Particulate Matter and NOx Exhaust Aftertreatment Systems

ABSTRACT

Fleet fuel consumption is greatly reduced through the introduction of the HSDI Diesel engine. The reduced fuel consumption is then reflected in a reduction of CO_2 emissions. The drop in fuel consumption and CO_2 emissions results in a rise in market acceptance, which is also the result of desirable driving performance and greatly improved NVH behavior. The continuously increasing demands on placed on emissions performance also needs to be addressed.

Particulate emissions can be reduced by more than 95% through the use of a diesel particulate trap. However, based on current knowledge, a further, substantial NOx engine out emission reduction for the diesel engine counteracts one of the other goals, which is reduced fuel consumption. Diesel engine compliance with current and future emission standards will require DeNOx technologies. Currently, the NH3-SCR and Lean NOx-Trap (LNT) technologies show the most promise as solutions to achieve the strict NOx standards. While the NH3-SCR technology addresses fuel consumption, the application of an additional reduction component is considered a drawback.

Combining DeNOx technologies with the application DOC/DPF requires a detailed and thorough analysis of exhaust system layout at the very beginning of the engine development cycle. Modeling and simulation of emission and fuel consumption are required to determine the appropriate level of technology needed for various applications.

The following information highlights the simulation results for aftertreatment components such as DOC, DPF, SCR and LNT and how various exhaust system layouts impact emission reduction.

INTRODUCTION

Diesel engine applications have achieved approximately a 50% market share in Europe and are beginning to gain a share of the U.S. market as well. The increased market share is due to its superior fuel economy, excellent driving performance, good acoustics as well as lower exhaust emissions. Advanced technologies such as common-rail, turbocharging, cooled EGR as well as sophisticated control algorithms have helped to increase the overall performance of the modern diesel engine. The particulate filter is becoming a state-of-the- art technology for diesel engines, to promote its image as a clean engine.

However, significant advancements in engine-out emissions as well as exhaust aftertreatment technologies will be required for these engines to achieve the upcoming strict emission standards such as EU6 or U.S. Tier2. Also, the state-of-the-art Diesel Oxidation Catalyst (DOC), the Diesel Particulate Filter (DPF) as well as highly efficient NOx aftertreatment technologies will become mandatory in the future.

Reducing emissions of the nitrogen oxide (NOx) in diesel engines will become one of the greatest developmental challenges for the future. The primary goal of the future is to maintain the diesel engine as a propulsion source with highest fuel economy. Currently, only the lean NOx trap (LNT) and SCR technology present promising capabilities to achieve the required NOx reduction targets. Recently, SCR technology has been marketed for HD applications in Europe and Japan /1/, /2/. It is also slated for market introduction for passenger cars and light-duty trucks in Europe as well as U.S. Europe and Japan have seen the introduction of LNT technology for lean-burn gasoline engines as well as for diesel engines as with the integrated DPNR technology approach made by Toyota /3/. In addition to pure LNT and SCR system concepts, combinations of LNT and SCR technology are currently being published, such as by DaimlerChrysler for the E320 Tier 2 Bin 8 BLUETEC concept /4/ or Honda with regard to their Tier 2 Bin 5 aftertreatment concept /5/, /6/.

Due to the increased interest in the marketplace, the highspeed DI (HSDI) Diesel engine contributes substantially to the decrease of fleet fuel consumption thus in the reduction of CO2. Typically, internal measures taken to decrease exhaust emissions – especially NOx emissions – inherit the drawback of increasing fuel consumption without compensation measures and therefore offset the realization of targets for CO2 emissions. Figure 1 illustrates that a NOx reduction only by internal measure (such as increased EGR or retarded injection timing) is directly related to a significant decrease in fuel consumption. Therefore, optimizing engine-out emissions as well as a integrating optimized, highly efficient aftertreatment technology is crucial towards achieving future stringent emission standards, while retaining excellent fuel economy.

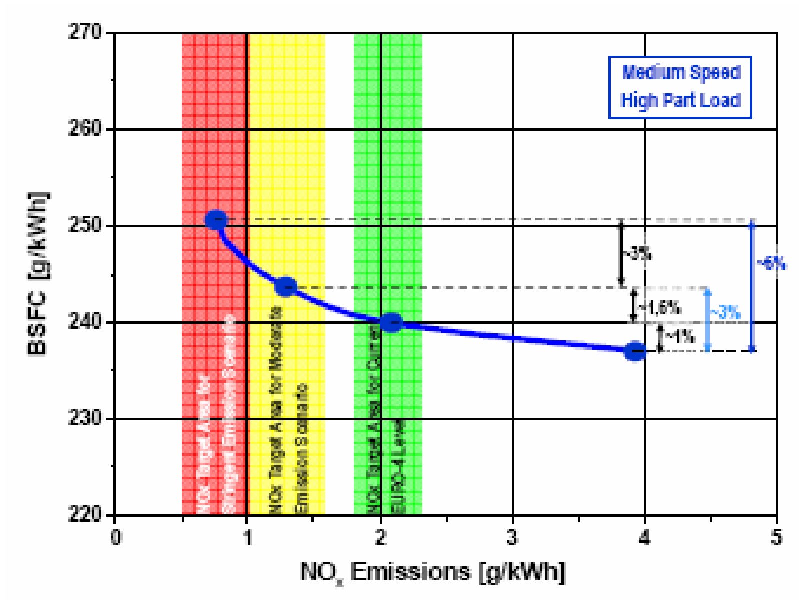

Figure 1: Impact of Conventional Internal NOx Reduction Measures on BSFC

NO_x AFTERTREATMENT TECHNOLOGIES

From today's point of view, only lean NOx trap (LNT) and SCR technology represent promising solutions to achieve future NOx reduction targets. The operating principle as well as the specific pros and cons of the two different technologies will be described in more detail in the following chapters.

