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# Drivetrain for Vehicles 2017

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# Control Solutions for Transmissions 2017

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# VDI-Berichte 2313

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# Drivetrain for Vehicles

# Transmissions in Commercial Vehicles

# Control Solutions for Transmissions

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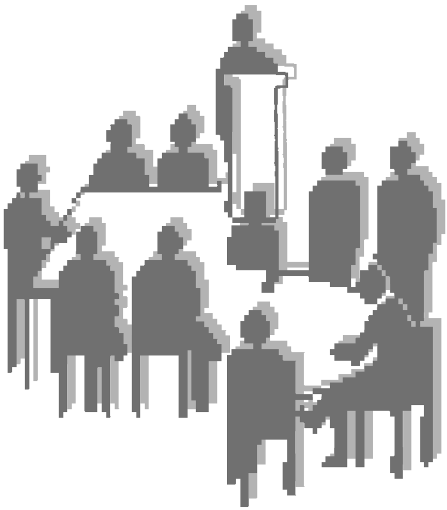

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## 3rd International Conference Control Solutions for Transmissions 2017



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### Actuators – Efficiency of auxiliary units

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# Risk-Oriented Security

**Christof Ebert**, **Dominik Lieckfeldt**,
Vector Consulting Services, Stuttgart

**Zusammenfassung**

Autos und Fahrzeuge sind wie jedes andere IT-System Sicherheitsangriffen ausgesetzt. Cyber-Security ist in jeder Domäne des Fahrzeugs kritisch, egal ob Getriebe, Antrieb oder Infotainment, denn ohne Cyber-Security gibt es keine funktionale Sicherheit. Daher muss eine Risikobewertung und Abschwächung systematisch durchgeführt werden. Die risikoorientierte Sicherheitstechnik für Automotive Systeme hilft bei der Entwicklung von robusten Systemen sowie bei einer effektiven Abschwächung von Angriffen oder von Schwachstellen. Cyber-Security muss frühzeitig in der Designphase eines Fahrzeugs umgesetzt werden, um die Bedrohungen und Risiken durchgängig zu adressieren. Die Sicherheitsanalyse liefert Anforderungen und Bedrohungsvektoren, und es können angemessene Maßnahmen für eine schlanke und dennoch wirksame durchgängige Absicherung abgeleitet werden. Wir zeigen in diesem Beitrag mit konkreten Beispielen, wie die risikoorientierte Cyber-Security in Fahrzeugen erfolgreich umgesetzt werden kann. Es werden drei Hebel für die Automobilsicherheit angesprochen: Produkt, d.h. Architektur und Design von Sicherheitsmaßnahmen für Komponenten und das Gesamtsystem, Prozess, d.h. die Implementierung von Cyber-Security-Konzepten in den Entwicklungsprozess, und Feld, d.h. Sicherheitskonzepte werden im gesamten Lebenszyklus und vor allem auch während der Serviceaktivitäten durchgängig angewendet.

**Abstract**

Cars and vehicles are like any other IT system subject to security attacks. Cyber-security matters for almost any automotive domain, be it dynamics or powertrain or infotainment, because without security, there is no safety. Therefore, advanced risk assessment and mitigation is the order of the day. Risk-oriented security engineering for automotive systems helps in both designing for robust systems as well as effective mitigation upon attacks or exploits of vulnerabilities. Security must be integrated early in the design phase of a vehicle to understand the threats and risks to car functions. The security analysis provides requirements and test vectors and adequate measures can be derived for balanced costs and efforts. We will show with concrete examples how risk-oriented cyber security can be successfully achieved

in automotive systems. Three levers for automotive security are addressed: Product, i.e., designing for security for components and the system, Process, i.e., implementing cyber security concepts in the development process, and Field, i.e., ensuring security concepts are applied during service activities and effective during regular operations

**Automotive Cyber-Security**

With the introduction of connectivity and increasing amount of IT in vehicles, precautions must be taken to increase the reliability and to reduce the vulnerability to the system [1]. The basic principle is simple to understand, yet difficult to achieve: Functional safety needs security [1,2,3]. Based on the specific challenges of automotive security, OEMs and suppliers have to realize an effective protection against manipulations of automotive E/E systems [1,4]. Automotive security has gained huge relevance in short time-frame. Attacks are reported today almost continuously and therefore systems must be protected and hardened. Safety needs security as a mandatory condition, which means that any safety-critical system as a minimum must also be protected for cyber security. Security must be integrated early in the design phase of a vehicle to understand the threats and risks to car functions.

Key points in the development of protected E/E systems are the proper identification of security requirements, the systematic realization of security functions, and a security validation to demonstrate that security requirements have been met. The following items need to be considered to achieve security in the car development process:

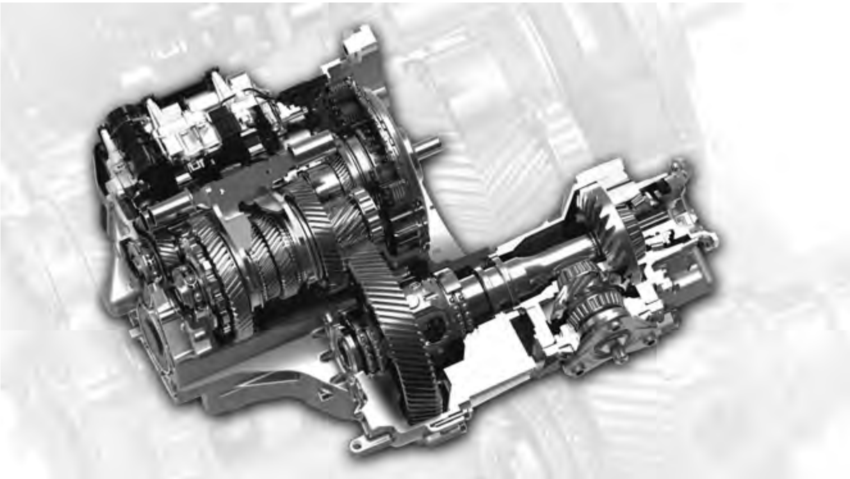
- Standardized process models for a systematic approach which is anchored in the complete development process. This starts on the requirements analysis through the design and development down to the test of components and the network.
- Quick software updates to close vulnerabilities in ECU software.
- Reliable protocols that are state-of-the-art and meet long-term security demands. Related to security this is often combined with cryptographic keys. So, a key management over the lifecycle of the vehicle must be maintained.
- In-vehicle networks and system architecture that provides flexibility and scalability and are designed under consideration of security aspects.

Risk-oriented security helps to balance growing security threats with increasing complexity over the entire life-cycle. Unlike many previous attempts our research and many practice projects indicate that while design for security is good, it is not good enough. Effective security must handle the entire life-cycle (Fig. 1).

# DQ381 – Die neueste Generation Doppelkupplungsgetriebe bei Volkswagen

# DQ381 – The Latest Generation of Dual-Clutch Transmissions from Volkswagen

Dr. **Hubert Gröhlich**, Dipl.-Ing. **Detlef Germershausen**,
Volkswagen AG, Wolfsburg



**Summary**

With the DQ381 dual-clutch transmission, Volkswagen presents a new member of its extremely successful DSG® family. The DQ381 is the successor to the DQ250, which has been in series production at the component plant in Kassel since 2003 as the world's first dual-clutch transmission. The new DQ381 has seven gears and is designed for torques up to 420 Nm. Like all of Volkswagen's dual-clutch transmissions, it provides sporty performance without compromising on comfort and efficiency. Its variable design allows it to be used in a wide range of models in the Volkswagen Group. It has been designed both for front-wheel drive and four-wheel drive models. It was developed on the basis of the modular assembly

matrix for transmissions with oil-cooled dual clutches with the goal of increasing the efficiency throughout the design. To this end, a number of optimizations were made in particular. The DQ381 completes Volkswagen's range of transmissions for the complete line of products using conventional powertrains. From the small-car segment up to the Transporter line of models, all are now available with 7-gear transmissions (Fig. 1).

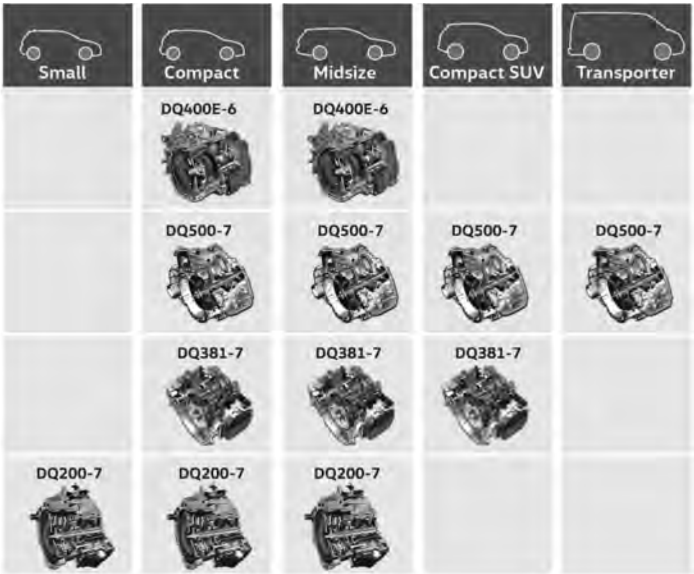



Fig. 1 *Overview of dual-clutch transmissions in the Volkswagen Group*

**1. Introduction**

Since 2003, Volkswagen has produced the world's first production dual-clutch transmission – the DQ250. That transmission features 6 gears and an oil-cooled dual clutch. Until today, it has been used very successfully in numerous vehicle models in the Volkswagen Group. Since the introduction of the DQ250, Volkswagen's market share of compact-class vehicles with automatic transmissions has continued to rise at a high rate. To extend the product range also to the small-car segment, in 2008 the DQ200 was introduced in the Volkswagen Polo. It was the first to feature seven gears and employed a dry dual clutch actuated hydraulically using a pressure accumulator. With its resulting efficiency, the DQ200 marked a milestone in the development of automatic transmissions. In production since 2009, the DQ500 extended Volkswagen's range of dual-clutch transmissions to the Transporter product

# $CO_2$ Potentials of DCTs – Competition Benchmark and Technology Outlook

**Martin Bahne**, **Ulrich Frey**, GETRAG, Magna Powertrain, Köln

**Abstract**

Within few years dual-clutch transmissions have reached an efficiency level that considerably contributes to reducing $CO_2$ and fleet consumption on a larger scale. One major contributor to this progress is advanced actuation technology. Moreover, continuous improvements are being made in areas like friction and splash losses etc., to some extent also thanks to technology synergies with other layshaft transmission types (MT etc.).

This lecture focusses on a $CO_2$ comparison of a small DCT to a typical CVT application in the B to C segment, based on real data and a setup with identical platform and engines. The purpose is to show how the small DCT performs in the direct competitive environment of automated small cars. Furthermore, it is shown how the results of this comparison change when moving from NEDC to the more dynamic WLTC, and using advanced engine technology.

Besides this efficiency comparison, the speech outlines the parameters that define the efficiency of DCT technology and the potentials for further efficiency improvement in terms of reducing losses, optimizing operation strategy etc. – including an outlook on advanced integrated design and development methods in future powertrains.

**Transmission development within the WLTC**

From September 2017, the $CO_2$ and pollutant emissions of new types of cars will be measured using the WLTC (Worldwide Harmonized Light-Duty Vehicles Test Cycle). As is known, the WLTC has higher dynamic requirements on the powertrain compared to the NEDC, maximum and average speed is higher, load is generally more complex, Fig. 1. Within the transition period until 2021, the results are converted to NEDC to determine the $CO_2$ emissions. However, for new car developments, OEMs practically need to design their powertrains according to the WLTC requirements even today.

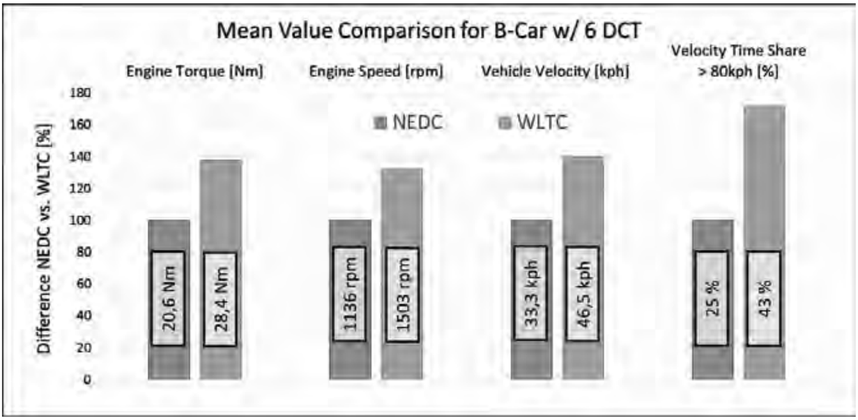



Fig. 1: Increased loads in the WLTC

With regard to transmissions, OEMs are confronted with a double challenge: Firstly meeting future $CO_2$ requirements will be generally tougher, and secondly the impact of the chosen transmission technology will change. The reason is not simply the need for best possible base efficiency. In addition, higher engine load changes the requirements to adapt transmission ratios and shift points to the consumption map.

**Basic differences of DCT and CVT technology**

Fig. 2 shows an efficiency comparison between MT, CVT, DCT and AT, based on VDA data [1]. In this study, GETRAG compares DCT and CVT technology for typical B to C segment high volume applications. These transmission types are common in global high volume applications and can affect fleet consumption to a large extent.

# Efficient and Industrialized Dual Clutch Transmission Family for Powertrains up to 350 Nm

Dr.-Ing. **G. Hellenbroich**, Dr.-Ing. **I. Steinberg**,
FEV Europe GmbH, Aachen;
**D. Freiholtz**, FEV Sweden, Trollhättan

**Zusammenfassung**

Die DCT-Familie von FEV setzt auf höchste Modularität und erlaubt so die wirtschaftliche Entwicklung und Fertigung von modernsten Doppelkupplungsgetrieben auch für Anwendungen mit kleinerer Stückzahl. Durch den Einsatz erprobter Subsysteme und Komponenten wie der Doppelkupplung, des Aktuierungssystems, des Steuergeräts und der Ölpumpe werden Entwicklungsaufwand und –risiko minimiert und ein hoher Gleichteileanteil innerhalb der Familie erreicht. Die mechanischen Komponenten wie Wellen und Zahnräder, Schaltgabeln und Gehäuse werden für jede neue Anwendung maßgeschneidert, wobei auf vorhandene Radsatzkonzepte für bis zu neun Vorwärtsgänge zurückgegriffen werden kann. Sowohl für die Integration der Übernahmeteile als auch für die Entwicklung der anwendungsspezifischen Inhalte kann FEV auf einen umfangreichen Erfahrungsschatz in der Serienentwicklung inklusive der Definition von End-Of-Line-Prozeduren und auf enge Verbindungen zu führenden Systemlieferanten zurückgreifen. Die Getriebe der Familie verwenden robuste, nass laufende Doppelkupplungen und bedarfsgerechte Aktuierungs- und Kühlungssysteme und erzielen dadurch hervorragende Gesamtwirkungsgrade auf Augenhöhe mit aktuellen Doppelkupplungsgetrieben mit trocken laufenden Kupplungen. Die Hybridversion mit ihrer P2-Architektur bietet sämtliche Hybridfunktionen und ist kompakt genug für die meisten aktuellen Fahrzeugplattformen.

**Abstract**

FEV’s DCT family uniquely combines latest technology and maximum modularity to create a business case also for applications with lower production volumes. Mature, carry-over subsystems and components such as dual clutch, actuators, control unit and electric oil pump are applied for minimum development effort as well as maximum robustness and commonality within the family. The mechanical components such as gears and shafts, shift forks and housings are customized and tailored to the requirements of each new application, including gearset architectures for up to nine forward speeds. For both the integration of the carry-over components as well as for the customized content, FEV can build upon strong ties with lead-

ing Tier-1 suppliers and profound development experience from series production programs with very similar transmission architectures and including end-of-line test procedures. The transmissions use robust wet-running dual clutch units with power-on-demand actuation and cooling systems and do feature excellent overall efficiency levels on par with the ones of contemporary dry dual clutch transmissions. The hybrid version with its P2 hybrid architecture enables maximum hybrid functionality and is compact enough for the engine bay package of most modern vehicle platforms.

**Introduction**

The reduction of CO2 emissions at vehicle level through the improvement of transmission efficiency represents the essential goal of transmission development engineers. New requirements, such as the recovery of the kinetic energy of the vehicle while coasting, the hybridization of drivetrains and autonomous driving, are challenges that can best be addressed with automatic transmissions. Dual clutch transmissions (DCT) with power-on-demand actuation systems offer a particularly efficient method of meeting the new requirements. How-ever, many markets show vehicle applications with production volumes of less than 100.000 units per year. FEV's new DCT family is conceived especially for customers in these markets. The re-use of proven subsystems which are already in series production results in a business case for applications with lower volumes also. This article introduces the transmission family, of which a first variant will hit production as early as 2017.

Table 1 gives an overview of the transmission family. The transversal installation for front-wheel or all-wheel drive and the input torque range of up to 350 Nm covers the majority of vehicles worldwide. A torque difference of at least 100 Nm between transmission variants is recommended in order to gain an advantage from reduced transmission weight and increased efficiency which outweighs greater diversity of components.

Table 1: Overview DCT (Dual Clutch Transmission) family from FEV

| [illegible] | [illegible] | [illegible] | [illegible] | Dual clutch | Clutch actuation | [illegible] | Oil pump | [illegible] |
|---|---|---|---|---|---|---|---|---|
| 5DCT130 | 130 | 5 + Rev | 170 or 183 | Wet, nested, feedthrough type | Hydraulic (low leakage) | Electro-mechanic incl. park-by-wire | Mechanic | Two input, single output |
| 7DCT250 | 250 | 7 + Rev | 183 | Wet, nested, CSC type | Electro-hydrostatic | Electro-mechanic incl. park-by-wire | Electric | Two input, two output |
| 7DCT350 | 350 | 7 + Rev | 195 | Wet, nested, CSC type | Electro-hydrostatic | Electro-mechanic incl. park-by-wire | Electric | Two input, two output |

# AT or DCT? MCT – The best of both worlds!

## Synthesis and Functionalities of Multi-Clutch Transmissions

Dr.-Ing. **Ch. Wirth**, M.SC. M.Eng **A. Garcia**, ZG GmbH, Munich

**Zusammenfassung**

Das an der ZG GmbH entwickelte Getriebesyntheseprogramm "PlanGear" kann Mischformen aus Automatik- und Doppelkupplungsgetrieben erzeugen. Die spezifischen Vorteile beider Konzepte lassen sich auf diese Weise vereinen.

Automatikgetriebe (AT) bestehen in der Regel aus einem Anfahrelement, mehreren Planetengetrieben und Lastschaltelementen. Die Gangwechsel erfolgen ohne Zugkraftunterbrechung. Wesentlicher Vorteil dieser Bauart ist die hohe Leistungsdichte, die sich im Wesentlichen durch die Mehrfachverwendung von Planetengetrieben in diversen Gangstufen und deren innere Leistungsverzweigung ergibt. Wirkungsgradrelevant sind die hydraulischen Verluste in geöffneten Schaltelementen und die Undichtigkeiten in der Druckölversorgung von Kupplungen an Drehdurchführungen. Somit ist ein generelles Ziel bei Automatikgetrieben, möglichst wenige Lastschaltelemente zu verbauen.

Doppelkupplungsgetriebe (DCT) bestehen in der Regel aus zwei reibschlüssigen Lamellenkupplungen, die zum Durchschalten der Gänge abwechselnd betätigt werden. Über formschlüssige Schaltelemente wird dazu der Leistungsfluss des nächsten Gangs parallel zum aktuellen vorbereitet. Die verschiedenen Gangstufen sind dabei meist durch Stirnradstufen unterschiedlicher Übersetzung dargestellt, sog. Windungsgänge mit Mehrfachnutzung einzelner Stufen sind die Ausnahme. Vorteilhaft gegenüber Automatikgetrieben sind die vergleichsweise sehr geringen Verluste in geöffneten Schaltelementen.

Die ZG ist in der Lage Multi-Clutch-Transmissions (MCT) zu synthetisieren, die aus Planetengetrieben, Stirnradstufen und mehr als 2 Lastschaltelementen bestehen können. Lastschaltelemente dürfen dabei prinzipiell auch einfacher bauende Lamellenbremsen sein. Es lassen sich nun geeignete Kompromisse aus beiden bisher getrennten "Getriebewelten" finden: Hohe Leistungsdichten, geringe Kosten, niedrige Verluste und hohe Funktionalität. Anhand ausgewählter Beispiele aus Basis der Lepelletier-Struktur werden im Vortrag Synthese und Funktionsweisen derartiger Getriebestrukturen beschrieben.

**Abstract**

The synthesis program „PlanGear“, developed by ZG GmbH, is able to generate mixed forms of automatic and double-clutch transmissions. This allows the combination of the specific advantages of both concepts.

Automatic transmissions (AT) generally consist of a start-up element, multiple planetary gear stages and load-shift elements. The gears are power shifted. A significant advantage of this design is the high power density, mainly due to the multiple use of planetary gear stages within various gear steps and their internal power-split. Hydraulic losses through open shift elements as well as leakage in the hydraulic oil supply of clutches at rotary feedthroughs are relevant for the efficiency. Thus, the general goal in the development of automatic transmissions is the reduction of the number of load-shift elements.

Double-clutch transmissions, also known as dual-clutch transmissions (DCT) normally consist of two multi-disc friction clutches which are actuated alternately to switch gears. Synchronized dog clutches set up the power flow of the next gear parallel to that of the actual gear. The different gears are represented by cylindrical gear pairs with different ratios. So-called “winding gears”, meaning the multiple use of single stages, are rarely in use. Advantageous when compared with AT are the comparatively smaller efficiency losses through non-engaged shift elements.

ZG GmbH is able to generate Multi-Clutch Transmissions (MCT) which may consist of planetary gears, cylindrical gears and more than two load-shift elements. Load-shift elements can also be space-saving multi-disc brakes in this case. Thus, suitable compromises between the advantages of the previous separated “transmission worlds” may now be found: high power density, low costs, small efficiency losses and high functionality. By means of selected examples based on the Lepelletier topology, synthesis and functionalities of MCT will be described in this paper.

**Advantages of AT and DCT**

The most important features of today’s manufactured DCT are listed in Table 1. The fundamental principles of DCT are the two (mostly) separated transmissions that are connected over two load-shift elements (LSE) with the input shaft of the DCT. One transmission supports the odd numbers of gears; the other transmission provides the gears with even numbers. The power flow is realized over the closed LSE and one transmission. Before power shifting a preselection of the next gear has to be arranged. Thus, a DCT has to provide multiple power flows over the two LSE. Synchronized dog clutches have to connect the appropriate gear stages to arrange the preselection.

# Advancement in Transmission- and Hybrid Technology to meet future market conditions

Dipl.-Ing. **Martin Grumbach**, ZF Friedrichshafen AG, Friedrichshafen

**Kurzfassung**

Weltweit werden die Rahmenbedingungen für den Verbrauch und die Emissionsvorschriften steigende Ansprüche an den Triebstrang künftiger Fahrzeuge erzeugen. Außerdem führen spezielle regionale Vorschriften ggf. zu marktspezifischen Ausprägungen, welche die Ausgestaltung des Triebstrangs dort beeinflussen. Zusätzlich gibt es (immer noch) regional unterschiedliche Vorlieben der Autokäufer, die zu angepassten Angeboten der Automobilhersteller führen.

In einer Übersicht wird gezeigt, welche künftigen Marktanteile für unterschiedliche Märkte und Antriebskonstellationen in Zukunft erwartet werden. Die Vorschriften müssen regional vom jeweiligen Hersteller erfüllt werden. Den Anforderungen z. B. an die Flotteneffizienz werden die Automobilhersteller mit unterschiedlichen Mitteln begegnen.

In dem Beitrag werden einige wichtige Fortschritte der Getriebe und Hybridsysteme aufgezeigt und erläutert. Außerdem werden vorausschauend wirkende Schaltprogramme/Schaltfunktionalitäten einen Einfluss auf den realen Kraftstoffverbrauch ausüben. Diese können von heute schon verfügbaren Informationen über die Umgebung ausgelöst werden oder künftig durch die Infrastruktur für das automatisierte Fahren auf der Straße oder im Fahrzeug unterstützt werden.

Anhand des Getriebe- und Hybridsystemportfolios der ZF wird der Einfluss der einzelnen Systeme auf den Kraftstoffverbrauch /Emissionen unter Berücksichtigung des inneren Wirkungsgrades und den Betriebspunktverschiebungen durch Gangzahl und Spreizung der Getriebesysteme beschrieben.

Während klar ist, dass es eine zunehmende Elektrifizierung in allen Märkten geben wird, ist die Ausprägung und Verteilung der möglichen Lösungen in der Zukunft höchst unklar. In diesem Zusammenhang wird erläutert wie zukünftige Baukastensysteme für die unterschiedlichen Antriebskonfigurationen helfen können, sich auf die unklaren Anforderungen flexibel vorzubereiten.

**Abstract**

The general conditions regarding consumption as well as emission regulations will lead to increasing global demands being placed on the driveline of future vehicles. In addition, special regional provisions may also result in market-specific characteristics which influence the driveline configuration in these areas. Furthermore, car buyers (still) exhibit preferences that vary from region to region and lead to the car manufacturers offering tailored solutions.

The expected future market shares for various markets and driveline constellations will be presented in an overview. The respective manufacturer must fulfill the provisions on a regional basis. The car manufacturers will use various resources to address the requirements such as those placed on fleet efficiency for instance.

This article will illustrate and explain some important instances of progression in the various transmission modules and hybrid systems. Furthermore, anticipatory shift programs/shift functions will also have an effect on the effective fuel consumption. Today, they can be triggered by the information concerning the surroundings which is already available. In the future, they may also be supported by the automated driving infrastructure on the road or inside the vehicle.

Using ZF's transmission and hybrid system portfolio, the article describes the influence of the individual systems on fuel consumption/emissions while considering internal efficiency and utilizing optimal engine operating points caused by the number of gears and ratio spread of the transmission systems.

Although it is clear that all markets will experience an increase in electrification, the future characteristics and distribution of the possible solutions remains extremely unclear. In this context, the article explains how future modular systems for the various drive configurations will be able to flexibly assist in preparation for the unclear requirements.

# Ein modulares Konzept für hybridisierte Handschaltgetriebe

# A modular Concept for hybridized Manual Transmissions

Dr. Ing. **Frank Casimir**,
GETRAG FORD Transmissions GmbH - Magna Powertrain, Köln

**Zusammenfassung**

Im Vergleich mit anderen Fahrzeuggetrieben verbinden Handschaltgetriebe die Vorteile von niedrigstem Gewicht, höchster Effizienz und geringsten Kosten. Das spiegelt sich im Marktanteil und den erwarteten weltweiten Stückzahlen von Handschaltgetrieben aus. Zukünftige Anforderungen der Märkte erfordern jedoch eine Anpassung des Konzepts eines von Hand geschalteten Getriebes:

- Die generelle steigende Erfordernis, Hybridelemente in die Antriebe zu integrieren, um zukünftige gesetzlich vorgeschriebene Emissionsgrenzen einhalten zu können
- Die Notwendigkeit, Schaltgetriebe mit fortgeschrittenen Fahrassistenzfuntionen kompatibel zu machen

Das GETRAG Konzept für diese Herausforderung basiert auf einer stufenweisen Erweiterung der Getriebefunktion, bei der jede Stufe auf der vorherigen aufbaut. Alle Komponenten und Funktionen sind dabei vollständig so in das Getriebe integriert, dass der Einbauraum im Fahrzeug-Motorraum berücksichtigt ist, was die Komplexität und den zusätzlichen Aufwand minimiert, welche damit einhergehen, im gleichen Fahrzeugtyp sowohl hybride als auch konventionelle Antriebe anbieten zu wollen.
Das GETRAG hybride Handschaltgetriebekonzept (HMT) bietet spezifische Vorteil für kleine und mittelgrosse Antriebe als kostengünstige Option, „mild hybrid“ Varianten auf der Basis von 48V elektrischen Systemen zu realisieren. Durch die Verwendung des standardisierten GETRAG Hybridbaukastens, der auch im GETRAG Hybrid-Doppelkupplungsprogramm (HDT200 / HDT300) Anwendung findet, lassen sich die Kosten begrenzen und die technischen und Entwicklungsrisiken minimieren. Für die Fahrzeugmontage bietet die integrierte Lösung den Vorteil, dass eine vollständig getestete Einheit fertig zum Einbau bereitsteht.
Die Modularität des Systems ermöglicht die Erweiterung zum automatisierten Hybridgetriebe (AHT) und zu Hochvolt Hybridantriebseinheiten für „plug-in“ PHEV Fahrzeuge.

**Abstract**

Manual transmissions combine the advantages of lowest weight, highest efficiency and lowest cost compared with all other light vehicle transmission types. This is reflected in the market share and the expected total volume of manual transmissions in the global markets. However, the concept of a manually shifted transmission needs to be adapted to upcoming market requirements:

- the need to integrate hybrid features in the powertrains to meet future legislated emission limits
- incompatibility of today's manual transmissions with advanced driver assistance functions

The GETRAG concept to address this challenge is based on a step-by-step upgrade of the transmission's function, where each step is building on the previous and provides a functional enhancement on it's own. All components and functions are fully integrated into the transmission in consideration of the installation package in the vehicle engine bay thus minimizing the complexity and specific effort to offer hybrid and conventional powertrains versions in the same vehicle.

The GETRAG hybrid manual transmission (HMT) concept offers specific advantages for small and mid size powertrains as a cost efficient option to create mild hybrid variants on the base of a 48V electric system. By the use of a standardized GETRAG hybrid part kit shared with the GETRAG Hybrid DCT program (HDT200 / HDT300) the cost are held low while technical and development risks are minimized. For vehicle assembly the integrated solution offers the benefit of a fully tested unit ready to be mounted into the vehicle.

The modularity of the system enables upgrade opportunities to automated hybrid transmissions (AHT) and to high voltage hybrid units for PHEVs.

## 1. Why invest into Manual Transmission Technology Upgrades?

Manual transmissions combine the benefits of lowest weight, highest mechanical efficiency with lowest cost (Figure 1). This is specifically important for smaller vehicles and developing markets. To safeguard those advantages MT need to be adapted to two market trends.

1. Expected $CO_2$ legislation. The governing bodies of all major markets are planning to enforce continuously reducing $CO_2$ limits (Figure 2). Depending on market specific limits and vehicle sizes, between 2020 and 2025 this will drive a high percentage of hybrid or electric drive technology when the capability of pure internal combustion

# PHEVplus
## Effizienzsteigerndes DHT* für Plug-in Hybridanwendungen

# PHEVplus
## Efficiency-raising DHT* for Plug-in Hybrid Applications

Dipl.-Ing.(FH) **Sven Herber**, GKN Driveline, Lohmar

**Zusammenfassung**

Im Förderprojekt „PHEVplus" wird ein mehrgängiges Multi-Mode-Getriebe in einer ganzheitlich optimierten Antriebsstrangkonfiguration entwickelt. Damit wird gegenüber heutigen PHEV- und REEV-Systemen eine Steigerung hinsichtlich des Wirkungsgrades, der Kompaktheit und der Reichweite bei gleichzeitig guter Fahrleistung für die Nutzerakzeptanz angestrebt. Die gesteckten Ziele werden durch ein neu entwickeltes Getriebekonzept und eine speziell hierfür entwickelte Betriebsstrategie erreicht. Das Getriebekonzept wurde hierbei von der „GKN Driveline“ entwickelt, die Betriebsstrategie wurde in umfangreichen Simulationen vom Projektpartner „Hochschule Ostwestfalen-Lippe“ erarbeitet. Zudem wurde innerhalb dieses Projekts vom Projektpartner eine Kupplung auf Basis magnetorheologischer Flüssigkeit (MRF) entwickelt [2], die als Trennkupplung zwischen Verbrennungskraft-maschine und Getriebe dient [4].

**Abstract**

Objective of the government funded advanced “PHEVplus”-project is the development of a multimode transmission for Plug-in Hybrid Electric Vehicles (PHEV) within a holistic optimised drive train. Compared with today’s PHEV- and REEV-systems a significant reduction of fuel consumption accompanied by a reduced package size, higher range and higher performance can be expected. This target will be reached by a combination of a sophisticated transmission concept together with a unique developed control strategy. This advanced transmission concept has been developed by “GKN Driveline” while the control strategy has been developed by the “University of Applied Sciences Ostwestfalen-Lippe” in comprehensive simulations. Furthermore the University of Applied Sciences also developed a coupling which works with magnetorheological fluids (MRF) [2]. This coupling is positioned between engine and transmission and is responsible for connecting / disconnecting both to / from each other [4].

*** Dedicated Hybrid Transmission**

## 1. PHEVplus → General Information

To comply with legal requirements for a significant $CO_2$-reduction the German Federal Government (Ministry of Economics and Energy = "Bundesministerium für Wirtschaft und Energie") supports the development of electro mobility by funding relevant projects. Aim is the registration of at least one million electric and plug-in hybrid vehicles in Germany until 2020. An essential key factor to achieve this target is the development of appropriate automotive powertrain components such as transmission systems. The name of this overall funding programme is "ATEM" (German abbreviation for "Antriebstechnologien für die Elektromobilität"). One of these funded projects named "PHEVplus" is aimed at developing a high efficient multimode transmission which also includes coupling technology based on magnetorheological fluids (MRF). Therefore, the MRF-coupling acts as the connecting device between the combustion engine and the transmission.

The project consortium consists of mainly two partners: "GKN Driveline" and the "University of Applied Sciences Ostwestfalen-Lippe" (→ "HS-OWL").

