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2007 Fuels and Emissions Conference

A SELECTIVE REPORT ON THE SAE INTERNATIONAL CONFERENCE

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The Society of Automotive Engineers (SAE) Fuels and Emissions Conference was held from 23rd to 25th January 2007 in Cape Town, South Africa. The main conference sponsor was Sasol Ltd. It is the first time the SAE have held a conference in South Africa. It was pointed out that this is an important event for Africa, because it brings together engineers, scientists and suppliers for a global discussion on the latest evolving technologies in fuels and lubricants, as well as future emissions controls.

The conference centred on a keynote lecture by an eminent speaker on each morning, followed by two or three parallel sessions of technical presentations. These sessions covered a wide array of topics, such as alternative and potential new fuels, hydrogen, engine technology, emissions control, and measurement and calibration techniques. Platinum group metals (pgms) feature prominently in these areas, for applications from fuel reforming to emissions control catalysis. The keynote lectures are described in some detail here, along with a brief summary of some of the other work from the technical sessions. Technical paper numbers are given in parentheses following the title of each paper, and are available through the SAE (1).

Synthetic Fuels

Johannes Botha (Sasol Ltd, South Africa) got the proceedings underway with a keynote address on 'Synthetic Fuels'. The presentation concentrated on coal/gas/biomass-to-liquid technologies (CTL, GTL, BTL, respectively) from the standpoint of Sasol, covering drivers, history, technological advances and future importance. The use of coal as a feedstock has been historically important to South Africa for a number of reasons, not least because it has large coal reserves; there is also the desire to become less dependent on imported oil. Today, 30% of transportation fuels in South Africa (equivalent to 205,000 barrels per day (bpd)) are supplied by coal- or natural gas-fed facilities, such as Sasol's GTL operations. Coal may well also be the fuel of the future in other countries and regions, such as China, India, the U.S.A. and Russia, where a large proportion of fossil fuel reserves are as coal. The environmental benefits of using synthetic fuels were highlighted: synthetic fuels burn much more cleanly than do conventional fuels derived from crude oil, resulting in lower particulate and sulfur emissions. Greenhouse gas emissions are also lower than with crude oil for BTL technology, and comparable to those with crude oil for GTL technology. The potential future importance of synthetic fuels produced by the CTL, GTL and BTL processes is evident from the number of plants currently under construction or in the planning stages in all the world's inhabited continents. However, even if all the current probable and possible plants were built, the amount of synthetic fuel produced would still be only a fraction of worldwide demand.

The exhaust emissions advantages of diesel fuels derived from GTL technology were also highlighted by Monica Larsson and Ingemar Denbratt (Chalmers University of Technology, Sweden): 'An Experimental Investigation of Fischer-Tropsch Fuels in a Light-Duty Diesel Engine' (2007-01-0030). Two synthetic diesel fuels were tested, and their performance compared with that of conventional diesel fuel in a single-cylinder research engine, where the effect of injection timing and exhaust gas recirculation could be studied. Lower carbon monoxide (CO), total hydrocarbon (THC) and soot emissions were seen with the synthetic GTL diesel. The improved particulate matter (PM) and hydrocarbon emissions with synthetic diesel were also confirmed by Taku Tsujimura and coworkers (National Institute of Advanced Industrial Science and Technology (AIST), Japan), in a joint study with the Mitsubishi Corporation: 'A Study of PM

Emission Characteristics of Diesel Vehicle Fueled with GTL' (2007-01-0028). Furthermore, Paul Schaberg and colleagues (Sasol Ltd), in a study with SasolChevron Consulting Ltd and DaimlerChrysler AG, found that very low NOx emissions were achievable with GTL diesel fuel, when used in combination with some economically and technologically viable engine hardware changes: 'HSDI Diesel Engine Optimisation for GTL Diesel Fuel' (2007-01-0027).

Future Fuels and Technologies

Day two began with a keynote lecture by Hans-Otto Herrmann (DaimlerChrysler AG, Germany). The lecture, entitled 'The Role of Future Fuels for Sustainable Mobility', was concerned with addressing the challenges for future mobility and identifying the major stakeholders in finding solutions to pollution problems, before concentrating on the role of the automotive industry. Five chronological steps toward "Energy for the future" were demonstrated from a DaimlerChrysler standpoint:

(a) optimisation of combustion engines
(b) improvement of conventional fuels
(c) CO_2-neutral biofuels
(d) hybrid vehicles
(e) fuel cell technology.

