PLASMA TECHNOLOGY FOR NO_x AND PARTICULATE REMOVAL FROM HEAVY DUTY VEHICLES

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Federal and State emission standards for heavy duty diesel engines have resulted in the evaluation of various engine modification (in-cylinder and EGR) and aftertreatment strategies to reduce NO_x and particulates from stationary and mobile diesel engines. Past emissions requirements have been achieved by controlling engine combustion parameters. Mandates on extremely low NO_x and particulate levels such as potential 2004 EPA regulations may require an external after-treatment device downstream of the engine.

Modern diesel engines employ stratified charge combustion with air/fuel ratios of ≈ 20, that produce lean exhausts (high O_2 levels) in the temperature range of 250°-850° F. Conventional thermal and catalyst technologies, such as three-way catalysts, have been found to be ineffective under these high O_2 conditions. The use of non-thermal plasmas offer the potential to selectively reduce NO_x and oxidize particulates in such high O_2 exhausts without the need for supplemental scavengers or additives.

This paper focuses on the non-thermal plasma technologies being developed at NOxTECH, Inc. for heavy-duty vehicles. Specifically, progress made on a gas phase pulsed power system and a plasma assisted catalyst system is reviewed with performance data on diesel exhaust for NO_x and particulate removal.

Non-thermal plasma technology involves the in-situ production of the desired active radicals and ionic species at low temperatures. The plasma environment consists of a number of highly energetic electrons which collide with the predominant molecules, viz. N_2, O_2, H_2O and CO_2 to form N, O and OH radicals. The two main reactions involved are:

$$NO + N \rightarrow N_2 + O \quad (1)$$
$$NO + O \rightarrow NO_2 \quad (2)$$

Reaction 1 results in the desired product N_2 while reaction 2 results in the undesired NO_2.

Figure 1 shows the NO_x reduction for the gas phase pulsed power system. This test was conducted on a slipstream from a 4 kW diesel engine with a baseline NO/NO_x concentration of 200/245 ppm, 13% O_2, 5% H_2O and particulates. Greater than 60%NO_x reduction was obtained at less than 5% energy. This performance was found to be better at higher baseline NO_x conditions. The selectivity ($\Delta NO_x/\Delta NO_2$) was found to be consistently higher than 3 and the NO_x removal efficiency was found to vary between 30 and 60 eV/molecule. Under these conditions, greater than 50% particulate removal was simultaneously obtained. The removal of NO_x was found to be largely invariable with respect to temperature up to 500° F. Additional data at higher temperature is being obtained.

Figure 2 shows a pictorial view of the second system, namely the plasma assisted catalyst system. This system also selectively reduces NO_x to N_2 and oxidizes particulates to CO_2 without the use of additives. In this system, the plasma is generated across a catalytic packed bed. Greater than 70%NO_x reduction at less than 5% energy was obtained on a slipstream of a 60 kW diesel genset with a baseline of 183/192 NO/NO_x, 17% O_2 and 8% H_2O. This is shown in Figure 3. The nature of the catalyst beads seemed to have a considerable influence on system performance. Similar to the gas phase system, a selectivity ($\Delta NO_x/\Delta NO_2$) of greater than 3 was obtained. Also, greater than 50% simultaneous removal of particulates was obtained.

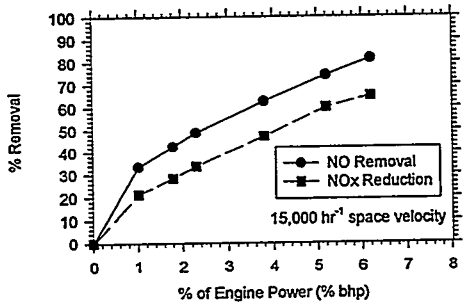

Fig. 1: NO Removal and NO_x Reduction for the Gas Phase Pulsed Power Plasma System

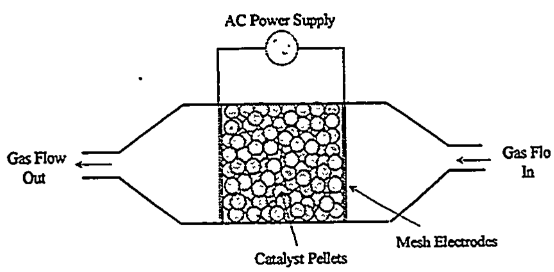

Fig 2: Simplified Schematic of the Plasma Assisted Catalyst System

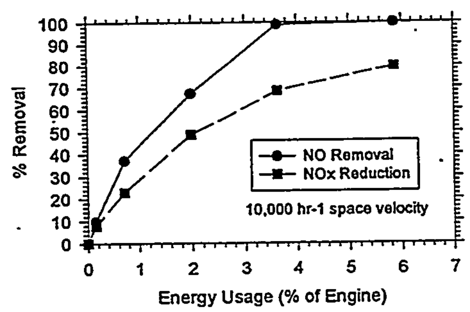

Fig 3: NO Removal and NO_x Reduction for the Plasma Assisted Catalyst System

Byproduct measurements showed no N_2O and less than 2 ppm HNO_3 under all conditions.

Also, the gas phase system was found to be insensitive to sulfur levels while additional work is needed to determine the sensitivity of the plasma assisted catalyst system to fuel sulfur levels.

NOxTECH is targeting a device that will allow engine manufacturers to meet 2004 regulations. Continuing development efforts are targeting greater than 80%NO_x and 70% particulate emissions at or below engine exhaust temperatures with less than 5% parasitic load on engine. A prototype system for an 80 hp diesel engine is planned for early 1998.

Present-day diesel engines are optimized for emissions and performance instead of performance and economy. The use of a cost effective plasma emissions reduction device will help boost combustion efficiency and may offer the potential for substantial reduction in engine cost.