THE EFFECT OF LEAN NO_x TRAP CATALYST ON NO_2 REMOVAL FROM DIESEL ENGINE

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"Saya akui bahawa saya telah membaca karya ini dan pada pandangan saya karya ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Termal-Bendalir)"

Tandatangan : ……………………………………………

Nama Penyelia : ENCIK FAIZIL BIN WASBARI

Tarikh : 26 OKTOBER 2009

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya telah saya jelaskan sumbernya."

Tandatangan	: ………………………………..
Nama Penulis	: Mohd Hisham B Baharuddin
Tarikh	: 27 Mac 2008

To my beloved mother and father

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ABSTRACT

Reliable power generation and distribution is a critical infrastructure for the public and industry. Large-bore spark-ignited natural gas reciprocating engines are a reliable source of power generation. Lean operation enables efficient operation, and engines can conveniently be placed wherever natural gas resources are located. However, stricter emission regulations may limit the installation and use of more natural gas reciprocating engines if emissions cannot be reduced. Natural gas engine emissions of concern are generally methane, carbon monoxide, and oxides of nitrogen (NO_x). Methane and carbon monoxide can be controlled by oxidation catalysts; however, NO_x emissions are difficult to control in lean exhaust conditions. One method of reducing NO_x in lean exhaust conditions is lean NO_x trap catalysis. Lean NO_x trap technologies, also known as NO_x adsorber catalysts, NO_x storage and reduction catalysts. The main objective of this project is to study and fabricate the LNT catalyst and produce a device which can help the vehicle users to utilize for health protection. In the work presented here, the feasibility of a lean NO_x trap catalyst for lean burn natural gas reciprocating engines will be studied. tests were conducted on a diesel engine on a dynamometer. The lean NO_x trap catalyst was controlled in a valved exhaust system that utilized natural gas as the catalyst reductant. Oxidation and reformer catalysts were used to enhance utilization of methane for catalyst regeneration. The feasibility of this approach will be discussed based on the observed NO_x reduction.

ABSTRAK

Penjanaan kuasa yang boleh dipercayai dan taburan adalah infrastruktur yang kritikal untuk orang awam dan industri. Lubang penyalaan bunga api menyalakan gas asli pada enjin-enjin adalah sumber yang boleh dipercayai. LNT membolehkan rawatan rapi pada enjin-enjin dilakukan dengan mudah. Bagaimanapun, peraturan-peraturan pemancaran lebih tegas boleh menghadkan pemasangan dan penggunaan lebih gas asli pada enjin-enjin jika pengeluaran tidak dapat diturunkan. Pengeluaran gas enjin secara semula jadi secara umumnya adalah seperti metana, karbon monoksida, dan oksida nitrogen (NOx). Metana dan karbon monoksida boleh dikawal oleh mangkin pengoksidaan; bagaimanapun, pengeluaran NOx sukar dikawal dalam keadaan ekzos condong. Satu kaedah mengurangkan NOx dalam keadaan ekzos condong adalah perangkap LNT. LNT, turut dikenali sebagai NOx “adsorber”, penyimpanan dan pemangkin pengurangan NOx. Objektif utama projek in adalah untuk mengkaji dan merekabentuk LNT dan menghasilkan sebuah alat yang boleh membantu pengguna-pengguna kenderaan untuk melindungi kesihatan mereka daripada kesan gas berbahaya. Dalam pembentangan ini kemungkinan sesuatu perangkap NOx untuk gas asli pada enjin-enjin akan dikaji. ujian-ujian dikendalikan atas enjin diesel yang disambung pada dynamometer. Perangkap NOx telah dikawal oleh satu injap pada sistem ekzos yang menggunakan gas asli sebagai bahan penurun pemangkin. Pengoksidaan dan mangkin pengubah adalah kebiasaan untuk meningkatkan penggunaan metana untuk penjanaan semula pemangkin. Kemungkinan pendekatan ini akan menjadi perbincangan berdasarkan kepada pengurangan NOx.

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INTRODUCTION

1.1 Overview

Recently, the application of the diesel engine has made rapid progress in the worldwide wherever the approximately 44 percent of the new vehicle especially the long vehicles are powered by diesel engines. A **diesel engine** is an internal combustion engine which operates using the Diesel cycle. Invented in 1892 by German engineer Rudolf Diesel, it was based on the hot bulb engine design and patented on February 23, 1893.

