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27th International Vienna Motor Symposium

The 27th International Vienna Motor Symposium from 27 to 28 April, 2006, was an outstanding event for leading engineers from all over the world. They presented their most recent development results and gave an outlook on future trends. This article presents the lectures of each session and gives an overview about their contents.

1 Introduction

After a welcome fanfare, **Figure 1**, performed by the members of the orchestra of the Vienna University of Technology, **Professor Hans Peter Lenz**, **Figure 2**, welcomed participants to the 27th International Vienna Motor Symposium.

As is the case every year, Prof. Lenz pointed out, it had by no means been possible to accept all applications for participation; the capacity of the venue was limited to one thousand, but thanks to the quota reserved for companies and organisations, comprehensive representation of outstanding experts from all disciplines of the profession was assured.

Prof. Lenz drew attention to the regrettable fact that both politicians and, to some extent, also the general public had hitherto failed to recognise the tremendous progress achieved in the reduction of pollutant emissions and fuel consumption in engine design over recent years. Instead, he explained, again and again horror scenarios were disseminated depicting the disastrous effect of particulate emissions and exhaust gases that influenced the climate.

Prof. Lenz expressed his hope that this conference would over and above its primary task of acting as a forum for the discussion of progress in automotive engineering also provide relevant information on all these issues to the general public.

After the joint plenary opening session, technical papers were presented in two parallel sections, **Figure 3** and **Figure 4**, which were chaired by Professors **H. Eichlseder**, **B. Geringer**, **G. Jürgens** and **R. Pischinger**. These lectures were complemented by a comprehensive and most impressive exhibition of new engines, components and vehicles, **Figure 5**, **Figure 6** and **Figure 7**.

A culturally sophisticated social programme with guided tours of modern and historic Vienna, as well as walks tracking the footsteps of Mozart and exploring the area around the Hofburg, were offered to those accompanying participants. Further to which, participants and accompanying persons spent an evening in the cordial atmosphere of a Viennese wine tavern to which the mayor of Vienna had invited them.

2 Plenary Opening Session

Dr.-Ing. E.h. B. Pischetsrieder, **Figure 8**, Chairman of the Board, Volkswagen AG, Wolfsburg: “Strategic Aims for Ensuring Sustainable Mobility”:

Following a description of the current situation, Dr. Pischetsrieder dealt with contemporary global challenges and subsequently treated the focal points of powertrain development. Dr. Pischetsrieder illustrated the impressive progress achieved in the reduction of fuel consumption and vehicle emissions over the past few years, and pointed out that European vehicle manufacturers had met the targets to which they had committed themselves. He expressed his regrets that carmakers had not succeeded in dispelling the prejudice of politicians who believed that the automotive industry was playing for time in addressing environmental issues. It was of no avail to anyone, he emphasised, and it was especially not in the interest of the environment if consumers postponed purchases of new cars – owing to the high costs brought about by extreme environmental standards – and instead continued to drive their old vehicles.

Figure 9 provides a survey of the global challenges facing us. In Dr. Pischetsrieder’s opinion, future development will have to have particular focus on taking full advantage of the potential of both gasoline and diesel technology, stressing that the new VW gasoline engine – featuring downsizing, direct injection and twin charger technology – was an excellent example of this approach. He went on to say that an excessive focus on minimal fuel consumption was not acceptable to customers as they favoured maximum driving pleasure. According to Dr. Pischetsrieder’s forecast, if a CO_2 tax is introduced in the European Union, expen-

The author

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

Bild 1: Begrüßungsfanfare, Mitglieder des TU-Orchesters
Figure 1: Welcome fanfare, members of the orchestra of the Vienna University of Technology

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

Bild 3: Festsaal
Figure 3: Festival hall

sive exhaust-gas after-treatment systems would become mandatory and by 2015 diesel engines will lose their attractiveness. The widespread use of hydrogen-powered engines is still a long way off, he argued, and at present nobody is able to predict how and at what cost renewable hydrogen can be supplied.

Mr. R.J. Johansson, BSc, MBA, **Figure 10**, Vice President, General Motors Powertrain Europe, Turin: "Global Powertrains – The GM Case":

Today, stressed Mr. Johansson, automotive engineering is confronted with the conflicting objectives of increasingly demanding customer expectations and evermore stringent legislation, and these goals could only be achieved through immense technological efforts and profound know-how. The diversity of markets with varying regional preferences, together with rising price and growing demand for energy, constituted further challenges. At the same time, it was one of General Motor's principles to offer its customers sustainable and affordable individual mobility. The worldwide development strategy of GM Powertrain, he pointed out, was based on exactly this philosophy: Efficient and at the same time cost-effective technologies were being developed for both gasoline and diesel engines which would satisfy all of today's demands as well as those expected in the future. GM defined its long-term strategy on the basis of a March to Zero, which will lead to the ultimate goal of neutral emission vehicles with a safe energy supply through the use of alternative propulsion systems. Relying on its unique worldwide development network, GM is taking advantage of the synergies of its competence centres throughout the world in devising its global development network. GM is well-armed for taking up this new challenge, and is already utilising the synergies of its competence centres throughout the world in devising a global development strategy. Modern powertrains are based on a common structure, owing to the modular system of components, however, they can be adapted to all markets. This development philosophy is one of the cornerstones of General Motors' position as the world's largest carmaker.

Dr. W. Vahland, **Figure 11**, President and CEO, Volkswagen Group China, Beijing: "The Automotive Industry in China and the Challenges for European Car Manufacturers":

After having provided an overview of VW's history in China, Dr. Vahland dealt with the development of the Chinese economy and the consequent expansion of its automotive market. Dr. Vahland pointed out that in the period from 2005 to 2010, China's export volume should double, from 1.4 billion to 2.8 billion US dollars, with China's share in world trade climbing from 7 % to 10 %.

Investments in China's automotive industry, which totalled 5.9 billion dollars between 1996 and 2000, rose 18.6 billion dollars between 2001 and 2005. In terms of deliveries to vehicles customers, China ranks fourth in the world after the USA, Japan and Germany. It is expected that China will move to second place, behind the US, by 2010.

China's export volume in the automotive sector expanded from 43,000 vehicles in 2003 to 78,000 in 2004, climbing to 165,000 in 2005. The number of Chinese passenger car manufacturers rose from 15 in 2000 to 55 in 2005, while during the same period the number of models increased more than six-fold, from 18 to 140.

Despite strong market growth it is expected that by 2020 the vehicle density would still be less than 6 %, i.e., fewer than six vehicles per hundred inhabitants. In 2004 the highway network in China had a total length of 34,000 km, which compares with 12,000 km in Germany; according to forecasts, China will have some 55,000 km of roads by 2010.

As regards its environmental policy, China intends to implement a number of changes:

- revision of the Vehicle Engine Displacement Tax (the maximum rate currently stands at 8 % will be increased to 20 % or 25 %)
- the introduction of a fuel tax (currently a rate of between 30 % and 100 % is envisaged)
- provision of state support for hybrid gas (CNG) and diesel engines
- introduction of the Euro3 standards throughout China and the Euro4 standards in the capital Beijing.

European car manufacturers will have to rise to tremendous challenges if they are to remain competitive.

3 Impact of Motor Emissions on Climate

Dr. U. Berner, Federal Institute for Geosciences and Natural Resources, Hannover: "Greenhouse Gas Carbon Dioxide – a Flashback to the Past and an Outlook on the Future":

Climate is not a constant, and a voyage through time illustrates the wide fluctuations to which our climatic system has forever been exposed. In the past, the forces behind such ongoing variation and change were natural factors such as, for example, changes in solar activity. Indeed, it has been understood for a long time that solar activity correlates well with the variations in climate. Although climate-effective trace gases, such as carbon dioxide have contributed significantly to the climate system in the past, they were not in themselves the trigger for climatic change. And with respect to climate in the modern era, only the interplay of several factors - such as the sun, climate effective trace gases as well as natural and anthropogenic aerosols - can explain the observed changes.

Emission and climate scenarios, based on investigations of past climatic variations, permit the prediction of changes that may occur in the future under certain conditions. As a rule, variations in the natural drivers of climate are excluded from these investigations, because they are hardly predictable. Only future scenarios permit an assessment of the bandwidth of future climate change. In this context, the results of climate modelling suggest that even cost-intensive emission reductions as demanded by the Kyoto Protocol will not have any significant influence on climate.

