Analysis of current and future trends in automotive emissions, fuels, lubricants and test methods

(Summary of the 2nd International Exhaust Emissions Symposium, 25/26 May 2011)

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Abstract

BOSMAL hosted the 2nd International Exhaust Emissions Symposium, entitled *Current and future trends in automotive emissions, fuels, lubricants and test methods*, which featured a total of eighteen presentations from experts on automotive emissions and aftertreatment and the fuel and lubricant industries. The symposium's technical programme consisted of two keynote lectures and four themed presentation sessions. The symposium also featured the opening of new engine test cells at BOSMAL. The entire event was an unqualified success, building on the achievements of the previous year's event. Some of the most important trends mentioned during the symposium included: changes to test procedures to reflect the challenge of quantifying ever decreasing emission levels, as well as measuring new compounds, the continued key role of catalytic aftertreatment systems in achieving low emission levels of gaseous pollutants and particulate matter, and the potential role for electrified powertrains and alternative fuels from various sources to meet our transportation energy needs over the coming decades.

Introduction

Concerns over the impact of the road transport sector on greenhouse gas (GHG) emissions and air quality remain high. Despite recent progress in fuel efficiency, road transport emissions are currently responsible for around twenty per cent of all greenhouse gas emissions in the European Union (EU).

Following the highly successful 1st International Exhaust Emissions Symposium hosted in 2010 [1, 2], BOSMAL Automotive Research and Development Institute Limited, (of Bielsko-Biala, Poland) recently hosted the 2nd International Exhaust Emissions Symposium, held over 26-27 May 2011. The 2nd symposium featured two keynote lectures from specially selected experts, as well as a total of sixteen presentations from both industry and academia, covering a broad range of automotive emission-related subjects: emissions legislation, fuel economy, new methods of PM and NO_x/NH_3 (also described in [3]) testing, compounds which are potential candidates for emissions regulation, emissions test equipment, emissions reduction technology, aftertreatment system and catalyst technology, emissions simulation, powertrain development and electrification, engine test method development, fuel development, alternative fuels, gaseous fuels (CNG, LPG), and engine oil development.

Aims, context and format of the symposium

This second symposium was hosted as a direct result of the successes of the 1st International Exhaust Emissions Symposium [1, 2]. The aim of the event was to provide attendees with an opportunity to both share and obtain information, knowledge and contacts in the fields of emissions testing, emissions reduction, aftertreatment systems, powertrain development, engine testing and the development of lubricants and fuels. The symposium also featured the opening ceremony of BOSMAL's new engine testing cells, echoing the opening of the Euro 5/6 climate-controlled emissions testing laboratory (described in detail in [4]) during the previous year's event [1]. Two highly experienced individuals were invited to deliver extended presentations as keynote lecturers, thereby enabling them to cover broad subject areas in depth. These lectures lasted approximately thirty minutes, plus a further five minutes for discussion. The presentations were divided into four themed sessions (see Appendix 1), each covering a particular aspect of automotive exhaust emissions: *Emissions legislation and test method development; PM and* NO_x *emissions test method development; Catalyst technology development for CI and SI engines;* and *Fuel and engine oil development*. Each presentation presented during these sessions lasted around twenty five minutes, with five minutes allocated for discussion at the end.

BOSMAL President Dr Antoni Swiatek formally commenced the symposium by delivering an opening address (Figure 1). After warmly greeting the delegates and thanking them for accepting their invitations, he mentioned how environmental legislation on the regulation of exhaust emissions had been a crucial driver of the development of combustion engines, and that this driver would continue to be of great importance in the future too.

The first item of the technical programme (see Appendix 1) was the first of two keynote lectures (Figure 2), followed by presentation session 1. The first presentation session was followed by the opening ceremony of BOSMAL's new engine testing cells (Figures 2-4), construction of which was completed shortly before the symposium. These new test cells, numbering five in total, feature engine dynamometer hardware from HORIBA (Figure 5) and AVL's Puma Open control system. The facilities are suitable for testing a range of engine types and sizes, and each of these installations is to be equipped with CNG fuelling facilities in addition to liquid fuels: gasoline, Diesel and biofuels. The inauguration of these new test facilities bears witness to BOSMAL's commitment to investing in the latest technology in order to satisfy both current and future customer demands. The installation of engine dynamometers with higher rated power absorption capabilities represents an a new step for BOSMAL – namely the expansion of its highly successful light-duty on-road engine testing services to include the execution of various tests on heavy-duty on-road and off-road engines, recreational marine engines and high-performance sporting engines.

Figure 1 – Dr Antoni Swiatek (BOSMAL, Poland) delivering his opening address to the 2nd International Exhaust Emissions Symposium

Figure 2 – Rudolf Moerkl (Horiba, Austria) being presented with a letter of gratitude for his firm's contribution to the construction of the new engine test cells

Figure 3 – Werner Moser (AVL, Austria) being presented with a letter of gratitude for his firm's contribution to the construction of the new engine test cells

Figure 4 – Emanuele Lorenzin (Fiat Powertrain Technologies, Poland) at the ribbon-cutting ceremony of the new engine test cells

Figure 5 – BOSMAL staff inspect the interior of one of the new test cells following the official opening

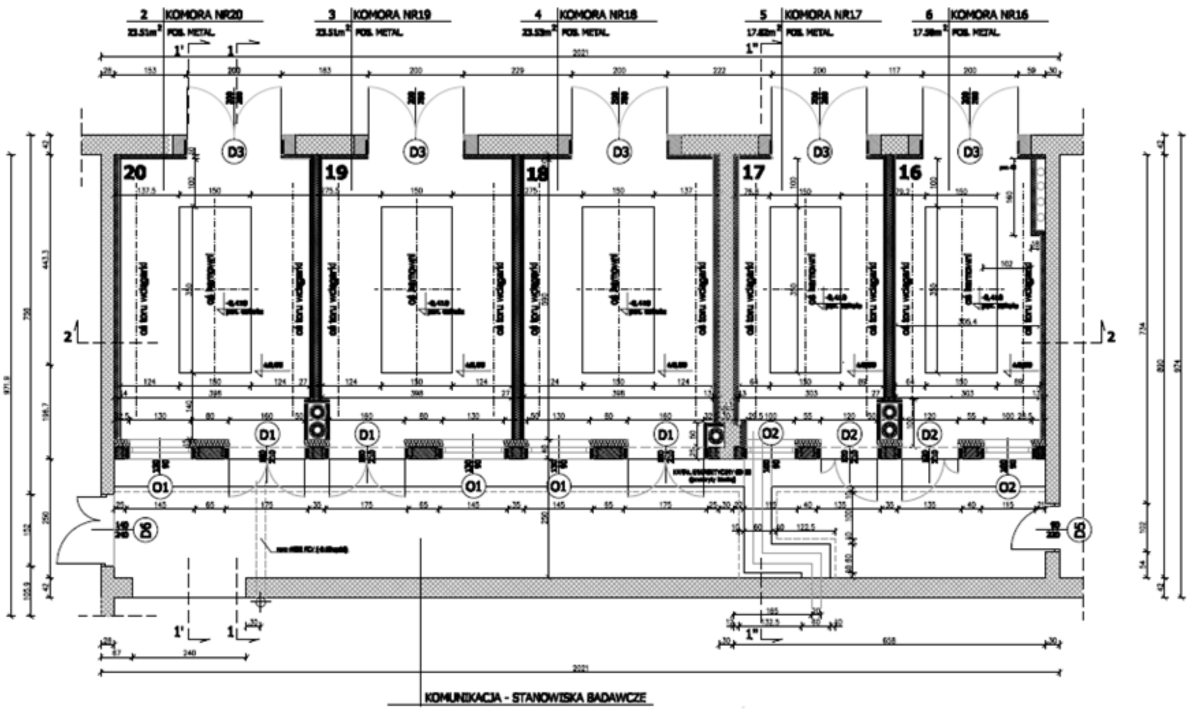

Figure 6 – Technical drawing of the new engine test cells

This opening ceremony was followed by sessions 2 and 3, which concluded the formal symposium proceedings for that day. A social dinner event organized in the mountains rounded off a very enjoyable first day of the symposium. The following day, delegates were first given the second keynote lecture, which then lead into the final presentation session. This was followed by a brief summary that formed the closing ceremony of the conference proceedings. Additionally, attendees were offered guided tours of BOSMAL's various departments and testing facilities, and time was available for networking and bilateral meetings.

Summaries and selected slides from keynote lectures and presentation sessions

1st day - Keynote lecture: 'Driving of low CO_2 future'

This lecture, delivered by Prof. Giovanni Cipolla (Director of IARE – General Motors/Politechnico di Torino Institute for Automotive Research & Education) gave an insightful and detailed overview of driving in a low CO_2 world. Passenger cars are often singled out as a major source of anthropogenic GHG emissions, but in reality they are simply another example of a broad range of human activities which lead to emissions of GHG (most notably CO_2). However, reducing the carbon intensity of road transportation has been both a political and technical target for some time. EU legislation (the so-called '20/20/20 targets') mandate reductions in energy consumption and GHG emissions, as well as an increase in the usage of energy from renewable resources. In light of this, a business-as-usual strategy is not a realistic option; certain changes to engines and vehicles can decrease the rate of GHG emissions increase to effectively zero, but longer term targets can likely only be met with the help of cellulosic biomass as a liquid fuel energy source. The other option is for vehicles partially or completely powered by electrical energy, which could play a significant role in the long-term picture, if improvements are made to the electricity grid. A broad portfolio of low emissions transportation technologies (liquid biofuels, electricity, hydrogen) could potentially meet ambitious targets set for 2050, providing that initial progress is brisk. The picture regarding electricity from nuclear sources (a low GHG intensity option) has recently become much more complex, following the Fukushima nuclear incident. Other, cleaner types of nuclear power remain under investigation, but are still far from ready for connection to the grid. There is growing and indeed renewed interest in alternative sources of energy suitable for producing electricity, but considerable financial and infrastructure-related obstacles remain. Additionally, the past century has shown liquid fuels to be the winner every time for automotive applications, despite the idea of gaseous fuels and electric powertrains not being new. Powertrain evolution and development is the current phase in a vision of future vehicle development (Figure 7), with the ultimate goal of having a fleet of zero-emission vehicles. Recovery of waste heat from exhaust gas is one option for on-board harvesting for conversion to electrical energy. Likewise, the kinetic energy of a vehicle travelling at speed is considerable (on the order of megajoules), yet remains unharnessed in vehicles without regenerative braking systems. In concert with these fundamental long-term changes to powertrain concepts, new vehicles should be progressively more functional, more exciting and more fun to drive.

