Selective catalytic reduction of oxides of nitrogen with ethanol/gasoline blends over a silver/alumina catalyst on a lean gasoline engine

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Introduction

The fuel efficiency of a stoichiometric gasoline engine can significantly be improved by operating the engine in a fuel-lean combustion mode. Reduction of oxides of nitrogen (NO_X) emissions in lean exhaust, however, poses a significant technical challenge. A three-way catalyst (TWC) is commonly used in engines operating with stoichiometric air-to-fuel (AFR) ratio. This catalyst effectively controls NO_X, carbon monoxide (CO) and hydrocarbon (HC) emissions. The TWC, however, is not effective at reducing NO_X under lean conditions. Thus, a different exhaust aftertreatment technology is required for the reduction of NO_X emissions from lean gasoline engines.

Recently, we have shown that ethanol/gasoline blends containing at least 50% ethanol are very effective in reducing NO_X over a silver/alumina (Ag/Al_2O_3) catalyst under a lean exhaust environment on a bench flow reactor.[1] With ethanol/gasoline-blended fuel available in many fuel stations in the USA, lean gasoline engines equipped with a Ag/Al_2O_3 catalyst have the potential to deliver higher fuel economy than stoichiometric gasoline engines and to increase biofuel utilization while meeting exhaust emissions regulations.

This work builds on our prior bench flow work and focuses on evaluation of a pre-commercial Ag/Al_2O_3 catalyst on a 2.0-liter BMW lean burn gasoline direct injection engine for the selective catalytic reduction (SCR) of NO_X with ethanol/gasoline blends.

Materials and Methods

The catalyst used in this study was a 2wt% Ag/Al_2O_3 provided by CDTi (formerly Catalytic Solutions, Inc.). The catalyst was washcoated on a 62 cells/cm^2 cordierite monolith by the supplier. Two 10.6 cm diameter by 11.4 cm long catalysts were placed in tandem in the exhaust downstream of a TWC. The ethanol/gasoline blends were delivered via in-pipe injection upstream of the Ag/Al_2O_3 catalyst with an engine operating under lean conditions. The lean burn gasoline direct injection engine used in this study came from a European Model Year 2008 BMW 120i vehicle. The engine was coupled to a motoring direct current dynamometer to control engine speed and load. Engine conditions were chosen to give a range of temperatures and space velocities for the catalyst performance evaluations. At each engine condition, a sweep of ethanol/gasoline blend concentrations was performed to probe the impact of HC dosing on NO_X conversion efficiency, HC slip, and fuel penalty.

Results and Discussion

The Ag/Al_2O_3 catalyst effectively reduces NO_X with 100% ethanol reductant, reaching greater than 92% conversion at $C_1/N = 4$ as shown in Figure 1. High NO_X conversions were also observed with ethanol/gasoline blends containing at least 50% ethanol; however, higher C_1/N ratio was needed to achieve greater than 90% NO_X conversion, which also resulted in significant HC slip. Selectivity to NH_3 and N_2O increases with increased HC dosing. Interestingly, the NH_3 selectivity was found to be lower than we observed previously on the flow reactor under similar conditions. Also, unlike the flow reactor experiments, CO emissions were found to increase with HC dosing.

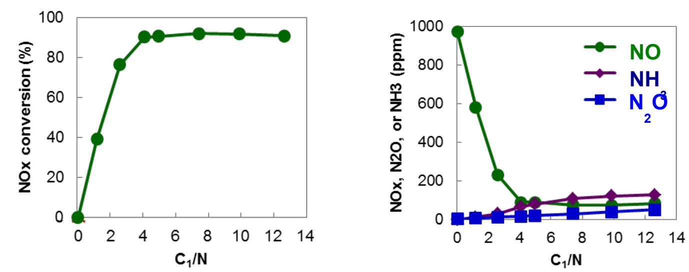

Figure 1: NO_X conversion and N-species emissions as a function of C_1/N with in-pipe injection of 100% ethanol

Significance

The effectiveness of a silver/alumina catalyst to reduce NO_X with bio-renewable fuels in lean exhaust presents a technical pathway for cost effective NO_X emissions control for fuel-efficient lean-burn gasoline engines that also increases biofuel utilization.

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References

1. Josh A. Pihl, Todd J. Toops, Galen B. Fisher, Brian H. West, "Selective catalytic reduction of nitric oxide with ethanol/gasoline blends over a silver/alumina catalyst," Catalysis Today, Volume 231, 1 August 2014, Pages 46-5