



CTI *MAG*

The Automotive TM, HEV & EV Drives magazine by CTI

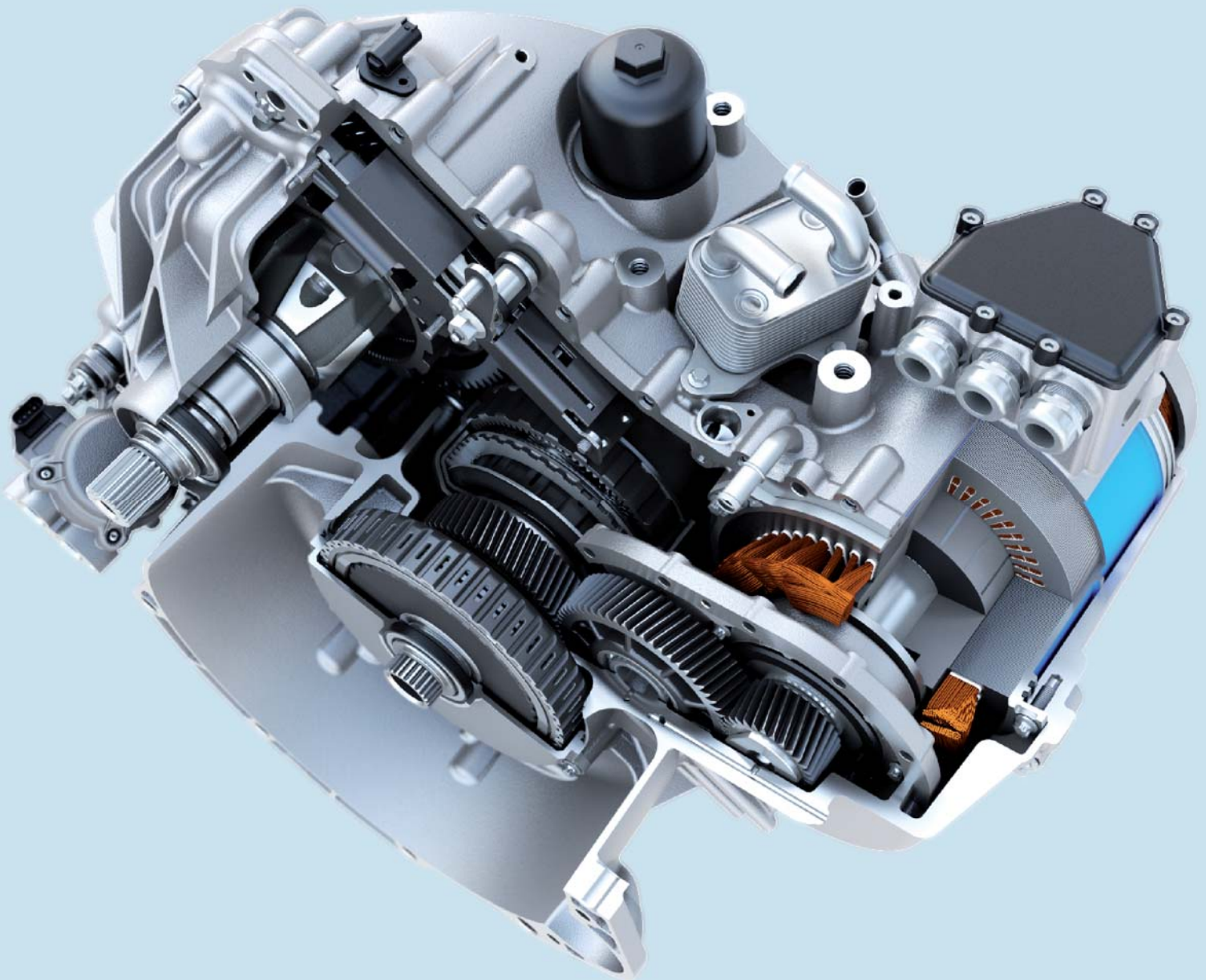
December 2015

Dedicated Hybrid Transmissions (DHT)

CTI Advisory Board defines new transmission category

Transmission Concept BMW 2 Series Active Tourer eDrive

Interview with
Charles Gray
Director, Transmission &
Driveline Engineering,
Ford Motor Company



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CTI *MAG* Contents

- 6 **Dedicated Hybrid Transmissions (DHT)**
AVL List
- 10 **Multimode Transmission – an unique Hybrid Transmission Concept**
GKN Driveline
- 13 **The Innovative Transmission Concept for the Plug-In Hybrid Powertrain for the BMW 2 Series Active Tourer eDrive**
BMW
- 18 **Scalable Hybrid Dual-Clutch Transmission**
GETRAG
- 21 **Efficiency Analysis of Multi-Mode Passenger Car Transmission Concepts featuring a VariGlide® CVT**
Dana Holding / Drive System Design
- 25 **BEREIT: Optimization of Parallel Hybrid Electric Vehicle (HEV) Fleets**
TU Darmstadt / TU Braunschweig
- 29 **Designing for Maximum Transmission Efficiency in Electric and Hybrid Vehicles**
Drive System Design
- 31 **Highly Integrated Launch Systems**
LuK
- 34 **Gear Shifts Twice as Good**
Hoerbiger
- 37 **Sonceboz Actuators: Shifting the Paradigm**
Sonceboz
- 39 **Smart Actuators – The Future of Automotive Systems**
Melecs EWS
- 42 **Less is More: SKF Presents Innovative New Sealed Deep Groove Ball Bearings for Automobile Drive Shafts**
SKF
- 43 **Goudsmit Magnetic Supplies – Dutch Quality**
Goudsmit
- 47 **Overcoming the Challenges of Hybrid Disconnect Clutch Control**
Drive System Design
- 49 **“Scale Will Come as Customers Adopt the Technology”**
Interview with Charles Gray, Director, Transmission & Driveline Engineering at Ford Motor Company
- 51 **“CVTs will Profit from Autonomous Driving”**
Interview with Dr Ryozy Hiraku, General Manager Powertrain at Nissan Motor Corporation
- 52 **Efficient Drives: A Reality Check**
Follow-up Report, 9th International CTI Symposium USA – Automotive Transmissions, HEV and EV Drives, 20–21 May 2015, Novi, Michigan

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Dear reader,

This issue of CTI Mag looks at the topic of DHTs in a lead article by Dr Robert Fischer, AVL List GmbH. DHTs are a new class of transmissions developed specially for hybrid drives. The term was introduced and dealt with in depth at the 14th International Symposium Berlin 2015. Key parameters in the articles on transmission components include functional integration, efficiency, comfort and driving dynamics.

Our interviews with Mr Gray and Dr Hiraku cover two topical themes: 'Dedicated and fuel saving hybrid transmission architectures' and 'How automated driving affects the requirements for automotive transmissions'. Among other things, the interviews yielded two interesting soundbites: "There is no single solution for all hybrid applications" and "CVTs will profit from autonomous driving".

We hope you enjoy reading CTI Magazine!

Best wishes,

*Your
CTI Mag Team*

PS: The sixth issue of CTI Mag appears in May 2016

The submission deadline for articles and adverts is 1 March 2016.

To get all the details, just send a brief email to michael.follmann@car-training-institute.com



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With increasing market share of hybrid powertrains dedicated hybrid transmissions (DHT) become beneficial with respect to efficiency, cost, package and weight

Dedicated Hybrid Transmissions (DHT)

CTI Advisory Board defines a new transmission category

■ Dr Robert Fischer, Executive Vice President, AVL List GmbH
Member of CTI Symposium's Advisory Board

Introduction

Reduction of CO₂ emissions as well as other regulated emissions remain to be a huge challenge and requirement for the automotive industry. Often the measures to reduce emissions are jeopardizing vehicle fuel economy, as related systems for instance, are throttling the exhaust system or requiring energy to be activated or adding weight to the vehicles. Legislation steadily decreases the emission limits as well as implementing aggressive targets to reduce CO₂ emissions further.

This has led to significant improvements for conventional powertrains. Their evolution brought innovative solutions to optimize the specific fuel consumption of internal combustion engines and challenged the transmission industry to utilize the engine's sweet spots (areas of low specific fuel consumption) as often as possible in the driving cycles. Down-sizing (of the internal combustion engines) and down-speeding are the main mechanisms, the latter provided through larger ratio spreads and more speeds of the transmissions.

Electrification offers an additional potential for reduction of fuel consumption but the customers are not ready to pay the significant add-on costs. Thus, the market share of HEVs and EVs is still small compared to vehicles with conventional propulsion, and for the most vehicle manufactures hybrids had been targeted for niche applications. To efficiently serve that still small market, modular Add-on concepts were advantageous. The installed investments in transmission products can be utilized to a large extent. The most popular concept is to integrate a module consisting out of an E-motor and a disconnect clutch between the existing transmission and engine, often substituting the torque converter if used by the base transmission. The major challenge of these Add-on systems is packaging, as transmission length increases due to the integration of the module between engine and transmission. We find Add-on hybrids mainly based on step automatic transmissions (AT), continuously variable transmissions (CVT) and dual clutch transmissions (DCT).

Definition of DHT

A DHT (Dedicated Hybrid Transmission) is a type of transmission, which has the power source for the electrical propulsion fully integrated and its functionality depends on the integrated electrical components. Without an E-motor the transmission cannot fulfill the transmission requirements (Figure 1).

The only DHT for several years – Toyota Hybrid System (THS), labeled "Hybrid Synergy Drive" on these vehicles – was developed already 20 years ago and launched in the Toyota Prius in 1997. It sells quite well and reaches attractive production volumes already for quite some time. So far no other hybrid transmission was able to reach similar production volumes.

The ever increasing pressure by legislation, society and consumers to reduce fuel consumption in the next decade will boost the market share of hybrid vehicles significantly. Probably the volumes of hybrid propulsion systems will exceed the current predictions. Based on that, the business cases for DHTs will improve significantly, the expected volumes will justify development and industrialization efforts for DHTs and enable the utilization of further benefits of this transmission category, e.g. reduced weight, package, complexity, etc.

DHT is a hybrid transmission using the E-motor(s) to fulfill functional transmission requirements. Simply replacing a launch element by an E-Motor doesn't make a transmission a DHT.

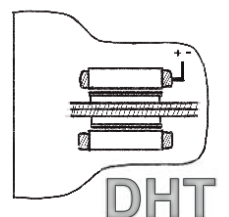


Figure 1 Definition Dedicated Hybrid Transmission (DHT)

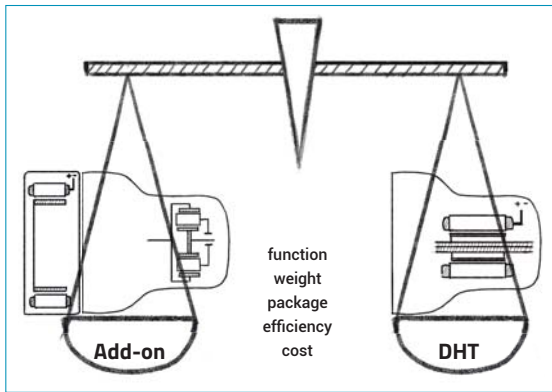


Figure 2 Comparison Add-on hybrid transmission versus DHT

A couple of years ago DHTs moved into focus and investigations in this area have started. Meanwhile many OEMs and key suppliers launched development programs for DHTs. This was the reason for the Advisory Board of the "CTI Symposium Automotive Transmissions, HEV and EV Drives" to define this new transmission category "DHT" and position it during the conference with three plenary speeches and an own section as focus during the 14th CTI Symposium "Automotive Transmissions, HEV and EV Drives" in Berlin 2015.

DHT perspectives

Fuel economy benefits of hybridization result from mainly three hybrid functionalities: Start-Stop, Recuperation and Shifting of Operating Points of the ICE. A significant part of these potentials are used with innovative conventional powertrains – by smart control of the generator, by broadening the area of low specific fuel consumption of the ICE, etc.

Is there a remaining effect on fuel economy by hybridization? Yes, the optimization of the hybrid powertrain in a holistic way offers many further potentials.

Indeed, hybridization is an enabler to reduce ICE operation with poor specific fuel economy and increasing ICE operation in the vicinity of its sweet-spots. For low-load conditions, when further reduction of the engine speed is not feasible, the load can be elevated by the E-motor. The generated electric energy is buffered in the battery to be used in later operation for electric driving: This is called intermittent operation, which for instance is realized in the Toyota Hybrid System (THS). Furthermore, additional degrees of freedom can be used for the combustion cycles and downsizing of the ICE: Cycles with improved fuel economy like the Atkinson-Cycle or aggressive downsizing generally impact the vehicle driveability due to lack of

low-end-torque. This can be easily compensated by using the E-motor for boosting in those driving maneuvers to achieve the required vehicle acceleration.

An additional benefit is given with respect to cost and weight. Rather than using multiple transmission speeds and small ratio steps to operate the engine at low specific fuel consumption, this shifting of operating point can be accomplished by the interaction of the two propulsion sources, ICE and E-motor. Thus fewer transmission speeds are sufficient which leads to cost and weight savings. For non-electrified powertrains, with modern engines providing a broad area of low specific fuel consumption, a 7 speed transmission is probably sufficient to utilize the potential of shifting of operating points; in hybrid applications this number can be further reduced to 4 or 5 speeds.

The reduction of the number of speeds in hybrid transmissions must be considered in terms of product cost. Key for the amortization of development and industrialization is the volume. Therefore only high volumes would justify developing and launching a 5-speed transmission for use in hybrid applications (that would be an exclusive use, because the use as conventional transmission is unlikely and not state-of-the-art anymore). But such a step would still be challenged by the option to use other existing base transmissions, unless the hybrid volumes are really high and production capacities of the base transmissions are already needed for conventional powertrains. In those cases a development of a 5-speed transmission could make sense, but to go one step further and develop a dedicated hybrid transmission (DHT) is probably the better choice, as the new base transmission would not be used for conventional powertrains anyhow. This gives additional degrees of freedom for concept and layout of such a transmission. And with tailored functionalities for the usage in a hybrid vehicle further cost benefits are possible (together with other improved properties).

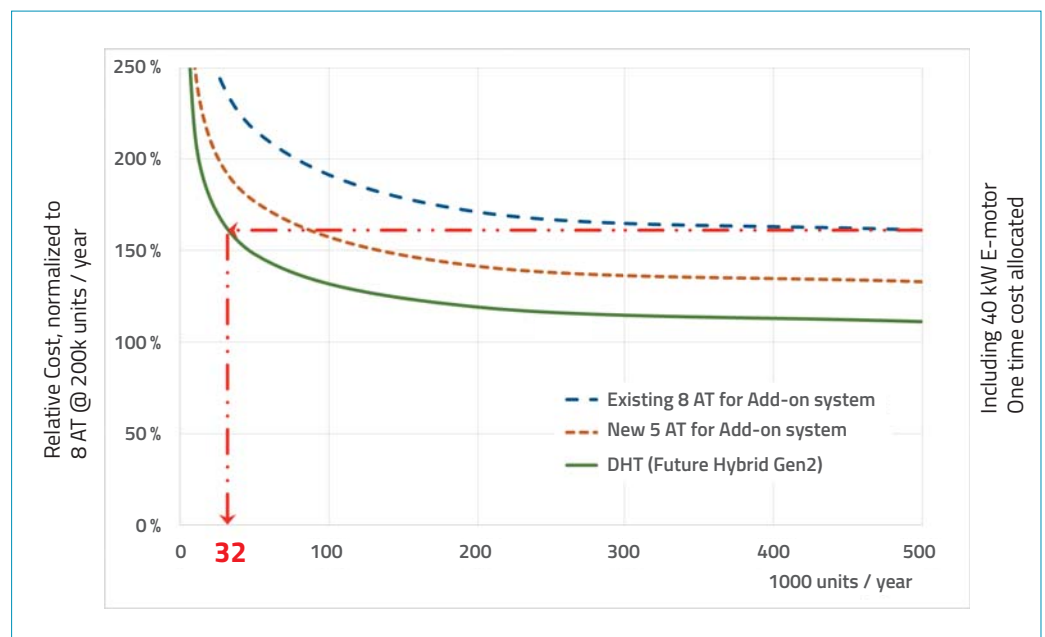


Figure 3 Volume sensitivity of Cost for Hybrid transmissions

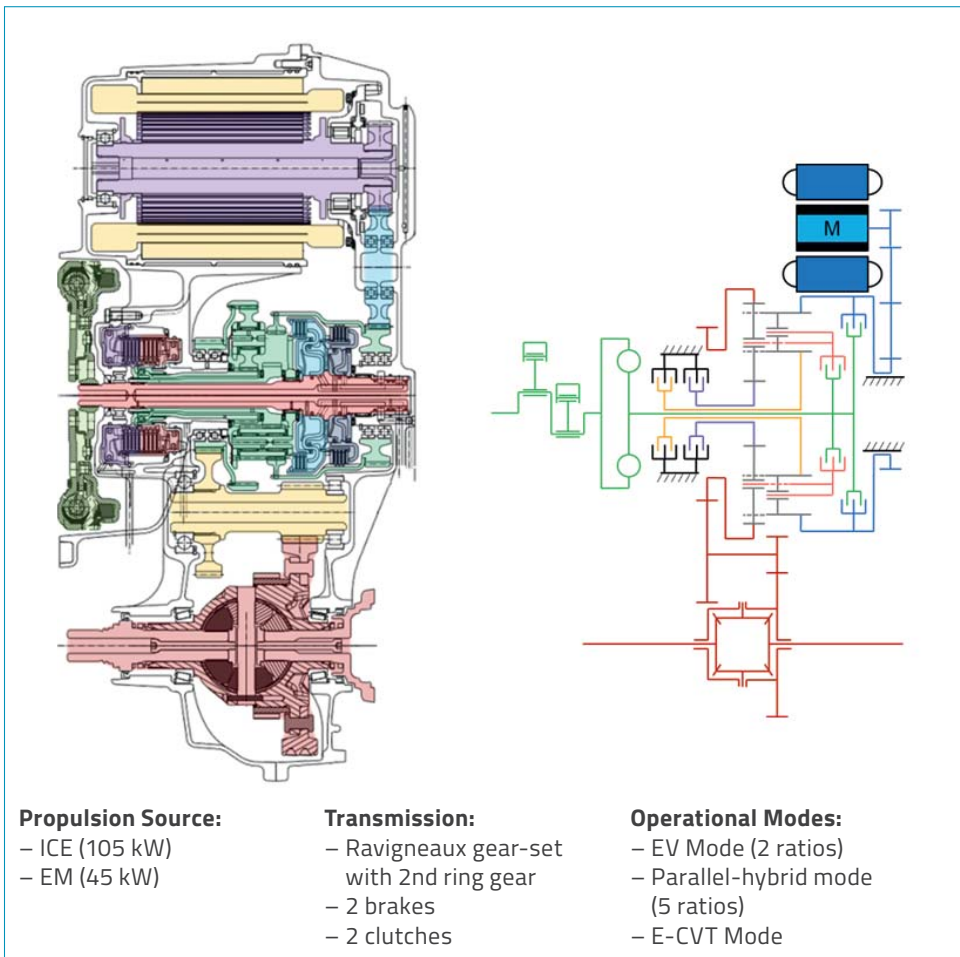


Figure 4 DHT Example: AVL's 2nd Generation Future Hybrid

Toyota, who pioneered in hybrid development and industrialization, continuously improving their "Toyota Hybrid System", contribute to the 14th International CTI Symposium "Automotive Transmissions, HEV and EV Drives" this December in Berlin with a plenary speech. GM will inform the plenum about their second generation "Voltec Drive System".

In the DHT section another presentation from Toyota is scheduled titled "Toyota Hybrid System (THS) – dedicated to high volume production". AVL will present their DHT concept called "Future Hybrid". The "EOLAB" is the DHT from the Renault / Nissan alliance. Prof. Tenberge will present a DHT concept with "compact mechanics" in development with a Chinese OEM. And from GKN the "Multi-Mode Transmission" will be presented, which is successfully used in Mitsubishi's Outlander plug-in hybrid SUV.

As the volumes of hybrid vehicles are steadily increasing, DHT will become very attractive from a product cost standpoint (Figure 3). The graphs show the manufacturing costs including amortized non-recurring development and start-up costs for transmission with E-motor over annual volumes, based on normalized cost analysis of such transmissions (should-cost / true cost analysis). The first transmission is an 8-speed step automatic, the second a 5-speed design. Cost are normalized for the 8-speed variant at 200.000 units per year without electrification. AVL's "Future Hybrid" (Figure 4) is used as DHT example in this cost comparison.

Conclusion

Dedicated Hybrid Transmissions (DHT) are currently under development at many vehicle manufactures and their key suppliers. With high probability the market perspective for DHTs is excellent and justifies the introduction of its own transmission category. Reflecting the concerns – all of them are of course justified – with respect to DHTs brilliant future, finally there is a good argument supporting the prognosis: Already today twice as many DHTs are sold as the sum of all other Full-Hybrid transmissions together (Figure 5).

DHT presentations at CTI Symposium Berlin 2015

More functionality at lower cost. The only "if" is the volume. And for sure, it will increase. The pressure on emission reduction and improved fuel economy will require more electrification. And customers will not accept strong limitations in driving range, so hybrids and plug-in hybrids will need to meet legislation and customer expectations.

