

# Review Study on Catalytic Converter for Emission Control in Diesel Engine

Harshil S. Patel<sup>1</sup> Prof. Dipak J. Parmar<sup>2</sup>

<sup>1</sup>P.G. Student <sup>2</sup>Assistant Professor

<sup>1,2</sup>Department of Mechanical Engineering

<sup>1,2</sup>L D College of Engineering, Ahmedabad

**Abstract**— Exhaust pollutants from the automobile engines have negative impact on air quality as well as on human health. Exhaust emission control by catalytic converter, is best way to reduce emission for automotive vehicles. 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. Research in area of non-noble metal based catalytic converter to be developed for reducing pollution generated by automobile diesel engine. Current study focuses on new developed Ferric Oxide based catalytic converter because existing available catalytic converters suffer from various problems like; poisoning, fracture, melting and higher cost.

**Key words:** Catalytic converter, Diesel Engine, Emission control

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. 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 (NO<sub>x</sub>) 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 converter, different materials of catalytic converter and also achievements of catalytic converter.

## I. INTRODUCTION

Air pollution created by vehicles is a major problem of general interest. Vehicle population is projected to grow close to 1300 million by the year 2030. Due to incomplete combustion in the engine, there are a number of incomplete combustion products CO, HC, NO<sub>x</sub>, particulate matters etc. Most vehicular transportation relies on combustion of gasoline; diesel and jet fuels with large amount of emission of carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NO<sub>x</sub>) and particulates matter (PM) are especially concern. HC and CO occur because the combustion efficiency is less than 100%. The NO<sub>x</sub> is formed during the very high temperatures (>1500 °C) of the combustion process resulting in thermal fixation of the nitrogen in the air which forms NO<sub>x</sub><sup>[1]</sup>.

Typical exhaust gas composition at the normal engine operating conditions are: carbon monoxide (CO, 0.5 vol.%), unburned hydrocarbons (HC, 350 vppm), nitrogen oxides (NO<sub>x</sub>, 900 vppm) hydrogen (H<sub>2</sub>, 0.17 vol.%), water (H<sub>2</sub>O, 10 vol.%), carbon dioxide (CO<sub>2</sub>, 10 vol.%), oxygen (O<sub>2</sub>, 0.5 vol.%).<sup>[11]</sup> Carbon monoxide is a noted poison that has an affinity for haemoglobin in the blood 210 times greater than the oxygen affinity prolonged exposure to levels above 9 ppm can lead to reduce mental acuity for some individuals.

HC and NO<sub>x</sub> lead to photochemical smog in presences of sunlight give secondary pollutants like ozone, nitrogen dioxide & peroxyacyl nitrate which cause also global environmental problems. As the emission standards were tightened, more advanced control strategies were applied that included modifications in engine design and fuel system, control of engine parameters and use of sophisticated exhaust after treatment devices. Reduction of toxic substances emission from combustion engines can be achieved by primary (inside engine) measure and secondary (outside engine) measures<sup>[11]</sup>.

## II. CATALYTIC CONVERTER

The pollutants have negative impact on air quality, environment and human health that leads in stringent norms of pollutant emission. Numbers of alternative technologies like improvement in engine design, fuel pretreatment, use of alternative fuels, fuel additives, exhaust treatment or better tuning of the combustion process etc. are being considered to reduce the emission levels of the engine. Out of various technologies available for automobile exhaust emission control a catalytic converter is found to best option to control CO, HC and NO<sub>x</sub> 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, NO<sub>x</sub> are emitted. The function of the catalytic converter is to convert these gases into CO<sub>2</sub>, water, N<sub>2</sub> and O<sub>2</sub> and currently, it is compulsory for all automobiles plying on roads in US and Japan to have catalytic converters as they use unleaded petrol. In India, the government has made catalytic converters mandatory for registration of new cars.

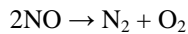
## III. TYPES OF CATALYTIC CONVERTER

### A. The Oxidization Catalytic Converter:

An oxidation catalyst is a device placed on the tailpipe of a car. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) 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<sup>[2]</sup>.

### B. The Reduction Catalytic Converter:

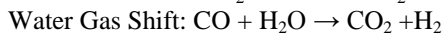
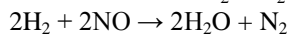
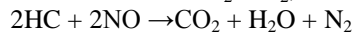
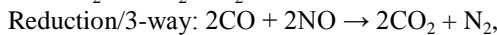
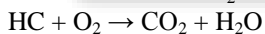
A reduction catalyst to control NO<sub>x</sub> can be used as a separate system in addition to the oxidation catalytic converter. The reduction catalyst is fitted upstream of the oxidation system. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to reduce 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<sub>2</sub>. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst forming N<sub>2</sub><sup>[2]</sup>.



