30th International Vienna Motor Symposium

As every year, leading automotive engineers and scientists from all over the world met at the 30th Vienna Motor Symposium which was held on May 7th and 8th, 2009. They presented the latest findings in engine developments and gave an outlook on future trends in the automotive industry. This report contains a summary of the lectures presented in the individual sessions.

1 Introduction

After a welcome fanfare, **Figure 1**, which was performed by members of the orchestra of the Vienna University of Technology, **Prof. Lenz**, **Figure 2**, welcomed the participants to the 30th International Vienna Motor Symposium.

Prof. Lenz pointed out that despite the all-pervasive sentiment of crisis, the symposium was fully booked. However, individual companies had substantially reduced the number of participants for whom they had originally reserved, which ran counter to the claim made at the same time that "they would now concentrate, in particular, on intensive development, research, and further education efforts".

With regard to the economic crisis, which currently dominated the general discourse, Prof. Lenz stressed that the automotive industry had not caused the crisis. In the automotive industry, developments followed an optimum trend, progress was continually made in all areas, and the same applied to production which was characterised by high efficiency and excellent quality.

The argument that the wrong models had been developed was simply not true, Prof. Lenz stressed. The automotive industry, he went on to say, always produced the models which buyers wanted and did not act as a teacher who would tell consumers what cars they should buy.

The problem resulted much rather from the hesitations of customers to buy cars, and this disinclination to buy had been triggered not by the automotive industry but by unscrupulous "financial jugglers".

Although the objective of the Symposium is and has always been to disseminate the most recent findings of automotive engineering and to cast a glance into the future, at this anniversary conference, a summary of all previous symposia was also presented.

Professor Gruden, **Figure 3**, who had formerly worked for Porsche and had attended all symposia without exception right from the start, described in his presentation entitled "30 years of the International Vienna Motor Symposium" how demands relating to environmental standards, oil reserves, alternative fuels, and powertrains had evolved over time. Prof. Gruden concluded his speech by saying that 30 years of International Vienna Motor Symposia meant 30 years of progress and success. If we applied the yardstick of our human lifespan, he pointed out, the International Vienna Motor Symposium was now in its prime.

Prof. Mikulic offered Prof. Lenz the illustrated book „30 Jahre Wiener Motorensymposium" (30 Years of the Vienna International Motor Symposium) and a bouquet of flowers to Mrs. Lenz, **Figure 4**.

After the joint plenary opening session, the participants split up into two parallel groups (**Figure 5** and **Figure 6**), in which technical papers were presented under the chairmanship of Professors **H. Eichlseder**, **B. Geringer** and **G. Jürgens**.

The Author

Univ.-Prof. Dr. techn. Hans Peter Lenz is President of the Austrian Society of Automotive Engineers (ÖVK) in Vienna, Austria.

Figure 1: Welcome fanfare performed by members of the orchestra of the Vienna University of Technology

Figure 2: Univ.-Prof. Dr. techn. Hans Peter Lenz

Figure 3: Prof. Dr. techn. D. Gruden

A comprehensive and impressive exhibition of new engines, components and vehicles complemented the technical presentations, **Figure 7** and **Figure 8**.

Accompanying persons were offered an ambitious cultural and social programme which comprised a one-day excursion entitled "Tracing the Footsteps of Joseph Haydn", a one-day tour "From Belvedere Palace to the Inner City – Baroque Buildings in Vienna" as well as the half-day tours "Ernst Fuchs, Artist and Designer – A Representative of Fantastic Realism" and "Downtown Vienna off the Tourist Track".

Upon invitation of the Mayor of Vienna, the participants and accompanying persons spent an evening at the wine tavern Fuhrgassl-Huber in Neustift.

2 Plenary Opening Session

Dr. H. Demel, **Figure 9**, COO Magna Vehicle and Powertrain Group, Oberwaltersdorf, delivered the first lecture in the plenary entitled "Well-to-Wheel Energy Efficiency of Different Vehicle Concepts":

The total energy requirement of a vehicle, starting with the production of fuels and all the different materials for components, the manufacturing and utilisation of a vehicle through to its recycling had come to play an ever greater role, Dr. Demel stressed. He went on to say that for the calculation of the total energy requirement, a well-to- wheel analysis did not suffice, as the overall life cycle had to be taken into account. Therefore, the following conclusions can be drawn:

- Lightweight construction permits substantial energy savings, but results in higher costs on account of the materials used.
- By using recycled materials or by processing and recycling used materials, considerable cost and energy savings can be achieved in vehicle production.
- If it is assumed that in the future mainly electric motor powered vehicles will predominate in the market, CO_2 emissions and other impacts on the environment depend, to a great extent, on the percentage of electrical energy that comes from fossil fuels and from renewable sources. Hence an electric motor powered vehicle with a consumption of 13.2 kWh per 100 km emits 58 g of CO_2/km in Austria, on an average 86 g CO_2/km in the EU, 110 g CO_2/km in the US and 191 g CO_2/km in China.

Prof. Dr. H. List, **Figure 10**, Chairman of the Board, AVL List GmbH, Graz, presented a report on the topic: "Future Powertrain Systems in a Rapidly Changing Global Environment":

In Prof. List's view, the rapidly changing environment for powertrain systems will not fundamentally affect the criteria that consumers apply when buying cars, such as purchasing price, fuel consumption, operating costs, driving dynamics and comfort as well as technology orientation, but the importance attached to these individual criteria in relationship to one another is certainly evolving rapidly. In order to be able to respond quickly to these changes in customer expectations, manufacturers will have to use modular powertrain systems which will permit them to conceive flexible, specific solutions for the individual market segments.

The electrification of powertrains will lead to a widening range in the technologies applied and thus increase the complexity of modular systems. At the same time, in addition to the further development of individual components, a shift in paradigm will call for a far-reaching optimisation of the overall system. The weighting of the thermodynamic and electrodynamic components in the powertrains of the future will be very significantly determined by the evolution of battery technology and further progress in the design of internal combustion engines.

The shift of paradigm in the design of powertrains, Prof. List pointed out, would also call for a paradigm shift in the development process itself as, for example, the consistent use of simulation models throughout the entire process would constitute an important prerequisite. In his opinion, only in this way would it be possible to design components rapidly and efficiently with a view to optimising overall solutions for the different market segments in an integrated, simultaneous process development environment.

Dr. K.-T. Neumann, **Figure 11**, Chairman of the Board, Continental AG, Hanover, was the last speaker at the opening plenary session. He gave a report on the topic "The Electrification of the Powertrain – Opportunities and Challenges for the Automotive Industry":

Dr. Neumann considered the electrification of the powertrain as the key to future mobility.

For lithium-ion batteries, assuming 100 % cell costs in the reference year 2010, he expects a cost reduction of 35 % by 2020, thanks to improvements in production, with 15 % resulting from the use of new materials, 10 % from standardisation, and 5 % from lower material costs.

At the same time, he believes power density and energy density will be strongly increased.

In addition, he emphasised, electric motor-powered vehicles should lead to entirely new business models.

3 New Otto Engines

Dipl.-Ing. P. Lückert, **Dipl.-Ing. F. Kreitmann** (lecturer), **Dr.-Ing. N. Merdes**, **Dr.-Ing. R. Weller**, **Dipl.-Ing. A. Rehberger**, **Dr.-Ing. K. Bruchner**, **Dipl.-Ing. K. Schwedler**, **Dipl.-Ing. H. Ottenbacher**, **Dipl.-Ing. T. Keller**, Daimler AG Stuttgart: "The New 1,8l Four-Cylinder Turbocharged Direct Injection Gasoline Engine by Mercedes-Benz for All Passenger Cars with Standard Drivetrains":

Over the past few years, the four-cylinder engine produced by Mercedes-Benz and designated internally as M 271, has proved to be an excellent model especially in the C, E and SLK vehicle categories.