These trends and perspectives were discussed in the CTI Symposium's advisory board. The definition of a new transmission category "Dedicated Hybrid Transmissions (DHT)" was concluded and I was asked to introduce this new transmission category to the plenum. The proposed presentations with respect to DHTs were combined in an own section and two more plenary speeches are scheduled:

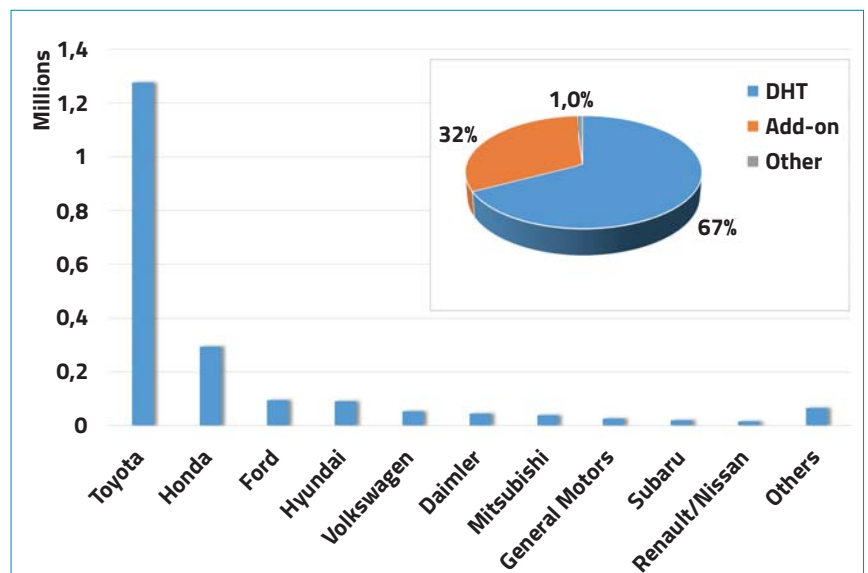


Figure 5 2014 Full Hybrid Production Volumes (IHS database 4th quarter 2014)

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Multimode transmission – one ratio, but multiple modes

Multimode Transmission – an unique Hybrid Transmission Concept

The Multimode transmission, developed by GKN Driveline and used first in the Mitsubishi Outlander PHEV, combines an internal combustion engine (ICE), Generator and eMotor to provide either fully electric, parallel or serial hybrid operation.

■ Theodor Gassmann, Director Advanced Engineering, GKN Driveline International GmbH

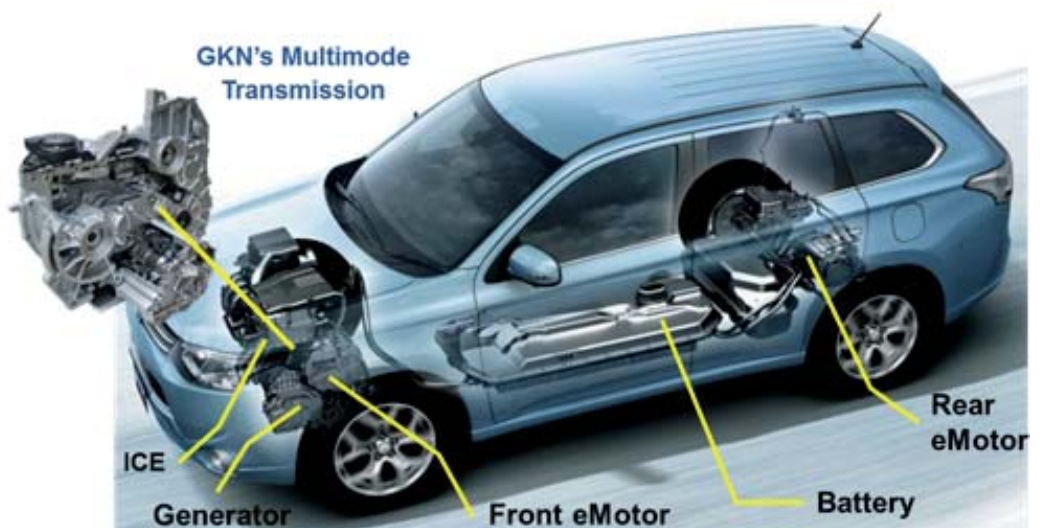
The MMC Outlander PHEV

Mitsubishi Motors' all-new Outlander Plug-in Hybrid Electric Vehicle (PHEV) comes with a unique powertrain layout. The vehicle launched in 2013 and has grown in popularity, becoming the best-selling hybrid car in UK this year. The vehicle is powered by two 60kW electric motors, one in the front and one in the rear, which are fed by a large capacity lithium-ion battery, as well as a petrol engine driving a 70kW generator and/or directly the front wheels. This unique powertrain configuration provides superior all-wheel drive (AWD) performance, with best-in-class fuel consumption. It uses the cutting edge GKN Driveline Multimode Transmission, developed in conjunction with Mitsubishi. This Transmission drives the front wheels and combines ICE, Generator and electric Motor to provide either electric, parallel or serial hybrid mode with smooth, comfortable transition, fully transparent to the driver. The vehicle automatically selects the most efficient drive mode to match all driving situations. This flexibility in operation modes provides unmatched performance in terms of fuel consumption and CO2 reduction.

GKN Multimode Transmission

While standard transmissions need only to consider torque flow from a single source, (the combustion engine), the Multimode Transmission has to manage two inputs, the ICE and the eMotor, and 2 outputs, the Generator and the output to the wheels. The key technical challenges were the extremely tight packaging, with a total in-width of less than 200mm, and the aggressive weight and efficiency targets. Silent

Figure 1 Hybrid Powertrain of the MMC Outlander PHEV with GKN Multimode Transmission



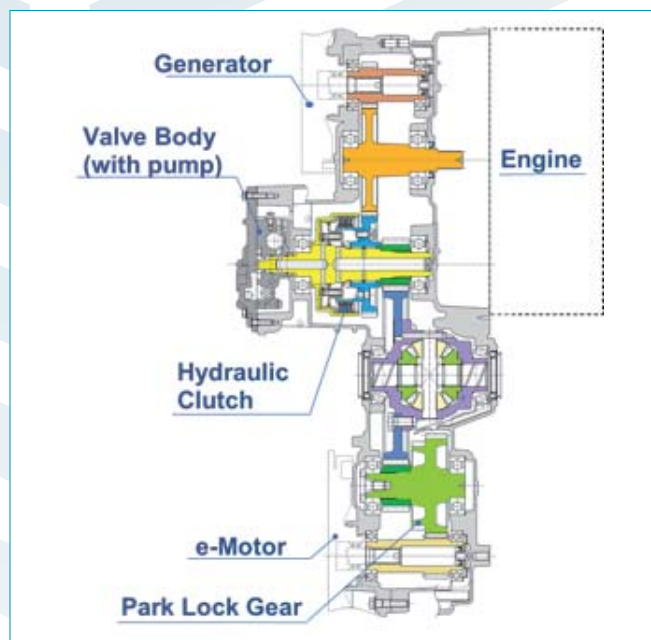


Figure 2
Cross section of the Multimode Transmission with the two distinguished gear trains, one for the eMotor and one for the ICE, both with a fixed ratio and jointly driving the differential.

operation in all modes and smooth shift between modes was also high on the performance agenda.

The Outlander Multimode Transmission consists of two distinguished gear trains, one for the eMotor and one for the ICE. Both gear trains have a fixed ratio and jointly drive the differential. The eMotor gear train is permanently engaged with the differential; the ICE gear train uses a hydraulically actuated wet-clutch to connect to the differential. The ICE drives the generator directly with a single-stage gearing to adjust ICE and generator speed. In EV-Mode, where the ICE is off and the clutch is open, only the eMotor is driving the front wheels. In Serial Hybrid Mode where the clutch is still open, disconnecting the ICE from the differential, again only the eMotor provides traction, while the ICE is driving the generator to provide additional electricity. By closing the clutch, the transmission switches to the Parallel Hybrid Mode, where the ICE and the eMotor are jointly driving the front wheels. A charging mode can be used to charge the battery at low state of charge (SOC) when the vehicle is parked. In this situation it is imperative that the clutch does not close. This safety critical requirement has had significant impact on the design of the clutch actuation system.

Key Transmission Features

An essential element of the Multimode transmission is the wet clutch to connect the ICE to the differential. By closing the clutch, the transmission switches from EV or Serial- to the Parallel Hybrid Mode, where the ICE and the eMotor are jointly driving the front wheels. The wet friction clutch with a torque capacity of more than 270 Nm has been optimized for smooth and quiet operation, lowest drag and best engagement response. This requires tight tolerance control during assembly and specific friction material with lowest wear over life.

The hydraulic clutch actuation system consists of a mechanically driven gear pump, a shift valve and a pressure limiter valve. The pump design and the arrangement of the pressure control valve have been optimized to achieve low power consumption of less than 200W @ 100kph by achieving the required clutch response time. The hydraulic system uses transmission oil, sucked from the oil sump through an oil strainer. The arrangement of the pump in the eMotor gear train prevents any clutch engagement when the car is in reverse or is parked (charging mode).

Key development targets for the gear train included superior NVH performance for near-silent operation in EV-mode and best efficiency for maximum range and fuel saving. Advanced simulation tools have been applied to find the right balance between durability, efficiency and NVH. The selected contact ratio of > 3.5 with optimized micro geometry supports the tough durability and NVH targets, while the use of low friction ball and taper-roller bearings and the advanced lubrication concept helps to minimize losses. The superior NVH performance has been confirmed in the car, with a rating of at least 8 and better in all operation conditions. At the same time efficiency of the transmission @ 80 °C oil temperature is close to 96 % in the EV mode and better than 96 % in the parallel hybrid mode.

The required Park-Lock system is arranged on the intermediate shaft of the eMotor gear train. It had to be designed to work with an existing electromechanical actuator. Extensive kinematic modelling was applied to be able to cope with the high vehicle mass of max 2365 kg, the high eMotor inertia and the very stiff eMotor gear train at the same time. The high safety requirements and the very tight speed range for Park-Lock engagement (min speed 3 kph, max speed 5 kph) requires challenging tolerances and perfect manufacturing process control.

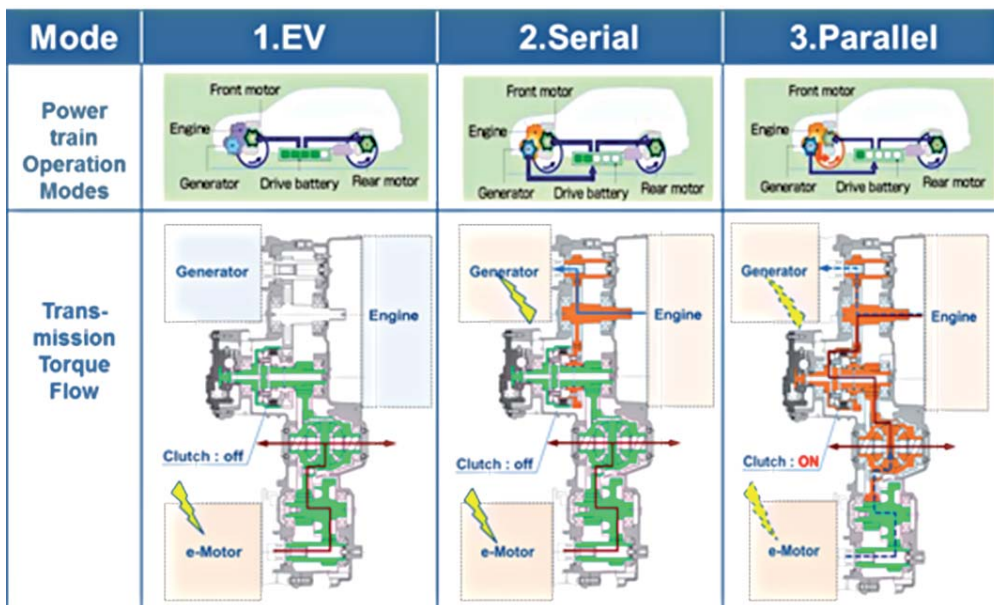


Figure 3 Overview of the Multimode Transmission operation modes, the according combination of the various power sources and power paths

Development Trends of Multimode Transmissions

Although the MMC Outlander PHEV has been first on the market with a Multimode Transmission, Honda introduced a very similar transmission concept in the MY2014 Accord PHEV. Traction motor and generator are coaxially arranged in the Honda transmission, but the working principle and the basic layout are same as the Outlander. This includes fixed ratio gear trains for eMotor and ICE, and a wet friction clutch in the ICE gear train to disconnect the combustion motor in EV mode and at low speed. The VW "Twin Drive" concept is another example of a hybrid powertrain with a single-speed/fixed ratio Multimode transmission.

The number of speeds in conventional transmissions has increased in recent decades in order to improve performance, comfort and fuel efficiency; a trend which might prove to have peaked with the 9-speed ATs recently introduced by ZF. There is considerable ongoing debate and investigation around how many speeds are actually required when adding a powerful eMotor to the powertrain. Whilst the single-speed Multimode Transmissions of the Outlander PHEV or the Honda Accord are obviously on the extreme opposite side of the scale, they demonstrate that old paradigms no longer apply to hybrid powertrains. Single speed concepts rely on the eMotor to launch the car before the ICE can be connected for parallel hybrid operation. Therefore these concepts require high eMotors power and an additional powerful generator for serial hybrid operation when battery SOC is low. Although the gear box of such a concept is simple and cost effective, the overall system cost is high due to the second electric machine. A more efficient solution would be to use both power sources (ICE + eMotor) from the outset to reduce installed eMotor capacity and maximize launch performance. Thus by avoiding the need for a serial mode, the generator might be eliminated, providing significant cost saving potential. Next generation Multimode Transmissions could, therefore, feature more than one speed but might come without Generator.

Summary

GKN Driveline has launched the first Multimode Transmission on the market. This transmission drives the front wheels and combines ICE, Generator and electric Motor to provide either EV, parallel or serial hybrid mode with smooth, comfortable transition, fully transparent to the driver. This flexibility provides unmatched performance with a range of 900 km and a fuel consumption of as low as 123.9 mpg (1,9 l / 100 km). Key elements of the transmission are the hydraulic clutch system which smoothly connects and disconnects the ICE to the front wheels, and the advanced gear design that achieves high efficiency and near-silent running. The single-speed Multimode Transmissions of the Outlander PHEV and the Honda Accord PHEV demonstrate that old transmission paradigms – such as "more speeds = better efficiency" – no longer apply to hybrid powertrains. Furthermore, the next generation Multimode Transmission could feature more than one speed without the need for a Generator.

The Innovative Transmission Concept for the Plug-In Hybrid Powertrain for the BMW 2 Series Active Tourer eDrive

The plug-in hybrid variant of the BMW 2 Series Active Tourer will be introduced to the market just 1 year after the first introduction of this BMW with front wheel driven powertrain architecture. The plug-in hybrid technology with street coupled hybrid powertrains is derived from the BMW i8 and facilitates the future use of this technology in mass produced vehicles. It is a combination of a turbo-charged 3-cylinder gasoline engine from the BMW construction kit and an optimised 6-speed automatic transmission on the front axle with an e-motor and a single-speed transmission incorporating a separation clutch on the rear axle.

- Dr.-Ing. Renate Vachenauer, Vice President Design Transmissions, 4-Wheel-Drive, BMW AG
- Dipl.-Ing. (FH) Lothar Wolf, BMW AG
- Dipl.-Ing. Daniela Kern, Manager E-Transmissions, BMW AG
- Dipl.-Ing. Tilo Marschall, Vice President Design Transmissions, 4-Wheel-Drive, BMW AG

The plug-in hybrid technology provides the following advantages of electric mobility to the customer: driving dynamics, outstanding efficiency, flexibility and unrestricted long-distance drive-ability. In addition to these general advantages, which are common for all BMW plug-in hybrid vehicles, the BMW 2 Series Active Tourer eDrive will provide an innovative electric all-wheel-drive-capability for the first variant in this vehicle segment. Furthermore this concept comes with dynamic characteristics supporting the joy of driving.

1.5 l displacement and a maximum power of 100 kW on the front axle is equipped with a belt driven high-voltage starter generator (HVSGR) and a 6-speed automatic transmission. The high-voltage battery storage system, which is assembled under the seats in front of the rear axle contains 16 cells giving an overall capacity of 26 Ah providing useable electric energy of up to 5.8 kWh.

The power ratio of a combustion engine combined with an e-motor of approximately 1.5 takes a significant step towards a higher degree of electrification.



Figure 1 The BMW 2 Series Active Tourer eDrive

System overview eDrive Technology

The main powertrain components of the BMW 2 Series Active Tourer eDrive are the fully electric rear axle with a 65 kW/165 Nm e-motor and single speed automatic transmission incorporating an electro-mechanically actuated dog clutch. The 3-cylinder gasoline engine with

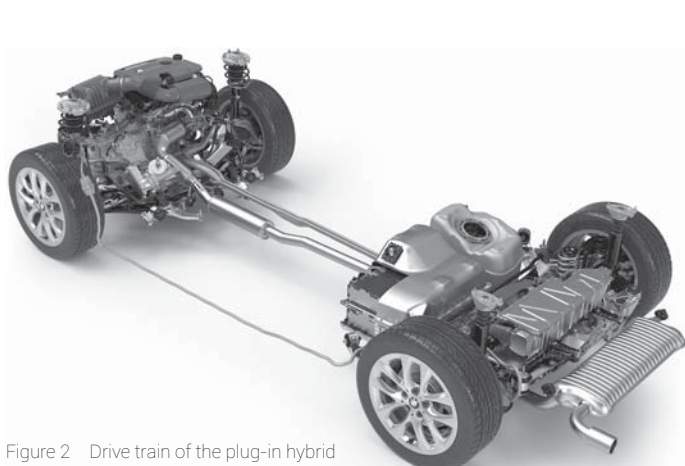


Figure 2 Drive train of the plug-in hybrid BMW 2 Series Active Tourer eDrive

The new e-gearbox

The new e-gearbox has been designed as a reduction of the 2-ratio-gearbox of the BMW i8. This new single speed design is the key to reaching a significantly reduced transmission weight and increased efficiency in order to maximise all-electric driving range and optimising needed installation space and costs for mass market vehicle applications. The speed limit for all-electric driving is specified as 125 km/h. The definition of the gear ratio was set to 12.5, enabling sufficient all-electric driving power and balanced wheel torques for the car, especially in all-wheel driving situations.

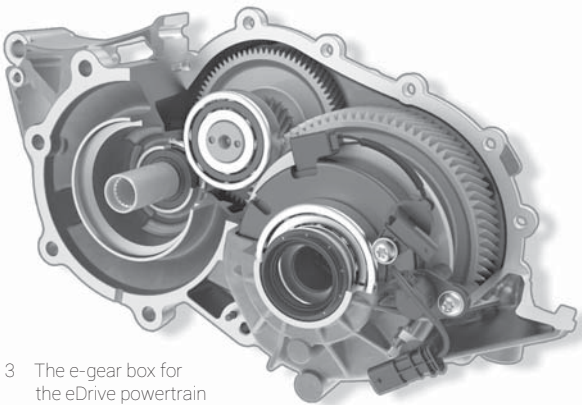


Figure 3 The e-gear box for the eDrive powertrain

The electrical drive train is disengaged at higher speeds to avoid excessively high rotational speeds in the e-motor. Within the differential, power flow is interrupted by means of a dog clutch. This means that, no electrical boost and recuperation is possible and only the combustion drive train will be active at these speeds. The normally open dog clutch is actuated by an electromechanical motor for which specially developed functions are executed in parallel to other tasks within the power electronic unit (PEU). Opening of the dog clutch is achieved with a disc spring removing the need for external energy.

The e-gearbox is optimized for efficiency. In particular, with an open coupling, swash loss is completely eliminated by locating the claw clutch inside the differential; when disengaged, and hence e-motor and gear sets are stationary, no swash will occur and the driveshaft only rotates inside the opened differential. Furthermore the gear teeth have been optimised in terms of acoustics and efficiency. The electric powertrain of the e-motor and e-gearbox is encapsulated to minimise noise emissions whilst maintaining a high comfort level of conventional 2series Active Tourer.

Hybrid Automatic Transmission

The combustion drivetrain uses a modified 6-speed automatic transmission from the BMW transmission kit (see Fig. 4), which was introduced for the first time in November 2013. On the hardware side the transmission has been adapted as follows:

The transmission has been adjusted for lower power and torque from the combustion engine as an activity in reducing weight and improving powertrain efficiency.

The mechanical gear-shift lever at the transmission user interface is carried over from conventional vehicles, in order to maintain familiarity with the controls for drivers.

The cooling concept of the transmission was adjusted for the installation position on the front axle. The external oil-to-air heat exchanger module is integrated into the vehicle's radiator grill. The system is equipped with a thermostat valve, which is directly mounted on the transmission housing, providing a constant oil temperature level in all environmental conditions.

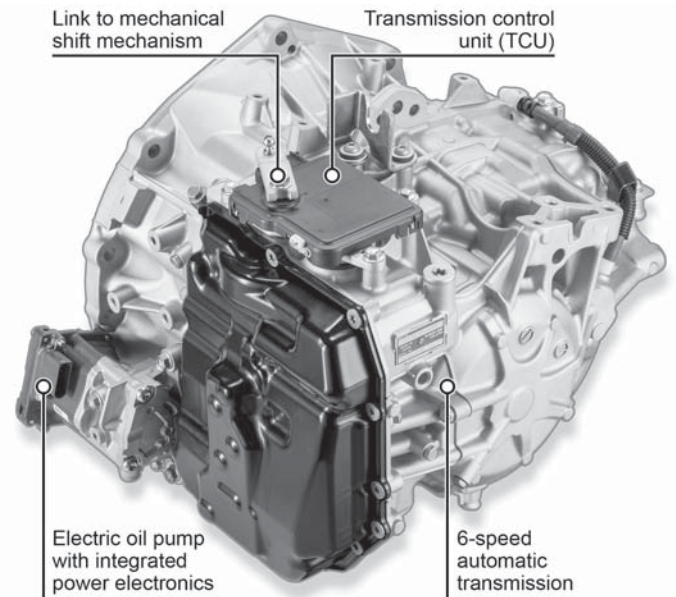


Figure 4 6-speed automatic transmission

The most significant change is the first introduction of an all new developed electrical oil pump with integrated power electronic unit. This external oil pump allows sufficient lubrication of the transmission when the combustion engine is turned off and additionally for filling of the shift elements before engine start-up upon e-drive. The functional enhancement of this pump allows for all-electric driving at temperatures as low as -4°C and improved performance when driving at lower temperatures.



Function network and driver interface in hybrid powertrain

The concept of wheel torque based powertrain coordination, known from the BMW i8, is also utilised in the BMW 2 Series Active Tourer. It allows for an effective distribution of power from multiple sources to multiple loads. This concept is adapted for the new driver interface and driving experience modes and includes new functions for operation strategy, such as an intelligent coasting function using navigational system data. The powertrain communication network and component interaction are illustrated in Figure 5.

