EXPERIMENTAL INVESTIGATION OF EXHAUST EMISSIONS USING CATALYTIC CONVERTER

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Abstract - *Emissions from the automobile contribute to major air pollution problems in cities as well as villages along with industrialized areas in developed and developing countries. Air pollution is one of the major factor that is the cause for global warming and the climate change problems. This paper focuses on mitigation of these problems using catalytic convertor to reduce the level of emissions of CO and HC in a diesel engine. Since most of the transportation vehicles rely solely on petrol and diesel for their operation, this results in large amount of carbon monoxide (CO), un burnt hydrocarbons (HC), nitrogen oxides (NOx), and particulate matters. Hence the experimental analysis of the catalytic converter is to study its effect in reduction of these toxicants.*

***Key Words*: catalytic converter, redox reactions, BS norms, ppm**

1. INTRODUCTION

Carbon monoxide is a poison that has high affinity toward haemoglobin. This reduces oxygen supply to the body leading to carbon monoxide poisoning. Long term exposure to HC and NOx leads to smog , which, in the presence of light from sun, would give rise to secondary pollutants like O_3, NOx, which cause global environmental issues[6]. The pollutants have negative impact on human health hence the stringent norms of pollutant emissions. As the emission standards were tightened, strategies were applied such as the BS IV (Bharat Stage IV) emission norms, Euro VI norms, etc. The aim is to reduce levels of exhaust emissions including NOx, CO, hydrocarbons, and particulate matter (PM) such as soot from diesel cars. Currently, the automobiles in India are to achieve BS VI Norms for all vehicles from April 2020. BS IV& VI norms are emission control standards that are developed on European regulations (Euro norms) but suitable for Indian conditions [7]. They set limits for air pollutants release from equipment using IC engines. Carbon monoxide (CO) a colorless, odorless, tasteless, and toxic air is produced in the incomplete combustion of carbon-containing fuels, such as gasoline, natural gas, oil, coal, and wood.CO may be a weak and direct greenhouse emission but it contributes to a majority of effects in heating of earth's surface. Bio fuels emit certain amounts of these toxicants, but relatively less than that of the fossil fuels [5]. Motor vehicles release a considerable portion of CO into the atmosphere along with hydrocarbons. Hydrocarbons react in the presence of NOx and light from the sun to create ozone gas that irritates eyes, damages lungs, and aggravates metabolic processes. Several exhaust HC's are toxic, with potential to cause cancer. These substances contribute to the greenhouse effect and global warming, deplete the ozone, increase occurrences of cancer and metabolism disorders, scale back the photosynthetic capability of plant life and do much harm to ecosystems.

1.1 Catalytic Converter:

A catalytic convertor (figure1) is an emission control device that is used to convert harmful gases and pollutants in exhaust from an IC engine into less harmful gases by redox reaction [1]. The convertors are used along with IC engine which is fueled by either diesel or petrol. A three way catalytic convertor is used for the experimental analysis. As of the current scenario in the automobile industry, a three way catalytic convertor is used widely to reduce HC, CO and NOx emissions which are formed during the combustion process [6]. A three way catalyst runs three tasks simultaneously with each other. One catalyst is responsible for the reduction of nitrogen oxide to both oxygen and nitrogen while the other catalyst is responsible for oxidation of carbon monoxide to carbon dioxide and using unburned HC's and oxidizing them to H2O andCO2.

The oxidation and reduction reaction takes place in the honeycomb monolithic structure. The role of the honeycomb structure of the substrate is to increase the surface area covered by the catalyst layer exposed to the exhaust gases. The monolithic structure is concealed with a thin layer of Rhodium as reduction catalyst and Palladium as oxidation catalyst. Platinum is also present in traces which helps both oxidation and reduction reactions [3]. The reactions happen on the metal catalyst surface. Vanadium is also used as an alternate catalyst material [4]. Hence greater the surface area, maximum conversion efficiency will be achieved because the oxidation reactions depend on the surface on which species can absorb and react.

