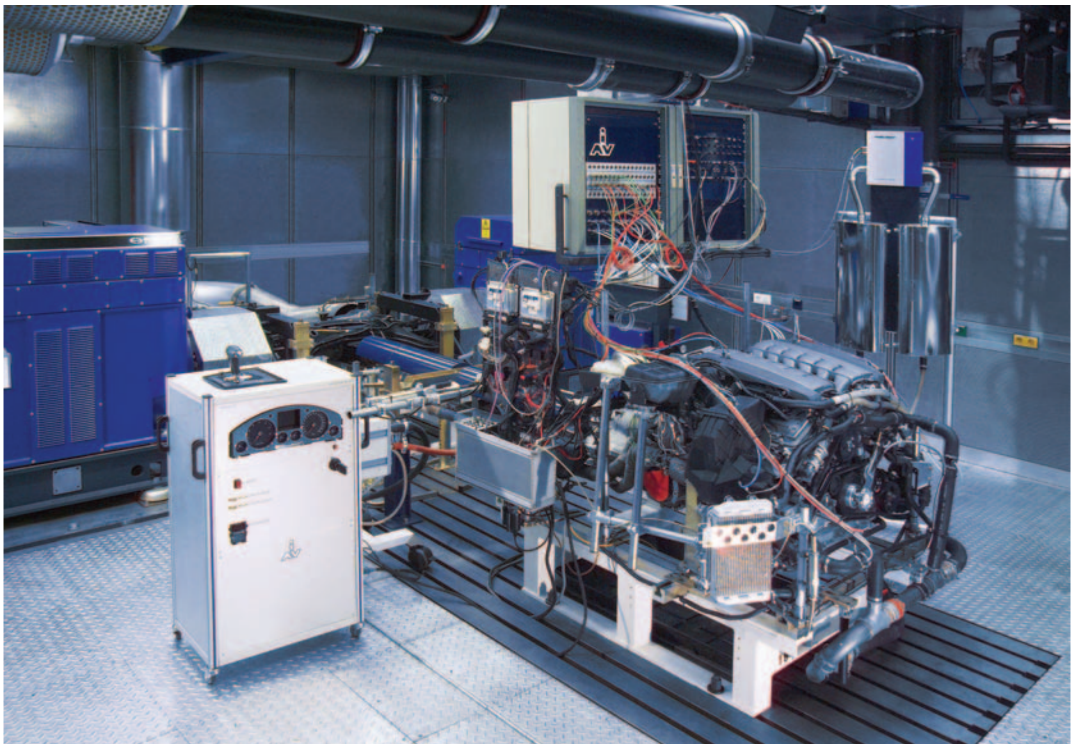
automotion

EDITION 2 | 2007 | IAV – AUTOMOTIVE ENGINEERING

IAV's new North American Powertrain Test Facility

Opening in 2008

by Utz-Jens Beister



Being focused on advanced powertrain engineering, IAV understands the challenges customers face when developing and refining powertrains that meet strict industry requirements. In order to become a full service provider to US customers, IAV is investing in a new 40,000-square-foot Powertrain Test Facility in Northville Township, MI, which will open in 2008.

The new state-of-the-art Powertrain Test Facility will house test and measurement equipment to fulfill the demands of today's increasingly complex gasoline, diesel and hybrid powertrain systems. The facility will be equipped with four engine dynamometers with full transient emissions capability. Two units will be used for light-duty engines, a third will be designated for heavy-duty diesels, and the fourth will be reserved for hybrid drivetrain applications. The Powertrain Test Facility will meet customers' needs related to:

- Combustion development and analysis
- Fuel economy and performance
- Reduction of exhaust emissions
- On Board Diagnostic (OBD) strategy development
- Hybrid strategy investigation
- Automated engine mapping, utilizing IAV's advanced techniques
- Design of Experiments (DoE) methodology
- Aftertreatment systems
- Development of engine components
- Injection system enhancements
- Cold start improvement
- Engine benchmarking
- Refinements to cooling and lubrication systems
- Noise Vibration and Harshness (NVH) development
- Certification

IAV's highly trained technical staff is helping OEM's to develop and refine powertrains which meet strict industry standards.