The immediate challenge is to improve internal combustion engine performance, so that diesel emissions can be reduced to the very low levels associated with gasoline engines, while gasoline engine fuel consumption is improved to match that of diesel engines. This is now becoming a reality in Europe due to such technical advances as exhaust gas recirculation (EGR), improved fuel quality, on-board diagnostics (OBD), and pgm-containing emissions control devices (e.g. filter systems, NOx traps and selective catalytic reduction (SCR) systems). (While SCR systems are not usually pgm-based, SCR systems contain pgms for the purpose of ammonia slip control.) However, the example diesel vehicle shown in the lecture relied on a NOx trap for NOx control. It is therefore not available in the U.S.A., because ultra-low sulfur diesel (ULSD) fuel is required. Herrmann's lecture addressed DaimlerChrysler's approach to aftertreatment, and two systems were presented: Bluetec I and Bluetec II (Figure 1). In Bluetec I, most of the NOx control is performed by the NOx trap component. However, when trap regeneration occurs, under rich engine conditions, some ammonia is produced; this can be stored on the SCR catalyst and used for some additional NOx removal activity. This system relies on sulfur-free fuel and has no urea injection.

The Bluetec II system is more expensive than Bluetec I, and employs urea injection (Adblue) in front of the SCR catalyst to control the NOx emissions. Depending on which system is chosen, DaimlerChrysler can achieve 50 to 80% NOx removal. The lecture also included some discussion on fuels, including detailing the importance of improving conventional fuel quality. It went on to consider the diversification of fuel types, starting with synthetic fuels such as those produced by Sasol, then leading on to biofuels, and in the future, hydrogen produced by renewable energy. By this route, fuels become progressively cleaner, in terms

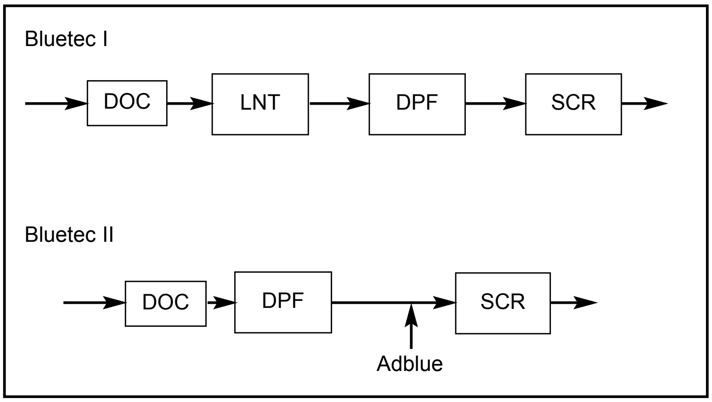

Fig. 1 Schematic of DaimlerChrysler's Bluetec I and Bluetec II systems. DOC = diesel oxidation catalyst; LNT = lean NOx trap; DPF = diesel particulate filter; SCR = selective catalytic reduction; Adblue = urea injection

of both PM/NOx and CO_2 emissions. Herrmann pointed out that GTL synthetic fuels can give some emissions advantages with no engine modifications, but by modifying and adapting an engine for GTL fuel it may be possible to achieve 70% NOx emissions reduction without a NOx removal device, as compared with the baseline emissions for a Euro IV engine. Therefore, the use of GTL fuels is a possible approach to meeting future stringent emissions legislation, though the scenario described requires dedicated GTL engines and GTL fuels which are both readily available and economically viable. Biodiesel was briefly discussed, particularly jatropha biodiesel in India (discussed in detail later). Biodiesel is currently two to three times more expensive than conventional diesel fuels, but its impact on CO_2 emissions is potentially huge. Finally, the route to fuel cell vehicles was outlined, with hybrid technology as an interim step, and this is expected to be especially important in Japan and the U.S.A. However, Herrmann was concerned that, despite the potential advantages of fuel cell vehicles, including zero emissions, low noise and high efficiency, there are still a number of challenges to be overcome.

Other measures discussed by Herrmann as important for sustainable mobility included: contributions from policy makers, such as improved road and traffic management and traffic light synchronisation; from consumers and drivers, for example, 20% fuel consumption savings can be made by adaptive driving behaviour, efficient acceleration and optimised gear shifting; and the oil industry, including optimised fuels, renewable fuels (BTL), and a hydrogen infrastructure. Herrmann's conclusion was that, for optimum results, interaction between the oil and auto industries is necessary.