<u>LNT technology</u>

The lean NOx trap (LNT) or NOx adsorber catalyst (NAC) is a discontinuously operating aftertreatment technology and is characterized by the following operating modes (Figure 2):

• NOx storage during lean engine operation
• NOx reduction during rich operation phases
• LNT desulfurization under rich conditions and high temperatures

The most challenging operating modes of a LNT under real transient conditions are the rich operation of the Diesel engine, the transitions between lean and rich operation, the desulfurization process as well as control of the LNT system including sensors.

Due to its operating principle the mixture-controlled (quality-controlled) Diesel engine operates with a high amount of excess oxygen, particularly under part-load, which is most relevant especially for light-duty applications. A thorough optimization of the Diesel engine air and fuel management is required in order to reduce the high amount of excess oxygen in the rich operating condition. The removal of oxygen is essential for a successful regeneration of the NOx adsorber catalyst /7/, /8/. Therefore efficient calibration methodologies based on DoE (Design of Experiments) approaches, which consider aspects like oil dilution, component limits, CO/HC-ratio, black smoke emissions, combustion noise, sensor requirements as well as the requirement for smooth maps and map transitions during the calibration process are necessary.

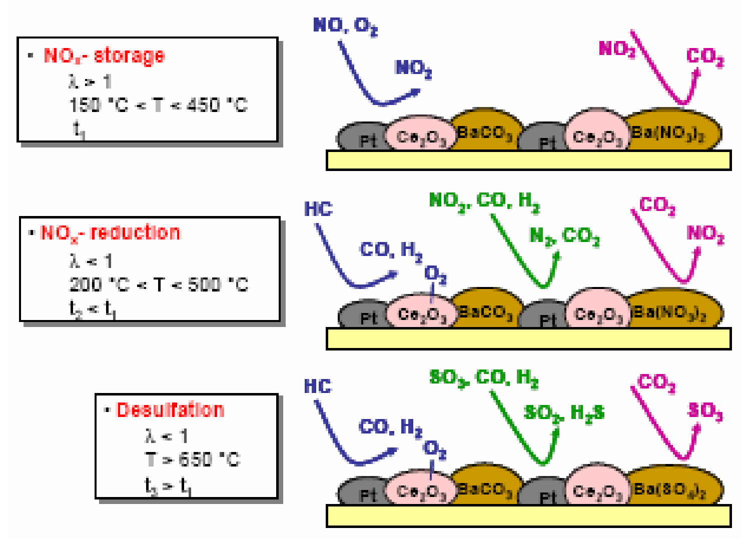

Figure 2: LNT Operating Modes

Furthermore sophisticated and robust control functionalities for the transition between lean and rich engine operation have to be developed and implemented. Besides the definition of a suitable control strategy, an appropriate sensor setup represents an important task. This includes detailed assessment of the sensor signal quality with regard to the demands for LNT system control in order to enable a control strategy targeting for high NOx-conversion efficiencies with lowest fuel consumption penalty and also enabling the detection of thermal aging as well as sulfur poisoning of the LNT /19/.

Efficient desulfurization of current state-of-the-art LNT technologies require high temperatures of at least 650°C in combination with locally rich exhaust gas conditions within the catalyst. To avoid severe thermal aging of the LNT, sophisticated temperature control strategies have to be developed. The major portion of sulphur will be released as H_2S from the LNT during an efficient desulfurization event. Because significant amounts of H_2S cannot be emitted into the atmosphere, a post-oxidation of the H_2S has to be ensured. This can be achieved by a suitable management of oxygen downstream of the LNT; e.g. using a control strategy based on the oxygen storage capacity of any catalyst placed downstream LNT in the exhaust line.

The main challenges of LNT technology can be summarized as follows:

- DeNOx regeneration by engine internal measures in terms of drivability and driver transparency
- Limited DeNOx regeneration operation area
- Sulphur poisoning / desulfurization
- Reliable desulfurization strategy
- Long-term stability / thermal aging
- DeNOx and DeSOx management / complexity of aftertreatment control

SCR Technology

SCR technology is based on reduction of NOx by ammonia, which has to be generated on-board from a suitable reductant (Figure 3), since a transportation of pure ammonia is not desired or advisable. Today the usage of urea/water solution ("Adblue") is most common for SCR systems. Aside of the liquid urea also alternative system concepts based on ammonia carbamate /9/ or solid urea /10/ are under development.

