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Investigation of effective storage capacity of Lean NOx Trap coated with NOx storage Materials

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ABSTRACT

Lean NOx trap (LNT) catalysts represent a major element in combined systems used for the after treatment of exhaust gas from automotive lean gasoline and diesel engines. It enables NOx adsorption under lean conditions and in rich conditions the stored NOx is regenerated. The present work investigates the lean NOx trapping performance of BaO (1.5, 2.5, 3.5, 5wt. %) of NOx storage catalysts, and 2 wt. % Pt/Al_2O part was mechanically blended to form a LNT cells. The LNT cell is tested in the diesel exhaust conditions at variable load conditions. In this method, it is observed that up to 95% reduction of NOx is achieved. The decomposed O_2 can oxidases other pollutant. Results show highest BaO dispersion on Al_2O_3 cell has maximum NOx decomposition. NOx storage capacity was investigated in steady-state and transient NO/O_2 adsorption reactions in the temperature range from 100°C to 300°C. As BaO loading increases, the catalysts exhibit nonlinear enhancement for NOx storage capacity.

KEY WORDS: LNT, NO_X, Catalyst, Al_2O_3, BaO.

1. INTRODUCTION

The Worldwide the emission standards has been more stringent, lot of efforts are focused on controlling the increased emissions from combustion sources. Lots of researches are focused on development of after treatment devices to control the regulated and non-regulated emissions. The 3 way catalytic converters are efficient device to control HC, CO, NOx emission, but it is not suitable for diesel engines because in oxygen rich environment it is difficult to chemical reduce NOx to nitrogen. The Diesel oxidation catalyst (DOC) is efficient in controlling HC and CO emissions from diesel engine, whereas to control NOx emission separate after treatment device is required. The selective catalytic reduction (SCR) and Lean NOx trap (LNT) is an efficient device for controlling NOx emissions. The SCR system still has his own complications like external reductant, storage tank and ammonia slips. The LNT system is recognized as a one of the most effective system for reducing NOx emission in diesel engines.

NOx absorber catalysts, also referred to as LNT, provide another catalytic pathway for reducing NOx in an oxygen rich exhaust stream. LNT device removes NOx in a lean (i.e. oxygen rich) exhaust environment for both diesel and gasoline lean-burn GDI engines. The mechanism of LNT is under normal lean diesel engine operation, the NOx absorber catalyst stores the NOx molecules into it. In order to reduce the trapped NOx to nitrogen, called the NOx regeneration cycle, the engine must be operated rich periodically for a short period. During rich conditions the stored NOx will be decomposed to N_2 and N_2O.

In this work the LNT device coated with BaO and Al_2O_3 is used and tested as a NOx storage material.it is observed that storage material is the important factor for trapping the NOx molecules.

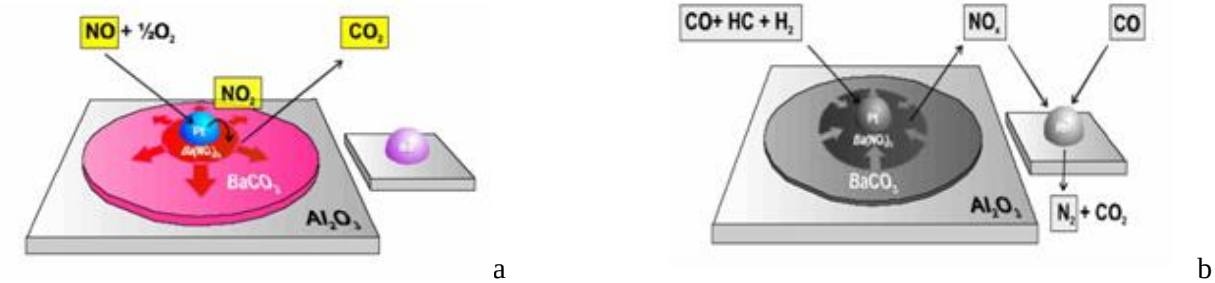

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Figure .1. LNT Mechanism

2. EXPERIMENTAL

Catalyst preparation: In this work various amount of storage materials are tested. Different amounts (1.5, 2.5 and 3.5, 5 wt. %) of BaO were loaded on Al_2O_3 (Aluminum oxide, specific surface area 158.4 m^2/g) through incipient wetness impregnation using $Ba(Ac)_2$ solutions. Impregnated materials were dried in air overnight at 100^0c and subsequently calcinated in air at 500^0c for 5 h to get the as prepared samples. The measured Ba amounts for three samples by XRF are 1.03, 3.07 and 4.73 wt. %, respectively.