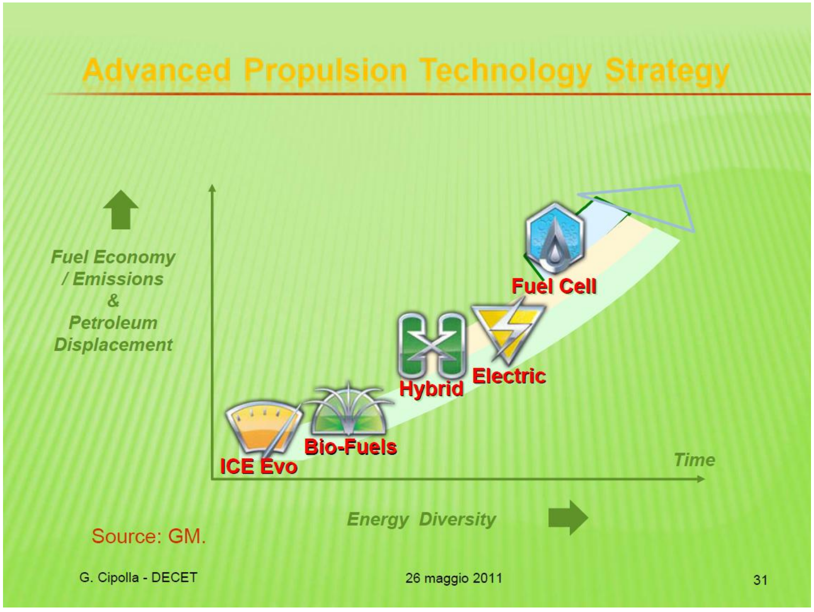

Figure 7 – Advanced propulsion technology strategy

Session 1 – Emissions legislation and test method development

Chair: Dr Piotr Bielaczyc, BOSMAL (Poland)

This first session examined the general theme of emission testing of vehicles and engines, in the context of the legislation which guides these testing procedures, and the legislation setting emissions limits. Kurt Engeljehringer (AVL-List GmbH., Austria) commenced the session with a presentation entitled 'Automotive Emission Testing and Certification – Past, Present and Future', which gave a detailed insight into the evolution of automotive testing in response to legislation and market demands in the EU and the USA. The considerable technical achievements in the development of the automobile over the past century have also been accompanied by significant improvements in the ecological credentials of IC engines, particularly in recent decades. Increasingly sophisticated engines with ever lower emissions levels have required more refined testing facilities during the course of this process, and this trend continues today. The main legislative trends of current importance are global harmonization of emissions standards, test procedures and driving cycles, regulatory changes in the USA and EU and the issue of in-use compliance to evaluate and mandate so-called 'real world' emissions. In the EU, the main issues are: reducing NO_x emissions from CI engines, particle number limits, CO_2 emission reduction, NO_2 emissions, and the introduction of more realistic driving cycles and emissions quantification procedures. Incremental fines will be used to enforce CO_2 emission reduction targets, thereby placing an even greater emphasis on accurate measurement of CO_2 emissions (Figure 8). In the USA, the main issues of concern for the EPA are new GHG standards (N_2O and CH_4, in addition to CO_2), and a new, unified test procedure in the Code of Federal Regulations (CFR). The CFR 1065 is highly exacting in its demands for both analyser hardware and calibration procedures. Growing trends for EU lawmakers include a focus on aftertreatment systems and their regeneration, as well as hybrid powertrain concepts. In the USA, off-cycle emissions, not-to-exceed (NTE) zone limits, in-use compliance (and the portable emissions measurement systems this will entail) are all hot topics for the future. Continuing this general theme, but with a different temporal focus, Les Hill (HORIBA, UK) delivered a presentation entitled 'Implications of Future Emissions legislation on emissions and Fuel Economy testing procedures and equipment'. Efforts and legal requirements to reduce fuel consumption and emissions of air pollutants, toxics and greenhouse gases will substantially change the test equipment and procedures required to provide evidence of progress made in this area (Figure 9). This has already begun in the EU, with the setting of Euro 5 and 6 limits, and with Euro 7 limits to follow. For the first time, light commercial vehicles will have to meet CO_2 emission reduction targets. Globalised legislation is also in the works, with the World Light Duty Vehicle Test Procedure (WLTP) currently under development. However, issues relating to the representativeness of the test procedure (such as the determination of road load and the range of ambient temperatures for testing) remain unresolved and remain the subject of intense debate. Various vehicle technologies for the reduction of emissions and fuel consumption, both those currently in production and under development, will require more sophisticated testing in order to quantify the (often marginal) benefits they provide. The EU's focus on alternative fuels, particularly biofuels, is having an impact both on vehicles and test procedures. In the near future, additional exhaust gas components will have to be measured: ethanol, aldehydes, ketones, nitrogen dioxide and ammonia. Accurate, repeatable measurement of several of these gases presents significant logistical challenges. Fortunately, recent advances in laser technology, including mid-range infra-red and quantum cascade technology, appear well-placed to handle these challenging measurement conditions. To round off the session, Piotr Bielaczyc (BOSMAL, Poland) examined the practical impact of legislation and changing customer demands on engine testing in a presentation entitled 'IC Engine test method development regarding emissions, alternative fuels, lubricants and future trends'. Despite radical advances in engine technology over the last 125 years, the potential for improvement and refinement of existing tried-and-tested designs remains. Pressure to reduce harmful emissions and GHG emissions has led to the introduction of a range of engine and emissions control strategies and technologies, including the implementation of new materials, improved electronics and even electrified (hybrid) powertrains. Engine design megatrends, such as downsizing and the safe and reliable usage of alternative fuels and low-viscosity lubricants have necessitated new tests, and made engine testing progressively more complex. Currently, the engine development community is faced with the challenge of meeting Euro 6 and EPA 1065 standards, the latter of which is highly significant, as it is based on not-to-exceed zone standards, rather than a single, narrow driving cycle. Potential issues regarding aftertreatment system effectiveness, durability, regeneration, poisoning and compatibility with new fuels and lubricants mean that testing these systems has become an integral part of engine research. A range of test methodologies is available to meet these demands: engine dynamometer tests (steady-state and transient/dynamic); chassis dynamometer tests (emissions testing, mileage accumulation; road testing (performance/drivability and mileage accumulation); and also powertrain testing (engine+gearbox). BOSMAL has invested heavily in all of these areas, the most recent examples of which are the climate-controlled chassis dynamometer and the new engine dynamometer tests cells, opened during last year's event and during this symposium, respectively. Demand for testing while running on various alternative fuels necessitates dedicated alternative fuel infrastructure, for example for LPG and CNG. The advanced aftertreatment systems required to meet Euro 6 emissions standard for CI engines require special test setups, with multiple heated lines to quantify the effectiveness of the DOC, DPF and SCR units, as soon to be procured by BOSMAL. In conclusion, IC engines have been in use in the road transport sector for 125 years, and will continue to dominate as long as liquid fuels remain available. Refinement of these engines, and the development of electronics, have allowed engineers to produce engines which are ever cleaner, ever more efficient, but ever more complex and challenging to test successfully and reliably (Figure 10).

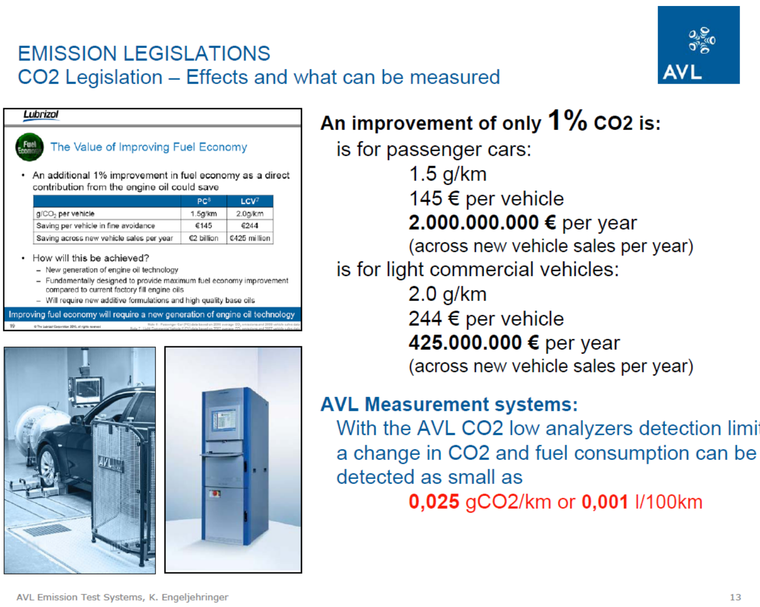

Figure 8 – Quantification of the economic implications of CO_2 emissions reduction

