

Critical Performance and Durability Parameters of an Integrated Aftertreatment System used to Meet 2007 Tier II Emission Standards

Bradlee J. Stroia, Neal W. Currier, Junhui Li, Roger D. England and John W. Bush
Cummins Inc.

Howard Hess
Johnson Matthey Catalysts

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ABSTRACT

Over the last decade, diesel engine emissions have been reduced significantly. The Tier II emissions requirements drive very low levels of NO_x, PM, and NMHC. Meeting these standards with changes in engine operation and architecture is not feasible, thus exhaust aftertreatment systems are required. Key to successful application of after treatment systems is the thorough integration of the engine and aftertreatment system operation, and a detailed understanding of the critical parameters controlling emissions reduction. The objective of this paper is to present the results of an integrated aftertreatment system used to meet 2007 EPA emissions standards for a diesel engine.

In this paper, the functional aspect of each aftertreatment system component will be described followed by a description of the total system function in order to lay the foundation for understanding the integration of the aftertreatment system with the engine. Discussed will be key aftertreatment performance and durability aspects and several durability test protocols developed to gain key insight into aftertreatment system durability. Results from the durability testing indicate that accurate and precise control of several critical parameters of the aftertreatment system, particularly during active regeneration, is necessary to maintain effective control of tailpipe emissions, and to maintain 2007 emission levels to the useful life of the product.

INTRODUCTION

Although the emissions of the Diesel engine have reduced significantly over the last decade, the low level of required tailpipe emissions require effective aftertreatment systems to be used in conjunction with the engine in order to meet the EPA Tier II, ULEV emission standard. Very low levels of NO_x, PM, and NMHC are required to meet the Tier II standards, achieving such low levels while maximizing fuel economy and

performance require close integration of engine and aftertreatment operation, and a thorough understanding of the critical control parameters for emissions reduction. The fundamentals of the development of the integrated system have been previously described [1], [2]. The objective of this paper is to present some details of an integrated aftertreatment system used to meet EPA Tier II emissions standards for a Diesel engine.

CATALYST DURABILITY

The main causes of catalyst degradation are well known, and can be classified into three main categories [3]:

1. Thermal

- a. Sintering
- b. Alloying
- c. Support Changes
- d. PGM-Base Metal interactions
- e. Metal/metal oxide support interactions
- f. Oxidation
- g. PGM Surface Orientation
- h. Metal volatilization

2. Chemical

- a. Poisoning: irreversible adsorption or reaction on/with the surface
- b. Inhibition: competitive reversible adsorption of poisons
- c. Poison induced reconstruction of catalytic surfaces
- d. Physical/chemical blockage of support pore structure

3. Mechanical

- a. Thermal shock
- b. Attrition
- c. Physical breakage
- d. Fouling – coke formation, (carbon deposits)

Of these catalyst deactivation mechanisms, the thermal degradation of the catalyst can be most detrimental to the overall catalyst function. The thermal deactivation of the catalyst can be caused by:

1. Loss of catalytic surface area due to crystallite growth of the catalytic phase
2. Loss of support surface area due to support collapse and/or catalytic surface area due to pore collapse on crystallites of the active phase
3. Chemical transformations of the catalytic phases to non-catalytic phases

Experimental observations have shown that sintering is strongly temperature dependent, but is also affected by the surrounding gas atmosphere (oxidizing and moist environments can increase sintering rates). The sintering of precious metals becomes significant above 600 C. The underlying mechanism of sintering of small metal particles is the surface diffusion, or at higher temperatures, the mobility of larger agglomerates.

The presence of specific additives is known to reduce the sintering of a catalyst: BaO, CeO2, La2O3, ZrO2 improve the stability of γ -Al2O3 towards sintering in the presence of high H2O content in the exhaust gas.

Thus, various forms of thermal deactivation of a particular catalyst and the temperature range in which they are active must be considered when designing durability cycles for the engine-aftertreatment system.

INTEGRATED AFTERTREATMENT SYSTEM

The schematic layout of the integrated aftertreatment system is shown in Figure 1. The aftertreatment system is comprised of three main components: (1) Close-coupled Catalyst, (2) NOx Adsorbing Catalyst (NAC), and (3) Catalyzed Soot Filter. Major functions, as classified by regeneration type are shown in the figure. Durability aspects of each aftertreatment component will be described in the following sections.

