25th International Vienna Motor Symposium

April 29th and 30th, 2004

By Hans Peter Lenz

Once again, the International Vienna Motor Symposium of this year was an outstanding event. Leading engineers of engine development from all parts of the world presented their latest development results and gave outlooks on the future trends.

The following report describes the most important statements of the technical papers. All lectures und discussions were interpreted simultaneously into the conference languages German and English.

1 Introduction

The 25th anniversary of the International Vienna Motor Symposium coincided with a grand event: the accession of another ten countries to the European Union. This milestone in the history of the EU was of particular significance for Austria, **Prof. Dr. H. P. Lenz**, the organiser of the symposium, **Figure 1**, explained, because in the time before 1918 the Czech Republic, Slovakia, Hungary, Slovenia and parts of Poland were joined with Austria in a confederation of states which was governed from the Imperial Palace in Vienna, today's venue of the Symposium. From now onwards the new Member States and the former 15 Member States constitute modern Europe. This presents a special challenge to automotive engineers in the old EU Member States as they will have to make up for the high labour costs in the latter by coming up with top rate solutions.

This also holds true for Austria as a country which has contributed significantly to the development of cars right from the beginning and which, in the course of the past few decades, has emerged as a genuine home for the development and production of motor vehicles, reporting an export ratio of more than 80 %. AVL, BMW Austria, Magna, MAN Austria, Miba, and Opel Austria rank among the outstanding enterprises in the international automotive industry.

Prof. Lenz thanked the sponsors, who once again made it possible for some 30 students to attend the symposium. "Today's students, our colleagues of tomorrow, should be given a chance as early as possible to establish contacts with us in this way, so that we can get to know each other", he emphasised. He paid special tribute to the lecturers, stressing that without their efforts and commitment, ranging from the preparation of their lectures to their presentations, it would not have been possible to hold this symposium. Prof. Lenz pointed out that the complaint that the universities did not always teach the state-of-the-art did not apply to our profession as was mirrored by the large number of colleagues from the different disciplines who participated in the conference. "For today and tomorrow there will be no lectures on engines, but next week the students will gain information on the latest developments straight from the horse´s mouth," Prof. Lenz stressed.

A brief concert was performed at the beginning to mark the occasion of the anniversary of the 25th International Vienna Motor Symposium. Prof. Lenz explained: "As we have so many excellent musicians among the graduates at the Vienna University of Technology, we should lend them our ears today". Therefore, we have resorted to Johann (1825-1899) and Josef (1827-1870) Strauß, the sons of Johann Strauß". Both studied successfully at the University of Technology at around 1850. The younger of the brothers, Josef, had a very special talent for engineering. Amongst other things, he drew up logarithmic tables with the aid of which his colleagues made their calculations. He also invented a street scavenging machine.

Figure 1: Prof. Hans Peter Lenz, Austrian Society of Automotive Engineers and Vienna University of Technology

The audience listened to the polka "Ohne Sorgen" (Without Sorrows) by Josef Strauß. "This is an excellent leitmotif for this 25th Symposium, because after all the progress that we have already made and we expect to make in the future, we can look to the 25 years to come without sorrows in the field of automotive engineering. In 25 years from now internal combustion engines will still be the main medium for propelling motor vehicles!" Prof. Lenz mused.

After this introduction with the polka "Ohne Sorgen", the audience listened to the waltz "Accelerations" by Johann Strauß which is the musical expression of the gradual start of a machine. This waltz was composed for the ball of the students of the Vienna University of Technology in 1860. The concert ended with the rapid polka "Elektrophor" (Electrophore) which Johann Strauß dedicated to the engineering profession in 1865. Strauß was deeply impressed by this device which is based on electric influence and supplies small quantities of electrical power.

The performers also came from within the ranks of the Vienna University of Technology: they are members of the University's symphonic orchestra, **Figure 2**. The audience applauded enthusiastically in order to express its special appreciation for this top quality "sound design".

After the joint plenary session, the audience split up into two parallel sections at which technical presentations were made. The sections were headed by the professors H. P. Lenz, R. Pischinger and G. Jürgens, **Figure 3**, H. Eichlseder, **Figure 4**, and B. Geringer, **Figure 5**. An impressive and very comprehensive exhibition of new engines, components and vehicles supplemented the lectures in an excellent manner, **Figure 6** and **Figure 7**.

Accompanying persons were offered a culturally sophisticated social program which included an excursion to the region south of Vienna: Wiener Neustadt and the Semmering Mountain, a walk along the Vienna Ring Road which is studded with magnificent buildings devoted to works of art and to music, a visit to a museum and to the china manufactury. The social program met with great approval. Upon the invitation of the Mayor of Vienna, the conference participants spent the evening in a pleasant atmosphere in the splendid rooms of the Vienna city hall where a fiery Hungarian band played up – a gesture of friendship by the Austrian organisers to this neighboring country.

2 Opening Plenary Session

Prof. Dr. F. Indra, Executive Director, **General Motors Powertrain**, Pontiac, USA, **Figure 8**, gave the first lecture in the plenary session. He talked about the topic "25 years Vienna Motor Symposium: Technical Highlights only?".

Prof. Indra explained "What started 25 years ago as a one-day symposium on the premises of the Austrian Association of Engineers and Architects, and was continued in Laxenburg Castle, finally emerged as the world's most important and most sought after engine symposium. Since its early days, the Symposium has always been booked out or overbooked even before the official invitations were sent

Figure 2: Vienna University of Technology Orchestra

out. In the course of time, the Vienna Motor Symposium established itself as a most attractive forum for engine and transmission experts from all parts of the world. Its lectures and lecturers, the ladies' programs, cultural events and its top-level organisation assure the lasting success of this conference. There can be no doubt: Prof. Lenz, his wife and his entire team deserve all our praise. “All of us do hope, dear Prof. Lenz, that you will continue along these lines for many years to come.”

Prof. Indra's plenary lecture dealt with the technical contents of the presentations made at the previous 25 symposia. He asked the question whether what had been presented was translated into practice, wholly or in part, or will it be applied in the future, or did perhaps even the opposite happen?

In view of the host of lectures, 692 to be precise, Prof. Indra was able to make an assessment of technical highlights only en bloc focusing on the most interesting topics. Naturally not all lectures were “technical highlights” Prof. Indra emphasised. Often the outcome of a technological development produces other results than those expected, the lecturer explained, but then you knew that next time you would have to apply a different method in order to make progress.

Dr.-Ing. G. Pachta-Reyhofen, Member of the Board, **MAN Nutzfahrzeuge AG**, Munich, **Figure 9**, continued the lectures in the plenary with the topic “Engines from MAN – From a Single Basic Principle to a Hightech Product”.

Rudolf Diesel's ingenious idea laid the groundwork for a drive technology which today constitutes the basis of nearly all engines in heavy-duty commercial vehicles worldwide. Thus he made a vital contribution to the exchange of goods at the national and international levels, which constitutes a determining factor of today's prosperity. Whereas steam engines had an efficiency of less than 10 %, Rudolf Diesel's first five-tonne engine immediately boasted an efficiency of 26 %. With an engine capacity of 19.7, the output was just about 15 kW. Over a century, diesel engines were developed further and their efficiency was raised to clearly more than 40 % in commercial vehicles. MAN was also involved in this development as a major player. The new engine generation D20 Common Rail for MAN trucks and buses with a total weight of over 16 tonnes will once again set new standards with regard to specific output, weight-output ratio, consumption levels and life cycle cost. Designed for an ignition pressure of up to 200 bar, this engine has a swept volume of 10.5 litre, produces an output of 430 HP and a maximum torque of 2,100 Nm. With its dry weight of 960 kg, it is the lightest engine in the 400 HP category. In road operation, its fuel consumption is 5 % lower than in tests.

Prof. host. Dr. E. h. W. Bockelmann, Member of the Board, **Volkswagen AG**, Wolfsburg, **Figure 10**, held the last lecture of the opening plenary session entitled:“The Combustion Engine in the Stress Field of Future Requirements”.

