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EFFECT OF NOx REDUCTION CATALYTIC CONVERTORS IN LEAN BASED ENGINES - A REVIEW PAPER.

V R Chavda[1], H V Mandlia[2]

[1]Lecturer in Mechanical Engineering, R. C. Technical Institute, Ahmedabad
[2]Lecturer in Mechanical Engineering, Government Polytechnic, Jamnagar

Abstract — *The awareness regarding the air pollution and its effects on our environment has inspired many researchers. Tail-end emission of pollutant gases such as NO_x, CO, unburnt hydrocarbons (HC), etc. from the engines are the biggest contributors in air pollution. Engines with a lean air-fuel ratio have better fuel efficiency and a low operating cost. However the NO_x emission from a lean engine is difficult to control. These economical engines produce exhaust fumes that are particularly rich in oxygen and therefore the conventional three-way catalytic converter is not suitable for converting the generated NO_x into nitrogen. This review paper discusses the usage of the NO_x storage catalytic convertor as a measure to reduce NOx emissions from such oxygen rich (higher a/f ratio) engines.*

Keywords- *Air pollution, NO_x emissions, lean air to fuel ratio, catalytic convertors.*

I. INTRODUCTION

The emission control technologies have faced many problems. Atypical exhaust gas composition at the normal engine operating conditions are: carbon monoxide (CO, 0.5 vol.%), unburned hydrocarbons (HC, 350 ppm), nitrogen oxides (NOx, 900ppm) hydrogen (H_2, 0.17 vol.%), water (H_2O, 10 vol.%),carbon dioxide (CO2, 10 vol.%), oxygen (O_2, 0.5vol.%) [3]. The NOx is formed at higher temperatures (~1500 0C) of the combustion process due to thermal disintegration of nitrogen molecule. The reduction of such hazardous emissions can be achieved by two measures: Primary (i.e. inside engine) and Secondary (i.e. outside engine). The primary measures include combustion of lean air fuel mixture, multistage injection fuel, loading of additional water into cylinder volume, etc. While secondary measures for engine exhaust includes a range of advanced technologies based on oxidation-reduction, 3-way catalyst adsorption storage and filtration process. As a result of researcher’s efforts to produce more efficient and low-emission engines, lean burn petrol and diesel engines have come to the market. Lean-burn engines effectively improve the fuel efficiency, but produces oxygen rich exhaust gases. Removal of NOx from such oxygen rich exhaust is extremely difficult by a conventional 3-way catalyst. The 3-way catalytic converter technology is successful for stoichiometric internal combustion engines, however it will not function at O2 levels in the emission exceeding 1.0% [5]. Because of the increasing need to limit NOx emission, technologies such as Exhaust Gas Recirculation (EGR) and selective catalytic reduction (SCR) have been used. However both the systems have their persistent limitations in their effectiveness. Hence NOx storage catalysts were developed.

II. EMISSION CHARACTERISTICS OF A LEAN BURN ENGINE

In a lean petrol or diesel engine the exhaust consists of a complex mixture, the composition depends on a variety of factors such as engine type (2 or 4 stroke, petrol or diesel), applications (stationary or mobile), speed, acceleration/deceleration, etc. Figure: 1 shows the effect of A/F ratio on composition of engine emissions and power:

