Technical journals online.com

Research Paper

DEVELOPMENT AND PERFORMANCE ANALYSIS OF NICKEL BASED CATALYTIC CONVERTER

Narendrasinh R. Makwana[1], Prof. Chirag M. Amin[2], Prof. Shyam K. Dabhi[3]

Address for Correspondence

[1]PG Student, Mechanical Dept., L.D.College of Engg. Ahmedabad
[2]Assi. Professor in Mechanical Dept., S.V.B.I.T. College.-Gujarat-India
[3]Assi. Professor in Mechanical Dept., L.D.College of Engg.-Gujarat-India

ABSTRACT:
Reduction of toxic substances emission from combustion engines can be achieved in automotive exhaust after treatment process is applied based on oxidation and reduction processes which are takes place in catalytic converter. Generally catalytic converter uses platinum group of metals like Pt, Pd and Rh. There are several types of problems and higher cost of noble metals associated with this noble metal based catalytic converter. These factors encourage for the possible application of non-noble metals (Nickel) as a catalyst in automotive catalytic converter.

KEYWORDS- Exhaust Emission, Catalytic Converter, OEM Catco, Modified Catco, Diesel Engine, Nickel Catalyst

INTRODUCTION

Automobiles are a 'necessary evil', while they have made living easy and convenient; they have also made human life more complicated and vulnerable to both toxic emissions and an increased risk of accidents. Due to incomplete combustion in the engine, there are a number of incomplete combustion products CO, HC, NO_x, particulate matters etc. These pollutants have negative impact on air quality as well as on human health also on environment that leads in stringent norms of pollutant emission. Numbers of alternative technologies like improvement in engine design, fuel pre-treatment, use of alternative fuels, fuel additives, exhaust treatment etc. are being considered to reduce the emission levels of engine. Among all the types of technologies developed so far, use of catalytic converters is the best way to control automotive exhaust emissions.Exhaust pollutants from the automobiles engines have negative impact on air quality as well as on human health. In previous section we have studied how emissions are produced by an automobile and effect of automobile exhaust emission on human as well as on environment and also discussed about exhaust emission control techniques. Current study focuses on new developed Nickel based catalytic converter because existing available catalytic converters suffer from various problems like; poisoning, fracture, melting & higher cost.The objective of this paper is to develop cost effective Nickel based oxidation catalytic converter to be used with four stroke diesel engine. Inexpensive CAT development, performance evolution and engine test results have been presented with discussion.

EXHAUST EMISSION

Due to incomplete combustion in the engine, there are a number of combustion products like HC, CO, NO_x, etc. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground- level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone. They also contribute to the formation of acid rain. Carbon monoxide reduces the flow of oxygen in the blood stream and is particularly dangerous to person with heart disease. Carbon dioxide does not directly impact human health, but it is a "greenhouse gas" that traps the earth's heat and contributes to the potential for global warming.

CATALYTIC CONVERTER

A Catalytic converter is a device used to reduce the toxicity of emissions from an internal combustion engine.

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.

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_2 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_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.

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.

PAST RESEARCH

Copper based catalytic converter (Chirag Amin et al.)

Chirag M. Amin, Prof. Pravin P. Rathod, Prof. Jigish M. Goswami (2011) present paper on "Copper based catalytic converter". Exhaust emissions of much concern are Hydrocarbon (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx) from the automotive vehicles. Catalytic converter oxidizes harmful CO and HC emission to CO_2 and H_2O in the exhaust system and thus the emission is controlled. 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 copper as a catalyst, which may by proper improvements be able to show the desired activity and can also offer better durability characteristics due to its poison resistant nature.

The present work is aimed at using copper as a catalyst for catalytic converter. Wire mesh copper catalytic converter is developed for a volume of 1.54 m^3. The experiment is carried out on 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.

Cost effective catalytic converter for diesel engine after treatment (P. V. Walke et al.)