The four-cylinder engine M 271 evo described by the lecturer represents the outcome of a consistent further step in the engine downsizing strategy which Mercedes-Benz has been applying for many years in its production vehicles.

Special attention was given to design measures that resulted in lower fuel consumption. At the same time, the performance and torque characteristics of the new engine were improved.

Essential changes in the design of the new engine comprise a homogeneous direct injection system instead of port fuel injection, and the substitution of a compressor by a single-stage waste-gate exhaust gas turbocharger. The configuration of the base engine with a displacement of 1.8 l was retained. As compared to the predecessor model, on balance, the new engine displays significantly better fuel economy thanks to improvements to the combustion process and a reduction of friction losses combined with more sophisticated control and application strategies.

Figure 4: From left to right: Prof. Dr. L. Mikulic, Mrs. M. Lenz and Prof. Dr. H. P. Lenz

Dipl.-Ing. T. Wasserbäch (lecturer), **Dipl.-Ing. M. Kerkau**, **Dipl.-Ing. F. Maier**, **Dipl.-Ing. J. Hawener**, **Dr.-Ing. H.-J. Neußer**, Dr.-Ing. h.c. F. Porsche AG, Weissach: "High Performance Engines Offering Maximum Efficiency – The New Family of Flat 6 Engines from Porsche"

The second generation of the Porsche Carrera 997, Boxster 987 and Cayman sees the introduction of a new family of water-cooled flat-six engines at Porsche. These engines represent a completely new design, which is characterised by a modular concept, several displacement variants and higher degree of integration with enhanced power unit rigidity. The engine family is structured to reflect the typical Porsche differentiation between the individual vehicle types in economic terms. The power output of the new flat-six engines ranges from 188 kW to 283 kW. The characteristics which are key for a high performance engine, such as a wide engine speed range, spontaneous responsiveness, low weight with a low centre of gravity and high lateral acceleration, have all been significantly improved in comparison with the predecessor engines. Performance and fuel consumption levels unmatched by competitors have been achieved thanks to the first-ever use of direct fuel injection in a flat-six engine, coupled with consistently enhanced cylinder charging and a reduction of internal engine friction.

Figure 5: Festival hall

Dr.-Ing. J. Böhme (lecturer), **Dipl.-Ing. H. Müller**, Audi AG, Ingolstadt; **Dipl.-Ing. M. Ganz** (lecturer), **Dipl.-Ing. M. Marques**, quattro GmbH, Neckarsulm: "The New 2.5-Litre-TFSI-Five-Cylinder Engine for the Audi TT RS":

Audi looks back on a long tradition of designing five-cylinder engines with turbocharging. The combination of direct injection with turbocharging is a consistent further development . With a displacement of 2.5 l, the engine has an output of 250 kW in the range of 5,400 to 6,700/min and 450 Nm at 1,600/min. In combination with an optimally adapted six-speed manual transmission, these engine data result in outstanding acceleration and elasticity characteristics comparable to the performance of sports cars, with reasonable fuel consumption.

4 Hybrid 1

Dipl.-Ing. M. Weiss (lecturer), **Dr. N. Armstrong**, **Dipl.-Ing. J. Schenk**, **Dipl.-Ing. F. Nietfeld**, **Dr. R. Inderka**, Daimler AG, Stuttgart: "Hybrid Propulsion with Highest Electric Power Density for the ML 450 BlueHYBRID":

The ML 450 BlueHYBRID is based on the current M-Class and is equipped with the innovative AHS-C two-mode hybrid system with two high-performance electric motors. The complete drive system, the battery and power electronics as well as the operating strategy which have been especially devised for this vehicle result in a significant reduction of fuel consumption and emissions.

Alongside the two high-performance electric motors, the power-split AHS-C two-mode transmission comprises four clutches and three sets of planetary gears. This transmission was designed jointly with Daimler's development partners at the production site in Troy in Michigan, USA.

The ML 450 BlueHYBRID utilises a high-voltage battery on a nickel-metal hydride basis. Liquid cooling is used for the first time, which offers stable operation in all situations. Together with the AHS-C two-mode hybrid system, the battery permits all hybrid-specific operating modes, such as electric-only driving, engine start-stop, regeneration and boosting.

Series production of the ML 450 BlueHYBRID will take place at the Mercedes-Benz production plant in Tuscaloosa, USA.

M. Cisternino (lecturer), GM Powertrain Europe, Torino; **J. Hendrickson**, **A. Holmes**, General Motors Corporation, Pontiac, USA: "General Motors' Front-Wheel Drive Two Mode Hybrid Transmission":

General Motors is now expanding the application of two-mode hybrid technology to front-wheel drive vehicles with the development of a hybrid electric transmission packaged into essentially the same space as a conventional automatic transmission for front-wheel drive. This was accomplished by means of a space-efficient arrangement based on two planetary gear sets and electric-motor generators with large internal diameters. A combination of damper and hydraulically controlled clutch permit comfortable shutdown and restarting of large-displacement engines in front-wheel drive vehicles. The hybrid system, which assures electric low-speed urban driving, features two continuously variable ranges of transmission speed ratios, four fixed transmission speed ratios, electric acceleration boosting, and regenerative braking. In its first vehicle application, the two-mode hybrid contributes to a reduction of fuel consumption by approximately one third.

R. Shimizu (lecturer), **K. Nakata**, **M. Kanda**, Toyota Motor Corporation, Shizuoka, Japan: "Analysis of a Lean Burn Combustion Concept for Hybrid Vehicles":

Lean-burn combustion is one of the most efficient technologies for improving an engine's thermal efficiency.

Toyota regards hybrid technology as the key to building vehicles with lowest fuel consumption levels. When the new lean-burn engine is combined with a hy-

Figure 6: Ceremonial hall

brid powertrain, the thermal efficiency under high load must be improved in order to lower CO_2 emission further. This means that under high load, NO_x emissions must also be reduced.

The lecturer explained that various combustion concepts had been analysed and homogenous direct injection in combination with lean-burn combustion had been selected as the new strategy for lowering CO_2 and NO_x emissions. With a view to achieving ultra-lean combustion with a homogenous air/fuel ratio, turbulence intensification measures had to be applied and the ignition system had to be adapted.

In combination with downsized boosting, it could be expected, he stressed, that when this new combustion concept would be applied in hybrid vehicles, massive reductions of CO_2 and NO_x could be achieved.

Figure 7: Exhibition: race cars in the design competition Formula Student

5 New Diesel Engines and Concepts

Dipl.-Ing. F. Rudolph (lecturer), **Dr.-Ing. J. Hadler**, **Dipl.-Ing. H.-J. Engler**, **Dipl.-Ing. A. Krause**, **Dipl.-Ing. M. Stamm**, Volkswagen AG, Wolfsburg: "Volkswagen's New 1.6l TDI Engine":

With its new 1.6 l 4V TDI, Volkswagen presents an entirely newly conceived unit which will form the basis for all of Volkswagen's future four-cylinder diesel engines.

On the basis of the 2.0 l 4V TDI which has a power output ranging from 81 kW to 125 kW, a wide variety of modifications were made to the new 1.6 l 4V TDI which has a maximum output of 77 kW. These modifications include the changeover of the injection system to the PCR 2-System supplied by Continental and operating at an injection pressure of 1600 bar and a two-piston high-pressure pump with an integrated mechanical pre-injection pump. In each cycle, up to six injections are possible. This unit also incorporates a piezo actuator with a seven-hole injector.