The equipment can measure powertrains with performance levels from 450 - 875 hp, torque from 510 - 2,580 lb.ft. within 0.3% accuracy over the full operating range, and up to 10,000 RPM. Sophisticated automation software including IAV MPI², IAV Velodyn, AVL PUMA Open 1.4.1 allow the test cells to operate unmanned and efficiently around the clock.

Additional features will include:

- DDC controlled utility systems
- Circulating air technology
- Continuous operation at constant controlled cell temperature
- Automated fire detection and extinguishing system
- Inlet air temperature and humidity control (variable)
- Controlled coolant, fuel and oil temperatures

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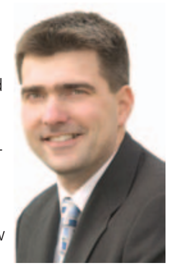
Editorial



Dear Readers,

As the 2007 year end approaches, I would like to provide an update on our engineering activities and on our new Technical Center in North America with this new issue of **auto**motion.

Sharply rising fuel prices and the objective to reduce CO_2 emissions continue to drive the development of fuel efficient powertrains and emphasize the need for suitable alternative propulsion systems. Over the past decade the automotive industry has been investing heavily in new technologies. Refined and efficient diesel and gasoline engines, advanced transmission systems, production ready hybrid electric vehicles and small quantities of hydrogen vehicles are the impressive result of these efforts.

With the investment in IAV's North American Technical Center, IAV will be prepared to push the envelope even further. However, it is not just the technology itself which defines a successful concept, especially when an increasing number of vehicle and powertrain variants need to be managed. By having a focus on production development programs IAV understands the importance of considering all boundary conditions such as system complexity, safety requirements, cost efficiency, legislative requirements, time to market, etc.

Examples of IAV's development capabilities can be seen in this automotion. IAV's new hydrogen test bench in Chemnitz will help customers to develop and further enhance a hydrogen fueled combustion engine. An interesting rear axle concept with hybrid functionality was developed by IAV and promises an interesting and cost efficient solution for many SUV applications. Furthermore, IAV offers audit services for safety critical systems which minimize risk when bringing X-by-wire systems into production. Last but not least please read about a model based approach for air path control to model the mass flow of an EGR system.

Please do not hesitate to contact me for further information. I wish you and your family a joyful holiday season.

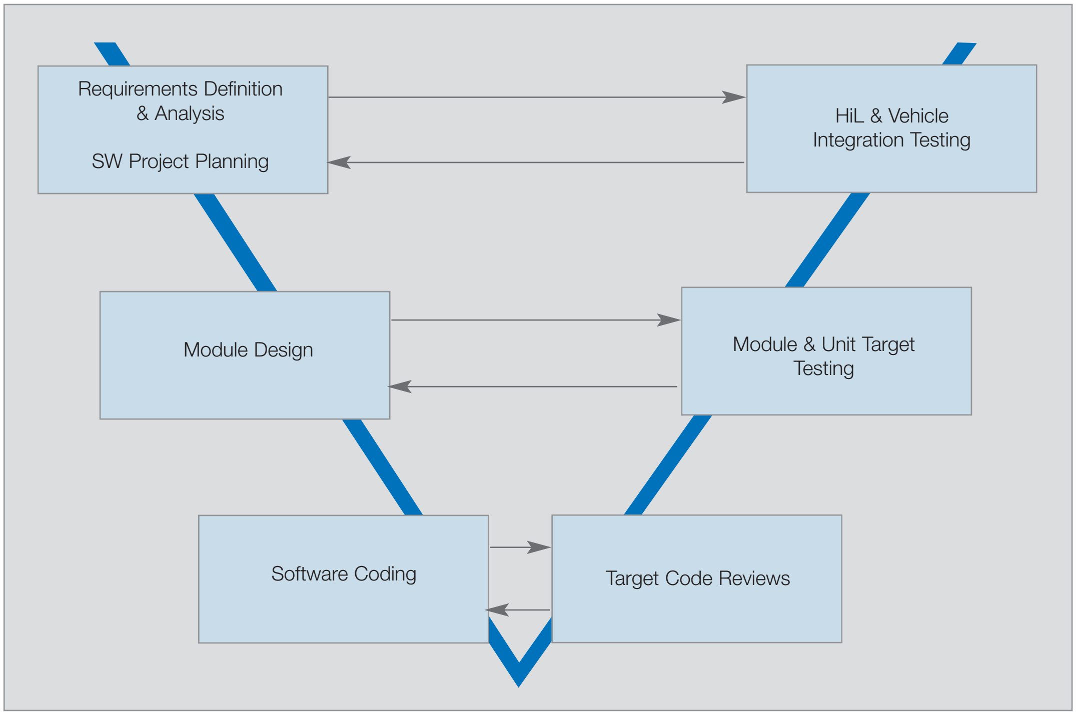
Utz-Jens Beister
President of IAV Inc.