### C. The Three-Way Catalytic Converter (TWC):

TWCs have the advantage of performing the oxidation of carbon monoxide (CO), hydrocarbons (HC) and the reduction of nitrogen oxides (NO<sub>x</sub>) simultaneously. Noble metals are usually used as the active phase in TWCs. Pd catalysts are especially attractive since Pd is by far the cheapest noble metal in the market and has better selectivity and activity for hydrocarbons. Rhodium the other essential constituent of three-way catalysts is widely recognized as the most efficient catalyst for promoting the reduction of NO to N<sub>2</sub>. The TWCs performance in the emission control can be affected by operating the catalyst at elevated temperatures (> 600 °C). Reactions occurring on the automotive exhaust catalysts are very complex as listed below. The major reactions are the oxidation of CO and HC and the reduction of NO<sub>x</sub>. Concept is based on incorporation of a Also, water gas shift and steam reforming reaction occur. Intermediate products such as N<sub>2</sub>O and NO<sub>2</sub> are also found. The NO<sub>x</sub> storage component into the three-way catalyst (TWCs) to store NO<sub>x</sub> during lean conditions for a time period of minutes<sup>[3]</sup>.

Reactions in Catalytic Converter:-



Oils, due in part to its high water and oxygen content, which can make it unstable until it undergoes further processing. Bio-oil can be hydro-treated to remove the oxygen and produce a liquid feedstock resembling crude oil (in terms of its carbon/hydrogen ratio), which can be further hydro-treated and cracked to create renewable hydrocarbon fuels and chemicals. Hydro-treating stabilizes the bio-oil preventing molecule-to-molecule and molecule-to-surface reactions and eventually produces a finished blend-stock for fuels. Bio-oil can be deoxygenated from its high initial oxygen content of 35-45 percent by weight (wt%) on a dry basis all the way down to 0.2 wt%<sup>[5]</sup>.

### D. Modern Three Way Catalytic Converter:

A typical design of a modern three-way catalytic converter is a stainless steel container that incorporates a honeycomb monolith made of ceramic or metal. The monolith acts as the inert substrate coating with washcoat and active catalysts. Washcoat is a layer of mixture (mainly aluminium) which

gives a further irregular and larger surface area also contains oxygen storage promoters and stabilizers. To prepare the substrate and the catalysts are then deposited on the washcoat or dipping the monolith into a slurry containing washcoat components and platinum group metals. The excess of the deposited material (washcoat) is removed using high-pressure air or by applying a vacuum. Then the monolith is calcined to obtain the finished catalyst. The monoliths geometrical characteristics play a key role in effecting the distributions of temperature and species throughout the device and then determining the efficiency of the converter. It combines the requirements of compactness, high volumetric flow rates and low back pressure<sup>[3]</sup>.

## IV. LITERATURE SURVEY

Chirag Amin et al present paper on catalytic converter based on non-noble material. This paper review problems associated with noble metal based catalytic converter. Catalytic converter may be due to factors converter meltdown, carbon deposit, catalyst fracture and Poisoning. The converter becomes too hot and melts inside so that the small particles come apart on the inside. The broken pieces can move around and get in position to plug up the flow of exhaust through converter. This meltdown is caused by converter having too much work to do. There is too much HC or CO to clean up. The converter doesn't know how to stop; It keeps up its reactions. The inside chamber of the catalytic converter gets coated with some contamination, like carbon, oil, coolant or other stuff, or they are just melted enough and reduce surface area. This paper reviewed the most common existing technologies available to reduce exhaust emission and catalytic exhaust after treatment. Methodologies to increase temperature of catalytic converter during cold starting were also discussed. Finally, research going on to replace noble catalyst were discussed<sup>[4]</sup>.

Narendrasinh R. Makwana et al present paper on development and performance analysis of nickel based catalytic converter. There are several types of problems associated with noble metal based catalytic converter. These factors encourage for the possible application of non-noble metal based material such as nickel as a catalyst. They have used Nickel as the oxidizing agent because of its non-poisonous nature, low cost and availability makes it preferred carrier in oxidation from the stationary pollution sources. Experimental tests were carried out on four cylinder four stroke diesel engine equipped with modified catalytic converter with using 30 mesh, 40 mesh and 50 mesh size of nickel coated wire mesh. It was found that most suitable for emission conversion rate is the 50 mesh size wire mesh. Because the surface area of 50 mesh size wire mesh is higher compare to 30 mesh size and 40 mesh size of wire mesh. By using nickel based modified catalytic converter, CO reduces up to 35% and HC reduces up to 40%. It was also found that the nickel is not effective for reducing the NO<sub>x</sub> content from exhaust emission. The price of nickel is approximately Rs. 900 per kg is very less as compared to platinum and palladium. Hence, nickel based catalytic converter is economically effective for diesel engine<sup>[5]</sup>.

