

# REVIEW PAPER ON CATALYTIC CONVERTER FOR CONTROLLING EMISSIONS

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## ABSTRACT

Since last decade automobiles were increasing in popularity all over the World; it is simultaneously damaging the environment. The exhaust that resulted from the automobiles is extremely harmful for the environment. Air pollution generated from automobile sources is a problem of general interest. Due to incomplete combustion in the engine, harmful gases such as carbon monoxide, hydrocarbons, nitrogen oxides and particulate matters etc are produced. These pollutants have negative impact on air quality, environment and human health. In order to control these adverse effects, governments are contributing by imparting 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. Among all the types of technologies developed so far, use of Catalytic converters found to be most effective way of reducing air pollution from IC engines in normal operating conditions. In this review paper exhaust emissions and its impact, various emission control techniques, catalytic converter, catalysts used in catalytic converter, its types and limitations will be discussed.

**Keywords:** Catalytic Converter, Catalyst, Exhaust Treatment, Exhaust Treatment.

## I. INTRODUCTION

India is abided of 1.35 billion people which are 17% of total population of world having rapid growing thirst of power from engines. From the last two decades, there has been a lot of increase in the demand of automobiles.

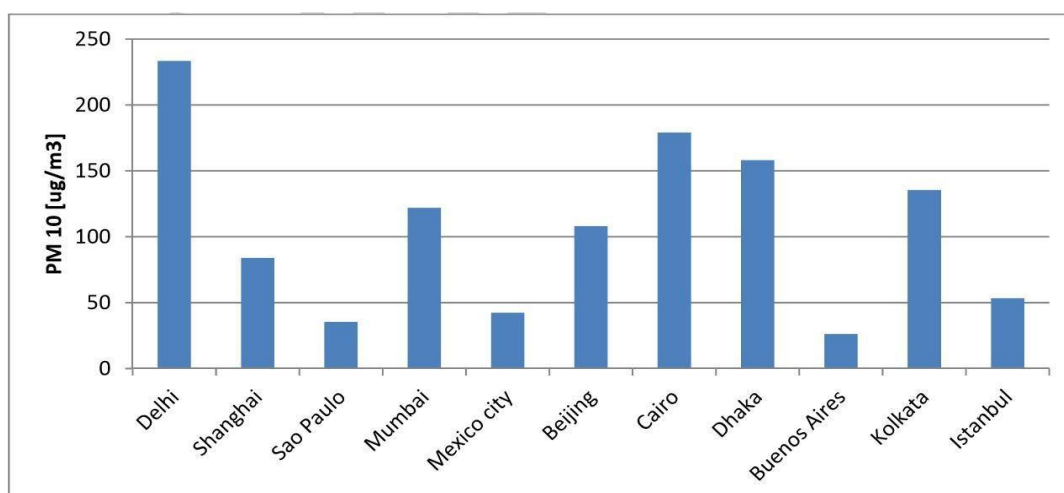


Fig.1: Top polluted cities of Asia in 2016

Vehicle population is projected to grow close to 1300 million by the year 2030. Air pollution generated from mobile sources such as automobiles contributes major air quality problems in rural as well as in urban and industrial areas in both developed and developing countries. A large amount of vehicle transportation relies on combustion of diesel, gasoline, jet fuels with large amount of emission of carbon monoxide (CO), Unburned hydrocarbons (HC), Nitrogen oxide (NO<sub>x</sub>) and particulate matters (PM) are specially concern. HC, CO occur because the combustion efficiency < 100%. The NO<sub>x</sub> is formed during the very high temperatures (>1500 C) of the combustion process resulting in thermal fixation of nitrogen in the air which forms NO<sub>x</sub>. Typical exhaust gases composition at the normal engine operating conditions are: Carbon monoxide (CO, 0.5 Vol. %), unburned Hydrocarbon (HC, 350ppm), Nitrogen Oxides (NO<sub>x</sub>, 900ppm), hydrogen (H<sub>2</sub>, 0.17vol. %), Water (H<sub>2</sub>O 10 vol. %), Carbon dioxide (CO<sub>2</sub>, 10 vol. %), Oxygen (O<sub>2</sub>, 0.5 vol. %).[1] Carbon monoxide is noted poison that has an affinity for Hemoglobin in the blood 210 times more than the Oxygen. The reduction of toxic substances emission from the combustion can be seen in the form of two measures:

