBT thermoplastic polyester resin, Hytrel® thermoplastic polyester elastomer, Kalrez® perfluoroelastomer parts, Rynite® PET thermoplastic polyester resin, Vamac® ethylene acrylic elastomer, Viton® fluoroelastomer, Zytel® high performance polyamide and of course Vespel® parts and shapes.

DuPont polymers are proven in use in manifolds and gaskets, air ducts, turbocharger hoses and resonators, EGR seals, hoses, valves, bushings, thrust washers, to name some. The in-depth and long-term experience in providing the automotive industry with optimal polymer and/or part solutions to meet their specific requirements and regulations – embracing downsizing, light weighting, fuel economy, alternative drive systems and safety – make DuPont an ideal partner to collaborate with.

CTI Mag: What are the advantages of working with DuPont?

J. Ruterbusch: Our customers benefit from the technical application development support services, ranging from concept design to product testing. We work closely with OEMs on computer simulation involving almost the entire driveline including axles, wheels, springs, shock absorbers. We also have in-house capability to run material behaviour projections that allow modeling of dynamic crash events in



Above chart shows the maximum potential torque loss reductions that can be reached using an optimized Vespel® material and seal ring design.
Image and chart: DuPont

Gear Condition Diagnosis using Cepstrum Analysis

Predicting gear pair defects by analyzing changes in vibration signal of gears pairs in operation is a very reliable method. Therefore, a suitable vibration signal processing technique is necessary to extract defect information generally obscured by the noise from dynamic factors of other gear pairs. This article presents the value of Cepstrum analysis in vehicle gearbox fault diagnosis. Cepstrum represents the overall power content of a whole family of harmonics and sidebands when more than one family of sidebands is presented at the same time. Cepstrum analysis is used for detection of an artificial pitting defect in a vehicle gearbox loaded with different speeds. Also, a method for fault diagnosis of gear faults is presented based on order cepstrum. The procedure is illustrated with the experimental vibration data of the vehicle gearbox. The results show the effectiveness of Cepstrum analysis in detection and diagnosis of the gear condition.

Mohamed El Morsy, Czech Technical University in Prague, Czech Republic / Helwan University, Egypt
Gabriela Achtenová, Czech Technical University in Prague, Czech Republic

I. Introduction

An efficient condition monitoring scheme is capable of providing warning and predicting the faults at early stages. For early detection of a fault vibration signal from the machinery is analyzed. There are many methods for analyzing vibration signals [1]. Many of these methods are effective in simple machinery components, but for complex components, such as a vehicle gearbox, the effectiveness of these methods degrades. For such conditions cepstrum analysis [2 – 4] provides more efficient results.

Spectrum analysis has some constraints in with respect to the vibration analysis which are overcome in a cepstrum analysis. 'Cepstrum' is the spectrum of a "spectrum on logarithmic scale". Thus, it is a further analysis of the spectrum reducing each harmonic and sideband family in the spectrum to a single component and a few 'rahmonics' (it may be noted that cepstral is the inversion of spectral in spectrum). The transmission of gear tooth meshing vibration from the tooth contact region to the shaft, through rolling element bearings and then through the gearbox casing can have an important influence on the measured vibration spectrum. In a conventional frequency analysis of a spectrum the effect of the transmission path obscure the true source signature. It is also not possible to pinpoint the defects accurately. Transmission path effects are additive and can be separated in cepstrum which also gives accurate detection of the periodic structure within a spectrum associated with many harmonics and sidebands as a single component for each family of sidebands without any difficulty in interpreting the sideband structure unlike in a spectrum.

In the particular case of a local fault in one of the teeth, a localized modulation effect takes place once per revolution of the faulted gear. Several modulation phenomena may be present, each producing a different family of sidebands characterized by the same spacing in the spectrum, equal to the corresponding modulating frequency. As a consequence, the sideband spacing contains diagnostic information, since it is related to the modulation source [5]. However, it can be difficult to distinguish and evaluate the sideband spacing by means of spectral analysis, due to the contemporary presence of several families of sidebands and other components. In order to overcome this problem, cepstrum analysis can be employed. Various forms of cepstrum exist, but all of them can be considered a spectrum of a logarithmic spectrum [5]. For applications in machine diagnostics, the power cepstrum, is well suited and generally applied, as shown in the literature [1] it is defined as the inverse Fourier transform of the logarithmic power spectrum.

II. Description of the Test Set-Up

The measurements are conducted on an open loop test bed consisting of three dynamometric machines. The gearbox is screwed via a flange, which normally serves for assembly with the internal combustion engine, to the test stand. The complete clutch is mounted and operated on the shaft. The input shaft is driven via a belt drive. Original vehicle joint shafts are mounted on the output flanges. The gearbox is shifted and the clutch is operated with the aid of a shift robot. The shifting speed and shift force can be tuned for each gear. The completely newly conceived test stand can reproduce with high dynamics the data measured during real vehicle operation. However, for our purposes we performed the measurements in steady state regimes only.

A. Investigated Gearbox

The gearbox is of the type most commonly used in modern small to mid-sized passenger cars with transverselly mounted powertrain and

front wheel drive; a five-speed gearbox with final drive gear and front wheel differential. The internal arrangement of gears, shafts and bearings is depicted in the Fig. 1. The fifth speed gear specifications are shown in Table I.

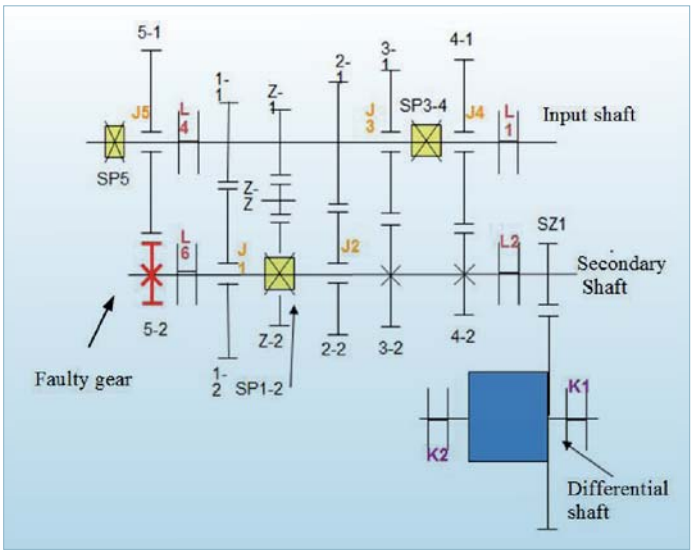


Figure 1 Diagram of the investigated five-speed automotive gearbox

Fifth Speed Gears Specification				
No.	Modal parameter	Notation	Drive Gear	Driven Gear
1	Location in gearbox	--	Input shaft	Intermediate shaft
2	No. of teeth	Z	50	37
3	Gear case	--	Healthy	Faulty (pitted)
4	Transmission ratio	Rp	0.74	

Table I Fifth Speed Gears Specification

B. Description of the Artificial Damage

Fig. 2 shows the pinion for fifth speed with damage on one tooth only. The mesh side of the tooth was damaged by grinding one a pit. The following figure depicts the artificially fabricated fault. The photos and measured data of the pit were acquired with the Video-Probe XLG3 from GE Measurement & Control Systems with the aid of 3D Phase Measurement. The total surface area of the pit is 4.58 mm². The gearwheel is treated as damaged if the surface of damage on one tooth is greater than 4 % of the tooth surface. In our case the damage equals 3 % of the tooth surface. This means there is a significant pit, but the pinion gear can't yet be treated as damaged.

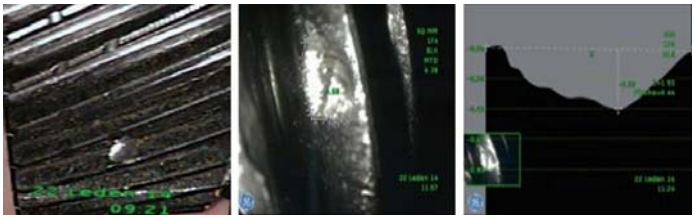


Figure 2 Detail of the pitting damage created on one tooth only

III. Cepstrum Analysis

These are multiplicative in the spectra and additive in the logarithmic spectra and the cepstra. A cepstrum is the forward Fourier transformation of the logarithm of a spectrum. It is therefore the spectrum of a spectrum, and has properties that make it useful in many types of signal analysis. One of its more powerful attributes is the fact that any periodicities, or repeated patterns, in a spectrum will be sensed as one or two specific components in the cepstrum. If a spectrum contains several sets of sidebands or harmonic series, they can be confusing because of the overlap. But in the cepstrum, they will be separated in a way similar to the way the spectrum separates repetitive time patterns in the waveform.

