32ND INTERNATIONAL VIENNA MOTOR SYMPOSIUM

As every year, more than 1000 leading automotive engineers involved in engine development and scientists from all over the world met at the 32nd International Vienna Motor Symposium, which took place on May 5th and 6th, 2011. They presented their latest findings in engine development and gave an outlook for future trends in the automotive engineering industry. This report contains summaries of the lectures presented by the individual authors.

AUTHOR

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INTRODUCTION

After a welcome fanfare performed by the members of the orchestra of the Vienna University of Technology, **Prof. Lenz**, ❶, welcomed the participants in the 32nd International Vienna Motor Symposium, which was again fully booked, ❷.

As in previous years, all lectures are contained in the VDI progress reports, including a CD with the English version of these texts. Upon request, the lectures presented by university professors and university assistants were submitted to a peer review that was conducted by Wissenschaftliche Gesellschaft für Kraftfahrzeug- und Motorentechnik e. V. (WKM: Scientific Society for Automotive Engineering and Engine Technology).

Prof. Lenz also drew attention to the search system of the Austrian Society of Automotive Engineers (Österreichischer Verein für Kraftfahrzeugtechnik), which offers users the opportunity to find titles of lectures as well as names of authors and companies of the preceding Motor Symposia as well as other lectures presented elsewhere by entering search words. Created in 1985, this data base now contains a total of over 1,000 lectures.

Prof. Lenz emphasized that the hype about electric vehicles that had prevailed until recently in the general public, and particularly amongst politicians and the media was now waning and giving way to a more realistic attitude. The internal combustion engine, he stressed, would remain the main drive unit in the future as well, but it would be assisted by an electric motor that would not only simplify the drive unit but also increase fuel efficiency. However, the internal combustion unit had also prepared the ground for the electric drive. Prof. Lenz pointed out that without the internal combustion engine acting as a range extender, the electric drive suffered from serious limitations. Hence we can expect to see a symbiosis between the internal combustion engine and the electric motor: as biologists would say, such a symbiosis consists in the interaction of two different species for mutual benefit. Therefore, the question no longer arises as to whether the future belongs to the internal combustion engine or to the electric motor: it belongs to a combination of both.

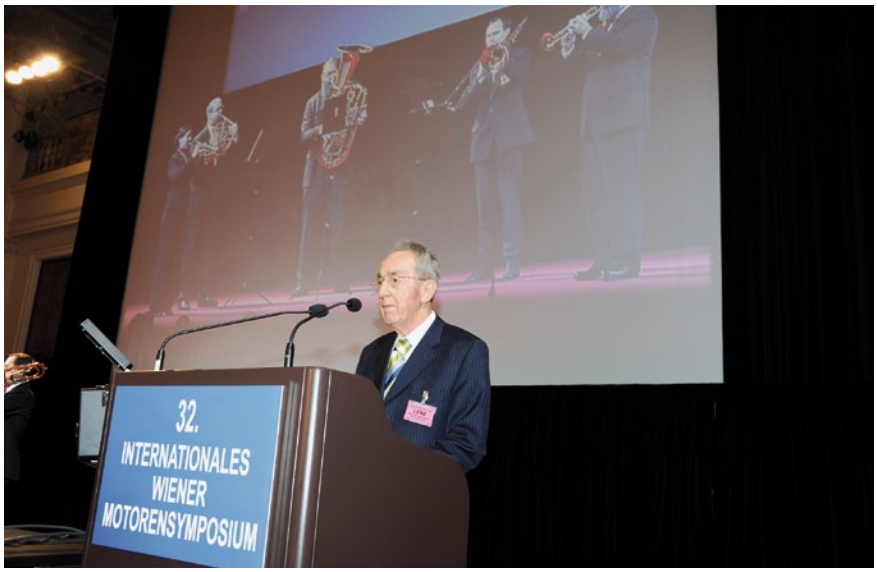
The internal combustion engine must avoid unfavourable efficiency ranges by shifting the load point. This can be achieved through partial electrification. In the coming decades second-generation biofuels will lessen our dependence on fossil fuels and will constitute a valuable supplement to these. In Prof. Lenz's opinion, this is an exciting and promising time for the global automotive industry, which is currently facing major challenges that need to be met by multiple solutions. In this process, the overall energy balance, the total-life-cycle concerning energy consumption, emission levels and resources will play an ever more significant role.

In the two parallel sessions which followed the joint opening plenary, ❸ and ❹, technical lectures were presented under the chairmanship of professors **G. Brasseur, H. Eichlseder, B. Geringer, G. Jürgens** and **H. P. Lenz**. An impressive exhibition showing a wide range of new engines, components and vehicles provided an excellent supplement to the lectures, ❺, ❻ and ❼.

Accompanying persons were offered a culturally sophisticated social programme which included an excursion to the churches and convents in the Vienna Woods, a "musical walk" through the city centre and a visit to the National Library. The conference participants spent a pleasant evening at the "Heurigen" Fuhrgassl-Huber, a typically Viennese wine tavern in Neustift am Walde.

❶ Univ.-Prof. Dr. H. P. Lenz

PLENARY OPENING SESSION



❷ Opening ceremony with fanfare performance

The first lecture in the opening plenary session was presented by **Thomas G. Stephens**, ❽, Vice Chairman and Global Chief Technology Officer, General Motors Company, Detroit, MI, USA: "World's Best Vehicles: Winning with the Right Bandwidth of Powertrains and Vehicle Architectures":

The speaker explained that driven by the desire to make vehicles petroleum-free and emission-free, and amid growing concern about greenhouse gases, energy supply and demand, fuel prices, and even urban congestion, there was an increasing realization that the automobile as we know it today is simply not sustainable. Convinced that there cannot be a single solution to the challenges faced by the industry, GM pursued a strategy that encompasses a range of options including alternative fuels, new technologies for conventional powertrains, and the electrification of the automobile through the introduction of multiple hybrid systems, plug-in hybrid vehicles, extended-range electric vehicles, battery-electric vehicles and ultimately fuel cells.

The lecturer went on to say that GM realized that moving toward a future with new types of vehicles and more reliance on electricity and hydrogen as energy carriers would take more time. Therefore, GM continued to develop evolutionary technologies that were already providing more efficient and lower-emission vehicles capable of using a wider range of fuels. The band-width of customer requirements spanned mini and small cars to large trucks. GM's hybrid systems, he concluded, began with stops-start technology and moved to the company's Voltec extended-range electric propulsion system.

Yoshihiko Matsuda, ❾, Managing Officer, Toyota Motor Corporation, Aichi, Japan: "Toyota's Powertrain Strategy for Developed and Emerging Markets":

Although the development of electric vehicles (EVs) is making progress, fossil fuels will continue to be used for a long time in combination with hybrid and plug-in hybrid technology. It can also be expected that biofuels and gaseous fuels, such as CNG, will play an ever more important role in the future. In conventional gasoline and diesel engines new technologies will be applied in order to maximize power and fuel efficiency while minimizing CO_2 emissions. Similarly, the performance characteristics of hybrid vehicles (HV) will in all probability be further enhanced. As the need for using electricity for mobility is better understood, greater emphasis will be placed on developing plug-in hybrid vehicles (PHV), which combine the advantages of low exhaust gas emissions and CO_2 for short-distance electric driving with the flexibility and range of combustion engines for long distance driving. Improvements in the energy density of batteries will result in better market opportunities for EV.

With the ever faster pace of motorization, the BRIC markets, most notably China, India and Brazil, are continuing to expand to a comparable or larger market size as the developed regions. Car makers are facing yet another challenge: they have to respond to the varying conditions for vehicle usage and diverse customer requirements in these markets, which expect the introduction of the same technologies as those currently applied in the developed markets. As the range of available fuel qualities and vehicle usage conditions widens, safety, environment and quality remain priorities rather than rapidly increasing sales volumes.

Dr. Karl-Thomas Neumann, ❿, President and CEO, Volkswagen Group China, Beijing, China: "What's Moving China? Powertrain Technologies for the Largest Car Market":

China is the world's largest and fastest growing automotive market; thus attention is increasingly focused not only on the country's economic importance, but also on the ecological impacts of its growth. The Chinese government is well aware of this and given the country's heavy dependence on oil imports and the ambitious goal to reduce CO_2 emissions, China sees the future of mobility in electric vehicles.

For cars with conventional internal combustion engines, the Chinese government is currently fixing maximum fuel consumption limits and will tighten these further in the near future. China has also clearly defined its strategies to promote electric mobility. The development of electric vehicles is heavily encouraged in China by means of sales targets, national and local financial incentives for electric vehicles as well as regional infrastructure investment plans. As in the rest of the world, a number of other challenges have to be met, such as reducing battery costs and charging time, extending the driving range of these vehicles and optimizing the energy mix at the national level.