Prof. Dr. R. Sausen (lecturer), **Dr. J. Hendricks**, DLR, Institut für Physik der Atmosphäre (Department of Physics of the Atmosphere at the German Aerospace Center), Oberpfaffenhofen: "The Influence of Traffic on Climate":

The mean near-surface temperature is rising globally as a result of climate change caused by numerous atmospheric variables. In all probability, a major portion of observed climate changes can be attributed to anthropogenic factors. Traffic certainly contributes significantly to climate change as approximately 25 % of all anthropogenic CO_2 emissions are caused by the combustion of fossil fuels and cement production. Road traffic is responsible for the lion's share of CO_2 emissions. Vehicles influence climate not only through the emission of long-lived greenhouse gases, such as CO_2 for example, but also through the precursors of secondary greenhouse gases (i.e. ozone), aerosols or aerosol precursors, as well as through modifications to cloud cover and the optical properties of clouds. The impact of all these factors on climate has yet to be consistently quantified, thus it is difficult to assess the effects of long-lived greenhouse gases in establishing an emission balance. Unfortunately such a quantification appears ever more urgent as it can be assumed that traffic will grow much faster than most other industrial activities.

The two preceding lectures reflected two different approaches. The discussion revealed that the division of opinion can mainly be ascribed to different time horizons, with Dr. Berner seeing the problem from the perspective of 500 million years, and Prof. Sausen from that of some 400,000 years. If these renowned experts from well-respected organisations disagree to such an extent, the conclusion may be drawn that the Kyoto Protocol rests on shaky foundations.

Dr. R. Stromberger (lecturer), **Dr. J. Theis**, BMW Group, Munich: "Integrated Approach: A Concept for Sustainable CO_2 Reduction":

In an effort to combat global warming, the Kyoto Protocol defines binding targets for reducing the emission of anthropogenic greenhouse gases. As a result of the EU's commitment to lowering emissions under the Kyoto Protocol, CO_2 emissions from all sources must be reduced. Hence CO_2 emissions from passenger vehicles must be lowered in accordance with EU strategy statute. The European Commission's European Climate Change Programme calls for cost-efficient ecological measures to reduce CO_2 emissions. In passenger cars, further vehicle design measures for CO_2 reduction can only be realised at considerable cost, and fail to represent an ecologically sound approach to the reduction of emissions. Against this background, the European automotive industry defined the integrated approach as a concept for cost-efficient and sustainable CO_2 reduction. This is a holistic approach which aims at the reduction of CO_2 emissions at a significantly lower cost than through vehicle design measures. Joint coordinated and harmonised cross-sectoral activities are decisive prerequisites for reaching the goal of reduced CO_2 emissions.

With the integrated approach, the reduction of CO_2 emissions can be achieved more expediently, quickly and efficiently, as well as at the lowest possible cost. This approach also contributes to safeguarding Europe's attractiveness as a business location in line with the European Union's Lisbon strategy. Thus the interests of the business community as a whole, as well as the automotive industry in particular, are taken into account.

4 New Diesel Engines

Dr.-Ing. R. Krebs, **Dr.-Ing. J. Hadler** (lecturer), **Dipl.-Ing. K. Blumensaat**, **Dr.-Ing. J.E. Franke**, **Dr.-Ing. G. Paehr**, **Dipl.-Ing. E. Vollmers**, **Dipl.-Ing. B. Hahne**, Volkswagen AG, Wolfsburg: "Volkswagen's New Generation of 5-Cylinder TDI-Engines for Light Duty-Trucks":

A new five-cylinder diesel engine generation meeting Euro 4 emission standards has been developed for the Crafter – a third generation of Volkswagen's light commercial vehicles. Besides compliance with the respective emission standards, special attention has been paid to the reduction of operating and service costs as well as a significant improvement of engine acoustics. The variable performance spectrum of the Crafter, with narrow graduation between 65 kW and 120 kW, is now covered by a base engine the geometric dimensions of which are based on the proven LT2 five-cylinder engine with distributor injector pump. A common rail system with piezo injectors is used for carburetion. All other engine components have been fundamentally redesigned in order to meet the pre-defined requirements so that the Crafter defines a benchmark with respect to driving performance, comfort and operating costs.

Eng. P. Brunet (lecturer), **Eng. D. Ellul**, **Eng. J.-L. Huet**, **Eng. S. Malcuy**, **Eng. C. Monereau**, **Eng. J. Piana**, Renault Powertrain Division, Rueil-Malmaison Cedex: "The New Renault 2.0 l Diesel Engine":

In order to comply with future customer demands and – at the same time – to be prepared for more stringent emission regulations, Renault and Nissan decided to develop a brand new family of 2.0 l diesel engines. In addition to challenging targets for fuel consumption and emission levels, engine specifications were focused on performance and NVH in order to produce top-class diesel engines in the 1.9 to 2.2 l diesel engine category. And with a view to also using these engines in smaller cars, the specifications also encompassed compact design.

Thanks to maximum power and torque (respectively 127 kW and 360 Nm), specific power of 63.7 kW/l can be achieved, while low-end torque has been optimised (e.g., 90 % of the maximum torque is available from 1600 rpm upwards). This new performance benchmark for a 2.0 l diesel is the outcome of an excellent trade-off between engine output and emission levels. This exceptional result was attained through the optimum match of combustion chamber configura-

Bild 4: Zeremoniensaal
Figure 4: Ceremonial hall

Bild 5: Ausstellung
Figure 5: Exhibition

tion, injection system design and friction characteristics, and using a maintenance-free particulate filter meeting Euro 4 emission standards proved to be no problem.

Very low noise levels were achieved through the optimisation of power transmission from the engine to the powertrain, as well as from new injection and tuning strategies. This new family of engines was designed for both manual and automatic transmission.

Production of the 127 kW version will commence in 2006, whereas the 110 kW version was launched back in 2005, and thanks to flexible production facilities, it will be possible to design advanced engine versions in the future.

Dipl.-Ing. M. Dietz (lecturer), **Dipl.-Ing. M. Hassler**, **Dipl.-Ing. G. Moll**, **Dipl.-Ing. K. Pranter**, **Dipl.-Ing. H. Hoffmann**, **Dr.-Ing. W. Eissler**, DaimlerChrysler AG, Stuttgart: „Trend-setting Small-Displacement Euro 4 Transporter/ Commercial Vehicle Engine":

The development of a new engine for the Sprinter range of small commercial vehicles presented a formidable challenge. Such an engine would not only have to meet the Euro 4 emission standards for passenger cars, but also those for commercial vehicles (freight transport, test bench homologation). The goal was thus to ensure the mechanical endurance of these engines, and their drivability at total traction weights of up to 7 tonnes using a variety of transmission systems and multiple axle ratios.

With the launch of the new Mercedes Sprinter class, it was necessary to ensure engine compliance with Euro 4 standards, providing for a reduction of the maximum permissible NO_X emission values by 30 % to 3.5 g/kWh and particulate limits by 85 % to 0.02 g/kWh. Achieving these values in this engine category was indeed a technological breakthrough. In view of the extremely low particulate emission level required, a particulate filter proved indispensable, whereas an EGR concept for full-load operation kept NO_X emissions below the maximum permissible values.

Engine operation with EGR under full load makes heavy demands upon the supercharger and exhaust-gas re-circulation characteristics. Thanks to a modern piezo common rail injection system, innovative software functions and not least a two-stage supercharger, it was possible to design a highly attractive, trend-setting engine for the Mercedes Sprinter. Thus this small-displacement, highly turbocharged 2.2 l four-cylinder engine reaches almost the same output and torque values as the preceding five-cylinder engine. With the new engine, emission levels have been drastically reduced, fuel economy improved and drivability enhanced. In addition, the new engine concept offers a further potential for complying with even more stringent emission limits. With the OM 646 ATL, DaimlerChrysler has introduced the world's first four-cylinder engine with two-stage supercharging and a low-end torque, as well as an emission concept which has reached new technological heights in the Sprinter market segment.