Audit of Safety Systems

Minimizing the risk by applying a third party review

by Jason McConnell

With the ever increasing number of by wire systems on today's vehicles, the need for a safe product design in the presence of these systems has moved into the mainstream development path. The development communities have responded to this challenge by introducing recommended practices for the development of safe systems, namely, CMMI, IEC61508, MISRA and SPICE to name a few. Organizations can look to these standards to provide a template for their own systems development processes, ideally helping them to achieve the safe system their customers require. As the complexity of the systems increases, the need for such a structured development process increases.



IAV engineers have extensive knowledge in the design and development of safety critical systems; including drive by wire systems such as Electronic Throttle Control, Shift-By-Wire, Steer-By-Wire or a comprehensive system such as the powertrain for a Hybrid Electric Vehicle or chassis systems such as vehicle stability and braking systems. A new approach to utilizing this safety system design expertise has been applied by an Independent Third Party Audit of a customer's safety critical system.

The System Audit allows a customer to gain confidence in their design by having a team of experts assembled to review and give an assessment of the customer's product design and their design process. This cross-functional team is comprised of experts in System and Software Process, Systems (Function) Engineering, System Diagnostics, System and Software Safety, Software Architecture and Software Verification & Validation. Typically, the audit begins with a focus on the development process that was followed by the customer's product development team. The process assessment confirms that it meets the requirements necessary for functional safety. Also, this process review provides the IAV Audit team an ordered path into the structure, minimizing the often overwhelming complexity of the tightly coupled system. This development cycle involves requirements, design, implementation, verification and validation testing, frequently represented by the structured v-chart above.

Although a structured design process can minimize the risk of safety hazards, the errors can not be completely eliminated by design standards and process alone. The IAV Audit team leverages its safety system design expertise by focusing on the components of the product design that will provide a significant risk. The scope of the design assessment typically includes:

- Detailed analysis of the safety features and functional safety design
- Specification and source code review
- Safety validation test results review

The design objective of any safety strategy is to minimize risk by preventing hazardous effects of faults and failures. This thorough review helps provide the client with confidence that their design, implementation and system validation and verification is demonstrated by a safe product.