Pt (2 wt. %) was loaded on Al_2O_3 by the same method as BaO/Al_2O_3, using Pt $(NO_3)_2$ solutions. Then as prepared Pt/c-Al_2O_3 sample was treated at 800^0c for 5 h at 10% H_2O in the air. The Pt/c-Al_2O_3 was donated as PA. PA sample as the NO oxidation catalysts were mechanically blended with BC samples in a 1:1 weight ratio without calcination. PA–BC is used to stand for Pt/Al_2O_3–Ba/CeO2, and PA–Ce to stand for Pt/Al_2O_3–CeO_2. The specific

surface areas and porous structures of the samples were measured by N_2 adsorption at 77 K with a Tristar 3000 Micromeritics apparatus. Prior to the measurement, all samples were degassed at 300^0c under vacuum for 3 h in order to eliminate the adsorbed species. The coating on the substrate is done by spray pyrolysis technique.

Experimental setup and testing: The engine is started and allowed to warm-up for about 15 minutes. The readings on dynamometer scale (load) time taken for 10cc of fuel consumption. Emission measurement is taken from AVL Di gas analyzer, smoke measurement in smoke meter has been recorded. This procedure is repeated by changing the loads from No load, 5 kg, 10 kg, 15 kg, 20 kg and 25 kg. The exhaust temperature was measured by a K type thermocouple. The eddy current dynamometer was calibrated before starting the experiment, so that loading errors are avoided. The temperature of lubricating oil and cooling water were held constant in order to avoid any interference with the results. The various sensors and emission measurement devices were calibrated to ensure the repeatability and are attached to the exhaust tail pipe after the engine attains steady state conditions.

The set of data compares the load and NOx emission. The graphs are plotted with load of the base engine on the horizontal axis against the NOx of the base engine on the vertical axis. The NOx level is high at higher loads, which is due complete combustion of fuel. The increase of break power will tend to increase the fuel consumption. It can be observed from the figure that the NOx level is high at high loads is due exhaust gas temperature is high. However at low loads temperatures are low and NOx formation reduce.

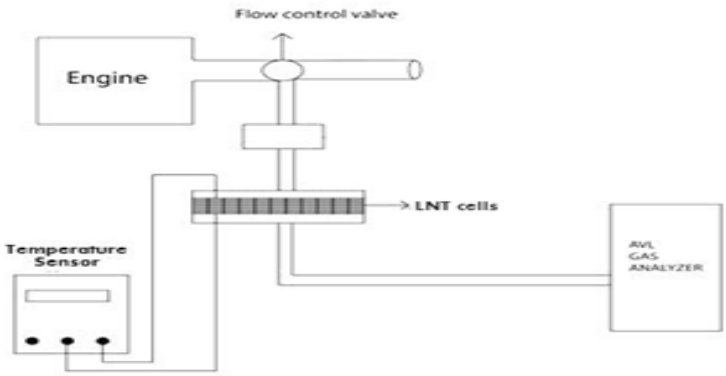

Figure.2. Experimental testing of LNT

Table.1. Engine specification

Manufacturer	Kirloskar oil engines ltd
Cylinder bore	80 mm
Stroke	110 mm
Rated Speed	1500 rpm
Compression ratio	17:1
Number of cylinders	1
Cubic Capacity	552 cc
Injection system type	Direct injection
Injection pressure	200 bars
Injection angle	23^O BTDC
Rated Power	3.7Kw
Cooling fluid	Water

3. RESULTS AND DISCUSSION

From the results for the base engine readings, it can be seen that there was an increase in NO_X with an increase in load. The increase was almost linear in nature. There was also an increase in the NO_x with an increase in exhaust temperature. This can be explained as a higher in cylinder temperature, that will help the reaction between nitrogen and oxygen consequently increasing the NO_x concentration, the increase in the NO_X with the exhaust oxygen content can be due to lean air fuel ratio leading to greater quantity of oxygen available during combustion, subsequently a greater amount of oxygen leads to a rise in the NO_X concentration. The Figure 3 shows the NOx storage efficiency of LNT cells coated with NOx storage materials. It is observed the coating of NOx storage material increases the efficiency of NOx decomposition. The LNT cell-1 and 2 has maximum NOx storage capacity because of the increased porosity of the material. The figure 4 shows the pores size distribution of the various LNT cells. The LNT cells 1 and 2 have maximum pores thereby the storage and regeneration of NOx molecules is higher in those cells.