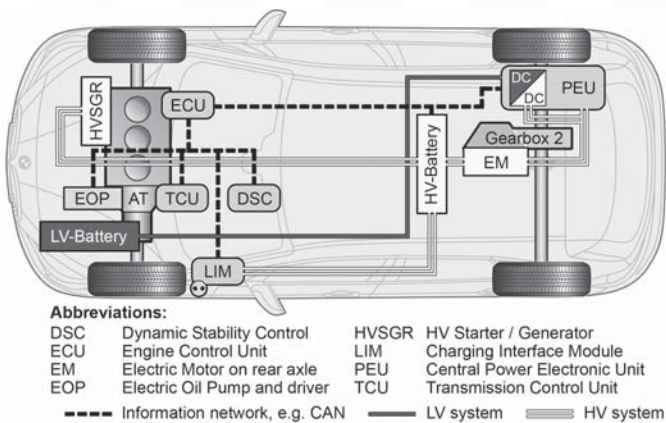


Figure 5 Schematic powertrain network of BMW 2 Series Active Tourer eDrive



Figure 6 Driving experience control and driver interface.

At first glance the driver interface of the BMW 2 Series Active Tourer eDrive is identical to the conventional variant. This adjustment should underline that hybrid technology can be understood as a usual 3rd powertrain variant like Diesel or gasoline engines. The Driving Experience Control switch has been adapted slightly to control the new eDrive modes "Auto eDrive", "max eDrive" and "Save battery". The functions of the eDrive modes and their interactions with the driving experience control are summarised in Table 1.

Innovative Transmission Functions

The BMW 2 Series Active Tourer eDrive utilises a lot of innovative transmission functions from the BMW function kit, such as navigation based shift point selection, driving condition dependant selection of re-engagement mode of the combustion engine and high shift dynamics. Furthermore the following function examples have been developed specifically for this vehicle.

Driving dynamics and interaction of the combustion powertrain with the eDrive

The development target of maximising the agility of the BMW 2 Series Active Tourer was achieved by providing maximum power response to the rear axle. The driver may experience a power provision comparable to a rear wheel driven car during dynamic driving situations, due to the fact, that the eDrive is much more responsive than the combustion powertrain. This rear axle oriented power distribution impacts the calibration of the automatic transmission, because the torque of the combustion engine at high load upshifts is smaller than in a conventional car. A minimum level of engine torque was defined to achieve shift times comparable with conventional vehicles.

Furthermore the behaviour of the vehicle is independent of whether it is being powered by combustion or electrical engines. For instance, the vehicle crawls in all-electric mode in the same way as a vehicle with conventional automatic transmission. Recuperation is dosed so that there is a smooth handover from recuperation to crawling. The recuperation limits via HVSGR or via the e-axle through the road are sufficient so as to cope with the larger part of all customer relevant deceleration situations. All engines HVSGR, e-axle and combustion engine are combined when there is a high acceleration demand from the driver. Especially in low speed areas and at low combustion engine torque the vehicle behaves in boost mode like a vehicle with a combustion engine with about 700 Nm torque. These functions maximize fun-to-drive especially on winding or mountain roads.

DRIVING EXPERIENCE MODES	ECO PRO	COMFORT	SPORT
	- Navi controlled eDrive. - Coasting function.	- Controlled Hybrid operation incl. Boost and eDrive.	- Controlled Hybrid operation with higher Boost.
POWERTRAIN MODES			
AUTO eDRIVE	- Combined hybrid and electrical driving.		- Engine start/stop and e-creeping.
MAX eDRIVE	Pure electric driving: - Pedal progression. - Recuperation. Low		High
SAVE BATTERY	- Controlled recharge of battery.		
S-RANGE	- Combustion engine always on incl. controlled recharge of battery. - Sportier shift programme and shiftmaps.		

Table 1 Overview of operation modes in BMW 2 Series Active Tourer eDrive

Strategies for the design of a coasting function

The general boundary conditions for a coasting function, such as a maximum speed of 160 km/h are similar to those of a conventional BMW car. The coasting function in ECO PRO mode minimises the drag torque in coasting situations, by mechanically opening the non-essential powertrain inside of the automatic transmission. In difference to a conventional car with coasting function, the eDrive is able to fully shut-down the combustion engine. Thus, both types of coasting function with and without active combustion engine are implemented in the BMW 2 Series Active Tourer.

This separation into 2 different types is a result of calculating the power needed during coasting and restarting the engine. Based on the results, the more efficient solution might be to keep the combustion engine running.

Strategies for compensation of powerdrop on eDrive axle

The decision to use a single speed e-gearbox was primarily driven by commercial aspects for mass produced vehicles and resulted in dimensioning challenges for the powertrain specification and finally, necessitated the introduction of a separation clutch system in order to avoid over-speed of the e-motor at speeds exceeding 125 km/h. An issue with the stepped torque drop at cut-off speed during a full-load acceleration drive remains. The vehicle will lose approx. 11 kW at this cut-off point giving a stepped, uncomfortable feeling, if no compensation is established. The following strategies had been applied to improve driving comfort:

- Over-boost of the combustion engine to rectify in the "power gap",
- Phase out of electrical boost on the eDrive axle, and
- Boost assist to the combustion powertrain via the high-voltage starter generator (HVSGR).

Figure 7 shows the results as a comparison of the situations with and without a compensation strategy.

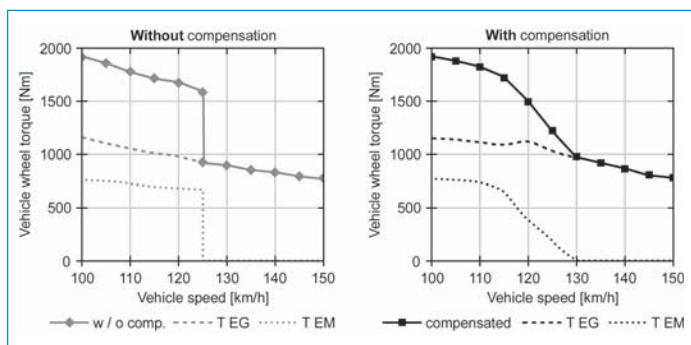


Figure 7 Schematics of torque drop compensation

Summary

The BMW 2 Series Active Tourer eDrive offers a combination of sporting ability, economy and everyday practicality unique to its segment. It is one of the first vehicles, which consistently adopts components and software from the BMW eDrive technology, which was launched in BMW-i vehicles for the first time. The street coupled combination of a 3-cylinder engine with 6-speed automatic transmission and an electric drivetrain makes BMW 2 Series Active Tourer eDrive the "little brother" of the BMW i8.

The all new developed single speed e-gearbox and optimized 6-speed automatic transmission are examples of hardware adaptations. The improvements on the software are a more sophisticated torque-coordination and a variety of newly developed functions for the entire powertrain.

The BMW 2 Series Active Tourer is not only a plug-in hybrid model with locally emission-free driving mode, but also delivers the hallmark BMW attributes for dynamic excellence, sporting ability and driving pleasure whilst offering the best performance in its segment.

References

- [1] Stefan Juraschek, Renate Vachenaier, Kai Lorenz, Tilo Marschall, Anton Stephan, Joachim Tachtler: The Efficient Plug-In Hybrid Drive In The New BMW 2 Series Active Tourer eDrive. 24th Aachen Colloquium Automobile and Engine Technology 2015
- [2] Tilo Marschall, Dr Robert Meyer, Martin Engelmann, Silke Steffens, Claas Henkel: Innovative Funktionen des Hybridantriebs im BMW i8. 14. Internationaler VDI-Kongress Getriebe in Fahrzeugen 2014

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Scalable Hybrid Dual-Clutch Transmission

With the tough CO₂ targets for 2020 of the European legislation, hybridization is one of the key elements to improve fuel efficiency. This article compares a 48V belt-driven e-machine solution with a solution based on a dual-clutch transmission with integrated e-machine. This so called torquesplit hybrid features a large scalability of the e-machine from mild to plug-in hybrid and a map-optimized interaction of engine and e-machine.

■ Uli Christian Blessing, Senior Manager Programs, Business and Strategy Chief Engineer Hybrid Transmissions, GETRAG

Introduction

Reducing CO₂ emissions and fuel consumption while meeting higher demands for dynamics and comfort are major development objectives for car manufacturers. This strong focus is being driven by end consumers as well as CO₂ regulations, through to zero-emission zones. Within the overall vehicle set up, the powertrain system is one of the key enablers to meet the requirements. Besides the need for lowest possible fuel consumption, the related costs are significantly important to enable a technology for the mass market. To achieve a remarkable effect on fleet consumption the fuel saving technology needs to be accepted by end customers, in that the real cost of ownership shows a benefit versus standard cars.

Today's available parallel hybrid solutions are only ready for niche market volumes and therefore purchased mainly due to their "green" halo effect instead of their benefit for real cost of ownership. A reasonable alternative is a hybrid kit suited for meeting various customer requests to enable higher overall volumes and development synergies. To start with, the 48V vehicle power is an ideal base for entry level hybridization, due to its lower cost for battery and electric components without the need specific safety measures like in high-voltage applications. The base component of this hybrid kit is the Getrag dual-clutch transmission. Thanks to the so called torquesplit design, this transmission can be flexibly scaled from mild to plug-in hybrid.

Base Transmission

Starting in 2015 the Getrag dual-clutch transmission 7DCT300, Figure 1, will be introduced in several vehicle programs by various OEMs. The

7DCT300 is the first model of a new transmission generation. The all new seven-speed wet dual-clutch transmission (DCT) with electrohydraulic clutch and electromechanical shift actuation was developed to ensure high fuel efficiency, low weight, low inertia and excellent drivability. The seven-speed gearset is ready for a maximum engine torque of up to 300 Nm and offers a gear ratio span up to 8.6. By using a newly developed low-inertia wet dual clutch with on-demand oil-cooling, the transmission is ready for downsized engines that are increasingly used.

Hybridization Kit

Dual-Clutch Transmissions are suitable for multiple hybridization topologies, as the e-machine can be connected to the transmission by different methods. Compared to an automatic transmission based on planetary gearsets or continuous variable transmissions (CVT), further optimisation potentials can be achieved. Getrag is focusing on the so-called torquesplit hybrid to achieve maximum fuel efficiency improvement with lowest possible on-cost.

Compared to usual parallel hybrid drives, a more flexible and efficient interaction of the e-machine and internal combustion engine is possible. Functionalities as efficient load shifting or re-start of the internal combustion engine during electric driving are inherent to the torquesplit design. Thanks to the two input shafts and output shafts for odd and even gears, the input torque of the internal combustion engine can be transmitted to the output by a mechanical path different from the torque path of



Figure 1 Dual-clutch transmission 7DCT300 with wet dual clutch, electrohydraulic clutch actuation and electromechanic shift actuation



Figure 2 Gearset including connection to rotor shaft

the e-machine. The torques are summed up at the ring gear that is connected to the differential.

As shown in Figure 2, the e-machine is connected to the input shaft with even gears. It is oriented axially parallel to the input shaft and connected via a single ratio step. The chosen gear ratio allows the use of high speed e-machines, which are operated in much higher speed ranges (> 18,000 rpm) than the internal combustion engine. Compared to a conventional parallel hybrid with the engine and motor running at the same speed, this arrangement is superior as to weight, inertia, package and cost.

Moreover, the torquesplit hybrid allows operating the internal combustion engine and the e-machine with different gears. When the internal combustion engine is connected to the output via an odd gear, the e-machine can be added to the torque path by closing clutch 2, assuming no even gears are engaged. Alternatively the e-machine can be connected to the torque path with an open clutch 2 and a selected even gear. Due to this flexibility, the e-machine can be operated in the best efficiency area over a large range of driving conditions. Typically, the e-machine and the internal combustion engine have their best efficiency area at different speed levels. Therefore independent ratios for both e-machine and internal combustion engine provide overall efficiency advantages.

Torquesplit hybrid transmissions offer full hybrid functionality:

- Stop/start
- extended sailing
- pure electric driving
- re-start of the internal combustion engine during electric driving
- Boost and recuperation via the e-machine

Besides functional aspects, one of the key elements for hybridisation is the in-

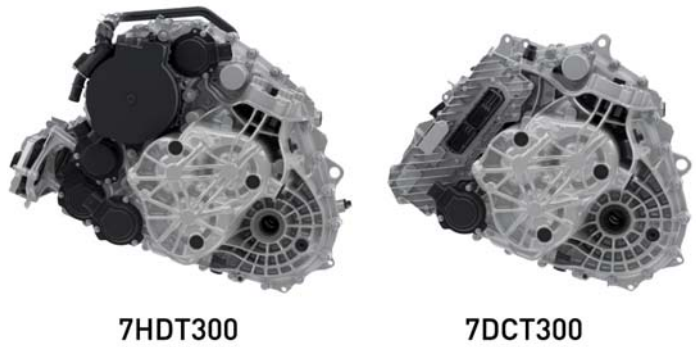


Figure 3 7HDT300 and 7DCT300 package compared

tegration of the e-machine within the available vehicle package. Figure 3 shows a comparison of the 7DCT300 base transmission with the 7HDT300 hybrid transmission. Thanks to a package-optimised design with a small high-speed e-machine the 7HDT300 can be used in many vehicle platforms in the given package. Scaling the e-machine can be done by modifying two parameters: the number of windings and the length of the assembly. The latter can be varied by changing the active length of the e-machine by reducing the number of stator and rotor steel plates.

48V Hybrid Transmissions Compared

In order to provide for additional electric consumers, the 48V power supply is gaining significance, as it needs no additional high-voltage safety measures. Thus the next logical step for introducing a 48V hybrid is adding a belt-driven e-machine to the engine. Especially the continued usability of existing 12V manufacturing technologies of conventional claw-pole alternators enables a cost-attractive solution. Moreover, this electrical system can be implemented with today's battery and semiconductor technology.

Figure 4 shows the layout of a hybrid drive with an e-machine connected by a belt and a torquesplit hybrid solution. Compared to the belt solution, the torquesplit design offers a number of advantages. As described above, the torquesplit hybrid features an e-machine that is integrated in the transmission case. For the belt solution an air-cooled claw-pole e-machine is used, whereas the integrated solution can be designed with an oil-cooled asynchronous machine or a permanent magnet synchronous machine. This flexibility offers more electric performance and thus more fun to drive. In Table 1 some key performance data of these different solutions are shown.

	Belt Solution	Integrated Solution
<ul style="list-style-type: none"> ■ electric creeping/driving ■ boosting ■ generator-mode ■ efficiency ■ extended sailing ■ driveability ■ costs 	<ul style="list-style-type: none"> ■ not possible ■ limited ■ possible ■ medium ■ no electric acceleration ■ limited improvement ■ low 	<ul style="list-style-type: none"> ■ possible (<20 km/h) ■ possible ■ possible (diff. gears) ■ high ■ initial electric acceleration ■ additional features ■ medium

Figure 4 Parallel hybrid with e-machine connected via belt (left) and torquesplit hybrid (right)

	Belt Solution	Integrated Solution
E-Machine Performance		
Max. Torque	50 Nm	up to 80 Nm
Max. Power	12 – 14 kW	up to 20 kW
Cont. Power	2.5 – 3.5 kW	up to 8 kW
Efficiency	up to 85 %	up to 92 %
Fuel Efficiency Improvement		
New European Driving Cycle	10 – 12 %	19 – 22 %
Worldwide Light Vehicles Test Procedure	7 – 9 %	14 – 16 %

Table 1 Comparison of belt vs. integrated solution.

As a consequence of the higher e-machine performance and efficiency, the fuel efficiency of the integrated version is superior to the belt solution. A conventional C-segment car without stop/start was used as a reference for the fuel consumption simulation. Major reasons for the higher efficiency of the torque split hybrid can be found in the ability for pure electric driving and extended sailing thanks to the elimination of the combustion engine drag torque. Depending on the battery capacity, pure electric driving up to 20 km/h is possible. As a result the 48 V torquesplit hybrid offers driving functionalities close to full hybrid versions but at much lower costs. The "bottleneck" of the belt solution can be seen in the lower continuous power of its e-machine and the missing option to avoid the engine drag torque losses. Another advantage of the mild torquesplit hybrid is the good compatibility with downsized engines that are gaining importance. These engines profit from the low inertia of the wet dual clutch. Furthermore, even the 48 V hybrid can add up to 80 Nm torque for engine support.

Torquesplit Plug-in Hybrid

In current full and plug-in parallel hybrids the e-machine is mounted between engine and transmission. In contrast to the belt solution a separating clutch allows for basically the same hybrid functions as the torquesplit hybrid. But the e-machine necessarily runs with the same speed as the engine. As a consequence a small high-speed e-machine is not applicable. Moreover, scalability within the package is limited, and the efficiency maps of engine and e-machine cannot be optimally considered by accordingly using different gears. In contrast to this parallel design, the e-machine support within the 7HDT300 is scalable to a large extent – from 48 V with 20 kW peak power up to battery voltages of up to 400 V with more than 80 kW peak power. In accordance to the installed engine, the hybrid system can be easily adapted by scaling the e-machine. The powerful e-machine allows pure electric driving up to more than 130 km/h. The technical data of this e-machine are shown in Table 2.

	Plug-In Solution
E-Machine Performance	
Max. Phase Current	420 A
Nominal Voltage	250 V
Max. Torque	165 Nm
Max. Power	> 80 kW
Cont. Power	> 30 kW
Max. Speed	> 18,000 rpm

Table 2 Technical data of the plug-in hybrid e-machine

Despite the high power density of this e-machine an asynchronous machine can be used to eliminate the commercial risk of rare-earth magnets. Depending on the capacity of the battery (e.g. pure electric mileage of up to 50 km), it is possible to achieve fuel efficiency improvements up to 80 % compared to a conventional vehicle.

Summary

Thanks to its wet dual clutch with electrohydraulic clutch actuation and its electromechanical shift actuation the new state-of-the-art Getrag7DCT300 dual-clutch transmission is a capable basis for hybridization. Compared to conventional parallel hybrid transmissions, especially the torque-split design and the scalability from 48V to 400V offer efficiency benefits. Scaling the e-machine needs no additional space in the transmission case, allowing high flexibility as to vehicle integration and applications.

The article describes the opportunities using the so-called torquesplit hybrid system with a dual-clutch transmission. This concept and its different power levels ranging from 48 V systems up to 400 V variants of battery voltage are explained. Even a 48 V solution. Especially in the 48 V solution the integration work enables additional fuel efficiency and a better driving performance than the belt solution. The scalable, flexible and modular approach opens the possibility to meet various customer needs thus accelerating the market penetration of affordable hybrid drives.

An Examination of Component Losses of FWD and RWD Continuously Variable Transmission Concepts

Efficiency Analysis of Multi-Mode Passenger Car Transmission Concepts featuring a VariGlide® CVT

Multi-mode powerpath configurations with a VariGlide continuously variable planetary transmission can yield wide ratio spreads with excellent transmission system efficiencies

■ Gordon McIndoe, Dana Holding Corporation and Joe VanSelous, Drive System Design, Inc.

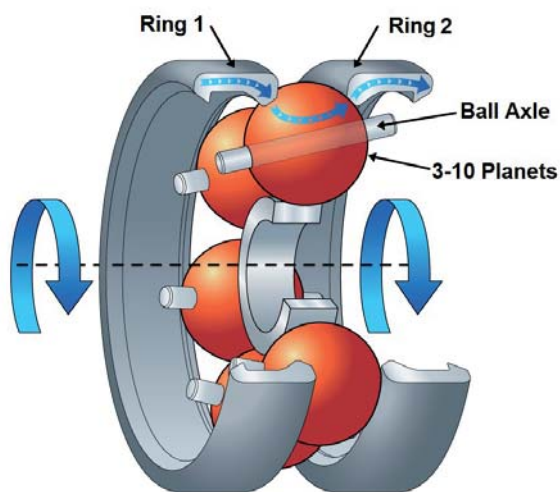


Figure 1

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Background

Dana's VariGlide CVT technology is a continuously variable planetary (CVP) ratio device that transfers torque elasto-hydrodynamically between rolling elements. Kinematically equivalent to a split ring planetary gear, see Figure 1, the CVP has ten native power paths including; CVT and IVT arrangements; along with power summing and power splitting.

The CVP power path chosen here is the simplest, which consists of input to one ring and co-axial output to the second ring. The rotational direction is the same for input and output.

The planets are balls with axles supported by a carrier assembly (not shown) that is fixed to ground. The sun element does not transfer any power but acts as an idler. The ratio range of this path is approximately 4 to 1 with a middle ratio of 1 to 1. The co-axial power flow also lends itself to integration into traditional geared planetary designs. The native power summing and power splitting capability is also ideal for P2 HEV adaptations.

When the CVP is combined with geared planetaries and clutching devices, the transmission ratio range is extended to equal the range of any 8 to 10 speed automatic.

Baseline Configuration: In this study, the starting point for analysis is a two-mode, synchronous shift demonstration transmission built by Dana. Here the CVP is paired with one compound and one simple planetary gear (see Figure 2). The connections and clutches enable two

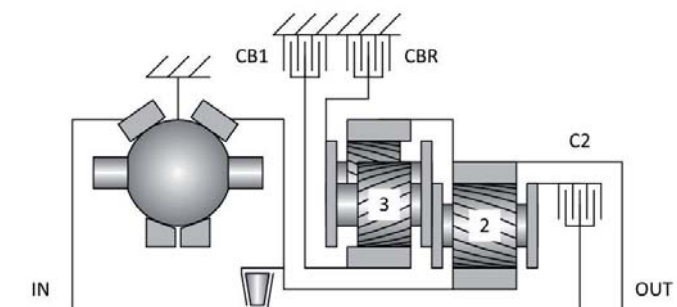


Figure 2

forward modes and one reverse mode. The demonstrator has this configuration, not because it is optimal, but because it has a simple gear set design and makes the best use of off-the-shelf parts. The resulting transmission ratios smoothly through a 7.6 to 1 ratio range using one synchronous shift between two modes.