IV. Vibration Measurements

The vibration acceleration has been recorded during the gearbox operation. A B&K portable frontend module type 3050-B-040 for 4 channel input 50 kHz analyzer is used. The speed is measured using a Tachometer Type MM360, and a tri-axial TeltaTron type 4524B with measuring range 500 m/s². The vibration signal in vertical and radial terms is presented in this article. The sampling frequency used was 6.4 kHz and signals of 0.5 sec duration were recorded.

V. Results And Discussion

Cepstrum enables detection of periodicities in quefrency domain usually as results of modulation. The frequency spectrum technique will not have information on wether changes come from the source or

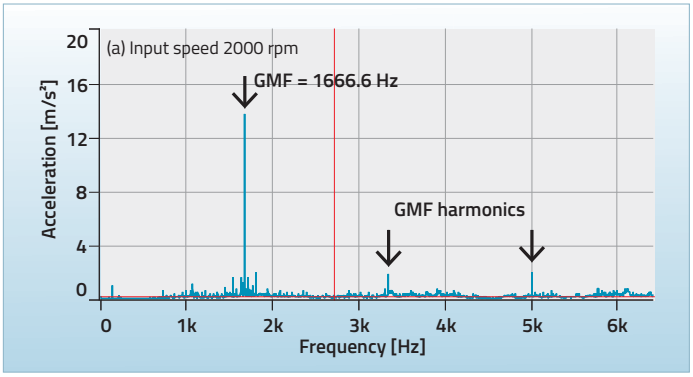


Figure 3 Frequency spectrum for faulty gear in fifth speed of 2000, and 3000 rpm, input load 130Nm

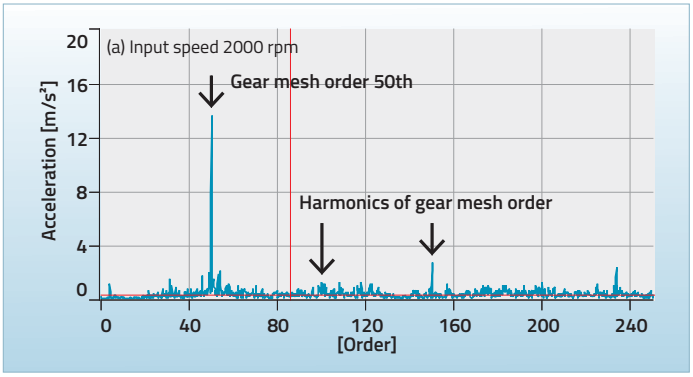


Figure 4 Order spectrum for faulty gear in fifth speed of 2000, and 3000 rpm, input load 130 Nm

transmission path. Harmonics and sidebands in the spectrum represent the concentration of excitation energy caused by the rotation component, and they are typically used to detect any abnormality in the operation.

The original non-stationary vibration signals with gear pit fault are displayed in Fig. 3 to Fig. 5 in terma of frequency, order spectrum and time domain, at different speeds and input load 130 Nm.

Fig. 3 displays the frequency spectrum of the vibration signals with the faulty gear and the mesh frequency and it harmonics are shown, the position of which depends on the rotation speed and number of gear teeth. It is clear that the resulting spectrum is significantly obscured by spectral smearing. In addition, traditional spectral averaging cannot be applied to the non-stationary signal. Fig. 3 clearly shows that spectral smearing substantially affects the result of conventional analysis based on time sampling. Therefore, classical Fourier analysis has some limitation such as being unable to process non-stationary signals.

Fig. 6a, and Fig. 7a show how severe the damage to the driven gear is, by presentation the number of rahmonics of driven shaft rotation as the source of the problem. Cepstrum is indicates periodicity at 22.22 m sec, which is 45 Hz or rotation by driven shaft for input shaft speed 2000 rpm and 14.8 m sec, which is 67.56 Hz or rotation by the driven shaft for input shaft speed 3000 rpm.

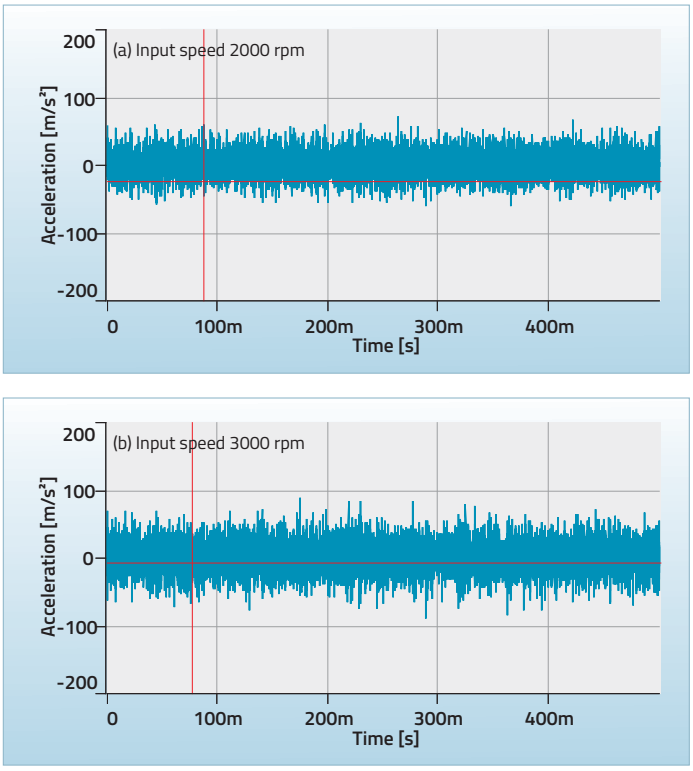


Figure 5 Time domain for faulty gear in fifth speed of 2000, 3000 rpm, and input load 130 Nm

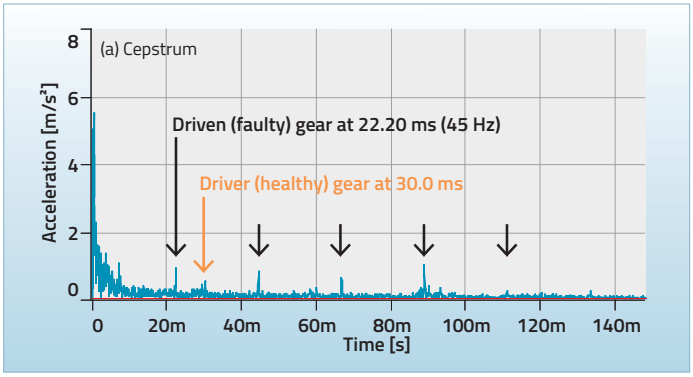


Figure 6 Cepstrum analysis at input speed 2000 rpm, and input load 130Nm

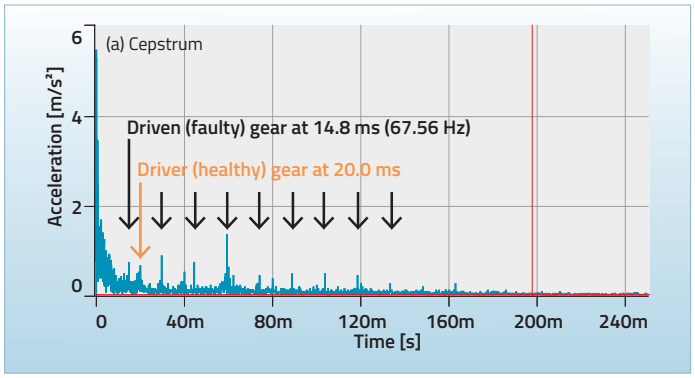


Figure 7 Cepstrum analysis at input speed 3000 rpm, input load 130 Nm

The order cepstrum is depicted in Fig. 6b, and Fig. 7b. In the case of the order cepstrum, it can be seen that the characteristic order for a faulty gear, gear mesh orders and its harmonics are represented in the order cepstrum. The simplicity of the order quantity representation can be put down to the ability of the order signal processing method to eliminate undesirable spectral smearing and modulation effects. Demonstrate the advantage of the order cepstrum for the analysis vibration signals generated at different input speed.

VI. Conclusion

Cepstrum analysis appears to be efficient for detecting changes not easily noticeable in the spectrum. A major benefit of using the cepstrum technique would be earlier damage identification, it is clear and easier to see the changes. The order cepstrum can identify the characteristic order. Therefore, it can be used in full fault diagnosis of gearbox.

Acknowledgment

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References

[1] Norton, M.P., "Fundamentals of vibration and noise analysis for engineers" Chap. 8, 2005.
[2] Hans Konstantin-Hansen and Henrik Herlufsen, "Envelope and Cepstrum Analyses for Machinery Fault Identification", SOUND & VIBRATION, Brüel and Kjaer, Nærum, Denmark, pp. 10-12 MAY 2010.
[3] Xinyan Zhang et al. "Summarization and Study of Fault Diagnosis Technology of the Main Components of Wind Turbine Generator System", ICSET, IEEE, pp. 1223-1226, 2008.
[4] Childers, D.G., Skinner, D.P. & Kemerait, R.C., "The Cepstrum: A Guide to Processing". IEEE Proc. Vol. 65, No. 10, pp. 1428-1443, October 1977.
[5] B.D. Forrester, "Advanced Vibration Analysis Techniques for Fault Detection and Diagnosis in Geared Transmission Systems", Ph.D. Thesis, Swinburne University of Technology, Australia, 1996.