5 New Otto Engines (1)

Dr.-Ing. M. Wirth (lecturer), **Dipl.-Ing. D. Zimmermann**, **Dr. M. Davies**, **Dipl.-Ing. B. Pingen**, **Dipl.-Ing. D. Borrmann**, Ford Werke GmbH, Cologne: „Downsizing and Stratified Operation – An Attractive Combination Based on a Spray-Guided Combustion System":

Downsizing in tandem with turbo-charging are today commonly regarded as key technologies in the design of gasoline engines, by way of which the dual challenges of reducing fuel consumption while at the same time improving drivability can be met. This combination of technology is indispensable for strategies aimed at meeting future fleet CO_2 emission limits. In view of the staged imposition of increasingly stringent limits, further technology elements must be added in order to be able to augment the potential which has been exhausted by downsizing. In this context, stratified part load operation could offer an attractive solution if full advantage can be taken of the optimum fuel economy potential of a spray-guided gasoline DI combustion system.

Whereas the combination of turbocharged and spray-guided stratified operation represents conflicting goals for automotive engineers, it also provides attractive synergies for the reduction of emissions to the PZEV level merely by making use of different injection strategies. An analysis of vehicle applications with different power-weight ratios demonstrates that the additional fuel economy which can be achieved through stratified operation is sensitive to the cycle driven, as was indeed expected. Improved fuel economy is also relevant for the customer, as are the favourable cost/benefit ratios that can be achieved, especially taking into account the current costs of exhaust-gas after-treatment in a lean burn operation.

Dr. E. Groff, GM Powertrain North America, Pontiac, Michigan, USA, **Dipl.-Ing. A. König-**

Bild 6: Ausstellung
Figure 6: Exhibition

Bild 7: Ausstellung
Figure 7: Exhibition

stein (lecturer), **Dipl.-Ing. H. Drangel**, GM Powertrain Europe, Rüsselsheim/ Södertälje: "The New 2.0 Litre High Performance Turbo Engine with Gasoline Direct Injection from GM Powertrain":

After the successful introduction of the 2.2 l Ecotec engine with gasoline direct injection in 2003, General Motors has now introduced the 2.0 l Ecotec turbo engine with direct injection and dual continuously variable cam phasing in the Pontiac Solstice GXP model for 2007. The combination of these technologies helps the Ecotec engine to produce more power with excellent response, while maintaining the lower fuel consumption of a small displacement port-injected engine. Developing 260 SAE horsepower (194 kW) and 260 lb-ft. (350 Nm) of torque, the engine is GM's highest specific output production engine ever, as well as the most powerful production engine in the Ecotec family. The 2.0 l Ecotec turbo-charged engine is GM's first in North America with direct injection.

The engine was developed with the global resources of GM Powertrain in the United States and Europe, drawing on expertise from the naturally aspirated Ecotec direct-injection and dual continuously variable cam-phased engines together with turbocharged engines already in production.

Dr. U. Thien (lecturer), Magna Steyr Fahrzeugtechnik AG & Co KG, Graz, **Dipl.-Ing. K. Schaffer** (lecturer), **Prof. Dr. H. Eichlseder**, Graz University of Technology: "1.6 l Supercharged Engine for CNG Motorization of a Sportive Vehicle":

The lecturers described the sports car power unit developed by Magna Steyr. One special feature of this vehicle concept is an engine which uses environmentally friendly fuel. Compressed natural gas – CNG – was selected for this purpose. A powertrain for monovalent operation using CNG was designed and produced on the basis of a supercharged 1.6 l gasoline series-engine. Accordingly, components for natural gas storage and a CNG-specific injection valve system, together with a suitable engine control unit concept, all had to be specially developed. The new control unit was calibrated and optimised for CNG operation on the stationary engine test bench of the Department for Internal Combustion Engines of Graz's University of Technology. In order to be able to meet the demands made upon vehicle dynamics and with a view to optimising start and comfort functions, the engine was tuned during on-vehicle driving tests. Presented to the public at the IAA 2005 in Frankfurt, the sports car fitted with the monovalent CNG engine meets all exacting demands regarding drivability.

6 Sound Engineering Diesel / Emissions (1)

Dipl.-Ing. A. Enderich (lecturer), **Dipl.-Ing. R. Fischer**, Mahle Filtersysteme GmbH, Stuttgart: "Sound Engineering for Diesel Engines":

The high acceptance of diesel engines has encouraged even more vehicle manufacturers to devise sporty diesel concepts. The more usual means of suppressing unpleasant sounds by means of extreme insulation does not appear to be adequate when the sporty character of a car is to be preserved, thus acoustics are no longer congruent with performance.

Mr Enderich reported that further development of the Mahle engine sound system using a pressure-resistant membrane and an integrated load-controlled flap, can endow diesel-powered vehicles with a sports profile as regards sound. Using the Mahle system, the specific acoustic disadvantages of diesel engines, such as "diesel knocking" or rough engine running can be masked. However, it has to be borne in mind that acoustic engineering should not result in a change in the specific character of the engine, but should much rather accentuate the strong torque characteristics of the engine in the medium speed range.

Prof. Dr.-Ing. S. Pischinger, **Dipl.-Chem. B. Sliwinski** (lecturer), RWTH Aachen, **Dipl.-Chem. J. Schnitzler**, **Dr.-Ing. A. Wiartalla**, FEV Motorentechnik GmbH, Aachen:

"Concepts for Integrated Regeneration of Diesel Particulate Traps and NO_X-Storage Catalysts":

Future emission limits will most probably impose further restrictions on particulate and nitrous oxide emissions. Alongside engine management measures, exhaust gas treatment components - e.g. particulate traps and NO_X adsorber catalysts - will see increasing application in emissions reduction. Here the question arises as to what extent synergies between the operation of different exhaust gas treatment systems can be achieved. In the course of studies of a particulate trap with an NO_X adsorber catalyst coating, as described by the lecturers, it was possible to identify the influencing parameters which cause a significant particulate reduction during typical $DeNO_X$ regeneration in NO_X catalysts.

These influencing parameters include

Bild 8: Dr.-Ing. E.h. Bernd Pischetsrieder, Volkswagen AG, Wolfsburg

Figure 8: Dr.-Ing. E.h. Bernd Pischetsrieder, Volkswagen AG, Wolfsburg

temperature profile during $DeNO_X$ operation, which results from the conversion of the reductant generated during rich engine operation. The maximum temperatures are significantly below those which are usually necessary for the rapid thermal regeneration of a particulate trap, and which are only reached for short periods of time. Furthermore, the catalytic coating can strongly influence activity in the conversion of reductants. Analytical results also reveal that soot from lean and rich engine operation differs significantly with regard to its composition and morphology. Apparently the ease of soot ignition can be boosted by controlling lean and rich engine operation, and therefore the overall combustion behaviour of carbon collected in the particulate trap may be manipulated.

Various approaches take advantage of particulate reduction by means of short temperature intervals in a particulate trap, and these are engendered by controlling the combustion process in the engine. Thus the loading can be effectively kept at a very low level. This permits the use of highly porous filter materials with reduced stability, which also results in a limited soot loading capacity. Furthermore, the reactive properties of soot from rich engine operation can be specifically used to achieve conventional particulate trap regeneration over an expanded engine map.

Dr.-Ing. G. Cipolla (lecturer), **Dipl.-Ing. A. Sanguedolce**, **Dr.-Ing. G. Boretto**, **Dr. B. Peters**, GM Powertrain Europe, Turin: "Diesel Particulate Filters – Field Experiences with Current Systems and Factors Defining Future Designs":

During the late 1990s, a coalescence of technology in fuel systems, substrate materials and catalytic coatings created an opportunity for the design of robust, diesel particulate aftertreatment systems for light-duty diesel engines. At that time, numerous research projects described many diverse concepts for particulate after-treatment, but these were not applied to volume production and therefore could not serve as a guide for the selection of a particular concept. Thus development engineers were faced with a dual task: namely, to select a technical concept and develop it as a production standard without being able to rely on historically defined requirements. The strategy selected for General Motors products in Europe was to use an underfloor-mounted coated wall-flow ceramic filter in conjunction with an oxidation catalyst system. Regeneration is exclusively controlled by the operation of the common rail fuel system. A broad range of vehicle applications was developed with due regard for specific packaging configurations. More than 160,000 units were produced between early 2004 and the end of 2005. Field experience demonstrated that a reliable technical strategy had been pursued. For new applications in vehicle platforms which are designed for the integration of particulate traps, and based on the experience gained in the current production of particulate aftertreatment systems and further advances in the development of coating and substrate materials, relatively cost-effective systems can be designed which are smaller but nevertheless retain the robustness required for the entire life of a vehicle.