NEW OTTO ENGINES

Dipl.-Ing. P. Langen (lecturer), **Dr.-Ing. J. Reissing, Dr. B. Lopez Alvaredo**, BMW Group, Munich: "The New BMW Engine Portfolio – A Basis for Sustainable Powertrain Solutions":

Sustainable powertrain solutions represent one mainstay of BMW's corporate strategy, EfficientDynamics, which seeks to achieve CO_2-free individual mobility. In this context, the lecturer explained the systematic and consistent development of the TwinPower turbo technology for gasoline engines and high-pressure supercharging of diesel engines as measures to reduce primary energy consumption. He also illustrated the Vision EfficientDynamics design optimized for fuel efficiency as an example for downsizing an internal combustion engine in hybrid drive systems and the market acceptance of this concept. The lecturer also described another mainstay of the EfficientDynamics strategy, the electromotive drive which is used in the BMW ActiveE.

Ing. F. Steinparzer (lecturer), **Dr.-Ing. H. Unger, Dipl.-Ing. T. Brüner, Dipl.-Ing. D. Kannenberg**, BMW Group, Munich: "The New BMW 2,0 Litre 4-Cylinder S.I. Engine with Twin Power Turbo Technology":

With the introduction of the completely redesigned 2.0 l S.I. engine with direct injection and turbocharging, BMW consistently pursued its EfficientDynamics strategy. The new engine will be used in the performance range of up to approximately 180 kW and thus replaces the 3.0 l six-cylinder naturally aspirated engine. This new all-aluminium engine uses a highly efficient BMW-specific TVDI combustion system that combines direct injection with central injector position, fully-variable intake valve control and turbo charging. One highlight is the first-time large-scale implementation of a new cylinder-liner technology based on electric-arc wire welding that allows a wider choice with regard to the geometric design of the engine and thermal conditions for crankcase design. Thanks to the consistent optimization of the base engine, sophisticated thermal management and the use of many fuel-saving technologies, such as, demand-based drives of auxiliary units, the new engine, in terms of fuel efficiency, ranks at the top of the list in its performance category.

As the new engine will be fitted in a wide variety of vehicles, from the 1series, 4 series, 5 series to the X3 series, it has been designed for excellent acoustic behaviour and vibration characteristics. In addition to the very high stiffness values of the base engine, mass balancing with height offset, a very high balancing wheel and a centrifugal pendulum-type absorber for reduction of rotational speed, irregularities play a significant role. The series launch of the new engine will be in the BMW X1, followed shortly by a rollout to almost the entire BMW vehicle fleet.

Dr.-Ing. T. Heiduk (lecturer), **Dipl.-Ing. R. Dornhöfer, Dipl.-Ing. A. Eiser, Dr.-Ing. M. Grigo, Dipl.-Ing. A. Pelzer, Dr.-Ing. R. Wurms**, Audi AG, Ingolstadt: "The New Generation of the R4 TFSI Engine from Audi":

With the new 1.8 l TFSI engine in the Audi B8 family (A4, A5), Audi launches the third generation of the four-cylinder in-line TFSI technology. The engine was completely revised in order to meet the ambitious CO_2 targets and ensure compliance with future Euro 6 emissions standards. With this development other strategic objectives were also pursued, such as cross-market applicability and integration into the VW Group's world-wide manufacturing network, which continue to constitute key elements of the EA888 global engine family.

This new generation features numerous innovative technologies, including a cooled exhaust manifold integrated into the cylinder head, a combined FSI/MPI fuel injection system with 200 bar high-pressure injection, and the Audi Valvelift system on the exhaust side in combination with an exhaust camshaft adjuster. A particular highlight is the world's first application of an entirely new rotary thermal slide control system which ensures implement intelligent thermal management. As a result of the fundamental revision of all functional groups with a view to optimizing thermodynamics, friction and weight, the first version of this new engine generation – the 1.8 l TFSI – represents a new benchmark in its class in terms of fuel efficiency and performance.

EXHAUST GAS AFTERTREATMENT / HYBRID COMMERCIAL VEHICLES

Dipl.-Ing. T. Dobes, Dr. G. K. Fraidl (lecturer), **Dipl.-Ing. P. Hollerer, Dr. P. E. Kapus, Dipl.-Ing. M. Ogris, Dipl.-Ing. M. Riener**, AVL List GmbH, Graz: "Measures to Comply with Future Particulate Number Standards with GDI Engines":

In contrast to conventional diesel engines in which due to heterogeneous combustion, particulate emissions cannot be entirely eliminated, in gasoline engines with homogeneous combustion a substantial reduction of particle numbers below the environmentally critical threshold can be attained through intensive development efforts, even without using a particulate tap.

However, particulate numbers represent the most complex emission component in gasoline engines with regard to measuring technique, conditioning, reproducibility, tolerance sensitivity, long-term stability,

❸ Festival hall

diagnosis as well as development methodology. In this process, the particulate counter itself has proved relatively uncritical. With regard to adequate conditioning of the engine, the vehicle and the dilution tunnel, however, comprehensive fundamental investigations will still be required. Although very low particulate numbers have been reached with individual prototype vehicles thanks to complex optimization measures, comprehensive fundamental studies will have to be performed before these low particulate emissions can be assured in series-production engines.

Dipl.-Ing. W. Maus, Dipl.-Ing. R. Brück (lecturer), **Dipl.-Ing. R. Konieczny, Dipl.-Ing. P. Hirth**, Emitec Gesellschaft für Emissionstechnologie mbH, Lohmar: "The Future of Exhaust Aftertreatment Design for Electrified Drivetrains":

In the debate about CO_2 emissions and fuel consumption, for political reasons, electric vehicles are often portrayed as the best solution. However, given the available energy capacity, the attainable range of these vehicles is severely limited, especially under real-world driving conditions. Electrified drivetrains, ranging from mild hybrids and full hybrids to electric vehicles with range extenders offer an alternative.

In combination with an electric motor, internal combustion engines require different catalytic converter system, depending on their specific design. This holds true, in particular, if the minimum residual emissions from internal combustion engines are not to impair the "zero-emission" image of electric vehicles. The lecturer described the application of a new catalyst design, the range-extender catalyst and illustrated both its design criteria and its impact on tailpipe emissions, particularly when used in gasoline engines.

Dipl.-Ing. S. Wallner (lecturer), **Dr.-Ing. M. Lamke, Dr.-Ing. M. Mohr, Dipl.-Ing. (FH) M. Sedlacek, Dr.-Ing. F. D. Speck**, ZF Friedrichshafen AG, Friedrichshafen: "Hybrid Platform: Economical Hybrid Drive for Commercial Vehicles":

To date, hybrid systems have been adapted to specific requirements for various applications in trucks, buses as well as special purpose vehicles and machines used in forestry and agriculture. From a technical point of view, this results in optimized hybrid drives for every vehicle application but because of the small number of units produced, such specific developments appear critical from the economic point of view. In response to the technical and economic requirements of the cost-sensitive commercial vehicle (CV) segment, ZF Friedrichshafen AG has come up with a solution in the form of a modular CV parallel hybrid platform, which comprises a hybrid modular system, an inverter, a battery system and hybrid software integrated into the overall vehicle.

Thanks to this intelligent combination of assemblies and the use of the largest possible number of common parts, a platform has been created that covers power ranges of between 60 kW and 120 kW, voltage bands between 350 V and 650 V, and a battery capacity of between 2 kW and 4 kWh. The dimensions of the platform elements were chosen with a view to ensuring easy integration into various commercial vehicle applications. The hybrid software required for vehicle-specific functions can also be configured for these individual commercial vehicle applications.

❹ Ceremonial hall

NEW DIESEL ENGINES

Dipl.-Ing. R. Bauder (lecturer), **Dr. C. Eiglmeier, Dipl.-Ing. A. Eiser, Dr. H. Marckwardt**, Audi AG, Neckarsulm: "The New High-Performance Diesel Engine from Audi, the 3.0 l V6 TDI with Dual-Stage Turbocharging":

Audi introduced the 3.0 l V6 TDI with dual-stage turbocharging as its top-of-the-range diesel engine for the new A6 and A7. The engine boasts a power output of 230 kW and has a maximum torque of 650 Nm. The compact dual-stage turbocharging system positioned in the inner V of the engine and above the gearbox constitutes the core of this engine. The high-pressure turbocharger features a variable turbine geometry with an electronic adjuster. The low-pressure turbocharger is wastegate controlled and designed for high throughputs, so that the engine reaches a high torque in the minimum engine speed range and maintains a power plateau up to the highest speed range. As a result, the vehicle shows an excellent starting performance and outstanding responsiveness that underlines the sporty character of the engine.

The base unit is the well-known 3.0 l V6 TDI of the second generation, which was upgraded with a view to delivering higher performance. All fuel economy features of the base engine have been retained, so that it was possible to combine this excellent performance with low fuel consumption.