Despite its history of more than one hundred years, the internal combustion engine continues to be the most important source of modern mobility and one of the strongest driving forces behind our economic development. Thanks to the rapid strides made in diesel and gasoline engine engineering, especially in the past 15 years, it was possible to continuously improve the fuel economy and driving performance of our cars despite ever more exacting demands made upon comfort and safety, while at the same time, reducing emission levels steadily. The main challenges in the future will derive from the need to offer

cost-effective solutions while at the same time meeting ever more stringent legal standards and conditions in order to be competitive in the marketplace. For this purpose, the differing requirements of the individual markets will have to be taken into account. On the path to the introduction of fuel cells, hybrid vehicles exhibit the largest potential for CO_2 reduction, but the trade-off between CO_2 reduction measures and production costs will have to be carefully analysed.

Against this background, a further optimisation of conventional technologies for the different engine assemblies is becoming ever more important. In diesel engines, the relatively higher emission levels as compared to gasoline engines can be reduced by means of partly homogenised combustion, in gasoline engines, the combination of direct injection and downsizing, supercharging appears as a promising alternative for improving fuel efficiency significantly. In addition, intelligent drivetrain management, such as, for example the Volkswagen direct mechanical transmission system will permit a further reduction of CO_2 emissions while improving driving comfort at the same time.

3 New Engines

Dipl.-Ing. P. Lückert (lecturer), **Dipl.-Ing. A. Waltner, Dipl.-Ing. E. Rau, Dipl.-Ing. G. Vent, Daimler-Chrysler AG**, Stuttgart: "The New V6 Gasoline Engine for the Mercedes SLK 350 – the Basis of a New Engine Generation"

In spring 2004, the new engine version with a swept volume of 3.5 litres, which is internally designated as M 272 E 35, was presented in the new SLK (R171). It is regarded as the basic model for a new engine generation which will replace the time-tested V engines M 112 one after the other in the years to come. Designed as a six cylinder induction engine in a 90 degree arrangement, this four-valve engine will be used in vehicles worldwide. Its high power output and torque permit a selective combination with both manual transmission, as well as different drivetrain designs, which meet all customer requirements over the entire range, from sporty cars to limousines with high travelling comfort. The prevailing features of these engines are strikingly low fuel consumption and emission levels as well as a sophisticated acoustic design, which is, however strongly influenced by different versions of vehicle concepts. The development time for this top-of-the-range engine was 36 months.

Figure 3: Prof. Rudolf Pischinger and Prof. Gunter Jürgens, Graz University of Technology

Figure 4: Prof. Helmut Eichlseder, Graz University of Technology

Figure 5: Prof. Bernhard Geringer, Vienna University of Technology

Dipl.-Ing. A. Eiser (lecturer), **Dr.-Ing. T. Heiduk, Dipl.-Ing. M. Fitzen, Dipl.-Ing. J. Gessler, Dipl.-Ing. W. Hatz, Audi AG**, Ingolstadt: "The new V6-FSI-Engine of Audi"

This completely redesigned V6 3.2 l 4V FSI engine impressively combines top torque and power output values in the category of naturally aspirated gasoline engines. With a specific power output of 60.3 kW/litre and a torque of 105.8 Nm/litre (> 100 Nm/litre in the range from 2,400 to 5,500 rpm) very good low-end-torque characteristics, combined with an excellent power output of up to 7,200 rpm, have been attained. The combination of fuel

Figure 6: Exhibition

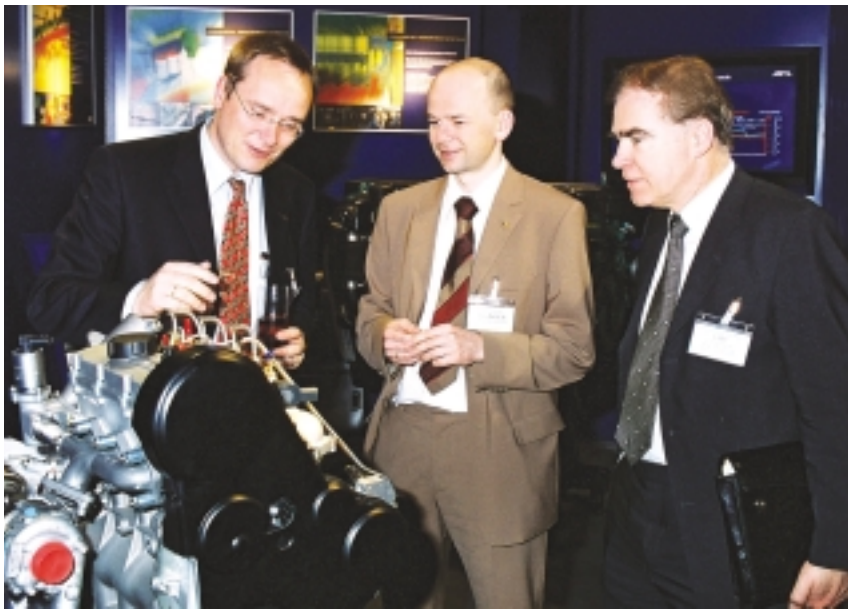

Figure 7: Exhibition: Prof. List, AVL (right), Dr. Fischer, AVL (left)

direct injection with a compression ratio of 12.5 and the engine's design for the fuel grades ROZ 95 and 91 has resulted in low fuel consumption. Thanks to a life time chain drive and flexible oil-changing intervals of up to a mileage of 30,000 km, vehicle operating costs are low and the engine is easy to maintain. This engine is offered in the new A6 with the following drive versions: a six-speed manual transmission system with front or Quattro wheel drive, a multitronic front-wheel drive, and a six-speed tip-tronic automatic transmission with quattro-wheel drive.

S. Abe (lecturer), **M. Sugiyama, H. Kishi, J. Harada, Toyota Motor Corporation**, Aichi, Japan: "Development of a New V6 High Performance Stoichiometric Gasoline Direct Injection Engine"

Toyota completed the development of its new V6 gasoline direct injection engine at the end of 2003. High performance, low fuel consumption, and low exhaust gas emissions were achieved by means of stoichiometric direct injection and variable intake and exhaust valve timing. The maximum engine output is 188 kW (63 kW/l) at 6,200 rpm and its maximum torque amounts to 314 Nm at 3,600 rpm, which makes this engine a top-of-the-range model in the category of 3.0 litre gasoline engines worldwide.

Toyota optimised its direct injection system by using slit nozzle injectors which generate a fan-shaped spray. This optimisation of the design of the intake port has contributed to improving the engine's power output. With conventional intake port designs, the flow-rate coefficient had to be reduced in order to generate an in-cylinder air flow which is required for homogeneous mixture formation. Thus the advantages offered by a direct injection system could not be fully utilised. In the development of this engine, CFD analyses were conducted for optimising the intake port which resulted in both a high flow-rate coefficient and a high tumble ratio.

With a view to improving fuel efficiency, variable intake and exhaust valve timing was used, which resulted in lower pumping losses and a higher expansion ratio. The outcome of combustion pressure analyses and the high speed analysis of hydrocarbons in the zone around the spark plug have demonstrated that the speed of combustion could be increased by means of internal EGR and that the engine can be operated at a higher exhaust gas recirculation rate (EGR) owing to the strong tumble flow and stratified charge combustion.

Dipl.-Ing. K. Borgmann, Dipl.-Ing. H. Fischer (lecturer), **Dipl.-Ing. K. Fröhlich, Dipl.-Ing. W. Hall, Dipl.-Ing. R. Hofmann, Dipl.-Ing. T. Melcher, BMW AG**, Munich: "The New High Performance Powertrain of the BMW X5"

Last autumn BMW gave its very successful X5 vehicle series a facelift. Amongst other modifications, the entire V8 powertrain was replaced by the new 4.4 l V8 Valvetronic engine and the 6-speed ZF automatic gearbox. The new powertrain constitutes the basis for the 4.8is high performance version which will be the successor model to the previous 4.6is engine. An increase in the displacement to 4.8 l, combined with a number of performance tuning measures in the base engine and the induction and exhaust systems resulted in an engine output of 265 kW and an improvement of the torque to 500 Nm. At the same time, the throttleless engine part-load control system Valvetronic in the new BMW V8 engines and the 6-speed automatic gearbox have resulted in a 10 % higher fuel economy.