GKN Driveline, the world's leading supplier of automotive driveline technology and systems (CVJ-, AWD-, eDrive Systems and Trans Axle Solutions), has worked out an advanced transmission concept. "HS-OWL" has two specialized divisions: "MotionControl" with expertise in the fields of MRF-technologies and "SimtS" (Simulation of technical Systems) with expertise in the field of real-time simulation of overall vehicles and drivetrain systems. Please see the project logo in figure 1:


Fig. 1: PHEVplus-logo

# New Concepts for Plug-In Hybrid and parallel Range-Extender Transmissions

## The Next Big Step of Powertrain Electrification

Dr.-Ing. **M. Horn**, Dipl.-Phys. **U. Griesmeier**,
Dr.-Ing. **B. Vahlensieck**, ZF Friedrichshafen AG, Friedrichshafen

**Zusammenfassung**

In der vorliegenden Ausarbeitung werden eigenständige Hybridgetriebe für Plug-in Hybrid-Fahrzeuge und Range Extender-Fahrzeuge mit jeweils einer elektrischen Traktionsmaschine diskutiert und verglichen. Zunächst sind funktionale Chancen und Risiken beschrieben. Darüber hinaus stellen die Autoren eine mögliche Vorgehensweise und wesentliche Herausforderungen bei der systematischen Suche und ganzheitlichen Bewertung derartiger elektrifizierter Getriebesysteme vor. Abschließend präsentieren Sie, wie im Hause ZF mit Hilfe eines Prototypgetriebes funktionale Fragestellungen erörtert sowie systembedingte Grenzen herausgearbeitet werden.

**Abstract**

In this paper Dedicated Hybrid Transmissions for Plug-in Hybrid vehicles and Range-Extender vehicles with one electric traction machine are presented and compared. Functional opportunities and risks of these concepts are described. Additionally the authors present a possible systematic approach and essential challenges for the systematic search and holistic evaluation of these electrified transmission systems. Finally it is shown how ZF uses a prototype concept to answer functional questions and to work out limitations systematically.

**Market Trends for Powertrain Concepts**

Future $CO_2$ restrictions for vehicles show a clear trend towards 95 g $CO_2$/km and less in several regions of the world for 2020 +. Especially for large and heavy cars with high driving resistances these targets can't be reached without electrification of the driveline. Therefore the already growing number of vehicles with electrified powertrains is expected to reach a market share of more than 50 % worldwide in 2030 (figure 1). Nevertheless most cars will still use an Internal Combustion Engine (ICE) as main propulsion system in 2030. Only approximately 13 % of the vehicles will drive fully electric without an ICE on board.

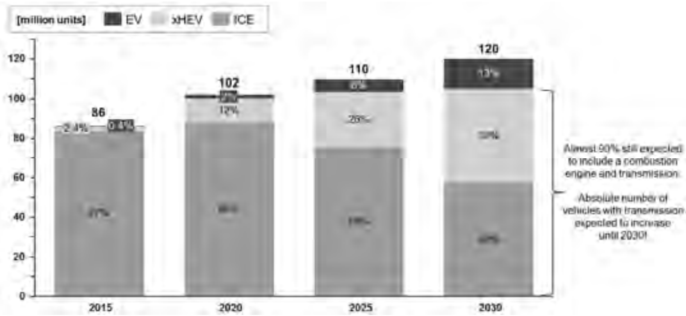



Fig. 1: ZF view on worldwide electrification development up to 2030

Within the group of electrified powertrains different degrees of electrification are expected to coexist on the market (figure 2). The listed concepts can be mainly differentiated by their electric drive functions and their electric range. Besides their overall functionality especially their costs will become a major buying criterion.

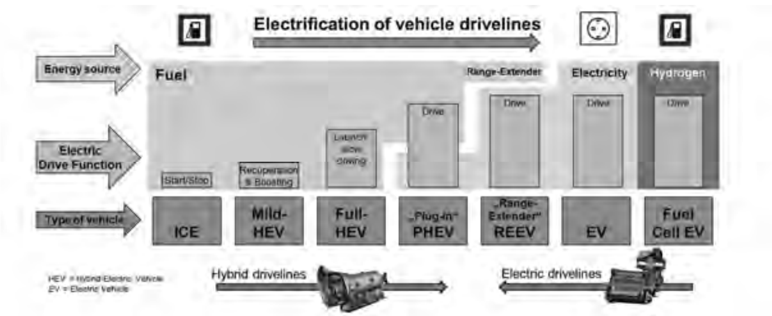



Fig. 2: Different degrees of powertrain electrification

# Modular Low-Cost Powertrain Platform for HEV and EV

Dr. **Christoph Danzer**, **Jens Liebold**,
**Erik Schreiterer**, Dr. **Joerg Mueller**,
IAV GmbH, Chemnitz/Stollberg

***Zusammenfassung***

Bislang sind bekannte Hybridsysteme technisch aufwändig, kostenintensiv und damit für viele Endkunden nicht zugänglich. Unter diesen Gesichtspunkten hat IAV ein kostenoptimiertes Minimalkonzept eines effizienten und modularen Baukastenantriebs für Elektro- und Hybridfahrzeuge entwickelt.

Das System basiert auf einem einheitlichen Radsatz für bis zu drei Gänge, welches mit nur einer reibungsbasierten Kupplung lastschaltbare Gangwechsel ermöglicht. Mit dem Baukastensystem können damit Antriebseinheiten bei maximaler Gleichteilenutzung sowohl für reine Elektrofahrzeuge, als auch für performante Hybride realisiert werden. Die ableitbaren Hybridderivate des Antriebsbaukastens sind zudem für den Einsatz von 48V-Elektromaschinen konzipiert, was in Kombination mit der realisierten Getriebetechnologie das maximale Kostenpotential erschließt. Das extrem einfach aufgebaute Baukastensystem ist darüber hinaus für unterschiedliche Fahrzeugklassen wahlweise mit oder ohne Hybridkomponenten skalierbar.

Der IAV LowCost Antriebsbaukasten stellt damit als kostengünstiges DHT eine Alternative für die Breitenelektrifizierung dar. Die Auslegung eines solchen Baukastenantriebs erfordert einen methodischen Ansatz. IAV nutzt dafür die Methodik der Antriebsstrangsynthese mit dem Ziel der Identifizierung von anwendungsoptimalen Technologiepaketen im Antriebstrang. Im Prozess werden Zyklussimulationen mit prädiktiven Betriebsstrategien, Fahrleistungs- und Kostenbewertungen für jede mögliche Antriebsstrangkonfiguration durchgeführt. Aus der Ergebnismenge von bis zu mehreren Millionen Varianten werden die optimalen Gesamtlösungen für das vorgestellte Baukastenkonzept systematisch ermittelt.

***Abstract***

Currently known hybrid systems are technically complex and cost-intensive and referring to this for many end customers not available. Under this boundaries IAV has developed a cost

optimal minimal concept of an efficient and modular powertrain platform for electric and hybrid vehicles.

The system based on one unity gear set for up to three speeds, which enables seamless shifting with only one friction based clutch. With this platform powertrain units can be realized by using a maximum number of carry over parts (COP) for electric vehicles as well as for powerful hybrids. The derivable hybrid powertrains of the platform system is designed for 48V electric motors which enables the maximum cost potential in combination realized gear set and transmission technology. The real simple powertrain platform concept is furthermore scalable for different vehicle segments optionally with or without hybrid components.

The IAV low-cost powertrain platform represents therewith a cost-efficient DHT as an alternative concept for a mass electrification. The dimensioning and design of such a hybrid powertrain platform requires a systematic approach. Therefore IAV applies the methodology of powertrain synthesis with the target of identification of application-optimal technology packages. The process includes cycle simulations with predictive hybrid strategies, driving performance analysis and cost assessment for every possible powertrain configuration. Based on this set of results with up to several million variants the total optimal design and dimensioning will be presented.

## ***Introduction***

The IAV low-cost powertrain platform represents a cost-efficient Dedicated Hybrid Transmission (DHT) as an alternative concept for a mass electrification. In contrast to previous hybrid concepts [1,2,3] the described powertrain platform focusses on maximizing fuel economy and functionality with a minimum of technology content and costs. For this concept the structural layout with shifting logic and feasible modes will be derived. The dimensioning and design of such a powertrain platform requires a systematic approach to ensure a maximum of fuel economy with minimal technology effort. Therefore IAV applies the methodology of powertrain synthesis with the target of identification of application-optimal technology packages. The process includes cycle simulations with predictive hybrid strategies, driving performance analysis and cost assessment for nearly every possible combination of parameters and maps. Based on the results of these variation studies with up to several million variants the total optimal design and dimensioning will be generated systematically for the complete powertrain platform. Furthermore a design forecast shows the large package-, weight- and cost-potential of the modular powertrain system.

# DHT concepts based on DCT design

Dipl.-Ing. **T. Seidel**, Dipl.-Ing. **A. Lange**, Prof. Dr.-Ing. **F. Küçükay**,
Institute of Automotive Engineering, TU Braunschweig

**Zusammenfassung**

In diesem Beitrag wird ein dediziertes Hybridgetriebe (DHT) vorgestellt, welches über eine Elektromaschine (EM) und ein 4-Gang DCT verfügt. Die EM ist über einen Planetenradsatz (PRS) und zwei zusätzliche Schaltelemente mit dem Eingang des DCT verbunden. Das 4-Gang DCT ist Teil eines modular aufgebauten 8-Gang DCT und kann durch Entfernen einer Triebwelle mit den Gängen 1,2,3 und 8 abgeleitet werden. Dadurch, dass über die EM und den PRS der Anfahrvorgang ermöglicht wird, kann eine nasse Kupplung als Anfahrelement entfallen.

Das 4-Gang DHT wird mit einem P2 8-Gang DCT verglichen, wobei die Berechnung der mechanischen Getriebeverluste im Fokus dieses Beitrags steht. Dazu wird eine am Institut für Fahrzeugtechnik entwickelte Getriebeverlustberechnung eingesetzt, mit welcher die einzelnen Verlustanteile sehr detailliert untersucht werden können. Dabei zeigt sich, dass die reduzierte Anzahl an mechanischen Bauteilen und der Verzicht auf nasse Schaltelemente eine Erhöhung des mittleren Getriebewirkungsgrads im WLTP um ca. 2 % ermöglicht. Dadurch, dass ein höherer Getriebewirkungsgrad auch die Rekuperationseffizienz erhöht, verbessert sich der Kraftstoff- bzw. Energieverbrauch um ca. 3 % im Hybrid- bzw. Batteriebetrieb.

**Abstract**

In this article, a Dedicated Hybrid Transmission (DHT) with one electric machine (EM) and a 4-speed DCT is described and investigated. The EM is connected to the input shaft of the 4-speed DCT trough a planetary gear set (PGS) and two shifting elements. The 4-speed DCT is part of a modular 8-speed DCT and can be derived by removing one drive shaft with the gears 1, 2, 3 and 8. Since the EM and the PGS are utilized for launching the vehicle, a wet clutch is not necessary. The 4-speed DHT is compared to a P2 8-speed DCT with focus on the mechanical transmission losses. To achieve this, a transmission loss calculation developed by the Institute of Automotive Engineering (IAE) is utilized, which allows a detailed analysis of the various loss components. The results show an increase of the average transmission efficiency in WLTP which is achieved by less mechanical components and

waiving of the wet shifting elements. Since the recuperation efficiency benefits from higher transmission efficiency, the overall fuel and energy consumption is improved by approximately 3 % both in hybrid and electric operation.

## Introduction

The integration of one or more electric machines (EM) into the drivetrain has resulted in many different powertrain concepts in recent years, which differ significantly from one another. A common variant is the P2 topology. As an add-on solution, an EM is integrated into a conventional drivetrain between the internal combustion engine (ICE) and the transmission. An additional clutch between the EM and the ICE allows electric driving without drag losses of the ICE. This type of hybridization is characterized by a relatively high mechanical complexity, since many gearings, bearings, shafts and shifting elements are present. As a consequence, mechanical losses are expected to be relatively high compared to hybrid concepts with two EM and a low amount of mechanical components like a series or a power split hybrid. However, a second EM increases costs which have to be considered in relation to savings in mechanical parts. Moreover, by realizing various transmissions ratios through an electrical path (power split), additional electrical losses occur.

Basically, with the realization of a Dedicated Hybrid Transmission (DHT), the mechanical effort can be reduced potentially through an intelligent use of an EM. By utilizing a planetary gear set (PGS) the transmission can offer a continuously variable operation. As a result, the launch element and several gears can be omitted possibly. Since the number of mechanical parts is reduced and no second EM is added, the total costs of the hybrid transmission may be reduced compared to a P2 topology. However, since hybrid units are often produced at a much lower volume than conventional transmissions, a modular approach is needed to take advantage of the mentioned concept.

In this paper, a DHT concept with one EM and four fixed gears (4-speed DHT) is presented and investigated. The four fixed gears are taken over from a modular eight speed DCT concept. The EM is connected through a PGS and two additional clutches. Since the synchronization is realized through the EM, all shifting elements can be realized as dry clutches potentially. As a consequence, drag losses may be reduced significantly because the 8-speed DCT uses wet clutches. The 4-speed DHT is investigated regarding the transmission losses by utilizing a transmission loss calculation and a modular simulation model. Additionally, the 4-speed DHT is compared to a P2 with the modular 8- speed DCT. [1]

# 12+12V and 12+48V Hybridization: a modular approach and transmission impacts.

## Enhancing low voltage hybridization road map

Dr. Ing. **Olivier Coppin**, Valeo Powertrain Systems, France

**Abstract**

Among the various hybridization levels, the 12+12 volts affordable architecture represents the basic architecture allowing the benefits of hybridization, thanks to the energy recovery during braking. The 12+48V electrical architecture is an easy way to enhance 12+12V functionalities and enter deeper in the hybrid application field. With the extended power field offer by 48V components, more vehicle segments and applications can have more benefits at a still limited over cost. We will illustrate the similar topology of 12+12V and 12V+48V systems and show how complementary functions such as electric supercharger boosting can be added in a modular way. This dual battery architecture is also the basic gateway to complementary functions requiring safety constraints.

This approach can help to lower the cost of the systems integration in vehicle which can be a significant part of the total system application cost. This can thus contribute to a large application field for mild hybrid systems and by the way contribute to a greater vehicle fleet CO2 reduction.

We will examine how 48V system can address more efficient hybridization architectures (from P1 to P4) allowing more CO2 emission reduction and even open the gateway for low cost pure electrical véhicule.

We then show how the different hybridization architectures can be addressed in a modular building bloc structure for components. This last level of modularity is an additional lever to lower the hybridization cost. Combining the electrical board net modular predisposition and the field of 48V hybridization would open ways to access further CO2 emission reduction with the best cost ratio.

At the end, we will introduce the impacts of hybridization and future vehicle functions on transmission and a global reflection of the requests for a dedicated one.

## INTRODUCTION

$CO_2$ reduction for the right cost is one of the main challenges of the next years. As the different car segments have various requirements we will show the interest of modular and scalable low voltage hybrid systems. A modular approach for the electric board net evolution and component plat forming can contribute to lower the total system cost. We then explain how to enhance the low voltage roadmap and analyze the impact on transmissions systems.

## DRIVERS FOR ELECTRIFICATION

It is well known that $CO_2$ regulations are becoming more and more challenging all over the world. Achieving the regulation targets requires a certain degree of electrification / hybridization. Fig 1 illustrates the world $CO_2$ regulation prospective. We can easily notice that worldwide regulations are converging, and so, solutions for $CO_2$ reduction will be global.

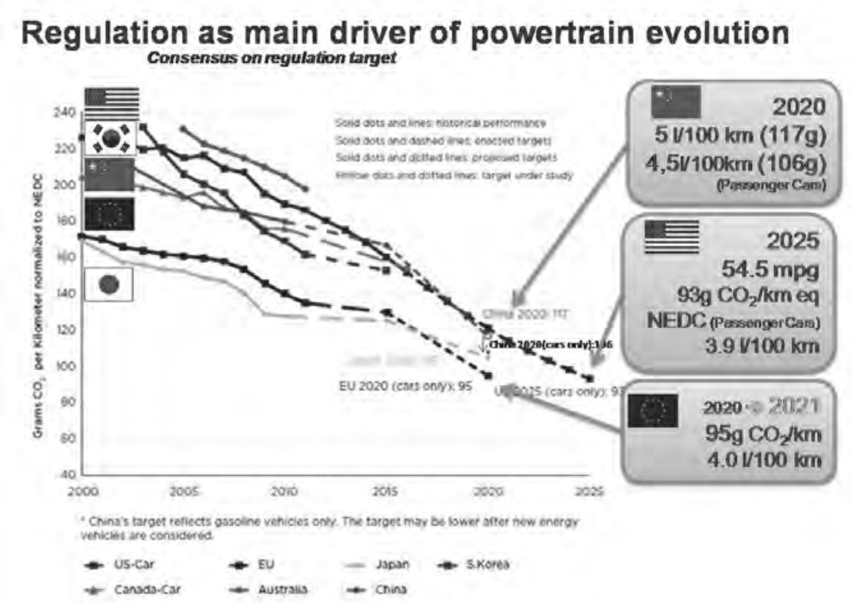



Fig 1 – World CO2 regulation prospective

In the same time, the reference drive cycle is changing in many countries. In Europe, NEDC will be replaced by WLTP. This new cycle impacts the cost benefit ratio of both existing and new functions addressed by hybridization.

# A 48-400V Off-Axis P2 Hybrid module with minimal impact on powertrain length

## Joint development between Volvo Cars and BorgWarner

**Rupert Tull de Salis,** BorgWarner, Ketsch;
**Jonas Forssell, Tobias Stalfors,**
Volvo Car Corporation, Göteborg, Sweden

**Abstract**

Among P0-P4 hybrid configurations the P2 layout enables the maximum benefit in cost-effective CO2 reduction, because the engine can be disconnected, while the e-machine still uses the ratios of the gearbox. P0-P4 positions are named according to the position of the e-machine, as shown in Figure 1. However, for transverse powertrains it has proven difficult to package the necessary components without moving the engine and the gearbox apart. This presents major problems when the powertrain has no space to grow in the axial direction, and this has led OEMs to conclude that a P2 architecture is simply not possible for some powertrains. Further obstacles are encountered in designing and packaging a suitable battery, particularly at 48V, close enough to the e-machine to minimize electrical losses.

A revolutionary solution has been created in a joint engineering project between Volvo Car Corporation (Volvo Cars) and BorgWarner, planned for series production from beyond 2020. It is a P2 hybrid with a chain-driven off-axis e-machine, which has been prototyped and tested in two versions – 48V (15 kW) and 350 V (65 kW), together with Volvo Cars unique 48V Li-ion battery, DC-DC converter and cooling system. The starter, alternator and 12V battery are deleted, and the AC pump is relocated to the P2 location, allowing the entire FEAD to be removed. The battery system is packaged in the engine compartment, close to the e-machine. The P2 module fits Volvo Cars entire engine range and transmission range, without the need to move the engine and transmission apart – an achievement unique in the automotive industry, and one that would be unlikely to occur except through close collaboration between an OEM and a system supplier.

Volvo Cars and BorgWarner collaborated under a novel Joint Development Agreement, whereby both companies are free to use the technology both with each other, and with other suppliers and OEMs.

In this paper we describe the technical innovations that were necessary for a successful solution, covering the battery, high speed chain drive, torsional damping, actuation, control strategies, lubrication and manufacturing processes. Of particular interest is the integration of damper, K0 clutch and chain, to achieve a package-neutral result, and the properties of the chain, which do not limit the power of the e-e-machine. Test results and simulations are included, showing the effects on CO2, performance, drivability and NVH.

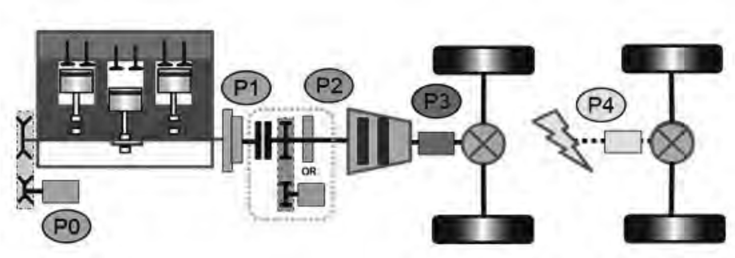



Figure 1: Alternative E-machine locations P0 – P4

**ICE and E-machine specifications**

The hybrid module is designed for Volvo Cars 4-cyl 2 litre engines with up to 560 Nm torque, both gasoline and diesel. The 48V BorgWarner 120-080-4P e-machine is cooled by the intercooler coolant circuit, and delivers peak power 20 kW (for 60 s) and continuous power 15 kW. The peak torque is 64 Nm. With a 3:1 ratio and Volvo's proprietary battery system, it can crank the engine at -30 deg C, allowing the 12V starter to be eliminated. The torque enhancement is shown in Figure 2 below.

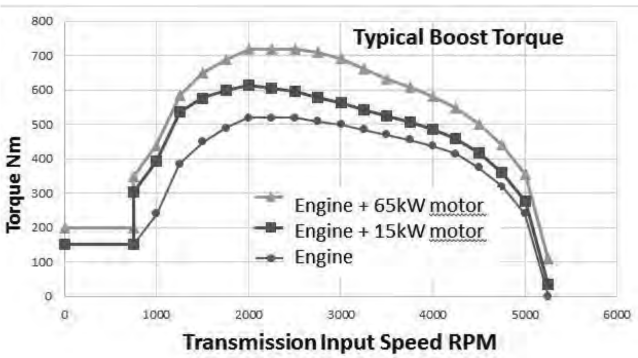



Figure 2: Boost torque.

# The 48 V P2 hybrid – More than a bridging technology

**Dierk Reitz**, **Andreas Englisch**, **Thomas Eckenfels**,
Schaeffler AG, Bühl

**Zusammenfassung**

Die 48 V Hybridisierung stellt eine Brückentechnologie dar, um den technologischen Wandel weg von verbrennungsmotorischen Antriebssträngen hin zu Plug-in Hybriden und reinen E-Fahrzeugen erfolgreich zu gestalten. Durch diese Art der Mildhybridisierung, welche zu den heute bestehenden Antriebssträngen kompatibel ist, lässt sich ein effizientes Hybridsystem darstellen. Hierbei ist der 48 V P2-Hybrid die zielführendste Topologie, weil er entscheidende Vorteile eines P0-Hybrides und P3/P4-Hybrides vereint. Diese Vorteile sind zum einen ein dynamischer Wiederstart des Verbrennungsmotors und zum anderen die Realisierung des rein elektrischen Fahrens auf 48 V Basis. Am Beispiel eines C-Segment Fahrzeuges wird die maßgeschneiderte Auslegung eines 48 V P2-Hybridmodules einschließlich der Teilsysteme Elektromotor und Trennkupplung erläutert. Um den Einsatz des Hybridmodules in verschiedenen Antriebssträngen zu demonstrieren, werden wahlweise eine Doppelkupplung, ein Drehmomentwandler und eine Anfahrkupplung in das Modul integriert. In einer Systembewertung werden Fahrbarkeit, Verbrauch ($CO_2$ Emissionen) und Zusatzfunktionen aus der Sicht des Endkunden bewertet.

**Summary**

48 V hybridization is a bridging technology which is designed to facilitate the successful technological shift from powertrains driven by internal combustion engines to plug-in hybrids and pure electric vehicles. Efficient hybrid systems can be produced using this type of mild hybridization which are compatible with the powertrains in use today. The 48 V P2 hybrid is the most expedient topology as it combines significant benefits from P0 and P3/P4 hybrids. These benefits include, on the one hand, a dynamic restart facility for the internal combustion engine and, on the other, realization of pure electric driving based on a 48 V system. The following provides details of the customized design of a 48 V P2 hybrid module for a C-segment vehicle which includes the electric motor and disconnect clutch subsystems. In order to demonstrate the use of the hybrid module in various different powertrains, a double clutch, a torque converter and a launch clutch are integrated into the module as options. An evaluation of the system assesses the drivability, consumption ($CO_2$ emissions) and additional functionality from the end customer's perspective.

**Introduction**

In addition to the current forecasts which predict a more rapid growth in purely electric mobility, there is also an increasing trend towards efficient entry-level hybridization in order to be able to meet the 2020 $CO_2$ targets. Nearly all these drives currently use a 48 V system. This means that gasoline engines can now achieve a comparable performance in terms of $CO_2$ emissions to that of diesel engines. It has been shown that, by using high-performance P2 and P3/P4 systems, there is considerably greater potential for reducing $CO_2$ compared to the current, established P0 systems with 8 to 10 kW output. Depending on the driving cycle used, the potential reductions range from up to 20% (NEDC) or up to 16% (WLTC) compared to vehicles with a conventional powertrain. Based on these consumption figures, Schaeffler estimates that the complete P2 system is more economical per gram $CO_2$ saved than a P0.

Various technical concepts have arisen from the current P0 to P4 topologies for a 48 V hybridization of the powertrain in vehicles driven by an internal combustion engine. The possible and useful performance range of 48 V systems and the achievable functions vary depending on the relevant topology. However, it is possible to access this potential by using 48 V systems in a P2, P3 or P4 topology.

Additional reductions in $CO_2$ can be achieved in P2 systems, particularly when compared to P0 systems, due to the option of decoupling the combustion engine using the additional disconnecting element (K0) between the electric machine and the internal combustion engine, as well as the option of using the gear ratio spread when recuperating. Furthermore, as far as their installation position and function are concerned, P2 systems are also not limited to an output of approximately 10 kW. This raises a significant question in terms of system design: What electrical output should be installed in a 48 V system in order to ensure that the maximum potential reduction in both consumption and $CO_2$ emissions is achieved within reasonable costs? These considerations should obviously also take into account the demands on the electrical output required to generate perceptible drive and boost functions from the customer's perspective.

The issue of the disconnect clutch (K0) must also be addressed with respect to the cost/benefit ratio. The savings in consumption from being able to disconnect the internal combustion engine are shown Figure 1. When considering good drivability, the potential for recuperation is reduced; however, there is a residual benefit of 5.5 % for the drive selected in

# Non-contact profile measurement machine

## Better insight into complex gear shapes with dense 3D scans

**K. Kanto**, **T. Yamada**, Nikon, Tokyo

**Abstract**

Consider with the presentation of Prof. Goch.

### 1. Introduction

Nowadays, the requirement not only for size measurement but also for evaluating the surface profile itself is increasing. The evaluation of the workpieces is usually performed by the size measurement and checking the result in its tolerance, but the demand for obtaining the target workpiece information as a volume profile and evaluating by using the whole profile data is growing. To satisfy this expectation, Nikon is proposing a non-contact measurement by using the optical principle and, in actuality, we are responding to the customer's expectations.

In general, the most important demand for non-contact measurement by an optical probe is "Get the whole profile within a short time." Everyone knows that profile data detection by the contact probe takes a long time. In addition, to shorten this measurement time is the most interesting goal for everyone. The fact that the non-contact probe can make the measurement time short was almost realized. However, the measurement accuracy of the current non-contact measurement greatly differs from current tactile measurement many times over, so that non-contact measurement could not be used for high-precision parts evaluation. Therefore, the main purpose of the non-contact measurement was only for the sheet metal part or large plastic injection mold parts.

In this presentation, we report that the "HN-C3030 (Fig. 1)" non-contact measurement machine improved the throughput, accuracy and density of point cloud data and, furthermore, enabled the evaluation of the profile as never before.


Fig. 1: Non-contact profile measurement machine HN-C3030

## 2. Overview of the non-contact measurement machine

### 2.1 Concept

The concept of HN-C3030 is a “Noncontact measurement machine for obtaining high accuracy and high density point cloud data with high throughput”.

It detects workpiece profiles that have a complicated shape as high accuracy and density point cloud data. The system can evaluate many things such as the profile, size and GD&T by using the point cloud data. Moreover, in the current way, workpieces that have a shiny surface need powdering, as a part of the preparation for measurement. However, in this system, there is no need.

### 2.2 System construction

This system has a non-contact probe (laser scanner) whose principle is triangulation. The system has 5 axes movement that comprises orthogonal 3 axes and a tilt arm axis and rotary table in order to bring out the best effectiveness of this probe. During the measurement, the system uses all 5 axes for scanning. This construction enables obtaining high throughput and high efficiency. In case of the requirement of measurement on the manufacturing floor, we can provide the temperature compensation option that uses a temperature control chamber. By using this option, the system can be used in a temperature range of 15 °C to 30 °C, while maintaining accuracy. The system’s total specification is shown below (Table. 1).

# Optical and Areal Measurements and Evaluations of Cylindrical Gears

**Gert Goch**, **Yue Peng**, **Kang Ni**,
Center for Precision Metrology (CPM), University of North Carolina at Charlotte (UNCC), Charlotte NC, USA;
**Anke Günther,** Reishauer AG, Wallisellen, Switzerland

**Abstract**

Optical sensors based on various measuring principles and integrated into CMMs or special Gear Measuring Instruments (GMI) today are able to capture several 10,000 measuring points per gear flank in reasonable time. Other than in conventional gear metrology, these points cover the whole flank instead of only one profile and one lead line, offering a substantially improved data base for gear inspection. This meets an increasing industrial need of holistic information on gear flanks for a better assessment of both, the gear manufacturing process and the functional properties of the measured gear.

The evaluation of these areal data requires new mathematical approaches and new software solutions. This includes a revision and updating of the widely-used gear deviation parameters (e.g. $f_{H\alpha}$, $F_{\beta}$, $F_{p}$) and their effective determination by two-dimensional orthogonal polynomials. This conference paper primarily will be focused on

- The mathematical approaches to extract the actual gear flank deviations and modifications out of the measured point clouds.
- The direct comparison of optical-areal measurements with conventional tactile measurements, obtained at an identical gear.
- The extension of the standardized, line oriented gear deviation parameters (e.g. $f_{H\alpha}$, $F_{\beta}$, $F_{p}$) to areal parameters and their meaning in terms of both, a control of the manufacturing process as well as an assessment of functional properties.

Simulated and measured gear data is analyzed and a proposal for a revised set of gear deviation parameters based on areal evaluation method are presented.

**Keywords: Gear, Optical, Areal inspection**

## 1 Introduction

Gear inspection plays a critical role in gear production industry in terms of quality control and process improvement. The decisive nature of the gears in vehicle transmission systems require a gear to meet high accuracy grades to reduce the noise emission and increase power density. The integration of CNC technology into tactile Gear Measuring Instruments (GMI) and Coordinate Measuring Machines (CMMs) has been a dominant method over the past decades in gear metrology [1]. Line oriented measurement and evaluation of gear geometric features such as profile, helix and pitch deviations have been well established in current gear tolerancing standards [2]. Based on this standardized procedure an automobile gear can be measured in a few minutes, however, for large gears (e.g. in wind energy system [3]), up to an hour of inspection time might be needed for carrying out a tactile based measurement.

Moreover, with the trend of introducing more complex surface structure on to the gear flanks to improve the functional performance, more area-related surface information is required to diagnose process variation, to assess the gear quality, and to predict the gear pair meshing conditions [4].

Figure 1 shows a typical CMM based gear measurement without a rotary table. A multiple styli configuration must be carefully selected to access all the teeth on a gear.

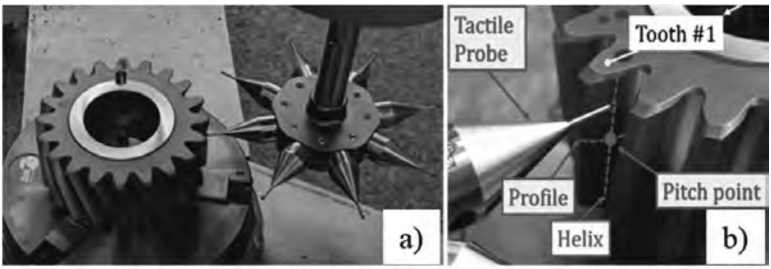



Figure 1: a) Gear measurement configuration of a tactile instrument with 8-star styli, b) Measured profile and helix line features and pitch point on a flank

Limited by the data acquisition speed, the tactile measurement instruments are rarely used to measure multiple lines on the flanks of more than four teeth, let alone the entire flank surfaces of all teeth. Thus, non-contact sensing technologies based on optical principles have gained a growing attention recently to fulfill the future needs of gear measurement [5,6].

### 1.1 Limitations of line oriented data evaluation for 3D gear geometry

In tactile measurements, the stylus is commanded to follow prescribed profile or helix lines located on the nominal geometry of a gear. Usually after the scanning operation, the raw

# Development of MRF coupling elements for Dedicated Hybrid Transmission

**C. Hegger**, Ostwestfalen-Lippe University of Applied Sciences - Electrical Engineering and Computer Science, Lemgo;
**J. Maas**, Technical University of Berlin - Mechatronic Systems Laboratory, Berlin

## Zusammenfassung

Zur weiteren Reduzierung der $CO_2$-Emissionen bei gleichzeitiger Reichweitenerhöhung sind neue Antriebsstrangkonzepte erforderlich, mit denen die Energieeffizienz erhöht werden soll. Im Rahmen dieser Zielsetzung behandelt dieser Beitrag ein Multi-Mode-Getriebe, das erstmalig den Einsatz von Kupplungselementen auf Basis von magnetorheologischen Flüssigkeiten (MRF) vorsieht. MRF-Kupplungselemente zeichnen sich durch eine hochdynamische, präzise und verlustarme Verstellung der Schubspannung aus und stellen deshalb eine energieeffiziente Alternative zu bestehenden Bremsen und Kupplungen dar. Für die vollständige Eliminierung viskoser Schleppverluste und zur energieeffizienten Ansteuerung wird die MRF-Bewegungssteuerung mit einem neuartigen Design des Magnetkreises und einem smarten Dichtungskonzept kombiniert. Experimentelle Untersuchungen der MRF-Kupplung belegen hochdynamische Kupplungsvorgänge sowie die energieeffiziente Betriebsweise.

