Abstracts

Session 8 – Diesel Engine Development and Durability

STATE-OF-THE-ART AND EMERGING TRUCK ENGINE TECHNOLOGIES FOR OPTIMIZED PERFORMANCE, EMISSIONS, AND LIFE-CYCLE COSTING

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ABSTRACT

The challenge for truck engine product engineering is and will be not only to fulfill increasingly stringent emission requirements, but also to maintain or improve the engine's economical viability as the powerplant that is the backbone of our economy. As emission limit values are to be reduced in big steps, continuous improvement is not enough but technological quantum leaps are necessary. In the past, the introduction and refinement of electronic control of all major engine functions have been such a quantum leap required to make full use of parameter optimization.

The next big step forward will be exhaust aftertreatment, which is successfully established since many years on Otto-cycle engines. The introduction of exhaust aftertreatment especially for diesel engines for commercial vehicles is a much more demanding task, but the limit values to be met starting in the 2005-2007 timeframe in Europe, the U.S.A., and Japan require this step and the engine industry is able to implement the new technology if all stakeholders support the necessary decisions.

One decision has already been taken: the reduction of sulfur in diesel fuel. This is comparable to the elimination of lead in gasoline as a prerequisite for the three-way catalyst. Now we have the chance to optimize ecology and economy of the diesel engine simultaneously by taking the decision to provide an additional infrastructure for a NO_x reduction agent needed for the introduction of the selective catalytic reduction technology, which is already implemented in electric power generation. This requires some effort, but the costs are significantly below the gains in fuel efficiency in comparison to other technologies. After long discussions, this decision has been taken in Europe and is supported by all truck and engine manufacturers. The necessary logistic support will be in place when it will be needed in 2005.

For the United States, the decision has to be taken this year in order to have the infrastructure available in 2007. It will enable the global engine industry to focus their R & D budgets on one direction not only for 2007 but for the years beyond 2010 with the best benefit for the environment, the customers, and the industry.

RECENT DEVELOPMENTS IN BMW´S DIESEL ENGINE TECHNOLOGY

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ABSTRACT

In Europe, diesel engines have begun to play a very significant role in the luxury segment of the automotive market. By reengineering the 6- and 8-cylinder engines for the new 7 Series, BMW again succeeded in significantly improving the customer-relevant product characteristics. The advanced engine technology used has also laid the foundation for meeting the more stringent emission requirements of the future.

Improved combustion processes, highly flexible injection systems, and high-performance exhaust aftertreatment are key elements in further reducing emissions. In order to allow manufactures to make a long term commitment to this technology for this market, there must be a holistic approach when considering the environmental benefits of diesel engines vis-à-vis their overall contribution to energy independence and maintaining individual mobility.

DEVELOPMENT OF SIMULTANEOUS REDUCTION SYSTEM FOR NO_X AND PARTICULATE MATTER FROM A DIESEL ENGINE

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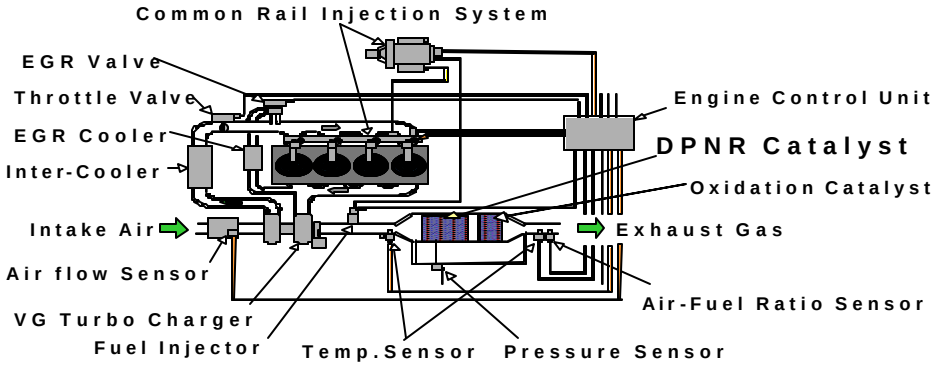
ABSTRACT

Toyota has developed a simultaneous reduction system for NO_x and particulate matter from a diesel engine (DPNR - Diesel Particulate and NO_x Reduction system) and tested it for various applications. We have verified that the DPNR has a high potential for realizing clean diesel engine use for various market segments, such as passenger vehicles in the European market and light-duty trucks in the Japanese market.

