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A Case Study in DOC OBD Limit Parts' Performance and Detection

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Abstract

The reduction of automotive emissions is instrumental in the fight against air pollution and its impact on global warming. This realization has empowered governments around the world to mandate lower levels of vehicle emissions requiring the Original Equipment Manufacturers (OEMs) to implement advanced aftertreatment technologies in their applications. Achieving emission levels as low as SULEV30 or SULEV20 would have been impossible only a couple of decades ago, however, these lower levels of emissions are now a possibility through advanced control strategies and aftertreatment systems. As a part of this mandate to lower emissions, OEMs are also continuously monitoring the health and performance of their aftertreatment and control components. The implementation of On Board Diagnostics (OBD) ensures that control systems are functioning robustly and the emission levels are achieved and maintained to high mileages for the life of the vehicle. To develop a robust OBD detection strategy, OEMs often create limit or threshold parts that mimic the failed part at the OBD detection limits. There are various methods for creating a limit part that would emit pollutant at the OBD limits.

In an effort to study different approaches to Diesel Oxidation Catalyst (DOC) limit part fabrication and their corresponding performance and detection, various DOCs were created each representing a unique failure mechanism. The emissions were measured and the impact of the damage on the emissions performance and OBD detection was investigated. From this, it was determined that only the limit DOCs which were created by cutting (volume reduction) and aging, have sufficient separation between their failed state and their acceptable emission performance, to be adequate for OBD activity during development.

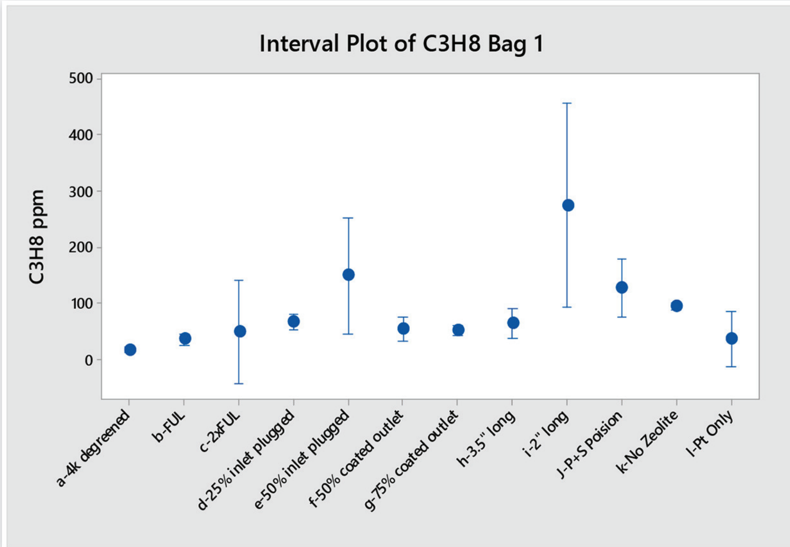
Introduction

OEMs are required by law to meet the mandated emissions levels of those countries where their products are sold. As the emission mandates become more stringent, more sophisticated controls and aftertreatment systems are introduced into the vehicle operation. Monitoring the health and performance of these control components is essential to the overall performance robustness of the vehicle through its life. In United States, OBD, introduced in 1980 and later refined to OBD-II in the 1990s, is mandated ensuring continuous on-board monitoring of the performance of various systems in a vehicle [1]. In gasoline applications, this OBD monitoring has enjoyed a 3 decades of progress and refinements. In diesel applications, the progress has been recent, slow and difficult as the methodologies used in gasoline monitoring cannot be transferred to diesel applications, thus new approaches need to be developed. In addition, the multiple component configuration of a diesel aftertreatment system adds to the complexity of the controls and to their OBD monitoring needs [2, 3].