7 Hybrid (1)

Dr. R. Fischer (lecturer), **Dr. K. Kirsten**, AVL List GmbH, Graz: „The Turbo Hybrid – an Integral Approach to a Modern Gasoline Hybrid Engine System":

In conjunction with the fuel economy that customers can achieve in practice, driving pleasure will become an increasingly important feature that will determine the acceptance of hybrids on a broad basis. In many cases these requirements can be easily met through the use of a power-split full hybrid; this, however, leads to substantially higher cost. If the potential fuel savings achievable through hybridizing a gasoline engine are analysed, load shifting is a more attractive alternative than recuperation of deceleration energy or idle switch-off in order to lower fuel consumption. The combination of an exhaust gas turbo-charged, gasoline direct-injection engine with a parallel hybrid in the 15 kW power range offers a highly cost-efficient solution for middle class passenger cars for two reasons:

The full-load characteristics of a turbocharged gasoline engine in combination with transient torque boost using the elec-

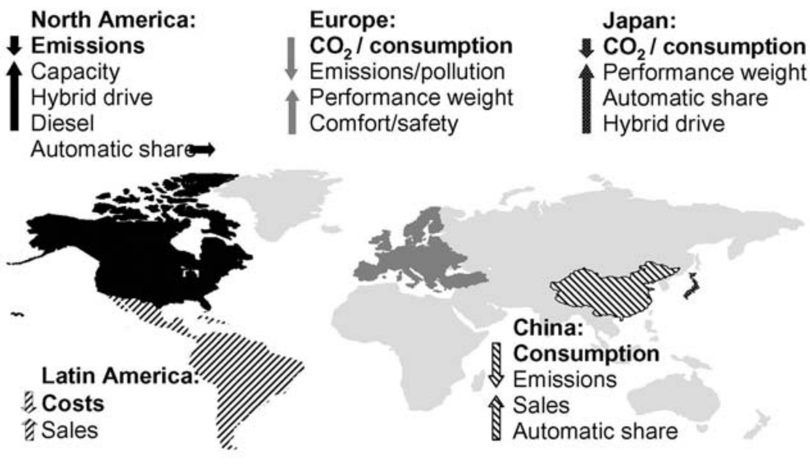

Bild 9: Märkte: Schwerpunkte und Trends

Figure 9: Markets: focal points and trends

tric motor facilitate a system design with optimised transmission ratios. Thus the potential fuel economy which can normally only be reached only by means of a power-split full-hybrid can almost be attained with much less effort and at lower cost, while at the same time driving dynamics are better and hence greater driving pleasure is assured.

The overboost capability of the turbocharged gasoline engine guarantees excellent driving performance and permits re-charging of the energy storage system even under worst scenario driving conditions. This leads to an improved trade-off between greater driving pleasure and the requisite energy storage capacity. Contrary to the well-known approaches, the dedicated low-end torque characteristics of turbo-charged gasoline engines offer a special advantage.

Accordingly, the additional costs required for the engine can be offset to a very great extent by the lower costs of the electrical system. In comparison with other hybrid concepts, this unit as a whole shows a significantly better cost/benefit ratio.

Mr. Y. Sonoda (lecturer), **Mr. S. Abe**, Toyota Motor Corporation, Toyota-shi, Aichi, Japan: "Hybrid System and Emission Control System Development for the Lexus GS450h":

The original Toyota Hybrid System (THS) was first introduced in the Prius in 1997, heralded as the world's first mass-produced hybrid passenger car. Since that time, the THS has been continuously improved. In 2006, the Hybrid Synergy Drive line-up was expanded to a rear-wheel-drive system in the Lexus GS450h, which is comparable to both 4.5 l class performance and compact class fuel economy, while meeting the most stringent emission standards – such as, for example, those met by SULEVs.

The GS450h uses a new V6 3.5 l gasoline engine (2GR-FSE), in which the superior version D-4S (direct-injection 4-stroke gasoline engine system) was integrated. This new stoichiometric direct injection system is equipped with two fuel injectors (a direct injection injector and a port injector) per cylinder. The possibility of retarding ignition timing during warm-up in order to reduce cold-start emissions is generally limited by engine torque fluctuations. Nevertheless, through the formation of an optimum weak stratified air-fuel mixture, it was possible to combat the problem of torque fluctuations by means of the D-4S injection system. With the variable intake and exhaust VVT-i (varible-valve-timing with intelligence) the internal EGR is used for atomising the fuel spray for better mixture formation. Thanks to a higher expansion ratio, HC combustion is boosted, and warming-up emissions after a cold start have been lowered as a result.

Univ.-Prof. Dr.-Ing. G. Hohenberg (lecturer), **Prof. Dr. F. Indra** (lecturer), University of Darmstadt: "Lexus RX 400h – Drivetrain Analysis and Test Results":

E-CVT - Electronically-controlled Continuously Variable Transmission - constitutes the core of the Toyota hybrid system. The rapid and infinitely variable adjustment of the transmission ratio allows optimum operation of combustion engines in terms of fuel consumption and exhaust-gas emissions. Depending on the operating point of the E-CVT, a portion of engine power is transferred to electrical power with relatively poor efficiency (multiple energy conversion). The operation strategy of the complete system "combustion engine – transmission – electric motors – battery" is crucial for the effectiveness of the hybrid system. In the range between 0 and approximately 60 km/h the combustion engine is operated cyclically (about 50 % combustion engine and 50 % electric drive). Thus it is possible to avoid using the lowest portion of load operation of the combustion engine in which extremely low efficiencies are recorded. Special attention was paid to the start/stop routine. By using a technically very demanding combination of valve timing adjustment, lower intake pressure and controlled ignition timing, this complex routine is successfully mastered in terms of driving comfort and exhaust emissions.

In real-world driving three different phases can be distinguished: In the low range of up to 60 kph (phase I) fuel consumption is significantly lower due to the cyclic operation of the combustion engine. In constant extra-urban and highway driving between 60 and 150 kph (phase II) a slight reduction in fuel consumption can still be observed as a result of engine optimization as well as the special operating strategy of the complete system. However, constant driving at speeds above 150 kph or driving at an average speed of 125 kph, the efficiency of the hybrid system and thus fuel consumption are distinctly worse than with comparable vehicles with conventional drivetrains. By further increasing technological efforts and complexity – such as adding a second gearing – the disadvantages of the Lexus RX 400h in the upper speed range can, in theory, be avoided. The potential recuperation rate, and consequent lowering of fuel consumption, is around 4 %, and therefore significantly below that which is theoretically achievable. This is due to the fact that owing to battery lifetime, the charging state may only be varied within narrow limits, while the charging current is also limited.

8 Injection – Development Status

Dipl.-Ing. V. Warnecke (lecturer), **Dr. E. Achleitner**, **Dr. H. Bäcker**, Siemens VDO Automotive, Regensburg: "Development Status of the Siemens VDO Piezo Injection System for Spray-Guided Combustion":

Spray-guided combustion systems offer the highest potential for the reduction of fuel consumption in gasoline engines. To explore these fuel consumption benefits, Siemens VDO developed a production-ready injection system, consisting of piezo-injectors, a high pressure fuel pump for a system pressure of 20 MPa and an engine control unit with the respective driver stages and necessary functions. The key component of the system is the injector, the outward opening nozzle of which generates a stable spray under all engine operating conditions and a reliable ignition of the mixture. In addition, the high dynamics of the piezo actuator allow extremely fast switching times of the injector and the use of multiple injections during a single cycle. Thus excellent combustion results are achieved while, at the same time, the area of stratified operation is significantly shifted towards higher engine speeds and loads, as has been proven by the pertinent engine evaluations. Siemens VDO is now able to offer the automotive industry a system that facilitates significant fuel consumption reduction in the base engine.

Dipl.-Ing. M. Frank, **Dipl.-Ing. M. Gesk**, **Dr.-Ing. W. Samenfink**, **Dipl.-Ing. J. Gerhardt**, Robert Bosch GmbH, Stuttgart; **Dipl.-Ing. B. Hackl** (lecturer), **Dipl.-Ing. M. Urbanek**, **Dr. P. Hofmann**, **Univ.-Prof. Dr. B. Geringer**, Vienna University of Technology: "New Methods for the Selection of Injectors and Start-Tuning of Gasoline Engines with Port Injection":

In a study into the starting phase, different mixture formation systems were analysed. Conventional standard injectors as well as injectors with reduced mean droplet size - SMD (Sauter Mean Diameter) were investigated for their potential to lower HC emissions during cold start. In addition, the options offered by a new strategy to improve spray atomisation were also evaluated.