## Abstract

In order to reduce $CO_2$-emissions while simultaneously extending the range, new transmission concepts are required to increase the energy efficiency. Within the scope of this objective, this article deals with a dedicated hybrid transmission, which utilizes coupling elements based on magnetorheological fluids (MRF) for the first time. MRF coupling elements provide a high dynamical and continuously adjustable torque transmission and offer an energy efficient operation in contrast to conventional coupling elements. In addition the MRF movement control allows the elimination of viscous drag losses. Based on this innovative concept, a novel design of a magnetic circuit and a smart MRF sealing is introduced for further improving the energy efficiency and compactness of the actuator. By experimental investigations of the proposed MRF-based clutch high dynamical coupling processes and the elimination of viscous drag losses and sealing friction are proven.

**Introduction and Motivation**

Reducing the $CO_2$-emissions upon a simultaneous increase of the driving range is an important key feature of the current design of powertrains and transmissions for hybrid and electrical vehicles. In the last years several different concepts of hybrid transmissions were developed and brought to market [1]. In the funding project PHEVplus [2] novel concepts of dedicated hybrid transmissions were developed to fulfil these objectives including coupling elements based on magnetorheological fluids (MRF) for the first time.

Magnetorheological fluids are smart materials, consisting of fine magnetic particles in an oil based carrier fluid, with the particular characteristics of changing their apparent viscosity significantly under the influence of a magnetic field. In Fig. 1 the functional principle of the shear mode for rotational MRF-based actuators is depicted. While the magnetic field is deactivated (off state) the carbonyl iron particles are homogeneously distributed in the shear gap Fig. 1 a). Due to the impact of the magnetic field $B$ (on state) the particles are orientated along the magnetic field lines in chains, Fig. 1 b). A relative movement resp. speed between the shearing surfaces results in a deflection of the particle chains by the angle $\Theta$ and a counterforce occurs Fig. 1 c), resulting in a controllable shear stress of the MRF. This property allows the design of mechanical devices for torque transmission, such as brakes and clutches, enabling a continuously adjustable torque transmission [7] with high dynamics In [8] a MRF-based clutch was designed integrated directly in the powertrain of a vehicle as a differential between the front and the real axle and developed by Magna Powertrain. Thereby, a large number of different shear gaps resulting in a high torque capability of up to $T$ = 700 Nm is realized in a very compact design. The clutch was tested in a Fiat Panda 4x4 [9].

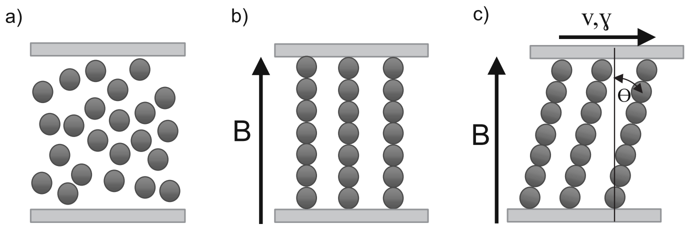



Fig. 1: Functional principle of MRF in the shear mode showing the homogeneous distributed particles a), the particle chains due to the impact of the magnetic field $B$ b) and the sheared particles chains due to the relative speed $v$ c).

# Analytical Process and KLT Generation based on a Manual Transmission Dry Clutch System

Dipl. Ing. **Andreas Tissot**, M. Sc. **Thomas Bosse**,
M. Sc. **Dennis Heße**, Ford Werke GmbH, Köln

**Abstract**

This paper presents the development of a model-based methodology, performed at Ford Powertrain Research & Advanced Department for durability prediction and to generate inputs for a Key Life Test (KLT) creation based on an example of a manual transmission dry clutch.
Characterization of driving pattern and drive behaviour variation for a manual transmission usage are shown. Development of a dry clutch thermal - and wear model will be explained as important aspects and required inputs to enable durability prediction and to perform attribute trade-offs by model-based iterations. As a result and input to an accelerated KLT results on clutch wear versus driver percentiles are shown for different vehicle pay loads.

**Kurzfassung**

Die vorliegende Veröffentlichung zeigt die Entwicklung einer Rechenmodell basierenden Methode zur Dauerhaltbarkeitsvorhersage und zur Generierung von Eingangsparametern für einen beschleunigten Lebensdauertest am Beispiel einer Trockenkupplung für Handschaltgetriebe.
Die Charakterisierung von Fahrprofilen und unterschiedlichen Fahrverhalten in Verbindung von Fahrzeugen mit Handschaltgetrieben werden dargestellt. Es wird gezeigt, dass zur Ableitung von Vorhersagen über die Dauerhaltbarkeit von Trockenkupplungen und zur Unterstützung ein Temperatur- und Verschleißmodell wichtige Eingangsgrößen sind. Abschließend und als Eingangswerte für einen KLT stellt ein Diagramm Verschleißergebnisse des Kupplungsbelages über die Benutzerbelastungsperzentile dar, hier für verschiedene Fahrzeugbeladungszustände.

## 1. Introduction

The clutch system has in both, automatic and manual transmissions, a key influence on the function, comfort, robustness and reliability of a vehicle, which are attributes with rising customer expectations. With an increasing demand on PT electrification and with enabling additional features to support demands in CO2 reduction, the load profiles for the manual transmission dry clutch will change and the durability targets have to be adjusted accordingly. Therefore it is necessary to take a deep dive into the dry clutch durability prediction and into a KLT development in order to make most use of their potential.

The dry clutch design usually lies in the hand of the clutch suppliers whom have detailed insights on the clutch design strength given by physical- and design parameters such as coefficient of friction, fading, lining wear and temperature behaviour, component heat capacities and - convection of the clutch system.

Conversely an Automotive Manufacturer has more detailed information in driver usage profiles, vehicle pay loads, geographical specifics for different countries and it's regions including but not limited to cooling time between actuations or to vehicle velocity traces. The vehicle - and driver usage information can be cascaded down to a specific powertrain sub system, e.g. dry clutch system, and can be used to define its individual load spectrum. With this knowledge, the specific clutch stresses and finally generation of a representative Key Life Test (KLT) for a manual transmission dry clutch can be created.

With this model-based methodology the development time, cost and resources during the system design process can be reduced significantly through an optimal balance between system stress, user representation and optimized test time. Supporting with the real world customer vehicle data, a highly focused Ford-Representative KLT will be generated. Due to the availability of a wide range of collected customer usage data this process can also be applied to other vehicle and powertrain subsystems.

As a first step global routes and usages of vehicles with a manual transmission dry clutch system, have to be identified and processed to driver's patterns. Furthermore a clutch temperature and wear model will be created for a defined baseline vehicle with known clutch system. This paper will focus on the generation of these three subsystem models and later incorporation into a vehicle plant model where a "virtual driver" will run on a multitude of routes to calculate the accumulated clutch wear and to generate the route severity. Based on those results a Monte-Carlo Method will be used for identifying severities and customer percentile usage.

Next step would be to develop an accelerated KLT for a single dry clutch system with its verification and finally its application within the Ford standard product development process.

# Driveline Control – Intelligent Actuator Inputs to Improve Component Protection, Performance and Comfort

M.Sc. **Truc Pham**, Dr.-Ing. **Christian Scholz**, Dipl.-Ing. **Gerd Bofinger**,
Dr. Ing. h.c. F. Porsche AG, Weissach;
Prof. Dr.-Ing. **Robert Seifried**,
Technische Universität Hamburg, Mechanik und Meerestechnik

**Zusammenfassung**

Der Zuwachs an elektronischen Geräten im Fahrzeug in den letzten Jahren ermöglicht es, immer gezielter situationsbedingt intelligent in das Fahrzeugsystem einzugreifen. Um unerwünschte Schwingungen im Antriebsstrang zu reduzieren, welche bauteilschädigend sind, Performance mindern und unkomfortabel wahrgenommen werden, sind Regelstrategien notwendig. Diese Schwingungen treten zum Beispiel auf Grund von Missbrauchmanövern, Lastwechselmanövern, Gangwechsel oder Drehungleichförmigkeiten des Verbrennungsmotors auf. So können in der Regelung je nach Antriebstyp und Szenario Motormoment, Kupplungsmomente bzw. Rotormoment als Stellgröße genutzt werden.

In diesem Beitrag werden unterschiedliche belastende Schwingphänomene im Frequenzband bis 60 Hertz vorgestellt und analysiert. Als Abhilfemaßnahme werden neu entwickelte Regleralgorithmen präsentiert. Hierbei wird auch speziell auf die Herausforderungen beim Reglerentwurf hinsichtlich Nichtlinearitäten, wie beispielsweise Totzeiten und mechanische Spiele, eingegangen.

**Abstract**

In the last years, the growing number of electronic units in passenger cars allows to intervene intelligently in the drive system for specific situations. In order to reduce undesired driveline oscillations, which can damage components, reduce performance and comfort, control strategies are necessary. These oscillations occur for example due to misuse maneuver, load changes, gear changes or irregularity of the internal combustion engine. Therefore, engine torque, clutch torque and torque of an electric machine, respectively, can be used as control input depending on the drive technology and scenario.

In this article various stressful oscillations in a frequency band to 60 Hertz are introduced and analyzed. To overcome these problems, new control methods are presented. Thereby, the challenges in nonlinear control design of dead time and mechanical backlash are specified.

## 1. Introduction

A major current focus in vehicle development is to accomplish multiple objectives simultaneously: more comfort, more agile longitudinal dynamics behavior and components protection as illustrated in Fig. 1. The goals are already conflicted, since higher torques or impulses are applied to the driveline for high performance and lead to driveline oscillations. These oscillations are uncomfortable for the passenger and stressing for driveline components.

A mechanical damper, such as torsion damper, reduces vibrations. However, the performance is usually reduced and the damper is often inefficient and thus bad for fuel consumption and emission. Thus, further additional comprehensive methods are needed.

The increasing number of electronic systems in the car allows x-by-wire. For instance, the torque of an engine or clutch can be used as control actuators. Control methods calculate torques for these actuators, such that oscillations are reduced without performance loss.


Fig. 1: Multiple objectives during reduction of oscillations

Moreover, driveline control is an adaptive method to overcome the rising complexity and variety of vehicles. There exists several studies on driveline control. For example, control during load changes are presented in [1], [2], [3], control during shifting are shown in [4] or control to reduce the stimulation of irregularity for hybrid electrified vehicles are discussed in [5].

The focus of this article is to represent driveline control in an overall context. Based on the role of gear ratio in the driveline as an amplifier of oscillations, various oscillation types are discussed in Chapter 2. In Chapter 3 control algorithm are presented. The concept of driveline control is demonstrated for a linear system as well for nonlinear systems by a simple example. The limits of a linear proportional control can be clearly seen in the nonlinear case. To

# From customer requirements to the optimal hybrid powertrain

## High-performance hybrid transmission for future plug-in hybrid drives

Dr. **Joerg Müller**, **Jens Liebold**, Dr. **Christoph Danzer**,
IAV GmbH, Chemnitz / Stollberg

***Zusammenfassung***

Dieses Paper beschreibt einen Weg, wie man mittels spezieller IAV-Vorentwicklungs-Werkzeuge, die richtigen Komponenten eines Antriebsstranges (Batterie, Elektro und Verbrennungsmotoren, Getriebe) findet, um die heutigen Kundenanforderungen bestmöglich zu erfüllen. Darüber hinaus wird daraus ein neues, leistungsstarkes Hybridkonzept abgeleitet, welches hochleistungsfähige Fahrzeuge mit guter Fahrleistung und niedrigem Kraftstoffverbrauch ermöglicht.

Um eine geeignete Antriebsstranglösung für zukünftige Fahrzeuge zu definieren, nutzt die IAV einen fortschrittlichen Vorentwicklungsprozess, der systematische computergestützte Entwicklungswerkzeuge intensiv einsetzt. Die Werkzeugkette beginnt mit der "Antriebsstrang-Synthese", welche die Startwerte und Randbedingungen für die folgenden Entwicklungsschritte bestimmt. Weitere spezialisierte Werkzeuge wie "Getriebe-Synthese" und "E-Motor-Synthese" finden die richtigen Lösungen, welche diese Anforderungen optimal erfüllen.

Das Ergebnis dieser Untersuchung ist ein Antriebsstrangkonzept, das auf einem Benzinmotor, kombiniert mit einem Elektromotor und einem 4-Gang-Planetengetriebe, basiert. Ein erstes 3D-Design des Getriebes zeigt, dass es möglich ist, den Elektromotor und den Radsatz des Getriebes in ein Gehäuse von ca. 360 mm Länge zu integrieren. Das Ziel-Fahrzeug des B-Segment kann in ca. 4 Sekunden von 0 auf 100 km/h beschleunigen und verbraucht 4,0 l/100 km Benzin im NEFZ, ohne Energie zu verwenden, die vor dem Start des Antriebszyklus in der Batterie gespeichert wurde („Charge-Sustaining“ Modus).

***Abstract***

This paper describes a way to right-size powertrain components (battery, e-motor(s), ICE, transmission) to fulfil today’s customer requirements in a best possible way by using special IAV's tools for advanced development. Furthermore a new powerful hybrid concept will be derived which enables high performance vehicles with good driving performance and low fuel consumption.

To define a suitable powertrain solution for future vehicles IAV uses an advanced development process which makes intensive use of systematic computer-aided development tools. The tool chain starts with the “Powertrain synthesis” which determines the initial boundaries for the following development steps. Further specialized tools like “Transmission synthesis” and “E-motor synthesis” find the right solutions which fulfil these requirements in a best possible way.

The result of this investigation is a powertrain concept that bases on a gasoline engine combined with an electric motor which is connected to a 4-speed planetary automatic transmission. A first 3D-design of the transmission shows that it is possible to pack the electric motor and also the whole gear set into a housing of around 360 mm length. The target B-segment vehicle may accelerate in around 4 seconds from 0 to 100 kph and consume 4.0 l/100 km gasoline in the NEDC without using energy which was stored in the battery before the start of the drive cycle (charge-sustaining mode).

# Customer-focused modular test procedure for driveline components

Dipl.-Ing. **Michael Hein**, Dr.-Ing. **Thomas Tobie**,
Prof. Dr.-Ing. **Karsten Stahl**,
Gear Research Centre (FZG), Technical University of Munich, Garching;
Dipl.-Ing. (FH) **Christian Kunze**, Dipl.-Ing. **Joon-Kyu Lee**,
Adam Opel AG, Rüsselsheim

**Zusammenfassung**

Dieser Artikel behandelt die Beschreibung des Entwicklungsprozesses einer neuen Testprozedur für den Nachweis der Lebensdauer des Antriebsstranges. Diese soll als Freigabetest für große Teile des Produktportfolios der Handschaltgetriebe bei GM entwickelt werden und verschiedene regionale Teststandards und –prozeduren ersetzen.

Die Entwicklung der neuen Testprozedur basiert auf vorgegebenen Kundenlastkollektiven für ausgewählte Fahrzeuge und Fahrer. Für beispielhaft ausgewählte Handschaltgetriebe wurden die drehmomentübertragenden Bauteile (Zahnräder, Wellen, Wälzlager etc.) modelliert und mit Hilfe einer (lokalen) Schadensakkumulation hinsichtlich verschiedener Schadensarten analysiert. Diese Methodik ermöglicht die Identifizierung des maßgeblichen Schadensmechanismus sowie der kritischen Komponenten und Betriebszustände des Rädertriebs im realen Fahrbetrieb und erlaubt somit die Ableitung einer kundennahen, modulbasierten Testprozedur.

Die entwickelte Testprozedur ist mit Hilfe existierender Testprozeduren auf Basis definierter Ziel-Kundenperzentile validiert und wurde für den weltweiten Einsatz in verschiedenen GM-Prüfzentren vorbereitet.

**Abstract**

Content of this paper is the description of the development process of a new test procedure for torque transfer durability. It is developed for product validation of major manual transmission programs at GM replacing various regional test standards and procedures.

The development of the new test procedure is based on specific customer load spectra for dedicated vehicles and drivers. For exemplary chosen manual transmissions, the torque transferring parts, i.e. gears, shafts, bearings, etc. are modelled and analyzed by means of a (local) damage accumulation regarding different failure mechanisms. This detailed study allows identifying the critical failure mechanisms as well as the critical driveline components

and operating conditions for real customer usage and hence makes the derivation of a customer-focused, module-based test procedure possible.
The developed test procedure is validated for defined customer target percentiles by comparison with formerly used test procedures and is scripted for global usage in all major transmission test facilities within GM.

## 1. Introduction and objective

In today's automotive development all OEMs are challenged by the conflict of targets in balancing cost, time and quality. These interactions are often named as „magic triangle" and latest development methods aim for reducing the area of the magic triangle sustainably.
This article describes the development of a modular test-concept for the torque transfer of manually shifted transmissions, as they are used in passenger vehicles for more than 50% globally [7]. The test concept accounts endurance and field reliability of the torque transfer subsystem under consideration of preferably wide applicability at concurrent test and development efficiency.
Main task of the proposed test concept is the validation of newly developed torque transfer systems in manual transmissions against customer usage under various operation conditions. Each module of the new test cycle is designed for individual failure modes, which are derived from Failure Modes and Effects Analyses (FMEAs). Based on FMEA ratings, predominating failure modes may be weighed and assessed. Through knowledge about physical main drivers to the failure mechanisms under customer usage conditions and the ability to quantify loads, a customer-relevant load spectrum for each individual failure mode of each torque transferring component may be derived. The severity of the test load spectrum is dependent on the failure effect and on the OEMs given quality and reliability requirements.
With the proposed test concept it is possible to validate torque transfer subsystems of various transmission systems with regard to customer reliability under consideration of time and thus also cost efficiency at a high quality level of the validation.
This is not achieved through selective modular test conditions, merging various tests which have been carried out previously as stand-alone procedures.
Utilizing a modular test setup in the test procedure it is possible to include new aspects of transmission testing in the test cycle which are driven by new technologies like hybridization or autonomous driving. On the other hand the modular concept offers the potential to omit individual modules, e.g. in case of carry-over parts from predecessor transmissions, to further optimize test time demand. The scripting architecture of the test concept allows global applicability on all AVL-Transmission-dynos within GM.

# Technological conversion of the automotive drivetrain – electrification as the key to success

**Peter Moelgg**, CEO/eDrive, GKN Driveline AG, Bruneck, Italien

## 1. Technological & Environmental Drivers

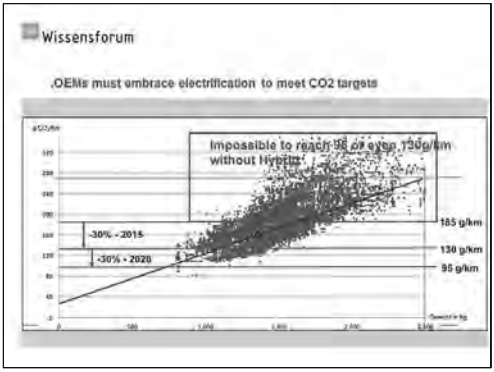
The world is progressively changing and the changes are driven by technological achievements, as well as by legislation.


(PIC1)

To start with legislation, we see, of course, the ever-tightening regulations on CO2 and NOx, which represent the strongest driver for electrification in the automotive industry. Up to now the industry has managed to cope with the challenge with rather conventional measures in improving the efficiency of combustion engines and weight reduction of the whole vehicle.


(PIC2)

However, forthcoming new, tighter regulations are making it virtually impossible to achieve the new targets without electrification.




(PIC3)

# Development of New Plug-in Hybrid Transaxle for Compact-Class Vehicles

## Dual motor drive system

**Koichi Kato**, **Yosuke Suzuki**, **Akiko Nishimine**, **Shinichiro Suenagav**, **Kohei Shimayabu**, **Mitsutaka Tsuchida**, **Shinichi Baba**,
Toyota Motor Corporation;
**Tomoyuki Miyazaki,** NSK-Warner K.K.

### Abstract

Recently, developing plug-in hybrid vehicles is very active among many automobile manufacturers to respond to demand for the green vehicle. To contribute to the protection of the environment more, a plug-in hybrid system which can keep EV driving mode and does not consume fuel due to engine running as possible even in need of a high driving force for a powerful acceleration is required. Therefore, Toyota Motor Corporation has targeted the development of new transaxle to achieve it. For the reason above, a new system called “Dual Motor Drive System” for plug-in hybrid vehicle and a new transaxle for this system have been developed. This system enables vehicle to run in EV driving mode with two motors. In this development, performance improvement has been achieved without increasing in size by changing parts of P610, which is installed in the 4$^{th}$ generation Prius, as minimum as possible. In particular, a generator which used to only idle in EV driving mode is used as a motor to generate the driving force by adding an one-way clutch between an engine and a planetary gear. Moreover, the new planetary gear has been developed and a part of lubrication system has been modified. The new Toyota plug-in hybrid vehicle(PHV) has achieved a powerful electric drive by getting the maximum potential of the Toyota Hybrid System(THS). This paper will explain “Dual motor Drive System” and a structure of the transaxle.

## 1. Introduction

Customer awareness of the global environment and requirements for environmental performance has continued to rise since the launch of the first generation Prius in 1997 as the world's first mass-production hybrid vehicle (HV) [1-2]. Furthermore, as environmentally friendly vehicles have become more widespread, customers have also started to require higher levels of dynamic performance and style in addition to excellent fuel economy. To meet customer's desire to drive their PHV in EV mode without engaging the engine, it's required greater driving force and range in EV mode. Therefore, this transaxle was developed to greatly increase dynamic EV performance under the concept of utilizing the components and capabilities of the THS in the new fourth generation Prius as far as possible.

This paper introduces the new PHV transaxle for compact vehicles that is installed in the all new Prius Plug-in.

## 2. Development Aims

The development objectives of the new PHV transaxle were as follows:

(1) Help achieve powerful EV mode driving force by placing a one-way clutch between the engine and power split device to realize the Dual Motor Drive System, which enables the vehicle to be driven using two motors.
(2) Help achieve powerful EV mode driving force and greatly extend the EV mode driving range by enhancing the cooling performance of the planetary gear and motor during EV mode through the use of an EOP.
(3) Utilize the existing components and capabilities of the HV transaxle in the Prius HV [3-4] when possible to maintain high performance in HV mode while also greatly improving performance in EV mode.

## 3. Basic Structure and Specifications

Figures 1 shows a cross section of the developed PHV transaxle. Table 1 shows the main specifications.

# Compact 6-Speed Hybrid Transmission for front-transverse Applications with 450Nm

**Max Weibring**, M.Sc., **Daniel Kupka**, M.Sc., **Mick Jordan**, M.Sc.,
Prof. Dr.-Ing. **Peter Tenberge**, Ruhr-University Bochum (RUB)

**Zusammenfassung**

Hybridgetriebe managen in Fahrzeugantrieben die Leistungsflüsse zwischen zwei Energiespeichern und den angetriebenen Rädern. Damit ermöglichen sie die Rekuperation der im Fahrzeug zwischengespeicherten potenziellen und kinetischen Energie und tragen dadurch erheblich zu den Verbrauchseinsparungen und Effizienzsteigerungen bei, die auf Grund des Klimawandels und der darauf begründeten gesetzlichen Regulatorien notwendig werden. Wegen der zusätzlichen Komponenten der Hybridantriebe bleibt der verfügbare Bauraum für das Hybridgetriebe sehr begrenzt. Nur P2-Hybridgetriebe auf Basis von Automatikgetrieben lassen sich durch den Ersatz des Drehmomentwandlers durch eine E-Motor im annähernd gleichen Bauraum bei gleicher Drehmomentkapazität darstellen.

Dieser Beitrag stellt ein besonders kompaktes, nur 367 mm langes 6-Gang-Hybridautomatikgetriebe (6HT) vor. Mit einem 250 Nm Elektromotor ist das Getriebe für ein maximales Gesamteingangsdrehmoment am Radsatz von 450 Nm und ein maximales Ausgangsdrehmoment von 3500 Nm ausgelegt. Dieses Getriebe wurde für kleine bis mittelgroße SUVs, insbesondere für den chinesischen Markt entworfen und befindet sich aktuell in der Prototypphase.

Der Radsatz des Schaltgetriebes besteht aus drei koaxial auf der Eingangswelle angeordneten Planentenradstufen mit drei Bremsen und zwei Kupplungen. Er bietet eine sehr harmonische Gangabstufung mit einer Spreizung von 6,49. Der Radsatz läuft in der 5. Fahrstufe als Block um und hat in allen Fahrstufen relativ geringe max. Drehzahlen und Zahneingriffsfrequenzen. Ein zweistufig ausgeführter Endantrieb mit einer Übersetzung von nur ca. 3 verbindet den Schaltgetriebeteil über eine sehr kurz bauende Zwischenwelle mit dem Differential. Das Zahnrad am Differential konnte deshalb klein bleiben. Der Achsabstand zwischen Antrieb und Differential beträgt nur 197 mm. Hierdurch baut das Getriebe sehr schmal und passt dadurch in viele kleine Bauräume.

Zusätzlich zeichnet sich das Getriebe durch ein besonders effizientes Hydrauliksystem aus, welches weitere Energieeinsparungen und Effizienzsteigerungen ermöglicht. Alle Regelelemente sind in einem kompakten Hydraulikblock zusammengefasst, der an der Seite

des Getriebes positioniert ist. Das Hydrauliksystem wird durch direktschaltende Magnetventile gesteuert. Diese ermöglichen schnelle Schaltzeiten und geringe Leckagen. Des Weiteren wird das Hydrauliksystem von zwei Pumpen bedarfsgerecht versorgt und umfasst zusätzlich ein kompaktes Packsperrensystem.

**Abstract**

Hybrid transmissions manage the power flows between two energy storages and the driven wheels in vehicle drivetrains. They allow the recuperation of the potential and kinetic energy which is buffered within the vehicle and thereby they contribute a substantial part to the fuel consumption savings and efficiency increases, which are necessary due to climate change and the associated legal requirements. Because of the additional components of a hybrid drivetrain the available space for the hybrid transmission is limited. Only P2 hybrid transmissions based on the automatic transmission technology can be realized in the same installation space and with the same torque capacity as conventional transmissions by substituting the torque converter with an e-motor.

This contribution introduces a very compact, only 367 mm long, 6-speed hybrid transmission (6HT). With a 250 Nm e-motor this transmission is designed for a maximal combined torque at the transmission input of 450 Nm and a maximal output torque of 3500 Nm. This transmission was developed for small to mid-sized SUVs especially for the Chinese market and is currently in prototype phase.

The transmission gear set consists of three coaxial planetary gear sets arranged on the input shaft with three brakes and two clutches. It offers a very harmonious gear stepping with a ratio range of 6.49. The gear set rotates as block in the fifth speed and has relatively low maximal shaft speeds and meshing frequencies in all speeds. A final drive with two spur gear stages and a ratio of about 3 connects the central transmission with the differential via a short counter shaft. This ratio allows a small differential gear. The center distance between the input shaft and the output shaft of the 6HT is 197 mm. Thus, the transmission is very compact and narrow and fits in many - also small - installation spaces.

Additionally, the transmission is characterized by a particularly efficient hydraulic system, which offers further energy savings and efficiency increases. All control elements are combined in one compact valve block, which is positioned at the side of the transmission. The hydraulic system is controlled by direct operating solenoid valves. These valves allow fast shifting times and low leakages. Furthermore, the hydraulic system is fed on demand by a two pump system and has integrated a compact Park-Lock system.

# Full hybrid planetary transmission with on demand actuation

## FEV´s newest member of the PREX transmission family

MSc. **Peter Janssen**, MSc. **Yi Zhang**, Aachen

*1.* Zusammenfassung

Im globalen PKW Markt ist ein deutlicher Trend in Richtung Elektifizierung zu beobachten. Bei Radsastsynthese für Planetengetriebe wird bisher aber auf Optimierung des Nutzungsgrades vom Radsatz fokussiert. Danach wird das Getriebe hybridisiert durch Installation einer E-Maschine ins Getriebe mit zumindest eine zusätzliche Kuppelung. Hierdurch wird zwar ein sehr guter Nutzungsgrad vom Radsatz erreicht, aber nicht notwendigerweise auch einen hohen Nutzungsgrad vom Gesamtsystem.

FEV hat seine Radsatzsynthese erweitert um bereits in der Synthese Phase mehrere Inputs (für hybrid) sowie weitere Systemparameter einzubeziehen, wie zum Beispiel eine Struktur die einfach on-demand aktuiert werden kann. Diese Synthese wurde kombiniert mit der bekannten ePGS Struktur. Ein erstes Ergebnis ist die PREX3 Getriebestruktur, welche ein Getriebe darstellt mit zwei (2) Eingänge, sechs (6) +R Gänge für den Verbrennungsmotor, drei (3) E-Drive Gänge und ePGS zum Anfahren. Diese Funktionen wurden realisier mit einem Radsatz mit 3 Planetensätze und 5 aktive Schaltelemente, der zudem ausgelegt ist für eine on-demand Aktuierung und neue Maßstäbe setz in Puncto Kupplungsverluste.

*2.* Abstract

In the global passenger car market a steady move towards electrification in powertrains can be observed. In today’s state of the art automated gear set synthesis for planetary structures showed solutions with which big leaps forward in terms of effort vs amount of functionality in gear set utilization is achieved. Good solutions for gear sets for conventional powertrains were generated with high degree of automation. Typically the hybrid solutions were designed as add-on system: they are mostly created as derivatives of conventional powertrains by adding an E-Motor and at least one clutch into the system. Basically the two power sources use the same input in the gear set. Those types of add-on solution require additional components such as disconnect and/or launch clutches to realize the necessary hybrid functionalities.

Future dedicated hybrid powertrains (DHT) require all hybrid functionalities within compact gearbox structure. FEV has extended its planetary gear set synthesis by considering two (2) inputs on one planetary gear set, while considering other constraints, such as protecting for on demand actuation friendly structures. This design philosophy was further elaborated by FEV´s well known ePGS structure for efficient launch with single E-Motor.

The result is a compact structure with a new level of functionality vs complexity. With three (3) planetary gears and in total only six (6) shift elements up to six (6) forward speeds, three (3) EM speeds, an e-PGS launch mode and a mechanical reverse gear can be realized.

All speeds are full power-shift capable, and the basic gear set is identical to well-known automatic transmission systems, with exception of the power on demand actuation, altogether packaged as a hybrid transmission not large than its conventional counterpart in size.

## 3. Background

In past projects, several innovative ideas were realized in the field of hybrid concept and gear set structures. In 2002, FEV presented world´s first diesel hybrid vehicle. This vehicle already had a highly integrated, oil cooled E-Machine into the transmission and used ePGS as a launch device. In the years to follow many ePGS like programs followed and in 2010 FEV presented a 7-speed planetary hybrid transmission with electromechanical on demand actuation. In 2016 the first mass production application using ePGS was launched.

Analyzing current state of the art transmissions shows that today’s transmission losses for automatic transmissions consist for over 80% out of 3 sources, which are roughly equal in their order of magnitude. Figure 1 shows an analysis of the losses in a state of the art transmission as an average over different driving cycles [1].

# The Electric Propulsion System in the new Opel Ampera-e

# Das elektrische Antriebssystem im neuen Opel Ampera-e

Dr.-Ing. **R. Jäger**, Dr.-Ing. **P. Ramminger**, Dipl.-Ing. **R. Matthé**,
Dipl.-Ing. **M. Herrmann**, Adam Opel AG, Rüsselsheim;

**Zusammenfassung**

Anfang 2017 hat Opel sein neues Elektrofahrzeug Ampera-e in den europäischen Markt eingeführt. Die Entwicklung des Antriebssystems dieses Fahrzeugs sowie des Chevrolet Bolt (EV) basierte auf Erfahrungen, die mit dem Chevrolet Spark EV gesammelt wurden, wobei die Anforderungen für den neuen Ampera-e deutlich erhöht wurden.

Das Antriebsystem treibt nun ein größeres Fahrzeug mit erheblich verbesserter elektrischer Reichweite an. Durch umfangreiche Berechnungen und Simulationen wurden die Subsysteme Antriebseinheit, Traktionsmotor, Wechselrichter, Energiespeicher, Ladeelektronik sowohl einzeln, als auch im Zusammenwirken optimiert. Die neue Auslegung des Antriebssystems und zahlreiche weitere Optimierungen führten zu einer deutlichen Vergrößerung der mitgeführten Energie für Traktion und Nebenfunktionen, sowie spürbar besserer Leistungsentfaltung, Achsmoment und Wirkungsgrad. In Summe steht das neue Serienfahrzeug nun für eine hervorragende Reichweite und begeisternde Beschleunigungs- und Fahreigenschaften.

Dieser Aufsatz beschreibt das Antriebssystem von der Anforderungsdefinition bis zur Auslegung der Subsysteme, welche mit bedeutenden konstruktiven Details aufwarten. Hierfür wurden modernste Analyse- und Simulationstechniken konsequent umgesetzt. Kenn- und Leistungsdaten des neuen Ampera-e werden mit denjenigen des Chevrolet Spark EV [5, 6] verglichen, der 2014 auf dem amerikanischen, kanadischen und koreanischen Markt eingeführt wurde.

Durch die großzügig dimensionierte Reichweite und modernste Auflade-Möglichkeiten eliminiert der Ampera-e die bekannte „Reichweitenangst“ nahezu vollständig. Das erheblich verbesserte Antriebssystem und die enorme Reichweite machen das neue Elektrofahrzeug für einen deutlich größeren Kundenkreis nutzbar als frühere Elektrofahrzeuge. So wird der Ampera-e einen erheblichen Anteil am Anstieg des Marktanteils von rein Batterie-elektrischen Fahrzeugen unter den Personenkraftwagen haben.