The new BMW "xDrive" four wheel drive technology integrating an electronically controlled multi-plate wet clutch in the transfer box allows a continuously

variable torque distribution between the front and the rear axles within a few milliseconds. This unique technology not only improves the traction of the vehicle, but being an integral part of the BMW DSC (Dynamic Stability Control) system, it heightens driving stability and active safety as well. This new powertrain, together with the high-performance and fuel efficient V8 engine, the 6-speed automatic gear box and the "xDrive" four-wheel drive system make the BMW X5 4.8is a vehicle that boasts outstanding driving performance, high fuel economy, outstanding comfort, very good traction, excellent active driving safety and thus a lot of driving pleasure.

Dipl.-Ing. R. Bauder (lecturer), **Dipl.-Ing. H.-W. Pölzl, Dipl.-Ing. T. Reuss, Dipl.-Ing. W. Hatz, Audi AG**, Neckarsulm: "Audi's New V6 TDI Engine"

In 1989, Audi introduced its 2.5 TDI, the first direct-injection diesel engine for passenger cars. This engine soon became the trendsetter in DI-diesel technology. The new 3.0 litre V6 TDI is the first diesel production engine of the new Audi-V-engine family with an axle distance of 90 mm. As a result of internal measures, this new engine meets the very stringent EU IV exhaust emission standards even in the luxury car category and with cars with automatic transmission and the Quattro drive train. The new 3.0 V6 TDI engine has a maximum power output of 171 kW and a torque of 450 Nm. Its features include four valves per cylinder and a turbocharger with variable turbine geometry. It is the first engine in the world market to use the Bosch third-generation piezo common rail system with a maximum injection pressure of 1,600 bar. The new V6 TDI is characterised by its very high performance and its impressive smoothness. With its compact dimensions and numerous new technical approaches, Audi has once again set a milestone in TDI technology.

Dipl.-Ing. W. Mattes (lecturer), **Ing. K. Mayr, Dipl.-Ing. W. Neuhauser, Ing. F. Steinparzer, BMW Motoren GmbH**, Steyr: "The BMW Six Cylinder Diesel Engine for Euro 4"

The new Euro 4 emission standards for passenger cars, which will apply Europewide from the 1st of January, 2006 onwards, call for a 50 % reduction of NO_x and particulate emissions as against the current Euro 3 standards. BMW has already begun to gradually adapt its volume fleet in order to be able to comply with the new emission legislation. The lecturer described the technological measures applied to the 3.0 litre six cylinder engine of the 5-Series with a view to complying with the Euro 4 standards. The main focus is on a marked reduction of untreated emission exhaust gas by means of internal measures and on the introduction of a particulate trap system. The internal measures include a redesign of injection hydraulics, an optimisation of the combustion chamber configuration and intake ports, as well as the development of an innovative, adaptive "compare and control" concept.

One highlight of this package of measures in preparation for Euro 4 is the new particulate trap. BMW uses a catalytically coated filter element. Thus soot particles are almost entirely eliminated thanks to an intelligent concept for continuously monitoring load and controlling discontinuous regeneration, while other customer-relevant characteristics are not impaired. All characteristics which are relevant to customers, such as fuel consumption, engine performance and sound design will be retained at their present high levels in engines that will meet the new Euro 4 emission standards.

Figure 8: Prof. Dr. Fritz Indra, General Motors Powertrain

4 Design, Calculation, Simulation

Dr. H. Sorger (lecturer), **Dipl.-Ing. (FH) A. Maier, Dr. R. Marquard, AVL List GmbH**, Graz: "Interface-Linked Design Methodology for Reduced Development Times – Theoretical Considerations and Successful Implementation"

AVL developed an integrated design method which allows designers to make creative contributions to engine development in the face of the most diverse demands, and to work together in a target-oriented development team to find optimum creative solutions. The design method described by the lecturer is an essential module in the optimised AVL product development process. This design methodology was successfully applied to the development of a new engine family consisting of gasoline and diesel engines in in-line and V configurations. This method contributed significantly to the shortening of development times as planned and enhancing product quality at the same time. By using this novel design method which has been tested in practise it has been possible to rely on these long-lead-components and procurement as a starting point for new engine projects and new engine concepts and to create synergetic effects by resorting to a joint data base in which all known and approved solutions are stored.

Dr. U. Thien (lecturer), **Dipl.-Ing. M. Mocnik, Dipl.-Ing. R. Kollau, Magna Steyr Fahrzeugtechnik AG & Co KG**, Graz: "Interventions in Engine Electronics to Successfully Minimise Load Alteration Jolts in 4x4 Vehicles – Calibration and Simulation"

Passenger cars which are expected to offer higher driving comfort are equipped with drivetrain dampening systems to counteract irritating noise excitation. This dampening is first achieved by the tuning of mechanical components. When major drive forces are released during acceleration, strong reaction forces arise. A comfortable drivetrain design and the desirable flexibility of modern axle designs may result in major shocks. Sudden jolts are perceived as extremely uncomfortable by drivers and passengers and are assessed as negative characteristics. Simulation studies illustrate the elasto-kinematic effects of the drivetrain in motor vehicles. With the aid of evaluations of measurements, the mechanical components can be optimised in order to meet dampening requirements. Selective calibration of electronic control units and higher performance of the respective units result in further improvements. Special attention is given to driving comfort and responsiveness. Using a four-wheel drive vehicle as an example, the lecturer showed how Magna Steyr dealt with load alteration jolts in four-wheel drive vehicles by calibrating electronic control

units and how this enhanced driving comfort in an optimum way while increasing the responsiveness of engines at the same time.

Dr. T. Fukuma (lecturer), **S. Nakayama, Y. Harada, A. Matsunaga, Toyota Motor Corporation**, Shizuoka, Japan: "Challenging the Vision of Calibration-Free Diesel Engine Development by means of Model-Based Control and Automatic Optimisation"

The approach in which model-based control compensates for dynamic performance differences from a steady state and experimental results as well as multi-parameter optimisation based on statistical procedures has demonstrated the potential for developing almost calibration-free diesel engines in the future. The lecturer illustrated the optimisation of nitrogen oxydes (NO_x) as an example for his procedure. NO_x represents an especially important factor in overall optimisation because of its interactions with other constraints. After optimisation by varying local NO_x parameters in steady state operation, the control of on-board intake oxygen concentration ensures that NO_x exhaust emission standards are met without the need for any further calibration of the vehicle. By taking into consideration EGR delays, the intake oxygen volume can be accurately predicted so that the dynamic response of the vehicle can be optimised efficiently while, at the same time, keeping smoke generation at a low level.

Figure 9: Dr. Georg Pachta-Reyhofen, MAN Nutzfahrzeuge AG

5 Acoustics

Prof. Dr. U. Bernhard (lecturer), **Adam Opel AG,** Rüsselsheim**; R. Sponsel, Dr. U. Grebe, Opel Powertrain GmbH**, Rüsselsheim: "Acoustic Optimisation of Opel´s New 1.6 l Twinport Engine"

Even in the compact car category customers today often decide to buy a car with up-level powertrains, as they not only consider fuel economy and emission behaviour but also attach great importance to driving pleasure and comfort. Special technical features will be accepted by buyers only if the additional costs for these extras are low and if these can be compensated by cost benefits over the entire life of the vehicle. In the category of gasoline engines of up to 1.6 litres swept volume, Adam Opel AG decided to consistently use Fiat-GM powertrain engines with port deactivation and high EGR rates. The first series-produced engine of this type was the 1.6 litre family twinport engine which was installed in the Opel Astra 2003. Through the targeted integration of acoustic requirements into the development of the engine concept, the full potential for lowering combustion noise and mechanical noise was exploited right from the beginning, in order to obtain better vibration and acoustic characteristics and thus improve the behaviour of the engine in the vehicle as compared to the predecessor model.