The crank angle-based HC mass flow was determined by means of high and low pressure indication, a one-D gas exchange calculation and measurements made with a fast flame detector. In addition to HC emissions, combustion characteristics as well as revving-up behaviour and wall-film deposits were also studied. Mixture formation and homogenisation can be improved during the start by reducing droplet diameter (SMD), so that despite leaning the mixture, energy conversion is much faster, with an optimum efficiency of combustion occurring during the first cycles. Alongside lower HC emissions, this approach resulted in significantly higher peak pressure levels, which shorten the revving-up phase and permit efficient catalyst heating comparable to the results achieved with retarded ignition.

BEng. H. Toduka (lecturer), **Dr.-Eng. T. Yoshinaga**, **BEng. T. Nakashima**, **MEng. S. Sugiura**, Denso Corporation, Kariya Shi, Aichi-ken, Japan; **BEng. K. Saitoh**, **MEng. S. Okabe**, Nippon Soken, Inc., Nishio Shi, Aichi-ken, Japan: "Flexible Design of Fuel Injection and Ignition Systems for Gasoline Direct Injection Engines":

The first generation of "wall-guided" DISI engines had stratified lean combustion with a wide spacing between the injector and the spark plug. As combustion timing tended to be too early in these engines, ideal efficiency of the thermodynamic process could not be attained. One option to overcome the disadvantages of "wall-guided" DISI engines consists in applying a "spray-guided" concept. This second-generation DISI process with stratified lean combustion allows small spacing between the injector and the electrode. In spray-guided DISI engines, the air-fuel mixture formation takes place independently of gas flow and piston movement. This offers an optimum option for raising the fuel economy of gasoline engines. Nevertheless, stratified lean combustion has been criticised for its high costs and the complexity of the aftertreatment process required to achieve particulate and NO_X emission levels meeting limit values. Shifting DISI development towards stoichiometric homogenous combustion has offered a solution to this problem. The lecturer reported on the current state of technology at the Denso Corporation and the future of two key technologies for DISI injection and ignition. He described, in particular, a multi-hole nozzle with highly flexible spray formation and a multi-spark ignition system with a high degree of energy flexibility, as well as advanced ignition methods involving plasma and laser ignition.

9 Injection – Development Trends

Dr.-Ing. R. Leonhard (lecturer), **Dipl.-Ing. J. Gerhardt**, Robert Bosch GmbH, Stuttgart: "Direct Injection – from Vision to Reality":

In spring 2006, Bosch launched series production of second-generation direct-injection systems. When comparing the performance of this second generation with the expectations that accompanied the gasoline direct-injection concept during the 1990s, it can be seen that the emphasis of development efforts has shifted from a focus on a pure lean combustion concept, primarily aimed at meeting CO_2 target values in Europe, to heightening fun-to-drive and further lowering emission levels. Implementing this diversity of concepts requires a flexible set of cost-efficient second-generation DI components. Highly variable high-pressure injection valves and pumps represent the centrepiece of this modular component set. The applicability of these components for the most diverse combustion methods and packaging situations is rounded off by an advanced electronic control unit with increased computing power. Thus application is possible in homogeneous and spray-guided naturally aspirated gasoline engines, as well as in DI turbo-charged engines, and even in SULEV and PZEV projects.

Going beyond these current applications, the direct-injection method represents the ideal basis for the further development of existing or entirely new combustion processes, including advanced spray-guided combustion methods, further downsizing of gasoline engines as well as the development of new combustion methods such as CAI / HCCI.

Dipl.-Ing. A. Waltner (lecturer), **Dipl.-Ing. P. Lückert**, **Dipl.-Ing. U. Schaupp**, **Dipl.-Ing. E. Rau**,

Bild 10: Roger Jan Johansson, General Motors Powertrain Europe, Turin

Figure 10: Roger Jan Johansson, General Motors Powertrain Europe, Torino

Bild 11: Dr. Wolfgang Vahland, VW Group China, Peking

Figure 11: Dr. Wolfgang Vahland, VW Group China, Peking

Bild 12: Prof. Dr.-Ing. Dr.-Ing. E. h. Burkhard Göschel, BMW Group, München

Figure 12: Prof. Dr.-Ing. Dr.-Ing. E. h. Burkhard Göschel, BMW Group, Munich

Dipl.-Ing. R. Kemmler, **Dr.-Ing. R. Weller**, DaimlerChrysler AG, Stuttgart: "Future Technology of Spark-Ignition Engines: Spray-Guided Direct Injection with Piezo Injector":

The completely novel second-generation direct-injection system for spark-ignition engines designed by Mercedes-Benz offers marked improvements in fuel consumption, power output and emission levels. Faced with the necessity of further reducing fuel consumption primarily in gasoline engines, the Mercedes-Benz combustion system represents a significant leap in technology.

The map range for stratified operation was noticeably expanded in comparison with the first generation. Thanks to the significantly improved efficiency of the engine, more useable energy is available and a substantial reduction of fuel consumption can be achieved in city traffic but also in long-distance highway driving at fairly constant speeds. These benefits make themselves felt not only in the test cycle, but also in real-world fuel consumption by customers. Following the principle of a modular system for technological advancement, the aspirated base engine was used as the starting point. Since the development of this combustion method for series production was not feasible using the hydraulic and ignition components available on the market, a new outward-opening piezo fuel injection had to be developed as a production standard, together with a 200-bar high-pressure fuel system, which was presented by the lecturer for the very first time, worldwide. This piezo injector assures stability and excellent mixture preparation, thus producing an optimal combustion mixture at the spark plug.

The potential of multiple injection in conjunction with stability in stratified operation, offers further benefits and possibilities of direct injection in order to reduce both fuel consumption and emissions.

Dr.-Ing. U. Dohle, **Dr.-Ing. M. Krüger** (lecturer), **Dipl.-Ing. D. Naber**, **Dipl.-Ing. J. O. Stein**, **Dipl.-Ing. Y. Gauthier**, Robert Bosch GmbH, Stuttgart: "Results of Combustion Optimization Using Multi-Hole Nozzles in Modern Passenger Car Diesel Engines":

Multi-hole concepts with two rows of holes offer an option for improving air/fuel mixture formation without impairing efficiency under higher engine loads. Such concepts are characterised by a high degree of freedom with regard to the design and arrangement of spray holes. Founded on the experience of Robert Bosch GmbH, and based on the afore-mentioned parameters, a nozzle matrix for the highest potential multi-hole configuration was defined and systematically investigated in order to find the optimum version. This optimised multi-hole version with an in-line configuration of the nozzle holes is characterised by a relatively large distance between the lower and the upper rows of holes and a convergent spray orientation with an identical impact point on the piston bowl wall.

A comparison of the results of this multi-hole variant with those achieved with an optimised combustion system using a conventional nozzle demonstrated that with the multi-hole concept, NO_X and particulate emissions are higher in the medium and upper load ranges, while HC emissions are reduced in the lower load range at a comparable rated output. Hence no overall improvement can be observed with regard to the trade-off between power density and high efficiency in the upper load range on the one hand and low emissions on the other.

10 Hybrid (2)

Dipl.-Ing. H. Kemper (lecturer), **Dr.-Ing. M. Pischinger**, **Dipl.-Ing. O. Lang**, **Dipl.-Ing. O. Rütten**, **Dipl.-Ing. P. Janssen**, FEV Motorentechnik GmbH, Aachen: "The Optimum Hybrid – Hybrid Drives with the Focus on the Cost-Benefit Ratio":

There are a huge number of potential hybrid drive train structures for passenger cars. Currently the worldwide hybrid market is dominated by the so-called power split full hybrid systems; parallel hybrid vehicles with a moderate degree of electrification rank second. A clear correlation between hybrid structures and vehicle classes or other categories has not been identified to date.

So the question arises: What would the optimum hybrid look like, and which influencing parameters determine the optimum? Starting from an analysis of the properties of the well-known structures, the most important parameters influencing the selection of the concept are discussed first. Cost to benefit considerations are given special attention, at which point a decision has to be taken as to what optimisation variables should be taken into account, which boundary conditions have to be dealt with, and what options exist in order to influence the overall outcome.

Such multi-dimensional, multi-variant and possibly time-dependent problems make it difficult to define a decision-making strategy. In this search for the optimum, support using appropriate CAE tools is essential. These tools permit an understanding of the complex component characteristics, market requirements, customer benefits and production limits. Thus a successful development and market introduction strategy for a new hybridised drive train can be planned well in advance.