**Abstract**

Opel has launched the new Ampera-e Electric Vehicle early 2017. The propulsion system for this car as well as for the Chevrolet Bolt EV [2] were developed with the experience from the Chevrolet Spark EV battery electric vehicle, but for increased vehicle capability. It now propels a new, larger electric vehicle with significantly greater electric driving range. Through extensive analysis, the primary propulsion system components, which include the drive unit, traction electric motor, power electronics, energy storage and on-board charging module, were optimized individually and as an integrated system. The new design and numerous optimization loops delivered improvements in propulsion system energy, power, torque and efficiency. The results deliver outstanding EV range and fun-to-drive acceleration performance.

This paper describes the new propulsion system, starting from its requirement definition all the way down to subsystems design and performance, including remarkable optimization details, resulting from rigorous analysis. The paper compares the performance characteristics with vehicle and subsystem level figures of GM's Chevrolet Spark EV [5,6[] which was previously introduced in US, Canada and Korea back in 2014.

The new Ampera-e virtually eliminates "range-anxiety" through greatly improved range and great charging options, while it further improves drive performance characteristics in comparison to the Chevrolet Spark. The improved propulsion system and range will make this car eligible for purchase by a much wider audience of customers and thus will substantially contribute to the rising share of Battery Electric Vehicles (BEV) under the passenger cars.

# Highly integrated eDrives

## Technology and Outlook

Dr. **Markus A. Schermann**, GKN Driveline, Bruneck

**Abstract**

Electrical drives play an important role in future drive trains. Both in battery electric vehicles (BEV) and in hybrid electric vehicles (HEV) the electric axle drives have become very common. The author introduces integration as general topic for future electric drives. There are drivers for higher integration and there are enablers for higher integration. The author attempts to consider different aspects why and how high level integration will take place. The contribution is concluded by a study how a next generation design could look like.

**Status quo of integrated electric drive system for HEVs and BEVs**

The electrical drive system consists of various elements with different kind of nature. Let us consider an electric axle drive system which converts electrical DC power of the battery into mechanical power in terms of torque and speed at the wheels. So the major input is the high voltage dc (HV DC) connection of the battery, the major output are the joints for the left and right side shafts. In addition there are several other interfaces to the vehicle according to the following diagram.

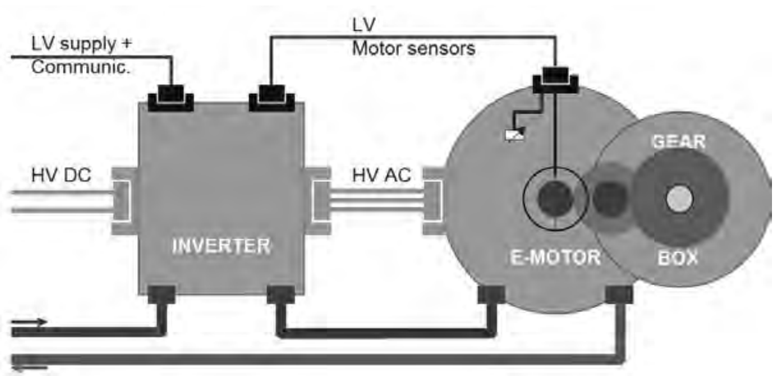



Fig. 1: Electrical drive system and its interfaces

Basically an electrical drive system consists of 3 basic components

- Inverter: for converting HV DC into HV AC for the E-Motor (often 3 phases)
- E-Motor: for converting electrical power into mechanical power
- Gearbox: for speed reduction and torque enhancement

In the first generation those three key components were more or less separated from each other. The Inverter was placed in a separate box, the motor lines were connected through HV cables and a HV connector. Also the LV lines between E-Motor and Inverter were facilitated by a wiring harness. The E-Motor was flanged to a gearbox and did not share any bearing shields or housing parts with the gearbox.

Nowadays the components get more and more integrated. That means that the E-Motor is embedded in the gearbox housing, the Inverter is attached close to the E-motor in order to save connectors and space. So integration means that the individual components share common parts and are finally placed in one system housing.

In the following there are some examples which were introduced by different companies.


Fig. 2: Integrated eDrive introduced by Siemens

Fig. 3: Integrated eDrive introduced by GKN

# Electric Axle Drives

## Scalable propulsion system for electrified powertrains

Dipl.-Ing. **Thomas Pfund**, Dipl.-Ing. **Matthias Gramann**,
LuK GmbH & Co. KG, Buehl;
Dipl.-Ing. (FH) **Thorsten Biermann**,
Schaeffler Technologies AG & Co. KG, Herzogenaurach

**Zusammenfassung**

Bei der Elektrifizierung des Antriebsstranges spielen elektrische Achsen eine entscheidende Rolle. Der Einsatz ist sowohl für hybridische als auch für rein elektrische Antriebskonzepte sinnvoll, wodurch sich anwendungsbezogen sehr verschiedene Leistungs- und Bauraumanforderungen ergeben. Funktional sind verschiedene Optionen, wie z.B. Parksperre, Differentialsperre oder Torque Vectoring zu berücksichtigen. Zur Optimierung von Bauraum, Gewicht und Kosten zeigt sich ein klarer Trend, Getriebe, Elektromotor und Leistungselektronik zu einem Aggregat zu integrieren. Dazu sind diese Hauptkomponenten so zu modularisieren, dass eine einfache Skalierbarkeit bei gleichzeitiger Optimierung des spezifischen Bauraums möglich wird.

Auf der Basis des Schaeffler Leichtbaudifferentials lassen sich Getriebelösungen mit hoher Leistungsdichte in koaxialer oder achsparalleler Ausprägung darstellen. Für den elektrischen Antrieb wurde ebenfalls ein skalierbares Modulkonzept entwickelt. Neben Magnetkreisen unterschiedlicher Technologie wurden für die Leistungselektronik Baugruppen definiert, die die hohen Anforderungen an Zyklenfestigkeit, Leistungsdichte und Robustheit in Bezug auf die Umgebungsbedingungen im Aggregat erfüllen. Der Beitrag zeigt den Aufbau der mechanischen und elektrischen Module und deren funktionale und physikalische Integration in eine spezifische elektrische Achse.

**Abstract**

In electrification of the powertrain, electric axles play a decisive role. They are appropriate for use both in hybrid and in pure electric drive concepts which, as a function of the application, have very different performance and design envelope requirements. In functional terms, various options such as parking lock, differential lock or torque vectoring must be taken into con-

sideration. For optimization of the design envelope, weight and costs, there is a clear trend towards the integration of the transmission, electric motor and electronic power system in one assembly. To this end, these principal components must be modularized in such a way that scalability is easily achieved while optimizing the specific design envelope.

On the basis of the Schaeffler lightweight differential, transmission solutions of high performance density can be presented in a coaxial or axially parallel design. A scalable modular concept was also developed for the electric drive. In addition to magnet circuits employing various technology, power electronics modules were defined that fulfill the high requirements for cycle strength, performance density and robustness in relation to the ambient conditions in the assembly. The paper shows the design of mechanical and electric modules as well as their functional and physical integration in a specific electric axle.

## 1. Review

With the electrically powered prototype vehicle Active eDrive, the Schaeffler Group presented a concept vehicle in 2011 containing a powertrain that then pointed the direction to the future. At Schaeffler, a Skoda Octavia Scout was converted into an electrically driven four-wheel drive vehicle that, in addition to the electric drive, facilitates intelligent electromechanical torque distribution over both the front and rear axle. The inverters for the traction and torque vectoring drives and the powertrain control unit were shown as prototypes in this demonstrator.

An essential USP of the Schaeffler e-axle was its coaxial design. The electric motor used was a PSM machine from IDAM (INA Drives & Mechatronics) designed as a hollow shaft motor with a maximum speed of 14 000 rpm.

The transmission was already based on the Schaeffler lightweight differential of a planetary design. The differential was integrated such that the output was delivered via the planetary carrier and one of the sun gears.

This gave the possibility of linking the output shafts to a superimposing gear set that is, on the input side, connected to a servo motor.

The differential, the superimposed transmission and the servo motor only rotate while cornering and stay stationary during straight line travel. As a result, losses are minimized. In deactivated state of the servo motor the differential acts like a standard differential with a somewhat higher lock-up value. The power rating of the servo motor was 7kW, allowing a differential torque of 1200Nm.

# EMC of Highvolt Traction Systems

## Typical Disturbance Pulses, new Measurement Setups and their practical Realization

Dr.-Ing. **Sebastian Jeschke**, Dipl.-Ing. **Marc Maarleveld**,
Dipl.-Ing. **Jörg Bärenfänger**,
EMC Test NRW GmbH, Dortmund

### Zusammenfassung

Die Elektrifizierung des Antriebsstrangs für Fahrzeuge hat auch einen wesentlichen Einfluss auf die bisherigen EMV-Strategien. Im Vergleich zu verbrennungsmotorisch betriebenen Fahrzeugen kommen bei Elektro- und Hybridfahrzeugen leistungselektronisch geregelte Antriebssystemen mit Leistungen im 100 kW-Bereich zum Einsatz. Diese Antriebsysteme verursachen sehr hohe elektromagnetische Störaussendungen, die eine enorme Herausforderung für die Sicherstellung der fahrzeuginternen EMV darstellen.
Um die Interoperabilität zwischen dem 12 V-Bordnetz und dem Hochvolt Traktionssystem zu gewährleisten, wird dieses isoliert als IT-Netz aufgebaut und vollständig geschirmt. Eine Schwachstelle dieses Schirmkonzepts stellt die Antriebswelle im Fahrzeug dar, die in der Regel ungeschirmt aus dem System geführt wird. Hierdurch ergeben sich über das Getriebe Stromflusspfade für die hochfrequenten Störströme, die in andere Teile des Fahrzeugs überkoppeln können.
Zudem geht der aktuelle Trend bei elektrisch angetrieben Fahrzeugen hin zu einer weiteren Steigerung des Wirkungsgrades. Dies wird im Wesentlichen durch eine Erhöhung der Traktionsnetzspannung, sowie über eine Verringerung der Schaltzeit erreicht. Diese Maßnahmen wirken sich jedoch negativ auf die EMV-Eigenschaften des Antriebsystems aus, wodurch zusätzliche Entstörmaßnahmen notwendig werden.
Um diesen Herausforderungen zu begegnen, werden aktuell die entsprechenden Normen im Fahrzeugbereich um die Komponenten des Antriebssystems, neue Messverfahren und angepasste Grenzwerte ergänzt.
Dieser Beitrag thematisiert die im Antriebsbordnetz auftretenden Störimpulse, die potentiellen Störquellen und Störsenken, sowie den Einfluss des Antriebsbetriebspunktes auf die Störaussendungen. Zudem wird auf den Einfluss der Effizienzsteigerungsmaßmahmen auf die EMV-Eigenschaften des Antriebssystems eingegangen.

Schließlich wird auf die praktische Umsetzung der neuen normativen Messverfahren eingegangen. Speziell bei Emissionsmessungen an Antriebsumrichtern ist die Realisierung einer motorischen Last innerhalb der Schirmkabine schwer zu realisieren. Alternativ kann hier eine rein passive Ersatzlast eingesetzt werden, welche die Impedanz des Drehstrommotors nachbildet. Hierdurch kann der gesamte Messaufbau innerhalb der Schirmkabine platziert werden, was die Flexibilität erhöht. Zudem treten im Traktionsbordnetz neue Impulse wie z.B. Bordnetzwelligkeiten auf, mit denen die Prüflinge im Rahmen von Störfestigkeitsprüfungen beaufschlagt werden müssen. Zur fahrzeuginternen Entkopplung der 12 V- und des HV-Bordnetzes müssen sämtliche HV-Bordnetzkomponenten eine Mindestschirmdämpfung aufweisen.

**Abstract**

Due to the powertrain electrification in electric and hybrid vehicles enormous challenges arise considering the EMC of these vehicles. Compared to vehicles with internal combustion engine in electric vehicle power electronic drive systems in the 100 kW range are used. These drive systems produce high broadband electromagnetic emissions (EMI), resulting in enormous challenges considering the vehicle’s inner EMC. In order to provide a safe and stable parallel operation of the classical 12 V wiring system and the highvolt (HV) traction system, traction system is built up completely isolated from the 12 V system (IT-Network) and thoroughly shielded. Unfortunately, as the shaft of the electric drive is not integrated in the shielding concept, it represents a weak point. The broadband emissions of the drive inverter can flow via the shaft into the gearbox and further into e.g. wheel sensor or other parts of the 12V system.

Furthermore, current measures to increase the efficiency of electric traction systems like increasing the voltage of the traction battery or decreasing the switching time of the power transistors used in the inverter result in an increase on the system’s EMI. Thus, additional shielding and filtering measures have to be realized in order to meet the EMC requirements.

In order to meet the challenges considering the electric vehicles EMC currently the new components, new measurement methods and new requirements considering the EMI and the immunity of the HV components are added to the automotive standards.

In this work the typical disturbances occurring inside the vehicle’s electric drive and their coupling paths are presented, especially focussing on the electric motor and the shaft currents. Furthermore the effect of current energy efficiency measures on the system’s EMI is analysed. Finally, the practical realisation of the new measurement setups is presented at

# The New AMG SPEEDSHIFT MCT 9-Speed Sports Transmission from the Mercedes-Benz Automatic Transmission Family

Dipl.-Ing. **Stefan Reisen**, Daimler AG, Stuttgart;
Dr.-Ing. **Wolfgang Novak**, Dipl.-Ing. **Martin Burgbacher**,
Dr.-Ing. **Moritz Stockmeier**, Dr.-Ing. **Thomas Kernstock**,
Mercedes-AMG GmbH, Affalterbach

**Zusammenfassung**

Basierend auf dem 2013 vorgestellten 9G-TRONIC Automatikgetriebe von Mercedes-Benz verschiebt das AMG SPEEDSHIFT MCT 9-Gang-Sportgetriebe die mögliche Leistungsübertragung deutlich nach oben. In der aktuellen Anwendung im Mercedes-AMG E 63 und E 63 S können damit bis zu 450 kW und 850 Nm abgedeckt werden. Die hohen Dynamik- und Performanceanforderungen in den AMG-Anwendungen konnten durch zahlreiche Verstärkungs- und Anpassungsmaßnahmen an dem bestehenden Getriebebaukasten erfüllt werden. Zusammen mit den neun Vorwärtsgängen und der hohen Spreizung von neun wird sowohl ein außergewöhnlich dynamisches als auch hoch komfortables Fahren ermöglicht.

Zur Steigerung der Dynamik und für ein agiles Ansprechverhalten wird in den extrem sportlichen AMG-Fahrzeugen im Rahmen des modularen Getriebekonzeptes eine gewichtsoptimierte nasse Anfahrkupplung eingesetzt. Diese ermöglicht die Darstellung eines Race-Starts für ein außerordentlich emotionales Anfahren mit sehr hoher Dynamik.

Das Torque-on-Demand-Verteilergetriebe erlaubt durch seine vollvariable Ansteuerung auf jeden Fahruntergrund stets eine optimale Momentenverteilung zur Ausnutzung der maximalen Performance am physikalischen Limit. Zur Erreichung der AMG-typischen Schaltdynamik wurden neben der optimierten Softwareabstimmung zusätzliche Maßnahmen in der Getriebeansteuerung getroffen.

Für die Absicherung und Erprobung der AMG-Anforderungen wurden neue und innovative Methoden eingesetzt, um die maximale Leistungsfähigkeit unter allen Betriebsbedingungen auf dem Niveau der Mercedes-Benz Qualitätsanforderungen zu gewährleisten.

Das neue AMG SPEEDSHIFT MCT 9-Gang-Sportgetriebe erweitert gezielt den Modulbaukasten der Automatikgetriebe-Familie von Mercedes-Benz und setzt erneut Bestmarken in der Performance und im Leistungsgewicht.

**Abstract**

Based on the Mercedes-Benz 9G-TRONIC automatic transmission which has been introduced in 2013, the AMG SPEEDSHIFT MCT 9-speed-sports transmission increases the possible power transfer significantly: up to 450 kW and 850 Nm can be covered with the current application in the Mercedes-AMG E 63 and E 63 S. It is possible to fulfill the high dynamic and performance requirements in the AMG applications through numerous reinforcements and adaptation measures to the existing modular transmission system. The nine forward speeds and the high gear ratio spread of nine allows exceptionally dynamic handling and highly comfortable driving.

As a part of the modular transmission concept, a weight-optimized wet clutch is being used in the extremely sporty AMG vehicles to increase dynamics and to provide nimble response times. This enables a race start for exceptionally emotional launch with high dynamics.

Due to its completely variable activation for every driving surface, the torque-on-demand transfer case always permits the optimum torque distribution to make use of the maximum performance at the physical limit. In order to achieve shifting dynamics that are typical for AMG, both additional measures for transmission control unit and optimized software tuning were used.

New and innovative methods were implemented for validating and testing the AMG requirements in order to ensure maximum performance under all operating conditions at the level of Mercedes-Benz's quality requirements.

The new AMG SPEEDSHIFT MCT 9-speed sports transmission is a specific extension of the modular system of the Mercedes-Benz family of automatic transmissions. Once again it sets a new standard in performance and in power/weight ratio.

# The CVT Pushbelt reinvented for Future Compact and Efficient Powertrains

**F. van der Sluis**, **S. Yildiz**, **A. Brandsma**, **P. Veltmans**, **M. Kunze**,
Bosch Transmission Technology B.V., Tilburg

**Abstract**

The global focus on $CO_2$ emissions increases pressure on conventional drivelines and intensifies the shift to electrification. The development of Continuously Variable Transmission (CVT) variator components responds to the characteristics of these new drivelines: comfortable, highly efficient, compact size with low weight, quiet and responsive. A radical new pushbelt design connects to these developments and sets a new milestone in CVT technology. The new single loopset design consists of a new element type with a centrally positioned single loopset. The new design cuts power losses by up to 40%. It furthermore reduces variator volume by 12% thereby reducing CVT weight and cost by respectively 10 and 3%.

## 1. Introduction

In recent years the use of CVT technology in automobile drivelines has expanded towards a global market of about 12 million units per year. A majority of applications is connected to the conventional driveline based on the Internal Combustion Engine (ICE). An increasing share finds its way in hybrid drivelines.

The growing focus on $CO_2$ emissions in the public domain increases the pressure on ICE based conventional drivelines and intensifies the shift to electrified drivelines. The availability of new variator components for either driveline architecture is a starting point for development.
New variator concepts respond to the characteristics and performance parameters of these new drivelines : highly efficient, compact size with low weight, responsive and quiet.

The development team at Bosch realized that for the new pushbelt to connect to these developments a radical new design was needed that sets a new milestone in CVT technology on all levels. This paper proposes a new concept with a new element design and loop configuration that:

- Cuts variator power losses by up to 40%.
- Reduces variator volume by 12%.
- Enables a 10% weight and 3% cost reduction of the CVT transmission.
- Further improves NVH by reduced mass and optional optimized element arrangement.

The new design and the specific measures to reach these challenging targets are discussed together with measurement and validation results. The new pushbelt is ready for the next generation of CVT.

## 2. Current status

### 2.1. Market

In 2016, 20% of the globally installed automatics was a CVT. On short term Bosch expects this number to increase to 25%. Factors that support the continuing growth (**figure 1**) are:

1. The global growth of vehicle demand and production that is expected to continue.
2. The share of conventional and electrified drivelines. In 2025 the share of electrified and electrical vehicles will lie near 20%. CVT will be suitable for a part of this share. For the resulting 80% of conventional drivelines CVT will remain an excellent solution.
3. Most electrified drivelines are automated. Comfort and fuel economy benefits result in a growing share of automated conventional drivelines. Although markets like Japan and the USA show signs of saturation, automatics take a growing share in China(1), Europe and emerging economies where manuals still are dominant. The global manual share of 46%(2) is an interesting target for automatic transmission manufacturers.

# Development of a New Torque Converter Clutch Control using Engine-CVT Harmonized Control

**Naoyasu Ikeda**, JATCO Ltd, Atsugi, Japan

**Abstract**

For automatic transmissions and continuously variable transmissions, torque converters provide good driving performance, especially during launch acceleration. However, the useful function of torque converter depends on fluid dynamics, therefore, behavior of engine speed sometimes needs to be improved. There has been long history of torque converter clutch slip control. In this presentation, the history will be briefly reviewed and a new torque converter clutch slip control will be introduced.

During development, engine speed behavior during launch was focused on and improved. By the combination of torque converter clutch slip control in CVT and engine torque control, extremely smooth and natural feeling during launch has been obtained. CVT control and engine control have been well harmonized during launch. And Systems Engineering was used in the development of the new TCC control.

## Introduction of Jatco CVT8

The Jatco CVT8 features low friction and wide ratio coverage. When mated to a gasoline engine, these features effectively contribute to an improved feeling of drivability and the attainment of segment-leading fuel economy. A newly developed torque converter and a new start-off slip control procedure are especially effective in achieving quiet, smooth launch performance. Drivability has been improved by adopting Dynamic Step Shift (D-STEP) control and the interval to the onset of engine start/stop control has also been shortened by adopting a new start/stop control procedure. These features contribute notably to improving fuel economy (Fig. 1 and Table 1)

Table 1: Specifications

| | |
|---|---|
| Torque capacity | 250Nm |
| Torque converter size | 236 mm |
| Pulley ratios | 2.631-0.378 |
| Ratio coverage | 7.0 |
| Final gear ratio | 5.097 |
| Number of selector positions | 5(P, R, N, D, L) |
| Overall length | 358.8 mm |
| Weight (wet) | 92.7 kg |

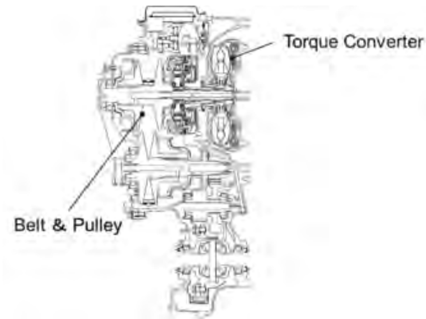



Fig. 1 Jatco CVT8 cross section

**Trend in launch performance**

1. Benchmarks for launch performance

The engine speed profile during vehicle launch at a small accelerator pedal angle (APA) differs among manufacturers (Fig. 2). The profile of company C shows a good directly connected feel in relation to the depression of the accelerator pedal without any engine speed flare. In contrast, the profiles of companies A and B indicate that engine speed flare occurs, resulting in an insufficient directly connected feel. The launch acceleration (G) profiles at a small APA for the same vehicles are shown in Fig. 3. The engines of companies A and B generate a rising G characteristic to elicit power performance, whereas company C's engine does not produce a rising G characteristic relative to the depression of the accelerator pedal, resulting in a feeling of insufficient G. In other words, there is a trade-off here. Providing a good directly connected feel without any engine speed flare means there is no rising G characteristic. Conversely, creating a rising G characteristic causes the engine speed to flare, resulting in an insufficient directly connected feel.

# A new approach for the investigation of synchronizations by different shifting characteristics

## Mixed virtual and physical investigation of speed adjustment with synchronizations under considering the individual driver-dependent shifting behavior during the development and validation of combustion, electric and hybrid transmissions.

Prof. Dr.-Ing. Dr. h.c. **A. Albers**, Dipl.-Ing. **U. Reichert**,
M.Sc. **K. Wolter**, Dipl.-Ing. **T. Pinner**, Dipl.-Ing. **S. Ott**,
IPEK – Institut für Produktentwicklung, Karlsruhe

**Zusammenfassung**

Zur Drehzahlangleichung zwischen Zahnrad und Welle während des Schaltvorgangs werden in PKW-Getrieben Synchronisationseinheiten eingesetzt. Dabei hängen Belastung und Verschleiß der verwendeten Synchronringe maßgeblich von der Synchronzeit, der Differenzdrehzahl und dem Reibmoment ab. Die Synchronzeit wird bei Handschaltgetrieben direkt am Schaltknauf vorgegeben und ist abhängig vom jeweiligen Fahrer. Um dieses individuelle fahrerabhängige Schaltverhalten auch bei der Entwicklung und Validierung von Getrieben berücksichtigen zu können, wurde eine neue Validierungsumgebung zur Untersuchung von Synchronisierungen entwickelt.

Der Prüfstand ermöglicht Untersuchungen bei unterschiedlichen systemischen Randbedingungen: Zum einen können Synchronisierungen während der Schaltvorgänge bei Hochdrehzahlantrieben untersucht werden, wie sie beispielsweise für schaltbare Getriebe [1] in rein elektrischen Antriebssträngen zukünftig eingesetzt werden. Zum anderen sind ebenso Synchronvorgänge in Automatikgetrieben im Drehzahlbereich verbrennungsmotorischer Antriebe darstellbar. So können Synchronvorgänge in Doppelkupplungs- sowie Hybridgetrieben durch den Prüfstand abgebildet werden.

Der Synchronisationsvorgang basiert dabei auf dem Prinzip, durch Reibkraft ein positives oder negatives Moment zu erzeugen, das zur Drehzahlangleichung genutzt wird. Durch diesen Vorgang entsteht Wärme, die üblicherweise durch eine geeignete Kühlung bzw. Schmierung abgeführt wird. Die Wärmeverteilung und das Verschleißverhalten im Synchronkontakt ist dabei u.a. abhängig von der Durchführung des Synchronvorgangs, der Reibgeometrie, von Oberflächenrauigkeiten der Reibpartner und von Fertigungstoleranzen. Mit Hilfe eines Simulationsmodells werden unterschiedliche Synchronisationsvorgänge und deren Einfluss-

faktoren abgebildet. Auf Basis dieser Simulationsergebnisse wurden die Anforderungen an den Prüfstand abgeleitet. Zusätzlich ermöglicht der Aufbau des Prüfstands die Integration einer faseroptischen Sensorik [2] zur Ermittlung der Temperaturverteilung im Synchronring. Dadurch können neue Erkenntnisse über die tatsächlichen Abläufe im Synchronisationsvorgang, sowie zur Ansteuerung der Synchronisationseinheiten gewonnen werden.

**Abstract**

To synchronize the speed between the gear wheel and the shaft during the shifting process, synchronization units are used in passenger car transmissions. The load and wear of the synchronizer rings used are decisively dependent on the shifting time, the differential speed and the friction torque. The synchronization time is set directly on the shift knob in manual transmissions and is dependent on the respective driver. In order to take this individual driver-dependent shifting behavior in consideration during the development and validation of transmissions, a new validation environment was developed for the investigation of synchronizations.

The test bench allows investigations at different systemic conditions. On the one hand, synchronizer during the shifting operations in high-speed electric drives can be investigated as they are used, for example, for shiftable transmissions [1] with electric machines in the future. On the other hand, synchronization operations in automatic transmissions can also be represented in the speed range of internal combustion engines. For example, synchronization processes in double clutch and hybrid transmissions can be mapped by the test bench.

The synchronization process is based on the principle of generating a positive or negative torque by frictional force, which is used for rotational speed adjustment. This process produces heat, which is usually dissipated by appropriate cooling or lubrication. The heat distribution and the wear behavior in the synchronous contact are dependent, inter alia, on the conduct of the shifting process, on the friction geometry, on the surface roughness of the friction partners and on the production tolerances. Using a simulation model, different synchronization processes and their influencing factors are mapped. On the basis of these simulation results, the requirements for the test bench were derived. In addition, the integration of a fiber-optic sensor system [2] to determine the temperature distribution in the synchronizing ring was taken into account during the design and construction of the test rig. As a result, new insights can be gained about the actual processes in the speed adjustment, as well as for controlling the synchronization units.

# Reducing $C0_2$ emissions by way of injection lubrication on manual gearboxes MLxx2

Dr. rer. nat. **Ivo Greiter**, Dipl.-Ing. **Wolfgang Leska**,
Manual Gearbox Development, Audi AG

## Content



## Abstract

In the course of developing MLxx2 gearbox modules, a number of measures were implemented to enhance efficiency compared to the predecessor gearbox ML311 . Initially, the new gearbox also employed immersion lubrication.

To further reduce $C0_2$ emissions, we developed an injection lubrication system that entered series production in August 2017.

All measures taken together reduced the degree of loss in the WLTP from a full 12% to about 8.5% compared to the predecessor gearbox ML311. The actual injection lubrication, which is the primary subject of this article, reduced $C0_2$ emissions in the Audi A4/A5 by between 1.2 and 1.6 g/km.

## 1. Gearbox design

### Performance specification requirements, development goals

In connection with the further reduction in $CO_2$ limits for vehicle fleets recently adopted by lawmakers, our task was to develop further potentials for manual gearboxes with respect to efficiency. The gearboxes used in longitudinal engine installation configuration on the Audi A4, A5, A6 and Q5 vehicle model series were equipped with injection lubrication instead of the optimised immersion lubrication used previously.
It should be possible to use the gearbox without having to modify the vehicle in current production.

The MLxx2-6F/Q gearbox modules comprise the ML322 6F and ML402 6F/Q and have the following key data:

| | |
|---|---|
| Max. torque | 400 Nm |
| Axial spacing | 77.35 mm |
| Axial spacing, spur gear stage | 129 mm |
| Hypoid offset | 0 mm |
| Number of gears | 6 forward gears and 1 reverse gear |
| Synchronisation | 1st gear: 3x; carbon friction lining (2x), molybdenum (1x) |
| | 2nd gear: 2x; carbon friction lining |
| | 3rd/4th gear: 1x outer cone; carbon friction lining |
| | 5th/6th gear: 1x outer cone; molybdenum friction lining |
| | Reverse gear: 1x outer cone; molybdenum friction lining |
| Gear wheels and control gears | As ML311 to the maximum degree possible |
| Maximum spread | 7.5 |
| Drive type | Front / quattro ultra longitudinal installation |
| Clutch | Single disc dry clutch |
| Isolation of vibrations | dual-mass flywheel with centrifugal pendulum-type absorber |
| Clutch actuation mechanism | central release bearing with wobble compensation |
| Engines | Four-cylinder engines: TDI and TFSI |

# The new small 5-/6-speed Manual Transmission of GM China

Dipl.-Ing. **Ulrich Kretzschmar**, B.Eng. **David Heck**,
Adam Opel AG, Germany

**Kurzfassung**

Das neue Schaltgetriebe von General Motors und SAIC, intern bezeichnet als NMT, hatte im Sommer 2016 zunächst als 5-Gang Variante seine Markteinführung mit einem 1.5l Saugmotor im neuen Chevrolet Cavalier in China. Seit Anfang 2017 wird die 6-Gang Variante in der gleichen Fahrzeugapplikation mit einem neuentwickelten 1.0l Turbomotor verbaut.

In Zukunft wird dieses Getriebe mit einer Drehmomentkapazität von bis zu 170Nm bei GM sowie SAIC in China und in Exportmärkten in verschiedenen Anwendungen zum Einsatz kommen und bestehende Getriebe ersetzen.

Ziel der Entwicklung war ein Getriebe mit einer flexiblen Architektur, welches sowohl als 5-Gang als auch als 6-Gang Variante Einzug in das GM sowie SAIC Portfolio des Klein- und Mittelklassewagensegments hält. Zudem sollten die Effizienz und der Schaltkomfort gesteigert und weiter verbessert werden.

Das von Grund auf neu entwickelte Getriebe weist ein gutes Geräuschverhalten auf und glänzt mit einem geringen Gewicht. Die niedrigen Schaltkräfte erlauben es, den verschiedensten Kundenanforderungen gerecht zu werden.

Zudem können optimierte Radsätze und Achsübersetzungen für den heutigen GB5-Zyklus und den künftigen GB6 sowie WLTP-Zyklus angeboten werden, ohne die Fahrleistungen zu vernachlässigen. So kann eine optimale Auslegung für verschiedene Anwendungen, von sportlich bis verbrauchsoptimiert, erzielt werden.

Um Funktionalität, Effizienz und Schaltkomfort sicherzustellen, wurden in der frühen Phase umfangreiche Simulationen durchgeführt. Dies führte zu einer optimalen Konstruktion in Bezug auf Kosten und Funktionalität.

**Abstract**

General Motors' and SAIC's new 5-/6-speed Manual Transmission, internally defined as NMT, has been launched as a 5-speed version in summer 2016 in the new Chevrolet Cava-

lier with a 1,5l Natural Aspirated Engine in China. Beginning of 2017 the 6-speed variant had its debut in the same vehicle application with the newly developed 1,0l Turbo Engine.
The new gearbox with a torque range up to 170Nm will be introduced broadly in GM's and SAIC's portfolio of small and compact vehicles in China as well as in Export markets and will continuously replace existing gearboxes.
Focus of the development was a transmission with a flexible architecture to support a 5-speed as well as a 6-speed variant. In parallel efficiency and shift comfort needed to be improved compared to available gearboxes. The completely new designed transmission has also been improved in regard to noise and weight. With very low shift forces the gearbox can fulfill the different demands of our customers.
Besides that, optimized gear sets and final drive ratios for today`s GB5-cycle as well as for future's GB6 and WLTP cycle can be offered without negative impact to driving performance to cover sporty as well as very economic applications.
To ensure the functionality, efficiency and shiftability numerous simulations have been done at a very early phase. This led to an optimized design with regard to cost and performance.