Dr. N. Alt (lecturer), **Dipl.-Ing. O. Lang, Dr. S. Heuer, FEV Motorentechnik**, Aachen: "Acoustics of New Gasoline Engine Gas Exchange and Combustion Process Concepts"

Alongside conventional engines, engines with direct fuel injection, turbocharging and fully variable mechanical valve trains are series-produced today. In addition to combinations of these technologies, other new concepts, such as engines with variable compression ratios, high boost pressure, and electrically activated fully variable valve trains are also being developed. All of these developments are focused on reducing fuel consumption while meeting the statutory limit values for noise and exhaust gas emissions. The lecturer evaluated the influence of the various engine concepts on the noise and vibration behaviour of engines, distinguishing between mechanical excitation, combustion noise and exhaust noise. He also illustrated the specific approaches to noise reduction of the individual concepts, and explained that the different concepts were assessed for their influence on acoustic behaviour on the basis of predicted interior vehicle noise.

Dr.-Ing. U. Dohle (lecturer), **Dr.-Ing. M. Dürnholz, Dipl.-Ing. J.-O. Stein, Robert Bosch GmbH**, Stuttgart: "The Impact of Future High Pressure Diesel Injection Systems on Noise and Emission Levels of Modern Combustion Processes"

With a view to being able to comply with ever more stringent limit values for emissions and meet the ever more exacting demands made on driving comfort and acoustic behaviour, new concepts must be developed. Robert Bosch GmbH conducted detailed studies in order to assess the influence of the injection rate on combustion noise and emission levels. As a result, an ideal injection curve has been defined which makes it possible to omit pre-injection, which has a favourable impact on acoustic behaviour but a negative influence on emission levels over a wide range of the engine map. By omitting pre-injection and optimising the shape of the injection curve during diffusion combustion, NO_x and particulate emissions can be significantly lowered while simultaneously attaining favourable noise characteristics. These findings were applied to the elaboration of the concepts for Bosch's 4th generation of common rail injection systems: the coaxial-vario nozzle and the pressure-amplified HADI system. In combination with state-of-the-art combustion processes, both systems produce lower emissions and significantly improve the noise characteristics of future diesel engines, thus contributing to the growing success of diesel cars.

6 Synthetic Fuels

Dr. R. Clark, Dr. J. Louis, Dr. W. Lüke, Dr. W. Warnecke (lecturer), **Shell Global Solutions**, London/Hamburg; **M. Gainsborough, Shell International**, London; **J. Jacometti: Shell International Gas**, London: "The Introduction of Synthetic Fuels"

In the medium term, it is envisaged that traditional oil-derived fuels will still dominate the transportation market, but there will be an increasing role for alternative fuels. A fuel strategy can assess the likely scenarios of the future fuel mix based on a number of inputs, including the strengths and weaknesses of the alternative fuel.

Within the range of potential alternative fuels, Shell sees GTL fuels as an important option offering a number of advantages – strategic diversification, compatibility and cost effective emissions reductions. These emissions benefits were considered in detail. The lecturer discussed the issues associated with bringing this new fuel to market, including the likely market model and options for both pure GTL and GTL blends. Engagement with key stakeholders from government, OEMs (e.g. Daimler-Chrysler and Volkswagen) and consumer groups played an important part in gaining acceptance for the new fuel concept, the lecturer explained. In this respect, GTL field trials played a key role in the market development stages; the lecturer examined recent examples conducted in Berlin, London and California. Customer acceptance was also a key factor with non-traditional fuels, and in this respect GTL had the advantage of maintaining the same familiar infrastructure and vehicles. Recent retail launches of GTL blends were described.

Dr.-Ing. W. Steiger (lecturer), **Dr.-Ing. V. Schumacher, Dr.-Ing. C. Kohnen, Volkswagen AG**, Wolfsburg: "Potential of Synthetic Fuels in CCS Combustion"

Figure 10: Prof. host. Dr. E. h. Wilfried Bockelmann, Volkswagen AG

Synthetic fuels are gaining ever greater importance as sources of energy for transport media. These fuels not only offer the advantage of being derived from a broad range of primary sources of energy, including renewable forms of energy, but given their molecular structure and formulations, they also hold out additional potential for present and future combustion processes. Homogenised, auto-ignition combustion systems, in particular, are influenced to a great extent by fuel properties. Studies have also demonstrated that today's common parameters, such as boiling point and cetane number, are no longer sufficient for the specification of new fuels for the HCCI process.

The simultaneous development of a new fuel and its combustion in the CCS process calls for a consistent use of the full range of development tools. Initial basic investigations of these fuels in the Fuel Ignition Tester (FIT), pressure chambers and single-stroke engines have shown differences in ignition and combustion behaviour. Simulations of in-cylinder flow, mixture formation and combustion are also indispensable tools. Only once all of these investigations have been completed, will it make sense to verify the findings on engine test benches and in vehicles and then subsequently optimise the fuels. The benefits of the new fuels are especially obvious under the boundary conditions of all processes. A significant enlargement of the holistically optimised operating ranges can be achieved by means of synthetic fuels.

Dr. H.-O. Herrmann (lecturer), **Dr.-Ing. N. Pelz, Prof. Dr. R. R. Maly, Daimler-Chrysler AG**, Stuttgart; **Dr. J. J. Botha, MSc.Eng. P. W. Schaberg, Sasol Oil (Pty.) Ltd.**, Randburg; **MSc.Eng. M. Schnell, Sasol Chevron Consulting Ltd.**, London: "The Effect of GTL Diesel Fuels on Emissions and Engine Performance"

The effect of GTL diesel fuel blends on emissions and engine performance has been studied in a detailed investigation. A sulfur-free European diesel fuel (EU diesel) was used as a reference and as a base stock. Dynamometer tests with a 220 CDI vehicle in the NEDC (New European Driving Cycle) emissions test cycle, without any changes to the basic EU3 engine calibration, revealed that GTL diesel fuels may reduce emissions significantly, even with a non-adapted engine. For neat GTL diesel fuel, CO and HC emissions were reduced by over 90 %, and PM emissions by up to 30 %. Slight improvements in the range of a few percent were observed for NO_x and CO_2 emissions.

Blending GTL diesel fuel with EU diesel revealed a strong non-linear characteristic: a 50 % blend exhibited properties close to those of neat GTL diesel fuel. In order to explore the available potential for further emission reductions, steady state engine test bed runs were carried out at operating points characteristic for the NEDC. Based on these data, the range of emissions reductions was calculated in accordance with the design of experiments (DOE) approach for a new soft calibration with optimised EGR rates and injection timing. For neat GTL diesel fuel, a conservative prediction projects possible simultaneous reductions of 35 % in both NO_x and soot. The non-linear blending characteristics were corroborated for two blending ratios: a 50 % and a 20 % GTL blend with EU diesel. Reductions in NO_x and soot were found to be 30 % and 15 % respectively compared to EU diesel. This corresponds in relative terms to a 86 % and 43 % recovery of the benefits of neat GTL. The heat release revealed an earlier start of pilot and main combustion in GTL diesel fuels.

7 Fuel Mixture / Gas Exchange

Dr.-Ing. P. Kreuter (lecturer), **Dr.-Ing. P. Heuser, Dr.-Ing. M. Wensing, Dipl.-Ing. R. Bey, Dr.-Ing. C. Fettes, Dipl.-Ing. J. Baltes, Dipl.-Ing. W. Cosler, Meta Motoren- und Energie-Technik GmbH**, Herzogenrath: "NO_x Reduction for Diesel Combustion Processes by means of High Energy Air-Guided Mixture Formation"

In state-of-the-art diesel engines, ever more sophisticated injection systems perform the tasks of controlling mixture formation and combustion. The air-guided swirl energy cannot be accurately controlled, but can only be shown for the overall engine map in the form of approximate values.

The lecturer described the application of an additional valve, designed for impulse charging of combustion engines, which controls mixture formation and combustion in diesel engines. This freely controllable electromagnetic unit is arranged upstream of the inlet valves in front of the induction ports. In the diesel engine, a common impulse charger is used for both the swirl port and the tangential port of each cylinder. When the impulse charger module remains closed during the intake stroke, a vacuum is generated by the downward motion of the piston. After the opening of the impulse charger, this vacuum generates a higher flow velocity and, thanks to the special port design, a higher swirl energy. The swirl energy used for

mixture formation is infinitely variable at all operating points by shifting the timing of the opening of the impulse charger.