Dipl.-Ing. J. Kahrstedt (lecturer), **Dipl.-Ing. R. Dorenkamp, Dipl.-Ing. S. Kuiken, Dipl.-Ing. M. Greiner, Dipl.-Ing. I. Kühne, Dipl.-Ing. G. Nigro, Dr. rer. nat. T. Düsterdiek, Dipl.-Ing. B. Veldten, Dipl.-Ing. N. Thöm**, Volkswagen AG, Wolfsburg: "The New 2,0 l TDI to Fulfill American Emission Standards in Volkswagen's New Passat":

The second-generation 2.0 l TDI engine known by its extensive use in Europe was

extensively reviewed and further developed for the new Passat so as to be able to meet American BIN5/ULEV emission standards. For this purpose, it was necessary to lower engine-out untreated emissions, and to ensure compliance with US emission standards over the entire service life of the car with the aid of selective catalytic reduction (SCR).

With a view to improving the LP-EGR system, special efforts were made to reduce pressure losses in the system and charge-air cooling was converted from air to water cooling. Water-cooled charge-air cooling permits temperature control of the intake pipe independently of the ambient temperature. Thanks to optimized air flow control the air volume, it was possible to improve driving dynamics while lowering fuel consumption. The closed-loop control of the indicated mean pressure and the centre of combustion by means of a pressure sensor integrated into the glow-plug, the influences of fluctuations in fuel quality, especially in cetane number were minimized, and component tolerances could be kept to an absolute minimum. The exhaust system was completely revised in order to achieve maximum NO_x-conversion in the SCR catalytic converter. The concept of the SCR system was taken over from the Passat BlueTDI which was introduced in Europe in 2009 and complies with Euro 6 standards. Given the stringent statutory Californian emission limits, the OBD system had to be upgraded for the model year 2013.

Dr.-Ing. N. Ardey (lecturer), **Dipl.-Ing. C. Hiemesch, Dipl.-Ing. J. Honeder, Dr.-Ing. M. Kaufmann**, BMW Motoren GmbH, Steyr: "The New BMW 6-Cylinder Diesel Engine":

The new 3.0 l six-cylinder diesel engine was launched in the market in September 2008. This engine is derived from the 2.0 l four-cylinder diesel engine and used in the majority of BMW's model lines in different power rating versions. With the new six-cylinder diesel engine, typical characteristics of the BMW brand were developed further. As a result of the engineering revision of the base engine and its thermo-dynamic optimization, it was possible to increase not only output and torque, but also to improve fuel efficiency and lower emissions. Thus the spontaneous response of the engine has been noticeably improved and, its already low noise emissions have been lowered further.

The new engine was first used in the BMW 530d xDrive in March 2011. In line with the EfficientDynamics concept, this six-cylinder engine features for the first time the auto-start-stop function as standard equipment.

FLEXIBLE USE OF FUEL

Dr.-Ing. J. Hadler, Dr.-Ing. R. Szengel, Dr.-Ing. H. Middendorf (lecturer), **Dipl.-Ing. H. Sperling, Dipl.-Ing. H.-G. Gröer, Dipl.-Ing. L. Tilchner**, Volkswagen AG, Wolfsburg: "The 1.4 l 118 kW TSI for E85 Mode – Expansion of the Most Economical Line of Petrol Engines from Volkswagen":

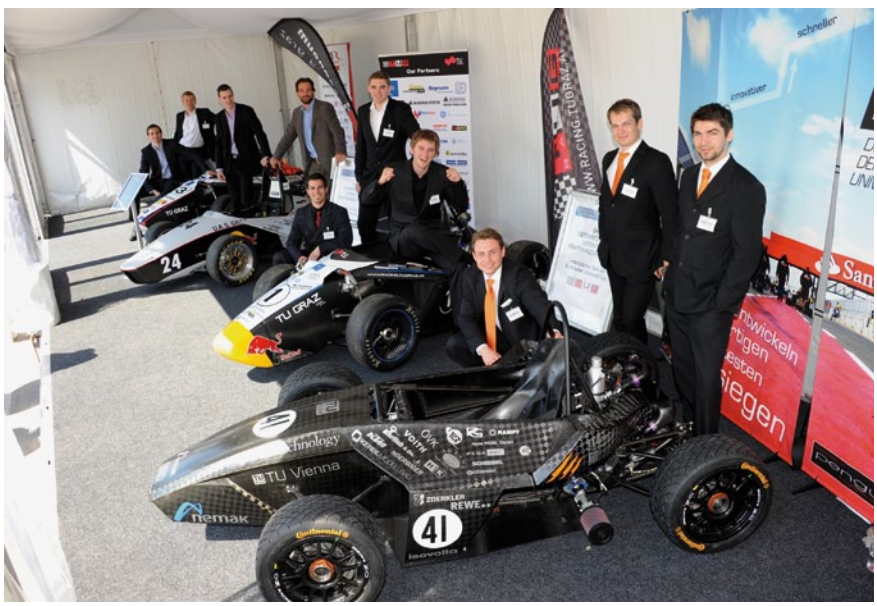
With the further development of the twin-turbocharged 1.4 l 118 kW TSI engine groomed for running on ethanol with E85 fuel, Volkswagen is expanding its range of environmentally friendly engines and thus making a further contribution to reducing CO_2 emissions from combustion engines.

The engine is intended for use in the Passat and Passat CC, initially in Sweden and Finland. By using materials specifically designed for operation with ethanol, and through a more sophisticated injection process, reliable operational and excellent starting behaviour have been assured for all ethanol grades up to E85. The combination of the new TSI with the Volkswagen seven-speed dual clutch gearbox (DSG) in the Passat saloon has resulted in a consumption of 8.8 l (E85), which corresponds to an emission level of 144 g CO_2/km in the New European Driving Cycle. This means that a 7 % CO_2 reduction has been achieved as compared to premium unleaded gasoline (ROZ 95).

Dr. C. Trapp (lecturer), **Dr. S. Laiminger, Dipl.-Ing. D. Chvatal**, GE Jenbacher GmbH & Co OHG, Jenbach; **ao. Univ.-Prof. Dr. A. Wimmer, Dr. E. Schneßl, Dr. G. Pirker**, Graz University of Technology: "The New Generation of GE's Jenbacher Gas Engines – Highest Efficiency with Two Stage Turbocharging":

With the new generation of two-stage turbocharged gas engines, which use groundbreaking combustion processes, GE introduced a new engine family within its Jenbach portfolio. This engine family can be optimally adapted to the most diverse applications, from pure power generation in moderate climates, to the cogeneration of heat and power, and from operation in tropical climates to CO_2 fertilization in greenhouses.

With an electrical efficiency of 48.7 % or an overall efficiency rate of over 90 %, this engine shows high flexibility with regard to all operating conditions and fuels and thus meets the ever more stringent emission standards world-wide. This significant increase in efficiency results from new combustion processes and ignition concepts, which permit significantly higher BEMP and lean-burn limits.



5 Exhibition

Thanks to the Miller valve timing, knock limits and nitrogen oxide emissions have been reduced markedly. **Dr.-Ing. R. Krebs** (lecturer), **Dr.-Ing. H. Manz, Dipl.-Ing. S. Lieske, Dipl.-Ing. J. Willand**, Volkswagen AG, Wolfsburg; **Dipl.-Ing. W. Schultalbers**, IAV GmbH, Gifhorn: "The Volkswagen Combined Heat and Power Unit – Automotive Know How Supports Intelligent Power Generation":

Renewable energy sources and the efficient use of resources will gain ever greater importance in the future. This phenomenon will not only affect the automotive engineering industry. Public attention is particularly focused on the market of thermal energy and electricity generation. Volkswagen's "EcoBlue 2.0" cogeneration plant makes a vital contribution to the efficient use of resources and constitutes a central building bloc of Volkswagen's environmental strategy. By drawing on the experiences gained in engine technology, acoustics, electronics, control systems and thermal management, Volkswagen has created a product enjoying a unique selling position amongst all competitors and thus allows the Group to attain large sales volumes.