The key technologies of the system incorporate the following: the DPNR catalyst; common rail fuel injection system to control catalyst bed temperature and air fuel ratio; an electrically controlled exhaust gas recirculation (EGR) system; and exhaust port-or-pipe injector in order to supply rich gas to the DPNR catalyst for NO_x reduction and sulfur discharging.

For the European market, Toyota has carried out a field trial project in which 60 vehicles with the DPNR system installed in 2L TDI have been tested in order to verify its operation and confirm the reliability of the system. In applying the DPNR to light-duty trucks, we have developed the DPNR for 2-ton payload trucks for the Japanese market. In this application, deterioration of the NO_x storage catalyst was a critical issue because of its long traveling distance. For this issue, we conducted extended durability tests on an engine test bed, using 40-ppm and 7-ppm sulfur content diesel fuel. As a result, the Japanese U-LEV (75-percent reduced emission level from Japanese new short-term regulation in Japan D-13 mode) emissions standard could be achieved when using fuel with sulfur content of 7 ppm even after 1,000,000 km.

When considering applications for the U.S. market, in addition to improving the DPNR performance, the quality and specification of diesel in the market are very important in order to meet severe emission targets (i.e., Tier 2 bin 5). That is, the cetane level and aromatics content need to be at least equivalent to the level required in the European and Japanese fuel standards.



PERFORMANCE AND DURABILITY OF PSA PEUGEOT CITROËN'S DIESEL PARTICULATE FILTER SYSTEM ON TAXIS FLEET IN PARIS AREA

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Technologies des Transports

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Aaqius & Aaqius

ABSTRACT

The use of diesel engines has strongly increased during the last years and now represents 40 percent of the sales in Europe and up to 50 percent of the number of cars in circulation fro some countries. This success is linked not only to the economical aspect of the use of such vehicles, but also to the recent technological improvements of these engines. The new technical solutions (high-pressure direct injection, turbocharger, etc.) have indeed allowed the increase of these engine performances while decreasing their fuel consumption, pollutant emissions, and noise level.

From an environment point of view, diesel engines are nevertheless penalized by their particulates and NO_x emissions. The study and the treatment of the particulates, highly criticized for their potential impact on health, are the subject of numerous works of characterizations and developments.

PSA Peugeot Citroën has recently (2000) launched its diesel particulate filter (DPF) technology in several types of vehicles (500,000 vehicles with DFP have been sold today). In order to evaluate the durability of this technology over a long period of time, a study program has been set up by ADEME (French Environmental Agency), IFP Powertrain, PSA Peugeot Citroën, and Taxis G7 (a Parisian taxi company).

The objective is to study the evolution of five taxis and their aftertreatment-system performance over 80,000 km in hard urban-driving conditions, which correspond to the recommended mileage before the first DPF maintenance, as well over 120,000 km, after the DPF maintenance and re-manufacturing. More specifically, the following evaluations are being performed at regular intervals (around 20,000 km): regulated gaseous pollutant emissions on NEDC cycle, particulate emissions, and unregulated pollutant emissions. The results obtained until now have not shown any degradation of the DPF efficiency (more than 90 percent).

This paper presents the methodology set up, and the explanation of the first results obtained. Indeed, a more specific study has shown that most of the aerosols, measured with a scanning mobility particle sizer are composed of liquid fractions, mainly sulfates due to the sulfur coming from the fuel but also from the lubricant. The impact of sulfates stored on the catalyst surface during low-temperature running phases and removed during high-temperature running phases has been also outlined.

COMBINATION OF DIESEL FUEL SYSTEM ARCHITECTURES AND CERIA-BASED FUEL-BORNE CATALYSTS FOR IMPROVEMENT AND SIMPLIFICATION OF THE DIESEL PARTICULATE FILTER SYSTEM IN SERIAL APPLICATIONS

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ABSTRACT

Diesel vehicles have an increasing market share in Europe. To further increase their environmental friendliness, control of particulate emissions is a key topic. Ceria-based fuel-borne catalysts have proven their efficiency to optimize the diesel particulate filter (DPF) efficiency and durability: since the market introduction of the DPF system in serial applications in May 2000 by PSA Peugeot Citröen, more than 500,000 vehicles have been DPF-equipped. Tracking the serial production current situation, several themes for improvement have been identified, including system simplification to limit its total cost as well as an optimized maintenance. The paper presents those upgrades that will be proposed in serial applications, in the near future.

Catalytic activity of ceria-based fuel-borne catalysts has been chemically tuned to meet the compromise between the catalytic activity (reduction in the temperature of soot burn-off and kinetics of DPF regeneration), the temperature peak generated during the DPF regeneration (exotherms of regeneration), and the density of the inorganic ash arising from the fuel-borne catalyst (ash build-up speed). A good compromise is proposed, based on the use of the iron-doped ceria nanoparticles as active catalytic ingredient.