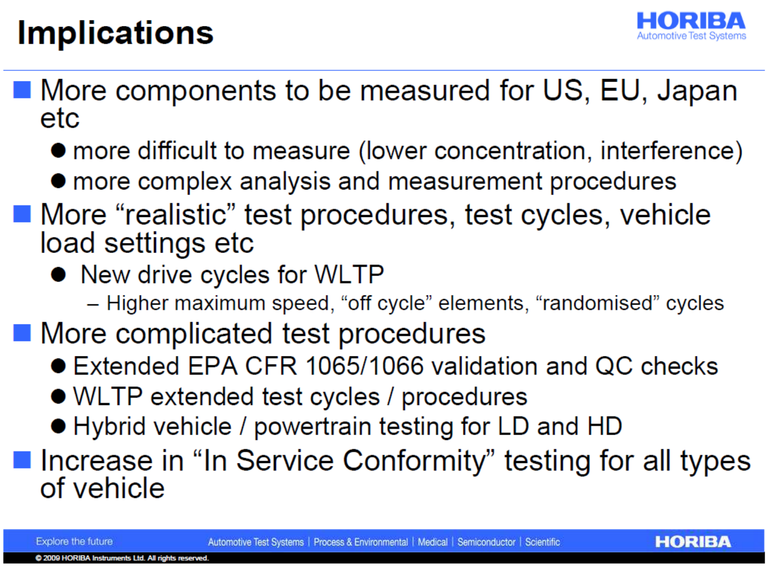

Figure 9 – Implications of future legislative moves on vehicle test procedures

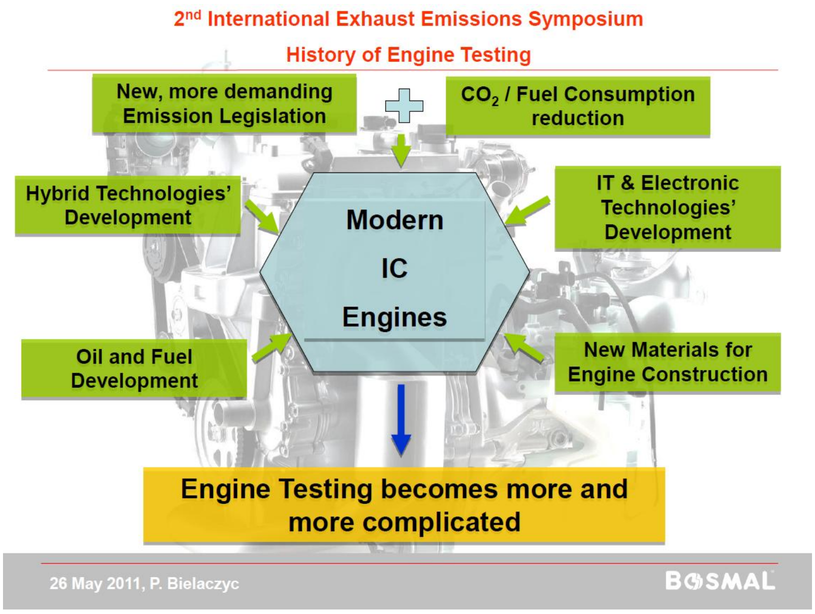

Figure 10 – Aspects of the development of modern engines contributing to increasing test complexity

Session 2 – PM and NO_x emissions test method development

Chair: Prof. Jorma Keskinen (Tampere University of Technology, Finland)

Douglas Trombley (General Motors Powertrain Europe, USA/Italy) presented information regarding his team's work on quantified emissions from DPF-equipped modern CI vehicles and engines in his presentation 'GM-AE activities on Particle Number and Size Emissions from Diesel Engines & Vehicles'. To quantify the particulate emissions (both mass and number based) from a modern diesel vehicle, a series of experiments were performed over the New European Driving Cycles (NEDC), using a dilution and sampling system according to the one required by legislation. Two particle counting systems, produced by AVL and HORIBA respectively, were used. Both systems provided very similar results both in capturing seconds-by-second emissions (as particles/cm^3) and in cumulated emissions (as particles/km). Results from the type-approval procedure (an NEDC following 3 EUDCs and a long soak time) indicated high effectiveness of the DPF (about 99.97%), thereby keeping PN emissions below the proposed Euro 6 limit (6×10^{11} particles/km). The trapping efficiency was found to be markedly reduced following a regeneration event, and then to increase steadily as the filter re-filled with soot. An analysis of the PN and PM data collected revealed the PN data to paint a much clearer picture: a variation of an order of magnitude in the PN results was barely detectable in the PM results-confirming that PM measurements are of limited use at such low emission levels. Additionally, this is a consequence of the specific class of particles that mainly contribute to the number emissions. A particle size classifier was also attached to the sampling system, indicating that the largest contributor to particle number was the 40-80 nm aerodynamic diameter size class, with the highest emissions observed during engine warm up and acceleration phases. In the case of aftertreatment system featuring a Lean NOx Trap upstream of the DPF, the impact of DeNOx pulses (rich combustion for few seconds) was also investigated. Results show a slight increase of PN emissions corresponding to lean-rich combustion transition, whose impact is minimal with respect to the total particle number emissions. Further studies in this field are ongoing. Increasing interest in the usage of biodiesel in CI engines makes work on biodiesel particle emissions, and biodiesel-ATS interaction and compatibility, essential. Standard Diesel ('B0'), 30% rapeseed methyl ester ('B30') and 30% jatropha methyl ester ('J30') were tested side-by-side on a light-duty CI engine on a test bed equipped with a scanning mobility particle sizer. During steady state tests, results for B0 and B30 were comparable in all engine operating points; for the J30 fuel, forced changes in the EGR rate appeared to cause increases in particle mass and number as well as mean particle size. Further measurements of particle size and number both upstream and downstream of the DOC for two different fuels during warm-up revealed significant differences between B30 and B0 at low engine temperature (Figure 11). As the engine warmed up, a shift was observed for both fuel types from a bi-modal distribution to a uni-modal distribution. The particle size distribution were generally not influenced by the DOC. Professor Jorma Keskinen from the University of Tampere (Finland) presented theoretical background, experimental results and analysis regarding the effect of Diesel aftertreatment technologies on the properties of exhaust particles in a presentation entitled 'The Effect of Technology on Diesel Exhaust Particle Properties'. Bringing together roadside measurements and laboratory testing will improve our understanding of automotive particulate emissions, and a range of experiments were carried out to determine the correlation between these two test strategies. The results indicate that while the mean particle diameter is barely affected, laboratory tests may underestimate particle number emissions (Figure 12). In recreating road conditions to assess particle number emissions, dilution is the most important factor; with care, real-world trends can be reproduced on a chassis dynamometer. Improvements in injection timing and increased injection pressure have resulted in reduced particle numbers, but the most dramatic reductions are achieved through the use of aftertreatment systems. Installing a DOC reduces PM a little, but the particle number remains virtually unchanged. A particulate oxidation catalyst (POC) may achieve a reduction in particle number of 50-90 %, but a DPF increases this figure to >99 %. Usage of a DPF also affects the charge of the particles, while the ionic state of particles downstream of a DOC is almost identical to the engine out flow, representative of core particles formed at high temperature. There is some evidence of a trade-off between number levels of these core particles and total soot particle emissions, with the former correlating positively with NO_x emissions. Werner

Moser (Eco Physics, Switzerland) gave an insightful presentation entitled 'Challenges in NO_x and NH_3 Emission Measurement', which outlined some important aspects of these two species as pollutants, their formation in IC engines and aftertreatment systems, aftertreatment options, and the difficulties encountered in accurately quantifying their emission from motor vehicles. Nitrogen oxide (NO), nitrogen dioxide (NO_2) and ammonia (NH_3) are the so-called reactive nitrogen compounds. Human activities are thought to contribute more reactive nitrogen to the global nitrogen cycle than all other sources combined. Ammonia can also react with NO_x to produce fine PM, and in this it form can be transported thousands of kilometres, with serious human health impacts. In light of this, there is growing interest in measuring emissions of reactive nitrogen compounds. Three main techniques are available for measuring reactive nitrogen compounds: absorption spectroscopy (using various parts of the spectrum), chemiluminescence, and even photoacoustic methods. While measurement of NO_x is a familiar part of the automotive test process, measurement of NH_3 remains a relatively little-known topic, with its own particular challenges and issues (Figure 13). The huge range of ammonia concentrations encountered (around six orders of magnitude) present a basic challenge for the design of accurate measurement systems. Analysers also require fast response times, as concentrations are highly dynamic and can shift rapidly. Ammonia is also a 'sticky' gas, which makes quantification of a variable source (e.g. an IC engine operating in transient mode) very difficult. The elimination of particulates, heating the sample to the required temperature, reducing the pressure and thorough flushing of the sample tubing are also of great importance. In addition to heating the sampling tubes, efforts should be made to reduce their internal pressure.