TOMORROW'S ENERGY AND MOBILITY

Prof. Dr. F. Schüth (lecturer), Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr; **Dr. E. Jacob**, Emissionskonzepte Motoren, Krailling: "The Future of Energy beyond Oil and Gas":

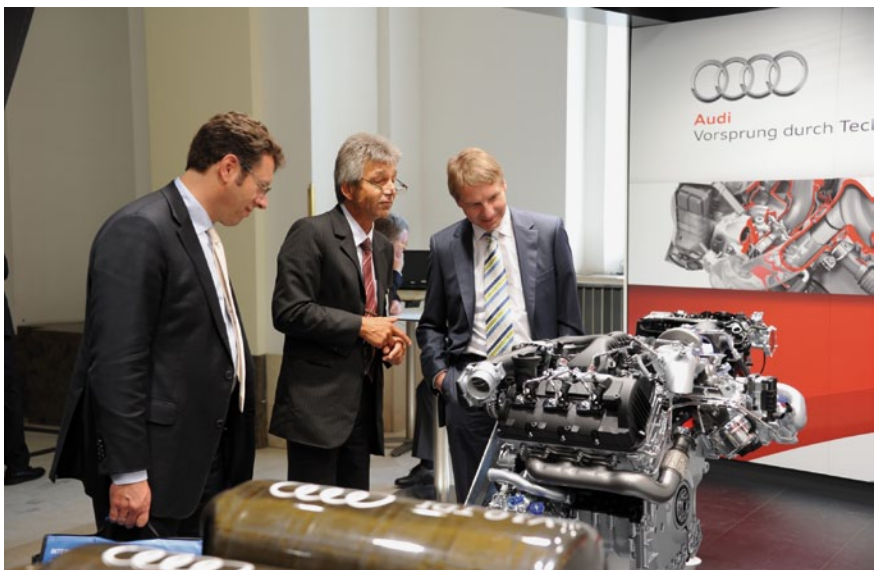
In the future, energy supply will be characterized by a departure from the current utilization of fossil primary energy sources. Today, electricity is largely produced from coal and nuclear energy, whereas mobility and heating systems are mainly based on oil and gas. Climate change calls for a more extensive use of non-fossil sources of energy, that, however, due to supply fluctuations depend on intelligent transportation and storage systems. In the future, a broadly diversified energy mix will be required which will have to ensure an efficient meshing of old and new, permanent and fluctuating, fossil and non-fossil sources of energy. This will create the need for a significant improvement in energy storage and transport technologies so that the burden on the environment and the climate can be kept to an absolute minimum. It is expected that electricity and mobility will merge into a joint field of application via intelligent energy storage systems. Energy supply will then be based on a mix of nuclear energy, coal, solar energy, hydropower and wind power, geothermal energy, non-fossil alcohols and ethers, as well as natural gas and biogas. The energy required for heating will stem primarily from solar thermal systems and biomass.

The composition of this energy mix will vary widely in different parts of the globe and will have to take into account prevailing social conditions, local resources, and CO_2 emission legislation. At present, the debate focuses on fuels such as methane and other hydrocarbons, methanol, ethanol in addition to hydrogen as effective substances for energy storage. At the same time, it is recognized that all of these options have drawbacks and limitations. In future energy systems, electricity will play an ever greater role. Progress made with lithium batteries has reached a certain plateau with regard to storage capacity and has to some degree failed to fulfill the expectations of the past few years. Therefore, new battery systems must be devised in order to be able to reach the ambitious objective of CO_2-free mobility.

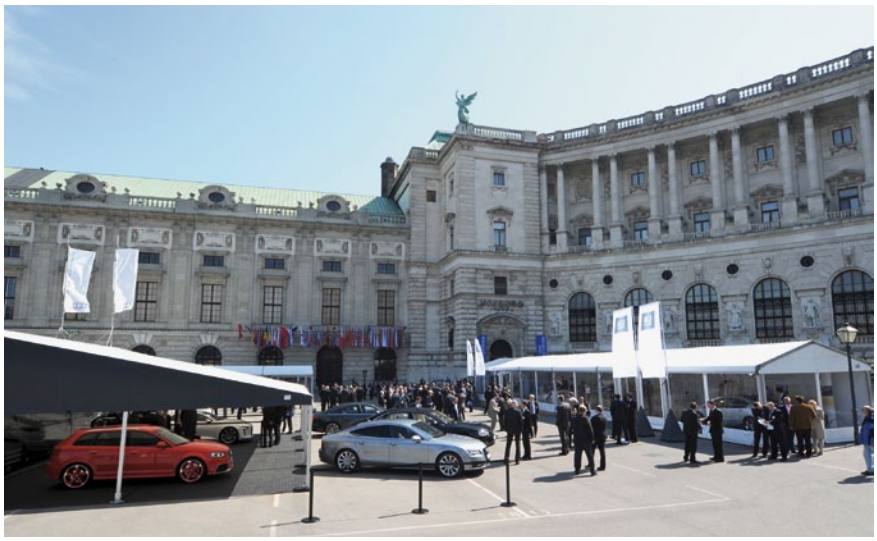
Prof. Dr. U. Stimming (lecturer), **H. Wolfschmidt**, Munich University of Technology; **Dr. M. Rzepka**, ZAE Bayern, Garching: "Hydrogen – Energy Carrier of the Future?":

Both from an ecological and economic perspective, the growing global demand for energy cannot be met through a massive expansion of energy generation alone. In this competition, efficient energy converters and accumulators will play a crucial role for automotive engineering as well as stationary applications. Long-term energy supply must be assured on the basis of regenerative (and other non-fossil) sources. Hence a wider variety of energy carriers will be needed that will have to be adjusted to, and chosen in accordance with energy requirements. This variety could range from energy carriers such as alcohols, hydrocarbons or hydrogen, electricity stored in batteries and mechanical storage systems. High energy densities, which are characteristic of chemical energy carriers offer particular benefits, especially with regard to the storage of energy, transport and automotive engineering applications. Thanks to state-of-the-art fuel cell systems, a highly efficient conversion of chemically stored energy can be achieved. A variety of systems, which simultaneously produce electricity and heat, are available for mobile applications, micro plants, vehicle drivetrains and large-scale commercial use. The challenge to be met results from the need to adjust fuel cells to the respective fuel, which can be achieved in many different ways through the generation of renewable forms of energy.

Dr.-Ing. J. Hadler, Volkswagen AG, Wolfsburg: "Mobility in the Conflict Area of Global Energy Chains":



6 Exhibition inside the Hofburg



❼ Exhibition in front of the Hofburg

Efficient use of energy is the dominant theme for the future of the automobile industry and will become even more important as resources continue to become ever scarcer. Although we are pressing ahead with detail technological innovations, some of which are specifically promoted, these are not the only approach to sustained mobility. We must, at the same time, focus on all-embracing, comprehensive solutions and ask ourselves a number of questions: How much energy do various sources supply? What are our energy needs? How can we obtain and distribute energy as efficiently as possible? The answers to these questions define humanity's overall scope for action and lead to decisive development perspectives for the automotive engineering industry.

The lecturer analyzed and compared the efficiencies of various types of energy carriers – biofuels and electric propulsion – from their sources to their use in motor vehicles. The results of this analysis show that in the long term, the sustainability potential of electromobility is very high, but that in the short and medium term biofuels have at least the same potential.

ENGINE VARIABILITIES

Dr.-Ing. K. Kirsten, Schaeffler Technologies GmbH & Co KG, Herzogenaurach: "The Variable Valve Train in the Debate on Downsizing and Hybrid Drives":

In the debate on drivetrain technologies for future passenger cars the buzz words downsizing, hybridization, variable valve trains, electrification etc. are more frequently heard. Thus the general public is gaining the impression that these technologies compete with each other and should be considered as alternatives. The lecturer sought to explain the reasons why, from the perspective of automotive engineers, the use of variable valve trains is desirable. He gave a systematic overview of the variable valve trains that are currently in use and described the function and influence of engine technology on the overall system based on selected examples. In addition, the lecturer illustrated the relationship between variable valve trains and other technologies and the contribution that valve trains, in combination with these technologies, can make to further improving internal combustion engines.

Dipl.-Ing. M. Kratzsch (lecturer), **Dipl.-Ing. M. Günther, Dipl.-Ing. S. Nicklitzsch, Dipl.-Ing. M. Medicke**, IAV GmbH, Berlin/Chemnitz: "The Quality-Controlled Gasoline Engine – A Consistent Approach Exhibiting Potential for the Future":

To date, development work on the gasoline engine has primarily concentrated on avoiding throttling losses. In part, these losses were already eliminated with VVL-concepts, stratified charge engines or downsizing strategies. In theory, the complete elimination of this type of losses could improve fuel economy by 30 % at highly throttled operating points.

In addition, there is considerable potential for reducing real gas losses, i.e. losses caused by combustion depending on the actua composition of the working gas. Therefore, a significantly leaner mixture can result in an approximation of the cycle process in the ideal engine. By consistently pursuing this approach a concept can be devised for a gasoline engine in which, in a similar way as with diesel engines, the load is adjusted by quality control instead of throttle control. With this procedure, fuel efficiency can be improved by up to 28 % over the entire engine map and up to 10 % in the driving cycle as compared to the currently applied stratified charge concept. The lecturer described the concept of a "quality-controlled gasoline engine", as well as its implementation and reported the result obtained from simulation studies and measurements on an engine test bench. On the basis of these results, he then explained the fuel efficiency potential in driving cycles.

Dr. P. E. Kapus (lecturer), **Dipl.-Ing. (FH) C. Spanner, Dipl.-Ing. (FH) B. Graf, Dr. G. K. Fraidl**, AVL List GmbH, Graz: "Cylinder Deactivation in 4 Cylinder Engines – An Alternative to 2 Cylinders?":

In the US, cylinder deactivation has proved a successful approach to improving fuel efficiency. The majority of European OEM favour downsizing or downspeeding. In doing so, some very advanced concepts have been conceived and use engines with a very low number of cylinders (twin cylinder) which has given rise to challenges with regard to NVH behaviour.