Catalysts and Converter Technologies

Louise Arnold and coworkers (Johnson Matthey PLC, U.K.) presented: 'Development and Application of New Low Rhodium Three-Way Catalyst Technology' (2007-01-0046). This is important because the rhodium price has increased enormously recently, while 83% of world rhodium usage is in three-way catalysts (TWCs). By employing advanced washcoat formulations and coating techniques, it has been possible to reduce rhodium loadings to 1 g ft^{-3} (from 5 g ft^{-3}), while still meeting Euro IV and Euro V (2) emissions limits, even after extended engine-bench ageing. Guillaume Brecq *et al.* (Gaz de France), in a study with the Université Pierre et Marie Curie: 'Comparative Study of Natural Gas Vehicles Commercial Catalysts in Monolithic Form' (2007-01-0039), employed commercial TWC systems for emissions control in natural gas vehicles (NGVs); all the TWCs tested were efficient for CO and NOx treatment. However, methane conversion proved to be a problem, with high light-off temperatures observed, typically in the range 315 to 400ºC. Also from Johnson Matthey, Andrew York and coworkers presented: 'Modeling of the Catalyzed Continuously Regenerating Diesel Particulate Filter (CCR-DPF) System: Model Development and Passive Regeneration Studies' (2007-01-0043). The model showed that the CCR-DPF (Catalysed CRT® or CCRT®) can operate successfully even over low-temperature drive cycles or with challenging NOx/PM ratios; the CCR-DPF is therefore applicable to a wider range of more challenging diesel applications than the CRT®. The model can be used to design the system and choose which is most suitable for a particular application.

Bernard Bouteiller and coworkers (Saint-Gobain and Université d'Orléans, France), in: 'One Dimensional Backpressure Model for Asymmetrical Cells DPF' (2007-01-0045), demonstrated that they had adapted a one-dimensional DPF model to operate with new asymmetric cell geometry DPF systems. Furthermore, Achim Heibel and Rajesh Bhargava (Corning Inc, U.S.A.), in: 'Advanced Diesel Particulate Filter Design for Lifetime Pressure Drop Solution in Light Duty Applications' (2007-01-0042), showed that these asymmetrical cell technology (ACT) DPFs show a 65% higher ash capacity for the same pressure drop in engine dynamometer tests, when compared with standard cell design substrates. Thus, using ACT it is possible to design filter systems with a lower lifetime pressure drop or longer service intervals for a particulate filter system of the same size. Frank-Walter Schütze and coworkers (Umicore AG and Co KG, Germany), in: 'Challenges for the Future

Diesel Engines Exhaust Gas Aftertreatment System' (2007-01-0040), briefly reviewed the importance of thermally stable catalysts for future diesel engine aftertreatment systems. The benefits of early integration of catalyst development and selection in the engine development process for optimum emissions reduction performance was highlighted. Finally in this section, Kevin Lang and Wai Cheng (Massachusetts Institute of Technology (MIT), U.S.A.) addressed the problem of fast catalyst light-off in a spark ignition engine: 'A Novel Strategy for Fast Catalyst Light-Off Without the Use of an Air Pump' (2007-01-0044). This is achievable using an exhaust air pump; however, the novel approach reported by Lang was to operate the engine on start-up using only three of the four cylinders, running under rich conditions, while the unused fourth cylinder is used as a 'pump' to supply air to the exhaust manifold. This air can then oxidise the products of incomplete combustion emitted from the engine, and hence supply a large amount of heat to the catalyst to accelerate its warm-up.

Biodiesel

On the final day, the keynote address was delivered by Manohar K. Chaudhari (Automotive Research Association of India), to highlight the current status of biodiesel in India, as well as alternative fuels such as ethanol and hydrogen-compressed natural gas (H_2-CNG). The Indian automotive industry is expected to grow enormously over the next 10 years. There is concern over fuel supply/demand in India. By 2016 India is expected to account for around 5% of the world's oil consumption, with 70% of the oil consumed being imported. The use of biodiesel as an alternative fuel is a reality in India; its potential has been widely surveyed and a number of feedstocks tested. India's tropical climate, which favours the growth of crops, combined with huge areas of waste land and cheap labour make India a prime candidate for biodiesel use. Jatropha is the most environmentally and economically feasible biofuel crop in India, and can theoretically provide 10% of its diesel requirements; this is ideal for use in a diesel blend. This will have a significant impact on the rural economy, and concerns over the environmental impact of growing large amounts of crops are currently being addressed. On the other hand, biodiesel provides some emissions benefits, compared to standard diesel, with lower CO, THC and PM emissions. In addition to biodiesel blends, compressed natural gas (CNG) and liquefied petroleum gas (LPG) are becoming more important in India. For example, in 1998 Delhi was listed as one of the 10 most polluted cities in the world; 70% of the pollution was from vehicles and the PM level was 10 times the legal limit. The use of CNG in Delhi's vehicles has resulted in much better air quality, and a CNG infrastructure is growing quickly there and in Mumbai, with plans to expand to a further 28 cities. This is leading to growing consumer confidence in CNG, even though it is necessary to tune engines for CNG use, otherwise increased NOx emissions result. LPG use is also growing, but at a much slower rate than CNG. Other fuels mentioned by Chaudhari as potential alternatives in India were 5% ethanol/gasoline blends and 5 to 20% H_2-CNG, though little detail on their application was given. Looking into the future, the use of hydrogen and fuel cells was proposed, with one million vehicles to be in operation by 2020.