In parallel, dosing strategies of ceria-based fuel-borne catalyst are being developed to match with the proposed evolution in the fuel-borne catalyst for serial applications. New designs of the automatic on-board dosing system are being developed to ensure the global accuracy in the diesel fuel treatment and to limit the maintenance operation for fuel-borne catalyst tank refilling.

Improvement and simplification of the DPF system for serial applications are based on the adaptation and the optimization of several functionalities of the global system. The next step of the "fit for life" target goes necessarily by co-developments between the various functionalities of global DPF system.

DIESEL PARTICULATE FILTER: A SUCCESS FOR FAURECIA EXHAUST SYSTEMS

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ABSTRACT

The presentation is based on more than 3 years experience in mass production of diesel particulate filters (DPF's) for passenger cars in Europe. Faurecia, the technology leader in diesel, has produced over 400,000 DPF's to date – around 70 percent of the present market.

We have developed a number of in-house tests and a wealth of expertise. The function of the DPF system on vehicles is explained, with a focus on the use of the Rhodia's Eolys™ fuel-borne catalyst for DPF regeneration. Several design factors are discussed: substrate and thermal conditions, different operating conditions of the system, linked to the driving profile, and their effect on function and durability. Measurement of thermal stresses on the substrate will be presented along with a method for filter sizing.

Service interval strategies related to filter size and regeneration system are discussed. As a full-system supplier, Faurecia provides a remanufacturing service, and the filter cleaning process used today in Europe is described.

CUMMINS/DOE LIGHT TRUCK DIESEL ENGINE PROGRESS REPORT – 2003

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ABSTRACT

Cummins has studied requirements of the light-truck automotive market in the United States and believes the proposed V-family of engines meets those needs. Design and development of the V-family engine system with DOE's partnership continues. The engine system is a difficult one since the combined requirements of a very fuel-efficient commercial diesel and the performance and sociability requirements of a gasoline engine are needed.

Results show that full EPA Tier 2 Bin 5 emission results are achieved, while also meeting the fuel-economy targets established by DOE. Various results of ongoing system development are shown including air-handling system, noise, and overall vehicle performance. General aftertreatment system design and direction are discussed.

ADVANCED DIESEL ENGINE AND AFTERTREATMENT TECHNOLOGY DEVELOPMENT FOR TIER 2 EMISSIONS

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ABSTRACT

Advanced diesel engine and aftertreatment technologies have been developed for multiple engine and vehicle platforms. Tier 2 (2007 and beyond) emissions levels have been demonstrated for a light-truck vehicle over a FTP 75 test cycle on a vehicle chassis dynamometer. These low-emissions levels are obtained while retaining the fuel-economy advantage characteristic of diesel engines.

The performance and emissions results were achieved by integrating advanced combustion strategies (CLEAN Combustion©) with prototype aftertreatment systems. CLEAN Combustion© allows partial control of exhaust species for aftertreatment integration in addition to simultaneous NO_x and particulate matter reduction. Analytical tools enabled the engine and aftertreatment subsystems development and system integration. The experimental technology development methodology utilized a range of facilities to streamline development of the eventual solution, including utilization of steady-state and transient dynamometer test-beds to simulate chassis dynamometer test cycles.

THE DEVELOPMENT AND ON-ROAD PERFORMANCE AND DURABILITY OF THE FOUR-WAY EMISSION CONTROL SCRT™ SYSTEM

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ABSTRACT

The progressive tightening of the heavy-duty diesel emissions legislation worldwide necessitates the development of pollution control systems capable of enabling engines to meet the incoming legislative requirements. It is clear that to maximize the benefit to the environment, as well as to meet the very stringent future standards (especially the U.S. 2010 limits), systems capable of high simultaneous conversions of all four major pollutants -- carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x) and particulate matter (PM) -- are required.

Very high conversions of CO, HC, and PM are achieved using catalyst-based diesel particulate filter (DPF) systems, such as the Continuously Regenerating Technology, (CTR®) system. High NO_x conversions can be obtained using selective catalytic reduction (SCR) systems, in which ammonia (generated from urea) is used to selectively reduce the NO_x. This paper summarizes the key steps in the development of the four-way SCRT™ system, which comprises the CRT system followed by an SCR system. Engine bench results obtained during the development of this system are presented and discussed.

However, the key to real-world emissions benefit is the actual on-road performance of such systems. It is well established that the CRT system provides very high and durable conversions of CO, HC, and PM so the focus of this current work was to demonstrate the NO_x conversion capability and durability of the SCRT™ system.

