Comprehensive Review of Three way Catalytic Converter

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Abstract – The air pollution is serious problem in present scenario if this continues to rise at such a rapid rate it would make human generation extinct. Emissions produced in internal combustion engine comprises of Carbon monoxide (CO)- a poisonous gas that is colorless and odorless Hydrocarbons or Volatile organic compounds (VOCs)- Produced mostly from unburned fuels that evaporates.

Sunlight breaks down to form oxidants which react with oxides of nitrogen. Nitrogen Oxides together Contribute to smog and acid rain and also cause irritation to human mucus membranes. Catalytic converter generally used in modern automobile vehicles is based on noble metal (platinum, rhodium and palladium). Catalytic converter based on noble metal has certain demerits. Automobiles are responsible for large scale air pollution hence clean air act 1970 is applied to all automobiles. According to this act the exhaust from automobiles must be within permissible limit. To carry out this process we induce catalytic converter which is fitted to exhaust of engine along with muffler to reduce toxic & harmful exhaust gases into harmless and non polluting gases. The paper is mainly concentrated on study of catalytic converter and to find out new innovative design to bring about best efficiency of this extremely useful device. Advance Exhaust System reduces CO level and HC level by 68% & 60% respectively.

Keywords: Catalytic Converter, Hydrocarbon, Exhaust Emission, NOx

I. INTRODUCTION

The main contribution to environment pollution is because of automobiles exhaust gases combustion of fuel inside cylinder leads to formation of hydrocarbons, carbon monoxide & oxides of nitrogen. These gases are extremely harmful and toxic for all living creature. As primary measures many different possibilities and technical methods of reducing exhaust gas emission are used e.g. combustion of lean air fuel mixture, multistage injection fuel, exhaust gas recirculation, fuel gas after burning, loading of additional water into cylinder volume. [1]

Nowadays secondary measures, in automotive exhaust after treatment processes a range of advanced technology is applied based on oxidation and three-way catalyst adsorption storage and filtration process. This enables reduction of the carbon monoxide (CO), hydrocarbons (HC), nitrogen oxide (NOx) and particulate emissions from a gasoline or diesel engine to meet the demands of current and future exhaust emission regulations. This review paper discusses

automotive exhaust emissions and its impact, automotive exhaust emission control by platinum (noble) group metal based catalyst in catalytic converter, types of catalytic convertor, and different materials of catalytic convertor and also achievements of catalytic convertor.

These are four areas in automobile, which can emit pollutants into atmosphere; these are fuel tank, carburetor, and crankcase and exhaust system. The fuel tank and carburetor emit fuel vapors, the crankcase give out the partly burnt air fuel mixture blown of through piston ring, while emission from exhaust system include unburned hydrocarbons, carbon monoxide, Nitrogen oxide & Sulphur oxides.[2] Therefore atmospheric pollution can be decreased by controlling these areas of automobiles. Mainly two different approaches have been followed: To reduce the formation of pollutants in emissions by redesigning the engine ventilation system, carburetor & fuel tank. The combustion chamber along with fuel system, cooling system, ignition system and exhaust system are also redesigned, thus improving upon the combustion efficiencies which reduce the emissions.

II. CATELYTIC CONVERTERS

The purpose of catalytic converter is to reduce harmful emission from the exhaust of combustion engine. Out of various technologies available for automobile exhaust emission control a catalytic converter is found to best option to control CO, HC and NOx emissions from petrol driven vehicles while diesel particulate filter and oxidation catalysts converter or diesel oxidation catalyst have so far been the most potential option to control particulates emissions from diesel driven vehicle. A catalytic converter is placed inside the tailpipe through which deadly exhaust gases containing unburnt fuel, CO, NOx are emitted.[3,4,5] The function of the catalytic convertor is to convert these gases into CO2, water, N2 and O2 It is accomplished through a combination of heat and a precious metal catalyst that causes the harmful emission to either oxidize or reduce to safe element in exhaust flow.