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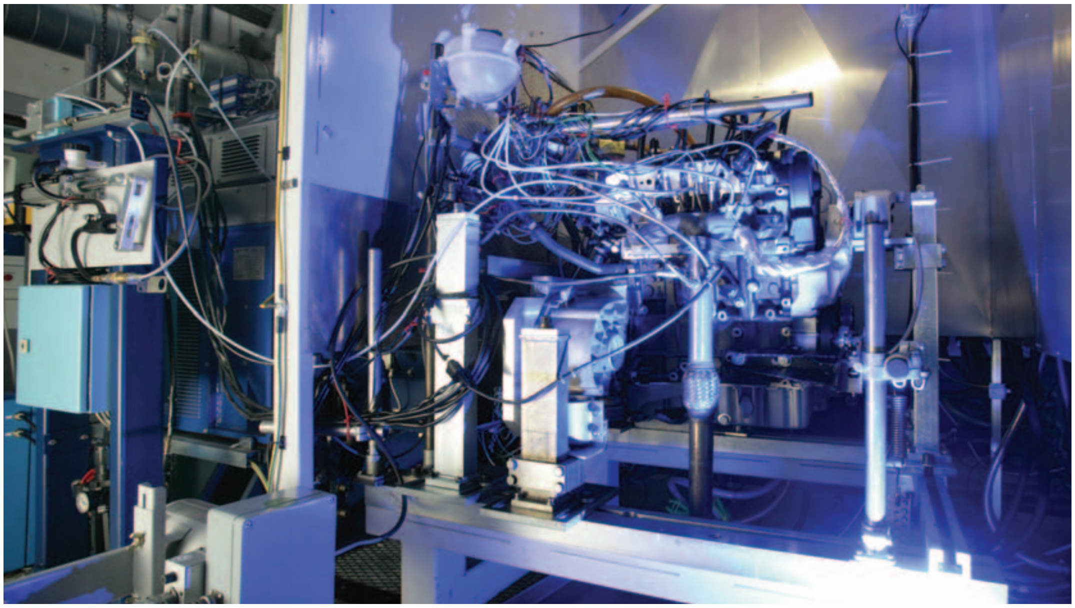
In honor of our valued customers, IAV has made a donation to a local food bank this holiday season.

We look forward to continuing to serve you and the community in 2008.

Ready for the Fuel of the Future

New dynamometer test cell for hydrogen combustion engines at IAV Germany

by Oliver Dingel and Jens Breitinger



Engine on hydrogen dynamometer test cell

According to Prof. Dr. Wolfgang Reitzle, Board Chairman of Linde AG, "Hydrogen is the logical 'next step' in producing energy. Only hydrogen occurs in truly unlimited quantities, it can be extracted from a vast selection of primary energy sources, and hydrogen generates – if these sources are regenerative – no harmful by-products whatsoever". Prof. Dr. Wolfgang Reitzle spoke the following words in a well-received lecture before a 1700-strong audience at the 15th Aachen Vehicle and Engine Colloquium. "The way to a hydrogen-based society is neither too expensive, nor too dangerous or even utopian. It is feasible", Reitzle continued.

Attaching immense importance to alternative fuels out of tradition, IAV is already gearing itself to the fuel of the future. After producing a hydrogen concept vehicle (see automotion 10/2005), a dynamometer test cell has now been set up for running hydrogen engines.

Designed for operating on gaseous hydrogen, the dynamometer test cell was devised and constructed in collaboration with the Linde Group and TÜV Süd (German technical service company) as a highly experienced cooperative partnership. The hydrogen can be compressed up to 300 bar in a high-pressure stage. At this pressure level, it is possible to operate hydrogen engines up to 220 kW brake power.

Together with TÜV, a comprehensive safety concept was drawn up with an explosion proof ventilation system as well as a large number of gas sensors for monitoring room air concentration. An important safety feature is the dynamometer test cell's additional engine enclosure that prevents hydrogen from mixing with room air in the event of a leakage.

Although research work on the hydrogen drive has been seen by the public to concentrate on converting hydrogen molecules in the fuel cell, the classic combustion engine has not yet had its day as a drive unit in the hydrogen age. To begin with, the fuel-cell concepts as they exist today are still unable to exhaust their theoretic potential. In addition, they demand the use of cost-intensive substances and raw materials, such as platinum for the catalyst which, in turn, boosts the appeal of the conventional combustion engine as a hydrogen drive. Projects, such as the hydrogen-powered buses from MAN and the Ford Motor Company or the BMW Hydrogen 7 as the first production passenger car to run on a hydrogen-fueled combustion engine, demonstrate the suitability of this concept in everyday practice.

However, to realize the expectations placed on a hydrogen vehicle in terms of power output and freedom from emissions, the modern combustion engine must be enhanced and optimized specifically for operation on hydrogen fuel. Direct injection and supercharging are capable of achieving power densities that are comparable to current high volume production natural aspirated gasoline engines. Initial project results show that the hydrogen-fueled combustion engine is capable of providing the basis for developing a virtually zero-emission, equivalent power and cost-effective drive for the future, thereby offering stiff competition to the fuel cell.