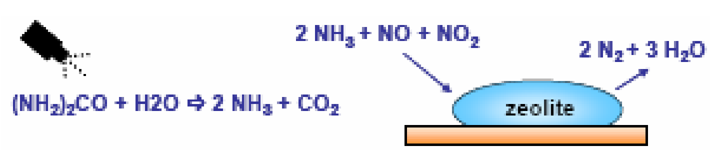

Figure 3: SCR Operating Modes

For passenger car and light-duty applications current concepts are utilizing non-air assist urea injection systems and zeolite type catalysts. For the urea dosing, a reliable operation of the injector and a uniform distribution of urea in the exhaust gas stream has to be achieved under all relevant operating conditions. Furthermore the dependency of low temperature activity on NO_2 content in the exhaust as well as the formation of exhaust components such as N_2O, NH_3, formic acid or iso-cyanuric acid has to be examined carefully. SCR catalysts are characterized by complex processes of ammonia storage, NOx conversion as well as ammonia slip and therefore detailed characterization of the SCR catalyst as well as sophisticated control algorithms are required in order to achieve high NOx conversion rates while maintaining low ammonia slip under transient operating conditions.

The main challenges of SCR technology can be summarized as follows:

- Reliable urea injection
- Uniform ammonia distribution in the exhaust
- NOx neutral SCR-catalyst heating-up strategy
- Dosing strategy
- Ammonia slip
- Vehicle package
- System costs

In the following chapter the specific attributes of SCR and LNT technology considering the arrangement in the exhaust line will be pointed out.

Comparison of LNT and SCR Technology

In order to achieve lowest NOx tailpipe emissions over the desired emission certification test cycles, the NOx conversion efficiency as a function of exhaust temperature is one of the most determining factors. Nevertheless, the specific boundary conditions and limitations of either LNT as well as SCR technology have to be considered in order to allow a fair comparison of the two aftertreatment technologies.

Systems configurations with a DeNOx system placed upstream of a CDPF, which are expected to be more beneficial with regard to NOx reduction performance under lower engine-out temperature conditions, will be more common in light-duty vehicle applications. A more detailed assessment of combined NOx aftertreatment and DPF systems will be performed in the following section

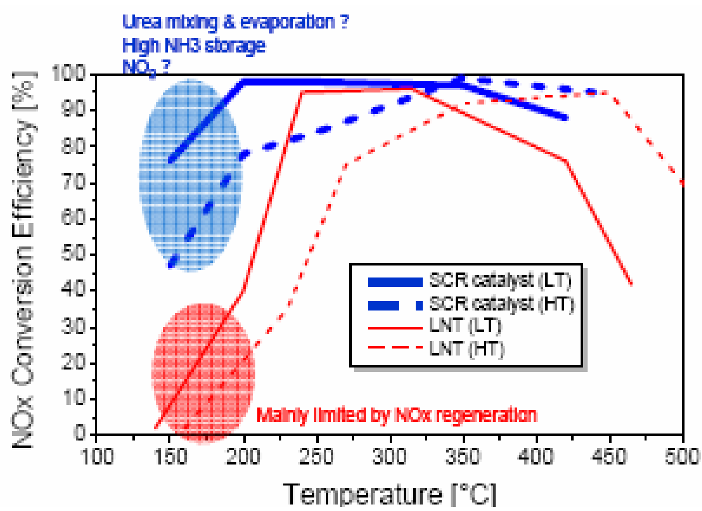

Figure 4: General Comparison of LNT and SCR Technology

Figure 4 shows typical idealized NOx conversion efficiency curves for LNT and SCR systems. For both technologies a more ´low temperature´ oriented coating technology as well as a more ´high temperature´ oriented coating technology are depicted. Considering the temperature dependency of the NOx conversion efficiencies, there is a clear advantage of the SCR technology, as SCR can achieve highest efficiencies at low temperature as well as high temperature areas. However with regard to low temperature activity some important differences between SCR and LNT technology have to be pointed out: High NOx conversion efficiencies can only be achieved using the SCR technology with NO_2 ratios of about 50% in the exhaust as well as significant ammonia storage on the SCR catalyst. This requires a sophisticated control strategy to avoid ammonia slip. Besides that, the evaporation and mixing of the liquid urea/water solution has to be guaranteed under such low exhaust temperature conditions. In contrast to that, the LNT technology is mainly limited with regard to NOx regeneration in the low temperature region, whereas LNT catalysts can store significant amounts of NOx even at low temperatures. This first consideration already points out, that a more detailed assessment of the different technologies is required in order to select a suitable technology for a specific application.

Furthermore it has to be taken into account, that an SCR catalyst cannot be positioned really close-coupled to the turbocharger outlet, as there is always a certain length in the exhaust line required for the urea injection and appropriate mixing. In contrast to that the LNT catalyst can be positioned comparably close-coupled to the turbine outlet position if the vehicle package conditions provide the necessary volume /20,21,22/. Due to this fact the exhaust temperature at SCR catalyst position will always be less compared to the close-coupled LNT position, especially during the warm-up phase after cold start. In Figure 5 this effect is considered by a temperature decrease of about 60°C between SCR and LNT catalyst position. As a result it becomes obvious, that the close-coupled LNT and the under-floor SCR show nearly the same low temperature performance.