- (1). Primary measures (Inside Engine): Here many different technical methods are used to reduce the exhaust emission i.e. Combustion of lean air fuel mixture, Exhaust gas recirculation etc.
- (2). Secondary measures Outside Cylinder): After the primary measures are used, there is an oxidation and reduction based on 3 way catalytic converter. This enables the reduction of CO, HC, And NO<sub>x</sub>, which is Desirable. [3]

## II. CATALYTIC CONVERTER

A Catalytic Converter is an emissions control device that converts Toxic gases and Pollutants in exhaust gases to less Toxic pollutants by catalyzing a Redox reaction (an oxidation and a reduction reaction). Catalytic converters are used with Internal Combustion Engine fueled by either petrol (Gasoline) or Diesel- including lean burn engines as well as Kerosene Heaters and Stoves.

### 2.1 Position of Catalytic Converter Vehicle

The Catalytic Converter is placed inside the tail pipe through which deadly exhaust gases containing unburnt fuel, CO, NO<sub>x</sub> etc. are emitted.

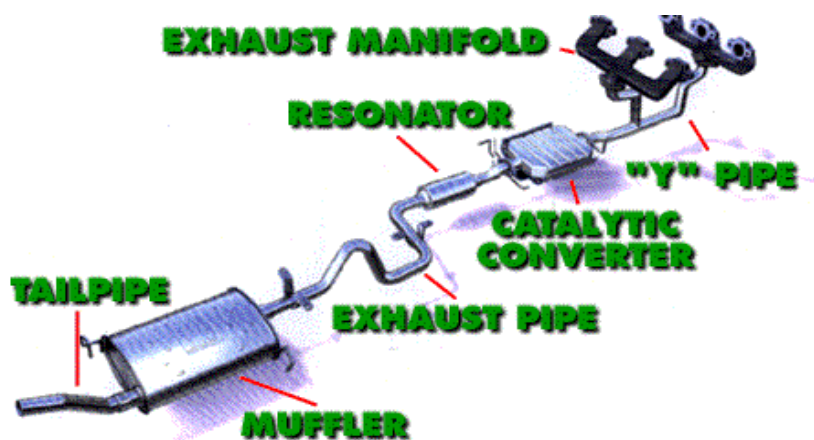


Fig 2: Position of catalytic converter in a vehicle



## **2.2 Working of Catalytic Converter**

The function of the Catalytic Converter is to convert the pollutants into CO<sub>2</sub>, Water, N<sub>2</sub>, O<sub>2</sub>, These are less harmful gases. A mixture of residual quantity of HC, CO, NO<sub>x</sub> are left over after combustion, consequently, a Catalytic Converter uses precious metal like - Platinum( PT), Palladium ( PD)as a catalyst to convert harmful pollutants into less harmful gases like- CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>O etc.

Although catalytic converters are most commonly applied to exhaust systems in automobiles, they are also used on electrical generators, forklifts, mining equipment, trucks, buses, locomotives and motorcycles. They are also used on some wood stoves to control emissions. This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulations.

## **III. HISTORY**

The catalytic converter was invented by Eugene Houdry, a French mechanical engineer and expert in catalytic oil refining, who moved to the United States in 1930. When the results of early studies of smog in Los Angeles were published, Houdry became concerned about the role of smoke stack exhaust and automobile exhaust in air pollution and founded a company called Oxy-Catalyst. Houdry first developed catalytic converters for smoke stacks called "cats" for short, and later developed catalytic converters for warehouse forklifts that used low grade, unleaded gasoline.[7] In the mid-1950s, he began research to develop catalytic converters for gasoline engines used on cars. He was awarded United States Patent 2,742,437 for his work. Widespread adoption of catalytic converters did not occur until more stringent emission control regulations forced the removal of the anti-knock agent tetraethyl lead from most types of gasoline. Lead is a "catalyst poison" and would effectively disable a catalytic converter by forming a coating on the catalyst's surface. Catalytic converters were further developed by a series of engineers including John J. Mooney and Carl D. Keith at the Engelhard Corporation,[7] creating the first production catalytic converter in 1973. William C. Pfefferle developed a catalytic combustor for gas turbines in the early 1970s, allowing combustion without significant formation of nitrogen oxides and carbon monoxide.