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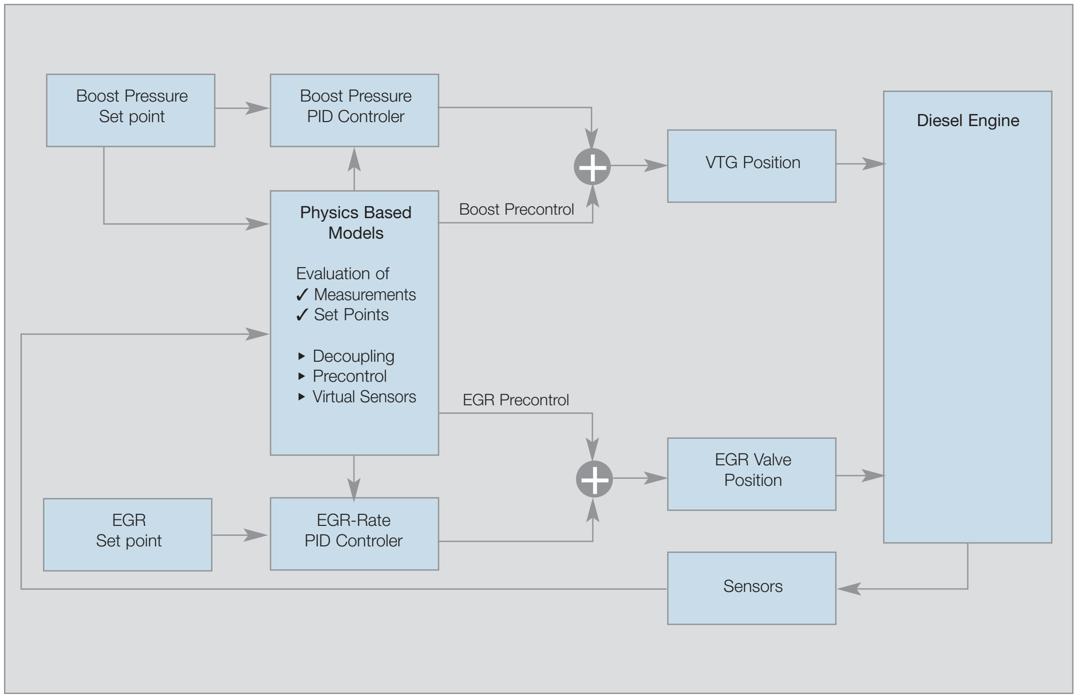
Compressor

Model Based Air Path Controls

Avoiding the interaction between EGR and turbocharging systems

by Michael Traver



Modern diesel engines typically require exhaust gas recirculation (EGR) in order to meet legislated low NO_X emissions limits. This burned gas is typically introduced in the intake manifold downstream of the turbocharger compressor where it replaces and mixes with the incoming fresh air. At the same time, many diesel engines employ variable geometry turbochargers (VGT) to improve launch performance and maintain efficiency in a range of operating conditions. Because both the EGR and turbocharging systems affect the exhaust and intake conditions, they interact and can “fight” against each other when using common PID methods of control. Avoiding this interaction is one of the main goals behind the Model-Based Air-Path (MBAP) control structure.

The MBAP control structure employs physics-based computational models to determine the mass flow of the EGR, exhaust, and intake fluids, and it uses common temperature and pressure sensors as inputs to these models. By knowing these mass flow amounts and understanding how changes in actuator position affect them, the control structure can account for sudden disturbances in the system and recommend appropriate pre-control values for the VGT and EGR governors. A traditional PID control system is then used to reduce the error between the pre-control values and the targeted set-point value.

The benefits of this control structure include faster and more accurate boost pressure control and the elimination of severe undershoot and overshoot of EGR values. By gaining better control of the EGR system, engine calibrators can operate closer to the engine’s misfire limits and squeeze out further reductions in NO_X emissions. Recent test results have also shown that turbocharging performance can be improved with a significant reduction in PM while maintaining the same NO_X emissions. The final results are all a matter of priority and the starting conditions of the base engine.