In accordance with the significant reduction of engine capacity, almost every single engine component had to be redesigned and friction losses were significantly brought down.

S. Kimura , **E. Matsumoto**, **M. Yamane**, Nissan Motor Co., Ltd., Kanagawa, Japan; A. M. de Hoyos (lecturer), Nissan Technical Centre Europe, Barcelona: "Nissan's New Clean Diesel Technology for Japanese Real New Long-Term Regulation":

A new 2.0 l L4 in-line diesel engine with direct injection was designed which optimised acoustic behaviour, vibrations and thermal emissions. Nissan's technologies, which are based on the EURO IV-technologies, were integrated into the new engine: a lean-burn NO_x trap (LNT) was combined with Nissan's new control technology.

This engine, fitted with piezo-electric injectors, delivers an output of 63.5 kW/l and its torque achieves 180 Nm/l at a low compression ratio. Instead of an oxidation catalyst, a three-way catalyst is used as an exhaust gas aftertreatment unit which will allow this engine to comply with the new long-term legal provisions. In order to achieve accurate rich-spike and desulphurisation control rapidly, Nissan devised a model-based control strategy which combines VGT, an exhaust gas return valve, an electronically activated throttle valve and an injector unit.

Dr.-Ing. W. Held, **Dipl.-Ing. G. Raab** (lecturer), **Prof. Dr.-Ing. K.-V. Schaller**, **Dipl.-Ing. W. Gotre**, **Dipl.-Ing. H. Lehmann**, **Dipl.-Ing. H. Möller**, **Dipl.-Ing. W. Schröppel**, MAN Nutzfahrzeuge AG, Munich, Nuremberg, Steyr: "Innovative MAN Euro V Engines without Exhaust-Gas Aftertreatment":

MAN seeks to offer its customers products in the different markets that are of economic interest. Therefore, it devised an AdBlue-free technology, which combined an externally cooled EGR system and a PM-Cat filter, for all MAN series even before the EURO IV legislation came into force. This technology was very well received by customers as it not only has well-known advantages as compared to an SCR technology but also does not result in higher operating costs.

As a result of the early introduction of EURO V in some European countries which generated benefits with regard to road toll fees, MAN Nutzfahrzeuge AG made use of its many years of experience with SCR technology, since the EURO V EGR solution described in detail by the lecturer was not yet available.

The motivation for the development of an AdBlue-free concept resulted from the positive response of customers to the MAN EURO IV EGR/PM cat technology.

Thanks to the new EURO V EGR solution, other EURO IV solutions can be devised to meet customer demands in the emerging markets, which means that MAN can offer a technology worldwide that requires no exhaust-gas aftertreatment.

This technology constitutes the basis for a platform concept for EURO IV / V and EURO VI, in which EURO IV can be realised

Figure 8: Exhibition

without aftertreatment, EURO V in conjunction with an oxidation catalytic converter, and EURO VI with an SCRT system.

6 Powertrain

Dipl.-Ing. E. Schneider (lecturer), **Dipl.-Ing. J. Müller**, **Dipl.-Ing. M. Leesch**, **Dipl.-Ing. R. Resch**, IAV GmbH, Chemnitz: "Optimised Transmissions as a Result of Integrated Powertrain Design":

On the basis of the power and energy required, the lecturer examined the potential for reducing CO_2 emissions through vehicle and transmission design measures. In keeping with efficiency improvements and the ensuing trend towards reducing swept volume and narrowing speed spreads, transmission systems as well as the influence of the total speed range and the number of speeds play a vital role. The integration of electric motors constitutes a further potential for lowering CO_2 emissions. In addition, the lecturer illustrated computer-aided synthesis programmes which systematically generate new transmission systems with optional hybrid functions with a view to tapping existing potential. As a result of this targeted research, a new eight-speed dual-clutch transmission system and an eight-speed hybrid automatic transmission system were developed. These structurally optimised transmission systems reconcile the conflicting goals of efficient map conversion and compact, cost-effective design.

M. Uchida, **S. Ishii**, Nissan Motor Co., Ltd., Kanagawa Japan; **K. Usuki**, Jatco Ltd., Kanagawa Japan; **M. Rowland** (lecturer), Nissan Motor Manufacturing (UK) Ltd., Louvain-la-Neuve, **K. Takemoto** (lecturer), Jatco France SAS, Lardy: "Brand-new NISSAN/JATCO Seven-Speed Automatic Transmission and Its HEV Derivative": Nissan and Jatco have developed a new seven-speed AT, which can reduce CO_2 emissions by up to 7 % as compared to the existing five-speed AT.

The lecturer addressed several new features used in the AT and its derivative which will be launched in the near future. As to the hardware, friction was minimised by means of an efficient design of each component combined with a newly developed transmission fluid.

As to the software, a new gear shift control logic and electric acceleration pedal "ECO-Pedal" which is controlled harmonically with the gear shift schedule optimises drivability and fuel economy. Finally, the lecturer described the derivative for an HEV version. He then also illustrated a derivative for electro-hybrid vehicles.

"ECO-Pedal"is a world first system, which assists eco driving by controlling the reaction force of the acceleration pedal harmonically with the gear shift schedule. The system detects the pressure applied to open the accelerator; when excess pressure is applied, a counter push-back tells the driver to ease up in order to save fuel. With this ECO-Pedal excessive acceleration can be avoided and fuel economy in the real world improved by 5 to 10 %.

The drive for electric-hybrid vehicles consists of an integrated motor and two clutches instead of a torque converter.

Dr.-Ing. J. Greiner (lecturer), ZF Getriebe GmbH, Kressbronn; **Dr.-Ing. B. Vahlensieck**, **Dr.-Ing. M. Mohr**, **Dipl.-Ing. P. Casals**, ZF Friedrichshafen AG, Friedrichshafen: "Fuel-Efficient Driveline Systems":

In the USA and Japan more than 90% of all customers have traditionally preferred automatic shifting, while, not long ago, the use of automatic transmissions on the European market was almost exclusively limited to premium cars with 6, 8 and 12 cylinder engines. One reason was high additional costs for the automatic transmission as an "extra", another reason was the image of this type of transmission which had the reputation of being very convenient but, above all, gas-guzzling and the opposite of sporty. This changed dramatically with the introduction of automatic transmissions featuring up to 8 gears and a high ratio spread as well as due clutch transmissions, which are regarded as being very sporty. By using optimised starting devices, intelligently arranging the gear sets and applying efficient electrohydraulic control systems, engineers have managed to design units which differ only marginally from manual transmissions both in terms of cycle and actual consumption.

Against the background of enormously increasing fuel costs it is to be expected that, based on such automatic transmissions, a significantly higher volume of micro, mild, and full hybrid versions will find their way into drivelines as so-called parallel hybrid systems. The range of functions includes the start-stop system with the micro hybrid, recuperation and boost mode in the case of the mild hybrid, and electric driving with the full hybrid.

The lecturer demonstrated the influence of the individual systems on fuel consumption by presenting the transmission and hybrid portfolios of ZF with due regard for the internal efficiency and load point shifting as a function of the number of speeds and the gear ratio. He pointed out that the different systems were compared and analysed and their interactions with future engine and vehicle technologies were assessed by means of simulations and efficiency measurements.

7 Future Powertrains

Dipl.-Ing. P. Langen (lecturer), **Dipl.-Ing. W. Nehse**, BMW Group, Munich: "BMW Efficient Dynamics – A Look into the Future":

The lecturer drew attention to the fact that no other car manufacturer had more strongly reduced CO_2 emissions across its whole model range than the BMW Group with its Efficient Dynamics strategy.