The lecturer dealt with the question of whether a reduction of the number of cylinders is necessary in all applications, or whether it would not be feasible to deactivate individual cylinders or cylinder groups in order to achieve the same improvement of the fuel efficiency of vehicles. The lecturer stated that in order to be able to answer this question, a systematic analysis of the entire drivetrain had to be carried out. An optimization of the internal combustion engine did not suffice, he explained, but the drivetrain and the vehicle would also have to be modified in order to achieve the lowest possible CO_2 emissions. In the lecturer's opinion, an intelligent combination of supercharging, cylinder deactivation and secondary measures was definitely as efficient as the reduction of the number of cylinder.

❽ Thomas G. Stephens

❾ Yosihiko Matsuda

FUNDAMENTAL ISSUES OF ELECTRIFICATION

Univ.-Prof.Dr. C. Beidl (lecturer), **Dipl.-Ing. M. Kluin**, Darmstadt University of Technology; **Univ.-Prof. Dr. G. Hohenberg** (lecturer), **Dipl.-Ing. C. Bacher**, IVD Prof. Hohenberg GmbH, Graz: "Electric Vehicles with or without Range Extender: Who Is the Driver – Technology, Customer or Legislation?":

The lecturers began their presentation by analyzing the basic technological context of e-mobility. The limited range of electric vehicles was the central issue, they explained and stressed that as the size of cars increased, ever more complex problems arose and driving speed as well as ambient conditions played a significant role. Therefore, the combination of an electric motor and an internal combustion engine acted as an enabler of e-mobility, at least from today's vantage point. This approach leads to drive systems that overcome the limitations of purely electric vehicles in terms of flexibility of use and available mobility. The lecturers illustrated the difference between parallel and serial drives on the basis of concepts that have already been translated into reality. They then described a new concept for a compact and cost-efficient solution (the ICE-Assist).

In the second part of their presentation, the lecturers dealt with the current legal framework, customer expectations and technological solutions. It was of critical importance, they pointed out, which concept would receive the envisaged government incentives as these would be indispensable for the acceptance of electric vehicles by the general public. Therefore, OEMs experienced considerable uncertainty with regard to the most viable concept, and were currently looking for solutions that could cover all possible variants, the lecturers stressed. This invariably resulted in compromises, which further added to the time and effort involved and pushed up costs.

Customers generally had a positive attitude towards electric driving, the lecturers stressed, but their expectations were determined by past experience. Range extender/plug-in/ICE-assist solutions thus had the potential to significantly boost electric driving and the distances covered by electric vehicles. For a breakthrough of electric mobility, the general public would first have to know what an electric vehicle is. And it was the task of governments to provide this information, the lecturers concluded.

Prof. Dr.-Ing. U. D. Grebe (lecturer), **Dr. L. T. Nitz**, General Motors Company, Pontiac, MI, USA: "Electrification of General Motors' Vehicles – A Portfolio of Solutions":

General Motors offers a wide portfolio of solutions for vehicle electrification to meet the expectations of customers. Micro-hybrids for engine stop-start systems will become a standard solution for many market segments. Thanks to mild and strong hybrid systems together with optimized combustion engines, propulsion system efficiency would make a quantum leap with regard to efficiency. Plug-in hybrids offer the possibility to supplement the energy in the fuel with energy from the grid.

The Chevrolet Volt and the Opel Ampera are electric vehicles with extended range. They operate as electric vehicles as long as battery is charged. However, in contrast to battery-electric vehicles they do not suffer from lost vehicle utility when the battery is depleted. Volt and Ampera can continue operating by using an internal combustion engine and a generator. General Motors will widen its portfolio by offering battery-electric vehicles and fuel cell electric vehicles in the near future. General Motors expects a coexistence of all the different electrified propulsion systems in the coming decades.

Univ.-Prof. Dr.-Ing. S. Pischinger (lecturer), **Dipl.-Ing. K. Wolff, Dr.-Ing. G. Eisele, Dr.-Ing. P. Genender**, FEV Motorentechnik GmbH, Aachen; **Dipl.-Ing. Dipl.-Wirt.-Ing. G. Schürmann**, RWTH Aachen University: "E-Mobility: How Does the Future Sound?":

The lecturer analyzed the interior noise of electric vehicles by showing the example of FEV Liiondrive and comparing it with the sound of the corresponding series vehicle Fiat 500. Alongside an objective analysis of the sound, audio lab panel tests that also comprised virtual sound modifications were performed for subjective evaluation. On account of the missing combustion engine noise, the Liiondrive is up to 12 dB(A) quieter than the ICE-vehicle. By reducing the high-frequency sound components of the gearbox and the electric motor, even more pleasant sound is produced. The low load dependency of the sound creates an undynamic impression which can be counteracted by adding load-dependent low-frequency electric motor orders. As the impression of sound is perceived as less comfortable, probably this option will be chosen only for vehicles in the sporty market segment. The sound emissions of range extenders should remain below the level of the speed-

dependent noise of electric vehicles. This can be achieved with a suitable engine concept, i.e. a rotary engine, in combination with the right engine suspension and encapsulation. The operating strategy of the range extenders supplies further degrees of freedom for optimizing the NVH. Below a speed of 30 km/h, the operation of the range extender should not be perceivable. A vehicle-speed adjusted range extender speed above 30 km/h optimally benefits from the masking effects produced by road and wind noise and, in addition, creates a more dynamic sound impression.

INJECTION SYSTEMS FOR OTTO AND DIESEL ENGINES

M. Miyaki, BEng, (lecturer), **K. Takeuchi, BEng, A. Kojima, BEng, K. Uchiyama, BEng**, Denso Corporation, Aichi, Japan; **M. Nakagawa, BEng, Dr.-Ing. O. E. Herrmann**, Denso Automotive Deutschland GmbH, Eching; **Dr.-Ing. F. Maassen, Dr.-Ing. H. J. Laumen**, FEV Motorentechnik GmbH, Aachen: "Fulfilling Euro6 Emission Regulations for Heavy Duty Engines without SCR-System – A Challenge to the FIE System":

The diesel engine will continue to play a vital role in mobility and goods transport, especially in the rapidly expanding markets. However, the more stringent emission standards imposed by Euro 6 and Tier 4 provisions represent a major challenge and call for advanced exhaust gas aftertreatment systems, at least in the initial phase. This does not offer a direct advantage to end users – as purchasing costs will go up, additional packaging space will be required and a second fuel will have to be used which makes handling more complex. Therefore, a further reduction of engine-out emissions would permit a simplification of the aftertreatment system, thus making up for the afore-mentioned disadvantages. To this end, Denso developed a common rail injection system which was initially conceived for an injection pressure of 2,500 bar and subsequently 3,000 bar. Denso has taken up this technological challenge as part of its "diesel revolution" which is the key to further simplifying the diesel drivetrain. Injection pressure values of up to 3,000 bar can be achieved by means of an optimized high-pressure pump design and a static leakage-free solenoid injector. Tests on a 2.2 l single-cylinder engine carried out by FEV have revealed the potential for complying with Tier 4f emission standards without SCR – without any reduction of combustion efficiency. If, as an alternative, a slightly modified SCR is used, an injection pressure of 3,000 bar reduces fuel consumption and soot emissions. Thus, thanks to ultra-high injection pressure, costs can be brought down and other benefits be achieved for end users, which will contribute to assuring the attractiveness of diesel engines also in the future.

⓾ Dr. Karl-Thomas Neumann

Ing. J. Warga (lecturer), **Dr.-Ing. T. Pauer, Dipl.-Ing. F. Boecking, Dipl.-Ing. J. Gerhardt, Dr.-Ing. R. Leonhard**, Robert Bosch GmbH, Stuttgart: "Consistent Further Development of High Pressure Diesel Fuel Injection Systems for Passenger Cars":

The continuous increase of maximum injection pressure constitutes a guarantee for further improvements of engine performance. Through downsizing, boosting engine performance, reducing friction losses in the engine and thus lowering CO_2 emissions or improving emission behaviour, injection pressure plays a major role as it can offer additional degrees of freedom. Furthermore, the demands made upon other characteristics of the injection system have also changed continuously as a function of injection pressure.

The lecturer described the further development of the Bosch common rail system for Euro 6 applications, which comprises the new Bosch 2,000 bar solenoid valve injector, innovative nozzle technologies as e.g. improved spray hole geometry or the modular common rail pump CP4. Current engine tests involving pressures of up to 2,500 bar have clearly demonstrated the further advantages of increased pressure in diesel engines for passenger cars. In addition, the hydraulic components, the combination of electronic control, sensors and innovative control algorithms improves system accuracy and robustness.

Dr.-Ing. D. Schöppe (lecturer), **Dipl.-Ing. A. Greff, Dr.-Ing. H. Zhang, Dipl.-Ing. H. Frenzel, Dr.-Ing. G. Rösel, Dipl.-Ing. Dr. E. Achleitner, Dipl.-Ing. F. Kapphan**, Continental Automotive GmbH, Regensburg: "Requirements for Future Gasoline DI Systems and Respective Platform Solutions":

In order to be able to meet ever more stringent requirements, Continental has devised a range of platform solutions for the air-fuel and ignition systems tailored to the needs of the different markets. The turbocharged direct injection gasoline engine constitutes the basic technology for lowering fuel consumption. Alongside modifications to the injection system, Continental conceived an innovative turbocharger which has resulted in an improvement of the dynamic behaviour of the engine. In combination with variable valve train functionalities, this technology opens up new scope for reducing fuel consumption by downsizing and downspeeding.