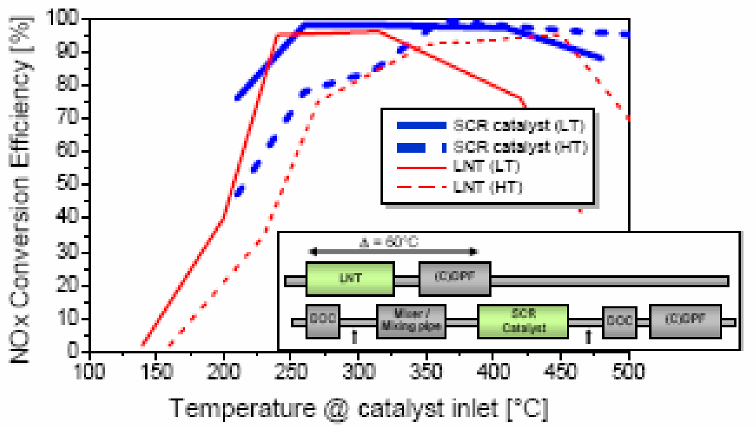

Figure 5: Comparison of LNT and SCR Technology Considering Possible Position in the Exhaust

The following scenario utilizes a split LNT design which is not possible for the SCR system. As pointed out in Figure 6, such an approach provides the potential to extend the operating window of the LNT concept. In this configuration the close-coupled LNT brick is used to convert the NOx in the low temperature area (e.g. over the FTP75), whereas the under-floor LNT provides the required efficiencies under high temperature operating conditions (e.g. the US06). Further improvements might be achieved with an optimized coating for both bricks.

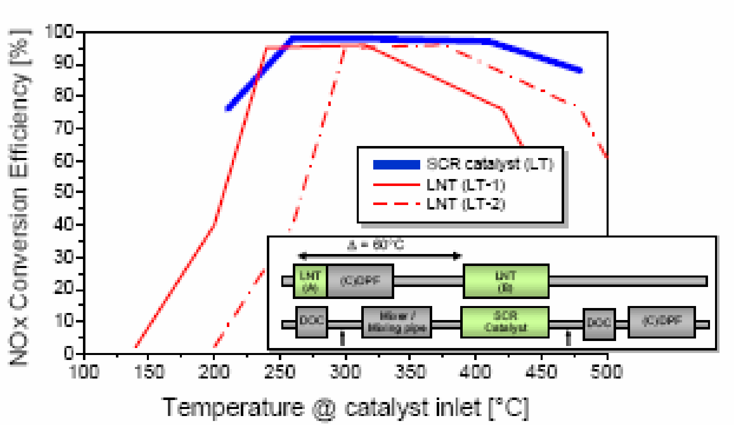

Figure 6: Comparison of LNT and SCR Technology Considering Split of LNT Catalyst into Two Bricks

<u>Heating strategies</u>

Both NOx aftertreatment technologies require a heating strategy in order to improve the low temperature performance and achieve high NOx conversion rates a short time after engine start as well as for low-load operating. These operating conditions are dominant during the European (NEDC) as well as US (FTP75) test cycles. As discussed above, the current state-of-the-art SCR catalysts show comparably low NOx conversion for exhaust temperatures below 200°C and the evaporation of urea and mixture formation in the exhaust remains difficult under these conditions as well. Therefore heating directly after engine start-up is required. In contrast to that, LNT technology mainly requires a heating strategy for DeNOx regeneration in order to provide a sufficient amount of reductants and to avoid excessive HC slip. In this case heating will be mainly required in case of a DeNOx demand. Thus the demands for heating and also the impact on fuel consumption will be completely different for SCR compared to LNT technology. With regard to the overall NOx reduction performance, such heating strategies have to be tailpipe emission neutral in any case and should not contribute to any significant oil dilution.

Based on these fundamental considerations it can be stated, that LNT/SCR catalyst conversion efficiency as a function of temperature cannot be taken as the decisive factor for selection of a suitable NOx aftertreatment technology. Further aspects like the combination of DeNOx and DPF technology, the specific vehicle boundary conditions as well as the desired test cycles have to be taken more into account as well.

An assessment of the different NOx aftertreatment approaches for combined DPF and NOx aftertreatment systems will be performed in the following section. A more detailed comparison of SCR and LNT technologies based on real vehicle measurement data and simulation of temperatures in the exhaust line as well as tailpipe NOx emissions will be presented and discussed later within this paper.

COMBINED PARTICULATE AND NOX AFTERTREATMENT SYSTEMS

For future applications any NOx aftertreatment system will have to be considered in combination with a DPF which can be placed up- or downstream the NOx aftertreatment unit. In contrast to SCR systems, the LNT provides the potential to be placed the in close-coupled location to the engine and/or to split the catalyst into two separate bricks. The different system concepts are depicted in Figure 7.