A diesel engine uses **compression ignition,** a process by which fuel is injected after the air is compressed in the combustion chamber causing the fuel to self ignite. By contrast, a gasoline engine utilizes the Otto cycle, in which fuel and air are mixed before entering the combustion chamber and then ignited by a spark plug.

The exhaust gases is flue gas which occurs as a result of the combustion of fuels such as natural gas, gasoline/petrol, diesel, fuel oil or coal. It is discharged into the atmosphere through an exhaust pipe or flue gas stack. Although the largest part of most combustion gases is relatively harmless nitrogen (N_2), water vapor (H_2O) (except with pure-carbon fuels), and carbon dioxide (CO_2) (except with hydrogen as fuel), a relatively small part of it is undesirable noxious or toxic substances, such as carbon monoxide (CO), hydrocarbons, nitrogen oxides (NO_x), partly un-burnt fuel, and particulate matter. It is well known that the all gases are harmful to human health and environment.

This project is to study the effect of the LNT catalyst in the exhaust system as well as reduction on NOx emission from diesel engine. The experimental method will be examining the emission after treatment system.

1.2 Objectives

The main objective to be archived for this project is to study the effect of the Lean NOx Trap (LNT) catalyst on NO_2 removal for diesel engine. There are:

- To study the principle of LNT
- To fabricate the LNT component
- To conduct experimental study on the effect of LNT catalyst with respect to different engine operating parameter

1.3 Project Significant / Problem Statement

1.3.1 Pollution

Pollution is the introduction of contaminants into the environment that cause harm or discomfort to humans or other living organisms, or that damage the environment. Pollution can be in the form of chemical substances, or energy such as noise, heat, or light. Pollutants can be naturally occurring substances or energies, but are considered contaminants when in excess of natural levels. Pollution is often categorized into point source and nonpoint source pollution.

Air pollution is the human introduction into the atmosphere of chemicals, particulates, or biological materials that cause harm or discomfort to humans or other living organisms, or damage the environment. Air pollution causes deaths and respiratory disease. Air pollution is often identified with major stationary sources, but the greatest source of emissions is actually mobile sources, mainly automobiles. Gases such as carbon dioxide, which contribute to global warming, have recently gained recognition as pollutants by climate scientists, while they also recognize that carbon dioxide is essential for plant life through photosynthesis.

1.4 Scopes

The scopes of the project are as below:

- This project can be focus to the national car especially to the Proton Wira Diesel 2.0 L.

- This experiment to determine that the design is working and experimental study about the temperature, the pressure and the emission.
- Development includes simple fabrication to demonstrate how the mechanism works.

1.5 Design Background

One of the most environmental problems nowadays is the reduction of the global CO\d2 emissions. In the field of automotive transportation, car manufacturers in Europe plan to reach the level of 140 g (CO\d2)/km in 2008). At this level, one of the most viewable solutions is the use of lean-burn engines. These kinds of engines are known for their combustion efficiency, but they present a major inconvenience NOx emissions and their post-treatment. Some technical solutions have been provided in the past years such as DeNOx catalysts. However these solutions won't be compatible with future European legislations: limits of diesel engine emissions will reach 0.25 g (NOx)/km in 2005.

Implementation of such technology requires advanced strategies of engine control, which consist in periodically rising fuel-to-air ratio from lean to rich. The design of such strategies requires real-time models describing the trapping and regeneration process.

The aim of this work is to propose such a NOx trap catalyst model. This model describes the trapping phase. It includes gas temperature and composition variations. The numerical simulations and comparisons with real data obtained from an experimental synthetic gas bench at IFP show the interest of such physical models.

The experimental setup consists of a quartz reactor containing the NOx trap sample, connected upstream to gas mass flow controllers and an analyzer bench downstream. Such NOx trap models can be easily connected to global engine simulations in order to design optimized regeneration strategies. The model has been derived after studying the slow and fast dynamics of the reactions occurring in the NOx trap. So, it was possible to deal with all these reactions using only one ‘simple’ first-order differential equation.

Currently, there are a lot of LNT model was developed in Europe to the solution in this problem. However, in Malaysia, especially in the national car, we have no technology to develop this mechanism. So, the objective this project is to determine the application the design to the diesel engine in national car.