## **IV. CONSTRUCTION**

The Construction of a Catalytic Converter can be seen in terms of its basic parts as following:

### **4.1 Substrate**

For automotive catalytic converters, the core is usually a ceramic monolith with a honeycomb structure. Metallic foil monoliths made of Kanthal (FeCrAl)[14] are used in applications where particularly high heat resistance is required. [14] Either material is designed to provide a large surface area

### **4.2 The Wash coat**

A wash coat is a carrier for catalytic materials and used to disperse the material over a large surface area. Aluminum oxide, Titanium oxide, Silicon dioxide, or a mixture of silica and alumina can be used. Catalytic materials are suspended in wash coat prior to applying to the core. The coat must retain its surface area and prevent sintering of the Catalytic metal particles even at the high temperature (1000 C).

These oxides are mainly added as oxygen storage promoters.

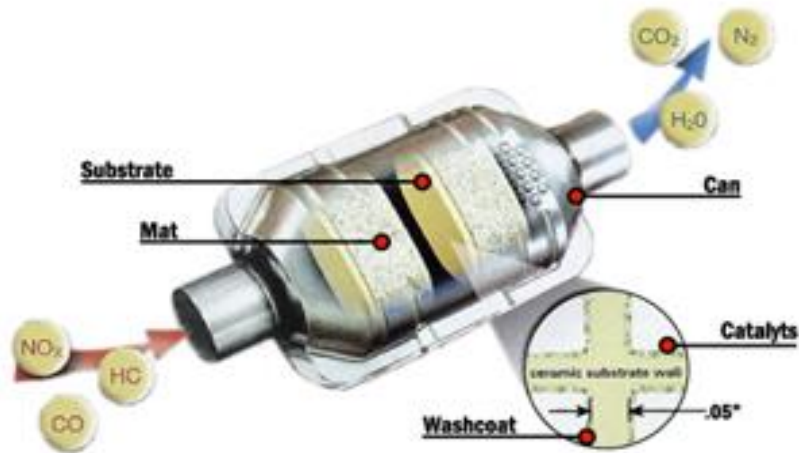


Fig. 3: Ceramic- Core converter

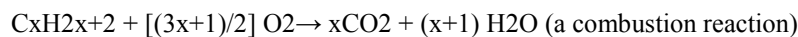
## V. TYPES OF CATALYTIC CONVERTER

Generally catalytic converter are classified into two categories-

### 5.1 Two –Way

A 2-way (or "oxidation", sometimes called an "oxi-cat") catalytic converter has two simultaneous tasks:

1. Oxidation of carbon monoxide to carbon dioxide:
2. Oxidation of hydrocarbons (unburned and partially burned fuel) to carbon dioxide and water:



This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions. They were also used on gasoline engines in American- and Canadian-market automobiles until 1981. Because of their inability to control oxides of nitrogen, they were superseded by three-way converters.

### 5.2 Three – way

Three-way catalytic converters (TWC) have the additional advantage of controlling the emission of nitric oxide and nitrogen dioxide (both together abbreviated with NO<sub>x</sub> and not to be confused with nitrous oxide), which are precursors to acid rain and smog. Since 1981, "three-way" (oxidation- reduction) catalytic converters have been used in vehicle emission control systems in the United States and Canada; many other countries have also adopted stringent vehicle emission regulations that in effect require three-way converters on gasoline-powered vehicles. The reduction and oxidation catalysts are typically contained in a common housing; however, in some instances, they may be housed separately. A three-way catalytic converter has three simultaneous tasks:

- Reduction of nitrogen oxides to nitrogen and oxygen:  $2NO_x \rightarrow xO_2 + N_2$ -
- Oxidation of carbon monoxide to carbon dioxide:  $2CO + O_2 \rightarrow 2C$

- Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water:  $C_xH_{2x+2} + [(3x+1)/2] O_2 \rightarrow xCO_2 + (x+1)H_2O$ .