In the meantime, 21 BMW models and six MINI models emit less than 140 g of CO_2 per kilometer.

Important elements of this development strategy include brake energy regeneration, the gear shift indicator, the engine start-stop function, intelligent energy and drive train.

The focus continues to be directed at the primary use of energy in the internal combustion engine. This is where a combination of different components from BMW's modular technology kit (Valvetronic, Bi-VANOS, High Precision Injection, Turbocharging) could contribute towards reducing CO_2 emissions to an ever greater extent in the future.

Especially through the use of exhaust gas energy for turbocharging in combination with fewer cylinders, an analysis of the entire drivetrain topography and the vehicle as a whole opens up new opportunities.

A comparison of various customer-oriented profiles reveals considerable potential for more extensive use of brake energy, especially in urban areas.

If an electric motor is used to convert this energy, we are then faced with the questions of how and when this energy is to be fed back into the vehicle. If the electric motor is sufficiently powerful, it can also perform drive functions and it has to be considered how the two drive units should be dimensioned relative to one another. In the context of a marginal analysis, the electric motor is capable of replacing the internal combustion engine completely.

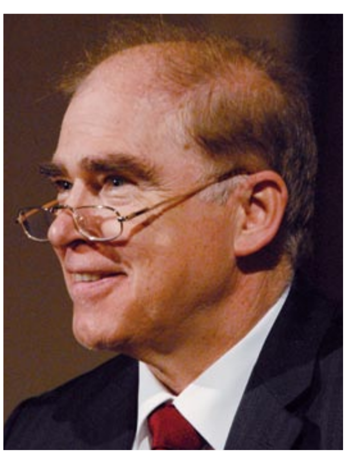

Figure 10: Prof. Dr. H. List, AVL List GmbH

The MINI E, the first electric vehicle launched in the market by the BMW Group, constitutes a field trial on the road as regards the alternative drive units of tomorrow.

H. S. Lee Ph.D., (lecturer), Vice Chairman R&D Division, Hyundai-Kia Motor Company, Gyeonggi-Do, Korea: "Hyundai-Kia's Powertrain Strategy for Green and Sustainable Mobility":

With "Blue Drive" products and technologies, Hyundai-Kia Motor hoped to be able to achieve a fleet average of 35 miles per gallon by 2015, the lecturer explained. This was five years ahead of the US government's deadline for fuel reduction. In the meantime, Mr. Lee pointed out, Hyundai-Kia Motor Company would also meet the European emission standards of 130 g CO_2/km by 2012. In his presentation, the lecturer explained his company's powertrain strategy in three parts:

- fuel efficiency improvements in the conventional internal combustion engine
- the development of engines using alternative energies
- the design of environmentally friendly vehicles.

He illustrated various new engines and transmission systems which were to improve fleet fuel economy while, at the same time, complying with more stringent emission standards. Bioethanol, biodiesel and CNG vehicles are being developed by Hyundai-Kia Motor to reduce its dependence on petroleum. The ultimate goal of developing environmentally friendly vehicles is to develop a pollution-free vehicle that has zero gas emission. The Hybrid Electric Vehicle (HEV) is considered as a possible alternative while the Fuel Cell Electric Vehicle (FCEV) is viewed as an ultimate solution. Hyundai-Kia Motor aims to rank among the world's top five automakers by 2010 in terms of sales, corporate social responsibility, and environmental performance.

Prof. Dr. L. Mikulic (lecturer), **Prof. Dr. H. Kohler**, Daimler AG, Stuttgart: "Powertrain Technologies for Sustainable Mobility at Mercedes-Benz":

Prof. Mikulic stressed that Daimler AG would meet future challenges with their roadmap for sustainable mobility. In addition to searching for better energy sources, this roadmap consisted of three steps, he explained. The first step began with the optimisation of internal combustion engines. The goal is to make the petrol engine as economical as the diesel engine and the diesel engine as clean as the petrol engine. Milestones on the way to the convergence of these two combustion principles are for example the petrol engine with second generation direct fuel injection and the BlueTEC-technology for diesel engines. These two combustion principles were reconciled in the DIESOTTO engine concept that combined the advantages of both.

Figure 9: Dr. H. Demel, Magna International

For further efficiency enhancements, the combustion engine will be assisted by electric motors in modular hybrid concepts as a the next step. Depending on the purpose for which it is used and on the demand of customers, the engine will be equipped with a start-stop function, boosting, recuperation as well as pure electric driving will be the options.

As a third step, these technologies will lead to emission-free driving with battery-electric and fuel cell vehicles. The future has just begun: Daimler AG is presently running the biggest fleet of test vehicles with battery-powered electric and fuel cell drives worldwide.

8 Emission Reduction

Dipl.-Ing. W. Müller (lecturer), **Dr.-Ing. I. Lappas**, **Dr. rer. nat. A. Geißelmann**, Umicore AG & Co. KG, Hanau: "After-Treatment Systems for Heavy Duty On- and Off-Road Applications":

Figure 11: Dr. K.-T. Neumann, Continental

In view of the future exhaust gas emission legislation it can be expected that all options for internal engine modifications destined to bring down emission levels must be utilised. In addition, a combined exhaust-gas after-treatment of particulate and nitrogen emissions will be required. The SCR technology which uses urea as a reducing agent is increasingly emerging as the method of choice for NO_x after-treatment in heavy-duty utility vehicles for on- and off-road applications.

The lecturer illustrated designs and technological solutions for the individual system components of catalytic converters (DOC, particulate trap, SCR) that will permit heavy duty vehicles to comply with the new standards.

He also described the activity features of a number of state-of-the-art Fe-zeolith-, cuzeolith- and vanadium-based SCR technologies. New trends in the development of SCR catalytic converters demonstrate a significant improvement of durability at high temperatures and intensified SCR activity at low temperatures even when exhaust-gas emissions have a low NO_x content.

Dr.-Ing. B. Mahr (lecturer), Mahle GmbH, Stuttgart; **Dr. sc. techn. M. Warth**, **Dipl.-Ing. J. Rückauf**, **Dr.-Ing. A. Elsäßer**, Mahle International GmbH, Stuttgart: "Innovative Exhaust-Gas Recirculation System for Cost and Fuel Efficient Compliance with Emission Standards"

The lecturer elaborated on an innovative exhaust-gas recirculation system which, by using a rotating flap, generates temporary negative pressure impulses in order to produce the desirable exhaust-gas recirculation rate under different engine operating conditions. Through an integrated control of both charge air and exhaust-gas mass flow, the EGR rate can be increased while the pumping work can be reduced at the same time by means of this system. Thanks to the highly efficient, flexible electronic activation flap on the intake side, high exhaust-gas recirculation rates can be attained without the need for adjusting exhaust-gas counter-pressure. With this arrangement, the EGR system is not burdened by high exhaust-gas temperatures and contamination. The highly dynamic response of the system and flexible electronic activation allow a nearly instantaneous control of EGR rates as required in different operating states across the entire map and during engine warm-up, which will become a much more significant feature in view of future test cycles. The lecturer presented the experimental results of an application of this system in a utility vehicle engine. He demonstrated that over wide map ranges, EGR flow rates could be increased by more than 50 %, with a marked reduction of NO_x emissions and specific fuel consumption.