The resulting measurements have demonstrated the effect of the impulse charger on the diesel-specific mixture formation, the combustion process and emission characteristics. At individual operating points, raw emissions were lowered by more than 60 % (NO_x), while particulate emissions were also reduced. Furthermore, the application of the impulse charger strongly supports the combustion process during starting.

Dipl.-Ing. U. Baretzky (lecturer), **Dipl.-Ing. T. Pfeffer, Dr.-Ing. P. Kuntz, Audi AG,** Neckarsulm**; Dr.-Ing. W. Ullrich, Audi AG**, Ingolstadt: "Optimised Development Methodology to Improve Fuel Mixture Preparation for the Audi R8 FSI Le Mans Engine"

After the successful development of the FSI direct injection technology for the 24-hour motor race in Le Mans in 2001 and 2002, the objective of further improving the output and efficiency could only be achieved by gaining a deeper understanding of the mixture formation and the combustion process itself. To this end, all relevant parameters, such as geometries, control values, etc. were isolated in order to examine their influence on mixture preparation and combustion in the development process with simultaneous engine testing and simulations. Cylinder pressure indication served as a vital tool for optimum validation of the results of the simulation computations. Subsequent computations of variants provided parameter settings for engine testing. This closely networked cooperation was established as an optimised development method which was first applied to the development of the 4.0 l V8 FSI engine, the engine behind the Bentley EXP 08's historic victory in the 24-hour race at Le Mans in 2003.

J. W. G. Turner (lecturer), **S. A. Kenchington, Lotus Engineering**, Norwich, Great Britain; **D. A. Stretch, Eaton Automotive**, Southfield, MI, USA: "Production AVT Development: Lotus' and Eaton's Electrohydraulic Closed-Loop Fully Variable Valve Train System"

Lotus and Eaton are collaborating to bring a production closed-loop control fully variable valve timing system, known as Active Valve Train (AVT), to market in the 2008-9 timeframe. The system uses electrohydraulic operation, movement of the engine poppet valves being initiated by oil flow into and out of a hydraulic chamber which is controlled by fast-acting electrohydraulic servo valves developed by the two companies.

Figure 11: Dr.-Ing. Dr.-Ing. E. h. Hans-Joachim Schöpf, Daimler-Chrysler AG

This in turn allows infinitely variable timing, duration and lift. The system, which is currently being engineered in prototype form for an OEM, will allow ready application of many advanced engine control strategies, such as throttleless operation, controlled auto ignition (or homogeneous charge compression ignition), fast start, variable firing order, differential cylinder loading and ultimately air hybridisation. The lecturer related the present development status of the system from a valve control standpoint and described some of the design features which have been adopted to fulfil the above requirements. He also made an estimate of BOM costs for a typical light-duty automotive application.

8 Diesel Engine in the Future?

Prof. Dipl.-Ing. M. Schittler, Dipl.-Ing. B. Heil, Dr.-Ing. A. Flotho (lecturer), **Dipl.-Ing. W. Schmid, Daimler-Chrysler AG**, Stuttgart: "MBE 4000 US´04: An Inline 6-Cylinder Diesel Engine with EGR for Heavy-Duty Daimler-Chrysler Trucks in the USA"

In 2001 Daimler-Chrysler launched its MBE 4000 engine for heavy-duty trucks which complies with the US´98 emission standards in the US market. In the meantime, the number of engines sold increased rapidly within a short period. Truck engines which will be produced for the US market after January 1, 2004 must meet the exhaust gas emission limits of US'04. The lower emission limit for nitrogen oxides NO_x calls for the introduction of a cooled exhaust gas recirculation system in heavy-duty Mercedes-Benz diesel engines. In passenger car diesel engines, the exhaust gas recirculation technology has been successfully used for several years. Compliance with the limit values for emissions of passenger cars are regularly checked in driving cycles in accordance with FTP. In this way, the impact of the legislation on other areas can be tested because in passenger cars the operating ranges typical of the US are relevant to the engine map in transient operation. In contrast to the provisions governing exhaust gas emissions of passenger cars, heavy-duty diesel engines for trucks must not exceed the low emissions limits over almost the entire engine map up to full load. For this reason, Daimler-Chrysler devised an innovative exhaust gas recirculation concept at an early stage, which guarantees sufficiently high exhaust gas recirculation rates up to full load. The lecturer described the development work on the successful MBE 4000 truck engine which was necessitated by the new US´04 emission legislation and which led to the introduction of the cooled exhaust gas recirculation technology.

Prof. Dr. F. X. Moser (lecturer), **Dipl.-Ing. R. Dreisbach, Dr.-Ing. T. Sams, AVL List GmbH**, Graz: "Lowest Engine-Out Emissions as the Key to the Future of Heavy-Duty Diesel Engines – New Development Results"

The most recent results of the development of heavy-duty diesel engines have demonstrated that from today's perspective it is possible to meet the limit values which will be imposed by US emission legislation in 2010. However, with attainable engine-out NO_x emissions of ≤ 1.0 g/kWh and particulate engine-out emissions of ≤ 0.06 g/kWh, the need arises to use exhaust gas after-treatment systems with a $DeNO_x$ and/or filter efficiency of at least 90 % in all vehicles. These engine-out emissions values call for engine concepts with a peak firing-pressure capability of at least 200 bar, cooled exhaust gas recirculation with EGR rates of 25 % at full load, injection systems with a pressure potential of 2,400 bar and two-stage turbocharging. Turbocharger efficiency rates of more than

50 % are required in order to keep the unavoidable increase in fuel consumption within acceptable limits. This would also apply in Europe if it introduced the same or similar limit values as the US. If the limit values for NO_x were fixed at 1.0 g/kWh instead of 0.27 g/kWh, the engine concept could be much less sophisticated as potentially higher engine-out emissions would be permissible, which would result in a significantly better fuel economy.

Dr.-Ing. J. G. Smyth (lecturer), **Prof. Dr.-Ing. F. Indra, Dipl.-Ing. C. Freese, Dipl.-Ing. D. Brown, Dipl.-Ing. M. Potter, General Motors Powertrain**, Pontiac, USA: "General Motors Perspective on the Potential of Diesel Vehicles for the U.S. Automotive Market"

The European market for diesel-powered vehicles has seen tremendous growth over the last ten years. This trend is driven by the superior fuel economy and reduced CO_2 emissions of diesel engines, tax policies that favour diesel-powered vehicles and emission regulations tailored to the capabilities of the diesel engine. The diesel growth observed in Europe has not been reproduced in the United States, due in part to an economic environment that does not favour diesel-powered vehicles and US light-duty emission regulations primarily based on the capability of the gasoline engine. The lecturer discussed the challenges associated with diesel market expansion in the United States and the technologies being developed to address these challenges. He concluded with an assessment of the potential for future US diesel vehicle market growth. In his assessment, the lecturer considered diesel engines as a central element in GM's global product portfolio. The lecturer also expressed his concern about the rising prices of diesel engines. Overall, he concluded, diesel engines had relatively poor chances of deeper market penetration in the US.

9 Powertrain

Dr.-Ing. S. Rinderknecht (lecturer), **Dipl.-Ing. M. Seufert, Getrag**, Untergruppenbach; **Dr. rer. nat. R. Ellinger, Dipl.-Ing. R. Schneider, AVL List GmbH**, Graz; **Dipl.-Ing. J. Wagner, ATB Thien**, Rankweil: "Eco Target: An Innovative Power Train to Fulfill Future Mobility Requirements"

Based on detailed entire system analyses, the mild hybrid system Eco Target was developed featuring a 1.2 litre diesel engine, a 6-speed automated manual transmission and a 10 kW 42 V e-motor, which is directly mounted onto the transmission. This powertrain was installed into a mid-class vehicle (test weight 1,350 kg). The objective of the project, jointly undertaken by Getrag, AVL and Thien, was to demonstrate the expected future CO_2 emission limits in the range of 90 -120 g/km within the New European Drive Cycle (NEDC), whilst fulfilling future emissions legislation and considering customer-specific driveability and comfort demands.