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Pressure-based Pilot-operated Clutch Control in Transmission Applications

The Closed-Loop Pressure Control (CLPC) concept takes advantage of fast-acting low-complexity solenoid actuators together with a pressure sensor to control the clutch pressure. In a pilot-operated framework, CLPC can achieve a rise time less than 50 ms and a static clutch pressure error lower than 10 kPa over an oil temperature range from –30 to 140 °C. Thanks to a double-V Model-based System Engineering approach the performance of the overall clutch system was optimize by maximizing the performance of the components and sub-systems in a physical domain sense.

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Introduction

The automotive industry has experienced a dramatic change in the last 10 years driven by emissions reduction and vehicle electrification. Governmental regulations and a green-mind set are imposing more restrictive and stringent requirements to the vehicles, which are not only reflected on the components, but also on the manner they are governed and controlled.

In order to meet the emissions and performance targets, OEMs are requesting low cost, high modularity, low weight and high performance transmission solenoids. These components shall maximize hydraulic volumetric efficiency while minimizing the electrical power consumption and the transmission weight. Moreover, actuators shall behave as linear devices so they can be employed in an open-loop current-to-pressure governor framework.

A trend has been set over the last years leading to the development of high complexity transmission solenoids. These are characterized by their low-leakage, linearity of the pressure-to-current map and low hydraulic hysteresis. Thanks to its hydraulic properties, this technology is seen as one of the key-enablers in terms of fuel-efficiency optimization nowadays.

However, direct linear actuators require high magnetic forces to displace and position the spools. Since the magnetic force is proportional to the square of the flux density, larger coils are needed to achieve higher magnetic forces, increasing the electrical power losses due to winding resistance and stored magnetic energy (reactive power). Moreover, the actuator response time is reduced by the augmented inductance and resistance values.

Often it is the case that the benefits obtained in terms of higher hydraulic volumetric efficiency are diminished by increased electrical loses and actuator weight. In addition, the linearity of the current-to-pressure trace increases the complexity of the actuator leading to a higher production cost.

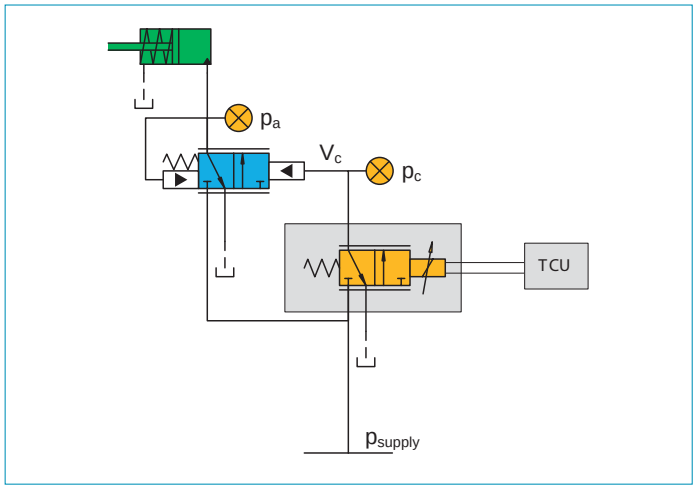

Figure 1 Hydraulic Layout Clutch System

System Description

Figure 1 shows the hydraulic layout of the system under consideration. It consists of a closed oil circuit composed of a 3/2 solenoid valve (pilot valve), a four-way spool flow control valve, a supply system (motor-driven pump), an actuator (hydraulic load), a drain and a measurement system. Supply volume flow Qs, pressure ps and temperature Ts, drain pressure pe, control volume flow Qc and pressure pc, spool valve downstream pressure pa and volume flow Qa, and solenoid voltage us and current is were directly measured.

A pilot-operated spool valve was selected to take advantage of the high power density of the hydraulic system. The spool valve serves as an amplifier and was dimensioned to meet the clutch flow demand.

The hydraulic load (accumulator) was designed to emulate the filling and emptying dynamics and the mechanical and hydraulic forces of the clutch. Its dimensions were selected to meet the dynamics of a 12 bar Normally Closed (NC) automatic transmission (AT) clutch system.

Two possible placements were foreseen for the pressure sensor 1. Pilot Valve Output Pressure (p_c) and 2 Spool Valve Output Pressure (p_a). The pressure in the clutch chamber was not considered due to the high integration effort and increased complexity with respect to the signal communication with the Transmission Control Unit (TCU) that this solution might have. The pilot valve was operated by the TCU using Continental's SDS4 valve driver with a chopper frequency of 3 kHz.

Performance Requirements

The clutch performance requirements were expressed in form of static and transient indexes for the clutch pressure. Figure 2 describes the transient performance characteristics of the clutch piston. The operation region is divided into two areas: 1. Clutch Engagement Range (Blue) and 2. Clutch Torque Transfer Range (Cyan). To demonstrate the performance of CLCP, a target response time t_r <80 ms, pressure overshoot M_p = 0 kPa and a tolerance band of Δ <10 kPa were set (Table 1).

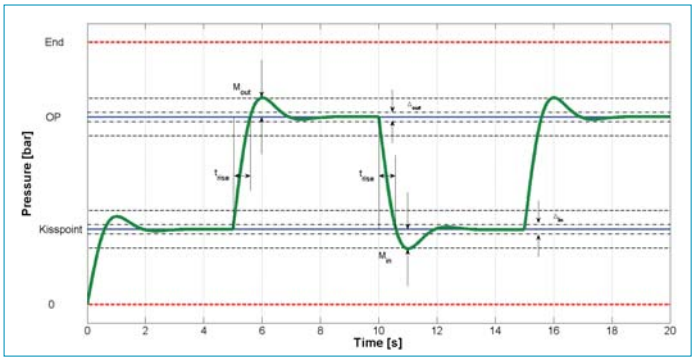

Figure 2 Clutch Functional Performance Requirements

Table 1 Indexes of Performance Clutch System

ID	Name	Symbol	Unit	Target
PR-C01	0-90 Rise Time	t_{rise}	ms	< 80
PR-C02	Settling Time	t_{ss}	ms	<100
PR-C03	Maximum Overshoot	M_p	kPa	0
PR-C04	Tolerance Band	Δ	kPa	<10
PR-C05	Hydraulic Damping Ratio	k	kPa/kPa-	0.7

Methodology

Based on the industry standards a subset of tools and procedures were selected for the development of a multi-domain simulation platform. Goal was to enable the integration of the solenoid driver, pilot-valve, spool valve and load models into other simulation environments to evaluate system behavior at different physical domains. Four (4) criteria were used for selecting the tools to be employed: Scalability, Reusability, Portability and Computing Effort.

A double V-process was set to facilitate component design and control synthesis on a common platform (Figure 3). Figure 4 shows the different simulation domains and the selected tools. This approach was aligned to the VDI 2206 Design Methodology for Mechatronic Systems [1].

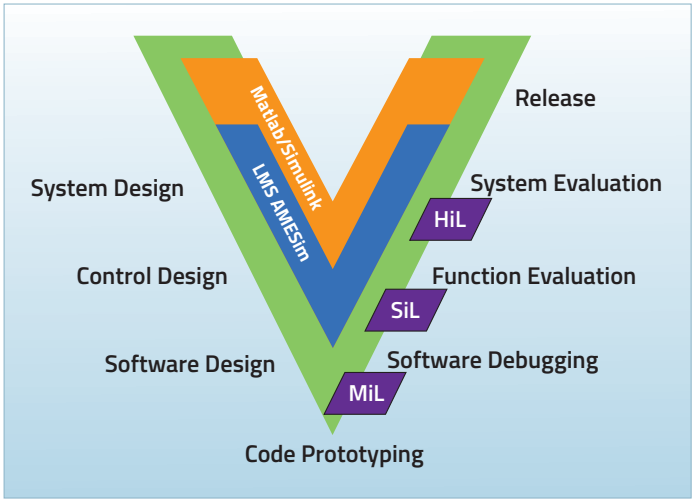

Figure 3 Double-V Development Process

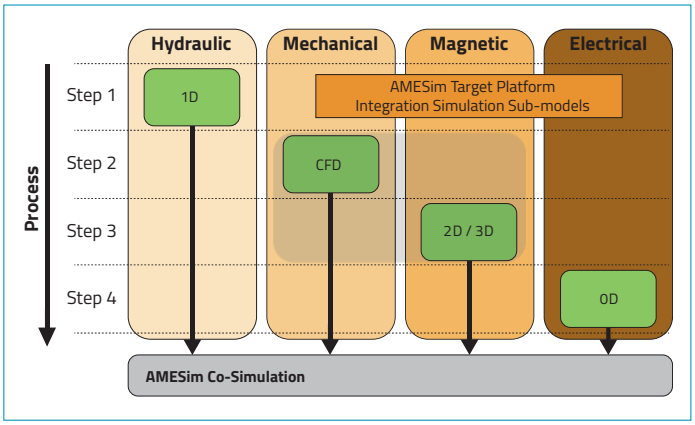

Figure 4 Multi-Domain Simulation Platform

A trade-off between computational effort and accuracy was made while guarantying compatibility with other components and sub-systems. The simulation platform was attuned to allow transient and steady-state performance at transmission system level while serving as a design tool for component development.