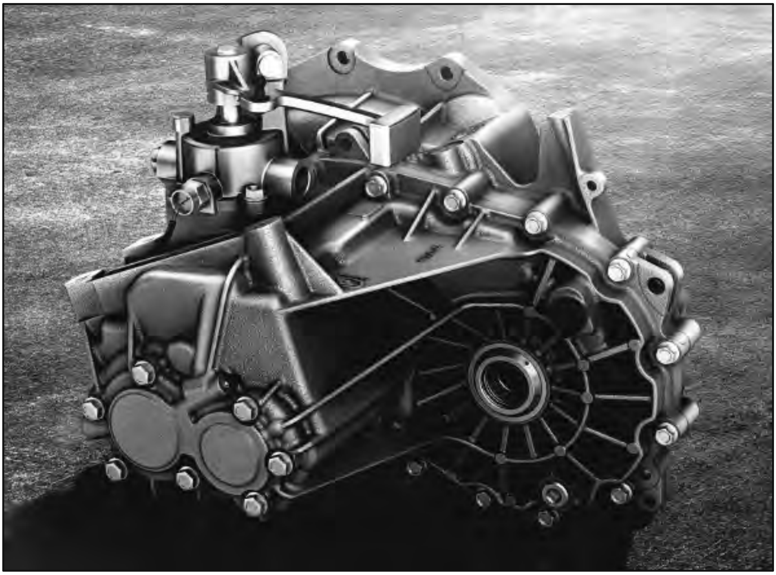


Fig. 1: NMT – The new 5-/6-speed manual transmission of GM and SAIC

# Clutch Protection Function – Clutch Design one Size smaller!?

Dr.-Ing. **Hubert Beitler**, Dr.-Ing. **Alexander Weidler**,
Dipl.-Ing. **Servane Lessi**, Dr.-Ing. **Uwe Keller**, DAIMLER AG, Stuttgart

**Summary**

On today's passenger cars with an internal combustion engine and manual transmission, the single-plate dry clutch is one of the few parts in the entire vehicle which can still be destroyed through operation error or ignorance, for instance by maintaining the vehicle for long periods on an incline by allowing the clutch to slip, thus preventing it from rolling back. The upshot is reduced torque transmission capability and, in the worst-case scenario, the vehicle breaking down due to the clutch overheating. To minimize this failure risk, the very latest vehicle generations feature an electronic clutch protection mechanism. The system presented here operates solely using intelligent software, without the need for any sensors that may fail. It fulfills the following main tasks:

1. ***Protection***

   Reliable identification of excessive stress on the clutch as a result of operation error or misuse. Engine management interventions which the driver barely notices. Clutch service life extended by up to 40%.

2. ***Warning***

   Alerts the driver in the event of critical clutch loading. Driver actively involved in the correct clutch operation. Learning effect for future driver behavior. Clutch failures reduced by approximately 70%.

3. ***Recording***

   Records all vehicle parameters of critical clutch loading. Previous safety reserves can be reduced for new products thanks to loading limit that can now be clearly identified. As a result, the size of the clutch can be reduced with advantages in terms of weight, agility and CO2.

## 1. Problem of vehicle total failure due to clutch damage

After analyzing the findings from the field, the prime causes of clutch damage can essentially be reduced to those stated below.

### 1.1. Damage causes

There are very specific driving maneuvers which are critical and may lead to clutch failure:

- Moving off in second or higher gear
- Moving off with high differential speed/sliding clutch
- Maintaining the vehicle for long periods on an incline simply by allowing the clutch to slip to prevent it from rolling back
- Shifting under full-load traction without easing off from the maximum accelerator pedal position
- Ignoring any warning signs (strong odor of burned plastic)

However, the previous supposition that

- frequently moving off in stop-and-go traffic, and/or
- continually moving off with/without trailer

may constitute the main causes of clutch failure cannot be confirmed. One common feature of all failures is the maximum input of slip-induced energy into the clutch as a consequence of misuse.

### 1.2. Friction coefficient with temperature dependence and dispersion

If the released thermal energy induces excessive temperatures on the contact surfaces of the pressure plate/friction lining and flywheel/friction lining (see Fig. 1), the friction coefficient on the contact surfaces (see Fig. 2) is reduced so that the specified torque given by the formula

$$M_K = F_N * \mu * r_m * z \qquad \text{(Equation 1)}$$

($M_K$ clutch torque, $F_N$ clamping force, $\mu$ friction coefficient, $r_m$ mean friction radius, z number of pairs of faces in contact) can no longer be transmitted.

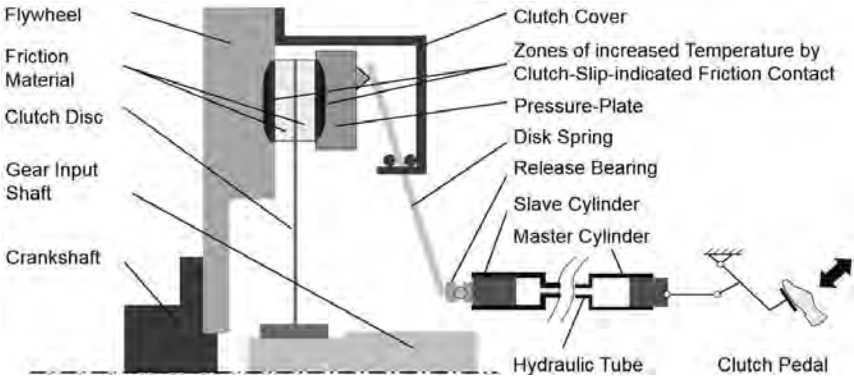



Fig. 1: Clutch system design

# Plug-in hybrid electric vehicle powertrain dimensioning under consideration of emission reduction targets, powertrain cost and modularity

Dipl.-Ing. **Axel Sturm**, M. Sc. **Daniel Förster**,
Prof. Dr.-Ing. **Ferit Küçükay,**
Institut für Fahrzeugtechnik, Technische Universität Braunschweig

**Kurzfassung**

Im Rahmen dieser Veröffentlichung präsentieren wir einen Prozess zur Auslegung und Optimierung von Antriebsstrangaggregaten unter der Berücksichtigung von Fahrzeugflottenaspekten. Hierzu wurde ein am Institut für Fahrzeugtechnik entwickeltes Auslegungswerkzeug um die Antriebsstrangoptimierung erweitert. Das erweiterte Auslegungswerkzeug ermöglicht die Auslegung sowie Optimierung von Hybridantriebssträngen für Flottenanwendungen auf der Basis von Fahrzeugparametern sowie Zyklus- und Kundenanforderungen frühzeitig im Entwicklungsprozess und kann so zu einer Verringerung von Entwicklungskosten, -zeit sowie Testaufwand beitragen. Die Integration von Flottenanwendungen erlaubt eine flottenübergreifende Antriebsstrangauslegung und kann darüber hinaus erweitert werden, um Flotten unterschiedlicher Antriebe (konventionell, hybridisch und rein elektrisch) auszulegen und zu optimieren.

Auf Basis einer exemplarischen Plug-in Hybrid Fahrzeugflotte wird der entwickelte Prozess angewendet, um eine optimale Antriebsstrangauslegung im Spannungsfeld von kombinierten $CO_2$ Emissionen im WLTP, Antriebsstrangkosten und der Modularität zwischen verschiedenen Fahrzeugklassen und Fahrzeugvarianten zu identifizieren.

**Abstract**

In this paper we present a process to dimension and identify the optimal dimensioning of powertrain components. For this, a validated tool for an automated powertrain dimensioning developed at the Institute of Automotive Engineering, has been extended for the optimization of powertrains. This tool enables OEMs to dimension and optimize hybrid electric vehicle powertrains for fleet applications solely by basic vehicle parameters and a catalog of requirements for a given driving cycle and customer use in early stages of development, which reduces costs, development time and the amount of testing. The integration of fleet applications allows a fleet optimal dimensioning of powertrain components and can be extended for the optimization of a powertrain mixture of conventional, hybrid and electric drives.

The tool is used for an explanatory plug-in hybrid vehicle fleet in order to determine the optimum between emissions based on the WLTP, powertrain costs and modularity between different vehicle classes and vehicle variants. By taking the costs for a hybrid powertrain on component level into account an optimal powertrain dimensioning for vehicles in different variants can be calculated.

**Approach to determine the optimal dimensioning of powertrain components**

The presented process to identify the optimal dimensioning of powertrains components is carried out for plug-in hybrid electric vehicles (PHEV) with a P2 topology. The powertrain has one electric motor, which is located between the internal combustion engine and the transmission. An additional disconnect clutch between the electric motor and the combustion engine allows pure electric driving without dragging the combustion engine. The transmission is a seven gear DCT transmission.

The optimization process consists basically of two steps. Within the first step, an automated dimensioning tool is used to calculate and simulate powertrains according to the different vehicle requirements in different vehicle classes. Based on the generated data sets, the relation between requirements and resulting dimensioning of the powertrain components can be represented using metamodels. Those models allow a – optimal in terms of calculation time – multi-criteria optimization of individual vehicle segments with regard to consumption, cost and performance. A scaling function is used to determine the performance score of a vehicle in this regard according to the acceleration times.

In the second step, the segment-specific pareto fronts serve to dimension an exemplary vehicle fleet as a database of optimal powertrain dimensioning for individual vehicles in the fleet. The fleet composition is adjusted iteratively based on the pareto fronts using a genetic optimization algorithm. For the evaluation of a fleet, an exemplary vehicle differentiation strategy, modularity between the different powertrain components and the resulting powertrain costs and $CO_2$ emissions are taken into account.

The exemplary segments are classified as C-, D- and E-segments as well as SUV in the following. The vehicle parameters assumed for the individuals segments are listed in **Table 1**. The vehicle mass without the powertrain can be estimated by a surrogate density of the vehicle and the given dimensions according to [1].

# Low Cost Plug-in Powertrain

## Plug-in for the Mass Market

Dr.-Ing. **K. Muehlbauer**, Dr.-Ing. **R. Pohlmann**, Dr.-Ing. **W. Hackmann**, **H.-P. Feustel**, Dr.-Ing. **E. Achleitner**, **M. Schweizer-Berberich**, **C. Schmidt**, Continental, Division Powertrain, Business Development & Strategy, Regensburg;
**D. Schoeneberger**, Prof. Dr.-Ing. **S. Rinderknecht**, Technische Universität Darmstadt, Institute for Mechatronic Systems, Darmstadt

**Zusammenfassung**

Plug-in hybridelektrische Fahrzeuge (PHEV) tragen dazu bei, die $CO_2$-Flottenzielwerte der Fahrzeughersteller zu erreichen. Aktuell befinden sich parallele (P2 und P4) und leistungsverzweigte PHEV in der Serienproduktion, jedoch werden die meisten zu einem deutlich höheren Preis als konventionelle Fahrzeuge mit reinem Verbrennungsmotorantrieb angeboten. Viele alternative Antriebsstrangkonzepte werden in der Literatur diskutiert und bewertet. Dieser Beitrag präsentiert ein innovatives Konzept, mit dem vorrangigen Ziel, die Antriebsstrangkosten zu reduzieren, gerade für preissensible Märkte wie China. Dies wird erreicht, indem mehrere Ansätze miteinander kombiniert werden. Erstens wird der elektrische Antrieb nicht an vorhandene Bauräume oder den Drehmoment- und Drehzahlbereich des Verbrennungsmotors angepasst, sondern kostenoptimal als Asynchronmaschine ausgelegt. Zweitens wird die Elektrifizierung des Antriebsstrangs dazu genutzt, das Getriebe zu vereinfachen. So werden die konventionelle Anfahrkupplung und der Rückwärtsgang entfernt, da das leistungsstarke, elektrische Traktionssystem das Losfahren des Fahrzeugs sowohl vorwärts als auch rückwärts übernimmt. Darüber hinaus ist keine mechanische Synchronisierung mehr nötig, da dies der elektrische Antrieb in Abstimmung mit dem Verbrennungsmotor übernimmt. Schließlich wird die Getriebegangzahl auf ein Minimum reduziert. Dieses Hybridgetriebe steht für eine Applikation einer sogenannten Dedicated Hybrid Transmission (DHT) [1]. Drittens wird ein kostengünstiger MPI-Verbrennungsmotor (MPI: Multipoint Injection oder PFI: Port Fuel Injection) vorgeschlagen. Mit diesem neuen Antriebsstrangkonzept werden alle typischen Anforderungen an einen Fahrzeugantrieb bei deutlich reduzierten Kosten gegenüber etablierten PHEVs abgedeckt. Die Auslegung des vorgestellten Antriebsstrangkonzeptes wird anhand von Simulation bewertet.

**Abstract**

Plug-in Hybrid Electric Vehicles (PHEV) contribute to fulfill the car manufactures $CO_2$ emission fleet targets. Currently, parallel (P2 and P4) and power-split PHEV are in series production, but most of them are offered for a much higher price than vehicles with conventional powertrains using combustion engines only. Many alternative powertrain concepts are discussed and evaluated in literature. This paper presents an innovative concept, which mainly reduces the cost of the powertrain system dedicated to price sensitive markets like China. This is achieved by combining several approaches. First of all, the electric machine design is not compromised by established package constraints and the torque and speed range of a combustion engine. For this investigation it is designed as induction machine (IM) for an optimal benefit-to-cost ratio. Secondly, the electrified powertrain is used to simplify the transmission. The conventional launch element and the reverse gear are removed because the powerful electric drive system facilitates the vehicle maneuvering forward and backward. Furthermore, mechanical synchronizers in the gearbox are not necessary anymore, because the synchronization is done by the coordination of electric drive and combustion engine. Last but not least, the number of gears for the transmission is reduced to a minimum. This gearbox is an application for a Dedicated Hybrid Transmission (DHT) [1]. Thirdly, a cost efficient MPI combustion engine (MPI engine: Multipoint Injection or PFI engine: Port Fuel Injection) is proposed. With this approach, all typical vehicle requirements and use cases of a conventional car are covered while its costs are significantly lower than that of established PHEV powertrains. In this paper the design of the proposed powertrain concept is evaluated by simulation.

**PHEV Powertrains in Series Production**

The major challenge for future powertrains is to further reduce the emissions. Plug-in Hybrid Electric Vehicles (PHEV) contribute to fulfill the $CO_2$ emission fleet target [2]. Parallel and power-split hybrids are currently in series production. These parallel hybrids on the market can be divided into P2 and P4 hybrids [3]. The P2 hybrid consists of an additional electric machine between the combustion engine and the gearbox based on a conventional powertrain. This electric machine is disc shaped and runs in the speed range of the combustion engine. Due to constraints with the package as well as the torque and power requirement for a typical PHEV the electric motor is designed as a permanent magnet machine (PSM) with concentrated windings. Typically the P2 PHEV is set up with a dual clutch transmission (DCT) and a gasoline direct injected engine (GDI). The Volkswagen Passat GTE is one typical example for a P2 hybrid architecture [4]. In a P4 configuration the electric traction motor

# Control of e-motor-assisted shiftings in dedicated hybrid transmissions

**Mick Jordan** M.Sc., **Daniel Kupka** M.Sc.,
Prof. Dr.-Ing. **Peter Tenberge**, Ruhr-University Bochum

**Zusammenfassung**

Seit ca. 100 Jahren gibt es Konzeptstudien und Erfindungen zu stufenlosen Fahrzeuggetrieben mit elektrischer oder hydraulischer Leistungsverzweigung. Vor ca. 20 Jahren kamen solche Getriebe mit elektrischer Leistungsverzweigung als Hybridgetriebe in Toyota-Fahrzeugen auf den Markt. Sie gelten als besonders zuverlässig und werden bis heute in großer Stückzahl produziert. Dieser Erfolg im Markt und der steigende Bedarf an Hybridfahrzeugen war für viele Ingenieure der Anlass, sich wieder an diese Getriebeklasse zu erinnern und neue Varianten der heute auch als „Dedicated Hybrid Transmission" bezeichneten Getriebe zu untersuchen.

Stufenlos elektrisch leistungsverzweigte Hybridgetriebe bieten durch ihre Flexibilität in der Leistungsübertragung viele Möglichkeiten der optimalen Wahl der Betriebspunkte der Antriebsmaschinen. In diesem Beitrag wird so ein Getriebekonzept untersucht, jedoch nicht nur im Hinblick auf die Betriebsstrategie, sondern insbesondere im Hinblick auf seine Vorteile bezüglich der Regelbarkeit und Effizienz des Schaltvorgangs. Den Gesetzen der Physik folgend, werden auch elektrische Fahrzeugantriebe für hohe Zugkräfte und marktfähige Höchstgeschwindigkeiten schaltbare Getriebestufen haben, um klein und bezahlbar zu bleiben. Bei teilweise oder komplett elektrisch angetriebenen Fahrzeugen steigt zudem auch der Anspruch an Schaltqualität und Schaltkomfort weiter an. Zu deren Beurteilung werden zwei Schaltvorgänge des neuen Getriebekonzeptes im Detail betrachtet und mit vergleichbaren Lastschaltungen eines konventionellen Getriebes verglichen. Darüber hinaus werden Hinweise gegeben, wie die Berechnung der Drehmomentverhältnisse im Getriebe für den Regelungsentwurf herangezogen werden kann.

**Abstract**

For about 100 years, there have been concept studies and inventions on continuously variable vehicle transmissions with electrical or hydraulic power splitting. About 20 years ago, such transmissions with electric power splitting were introduced as hybrid transmissions in Toyota vehicles. They are regarded as highly reliable and have been produced in large

numbers. This success in the market and the growing demand for hybrid vehicles were reasons for many engineers to recollect this transmission class and to examine new variants of the transmissions, which are also known as "Dedicated Hybrid Transmission".

Continuously variable hybrid transmission systems offer many possibilities for optimising the operating points of the drive units due to their flexibility in power transmission. In this article, a transmission concept is examined, but not only with regard to the operating strategy, but in particular with regard to its advantages with respect to the controllability and efficiency of the shifting process. Following the laws of physics, electric vehicle drives will also have switchable gear stages for high traction forces and marketable maximum speeds in order to remain small and affordable. In the case of partly or completely electrically driven vehicles, the requirements for shift quality and shift comfort also increase further. For their assessment, two gearshifts of the new transmission concept are considered in detail and compared with comparable load shiftings of a conventional transmission. In addition, some information is provided how the calculation of the torque ratios in the gearbox can be used for the control design.

## 1. Introduction

As long as a technology for compact batteries for purely electrically driven vehicles with marketable ranges is not ready for mass production, hybrid vehicles with smaller batteries and smaller electrical driving ranges will cover the need for vehicles with low emissions and consumption. Hybrid vehicles have either classic transmissions (AT, DCT, CVT) with attached electric motors or new gearboxes, which are specifically designed for the optimal interaction of combustion engines and electric motors to drive a car.

Such transmissions, also referred to as “Dedicated Hybrid Transmissions" (DHT), are known from old patents like many other drive technologies used today. For at least 100 years there have been inventions for continuously variable gearboxes with electric, hydraulic or hydrostatic actuators in vehicle applications [1, 2, 3]. In buses, field tractors and construction machines hydraulic powersplit transmissions have been in use for decades [4, 5]. For more than 20 years, Toyota and others [6, 7] have been dealing with electric powersplit gearboxes. More than 9 million hybrid vehicles from Toyota with such a hybrid drive [8] have been produced since then. In the defect reports of the German TÜV, these vehicles are characterised by extremely low failure rates.

Toyota’s success with their Hybrid System and the increasing demand of Hybrids have been two reasons why in the last couple of years several transmission manufacturers and

# NVH Optimization of a Transmission Oil Pump

**Sueharu Ebina**, Toyota Motor Corporation;
**Yuuki Asaoka**, JTEKT Corporation;
**Takashi Kusada**, **Tetsuya Hyakutake**, Nippon Soken, Inc.

**Abstract**

In recent years, the market demands of the vehicle quietness are increased, therefore the reduction of the vibration and noise from transmission (T/M) is essential. The noise generated by the T/M oil pump (O/P) poses a particular challenge in the drivetrain engineering, and this paper describes how the noise mechanism was analyzed by the measurement of the inside pressure and the gear behavior in the O/P. This paper introduces the mechanism and the 3 examples of the noise reduction methods based on the study result.

## 1. Introduction

In recent years, the market demands of the vehicle quietness are increased, therefore the reduction of the vibration and noise from the T/M is essential. The O/P noise of the T/M becomes more pronounced, because the background noise reduces.

The O/P noise reduction methods are the addition of the insulator and the vibration absorption at the Engine mount etc. But these methods can't reduce the O/P noise sufficiently.

Therefore the noise reduction methods in the noise occurrence points of the O/P and the T/M are required.

To reduce the O/P noise of the T/M further, the O/P noise mechanism was analyzed by the measurement of the inside pressure and the gear behavior in the O/P. This paper introduces the mechanism and the 3 examples of the noise reduction methods based on the study result.

## 2. Structure of the O/P

This paper focuses on the O/P in automatic transmissions (AT). The O/P in this paper is a coaxial internal gear pump that is driven by the combustion engine. Figure 1 shows the structure of the O/P. Table 1 shows the O/P specification.

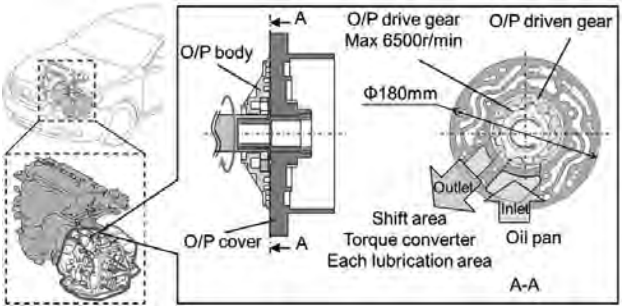


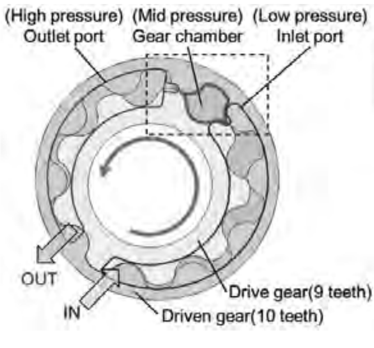

Fig.1: Structure of the O/P

Table1: O/P specification

| | |
|---|---|
| O/P type | Internal gear pump |
| Gear number(Drive/Driven) | 9/10 teeth |
| Max outlet pressure | 1200kPa |
| Max engine speed | 6500rpm |

### 3. Dominant force of the O/P

Figure 2 shows the pressure distribution in the O/P. By the rotation of the O/P gear, the oil flows from the inlet port to the outlet port. The outlet port is high pressure level. The inlet port is low pressure level. The gear chamber between the outlet port and the inlet port is mid pressure level. The result occurs the overshoot pressure in the gear chamber by the pressure difference, immediately after connecting the gear chamber and the outlet port (Figure 3).



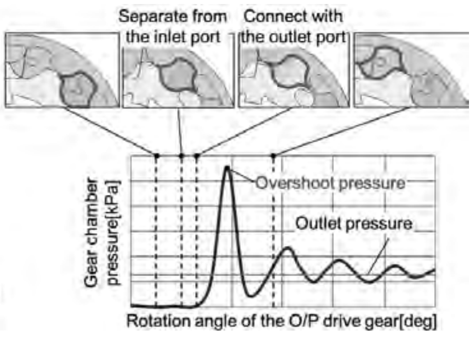




Fig.2: Pressure distribution in the O/P

Fig.3: O/P working condition

# Vibration Behaviour of High-Speed Gearings for Electrically Driven Powertrains

Dipl.-Ing. **Philipp Gwinner**, Dr.-Ing. **Michael Otto**,
Prof. Dr.-Ing. **Karsten Stahl,**
Gear Research Centre (FZG), Technical University of Munich

**Kurzfassung**

Das Gesamtziel des BMWi-geförderten Verbundprojekts Speed2E ist die Entwicklung und der Aufbau eines Hochdrehzahlantriebsstrangs für die Anwendung in rein elektrisch betriebenen Automobilen. Durch eine Anhebung der Motordrehzahl auf 30.000 $min^{-1}$ lassen sich die Leistungsdichte, Effizienz und Wirtschaftlichkeit elektrifizierter Antriebsstränge deutlich steigern. Im Rahmen des Projekts wurde an der Technischen Universität München ein hochfunktionaler Antriebsstrangprüfstand aufgebaut, um die Herausforderungen höchster Betriebsdrehzahlen im Hinblick auf den Wirkungsgrad, das Schmierungsverhalten sowie das Schwingungsverhalten zu erforschen. Dafür wurden mehrere Prüfverzahnungen für die Getriebeeingangsstufe ausgelegt, um auch den Einfluss unterschiedlicher Verzahnungsgeometrien auf die genannten Herausforderungen bewerten zu können. Das Schwingungsverhalten der Varianten wurde anhand von umfangreichen Körper- und Luftschallmessungen auf dem Prüfstand untersucht. Ein schwingungstechnischer Vergleich der Verzahnungsvarianten wird im Folgenden präsentiert, um anregungs- und geräuscharme Verzahnungen für Hochdrehzahlkonzepte elektromechanischer Antriebsstränge ableiten zu können.

**Abstract**

The overall objective of the Speed2E joint research project is the development and construction of a high-speed powertrain for use in purely electrically-driven automobiles. Increasing the motor speed up to 30,000 rpm leads to a higher power density, efficiency and profitability of electrified powertrains. Within the context of the project, a highly functional powertrain test rig has been developed at the Technical University of Munich to investigate the challenges of high operating speeds in terms of efficiency, lubrication distribution and vibration behaviour. To this end, numerous test gear sets have been designed for the transmission input gear stage to rate the influence of different gear geometries on the aforementioned aspects. The vibration behaviour has been investigated based on comprehensive structure-borne and airborne noise measurements on the test rig. A comparison of the vibration behaviour is then

presented to derive low excitation and low noise gear geometries for high-speed concepts of electromechanical powertrains.

**Introduction**

The trend in designing powertrains for all-electric vehicles focuses on efficient, high-speed concepts to extend the vehicle range by enhancing the power density. High operating speeds of axle drives give rise to new design challenges with respect to noise emission, efficiency and load-carrying capacity. As part of the Speed2E research project, which is sponsored by the Federal Ministry for Economic Affairs and Energy (BMWi) and supported by the Forschungsvereinigung für Antriebstechnik e. V. (FVA), a high-speed E-Drive with input speeds of up to 30,000 rpm is being developed and investigated. Alongside the consortium leader (the Gear Research Centre (FZG) of the Technical University of Munich), a number of institutes at the Technical University of Darmstadt and the Leibniz University Hannover, as well as the Magna subsidiary GETRAG GmbH & Cie KG and Lenze SE, are partners in this project [1, 2, 3].

**Powertrain Layout**

The powertrain has been designed for a virtual reference vehicle from the C-segment, which includes compact-class vehicles for suburban use. The front-wheel drive reference vehicle should reach a maximum speed of 160 kmh. The powertrain consists of two sub-transmissions (Fig. 1), both of which are driven by an identical permanent magnet, synchronous machine with a maximum output power of around 62 kW. Sub-transmission I has a two-stage helical gear train and a fixed gear ratio of 21, whereas sub-transmission II consists of a two-speed helical gear train and three gear stages. The first speed with gear ratio 32 is designed to reach a high starting torque. The second speed, with a gear ratio of 15, was supposed to minimize the energy consumption of the powertrain, taking into account characteristic driving cycles for the reference vehicle. The input power of both sub-transmissions is added together at the final drive, which features a conventional bevel gear differential inside that has been provided by the project partner Magna GETRAG [1]. Moreover, the power split transmission architecture enables powerful operating strategies by individually distributing the required axle torque to both sub-transmissions. The operating strategies can be applied to either increase the powertrain efficiency [2] or to reduce the noise emission [2, 4]. In the first part of the experimental investigations, each sub-transmission is individually tested on a test rig at the FZG (sub-transmission I) and at the IMKT in Hanover (sub-transmission II). The scope of testing at the FZG focuses on an analysis of the vibration and efficiency behaviour of sub-transmission I. The investigations in Hanover cover the investigation of the lubri-

# 3 cylinders and cylinder deactivation: which dampening challenges?

**Marc Theobalt**, **Hervé Mahe**, **Carlos Lopez Perez**,
VALEO Transmissions Systems

## ABSTRACT

$CO_2$ emission regulation leads OEM (Original Equipment Manufacturers) to downsize drastically the engines, and cylinder deactivation is now a mainstream, whatever the transmission type. Current technical bricks such as pendulum dampers have to be customized to this new challenge. And opportunity is given to introduce technical breakthrough to fit specific demanding applications.

An example will be given a new “Zero Gravity” technical solution for a Dual Clutch Transmission with 4 to 2 cylinders deactivation. And another focus will be done on an Automatic Transmission equipped with a new dampening concept**.**

## INTRODUCTION

Transmissions development changes since many years have already been driving by the CO2 emission reduction request. The regulation on CO2 emission is more and more stringent over many years, as shown on figure 1. New targets for 2020 have been defined all over the world such as 95g in EU in 2020 and 109g in the US in 2015.

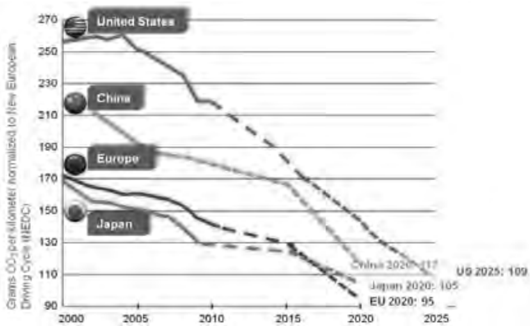



Figure 1: $CO_2$ emission regulations worldwide

These are huge constraints for OEM which are forced to a completely re-engineering of either the engine or the gearbox. Beside electrification, main tendencies prevail to handle these new targets at Internal Combustion Engine (ICE):
1) ICE downsizing, by reducing number of cylinders, and increasing injection and compression pressure. The same torque level is delivered with a smaller cylinder displacement, which means an increase of specific torque (in Nm per liter) delivered.
2) ICE downspeeding: the purpose is to allow the driver to use his engine at very low engine speed but almost full torque, especially at high gear.
As a consequence, 3 cylinders engine are systematically offered up to segment B and C, for which the comfort and NVH requirements are significant.

The purpose of this paper is:
- to explain the consequences of these trends for the clutch dampening system's architecture.
- to focus on 2 examples, showing new damper's technology that can be proposed for Automatic Transmission (AT), or Dual Clutch Transmission (DCT) with 3 cylinders, cylinder deactivation, and 2 cylinders mode.

## 3 CYLINDERS ENGINES AND CYLINDER DEACTIVATION

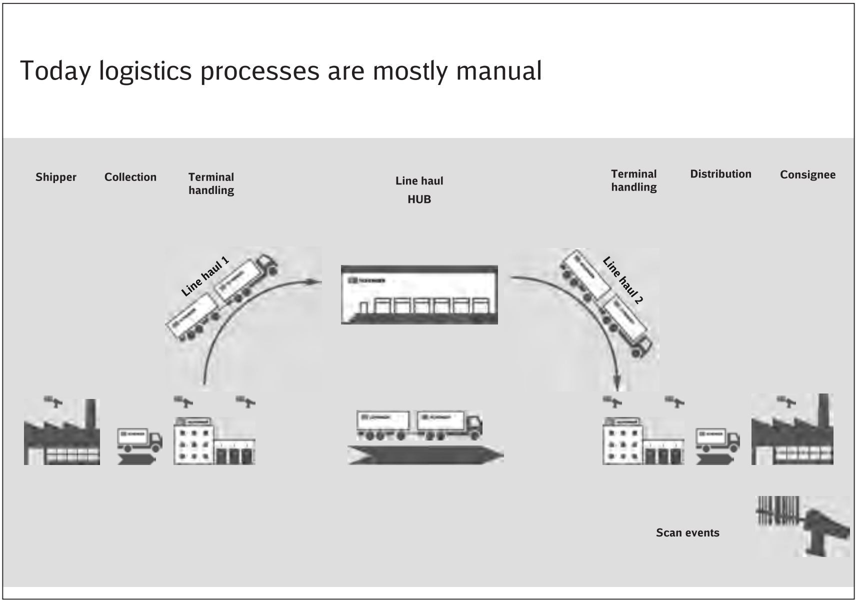
The downsizing of the engine, from 4 cylinders to 3 cylinders for example, means an increase of the specific torque. That is obtained by increasing the combustion pressure, and the consequence is an enhancement of torque, and speed fluctuations between 2 consecutive engine piston firings.
Generally associated with the reduction of cylinders number, maximum torque is delivered at lower thermal engine rotation speed: close to 1200 rpm, instead of 1500 rpm, for previous generation.
Besides, the firing order changes and is lowered with cylinders reduction: for a 4 cylinders, there are 2 firings during one complete engine revolution, each cylinder being fired every 2 engine revolutions. It is said that firing is at order 2 compared to crankshaft revolution at order 1. A 3 cylinders engine will fire 3 times during 2 engine revolutions, so that firing order is 1.5. This means a reduction of the excitation frequency at a same engine speed. This has a great impact, for both torsional vibrations filtering and for engine start, especially with a Dual Mass Flywheel (DMF) as it will be explained later.

5th VDI Conference

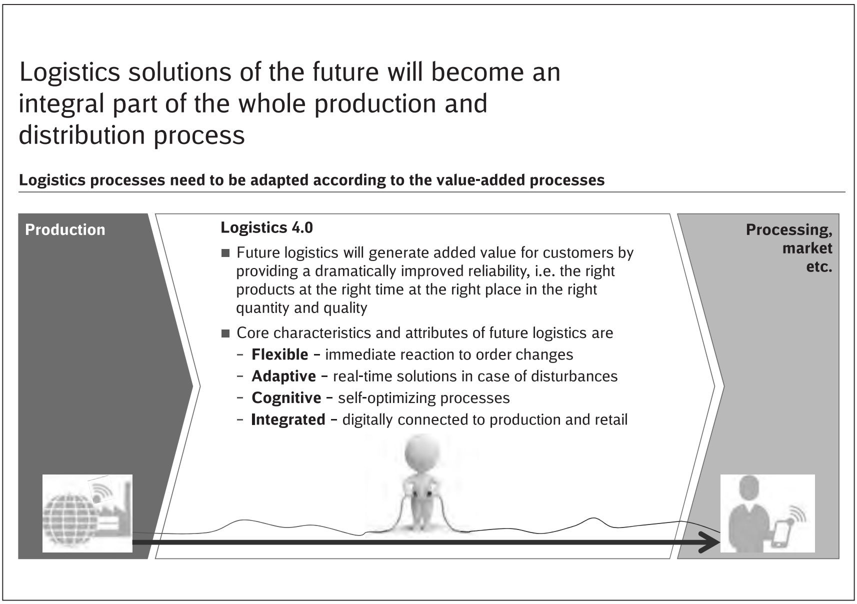
Transmissions in Commercial Vehicles 2017

# Logistics 4.0 –Vision und Herausforderungen

Dr. **Chung Anh Tran**, Deutsche Bahn AG, Frankfurt a. M.