The injection system plays a vital role in complying with future emission standards. Accurate fuel metering, particularly for very small injection quantities, and spray preparation are the key parameters which require optimization. Innovative injection systems incorporating these features are part of Continental's portfolio. Thanks to a mechatronic approach, the performance of the injection components can be improved so that future demands made upon the injectors with regard to metering accuracy and mixture preparation can be met. The noise emissions of the high-pressure pump can be counteracted by means of mechatronics. Turbocharged direct-injection engines require more ignition energy than naturally aspirated engines. These requirements are met

by an innovative ignition system. The open-architecture, scalable EMS 3 engine management platform presented at last year's Vienna Motor Symposium offers a convenient way of integrating various new functionalities for different markets and requirements.

COMPARISON OF DIFFERENT ENERGY STORAGE SYSTEMS

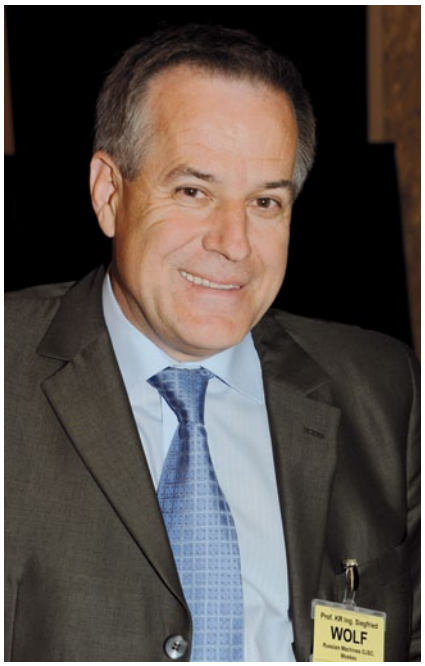
Prof. Dr. S. Passerini, Prof. Dr. M. Winter (lecturer), University of Münster: "The Electrification of the Powertrain with Lithium Ion Technology":

Lithium-ion-batteries were launched in the market in 1990/1991, but series production in significant quantities only started in the middle of the 1990ies. Within a short period, lithium-ion batteries emerged as the market leader in the segment of rechargeable small-sized batteries.

The progress of lithium-ion-batteries can be ascribed to both technological evolution and technology leaps, i.e. with the advent of new, active electrode materials possessing higher reactivity and voltage, higher energy densities can be achieved. To this end, however, all materials used in the batteries must be modified, which makes the development of materials for lithium-ion-batteries a complex task. These new systems are still based on the lithium-ion battery principle.

Significantly higher energy densities exceeding 300 Wh/kg can only be reached if battery systems other than the lithium-ion technology are used. Lithium-sulfur batteries attain specific energy levels of more than 400 Wh/kg, and metal-air systems reach energy densities exceeding 600 Wh/kg. In contrast to the usually closed battery systems, metal-air batteries are open systems in which ambient oxygen passing through an air-permeable membrane is electro-chemically transformed by means of reactive metals inside the battery. At present, special attention is being focused on the lithium-air system.

The recharging capacity of a battery is not a simple matter of course. A continuous process chain involving more than thousand charging/discharging cycles which assures the storage of active electrode materials, their electro-chemical conversion, the storage of reaction products and the electro-chemical reconversion requires compromises.



⓫ Prof. Siegfried Wolf

Dr. M. Klausner (lecturer), Robert Bosch GmbH, Stuttgart; **Dr.-Ing. J. Fetzer, Dr.-Ing. H. Fink, Dr.-Ing. C. Pankiewitz**, SB LiMotive Germany GmbH, Stuttgart: "Technological Challenges for Automotive Lithium-Ion Batteries and Possible Solutions":

Traction batteries must meet a variety of challenging requirements with respect to cost, lifetime, functionality, safety and quality. High standards of safety and reliability must be met from the beginning as they have a high impact on the market acceptance of electric vehicles. Cost and functionality will improve over time.

The lecturer described in detail the demands made upon traction batteries, focusing, in particular, on two issues: safety and service life. He showed how functional safety requirements impact on the design of batteries, cells, and battery management systems, and illustrated the basic options for meeting functional safety requirements. He described the problem of specifying representative field loads as a basis for both the design for specific lifetime (DfSL) and validation testing of traction batteries. He introduced the concept of using representative field load data from other domains of vehicles with internal combustion engines in order to overcome the problem that field load data from electric vehicles are not yet available.

Dipl.-Ing. T. Körfer (lecturer), **Dipl.-Ing. A. Kolbeck, Dr.-Ing. T. Schnorbus, Dr.-Ing. H. Busch, Dipl.-Ing. B. Kinoo, Dipl.-Ing. L. Henning, Dr.-Ing. C. Severin**, FEV Motorentechnik GmbH, Aachen: "Fuel Consumption Potential of Passenger Car Diesel Engines after Euro 6":

In accordance with future scenarios assuming more stringent limit values, the simultaneous reduction of CO_2 and exhaust gas emissions appears necessary. To this end, innovative and comprehensive technological approaches must be adopted so that the new requirements can be met. Under these conditions, operating ranges with unfavourable efficiency rates should be eliminated to the greatest possible extent. This can be achieved by shifting load points, i.e. through downsizing or downspeeding, and also through partial electrification. In addition, a further improvement of fuel-efficient operating points in the engine map is indispensable. This calls for a further reduction of friction losses and an improved combustion efficiency in fuel conversion.

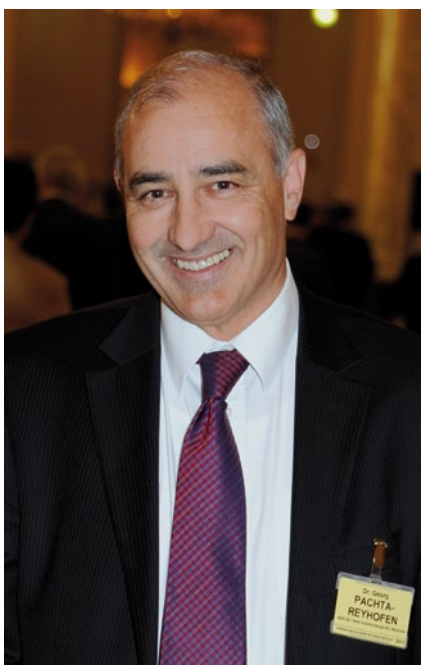
In the case described by the lecturer, which is representative of the B/C, C, and C/D segments of passenger cars, one possible approach is a powertrain concept featuring a parallel hybrid powertrain, which consists of an advanced 1.6 l diesel engine and a 20 kW electric motor, including a switchable coupling between the two power units. The fuel consumption benefits which can be achieved with this concept are approximately 18 % and 20 % in the classical driving cycles NEDC and FTP-75. These results derive from verified improvements of the base engine and conservative and realistic assumptions regarding the electric components and the selected operating strategy. In line with findings from tests on the already available hybrid vehicles using gasoline engines, the higher fuel efficiency is particularly significant in the urban driving mode (stop-and-go traffic). Mention should also be made of yet another benefit: Thanks to the specific configuration of the exhaust gas system, pollutant emissions, especially of gaseous pollutants, were markedly reduced. As a result of the selected combustion technology (low compression ratio, low-pressure EGR) it was possible to keep emissions below the limit values during phases in which only the combustion engine operates. On the

one hand, this effect can be ascribed to the elimination of critical low load operating modes, and to the significantly altered temperature level at the inlet of the oxidation catalyst, on the other.

SUPERCHARGING / MIXTURE PREPARATION

Dr.-Ing. H.-J. Neußer (lecturer), **Dipl.-Ing. M. Kerkau, Dipl.-Ing. D. Schwarzenthal, Dipl.-Ing. N. Hemmerlein**, Dr. Ing. h.c. F. Porsche AG, Weissach: "40 Years of Porsche Turbo Engines – The Basis for Future Innovations":

Porsche has been developing turbocharged gasoline engines for road and race vehicles for more than 40 years. Many significant innovations in turbocharging technology have been realized, particularly in the development history of the 911 Turbo. With its downsizing concept, this engine has remained a synonym for high performance and incomparable fuel efficiency in the high performance car category. The combination of turbocharging, smaller engine displacement and the reduction of the number of cylinders constitutes the basis for devising future fuel consumption concepts. All necessary and innovative technologies, such as turbocharging based on variable turbine geometry (VTG), mixture formation with direct fuel injection (DFI) and the variable valve timing system VarioCam Plus are already used in Porsche production engines and impressively demonstrate the potential of modern turbocharged engines. The lightweight TiAl turbine wheel that will be integrated into the Porsche Panamera represents the latest innovation leading to a further improvement of throttle response. With this set of technologies, it is possible to resolve the conflict between the goals of high performance and low fuel consumption.