Integration tests were carried out from electromagnetic to hydro-mechanic components (see Figure 5) Co-simulation pSpice – Matlab/Simulink – AMESim was applied for Model-in-the-Loop validation.

Validation & Verification

With the aim to assess the fulfillment of the transient specification, step, ramp and disturbance response tests were carried out (see Figure 6). A total of six scenarios were defined with the aim to excite all different clutch operation regions (Table 2).

Table 2 Validation Scenario Clutch Performance Assessment

ID	VS-CS01	VS-CS02	VS-CS03	VS-CS04	VS-CS05	VS-CS06
Description	Undercut	0 to OP_1	0 to OP_2	Kisspoint	Engage	Clutch on/off

Model-in-the-Loop and test bench validation and verification tests were conducted to assess the capability of the CLPC for oil temperatures between –30 °C and 140 °C and a supply pressure from 0.6 to 1.2 MPa.

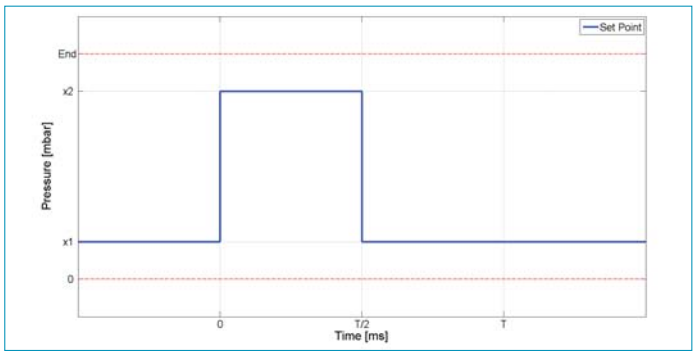

Figure 6 Test Signals Clutch Performance Assessment

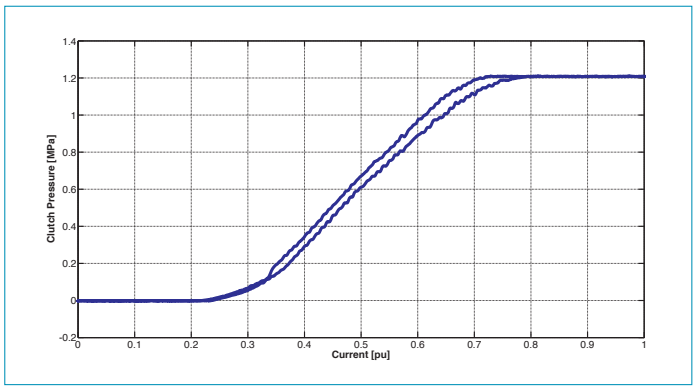

Figure 7 Clutch Pressure-to-Current Map

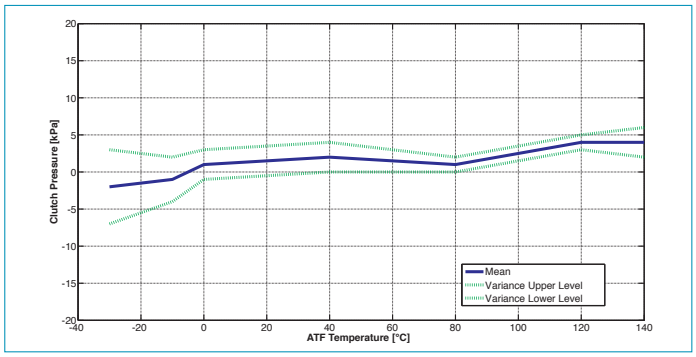

Figure 8 Clutch Pressure Steady-State Error

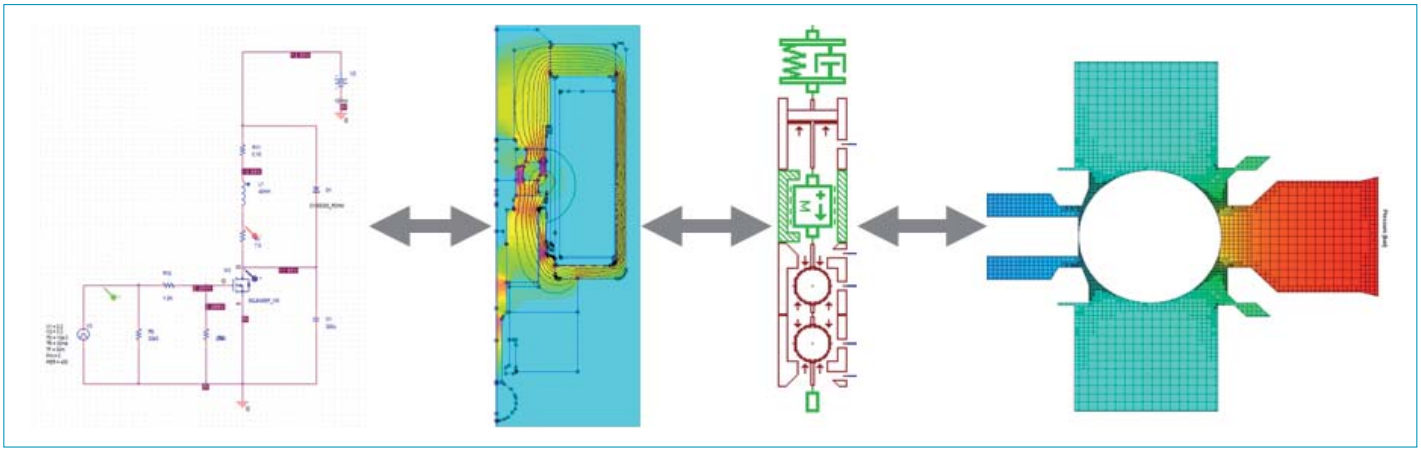

Figure 5 Simulation Domain

To assess the repeatability and reproducibility of the test, a duty cycle containing at least a sequence of ten (10) elements was selected. Variations in the boundary conditions were allowed during tests, i.e. supply pressure and oil temperature.

Results

The static performance was assessed by evaluating the linearity of the pressure-to-current map and the steady-state pressure error. Figure 7 shows that the maximal hysteresis of the clutch system is less than 100 kPa. CLPC® guarantees a steady-state pressure error less than 10 kPa for the entire temperature operation range (Figure 8).

The dynamic performance assessment showed that CLPC® in conjunction with the actuator pressure measurement pa can achieve a rise time t_r <50 ms for oil temperatures larger than 20 °C (Figure 9). At temperatures below zero Celsius, the interaction with supply system limits the maximal achievable performance. However, the tracking capability of CLPC® is not influenced (see. Figure 10 and Figure 11).

Conclusion

1. Reduce clutch pressure response time
   a. Flexibility to adjust controller performance to meet sportive, comfort and economy clutch performance requirements through CLPC®
   b. Flexibility to adjust supply pressure to reduce fuel-consumption

2. High tracking capability
   a. Increase steady-state hydraulic stability of the clutch pressure independent of oil temperature
   b. Flexibility in the pressure set point generation give flexibility in the trajectory generation for clutch pressure.