SCHENKER
DB SCHENKER


Logistics solutions of the future will become an integral part of the whole production and distribution process
Logistics processes need to be adapted according to the value-added processes
Production
Logistics 4.0
Future logistics will generate added value for customers by providing a dramatically improved reliability, i.e. the right products at the right time at the right place in the right quantity and quality
Core characteristics and attributes of future logistics are
– Flexible – immediate reaction to order changes
– Adaptive – real-time solutions in case of disturbances
– Cognitive – self-optimizing processes
– Integrated – digitally connected to production and retail
Processing, market etc.

# Historical and future development fields are shown as well as TCO optimization aspects

Dr.-Ing. **Martin Lamke**, Dr.-Ing. **Christoph Rüchardt**,
Dipl.-Ing. **Marcus Raeder**, ZF Friedrichshafen, Friedrichshafen

**Zusammenfassung**

AMT werden im Fernverkehrssegment voraussichtlich noch für Jahrzehnte in Serie produziert. Um den Weg von ZF TraXon in die Zukunft zu verdeutlichen, wird zunächst auf ZF Vorgängerprodukte wie AS Tronic und bisherige Hybridentwicklungen eingegangen. Über die Entwicklungs¬¬ziele von TraXon und durchgeführte Methoden für einen erfolgreich absolvierten Serienstart 2015 hinaus werden Ausblicke auf zukünftige Entwicklungen und Methoden gezeigt, die sowohl eine weitere Reduzierung der TCO als auch einen effizienten Einstieg in die Serienproduktion von E-Mobility-Produkten ermöglichen.

**Abstract**

AMT in the long-haul segment will probably remain for decades to come in series production. In order to illustrate the future of ZF TraXon, predecessors as ZF- AS Tronic or Hybrid developments are shown. Development targets and carried out methods to enable a successful SOP in 2015 mark the way to future developments and methods, which will ensure a further reduction of TCO as well as an efficient entry into series production of E-Mobility-Products.

[1] Dipl.-Ing. Wilhelm Härdtle, Dr.-Ing. Christoph Rüchardt, Dr. Stephan Demmerer, Dipl.-Ing. (LRT) Axel Mors, ZF-Friedrichshafen AG:
„Das modulare Getriebesystem Traxon“; ATZ, Ausgabe 05/2013

[2] Dr.-Ing. Christoph Rüchardt, Dr.-Ing. Thomas Jäger, Dipl.-Ing. Karl-Fritz Heinzelmann, Dipl.-Ing. Michael Bodenmüller, ZF-Friedrichshafen AG
„TraXon, das hochintegrierte, automatische Nutzfahrzeuggetriebe
Neuer benchmark für Antriebe der Zukunft“
Getriebe in Nutzfahrzeugen, 18.06.2013 – 19.06.2013, Friedrichshafen

## ZF TraXon Transmission System: Paths Into the Future
## Agenda

**Historical ZF Background of HD-AMT & Hybrid**

**TraXon: Development Targets & Implementation**

**E-Mobility & TCO Optimization**

**Conclusion**

Internal 

## Historical ZF Background of HD-AMT & Hybrid
## Predecessors of TraXon

**AS Tronic 1st generation**

- 1st AMT in Europe without clutch pedal for HD market
- 2 countershaft design, 12- and 16-speed, spur gears
- SOP in 1997

**AS Tronic 2nd generation**

- Transfer of basic design from AS Tronic 1
- All gears with helix angle, completely new mechatronic
- SOP in 2000; production in Friedrichshafen / Germany and Sorocaba / Brasil
- Up to now close to 1.4 millions transmissions have been produced
- Numerous worldwide customers in all kind of HD applications

Internal 

# Development of highly functional dual-clutch transmissions for future commercial vehicles

Dr.-Ing. **Jörg Müller**, Dipl.-Ing. **Rico Resch**, **Erik Schreiterer** M.Sc.,
Development Engineer, Transmission Synthesis & Concepts, IAV GmbH

**Kurzfassung:**

Für die kommenden Jahre wird weiterhin ein stetiges Wachstum des Gütertransports prognostiziert. Die mit der Verknappung von Ressourcen einhergehende Kostensteigerung ebendieser, erfordert wirtschaftliche Lösungen sowohl für Hersteller als auch für die Betreiber von Nutzfahrzeugen. Neben Maßnahmen am Fahrzeug kann der Antriebsstrang durch Senkung des Primärenergiebedarfs einen signifikanten Beitrag zur Reduzierung der bei Nutzfahrzeugen im Vordergrund stehenden Betriebskosten liefern.
Zur Definition systemoptimaler Antriebsstränge zukünftiger Nutzfahrzeuge darf nicht mehr nur jede Komponente einzeln verbessert werden. Neue Verbrennungsmotoren realisieren beispielsweise bei verringerter Drehzahl die gleiche Leistung. Solche Änderungen haben Auswirkungen auf die im Getriebe erforderlichen Übersetzungsreihen als auch auf die zu übertragenden Drehmomente. Die perspektivisch zu erwartende Hybridisierung von Nfz-Antriebssträngen wird deren Komplexität steigern. Gleichzeitig eröffnen sich dadurch Möglichkeiten für unterschiedliche hybride Topologien. Über zentral gesteuerte Fahrleitrechner können zukünftig die Geschwindigkeitsprofile der Fahrzeuge und damit auch die Übersetzungswahl im Getriebe beeinflusst werden.
Der Beitrag konzentriert wird sich auf die Auswirkungen solcher Veränderungen auf das Getriebe. Dabei stehen Lösungen für hochfunktionale Doppelkupplungsgetriebe im Fokus. Diese Ergebnisse sind die Basis für spätere Vergleiche mit anderen Getriebetechnologien, wie AMT oder AT, hinsichtlich Funktionsumsetzung, Verbrauch, Bauraum, Gewicht und Kosten verglichen. Ziel ist die Generierung neuer Trendaussagen für den Einsatz verschiedener Getriebetechnologien in zukünftigen Nutzfahrzeuganwendungen unter Beachtung der sich ändernden Randbedingungen.

**Summary:**

For the following years current forecasts see a steady growth of transport of goods. The shortage of resources will lead to increasing costs and therefore will require economical solutions for OEMs as well as operators of commercial vehicles (CV). Besides measures on the vehicle side new powertrain topologies may significantly contribute to a reduction in operating costs which are main cost drivers.

For defining CV power trains which are an optimum for the whole system it is necessary to improve all components in a system and not one for each other. Exemplarily new combustion engines realize the same power at lower engine speeds. Such changes have a direct effect on the required series of ratios of the transmission, on the torque which has to be transferred. The electrification of CV power trains offers further potentials to reduce the fuel consumption. Electric motors which have to be integrated into the power train increase its complexity and open up new possibilities for different hybrid topologies.

The contribution concentrates on the effects such changes imply for the transmission. Thereby solutions of highly functional dual-clutch transmissions are in focus. These results are the basis for later comparisons with other transmission technologies, like AMT or AT. Such assessments may be done with regard to fuel consumption, design space, weight and costs. Target is to detect trends for the use of different transmission technologies in future CV applications by considering the changing boundaries.

# Entwicklung eines 8-Gang-Automatikgetriebes für mittelschwere Lkw und Busse

## Marktanalyse, Konzept-Auswahl, -Detailbestimmung und -Vergleich sowie Umsetzung eines segmentoptimalen Getriebesystems

# Development of an 8-speed Automatic Transmission for Medium-duty Trucks and Buses

## Market analysis, selection, detailed definition and comparison of concepts and rollout of a segment-optimized transmission system

Dipl. Ing.(FH) **Frank Sauter**, Dipl. Ing. **Herbert Mozer**,
Dipl. Ing. **Bernhard Fessler**, Dipl.-Ing.(FH) **Johannes Glückler**,
Commercial Vehicle Driveline Technology; ZF Friedrichshafen AG

**Abstract**

Welche der vielen, stark unterschiedlichen Getriebetechnologien eignet sich generell und welche Ausprägung davon am besten, wenn der Entwicklungsauftrag ein fortschrittliches Getriebesystem für ganz spezifische Fahrzeugsegmente fordert? Welche Kriterien muss dieses im Speziellen erfüllen? Und wie gelingt es anschließend, das analytisch ermittelte Idealkonzept unter Berücksichtigung strenger Kostenziele in ein Serienprodukt zu umzusetzen, das auch in der Praxis Benchmarks setzt? Um diese und weitere Fragen zu beantworten, zeichnet der vorliegende Fachartikel jenen Weg nach, den ZF bei der Realisierung eines neuen Getriebes für mittelschwere Lkw und Busse beschritten hat. Am Anfang stand eine globale Marktanalyse, die untersuchte, welche Getriebetypen für die anvisierten Nutzfahrzeugsegmente in Zukunft gefragt sein werden. Unter diesen bescheinigte eine weitere Analyse den lastschaltfähigen Technologien – sprich Wandler-Automatgetrieben (AT) und Doppelkupplungssystemen (DCT) – das größte Potenzial, die aktuellen und kommenden Anforderungen der Zielfahrzeuge zu erfüllen. Daraufhin ergab sich per eigens dafür entwickelter, hochkomplexer Simulations- und Analysemethodik, dass beim DCT 7 Gänge und eine Spreizung von 10,1 sowie beim AT 8 Schaltstufen mit einer Gesamtspreizung von 7,65 als Optimum gelten.

Eine daran anschließende Untersuchung verglich, wie diese Systeme in den wesentlichen Kriterien Gewicht, Bauraum, Verbrauchssenkungspotenzial, Gasmotor-Eignung, Hybridisierungsmöglichkeiten und Performance abschneiden. Um die Ergebnisse besser deuten zu kön-

nen, umfasste die Analyse auch ein sehr weit verbreitetes automatisiertes Schaltgetriebe mit 6 Gängen. Am Ende ging daraus das 8-Gang-AT-Konzept, wie es von ZF für Pkw seit langem den Maßstab setzt, als optimal für die neuen Anwendungen hervor.
Ausgehend von diesem als ZF 8HP bekannten Getriebe entwickelte ZF unter Nutzung größtmöglicher Synergien schließlich ein neues System für mittelschwere Lkw und Busse, das sämtliche nutzfahrzeugspezifischen Anforderungen erfüllt und in der Summe seiner Eigenschaften mit großem Abstand einen neuen Segment-Benchmark setzt – ganz besonders bei der Effizienz, der Performance, der Zukunftsfähigkeit und dem Komfort.

**Abstract**

Which of the many, very different transmission technologies are generally suitable and which of variant is best suited when the task is to develop an advanced transmission system for specific vehicle segments? Which specific criteria must this system fulfill? And, once the ideal concept has been calculated, how can it be transformed into a volume production product without losing sight of strict cost objectives while still setting benchmarks in practice? To answer these and other questions, this paper discusses which actions ZF has taken so far in designing a new transmission for medium-duty trucks and buses. The first step was to conduct a global market analysis examining which transmission types will be in demand for the targeted commercial vehicle segments in the future. This analysis pointed to an increasingly strong trend towards automatic shift systems.
A further analysis confirmed that powershift technologies – in other words, torque converter transmissions (AT) and dual-clutch systems (DCT) – had the most potential to fulfill the current and future requirements of the target vehicles. Further testing using a highly complex simulation and analysis method developed specifically for this application revealed that the best results were achieved with a DCT featuring 7 speeds and a spread of 10.1 as well as with an AT featuring 8 speeds and a total spread of 7.65.
A follow-on investigation then compared how these different systems rated in terms of the key criteria, i.e., weight, installation dimensions, potential fuel consumption savings, gas engine compatibility, hybridization options and performance. To help put these results into perspective, the analysis also included a widely used automated manual transmission with 6 speeds. At the end of this analysis process, the 8-speed AT concept, with which ZF has been setting standards for passenger cars for a long time, was confirmed as the optimum transmission for the new applications.
Based on this transmission known as ZF 8HP, ZF harnessed maximum synergies to develop a new system for medium-duty trucks and buses which meets all specific commercial vehicle requirements. Its combination of characteristics sets a significant segment benchmark – particularly in terms of efficiency, performance, future compatibility and comfort.

# Clutch NVH performance to answer engine down speeding trends

**Stephan Gaudé**, **Laurent Lefolle**, **Clément Derville-Helluin**,
Valeo, Amiens, France

## Abstract

Fuel saving is a key driver to reduce TCO (Total Cost of Ownership) in Commercial Vehicle market. To answer this demand and in parallel to higher engine torque needs, engine efficiency optimization through loss reductions is currently a major trend for medium-duty and heavy-duty new engine developments.

Down speeding - reduction of the rotational speed of the engine to reach maximum torque at lower engine speed - is one of the solutions that can apply to this challenge. Clutch dampening capacity has to be drastically changed and new technical solutions have to be developed in order to keep NVH aspects compatible with torsional filtration requirements and, finally, to improve NVH comfort and vehicle durability.

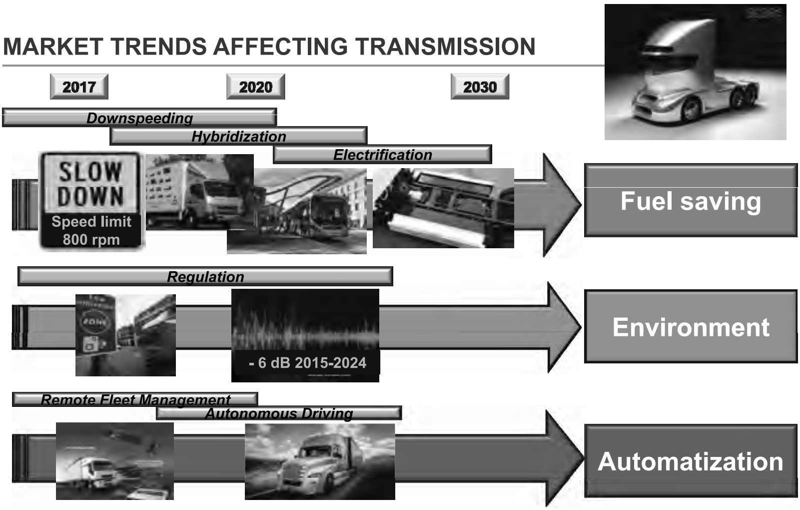
VALEO is developing new clutch dampening solutions to answer to the growing requirements of the commercial vehicle markets. The need to decrease development durations and costs implies also to apply robust and quick adapted methodologies. Thus, simulation specific tools have been developed in parallel with pragmatic approach based on vehicle & test bench experimentations.

In a first step, the simulation approach is mandatory to support new developments. The whole driveline is taken into account and analyzed in 1-D simulation by integrating all parameters of a given driveline, from the engine excitation up to the side shafts and wheels. Effects of engine up-torquing and down speeding will be considered and introduced into the simulation. In a second step, an experimental testing phase is made on vehicle to correlate the simulation results with NVH measurements and to confirm quantitative and qualitative performances versus final customer requirements.

Then we are able to present some of the innovative dampening solutions that have been developed by this way such as Long Travel Dampers, Pendulum Absorbers or Dual Mass Flywheel. The performances of those dampening solutions are confirmed through the double combined approach of simulation and vehicle testing on commercial vehicle applications.

[1] Trucking efficiency confidence report : Downspeeding Executive Summary

## MARKET TRENDS AFFECTING TRANSMISSION

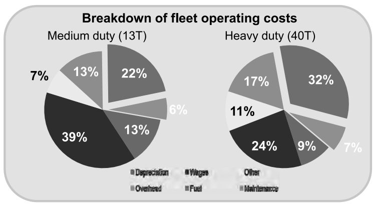



## FUEL SAVING

- **Market need**

  *Reduction of TCO (total cost of ownership)*

  - *Fuel consumption is in first place*

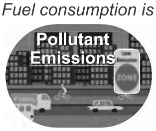




Source: Deloitte

- **Environment Regulations**

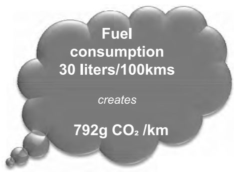
  *After pollutant emission limitation, Green House gas are targeted through legislation about CO2 emissions*

  - *Fuel consumption is still involved*




*Euro VI.C; China VI, US Tiers 3*
*Low Emission Zones*


*US GHG Phase II*
*Europe 2020*



# Disengageable Retarder

## The only way to completely avoid the slip losses

Dr. **Mikael Sannelius**, Scania CV AB, Södertälje, Sweden


### Abstract

Heavy trucks and buses of today are often equipped with a hydrodynamic auxiliary brake (retarder) connected to the output shaft of the gearbox. In the retarder a fluid is twisted between two blade wheels producing a braking torque on the driving wheels. When not using the retarder slip loss occurs due to gas circulation between the blade wheels and for fuel economy reasons it is very important to keep those losses as low as possible. Traditional slip loss reduction methods decrease the losses to around 1 % of the vehicles total driving force but with the use of mechanical disengagement the losses can be reduced to nearly nothing, see Fig. 1.

Disengagement can be done with different solutions but the Scania choice has been to use a synchromesh on the gearbox output shaft, see Fig. 2. This allows engagement within 2 – 4 tenths of a second and gives benefits regarding modularization, synchronization power and physical integration. The high speed difference in the synchronization phase is compensated by low inertia allowing the use of the same synchromesh parts as for the 1:st gear in the main gearbox.

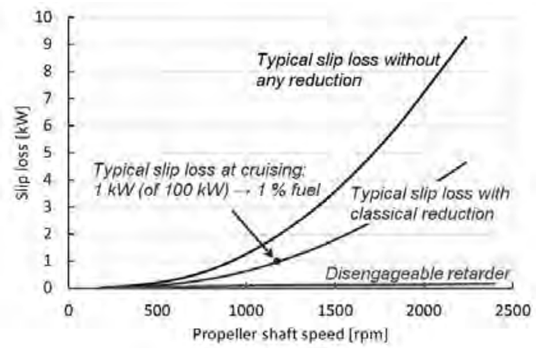




Fig. 1: Slip loss from retarders with different grade of loss reduction

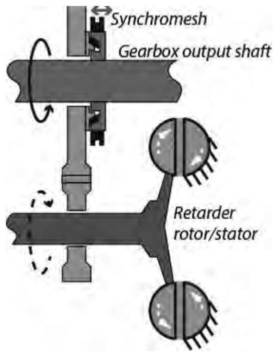



Fig. 2: Disengageable retarder

## CONTENTS

- General retarder introduction
- The mechanism of slip losses from a retarder
- Loss reduction methods
- Challenges making the retarder disengageable (freewheeling)
- Choice of disengagement method and reasons for that
- Real application example
- Example of fuel savings

## RETARDER – HYDRAULIC AUXILIARY BRAKE

- Brakes the driving wheels by swirling a fluid between two blade wheels
- The braking power transfers to heat which is cooled off by the ordinary engine cooling system
- Saves service brakes and admits high downhill speed
- Can normally be activated by a hand lever, by the service brake pedal, by the cruise control system or by the cab heating system

# The last mile

## Findings of the ZF Future Study 2016 about last mile logistics

Prof. Dr.-Ing. **Uwe Clausen**, Dortmund

**Zusammenfassung**

Die ZF- Zukunftsstudie 2016 betrachtet die Logistik auf der „letzten Meile“. Die Studie unterscheidet zwischen ländlichen, städtischen und Metropol Räumen. Die Ursache für jede Aktivität auf der letzten Meile ist letztlich der Kunde. Kundenwünsche und -anforderungen schaffen entweder direkt oder indirekt die Leitlinien für die Gestaltung der letzten Meile (Annahme #1). Die Umgebung, Infrastruktur, Gebäude und Verkehrsaufkommen definieren den lokalen Handlungsspielraum für alle Akteure der letzten Meile. Diese müssen die Rahmenbedingungen bei der Gestaltung ihrer letzten Meile (Annahme #2) berücksichtigen. Technische Trends und Innovationen können neue Antworten auf Kundenanforderungen sowie auf die Anforderungen der Umgebung (Annahme #3) geben. Die Studie beschreibt Trends wie demographischen Wandel, Frischelogistik, Same Day Delivery und ökologisches Bewusstsein. Alles in allem erhöhen diese Trends den Kostendruck und schaffen für die letzte Meile strengere zeitliche Vorgaben. Autonome Fahrzeuge und elektrische Antriebstechnik ebnen den Weg zu neuen Konzepten und Strukturen der letzten Meile, zu neuen Geschäftsmodellen und Fahrzeugtypen. Drohnen werden weiterentwickelt und zu spezialisierten Nischenanwendungen der letzte Meile. Kleine Bodenfahrzeuge ergänzen als Roboter die Paketverteilung.

**Abstract**

The ZF Study on the Future 2016 takes a look on last mile logistics. The study distinguishes between rural, urban, and metropolitan areas. The final cause of any activity on the last mile is the customer. Customer aspirations and requirements either directly or indirectly create the guiding principles for the design of any last mile system (Assumption #1)

The surrounding area, infrastructure, buildings, and traffic volumes, define the local scope of action for all players involved in last mile logistics. These have to consider the frame conditions when designing their last mile (Assumption #2).

Technical trends and innovations may provide new answers to customer demands as well as to requirements imposed by the surrounding area (Assumption #3).

The study describes trends such as demographic change, fresh produce logistics, same day delivery, and environmental awareness. All in all, these trends increase cost pressure and create stricter time constraints for the last mile. Autonomous vehicles and electric drive technology pave the way to new concepts for last mile structures, business models (such as night delivery) or even vehicle types. Drones mature and enter the last mile for specialized niche applications. Small ground vehicles (robots) supplement parcel distribution.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# Application on e-Mobility in Commercial Vehicle

Dr. **Götz von Esebeck**, **Tassilo Pflanz**, MAN Truck & Bus AG


### Abstract

Looking into requirements of the market a strong push is seen to "green" vehicles in commercial vehicles. Frontrunner in commercial vehicles is the city bus segment driven by political pressure to offer zero emission mobility in inner city area. Meanwhile the distribution sector as well is requesting zero emission vehicles with limited range for different applications.

All OEMs strengthen their activities on e-mobility. An important barrier to introduction of EVs is costs, another the lifetime of the main components for traction drive and electrified auxiliaries in heavy duty applications. Currently Bus OEMs are asked for many different drive traction systems: resulting in high costs for a small number of specialized busses.

It will be shown how MAN is expecting the market to develop in Europe at the example of city busses and how MAN is preparing for that. Key technologies here are the e-motor, battery technology and energy management. Especially on e-motor different technology paths will be seen in the market which influences other components as transmissions up to the vehicle concept. The major item of course is the electric range which is depending on the battery and charging technology – with big influence on the costs.

Following a project is shown which addresses possibilities on modular approach to be able to offer different drivetrain concepts and possible cost reductions possibilities: The ECOCHAMPS project addresses the topic GV-04-2014 Hybrid Light and Heavy Duty Vehicles under Horizon2020. This project is realized, through the activities of a 26-member consortium. The overall objectives are to achieve efficient, compact, low weight, robust and cost effective hybrid powertrains for both passenger cars and commercial vehicles, with increased functionality, improved performance, comfort, safety and emissions levels below Euro 6 or VI. In particular, to achieve 20% powertrain efficiency improvements and weight plus volume reductions with respect to the best in class vehicles on the market at the time of proposal, whilst having a maximum of a 10% cost premium. At the time of the TRA2018, the project will just be completed. The bus application, a serial hybrid vehicle with Diesel ICE, as being worked on by MAN and partners in Work Package 6, will be presented in this paper.

From this background, the following possible cost reductions are being evaluated in a

1. Using components from standardization, in particular OEMs create common, standard requirements for components;
2. Using components or derivatives from “high volume production”, such as passenger car components;
3. Especially for busses: definition of a basic E-Bus, which can be readily changed from Diesel Hybrid to Fuel Cell or Full Battery.

According to 1., auxiliaries for heavy duty application that can be easily shared between busses and trucks are, e.g., the electric steering pump system, electric air compressor for braking and DC-DC-converter for 24V supply. Such components are being developed by the suppliers within WP2, before being fitted to the demonstrators.

To realize 2., the traction drive of a small car is analyzed: typically, this has a high speed electrical machine combined with a gearbox. Therefore, such a machine with inverter will be used, but the gearbox adapted to the torque and speed necessary for a city bus. If successful, costs are significantly reduced. The drive will be developed and tested, to show the efficiency and maturity of such a concept. Modified battery systems will be evaluated for their suitability for inner city cycle operation.

The idea of 3. is the identification of the main system components and modularization of the bus-structure. Here, the bus roof is the easiest place to realize several vehicle types. The basic vehicle is a complete electric bus with all auxiliary systems and equipped with “short term electric energy storage”, mainly used for recovering brake energy. Thereafter, the bus will be completed with an electricity source according to customer wishes using the preferred “fuel”: Diesel-Hybrid, fuel cells or EV, fully equipped with batteries.

Finally it will be shortly explained how MAN is transforming from a truck and bus manufacturer to a mobility supplier for commercial vehicles. A broader approach is necessary to develop the market for electric commercial vehicles.

# Integrated Electric Axle for Trucks

Dipl.-Ing. **Jürgen Tochtermann**,
AVL Commercial Driveline & Tractor Engineering GmbH, Steyr, Austria


## Zusammenfassung

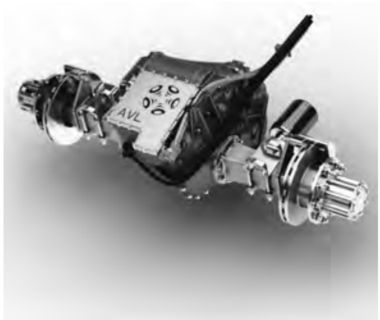
Die Gesetzgebung treibt weltweit den Bedarf an rein elektrisch angetriebenen LKW für den innerstädtischen Verteilerverkehr. Um diese Anforderung zu bedienen, arbeitet AVL im Rahmen eines R&D-Programms an der Entwicklung einer integrierten elektrisch angetriebenen Achse für diese Fahrzeug-Kategorie.
Ein wichtiger Startpunkt ist die Festlegung der für die Auslegung relevanten Systemspezifikationen. Darauf basierend wurden verschiedene Antriebsstrang-Architekturen untersucht und eine abgestimmte Kombination aus E-Maschine und Getriebe abgeleitet. Bei der konstruktiven Umsetzung wurde besonders darauf geachtet, alle für den elektrischen Antrieb notwendigen Komponenten in die Achse zu integrieren. So wurde der Einbauraum optimiert und eine geringe Anzahl der externen Schnittstellen erreicht. Ein weiteres Ziel war es, eine variable Anordnung darzustellen, die an verschieden Fahrzeugumgebungen anpassbar ist. Für die Dimensionierung der Batterien wurde auf Basis von realen repräsentativen Fahrzyklen der Energieverbrauch simuliert.

## Abstract

The legislation worldwide drives the demand for pure electrically driven trucks for urban distribution. In answer to this trend AVL started an R&D program for the development of an integrated electrically driven axle for this truck class.
The definition of the relevant system specifications is an important starting point for the development. Derived from the specifications different drivetrain architectures had been investigated, resulting in a balanced definition of E-machine and transmission. The main focus of the design work was the integration of all required components into the axle body. So the packaging space was optimized and the number of external interfaces was reduced. Another target was to reach a variable arrangement of the components so that the E-axle can be adapted to different vehicle boundaries.
For the dimensioning of the batteries the energy consumption was simulated, based on real representative drive cycles.

## INTEGRATED ELECTRIC AXLE FOR TRUCKS

Content:
- System Specification
- System Investigations
  - Vehicle packaging
  - Matching of E-machine and transmission
  - Cooling system
- Concept Design and integration of components
  - E-Axle packaging
  - E-Machine
  - Inverter
  - Transmission
- Drive cycle and energy consumption




Public VDI 2017: Getriebe in Nutzfahrzeugen / Transmissions in Commercial Vehicles Jürgen Tochtermann | H_DD | 07 April 2017 | 2

## SELECTION OF TARGET VEHICLE

- Relevant truck classes for urban delivery
  - 7.5…16 tons GVW, 4x2
  - 18…26 tons GVW, 6x2
- Selection for further development
  - **MD truck with 16 tons GVW**
    - Relevant for most markets worldwide
    - 16 tons: Largest vehicle in class
      - Highest power demand
      - Downsizing for lighter vehicles possible

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# Driveline Electrification in Commercial Vehicles

## Combustion powered long-haul & electric driven distribution

**Konstantin Neiß**, Daimler AG, Stuttgart

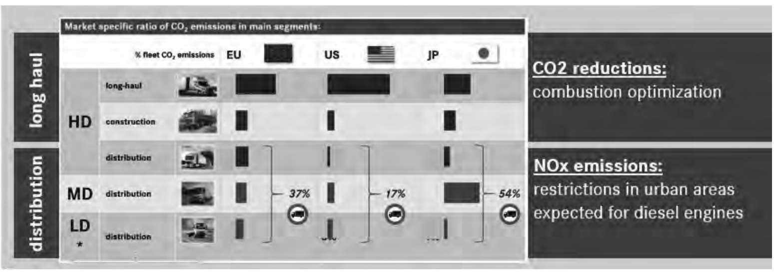

### Zusammenfassung

Mit Einführung der Getriebeautomatisierung und dem Einsatz von GPS gestützten Schaltstrategien hat sich die Triebstrang-Elektrifizierung bei Fernverkehrs-LKW etabliert. Zukünftige Optimierungen bei den Fahrfunktionen, der Schaltperformance, der Verbrauchsoptimierung und auch bei Komponentenkosten werden an Beispielen aufgezeigt, die bis 2020 auf der Straße zu sehen sein werden. Die Vision für das Nutzfahrzeug im Verteilersegment liegt hingegen beim Mercedes-Benz Urban eTruck und damit bei dem rein elektrisch angetriebenen Fahrzeug. Beide Antriebskonzepte werden in den nächsten beiden Jahrzehnten eine bestimmende Rolle einnehmen und zur Reduktion fossiler Treibstoffe beitragen und die CO2 Belastung herabsetzen.

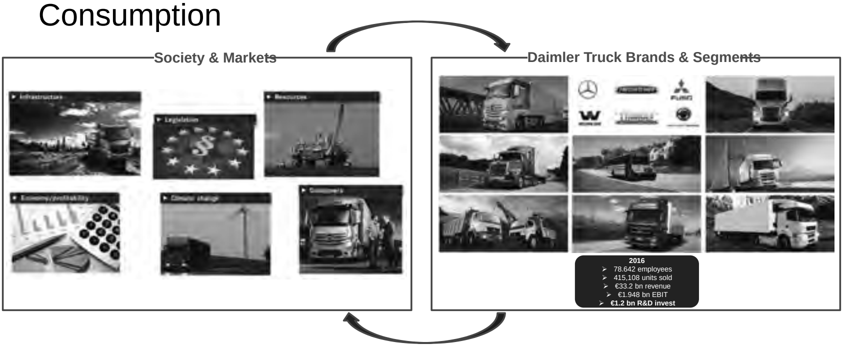
### Abstract

Automated transmissions and GPS based shift strategies became standard in commercial vehicles in the long-haul segment and build the foundation for future optimizations to further improve driving functions, shift performance, fuel economy and to reduce component costs for products planned to be launched until 2020. Our vision for the distribution segment is an all-electric drive concept, the Mercedes-Benz Urban eTruck. The co-existence of combustion based drivelines and electric drivelines is expected to remain in place for the next two decades and will reduce fossil fuels and CO2 emissions.


Table 1: Example of a fleet's CO2 contribution by segments and markets

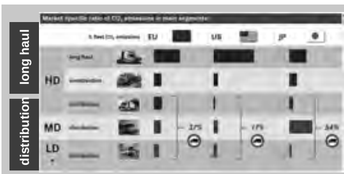


## Industry Striving to Reduce Emissions and Fuel Consumption




**Global powertrain solutions required to address similar challenges**

## Long-Haul and Distributions Segments




| | | |
|---|---|---|
| **CO2 reductions** | ⟩ | Combustion optimizations, i.e. CNG, eFuels, 48V, EHR … |
| **NOx emissions** restrictions in urban areas expected for diesel engines | ⟩ | Urban eTruck & eCanter |

**Co-existence of combustion technology and eDrive technology**

# The next generation active prediction based powertrain control strategies

## Utilizing the vehicle's kinetic energy as energy storage

**Fredrik Roos**, PhD, Expert Engineer, **Oscar Flärdh,** PhD,
Powertrain Control Strategy, Scania CV AB, Södertälje, Sweden

**Abstract**

The Scania active prediction system have been in production since 2012. The heart of the system is the map-database containing gradient information of just about all roads in Europe. The control system uses the road gradient data to build a virtual horizon of the road segment in front of the vehicle. A set of predefined driving strategies are then evaluated over the horizon and the most fuel-efficient one is selected.

The system has been updated with new and improved functionality several times since 2012, one of the largest updates where in 2014 when eco-roll and gear selection strategies where added to the system. Now in 2017 it is time for a new update, this time with a function that aims at increasing the mean efficiency of the combustion engine: Pulse & Glide.