The OBD requirement for emissions components dictates a threshold for each emissions constituent at any certification level, ensuring that a Malfunction Indicator Light (MIL) light is illuminated once the emissions surpass the allowed level. A component which emits pollutions at levels just below its regulatory mandated level is referred to as Worst Performing Acceptable (WPA). A part which emits pollutant at levels slightly above this mandated level is not deemed a failure. For a failure to be identified and for the MIL light to become activated, under the LEVIII standards, the emissions of the said component will need to be at 175% of its regulatory level for NMHC + NOx Emissions (150% for CO and 200% for PM). A part that emits pollutants at levels just below these maximum allowed levels is referred to as Best Performing Unacceptable (BPU) and should cause the MIL light to turn on. Often in development, engineering margins are also added thus reducing the BPU levels to somewhat less than 175% of the emissions levels. This developmental target ensures robustness of the controls at the BPU levels.

In order to have a robust monitoring of the controls' performance, ideally, these two emission levels have a non-overlapping separation. The ideal separation for an optimum monitoring of the performance is either at least two sigma from the mean of BPU to the threshold and 4 sigma from the mean of WPA to the threshold [4]. To develop robust OBD monitoring of controls, OEMs routinely create parts which

FIGURE 13 Propane, C_3H_8 concentration reduction corresponding to the activity of the limit DOCs.



formaldehyde (HCHO) are the dominant species by concentration. These HC species passing through the DOC, undergo various levels of oxidation depending on the catalyst activity with the exception of ethane (C_2H_6). Ethane shown in **Figure 12a** is the only species measured were the non-washcoated DOC out concentration is lower than the amount after the DOC suggesting that the oxidation of various unsaturated HCs passing through the DOC result in production of ethane. Propane (C_3H_8) (**Figure 12b**), shows a major decrease when passing through the DOCs indicative of oxidation only due to the low affinity for HC storage of this molecule. Expanding the plot from **Figure 12b** by focusing on all but the engine out/no washcoat concentration, the picture which emerges is very similar to the rest of the plots in **Figure 12** and the conversion efficiency graphs previously shown indicating performance is mostly impacted by effective volume reduction of the catalyst (2" long DOC, 50% plugged DOC). This is shown in **Figure 13**.

The reduction of all other species across the DOCs show a similar trend relative to each other.

All species tend to have their highest emission or lowest conversion with 2" long DOC and 50% plugged DOC further supporting the conclusion that these two examples provide sufficient reduction in activity to allow reasonable separation as potential candidates for BPU DOC fabrication.

Conclusion

In this study, 11 various limit DOCs were created that represent failed components in the field, correlation between TP conversion efficiency and regeneration performance was investigated.

It was observed that there is a possibility where a component showing adequate performance during monitoring has surpassed the WPA emissions levels but not to the extent that would require a fault activation. It also suggests that perhaps the OBD detection logic used in this study is required to be further developed to create a better separation between the data. For this to be achieved, a representative BPU limit system is required where it clearly shows failure both at the TP and during monitoring with adequate separation.

It was also observed that the DOC is a very robust component and it required an extreme measure in order to reduce its emission performance to the required limit levels. In this case, reducing the catalyst to 40% of its size (2" long DOC) or plugging 50% of it channels, followed by an additional hydrothermal aging at 800°C for 20 hrs, were sufficient to deteriorate the catalysts' performance to higher than certification emission levels. Yet only the 2" long DOC was capable of exceeding the set OBD monitoring threshold during regeneration and thus an appropriate candidate as a BPU limit part.

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Definitions/Abbreviations

ATS - Aftertreatment System
BPU - Best Performing Unacceptable
CEL - Check Engine Light
DOC - Diesel Oxidation Catalyst
DPF - Diesel Particulate Filter
EO - Engine Out
FUL - Full Useful Life
HC - Hydro Carbon
MIL - Malfunction Indicator Light
OEM - Original Equipment Manufacturers
OBD - On Board Diagnostics
RHU - Rapid Heat Up
TP - Tail Pipe
WPA - Worst Performing Acceptable

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