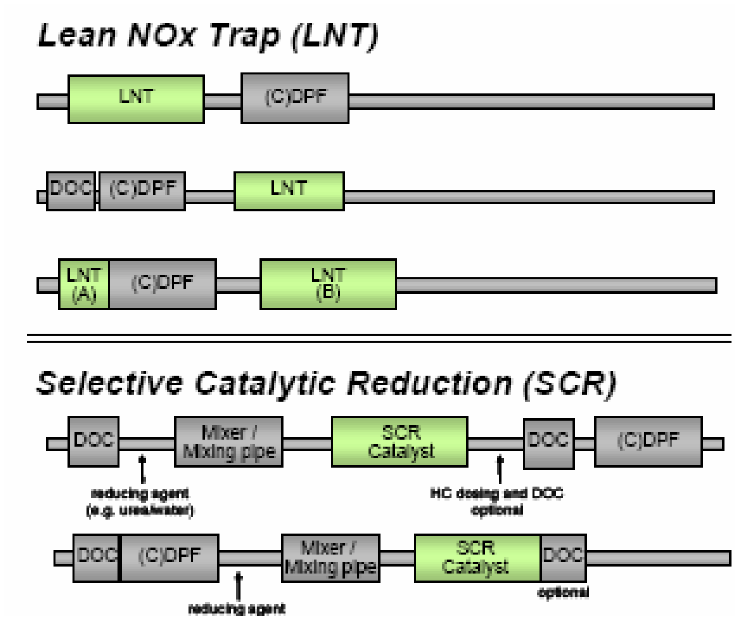

Figure 7: Concepts for Combined DPF and NOx Aftertreatment Systems

Figure 8 shows an assessment of the different concepts with regard to important factors such as:

- Low / high temperature activity
- Effort for active DPF regeneration
- Possibility for soot oxidation by NO_2
- Risk and degree of thermal aging
- Risk of sulfur poisoning / effort for desulfurization
- Potential for NOx reduction during DPF regeneration (with regard to emission adjustment factors)
- Packaging demands / system complexity
- Potential with regard to fuel consumption

It has to be mentioned, that cost as well as infrastructure related issues are not considered in this assessment.

A comparison and assessment of the different system concepts shows, that there are specific pros and cons for each system. Different approaches result in the optimum choice for each individual application. The LNT technology is favored with regard to packaging conditions and therefore for small vehicle applications.

LNT systems have to be considered as bearing significantly higher risk with respect to thermal aging and sulfur poisoning. In general the LNT provides advantages during low temperature operation, whereas a system layout with SCR downstream CDPF is the only concept enabling significant NOx conversion during DPF regenerations. With regard to DPF related aspects, the LNT has to be considered as more beneficial compared to SCR technology. Thereby SCR is the only technology which even can offer potential for fuel consumption benefits in case of limited NOx reduction demands.

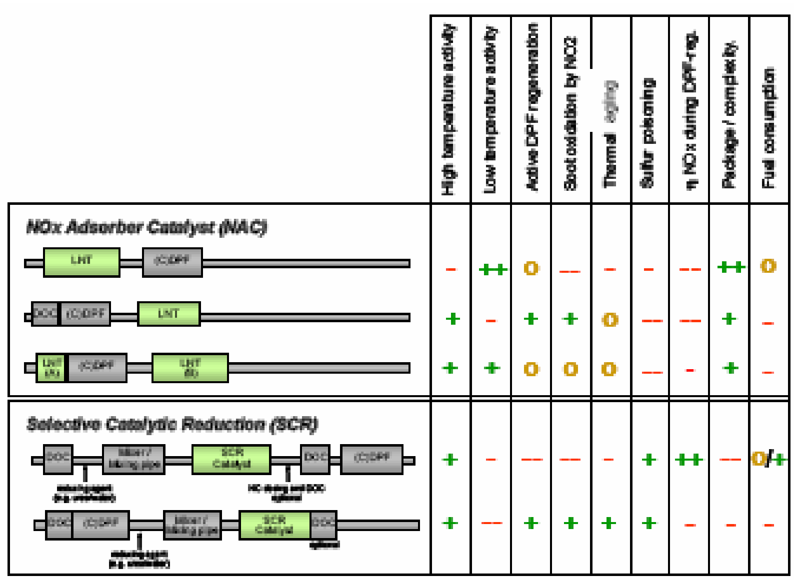

Figure 8: Assessment of Concepts for Combined DPF and NOx Aftertreatment Systems

As a conclusion, any aftertreatment system layout has to be addressed with specific weighting factors for each individual vehicle application.

Once the required NOx conversion rates, the specific boundaries of the legislative test cycles as well as the available space in the vehicle are quantified as decisive factors for the selection of the appropriate NOx aftertreatment technology, the following general trend can be observed: The SCR system is proposed as first choice for large vehicles which require high NOx conversion efficiencies over high vehicle mileage (such as SUVs for US Tier 2 Bin 5 emission standards). The LNT technology is considered as an attractive alternative for smaller vehicles with lower NOx reduction efficiency demand (e.g. for EU5 and post EU5 legislation), see Figure 9. Therefore the selection of the aftertreatment technology as well as exhaust system layout is required for each specific application, which has to be supported by simulation of the exhaust system including temperatures in the exhaust system as well as emissions in different driving cycles.