Dr.-Ing. M. Flik (lecturer), **Dr.- Ing. S. Edwards**, **Dr. E. Pantow**, Behr GmbH & Co. KG, Stuttgart: "Emission Reduction in Commercial Vehicles through Thermal Management":

Through the combination of exhaust-gas recirculation and exhaust-gas after-treatment, significant progress was made over the past few years so that compliance with future emission standards is assured. At the same time, it was possible to reduce fuel consumption through these measures.

Despite the progress made over the past few years, roughly 50% of the energy contained in the fuel still goes unused as it is released into the atmosphere in the form of hot exhaust gases. Against the background of climate change and the significant role freight traffic plays for national economies, greater attention must be given to energy recovery in vehicles.

The design of the vehicle cooling system and the specific components used are decisive factors for harnessing the energy contained in hot exhaust gases. The lecturer illustrated methods for energy recovery in vehicles and the impact of these on the vehicle cooling system and analysed these methods for their economic feasibility.

Under real-life driving conditions, the lecturer stressed, the potential for reducing fuel consumption through thermal management, including the recovery of heat contained in exhaust gases, amounted to approximately 10 %.

9 Hybrid 2

Dr. R. Fischer, AVL List GmbH, Graz: "The Electrification of the Powertrain – From Turbohybrid to Range Extender":

AVL expects a distribution of electrification by the year 2025 which presents the following picture: a focus on both mild hybrid systems, which will be applied on a broad basis, and electric-motor powered vehicles with integrated range extenders which will primarily be used in intra-urban traffic.

In order to obtain the optimum cost/benefit ratio, new engine concepts are being developed, with the key always being system optimisation, i.e. the engine, the transmission, the electric motor, the battery and control strategies must be optimally adjusted to one another. The lecturer quoted as examples two concepts on which developments are mainly focused:

- The turbohybrid: using additional functions of the combustion engine permits a simplification of the electric system: Through supercharging and electric motor traction support during starting, the potential for higher fuel economy

through load point shifting can be tapped to a great extent by means of a low-cost, mechanical transmission with optimised efficiency. The overboosting capacity of a turbocharged engine permits permanent recharging of the battery which results in a marked reduction of the required battery capacity and thus also in lower system costs. Such a combination, as implemented in the turbo-hybrid, constitutes an attractive universal strategy assuring excellent fuel economy and great driving pleasure.
– Range extenders: two different approaches are possible: Solutions with direct drive or range extenders without direct drive. The demands made upon pure range extenders (PRE) are completely different from those made upon today's combustion engines. The basis is an electric vehicle, and potential customers are buyers of electric vehicles, which means that these are primarily designed for urban driving. For cost and weight reasons, however, the battery should be as small as possible, i.e. for distances that are rarely driven this battery would not be suitable. The operating range of the combustion engine is limited to single-point operation for recharging the battery. This gives rise to entirely new, low cost, weight-optimised concepts for combustion engines. The acoustic behaviour of and packaging space for such PREs are a particularly significant parameter.

Dipl.-Ing. P. Langen, **Dr. M. Klüting**, **Dr. M. Wier**, **Dipl.-Ing. F. Kessler**, **Dr. B. Curtius**, **Dipl.-Ing. H.-S. Braun** (lecturer), **Dipl.-Ing.G. Thiel**, BMW Group Munich: "The Full Hybrid Powertrain for BMW X6 (BMW ActiveHybrid)":

In 2008, the BMW Group launched the new BMW X6 XDrive and the new BMW 7-series.

In line with its EfficientDynamics-Strategy, the BMW Group developed a full hybrid powertrain for the X6 and a mild hybrid powertrain for the BMW 7-series to complement the highly efficient gasoline and diesel powertrains.

As a result of the close interaction between the combustion engine, the electric motor and the transmission, the features of this product are strongly determined by software functions. Efforts to achieve this interaction predominated in the development of the hybrid powertrains.

Despite the additional weight of the hybrid components, typical BMW dynamics have been maintained and even improved. CO_2 emissions were significantly reduced at the same time, and fuel consumption rates are extremely low.

Even though the transmission hardware and basic software were conceived in co-operation with GM and Daimler, BMW succeeded in retaining the typical characteristics of its brand in the BMW X6 Active Hybrid.

In combination with the V8 twin power-turbocharged engine and an electric engine mounted on the crankshaft and the new eight-speed transmission, BMW was able with its BMW 7-series active hybrid to lower fuel consumption drastically while improving driving behaviour at the same time.

Dipl.-Ing. O. Vollrath (lecturer), **Dr. N. Armstrong**, **Dipl.-Ing. J. Schenk**, **Dipl.-Ing. O. Bitsche**, **Dr.-Ing. A. Lamm**, Daimler AG, Stuttgart: "S 400 BlueHYBRID – the First Hybrid Vehicle with Li-Ion-Technology":

Mercedes-Benz is forging ahead with the electrification of the powertrain for vehicles in all performance classes and across all model series from the start-stop system to the full hybrid vehicle.

The S 400 BlueHYBRID thus represents the first Mercedes-Benz hybrid. Equipped with the features of a start-stop system as well as regenerative braking and electrical drive support, it achieves a reduction in fuel consumption of approximately 20 %.

The goal in packaging was to prevent any impairment of customer benefit.

The design of the components and the selection of standard installation spaces allowed all components specific to the hybrid system to be accommodated in the front end. In this respect, the battery technology played a special role, because it was possible to design a hybrid battery that was no larger than a conventional starter battery, and also fitted into the installation space. This lithium-ion battery was used in a passenger car for the first time.

10 Supercharging and Gas Exchange

Dipl. Ing. N. Klauer, **Dr. M. Klüting**, **Ing. F. Steinparzer** (lecturer), **Dr. H. Unger**, BMW Group, Munich: "Turbocharging and Variable Valvetrains - Fuel Economy Technologies for Worldwide Use":

With its holistic BMW EfficientDynamics approach, the BMW Group started already many years ago to respond adequately to changed requirements so as to safeguard sustainable mobility. Electrification, energy recovery, engine start-stop units and efficient powertrain technologies constitute the vital elements of this strategy.

In the foreseeable future, combustion engines will continue to play the main part as drive systems and therefore further efforts to reduce fuel consumption will remain focused on combustion engines.

With the integration of the Valvetronic 2001 into BMW's gasoline engines, a significant reduction of fuel consumption was achieved for the first time in mass produced engines. With direct injection and turbocharging, further milestones were reached on the path towards higher fuel economy through new engine technology.

Consistent further improvements in design and an intelligent combination of these engine and powertrain concepts could play a central role for innovative drive systems for worldwide use.

T. Tomoda (lecturer), **T. Ogawa**, **H. Ohki**, **T. Kogo**, **Dr. K. Nakatani**, **E. Hashimoto**, Toyota Motor Corporation, Shizuoka, Japan: "Improvement of Diesel Engine Performance through Variable Valve Timing":

Toyota studied the effects of variable valve timing and lift in order to improve the thermal efficiency of diesel engines,

Figure 12: Koei Saga, Toyota

while reducing engine-out emissions at the same time.

Under high load, the early closing of one or the early opening of both intake valves intensifies swirl motion without leading to higher pumping losses. Late closing of the intake valves results in a reduction of the effective compression ratio, so that it is possible to increase the EGR ratio and advance the start of fuel injection. As a result, low NO_x formation and improved thermal efficiency can be achieved simultaneously.

Under low load conditions, heat release is small and fuel is dispersed finely through the swirl because of the small fuel injection quantity. Therefore increasing the effective compression ratio through advanced intake valve closing is effective for reducing HC-formation.

Variable valve timing can also be applied to a wide operating range, thus bringing down NO_x raw emissions by as much as 40 % and improving fuel efficiency by 4 % in the NEDC.