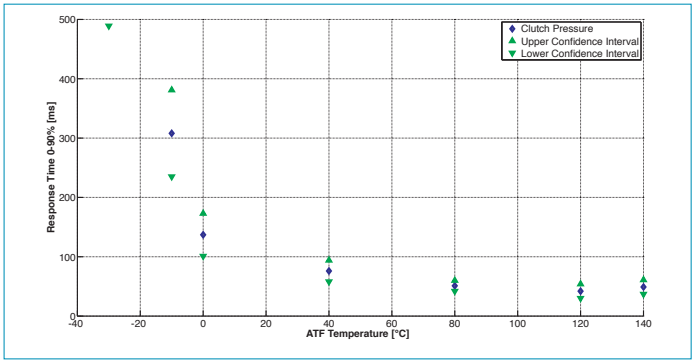

Figure 9 Clutch Pressure Rise Time 0 – 90 %

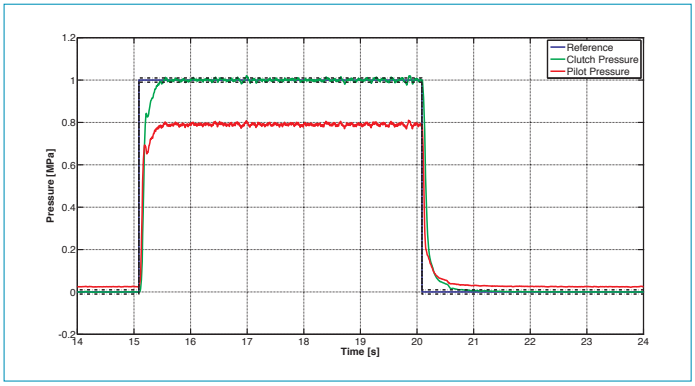

Figure 10 Clutch Pressure Step Response ATF 0 °C

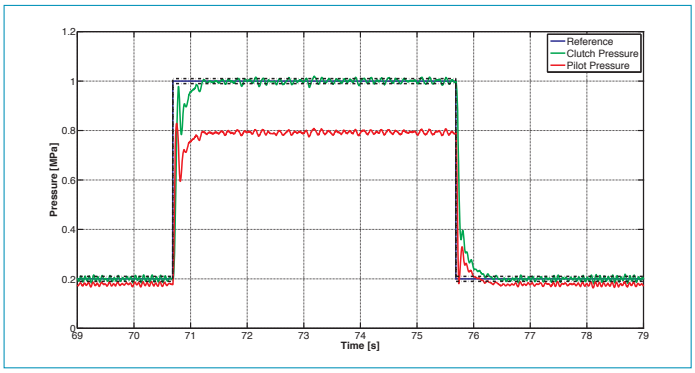

Figure 11 Clutch Pressure Step Response ATF 80 °C

References

[1] VDI, "VDI 2206 – Design Methodology for Mechatronic Systems", Verein Deutscher Ingenieure, Düsseldorf, 2004.

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by Ralph Heckmann, Head of Technical Sales at the teamtechnik Group, Germany

Nowadays, calibrating and teaching functions are a major part of the tasks performed by a test bench. Flexible interfaces and functions that record measurement data quickly are essential elements of test technology, making it possible to meet the demands of modern testing processes. At the same time, although volume numbers are falling, the number of variants and complexity of transmissions continues to rise. MT, CVT, AT, DCT, hybrid applications, transfer cases, and differentials are becoming increasingly complex systems, with a growing number of interfaces to the test system.

These demands can only be met by test software that has maximum flexibility, exceptional performance, and maximum possible compatibility with external interfaces. The best solution will also be user-friendly and easy to use.

Meeting the requirements of any type of production system and transmission type

Teamtechnik is one of the world's leading companies in the field of flexible transmission test benches. The company has developed a modular machine platform which could be used to test a wide variety of different transmission types on the same platform – from development to preseries tests, and right up to series production. Modular software architecture has made it possible to create a completely standardized machine platform. "teamsoft.TEST" lies at the heart of this software architecture. This test software covers the requirements of all production systems and transmission types, from MT, DCT through AT to PTU and RDM, and hybrid applications. The software consists of five modules: the programming system, database, analysis, runtime system, and visualization. Test sequences can be generated as web-based graphics, which can then be run on a National Instruments® LabVIEW® runtime system. Tests can be broken down into individual modules, which can be reused and recombined for new and different tasks. Test sequences can be implemented in a modular fashion with no limit on the depth of embedding.

Creating test sequences with drag & drop

The software has been designed for the fully automatic testing of components in the type mix in manually loaded test benches, develop-

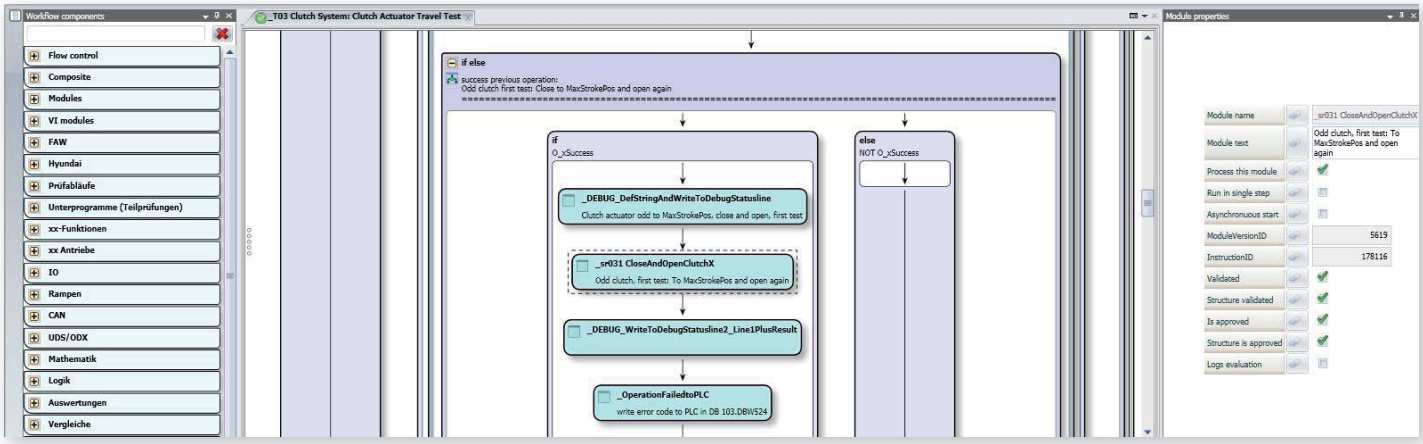

Figure 1 Programming system: creating a test sequence as a graphic. Test sequences can be implemented in a modular fashion with no limit on the depth of embedding.

ment test benches, and fully automated series test benches. As well as being able to perform typical functional test sequences, it can also carry out calibration, placement and diagnostic processes. New processes can be prepared, or new parameters can be set for test specimen types, even whilst other tests are being performed. This has no effect on the tests that are running.

Another benefit: you don't need to be an IT expert to create a test sequence. The software runs seamlessly from any PC that is connected with "teamsoft.TEST" over the company intranet. Simply call it from a browser. The web-based programming system also enables you to configure the test bench and database, and to create and enter parameters for test sequences, without any programming knowledge. The software provides a multitude of wide-ranging evaluations and analyses for transmission testing. A test sequence can be changed and optimized flexibly without any specialist knowledge of the software. The sequence is created with a drag and drop process and there is an extensive library of functions.

Benefit from a mature diagnostics solution

Existing basic functions can be extended to meet specific requirements and combined to form new modules. Individual values and curves can be displayed and analyzed. The test results can be analyzed as a production report with batch tracing, visualization of characteristic curves, statistical production analysis, and system status and system faults. The test results can also be exported to an Excel or PDF file, or printed out as a report. This software solution also has open interfaces to transmissions and to measurement and control system sub-systems. Other systems, such as noise analysis systems, or external measurement and control technology, can also be integrated without any difficulty. Users benefit from a fully developed solution which supports OEMs by ensuring cost-effective, reliable production.

Figure 2 The teamsoft.TEST graphical program system is a web application: the software can be called from any PC, simply by opening a web browser

Figure 3 Flexible test benches expect flexible and modular transmission test software

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PPS – Powertrain Production Systems: Innovative Solutions

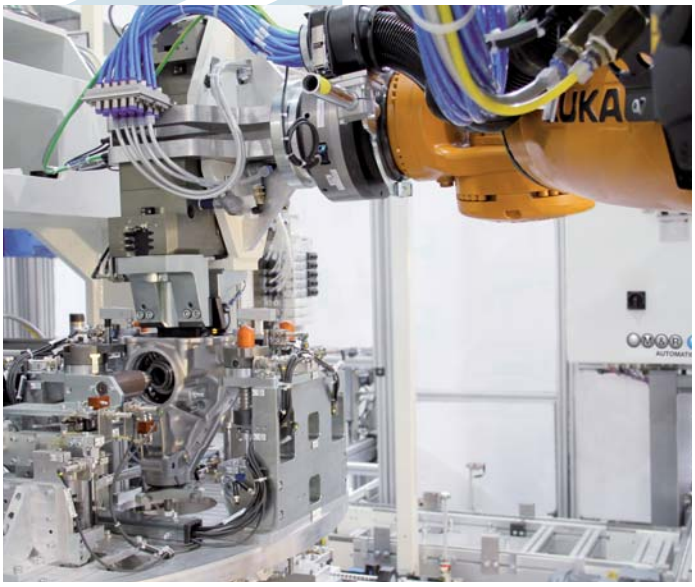
Due to growing cost pressures, engine and transmission manufacturers require increasingly more flexible production solutions. Over the past few years, M&R Automation GmbH has developed the Powertrain Production Systems (PPS) modules into intelligent and highly flexible technology building blocks, to deliver efficient, lean solutions to meet global challenges and requirements including hybrid and electronic drive systems. The PPS modules unite innovation, quality, and efficiency.

by Norbert Kahr, Director of Sales, M&R Automation

Various types of engines as well as automatic, manual, and dual-clutch transmissions together with transfer gears, axle drives and their components are high-end automotive parts that call for high-end production solutions. It is in exactly these areas, with increasing cost pressure, that demands for intelligent and cost-effective production systems are becoming ever more pronounced in the race to maintain market leadership as a manufacturer. At the same time, efficiency, quality, flexibility, and availability in production must continue to increase. Process reliability cannot be left by the wayside in the wake of cost-saving measures. The solution lies in modular production systems, which M&R Automation GmbH (M&R) has developed using years of tried and tested technological expertise paired with the latest developments in measurement and testing technology. The PPS modules from M&R unite innovation, quality and efficiency under one roof.