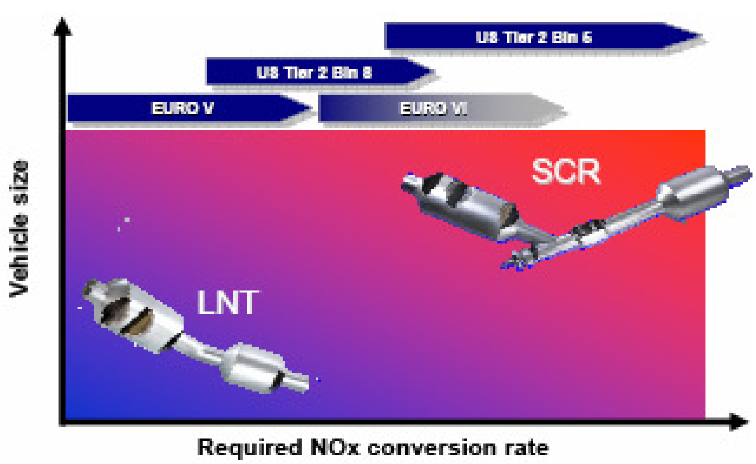

Figure 9: Development Trends for LNT and SCR Technology

SIMULATON APPROACH

In the following a tool for fast simulation of temperatures in the exhaust line as well as vehicle tailpipe emissions will be presented and examples for simulation results will be discussed. Such simulations are considered to be essential with regard to selection of a suitable NOx aftertreatment technology for a specific application, e.g. considering factors such as:

- Vehicle inertia weight
- Engine-out emission profile
- Vehicle packaging situation
- Driving cycle

Simulation of the temperature profile along an exhaust system is critical to calculate the reduction performance of DeNOx systems. The tool used for the calculations within this paper is based on a Simulink model, which provides the possibility for fast and easy abstraction of an exhaust aftertreatment design (Figure 10).

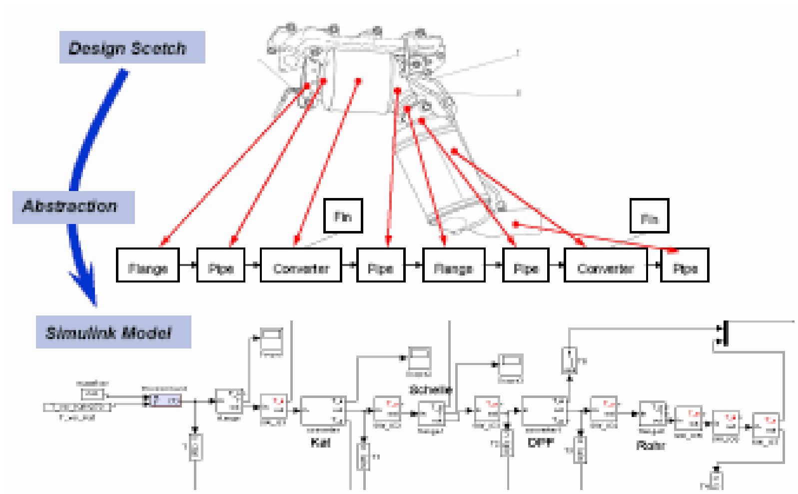

Figure 10: Aftertreatment Simulation - Simulink Temperature Model

Figure 11 depicts the high level of agreement between measured and simulated temperatures along the exhaust systems especially also at the beginning of the FTP75 driving cycle. Heat releases by chemical reactions as well adsorption and desorption of gaseous compounds on the catalyst surface are implemented by parameterized functions dependent on brick temperature and gaseous matrix.

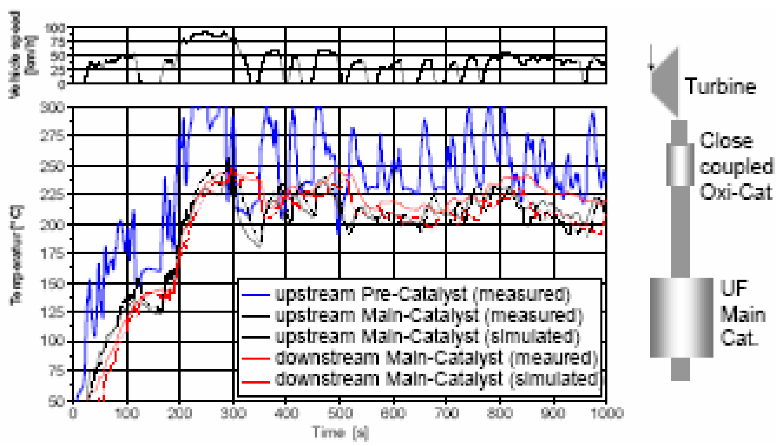

Figure 11: Comparison of Temperature Measurement and Simulation during FTP75-Driving Cycle

Overall each catalytic brick in the exhaust system can be divided in up to 3 zones with different activity. The basis of the simulation for the DeNOx systems are laboratory experiments on FEV's own engineered catalyst test bench. Within this test bench catalyst bricks with a maximum length of 8'' and a diameter of 2" at space velocities between 10,000 and

125,000 1/h can be evaluated with different exhaust gas compositions. It is possible to run validation tests within a temperature range between 25°C and 800°C.