Furthermore, low-end torque was raised by 40 % through exhaust pressure pulsation. In order to achieve these results, a new piston chamber design with deep valve pockets was also required.

Dr.-Ing. B. Huurdeman (lecturer), **Dipl.-Ing. (FH) J. Kosicki**, **Dipl.-Ing. (BA) H. Schick**, **Dipl.-Ing. (BA) D. Talmon-Gros**, MANN+HUMMEL GmbH, Ludwigsburg: "Development of Turbo Charger Parts Using High Performance Plastics":

As a downsizing measure for gasoline engines, the turbocharger has reached the volume market of base engines which has increased the pressure on cost and weight. For Diesel engines, additional variability in the flow path is being developed. The switching operation requires flaps, valves or variable guide vanes in the area of the turbine or the compressor. These switching devices make high demands on temperature and corrosion resistance and have to be integrated into the charging components because of packaging space and mass restrictions.

In order to develop cost-effective, lightweight and integrated solutions for ducts, housing and switching devices on the compressor side of the turbocharger, it makes sense to use plastic parts. But at high temperatures, only high performance plastic materials can fulfil the requirements of durability and dimensional stability.

Over the past few years, MANN+HUMMEL which is a supplier for air intake systems has carried out many investigations and designed innovative parts.

The lecturer described two switching devices in the flow path close to the compressor and also a compressor housing made of the high performance thermoplastic resin PPS, and illustrated the options and restrictions that must be realised when using plastic materials. The results of tests on component and engine test benches indicated, he went on to say, a promising future for plastic materials on the basis of the current state of the art.

11 Future Energy Supply

Dr. J. Adolf, Shell Deutschland Oil; **Dipl.-Ing. R. Huibers**, **Dr. W. Warnecke** (lecturer), Shell Global Solutions Deutschland GmbH, Hamburg: "Shell Passenger Car Scenarios to 2030 – Facts, Trends and Options for Sustainable Auto-Mobility in Germany":

The 25th edition of the Shell Passenger Car Scenarios is characterised by transition. Following a uniform socio-economic lead scenario, the present Passenger Car Study 2009 starts by analysing the possible consequences of demographic change on future auto-mobility in Germany. It tracks continuation of today's car ownership and mileage patterns up to 2030, differentiating by age and sex. The state of auto-mobility in Germany will in future be characterised more strongly by women and by older people. The motorisation of the German population will continue to increase. Passenger car mileage will continue to rise till 2020, dropping back to today`s level towards 2030 .

The study uses two mobility scenarios to examine the sustainability of auto-mobility in the coming years, in terms of energy consumption and CO_2 emissions. One of these scenarios, called "Automobile Adaptation", assumes a continuation of today's trends and behaviour patterns in the future, and already shows a substantial reduction in energy consumption and CO_2 emissions of the passenger car fleet. The alternative scenario "Auto-Mobility in Transition" is characterised by rapid technological change and greater diversification of propulsion and fuel technologies. But conventional

Figure 13: D. M. Hancock, GM Powertrain

propulsion systems and fuels will still be playing a key role by 2030.

Dr. A. M. Lippert, **Dr. G. J. Smyth** (lecturer), General Motors R&D and Strategic Planning, Warren, USA: "Global Energy Systems in Transition: Next Steps in Energy Diversity for Transportation":

The challenges and opportunities for transforming the world's transportation energy systems for long-term sustainability of mobility have never been greater. Volatility in petroleum markets has contributed to economic disruption. Environmental and energy supply concerns continue to intensify. These externalities must be addressed with a robust portfolio of solutions that promise to transform the energy system for personal mobility.

In the past two years alone, these solutions have made significant advances:

- improved energy efficiency of internal combustion engines and transmissions, and increasing capability to utilise existing biofuels
- electrification of the vehicle propulsion system through hybrids (including plug-in), extended-range electric vehicles, and fuel-cell electric vehicles
- a shift in the use of energy resources towards low-carbon fuels, such as biofuels and renewable electricity, which can be used in both conventional and electrified propulsion systems.

In view of today´s large vehicle population, the introduction of new technolo-

Figure 14: Prof. Dr. M. Winterkorn, Volkswagen AG

gies initially has only a small overall impact, but an accelerating displacement of the existing fleet can be expected as time progresses. It is imperative to maintain constancy of purpose with regard to the technological transformation of vehicle propulsion and energy supply systems, as well as policies, infrastructure, and social objectives. Doing this will ensure that market tipping points can be achieved by 2025 across this portfolio of solutions, and the challenge of sustainable personal mobility will be solved by a commercial roll-out of new technologies in large numbers.

Univ.-Prof. Dr. G. Brauner, University of Technology, Vienna: "Electrical Energy Supply and Mobility in Europe":

Two parallel paths are followed in order to assure a sustainable supply of energy for mobility. On the one hand, combustion engines and their exhaust gas after-treatment systems are further improved with a view to lowering emissions significantly, thus reducing specific energy demand. It can be assumed that combustion engines will be used in the long run in vehicles offering high driving convenience. Second and third generation biogas and biofuels can contribute to their sustainability.

On the other hand, electric-motor driven vehicles will gain ground especially in short-distance traffic in the suburban areas of metropolises. In this sector, small electric cars which can run on renewable energies offer major advantages, as they operate without emissions and produce little noise. On account of the high efficiency of the electric drive and braking energy recuperation they also have a lower specific energy demand. Eletric vehicles are best suited for suburban office hour traffic in the megacities of the future, which will be characterised by stop-and-go traffic. The electric batteries of these vehicles can also be used as a storage medium for renewable energy in energy-active settlements in the grid-to-car or car-to-grid mode. Thus day and night balancing of photovoltaic energy supply or compensation for natural fluctuations in the supply of energy from predominantly regenerative sources is possible.

12 Combustion and Downsizing Concepts

D ipl.-Ing. J. Willand, **Dr. J. Jakobs** (lecturer), **Dr. E. Montefrancesco**, **Dr.-Ing. M. Daniel**, **Dipl.-Ing. V. Vortkamp**, **MBE**, **Dr.-Ing. B. Läer**, Volkswagen AG, Wolfsburg: "The Volkswagen GCI Combustion System for Gasoline Engines - Potential of and Limits to CO_2 Emission Reduction":

The Golf with the 1.6 l GCI-engine which was launched in late 2006 was the first passenger car worldwide presented to the public and ready for driving that is equipped with a self-ignition gasoline engine. The Volkswagen GCI combustion system integrated into the engine uses a part load combustion process based on homogenous self-ignition of the fuel which combines improved fuel economy as compared to conventional spark plug-induced stochiometric combustion with minimal nitrogen raw emissions.

The lecturer described the method applied in designing the GCI combustion process which involved the intensive use of various calculation methods, three-dimensional simulation of mixture formation and coupling CFD flow simulation with chemical reaction kinetics for shaping the self-ignition process.

Subsequently he explained the steps that had to be taken in engine management when transferring the GCI combustion process from the engine test bench to the vehicle.

A fundamental analysis of options and limits of part-load combustion over the entire system for reducing fuel consumption in real life driving showed that while fuel economy can be improved through these combustion processes, the combustion rates attained through downsizing with TSI technology cannot be reached under the boundary conditions relevant for Volkswagen. This can mainly be ascribed to the short time spans during which the engine is operated in the fuel-efficient, limited part load range. When an engine having the same capacity is operated outside this part load range, the relevant specific fuel consumption rates are clearly higher than those of a lower-capacity downsized engine.