1.6 CPOx for LNT Regeneration

CPOx is a method for reforming hydrocarbon fuels to hydrogen and carbon monoxide by catalytic reaction with an oxidant. The moderately exothermic process is carried out in a compact, rapid response reactor with minimal requirements for additional inputs such as heat or electrical energy. Hydrogen Source, a joint venture of Shell Hydrogen and United Technologies Corporation Fuel Cells (UTC FC), has extensive experience with reforming in general, and CPOx in particular, using a variety of liquid and gaseous hydrocarbon fuels. This process is well suited to efficiently produce syngas in a vehicle. Hydrogen and carbon monoxide are more effective reductants than diesel and lighter hydrocarbons for regenerating LNTs to reduce NOx from diesel engine exhaust.

Tests were conducted to demonstrate that syngas produced from a CPOx reformer is effective for regenerating LNTs in a diesel engine after treatment system. The benefits of syngas were expected to be most pronounced at low temperatures (<200 °C), where reductant generation from diesel injection into the exhaust is not practical. In these tests, the reformer used was designed for another application and had a maximum throughput considerably less than desired. It was operated on naphtha, a fuel similar to gasoline, air and water. The after treatment system installed on the 5.9-liter diesel engine contained a

14-liter LNT. The exhaust configuration simulated one leg of a dual leg LNT system. Valves directed the flow of engine exhaust and syngas to the either the LNT or to a bypass, depending on the cycle, as shown in Figure 1. The reformer and diesel engine were operated at steady state. No attempt was made to optimize the regeneration strategy; fixed trapping and regeneration cycle times were employed. The typical CPOx reformate composition is given in **Table 1**.

Table 1: Syngas composition for LNT regeneration testing

	Composition (volume %)	
	Dry basis	Wet basis
H_2	33	30
CO	18	16
CO_2	6	5
N_2	42	38
H_2O	-	10
Total HC	<1	<1