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. For gasoline combustion. This ratio is between 14.6 and 14.8 parts air to one part fuel, by weight

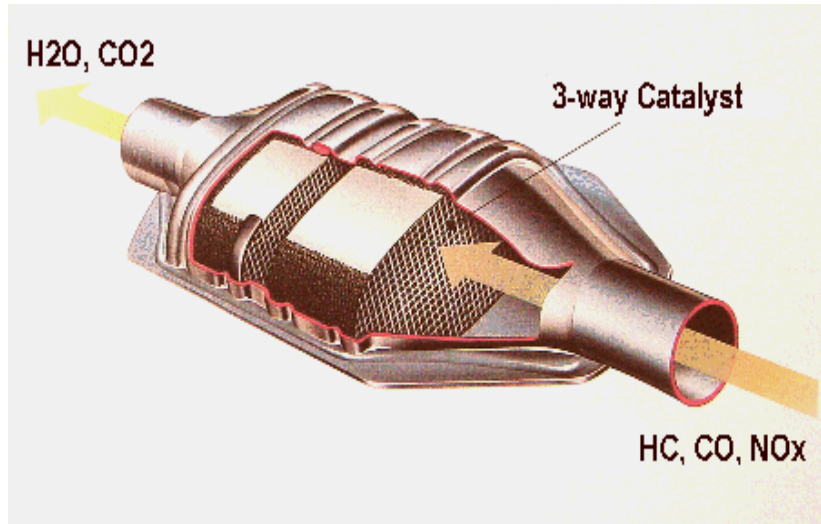


Fig. 4: A three way catalytic converter

### 5.3 Comparison between Two-way and Three- way catalytic converter

Three ways catalytic converter are better than the two ways in terms of efficiency and effectiveness as we can see from the following chart

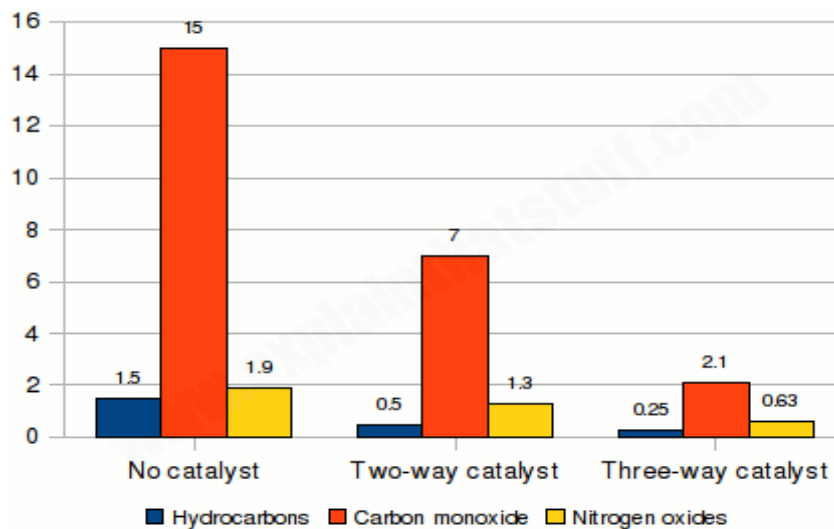
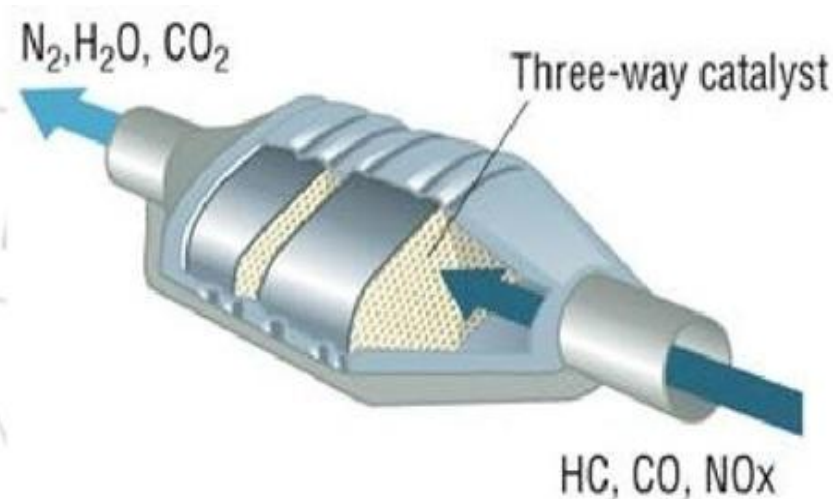


Fig. 5: Effectiveness of catalytic converters

## VI. CONVENTIONAL CATALYTIC CONVERTER

A conventional catalytic converter is a ceramic block, which is honeycombed with microscopic channels that are coated in a rare metal such as platinum.. Emissions travel from the engine to the exhaust system and through

the channels, where the precious metal causes a chemical reaction to occur that eliminates the harmful pollutants. The researchers have advanced an existing manufacturing process to improve the structure of the microscopic channels, increasing the surface area and enabling the rare metal in the device to be distributed more effectively so that less metal is used. The increased surface area also makes the catalytic converters chemical reaction process more efficient.