Chirag M. Amin et al present paper on copper based catalytic converter using four stroke single Cylinder CI engine. The optimum values of exhaust emissions found at full load are HC (130 ppm), CO (0.07 %). By using

copper based catalytic converter it is found that HC is reduced by 38 % and CO by 33 % at full load. Though not a noble metal, copper works as a catalyst for the conversion of pollutants in exhaust but in a limited proportion. Experimental results shows that, by using copper based catalytic converter, HC reduces by 38% and CO reduces by 33%. It is therefore concluded that development of copper based catalytic converter is feasible since it gave satisfactory results for given operating conditions and reduction of HC and CO emissions. Thus the copper based catalyst system can be the effective approach in place of expensive noble metal based catalytic converter, but NO<sub>x</sub> emission is not measured in this research. The expenditure for fabricating a single catalytic converter is Rs. 2000 to Rs. 2500 but on mass production this cost can be reduced to economic range<sup>[6]</sup>.

D. Reichert et al present paper on study of the reaction of NO<sub>x</sub> and soot on Fe<sub>2</sub>O<sub>3</sub> catalyst in excess of O<sub>2</sub>. This paper presents characteristics of a new catalytic converter based on ferric oxide ( $\alpha$ -Fe<sub>2</sub>O<sub>3</sub>) in relation with NO<sub>x</sub> and soot reduction in emission. Experiments are performed with and without Fe<sub>2</sub>O<sub>3</sub> catalyst using different gas mixture. Examinations show that the NO<sub>x</sub> reduction on the Fe<sub>2</sub>O<sub>3</sub>/soot mixture occurs on the soot surface without being directly affected by the catalyst. Furthermore, O<sub>2</sub> is considered to be crucial for the NO/soot reaction as it produces CC(O) complexes that decompose and lead to the formation of active carbon sites with suitable orientation of the atomic orbitals. Such appropriate surface configuration facilitates the dissociation of NO and formation of N<sub>2</sub>. At these locations the oxygen is transferred to the soot, whereas the contact points maintain even up to high soot conversion levels. Thus, it is concluded that the catalyst affects the soot oxidation without intermission. Finally, our studies show that only surface and sub-surface oxygen of the Fe<sub>2</sub>O<sub>3</sub> catalyst is involved in the oxygen transport. So, from this research paper it is concluded that Fe<sub>2</sub>O<sub>3</sub> catalyst may become more crucial for reduction of NO<sub>x</sub> in the exhaust emission of vehicles<sup>[7]</sup>.

Steffen Wagloehner et al present paper on study on the mechanism of the oxidation of soot on Fe<sub>2</sub>O<sub>3</sub> catalyst. For the removal of soot from the exhaust of diesel engines so called diesel particulate filters (DPF) are currently applied. These filters operate with high efficiency by forcing the exhaust to flow through their porous walls. In this paper we conclude a scheme of global reactions describing the mechanism of the catalytic soot oxidation on Fe<sub>2</sub>O<sub>3</sub>. According to this scheme illustrated in oxygen is transferred from the catalyst surface to the soot by contact points. The resulting oxygen defects of the catalyst surface are refilled either by surface migration and final re-oxidation by gas-phase oxygen, respectively, or by diffusing bulk oxygen. The oxygen deficiency of the lattice is balanced by migration of oxygen from the surface or sub-surface to the bulk of the catalyst. Furthermore, the heat capacity of the catalyst reveals strong effect on the heat evolution upon soot oxidation thus affecting the local temperature and the rate of soot oxidation. Hence, for maximum soot oxidation rate an optimum mass of catalyst is required. Additionally, high catalytic activity is closely related to a sufficient amount of contact points between Fe<sub>2</sub>O<sub>3</sub> and soot<sup>[8]</sup>.

Ronald M. Heck et al present paper on automobile exhaust catalyst. This paper based on short review will discuss the basis for improvements and highlight technology area, which will require further improvements in emissions and fuel economy. Some of the issues related to fuel cells which some believe may replace the internal combustion engines for automobile applications is also be briefly discussed. Because of the large vehicle population, significant amounts of HC, CO and NO<sub>x</sub> are emitted to the atmosphere. The formation of ground level ozone occurs as a result of a chemical reaction between HC and NO<sub>x</sub> and sunlight. Of course, CO is a direct poison to humans. The benefits of catalytic controls have been documented and it is now estimated that by the year 2000, over 800 million tons of combined pollutants of HC, CO and NO<sub>x</sub> will have been abated using auto exhaust catalyst and prevented from entering the atmosphere. The key features in regard to catalyst performance are the use of an engine designed lean cold start and fuel management to supply oxygen for the catalytic oxidations and the reduction of heat loss during cold start<sup>[9]</sup>.

## V. CONCLUSION

According to above Literature Survey, catalytic converters based on noble metals have several problems like Converter meltdown, Carbon deposit clogging, Catalyst fracture and Poisoning. So, non-noble metal based catalytic converter have been developed and analysed for reduction of emission generated by automobile vehicles. Experimental analysis on Copper and Nickel based catalytic converter has been done so far. In their research emission of Hydrocarbon (HC) and Carbon Monoxide (CO) is considerably reduced, but not much effect analysed in reduction of Nitrogen Oxide (NO<sub>x</sub>). So, Ferric Oxide (Fe<sub>2</sub>O<sub>3</sub>) can be used as catalyst for effective reduction of Nitrogen Oxide (NO<sub>x</sub>) and soot particles.

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