A synchronous mode shift is one that does not require the CVP to reset its ratio from high to low at the mode change. The overall transmission ratio range is extended as the CVP ratios back through its range. In the first forward mode, all power flows directly through the CVP and then through a planetary reduction. As the vehicle speed increases there is a synchronous shift into mode two and power is now split between the CVP and a mechanical path with some power recirculation.

Simulation Methodology

As no single modeling tool yet exists to model a VariGlide CVP enabled transmission, various methods are used to model the transmission component and subcomponent loss functions which are aggregated into comprehensive global modeling tool:

- CVP, One-Way Clutch and CVP Seals – Losses are derived empirically from test data.
- Seal Losses – Interpolation of supplier data for seal loss speed vs pressure by seal size.
- Pump – Calculations based on industry established first principle methods based on flow and pressure requirements.
- Open Clutch Losses (drag); Gear Losses; Bearing Losses and Churning Losses – Calculations are performed by the global model, using first principle methods.

[Note: The global model referred to is an industry accepted, off-the-shelf, transmission modeling tool.]

Validation – Correlation studies of the baseline transmission use test stand data at 3 engine speeds, 4 input torques and 4 CVP ratios (in each transmission mode) and show excellent validation. The model predicts the losses to within an average of 3% of measured values (Figure 3).

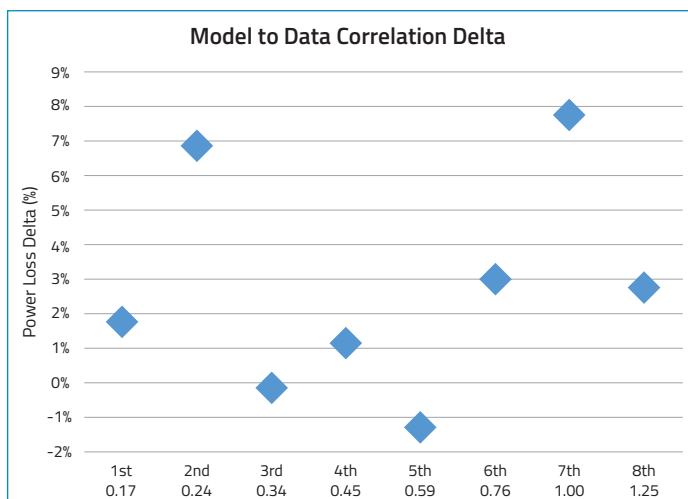


Figure 3



Configuration Optimization: To reduce the baseline transmission's losses and cost, two opportunities are explored; elimination of the Mode 1 compound planetary and minimization of the gear train in the power flow.

Three configurations, shown in Figure 4 as Options A, B, and C, meet that criteria. Like the baseline, each of these configurations has two forward modes and one reverse mode. Unlike the baseline, they all make use of simple planetaries.

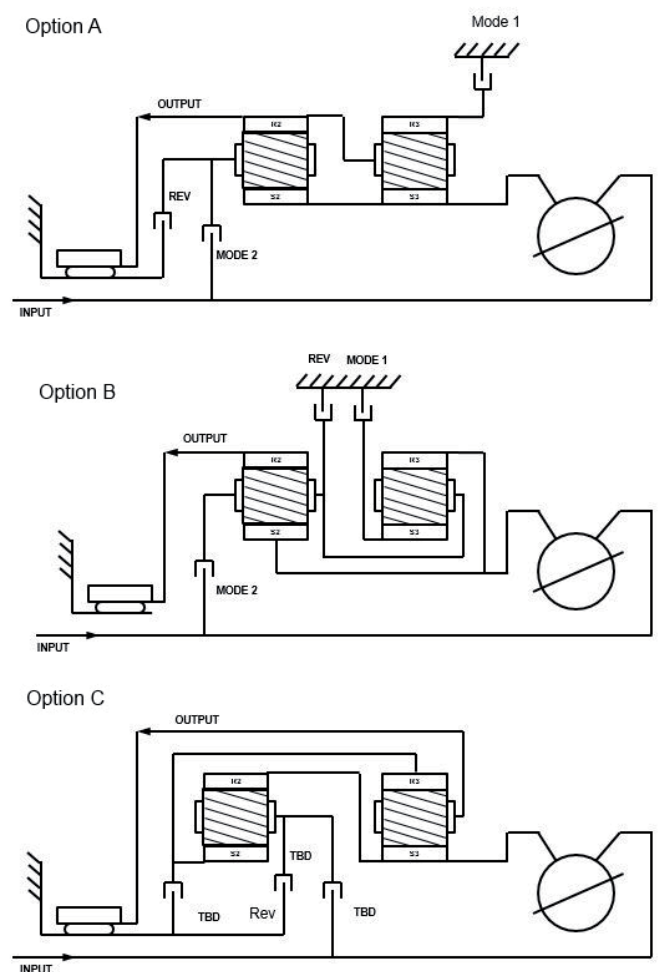


Figure 4

An assessment of power split and recirculation for each configuration is done at nine conditions along a road load curve. A high level of recirculating power is observed in Mode 1 for Options B and C. Power recirculation increases load on the CVP and gear train, requiring component size increases and the associated increase in cost and losses. Option A has no power recirculation in Mode 1. In Mode 2, more power is going through the CVP for Options B and C than for Option A. To minimize transmission losses during cruising, more power through the mechanical gear is desired.

Option A is selected for best efficiency due to the absence of a recirculating power flow in Mode 1 and a smaller power split through the CVP in Mode 2 cruise conditions. Another advantage of Option A is that the CVP is near its peak efficiency during cruise.

Opportunities for loss reduction can also be found in the pump. A fixed displacement dual output pump is compared to a dual displacement pump. For each there is a high pressure, low flow circuit controlling the friction elements and CVP actuator, and there is a low pressure, higher flow circuit to cool and lubricate the gearbox. The results show a significant reduction in pump power (Figure 5).

To reduce gear and bearing losses, gear tooth helix direction is analyzed. The initial investigation focuses on combinations that cancel loads to axial thrust bearings to reduce bearing losses. In another pass, the configurations are measured for efficiency. Bearings are sized based on contact stress at spike load conditions. Gears are sized for bending and contact safety factors in the drive cycle. Clutches in this transmission do not have any energy concerns as the shifts are either at idle or at a synchronous point. Their design is based only on static torque capacity.

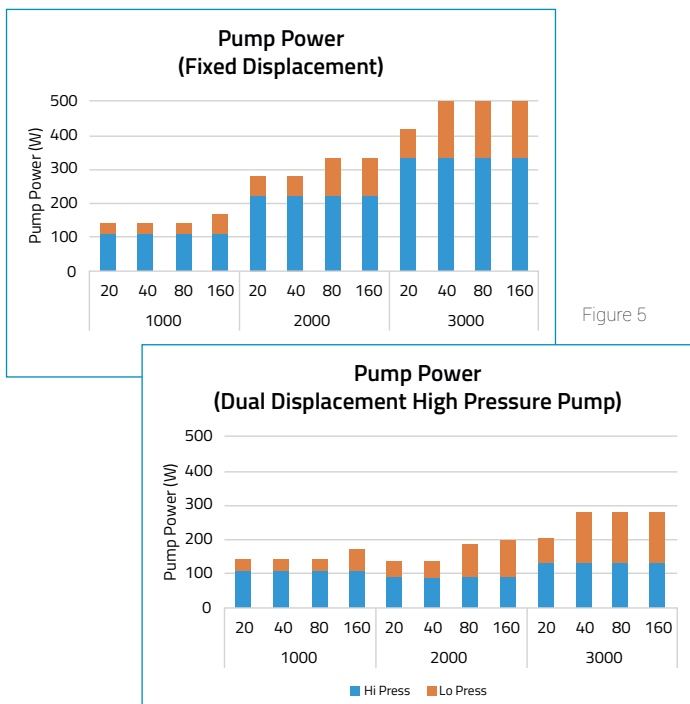


Figure 5

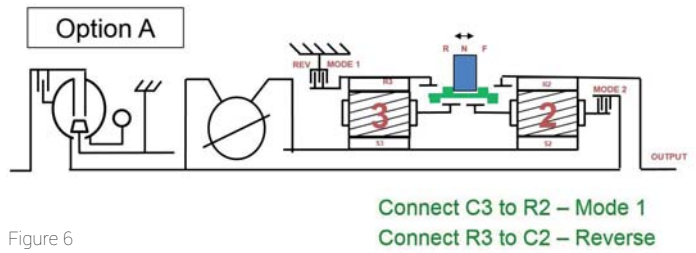


Figure 6

Packaging Option A: To package Option A for RWD it is necessary, in order to make the proper connections, to multiplex the Mode 1 brake for both Mode 1 and Reverse function through the use of a double dog switching device (Figure 6).

An advantage of the double dog feature is the elimination of a brake. The Mode 1 and Reverse brake is multiplexed and used twice. Another advantage is that in Mode 2 the sleeve position has no functional impact. However; an efficiency analysis with the dog in each position shows that the sleeve in neutral incurs the least drag loss. Because a brake can be eliminated, this feature is also implemented for FWD.

Packaging of the FWD and RWD transmissions are shown in Figure 7 and Figure 8 respectively.

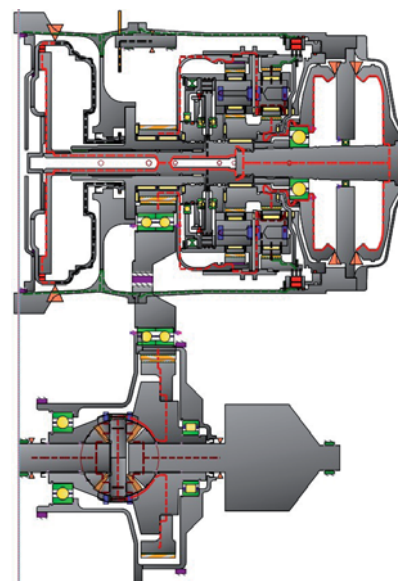


Figure 7

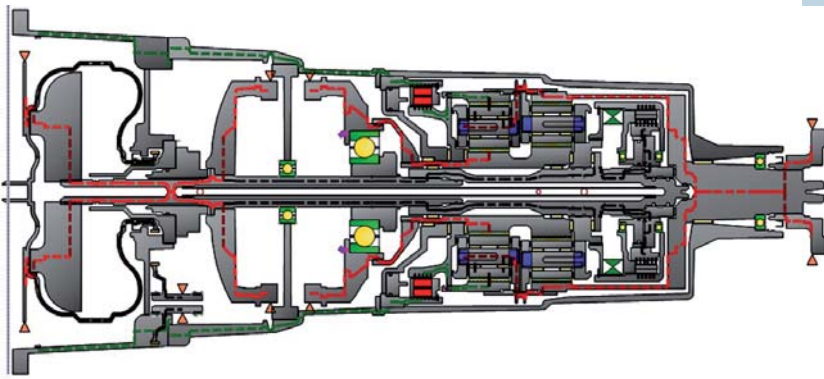


Figure 8

Option A Simulation

Simulation runs at eight discrete transmission ratios (Figure 9) are performed for both FWD and RWD.

Mode 1 is very straightforward as all of the input power progresses through the CVP; however, the model set up for Mode 2 presents a challenge. The global model does not have a direct means to simulate the varying percentage of power split at each CVP ratio. This limitation was overcome by using a surrogate gearset (for each Mode 2 CVP ratio) in place of the CVP.

The model output transmission losses for four input load cases (25 Nm, 50 Nm, 100 Nm and 200 Nm) at three input speed conditions (1,000 rpm, 2,000 rpm and 3,000 rpm). The load conditions for the FWD are 20 % less than the RWD. The total loss in each case is partitioned into the constituent component losses; CVP, clutches, seals, pump, gears and bearings.

	'Gear No.'	Trans SR	CVP SR
Mode 1	1	0.17	0.51
	2	0.24	0.72
	3	0.34	1.03
	4	0.45	1.36
Mode 2	5	0.59	1.77
	6	0.76	1.45
	7	1	1
	8	1.25	0.53

Figure 9

Rear Wheel Drive Results

The results at 2,000 rpm and 200 Nm (Fig 10) are representative. The CVP losses dominate in Mode 1; bearing and losses are secondary and tertiary. However, in Mode 2 the CVP losses drop significantly causing the total losses to drop. In 8th gear the CVP losses have reached their lowest levels, transmission losses are now larger than the CVP losses which are dominated by bearing and clutch losses.

Front Wheel Drive Results

Similar results (Figure 11) are seen for the FWD transmission, but the bearing losses are significantly higher than the RWD transmission. This is attributed to an increase in bearing count for the FWD unit.

Conclusions

Overall transmission losses are dramatically reduced in the second forward mode due to the power split between the CVP and the pure mechanical path. Peak transmission efficiencies in this study for FWD and RWD were determined to be 94 % and 95 % respectively.

Loss reductions are successfully achieved in all categories. FWD bearing losses could be further reduced in close cooperation with bearing suppliers. A parametric study of gear geometry effects should be undertaken early in the detail design phase to optimize these mesh losses and their effects on bearings. Pump loss reductions took advantage of reducing the high pressure pump displacement at higher speeds.

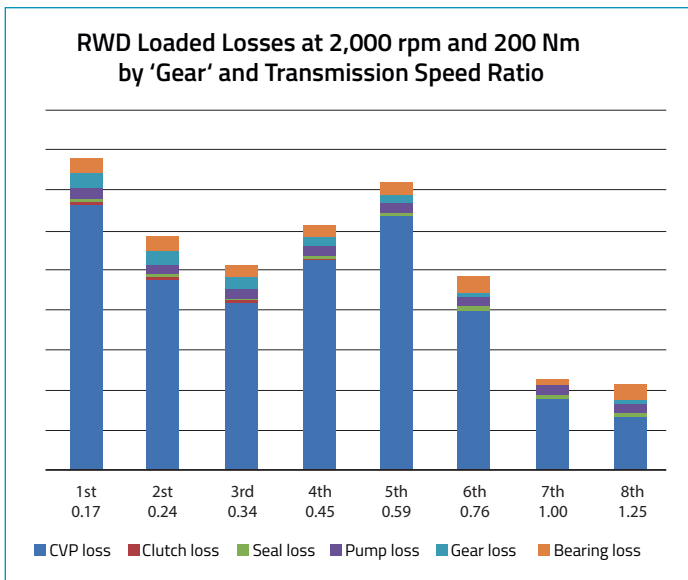


Figure 10

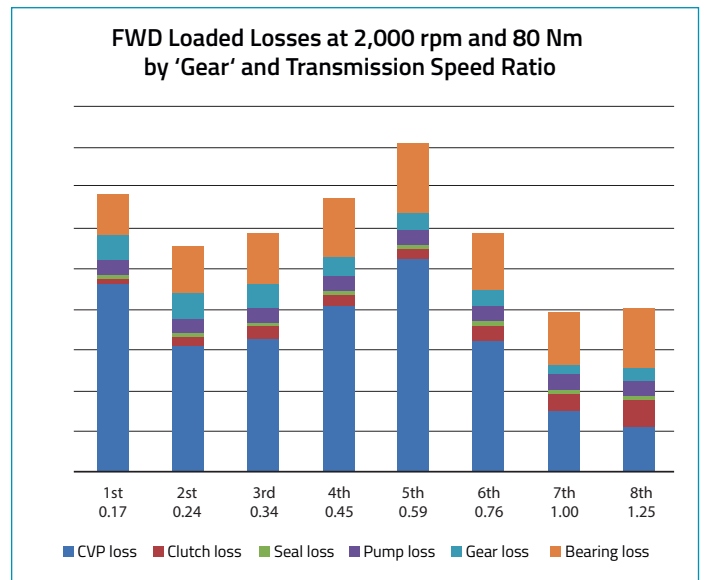


Figure 11

Affordable electric range due to modularity

BEREIT: Optimization of Parallel Hybrid Electric Vehicle (HEV) Fleets

Case study on OEM cost reduction potentials due to simplified transmission systems for an Axle-Split HEV fleet

- Jean-Eric Schleiffer, M.Sc., Prof. Dr.-Ing. Stephan Rinderknecht, Institute for Mechatronic Systems in Mechanical Engineering, TU Darmstadt
- Dipl.-Ing. Andreas Lange, Prof. Dr.-Ing. Ferit Küçükay, Institute of Automotive Engineering, TU Braunschweig

Motivation

The collaborative research project BEREIT investigates the potentials of using modular solutions across variants for parallel HEV powertrains. Modular parallel HEV powertrains can be designed diverse: With "add-on" solutions synergies can be exploited through the use of assemblies from conventional powertrains. Besides, new modular assemblies for HEV powertrains may allow using assemblies from pure electric drive vehicles (BEV).

By use of simulative assessment methods, suitable HEV powertrain layouts and assemblies for manifold requirements can be investigated with respect to efficiency, performance and costs.

Focus of the following will be the selection and design of suitable transmission systems for HEVs with Axle-Split powertrain (AS) in particular. This layout enables either to use conventional high volume automated transmission systems (typically DCT in FWD applications) or newly developed simplified transmissions at the axle that is driven by internal combustion engine (ICE).

Simplified transmissions are of particular interest in this case due to reduced demand of the number of gear ratios in HEVs^[1] as well as the possibility to outsource transmission functions into the electric drive system (e.g. torque fill in). On the one hand costs could be reduced due to lowered mechanical effort. On the other hand production quantities have to be taken into account, especially for low volume vehicles.

This investigation aims on cost reduction potentials for OEMs by taking synergies across different vehicles of a vehicle family into account. The example is based on a FWD vehicle family consisting of a small family car (SFC – #1), a compact multi-purpose vehicle (cMPV – #2) and a compact crossover utility vehicle (cCUV – #3) in an optimistic foresighted scenario.

Scenario Quantity Assumptions

It is assumed that there will be conventional vehicles, parallel HEVs and BEVs concurrently. Additional HEVs will supplement the existing powertrain architectures prospectively.

Besides an estimated future quantity of approx. 120,000 conventional vehicles per annum in this family there are also 120,000 1/a HEVs assumed with following distribution: 55,000 1/a SFCs, 40,000 1/a cMPVs and 25,000 1/a cCUVs.

Furthermore, there are 10,000 1/a subcompact BEVs expected with electric drive assemblies related to those in HEVs and a power rating of 60 kW.

Specific HEV Design Optimization

Basis for the following investigations is a proposed optimization method for the design of specific HEV powertrains by simulation^[2] in extension of the EVID method^[3]. Further complements in BEREIT, among others, are additional powertrain architectures, an extended operational strategy and more detailed, quantity dependent cost models.

The method and its extensions are based on simulative multi-criteria optimization using mathematical meta models to speed up function evaluation in a genetic algorithm optimization environment (see Figure 5).

Design Parameters

Besides the parallel HEV powertrain layout itself (P2, P3, AS) the optimization method and the subordinated simulation model cover assembly selection (ICE, transmission, different types of electric machines, ...) based on a powertrain assemblies building set and the parametrization of these assemblies according to Table 1.

Parameter	Assembly	Description
P_{EM}	electric machine	power rating electric machine
$Z_{G, TM}$	transmission	number of gears of front axle transmission
$n_{ICE@120 \text{ km/h}}$	transmission	ICE rev speed @ 120 km/h @ top gear
$\Phi_{2, TM}$	transmission	progression factor
$Z_{G, eTM}$	e-transmission	number of gears (eTM)
$v_{max, el}$	e-transmission	top speed in ED

Table 1 Design Parameters (DP)

Performance and Efficiency Assessment

Characteristic parameters for performance and efficiency assessment are determined by simulation in different driving cycles and operation modes. A universal HEV operational strategy is used across topologies and variants for comparable results based on ECMS^[4] with variable shift patterns^[5] High Speed Flywheel Hybrid Vehicle (HSF-HV).

For all possible assembly combinations, design parameter sets are generated with aid of DoE plans. The input (design parameters DP) and output (characteristic parameters CP) relations are transferred to mathematical meta models (artificial neural networks).

Afterwards the optimization process only evaluates the meta model associated to an assembly combination to assign CPs for candidate DP sets, whereby optimization time is reduced and an efficient sensitivity analysis is relieved.

Cost Assessment

All cost assessments are based on a two-step procedure:

First of all models of technical parameters of the assemblies are evaluated based on the assumption of a high volume production (reference quantity; estimated to 70,000 1/a). Afterwards this technically oriented basic cost estimation of the assemblies is adjusted by taking their targeted production quantities into account.

Expert opinions resulted in assumptions that an increase of quantities of 250 % leads to a decrease of total manufacturing costs of (only) 10 %. In contrast a decrease in quantities of 50 % is expected to cause a significant increase in costs of 50 %.

Transmission Costs

For a general technical cost assessment of transmission systems a distinction between different types, actuation principles and number of gear ratios is carried out.

Based on a bottom up approach, considering part lists of real transmissions, a top down approach is used to estimate base costs at reference quantity (see Figure 1).

In case of transmission systems these assumptions for costs depending on production quantities lead to a critical quantity of HEVs to enable lower numbers of gears at all regarding to Figure 2.