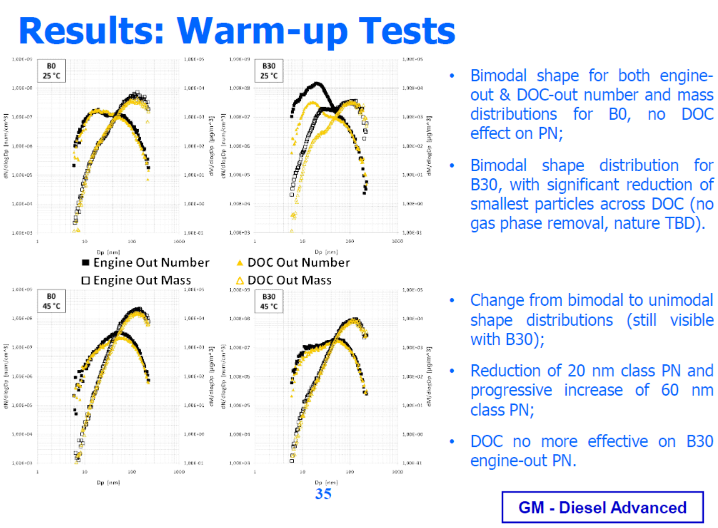

Figure 11 – Particle number and mass as a function of particle diameter

for two different fuels during engine warm up

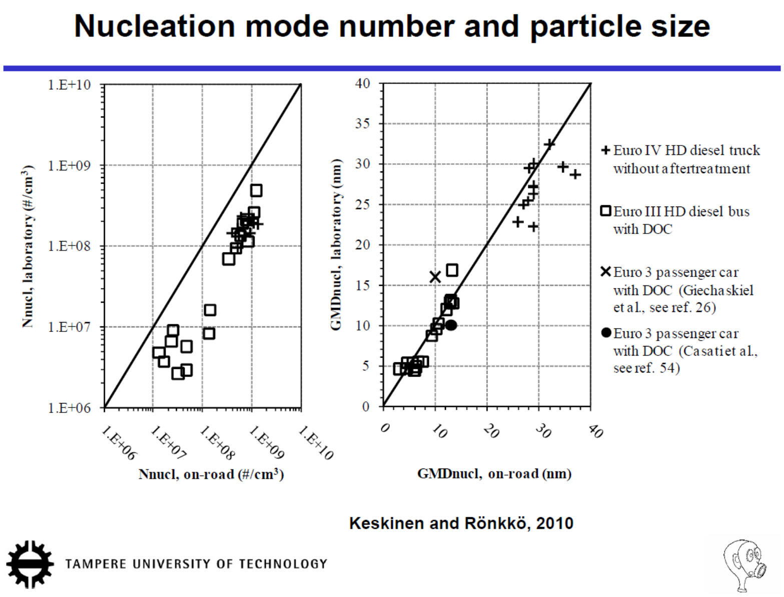

Figure 12 – A comparison of particle number and mean particle size results for

Diesel vehicles tested on road and on the chassis dynamometer

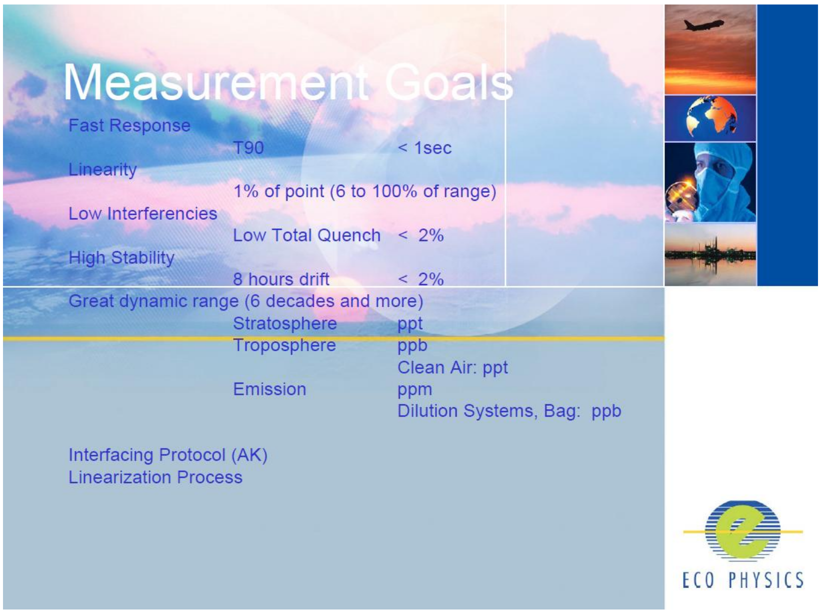

Figure 13 – Measurement goals for reliable quantification of ammonia emissions

Session 3 – Catalyst Technology Development for CI and SI engines

Chair: Prof. Giovanni Cipolla (GM/PoliTo Institute for Automotive Research and Education, Italy)

The session commenced with a presentation delivered by John May (AECC, Belgium), with the title 'Emissions Control Technologies to meet Current and Future European Vehicle Emissions Legislation', which provided attendees with a clear overview of the usage of catalytic aftertreatment systems in road vehicles. Since the 1970s, catalytic aftertreatment systems have been employed on passenger cars, and are increasingly being fitted to other types of vehicles and machinery which feature IC engines. The list of current available technologies for the automotive field consists of: three-way catalysts, for the conversion of HC, CO and NO_x; oxidation catalysts, for the conversion of HC and CO; DPFs, for reducing the number and total mass of particulates; SCR and LNT, both for NO_x reduction. DPFs and LNT require periodic regeneration, which can be achieved in a number of ways; continually regenerating DPFs are also a concept that is available. The urea (AdBlue) SCR system can achieve reductions in NO_x emissions of over 85 %, but adds further cost and complexity to the total aftertreatment system. SCR systems have been in use in heavy-duty and marine applications for some time, and will be required in order to meet the highly stringent Euro 6 CI NO_x limit (Figure 14). A series of tests were conducted on a range of vehicles to determine to the effect of various emissions control technologies on regulated emissions in relation to legislative emissions limits. Without aftertreatment, the NO_x emissions of CI engines are massively higher than those from SI engines, and remain a major topic for catalysis research. Additionally, the legislative NEDC driving cycle can generate lower NO_x emissions than the CADC cycles. No significant differences were observed when DPF-filtered Diesel particle emissions were compared over these two test cycles. An investigation of aftertreatment systems' ability to meet Euro 5 limits revealed the systems to be effective, but that the conversion efficiency depended on the duty cycle, more so in the case of CO and NO_x than for HC, PM and PN. A series of tests were conducted on an engine designed for non-road mobile machinery retrofitted with a DOC, a catalysed particulate filter (C-DPF), and urea-SCR with an ammonia slip catalyst. High effectiveness of the combined aftertreatment systems was revealed over a total of 10 duty cycles, but again this effectiveness was a strong function of the duty cycle employed. For two-wheeled vehicles, the emissions control issues are HC and NO_x, limits for which will be severely reduced in the Euro 6 standard. Mileage accumulation tests on a Euro 3 motorbike quickly exceeded limits at relatively low mileage. When viewed together with system electronics and fuel quality, continuous improvement of catalytic aftertreatment systems offer the possibility of substantial progress in the on-going drive for reduced tailpipe emissions from a variety of vehicular applications. Building on the impressive overview delivered in the preceding presentation, Pankaj Dhingra of Nanostellar (USA) presented an exploration and discussion of his company's approach to catalytic aftertreatment system development in a presentation entitled 'Rational Design – a Powerful Set of Tools for Developing Innovative New Materials for Emissions Control Systems'. A nano-material computer-aided design paradigm is employed to enable radical innovation is various fields of application, beginning with automotive DOCs. The rational design technique employs modelling to provide insights into the reaction pathways of both desired and undesired reactions, together with information on how to promote the former and prevent the latter. The next generation of DOC technologies will not use precious metals for the oxidation of CO and NO, and work is on-going into eliminating these metals from the DOC's HC oxidation method. Research into the exact cause of the CO light-off point revealed that CO swamps the platinum surface at low temperatures, and a certain temperature must be reached in order to allow thermodynamic desorption and thereby allow oxygen molecules access to the active sites. Through the rational design process, it was determined that adding bismuth-based doping agents to the platinum surface inhibited local CO binding, thereby creating an archipelago of CO-free 'islands', which allow the self-sustaining oxidation reaction to commence (Figure 15). In a parallel development, it was determined that the addition of gold to palladium surfaces increased the oxidative resistance, thereby potentially allowing palladium (a highly effective catalyst) to be used in Diesel applications in the presence of excess oxygen. Catalysts which do not feature platinum-group metals (PGMs) offer multiple potential benefits. Tests on catalyst concepts of this type revealed lower CO light-off temperatures in comparison to established technologies, caused by lower HC inhibition of the active sites. The thermally stability and sulphur tolerance exhibited by this technology, together with the synergistic effect of increased thermal output from the CO reaction on the reactions for HC and NO_x, make this technology an option of considerable interest. The search for a better NO oxidizer than platinum and platinum-palladium mixtures has led to the creation of three prototype materials, which show improved performance at high temperatures. Based on these success stories, and the good performance of these new technologies under real-world conditions, the rational design methodology has been recognized as a key player in the chemical development of catalytic systems, which continue to be of ever-greater importance to the automotive industry. Moving into territory covering research and development on heavy-duty emissions control, Gerardo Carelli (Umicore, Italy/Germany) delivered a presentation with the following title: 'Heavy Duty Engines Catalyst Technology for On Road and Off Road Applications'. Increasingly stringent NO_x and PM limits will make the use of coated DPFs and SCR systems will become necessary for both on-road and off-road applications. Engines will feature aftertreatment systems consisting of a DOC, coated DPF, and an SCR system with an ammonia slip catalyst. Each component of the combined aftertreatment system, together with the system as a whole, must meet certain specific performance and durability requirements, and each component can be optimized following investigations into alternative metals and regeneration strategies. Umicore's advanced DOC concept has proven successful in both the active and passive regeneration of particle filters (Figure 16). The platinum-palladium ratio employed in DOCs and coated DPFs exerts a strong influence on durability, regeneration thermodynamics and NO_2 production rates, with Pt-Pd mixtures outperforming Pt alone in these areas, although NO_2 formation is reduced as Pt is substituted with Pd. The price disparity between these two metals means that significant savings can be made through substitution. Altering the catalyst architecture is a good method by which the same emissions reduction performance can be achieved with a lower precious metal loading, thereby obtaining a significant cost reduction. SCR concepts based on metal-zeolites and vanadium have been shown to exhibit high durability, and better activity at low temperatures, thanks to a reduced sensitivity to departure from the 50:50 $NO:NO_2$ ratio. When using these metal combinations in conjunction with an SCR system, around 95 % conversion of NO_x was observed for all three, although at lower temperatures differences between the three were observed in terms of the response to variations in the levels of NO_2. The Fe-zeolite combination has the potential to reduce the SCR volume, as this technology was observed to perform well, even at high space velocities. During an extended ageing procedure, the NO_x conversion of the SCR system was proven to be stable. While the performance credentials of these technologies have been amply demonstrated, challenges remain regarding cost and the complexity of application of these devices in vehicles. Toni Kinnunen of Ecocat (Finland) discussed the impact on catalysts of growing interest in the ecological credentials and impacts of alternative fuels in a presentation entitled 'Alternative Fuels – Optimization of Catalysts'. Due to pressure from various sources to reduce emissions of greenhouse gases and harmful compounds and because of the finite nature of crude oil reserves, interest has been growing in employing alternative fuels (CNG, LPG, H_2, bioethanol, biodiesel, x-to-liquid fuel, biogas, etc.) in automotive applications. Targets set by the EU in this area increase political pressure to adopt such fuels. Since some of these fuels are chemically very different from the fuels they will replace, it follows that the chemistry of engine out emissions is radically altered. Fuel impurities are another issue. Difficulties arise regarding molecules which are hard to convert, or hard to prevent from entering into unwanted side reactions. In response to this, catalytic aftertreatment systems must be customized, to ensure acceptable performance and durability. Natural gas is a promising option for an automotive fuel, although it currently suffers from an underdeveloped infrastructure, it provides multiple emissions benefits. However, the HC treatment required is different, since this fuel is composed almost entirely of methane (CH_4). The oxidation reaction is problematic and has required development work to achieve good performance (Figure 17). This technology has been shown to reduce emissions of THC, CO and NO_x simultaneously. Specialized applications developed to be dedicated to CNG have shown reduced CH_4 light-off temperatures, and when coupled with engine optimizations, have shown very high CH_4 and NO conversion efficiencies. Interest in adding ethanol to Diesel has made this an important research topic. Since ethanol is an oxygenated hydrocarbon, and very small and light compared to Diesel fuel component compounds, optimization of the aftertreatment system is required for its elimination. Various experiments were performed to determine the optimum Pt loading for conversion of ethanol in various ethanol-alkane mixtures, with a loading of 40-70 g/foot^3 emerging as the best value for the particular system tested. Similarly, the addition of bioethanol to petrol alters aftertreatment system requirements. While the light-off behaviour for CO is the same for pure petrol and petrol-ethanol blends, light-off occurs earlier for HC and NO_x when operating on ethanol. Natural gas requires dedicated catalysts; LPG and ethanol can be catered for by fine-tuning existing gasoline catalysts; challenges remain with biodiesel, but this may be more of a case of improving fuel quality and reducing impurities and batch-to-batch variation in order to improve emissions reduction performance in a DOC. Rounding off the session with a detailed discussion of a specific technological application, Juergen Pilsl (Huber Group, Germany) discussed virtual NO_x sensors in his presentation 'NO_x Determination in Diesel SCR Systems by Neural Networks'. The conventional Diesel NO_x aftertreatment SCR solution requires two NO_x sensors – one upstream of the urea (AdBlue) injector, and another downstream of the SCR itself. Given that each of these sensors costs around €80, the possibility of eliminating one of these sensors from the system, while retaining performance and functionality, is an attractive cost-reduction option. The upstream sensor can be eliminated, and a predictive model of some sort can be used to control the AdBlue injection rate (Figure 18). Following the realization that modelling was too costly and error-prone to replace the sensor with a 'virtual sensor', an artificial neural network (ANN) approach was decided upon. The ANN was also developed to be able to predict the proportion of NO_2 in the NO_x flux, and thereby optimize the instantaneous AdBlue dosing, according to the prevailing conditions. The sine qua non of an ANN system is its ability to learn. The network takes the structure of an input layer (12-14 inputs, including: engine speed, air mass, air temperature, EGR %, etc.), and passes this information through a hidden module layer to produce the output – an NO_x concentration value. The modules that make up each layer are 'neurons', each one of which is a simple arithmetic unit. The system must be 'trained' by feeding it selected data; after this phase the aim is to use the system to predict the output using input data not previously supplied to the network. During the training, variable weightings are assigned to the connections between the various neurons. Once the training is complete, these weightings are fixed and retained for future use. After a learning time of approximately 5 hours, the output error had been reduced to less than 1 %; after 30 hours' training the error was negligible. Training input data came from real-world driving experience and test cycles. Validation was performed by using various driving cycles, performing altitude testing and attempting to transfer the ANN to a comparable vehicle. Results were promising, with an excellent correlation between measured NO_x concentrations and the NO_x concentrations predicted by the ANN over a variety of driving conditions.