Dipl. Ing. R. Weinowski (lecturer), **Dipl. Ing. A. Sehr**, **Dipl. Ing. S. Wedowski**, **Dr. Ing. S. Heuer**, **Dipl. Ing. T. Hamm**, **Dipl. Ing. C. Tiemann**, FEV Motorentechnik GmbH, Aachen: "Future Downsizing of S.I. Engines – Potential and Limits of Two- and Three Cylinder Concepts":

Today, downsizing, in combination with intake air pressure charging, is one of the most promising opportunities for the reduction of CO_2-emissions from internal combustion engines. In the small size vehicle class with relatively low capacity engines, three cylinder, instead of conventional four cylinder engines are increasingly being applied. Any further decrease of engine swept volume gives rise to the question as to whether a further reduction of cylinder displacement

Figure 15: Contented faces at the end of the successful symposium: from left to right: D. M. Hancock, GM; K. Saga, Toyota; Prof. Dr. M. Winterkorn, VW; Prof. Dr. H. P. Lenz

or the introduction of two cylinder engines would be preferable. Furthermore, the high cost sensitivity in this vehicle class and the required technological input have to be considered.

Based on the current state-of-the-art of small gasoline engines, the potential for lowering CO_2-emissions through downsizing while maintaining similar driving performance was analysed and the limits to reducing single-cylinder displacement were described.

The lecturer pointed out that besides the combustion chamber configuration determined by design and thermodynamic considerations, questions relating to the response behaviour of potential charging units, maximum engine performance, emission levels and friction losses played a vital role.

At the end of his presentation, the lecturer briefly evaluated the NVH behaviour of two- and three-cylinder engines.

Dr.-Ing. P. Kreuter, **Dipl.-Ing. U. Peter**, **Dipl.-Ing. M. Kier**, **Dipl.-Ing. S. Wegner**, **Dipl.-Ing. M. Müller**, **Dipl.-Ing. R. Bey** (lecturer), Meta Motoren- und Energie-Technik GmbH, Herzogenrath: “Meta Downsizing Concept: Reduction of CO_2-Emissions to 75 g/km“:

In the light of today’s state-of-the-art, downsizing strategies for base engines used in smaller vehicles, i.e. small displacement engines, can be successfully applied only to a limited extent. For the subcompact vehicle category, the boundary conditions for effective downsizing in terms of thermodynamics can be markedly improved through the reduction in the number of cylinders. However, a smaller number of cylinders in combination with high supercharging rates also lead to high rotational irregularities at the crankshaft, thus resulting in lower driving comfort.

The Meta Downsizing strategy applied to a two-cylinder engine comprises the following technology approaches and measures:

- downsizing and simultaneously reducing the number of cylinders
- supercharging by means of a spontaneous charging device
- balancing torque fluctuations on the crankshaft
- Fuel: CNG.

As compared to the base engine this strategy results in improved performance and a reduction of CO_2-emissions by 75 g/km in the NEDC (in the compact car category) if vehicle design modifications are also made.

13 Downsizing – Otto Engines

Dr.-Ing. J. Hadler, **Dr.-Ing. R. Szengel**, **Dr.-Ing. H. Middendorf** (lecturer), **Dipl.-Ing. A. Kuphal**, **Dipl.-Ing. W. Siebert**, **Dipl.-Ing. Lars Hentschel**, Volkswagen AG, Wolfsburg: “Minimum Consumption – Maximum Power: TSI-Technology in Volkswagen’s New 1.2l Engine“:

After Volkswagen, three years ago, laid the foundations for the worldwide success of small gasoline engines with outstanding low-end torque and very low fuel consumption with its 1.4 l 125 kW TSI by combining double supercharging and direct injection, the 1.4 l 90 kW TSI engine which was launched last year represented a breakthrough for TSI technology also in the mid-size engine category.

Therefore, Volkswagen extended its TSI strategy by launching the new 1.2 l TSI engine which, having an output of 77 kW, is destined for the Polo and Golf class. The further evolution of engine technology for the small but powerful EA111 engine series included a consistent optimisation of friction losses and lightweight design. The engine, which boasts a new weight-optimised aluminium crankcase and an entirely novel combustion process, combines high performance, low fuel consumption and affordable costs for mass production.

Dipl.-Ing. D. Borrmann (lecturer), **Dipl.-Ing. B. Pingen**, **Dipl.-Ing. B. Müller**, **Prof. Dr. P. Kelly**, **Dipl.-Ing. K. Küpper**, **Dr.-Ing. M. Wirth**, Ford Werke GmbH, Cologne: “The Powertrain with a Small Downsized Engine: Design Strategies and System Components“:

The technology for downsizing gasoline engines is currently gaining ground in the compact cars of the C- and also the B-class. The additional combination with downspeeding results in a further reduction of CO_2-emissions.

This, however, calls for engine sizes and swept volumes which may have considerable disadvantages in the practical handling of vehicles.

Special attention was given to starting behaviour, switching requirements and transient acceleration capability.

Therefore, the entire drivetrain must be regarded for the successful implementation of a downsizing and downspeeding strategy, in order to find solutions that eliminate potential weaknesses on the one hand, but can also be applied to cost-sensitive market segments on the other.

Alongside calibration strategies for optimum starting behaviour, the stepping of gears was modified, which facilitates starting in the first gear but at the same time permits downspeeding over a broad range. If the available torque is properly conceived, an increase in the number of gears is not necessary. Automatic transmission guarantees customer acceptance. In order to reach similar driving behaviour with manual transmission, intelligent coupling systems can be used which decouple the clutch engagement from typical pedal motion characteristics of the driver.

Y. Boccadoro, **O. Tranchant** (lecturer), **R. Pionnier**, **H. Engelhardt**, Renault s.a.s., Rueil-Mailmaison: "The New TCe 130 1.4 l Turbocharged Gasoline Engine of Renault":

Renault is extending its TCe engine family which began with the TCe 100 with a swept volume of 1.2 l launched two years ago.

The lecturer described the supercharged 1.4 litre gasoline engine TCe 130. The goal was to design an engine that could replace a 2.0-litre naturally aspirated engine in the 100 kW-class and reduce CO_2-emissions.

The new engine has a maximum torque of 190Nm above the speed of 2250/min and a maximum performance of 96 kW at 5500/min. Special attention was given to acceleration in the low speed range.

As compared to the 2.0 l naturally aspirated engine, the TCe 130, which is used in the new Mégane III, shows 19% lower fuel consumption in the European Driving Cycle.

The engine is based on the Nissan 1.6 l naturally aspirated engine. The main design characteristics of this engine, which is entirely made of aluminium with iron-cast liners, are a forged crankshaft with eight counterweights, and a variable valve timing system on the inlet camshaft.

The TCe 130 was developed jointly by Reanult and Nissan .

14 Mixture Formation

Dr.-Ing. M. Dürnholz, (lecturer), **Dr.-Ing. R. Busch**, **R. Baskaran**, **B.Sc.**, **B.Tech.**, **MBA**, **S. L. Kulkarni**, **BE (Mech.)**, **G. Anthony**, **BE (Mech.)**, Bosch Ltd., Bangalore, India: "Bosch Common Rail System for Small Diesel Engines in Emerging Markets":

India in particular is showing signs of becoming a potential global hub for the small car market in the future. The per capita income in India is about 1000 US$, whereas in Germany the per capita income is about 38.000 US$. This translates into a very small population of Indian consumers who can afford products currently marketed in Western Europe and the USA. The challenge both for OEMs and suppliers is to offer unique products at dramatically lower costs to meet the special needs and match the lower purchasing power of buyers in most emerging markets.

