Ambient temperature NO\textsubscript{x} emission control for lean-burn engines by electro-catalytic tubes

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A R T I C L E   I N F O

Article history:
Received 14 May 2012
Received in revised form 24 July 2012
Accepted 13 August 2012
Available online 20 August 2012

Keywords:
Nitrogen oxide
DeNO\textsubscript{x}, activity
Ambient temperature
Lean-burn engine
Emissions control
Electro-catalytic tube

A B S T R A C T

Lean-burn gasoline and diesel automobiles can have superior fuel efficiency but require advanced DeNO\textsubscript{x} technology. For a catalytic converter to be put underneath the passenger cars, it must be compact enough. Effective automotive DeNO\textsubscript{x} treatment should start at ambient temperature to avoid a heating period when the pollutant cannot be effectively treated. An electro-catalytic honeycomb, composed of electro-catalytic tubes, would fulfill this size requirement. This work demonstrates that effective lean DeNO\textsubscript{x} can be performed at ambient temperature by an electro-catalytic tube. The DeNO\textsubscript{x} activity is relatively insensitive to the variation of temperature from 200 to 600 °C and increases slightly when temperature decreases from 200 °C to ambient, but is quite sensitive to that of either the oxygen concentration or the NO\textsubscript{x} concentration. When the oxygen concentration and the NO\textsubscript{x} concentration increase from 0.5 to 14% and from 250 to 3800 ppm, respectively, the DeNO\textsubscript{x} activities increase considerably. The NO\textsubscript{x} conversion also increases with decreasing NO\textsubscript{x} concentration below 250 ppm, when there is zero NO\textsubscript{y} yield; these can result in zero NO\textsubscript{x} emission.

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1. Introduction

Catalytic converters, especially those employing three way catalysts (TWCs), have been very successful on automotive emissions control for over three decades [1,2]. Increasingly stringent emissions standards have so far been fulfilled at the expense of fuel efficiency. Currently, TWC is used for emissions control of gasoline car with stoichiometric-burn engine [1], and urea-based selective catalytic reduction (SCR) is used for NO\textsubscript{x} emission control of diesel engine with exhaust gas recirculation (EGR) [3]. The fuel efficiency can be increased considerably by converting stoichiometric-burn engine to lean-burn [2] and by deleting EGR. However, thus-emitted engine exhaust contains very high concentration of NO\textsubscript{x} (NO + NO\textsubscript{2}) with excess oxygen [4], and thus existing DeNO\textsubscript{x} technologies cannot or have difficulties to treat it.

Lean-burn engines can offer superior fuel efficiency but contains excess oxygen; thus, TWC can no longer function on their DeNO\textsubscript{x} after-treatment. Urea-based SCR is promising but has to limit the NO\textsubscript{x} concentration in the engine exhaust due to the consumption of ammonia [5]. Therefore, the NO\textsubscript{x} concentration in the exhaust is lower the better for the after-treatment. This is why EGR is practiced to reduce the NO\textsubscript{x} concentration [3]. Deleting EGR increases both the temperature and the oxygen concentration in the engine [6]. This should reduce emissions of hydrocarbons (HCs), CO and particulate matter (PM); the fuel efficiency should increase, at least by burning more HCs, CO and PM precursors in the engine instead of emitting them. However, this can result in very high NO\textsubscript{x} concentration.

A technology capable of reducing NO\textsubscript{x} of very high concentration can increase the fuel efficiency, at least by deleting EGR. Such lean DeNO\textsubscript{x} technology has been realized by solid oxide fuel cell (SOFC) [7–17] and electrochemical-catalytic cell (ECC) [18–21]. However, the consumption of the SOFC anode fuel (a reductant) is required for SOFC-DeNO\textsubscript{x}; this adds inconvenience to its application onboard automobiles. On the other hand, although the ECC does not consume the reductant, its current design is a stack of ECCs. The ECC stack is as bulky as the SOFC stack and is much bulkier than the honeycomb of TWC, and it may thus be difficult to put this stack underneath the passenger cars; this limits its applications. In addition, current technologies for automotive emission control cannot perform the after-treatment effectively at ambient temperature and generally require a heating period; consequently, effective after-treatment is delayed. A technology for effective emission control at ambient temperature can start the after-treatment without delay.

An electro-catalytic honeycomb, composed of electro-catalytic tubes (ECTs) as shown in Fig. 1, has been proposed as an automotive catalytic converter for lean DeNO\textsubscript{x} [22]. The DeNO\textsubscript{x} reactions in the ECT are the same as those in the ECC [18–21], as shown on top of Fig. 1; the working principles are also the same. DeNO\textsubscript{x} is