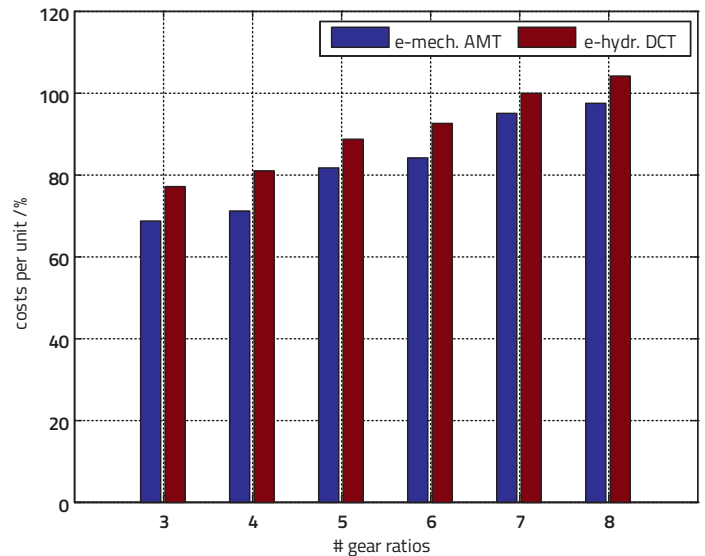


Figure 1 Transmission Cost Model

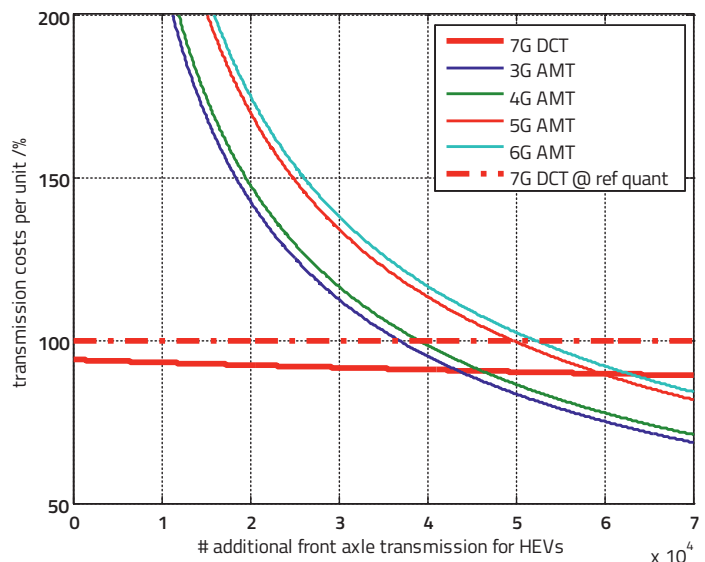


Figure 2 Quantity Dependent Transmission Cost Model

In this case simplified transmissions for HEVs only become relevant in cost assessment in comparison to a high volume production conventional transmission (7G DCT) if the quantity of HEVs is at least higher than ~43,500 1/a (3G AMT possible).

Electric Drive Costs

The electric drive costs are subsumed as the sum of the costs of the electric machine (EM) and the power electronics (PE).

The EM costs are calculated through a combination of costs for active modules and basic parts, such as the housing or bearings. The power of an EM can be rescaled by increasing the number of active modules of the EM. For example to double the amount of EM power the number of active modules has to be doubled as well. Since the unit costs of an active module decreases when its production volume is increased, the technical cost assessment of an EM contains already a unit dependency (see Figure 3).

The costs of the PE are basically a linear function of the power. Scaling effects can only be utilized if their number is increased with identical PE power rating.

Due to low production quantities of BEV electric drive systems (1/7 of the assumed reference quantity per annum of the cost model) the costs per unit are strongly dependent on quantities.

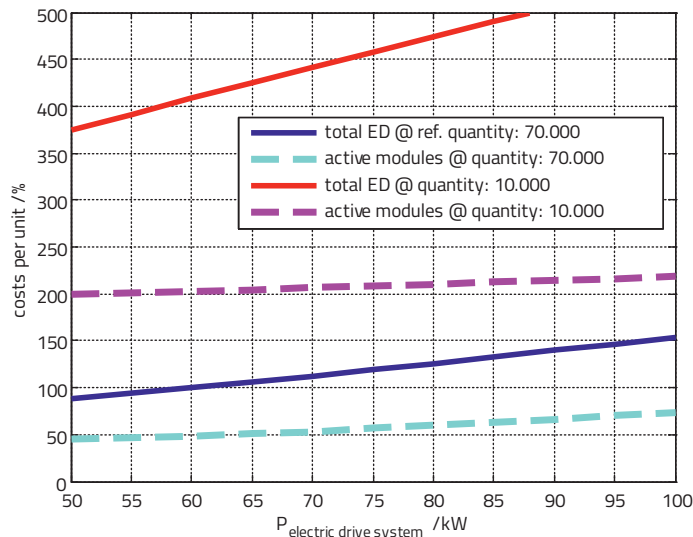


Figure 3 Electric Drive Cost Model

For a reference electric drive system power rating of 60 kW (100% costs at reference quantity) the costs evolve over quantities like shown in Figure 4. In this contemplation an increase of quantities has a much bigger influence on unit cost reduction than a decrease of power.

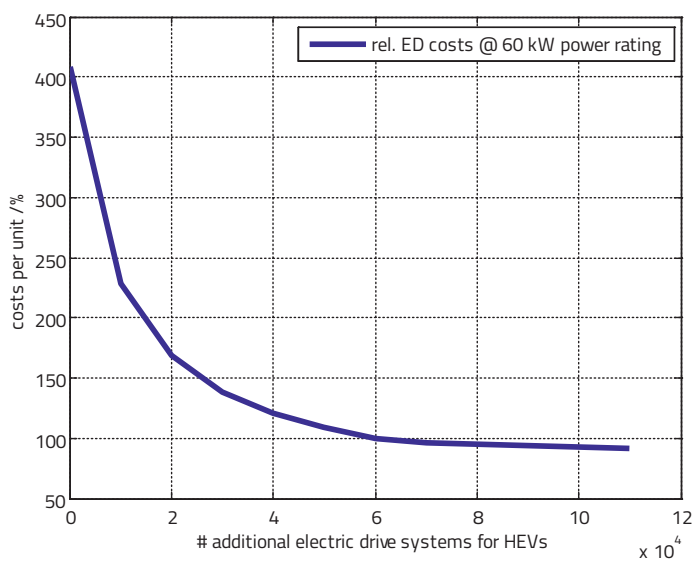


Figure 4 Quantity Dependent Electric Drive Cost Model

Overall Design Assessment

The characteristic values gained by performance (P) and efficiency (E) assessment as well as cost (C) assessment are merged with aid of a weighting function (see Table 2). The weighting function is setting dif-

fering physical dimensions of the characteristic values from the main categories (clusters) in relation to each other by normalizing to pre-defined bounds (10 = best, 0 = worst).

The multi-criteria optimization problem is reduced to a single-objective optimization for a best compromise depending on chosen weights.

Cluster	Characteristic Parameters (CP)	Cluster Weight
Performance	pure electric acceleration times (0–60 km/h, 60–100 km/h, 80–120 km/h), pure electric gradeability, hybrid acceleration time (0–100 km/h), hybrid top speed	25 %
Efficiency	Charge Depleting (pure electric) cycle energy consumption, Charge Sustaining (hybrid) cycle fuel consumption (both NEDC and WLTC)	35 %
Costs	front axle transmission system and electric drive costs	40 %

Table 2 Weighting Function

The weighting function accounts for customer concerns, legislation and economic viability at the same time. It should be noted that the result of the optimization is shaped by the weights and bounds of each characteristic value and thus the design focus can also be modified upon aim of the investigation.

In particular the upper cost boundary is limited in this example to find solutions which guarantees that the costs for front axle transmission and electric drive system together do not exceed approx. double the costs for a conventional front axle transmission in ref. quantity.

OEM-Fleet Optimization

Subsequently, the method is expanded to optimize vehicle powertrains with respect to the powertrain design of related vehicles.

Thereby it can be accounted for effects based on economies of scale in the design process of each vehicle in parallel. One single vehicle is able to benefit from equal parts in other vehicles of the family due to increase in quantities in regards of cost assessment.

Thereby variants with weaker efficiency and performance assessment (e.g. due to reduced number of gears) may achieve better overall ratings in the multi-criteria optimization process due to reduced costs.

The combination of all steps described above leads to the fleet optimization method depicted in Figure 5. One challenge is to specify the weighting between the considered vehicles. In this case study they are treated equivalently (overall design assessment of each vehicle equals of the total fleet assessment). Alternatives might be weighting by quantities or margins.

Case Study: Axle-Split Front Axle Transmission Design

In this case study the choice of assemblies is fixed. The investigation is based on a 4 cylinder ICE, a scalable ASM as electric drive and a fixed gear ratio e-transmission. The influence of P_{EM} on the e-transmission costs is neglected.

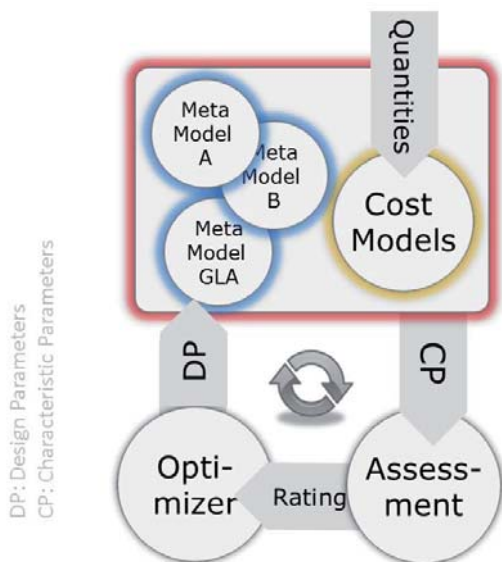


Figure 5 Fleet Optimization Method

Results and Comparison

The optimization results of both approaches described above differ in the final suggested powertrain designs for each vehicle: The specific HEV design optimization treats every vehicle independently and is searching for the best solution under the given boundary condition of comparatively low quantities. Thus, absolute values of costs for all components are higher than in fleet optimization method. Therefore other compromise solutions for the design parameters in the conflict of interests between weighted, clustered characteristic parameters performance (P), efficiency (E) and costs (C) are suggested. In Table 3 changes in the final, optimal design parameters and assessments in comparison between specific HEV design (left) and OEM fleet optimization (right) for each vehicle are shown:

	SFC – #1	cMPV – #2	cCUV – #3
P _{EM/kw}	90→95	90→95	80→95
Z _{TM}	3→3	7→3	7→3
Rating P	8.9→9.2	8.4→9.0	6.1→8.8
Rating E	7.6→7.6	7.3→6.9	5.9→5.5
Rating C	3.9→6.0	1.7→5.9	0.0→5.8
Total Rating	6.5→7.3	5.3→7.0	3.6→6.5
Cost reduction per unit	14%	25%	31%

Table 3 Comparison of Optimization Results

The central outcome is a significant overall cost reduction for front axle transmissions and electric drive systems for all HEVs of the considered vehicle fleet together: From OEMs perspective there seems to be a 23 % total cost reduction in comparison to a fleet that is based on specific design optimization powertrains. The cost assessment in the specific HEV optimization does not account for coincidental synergies with other vehicles, so of course the net impact in costs would be lower, but notably the powertrain design proposals differ significantly: Over and above the cost reduction it is noteworthy that even performance of all vehicles is increased due to the superior electric drive system power ratings. Beside that the drawback in efficiency rating for cMPV and cCUV because of the chosen simplified transmissions is negligible.

Due to the upper cost limitation the specific HEV design optimization is not able to find a sufficient solution for cCUV: due to limited quanti-

ties the cost rating as well as the overall assessment is poor. Especially in this heavy car of the fleet with at the same time low quantities it is not possible to increase the cost rating (means to decrease the costs) since this will cause a strong decrease in performance rating (compare Figure 3 and Figure 4).

In the specific HEV design optimization with quantity considering cost models for cCUV there would be no meaningful solution of hybridization in this assessment. In contrast, with OEM-fleet optimization for all vehicles rational and purposeful powertrain parameters are identified.

Furthermore there is a significant impact in costs for the electric drive system because the number of reference active modules of 10,000 1/a is increased not only to 130,000 1/a (sum of BEVs and HEVs) but reaches about due to 200,000 1/a the assumptions of power rating scalability via active module number increase.

Thus, the unit cost for one electric vehicle drive systems drops to about ¼ and there is a significant benefit for every BEV from the HEVs with related electric drive systems.

Conclusion

By taking vehicles of the same family into consideration the optimization method is able to account for increasing quantities already in the early design process of each specific vehicle. Therefore the introduced OEM-fleet optimization approach is able to reduce total costs for fleet production and at the same time to improve performance assessment. Furthermore new, simplified transmission systems are getting into focus for hybrid applications, even if quantity of one specific vehicle is low.

Outlook

Next steps will include investigations of sensitivities of input parameters (design parameters, weighting function, boundaries, cost model parameters and especially scenario vehicle quantity assumptions) on the optimization results as well as further studies on different parallel HEV layouts and assemblies. Beyond that a change of perspective e.g. from OEM to suppliers point of view is enabled.

Acknowledgments

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References

- [1] R. Fischer, R. D. Ellinger, P. Kapus, K. Erjawetz, M. Pongratz, P. Ebner, and B. Klima, 'Four are enough', in 11th International CTI Symposium – Volume 1, Berlin, 2012, pp. 75–94.
- [2] T. Meier, 'Multikriterielle Optimierung hybrider Antriebsstränge mittels statistischer Versuchsplanung', doctoral thesis, TU Darmstadt, 2014.
- [3] M. Eghtessad, T. Meier, S. Rinderknecht, and F. Küçükay, 'Antriebsstrangoptimierung von Elektrofahrzeugen', ATZ – Automob. Z., vol. 117, no. 9, pp. 78–85, Aug. 2015.
- [4] A. Sciarretta and L. Guzzella, 'Control of hybrid electric vehicles', IEEE Control Syst., vol. 27, no. 2, pp. 60–70, Apr. 2007.
- [5] I. Trivic, 'Comparative Analysis of Alternative Hybrid Systems for Automotive Applications', doctoral thesis, Università di Bologna, 2012.

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Designing for Maximum Transmission Efficiency in Electric and Hybrid Vehicles

For an electric vehicle (EV), improved vehicle efficiency is particularly important because it translates directly into increased range from the available battery charge. Maximum transmission efficiency can only be achieved if built in from the outset as a design attribute, rather than imposed later as a development target.

■ Matt Hole, Design Manager, Drive System Design

Over the last few years NVH has become a priority attribute for EV and hybrid applications because of the lower ambient noise level in the cabin of a vehicle. Software tools have been developed to allow NVH modelling as part of the design/analysis procedure, although not necessarily fully integrated into the process. With growing pressure to reduce greenhouse gas emissions from vehicles, efficiency is now becoming a top line attribute.

To optimise efficiency, refinement, durability and cost requires an interconnected suite of analysis tools, but no single software vendor

excels in all these areas. Engineers must re-create the rules of thumb as better and better software packages emerge and use them within a system engineering approach.

Specialist companies, such as Drive System Design (DSD), are not constrained to use tools from a single supplier and have become adept at harnessing the strengths of different software vendors, changing the way tools are employed to optimise all the attributes of a new transmission simultaneously. Delivering the maximum efficiency from a new transmission using a 'clean sheet' design presents so many choices that rapid and effective evaluation of each design option is essential.

The trade-offs made at component and sub-system level illustrate this point: clutches trade package and cost for efficiency, balancing the number of shearing surfaces against their relative speed; gears trade efficiency against refinement through the choice of tooth geometry; bearings trade package against cost to suit their load type and direction; the lubrication system trades efficiency against cost in the choice of an active, passive or managed passive arrangement; even the design of the casings trades durability against NVH through the choice of mounting strategy.



Figure 1 Lubrication optimisation has become an increasingly important part of transmission efficiency

Using this system approach in the real world

A series of sensitivity sweeps were performed on a multi-speed EV transmission, examining the influence of multiple parameters of the gear geometry, bearing specification, and lubrication regime in order to achieve the optimum solution for efficiency whilst maintaining durability and NVH targets.

Examples of specific design outcomes from the project include: the use of lower tooth depth gear forms with axial contact ratio increased rather than transverse contact ratio; the trade-off between axial load and the requirement for less efficient bearing types; the influence of the major losses in 'real world' driving conditions rather than NEDC load cases, reflected in the selection of bearings with low parasitic losses and the effect on gears at higher torque loads.

DSD's ground-up approach predicts up to twice the improvement achievable through conventional revisions to an existing transmission. Where a redesign may improve efficiency by between 4 and 6 percent, the system approach can produce an improvement of between 6 and 8 percent. The efficiencies calculated by the model have been correlated against physical measurements performed on a rig-based prototype transmission.

In another study DSD investigated the 'dry sumping' of a client's transmission to minimise the losses from oil churning; the cost of additional components to pump oil to areas critical for lubrication and cooling was traded against the saving in potential fines for non-compliance with CO₂ targets.

The systems approach is equally effective in optimising the efficiency, refinement, durability and cost of axles for volume production. In a study for a Tier One supplier, DSD improved the existing design by reducing sliding speeds through the use of a lower hypoid offset and compensated by increasing face width by using a less conventional milled design, while managing the second order NVH challenges. The optimum efficiency speed range of angular contact bearings was appropriate for the duty cycle so these were evaluated against high efficiency taper roller bearings; gear flank topology was revised to accommodate increased gear misalignments with the more efficient bearings.

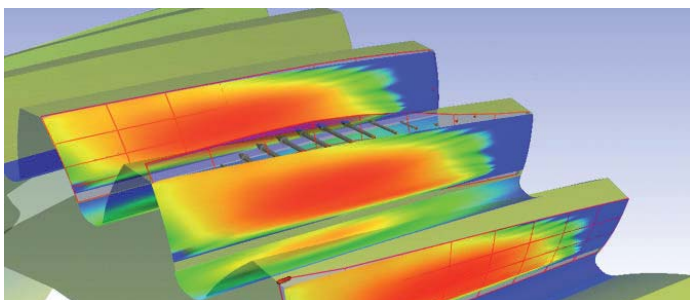


Figure 2 Gears trade efficiency against refinement through the choice of tooth geometry

The future of transmission efficiency

The trend towards 'light weighting' is increasingly important for transmission designers but, far from conflicting with the other attributes, DSD has found this may lead to synergistic opportunities in some cases. The company is involved with several research projects considering the use, or partial use, of plastic for transmission casings and the systems approach is able to take advantage of potential synergies.

The higher damping coefficient of plastic materials allows gear design to be biased towards higher efficiency, with less concern for transmission error. This also makes feasible the use of low viscosity oils which demand lower entrainment speeds at the mesh to avoid boundary lubrication issues that could initiate gear scuffing or micro pitting. The result is a compounding effect where lightweight housings allow higher efficiency gears which enable the use of lower viscosity lubricants, further improving efficiency. It would be extremely difficult, if not impractical, to identify and implement these synergies without the systems engineering approach developed by DSD.

Even with unprecedented computing power and better, more sophisticated tools, a well-informed and experienced engineer remains the most effective route to the best trade-off between key attributes. The success of the systems approach comes from providing summary attribute information to lead engineers in a timely way.

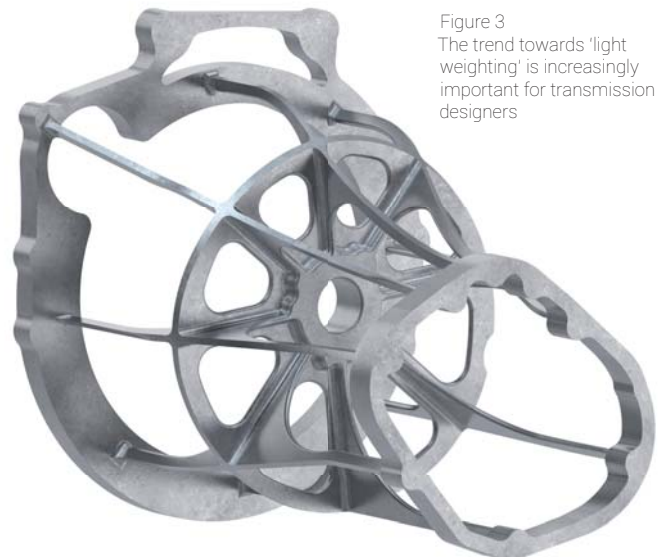


Figure 3 The trend towards 'light weighting' is increasingly important for transmission designers

For best comfort with improved fuel economy

Highly Integrated Launch Systems

The launch devices are divided into single dry clutches for manual transmissions (MT), dry and wet running double clutches for DCT, and hydrodynamic torque converters for AT and CVT. They are integrated with the damper system for the isolation of the excitation of the internal combustion engine (ICE) from the transmission and from the drivetrain. Trends to improve the fuel economy of the powertrain like downsizing, downspeeding and cylinder deactivation are putting stronger requirements to the damper system consisting of dual mass flywheel (DMF), double torsional damper (DTD) and centrifugal pendulum-type absorber (CPA). Finally, P2 hybrid modules are implemented to further reduce the CO₂ emission by electrification of the powertrain and delivering pure electric launch and electric drive.

■ Dr.-Ing. Hartmut Faust, Senior Vice President R&D Transmission Systems, LuK GmbH & Co. KG

Trends of mobility for tomorrow

When bringing together the mobility for tomorrow and the environment protection we have to take care about the further reduction of CO₂ emissions of the vehicles. Besides hybridisation the fuel economy of internal combustion engine (ICE) driven powertrains is improved by measures like downsizing, downspeeding and reduction of throttle losses with improved valve control variability and also with cylinder deactivation. As this measures do not allow any downside effects on NVH behavior even that the torsional excitation from ICE side to the drivetrain is significant increased, higher sophisticated launch systems and damper systems have to be introduced to fulfill the requirements about the isolation of the vibrations.

At the same time transmissions with bigger ratio spread and higher number of gears are introduced to support the downspeeding trend with longer overdrive ratios. With regard to the launch devices the drag torque in certain driving conditions and the inertia is minimized while also the installation space needs to be reduced to have the chance to integrate improved damper systems.

The history starting with conventional single mass flywheels and damped clutch disks shows a milestone in the torsional isolation effectiveness when introducing the dual mass flywheel (DMF) to the common single dry clutch of manual transmissions (MT) in 1985 as enabler for the introduction of turbocharged diesel engines in passenger cars.





DCT launch with software strategy

The DMF principle also is used for dual clutch transmissions (DCT) to isolate the torsional excitation of the engines in the torque flow in front of the clutch. DCT with wet double clutch and DMF were introduced to the market in 2003 with minimum requirement of microslip for further isolation. With the electronic controlled clutch of the DCT the launch behavior can be formed by software strategy. Depending on the driver request the software can deliver a good link from the engine to the wheels with short slipping times up to performance or race launch functionalities in sports vehicles with optimal traction controlled wheel slip or even with fulminant spinning wheels. The software control is supporting the driver to handle the launch easily like experienced drivers are doing. This is advantageous for the controllability of engines with very high torque as well as to avoid engine stall-out with extremely downsized concepts with unsatisfactory low-end torque.