One outcome of such an innovative model is the Tata Nano which was unveiled at the Auto Expo India 2008. Developing and creating low-cost products is not tantamount to low-tech products. It is about having a holistic approach consisting of local development and local manufacturing in line with clearly defined price-performance targets.

These ultra low cost automobiles target the huge consumer base in the emerging markets who drive two-wheelers today (7 million new motor cycles are bought every year in India alone). By 2010, automobiles in major Indian cities will have to comply with BS4 emission standards (equivalent to Euro IV). Under these boundary conditions, Bosch conceptualised a robust, highly competitive common-rail system for small diesel engines which meets the demands of car-makers for a state-of-the-art technology that will comply with future emission standards while offering a realistic price-performance ratio. The lecturer then explained the need for adopting highly advanced technology to the segment of low-cost vehicles and meeting the requirements made upon an injection system under difficult boundary conditions. At the end of his presentation, the lecturer gave an outlook for the future potential of this system.

Dr.-Ing. D. Schöppe (lecturer), **Dipl.-Ing. S. Zülch**, **Dipl.-Ing. D. Geurts**, **C. Gris**, **Dr.-Ing. R. W. Jorach**, Delphi Diesel Systems, Europe: "Delphi's New Direct Acting Common Rail Injection System":

In the Direct Acting Common Rail System, the injector needle is set in motion by a piezo ceramic actuator instead of an indirect control incorporated in an electro-hydraulic servo mechanism used by conventional fuel injection technologies. Thus the nozzle needle can be opened and closed very rapidly, independently of rail pressure. With the aid of a two-stage needle motion amplifier, the injection process can be accurately controlled at any time. The integrated additional fuel accumulator operates as a "rail in the injector" and improves injection quality, especially for multiple injection. The injector operates without any leakage.

The use of a piezo actuator as the driver for the direct acting injector has given rise to a number of new demands upon electronics. Therefore, a new electronic control system was devised in order to assure optimum actuation of the direct acting injector.

The lecturer elaborated on the design and operating principles of the direct acting CR system and its performance characteristics, which constitute the basis for a premium diesel engine.

Dipl.-Ing. M. Miyaki, **Dipl.-Ing. K. Takeuchi**, **Dipl.-Ing.K. Ishizuka**, **Dipl.-Ing. S. Sasaki**, Denso Corporation, Aichi-Ken, Japan; **M. Nakagawa** (lecturer), Denso Automotive Deutschland GmbH, Wegberg: "Breakthrough in Common Rail Systems: Controlled Injection by means of an Injector with Built-in Pressure Sensor":

Denso has developed the world's first common rail system injector with built-in pressure sensor. This technology permits closed loop injection control in the cylinders. With the recently developed combustion technology, the desired reduction of NO_x-emission is achieved primarily through high EGR rates and process strategies close to conventional limits (and the range for attaining these is extremely narrow).

With this newly developed technology, the fuel injection rate, which determines the combustion process in the engine cylinders, is directly detected and controlled in a closed loop to allow precise compensation of the injection system for its entire service life. Highly advanced injection control allows extremely close multiple injections, and variable injection rate control can be assured in mass production for the first time. In addition, the use of this technology offers three major advantages for the overall engine system. Alongside the expansion of the possible calibration range, which improves fuel economy and reduces emissions, it heightens the overall robustness and reliability of the engine. With closed-loop control, the number of man-hours required for calibration can be significantly reduced.

15 Plenary Closing Session: A View into the Future

K. Saga, Managing Officer, Toyota Motor Corporation, Aichi-ken, Japan, **Figure 12**: "Does Hybrid Technology Mean the End of Conventional Combustion Engines?":

Fossil fuel depletion, global warming due to increased atmospheric CO_2, and urban air pollution caused by exhaust emis-

Figure 16: From right to left: Prof. Dr. M. Winterkorn, VW; Prof. Dr. F. Piëch, VW; Mrs. U. Piëch, Mrs. M. Lenz

sions are some of the issues surrounding the future of the automobile. One high profile solution to these problems is the hybrid vehicle. Currently, coming into wider use throughout the world, HVs use energy regeneration and other functions to boost fuel economy and reduce CO_2. Based on the history of Toyota's HV development, the lecturer explained Toyota's view that hybrid technology will not mean the end of conventional combustion engines, but, on the contrary, will extend fossil fuel availability as a result of lower consumption rates and will thus prolong the life of the conventional combustion engine.

Combustion engines would no longer be able to survive once all conventional fuel reserves were depleted, the lecturer stressed.

D. M. Hancock, Vice President, General Motors Corporation, Pontiac, USA, **Figure 13**: "GM´s Voltec Propulsion System: A Further Step in the Electrification of the Vehicle":

In late 2010, General Motors will begin volume production of the Chevrolet Volt, followed approximately one year later by the Opel/Vauxhall Ampera. These automobiles are extended-range electric vehicles (E-REVs) based on GM's Voltec electric propulsion system. They use a rechargeable onboard energy storage system – specifically an advanced lithium-ion-battery – and an electric traction motor to provide full-performance electric propulsion exclusively for up to 64 km driving range (based on Euro MVEG cycle, 40 mile range based on the EPA city and highway cycle). The battery can be recharged by plugging into a standard European 220 Volt (U.S. 120 V or 240 V) outlet or other level 1 and level 2 charging standards. The Voltec propulsion system also includes an onboard electric generator powered by a small internal combustion engine. The generator is engaged automatically to extend the vehicle's total operating range.

The car's 64-km range on initial charge is well suited to most European and North American drivers, who typically travel less than that distance each day. In those cases, the Volt and Ampera may never engage their onboard generators and thus would produce little or no carbon dioxide or other tailpipe emissions over much of the vehicle's life cycle.

Prof. Dr. M. Winterkorn, Chairman of the Board, Volkswagen AG, Wolfsburg, **Figure 14**: "The Multi-Brand Philosophy of the Volkswagen Group":

In his impressive closing lecture, Prof. Winterkorn pointed out that the automotive industry was facing enormous challenges in many respects. Two factors would be crucial to future success: the first was strong, clearly positioned brands and attractive vehicles, and the second was economic and technological capability.

This is where the multi-brand philosophy of the Volkswagen Group came into its own. Nine successful automobile brands – from Audi to Scania, from Volkswagen to Lamborghini – met every customer wish all over the world. And the Group alliance not only gave the brands the required critical mass, but also offered a technological, ecological and economic potential which no other automaker could match. The Volkswagen Group's cross-brand Modular Matrices were the technological backbone for leveraging this potential to the full, the lecturer concluded. On this basis, Europe's largest automaker has set its sights on an ambitious goal: to lead the global automotive industry by 2018.

With this closing lecture, which was followed by a discussion to which leading figures from the automotive industry contributed, the 30th International Vienna Motor Symposium was concluded, **Figure 15** and **Figure 16**.

Conference Documentation

The lectures presented at the 30th International Vienna Motor Symposium are published in their in extenso versions, in the VDI-Fortschritt-Berichte, series 12, no. 697, volumes 1 und 2 (including a CD), and additional brochures.

Illustrated Book "30 Jahre Wiener Motorensymposium" (30 Years of the Vienna International Motor Symposium).

This book contains photographs from 30 years of the Vienna Motor Symposium.
All documents can be obtained from the Austrian Association of Automotive Engineers (Österreichischer Verein für Kraftfahrzeugtechnik, ÖVK).

Invitation

The 31st International Vienna Motor Symposium will take place on April 29th and 30th, 2010 in the Congress Centre Hofburg Vienna.
We should like to extend a cordial invitation to you already at this point in time. After the announcement of the programme on the internet, which will probably be made around mid-December 2009, we urgently recommend that you apply in good time.

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