P. V. Walke, N. V. Deshpande (2011) present paper on "Cost effective catalytic converter for diesel engine after treatment", This paper presents cost effective catalytic converter (CAT) to be used for diesel engine. The CAT was developed based on catalyst materials consisting of combination of metal catalyst such Cerium Oxide (CeO_2), zirconium dioxide (ZrO_2), silver nitrate ($AgNO_3$) and copper nitrate ($Cu(NO_3)_2$) with pellets substrate. These catalyst materials are inexpensive in comparison with convectional catalysts (noble metals) such as palladium or platinum. Cost effective catalyst combination and pellets type natural substrate were developed for catalytic converter for diesel engine[5]. The catalyst combination (Cu/CeO_2 /ZrO_2 + (Ag/CeO_2 /ZrO_2) gives maximum back pressure (78 - 290 mbar). All three major pollutants HC, CO and NOx reduce with emission conversion efficiency of 62.29%, 64% and 59.7% respectively. The catalyst combination ($Cu/Ag/CeO_2$ /ZrO_2) gives minimum back pressure (46 -148 mbar). All three pollutants HC, CO and NOx reduce with emission conversion efficiency of 61.1%, 62% and 64.3% respectively.

CATALYST AND SUBSTRATE PREPARATION

- **Material selection for Catalyst:** The Nickel is used as the oxidizing agent. Its non poisonous nature, low cost, and availability makes it preferred carrier in oxidation from the stationary pollution sources.
- **Material selection for Substrate:** The substrate material is stainless steel, as it is widely used in the automotive exhaust system not only due to its advantages in mechanical and physical properties but also low-cost. The stainless steel wire mesh was cut to a circular shape prior to catalyst coating.
- **Treatment for wire meshes Substrate:** The stainless steel wire mesh pieces were coated with metal catalyst (Nickel) before arranged onto a straight bar. Following procedure is carried out for Nickel coating on substrate:
  - ✓ Cleaning of wire mesh with 10% HCL for 1 hr.
  - ✓ Activation of wire mesh with solution of sulphuric acid of concentration of 20%.
  - ✓ Electro plating with Nickel.

During this procedure Nickel was kept as anode and operating voltage during this process was 3 to 5 volts. Thickness of nickel coating on wire mesh was 1 micron.

FABRICATION AND ASSEMBLY OF NEW CATCO FROM OEM CATCO

Fig. 1 Fabrication processes for CATCO chamber

(a) C/S of OEM CATCO
(b) Wire mesh honeycomb from OEM CATCO
(c) Fabricated catalytic chamber before flanged
(d) Completely modified CATCO chamber

The fabrication of catalytic converter consists of few components, namely the converter chamber, substrate and insulator. The catalytic converter casing and chamber remain as same as originally installed into the vehicle system. The same outer dimensions were purposely fixed in order to avoid redesign of the existing exhaust system, which then required further thermal optimization and design validation studies. Holes are drilled and provision is provided on converter chamber to mount thermocouple as well as manometer.

Fig. 2 Various position of modified CATCO

(a) Insulating of modified CATCO inlet & outlet
(b) Completely insulated modified CATCO
(c) Mounting of modified CATCO on engine setup
(d) Completely mounted CATCO with manometer & temp. Sensor

EXPERIMENTAL SETUP AND PROCEDURE

A four cylinder four stroke diesel engine coupled with electrical dynamometer was used for data collection. The engine is a water cooled, naturally aspirated and DI diesel engine. The main specifications are given in below table:

Table 1. Engine Specification

Parameter	Specification
Name of Engine	1.4 L I-4
Engine Bore	75 mm
Engine Stroke	79 mm
Swept Volume	1405 CC
No. of Cylinders	4
Power	39.9 KW @ 4500 rpm
Compression ratio	21:1
Injection Pressure	185 bar
Fuel Type	Diesel

The engine is a completely self-contained test bed incorporating electrical dynamometer, with panel board consists of ammeter and voltmeter fuse carries. The electrical dynamometer which is capable for 30 hp @ 2000 rpm.