Principals of the Technology Building Blocks – Stations for Every Need

The required sub-processes in the assembly of various powertrain components are, in principle, very similar. Depending on sequencing and scope, individual production steps will come together to form a process sequence that will accommodate the interactions of gear and bearing adjustment processes. To meet project requirements, individual technology modules from the PPS building blocks can be developed into stations and brought together in an overall system. Highly efficient manual, semi- and fully automatic assembly and measurement modules can be selected to meet requirements, resulting in the highest level of cost-effectiveness and process reliability producing high-quality parts with minimal rates of rework. M&R will of course adapt modules to individual customer specifications to ensure factory-oriented standards



Advantage of the PPS module series: to meet production location and volume requirements, the proven technology modules can be combined in almost every way desirable to form project solutions that facilitate the implementation of lean concepts.

are met for operators and maintenance personnel (e.g. unified operating interface and machine components). No advantages of M&R's tested and proven technology are lost in this process. Highly technical measuring processes play a key role in many production lines. Experience and technological expertise are of extraordinary importance in these operations. Particularly when adjusting gears, highly precise systems such as dynamic circumferential backlash measuring devices built according to patented M&R technology are a sure way to construct premium powertrain assemblies. M&R pays special attention to the energy efficiency and sustainability of PPS modules. The mechanical and electrical design of PPS modules is in line with the most modern manufacturing principles and processes.

Lean Manufacturing – Adjusted for the Realities of the Project

The expressions "lean manufacturing" and "lean production" as a so-called manufacturing panacea first appeared at the end of the 80s when the simple, sleek production concepts from Asia confronted the complex industrial solutions from North America and Europe. Ever since then, production experts have been trying in vain to lay out standard worldwide criteria for successfully making manufacturing processes "lean". The range of economic considerations has failed to yield a unified system for all global applications. Differences in requirements are enormous: OEM or parts supplier (product life cycle), industrialized nation or emerging market (salary costs, level of education), high-volume or low-volume product (investment costs per part). PPS modules attempt to bridge the gaps between the many different manufacturing requirements and to unite the demands of global lean production thought in a system of building blocks for every need – without trade-offs in production technology and therefore without sacrificing quality. In addition to these demands, the impact of aging workforces must also be taken into account in Europe – something that the PPS module series has mastered. In Southern Germany, several systems suited to the age of the workforce have been installed by M&R – one of them being the world's fastest production line for axle drives with a cycle time of 16 seconds. The large markets of the USA and China are currently investing intensively in new production systems, but with very different lean parameters. While nearly identical production conditions prevail in the USA and Europe, in China it is necessary to carefully consider which system concept would be suitable for each site. Even within China itself, the requirements for lean parameters can vary greatly. While western companies in China will not allow for quality to be sacrificed when dealing with production for Europe or the United States, Chinese OEMs and parts suppliers currently face a different situation. This inevitably results in different production concepts for very similar products.

Idea to Market – And Fast!

In addition to growing pressure to reduce costs and fuel consumption, time to market also plays a central role in powertrain production. New versions of products must be delivered quickly and efficiently to remain marketable. Increasing numbers of product variants released by project development departments and meant for production on flexible lines shorten the acquisition time for production systems. To relieve pressure on product development and launch timelines, it is necessary to further shorten supply times for production systems. M&R's PPS modules are prepared to meet even these demands, since much of the engineering is already done and risks are lowered by using proven processes to shorten production ramp up time for new assembly lines. Time will therefore be an important factor for decision-making in the future when acquiring new production systems.

Best Practice at Daimler AG

One of the most successful automobile companies in the world relies on M&R's proven and efficient solutions. The Daimler Group is one of the biggest producers of premium cars and the world's biggest manufacturer of commercial vehicles with a global reach and has been using M&R production systems to manufacture powertrain components for several years. Two of the many technical innovations from Daimler AG are a friction-optimized drivetrain and a new generation of fuel-efficient axles. Several M&R modular lines with integrated laser welding cells and testing stations are currently being constructed for production of the new FE front- and rear-axle drivetrain. The PPS technology building blocks provide the foundation for assembly, measurement, and testing stations that are optimized for operator ergonomics and the product-specific manufacturing processes.

Flexible Laser Welding of Powertrain Components

Laser welding of powertrain components requires the highest standards of quality and process reliability. Since 2008, TRUMPF and M&R have been intensively collaborating in the area of powertrain laser welding and have jointly developed technologically advanced solutions for the creation of laser welded joints and the flexible integration of this technology into assembly lines. The TRUMPF group is one of the world's leading manufacturers of CO_2 and solid state industrial lasers and has played a major role in partnership with the assembly and test device specialists at M&R. The partnership enables M&R to offer fully integrated powertrain production systems.

M&R Automation GmbH

M&R Automation is a global supplier that offers its customers innovative production systems in the areas of assembly, measuring and testing technology. Since 1989, the M&R team has been developing and producing customized production and testing systems for the automobile, electronics, and consumer goods industries as well as for medical technology. Emphasis is put on the manufacture of systems for powertrain production. With its locations in Europe, North America, and China, M&R Automation employs more than 400 employees.

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Follow-up Report on the 8th International CTI Symposium USA

Gernot Goppelt, technology journalist, Germany

Together toward 54.5 mpg

In 2011, U.S. President Barack Obama announced that by 2025, fleet consumption in the U.S. is to be reduced to 54.5 mpg. This equals a consumption level of 4.31 liters per 100 kilometers. The contribution that transmission technology can make to this target was discussed at the 8th International CTI Symposium on May 14 and 15, 2014 in Rochester. One of the issues under debate was the expectations of American drivers and changes in social parameters, which might require new approaches. This year saw only few proponents of the pure electric car; better chances were attributed to mild hybrids as well as, in the long run, plug-in hybrids for urban scenarios. While diesel engines for cars were no major issue, gasoline engines were still seen as offering major savings potential. As for transmission development, there was agreement despite differences in approaches. The requirements concerning efficiency and flexibility of the transmissions will continue to increase, but this must not happen at the expense of comfort.

As chairman of the symposium, Ernie J. DeVincent, Vice President Product Development of Getrag, welcomed 420 international attendants – an increase of 50 compared to 2013. A total of 72 percent were from North America, 21 percent had arrived from Europe, and 7 percent from Asia Pacific. The plenary addresses on days one and two focused on the effort to achieve 54.5 mpg, looking at the issue from a variety of angles – ranging from those of the regulatory agencies to automobile associations and all the way to representatives of OEMs, suppliers, and development service providers as well as market researchers. Another interesting approach was to take a look at spending behavior from a psychological and sociological point of view. The diverse interdisciplinary discussion demonstrated the complex challenges that transmission developers are facing.

54.5 mpg – a challenge for the automotive industry

Chris Nevers examined how rocky the "road to 54.5 mpg" can be from the point of view of the American Alliance of Automotive Manufacturers. He was careful to remind the audience that Phase 2 of the U.S. legislation on emissions has not been clearly defined yet. The background facts: While the EPA and NHTSA already outlined the development of CO2 emissions from 2017 to 2025 back in 2012, NHTSA, EPA, and the California Air Resources Board will make a "midterm evaluation" for the phase from 2022 to 2025. According to Nevers, the Manufacturers Alliance is worried about the technical feasibility of the annual CO2 reduction by 5 percent. He also pointed out the behavior of drivers: Americans are buying more and more SUVs, and "fuel consumption is only number 12 on their list of priorities." Moreover, Nevers is worried that overly aggressive engine calibration and efficient DCTs and CVTs might spoil the fun of driving.