Dry double clutch for improved fuel economy

In 2007 the first DCT with dry double clutch with decreased drag torque of the inactive transmission part compared to the wet version and power on demand actuation replacing the conventional hydraulic control for further improved fuel economy by about 5 % was introduced. In this application the DMF principle uses the inertia of the thermal mass of the dry double clutch -which anyhow is present- in a way of functional integration as the secondary mass to reach an effective torsional isolation.

E-clutch

Coming back to manual transmissions some activities to introduce e-clutch systems for improved comfort in MT can be seen. The first step called *MTPlus* is the implementation of an actuator in parallel to the clutch pedal just to support automatic sailing strategies where it makes sense to reduce the fuel consumption. The positive effect can be seen in WLTC (Worldwide Harmonized Light duty Testing Cycle) already and it is even bigger in real world driving, depending on the driver familiarisation. The further steps of the e-clutch implementation are clutch by wire (CbW) with electronic decoupling between pedal and clutch actuation for improved comfort and electronic clutch management (ECM) with full omission of the conventional clutch pedal. With this systems steps towards automated driving based on MT technology are done.

Torque converter with lock-up

In parallel the hydrodynamic torque converters (TC) in AT and CVT are in use delivering soft engagements and a torque multiplication during launch while on the other hand having less possibilities for launch control strategies depending on driver request or adaptation to support the launch performance at very cold temperatures. For the reduction of continuous slip during drive they are equipped with lock-up clutches to lock the hydrodynamic device after the launch. TC as well are faced with high excitation amplitudes from engine side and stronger requirements for minimum lock-up speed and to reduce microslip losses. So they are equipped with more complex lock-up damper systems, e. g. with double damper and turbine damper setup.

CPA for downsizing and downspeeding

A second major step in improving the isolation is done by Schaeffler with the implementation of the centrifugal pendulum-type absorber (CPA). They are matched to the main engine excitation order meaning that the tilger frequency is inherent adapted linear to the increasing engine speed using the fact centrifugal forces being increased with the square of the rotational speed. The CPA is integrated on the secondary inertia of the DMF and started mass production in 2008. While the DMF is already isolating the engine irregularity by far, the CPA further reduces the remaining irregularity at the input of the transmission to avoid gear rattle and boom noise in the vehicle.

The DMF with CPA fulfills the increasing requirements put to the drivetrain with higher irregularities produced by the ICE when improving the fuel economy with downsizing and downspeeding measures. As a result, good NVH behavior of the vehicle allows to drive with low engine speeds also at high torques. This is the case not only with MT, but with DCT also being equipped with DMF and CPA. Schaeffler is also working on ideas to integrate the CPA directly to the double clutch on transmission side with advantages in required overall space for the launch system including the damper.

From TC to iTC

The same principle of the CPA is used in TC applications since 2009. In this case the CPA is positioned on the secondary side of the lock-up damper on the turbine side. In effect, the irregularity of the AT or CVT input shaft is reduced significant so the lock-up speed can be further

reduced. Additionally, microslip in the lock-up clutch can be avoided to get further fuel economy improvement.

In the latest step Schaeffler is developing an integrated TC (iTC), where the lock-up is realised with omission of the piston by direct integration to the TC turbine. With this design feature weight and space can be reduced which improves the launch performance of the vehicle. The available space is used to further improve the damper capacity and to integrate the CPA to the iTC for reaching best NVH with optimum CO₂ emission reduction.

Solutions for cylinder deactivation

With this setup of damper systems -based on DMF principle, double dampers and CPA implementation, in some applications also positioned on the clutch disk- the trends to improve the ICE efficiency in conventional powertrains without any drawback on NVH side are supported. Solutions are also available for cylinder deactivation not only for 8-cylinder, but also for 6-, 5-, 4- and 3-cylinder engines with CPA systems being matched to the main excitation orders for full or part engine operation.

Hybridisation of the powertrain

For the electrification of the conventional powertrain P2 hybrid modules are offered allowing recuperation, boosting support for the ICE and pure electric driving to reduce the CO₂ emission. The P2 module provides electric launch, ICE driven launch and also hybrid launch driven by the combination of ICE and e-motor. Such systems integrating the e-motor, K0 with actuation and damper system, also including CPA, are available with a wet or dry K0 clutch in combination with a TC or with wet or dry double clutches.

For the hybridisation of DCT it also is possible to locate the e-motor parallel to the axis driving one of the input shafts. In this case the gears of one part transmission, e. g. 2, 4 and 6 including reverse, are available for the e-motor driving the wheels without the engagement of a clutch. Another version of hybrid DCT is in production where the e-motor is located directly in the transmission on the solid input shaft driving the wheels directly in the gears 1, 3, 5 and 7. In this cases without a need for additional K0 the dry or in another application the wet double clutch can be used to start the ICE and to launch the vehicle via the ICE with or without boosting by the e-motor.

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Gear Shifts Twice as Good

With ClassicLINE DCT-Type, HOERBIGER has unveiled the world's first synchronizer that features a custom design specifically for dual clutch applications – and effectively helps make this type of transmission more attractive yet again.

■ Dr. Ing. Ansgar Damm, Head of Research and Development, HOERBIGER Antriebstechnik Holding GmbH, Schongau, Germany

■ Dipl.-Ing. Ottmar Back, Head of Product Management, HOERBIGER Antriebstechnik GmbH, Schongau, Germany



Following its production debut in 2003, dual clutch technology (dual clutch transmission, DCT) rapidly established itself in the growing market of automatic transmissions (AT). Along with torque-converter transmissions and continuously variable transmissions (CVTs), today this technology forms a third pillar for which demand proportionally continues to grow.

Among ATs, DCTs are most closely related to manual systems in terms of design; in principle, they are based on two semi-automatic transmissions. It was for this reason – and until now, also for a lack of alternatives – that they also used substantially the same synchronizers. HOERBIGER has now, for the first time, made it possible to change the status quo in favor of the specialized ClassicLINE DCT-Type solution. This product offers advantages in all the criteria that are particularly relevant for DCTs: installation space requirement, shifting speed, NVH (noise, vibration, harshness) behavior and, last but not least, the manner in which drag torque of the clutch impacts shifting quality.

Flattening instead of pointing

The underlying design idea of ClassicLINE DCT-Type is to flatten the teeth of the engagement disks and provide the sleeve on the right and left with only a one-sided chamfer – instead of using pointings, as in the past (which remains the optimal design for manual transmissions, or MTs). The fundamental task of the teeth does not change: they primarily ensure the locked position of the blocker ring. The ring allows a new gear to only be engaged once the synchronizer has matched the rotational speeds of the gearbox shaft and idler gear. For construction-related reasons, however, every other tooth has been eliminated on the DCT-Type blocker rings.

Using cost-efficient simulations, HOERBIGER demonstrated the fundamental feasibility as well as the effectiveness of the special DCT synchronizer even at the start of the project. Based on a front-transverse dual clutch transmission in the 300 to 400 Newton meter input torque segment, the specialists conducted a total of more than 40,000 virtual shift process simulations at varying parameters. They also analyzed what configuration the flat teeth should have in the ideal case. HOERBIGER then implemented prototypes of the geometries that



Picture 1 Composition of the ClassicLINE DCT-Type synchronizer

were best suited and tested these on the test bench. This illustrated how diverse the advantages of the now production-ready ClassicLINE DCT-Type are compared to existing synchronizers for this type of transmission.

Increased power density

A crucial advantage of this innovation is the significantly lower installation space requirement. Specifically, four millimeters may be saved axially per synchronizer unit over conventional systems. This allows a reduction in length of up to eight millimeters in current DCTs with front-transverse installation, and the maximum space gained in front longitudinally mounted applications can be as much as 12 millimeters. Considering the progressing electrification of the drive train, this creates new, valuable freedom of design. Hybrid systems, for example, can be accommodated more easily. Alternatively, ClassicLINE DCT-Type opens up the possibility to implement a larger number of gears at approximately the same transmission length, or else to transmit higher torque using wider gear wheels.



Picture 2
Lower installation space requirement – comparative illustration: ClassicLINE DCT-Type synchronizer at the top, traditional synchronizer at the bottom

Technologically, this is based on a comparatively simple geometrical fact: thanks to the flattened teeth, the backtaper, i.e., the longitudinal overlap between the synchronizer dog clutch teeth and the sleeve necessary for force transmission, is reached sooner. Additionally, the shift travel is reduced by exactly the distance which, in MT synchronizers, is needed for the required tooth pointings.

More dynamic gear shifts

One distinctive feature of DCTs is gear shifts with no loss of traction. The transition between opening the “offgoing” clutch of one partial transmission and closing the “oncoming” clutch of the other is seamless. Still, at the speed drivers have grown accustomed to, this was possible until now only if the desired next gear had previously been fully synchronized by the particular partial transmission and (pre-)engaged.

If problems arise in the process, the automatic gear shift can be appreciably drawn out. A potential trigger of this situation is known as the tooth-on-tooth position within traditional synchronizers. This position may cause the sleeve to block, for example due to high drag torque of the clutch, whereby the entire shift sequence must start anew.

The smoother teeth of ClassicLINE DCT-Type, combined with adapted shifting software, reverse this scenario. As a result of the new design principle, it is now instead desired for the clutch actuator to build its pressure even before synchronization is completed; additionally, clutch drag torque now favors the shifting process. Depending on the particular DCT transmission, each shift is carried out up to 100 milliseconds faster, which is clearly noticeable for drivers. Even in the case of the tooth-on-tooth position, the changing of gears no longer has to start from the beginning: the sleeve can remain pressed on and simply engages in the next possible angle position.

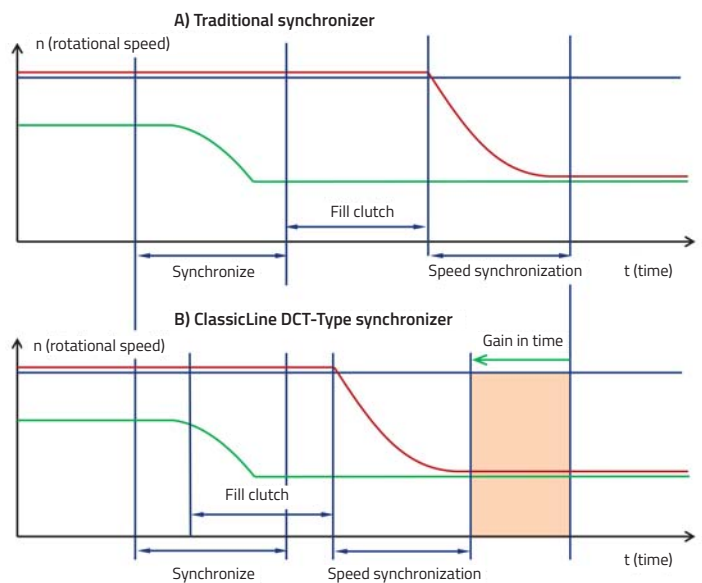


Figure 1 Shifting process of the traditional synchronizer (illustration A) compared to the ClassicLINE DCT-Type synchronizer (illustration B)

Greater reduction in noise

Ongoing optimization efforts of the NVH behavior have high priority in DCTs. While vehicle users directly associate potential shifting noise in MT drive trains with the changing of gears and, as a result, consider this noise to be the norm, similar acoustic feedback in DCTs is immediately perceived as unpleasant, or erroneously even interpreted as a transmission defect. Synchronization, or more precisely the above-mentioned engagement of the next required gear prior to closing the clutch, may be one source of noise. This process generates a clicking sound, and the higher the angular momenta which must be minimized during meshing of the sleeve teeth, the louder this noise will be. Drivers hear this sound, for example, when they coast their car, with the window open, into an underground parking garage or other structure which intensively reflects all of the car’s sound waves.



ClassicLINE DCT-Type offers major benefits to dual clutch transmission manufacturers since the meshing of smoother teeth creates considerably lower angular momenta, or results in smaller rotational speed differentials than in conventional teeth featuring pitches. The ensuing noise reduction is considerable at low drag torque and high shifting forces.

The innovative HOERBIGER synchronizer consequently makes a significant contribution to dual clutch transmissions steadily approaching the high shift comfort standard of a modern torque-converter transmission, even in terms of NVH.

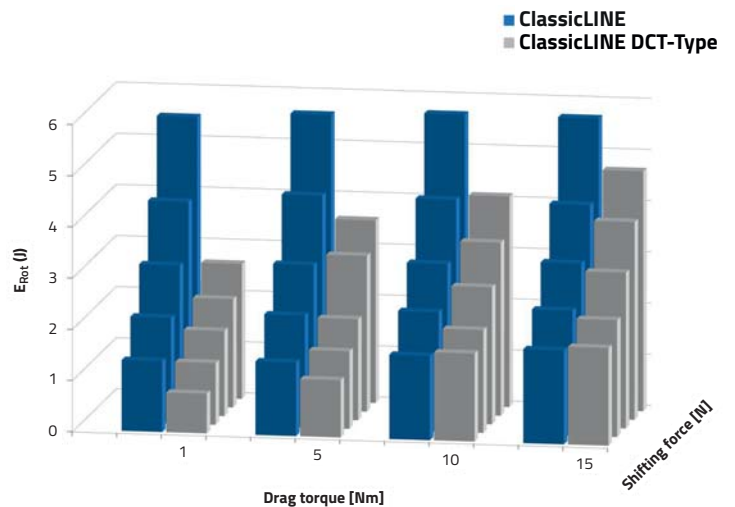


Figure 2 Noise reduction due to lower angular momenta of the ClassicLINE DCT-Type synchronizer compared to the traditional synchronizer, most notably at high shifting forces and low drag torque

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Sonceboz Actuators: Shifting the Paradigm

For many years, conventional automatic and manual transmissions have predominated across all sectors of the automotive market. But today's and tomorrow's advancing customer requirements, market demands, and competition have pushed transmission developers to devise better and more efficient solutions. Challenging new efficiency regulations and tight CO₂ emission limits, headed downward to just 95 g/km in 2020, mean powertrain efficiency research must be seriously accelerated to develop new solutions for compliance without sacrificing performance, driveability, or dependability. EVs, Hybrids, plug-in-hybrids, DCTs, CVTs, and AMTs are among the solutions reaching the market, each with its own advantages and suitabilities. With regards to these new solutions, two important topics are definitively emerging, and are on the way of Sonceboz: electrification and position shifting.

■ Benoit Fueg, Business Unit Manager, Sonceboz

Sonceboz recognized these new needs and challenges early on; and transmission customers around the world have likewise recognized the Swiss supplier's competence and expertise. Working closely with customers, Sonceboz has robustly extended their product portfolio for transmission applications. A wide range of innovative solutions are already in volume production, with many more in advanced development phases.

For example, Sonceboz developed their 5600 series BLDC actuators, used by BMW for their Valvetronic technology, into a wide product range with specific benefits for transmission applications including high power density, low mass, high dynamism, and small packaging.

These direct-drive actuators are ideal wherever power or torque is needed, or a position must be achieved quickly and accurately for tasks including dual-clutch actuation, gear shifting, and drum positioning. And the Sonceboz direct-drive technology also dependably handles functions like clutch coasting and torque vectoring.

The space constraints around an engine or a gearbox continue to grow ever tighter; in response, Sonceboz's newest 3rd-generation actuator has been specifically optimized with remarkably compact packaging. This new design can be easily integrated into virtually any design, while saving up to 40 % in mass compared to other solutions. In an automated manual or dual-clutch transmission, for example, using



Figure 1 Rotor and Stator for Sonceboz 5600 BLDC Actuator



Figure 2 Sonceboz BLDC flat design

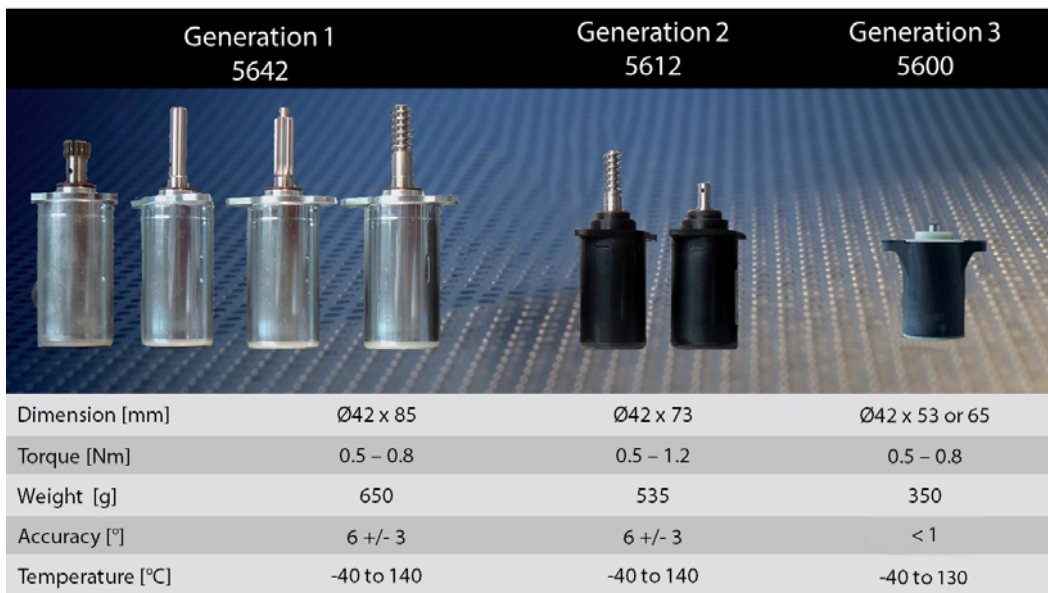


Figure 3 Evolution of Sonceboz 5600 BLDC actuators

five Sonceboz 5600 gen-3 actuators means a weight savings of more than 1 kg, which translates directly and significantly to reduced CO₂ emissions.

Sonceboz's patented stator and rotor design dependably render top-class torque density output, along with great packaging flexibility (flat

design) with scalable performance. The electrical and mechanical interfaces of this brushless drive can be adapted to customer specifications for optimal integration into any type of application; for every mechatronic drive need, there is the ideal Sonceboz solution.



In our plants and in our products, we're all about better performance.

At BorgWarner, we never stop improving. It's a goal we set for our production capabilities as well as our market-leading products. We're making significant investments in our award-winning manufacturing facilities to bring the next generation of innovative transmission technologies to the automotive marketplace. Our investment in state of the art manufacturing processes is safely and efficiently delivering world-class quality products to our customers around the globe. At BorgWarner it's what product leadership is all about.



Smart Actuators – The Future of Automotive Systems

A close look on the automotive supply chain shows clearly, that there are many problems that need to be solved; restricted space, thermal conductivity and high power density are challenging issues. Therefore, smart actuators could be an alternative to meet these challenges, creating additionally some benefits.

■ Ing. Philipp Neumann MSc, MELECS EWS GmbH & Co KG

Introduction to Smart Actuators

First of all, smart actuators may not be suitable for all kind of automotive application. At least, there is not automatically a need of replacement. There may exist many reasons for not choosing the highly integrated solution; one of them is the cost of development. A "normal" solution may fit for low quantities, since the development is often cheaper and there are more suppliers available.

To manufacture a smart actuator is not easy. System integrators with experience and having an appropriate network of partnerships along the supply chain are needed. Highly integrated systems like smart valves or power packs have the advantage that they require less weight and space than conventional alternatives. They also reduce EMC problems but the interfaces of the different parts need to fit together. The system integrator should have the ability and the deep understanding of all main components being able to design them in close cooperation with the relevant partners to finally get a completed and optimized system.

Thermoset overmolding of electronics

To get an integrated system the housing design especially for the electronics is a very critical issue. There are many points that need to be covered accordingly like size, weight, thermal conductivity, mounting points, connectors and integrated bearing shields. All this and more is possible in one part if you overmold the electronics with thermoset. This has the advantage that there is no air gap between the components on the PCBA and the housing. A very good thermal connection between the power components and outside can be archived with a thermal connectivity of about 0.5 to 2.0 W/mK, even up to 10 W/mK is possible but more expensive. A method to avoid hitting the limits in

point of price or thermal conductivity of thermoset is to insert metal inlays to get heat guides to external heat sinks.



Figure 1 2K molded housing with features

Another point of consideration is that if you overmold the electronics with thermoset using proper connectors and materials you get oil and even gas tight parts. This is because the thermoset gets into a molecular connection with few other materials. Finally the question is why not simple use the well known thermoplast for overmolding the electronics? Thermoplast shows high molding temperature and pres-

sure whereas thermoset has a molding temperature of about 180°C with under 10 bar injection pressure. So overmolding electronic PCBs is only possible with thermoset but not every supplier can provide this service.



Figure 2
Thermoset overmolded electronics

Valves in automotive applications

In a modern car there are plenty of valves grouped on one electronic control unit (ECU) but sometimes there are only a few valves where an external ECU is oversized. In these cases an integrated valve is a good solution. The advantage of inserting the ECU into a valve is remarkable: Despite of space savings, weight reduction and EMC problems, some interesting software features are possible as well, e.g. to calibrate the hysteresis of the valve and store it into the internal microcontroller to remove the production tolerances. With Flowtronic there is a valve available that works with 12 Volt with CAN communication on two connector pins. The output of the proportional valve is a controlled pressure up to 40 bar with a coil-current of 3 Ampere all inside a valve with 30 millimeter diameter.



Figure 3 Smart valve Flowtronic [Ø30x80mm]

Power packs for gearbox applications

Small 12 Volt motors are commonly used in powertrain applications mainly with external ECU's. This was the common way of doing it because the electronic housing and components were not small or in the small package not powerful enough. With thermoset housings it is possible to solve that complexity of the housing in point of mounting and internal features, getting thermal assistance for the PCBA components as well. The Micro Power Pack (MPP) features a 12 Volt supply (150W) with CAN communication. The BLDC motor has a speed of 3000 RPM with 0.5 Nm. It is also possible to integrate the motor winding interconnections for parallel wound motors into the PCB which saves unit space and reduces EMC and eliminates an additional lead frame.



Figure 4 MPP100 with demo pump mounted [Ø66x70mm]

Hydraulic smart actuators

If thermoset overmolded electronics seems to be too expensive or the customer prefers to stay within the well known manufacturing processes, a "normal" assembly will be suitable. Housing made of aluminum has the advantage of a good thermal connection from the PCB to the heat sink, which is mostly not the air around the housing but the mounting on the gearbox itself. The disadvantage is that an electrical isolation from PCB to the housing is needed. This could be done in many ways; one of them is to insert isolation material between the two parts. This adds part costs and width. Therefore, Melecs uses its patented design which includes electrical isolation into the PCB layer stack and saves costs and assembly time.