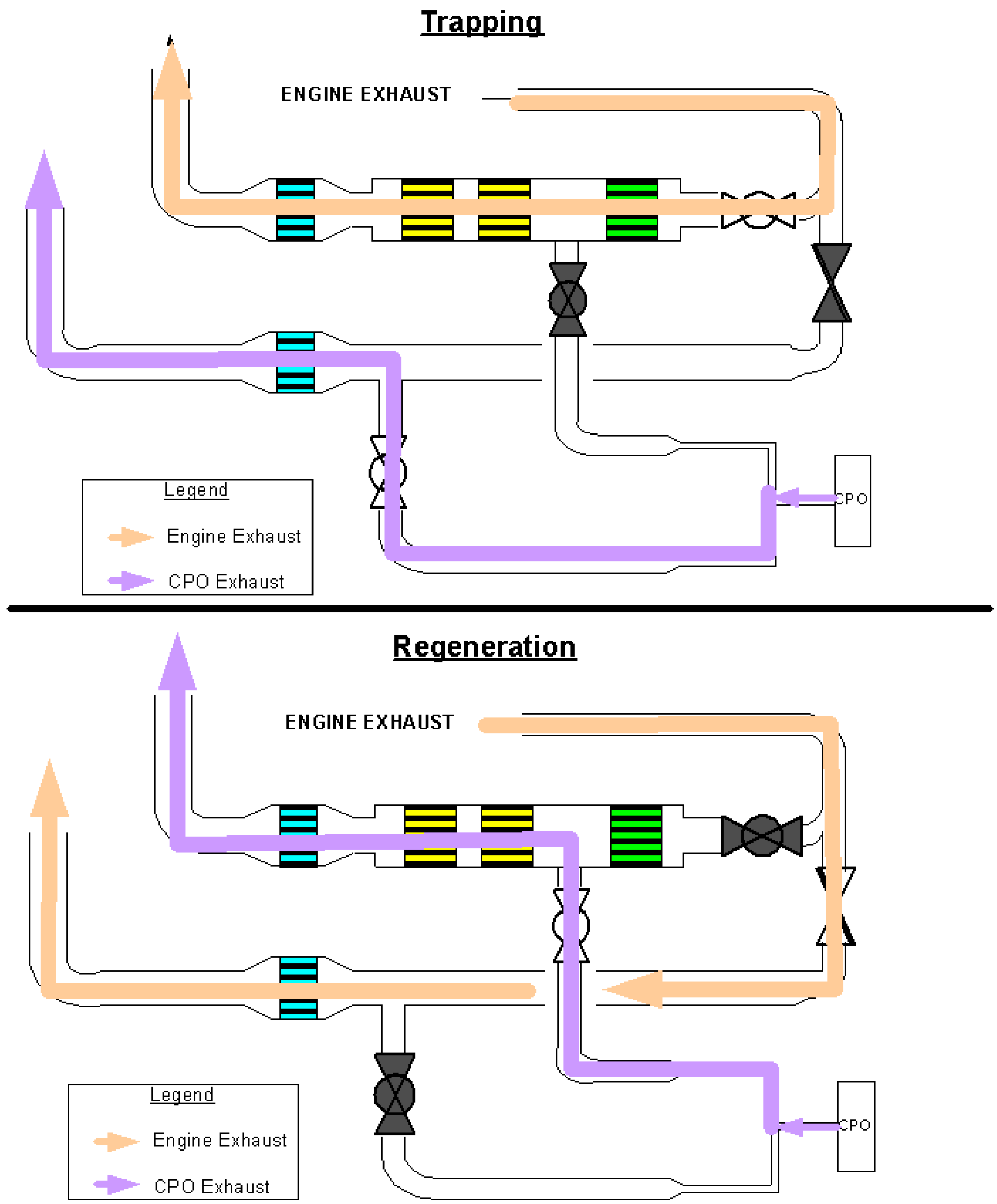

Figure 1: Flow Configuration for LNT Regeneration Testing

Hydrogen Source is developing a CPOx reformer to operate with ultra low sulfur diesel (ULSD), wih a maximum of 15-ppm sulfur as the fuel and lean engine exhaust as the source of oxidant. All diesel sold in the U.S. must meet the ULSD specification beginning in 2006, in advance of the most restrictive light and heavy duty NOx emission standard presently required. CPOX reformers can be used in conjunction with any LNT system since the reactant will be present in all on-road diesel vehicles.

Hydrogen Source is applying its CPOx experience with gasoline to diesel reforming. These data will obtain with air, water, and ULSD fuel as a reactants. The water (steam) to carbon molar ratio (S/C) in the tests was 1.0. One of the challenges resulting from the use of engine exhaust as the oxidant is its relatively low water content. Although water is not required, it has a beneficial effect on CPOx performance, both in syngas yield and catalyst durability.

Depending on the engine air/fuel ratio (A/F), the resulting S/C for a reformer operating on engine exhaust ranges from approximately 0.2 to 0.7. The syngas yield decreased to slightly more than 80% of its initial value during the test. The figure also displays a logarithmic extrapolation of the data, which is characteristic of certain catalyst performance loss mechanisms. The syngas yield can be extrapolated to be about 70% of its initial value aft10, 000 hours. This time period is consistent with the 435,000-mile warranty requirement for heavy-duty diesel engines. The performance loss indicated by the extrapolation can be accommodated in the CPOx reformer design and is considered acceptable.

Another imposing aspect of applying CPOx reformers to diesel engine after treatment is the requirement to cycle from idle to an operating condition frequently. Depending on the LNT regeneration strategy and useful lifetime of the system, as many as several hundred thousand cycles can be expected. Thermal shock resistance is a requirement since the CPOx process generates internal temperatures in excess of 800 C. Hydrogen Source evaluated the effects of up to 1000 thermal cycles of magnitude greater than 800 ^{o}C, resulting from on/off operation, on two types of catalysts. While the natural gas catalyst showed no change in syngas yield, the yield for the naphtha catalyst decreased approximately 6%, acceptable range for exhaust after treatment.

Syngas from a catalytic partial oxidation reformer highly effective for generating NOx adsorbers. NOx conversion efficiencies greater than 90% have been demonstrated at an adsorber temperature of 150°C. The fuel penalty associated with producing syngas can be as low as1.5%. The use of syngas may also provide advantages to the desulfation process and improve LNT durability.

A CPOx reformer was designed to operate on ULSD and engine exhaust. A catalyst formulation was developed with improved stability, and may give acceptable syngas yield for the target of 435,000 miles of vehicles operation. Similar CPOx catalysts have been shown to tolerate 1000 thermal shock cycles with minimal degradation.

The cost of LNT regenerated with syngas from a CPOx reformer may less than an LNT regenerated in another way due to the effectiveness and benefits of syngas. There is a need to compare the cost of various after treatment options on the basis of an integrated system rather than on the cost of individual components, which is beyond the scope of this paper.