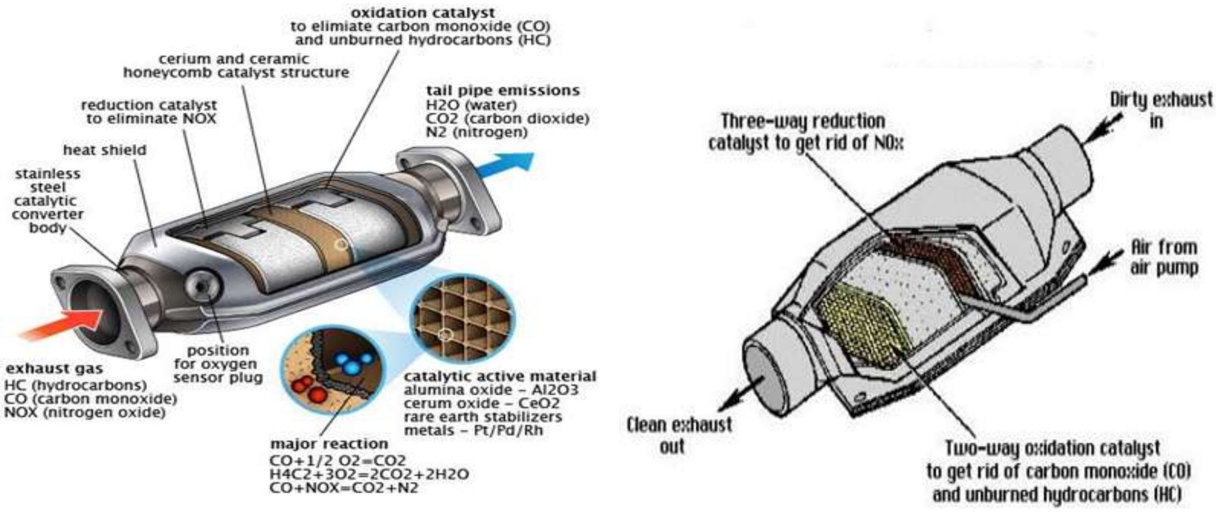


Figure 1: detailed schematic of catalytic converter and various chemical reactions in it. *(Image courtesy: ClearMechanic.com*

1.2 Redox reactions in the Catalytic Converter:

The following reduction and oxidation reactions take place in the converter at various stages of reducing the toxicants from the exhaust gases passing through it.

a) Two Way Catalytic Converter:

In two way catalytic converter, it will control the emission of two different toxic sources. The carbon monoxide and hydrocarbons will be converted into carbon dioxide and water.

1) Oxidation of carbon monoxide to carbon dioxide:

$2CO + O_2 \rightarrow 2CO_2$

2) Oxidation of hydrocarbons to carbon dioxide and water:

$4HC + 5O_2 \rightarrow 4CO_2 + 2H_2O$

The two way catalytic convertor is superseded by three-way converters because of their inability to control oxides of nitrogen[1].

b) Three Way Catalytic Converter:

The oxides of nitrogen are more toxic than carbon monoxide and hydrocarbons, to control the toxic content of nitrogen oxides effectively with the carbon monoxide and hydrocarbons, three way converters are designed and used in the automobileindustries.

1) Reduction of nitrogen oxides to nitrogen and oxygen [1]:

$2NO \rightarrow O_2 + N_2$

2) Oxidation of carbon monoxide to carbon dioxide:

$CO + O \rightarrow CO_2$

3) Oxidation of hydrocarbons to carbon dioxide and water:

$2HC+5O \rightarrow 2CO_2+H_2O$

2. Methodology:

A suitable catalyst is chosen which accelerates a chemical reaction. It doesn't take part in the reaction and hence works indefinitely unless degraded by heating, aging or by contamination. The catalyst materials most commonly used are Platinum, Palladium, and Rhodium. Platinum plays an especially active role in the hydrocarbon reaction. A catalytic converter is selected in such a manner so as to accommodate the catalytic material which promotes the oxidation of emission contained in the exhaust flow[2][6]. The catalyst aids in the reaction of Carbon monoxide and Hydrocarbons with the remaining oxygen in the exhaust. The efficiency of the catalyst is very much dependent on temperature. It is ensured that when a converter in good working condition is operated at a fully warmed temperature of 155°C. The catalytic converter should be operated hot to be efficient, but not hotter as serious thermal degradation may occur in the temperature of above 500^0c.

3. Experimental Setup:

The experiment is carried out on single cylinder 4-stroke diesel engine (figure 2). Initially the engine is run without catalytic converter and the pollutants are measured for different loading conditions. Then by attaching the catalytic converter, the pollutants are measured at 155^0C. Hydraulic dynamometer is used for loading purpose.

Engine specifications :

B.H.P : 5

R.P.M : 1500

Stroke : 110mm

Bore : 80mm

Compression ratio : 16:1

Load type : Hydraulic dynamometer

Loading steps : 0,5,10 kgf.