Methodology of the Research

The main objective is to study the efficiency of the catalytic converter to improve the design of the catalytic converter. The three ways of evaluation the catalytic efficiency are as follows:

1. By evaluation of amount of NOx & CO.
2. By using exhaust gas sensor.
3. By measuring the outer temperature.

Types of Catalytic converter

The Oxidization Catalytic Converter

An oxidation catalyst is an expedient placed on the tailpipe of a car. The oxidation catalyst is the second stage of the catalytic converter. It decreases the unburned hydrocarbons and carbon monoxide by burning them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

$HC + O_2 = CO2 + H_2O$

$2CO + O_2 = CO_2$

The Reduction Catalytic Converter

A reduction catalyst to control NOx can be used as a distinct system in addition to the oxidation catalytic converter. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to decrease the nitrogen oxide emissions. When such molecules come in contact with the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst forming N_2. [6,7]

$2NO = N_2 + O_2$

The Three Way Catalytic Converter (TWCs)

TWCs have the benefit of performing the oxidation of carbon monoxide (CO), hydrocarbons (HC) and the reduction of nitrogen oxides simultaneously. Noble metals are usually used as the active phase in TWCs. Pd catalysts are especially attractive since Pd is by far the inexpensive noble metal in the market and has well selectivity and activity for hydrocarbons. Rhodium the other vital constituent of three-way catalysts is broadly recognized as the most efficient catalyst for promoting the reduction of NO to N_2. The TWCs performance in the emission control can be affected by operating the catalyst at elevated temperatures greater than 625°C.

The major reactions are the oxidation of CO and HC and the reduction of NOx. Also, water gas shift and steam reforming reaction occur. Intermediate products such as N_2O and NO_2 are also originated. The NOx storing concept is based on combination of a storage component into the three-way catalyst to store NOx during lean conditions for a time period of minutes.

Reaction in the Catalytic Converter

$2CO + O2 = 2CO2$

$HC + O_2 = CO_2 + H_2O$

$2CO + 2NO = 2CO_2 + N_2$

$HC + NO = CO_2 + H_2O + N_2 + 2H_2$

$2NO = 2H_2O + N_2$

$CO + H_2O = CO_2 + H_2$

$HC + H_2O = CO_2 + H_2$

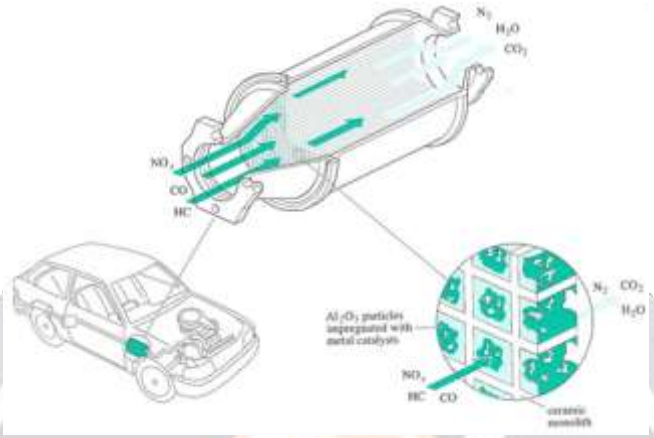

Fig.1 ***Diagram of Three Way Catalytic Converter***

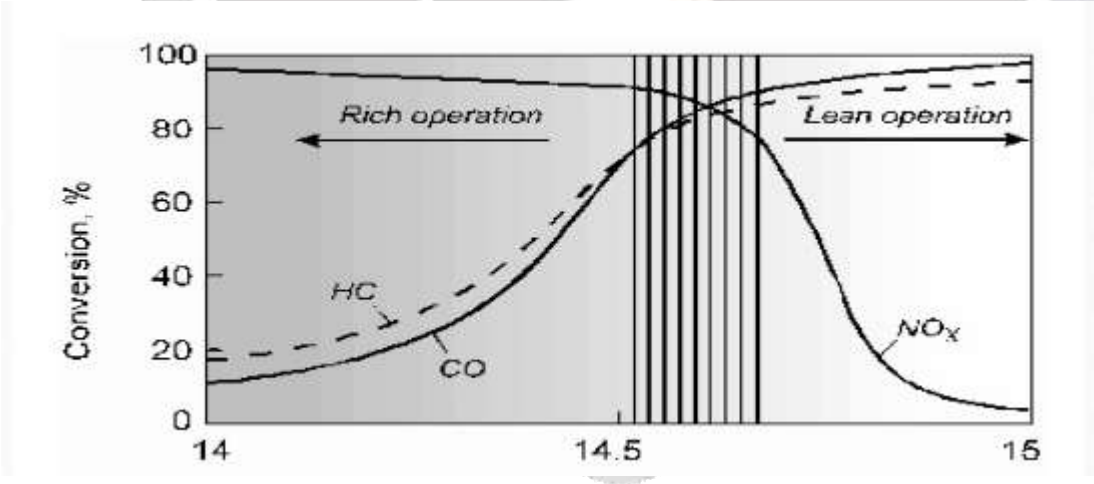

Fig. 2: Air fuel Ratio

The conversion efficiency of CO, NO and HC as a function of A/F ratio is shown in three way catalytic converter. It represents the conversion efficiency of NO, HC and CO as a function of A/F ratio. There is a fine range of air- fuel ratio near stoichiometry in which

high conversion efficiencies for all three pollutants are attained. The width of this window is narrow about 0.1 air-fuel ratio for catalyst with high mileage use and be contingent on catalyst formulation and engine working conditions.[8]