The fuel consumption improvement potential of the Eco Target system is based on engine load operation shift by downsizing and automated gear selection, and the hybrid system's potential for start-stop operation and regenerative braking. In addition, the system offers the possibility of reducing traction interruption during the shift process, with consequently improved comfort compared to conventional automated manual transmissions. The characteristics of the e-motor assure very good overall steady state and especially transient performance figures. Therefore the reduced performance and low torque due to downsizing can be compensated. Current chassis dyno results show emissions of 98 g/km CO_2 at Euro 4 emission level feasible.

Dipl.-Ing. T. Urasawa (lecturer), **Dipl.-Ing. K. Hayasaki, Nissan Motor Co., Ltd.**, Kanagawa, Japan; **Dipl.-Ing. K. Sugano, Jatco Ltd.**, Kanagawa, Japan: "Development of a New Generation Belt CVT with High Torque Capacity for Front Wheel Drive Vehicles"

Figure 12: Prof. Dr.-Ing. Burkhard Göschel, BMW AG

Nissan and Jatco have jointly developed a new belt CVT with high torque capacity for the E segment and front-wheel driven SUV vehicles. The new CVT has been designed for a maximum torque of 350 Nm which is the highest torque capacity for a belt CVT worldwide. In addition, it is very compact. This CVT also gives a new driving experience. It permits rapid acceleration from any vehicle speed, with an excellent sensation. There is no longer a feeling of unnatural acceleration as was perceived in cars of the previous CVT generation. As compared to the previous CVT generation, fuel efficiency has been markedly improved. Thanks to the newly designed hardware, a very sophisticated algorithm and an engine calibration best suited to the new CVT, the new transmission achieves best-in-class fuel economy and acceleration performance. The lecturer described the main specifications, the structure and characteristics of the new CVT.

Dipl.-Ing. M. Sattler (lecturer), **Dipl.-Ing. B. Stahl, ZF Sachs AG**, Schweinfurt: "The Integration of Electric Drives into Powertrains of Hybrid Vehicles"

Although pursuing varying strategies, nearly all vehicle manufacturers are currently preparing themselves for the launch of hybrid vehicles in the market. Most of them have adopted concepts which aim at offering hybrid powertrains as an option in conventional production vehicles. For this purpose, the hybrid powertrain must be accommodated in the space between the engine and the gearbox in addition to the conventional powertrain components. In order to be able to meet this packaging challenge, electric drives with optimised power densities and specially designed for use in the powertrain are required. However, the packaging specifications can only be met if these electric motors are integrated into modified powertrain components, which results in compact modules. The lecturer illustrated an integration concept for the application of a hybrid system in a drivetrain with automated manual transmission.

10 Components

Dr. G. Lugert (lecturer), **Dipl.-Ing. R. Knorr, Dipl.-Ing. G. Grassl, Dipl.-Ing. F. Lohrenz, Dr. H. Stocker, Siemens VDO Automotive AG**, Regensburg: "Electrical Energy Supply in Future Powertrains – Challenges and Solutions"

The average electrical energy consumption of vehicles has grown continuously over the past few years. In the short and medium term, it can be assumed that electrical energy consumption will rise sharply, despite an electrical energy management which is already taking on contours. This need for more energy is mainly attributable to additional loads because of ever more exacting demands on comfort, safety and communication. Additional loads will be required around the powertrain, in order to boost the efficiency of the internal combustion engine (CO_2 emissions) and to reduce exhaust gas emissions in order to be able to comply with the emission legislation. Another major challenge facing automotive engineers comes from customers who make contradictory demands by wanting more driving fun as well as minimum fuel consumption.

It can be foreseen that the measures already initiated aimed at controlling the energy needs of the 14 V electrical system of passenger cars by means of an intelligent load control and power-management system will not suffice in some cases. The integration of mild or power hybrids into the powertrain as sources of energy constitutes one medium-term option for eliminating the shortage of electrical energy supply in the vehicle electrical system. Moreover, the option of recovering kinetic energy released during deceleration offers an opportunity to reduce fuel consumption markedly in intra-urban driving (2020 to 2030). Once fuel-cell powered vehicles are launched in the market in the remote future, there will no longer be a shortage of electrical energy.

H. Ichinose (lecturer), **T. Takaoka, H. Kobayashi, Toyota Motor Corporation**, Shizuoka, Japan: "Toyota´s Heat Management System – Coolant Heat Storage for Mass Production Today, New Technologies for the Future"

Under normal driving conditions, only about 30 % of the total fuel energy is used for the propulsion of the vehicle and its air-conditioning, whereas 60 % of this fuel energy is wasted in the form of exhaust gas, thermal losses and warming-up losses. Therefore, it appears imperative to consider the total thermal energy in a vehicle with a view to improving thermal efficiency. The principle to be applied is to reduce thermal losses in order to increase exhaust gas temperatures, as well as storing thermal energy and using it for pre-heating during the next warming-up phase. Further developments will focus on thermal management strategies that rely on turbocharger and heat exchange concepts, making it possible to recover exhaust gas energy.

Figure 13: Dr. Herbert Demel, Fiat Auto S.p.A.

Toyota devised the Coolant Heat Storage System (CHSS) as one version of such a heat management system, in order to reduce cold emissions and improve cabin comfort. This system permits the storage of hot coolant in a heat storage tank in the warmed-up state. During the next cold start, CHSS reduces the unburnt hydrocarbons by rapidly pre-heating the intake ports using the hot coolant in the tank. CHSS was introduced in the US model 2003 of the hybrid vehicle Prius. The vehicle meets the ATPZEV limit values, which are the strictest exhaust emission standards in the US. The lecturer gave a survey of heat management systems, focussing on the newly developed CHSS.

In his lecture at the 17th International Vienna Motor Symposium, Mr. Hofmann et al., Vienna University of Technology, drew attention to the fundamental benefits of such heat management systems.

Dr.-Ing. W. Iißler (lecturer), **Dipl.-Ing. (FH) E. Kopf, Mahle GmbH**, Stuttgart: "Modern DI Diesel Pistons – Development and Technologies"

Passenger car engines are now partly designed for specific power of 60 kW/litre and more. Mean pressure rates, including those in heavy-duty engines, are markedly above 20 bar. This results in larger quantities of thermal energy to which pistons are exposed, hence efficient piston cooling is required. Mechanical stress due to peak combustion pressure rates of 170 to 200 bar, or even higher cylinder pressure loads in the heavy-duty engines represent a major challenge in piston design. A combustion process leading to such high ignition pressure rates may result in pressure curves which impair piston-cylinder dynamics (noise, cavitation). Numeric simulations of piston motion taking into account component stiffness and design parameters were used for system optimisation. The results of these simulations were validated by measurements during engine tests and can therefore be successfully applied to parameter studies. Aluminium pistons with different cooling systems, with or without local fibre reinforcement and sometimes with shrink-fitted bushings and, in addi-

tion, primarily for heavy-duty engines, forged steel pistons, mainly of single piece design, are the state-of-the-art, safely allowing peak cylinder pressures of 180 to 200 bar and more.

11 Supercharging

Dr.-Ing. R. Krebs (lecturer), **Dr.-Ing. J. Böhme, Dipl.-Ing. R. Dornhöfer, Dr.-Ing. R. Wurms, Dipl.-Ing. K. Friedmann, Dipl.-Ing. J. Helbig, Dipl.-Ing. W. Hatz, Audi AG**, Ingolstadt: "The New Audi 2.0T FSI Engine – Audi's First Direct-Injection Turbo Gasoline Engine"

In the 2.0T FSI engine Audi has for the first time combined direct injection in gasoline engines with turbocharging and has thus demonstrated the progressive development of its FSI technology. The 2.0T FSI engine takes advantage of the FSI combustion system and combines this with the dynamic characteristics of turbocharging. The outcome is an extremely lively engine which with an output of 147 kW, its outstanding torque curve (280 Nm in the range of 1,800 to 4,700 rpm) and a superior response offers a lot of driving pleasure at moderate fuel consumption rates. This engine will be used in both longitudinal and transversal applications as a platform for all vehicle models of the VW Group. In the development of this engine, attention was focused on designing the maximum number of identical components. This engine not only meets Euro 4 and ULEV 2 limit values but will also comply with future OBD regulations.