⓬ Dr. Georg Pachta-Reyhofen

Dipl.-Ing. S. Schmuck-Soldan (lecturer), **Dipl.-Ing. A. Königstein**, Adam Opel AG, Rüsselsheim; **Dr.-Ing. F. Westin**, General Motors Powertrain – Europe S.r.l., Torino: "Two-Stage Boosting of Spark Ignition Engines":

Reducing fuel consumption while ensuring excellent driving performance and drivability is a central goal of engine development. In order to meet this challenge, downsizing and downspeeding by means of turbocharging have already been successfully applied in production vehicles. Conventional, single-stage charging systems attain downsizing ratios of 30 to 40 %. But if more aggressive downsizing is pursued, reduced low-end-torque and slower transient response impair performance and drivability. The lecturer illustrated a new approach to overcoming this limitation by applying two-stage turbocharging to extend the downsizing ratio potential to 60 %. He stressed that the successful implementation of this concept involved intensive optimization of the high- and low-pressure stages via simulation of both steady-state and transient operation. Special design measures had to be taken to ensure optimal functionality and durability and to minimize heat loss. With this optimized concept, a specific power of 113 kW/l can be reached while still producing 26.4 bar brake mean effective pressure (BMEP) already from 1,500 rpm onwards. The mean effective pressure can be raised to 30 bar, but this requires a further optimization of the combustion system. A 2.0 l engine with two-stage turbocharging in a mid-sized sports utility vehicle (SUV) shows an approximately 10 % higher fuel efficiency than a 5.3 l naturally aspirated engine in the combined US FTP75/highway driving cycle.

Dipl.-Ing. P. Lückert (lecturer), **Dr.-Ing. H. Breitbach, Dipl.-Ing. A. Waltner, Dr.-Ing. N. Merdes, Dr.-Ing. R. Weller**, Daimler AG, Stuttgart: "Potentials of Spray-guided Combustion Systems in Combination with Downsizing Concepts":

The advantages of the spray-guided lean-burn combustion system are clearly apparent during part load operation of the gasoline engine, as a result both of the reduction of throttling losses and the improved efficiency of the thermodynamic process. Early on, Mercedes-Benz raised the question, of whether the advantages of this combustion system could be retained, if downsizing led to a reduction of throttling losses through an increase of the specific output of the engine in the NEDC. In this context, it was also necessary to determine the extent to which turbocharging would give rise to new challenges for the combustion process. This question, the lecturer pointed out, was discussed on the basis of consumption and emission investigations. He focused in particular on the demands made upon the components of the injection system and the turbocharger for achieving optimum overall system efficiency. Likewise, he outlined the challenges regarding the stability and accuracy of the components.

As investigations have shown, downsizing by means of turbocharging can be excellently combined with spray-guided lean-burn combustion. Thanks to advanced concepts, it has been possible to extend the operating range of the stratified combustion process to higher loads, so that even small, turbocharged engines can be operated in the lean-burn mode in up to 90 % of the NEDC. At the same time, highly efficient turbocharging with the aid of a mixed flow turbine operating with a maximum exhaust gas temperature of 1,050 °C was applied with a view to optimizing fuel consumption in customer operation even under high loads.

OFFROAD AND HIGH PERFORMANCE ENGINES

Dipl.-Ing. W. Kasper (lecturer), **Dipl.-Ing. (FH) H. Wingart**, MTU Friedrichshafen GmbH, Friedrichshafen: "The MTU Series 2000-06 – The Next Generation of Diesel Engines for Off-Highway Applications with Emission Standard EPA-Tier 4i":

Since January 2011, the more stringent emission limits as specified by EPA-Tier 4 interim – 3.5 g/kWh for NO_x and 0.1 g/kWh for particulates – have applied to engines

⓭ Prof. Dr. Martin Winterkorn

for off-highway applications with a rated power of more than 560 kW. In order to comply with these emission standards, the previous PLN (Pump Line Nozzle) series 2000 engines for C&I and O&G applications have been replaced by a newly designed series consisting of 12V and 16V engines. These new engines feature common rail injection, an EGR combustion system based on the dispensing-cylinder concept, and compact, two-stage, regulated turbocharging. For the first time, the newly developed, map-controlled waste gate and the new series ZR125 exhaust turbocharger are used in these engines. Specific customer demands made upon industrial engines – such as robust design, a variety of application options and a wide engine performance map – have been rigorously met. Despite the more stringent emission limits, the new engines have a wider range of applications and lower fuel consumption than the predecessor models.

T. Okamoto (lecturer), **H. Kawamura, K. Tsukamoto, M. Nagai, T. Uchida**, Toyota Motor Corporation, Aichi, Japan; **H. Maruyama**, Yamaha Motor Corporation, Shizuoka, Japan: "The New Toyota 4.8L V10 Petrol High Performance Engine for the Lexus LFA Super Car":

The new 1LR-GUE V10 high performance engine was designed exclusively for the Lexus LFA super sports car. Achieving the speed and performance of a true super sports car was merely the starting point. The engine was conceived with a view to creating a feeling of maximum acceleration potential. Response is instant and based on a clear understanding of the driver's reactions. Vehicle handling combines unsurpassed response and feedback thanks to ideal transient torque characteristics. The excellent performance of this engine was attained by combining a world-class high-revolution speed concept and high power per litre. The new 4.8 l engine produces 412 kW at 8,700 rpm and its maximum speed is 9,000 rpm. The fuel cut-off speed is 9,500 rpm. This engine meets the current emission standard Euro 5 and shows high fuel efficiency with an extended stochiometric air/fuel ratio range up to a vehicle speed of approximately 240 km/h.

Dipl.-Ing. U. Baretzky, Dipl.-Ing. H. Diel (lecturer), **Dipl.-Ing. W. Kotauschek, Dipl.-Ing. (FH) S. Dreyer, Dr.-Ing. P. Kuntz, Dipl.-Ing. T. Reuss, Dr.-Ing. W. Ullrich**, Audi AG, Ingolstadt/Neckarsulm; **Dipl.-Ing. W. Hatz**, Volkswagen AG, Wolfsburg: "The V 10 TDI for the 24 h of Le Mans":

Since the historic first victory of Audi's V12 TDI in the 24 hours of Le Mans race in 2006, the world's hardest endurance race has been won exclusively by diesel-powered cars. Thus Audi, the pioneer of direct-injection diesel engines for passenger cars, has managed not only to safeguard a permanent place for diesel engines in car racing, but also to keep pace with the typically rapid pace of development in motor sports. The new, victorious V10 TDI is another innovative engine. Thus Audi has again demonstrated its philosophy: developing and testing new technologies on race tracks before incorporating these into vehicles sold to customers.

VEHICLE ELECTRIFICATION

C. Chehab (lecturer), **Y. Le Neindre, K. Deutrich**, PSA Peugeot Citroën, Paris; **Dr. M. Küsell** (lecturer), **C. Willke, V. Barth, Dr. J. Lichtermann**, Robert Bosch GmbH, Stuttgart: "The Electric Axle-Hybrid System Made by PSA and Bosch":

At present, a wide variety of hybrid technologies are being developed. The axle-split hybrid vehicles, which comprise an electric axle drive and a high-voltage generator mounted on the internal combustion engine offer particular advantages. This configuration not only permits a reduction of CO_2 emissions but also offers considerable benefits in terms of vehicle performance. The lecturer illustrated the newly developed double inverter with an integrated DC/DC converter and hybrid control as well as two electric motors from Bosch used in this axle-split hybrid vehicle. The electric axle-split hybrid will be integrated first into Peugeot and Citroën vehicles in 2011. The speaker focused on the advantages of the system and its impact on CO_2 reduction.

Dipl. Wirtsch.-Ing. (FH) M. W. Ott (lecturer), **Dr. rer. nat. B. Blankenbach, J. Schäfer, Dr. rer. nat. D. Walliser, Dipl.-Ing. M. Kühn**, MBtech Group GmbH & Co. KGaA, Sindelfingen: "DualX E-Drive: A Flexible Powertrain for Plug-in Hybrids":

Although, plug-in hybrids permit emission-free driving over considerable distances, large and therefore expensive traction batteries must be used for this purpose. As a consequence, the cost pressure on traction batteries and all other hybrid components is extremely high. MBtech developed the DualX E-Drive concept as part of an in-house plug-in hybrid project for a van. The results of an MBtech study concerning the requirements for the hybridization of light-weight commercial vehicles served as the starting point. As with "P4"– or "through-the-road" powertrains, the DualX E-Drive combines a conventional combustion engine powertrain with an electromotive traction unit that drive different axles. In addition to the typical advantages of hybrids, the DualX E-Drive has a four-wheel powertrain. The "off the shelf" combustion engine drives the front wheels via a five-speed automatic transmission. The electromotive powertrain, consisting of a high-speed synchronous motor and a two-speed transmission, is mounted on the rear axle. The maximum torque and power output of the drive units have been optimized by means of simulations. For the vehicle described by the lecturer, the maximum performance of the two drive units is approximately the same. Alongside range, fuel consumption and dynamics, other parameters, such as costs, weight and packaging dimensions have been taken into account. Depending on the desired approach – "green" versus "long range at low cost" – the conventional powertrain can be fitted with a CNG, diesel or gasoline engine. If an intelligent hybrid man-

Contented faces at the end of the Symposium, from left to right: Dr. Pachta-Reyhofen, Prof. Wolf, Prof. Lenz, Prof. Winterkorn

Distinguished guests, from left to right: Mrs. Piech, Prof. Piech, Mrs. Lenz

agement system is used in combination with the large battery, a high-voltage starter generator is not necessary.