The correlation was somewhat weaker, but still strong, when the ANN was applied to another vehicle. The system also successfully predicted results for the NO_2 concentration (thereby providing an $NO:NO_2$ ratio), with a relatively high correlation coefficient of 0.89. The ANN was concluded to outperform model-based approaches and prove a viable cost reduction strategy in this area. Given the extra cost involved in implementing Diesel SCR systems to meet the upcoming NO_x emissions limits, such cost-cutting technologies are likely to remain of interest.

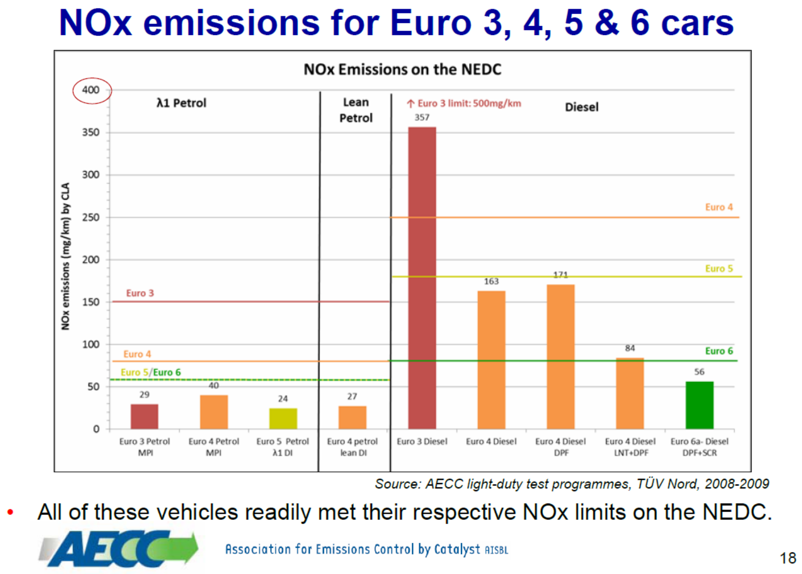

Figure 14 – A comparison of NO_x emissions for different vehicle ages and types,

presented in comparison to the EU's legislative limits

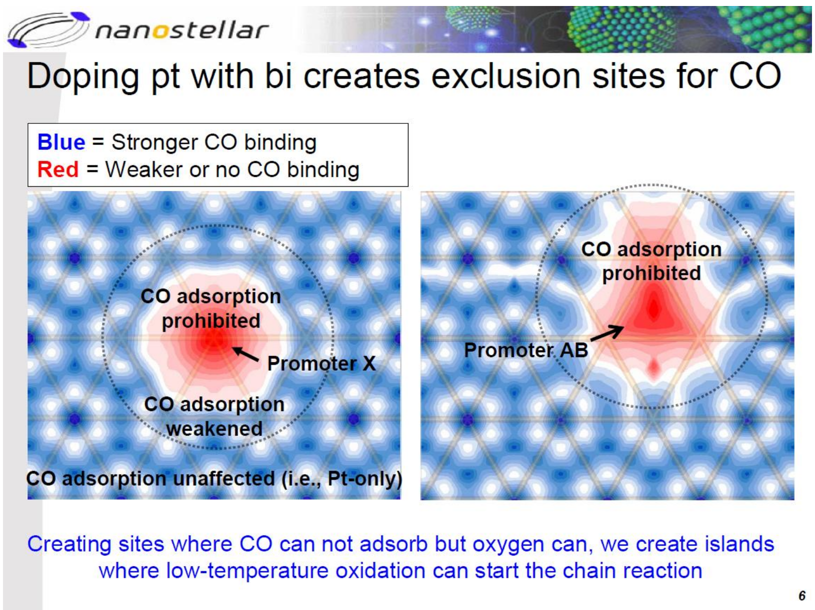

Figure 15 – CO exclusion islands created on the Pt surface through use of a doping agent

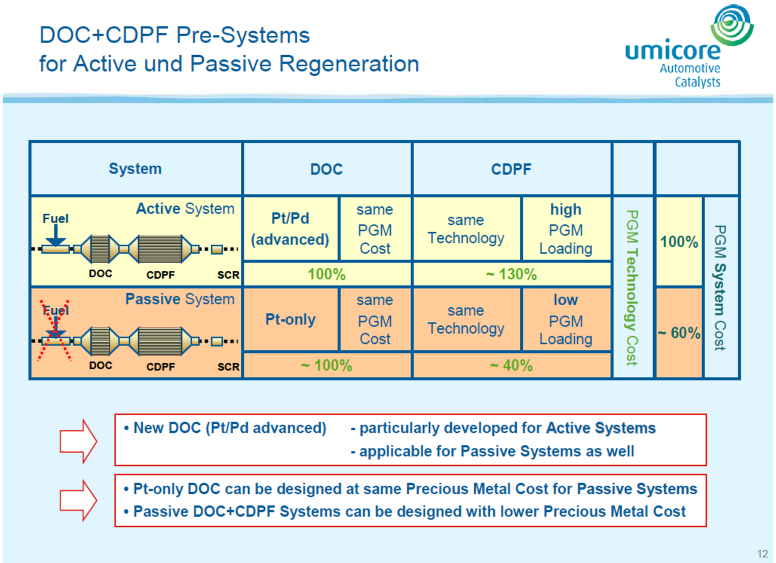

Figure 16 – Active and passive systems using Pt/Pd and Pt only DOC designs

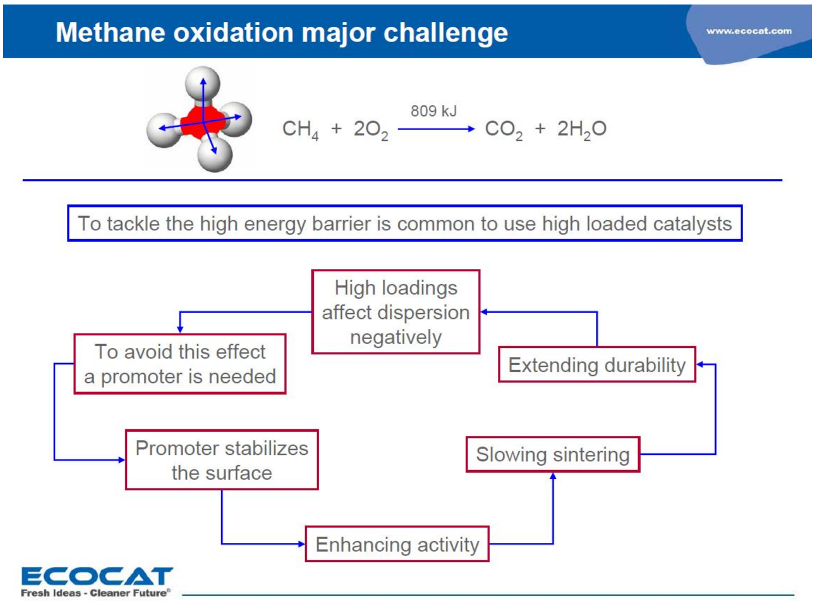

Figure 17 – Problems and solutions related to the oxidation of methane

in a catalytic aftertreatment system

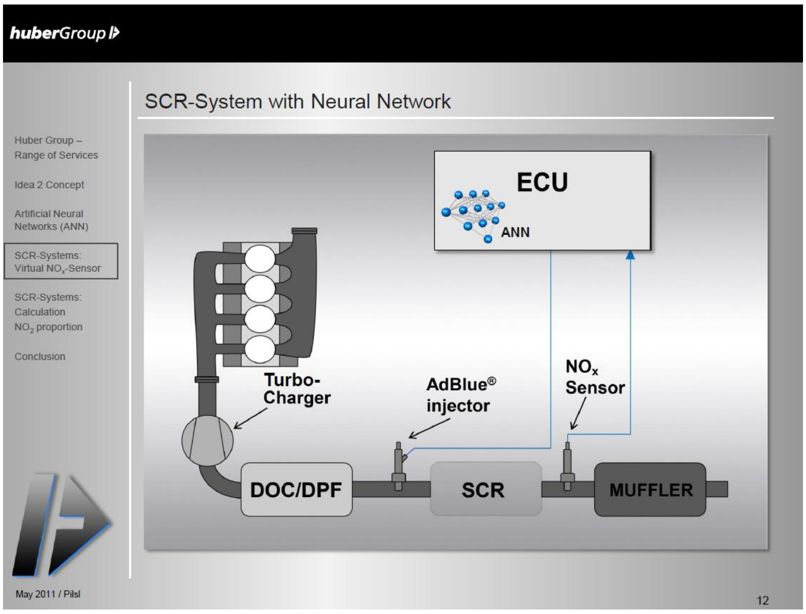

Figure 18 – Usage of an artificial neural network (ANN) embedded into the ECU to control the AdBlue injector, thereby eliminating the need for a second NO_x sensor