CCC - CCC function requires oxidation of various species during lean mode (HC, CO, NO). During rich operation, the CCC must react residual oxygen from the exhaust in order to reach the reducing condition required for NOx regeneration. The CCC is also capable of In-situ reforming during the rich regen event, producing potent regeneration species from hydrocarbons for NOx removal and reduction on the NAC. The function of the CCC during deSOx is similar to that during deNOx. During DeSOx regeneration, lean/rich cycling is used to remove sulfur as well as for temperature control.

Integrated Aftertreatment System

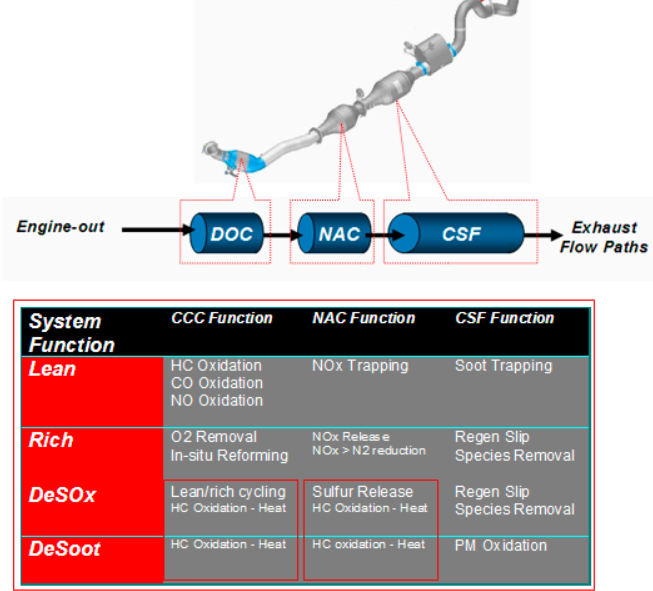


Figure 1. Integrated Aftertreatment System

Robust sulfur removal during DeSOx is paramount in order to maintain good NOx trapping capability [4].

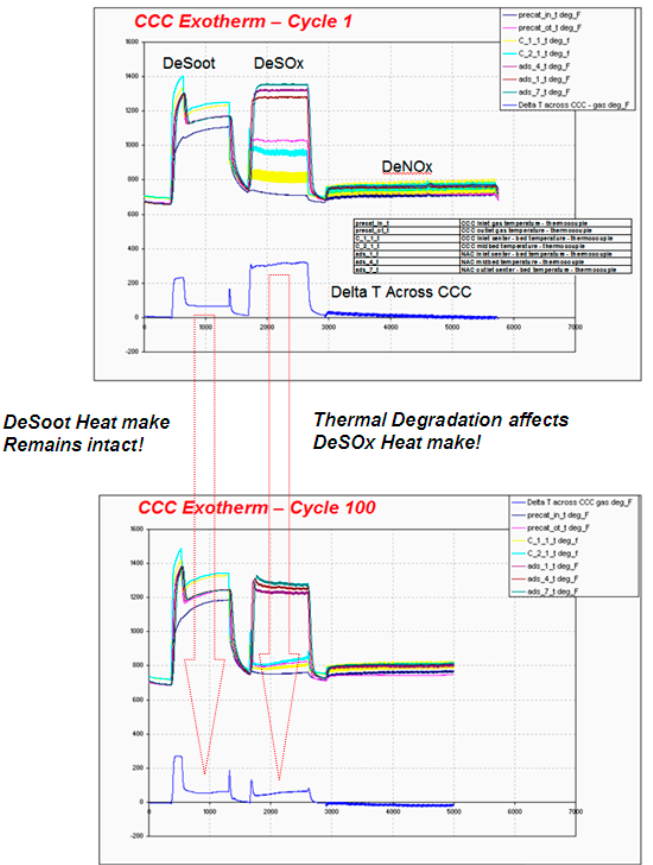


Figure 2. Thermal Degradation of CCC