

Editorial

Aftertreatment DeNO_x Systems for Future Light Duty Lean-Burned Emission Regulations

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Future light duty vehicles in Europe and the United States are required to be certified, owing to progressively more and more stringent regulations. Improving the exhaust aftertreatment systems must be considered as an integral part of the 21st century vehicle development process. The current potential technologies for NO_x removal, namely, NO_x storage and reduction (NSR) and selective catalytic reduction (SCR), present some limitations and uncertainties for extensive application in light-duty automobiles (Reference [1], Table 3). The cold phase during the startup of the engine is now heavily weighted, and improving the efficiency of the catalyst during this phase is crucial to meeting the low tail-pipe emission targets. The combination of LNT with SCR catalysts is an open strategy for expanding the temperature window for efficient operation and lowering precious metals loads [1].

This Special Issue collects two reviews and four original research papers focused on the challenges for a new generation of DeNO_x catalysts. Diverse aspects on surface chemistry and physics for high efficiency, low-temperature catalysis and after-treatment architectures with low cost, high NO_x removal efficiency, and long durability to meet the ever rigorous NO_x emission are proposed, with the aim of revealing promising signs that NO_x can be reduced significantly below current standards.

The selective catalytic reduction promotes NO_x removal with an externally added reducing agent such as NH₃ (NH₃-SCR). Ammonia is produced upon thermal decomposition of urea-water solution (UWS), which is stored on-board. Urea is injected in the engine exhaust tail-pipe and needs to be homogeneously mixed with the gas stream to boost NO_x removal. The development of compact SCR units located close to the engine, offer a huge potential for NO_x reduction due to higher exhaust temperature and lower warm-up time. However, the close-coupled configuration reduces the available distance for mixing the urea. Hence, the properties of the urea-water solution spray become particularly critical for enhancing NO_x elimination. There are two papers of this special issue devoted to study the injection and mixing of the urea-water solution [2,3]. Kapusta et al. [2] have studied the flow characteristics and have determined the global and local spray parameters for the urea-water solution compared to pure water. They observed differences in almost all considered spray parameters for urea-water solutions with respect to pure water. Thus, the importance of precisely determining the spray parameters of urea-water solutions was highlighted for obtaining reliable results by CFD simulations. On the other hand, Qian et al. [3] focused their study on the design of the urea-water solution nozzle. Using CFD simulation, they proposed and optimized nozzle design that can increase the uniformity of the NH₃ distribution at the inlet face of the SCR from 0.58 (for the standard design) to 0.92. Besides, the optimized design reduced significantly deposit formation at low temperature (250 °C), due to faster urea pyrolysis rate.

The research progress in the last 20 years related to the utilization of WO₃-V₂O₅ based materials as SCR catalyst is reviewed by Zhang et al. [4]. To date, WO₃-V₂O₅/TiO₂ catalysts are the most effective systems to reduce NO_x by NH₃-SCR in large-scale transport



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facilities. Therefore, the effect of WO_3 and V_2O_5 on the catalytic performance must be understood for further research in this area. The effect of the preparation method on the activity and selectivity is first analyzed. Then, attention is paid to the chemical composition of the catalyst. In this section, the role of the support and the addition of doping elements or promoters is studied. Finally, the main deactivation causes are analyzed. Besides, the influence of SO_2 and H_2O in the reaction mixture is addressed.

Lean NO_x trap (LNT), or NO_x storage and reduction (NSR) technology is an effective strategy able to attain high NO_x conversions over a wide range of temperatures without the need of additional on-board reductants. One of the main drawbacks for the practical application of NSR technology is its susceptibility to sulfur poisoning. The as-formed sulfates onto the basic storage sites limit the ability of the catalyst to store NO_x . Periodic high temperature excursions are needed to decompose sulfates, leading to higher fuel consumption and catalyst aging. De Abreu Goes et al. [5] analyze the sulfur poisoning effects on modern Lean NO_x Traps. Al_2O_3 , $\text{Mg}/\text{Al}_2\text{O}_3$, and $\text{Mg}/\text{Ce}/\text{Al}_2\text{O}_3$ mixed with Pt, Pd, and Pt–Pd were used as model catalytic compounds. Micro-flow reactor tests together with DRIFTS was employed to investigate the stability of sulfates. It was observed that the addition of Pd and Mg into the catalyst formulation can improve the desulfation behavior and reduce the temperature at which sulfates are decomposed.

LNT formulation requires high loadings of noble metals to achieve high NO_x removal efficiency, which increases the cost. Recently, perovskites-type oxides (ABO_3) have emerged as alternative to noble metal based formulations. In fact, Onrubia-Calvo et al. [6] present the perovskite-based catalysts as efficient, durable and economical LNT formulation. The activity of the perovskite-based materials is reviewed as a function of the synthesis method and chemical composition. Specifically, the activity of LaCoO_3 and LaMnO_3 perovskites doped with strontium is compared to model Pt-based LNT formulation for the oxidation of NO to NO_2 , which is considered a primary step for NO_x adsorption. The oxidation ability of the perovskites greatly exceeds that of Pt-based LNT formulation. Finally, the effect of the inclusion of SO_2 and H_2O in the feed is analyzed.

The combination of a close-coupled LNT and downstream SCR catalysts is considered crucial to meet the forthcoming NO_x emission regulations. The concept of coupling LNT with SCR is based on producing a controlled amount of NH_3 in the LNT, which is stored on the downstream SCR catalyst to reduce the remaining NO_x . Cortés-Reyes et al. [7] present a combined LNT-SCR system for DeNO_xing in the presence of CO_2 and H_2O . Pt–Ba–K/ Al_2O_3 is used as LNT and small pore size zeolite SAPO-34 with 2% Cu inside the structure as SCR. The lean–rich phase time ratio and H_2 concentration is together analyzed to construct operational maps and determine the optimum operating conditions. Onrubia-Calvo et al. [6] also used perovskite based LNT formulation in combination with 4% Cu-SAPO-34 for enhancing NO_x removal. They confirmed that NO_x and NH_3 conversion are significantly enhanced for the combined NSR-SCR while maintaining high N_2 selectivity.

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