The SCRT™ unit was installed on a long-haul truck powered by a 15L Cummins engine. On-road NO_x emissions performance was measured using NO_x sensors located upstream and downstream of the SCRT™ unit. Over an 850-km evaluation route, the average on-road NO_x conversion obtained was up to 82 percent, even when the urea injection quantity was set to give a maximum NO_x conversion of around 85 percent. The durability of the system has also been assessed. Over the course of 150,000 km, no reduction in the NO_x conversion efficiency of the system was observed.

The results presented in this paper demonstrate that the SCRT™ system provides very high on-road NO_x conversion and that the system has excellent durability within real-world applications.

VARIABLE CHARGE MOTION FOR 2007 - 2010 DIESEL ENGINES

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ABSTRACT

The use of direct-injection diesel engines in U.S. heavy-duty pickup truck applications is becoming increasingly popular, with over 250,000 produced in 2002. The high torque density and greatly improved fuel consumption offer distinct advantages to the end user.

The 2007 and 2010 emissions legislation will present another set of technical and product-cost challenges to this type of powertrain. The introduction of efficient aftertreatment systems is mandatory for the success of these engines, but optimization of engine-out emissions is also a critical element.

Much has been written about the improvements in modern fuel systems, which offer great flexibility for the direct introduction of fuel into the cylinder. This paper presents complementary technologies that allow improved air/fuel mixing processes by the additional flexibility of variable in-cylinder charge motion. This approach is particularly applicable to pickup truck engines, which require high BMEP levels across a wide engine speed range to offer the driveability demanded by the consumer.

Design solutions for 2-valve and 4-valve engines are presented along with the potential emissions and fuel consumption benefits.

DIESEL EXHAUST EMISSIONS CONTROL FOR LIGHT-DUTY VEHICLES

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Kenneth Howden

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ABSTRACT

Results of diesel exhaust aftertreatment testing and analysis being conducted at Cummins, Inc., under the FreedomCAR program are presented. Various NO_x adsorber aftertreatment configurations were tested both in steady state and in transient in an effort to reduce the size and cost of the system while minimizing the fuel economy penalty. Both systems, discrete (adsorber and catalyzed particulate filter) and 4-way (NO_x, HC, CO and particulate matter [PM]), were tested.

After various iterations of the catalyst formulation, regeneration strategy, catalyst configurations etc., the aftertreatment components were integrated and optimized for the light-duty application. The optimized exhaust aftertreatment system was first tested under steady-state conditions in the test cell to evaluate performance and optimize regeneration strategy. The system was then tested in the transient test cell and on the chassis dynamometer. Emission results for FTP-75, US06, HWFET, and UDDS cycles were obtained at different test weights.

Encouraging reduction in both NO_x and PM emissions was observed for all test cycles. Even though the engine-out emissions were high for the aggressive US06 cycle, the system-out results were low, meeting the SFTP Tier II targets. Durability testing was conducted for both the discrete and the 4-way system, the results of which are presented in the paper.

A transient adsorber-modeling tool has been developed to predict and further assist in improving system performance. Results for various other issues including low-temperature light-off, engine-managed regeneration, exhaust sulfur management, system integration, and design trade-off, are also presented and discussed.

ANALYTICAL TOOL DEVELOPMENT FOR AFTERTREATMENT SUB-SYSTEMS INTEGRATION

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ABSTRACT

The stringent emissions standards of 2007 and beyond require complex engine, aftertreatment, and vehicle systems with a high degree of subsystem interaction and flexible control solution. This necessitates a system-based approach to technology development, in addition to individual subsystem optimization. Analytical tools can provide an effective means to evaluate and develop such complex technology interaction as well as understand phenomena that are either too expensive or impossible to study with conventional experimental means. The analytical effort can also guide experimental development, and this lead to efficient utilization of available experimental resources.

A suite of analytical models has been developed to represent particulate matter and NO_x aftertreatment subsystems. These models range from computationally inexpensive zero-dimensional models for real-time control applications to computational fluid dynamics (CFD)-based multi-dimen-sional models with detailed temporal and spatial resolution. Such models, in conjunction with well-established engine-modeling tools (such as engine-cycle simulation, engine controls modeling, CFD models of non-combusting and combusting flow, and vehicle models), provide a comprehensive analytical toolbox for complete engine, aftertreatment, and vehicle subsystems development and system integration applications. However, the fidelity of aftertreatment models and application going forward is limited by the lack of fundamental kinetic data.