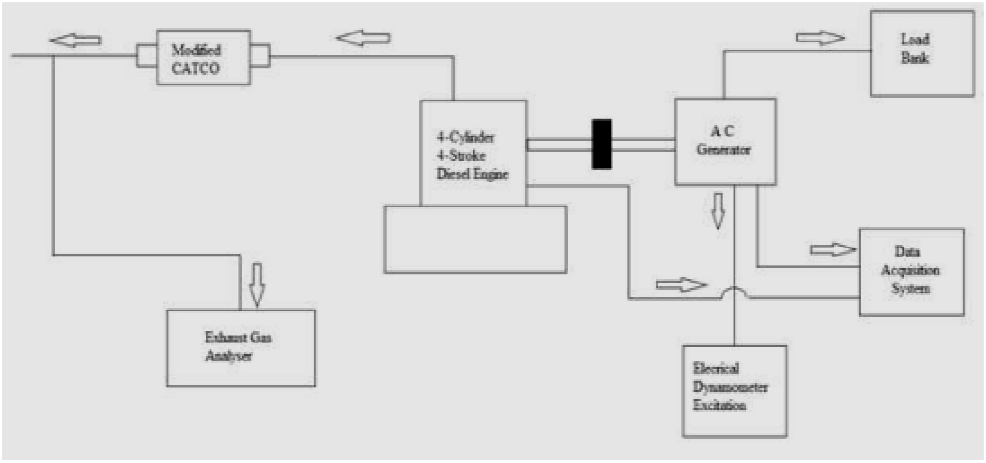

Fig. 3 Layout of Experimental Setup

As shown in Fig. 3, four stroke four cylinder diesel engine is coupled with generator. Power produced by engine will be supplied to generator by means of coupling joint to produce electrical power. Amount of power generator in to the generator will be supplied to load bank which has heaters which will consume that power. A probe is mounted at exhaust of engine which will supply sample of exhaust gas to the exhaust gas analyser. Amount of HC, CO & CO_2 present in exhaust can be read at indicator panel of exhaust gas analyser.

RESULTS AND DISCUSSION:

From experimental data following analysis can be carried out when diesel was used as fuel. It can be seen from fig. 4, that during starting of diesel engine carbon monoxide contents are highest in the exhaust because during starting of engine rich air-fuel ratio is supplied to the engine sand also due to incomplete combustion of fuel.

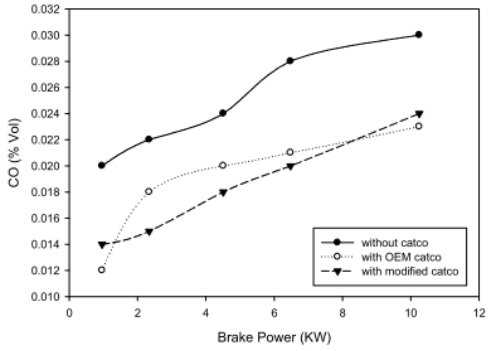

Fig. 4 BP V_s CO

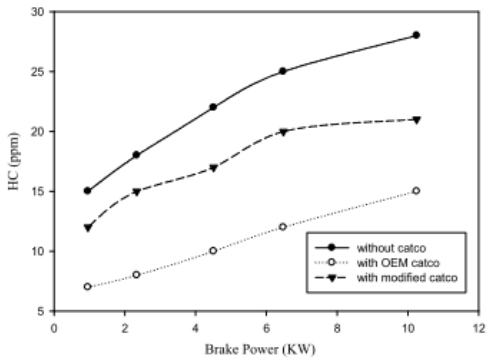

Fig. 5 BP V_s HC

When the air-fuel mixture is too rich there is insufficient air for complete combustion and some the fuel will not be burnt or at least only partially burnt. Since hydrogen has a greater affinity for oxygen, hydrogen will take all the oxygen it needs leaving the carbon with a deficiency of oxygen. As a result of the shortage of oxygen a percentage of carbon will be converted to carbon monoxide. As load on engine increases, more amount of air is supplied compared to fuel. The air-fuel ratio becomes lean and hence amount of carbon monoxide reduces due proper combustion of fuel. Again as load on engine increases fuel consumption also increases which can be seen in fig. 4.