The EPA is focusing on highly efficient transmission concepts

Michael Olechiw, Director of the U.S. Environmental Protection Agency (EPA), took the point of view of a regulatory agency and added some technical suggestions. As for gasoline engines, he mentioned improved valve trains, spray-guided direct injection and turbocharging, plus downsizing to further optimize the gas-exchange cycle. He furthermore pointed out hybridization and such measures as electromechanical steering and optimized air-conditioning systems. With respect to transmissions, the EPA sees the solution in higher final gear ratios as well as dual-clutch transmissions and CVTs. According to Olechiw, the greatest potential for CO2 reduction lies in an aggressive shift strategy (5 to 7 percent), improved mechanical efficiency (roughly 5 percent) and transmissions with good efficiency, such as DCTs with dry clutches. Olechiw presented the OMEGA calculation model (Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles), which looks at the market penetration of different types of transmission irrespective of regulations. Olechiw: "With strong regulation, the percentage of dual-clutch transmissions with seven or eight gears will climb to 56 percent by 2025." This estimate made even proponents of the DCT prick up their ears.

Which types of transmission come out on top in North America?

David Petrovski from the market research firm IHS presented significantly different results. IHS based its predictions primarily on statistical methods and anticipation data from the OEMs as well as a semantic analysis of articles in the press and social networks. These indicate that the percentage of DCTs on the U.S. market will shrink until 2021, making up no more than a small, single-digit percentage. One reason for this prediction is that according to IHS, most U.S. manufacturers focus on automatic torque converter transmissions with eight to ten gears, and only some of them on CVTs. GM, for example, is developing a continuously variable transmission (CVT) with high torque capacity, which will be market-ready by 2017. The portfolios of the international manufacturers are more diverse. At least Honda, Mercedes, and Volkswagen will offer DCTs with seven and eight gears. Honda's "TC-DCT" constitutes a special case, as it is the only dual-clutch transmission with torque converter. However, Petrovski believes that considering its small unit numbers alone, this combination will remain an oddity.

"How does the DCT respond or reinvent itself?" David Petrovski asked in view of the numbers presented – a question that Bernd Eckl, Executive Vice President Sales, Marketing, & Business Development of Getrag, addressed immediately following his presentation.

Eckl explained how customer feedback impacts the development of dual-clutch transmissions. U.S. customers had given negative feedback especially on the launch behavior of DCTs with dry clutches. This is also due to the fact that U.S. customers are accustomed to the combination of smoothness and torque multiplication being typical for torque converters. Interestingly, hardly any criticism of this kind was voiced from Europe and Asia. In the current generation of transmissions with dry clutches Getrag already made some adjustments, for example by offering improved software, new clutch materials, and by using more dual-mass flywheels. As for the next generation, Eckl announced the "smart actuation," which allows for the highly efficient actuation of the wet clutches. In combination with a seventh gear and a gear spread of 8.5, fuel consumption is to be reduced by another two

to four percentage points compared to the current, dry DCT. Thanks to shorter and more closely spaced gears one and two, there will be more launch torque and launch comfort, and wet clutches offer less inertia and more freedom to design their behavior. Bernd Eckl's clear promise: "We listen to our customers and transform their requirements into technology."

Similarly to David Petrovski from IHS, Shinji Morihiro, Vice President at Jatco, believes that the percentage of CVTs in North America is going to increase. Their major challenge is to make the frictionally engaged connection as efficient as possible. Morihiro believes that mechanical efficiency of the CVT has a potential of over 90 percent, and that among the competing transmission concepts, only dry dual-clutch transmissions are better. He stated that measures to reduce fluid churning, a new belt and chain layout, and more efficient oil pumps will achieve the main improvements in efficiency.

Transmissions as partners of new engine concepts

Transmissions and engines must complement each other optimally. Dr. Günter Fraidl from AVL List demonstrated the savings potential that combustion engines still contain and what this means for the interaction. Today, aspirated engines are combined with CVTs in Japan, because drivers there accept performance through high engine speeds. By contrast, the focus in Europe tends to be on turbocharged downsizing engines and on shifting the load points by down-speeding. On a global scale, Fraidl sees a trend toward charged gasoline engines with direct injection. There is still great development potential, he said, whether in terms of two-stage charging, electric chargers, externally cooled EGR, or variable valve timing – all the way to using the Miller cycle and variable compression. Once all possibilities have been exhausted, Fraidl believes that consumption levels in the diesel range may be achieved. By 2020, a consumption rate of 200 g/kWh may be possible. The way he compared consumption measuring cycles and engine technology was also interesting. It showed that NEDC and FTP-75 tend to favor low consumption with low power, while WLTP,

and even more so US06 and planned real driving emissions (RDE), request for high engine power. To satisfy future standards, the fuel consumption map must therefore be laid out more evenly. This in turn might result in needing fewer gears in the future, because a broader range of high mean effective pressure will be available. Generally speaking, however, greater flexibility is always called for, so optimum use can be made of the efficiency potential.

Hybridization is necessary – and requires a great deal of development discipline

In addition to the strict gasoline engine-related measures, Fraidl also mentioned hybridization as a complementary solution that makes sense, especially since the electric motor can help to make optimum use of the combustion engine's "sweet spot." His colleague at AVL, Jerry Klarr, looked at the trends in electrification and their consequences for the developments in transmissions. He expects an increase from two million electrified vehicles today to six million by 2020, and predicted that a modicum of hybridization – start-stop and belt-operated or integrated starter generator all the way to mild hybrid – will be standard in all car segments. According to Klarr, hybrid development requires a particularly large degree of systems engineering discipline in order to master the complex interaction inside the car. He explained this using the example of the eAxle project, where a through-the-road hybrid with an electric rear-axle module was built. The development targets were reduced fuel consumption, all-wheel drive, and torque vectoring, as well as an economical modular design – and an implementation time frame, from design to demonstration car, of 18 months. Klarr stated that AVL managed to develop nearly 80 percent of the functions at the model level, even fine calibration.

What drivers expect from transmissions

Aside from technical considerations, psychological and social aspects of transmission development were examined as well in Rochester. Alexander Edwards from Strategic Vision, for instance, looked at what psychology has to do with transmissions. He first presented a model according to which customers make their decisions. The first basic requirement is a sense of safety, which is followed by freedom, valuation, balance, and "love" or enthusiasm for something. Translated to

transmissions: "First of all, they have to work perfectly." And vice versa, if a transmission turns out to be unreliable and therefore unsafe, this does not leave much room for enthusiasm. Edwards also explained, which product qualities customers find important. For example, comfort, handling, and agility are important criteria, and fuel consumption is also among the top third of criteria. A criterion such as "environmentally friendly", on the other hand, is near the bottom of the list of preferences. It is also interesting to note that customer evaluations are strongly dependent on context: frontrunner in a survey of "transmission smoothness" was the Porsche Boxster, whose transmission 95 percent of those surveyed "love." In second place comes the electric car Honda Fit EV, followed by Porsche Cayman and Audi RS8. As this illustrious hit list demonstrates, even such a seemingly clear-cut term as "comfort" greatly depends on the angle from which it is looked at.

Mobility research as a social task

By contrast, the Argonne National Laboratory is not so much guided by individual as by explicitly national concerns. Argonne is a multidisciplinary science and technology research center where experts work

together in order to meet challenges in the fields of clean energy, environment, technology, and national safety. Argonne's Director Don Hillebrand introduced the "Jevons paradox" as a guideline of his lecture: It proposes that technological progress and greater efficiency do not end up saving but even wasting resources. He made a case for taking unexpected developments into consideration, too. Look at electric cars, for example: the energy density of batteries is currently improving by at least 5 percent annually, but still hardly anyone buys an electric car. They are too expensive, their cruising range shrinks drastically in cold weather, and California with its strict emission legislation "is great, but most of us don't live there." In other words, without any pressure, no one will put up with additional costs. On the other hand, Hillebrand does not believe that the Toyota Prius makes much sense technologically, but "it simply works." He also regards pure electromobility with skepticism and puts more stake in improved combustion engines and plug-in hybrids, as long as they compare with conventional cars in terms of affordability. He had questions concerning autonomous driving, too: Are the systems vulnerable? How much privacy is lost? Does driving get boring? The main thrust of Don Hillebrand's argument is that we must conduct research in all directions and should not rely on predictions.