S. Nakazawa, MA, Nissan Motor Co., Ltd., Kanagawa, Japan: "The Nissan Leaf Electric Powertrain":

The need for CO_2 reduction to counteract global warming and the departure from our dependence on oil in order to safeguard energy supply are burning issues. One of the priority goals for reaching these objectives is the development of a "zero emission vehicle", such as an electric vehicle or a fuel cell vehicle and the generation of clean energy. Nissan have devised a new powertrain for electric vehicles which is installed in the Nissan Leaf. Nissan launched the Leaf in North America, Europe and Japan in 2010 and plans to sell it globally in 2012. With a view to attaining longer range, higher power output and improved drivability, Nissan have employed a high efficiency synchronous motor, a water-cooled inverter and a reducer. In addition, the Nissan Leaf boasts a 3.3 kW AC and a 50 kW DC rapid charging system. The lecturer showed the features of the electric powertrain that was introduced with the Nissan Leaf.

PLENARY CLOSING SESSION: VIEW TO THE FUTURE

Prof. KR Ing. Siegfried Wolf, ⓫, Chairman of the Board of Directors, Russian Machines OJSC, Moscow: "The Future of the Russian Automotive Industry":

The automotive industry – with its high value creation and the jobs it offers – acts as the driving force behind Russia's transformation into a modern industrial state. This change is already under way and promoted through Russian policies. The industrial policy environment serves as a basis and beacon for market development not only for local production but also for preparing the way for the transition to a fully integrated industry with upstream activities, such as research and development and downstream activities, such as marketing, services and finance. The building up of a competitive supplier industry remains a major challenge. It will be the task of both manufacturers and suppliers to improve the pre-conditions for this effort via a cluster approach.

However, the most important perspective concerns the long-term potential of a large, rapidly growing domestic market with 140 million people, which, at the same time, offers favourable opportunities for exports, primarily to the GUS states with a total of 130 million inhabitants as well as many other markets beyond this region. It is up to us to build a bridge to this market and to take advantage of it for the benefit of our industry.

Dr. Georg Pachta-Reyhofen, ⓬, CEO, MAN SE/MAN Nutzfahrzeuge AG, Munich: "The Future Development of Worldwide Goods Traffic and its Impact on Drive Technologies":

Worldwide goods transport will continue to see strong growth in the future. The scarcity of fossil fuels and the need for ecologically sustainable mobility are the two main challenges facing goods transport in the future.

Current emission regulations are primarily aimed at pollutants, and have already led to a significant reduction of emissions. With Euro VI, the first commercial almost pollutant-free vehicle will become reality in the European commercial vehicles sector from 2014 onwards. Creating incentives to replace old vehicles with new, more efficient ones could boost this effect substantially. Similar progress has been made in the maritime traffic segment, though the biggest hurdle is yet to come in the form of IMO Tier III. Given the long life cycles of ships, retrofitting solutions, in particular, appear to make sense. With the strong focus on pollutant emissions the reduction of fuel consumption has been neglected. Fuel consumption of trucks has remained unchanged over the past ten years. We desperately need to to review our thinking in this area.

Options for boosting the efficiency of vehicles used in long-distance truck traffic primarily lie in aerodynamics and the optimization of shipping volumes. However, legal restrictions on vehicle length need to be eased throughout the whole of Europe in order to leverage major potential for a reduction of fuel consumption. By contrast, hybrid technology will catch on in the medium term for commercial vehicles in intra-urban traffic since it permits the recuperation of energy from braking. The use of second-generation biofuels in the commercial vehicles industry and gaseous fuels in the marine sector offer major potential for reducing CO_2. The course of technology has been charted – the diesel engine will continue to play a dominant role in worldwide goods transport in the future.

Prof. Dr. Martin Winterkorn, ⓯, Chairman of the Board, Volkswagen AG, Wolfsburg: "Electromobility for Everyone? An Industry Electrified":

The electric car plays a key role on the path to achieving sustainable mobility – alongside more efficient internal combustion engines, intelligent light-weight design and alternative sources of energy, such as natural gas and biogenic fuels of the next generation. Therefore, the Volkswagen Group is fully committed to electric mobility and is driving the development of electric cars by pursuing its modular assembly strategy. The results can already be seen in the XL1 and the Golf blue-e-motion. Before Volkswagen can produce a practical, affordable "electric car for everyone", however, four major challenges have to be met: further developing the technologies (especially for battery storage), setting up an extensive standardized infrastructure, ensuring an environmentally friendly source of electricity, and driving down costs to a competitive level. All this makes electric mobility the challenge of the century – for the automotive industry and the European industrial community as a whole. It is an issue that concerns us all: manufacturers, suppliers, energy providers, scientists and politicians alike.

The following two contributions were made in the form of poster presentations:

Ass. Prof. Dipl.-Ing. Dr. techn. R. Kirchberger, Dipl.-Ing. J. Tromayer, Univ.-Prof. Dipl.-Ing. Dr. techn. H. Eichlseder, Graz University of Technology: "Concepts for Emission Reduction in Small Capacity Four Stroke Engines":

As a result of ever more restrictive emission regulations in the global motor cycle market, the introduction of new technologies is indispensable. In order to meet these standards, the use of an electronic injection system in combination with lambda control would appear suitable. A large number of manufacturers, workshops and customers in developing and threshold countries are, however, either not prepared to pay for the required investments or they are unable to work with such systems. The lecturer discussed the question whether it will be an absolute must to change over the lambda controlled ($\lambda = 1$) operation or if simple carburettors combined with innovative concepts would be sufficient in order to reach this objective. In theory, a variety of approaches are discussed and a catalogue of measures has been elaborated for the respective displacement categories. For the categories 50 cm³ and 125 cm³, two prototype engines have been developed on the basis of the components of the existing base engines and subsequently tested on engine test benches and roller dynamometers. The measured values confirm that even with low-cost measures compliances with the future emission standards can be assured. Hence with the prototype engines it was possible to reach the goal of lowering emissions to 50 % of the maximum permissible values.

Dipl.-Ing. M. Jakobi, Assoc. Prof. Dr. P. Hofmann, Univ.-Prof. Dr. B. Geringer, Vienna University of Technology: "New Heat Storage Technologies for the Application in Future Vehicles":

The storage of waste heat released by combustion engines and the use of this heat during cold starting in order to shorten the warming-up phase constitutes a feasible approach to reducing the fuel consumption of vehicles. To date, however, this approach has not been widely implemented – apart from some sporadic cases of series production. The reasons are manifold: it is difficult to accommodate storage media in the vehicle, the storage density is low, and major losses occur when the vehicle is not in operation over extended periods of time. The storage media that have been devised so far were based on the thermal insulation of a storage medium – in some cases, advantage was taken of the transition of the stored material from one phase to another. Reversible chemical reactions triggered by the supply or release of thermal energy can, in principle, be used for heat storage. Alongside loss-free storage over extended periods of time and the generally higher storage energy density, this technology can also be employed for air-conditioning the vehicle.

The lecturer presented the initial findings of a research project financed out of the funds of the CO_2 special research programme of the FVV (the Research Association for Internal Combustion Engines) earmarked for industry, which seeks to analyse the suitability of thermo-chemical heat accumulators for use in vehicles and shows the relevant processes and reaction partners. Analyses of various combinations of substances were carried out on a heat accumulator test bench specifically developed for this purpose. These analyses sought to clarify the reaction processes and assess heat release. One important criterion was the reaction process at low temperatures. Methanol which was used as a sorbate showed good characteristics at a temperature of -15 °C.

Subsequently, a prototype heat accumulator is to be developed which will also be used for investigations on vehicle-near applications. In principle, this technology is also promising for the thermal management (heating, air-conditioning of vehicles with alternative drive system).

Conference Documentation

The lectures presented at the 32nd International Vienna Motor Symposium are contained in the VDI (Association of German Automotive Engineers) reports, series 12, no. 735, volumes one and two (the English versions can be found on the CD), and in additional brochures. All documents can be obtained from ÖVK (Austrian Society of Automotive Engineers).

Invitation

The 33rd International Vienna Motor Symposium will take place on April 26th and 27th, 2012 in the Congress Center Hofburg Vienna. We should like to extend a cordial invitation already at this point in time. In view of the expected large number of participants we recommend you to send in your application immediately after the announcement of the programme on the internet in mid-December 2011.

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