320e Monitoring and Fault Detection of Catalytic Automotive Emission Control Systems

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In order to ensure that the components of a catalytic automotive emission control system continue to operate properly with age, effective and robust on-board system monitoring is essential. Because emissions from a small fraction of malfunctioning vehicles account for a large fraction of the total automotive-related emissions, effective on-board monitoring and diagnostics has the potential to significantly reduce hydrocarbon and nitrogen oxide pollutants. This observation, along with OBD-II and SULEV legislation that mandate on-board diagnostic (OBD) systems to monitor the health and performance of the catalyst system, has led to interest in monitoring strategies that are able to reliably indicate when the emission control system is no longer meeting specification or when a fault is present.

Monitoring the performance of catalytic automotive emission control systems is particularly challenging due to a lack of a cost effective and reliable automotive hydrocarbon sensor. This limitation has led to monitoring approaches that consider the oxygen storage state of the catalyst rather than the hydrocarbon and nitrogen oxide conversion. Three-way automotive catalysts are able to store and release oxygen due to the adsorption and deadsorption of oxygen with the cerium oxides contained in the catalyst formulation. Although the oxygen storage state of the catalyst cannot be measured directly, it can be inferred using the pre- and post-catalyst exhaust gas oxygen (EGO) sensors. There are several difficulties with the use of oxygen storage as a monitoring metric. The first is that conversion is not solely a function of the catalyst oxygen state. The second is that the post-catalyst EGO sensor signal is subject to distortion based on exhaust composition and this distortion can have a significant detrimental impact on EGO sensor-based monitoring strategies. Finally, the complexity of the catalyst models that can be implemented on-line in the engine control module (ECM) is severely limited by the computational restrictions inherent in the module. This restriction provides a particular challenge with incorporating the EGO sensor information into an effective model-based catalyst monitoring strategy.

We present a model-based approach to automotive catalyst system monitoring utilizing a novel catalyst oxygen storage model that specifically includes the EGO sensor distortion and exploits this distortion to quantify the effects of reversible catalyst deactivation. Reversible deactivation, due to carbonaceous coating of the surface or sulfur inhibition, causes a significant dynamic degradation of conversion and increase in tailpipe emissions. Catalyst oxygen storage models that ignore this effect may indeed predict the post-catalyst sensor signal quite closely, yet fail to provide good predictions of tailpipe emissions. This distinction is important because diagnostics of emissions, rather than post-catalyst sensor signal, is the ultimate goal of a model-based diagnostic strategy. We demonstrate this strategy using actual EGO sensor and emissions data generated by the engine testbed and exhaust gas analysis facilities at Ford Motor Company and the Automotive Research Laboratory at Villanova University.