2nd day - Keynote lecture: 'Unified Tool Platform for Powertrain Development'

This lecture, delivered by Dr Gotthard Rainer (Vice President, Advanced Simulation Technologies, AVL, Austria), communicated both the theoretical and the practical benefits of making use of AVL's unified tool platform in the powertrain development process. The development of the motor vehicle over the past century has immeasurably improved the quality of vehicles but has also dramatically increased the number of parameters which must be controlled for their optimization. The continued development of vehicles, engines, drivetrains, components and electronics means the number of parameters continues to increase still further. AVL's solution for this is to integrate powertrain engineering, simulation and test system instrumentation to provide a toolset to support the development process. A schematic of various aspects of the process is shown in Figure 19. The simulation phase uses multiple physical models to provide simulation at all levels, from individual components to subsystems and the entire system. Simulation software is paramount in this stage, using real-world data to provide frontloading for the simulation process. Simulation tasks include thermal and energetic management, combustion and emissions. The outputs of the simulation applied to base elements of the powertrain (IC engine, control strategy, etc.) increase the capabilities and the efficiency of the testing phase. The thermodynamics of aftertreatment systems such as SCR and DPFs can be simulated in one or three dimensions, to be used in online and offline modelling of pollutant formation and exhaust aftertreatment system effectiveness. The validation of these models yields excellent correlations with real-world data. The development of innovative powertrain concepts such as a fully electric powertrain with range extender can be aided and strengthened through usage of the unified toolset. The unified platform approach provides a powerful and necessary tool for the development of low emission powertrains. The system covers each stage and facet of the process: simulation and optimization of parameters, interactions between systems, subsystems and components, validation of models and testing.

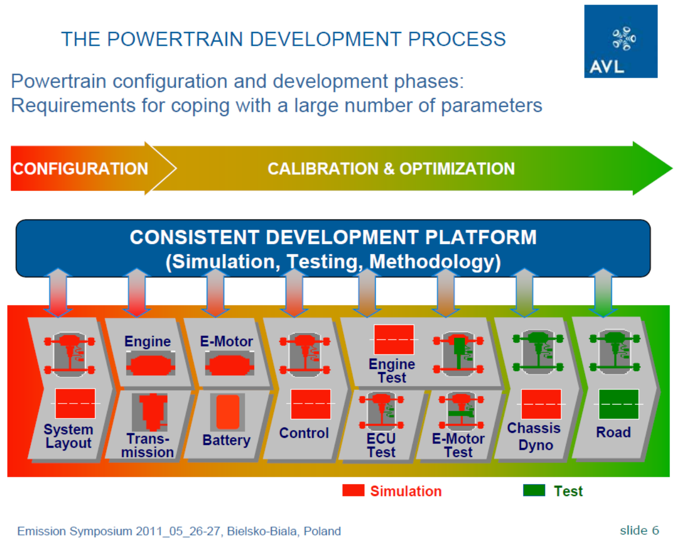

Figure 19 – Simulation and test parameters fed into the

Unified Tool Platform Powertrain Development process

Session 4 – Fuel and engine oil development

Chair: Prof. Jerzy Merkisz (BOSMAL/Poznan University of Technology, Poland)

Gianni Cecconello (Petronas, Italy) commenced with a discussion of one of the main areas of interest regarding lubricant development in a presentation entitled ‘Lubricant Development Process for CO_2 Reduction’. Given that a large amount of the chemical energy contained in the fuel burned in a reciprocating IC engine is wasted overcoming friction, lubricants which cause lower frictional losses are of considerable interest as options for reducing fuel consumption and therefore CO_2 emissions. While the start-up period is critical regarding lubricant viscosity and the accompanying effect of fuel consumption, viscosity is still of importance during high load, high speed conditions. In general, it can be stated that fuel consumption is proportional to friction, although this is not always true in every case. Additionally, a lubricant which reduces fuel consumption in one engine may not demonstrate similar benefits in another engine design. However, driving down the viscosity as far as practicably possible is not the only consideration, as the lubricant must maintain its ability to form boundary films, and thereby prevent direct contact between the components, which would rapidly lead to increased friction and engine damage. The viscosity of several candidate lubricants was assessed at temperatures from 25 °C - 120 °C. The lubricants were subjected to a range of tests, including frictional comparison, oil pressure comparison, and fuel consumption tests at three different lubricant temperatures (Figure 20). Further tests were run on a vehicle equipped with a larger engine on a chassis dynamometer over the NEDC, using robotic drivers. Research and development work continues into lubricants which offer a combination of reduced friction and reduced fuel consumption over a wide range of operating conditions, for different engine sizes and types. Moving from lubricants to fuels, Leonardo Pellegrini (Eni, Italy) delivered his presentation ‘Influence of Chemical Composition of Surrogate Diesel Fuels on Regulated Emissions’. The different types of hydrocarbon compounds present in Diesel fuel all exert different effects on various fuel properties, such as cetane number, low temperature operability and exhaust emissions. The cetane number generally increases proportionally with a compound's carbon number, but the rate of increase is far from constant. In contrast, the relationship between the melting point of paraffins and their carbon number is much more regular. A summary of previous studies on Diesel fuel properties' effects on regulated emissions (Figure 21) revealed the existence of three relationships between fuel parameters and emissions: directly proportional, no effect, or inversely proportional. However, vehicle variance may account for a much larger proportion of the variation in regulated emissions than the fuel. A fuel matrix was constructed to explore options for producing synthetic Diesel using a variety of streams, while maintaining a fixed cetane number and T_{95} boiling point. A series of tests was conducted to determine the performance of the various synthetic Diesel fuels studied on regulated emissions. The addition of relatively small quantities (around 10%) of certain compounds was found to have a significant effect on emissions, with a range of compound increasing the PM and PN emissions. Hydrocarbon emissions were substantially increased by the addition of diaromatics to the blend; NO_x emissions were not significantly affected. A major environmental goal for this type of research is to produce fuels with a lower tendency to produce PM mass and PN emissions. The research performed showed that the addition of paraffin with a limited degree of branching to Diesel fuel is a worthwhile strategy to increase the environmental friendliness of the Diesel engine. Next, Catherine Maillard of Shell (UK) gave an excellent overview of *next generation fuels in the transport sector* in her presentation of the same title. Continuing demand for energy, coupled with a growing global population, will mean that global energy consumption will more than double by the year 2050. Transport energy demand will increase rapidly (by 2050 there will be more than 2 billion vehicles on the road), and no single fuel will be able to meet the demands of this area. Nation states and regions will have to develop their own fuels portfolios, based on local availability, infrastructure, etc. Emerging technologies such as electric powertrains and hydrogen will become progressively more important, and natural gas will continue to expand in niche markets, but IC engines and liquid fuels will continue to play an important role. Political pressure to switch to biofuels is now being keenly felt – over 65 countries, including the USA, China and all the EU member states, either currently have or are developing renewable fuels mandates. Biofuels are already in use, the most common being ethanol (from the fermentation of crops rich in sugar) and fatty-acid methyl ester (FAME) biodiesel produced from the transestrifiction of vegetable oil crops. Hydrogenated vegetable oil is also an option. A number of objections have been raised to the use of crops, particularly edible crops, for fuel production. The well-to-wheel energetic performance of biofuels must be accurately quantified, to reward the best performers. Legislation must address concerns regarding workers' rights, water pollution, etc. A consortium of stakeholders are now discussing the details of a standard to be applied in concert with the EU's recent Renewable Energy and Fuel Quality directives. Another area of interest is the production of gas to liquid fuel. The production process involves the processing of natural gas to produce a liquid fuel suitable for use in CI engines. Shell's most recent investment in this area is a facility with a rated capacity of 140 000 barrels/day. The GTL fuel produced is a clean-burning fuel with desirable properties from the emissions point of view (Figure 22). When applied to unmodified engines, the emissions benefits are notable but generally modest. However, by optimizing an engine for usage with GTL fuel, massive emissions reductions are realizable for light-duty engines. For heavy duty engines the reductions are smaller, but still significant. The credentials of this fuel have been proven during test programmes conducted on light- and heavy-duty vehicles at twelve locations worldwide. Prof. Miroslaw