The evaluation results of a typical fresh (de-greened) low temperature LNT are used as an input for the driving cycle simulations, such as NOx storage capacity as a function of temperature, stored NOx and NO_2/NOx ratio /14/, /15/, /17/. The regeneration efficiency for the LNT is simulated as a function of temperature. The management of DeNOx (rich exhaust gas) regeneration is simulated by limitation of maximum fuel consumption penalty (in this case 3.5% are used) and of the maximum amount of stored NOx (in this case 0.3 g are used). The temperature dependent NOx storage capacity of the LNT used for the calculations within this paper is shown in Figure 12.

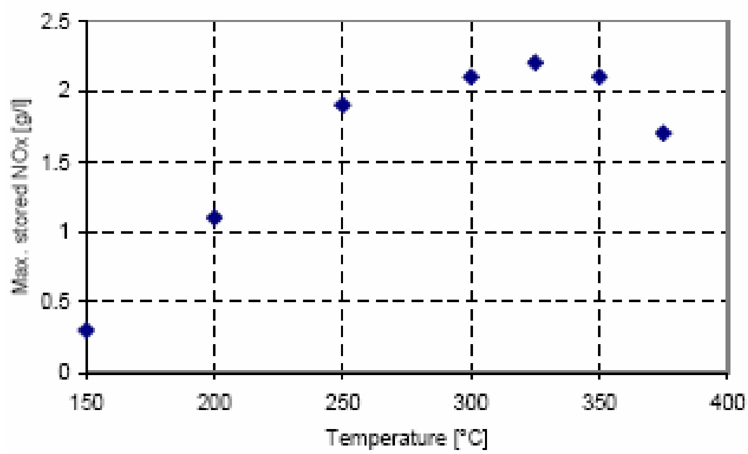

Figure 12: NOx Storage Capacity of the Fresh LNT as a Function of Temperature, SV 50,000 1/h

As an input for the SCR zeolite based catalyst the NH_3 storage behavior as a function of temperature and stored NH_3 as well the NOx conversion efficiency as a function of temperature and stored NH_3 are used in the model simulation /16/, /18/. Figure 13 illustrates the maximum NOx conversion efficiencies at SV 50,000 1/h.

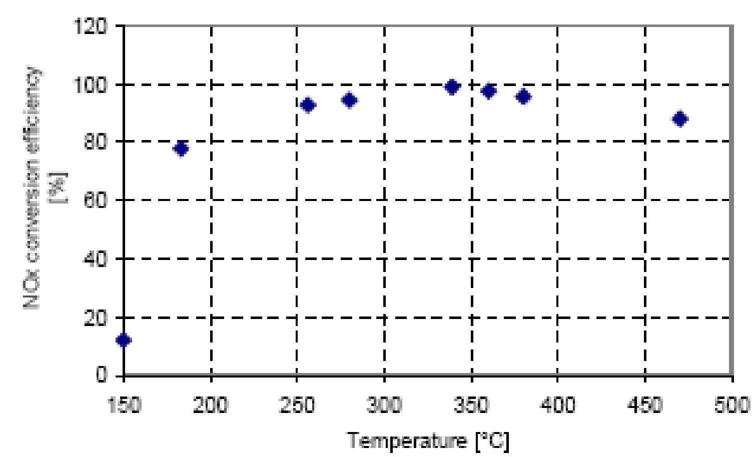

Figure 13: Maximum NOx Conversion Efficiency of the Fresh SCR Catalyst as a Function of Temperature, SV 50,000 1/h, Feed Ratio = 1.0, at max. NH_3 Storage

CONCLUSION

SCR and LNT applications will be developed for market introduction to address increasingly stringent current and future exhaust emission standards. Both technologies provide specific advantages and disadvantages and are based on the following individual parameters:

- Package conditions
- Vehicle size
- Ratio between engine displacement and vehicle mass
- Test cycle

- Required NOx conversion efficiency

One of the technologies or a combination of the two will be the optimum choice for each selected vehicle application. General considerations and simulations for specific applications illustrate that SCR is the preferred technical solution for heavy vehicle applications targeting the U.S. Tier 2 Bin 5 emission limits, whereas LNT technology is an alternative option for lighter vehicles.

A major challenge in the future for LNT technology is desulfurization and thermal aging and thus the long-term stability. Conversely, system packaging in the vehicle including the required SCR catalyst, tank volume and the low temperature activity will be important issues to be solved for SCR technology.

A second considerable challenge remains, which is the issue of the infrastructure for the urea distribution, especially in the U.S. The concerns of the EPA regarding this technology remain and have to be addressed by each manufacturer that attempts to launch a diesel vehicle in the U.S. using SCR exhaust aftertreatment.