Dr. N. Schorn (lecturer), **Dr. L. Gaedt, Dr. H. Schulte, Ford Forschungszentrum Aachen; O. Salvat, E. Strusi, PSA Peugeot Citroën**, La Garenne-Colombes: "Electrically Driven Compressors to Supplement Exhaust Gas Turbocharging"

The lecturer presented different boosting systems which have the potential for improving transient response, starting performance, and engine power. He then reported in detail on electrically driven compressors as the predecessors of conventional exhaust gas turbochargers. With the aid of a functional test rig for electrically driven compressors, the main parameters of different load versions were determined. Test bench and vehicle analyses have demonstrated the potential for increasing torque, as well as improving elasticity and cold starting behaviour, but at the same time also the need for further development. Based on vehicle tests involving a passenger car and a light-duty commercial vehicle, load profiles were elaborated for the electrical booster and the demands made upon the vehicle electrical power system defined.

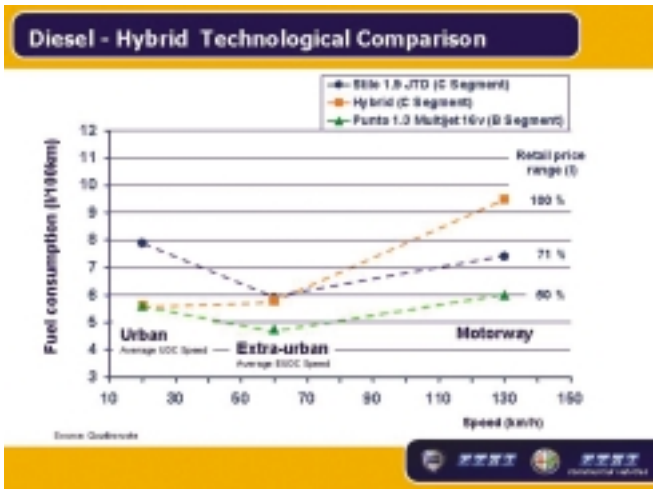

Figure 14: Diesel-Hybrid technological comparison (Fiat)

Dipl.-Ing. A. Franz (lecturer), **Dr.-Ing. S. Wild, Dipl.-Ing. H. Katsivelos, Mann+Hummel GmbH**, Ludwigsburg: "Status of Competition between Turbo Machines and Impulse Chargers regarding Optimised Transient Behaviour and Exhaust Emissions of Internal Combustion Engines"

High torque over the widest possible speed range as well as favourable transient behaviour constitute major engineering goals for combustion engines. Mann+Hummel is starting to achieve these goals by elaborating innovative concepts for raising air expenditure, intensifying gas dynamic processes during gas exchange and allowing additional degrees of freedom in valve timing. A substantial increase in torque should primarily be achieved in the speed range of between 1,000 and 3,000 rpm. The lecturer elaborated on the state of development of fast switching flags and electrically driven boosters in air intake systems. He also presented initial test results obtained from prototype testing in test engines.

12 Special Engines

T. Reid (MEng), R. Poirier (BEng), J. Stueven (MEng), B. Beilfuss (BEng), Dipl.-Ing. C. Bruestle (lecturer), **Mercury Marine**, Fond du Lac, Wisconsin, USA: "Mercury Marine´s New High Performance 6-Cylinder Engine Family: the Next Generation in Marine Technology"

With its entirely redesigned 6-cylinder in-line engine family with mechanical boosting, Mercury Marine succeeded in meeting the numerous and complex demands made upon a four-stroke engine concept for the outboarder market. Superior torque characteristics, a top-class engine-weight ratio and smooth NVH leave no customer wish unfulfilled as regards marine engines. Power-assisted steering combined with electronically controlled shifting, E-gas and a range of engine management features set new standards in the marine engine market.

R. Stefansson (lecturer), **B. Andersson, AB Volvo Penta**, Gothenborg; **Prof. Dr. F. X. Moser, W. Petutschnig** (lecturer), **Dipl.-Ing. F. Zieher, AVL List GmbH**, Graz: "Volvo Penta's All New High Performance Marine Diesel Engine Family"

A new family of diesel engines was developed for pleasure boats, which boasts superior power density, a fully electronic common rail system, four valve technology, and an especially favourable weight-output ratio. With a view to controlling peak combustion pressure rates of more than 100 bar, state-of-the-art simulation tools were used in order to be able to fully benefit from the properties of materials while, at the same time, assuring operational reliablity. It was the first time in the development of such engines that Volvo resorted to the know-how and comprehensive experience of the engineering enterprise AVL on a broad basis and jointly with it developed these engines for production.

Dipl.-Ing. W. Nehse (lecturer), **Dipl.-Ing. S. Rudert, Dr.-Ing. J. Reissing, BMW Motorrad**, Munich: "Evolutions of the Boxer Engine by BMW Motorrad"

The lecturer reported on the construction and design of BMW's new R 1200 GS Boxer engine. He described the base engine and the gearbox, as well as the engine periphery including the induction, exhaust and auxiliary systems. Furthermore, he illustrated various optimisation steps taken during the development process as well as design criteria and objectives for the different components and the engine as a whole. With a view to reaching the

defined goals, BMW not only conducted comprehensive experimental analyses but also successfully employed a series of numerical simulation procedures. The lecturer went on to present some examples of studies on flow simulation, structure optimisation and gas exchange. The experimental analysis of the engine, amongst other things, yielded detailed findings relating to friction behaviour, internal combustion and gas exchange effects. He then presented the findings on basic engine parameters and exhaust emission behaviour before finally illustrating the engine management system used, which was the outcome of a specific diagnostic concept.

13 Exhaust Gas Purification

Dipl.-Ing. J. Kahrstedt (lecturer), **Dipl.-Ing. G. Buschmann, Dipl.-Ing. O. Predelli, Dr.-Ing. K. Kirsten, IAV GmbH**, Berlin: "Homogeneous Diesel Combustion Process for Euro 5 and TIER2/LEV2 – Implementation of the Modified Working Cycle using Innovative Hardware and Control Concepts"

The lecturer illustrated the potential of a homogeneous diesel combustion process as a concept for the lower part-load range of the engine map. This process which is designated as the Homogeneous Charge Compression Ignition (HCCI) permits combustion virtually free from NO_x and particulate emissions, and significantly reduces the need for cost-intensive active EGR systems. The lecturer analysed currently available engine concepts on the basis of relevant legislation and state-of-the-art homogeneous diesel combustion processes. He illustrated the demands made upon the realisation of changes in process control by examining chemical kinetics in combination with engine process simulations, the results of which were verified through measurements on a single-engine. Future developments aimed at broadening the load range will have to focus on process control (intake temperature, compression, exhaust gas recirculation, boost pressure, charge mass, injection and mixture formation) which calls for engine control systems based on physical models. The lecturer demonstrated that the approach to homogeneous diesel combustion essentially correlated with the evolution of today´s diesel engines used in passenger cars.

Dr.-Ing. J. Schommers (lecturer), **Dipl.-Ing. C. Enderle, Dipl.-Ing. R. Binz, Dr.-Ing. F. Duvinage, Dipl.-Ing. N. Ruzicka, Daimler-Chrysler AG**, Stuttgart: "The New Mercedes-Benz Diesel Particulate Trap Concept for LDV in Combination with Euro 4 Emission Standards"

In 1985, Mercedes-Benz was the first car manufacturer worldwide to introduce a passenger car with a diesel particulate trap in the US market. Based on this experience, since October 2003 Mercedes-Benz has been selling the first passenger car worldwide with a diesel particulate trap that also meets the stringent Euro 4 emission standards. The regeneration of the particulate trap was effected by means of modifications to the combustion process, without the need for fuel additives. Field tests confirmed that this new particulate filter concept permits reliable and safe operation under all customer-relevant driving conditions.