Wyszynski (University of Birmingham, UK) continued the biofuel development discussion in his presentation 'Properties and Engine Testing of new Biofuels and the Low Temperature AVL Transient Test Facilities at Birmingham'. A number of possibilities are under investigation as potential candidates for future biofuel options. Natural gas performs well in SI engines, but its performance can be further improved through reforming the fuel by adding hydrogen. The addition of this hydrogen was observed to reduce cycle-to-cycle and cylinder-to-cylinder variations. The speed-torque regime currently achievable for homogenous charge compression ignition (HCCI) can be extended by the use of hydrogen as a fuel reformer. The fuel economy realized through the enabling of HCCI combustion is considerable. The addition of reformed fuel to standard gasoline was also observed to lead to substantial emissions reductions. One of the key next steps for the fuels of the future is the development of 2nd generation biofuels obtained from inedible feedstocks such as cellulosic biomass. A reaction scheme is shown in Figure 23. One output of these reactions, DMF (2,5 dimethylfurane) is of interest as a fuel for SI engines, particularly GDI engines, due to certain favourable properties. Emissions benefits were observed for CO, HC and NO_x when running on this fuel type, in comparison to standard gasoline. Particle number emissions remained relatively constant, with a slight shift in the mean particle diameter. Based on these results, DMF would appear to be a promising short- to mid-term solution to concerns over global warming. Research work was conducted on the usage of animal tallow (fat obtained from carcasses) to produce fuel for use in CI engines. This waste product could potentially supply up to 1/70th of the United Kingdom's energy needs, as substantial quantities remain unexploited. Combustion of tallow leads to reduced emissions of CO, HC, PM, and SO_2; emissions of NO_x increase somewhat. Other research has focused on the emissions benefits which can be realized through mixing gasoline and Diesel. Particle number emissions were found to reduce in proportion to the blend gasoline content. Additionally, blending Diesel into gasoline extends the HCCI operating range, allowing it to occur unproblematically at lower pressures than would otherwise be possible. Research work continues on alternative fuels including dimethylfurane, synthetic bio-derived Fischer-Tropsch fuels, alcohols, hydrogen and animal fat as potential solutions for reducing emissions of harmful compounds and CO_2, and increasing the security of supply. Bringing the final session to a close, BOSMAL's Dr Andrzej Szczotka explored *the evolution of automotive fuels and fuel test methods in response to emissions and GHG legislation* in a presentation of the same title. The energy consumption of the transport sector is significant and is growing year-on-year. At present, the transport sector has near-total reliance on fossil fuels. Based on political factors, interest has been growing in using various sources other than fossil fuels to produce energy carriers such as alternative liquid fuels, gaseous fuels, and even hydrogen and electricity. A large number of factors influence fuel development, ranging from legislative (emissions and GHG regulations); financial (globalization, tax and subsidies); and technical (performance, interactions with engine components, lubricants and aftertreatment systems); all tied to the inescapable fact that fossil fuel resources are finite and essentially non-renewable. Substantial progress has been made in reducing emissions from both SI and CI engines, and this success is due to advances in fuels, as well as engine refinements. Highly ambitious fleet average CO_2 emissions limits planned for introduction in the EU in 2020, together with incremental fines for non-compliance, mean that fuels with lower carbon:hydrogen ratios will be of considerable interest in the next few years. The broad range of fuels and fuel types which now require testing have altered the range of fuel testing activities. Fuel testing is now multi-faceted, with an array of techniques available for accurate, methodologically sound assessment of the relative merits of a given fuel (Figure 24). BOSMAL has over 35 years' experience in testing various fuel types via various methods, including:

dynamometer testing (steady state, transient/dynamic), emissions tests on a chassis dynamometer, and vehicle road testing. Growing interest in particulate matter emitted by certain types of engine has led to the introduction of a particle number emissions limit in the EU. This fact is significant, as PN now effectively places PM as the metric for particulate filter systems. Fuel benchmarking on engine test benches continues to be an important method by which to differentiate between fuels in respect to parameters such as regulated emissions, brake-specific fuel consumption, absolute fuel consumption, torque and power output. The effect of a fuel property such as cetane number, sulphur content, or the effect of a particular additive (such as rapeseed methyl ester biodiesel) on emissions and fuel consumption can be assessed by testing graduated blends of varying composition on a vehicle on a chassis dynamometer, or engine on a dynamometer, allowing comparison of exhaust emissions, fuel consumption, etc. Biodiesel is associated with some issues, such as injector coking, and tests on clogging and the effectiveness of anti-clogging additives are important tools for overcoming such difficulties. IC engines and fossil fuels will remain the dominant combination for power sources for road transport in the years up to 2030. By that year, highly-refined SI and CI engines will dominate the sector, together with smaller numbers of hybrid and electric powertrains. The continued development of engine fuels, with a greater share of carefully-selected biofuels and other alternative fuels is the right direction to take in the continuing drive for lower pollutant emissions and CO_2 emissions reduction. Thanks to its expertise and ongoing investments, BOSMAL is very well placed to perform high quality research and development in all these areas of the fuel testing and development process.

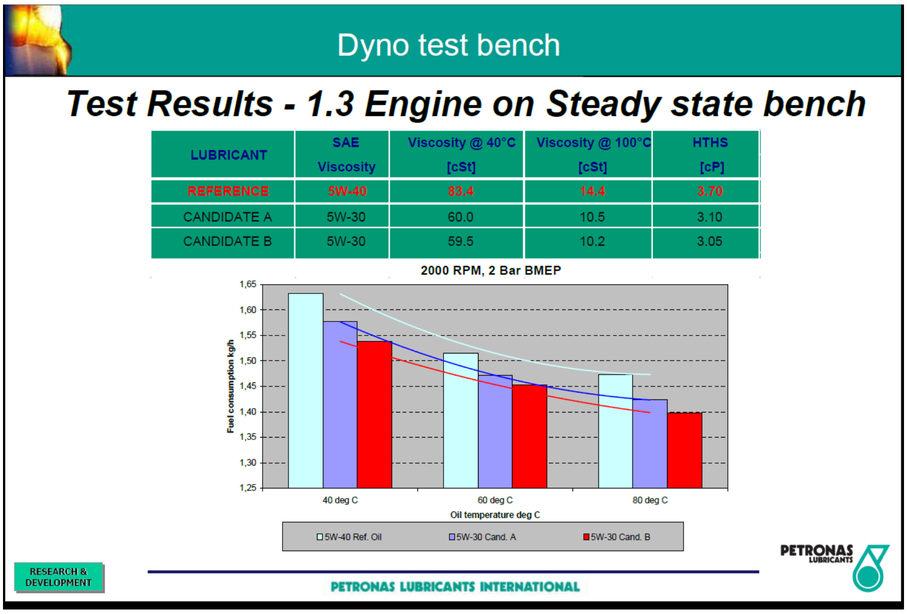

Figure 20 – Viscosometric and fuel consumption data for the three lubricants examined

Summary of past studies on fuel-emissions relationships

Fuel property	HC	CO	NOx	PM
Density	+/-	+/-	+/-	+
Monoaromatics	+	0	+	+
Diaromatics	0	0	0	+
Polyaromatics	+/-	+/-	+	+
Cetane number	-	-	+/-	+/-
Back end volatility (T95)	-	+/-	+/-	+
Sulphur	0	0	0	+

+ directly proportional
0 neutral or minor effect
- inversely proportional

Synthesis of regression equations from the EPEFE (1991-1995), EPA HDEWG (2000) and ATRI/JPEC (2005) programmes

refining & marketing

eni

Figure 21 – Summary of previous studies on Diesel fuel-emissions relationships

Why is GTL fuel beneficial for emissions?

Property	Refinery diesel	Shell GTL Fuel	Implications
Sulphur content, ppm	10-5000	~ 0	➢ Lower local pollutant emissions (SOx) and particulates ➢ Better performance with S sensitive after-treatment systems
Cetane number	40-55	75-80	➢ Lower gaseous (CO, HC and NOx) and particulate emissions ➢ Less engine noise and smoother acceleration ➢ Higher fuel efficiency in dedicated engines
Density, kg/l	0.82-0.86	0.78	➢ Lower particulate emissions ➢ Slightly higher fuel consumption on volume basis
H/C ratio	~ 1.86	2.09	➢ Lower CO_2 emissions per km travelled
Calorific value, MJ/kg	~ 43	44.1	➢ Slightly lower fuel consumption on mass basis and lower CO_2 per km travelled

25

Figure 22 – A side-by-side technical comparison of refinery Diesel and Shell's GTL fuel

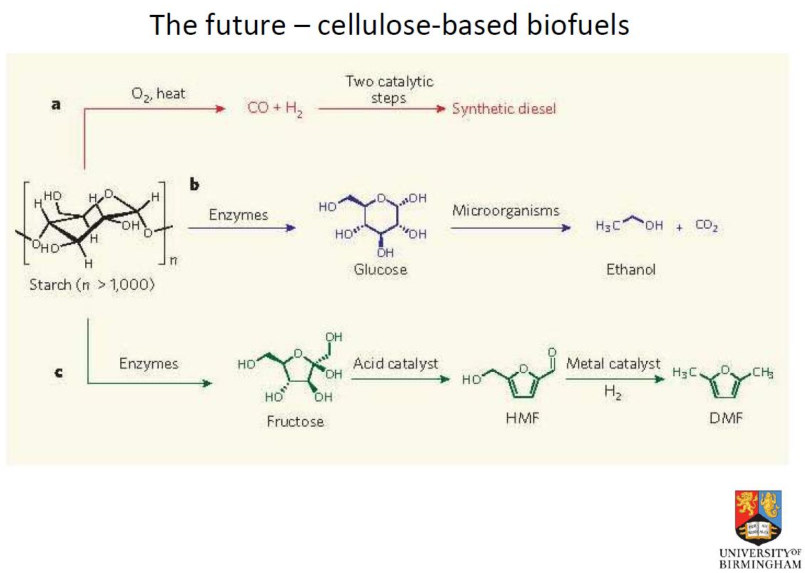

Figure 23 – Simplified reaction scheme for the production of biofuels from cellulosic biomass