**Fig. 6: A Conventional three way catalytic converter**

## VII. CATALYSTS USED INCATALYTIC CONVERTERS

In chemistry, a catalyst is a substance that causes or accelerates a chemical reaction without itself being affected. Catalysts participate in the reactions, but are neither reactants nor products of the reaction they catalyze. In the human body, enzymes are naturally occurring catalysts responsible for many essential biochemical reactions. In the catalytic converter, there are two different types of catalyst at work, a reduction catalyst and an oxidation catalyst. Both types consist of a ceramic structure coated with a metal catalyst, usually platinum, rhodium and/or palladium. The idea is to create a structure that exposes the maximum surface area of catalyst to the exhaust stream, while also minimizing the amount of catalyst required, as the materials are extremely expensive. Some of the newest converters have even started to use gold mixed with the more traditional catalysts. Gold is cheaper than the other materials and could increase oxidation, the chemical reaction that reduces pollutants, by up to 40 percent.

There are mainly three catalysts that are used in a catalytic converter –

[1] Palladium (Pd) - It is used in Oxidation Reactions. 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.[9]

[2] Rhodium (Rh) –It is used in Reduction Reactions. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. When an NO or NO<sub>2</sub> molecule contacts 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>. [9]. [3] Platinum (Pt.) –It is used in both Oxidation and Reduction Reactions as well.



## VIII. CONCLUSION

Today's automobiles are meeting emission standards that require reductions of up to 99% of HC, CO and NO<sub>x</sub> compared to the uncontrolled levels of automobiles sold in the 1960s. Environmental, Ecological and Health concern result in increasingly stringent emissions regulations of pollutant emissions from vehicle engines. Uses of metal monolith type catalytic converters are the best way to control the auto exhaust emissions. The economic reasons, limited resources of platinum group (Noble Group) metal and some operating limitations of platinum group metal based catalytic converters have motivated towards the investigation of alternative catalyst materials. This type of catalytic converters has also been developed for the use on trucks, buses and motorcycles as well as on construction equipment lawn and garden equipment etc. In 2005, 100% of the new cars sold in the U.S. were equipped with a catalytic converter, and Worldwide over 90% of the new cars sold had a metal monolith type Catalyst.

## REFERENCES

- [1] Smog — Who Does It Hurt? What You Need to Know About Ozone and Your Health (EPA-452/K-99-001)" (PDF). United States Environmental Protection Agency. July 1999
- [2] Prof. Bharat S Patel and Mr. Kuldeep D Patel. "A Review paper on catalytic converter for automotive exhaust emission" Vol. 7 No. 11, 2012 ( ISSN)
- [3] Abhinesh, Arun Kumar, and Dinesh Kumar. "Minimization of Engine emission by using Non – Noble metal based catalytic converter" Vol. 4, Issue, 11, pp. 2663-2468, November, 2014
- [4] Monil Shah, Chirag Mistry and Naresh Shimpi."Emission Norms (Case Study)"Vol. 5, Issue 3, March 2016 (IJSR).
- [5] Julie M Pardiwala, Femina Patel and Sanjay Patel "Review paper on Catalytic Converter For Automotive Exhaust mission" 8-10 December, 2011.
- [6] Journal Papers:
- [7] P K Pavan Kumar, Dr. K. Rajagopal, Dr. Hiregoudara Yerrennagoudaru, Kalburgi Bharath," An Investigation to reduce emissions from IC Engines" Vol 13, Issue 5 Ver. II (Sep. - Oct. 2016), PP 115-118
- [8] Books:
- [9] Marcus Hook, The Houdry Process (American Chemical Society, April 13, 1996).
- [10] [https://en.wikipedia.org/wiki/Catalytic\\_converter#Placement\\_Of\\_Catalytic\\_Converters](https://en.wikipedia.org/wiki/Catalytic_converter#Placement_Of_Catalytic_Converters)
- [11] <http://auto.howstuffworks.com/catalytic-converter2.html>