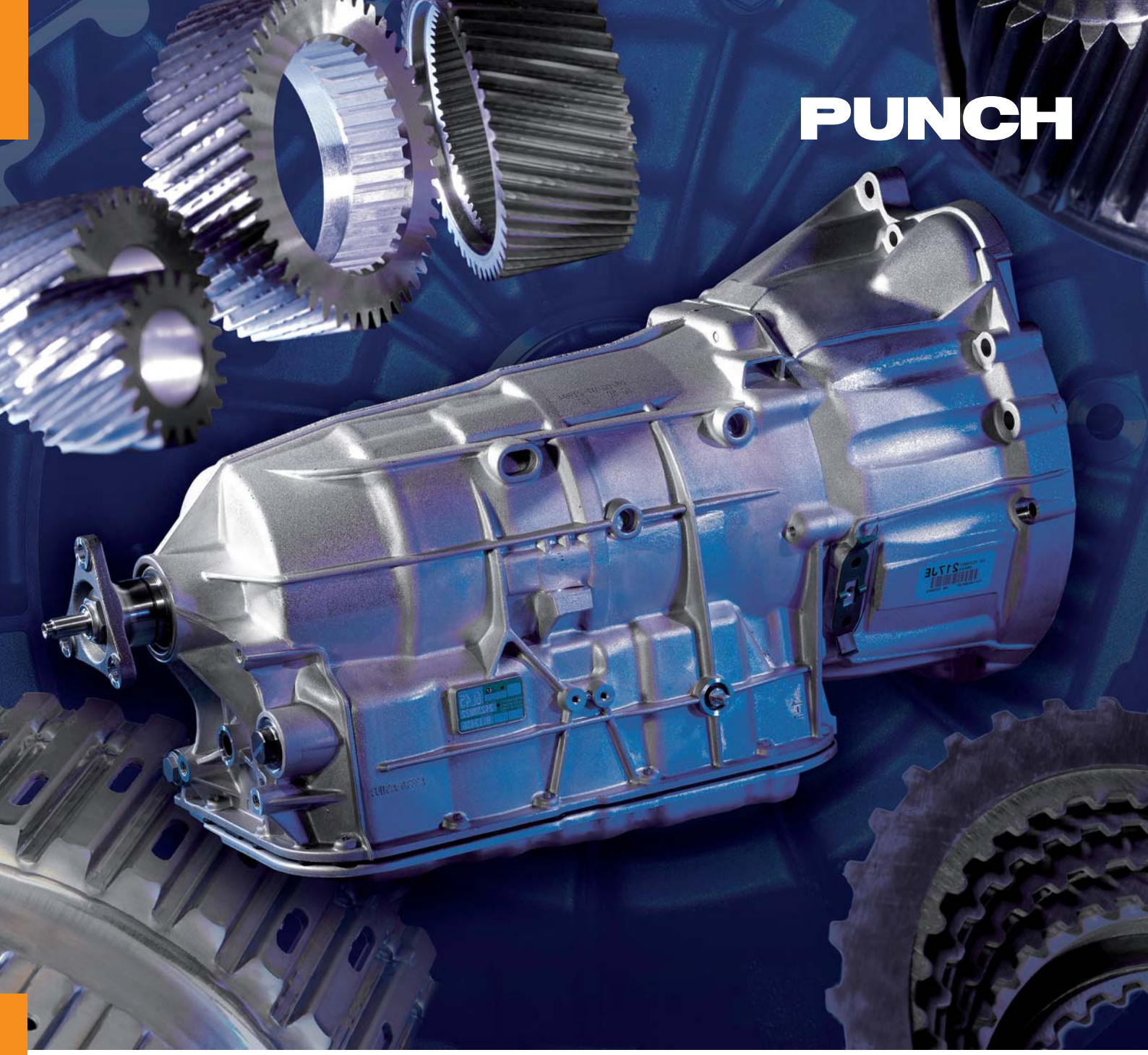
Changed requirements as a result of urbanization

Charles Chesbrough from IHS Automotive also cautioned the audience, explaining the impact of a change in social paradigms on the future of the automotive industry. The increasing urbanization process, he argued, may slow down the growth of individual mobility. Rising costs, traffic jams, and alternative transportation options might temper the interest in cars: "Urban motorization can be self-limiting." Moreover, on a global scale fewer and fewer people have a driver's license. This is particularly conspicuous in Japan and South Korea, highly urbanized countries with an especially high level of mobile communication. Cities and countries are investing more in public transportation, and regulate car traffic. The percentage of the urban population will grow from currently 50 percent to 60 percent by 2035, according to Chesbrough. Plus, the percentage of old people is increasing, and they may wish to drive less themselves. Moreover, the middle classes seem to be losing in spending power. IHS concludes that by 2025, it is just as possible that only 100 million new light vehicles are produced rather than the anticipated 130 million cars. Therefore automobile manufacturers should prepare their capacity planning for the long haul. On the technological level, it will be necessary to look into special city cars, car sharing concepts, and the requirements of autonomous vehicles. Due to the electrification of engines, transmissions might need fewer gears, they may have to be designed for longer-term operation, and for being operated by different drivers. Chesbrough concluded by pleading: "Be open for the signals."

Growth in a personal atmosphere

A highlight of every CTI symposium is the panel discussion, which was again marked by diverse opinions in Rochester. It was led by Larry T. Nitz, who is in charge of GM's global transmission and electrification activities. The discussion reflected much of the enormously dynamic context of transmission development. Also characteristic of the convention in Rochester was the summary provided by Chairman Ernie DeVincent, Getrag, who managed to give the conclusion of the symposium an almost familial touch even though it became bigger in 2014 in all respects: 420 participants established a new record, and the professional lectures were held in four rather than the previous three sections on both days. There were eleven rather than nine plenary addresses, 47 and not 38 professional lectures, and the number of exhibitors climbed from 26 to 29. The audience stayed until the very end – demonstrating that despite complex requirements and very different answers, the road toward 54.5 mpg is one shared by all.

Info and photos
www.transmission-symposium.com/usa



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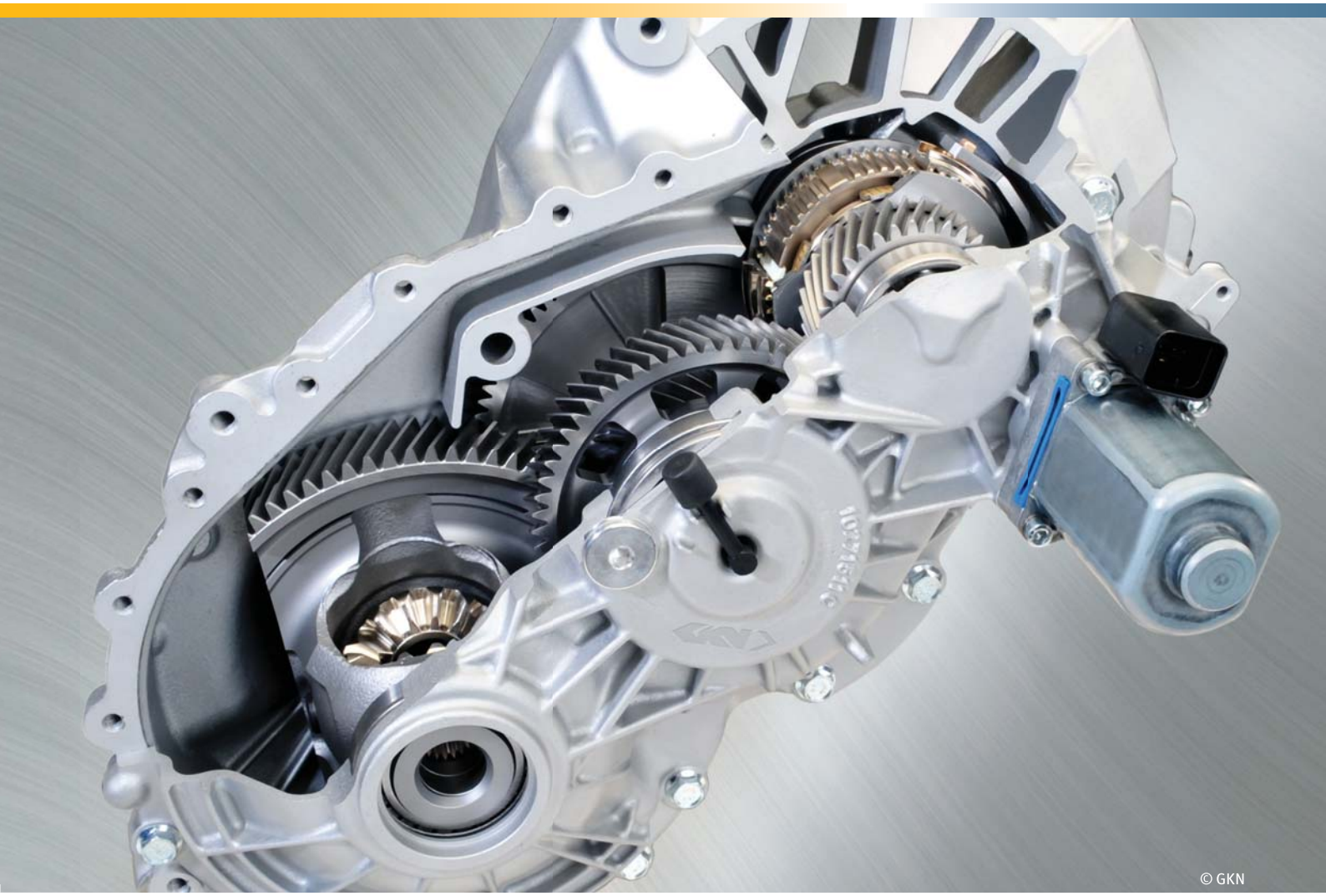

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