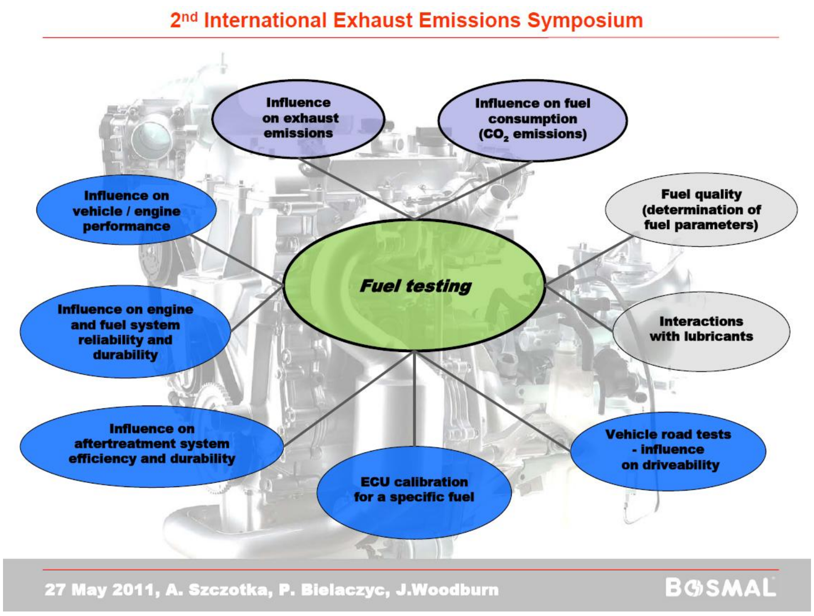

Figure 24 – Aspects of the development testing of vehicular fuels

Symposium summary

Prof. Jerzy Merkisz (BOSMAL/ Poznan University of Technology, Poland)

Professor Jerzy Merkisz, the current chairman of BOSMAL's Advisory & Scientific Boards, concluded the symposium by summarizing the key themes which had surfaced in the proceeding presentations and offering his own interpretations and commentary on the 2nd International Exhaust Emissions Symposium. Prof. Merkisz mentioned that powertrain development is moving the direction of reduced level of emissions of harmful compounds and CO_2 emissions. The technologies to achieve this goal, namely: measurement systems, testing systems, exhaust gas treatment systems, and fuel were all discussed during the symposium. The local and regional variations of emissions standards and test procedures stand in contrast to the unified character of the automotive markets, and unification and harmonization of emissions regulations is an important goal for the emissions testing community and lawmakers involved in this area.

Conclusions

The keynote lectures and presentations summarised above gave an excellent account of the current situation within the automotive, fuel and lubricant industries; as well as indications of trends for the near future. On-going trends towards cleaner vehicles require accurate quantification of ever-decreasing concentrations of regulated pollutants. This trend, together with legal measures to reduce fuel consumption and general pressure to develop alternative powertrain concepts, are profoundly affecting the way in which vehicles are tested, as well as the facilities and equipment used in the testing process. Similarly, the introduction of the particle number counting requirement for type-approval and conformity of production procedures introduces both a new class of equipment and a new metric to Diesel testing procedures and Diesel test setups, soon to be applicable also to GDI engines.

CO_2 emissions reduction is a challenge for the industry, driven by political, economic and technical factors. Ambitious mid- and long-term fleet average CO_2 emissions targets represent multiple difficulties for vehicle manufacturers, requiring considerable R&D investment. Simultaneously, emissions regulation is becoming more stringent, with new pollutant compounds to analyse and test for: particle number (to become more important than PM mass), with NO, NO_2, N_2O, NH_3 and specific organic compounds as potential candidates for EU legislation.

Despite these two existential threats, IC engines appear highly likely to remain the most important power source for land transport, and development of these engines requires sophisticated test methods and very well-equipped laboratories, in order to meet these twin challenges. The design process must reflect the fact that an engine is no longer simply a collection of moving metallic components – fuels, lubricants and aftertreatment systems must be borne in mind during the engine design, development and testing processes. Promising new technologies and new, more cost-effective metal combinations (currently under investigation) will ensure that catalytic aftertreatment systems remain very important for the reduction of emissions. Similarly, biofuels and advanced lubricants will also be vital tools in our campaign to reduce harmful emissions, GHG emissions, and increase the security and sustainability of the transportation energy supply.

The social programme organized as an integral part of the conference was thoroughly enjoyed by all who attended, echoing similar scenes from the previous year. Based on the quality of the presentations, the standing of the presenters, the excellent standard of the high-powered keynote lectures, and the positive feedback from attendees, BOSMAL's exhaust emissions symposia look set to become a steady feature of the automotive testing community's calendar.

The proceedings from the 2nd International Exhaust Emissions Symposium have been archived on a CD entitled 'Current and Future Trends in Automotive Emissions, Fuels, lubricants and Test Methods', ISBN: 978-83-931383-1-9. As with the previous year's event, a DVD containing video reportage of the event accompanies the proceedings CDROM.

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[1] Bielaczyc, P., Woodburn, J. Global trends in emissions regulation and reduction. Combustion Engines, 3/2010 (142), 3-27, 2010.

[2] Bielaczyc, P. (editor) and 13 co-authors. Global trends in emissions regulation and reduction from the perspective of powertrain and fuel development, Proceedings of the 1st International Exhaust Emissions Symposium, ISBN 978-83-931383-0-2.

[3] Bielaczyc, P., Swiatek, A., Woodburn, J. A technical discussion of the emission of ammonia from SI vehicles fitted with three-way catalyst. Combustion Engines, 1/2011 (144), 63-71, 2011.

[4] Bielaczyc, P., Pajdowski, P., Szczotka, A., Woodburn, J. Development of vehicle exhaust emission testing methods – BOSMAL's new emission testing laboratory. Combustion Engines, 1/2011 (144), 3-12, 2011.

Abbreviations and definitions

ANN	Artificial neural network
ATS	Aftertreatment system
CADC	Common Artemis Driving Cycle
CI	Compression Ignition
CNG	Compression Natural Gas
GTL	Gas-to-liquid
CO	Carbon monoxide
CFR	Code of Federal Regulation (USA)
CO_2	Carbon Dioxide
DMF	Dimethylfurane
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EGR	Exhaust gas recirculation
EPA	Environmental protection agency
EU	European Union
FAME	Fatty-acid methyl ester
GDI	Gasoline Direct Injection
GHG	Greenhouse gas
HC	Hydrocarbons
HCCI	Homogenous charge compression ignition
LNT	Lean NO_x Trap
NEDC	New European Driving Cycle
NH_3	Ammonia
NO_x	Oxides of nitrogen
NTE	Not-to-exceed zone
Pa	Palladium

PGM	Platinum group metals
PM	Particulate matter
PMP	UN-ECE Particulate matter programme
PN	Particle Number
POC	Particulate Oxidation Catalyst
Pt	Platinum
RNC	Reactive nitrogen compounds
SCR	Selective catalytic reduction
SI	Spark ignition
UN-ECE	United Nations Economic Commission for Europe
WLTP	World Light Duty Vehicles Test Procedure

Appendix 1

BOSMAL®

Bielsko-Biała, Poland

2nd International Exhaust Emissions Symposium
26/27 May 2011, BOSMAL, Bielsko-Biała, Poland
The Symposium Programme

Thursday, 26th May 2011

Symposium opening

- Dr Antoni Swiatek, CEO, BOSMAL Automotive R&D Institute

Keynote lecture

- Prof. Giovanni Cipolla, Director of IARE (GM/PoliTo Institute for Automotive Research & Education), Politecnico di Torino, Italy - **Driving of Low CO_2 Future**

Session 1 - Emissions legislation and test method development

Chair: Dr Piotr Bielaczyc

- Kurt Engeljehringer, AVL, Austria - **Automotive Emission Testing and Certification - Past, Present and Future**
- Les Hill, HORIBA, UK- **Implications of Future Emissions Legislation on Emissions and Fuel Economy Testing Procedures and Equipment**
- Dr Piotr Bielaczyc, BOSMAL Automotive R&D Institute, Poland - **IC Engine Test Method Development Regarding Emissions, Alternative Fuels, Lubricants and Future Trends**

Opening Ceremony of BOSMAL's new Engine Testing Cells

Session 2 - PM and NOx emissions test method development

Chair: Prof. Jorma Keskinen

- Douglas Trombley, Dr Andrea De Filippo, GM Powertrain, USA/Italy - **GM activities on Particle Number and Size Emissions from Diesel Engines & Vehicles**
- Prof. Jorma Keskinen, Dr Topi Rönkkö, Tampere University of Technology, Finland - **The effect of technology on diesel exhaust particle properties**
- Dr Mattias Kutter, Dr Werner Moser, Eco Physics, Switzerland - **Challenges in NOx and NH_3 Emission Measurement**

Session 3 - Catalyst Technology Development for CI and SI engines

Chair: Prof. Giovanni Cipolla

- Dirk Bosteels, John May, AECC, Belgium - **Emissions Control Technologies to meet Current and Future European Vehicle Emissions Legislation**
- Pankaj Dhingra, CEO, Nanostellar, USA - **Rational Design - a Powerful Set of Tools for Developing Innovative New Materials for Emissions Control Systems**
- Dr Gerardo Carelli, I. Lappas, C. Reith, Umicore, Italy/Germany - **Heavy Duty Engines Catalyst Technology for On Road and Off Road Applications**
- Dr Toni Kinnunen, Dr Kauko Kallinen, Dr Teuvo Maunula, Ecocat, Finland - **Alternative fuels – optimization of catalysts**
- Juergen Pilsl, Huber Group, Germany - **NOx- Determination in Diesel SCR-Systems by Neural Networks**

Friday, 27th May 2011

Keynote lecture

- Dr Gotthard Rainer, Vice President, Advanced Simulation Technologies, AVL, Austria - **Unified Tool Platform for Powertrain Development**

Session 4 - Fuel and engine oil development

Chair: Prof. Jerzy Merkisz

- Gianni Cecconello, Petronas, Italy - **Lubricant Development Process for CO_2 reduction**
- Salvatore Florio, Leonardo Pellegrini, Elena Rebesco, Eni, Italy - **Influence of Chemical Composition of Surrogate Diesel Fuels on Regulated Emissions**
- Catherine Maillard, Shell, UK - **Next Generation Fuels in the Transport Sector**
- Prof. Miroslaw Wyszynski, Birmingham University, UK - **Properties and engine testing of new biofuels and the low temperature AVL transient test facilities at Birmingham**
- Dr Andrzej Szczotka, BOSMAL Automotive R&D Institute, Poland - **The evolution of automotive fuels and fuel test methods in response to emissions and GHG legislation**

- **Symposium summary & closing ceremony**

Prof. Jerzy Merkisz, Chairman of the Advisory & Scientific Boards, BOSMAL Automotive R&D Institute

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