REFERENCES

/1/ T. Braun, K.-J. Marquardt, W. Müller : „Erfüllung zukünftiger Abgasgrenzwerte mittels NH3- geregelter SCR-Technologie“, 2. FAD-Konferenz, 10.-11.11.2004, Dresden

/2/ “Nissan launching Quon Truck with Urea-SCR system”, www.dieselnet.com, November 2004

/3/ T. Tanaka : “Simultaneous Reduction of PM and NOx – A New After-Treatment System”; 22nd International Vienna Motor Symposium, 2001

/4/ J. Schommers, C. Enderle, H. Breitbach, et.al.: „World Wide Emission Strategy with BLUETEC for Diesel Passenger Cars“, 15. Aachener Kolloquium Fahrzeug- und Motorentechnik 2006

/5/ N. Satoh, H. Ohno, T. Nakatsuji : A NOx Reduction System Using Ammonia Storage-Selective Catalytic Reduction in Rich and Lean Operation“,15. Aachener Kolloquium Fahrzeug- und Motorentechnik 2006

/6/ „Honda Previews Next-Generation Engine and Power Technologies”, www.greencarcongress.com, 25. September 2006

/7/ S. Pischinger, H.O. Herrmann, V. Scholz, J. Schnitzler : „Untersuchung zum Einsatz eines NOx- Speicherkatalysators im Pkw-Dieselmotor“, 10. Aachener Kolloquium Fahrzeug- und Motorentechnik, 2001

/8/ S. Pischinger, J. Schnitzler, V. Scholz, A. Wiartalla : “Investigation of a NOx-Adsorber Catalyst used with a Passenger Car Diesel Engine”, MTZ Worldwide 03/2003

/9/ M. Krüger, P. Nisius, V. Scholz, A. Wiartalla : „A compact Solid-SCR System for NOx-Reduction in Passenger Cars and Light Duty Trucks“, MTZ Worldwide 06/2003

/10/ W. Müller, A. Herr, S. Käfer, A. Lacroix, E. Jacob: „SCR using solid urea“, 3. Internationales Forum ´Abgas und Partikelemissionen´, Sinsheim, 14./15.9. 2004

/11/ Jacob, E.: Perspektiven der mobilen SCR-Technik, 15. Aachener Kolloquium Fahrzeug- und Motorentechnik 2006

/12/ I. Grißtede, S. Bremm, W. Müller, et.al.: „NOXNachbehandlungssysteme bei Dieselmotoren zur

Serieneinführung in Nordamerika“, 15. Aachener Kolloquium Fahrzeug- und Motorentechnik 2006

/13/ Breitbach, H.; Schön, C.; Leyrer, J.: „Potenzial und Grenzen der Abgasnachbehandlung durch NOx-Speicherkatalysatoren“, 14. Aachener Kolloquium Fahrzeug- und Motorentechnik 2005

/14/ Hepburn, J. S.; Thanasiu, E.; Dobson, D. A.; Watkins, W. L. Experimental and Modelling Investigations of NOx Trap Performance, SAE 962051, SAE 962051, 1996.

/15/ Kobayashi, Yamada, Kayano Study of NOx Trap Reaction by Thermodynamic Calculation, SAE- 970745SP1248, SAE, 1997.

/16/ Waltz, Ch. NOx-Minderung nach dem SCRVerfahren: Untersuchungen zum Einfluß des NO2-Anteils, Diss., Karlsruhe, 2000.

/17/ Ketfi-Cherif, A.; Wissel, D.; Beurthey, St. Modeling and Control of a NOx Trap Catalyst, SAE 2000-01-1199

/18/ Schär, C.M.; Onder, C.H.; Geering, H.P. Control-Oriented Model of an SCR Catalytic, 2004-01-0153, SEA, 2004.

/19/ Tomazic D., Tatur M., Thornton M. “Development of a Diesel Passenger Car Meeting Tier 2 Emissions Levels,” SAE Paper 2004-01-0581, March 2004, Detroit, Michigan.

/20/ Tatur M., Tomazic D. Thornton M. “Tier 2 Useful Life (120,000 miles) Exhaust Emission Results for a NOx Adsorber and Diesel Particle Filter Equipped Light-Duty Diesel Vehicle” SAE Paper 2006-01-0424

/21/ Tatur M., Tomazic D. Thornton M. “Desulfurization Effects on a Light-Duty Diesel Vehicle NOx Adsorber Exhaust Emission Control System” SAE Paper 2006-01-0423

/22/ Tatur M., Tyrer H., Tomazic D., Thornton M. McDonald, J. “Tier 2 Intermediate Useful Life (50,000 miles) and 4000 Mile Supplemental Federal Test Procedure (SFTP) Exhaust Emission Results for a NOx Adsorber and Diesel Particle Filter Equipped Light-Duty Diesel Vehicle,” SAE Paper 2005-01-1755

/23/ Tomazic D., Tatur M., Thornton M. “APBF-DEC NOx Adsorber/DPF Project: Light-Duty Passenger Car Platform,” DEER Paper, August 2003, Newport, Rhode Island.

/24/ McDonald, J. “Progress in the Development of Tier 2 Light-Duty Diesel Vehicles,” SAE Paper 2004-01-1791, March 2004, Detroit, Michigan.

/25/ Thornton M., Tatur M., Tyrer H., Tomazic D. “Full Useful Life (120,000 miles) Exhaust Emission Performance of a NOx Adsorber and Diesel Particle Filter Equipped Passenger Car and Medium-Duty Engine in Conjunction with Ultra Low Sulfur Fuel,” DEER 2005..

CONTACT

Jürgen Schnitzler, FEV Motorentechnik GmbH,
SeniorEngineer Diesel Aftertreatment,
E-Mail: schnitzler@fev.com