Challenges for Diesel Emissions Aftertreatment Catalysts

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Introduction

Diesel engines have long served the on- and off-highway transportation industries, delivering power for highly transient duty cycles with excellent fuel economy. Current and upcoming air quality regulations are requiring drastic cuts in soot and NO_x emissions from diesel engines in the US and throughout the world. At the start of this year, regulated emissions levels were reduced to below what can be achieved by improvements on in-cylinder combustion. As such, catalytic aftertreatment is required to meet emissions regulations. In 2010, US on-highway regulations will be considerably stricter, requiring even more catalytic aftertreatment to reduce soot and NO_x. Soot reduction is achieved with a diesel particulate filter (DPF), which traps soot during normal operation, and which is subsequently burnt off by periodic high temperature operation. NO_x reduction is achieved either with a lean NO_x trap (LNT) or a selective catalytic reduction (SCR) catalyst system. The LNT catalyst captures NO_x during lean operation, and when the trap is full, the exhaust is cycled to operate rich to release and reduce the trapped NO_x [1]. The SCR catalyst reduces NO_x with ammonia, usually obtained by hydrolysis of urea [2].

Eaton is developing an aftertreatment system which combines the LNT and SCR catalyst functions. The system uses an in-line fuel reformer to convert injected diesel fuel to hydrogen-rich reformate, which is used as the rich component for regenerating the LNT. During the LNT regeneration process, ammonia (NH_3) is produced, which enables further NO_x reduction in a downstream SCR. A DPF is also integrated in the system, providing for full NOx and PM reduction capability [3,4].

Materials and Methods

The hydrocarbon doser and the catalyst elements were tested offline prior to full scale system assembly and testing. Droplet size distribution and spray patterns were measured by laser methods. Droplet vaporization and mixing were modeled in computational fluid dynamics (CFD) simulations. Monolithic reformer, LNT, and SCR catalyst cores were tested by cyclic operation in simulated diesel exhaust in subscale rigs. Reformer lightoff and reformate production were measured by pulsing diesel fuel and monitoring temperatures and effluent composition by FID, MS, and NDIR. LNT catalyst performance was evaluated by lean-rich cycling and measuring the outlet composition with FTIR. SCR catalyst performance was evaluated by cyclic ammonia dosing, and also using FTIR.

Full scale system NO_x reduction performance was verified in engine test cells, with both 2004 compliant (2.5 g/hp-hr) and 2007 compliant (1.2 g/hp-hr) engines. Exhaust measurements were made with FTIR, NDIR, FID, chemiluminscence, and MS.

On-road data was also obtained to show system performance in real world transient operation.

Results and Discussion

Doser and mixer testing and simulations have driven design decisions regarding optimization of hardware and packaging. Subscale and engine testing were used to optimize catalyst formulations and to develop controls algorithms for driving the lean-rich cycling. In engine test cells, NOx reductions of >90% have been achieved with reasonable fuel penalty, with 20% of that reduction provided by the SCR catalyst. On-road controls are used to evaluate the states of the catalyst elements and of the engine to determine the timing and parameters of rich operation.

On-road data will be presented, showing system performance in real world driving. The removal of soot and accumulated sulfur from the DPF and LNT are also demonstrated.

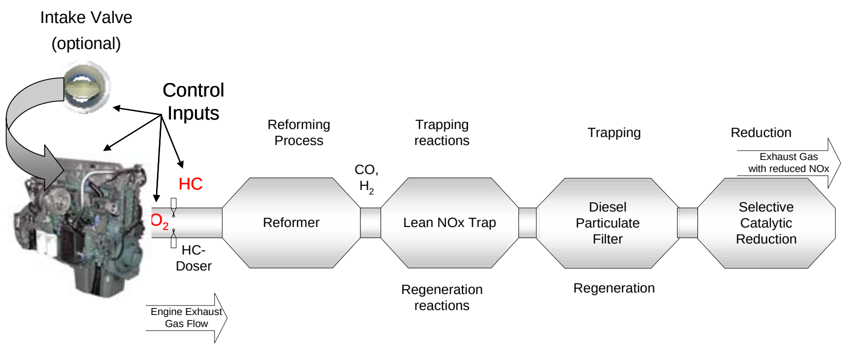

Figure 1. Eaton Aftertreatment System (EAS) layout.

Significance

The EAS presents an alternative to SCR NO_x aftertreatment which does not require additional hardware for carrying and dispensing liquid urea. Current efforts target commercialization of both on- and off-highway applications.

References.

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