This consequently leads into developing a Micro Hydraulic Power Pack (MHP) which results in a tiny product with dimensions of 155x80x93mm, including an inverter for 24 or 12 Volt supply within the same

electronic PCBA design. The whole system needs 200W of power and has an output of up to 450 l/h with 8 bar of pressure. All this gets paired with an ECU that is capable of CAN wake-up and KL15 wake-up to have simultaneous possibilities of enabling and disabling the system. With this feature the system have the opportunity of an intelligent limp home mode in case the CAN bus or the KL15 has a faulty behavior.

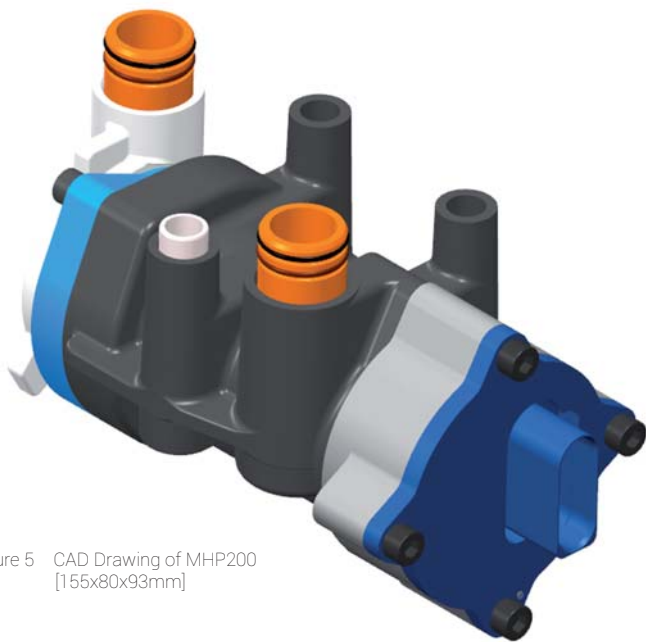


Figure 5 CAD Drawing of MHP200 [155x80x93mm]

High power applications in cars

When the power ratings are higher and the installation space does not expand, there are many problems that need to be solved. For example, the PCB layer stack looks different for logic or power board with two possible solutions. The first one is to make a mixed layer stack in one PCB for logic and power part. Unfortunately, this solution has not the best internal construction available but fits both needs with one single PCB. The second – and by the way – better solution is to split the PCB and make one logic board and one power board with an internal connector. The result is an optimum PCB stack for each one. Additionally, by splitting the PCB the cost savings are noteworthy as the logic board needs more layers than the power board. On this way, a small multi layer logic board with e.g. eight layers can easily be combined with a bigger power board with more copper in each of the four layers. This has also the advantage that a generic logic PCBA is available which can be reused for multiple upcoming projects. At input powers of up to 3000W at 48 Volt special supply connectors are needed. Therefore, splitting the power supply and the logic connector, like the PCBAs, is the best way to go.

In 48V systems most OEM's require "splitted grounds". This means, there are no connections allowed between 48 to 12 Volt bord grid. Having to separate grounds is not as simple as it seems to be. It is not only the two separated pins; it is also the fact that you need a communication between the boards and should not have the same grounding. So one way is to use inductive couplers, which raises the system costs. The second problem: If the logic unit is turned off, electrical power need to be provided to the CAN transceiver ensuring CAN wake-up features. So with an intelligent design it is possible to get a Hydraulic Power Pack that has the ability of generating 100 bar with a flow rate of 12 l/min with only 117 × 117 × 216 mm in dimension.



Figure 6 CAD Drawing of HPP3000 [117x117x216mm]

Conclusion

Finally, the recommendation to everybody who wants to design a smart actuator is to have a detailed look at the application, while considering if a smart actuator is the right solution. Also important is to ponder whether the company has the possibilities and the network of partner companies being able to develop and manufacture such complex systems accordingly. We at Melecs are convinced that smart actuators are the future of many applications all around the car but they need to be tailored precisely to the requirements of the application, installation space and environmental conditions around the smart product.

For more information please contact:

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Less is More: SKF Presents Innovative New Sealed Deep Groove Ball Bearings for Automobile Drive Shafts

One of the new products to be launched by SKF at this year's CTI Symposium in Berlin (8 – 9 December 2015) will be cutting-edge sealed deep groove ball bearings for automobile drive shafts: an innovative sealing design renders external protective measures obsolete, doing away with the need for additional components such as cover plates or other seals. The result? A compact solution which is simple and fast to install.

■ Dietmar Seidel, Head of Technical Trade Press Germany, SKF

Despite its overall "svelte" construction, the new seal is a great improvement in protection against external influences such as water and mud, even in the toughest of environments. SKF's new sealed deep groove ball bearing for drive shafts are suitable for use in intermediate shafts in front-wheel drive cars and small vans, as well as in propeller shafts in four-wheel and rear-wheel drive vehicles. The sealed ball bearings can also be used in a wide range of other situations where dirt and mud can be a problem.

These new SKF ball bearings have an integrated stainless-steel oil slinger which works in conjunction with the FPM composite seal to form a fluidic effect to improve the seal. This also optimises the axial sealing lip contact. Last but not least, efficient high-temperature grease ensures the ball bearings remain protected.

In short, this reliable sealing concept minimises the risk of solid and liquid impurities entering the ball bearings, thereby increasing service life. For even greater reliability, SKF has also made this easy-to-install compact solution even more robust. The improved features of the ball bearings have already been put to car manufacturer test and proven themselves in practice runs.

In addition to the new sealed deep groove ball bearings, SKF will also be presenting other efficiency-improving solutions for the automotive industry at the CTI Symposium in Berlin: a high-capacity gear-bearing unit, friction-minimising seals and sensor bearing units for use in both electrical and hybrid vehicles.

You can find out more by visiting SKF's stand (F02) between 8 – 9 December 2015 at the CTI Symposium which is being held in Berlin at the Estrel Hotel.



One of the new products to be launched by SKF at this year's CTI Symposium will be cutting-edge sealed deep groove ball bearings for automobile drive shafts. Images: SKF

For more information please contact:

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If you take 10 minutes to read this article, we will explain you how you can increase your product quality by partnering with a reliable, knowledgeable and dedicated automotive supplier.

Goudsmit Magnetic Supplies – Dutch Quality

Goudsmit Magnetic Supplies forms part of the globally operating Goudsmit Magnetics Group, a family business incorporated in 1959 with branches in the Netherlands, France, Germany, the UK, and the Czech Republic. The company is specialized in delivering high quality permanent magnets and magnet systems to the automotive, electronics and medical industries.

■ Jeff Hagelen, Commercial Director, Goudsmit Magnetic Supplies BV

Supply chain integration

OEMs competing in the international market have been outsourcing the manufacturing of sub-assemblies and larger non-core components to strategic suppliers for quite some time and are now increasingly outsourcing the design, development and testing of the equipment they manufacture as well. What they are doing, in fact, is giving suppliers full responsibility, from design to manufacturing all the way through to quality assurance. Is it here that our more than 50 years of experience in the field of sourcing, manufacturing, testing and supplying magnetic systems and components comes into play and provides added value to our current and future partners.

The key to successfully addressing trends such as falling cost prices, increased flexibility and global sourcing is long-term, reliable, predictable relationships between OEMs and the tier1, tier2 and tier3 suppliers. Establishing strong relationships requires excellent collaboration and communication throughout the chain and mapping out the improvement potential of the whole chain so it can compete, or continue to compete, at an international level.

Our role in supply chain integration is to serve as a sounding board for our customers and to be part of the engineering, development and testing process for the component or assembly by utilizing our extensive experience not only in application engineering but also in the sourcing of high quality products.


When sourcing goods we do so according to our well-defined sourcing strategy, including locating the best supplier for our particular needs. Too few companies do the proper due diligence when sourcing products. As a result, price, quality, functionality and timely delivery are not always assured. To avoid this uncertainty we employ a methodical sourcing strategy.

Our successful sourcing strategy includes:

- Supplier identification through the internet, social media and trade shows
- Alignment of business ethics between supplier and Goudsmit
- Mandatory ISO/TS 16949 compliance
- Having our suppliers perform a periodic self-assessment
- Regular audit visits by our purchasing and QA employees
- Ensuring that quality control is in line with our standards and those of our customers
- Continuous monitoring through a vendor rating system

Quality control

What you and your customers want are products that are 100% ship-shape. Our aim is therefore zero defects, and to achieve this we strictly respect – and work according to – the ISO/TS16949:2009 and ISO 9001:2008 directives.



Our quality philosophy is based on two principles:

- 1) acquiring and maintaining quality certificates in order to meet the requirements of our customers and to be able to work as efficiently as possible
- 2) implementing programmes for continuous improvement in order to continue delivering products and services of superior quality

We work with a variety of documentation and equipment in order to maintain the highest level of product quality and customer satisfaction possible. But what exactly do the ISO/TS16949:2009 directive and these processes involve? And what equipment is required to perform proper analysis and testing? We explain below.

Production Part Approval Process (PPAP)

The Production Part Approval Process (PPAP) is a standardized process that helps manufacturers and suppliers communicate and approve production designs and processes before, during and after manufacture. Created to promote a clearer understanding of the requirements of manufacturers and suppliers, PPAP helps to ensure that the processes used to manufacture parts can consistently reproduce the parts at stated production rates during routine production runs. Obtaining approval requires Goudsmit to provide sample parts and documentary evidence showing that the client's requirements have been understood, the product supplied meets those requirements, the process (including those of sub-suppliers) is capable of producing conforming product and that the production control plan and quality management system will prevent non-conforming product from reaching the client or compromising the safety and reliability of finished vehicles.

Failure Mode and Effects Analysis (FMEA)

FMECA is a design tool used to systematically analyse postulated component failures and identify the resultant effects on system operations. The analysis is sometimes characterized as consisting of two sub-analyses, the first being the failure modes and effects analysis

(FMEA), and the second, the criticality analysis (CA). Successful development of an FMEA requires that we include all significant failure modes for each contributing element or part in the system. FMEAs can be performed at the system, subsystem, assembly, subassembly or part level.

The FMECA is a living document during development of a hardware design and it is scheduled and completed concurrently with the design. The usefulness of the FMECA as a design tool and in the decision-making process is determined by the effectiveness and timeliness with which design problems are identified. Timeliness is probably the most important consideration for us. While the FMECA identifies all part failure modes, its primary benefit is the early identification of all critical and catastrophic subsystem or system failure modes so they can be eliminated or minimized through design modification at the earliest point in the development effort; therefore, the FMECA should be performed at the system level as soon as preliminary design information is available and extended to the lower levels. This again underlines the relevance of our early participation in the development process.

Advanced Product and Quality Planning (APQP)

APQP or Advanced Product Quality Planning is a structured method of defining and establishing the steps necessary to ensure that a product satisfies the customer. Effective product quality planning is fully dependent on our management commitment to the effort required to meet customer specifications. The bottom-line goals of product quality planning are effective communication with all those who are involved in the implementation scheme, timely completion of required goals, minimal or no quality problems and minimal risks related to quality during product launch.

The general benefits of APQP are that recourses are directed towards our customer satisfaction. If changes are required they will be identified early in the process, avoiding their release after product launch.

VDA6.3

The VDA6.3 norm was developed by the German Automotive sector in light of a series of VDA6- norms, focusing on suppliers to the German construction industry. The norm was re-evaluated in 2010 and aligned with changes in the ISO/TS16949:2009 directives, embedding customer-specific requirements in the automotive sector. Since the beginning of 2015 Goudsmit has had the knowledge and ability to perform self-auditing according to this VDA6.3 standard.

Moving beyond the process-oriented approach of internal audits, VDA6.3 offers additional tools.

For example, it enables us to apply our standard approach to internal auditing for every department and division, making results comparable. The revised methodology also obliges us to define potential risks during the preparation for a project and put additional focus on these risks during the audit itself. As a result, the reports we produce perfectly describe the strengths and weaknesses in the audited process and thus form a sound basis for defining a roadmap for improvement.

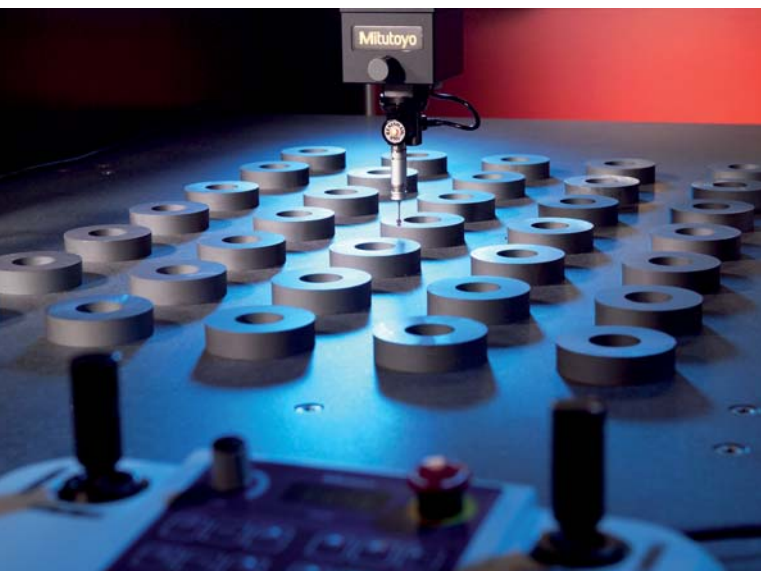


Figure 1 A wide range of contact probes enable numerous kinds of measurement to be performed, all backed up by comprehensive analysis software for interpreting measurement results

CMM

The typical 3D 'bridge' CMM is composed of three axes, X, Y and Z. These axes are orthogonal to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine reads the input from the touch probe, as directed by our operator. The machine then uses the X, Y and Z coordinates of each of these points to determine size and position with micrometre precision. This data is converted into a report and – supported by our Permagraph curve and Helmholtz coil measurements – sent to our customers.

Helmholtz coil

Measurement of magnetic moment with a fluxmeter and a Helmholtz coil is a convenient way to test permanent magnet materials. Other values, such as operating flux density (Bd), operating field strength (Hd), coercive force (Hc), residual flux density (Br) and maximum energy product (BHmax), can be derived from the measured moment value. Although this method is not as accurate as hysteresisgraph measurement, the measurement process is easy and values are useful and reliable.

Hysteresis loop

A great deal of information can be learned about the magnetic properties of a material by studying its hysteresis loop. A hysteresis loop shows the relationship between the induced magnetic flux density (B) and the magnetizing force (H). It is often referred to as the B-H loop.

The loop is generated by measuring the magnetic flux of the magnet while the magnetizing force is changed. A number of primary magnetic properties of a material can be determined from the hysteresis loop.

- Retentivity – A measure of the residual flux density corresponding to the saturation induction of a magnetic material. In other words, it is a material's ability to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation.
- Residual magnetism or residual flux – The magnetic flux density that remains in a material when the magnetizing force is zero. Note that residual magnetism and retentivity are the same when the material has been magnetized to the saturation point. However, the level of residual magnetism may be lower than the retentivity value when the magnetizing force did not reach the saturation level.
- Coercive force – The amount of reverse magnetic field which must be applied to a magnetic material to make the magnetic flux return to zero.
- Permeability – A property of a material that describes the ease with which a magnetic flux is established in the component.
- Reluctance – The opposition that a magnetic material shows to the establishment of a magnetic field. Reluctance is analogous to resistance in an electrical circuit.



Figure 2 The new 3D optical scanner offers Goudsmit a whole new level of measurement technology and deliver three-dimensional measurement data and analysis for industrial and automotive components.

3D optical scanner

With our most recent test equipment acquisition, a 3D optical scanner, we enter a whole new level of measurement technology and deliver three-dimensional measurement data and analysis for industrial and automotive components. Instead of measuring single points, we capture an object's full surface geometry and primitives precisely in a dense point cloud or polygon mesh. Compared to the conventional static CMM, we can now retrieve much more data that is of great relevance to us and our customers, enabling us to better understand the product's properties and behaviour in a particular environment or assembly.

Brainport Industries

In June of this year Goudsmit joined the highly acclaimed supply-chain platform Brainport Industries. Brainport brings suppliers together so they can share experience and knowledge to the advantage of the entire high-tech supply chain. In this way, high-tech suppliers strengthen their position and have all the resources and knowledge necessary to make high-value products and ensure quality.

The 'open supply chain' within Brainport offers the company the opportunity to act as an involved supplier by being part of the development of components and machines for OEMs starting at a much earlier stage and continuing on to a much later stage in the cooperation.

Joining forces in terms of resources, knowledge and development leads to innovative products in the fields of high-tech systems & materials, food, automotive, lifetec and design, and it provides us access to new foreign markets. In addition, Brainport serves our need for the exchange of knowledge in the field of chain management and optimization.

In a nutshell

Being able to source high quality products, manage logistics, be a sparring partner in design and development, validate component requirements with state-of-the-art equipment and contribute to an optimized supply-chain make us a valuable and serious partner for the automotive industry.

Goudsmit Magnetic Supplies. Knowledgeable. Empathetic. Reliable.

For more information please contact

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Photos: copyrightfree



Figure 3 Goudsmit Magnetic Supplies forms part of the globally operating Goudsmit Magnetics Group, and is specialized in delivering high quality permanent magnets and magnet systems to the automotive, electronics and medical industries.

Overcoming the Challenges of Hybrid Disconnect Clutch Control

The parallel hybrid layout is generally considered to be the most functionally versatile for a hybrid vehicle, offering: reduced CO₂ output and improved fuel economy; increased performance; an EV mode for short journeys; and the range of a fossil fuelled vehicle.

■ Pedro Zabala, Principle Engineer – Control, Drive System Design

In order to achieve an EV mode without the engine rotating, a disconnect clutch (or KO clutch) is required in a parallel hybrid system, to allow the engine to be disconnected from the e-motor. Vehicles with this configuration often also use the disconnect clutch to start the engine, dispensing with a conventional starter motor.

Drive System Design (DSD), a UK-based engineering consultancy specialising in vehicle drivelines, has extensive experience of KO clutch applications. Dry clutch solutions are more challenging as they are non-linear in control terms but offer advantages because of their significant cost benefit and reduced drag losses when running in e-mode, compared to wet clutches. However, successful application means overcoming a number of technical challenges including packaging, torsional damping, thermal management and control.

Packaging

Hybrid vehicles usually share a vehicle platform for economic reasons. The only package space available for the hybrid system is typically that which is liberated by using a downsized engine with fewer cylinders, or a simplified transmission, perhaps with a torque converter deleted. Typically the axial space identified from improved powertrain packaging, cylinder deletion and FEAD deletion generates 120mm-150mm. New architectures are targeting 90-120kW of electrical power creating significant motor packaging requirements, this can compromise the disconnect clutch inertia, damping, cushioning and wear compensation, leading to additional design challenges and further non-linearities to be controlled.

Torsional Damping

The reduced cylinder count and high level of boosting common in a downsized engine for a hybrid means that, though not nominally high

in magnitude, the torsional vibration signature is quite aggressive. Combined with package constraints on inertia, this means that the peak loads through the drive train can be significantly higher than the nominal torque output of the engine. Unlike a manual clutch and transmission, there is a substantial inertia on either side of a hybrid disconnect clutch.

The damper challenge is that the stiffness is likely to fall within the operating speed range of the engine. DSD has solved this by using a firing-pressure driven flexible dynamic model that includes the driveline, to design the damper and identify the operating modes. There are two options: soften the springs until the modes drop below engine idle speed, which requires long spring travel, or reduce the damping, which allows engine peak torques to be seen farther down the system. This means care needs to be taken with any backlashes to avoid rattle and detailed modelling to understand the magnitudes is critical. The higher peak torques across the clutch result in higher clamp loads which makes control harder still.

Thermal

Where packaging reduces the mass and inertia of the clutch and restricts cooling, start events will also be thermally challenging. Significant thermal control and adaption strategies must be implemented to avoid functionality loss, performance degradation and sensitivity issues.

DSD uses the most aggressive stop-start schedule to identify the worst design case. Axial package constraints usually dictate a thin flywheel and pressure plate, limiting the use of conduction as a heat transfer mechanism. The way the stop-start event is administered has a significant effect on temperature, with the simplest strategies gener-

ating greatest slippage. DSD's approach is one of: start engine; once firing, open the clutch; run engine up to target speed; kiss point adaption; close clutch. This minimises the thermal input into the clutch/ flywheel but relies on the engine control system for speed control.

Control

Assuming the traction motor shall be used to start the engine then transient torque events during engine switch ON and OFF must be managed in coordination with other power sources in order to maintain refinement, avoiding unwanted disturbances in the system. Accuracy of the torque figure at the wheels must be maintained regardless of the source of the torque, to maintain an imperceptible feel to the driver as the ICE clutches in and out.

Accurate and consistent torque control requires deep understanding of the dynamics of the system, its thermal behaviour, its wear characteristics and the correct interaction with other systems when integrated into a hybrid solution. These are many of the same issues that transmission engineers are familiar with as they have arisen in AMT and DCT applications with dry clutches.

Writing high fidelity control models is the first part of the solution but for these to be of value the parameters have to be measured. DSD has developed systems using a dedicated in house clutch test rig to characterise the friction, thermal and judder characteristics of the clutch and ensure the control algorithms for adaption work well at different temperatures, and operate consistently with long term wear. The rig can be instrumented to measure torque on each side of the clutch, multiple temperatures, positions and pressure within the actuation system. The rig can also be adapted to mount an engine for cold cranking simulation.

The data gained from this can be used to write strategies in the control system to include continuous estimation of the clutch torque characteristics and kiss point position. This level of control is essential to meet refinement targets and prevent potentially dangerous situations during an engine start event.

To be effective, the control system must feature a high integrity real time thermal model specifically tailored to the environment where the clutches operate, with initial rig work correlating the model. For a high gain system, the thermal model's maps need inputs that include engine temperature, motor coolant temperature, transmission temperature, number and frequency of recent activity and wear prediction.



