Impact of catalyst activity and geometry on diffusion and SCR kinetics under elevated pressures

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Abstract

In marine diesel engine applications, selective catalytic reduction upstream of the turbocharger may become the preferred technology when dealing with high sulfur fuels and low exhaust gas temperatures. The target nitrogen oxide reductions in combination with minimum ammonia slip and reduced gas diffusion rates under elevated pressures require understanding of the impact of catalyst geometry on the SCR kinetics. The extent, trends and sources for this observation are elucidated in this work by systematic testing of catalysts having equal geometry and/or intrinsic activity.

Introduction

Selective catalytic reduction (SCR) has proven to be an effective and cost efficient method for nitrogen oxides (NO_x) removal from combustion generated exhaust gas. The importance of NO_x abatement is imminent due to the noxious nature of these emissions which is claimed to cause more than 38,000 premature deaths globally on an annual base just because of excess NO_x emissions from on-road diesel applications.[1]

In many of the densely populated coastal areas, however, contributions of passenger car NO_x emission are smaller than the amount of NO_x emitted from marine transportation.[2-4] In order to improve this situation, the International Marine Organization's (IMO) Tier III regulation for emission control areas (ECA) is pushing for a 76.4% NO_x reduction compared to the previous Tier II level, thereby fostering the introduction of SCR also for marine applications.[5] The US adopted this regulation since January 1st 2016 for an ECA of 200 nautical miles off their coastlines and around their territories in the Caribbean Sea. While the impact of this unique ECA is limited so far, the introduction of a Baltic Sea and English Channel ECA for NO_x in 2021 is expected to finally lead to a strong global increase of vessels equipped with SCR systems due to the global trade pattern of merchant vessels.

The fuel sulfur content for marine vessels is regulated to 0.1% in ECA's, outside the global limit is still at 3.5%, though a reduction to 0.5% is scheduled for 2020. However, if a sulfur oxide removal system is installed in the exhaust duct, fuel sulfur contents of 3.5% and possibly even higher may still be used as long as the effective SO_x emissions are equivalent to the prescribed sulfur content fuel.[5] The resulting concentrations of SO_3 and H_2SO_4 in the exhaust can impose challenges for the SCR process due to the formation of ammonium bisulfate (ABS) deposits on the catalyst surface.[6] As marine engines are heavily optimized for highest fuel efficiency,[7] the exhaust gas temperatures at which the SCR needs to operate are low compared to other diesel engine applications.

One solution to cope with both, potential issues due to ABS deposits and low exhaust gas