**Minimizing the Fuel Consumption of a Truck with just Control Algorithms**

The problem of minimizing the fuel consumption may be divided into two parts:

1. Minimize the energy needed on the engine's flywheel to travel from A to B
2. Maximize the mean efficiency of the engine over the route

A typical distribution of “energy consumers” in long-haulage is shown in figure 1 below. As seen the largest energy consumers are the rolling- and air-resistance, which represents approximately ¾ of the total energy consumption. However, the control system have limited possibilities to effect these two. Nevertheless, the air-resistance could be lowered by utilizing the slip-stream effect behind other trucks in an intelligent way (platooning / ACC). Otherwise the possibilities, from a control system perspective, to lower these two losses are limited.

On the other hand, the three remaining losses (the last ¼ of the total energy consumption): engine friction, drivetrain friction and braking are effected by the control system more or less directly.

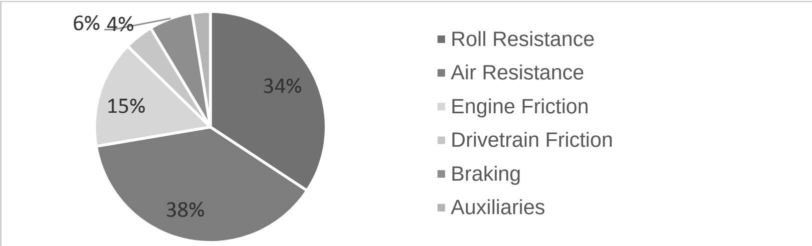



*Figure 1. Energy distribution long-haulage*

The braking losses could be reduced by a smart cruise control (look-ahead cruise) which lowers the speed before steep/long-downhills. A smart control strategy behind other vehicles (ACC) also has the potential of lowering the braking losses. The engine and drivetrain losses depends on the gear selection strategy and particularly on the freewheeling (eco-roll) strategy.

Part 2 above, engine efficiency, depends of course on the engine operating point, which the gear selection strategy can chose. However, the gear selection strategy is very limited in which points it can chose from (generally two, or maximum three, different gears could be considered at the same time and the torque is generally given by the current power requirement). In order to control this in a more precise way a more advanced transmission (e.g. a CVT) and/or an energy storage would be required. The CVT could be used to control the engine speed and the energy storage makes it possible to run the engine at loads higher or lower than the current power requirement.

**The Scania Active Prediction System**

The Scania active prediction system is based on a map-database containing road gradient. The map is matched with the GPS position and a virtual horizon of about 2 km is created in the vehicle control system. Several driving strategies, as for example eco-roll, speed decrease, speed increase, different gear selection patterns, are simulated over the horizon. The resulting speed profiles are checked with respect to maximum and minimum speed, if they stay within the pre-defined speed-window they are classified as ok. In addition, for the gear changing and eco-roll, the results are checked with respect to time on each gear, strategies with too short times on a gear/eco-roll are disqualified. If a strategy/simulation passes through the speed and time check, it is assumed to be valid for execution. The different strategies are prioritized with respect to their fuel efficiency, hence the system

# The basis for overall connectivity within heterogeneous logistics industry: A new platform

## How RIO improves B2B processes, costs and margins

**Rabea Böhme**, MAN Truck & Bus AG, Munich

**Zusammenfassung**

Neue Ansätze zur Vernetzung der Transportwelt rücken zunehmend in den Vordergrund. Mit RIO werden die Weichen für die Logistik der Zukunft gestellt. Denn es ist eine offene, herstellerunabhängige Geschäfts- und Technologieplattform, die individuelle und einzigartig intuitive digitale Services für das gesamte Transport- und Logistik–Ökosystem bereitstellt. Eine solche Connectivity-Plattform muss vier Kriterien genügen, um erfolgreich sein zu können:

(1) Multi-Brand: offen und herstellerunabhängig - vom Fahrzeug- und Aufbauhersteller bis hin zum Software- und Serviceanbieter
(2) Multimodal: alle Verkehrsträger umfassend – Straße, Schiene, Wasser und Luft
(3) Effizient: nicht nur auf Kosteneinsparungen fokussiert, sondern darüber hinaus auch die Ertragsseite der Logistiker stärkend
(4) Integrativ: schafft Nutzen für alle Stakeholder der Branche – angefangen von den Versendern über die Flottenmanager und Disponenten bis hin zu den Fahrern und den Kunden der Kunden

Durch RIO können Unternehmen ihre Logistikprozesse optimieren und ihre Warenströme durch intelligente Vernetzung effizienter steuern. Dabei wird unter anderem auch ein Fokus auf die Entwicklung von Konzepten im Bereich „Predictive Maintenance“ gelegt, in die der Vortrag Einblicke geben soll.

**Abstract**

New approaches how to connect all stakeholders of a supply chain becomes more important. RIO enables logistics to be fit and digital for the future. Because RIO is an open and independent of the vehicle manufacturer business and technology platform which offers individual and unique intuitive digital services for the overall transport and logistics ecosystem. Such a connectivity platform is only successful if the following four criteria are met:

(1) Multi Branding: open and independent of the vehicle manufacturer – starting from vehicle and body manufacturer including software and service provider
(2) Multi modal: encompasses all modes of transports – road, rail, sea and air
(3) Efficient: not only focusing on cost savings but also improves logistics margins
(4) Integrative: delivers benefits to all stakeholders of the industry (forwarder, fleet manager, dispatcher, truck driver and also the customer of the customer)

Companies which are using RIO are able to optimize their logistics processes and steer their material flow much more efficient because of the intelligent connectivity. In our presentation we would like to give more inside in one of the solutions of the RIO platform which is “Predictive Maintenance”.

# Light weight design, manufacture and test results of powder metal gear transmissions

**Anders Flodin**, Höganäs AB, Sweden

**Abstract**

Findings from redesign, building and testing of powder metal (PM) gears in prototype transmissions will be presented. Several transmission rebuild projects have been undertaken during the past 8 years and there has been a lot of knowledge built up in the different aspects of PM gearing. Topics that will be dealt with in this paper is light weight macro design through the unique manufacturing process that PM offers. There are also differences in micro design between steel and PM gears due to the difference in Young's modulus, which will be explained and exemplified.

PM gear manufacturing technology will be discussed. There are several manufacturing steps that can be combined that will lead to different performance levels of the PM gears, this will be touched upon and solid fatigue data presented.

NVH is increasingly important with electrification of vehicles and PM offers some material inherent advantages due to the porosity and test results from a 6 speed manual transmission will be shown.

PM gear wear has also been studied and will be quantified from duty cycle testing in rig as well as from topographic measurements before and after running.

**Keywords:** Powder metal, Sinter, gears, NVH, wear, lightweight design.

Light weight design, manufacture and test results
of powder metal gear transmissions


Presentation overview

Introduction
Powder metal (PM) compaction and tooling
Gear manufacturing using PM
Tolerances achievable
Gear technology making use of PM
M32 transmission project
- Redesign
- Testing

# Additive manufacturing of high strength wear resistant materials

## -3D-printed metals gives new possibilities

Tech. Dr. **Ulrik Beste**, CTO VBN Components AB, Uppsala, Sweden

**Abstract**

The additive manufacturing industry (3D-printing) is growing quickly and are being more and more adapted to specific industrial needs. This presentation will present extremely wear resistant high strength materials made by additive manufacturing. The materials presented are Vibenite®150, Vibenite®280, and Vibenite®350. The materials are PM-based with high carbide content and with a unique combination of wear resistance, strength and toughness. The top material Vibenite®280 has a hardness of over 70 HRC and with the high carbide content, it has been proven to work very well in hobs for machining of gears and other wear applications.

These materials have been developed from the idea that the major possibility with 3D-printing is the *combination* of high wear resistance and complex geometries in near-net-shape (NNS), so that it is possible to choose better materials in a tool or a component without need for soft machining. The presentation will show data of additive manufactured materials and a special highlight on gear cutting tools.

**Highlighted: additive manufactured gear cutting tools**

As one example of an important tool manufactured in Vibenite®280 is gear cutting hobs. The VBN technology is to provide the tool makers with a hardened NNS-blank in extremely wear resistant material for the tool maker to finishing with grinding, see example Fig. 1. Before using it in gear cutting, the hobs are coated. A number of Vibenite® gear cutting tools for heavy trucks have been tested in real production at Volvo, Sweden, and a sum of results from one hob type at Volvo Construction Equipment is presented in Fig. 2. It has been shown that it is possible to increase feed and, also, get much lower edge wear.


Fig. 1. Finished light weight gear cutting hob before coating. In the near hob end, the rest of additive manufactured support structure is seen (grinding not necessary). Material: Vibenite® 280 Optimum 70.

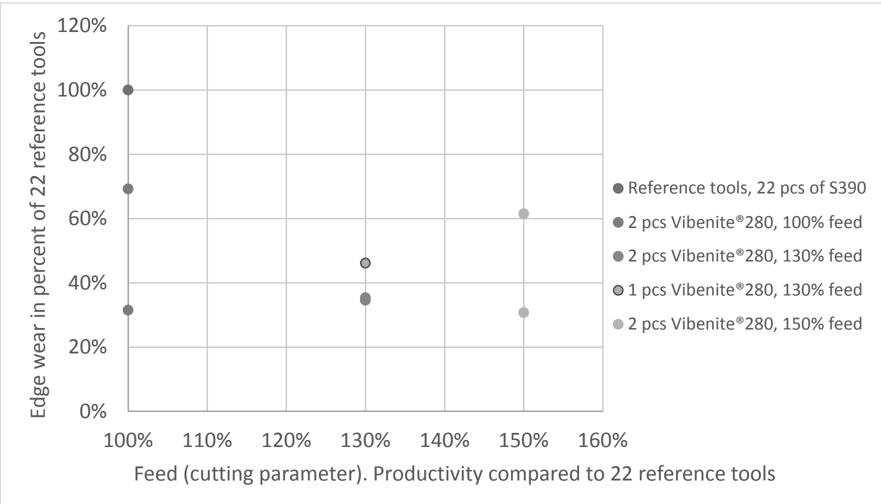



Fig. 2. Wear data of additive manufactured gear cutting hobs in Vibenite®280 Optimum 70. While increasing feed rate for higher productivity, the edge wear is decreased. Optimum is not found yet.

3rd International Conference

Control Solutions for Transmissions 2017

# Elektrifizierung und Vernetzung – Chancen für zukünftige Antriebsarchitekturen

Prof. Dr.-Ing. **Lutz Eckstein**, Institut für Kraftfahrzeuge, RWTH Aachen;
Dr.-Ing. **Manfred Crampen**, Forschungsgesellschaft Kraftfahrwesen mbH Aachen

**Zusammenfassung**

Kraftfahrzeuge mit verbrennungsmotorischem Antrieb haben in ihrer mehr als 100-jährigen Geschichte eine weltweite Verbreitung in allen Sparten erreicht und waren bis vor nicht allzu langer Zeit sehr gut an die Anforderungen der Gesellschaft und der Kunden angepasst. Nun ändern sich diese Anforderungen innerhalb sehr kurzer Zeit aufgrund der global akzeptierten Erkenntnis, dass fossile Rohstoffe und Kraftstoffe endlich und die bei deren Verbrennung entstehenden Emissionen nicht mehr akzeptabel sind.

Auch in der Erdgeschichte finden wir Beispiele, welche Folgen schnelle Veränderungen der Umgebungsbedingungen für den Fortbestand bis dahin erfolgreicher Populationen haben können, wenn Anpassungsprozesse nicht flexibel und schnell genug bewältigt werden: Spezies, die bis dahin nur ein Nischendasein führten, gewinnen die Oberhand oder solche Arten, die schon immer eine schnelle Generationenfolge hatten, behaupten sich.

Die Antriebssysteme von Kraftfahrzeugen erfahren aktuell ebenfalls einen solchen schnellen Wechsel der gesetzten Rahmenbedingungen, so dass die etablierten Hersteller mit ihren etablierten Strukturen und Prozessen sowie ihren spezialisierten Produktionsstätten vor großen Herausforderungen stehen. Auch neue Player aus anderen Brachen werden heute zu ernst zu nehmenden Konkurrenten, aber auch zu potentiellen Kunden.

Der Vortrag analysiert vor diesem Hintergrund die Herausforderungen an die zukünftige Antriebsentwicklung und zeigt auf, in welcher Systematik Antriebsarchitekturen neu gedacht werden können. Es werden Anregungen gegeben, wie die Antriebsentwicklung mit anderen Domänen verknüpft werden kann, um auf Grundlage eines effektiven, durch modernste Simulationswerkzeuge unterstützten Prozesses zu ganzheitlichen neuen Lösungen und letztendlich zu neuen Fahrzeugkonzepten und einem erlebbaren Mehrwert zu gelangen.

# Electrified and Connected – Opportunities for Future Drivetrain Architectures

Prof. Dr.-Ing. **Lutz Eckstein**, Institut für Kraftfahrzeuge, RWTH Aachen;
Dr.-Ing. **Manfred Crampen**, Forschungsgesellschaft Kraftfahrwesen mbH Aachen

**Abstract**

In the course of more than 100 years of history, road vehicles driven by combustion engines have reached a significant global spread in many fields of applications. Until recently, they appeared to be well adapted with regard to the needs and requirements by society and individuals. Currently, these requirements are rapidly changing due to the now globally accepted fact, that fossile ressources and fuels are limited and cause emissions, which are no longer accepted by society.

Looking at the history of earth, we find examples for significant consequences, when boundary conditions rapidly changed and evolution of dominant species was too slow to adapt. Other, until then less relevant species suddenly became more relevant.

Drive trains of road vehicles currently face a similar radical change in boundary conditions and legislation. Consequently, successful manufacturers of established technologies are confronted with the question, what consequences these changes might have with regard to their compentences and investments in production facilities. In addition, players from other domains pick up on automotive technology, forming new competitors but also customers.

This presentation analyses the challenges and requirements concerning future drive train development und proposes a structure, in which innovative topologies and functionalities can be developed. Moreover, stimuli and ideas are presented, how drive train development can be combined with other domains in order to identify and develop revolutionary solutions in an effective development process, which incorporates latest simulation technologies. Finally, this approach will not only lead to innovative drive trains, but to new and exciting vehicle concepts.

# Bond graphs and transmission output torque control during gearshift

## Improved shift quality and reduced calibration effort for automatic transmission control using bond graphs

Dipl. Ing. **Thomas Buchberger**, IMB GmbH, Kirchdorf an der Krems

### *1* Zusammenfassung

Regelkonzepte für aktuelle Seriengetriebe stellen meist die Übergabe des Motormoments zwischen den beteiligten Komponenten und die Regelung des Drehzahlverlaufs in den Vordergrund.

Durch eine geeignete Wahl der zeitlichen Abläufe wird versucht das Ausgangsmoment derart zu beeinflussen, dass sich ein möglichst stetiger Verlauf und eine hohe Schaltqualität ergeben.

Erfolgreiche Konzepte benötigen in der Regel eine hohe Anzahl von Applikationsparametern, die spezifisch für jede einzelne Schaltung eingestellt werden müssen. Insbesondere bei modernen Konzepten mit acht oder mehr Gängen und demzufolge zwischen 40 und 100 Einzelschaltungen geht damit ein erheblicher Aufwand für Software- und Applikationsingenieure einher.

In diesem Bericht wird am Beispiel eines ZF 8HP70 Getriebes ein auf Bond Graphen Modellierung basierendes Regelkonzept vorgestellt, das einen applizierbaren Verlauf des Getriebeausgangsdrehmoments und des Motordrehzahlverlaufs während der gesamten Schaltung erlaubt.

Anforderungen an Hardwarekomponenten und Motoreingriffe sowie deren Abhängigkeiten von physikalischen Eigenschaften des Antriebsstrangs können klar und zum Teil sogar analytisch beschrieben werden.

Dieses Regelkonzept erlaubt es den Applikationsingenieuren die Schaltqualität direkt zu beeinflussen, wobei innerhalb der Grenzen der Getriebe- und Motorhardwarekomponenten das gesamte Spektrum von sportlich bis komfortabel möglich ist.

### *2* Abstract

Shift control strategies for modern automatic transmissions are usually focused on two tasks: Handover of torque between shift elements and speed control.

Additionally a clever design of sequential control and timing is necessary in order to achieve a continuous output torque characteristic and a high shift quality.

Current concepts use a high number of application parameters which are optimized for each single shift.

Especially for modern concepts with 8 or more gears and therefore between 40 to 100 shift variants the effort for software and application engineers is huge.

This report presents a control concept which is based on bond graph modeling and allows a tunable characteristic of output torque during the whole shift. The ZF 8HP70 automatic transmission is used as an example system.

For a predefined shift quality target it is possible to calculate requirements for hardware components and engine intervention.In many cases analytical expressions can be found. Within the limits of the transmission and engine components any characteristic between sportive and comfortable can be achieved.

## 3 Bond graphs and the concept

State of the art development processes use closed loop simulation and rapid prototyping of control systems. With closed loop simulation realistic tests can be done even before hardware components exist. Rapid prototyping for control systems facilitates tests at the real system early in the development process.

It is a legitimate question if and what bond graph models can contribute in addition to the common methods.

The advantage gets clear when considering the normal development process: Simulation and rapid prototyping are used to test control strategies that have been engineered for certain transmissions. If deficiencies are discovered the control strategies are changed and improved.

Rather than doing this it is more efficient to define the desired properties of the shifts such as the shape of output torque or speed and to calculate how the control components have to be operated to achieve the desired result.

Bond graph models produce accurate state space systems and therefore can be used exactly for this purpose. The following pages shall describe this process in detail.

## 4 Introduction to bond graph models for transmissions

Any dynamic physical system has a graphical representation as a bond graph. The bond graph shows the power flow through the system. Each power flow is represented by an arc (arrow).

# Comparison of P2 Hybrid DCT Actuation Control System

## An Evaluation of Integration Complexity, Energy Consumption, and Cost

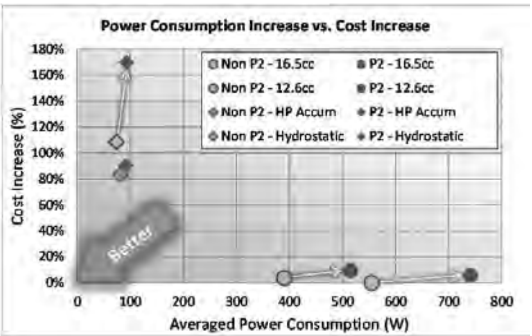
**Mitsuru Ishihara**, BorgWarner, Auburn Hills, USA


### Abstract

Due to the increasing challenges to reduce $CO_2$ emission and fuel consumption, development of more efficient powertrain technology has been one of the key focuses for the automotive industry in recent years. Since the debut of first hybrid powertrain system for mass production vehicle in 1997, various hybrid powertrain systems have been developed as one of the solutions to achieve the $CO_2$ emission target and P2 hybrid system is becoming more popular powertrain solution next to dedicated-hybrid-transmission systems in recent years. This paper will be focusing on value analysis of various P2 hybrid DCT actuation control system from P2 integration complexity, energy consumption, and cost perspectives. In this study a conventional DCT actuation system is used as the baseline and various options for controlling an add-on P2 system are evaluated.


Based on BorgWarner previous study on DCT actuation energy consumption result [1], four systems were selected for this P2 system analysis.  The first system is 16.5cc/rev mechanical pump system.  The second system is employing 12.6cc/rev mechanical pump.  The third system is high pressure accumulator system. The fourth system is hydrostatic system.

In Graph 1 below shows the overall result of this analysis in cost increase and power consumption increase by P2 hybridization.  In order to maximize the value of P2 hybrid system, it is important to develop a non-hybrid DCT system with future P2 hybridization in mind, since the most efficient actuation system for non-hybrid DCT is not the same as the optimal actuation system for P2 hybrid system.

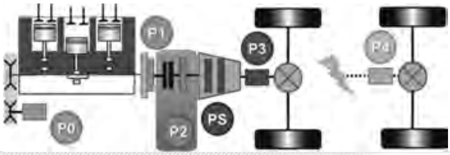



Graph 1: Power Consumption Comparison

[1] Guo, C., Semenov, D., Moser, A., and Spangler, C.: Comparison of DCT Actuation Systems, CTI Symposium, Shanghai 2015

## Introduction

- P2 hybrid architecture is expected to be one of the popular electrification technologies next to Power-split for full hybrid or PHEV
  - Minimize power consumption by transmission
- System cost is the key differentiator to Power-split hybrid architecture
  - Minimize integration complexity and cost by utilizing existing transmission






## Objectives

- Determine power consumption for various P2 Hybrid DCT actuation systems
- Compare P2 Hybrid integration complexity for each actuation system
- Compare integration cost for each actuation system
- Compare the value of P2 Hybrid DCT actuation systems

# Flexible Electronics Integration Platform for future Transmission Applications

Dipl.-Ing. **Markus Weiss**, Dipl.-Ing. **Timo Witzemann**,
Robert Bosch GmbH, Schwieberdingen and Reutlingen

**Zusammenfassung**

In vielen Getrieben kommen integrierte elektronische Steuereinheiten (Elektronikmodule) zum Einsatz. Die Integration der Elektronik in das Getriebe bietet Vorteile hinsichtlich Aufbau und Gewicht, vermeidet zusätzliche Steckverbindungen und Kabeldurchführungen durch die Getriebewand und ermöglicht Qualitätsverbesserungen im Gesamtsystem. Vereinfachungen beim Handling, der Logistik und Prüfbarkeit führen zu Kostenreduzierungen in der Wertschöpfungskette des Getriebeherstellers.

Andererseits stellt die Getriebeintegration besondere Anforderungen an die Elektronik hinsichtlich Temperaturfestigkeit, Vibrationsbeanspruchbarkeit und Medienschutz. Derzeit kommen in Serienapplikationen vorwiegend Technologien zum Einsatz, die zu hohen Einmalkosten führen (z.B. werkzeuggebundene Prozesse mit applikationsspezifischen Geometrien) oder Sondertechnologien im Bereich der Elektronik. Zwar sind diese Technologien beherrscht, jedoch schränken sie aus kommerzieller Sicht den Einsatz von Elektronikmodulen auf Getriebeprojekte mit hohem Volumen und langer Laufzeit ein.

Im Gegensatz dazu erleben wir derzeit im Markt einen Trend zur Diversifizierung bei Verkleinerung der projektspezifischen Volumina. Im vorliegenden Vortrag stellen wir ein Direktverpackungskonzept für Elektronikmodule vor, bei dem die Bauelemente in einem Standardprozess bestückt, kontaktiert und durch ein polymeres Schutzsystem vor den anspruchsvollen Umgebungsbedingungen geschützt werden. Mit diesem innovativen Verfahren kann erstmals auf Sondertechnologien und werkzeug- sowie kavitätsgebundene Prozesse verzichtet werden, ohne Einschränkungen bei der Robustheit der Elektronik für den Einsatzfall der Getriebeintegration hinnehmen zu müssen. Mit dieser neuen Technologie lassen sich Marktsegmente für Elektronikmodule erschließen, für die bisher nur Wegbau- oder Anbau-Steuergeräte zum Einsatz gekommen sind.

**Abstact**

Integrated electronic control units (also known as Electronic Modules) are used in many transmissions. The integration provides advantages regarding the conception and weight of the transmission, reduces the number of connectors and cables through the transmission housing and improves the quality of the system. Reduced complexity regarding handling, logistics and testing offers cost reduction potential in the transmission maker's value chain.

On the other hand, integration of electronics into the transmission increases the requirements for temperature-, vibration- and media resistance. In today's production applications, technologies are used, which lead to significant one-time costs (e.g. processing tools and application specific geometries) or special electronic technologies. Those technologies are proven to fulfill the technical requirements. From a commercial point of view, however, they are limited to high volume transmission projects with long lifetime.

Currently, we see a diversification in drivetrain concepts in the market along with a reduction of corresponding single transmission project volumes. In this article we present a direct packaging concept for electronic modules, where the components are mounted and contacted using standard SMT processes and protected by a polymer protection system. This innovative concept enables, for the first time, to avoid special technologies as well as tool- and cavity- dependent processes, without having limitations to the robustness of the electronics for transmission integrated applications. Hence, based on this concept, market segments are opened for using Electronic Modules, which up to now had been reserved for stand-alone or attached transmission control units only.

# Overall optimization of electrodynamic shifting systems

## Optimization and improvement of the electrical path, mechanical path and control by a new development approach

**Andreas Reul** M.Sc., **Ruben König** M.Sc.,
Prof. Dr.-Ing. **Stephan Rinderknecht**,
Institut für Mechatronische Systeme im Maschinenbau, TU Darmstadt

**Zusammenfassung**

Die Schaltaktorik eines Getriebes hat einen wesentlichen Einfluss auf die Dynamik, die Kosten und den Komfort des Getriebes. Über eine gesamtheitliche Betrachtung der Schaltaktorik ist es möglich Optimierungspotential an der Regelung, der mechanischen und der elektrischen Strecke von elektrodynamischen Schaltaktoriksystemen aufzuzeigen. Dazu werden verschiedene Simulations- und Optimierungsmodelle eingesetzt. Speziell durch einen neuen Optimierungsansatz ist es möglich in einem frühen Stadium des Designprozesses Optimierungsverfahren einzusetzen und für das Design und die Modellbildung zu nutzen. Durch eine detaillierte Betrachtung des Synchronisierungsvorgangs ist es zudem möglich die Dynamik des Schaltvorgangs weiter signifikant zu verbessern. Unterstützt wird dies durch ein modulares und kosteneffizientes Prüfstandskonzept, das den Abgleich von Simulationsergebnissen mit Messerungen ermöglicht. Weiterhin können mit dem Prüfstand Versuche mit Klauenkupplungen durchgeführt werden.

**Abstract**

The internal shifting system of a transmission has a significant influence on the dynamics, costs and comfort of the transmission. A comprehensive study of the shifting system makes it possible to show optimization potentials on the control, the mechanical and the electrical path of electrodynamic shifting systems. Therefore, various simulation and optimization models are used. Especially through a new optimization approach, it is possible to use optimization procedures at an early stage of the design process and to use them for design and modeling. By a detailed consideration of the synchronization process, it is also possible to further significantly improve the dynamics. This is supported by a modular and cost-efficient test rig concept, which makes it easy to compare the results and the models. It is also possible to carry out tests with the test rig using dog clutches.

## Motivation

The internal shifting system of a transmission has a high influence on the dynamics, the costs and the comfort of the transmission. Due to the electrification of powertrains, electro-dynamic shifting systems are becoming more and more important. They are characterized by a less complex and a cost-effective design than electrohydraulic systems. The aim of this work is to simplify the design process by using simulation and optimization models right from the beginning of the process. This results in a shorter design phase, an improved design and a simplified application process. The optimization model pursued a multi-domain approach to take into account interactions between the different domains. The idea is to support the developer and not to replace him.

As reference, a shift drum system from a conventional dual clutch transmission is used. A general formulation is striving to make it easy to apply the models to different shifting systems, like in transmissions without a conventional synchronization with different boundary conditions. For the verification of the results a test rig is used. In this work a very modular and cost effective test rig was designed to test different synchronization strategies and it is also possible to implement different shifting systems.

## Development Approach

In literature, different development approaches for mechatronic systems can be found and serve as a reference [1]–[4]. This work aimed to take into account interactions between the different domains (electric, mechanic and controller). The development method of this work is presented in Fig. 1. Starting from the shift drum system different simulation models were built. For the optimization of the mechanical and the electrical path, a simplified model of the shifting system is used. The detailed model includes a model of the control software which makes it possible to analyze and improve the control strategy in detail. Further, an additional synchronization and drivetrain model is implemented to represent the process.

The models are used to define the design space and the results are used to redefine the models where necessary. As objective function for the optimization, different criteria can be considered. The models are validated by a test rig, which can also be used for the verification of an improved shifting systems. Besides the use of the model for improvements of the shift drum system, especially the optimization method and the test rig is designed to investigate different shifting systems with dog clutches as they may be used in electric vehicles.

The aim of the development approach is to use optimization right at the beginning of the development process by a suitable simplification of the system. This simplification is necessary to reduce the modelling and calculation effort. The benefit is to get a good knowledge of the

# Novel actuation and control for a multi-speed powershifting transmission for electrified vehicles

## Direct acting electromechanical gear engagement

## Angular engagement dog position control

Dr. **Richard Taylor** PhD BEng CEng MIET, Vocis Limited, UK

**4SED Clutchless power-shifting transmission consists of two electric motors, and two separate gear trains with a single final drive**

Vocis and Oerlikon Graziano have together developed a novel, direct-acting electromechanical actuator and applied it to their patented 4 speed clutch-less and synchroniser-less transmission for electric vehicles. In this paper, the application of the actuation technology is described and shown to provide clear benefits in terms of packaging, efficiency and actuation speed by removing the need for more traditional actuation technologies such as hydraulics or motor and barrel cam combinations

**Contactless Electro-Mechanical Actuation (EMA) is used to engage the torque path into one of two gears for each of the electric motors, with simple dog engagement**

The actuation system, which was designed to replace the original mechanism of motor, cam, shift rail and fork with a single electromechanical element acting directly on the engagement sleeve, is described in detail, including early prototype trials of the actuator in isolation and testing of a full transmission system on rig and in-vehicle.

**Angular Control ensures of the dog engagement is precise and largely free of tooth to tooth contact**

One of the benefits of the actuation technology is that it allows for very rapid control of the dog engagement, and Vocis have utilised this characteristic along with novel electronic hardware design, sleeve position control and cutting edge dog angular position control. The result is a multi-speed , power-shifting electric vehicle transmission that is mechanically very simple, compact and light and yet provides seamless powershifting

## Background

**Transmission and driveline demands in an increasingly electrified world....**

- Do I need a multi-speed gearbox at all?
  - We think the answer is yes.........
  - Increasing evidence shows that multi-speed solutions can offer
    - Better pull-away performance
    - Better gradeability
    - Higher efficiency and potential to increase vehicle range
    - .....whilst still keeping overall system cost at competitive levels
- OEMs are soon to release multi-speed gearboxes for hybrids
  - We expect that trend to continue; there will be more of them
- The key demand is a multi-speed gearbox must support seamless shifting
  - Driver must not feel interruption in driveline torque



## 4SED Transmission Concept

- A patented 4-speed powershifting transmission for vehicles with 2 traction motors
- Predicted 15% reduction in energy consumption over NEDC
  - Motors used close to their peak operating efficiency
  - Gearbox with only 2 stage helical mesh and splash lubrication
- Very simple gearbox
- Weight approx. 24kg
- Fully functional design proven and running in demonstrator vehicle
- Different driving strategies for economy and performance
  - 1-motor driving OR 2-motor driving
  - 7 gear combinations
- Improved acceleration and terminal velocity


**EM(x2):** 75Nm, 35kW, 15,000rpm

# Innovative dog clutch actuator with integrated sensor function for 48V ZF hybrid drives

## How an electromagnetic actuated dog clutch with “sensorless” position detection meets the requirements of P2 mild-hybrids with maximum efficiency and optimized packaging

**Martin Ruider**, Dr.-Ing. **Johannes Winkler**,
ZF Friedrichshafen AG, Friedrichshafen;
**Markus Heiartz**, ZF Friedrichshafen AG, München

**Zusammenfassung**

Mit zunehmenden Anforderungen an die Energieeffizienz von Kraftfahrzeugen und der Reduktion lokaler Emissionen in Ballungsräumen kommt hybriden Antriebskonzepten eine immer größere Bedeutung zu. In diesem Zuge wurde bei ZF ein Mild-Hybridmodul auf Basis 48V entwickelt, welches zwischen Verbrennungsmotor und Getriebe platziert werden kann. Es beinhaltet neben einer elektrischen Maschine eine vollintegrierte Ansteuerelektronik und eine elektromagnetisch betätigte Klauenkupplung. Diese ermöglicht das Abkoppeln des Verbrennungsmotors (P2-Konfiguration) und damit ein effizientes rein elektrisches Fahren sowie Segeln.

Die Präsentation beschreibt zunächst die Ansprüche an die zu realisierende Trennfunktion hinsichtlich Dynamik, Packaging und Effizienz. Die Erfüllung der in Wechselwirkung stehenden Anforderungen mittels modellbasierter Entwicklung des elektromagnetischen Aktors und der Klauenkupplung wird beleuchtet. Darüber hinaus wird auf die funktionale Integration eines „sensorlosen“ Positionsrekonstruktionsverfahrens eingegangen. Die Optimierung der Schaltdynamik sowie die Implementierung neuer Ansteuerfunktionen bilden den Abschluss.

**Abstract**

Concepts for hybrid drives becomes more and more important because of increasing requirements on the efficiency of vehicles and the reduction of local emissions in metropolitan areas. Therefore a mild-hybrid module based on 48V was developed by ZF, which can be placed between the internal combustion and the gearbox. An electric machine with fully integrated control electronics and also an electromagnetically actuated dog clutch

are included. This allows the disengaging of the internal combustion engine (P2 configuration) and thus a efficient purely electric driving and coasting.

The presentation first describes the demands of the disconnect function to be implemented with regard to dynamics, packaging and efficiency. The fulfillment of the interacting requirements using model-based development of the electromagnetic actuator and the dog clutch are illustrated. In addition, the functional integration of a "sensorless" positioning measurement method is discussed. The presentation concludes with the optimization of the shifting dynamics and the implementation of new control functions.