Dr.-Ing. H. Schäfer, Siemens VDO Automotive, Regensburg: "New Electrical Drive Configurations for Hybrid Vehicles":

The lecturer described the novel hybrid drive configurations which include, for example, solutions without torque converters in combination with automatic transmissions and a continuously variable transmission system (CVT). Solutions that did away with conventional transmissions and which consist of a combination of electric motors with one or two planetary gears were also illustrated. Dr. Schäfer also reported the analysis of advanced drive configurations by means of torque tables and power flow characteristics, and presented an innovative development based on a special electronic drive structure which did away with the need for mechanical transmission. In conclusion, the lecturer dealt with the general design criteria applied to electric motors.

Mr. L. Nitz, (lecturer), General Motors Powertrain, Pontiac, Michigan, USA, **Dr.-Ing. A. Truckenbrodt** (lecturer), DaimlerChrysler AG, Troy, Michigan, USA, **Dr. W. Epple** (lecturer), BMW Group, Munich: "The New Two-Mode Hybrid System Developed by the Global Alliance for Hybrid Co-operation":

As automobile manufacturers committed to addressing global fuel consumption concerns, environmental issues and consumer needs, General Motors, DaimlerChrysler, and the BMW Group have embarked on a co-operative project for the development of a two-mode hybrid system, which will offer consumers a wider choice of models and assure the application of hybrid drives on a broader basis. The lecturers explained the demands customers make upon a hybrid system, and the motivations for – and advantages of – co-operation. Subsequently, they gave a technical description of the two-mode hybrid system, stating that the latter was being developed with a view to meeting the broadest possible range of customer requirements. In addition, they pointed out that this collaboration served as a model for creating commercial and technological synergies.

11 Fuels

Dr.-Ing. W. Warnecke (lecturer), **Dr. W. Lueke**, **Dr. L. Clarke**, **Dr. J. Louis**, Shell Global Solutions, Hamburg and Chester, UK; **Dr. S. Kempsell**, Shell International Petroleum Company, London, UK: "Fuels of the Future":

The reduction of greenhouse gases is a prime mover behind the development of non-conventional fuels, while the only short-term option available is the introduction of bio-fuels. First generation bio-fuels, such as bio-ethanol and esterified vegetable oils typically reduce greenhouse gas emissions by 50 %. Advanced bio-fuels can lower greenhouse gas emissions by over 90 %. Shell has made considerable investments in two advanced bio-fuels processes, which offer the additional advantage that they can be produced from waste biomass. In the Iogen process, Eco-Ethanol, is produced from straw using enzymes. The combination of Choren gasification with Shell's Fischer-Tropsch technology results in the production of BTL (Biomass To Liquid) fuel, which combines the performance benefits of GTL (Gas To Liquid) fuel with a significant reduction in greenhouse gases. Woodchips are one possible feedstock for this process.

Locally optimised solutions will lead to a range of non-conventional fuels becoming available in the near future. These are likely to be added to conventional gasoline and diesel as blending components. Such a diversity of fuel options poses challenges to ensure ongoing compatibility between future fuels and engine technologies; nonetheless, this diversification strengthens the robustness of the transport fuel market and thus alleviates potential energy supply uncertainties in the future. In order to be able to meet future environmental challenges, the integrated development of advanced fuels and powertrains will be absolutely essential

Dr.-Ing. H.-O. Herrmann (lecturer), **Dr.-Ing. S. Keppeler**, **Dipl.-Ing. W. Friess**, DaimlerChrysler AG, Stuttgart; **Dr. J.J. Botha**, Sasol Technology (Pty) Ltd., Rosebank, Johannesburg, RSA; **MSc.Eng. P. Schaberg**, Sasol Advanced Fuel Laboratory, University of Cape Town, RSA; **MSc.Eng. M. Schnell** (lecturer), SasolChevron Consulting Ltd., London, UK: "The Potential of Synthetic Fuels to Meet Future Emission Regulations":

The potential of GTL diesel fuel for further improving engine performance and reducing exhaust emissions beyond Euro4 was investigated in a Mercedes-Benz E320 CDI passenger car. Stating the properties of GTL fuel, which is free of sulphur and aromatics and has a Cetane number in excess of 70, and describing the outlook for future production and against the background of anticipated demand for diesel, the lecturer addressed the impact of GTL diesel fuel on heavy-duty and light-duty engines. Based on preceding work on unadapted engines – which was presented in an earlier lecture at the 25th International Vienna Motor Symposium in 2004 – the hardware configuration and software calibration of the E320 engine had now been modified to better utilise the advantages of Sasol Chevron GTL diesel fuel. In order to keep engine changes to a minimum, hardware modifications were limited to lowering the compression ratio and optimising the injection system.

These hardware modifications required the adaptation of the engine software calibration, such as injection system parameters, boost pressure adjustment, and EGR rates. Detailed bench work and chassis dynamometer testing have shown that the vehicle, which is equipped with a DPF and has a Euro4 calibration in its original form, complies with the very stringent NO_X emission limits of 0.08 g/km (NEDC) when moderately modified and operated using GTL diesel fuel. This opens up many promising vistas for a cost-efficient reduction of emissions, and again highlights the benefits that may be obtained with cleaner fuels.

Dr. W. Steiger (lecturer), **Dr. C. Kohnen**, Volkswagen AG, Wolfsburg: "New Combustion Systems Based on a New Fuel Specification":

New alternative fuels offer an optimum solution in meeting the future challenges for combustion-engine drive systems. If the specifications for fuels are properly targeted, new combustion methods, such as the CCS (Combined Combustion System) can be developed on the basis of such fuels, as these allow a combination of lowest emission levels and high efficiency.

Through an examination of the system development sequence and the results obtained with the CCS unit in full engine tests, the lecturer examined the benefits and advantages of CCS fuels in comparison with conventional diesel. A comparison of the homogeneous early-injection and conventional operating modes completed these investigations. In conclusion, a detailed outlook of bases from which further improvements could be expected in order to achieve the dual objective of lowering emissions and fuel consumption was provided. Such conclusions also form the foundation of Volkswagen's ongoing research efforts that shall enable the company to create the flex-mode engine of the future.

12 Emissions (2)

Dipl.-Ing. R. Brück, **Dipl.-Ing. P. Hirth**, **Dipl.-Ing. W. Maus** (lecturer), Emitec GmbH, Lohmar; **Mr. O. Deutschmann**, **Mr. N. Mladenov**, Karlsruhe University (TH): "The Fundamentals of Laminar and Turbulent Catalysis – Turbulent Beats Laminar":

For the past 30 years, monolithic, laminar-flow catalysts have been used in the automotive industry for catalytic aftertreatment of exhaust gas hydrocarbons, carbon monoxide and NO_X. Nevertheless, it continues to be difficult to understand the turbulent inlet and predominant laminar flow regimes in the narrow channel of a catalytic converter. It is an even more complex task to model the conditions for non-linear heat and mass transfer. For this reason, research on catalytic base materials has stagnated, and improvements were only achieved through higher cell densities and thus shorter diffusion paths of pollutants in the catalytically active wall. Thanks to the consistent application of calculation models and test programmes, it has been possible to design the next generation of "turbulent-flow" catalytic converters. Simulation and test results have made apparent the cost-savings potential of the new generation of catalytic converters.

Dr. E. Jacob (lecturer), **Dr. R. Müller**, **Dr. A. Scheeder**, Emitec GmbH, Lohmar; **Dipl.-Ing. T. Cartus**, **Dipl.-Ing. R. Dreisbach**, AVL List GmbH, Graz; **Mr. H.-P. Mai**, Roth-Technik-Austria GmbH, Gaggenau; **Dr. M. Paulus**, **Dr. J. Spengler**, Süd-Chemie AG, Bruckmühl-Heufeld: "The High Performance SCR Catalyst System: Elements to Guarantee the Lowest NO_X Emissions":

In accordance with the state of the art, SCR exhaust gas aftertreatment will form an integral part of future engines producing the lowest NO_X emissions. Cost pressure and limited packaging space call for compact and highly efficient exhaust emission control systems. A forward-looking concept for further investigations is a two-stage, advanced high-performance SCR system with increased volume-specific catalytic activity, which is characterized by the use of both a turbulent catalyst with internal flow exchange, allowing increased mass transfer and optimising the homogeneity of the chemical reactants inside the catalyst; and auxiliary catalysts, namely a urea-decomposition catalyst (H-catalyst), with system configuration in a slip-stream (the so-called 1/H-prereactor) or with H- and V-catalysts (V-catalyst, i.e., a pre-oxidation catalyst), the so-called V/H-pre-reactor, upstream of the SCR-catalyst arranged in parallel.