The MBAP models are created in the MATLAB/Simulink environment and are easily modified to accommodate variations of the traditional diesel air-path system. In addition to the air-path structure described above, IAV is researching ways to incorporate low-pressure EGR systems and multi-turbo applications. These modifications are tested and verified using IAV’s own HiL and SiL tools and then applied to test engines with one of a variety of rapid prototyping systems familiar to our engineers. The overall process is highly efficient and reduces test cell development time while saving money for our customers.

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Continued from page 1, “IAV’s new North American Powertrain Test Facility”

The test facility will encompass measurement devices such as:

- Fuel scale: AVL735
- Air mass: Sensyflow
- Blow-by: AVL 442
- Combustion Analyzer: Dewetron 5000
- Knock Indication System (IAV K.I.S.)
- Exhaust: Horiba Mexa 7100 FX and 7100 DEGR and AVL FTIR; Two-line measurements are optional
- Particle: AVL-Opacimeter 439 and AFL-Smokemeter 415S

IAV is confident that with the addition of this new Powertrain Test Facility IAV can further expand its portfolio and serve customers as a preferred engineering partner for future powertrains programs.

Construction of the Technical Center, which includes the Powertrain Test Facility, is scheduled to start in December 2007.

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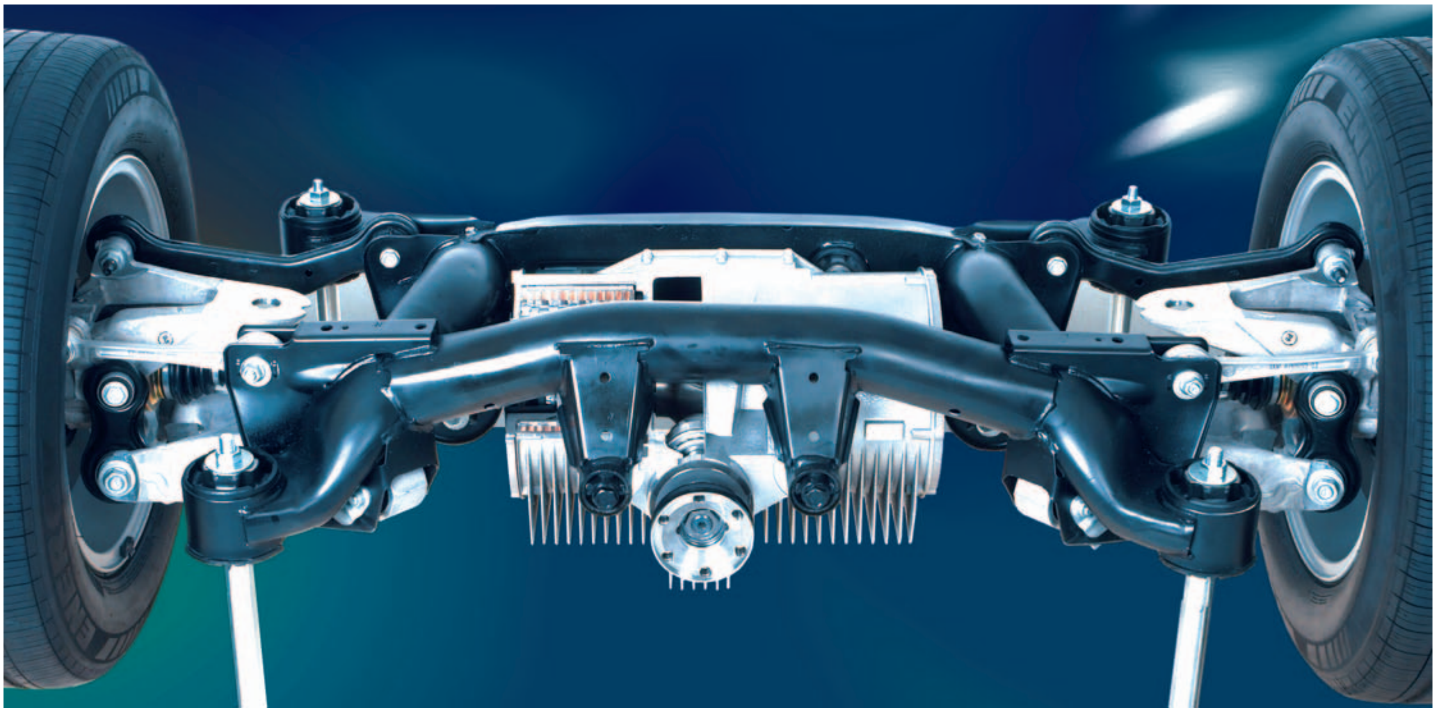
Concept for an Active Axle Differential with Hybrid Functionality