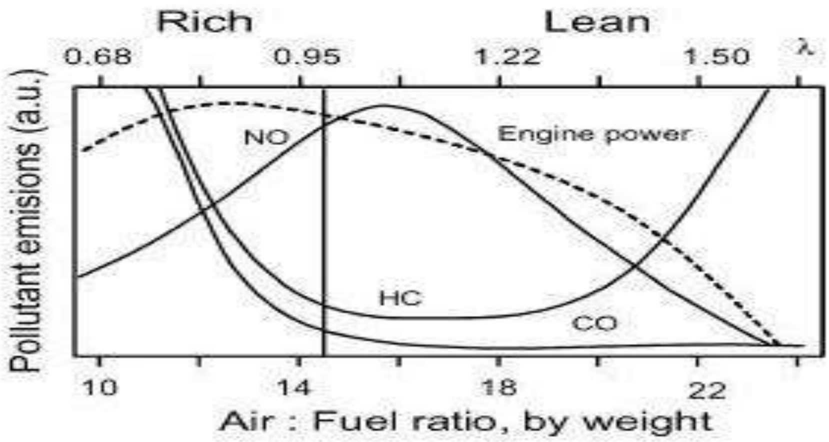

Fig. 1 Effect of A/F ratio on engine emissions and engine power

In general, the exhaust emissions depend on the Air-to-fuel (A/F) ratio as describes in fig.1. Tuning of the engine to rich feed gives the highest power output, which, however, occurs at expenses of high fuel consumption. However under lean conditions the NOx emission increases up to certain level and then substantially decreases due to misfire which occurs at higher A/F ratios.

Table 1: comparison of exhaust conditions for four stoke stoichiometric burn spark ignited (SI) engine and a four stroke lean burn SI engine [7].

Exhaust components	Four stroke stoichiometric burn SI engine	Four stroke lean burn SI engine
NO_x	100-4000 ppm	1200ppm
HC	500-5000 ppm C	1300 ppm C
CO	0.1-6%	1300 ppm
O_2	0.2-2%	4-12%
H_2O	10-12%	12%
CO_2	10-13.5%	11%
SO_x	15-60 ppm	20 ppm
A/F ratio	14.7	17

There are several advantages in removing NOx from the exhaust under the lean conditions (i.e. A/F > 14.5) compared to stoichiometric condition (A/F = 14.5) of a petrol engine where emissions are controlled by a conventional Three Way Catalytic converter (TWC). Another important aspect is the fuel economy which is higher in lean engines. In 1990's due to introduction of the TWC's in vehicles by the enforcement of strict environmental laws, an increase in fuel consumption of vehicles occurred. This was due to the fact that TWC's require a stoichiometric A/F ratio to achieve best performance. Apart from this, several other reasons such as the increase in vehicle weight due to air conditioning, security features, etc. significantly contributed to increased fuel consumption.

Another advantage of a lean burn engine is that the highest exhaust temperatures are lower (~ 800-8500C)[6] compared to stoichiometric engines where highest temperature of the exhaust reaches to 11000C. Such a high temperature may result into catalyst failure in terms of durability.

III. CATALYSTS FOR NOX REDUCTION IN LEAN ENGINES

In the modern times, there is a race among the automobile giants to reduce the fuel consumption in vehicles along with lowering the end emissions. The reason behind this is mainly the rising prices in fossil fuels and strengthening of the laws and legislations pertaining to environment. Hence this has prompted the necessity to develop more effective and advanced catalysts to reduce NOx emissions. As we discussed earlier that lean burned engines have considerable fuel savings due to a higher A/F ratio, however under these conditions the conventional catalytic converters (TWC's) are inefficient. This is primarily due to excess O_2 which competes for a reducing agent, especially CO.

Thus the studies on NOx reduction under lean conditions have been the interests of many. After it was discovered that hydrocarbons (HC's) could act as selective reducing agents under excess O_2 in the early 90's, a feverish activity in the field of lean NOx reduction was followed. And more than 50 catalysts were reported in 1991-92 [6]. Lean DeNOx catalysts are based on direct reduction of NOx, usually by Pt/Al2O3 catalyst (for low temperatures) and metal loaded zeolite (for high temperatures). Such types of adsorption catalysts are also called NOx reduction and storage (NSR) catalysts. Let us examine some of the systems briefly:

- **Pt/Al_2O_3 CATALYTIC SYSTEM**

The use of noble metals in catalytic convertors is well known. Hence we will summarize the typical reaction profile for NOx reduction over Pt/Al_2O_3 catalyst. It is evident that maximum number of NO conversions occurs at lower temperatures [7]. Such catalysts use unburnt HC's as a reducing agent, and hence there is a significant NO_2 formation at high temperatures because at higher temperatures all the HC is completely burnt. The nature of reducing agent also effects the conversion of NO due to its higher sensivity. At low temperatures there is a significant formation of N_2O (di-nitrogen oxide), and Pt catalyst has poor selectivity towards N_2O[8]. Thus, selection of Pt catalysts is highly dependent on the nature of the reducing agents.