By using turbulent LS/PE structures with integral flow exchange in smooth substrate channels within V/H-RO systems and auxiliary catalysts, the volume of SCR catalysts can be increased by up to 40 % without losses in conversion performance or an impairment of cold-starting characteristics. These advances have resulted from a new coating process developed by Süd-Chemie AG for turbulent-flow catalyst substrates with internal flow exchange.

Dipl.-Ing. W. Müller (lecturer), **Dr.phil.nat. U. Göbel**, **Dr.-Ing. T. Kreuzer**, **Dr.rer.nat. J. Leyrer**, **Dipl.-Ing. A. Matutt**, Umicore AG & Co. KG, Hanau-Wolfgang: "Innovative NO_X-Storage Catalyst Systems for Spray-Guided Direct-Injection Gasoline Engines":

The most significant reduction of fuel consumption in gasoline engines can be reached by means of stratified, spray-guided gasoline direct injection. The development of an innovative exhaust gas aftertreatment concept constitutes one of the main success factors in these efforts. In gasoline production engines with direct injection, NO_X storage catalysts have emerged as one of the best options of all possible technologies for the reduction of nitrogen oxides in lean-burn operation. The most important development goals for NO_X storage catalysts are the enlargement of the active temperature window and the improvement of high-temperature stability. After catalyst ageing, the width of the dynamic NO_X storage window will determine in which ranges optimum engine operation is assured. This is essential for utilising the fuel economy potential in the most efficient manner.

The lecturer described the systematic development steps preceding series production of an exhaust aftertreatment system with NO_X storage catalysts for gasoline engines with spray-guided direct injection.

13 New Otto Engines (2)

Dipl.-Ing. M. Kerkau (lecturer), **Dipl.-Ing. S. Knirsch**, **Dr.-Ing. H.-J. Neusser**, Dr.Ing.h.c.F. Porsche AG, Weissach: "The New Six-Cylinder Bi-Turbo Engine with Variable Turbine Geometry for the Porsche 911 Turbo":

The development of variable turbine geometry (VTG) for gasoline engines necessitated the use of innovative materials from the aerospace sector. Furthermore, entirely new functions had to be conceived for boost pressure control in order to meet the exacting demands made upon agility and response. The new 3.6 l engine boasts outstanding torque and performance data: 620 Nm torque at 1950 to 5000 rpm, and a power output of 353 kW at 6000 rpm. Another novel feature is the overboost function for driving in the sports mode, which permits a further torque increase of 60 Nm up to a maximum of 680 Nm at between 2100 and 4000 rpm. A number of parameters, such as a special power output of 98 kW/l and specific torque of 189 Nm/l in the overboost mode, meet the highest demands in the sports car segment and are unrivalled by competitors.

The basic engine is a modification of its predecessor, but upgraded in many respects in order to take account of the higher load levels. Gas exchange was further improved and the engine weight reduced. By revising the switching strategy of the Variocam Plus system, fuel consumption of the Tiptronic gearbox version was reduced by 0.3 l per 100 km according to the NEDC cycle. The new 911 Turbo thus meets the current EU4/LEV and LEV2 emission standards.

Mr. N. Tsuji (lecturer), **Mr. M. Sugiyama**, **Mr. S. Abe**, Toyota Motor Corporation, Toyota-shi, Aichi, Japan: "The New 3.5 Litre V6 Gasoline Engine with the Innovative D-4S Stoichiometric Direct Injection System":

This new engine is equipped with a newly developed stoichiometric direct injection system with two fuel injectors in each cylinder – the D-4S direct injection 4-stroke gasoline engine system. One direct injector generates a dual-vertical-fan-shaped spray with wide dispersion, whereas the other one is a port injector. This new fuel injection system maximises the DI advantage for full-load performance, and simultaneously optimises the intake and exhaust systems in turn heightening the stiffness of moving parts, such as the timing chain and valvetrain system. Thus the engine reaches a specific power output of 67 kW/l and 234 kW at 6400 rpm, placing it amongst the top performers of all naturally aspirated production gasoline engines. By employing Toyota's intelligent Variable Valve-Timing system (VVTi) on both the intake and exhaust side, as well as a long dual exhaust pipe, an excellent maximum torque of 380 Nm has been achieved at 4800 rpm, with at least 90 % of the maximum torque being available over a wide rev range from 2000 rpm to 6500 rpm.

In part-load operation and after cold start, stable combustion with low fuel consumption and low emissions can be assured through the simultaneous action of both injectors. Thus the GS450h complies with even the most stringent emission standards, including those applicable to SULEVs.

Dipl.-Ing. J. Königstedt (lecturer), **Dipl.-Ing. R. Müller**, **Dipl.-Ing. J. Jablonski**, **Dipl.-Ing. T. Dirschnabel**, **Dipl.-Ing. J. Uhrich**, **Dipl.-Ing. W. Hatz**, Audi AG, Ingolstadt and Neckarsulm: "Audi's New V10-FSI Engine":

Audi's new 5.2 l V10-FSI engine is the most powerful within the new Audi V-engine family. With a power output of 331 kW and a torque of 540 Nm it powers the luxury Audi S6 and S8 limousines.

The engine concept is based on the Audi V6 and V8 FSI engines, from which the synergies of major components were taken over. The V10-specific dimensioning of charge-cycle components has resulted in exceptional power and torque values. At the same time, the use of a split pin crankshaft in combination with a balancing shaft guarantees optimum smoothness and comfort. A very distinctive feature of the Audi V10 FSI engine in the segment of ten-cylinder engines is its high low-end torque in the low speed range. With this feature, the compact V10 engine underlines the character of the Audi S-models which are known for their pronounced sportiness and unrestricted suitability for everyday use.

14 Components / Control

Dipl.-Ing. K. Blumenröder, **Dipl.-Ing. G. Buschmann** (lecturer), **Dipl.-Ing. J. Kahrstedt**, **Dipl.-Ing. A. Sommer**, **Dr.-Ing. O. Maiwald**, IAV GmbH, Berlin: "Variable Valve Trains for Passenger Car Diesel Engines – Potentials, Limits and Methods of Realisation":

The challenge facing developers of diesel engines for passenger cars lies in meeting drastically reduced emission ceilings while maintaining or even enhancing the specific advantages of diesel engines, and with due regard for the cost aspect playing an increasingly important role. In the course of its advanced combustion system (ADCS) development, IAV analysed - amongst other factors - what contributions a variable valve train could make to meeting these challenges.

The lecturer initially assessed the potential offered by all known variable valve timing concepts with regard to reducing exhaust gas raw emissions in both steady-state and transient engine operation. He stressed that the most promising approaches were subsequently applied to running suitable tests on a single-cylinder engine with a fully variable valve train. The test results, the lecturer pointed out, showed improvements both in steady-state operation and in the transient mode. For homogenised combustion processes, this opens up options for rapid combustion phasing through control of the charge composition and gas temperature.

The next step, he stressed, constituted the implementation of a variable valve train in a multi-cylinder engine, and also illustrated the integration of the design into the cylinder head and a closed-loop control strategy for transient engine operation.

Dipl.-Ing. R. Marzy (lecturer), **Dipl.-Ing. M. Messing**, **Ing. A. Hölzl**, **Ing. R. Penzinger**, Magna Powertrain, Engineering Center Steyr, St.Valentin: "Mass Balancing Systems for Combustion Engines: New Simulation Tools – Alternative Materials – Future Concepts":

Over the past few years, more exacting demands made upon driving comfort have resulted in the intensified application of mass and torque balancing units in engines of premium mid-size cars. There is a trade-off be-

Bild 13: Dr. Michael Paul, ZF Friedrichshafen AG, Friedrichshafen
Figure 13: Dr. Michael Paul, ZF Friedrichshafen AG, Friedrichshafen

tween the advantage offered by mass-balancing systems in the low-frequency vibration range and the disadvantage of high-frequency acoustic phenomena. Comprehensive research projects investigated possibilities to reduce noise by using simulations and analysing the noise characteristics of different materials. The lecturer presented a new simulation tool for calculating the clash of tooth systems, thus facilitating the up-front assessment of noise - both in terms of quality and intensity - that emanates from gear meshes. As a result, alternative materials for gear-wheel teeth, such as sintered materials and – ultimately – plastics, could also be examined for their noise characteristics and used instead of steel. Mass balancing systems in combination with oil pumps, ladder frames and oil scrapers form an integral part of engines and are increasingly used in design concepts. In this context, Magna Powertrain presented a high-speed oil pump which is intended for both diesel and gasoline production engines.