For Rich Mixture

The carbon monoxide content of the exhaust rises and the oxygen content falls. This provided a high efficiency operating environment for the reducing catalyst (rhodium). The oxidizing catalyst maintains its efficiency as stored oxygen is released. Effect of A/F ratio on the conversion efficiency of three-way catalysts narrow A/F window at the stoichiometric point is the impression of an effective TWC system.

For Lean Mixture

The oxygen % of an exhaust jet increases and the carbon monoxide content decreases. It results a high efficiency operating environment for the oxidizing catalysts. During this lean cycle the catalyst also stores extra oxygen which will be released to promote superior oxidation during the rich cycle.

III Limitations of catalytic convertor

Some early converter designs greatly restricted the flow of exhaust, which negatively affected vehicle performance and fuel economy. Because they were used with carburetors incapable of precise fuel-air mixture control, they could overheat and set fire to flammable materials under the car.[9]

Since the performance of the catalyst drops off over time, excess metal must be added. Due to the fact that the PGM are created due to the scrape of an automotive catalyst wash coat. That is why the road traffic is responsible for metallic and organic pollutant – emissions which contaminate the environment. Vehicles emit most of their pollution during the first five minutes of engine operation before the catalytic converter has warmed up sufficiently to be effective.

Removing a modern catalytic converter in new condition will not increase vehicle performance without retuning, but their removal or "gutting" continues. In such cases, the converter may be replaced by a welded-in section of ordinary pipe or a flanged "test pipe" ostensibly meant to check if the converter is clogged by comparing how the engine runs with versus without the converter, which facilitates reinstallation of the converter in order to pass an emission test.[10]

IV CONCLUSION

Automobiles are meeting emission standards that need to reduce percentage of CO, Unburned Hydrocarbons and NOx . Three-way catalyst with stoichiometric engine control systems continues the state of art technique for controlling hydrocarbon, CO and NOx. The emission of Hydrocarbon (HC) and Carbon Monoxide (CO) is considerably reduced, but not much effect

analysed in reduction of Nitrogen Oxide (NOx).So, Ferric Oxide (Fe_2O_3) can be used as catalyst for effective reduction of Nitrogen Oxide (NOx) and soot particles.

REFERENCES

[1] P. O. A. L. Davies 1988 Journal of Sound and Vibration 124, 91- 115. Practical Flow Duct Acoustics.
[2] A. J. Haagen-Smit, Ind. Engng. Chem., 1952,z A. J. Haagen-Smit and M. M. Fox, Ind.
[3] L. H. Rogers,?. Chem. Educ., 1958, 35, 310
[4] K. L. Chass, P. S. Tow, R. G. Lundie andN. R. Shaffer, Air Pollution Control Assn. J.,1960,10, 351
[5] E. L. Pollitzer, Platinum Metals Rev., 1972, 16,(2), 42-47
[6] G. J. K. Acres, Platinum Metals Rev., 1970, 14,(I), 2; Ibid., 1971, 15, (I), 9; Ibid., (4), 132
[7] G. J. K. Acres, Ibid., 1970, 14, (3), 78
[8] Koenigsberg, J., "Should Your Laboratory Be Equipped with a Hazardous Exhaust System?" R&D Magazine, Laboratory Design Newsletter, Volume 7, #13, March 2002.
[9] E.F. Doyle, P.S. Patel, "Compounding the truck diesel engine with an organic rankine cycle system," 760343, Society of Automotive Engineers (SAE), 1976.
[10] V Ganeshan, "Internal Combustion Engine," Tata McGraw Hill Publishing company Limited, Second Edi
[11] V. Johnson, "Heat-generated cooling opportunities in vehicles," SAE Technical Papers, No. 2002, 2002-01-1969. International Journal of Automotive Technology, (2008) Vol. 9, No. 2, pp. 155-160.
[12] Vijay Chauhan, "A Review of Research In Mechanical Engineering On Recovery Of Waste Heat In Internal Combustion Engine," International Journal Of Research In Engineering & Applied