- **OTHER DeNOx CATALYTIC SYSTEMS**

Other DeNOX catalysts mainly include Cu-ZSM_5 and other metal oxide catalysts. Even though Cu-ZSM_5 catalysts face problems such as poor hydrothermal stability due to presence of Cu ions in the zeolite frame and poor NOx affinity at high exhausts velocities[8], the Cu-zeolite systems show appreciable activity at high temperatures. Hence such catalysts are more favourable for lean based engines, where such high temperatures are easily met.

At higher temperatures, to improve the thermal stability of zeolite structure, a variety of metal oxides have been tried with Cu. Such metal oxides include oxides of Chromium (Cr), Silver (Ag), Manganese (Mn) and Cerium (Ce). Such additives improve the activity as well as the temperature range of the catalyst.

- **NOx ADSORBERS**

The base of such NOx traps was laid by the Toyota Group after the discovery of so-called NSR catalysts. In such NOx adsorbers, NOx gases are stored under oxidising conditions at the surface of Barium (Ba)- based catalyst in form of nitrides or nitrades. After certain period of time the engine is made to run at a lower A/F ratio and the stored NOx is reduced over Pt catalyst in presence of unburnt HC. However this is a complex process due to the complex nature of the species.

IV. CONCLUSIONS

There has been a significant development in the field of catalytic converters in the last few years due to more and more demanding government regulations on pollution control. The requirement of more efficient engines must be alongside with the developments in the field of catalytic converters. Moreover the problem of NOx removal under oxidising conditions requires huge efforts. Even though, many efforts have been made in developments of DeNOx catalysts, their performance is still insufficient. Also the durability of such converters should be same as that of the car. Technology for control of pollution will find an increasing demand in the next years. In particular, technology pertaining to the use of "Nano-technology" can transform the conventional strategies of pollution control. This is further necessary in order to obtain a miniaturisation of the system without compensating its effectiveness, and therefore application in automobiles.

REFERENCES

[1] Parks, J. E., D. Ferguson, and John ME Storey. *NOx Reduction with Natural Gas for Lean Large-Bore Engine Applications Using Lean NOx Trap Aftertreatment*. United States. Department of Energy, 2005.

[2] Netherlands Organization for Scientific Research. "Economical And Cleaner Cars With Lean-burn Catalytic Converter." ScienceDaily. ScienceDaily, 17 July 2007. <www.sciencedaily.com/releases/2007/07/070712134929.htm>.

[3] PATEL, BHARAT S., and Mr KULDEEP D PATEL. "A Review paper on Catalytic Converter for Automotive Exhaust Emission." *International Journal of Applied Engineering Research* 7.11: 2012.

[4] Matsumoto, Shin'ichi. "Catalytic reduction of nitrogen oxides in automotive exhaust containing excess oxygen by NOx storage-reduction catalyst." *Cattech*4.2 (2000): 102-109.

[5] Church, Michael L., Barry J. Cooper, and Philip J. Willson. *Catalyst formulations 1960 to present*. No. 890815. SAE Technical Paper, 1989.

[6] Kašpar, Jan, Paolo Fornasiero, and Neal Hickey. "Automotive catalytic converters: current status and some perspectives." *Catalysis Today* 77.4 (2003): 419-449.

[7] Burch, R., and T. C. Watling. "Adsorbate-assisted NO decomposition in NO reduction by C3H6 over Pt/Al2O3 catalysts under lean-burn conditions."*Catalysis letters* 37.1-2 (1996): 51-55.

[8] Shelef, M. "Selective catalytic reduction of NOx with N-free reductants."*Chemical Reviews* 95.1 (1995): 209-225.

[9] Matsumoto, Shinichi, et al. "Development of NO~ x Storage Reduction Catalyst for Automotive Lean-Burn Engine." *Nippon Kagaku Kaishi* (1996): 997-1002.

[10] Takahashi, Naoki, et al. "The new concept 3-way catalyst for automotive lean-burn engine: NOx storage and reduction catalyst." *Catalysis Today* 27.1 (1996): 63-69.