Dr. H. Hülser (lecturer), **Dipl.-Ing. K. Neunteufl**, **Dr. C. Roduner**, **Dipl.-Ing. R. Schneider**, AVL List GmbH, Graz: "New Control Concepts for Gasoline, Diesel and Hybrid – The Theory and Practice of Algorithm Design":

With increasingly stringent emissions standards, more degrees of freedom are required for the electronic control of actuators in powertrains, whilst shortening development times call for new approaches in the design and calibration of control algorithms. Conventional PID control soon reaches its limits when two highly interactive variables that display a similar dynamic response have to be controlled simultaneously. The MMCD process, which AVL devised over the course of several years, made it possible to calculate control algorithms for single and multi-variable control tasks based on a common methodology. These algorithms are highly efficient and to a great extent can be calibrated automatically. A dynamic behaviour model of the controller plant is automatically calibrated and the controller functions, including the relevant parameters, are automatically derived from this model. The lecturer emphasised the advantages of this approach which permitted a significant shortening of development times. The process was explained through the example of a co-ordinated control of exhaust gas recirculation (EGR) and boost pressure, by way of which – it was stressed – a double-digit reduction in commercial-vehicle engine NO_X emissions of was feasible in the transient mode. The same methodology was applied to the development of a closed-loop engine torque control based on an in-cylinder pressure sensor.

15 Plenary Closing Session: View into the Future

Prof. Dr.-Ing. Dr.-Ing. E.h.B. Göschel, **Figure 12**, Member of the Board of the BMW Group, Munich: "Quo Vadis Hybrid? The Further Development of Efficient Dynamics":

In his lecture, Dr. Göschel focused on the following elements of BMW's corporate strategy:

The BMW Group concentrates on an integrated, function-oriented approach to efficient dynamics in order to reconcile the conflicting goals of improved driving performance and higher fuel economy. Assuring efficient dynamics is the BMW's Group path to meeting brand-specific customer expectations and complying with statutory provisions in an optimum way without neglecting business management considerations. Highly efficient combustion engines continue to constitute the basis for drive trains. With a view to benefiting from additional potential efficiency gains, the BMW Group relies on flexible measures in order to achieve an intelligent energy management in vehicles. The BMW-Group seeks to avoid dead ends and concentrates on modular components which can be combined as needed in order to create a "best of hybrids" concept and obtain customised solutions for different vehicle categories.

Wherever it makes sense, hybrids will find their place within the BMW-Group's strategy of efficient dynamics. Thus hybrids can and will contribute to safeguarding sustainable mobility. In order to be able to offer its customers optimum tailor-made solutions, the BMW-Group intentionally keeps its options open with regard to the technological solutions employed in hybrids. Thus it is not a decisive question whether and in what form a BMW will be driven with a "hybrid inside". What really matters is that future BMW cars will show more efficient dynamics and thus offer more driving pleasure than ever before.

Dr.-Ing. M. Paul, **Figure 13**, (lecturer), Member of the Board, **Dipl.-Oec. K. Kimmelmann**, ZF Friedrichshafen AG, Friedrichshafen: "New Asian Players – a Challenge for the European Supplier Industry":

European component suppliers operate in a global market environment and thus have to take into account the specific conditions prevailing in their traditional home market Europe and, at the same time, search for opportunities which present themselves in emerging markets. Moreover, a change of market and competitive structures has manifested itself in the course of globalisation. Nowadays Asian vehicle manufacturers and their Asian component suppliers exert increasing pressure on European and American markets, customers and manufacturers. These trends create new opportunities for European suppliers, but at the same time, also pose new challenges – both in the European core market and in new growth markets.

Strategic approaches aimed at taking full advantage of these new opportunities are manifold: customer orientation, individualisation of markets with tailor-made solutions for specific customers and regions, accordingly taking into consideration differences in culture. New markets and market players not only influence traditional domestic markets, but are also striving for technology leadership in individual regions, while the degree of innovation is defined by local market needs. And, most importantly, all processes have to be oriented to local skills and cost structures. The build-up of local production facilities and a supplier base constitute decisive success factors. Moreover, it must be realised that a "world" design is not the right strategic option. Much rather localisation, i.e., the adaptation of products to regional demands, together with regional research, will prevail.

Dr. T. Weber, **Figure 14**, Member of the Board, DaimlerChrysler AG, Stuttgart: "Advanced Power": Future-Oriented Powertrain Technologies for our Customers":

With a view to reducing emissions caused by vehicles, it is not enough to concentrate on automotive engineering alone. Vehicle manufacturers, the mineral oil industry, politi-

Bild 14: Dr. Thomas Weber, Daimler-Chrysler AG, Stuttgart
Figure 14: Dr. Thomas Weber, Daimler-Chrysler AG, Stuttgart

Bild 15: Zufriedene Gesichter nach der Schlusssektion v. l. n. r.: Dr. Thomas Weber, Daimler-Chrysler, Dr. Michael Paul, ZF Friedrichshafen, Prof.Dr.H.Lenz, Prof.Dr. Burkhard Göschel, BMW AG
Figure 15: Contented faces at the end of the symposium f. l. t. r.: Dr. Thomas Weber, Daimler-Chrysler, Dr. Michael Paul, ZF Friedrichshafen, Prof.Dr.H.Lenz, Prof.Dr. Burkhard Göschel, BMW AG

cians and ultimately customers can, and indeed must, join forces. Customers can contribute to environmental protection through a fuel-saving driving style adapted to individual traffic situations. The mineral oil industry can, for example, make a major contribution to the reduction of CO_2 emissions by adding alternative fuels to conventional ones.

Through Alliance for Synthetic Fuels (ASFE) car makers and the oil industry have taken an important step in the right direction. As with DaimlerChrysler and the United Nations Environment Programme (UNEP), the German Association of Automotive Engineers (VDA) advocates a ten percent addition of bio-fuels to conventional ones. With a view to persuading companies to commit themselves more strongly to this goal, this idea should be promoted on a broad basis at the European level, and politicians should look into the many new options available in achieving this goal. In Germany, tax exemption for regenerative fuels created an important incentive and emitted a clear signal. The envisaged taxation of bio-fuels must not lead to a negative impact on the positive trend towards the wider use of such fuels. It is far more important to create an environment conducive to stimulating the necessarily massive long-term investments into this area.

Car manufacturers can make a significant contribution to the reduction of fuel consumption and emissions by optimising engine technologies and creating alternative drive concepts. DaimlerChrysler is pursuing a clear strategy to this end and has made considerable investments into research and development in this arena. The focus is on both hybrid and fuel cell drives, as well as the use of alternative fuels and suitable engine concepts. However, the classical combustion engine will remain at the centre as its potential will not be exhausted for a long time. Second-generation direct injection represents another method of improving gasoline engines and BlueTec will revolutionise diesel technology. By way of this modular technology package, DaimlerChrysler has created the preconditions for being able to meet the most stringent exhaust gas standards worldwide. Innovations such as BlueTec are necessary in order to safeguard sustained mobility that makes sparing use of resources and is, at the same time, environmentally friendly.

Prof. Lenz, **Figure 15**, closed the congress by extending an invitation to all participants to attend the 28th International Vienna Motor Symposium which is to be held on April 26 and 27, 2007. ■

Congress Documentation

The lectures presented at the 27th International Vienna Motor Symposium are contained in their in-extenso versions in the VDI Progress Reports (VDI Fortschritt – Berichte), Series 12, No. 622, volumes one and two (including a CD) and additional brochures. All documents can be obtained from the Austrian Society of Automotive Engineers (ÖVK).

Invitation

We should like to extend a cordial invitation to the 28th International Vienna Motor Symposium which will take place on April 26 and 27, 2007 at the Congress Center Hofburg in Vienna. We ardently recommend you to send your applications in due time following the on-line publication of the programme in late December 2006.

Contact

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