Rapeseed methylester (RME) biodiesel was tested on a heavy-duty diesel engine by Hu Li and coworkers (University of Leeds, U.K. and Universidad Nacional de Asuncion, Paraguay): 'Study of Emission and Combustion Characteristics of RME B100 Biodiesel from a Heavy Duty DI Diesel Engine' (2007-01-0074). The emissions were compared with those from conventional diesel, and a significant reduction in PM, volatile organic fraction (VOF), CO and THC was observed. This was confirmed by Sathaporn Chuepeng and coworkers (University of Birmingham, U.K.), in collaboration with Jaguar Cars Ltd, U.K.: 'A Study of Quantitative Impact on Emissions of High Proportion RME-Based Biodiesel Blends' (2007-01-0072). They varied the proportion of biodiesel contained in diesel blends, and found that the amount of biodiesel affected the emissions: increased NOx was observed, but the use of high RME blends resulted in significant reduction in PM. Finally, Delanie Lamprecht (Sasol Ltd), in: 'Elastomer Compatibility of Blends of Biodiesel and Fischer-Tropsch Diesel' (2007-01-0029), investigated the effect of the use of biodiesel on elastomers typically used in sealing applications in engines. It is known that neat biodiesel, and high percentage blends, can degrade certain types of elastomer over time. Using standard nitrile-butadiene rubber (NBR), it was found that elastomer compatibility should not be a problem with the 20% biodiesel/GTL synthetic diesel blend employed in the study.

Other Oxygenated Fuels

A number of presentations addressed other oxygenated fuels. For example, Mitsuharu Oguma and Shinichi Goto (AIST, Japan) presented the successful operation of a medium duty truck on public roads using dimethyether (DME) fuel: 'Evaluation of Medium Duty DME Truck Performances – Field Test Results and PM Characteristics' (2007-01-0032). Jamie Turner *et al.* (Lotus Engineering, U.K.), in: 'Alcohol-Based Fuels in High Performance Engines' (2007-01-0056), discussed the operation of a high-speed sports car engine running on an ethanol-based fuel (ethanol containing 15% gasoline by volume: E85). Some engine modifications were required for optimised running, for example, to injectors. The results of the study were applied to a Lotus Exige 265E sports car: better CO_2 emissions, compared with gasoline, were observed, as well as excellent performance. Also, Miloslaw Kozak and coworkers (Poznan University of Technology and BOSMAL Automotive R&D Centre, Poland) presented an investigation of the effect of dosing Euro V diesel fuels with 5% of an oxygenated fuel additive on the exhaust emissions from a Euro IV passenger car: 'The Influence of Synthetic Oxygenates on Euro IV Diesel Passenger Car Exhaust Emissions' (2007-01-0069). The general conclusion was that the addition of some oxygenates, such as triethylene glycol dimethylether, can significantly reduce the emissions of CO, THC and PM, but with slightly higher NOx emissions.

Concluding Remarks

Summarising, the general theme running through the entire conference was the well-known problem of ensuring a secure and adequate fuel supply, which is only likely to worsen in the future. Therefore, a wider range of fuels will become available, necessitating improved engine design and aftertreatment devices that operate with a wide range of fuels. In addition, reducing emissions will continue to be a challenge.

The obvious effect of this will be the future need for more and improved pgm and other catalysts for a whole host of applications. For example, enormous amounts of catalysts for use in gas-to-liquids, coal-to-liquids and biomass-to-liquids plants will be required to bring the extra synthetic fuels capacity to the levels desired, as discussed in the conference. Furthermore, biodiesel manufacture, for example by transesterification, will become more important. The knock-on effect of this wide range of new fuels on emissions control will need to be studied and understood: for example, what will be the effect of using biodiesel on the efficacy of a particulate filter in controlling emissions of particulate matter? Finally, in the long term, the use of hydrogen as an alternative fuel will place demands on materials manufacturers. This will be due not only to the requirements of hydrogen production, using alternatives to fossil fuels as feedstocks, together with new catalyst technologies, but also because of the need for efficient and high-capacity hydrogen storage media.

References

1 2007 Fuels and Emissions Conference, South Africa, Technical Papers, SAE, Warrendale, PA, U.S.A.; http://www.sae.org/servlets/PaperEvents?OBJECT_TYPE=PaperEventsInfo&PAGE=getPaperTopics&GEN_NUM=144556

2 For information on the proposed Euro V limits see: 'Clean cars: Commission proposes to reduce emissions', Europa press releases, Brussels, 21/12/2005, Reference IP/05/1660; http://europa.eu/rapid/pressReleasesAction.do?reference=IP/05/1660&format=HTML&aged=0&language=EN&guiLanguage=en

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