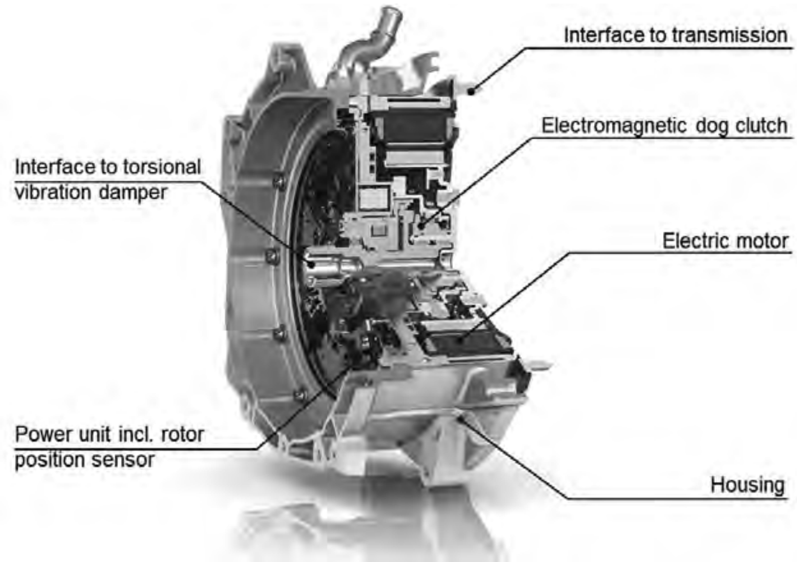



Bild 33: Schnittdarstellung des 48V Mild-Hybrid Systems von ZF mit elektromagnetischer Klauenkupplung und integriertem Positionsmessverfahren

[1] M. Ruider, M. Heiartz, F. Weinl: Implementation of a "sensorless" position measurement method for dog clutch actuators in 48V ZF hybrid drives. Presentation: ELIV: ELectronics In Vehicles, ZF Friedrichshafen, Bonn, 2017

[2] Pawelczak, D.: Nutzung inhärenter Messeffekte von Aktoren und Methoden zur sensorlosen Positionsmessung im Betrieb. Doktorarbeit, Univ. der Bundeswehr, Aachen and München, 2005

# Innovative Measurement and Calibration solution for Transmission ECU‘s

Dipl.-Ing. (FH) **Alfred Kless**, Vector Informatik, Stuttgart


## Zusammenfassung

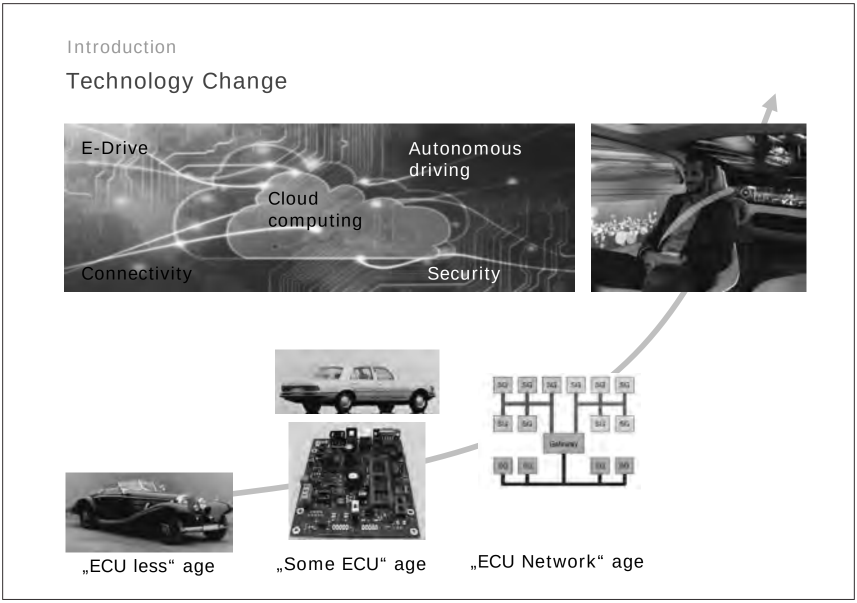
Fünf Themen werden in der Präsentation behandelt:

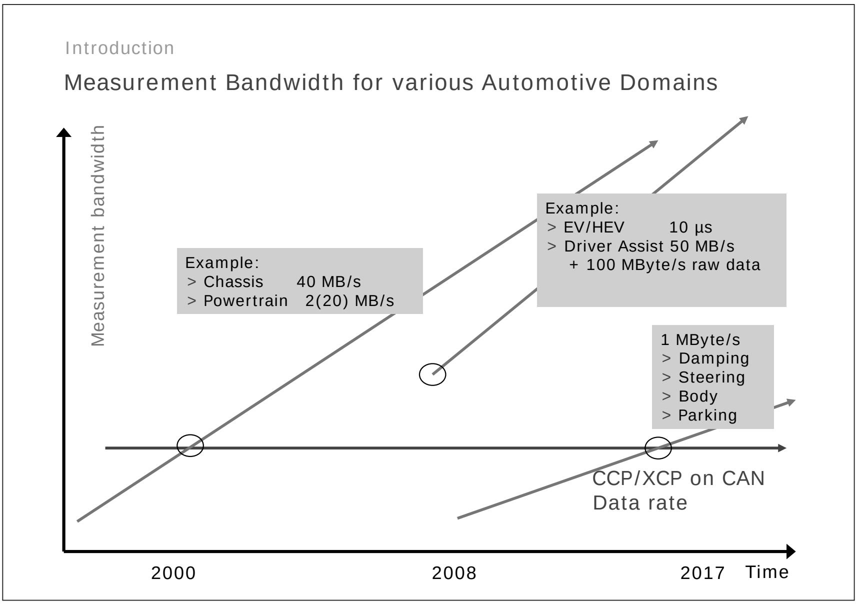
1) Einzigartige High-Speed Messtechniklösung für Getriebesteuergeräte in Ölsumpf.
2) Spezielle Messtechnikanforderungen von Hybrid / E-Drive Inverter ECU’s
   z.B. Messung von ECU internen Signalen mit sehr hohen Abtastraten ( kleiner als 10 µs/100 kHz )
3) ASAM Standardisierungsanpassungen für das Tool Interworking von Mess- und Kalibrier Hardware und Software von verschiedenen Toolanbietern.
   3.1 Neuer ASAM POD Standard: Standardisierung des notwendigen ECU Treibers für Mess- und Kalibierhardware.
   3.2 Erweiterungen des bestehenden XCP Standard => XCP V1.4
4) Komfortable, teamübergreifende Parameterabstimmung
5) Automatisierte Getriebe-Messdatenauswertung

## Abstract

Five aspects will be handled in the presentation:

1) Unique high speed measurement solution for Transmission ECU in the oil pan
2) Special measurement requirements of Hybrid / E-Drive Inverter ECU
   I.e. Measurement of ECU internal signals with extreme fast sampling rates (less than 10µs/100 kHz sample rates)
3) ASAM Standardization impact for tool Interworking of Calibration Hardware with Calibration Software from different Tool supplier
   3.1 New ASAM POD Standard: Standardization of necessary ECU software driver for Calibration-HW.
   3.2 Extension of the existing XCP Standard => XCP V1.4
4) Comfortable team-wide parameter adjustment based on cloud technology
5) Automated transmission data analysis


Introduction
Technology Change
E-Drive
Autonomous driving
Cloud computing
Connectivity
Security
„ECU less“ age
„Some ECU“ age
„ECU Network“ age


Introduction
Measurement Bandwidth for various Automotive Domains
Measurement bandwidth
Example:
> Chassis 40 MB/s
> Powertrain 2(20) MB/s
Example:
> EV/HEV 10 µs
> Driver Assist 50 MB/s
+ 100 MByte/s raw data
1 MByte/s
> Damping
> Steering
> Body
> Parking
CCP/XCP on CAN
Data rate
2000
2008
2017
Time

# Modelling, Simulation and Optimisation in the Development of Transmission Control Units

Prof. **Clemens Gühmann**, TU Berlin, Berlin;
Dr. **Hua Huang**, Schaeffler Technologies AG, Herzogenaurach;
Dr. **René Knoblich**, IAV GmbH, Berlin

## Abstract

To show the effectiveness of the model-based development of transmission control units, the gearshift calibration of an automated manual transmission is chosen as example. The shift quality calibration is typically performed in real vehicles on the road, where the calibration engineer has to try different control parameters till the subjective assessment on the shift quality meets certain requirements, such as shifting comfort or sportiness. However, compared with today's multiplying number of variants in vehicle-engine-transmission combinations and exponential growth of control parameters, this traditional method is backward and costly. In contrast to the conventional development shift quality calibration, the presented method uses a closed loop approach based on a dynamic model instead of human know-how. In the first step, a non-linear dynamic transmission model is built to describe the transient behavior during gear shifting in detail. Black box, grey box and white box models are combined and with the help of a test bench parametrised. Afterwards, the hydro-mechanical synchronisation system is used as an example, and a position trajectory based shift quality optimisation process is presented.

Um die Effektivität des modell-gestützten Entwicklungsprozesses für Getriebesteuergeräte zu verdeutlichen, wird als Beispiel die Kalibrierung des Gangeinlegens eines AMTs gewählt. Der Kalibrierungssprozess wird in der Regel im Fahrzeugversuch auf der Straße durchgeführt. Der Kalibrierungssingenieur versucht unter diesen nicht reproduzierbaren Bedingungen verschiedene Steuerparameter zu adaptieren. Dies wird für eine Schaltung solange durchgeführt, bis die subjektive Beurteilung der Schaltqualität und die zugehörigen Eigenschaften, wie zum Beispiel Schaltkomfort und Sportlichkeit, erfüllt sind. Dieser beschriebene Prozess ist zeit- und personalaufwendig, was mit dem aktuellen Angebot an Fahrzeug-Motor-Getriebevarianten kaum bewältigt werden kann. Im Gegensatz zu der herkömmlich auf Fahrversuche basierenden Kalibrierung der Schaltqualität verwendet dieses neue Verfahren ein dynamisches Modell in einer geschlossenen Schleife. Im ersten Schritt wird ein dynamisches nichtlineares Simulationsmodell vorgestellt, das eine Kombination aus White-Box-, Grey-Box- und Black-Box-Modellen ist. Anschließend wird für ein hydro-mechanisches Synchronisationssystem die Schaltqualität optimal abgestimmt.

## Outline
Modelling, Simulation and Optimisation



## Motivation and Development Process
TCU Development

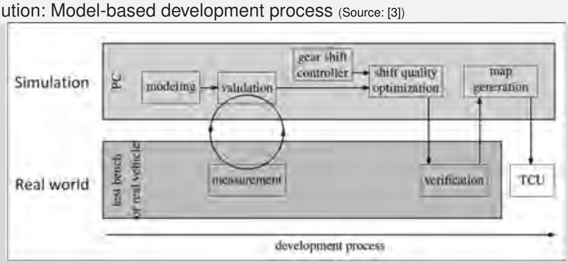
**Development of TCUs**

- Development of Control-Algorithms
- Optimisation and Calibration
- Software and function test

**Problems**

- Availability of prototype vehicles
- Optimisation needs time
- ... your problems?

**Solution: Model-based development process** (Source: [3])



# Actuation Synthesis for New Hybrid Transmission Application (DHT)

Dipl.-Ing. (TU) **André Uhle**, IAV GmbH, Stollberg

## Abstract

The growing number of technically diverse actuation systems as well as their ever greater functional integration in the course of electrifying vehicle powertrains significantly increases the complexity involved in selecting a suitable transmission actuation system.

A newly developed, consistent simulation method makes it possible to analyze, evaluate and optimize transmission actuation systems in relation to efficiency, package, costs and shifting characteristics as early as the advance engineering process.

This method is based on systematically varying the parameters of shifting systems as a way of optimizing their design and adapting them to suit the specific application. By linking transient 1D shift simulation with a simulation of longitudinal dynamics, information can also be gathered on the potential provided by different actuation systems to reduce $CO_2$ emissions in specific vehicle and driving cycle applications.

By way of example, the process is described using a specific vehicle application with hybridized dual-clutch transmission. The results make it possible to draw conclusions regarding the suitability of various electromechanical actuation systems and permit direct comparison with hydraulic systems.

Taking numerous influencing parameters into consideration, the method described in this paper can make a significant contribution to optimizing transmission shifting systems while at the same appreciably reducing development time and costs.

# 1 Motivation

Automated transmissions use a wide range of different systems for actuating clutches and gear selectors. Beside the classic hydraulic systems, diverse electromechanical and decentralized electrohydraulic systems have come onto the market in the last ten years.

One reason for this new diversity lies in the greater number of functions performed by modern actuation systems. Through transmission hybridization, the classic functions of gear and clutch actuation, lubrication and clutch cooling are being joined by additional cooling and shifting functions for integrated electric traction motors and disconnecting clutches. A further reason is found in the tougher legal demands being made on efficiency which are hard to meet with classic hydraulic transmission control systems.

The broad diversity within the group of electromechanical actuation systems as well as the tighter requirements profile is making it more complicated to select a suitable gearshift actuation system. A large number of influencing factors must be taken into consideration. The type and number of gear-shifting elements, the available package, the shifting time demanded, the different amounts of energy systems consume and the different on-board voltage levels in the vehicle are just a few of these influencing variables.

Against this backdrop, the paper also presents a new systematic simulation method for selecting and optimizing electromechanical shifting systems in vehicle transmissions. This consistent technical development process is intended to take account of ever shorter development times as well as higher demands on quality and cost in developing gear-shifting concepts. In this context, electromechanical selectors can be analyzed, evaluated and optimized with regard to efficiency, package, shifting time and cost as early as the advance engineering process. This provides the basis for comparing systems objectively.

# Design of a hybrid mode and shift coordinator [hmsc] for the central control software of a range extender powertrain

**Mubin Bhai**, **Xianghui Shen**,
MBTech Group GmbH & Co. KGaA, Fellbach

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

KEYWORDS – gear shifts, hybrid mode changes, hybrid powertrain, powered shifts

ABSTRACT

The two electric traction machines parallel-series range extender (DE-REX) is an innovative powertrain which comprises a DHT [1] with two parallel sub-transmissions. Each electric traction machine is coupled to a two-speed sub-transmission and their torque is aggregated at the final drive.
The electric traction machines perform speed synchronisation during gear shifts and hybrid mode changes. Due to this, it is possible to replace all friction clutches or synchronizers with dog clutches. For this project, the central functional control software is being developed on a rapid prototyping platform. The control software (SW) will be tested using a prototype transmission and electric traction machines on a powertrain test bench and a demo vehicle. The HMSC, which is a key component of the central control SW, will be the focus of this paper.

TECHNICAL PAPER

## 1. TWO-DRIVE-TRANSMISSION

DE-REX is a publicly funded research project for the development of the powertrain concept "Two-Drive-Transmission (TDT)". This transmission consists of two sub-transmissions (STM) and two identical small electric machines with a maximum power output of 48 kW. Each sub-transmission is a two-stage automated manual transmission (AMT) and is driven by one electric machine (EM). The 3-cylinder turbocharged 65 kW ICE can be coupled with powertrain through the separator clutch C0. The tooth couplings/dog clutches are utilized as shifting elements, instead of the friction elements (e.g. friction clutch or synchronizer ring), and are actuated by a shifting system based on AMT-technology (electromechanical driven shift drum). Furthermore, by engaging two gears within one STM, the transmission is mechanically locked, which fulfills the role of the parking lock. The DE-REX combines the advantages of parallel hybrid architectures of plug-in hybrid electric vehicles (PHEV), as well as the advantages of series hybrid architectures, as found in extended-range electric vehicles (EREV). Figure1 shows a schematic representation of the DE-REX powertrain.

However an AMT has the disadvantage of torque interruption during gear shifting. This disadvantage of the AMT-technology can be compensated for with the DE-REX powertrain, since one of the two sub-transmissions is always engaged. During the gear shifting of the other STM, the coupled STM provides driving torque, in order to eliminate the torque interruption.

The DE-REX aims to boost the efficiency of the powertrain, by maintaining  the ICE and EMs in their optimal efficiency range.With increasing market of hybrid and pure electrical powertranis DE-REX is beneficial powertrain concept with respect to efficency, cost, package and weight. The scope of this paper is to discuss the shift and modi change algorithm rather than substantiating the efficieny claims.

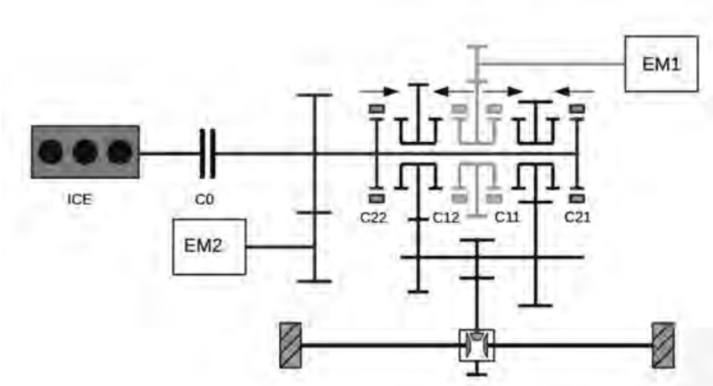


Figure 1: DE-REX Powertrain Structure

## 1.1 Overview of the Driving Modes

The DE-REX concept offers a variety of driving modes in both pure electric drive and hybrid drive (Figure 2). During electric drive, the vehicle can be driven by one EM or both EMs at the same time. The gear in one STM can be selected  independently of the other. Three modes can be distinguished in hybrid drive. There are two parallel hybrid driving modes in which the ICE can be combined with one or two EMs to drive the vehicle. The third hybrid mode is a series hybrid, that is EM1 drives the vehicle, ICE and EM2 generate electrical energy. All driving modes will be discussed in detail in chapter 3.

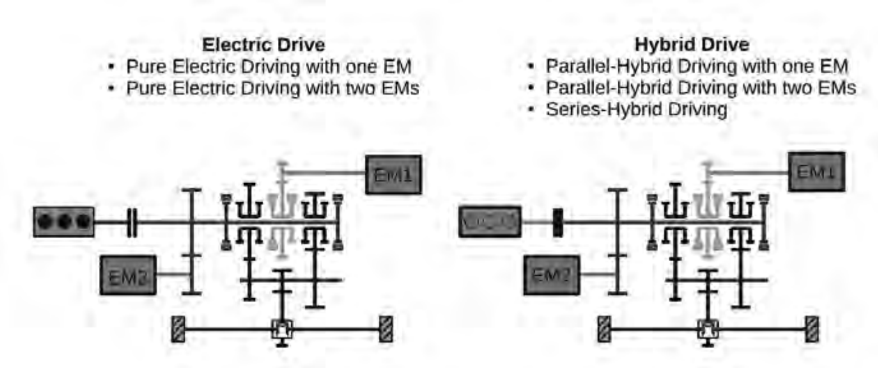


Figure 2: Driving Modes of DE-REX

# The Audi 48V Mild Hybrid

## System integration with maximum customer benefit

**Walter Galli**, Dipl.-Ing. **Josef Bast**, Dipl.-Ing.(FH) **Oguz Eksi**,
Audi AG, Ingolstadt

**Zusammenfassung**

Die Elektrifizierung des Antriebsstrang bietet eine Reihe von neuen Funktionen und Vorteilen für den Kunden. Mit der 48V Spannungslage ist es möglich durch ein hervorragendes Kosten/Nutzen Verhältnis diese Eigenschaften für jeden Audi-Fahrer erlebbar zu machen. Die kompakte Bauart der Komponenten und die optimale Systemintegration in die bereits existierenden Antriebsstränge und Fahrzeuge stellen die gewohnte Nutzbarkeit des Fahrzeugs bei vollem Funktionsumfang eines Mild Hybriden sicher.

Oberstes Entwicklungsziel ist die hohe Verfügbarkeit des Systems, kombiniert mit möglichst geringem Aufwand. Erreicht wird dies durch die optimale Ausnutzung der verwendeten Komponenten mittels ausgefeilter Funktionen. Zu den Funktionen im Antriebsstrang ist das leistungsfähige 48V Bordnetz der Garant für die Absicherung des Fahrzeugs mit elektrischer Energie und die Basis für weitere neue Systeme im Fahrwerks- und Komfortbereich.

Mit der Funktion Freilauf-Motor-Aus, auch als emissionsfreies Segeln bezeichnet, ist der Verbrauchsvorteil vor Kunde wesentlich größer als durch die bekannten Zyklen ausgewiesen wird. Kombiniert mit den Prädiktiven Assistenzsystemen von Audi werden signifikante Verbrauchsvorteile erreicht und der Fahrkomfort gesteigert. Der Rollout wird mit dem neuen Audi A8 der 5. Generation gestartet und auf die folgenden Fahrzeugbaureihen übertragen.

**Abstract**

Electrification of the powertrain offers a number of new functions and benefits for customers. With the 48V system, it is possible to deliver those attributes to every Audi driver based on an outstanding cost/benefit ratio. The compact component design and optimal system integration into existing powertrains and vehicles assure the accustomed vehicle usability allied to the full functionality of a Mild Hybrid.

The primary development goal is a high level of system availability, combined with the lowest possible expense. This is achieved by optimal utilisation of components based on high-tech functionality. The powerful 48V on-board system assures electric power supply to the vehicle's powertrain functions, and provides the basis for further new suspension and comfort related systems.

The zero-emission engine-off coasting function means the benefit to customers in terms of consumption is much greater than based on the familiar cycles. Combined with Audi's predictive assistance systems, significant consumption benefits are achieved and ride comfort is enhanced. The roll-out will begin with the new fifth- generation Audi A8, and continue through subsequent models.

## 1. Influencing factors and motivation behind electrification

The challenges in vehicle development are subject to a wide variety of influencing factors. In terms of legal requirements, the prime drivers of electrification are the CO2 targets set by different countries, as well as the need to comply with stringent emissions limits. The competitive environment, with its new players, is a strong motivating force and serves as an incentive to maintain Audi's technology edge in keeping with its "Vorsprung durch Technik" motto. Another key factor is the usability of the systems in as many different platforms and drive system variants as possible. This will ensure their broadest possible application.

The most important criterion, however, is customer satisfaction. The 48V system enables new functions to be generated and also provides a sound basis for additional systems to build on in the future. A feature of the 48V Mild Hybrid is that it is capable of contributing to all those tasks. The sum of the individual system benefits makes it financially viable to install this infrastructure across the board in all vehicles.


Fig. 1: Influencing factors and motivation behind electrification

# Influence of electric drive systems and their control on the NVH behavior of hybrid and electric vehicles

Dr. **Marco Falco**, CEO, hofer eds GmbH, Würzburg


## Zusammenfassung

Ein gutes NVH-Verhalten ist mitentscheidend für die Marktdurchdringung von Hybrid- und Elektrofahrzeugen. In konventionellen Fahrzeugen sind die „Mechanismen“ bezüglich NVH hinreichend bekannt. Bei Hybrid- und Elektrofahrzeugen kommt mit dem elektrischen Antrieb jedoch eine neue, hochdynamische Drehmomentquelle hinzu, die das NVH-Verhalten unter Umständen ungünstig beeinflussen kann, was z.B. unter anderem zu Schwingungen beim Anfahren oder bei Lastwechseln führt. Damit bildet der elektrische Antrieb in Hybrid- und Elektrofahrzeugen eine weitere Quelle für mögliche Schwingungsanregungen und ist somit bei der Optimierung des NVH-Verhaltens nicht zu vernachlässigen. Denn letztendlich fungiert auch der elektrische Antrieb als überlagerte Störungsquelle für mechanische Schwingungen im Antriebsstrang. Elektrische Antriebe setzen eine Einspeisung mit variabler elektrischer Frequenz voraus. Durch die Oberwelleneigenschaften der elektrischen Maschine im elektrifizierten Antriebsstrang und deren Ansteuerung mit variabler Frequenz ergibt sich an deren Welle eine prinzipbedingte Drehmomentwelligkeit. Besonders die Regelung/ Ansteuerung der elektrischen Maschine zusammen mit dem Maschinen-Design/Topologie hat maßgeblichen Einfluss auf das NVH-Verhalten von Hybrid- und Elektrofahrzeugen. Ferner tragen auch Abweichungen in den Istgrößen der Regelung, hervorgerufen durch Ungenauigkeiten und Messfehler von eingesetzten Sensoren, maßgeblich zur Drehmomentwelligkeit der elektrischen Maschine bei. Im Rahmen dieses Fachbeitrages werden diese Zusammenhänge detailliert erklärt und anhand von Beispielen und Messungen interpretiert. Darüber hinaus werden Lösungen und Abhilfemaßnahmen an bereits vorhandenen Antrieben vorgestellt sowie neue Lösungsansätze mittels Kompensationsalgorithmen und Lernalgorithmen zur Verbesserung des NVH-Verhaltens präsentiert.

## Abstract

A good NVH performance is crucial for the market penetration of hybrid and electric vehicles. In conventional vehicles, the "mechanisms" regarding NVH are known sufficiently. The electric drive used in hybrid and electric vehicles, adds a new high dynamic torque source which also can affect the NVH performance leading to vibrations during start-up or

during load changes. Thus, the electric drive is a further source of possible vibrational excitations in hybrid and electric vehicles and therefore cannot be neglected in the optimization process of the NVH behavior. Finally the electric drive also acts as superimposed disturbance source for mechanical vibrations in the drive train. Electric drives require an electrical supply with variable amplitude and frequency. Due to the harmonic characteristics of the electric machine and the used control with variable frequency, a torque ripple at the shaft of the electric machine results by physics. Especially the control of the electric machine in combination with its technology and topology has significant influence on the NVH behavior of hybrid and electric vehicles. Furthermore, deviations of sensor signals used as control reference of those variable frequencies and amplitudes play an important role regarding erroneous torque ripple at the shaft of the electric machine. In this article, these physical relationships are explained in detail and interpreted by means of practical examples and real measurements. Some solutions and remedial actions are shown to existing electrical drives and new approaches to improve the NVH performance using compensation algorithms and adaptive control methods are introduced.

# Power Electronics for Electric Drives in Power Train Applications

## Leistungselektronik für elektrische Antriebe am Antriebsstrang

Dipl.-Ing.(FH) **Hans-Peter Feustel**,
Conti Temic microelectronic GmbH, Nürnberg

**Zusammenfassung**

Leistungselektronik für elektrische Antriebe für Hybrid- und Elektroantriebe unterscheidet sich von solchen im allgemeinen Industriebereich vor allem in 2 Anforderungen, den Umgebungsbedingungen und der Leistungsdichte. Der Einbauort, meist direkt an Elektromotor und Getriebe, zwingt zu äußerst kompaktem Aufbau und hoher Ausnutzung der leistungselektronischen Komponenten.

Das Steuerverfahren zur Regelung der elektrischen Maschine ist das Prinzip der feldorientierten Regelung und wird hier kurz dargestellt. Steuerungstechnische Maßnahmen wie Sternpunktverschiebung und Flat-Top-Control sind zusätzliche Maßnahmen zur Erhöhung der Ausgangsleistung.

Einen besonders wichtigen Anteil zur Erreichung der Leistungsdichte hat der Aufbau des Leistungsteils sowie die Ausführung der Kühlung.

Zum Abschluss des Vortrags erfolgt ein Ausblick auf sich abzeichnende Trends.

**Abstract**

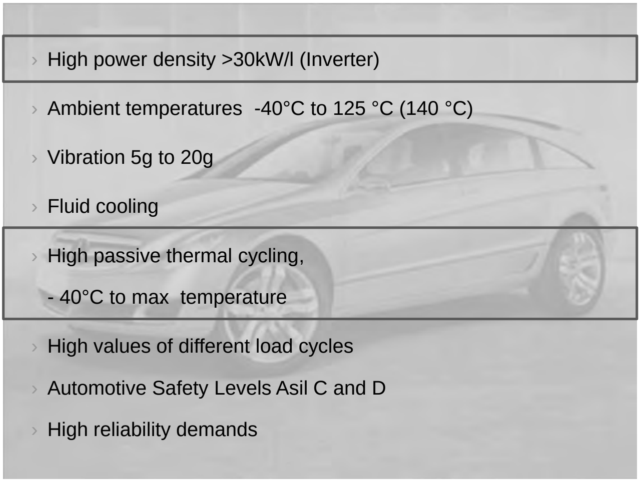
Power Electronics for electric propulsion in hybrid and electric vehicles are different to in**v**erters in industry applications. The main differences are the required ambient conditions and power density. The mounting place, normally direct at the electric motor and gear box, requires an extremely compact assembly concept and a maximum utilization of the power components.

The control method to control an electric motor is the field-oriented control principle. Control techniques like star point shift and flat top control are additional measurements to increase the output power.

.A huge influence to achieve the high power density is given by the assembly concept of the power stage and also the cooling.

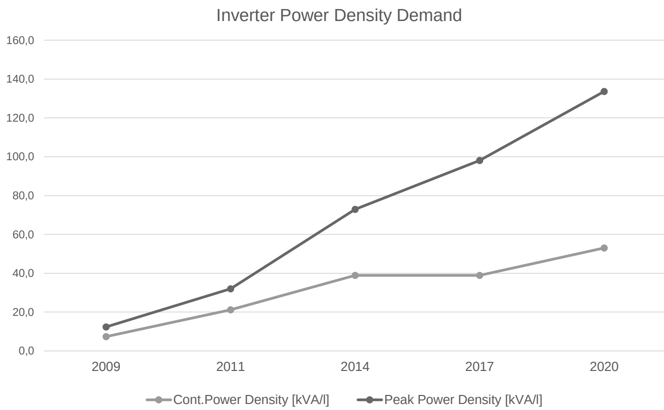
At the end of the presentation, we will look at emerging trends.

## Technical Requirements HEV and EV Electronics



- High power density >30kW/l (Inverter)
- Ambient temperatures -40°C to 125 °C (140 °C)
- Vibration 5g to 20g
- Fluid cooling
- High passive thermal cycling,
  - 40°C to max temperature
- High values of different load cycles
- Automotive Safety Levels Asil C and D
- High reliability demands

## Technical Requirements HEV and EV Electronics
### Increase in Inverter Power Density Demand




Source: Continental

# Generic Control Approach for Multimode-Hybrid Transmissions

## Using a Virtual Dual Clutch Framework

**Alexander Lampe**, Dr. **Uwe Mettin**, IAV GmbH, Berlin

**Zusammenfassung**

Der Trend zur Elektrifizierung des Antriebsstrangs wirkt sich stark auf die Konzept- und Variantenvielfalt von Fahrzeuggetrieben aus. Neben der Entwicklung von reinen Parallelhybriden und eCVTs geht der Trend hin zur Verschmelzung beider Getriebekonzepte zu sogenannten Multimode Hybridgetrieben, um die Vorteile beider Systemansätze zu nutzen. Die erhöhte Funktionalität wirkt sich auch auf die Komplexität der Getriebesteuerung aus, weil anstelle der reinen Kupplungssteuerung ein ganzheitlicher Ansatz zur Steuerung von Getriebe und mehreren Antriebseinheiten nötig ist, um Effizienz und Komfort zu gewährleisten.

Typischerweise werden im Frühstadium der Entwicklung spezifischer Ansteuerungskonzepte und Konstruktion vereinfachende Annahmen getroffen, bei denen vor allem die dynamischen Rahmenbedingungen für lastschaltende Multimodewechsel keine Berücksichtigung finden. Somit ergeben sich Entwicklungsunsicherheiten und Risiken hinsichtlich des zu erwartenden Leistungsvermögens des Hybridgetriebes im Fahrbetrieb.

Als Lösung für die steigende Variantenvielfalt und durch die Hybridisierung einhergehende Systemkomplexität stellt IAV einen generischen Steuerungsansatz vor, der alle gängigen Getriebevarianten und Hybridisierungsgrade abdeckt. Der Ansatz basiert darauf, dass jedes Getriebe in eine (erweiterte) virtuelle Doppelkupplungsstruktur überführt werden kann. Dies ermöglicht nicht nur die Anwendung der Steuerungsalgorithmen für beliebige Getriebetypen, sondern erleichtert auch die Entwicklung und Wartung aufgrund der Reduzierung der Systemkomplexität. Die Präsentation stellt den generischen Ansatz für die Elektrifizierung eines konventionellen Stufenautomaten beispielhaft dar. Hierbei wird deutlich, wie sich aus der Kontrollstruktur einer reinen Kupplungssteuerung eine ganzheitliche Steuerung der Quellenmomente und Schaltelemente entwickelt.

**Abstract**

Nowadays, the technological evolution of vehicle transmissions shows an increase of variants and concepts mostly due to electrification. Besides the development of transmissions with pure Parallel Hybrid or eCVT functionality the trend is to merge these concepts to take advantage of their beneficial characteristics. These often called Multimode-Transmissions offer high functionality but also require a sophisticated software which provides the algorithms to control all actuators and multiple power sources simultaneously to perform efficient and seamless shifts.

Hence, the development of control algorithms for such advanced transmission concepts is a very complex task and therefore very cost and time intensive. That is why, early stage transmission design is typically based on simplified considerations for control analysis and construction which do not take into account complex operating scenarios such as various kinds of mode shifts under power shift constraints. This increases uncertainties and investment risk with respect to the expected system performance in real application.

In this presentation IAV provides an approach for a generic shift control strategy of conventional and electrified transmissions with multiple modes. This enables detailed simulative investigations of early stage transmission concepts and provides rapid prototyping software that decreases the overall effort in the development process of real applications. This is obtained by transforming the physical model of a transmission into a virtual Dual Clutch Transmission (DCT). Based on this virtual DCT framework the control algorithms are implemented such that they are independent of the real system complexity. Consequently, the control strategy is generic for various transmission structures including multiple power sources. The presentation shows the evolution of the generic approach starting with power shift handling of conventional transmissions. Based on that, the concept can be easily extended for electrified (multimode) transmissions like Parallel Hybrids, dedicated hybrid transmissions (DHT) and eCVT. An illustrative example will be presented that shows the capability of the generic approach starting with a conventional transmission and ending up with a multimode transmission by gradually adding hybrid functionality obtained through electrification options.