Dipl.-Ing. M. Ganz (lecturer), **Dipl.-Ing. S. Hackmayer, quattro GmbH**, Neckarsulm; **Dipl.-Ing. C. Kruse, Dipl.-Ing. A. Reck, Emitec GmbH**, Lohmar: "Advanced Catalyst System for the Audi RS6, 8 Cylinder, 4.2 ltr, 331 hp with LEV Certification"

The sporty Audi RS6 TLEV with its eight cylinder bi-turbo engine has been in production since 2002. This high-performance engine with a swept volume of 4.2 litres has an outstanding torque of 560 Nm. In order to be able to meet continued brisk demand in the US, the engine had to be designed in such a way as to comply with the LEV legislation. With a view to reducing emissions by 50 %, both engine modifications and an innovative catalyst system were required, while the exhaust back pressure and the combustion chamber configuration were to be retained unchanged. For exhaust gas aftertreatment, two closely coupled and two underfloor catalytic converters with a metal substrate structure were used.

In the Audi RS6 with LEV certification an entirely new catalyst concept known as the PE design was used for the first time worldwide. The metal foil used in the precatalytic converter is perforated with holes of 8 mm diameter. With the aid of this so-called PE foil it is possible to assure the crossflow of exhaust gases from one cell channel into adjacent channels for the first time. Thanks to the perforations and the use of a thinner foil, it was possible to reduce the thermal capacity of the metal substrate as compared to the TLEV version. Accordingly, the catalytic converter reaches its operating temperature faster during cold starting. The cold starting characteristics are enhanced by the design of the catalytic converter shell with integrated air gap insulation which minimises thermal losses during cold starting, particularly in the front section. In combination with engine modifications and the coating developed by Engelhard Technologies it was possible to keep emission limits markedly below the LEV limit values, even after 60,000 miles of endurance testing under real-life conditions.

14 Final Plenary Session: Future Perspectives

Dr.-Ing. Dr.-Ing. E. h. H.-J. Schöpf, Member of the Board, Mercedes Car Group, **Daimler-Chrysler AG**, Sindelfingen, **Figure 11**: "Mercedes Car Group – Perspectives for the Future of the Automobile"

On the basis of 35 years of development and design work on passenger cars and engine technology, the lecturer gave an outlook on future developments. Engines that can be further developed in the future constitute the prerequisite for the future of passenger cars. New legislation should not be guided by political actionism but rather by reason and vision and, as far as possible, should create uniform conditions worldwide. The traditional subdivision of the passenger car market into compact, medium-sized and luxury cars lost its significance in the early 90ies. Instead, today we see a wide variety of different categories of cars, such as roadsters, coupés, off-road vehicles, high-capacity saloon cars, etc., which, of course, has an impact on engine design. Mercedes identified this trend at an early point in time and launched 16 new models within a period of seven years.

With regard to drivetrains, Mercedes applies a four-stage concept: the further development of conventional gasoline and diesel engines, the use of synthetic fuels and the work on alternative drive units, such as hybrids and fuel cells. Schöpf assumes that an optimum cost-benefit ratio and an approximately 10 % reduction in fuel consumption will be attained by means of the second generation of direct injection systems for gasoline engines. In diesel engines, particulate traps will be required, and raw emissions will have to be lowered by means of a more homogeneous fuel mixture formation. Other options are NO_x storage catalysts and the SCR technology.

Production was recently started of a sedan car equipped with an E200 compressor and a bivalent gasoline/natural gas engine. With regard to hybrid technology, Schöpf expressed his doubts as to whether this complicated technology made sense. Mercedes-Benz is currently testing some 100 fuel cell vehicles for their practical use.

Prof. Dr.-Ing. B. Göschel, Member of the Board, **BMW AG**, Munich, **Figure 12**: "Options for Hybrid Drive in BMW Cars"

Figure 15: Satisfied faces in the audience

Prof. Göschel addressed the issue of why public attention had recently been riveted on hybrid engines and whether these could really offer a solution to the environmental problem in the 21st century. When taking a closer look at hybrid technology, it becomes obvious that with the combination of two engines it will not only be necessary to raise braking energy but the entire energy chain must also be analysed in order to optimise energy consumption, emission behaviour and brand-specific properties. Prof. Göschel explained that hybrid engines did not constitute appropriate examples of sustainable overall optimisation. Today's concepts much rather aim at meeting specific requirements, he stressed, such as, for example, the demand to produce ZEVs or to introduce a city toll in London. Prof. Göschel expressed his conviction that today and in the future, internal combustion engines were and would remain the best medium to assure sustainability on the one hand and meet customer demands on the other. Nevertheless, he went on, BMW regarded an intelligent use of electrical systems as an interesting option for further development of internal combustion engines.

In the BMW research concept "X5 Efficient Dynamics", an electric motor arranged between the internal combustion engine and the gear box assists the conventional engine during acceleration. The combination of the electric motor and the internal combustion engine results in a considerable increase in torque and an excellent response behaviour. High performance capacitors are used as energy storage units, as these have the highest efficiency for storing recuperated energy. For the future, an "active transmission" system appears feasible: this would be a compact, intelligent unit with a low total weight, into which the electric engine and all electronic power components could be integrated. Energy would be stored in capacitors.

Hybrid versions represent an interesting idea but must be properly understood and intelligently used. Not everything that was technologically feasible in this area would at the same time make ecological and economic sense and, in particular, would not necessarily be accepted by customers, the lecturer concluded.

Dr. H. Demel, Chief Executive Officer, **Fiat**, Torino, **Figure 13**: "Fiat Fiat"

Demel, who in late 2003 was appointed CEO and thus assumed the horrendous task of turning Fiat around, explained his strategy in his presentation "Fiat Fiat", which translates more or less as "may Fiat flourish once more". He pointed out that over the past ten years passenger car prices adjusted for inflation had remained unchanged, a trend that could also be expected to continue in the future. Accordingly, car makers could not realise higher revenues by raising prices, Demel argued. Nevertheless, Fiat should reach its operational break-even point by 2005, and the net break-even point by 2006, the lecturer explained. This objective was to be attained by improved positioning in the market, product development, cost reductions and deeper penetration of markets. In 2004, a series of new models will be introduced: Fiat's Idea and Panda 4WD; Alfa Romeo's Alfa cross vehicle; Lancia's Musa; existing models will be given a facelift.

Demel emphasised that Fiat had often been the first vehicle manufacturer to launch technological innovations which, however, had not attracted much attention in the automotive engineering world: in 1987, it had presented the first compact

Invitation

The **26th International Vienna Motor Symposium** will be held at the Congress Center **Hofburg in Vienna** from **April 28th - April 29th, 2005**. The ÖVK should like to take this early opportunity to invite you most cordially to participate in this conference. In view of the large number of participants expected, we recommend that you apply at your earliest convenience once the program has been announced on the internet in December 2004.

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direct-injection diesel engines worldwide, in 1997 the first CR-DI engine worldwide, and in 2003 the first multiple injection CR-DI engine worldwide, Demel pointed out. Explaining Fiat's development work on alternative engines, the lecturer presented an interesting fuel consumption and cost comparison between diesel and hybrid technologies, **Figure 14**, for a Stilo 1.9 JTD (C-Segment), a Hybrid (C-Segment), a Punto 1.3 Multijet 16V (B-Segment). This comparison showed that a hybrid engine is much more costly in intra-urban operation and consumes more fuel during motorway driving than a diesel engine.

With regard to the envisaged deeper penetration of markets, Demel set the priorities as follows: European Union; Brazil; Turkey; China; India. He also reported that in the first quarter of 2004, Fiat sales in Italy had gone up by 4.3 % and in the rest of Europe by 2.8 %, which he considered a favourable performance.

Paraphrasing the Latin title of Demel's lecture, Prof. Lenz expressed his wish for the future: "Fiat vivat, floreat, crescat"; may Fiat live, flourish and grow.

Extending an invitation to the 26th International Vienna Motor Symposium, Prof. Lenz closed the Symposium with the audience applauding enthusiastically, **Figure 15**. ■

Conference Report

The in extenso versions of all the lectures are contained in the VDI Research Reports, series 12, no. 566, volumes 1 and 2 (including a CD) and attachments. The documentation is available from the Österreichischer Verein für Kraftfahrzeugtechnik (ÖVK).

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