Figure 2: Experimental Setup

4. Results:

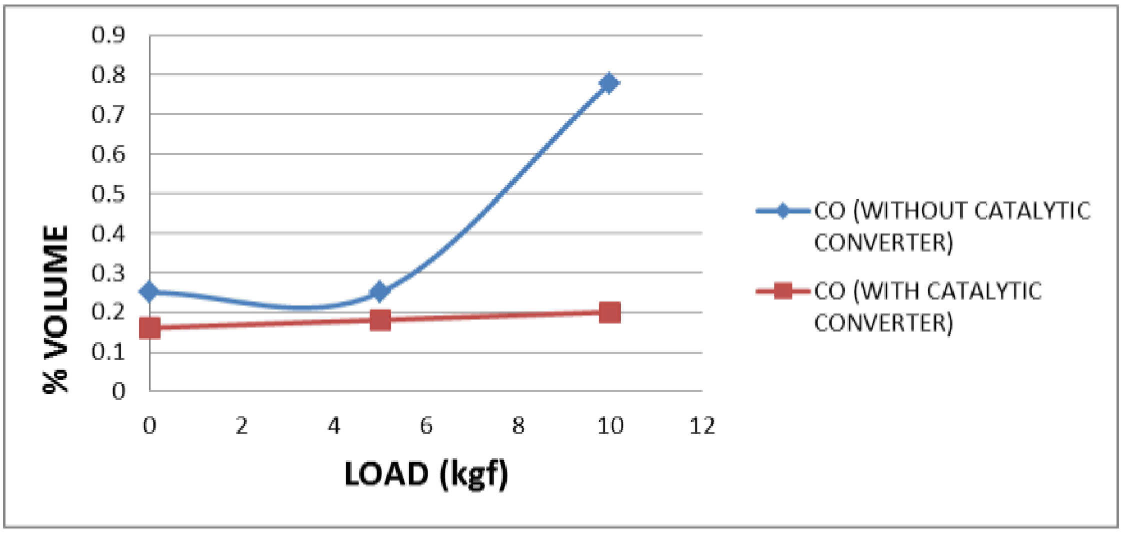
The influence of Catalytic converter by using diesel engine on various loads has been experimentally investigated in this study. Experimental readings pertaining to various loads and exhaust emission were recorded in different trials and tabulated.

a) CO emission variations with and without catalytic converter:

Graph 1 depicts the changes in carbon monoxide emission with respect to various loads. These graphs show that CO emission increases with increase in engine load. Therefore, from the graphs we observed that the emissions get reduced by introducing catalytic converter by various loading conditions such as no load, 5kgf, 10kgf.

Load in kgf	Without catalytic converter	With catalytic converter
0	0.25	0.16
5	0.25	0.18
10	0.78	0.20

Table 1: CO emissions in % vol



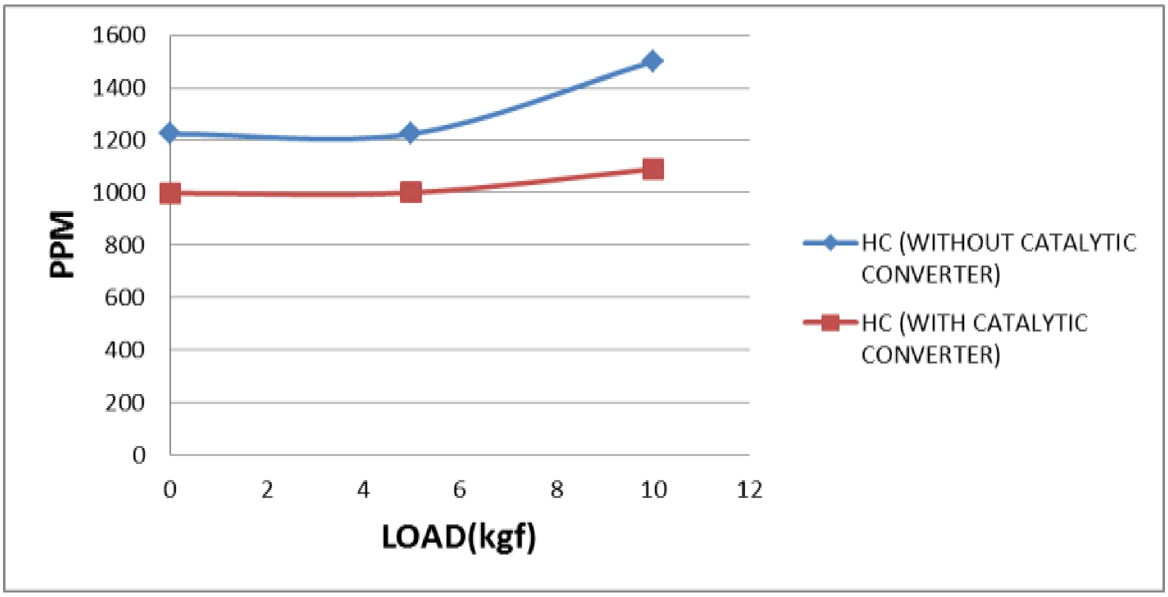
Graph 1: Variations of CO at various loads

b) HC emission variations with and without catalytic converter:

Graph 2, depicts the changes in hydrocarbons emission with respect to various loads. These graphs show that HC emission increases with increase in engine load. Therefore, from the graphs we observed that the emissions get reduced by introducing catalytic converter by various loading conditions such as no load, 5kgf, 10kgf.

Load in kgf	Without catalytic converter	With catalytic converter
0	1225	0998
5	1225	1000
10	1500	1090

Table 2: HC emissions in ppm



Graph 2: Variations in HC at various loads

6. CONCLUSION:

In this paper the performance of catalytic converter is analyzed at various conditions i.e. no load, 5kgf, 10kgf at a temperature of 155°C. We concluded that as the engine load increases the exhaust emissions also increase, which can be reduced by using a suitable catalytic converter.

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