From fig. 5, it can be seen that as brake power of engine increases, hydrocarbon content increases because of increase in fuel consumption. Generally, hydrocarbon produces due to incomplete combustion. Due to existence of local very rich mixture pockets at lower temperature than the combustion chamber, unburnt hydrocarbons will appear in the exhaust. The hydrocarbons also appear due to flame quenching near the metallic walls.

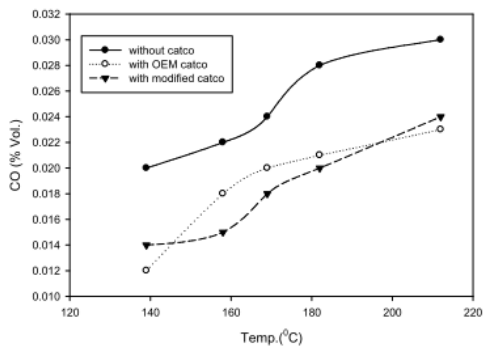

Fig. 6 Temp. V_s CO

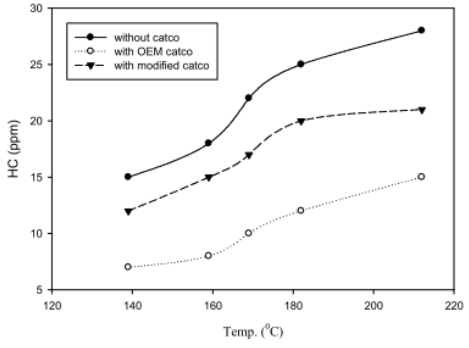

Fig. 7 Temp. V_s HC

From above diagrams it can be seen that as temperature of catalyst increases, its ability to convert CO and HC into H_2O and CO_2 increases or simply we can say that its conversion efficiency increases. It can be seen from fig. 6and fig. 7, at

lower temperature amount of CO is highest as temperature of catalyst increases amount of CO in exhaust reduces.

CONCLUSION

This study introduces a simple low cost; non noble (nickel) based catalytic converter to reduce diesel engine exhaust emission. Though not a noble metal, nickel works as a catalyst for the conversion of pollutants in exhaust but in a limited proportion. By using nickel based catalytic converter, HC reduces by 40% and CO reduces by 35%. So we conclude that the nickel based catalyst can be effective approach in place of expensive noble metal based catalytic converter.

REFERENCES

1. Ronald M. Heck, Robert J. Farrauto, "Automobile exhaust catalysts", Applied Catalysis General, vol.-221 (2001) pp. 443-457
2. Chirag M. Amin, Jigish J. Goswami, "Copper based catalytic converter", IJERT journal, vol.-1, Issue 3, 2012
3. Chirag Amin, Pravin P. Rathod, "Catalytic converter based on non-noble material", IJAERS, vol.-1, Issue 2, 2012, pp. 118-120
4. Grigorios C. Koltsakis, Anastasios M. Stamatelos, "Catalytic automotive exhaust after treatment", Prog. Energy Combustion Science, vol.-23, pp. 1-39,199
5. John P. A. Neeft et al. "Diesel particulate emission control", Fuel Processing Technology, vol.-47, 1996, pp. 1-69
6. EPA 400-F-92-007, "Automobile Emission: An Overview", pp. 1-4
7. Jhonson Matthey, "Catalyst Handbook"
8. R. M. Heck et al. "Catalytic air pollution control: commercial technology", Platinum metal rev., 2010, 54, 3, pp. 180-183
9. Jonathan Zhang, "Catalytic Converter- Part 1of Automotive After-treatment System"
10. B. P. Pundir, "Engine Emission: Pollutant formation and Advances in Control Technology", Chapter 4, pp. 115-155
11. M. Shelef , K.Otto, and N.C. Otto, "Poisoning of Automotive Catalyst", Advances in Catalysis, vol.-27, pp. 311-365
12. Zbigniew Zmudka, Adam Ciesiolkiewicz "Comprehensive approach to the work of Catalysts in Engine exhaust system", Journal of KONES i.c. engine , Vol. 11, pp. 368-375
13. P. V. Walke, N. V. Deshpande, "Cost effective catalytic converter for diesel engine after treatment", International journal oe engineering research and technology, vol.-4, 2011, pp. 9-20