Figure 1 Drive System Design (DSD), a UK-based engineering consultancy specialising in vehicle drivelines, has extensive experience of KO clutch applications



Figure 2 Unlike a manual clutch and transmission, there is a substantial inertia on either side of a hybrid disconnect clutch

Depending on the actuation technology, a range of open loop and closed loop clutch control strategies can be created utilising either localised or remote sensing. This allows the flexibility to adapt to different platform requirements in terms of system architecture, refinement and performance. In order to pursue open loop control and delete the cost of a Concentric Slave Cylinder (CSC) position sensor DSD designed its own CSC for clutch actuation with reduced hysteresis, to provide a more stable kiss point than could be achieved with proprietary slave cylinders.

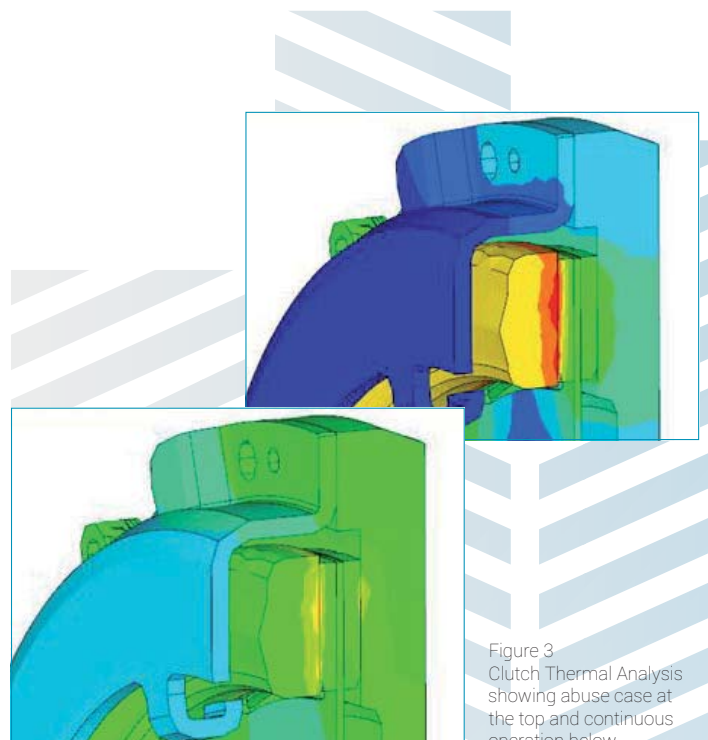


Figure 3 Clutch Thermal Analysis showing abuse case at the top and continuous operation below

Interview

“Scale Will Come as Customers Adopt the Technology”

There are numerous opportunities for dedicated and fuel-saving hybrid architectures. However, large-scale standard designs can help to create viable business cases. What is the right way between these options? We spoke to Charles Gray, Director, Transmission & Driveline Engineering at Ford Motor Company.



Mr. Gray, hybrid technology has increased the choice of powertrain options. Which do you prefer?

I am personally a fan of the Ford PowerSplit architecture, which uses a simple planetary gearset, the engine and two motors arranged around it. As an engineer, you look at design simplicity and eloquence, and that is represented in the PowerSplit system. I can dial-in at any point through my control system, maximise the efficiency of motor, engine and the electric power supply, because the planetary arrangement gives me a perfect CVT function.

For mild hybrids, I think that it makes sense to choose an add-on solution and add the electric drive to the given powertrain. I think you will see them coming to the market, providing a solution that gives the customer good efficiency and good value. There are proposals that early adoption in Europe would be the trend. I think it has certain advantages for the driving cycle and the customer base there.

Are mild hybrids an option for America or Asia as well?

It is more promoted in Europe, but I think it could be beneficial in these regions as well. However, there is a cost eventually for the technology, even to get to this level at 48 Volts. There is certainly an added value in the luxury car segment, where you operate more electrical load for other purposes anyway. The combination of these benefits makes the whole package attractive to carmakers. So I think it is in Europe where you will see the highest penetration.

We are just discussing two extremely different approaches. Does a common transmission concept for all hybrid scales make sense to you?

Possibly. I think the bigger challenge in the way we plan is that scale will come as customers adopt the technology, and purchase the vehicles of whatever variety or flavour. Any technology needs a certain minimum of scale in terms of quantities to be viable. I always point back to, “What engine won in the past?” There is not the single solution in a hundred-year history of the IC engine. Europe has the Diesel, now we have boosting and downsizing. It’s always evolving, and typically, you’ll see a technical convergence of a solution for a particular segment and purpose. If we look at hybrid options, the number of possible solutions and combinations is even bigger, so I think there is no single solution for all hybrid applications. I think we will see this kind of convergence with hybrid as well, but it will not be a single solution.



Could plug-in hybrids be the better solution in comparison to e-drives in the longer run?

I like the plug-in hybrid, because it gives you the option to make short trips on electric charge. Studies have shown in the US and Europe, that average distances are less than 20 to 25 miles per trip. So having a vehicle that can do that entirely through the speed range and the plug from your house or at work, I think is a brilliant solution. On the weekends, many will travel and visit family or friends, not being limited by battery storage for electric only operation. I think the energy density and flexible storage of liquid fuels remains a huge advantage. One of the big challenges is, people want to drive as much electrically as they can. To give an example, the fuel gets sour in the tank, so we need strategies to encourage the driver to use the engine from time to time. Both our competitors and us have a cycle to deal with that.

Fuel prices are currently low. What does this mean for customer acceptance?

I think the biggest challenge that we have is customer's behaviour, because they obviously take into account things like the price of fuel. The fact that the price is currently low clearly has an impact on hybrid vehicle sales, at least in the U.S. This is certainly a headwind that we have to look at. We really need to focus on what the customer needs, what the regulations are, and the how do we fit a plan around that that also meets our scale needs.

Interview: Gernot Goppelt, CTI correspondent



Charles Gray during his speech on the 9th International CTI Symposium in Novi, Michigan (18 – 21 May 2015)



Interview

“CVTs will Profit from Autonomous Driving”



Autonomous driving will change the requirements for automated transmissions. How will this affect the evaluation of different technologies? We spoke to Dr Ryozu Hiraku, General Manager Powertrain at Nissan Motor Corporation.

Dr Hiraku, how can autonomous driving change our relationship with cars?

Personally, I think that for the time being, autonomous driving will stay limited to situations where it helps to improve efficiency and make driving more comfortable. That means situations like stop-and-go, long-distance motorway driving or bad weather. My expectation is that whenever driving is fun, we will still have the option of driving ourselves. As long as autonomous systems do not patronise the driver, they could even increase how satisfied we are with our cars.

How long until autonomous driving becomes reality, and how will it affect transmission technology?

It is hard to say how long it takes until we see fully autonomous driving. Functions like motorway platooning may take just a few years. Technically, semi-autonomous driving within a defined framework is already possible – but someone needs to take the first step to commercialise the technology. Transmissions will need to become even more flexible: gearshifts should be quick and seamless, and shift and ratio flexibility will be more important than base efficiency.

How do autonomous driving systems change the requirements for powertrain design?

NVH will become even more important. When you are driving, sounds and vibrations are directly linked to your actions, so they do not bother you so much. But when you are being driven, they intrude more. We have to deal with that. Also, we may need to find new ways of increasing robustness for autonomous driving. Electrified powertrains can help to meet that need. They enable gentler driving strategies, and more efficient interaction between engines and transmissions.

Speaking of efficiency, we have been discussing aspects like the number of gears, gear spread or the effect of parasitic losses in recent years. Will we see a re-evaluation of these attributes?

Gear spread will still be an important criterion, but there may be a need for more gears. As I said earlier, they help to improve comfort with regard to NVH. Also, the more intelligence an automated system provides, the more effectively gear steps can be adapted to the best operating points of the engine. I think CVTs are the best solution in this respect. Potentially, autonomous driving can improve powertrain efficiency through intelligent control strategies. With CVTs and autonomous driving, we can expect to improve real-world fuel efficiency by more than 10 or 15 percent.

CVTs, AMTs, DCTs, ATs and DHTs: which transmission technologies will profit from automated and autonomous driving, and why?

First of all, the most suitable powertrain for autonomous driving is an e-motor-based drive system, as typified by EVs. Of all the conventional powertrains, I think CVTs are the best solution for automated and autonomous driving. They offer better NVH characteristics, and their overall efficiency benefits most from autonomous driving. If we add an electric motor with, say, 10 kW, dry DCTs are a very good solution too. The e-motor improves shift comfort, and enables the combustion engine to be used more efficiently. AMTs are also better in a hybrid version, because you can fill the torque interrupts to a certain extent. I am not in favour of ATs, which combine wet actuation with a stepped gear set. So summing up, DCTs and DHTs have good prospects, as long as they are dry. And among conventional and hybrid powertrains, CVTs are our first choice.

Dr Hiraku, many thanks for the interview.

Interviewer: Gernot Goppelt, CTI correspondent

Follow-up Report, 9th International CTI Symposium USA – Automotive Transmissions, HEV and EV Drives, 20–21 May 2015, Novi, Michigan

Efficient Drives: A Reality Check

Crude oil became significantly cheaper in 2015, not least because the USA is now an oil exporter again, and there is a global surplus. How long this cosy situation will last remains to be seen, but as the 9th CTI Symposium in Novi, Michigan (May 20–21) again showed, it has an impact on the debate over tomorrow's drives. Even more than last year participants discussed, which and how much fuel-saving technology is needed to effectively reach fleet consumption targets like CAFE.

Chairman Ernie J. DeVincent, Vice President Product Development, Getrag, welcomed this year's participants in a new setting: the Suburban Collection Showplace in Novi, Michigan. The event centre and attached hotel have more space for the symposium, which grew once again this year: some 520 participants attended, around 30 percent more than last year. Besides the eight plenary lectures, attendees could choose from 63 technical presentations and meet 40 exhibitors. With the exception of the 'crunch year' 2009 the North American CTI Symposium has grown steadily since 2007, and is now a central discussion platform for American and international transmission and powertrain developers.



How Can Transmissions Reduce Fuel Consumption?

In the opening lecture of the symposium on Day One, Getrag COO John McDonald made it clear there is no reason to relax just because oil prices have dropped. According to BP figures, oil reserves will not last much longer than 50 years based on today's global population figures; in reality, strong global population growth and further variables could reduce that period further still. But as McDonald pointed out, transmission developers have more on their plates than calls for lower fleet consumption due to volatile resources. They also need to offer affordable solutions in a globalized market with differing customer requirement sets. McDonald says the 'Getrag Approach' to this problem involves transmission technology that combines scalability and flexibility with a

high degree of modularity and commonality. Thanks to on-demand actuation and clutch cooling – plus the inherently superior efficiency of layshaft transmissions – he says third-generation Getrag DCTs are now the most efficient form of automation, roughly 5 to 6 percent cheaper than a current 9-ratio automatic torque converter transmission. The speaker also noted that third-generation DCTs are scalable right up to a plug-in hybrid with high levels of modularity and commonality. As a result, McDonald concluded, Getrag can already offer transmission solutions that are future-proof, efficient and tailor-made.



The Right Transmission for the Right Vehicle

Mike Harpster, Director Propulsion Systems Research Lab, General Motors, provided an OEM's take on powertrain requirements up to 2020 and beyond. The real challenge, he said, lay in meeting CAFE 2025 requirements without compromising on driveability. He believes in the 'right transmission for the right vehicle, which means fundamentally different solutions can each make sense. In certain circumstances, for example, a CVT could be more fuel-efficient than a fixed-ratio transmission despite its lower inner efficiency. For the automatic torque converter transmissions that remain popular in North America, GM is opting for 9 to 10 ratios – plus a cooperation with Ford to ensure the transmissions are not just efficient and comfortable, but affordable too. GM is taking a different route again with the second-generation

Chevrolet Volt, which has a redesigned Range Extender drive with two electric drive modes and three Range Extender modes. The transmission is a planetary unit that manages the power of the internal combustion engine and two electric motors.



On the other hand, given the advanced state of hybrid technology, Mike Harpster's statement that "conventional drives will come closer to hybrids in terms of fuel consumption" was surprising. He says the role of transmissions as 'transformers' will diminish, and that they should always be seen as part of the overall system – particularly in view of the fast-growing importance of auto electronics, right up to car-to-x communication and automated driving.

Efficient Technology Has To Pay

As an environmental agency representative, Don Hillebrand, Director Argonne Center for Transportation Research, faces a real dilemma: how to bring fleet consumption figures down to 54.5 mpg in 2025 without overburdening the industry and auto drivers. One option would be to raise vehicle tax like 'they do everywhere else in the world', which he says is hardly feasible in the USA: when the Clinton administration tried, it lost control of Congress to the Republicans for the first time in 40 years. Raising taxes, Hillebrand points out, is tantamount to political suicide. As a result, the USA approach involves making fleet consumption figures for CAFE (Corporate Average Fuel Economy)



stricter for manufacturers every year until they hit 54.5 mpg in 2025, but also rewarding sensible technology that can cut fuel consumption. Hillebrand said the technologies already exist, but the issue was their price point. Even the most energy-efficient technology is no use if hardly anyone buys it. Summing up, he said the USA approach comprised ever-stricter fleet consumption figures, plus intensive research into the most efficient fuel reduction technologies as a way of cutting costs.

Efficiency by Low Friction

Philip A. George, Director Advanced Development, Schaeffler, began his lecture by summing up the dilemma all auto developers currently face. Emissions regulations are getting stricter, fuel is cheap ... and on top of that, drivers expect comfort, not frugal, fun-free transportation. He said there was a huge set of technologies available, but that simply adding them up did not work. In his example, he showed how in reality, 1+1+1 is often less than 3, or even less than 2. In George's view, the solution involves a systemic approach and two core challenges: fur-

ther improving mechanical components, and affordable low voltage electrification that builds on those improvements. Accordingly, one



core challenge involves reducing or eliminating friction. He said on a reference car with a footprint of 4.2 m² (a mid-sized car according to CAFE rules), these mechanical improvements alone cut fuel consumption from 24 to 29 mpg. As an example of efficient hybridization, George presented the TDA (Transmission Driven Accessories) concept. This has an engine boost feature, plus the ability to avoid engine drag loss by separating secondary drive units from the powertrain.

2500 Years of Planetary Transmissions

Charles Gray, Director Transmissions and Driveline Engineering, Ford, gave interesting insights into the history of planetary gearsets. He noted that the ancient Greeks had the idea around 500 years B.C., but that it was not until 1908 that Ford fitted a two-ratio transmission in the Model T. Since then, he said, the technology has evolved continuously. From the Ford perspective, the latest high points are the patent application for an 11-ratio automatic transmission in 2015, and the introduction in 2017 of the 10-ratio automatic shift developed together with GM. Gray sees considerable room for improvement in production methods, now and in the future. These include gear tooth modifications to improve durability and NVH, hard finishing for NVH-critical gears only and further improvements to manufacturing methods, but also advanced torsional vibration absorbers and lower drag loss in clutches. Charles Gray also cited Moore's Law, which states that the number of transistors on an integrated circuit doubles every two years. As a result, 10 or 11 ratios can now be handled – a number that used to be unthinkable. The lecture title was 'Can we make it?'. Gray's answer: "Look how far we have come ... can we make it? Yes, together".



CVTs – a Partner for Dynamic and Autonomous Driving

Hiroyuki Kai, President Jatco Mexico, began by referring to the global trend that predicts over-proportional growth for CVTs and DCTs in the market for '2-pedal' transmissions' up until 2020. He believes 85 percent of all automobiles will still have a combustion engine in 2030 (increasingly as part of a hybrid drive), and around 50 percent even in 2050. Jatco's response is a straightforward CVT that can be hybridized with little effort, and has a commonality factor of over 70 percent. Mr. Kai also emphasized the functional flexibility of CVTs. On one

hand, he said, the CVT ideally complements automatic and autonomous driving, because stepless operation made it particularly easy to keep the engine within its optimal efficiency zone. On the other, he said, Jatco also satisfies customers who like fixed-ratio transmissions with the 'D-Step' feature that is now available on several series production Nissan models. Like Charles Gray before him, Kai showed how much untapped potential still lies in optimizing manufacturing processes. Improvements included continuously synching production and customer wishes (Douki), leaner manufacturing concepts, and enhanced manufacturing methods such as micro shot peening for the pulley surface so that CVTs can master even higher torque.



Turbine Powered Range Extender

Ian Wright began his career as a radio engineer in New Zealand, co-founded Tesla Motors, and is now the CEO of Wrightspeed Inc. His fascinating and unusual topic: a Range Extender drive for trucks that uses a gas turbine to generate electricity. Further downstream are two electric motors with two gear ratios each, to permit the use of high-speed electric motors, and a 200 kW inverter in between that Ian Wright calls a CVT. Why the analogy? Because like a CVT, the inverter enables power to be used steplessly – only with no clutches, converters, synchronizations or differentials. Wright says the stepless regulation is achieved simply by regulating the motor frequency. So why a turbine, not a combustion engine? Wright explained it's because gas turbines deliver good efficiency only under maximum load, which is always given in a range extender configuration, but also because they are much smaller than engines, very reliable, need little maintenance and require almost no afterburn treatment (unlike diesels). He pointed out that the electricity generated was actually cleaner than the power mix delivered by power stations in the USA. Compared to a diesel truck, he said, the savings and benefits were impressive: – 93 % particulate matter, – 82 % NO_x, – 69 % HC, – 69 % CO₂ – and a lot less noise.



The Future of Autonomous Driving

'Roadmap to Autonomous Driving', the lecture by Ali Maleki, Vice President Business Development, Ricardo North America, stayed a little closer to familiar concepts, yet was still deliberately provocative. His statements: "By 2050, all automobiles will drive autonomously" and "the majority of automobiles will be part of a sharing concept". Maleki began by explaining how the different stages of autonomous driving

are classified today. Under SAE J3016 there are: 0 = no automation, 1 = driver assistance, 2 = partial automation, 3 = conditional automation, 4 = high automation and 5 = full automation. Maleki believes 95 percent of all driving tasks can be mastered using 'conventional' algorithms; the remaining five percent would need heuristic algorithms, i.e., the ability to conjecture and make decisions based on available information. This, together with concerns over data security, are currently the two most critical points in the public's opinion of autonomous driving. Maleki reminded listeners that uncertainties of this sort existed at the dawn of the automobile age too: "We have been there before and we will resolve this". He said the necessary sensors are already there, and that the bigger challenge involved defining functional modules in a way that avoids excess complexity. Maleki expects integrated control modules to be created in software, grouped in an application framework, and based on the operating system and an ASIL layer (Automotive Safety Integrity Level) that interacts closely with the hardware. But the biggest challenge of all, he warned, lay elsewhere: What will the industry do if US auto sales drop by 40 percent over the next 25 years?



Driving Must be Fun

One way might be upholding fun-to-drive: Ian Wright for example, had given a second reason why he is backing gas turbine range extenders: "Call it green, call it clean – we just call it cool". In his lecture, Charles Gray had also explained how important motorsport still is for Ford. John McDonald had spoken of 'four transmissions' in one, by which he meant that software could not only make DCTs more fuel efficient, but comfortable, sporty or even supersporty too. The fact that CVTs from OEMs like Nissan or Subaru now ship with shift programs just because of the fun factor speaks for itself. One insight often heard at Novi was that ultimately, it's automobile drivers who decide what they want – and driving enjoyment is definitely part of the mix.

Once again, the CTI Symposium USA had more participants and topics than the year before. The event showed that transmissions face an increasingly diverse range of tasks at the interface between efficiency and driving enjoyment. Another trend at Novi was that for developers, it now goes without saying that hybridization is one of many measures needed for compliance with CAFE. Each individual measure needs to be seen as part of the overall system, and the end result has to be affordable for drivers. Philip George from Schaeffler surely expressed the sentiments of many participants when he said: "At the end of the day, it's the volume that goes into CAFE".

More information and images:
www.transmission-symposium.com/usa/
 Author: Gernot Goppelt, CTI correspondent



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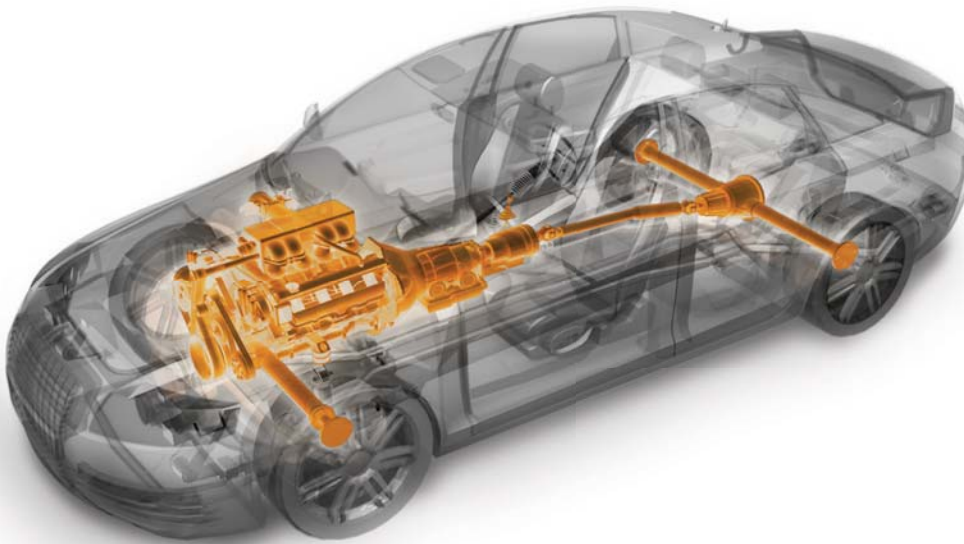
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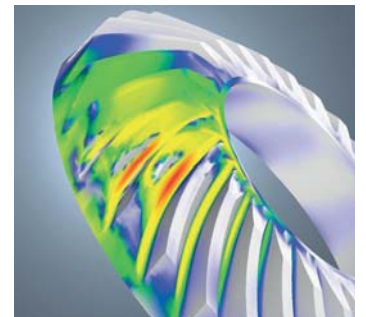
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