Optimizing vehicle dynamics and energy balance by integrating electric machines

by Erik Schneider and Tom Reedy



Example of the active differential integrated in the rear axle of a SUV application

Optimizing the energy balance and torque vectoring on a wheel-specific basis to improve vehicle dynamics and safety are major challenges in powertrain development. These issues are currently being addressed by hybridizing the powertrain and the usable braking energy that is recovered and stored, as well as by developing systems for variable longitudinal and lateral torque vectoring.

Positioning the electric machines is an essential aspect in defining the concept for an electric hybrid drive.

Configuration

Following this train of thought, IAV has developed a concept that includes two electric machines in an open differential. Each of the electric machines is assigned directly to one of the driven shafts.

The low (wheel) speeds permit the use of an e-machine concept that is distinguished by a high power and torque density. In the IAV configuration (based upon a mid-sized SUV) it was possible to install additional power of 60 kW and an additional axle input of 700 Nm. Both machines can be operated independently of each other in the motor and generator mode, with the direct flow of electrical power producing an electromechanical boost to the main powertrain unit.

Working principle of the open differential

The unit behaves with the properties of an open differential when the electric machines are not activated. As with any open differential, torque is balanced between the driven shafts.

Working principle of lateral torque management and vectoring

To allocate torque on a wheel-specific basis (torque vectoring), the differential unit can be employed as an autonomous system without energy storage capability. In a split Mu situation, one electric machine operates in the generator mode and, through the electrical power split, delivers energy to the second machine working in the motor mode. By supporting the generator through the open differential, additional differential toque is built up through the mechanical power split.

This makes it possible to produce a vectoring torque that is approximately twice as high as would be permitted by the limiting torques of an electric machine. This means it is possible, independently of the torque applied to the axle, to achieve an asymmetrical lateral distribution of wheel torque, thereby responding to available grip and meeting the demands of the particular driving situation. The improvement in traction particularly in cases where road friction coefficients differ, results in better vehicle yaw dynamics. The influence on lateral dynamics improves cornering behavior and agility, and makes it possible to actively influence steering which, in turn, enhances vehicle safety.

Hybrid functionality

Using an adequately dimensioned energy storage system, hybrid functionality can be introduced to produce a parallel hybrid drive by operating both electric machines in the motor or in the generator mode. Boosting and energy recovery take place in direct wheel proximity without increasing the unsprung wheel mass. Depending on the vehicle energy storage system and operating strategy, initial simulations in the NEDC show a significant potential to save fuel.

Avoidance of traction interruption

An additional benefit of the use of electric machines in the differential, is the introduction of torque-smoothing. By topping up with “electric” torque during the torque-interrupting shift pauses occurring in a manual or automated transmission, it is possible to achieve effects similar to dual-clutch transmissions.

Advantages of integration

In view of development costs and investments as well as the associated risks, flexible solutions that vary in complexity and involve familiar and existing production technologies are of interest in powertrain development. The approach of adopting any engine/transmission combinations to suit market requirements and of providing additional functionalities through a retrofit-type modularity may play a significant role.

For package reasons, integrating high electrical power levels of the type necessary for future hybrid applications is subject to tight limits in the engine/transmission unit. Utilizing potential in the area of driven shafts may represent a meaningful step in this context as the lower ambient temperatures that prevail here also speak in favor of this configuration. The concept presented can be implemented in front, rear and four-wheel drive vehicles and provides the basis for designing an electric axle.