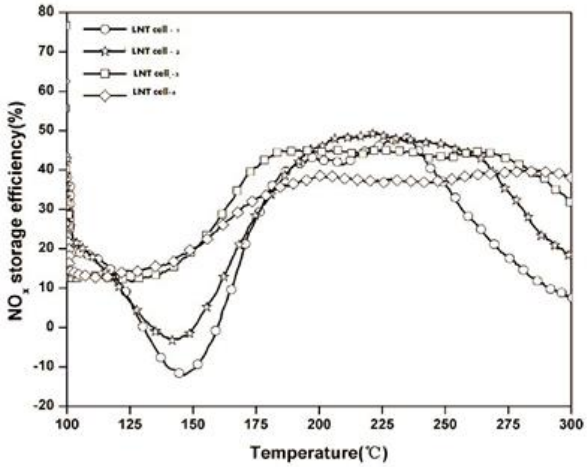

Figure.3. LNT cells efficiency

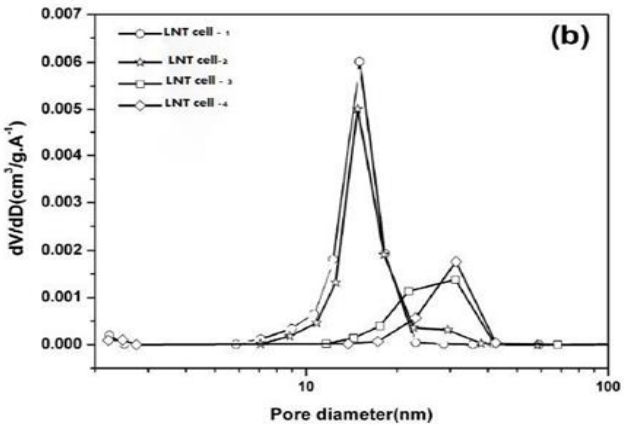

Figure.4. LNT cells pore size distribution

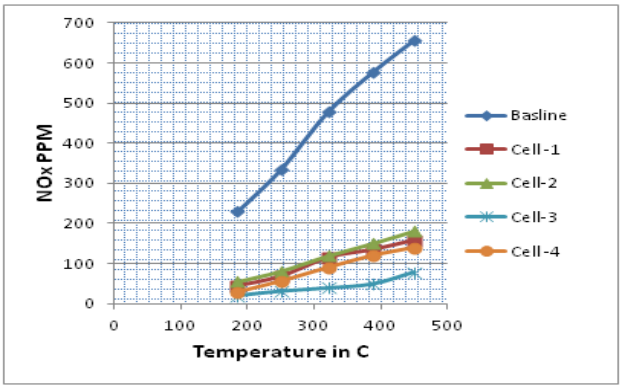

Figure.5. NOx decomposition of LNT catalyst

The variation of NO_X with catalyst bed temperature was also studied .The figure 5 shows the NOx decomposition rate of LNT catalytic cells.it was seen that there was an initial increase in NO_X with temperature. The LNT catalyst of cell 1 and 2 has maximum NOx decomposition when compared with other two cells. The BaO layer on the substrate increases the adsorption rate in the catalyst. The material thickness is important for catalytic activity of the LNT.

4. CONCLUSION

The base metal-based LNT catalysts BaO/Al_2O_3 and PT are active for NOx storage and reduction in cyclic lean/rich conditions. In this work LNT catalyst of four different cell arrangements were test in the real exhaust conditions. It is observed that the LNT cells 1 and 2 have a good NOx decomposition because of the high porosity of the catalyst. A very high NOx reduction percentage 95% is achieved in this method.

The future work would involve a better study of the high temperature characteristics of the catalyst and an investigation of the various NOx storage materials and the effect of thermal ageing of the catalyst in the NO_X conversion of the catalysts.

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