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More Than Just Knock Detection

The KIS3 knock indication system

by Dr. Michael Lindemann and Jens Breitinger

The KIS3 system can be used both on the test bench as well as in the vehicle

Unless recognized in time, knocking combustion can lead to irreversible engine damage. In the past, the oscilloscope and stethoscope were the tools of choice in the dynamometer cell or test bench. Currently, the online evaluation of the in-cylinder pressure signal can be used to evaluate and validate acoustic piezo-electric external sensors. Unfortunately this approach is still not user friendly and there is often a reliance on a trained dynamometer technician's ear. Certainly, the need for user-friendly and universal knock detection systems has to a large extent been acknowledged. Furthermore, there is a demand, in the everyday calibration business, for knock detection systems that can be integrated into and communicate with other tools through suitable interfaces.

This explains the success of our KIS3 system. Initially intended as a simple measuring tool to assist knock detection, KIS has developed into a system that is used both on the dynamometer test bench as well as in the vehicle.

Control unit signals can be incorporated and automatically synchronized. Measurement signals can be transferred to other tools in the calibration system regardless of the sensor configuration of the systems. In addition to characteristic knock variables, the system computes useful indication variables, records analog signals and evaluates knock sensor signals. KIS3 has impressive capability even permitting operation with up to 12 cylinders at over 10,000 rpm.

The hardware is supported by high-performance software that offers important online statistics, such as knock state and knock frequency, and provides a wide range of different evaluation modules. All of these properties make the KIS3 system unique in the world of indication systems. IAV may have developed the KIS system but it is the popularity with users that has made it what it is. Our clients have prompted the evolution of the KIS product and IAV has been constantly and promptly implementing a wide range of different functions. Much attention has been focused on ensuring ease of operation and universal applicability. This is why more than 50 systems are currently in use at our OEM clients across the globe.

In a move to continue satisfying customer requirements, we have already begun work on the next generation of KIS. New features include the computation of combustion curve variables, data streaming of pressure and knock-sensor channels, user programming of causal and non-causal filters for knock evaluation as well as the ability to link in standard calibration systems via XCP.

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Public Appearances & Publications

Congresses
with accompanying trade exhibitions

Nov 28-29, 2007
Conference "Spark Ignition Engine"
Strasbourg, France

Dec 05-08, 2007
EUROMOLD 2007
Frankfurt/Main, Germany

Dec 04-05 2007
CTI Conference "Innovative Automotive Transmissions"
Berlin, Germany

Feb 06-08, 2008
EUROFORUM
Munich, Germany

Apr 14-17, 2008
SAE World Congress
Detroit, USA

Apr 24-25, 2008
29th International Vienna Engine Symposium
Vienna, Austria

May 06-08, 2008
Testing Expo Europe 2007
Stuttgart, Germany

May 21-23, 2008
JSAE
Kyoto, Japan

IAV Conferences

Feb 20-21, 2008
5th Symposium Hybrid Vehicles and Energy Management
Braunschweig, Germany

May 26-27, 2008
3rd Conference "Simulation and Testing in Developing Algorithms and Software for Automotive Electronics"
Berlin, Germany

Jun 19-20, 2008
2nd Conference "MinNO$_x$ –Minimization of No$_x$ Emissions Through Exhaust Gas Aftertreatment"
Berlin, Germany

Sep 17-18, 2008
3rd Conference "Gas-Powered Vehicles"
Berlin, Germany

Papers

Nov 28-29, 2007
SIA-Conference "The Spark Ignition Engine of the Future - Technologies to Meet the CO_2 Challenge", Strasbourg, France

"Using EGR in Turbo Charged Gasoline Engines for Replacing Fuel Enrichment - Potentials, Challenges, Solutions"
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"Bridging the Ring Gap with Pressure and Holes - the Approach to an Affordable Injector for Future Gasoline Direct Injection Systems"
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oliver.tremmel@iav.de,
jens.stegemann@iav.de

"Driving Cycle Optimisation - a Coupled Approach Based on Engine and Catalyst Models and Dynamic Design of Experiments"
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ZITRUSBLAU · www.zitrusblau.de
Frequency:
three times a year