Effect Of Non-Nobel Copper Oxide Coating of the Catalytic Converter on the Exhaust Gases of a Diesel Engine

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Abstract

The diesel engines are one of the most pollutants emitting engine. With the increased demand for the private transportation and higher cost of the alternatives to the diesel engine makes it as one of the most sought engines in the near future. The reduction of the amount of the toxic fumes like nitrogen oxides, carbon monoxide, other hydrocarbons and soot from the emissions will reduce the strain on the atmosphere. In the present study, an attempt was made to reduce the quantity of pollutants from the exhaust gases by introducing a copper coating to the catalytic converter. The exhaust gases were collected when the engine run on different loads like 0%, 25%, 50%, 75%, and 100% of the maximum rated load. The collected exhaust was tested for the concentration of carbon monoxide, hydrocarbons and oxides of nitrogen. The addition of the copper coated catalytic converter at the exhaust reduce the emission of carbon monoxide, hydro carbons, and oxides of nitrogen by 79.78%, 60.58%, and 41.25% respectively when the engine was operated at 100% of maximum rated load.

Key words: Copper Coated, Catalytic converter, Diesel engine exhaust, carbon monoxide, Hydrocarbons.

1. Introduction

Air pollution is caused by solid and liquid particles and certain gases that are suspended in the air. These particles and gases can come from car and truck exhaust due to the use of internal combustion engines. The main reasons for air pollutants by engines is due to reason that the time available for is limited by the engines cycle to just a few milliseconds. So result of which the pollutants enter air after combustion process. The incomplete combustion of fuels in the engine leads to emission of partially oxidized products like carbon monoxide (CO), oxides of nitrogen (NOx) and a wide range of volatile organic compounds (VOC), including hydrocarbons (HC), aromatics and oxygenated species. These emissions are particularly high during both idling and deceleration, when insufficient air is taken in for complete combustion to occur. Carbon monoxide is a product of a partial combustion of hydrocarbons in fuel. It is always present when there is a lack of oxygen during combustion and thus directly dependent on the applied engine air/fuel ratio. There are several paths that cause hydrocarbons in the exhaust. The most obvious is, as in the case of CO, a lack of oxygen when the air/fuel mixture is rich. The other reasons that can cause hydrocarbon emissions even with lean mixtures are crevices (piston top, threads around the spark plug), the quench layer (due to a lower temperature of the cylinders‟ walls), porous deposits, and absorption by oil. NOx is formed during combustion in the engine when oxygen reacts with nitrogen because of a high combustion temperature. So as a result of which an indigenous device known as catalytic converter was invented in order to decrease pollutants during emission.

1.2 Catalytic Converter: - A catalytic converter (Cat-Con) is an essential part of the exhaust system of automobiles. It takes very dangerous pollutants like carbon monoxide andconverts them chemically to less dangerous pollutants like carbon dioxide. The harmful compounds mainly include nitrogen gas, carbon monoxide, hydrocarbons, nitrogen oxides, etc. The catalytic converter device in automobiles will reduce overall harmful emissions.

1.3 Working of catalytic converter: - 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 O2.

The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N2. For example:

$2NO \rightarrow N_2 + O_2$

(or)

$2NO_2 \rightarrow N_2 + 2O_2$

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.

For example:

$2CO + O_2 \rightarrow 2CO_2$

$HC + O_2 \rightarrow CO_2 + H_2O$

There are two main types of structures used in catalytic converters --- **Honey comb and ceramic beads.** Most cars today use a honeycomb structure.

1.4 Types of Catalytic Converters: -

1. Two-way catalytic converter
2. Three-way catalytic converter

Two-way catalytic converter: - A two-way (or "oxidation") catalytic converter has two simultaneous tasks:

- Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$
- Oxidation of hydrocarbons (unburnt and partially burnt fuel) to carbon dioxide and water:$C_xH_{2x} + [(3X+1)/2]\, O_2 \rightarrow XCO_2 + (X+1)\, H_2O$ (a combustion reaction).

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. Three-way catalytic converter: - A three-way catalyst oxidizes exhaust gas pollutants – both hydrocarbons (HC) and carbon monoxide (CO) - and reduces nitrogen oxides (NOx) into the harmless components water (H_2O), nitrogen (N_2), and carbon dioxide (CO_2). Depending on the operating conditions of the engine and the exhaust gas composition, conversion rates upwards of 98% can be achieved at close to stoichiometric (lambda one) conditions.

The necessary reaction conditions can be reached after less than a minute by the introduction of special cold-start measures, especially a fast heat-up of the exhaust gas after engine cranking. This is especially important for city driving, characterized by frequent start stop events.

- Reduction of nitrogen oxides to nitrogen and oxygen: $2NO_x \rightarrow XO_2 + N_2$
- Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$ • Oxidation ofunburnt hydrocarbons (HC) to carbon dioxide and water:

$C_xH_{2x} + [(3X+1)/2]\, O_2 \rightarrow XCO_2 + (x+1)H_2O$

Catalytic converters are playing a major role in modern world. They are found to be more significant due to increase in the rate of pollution in day-to-day life [1-9]. As result of which a number of experiments and reports were submitted to increase their efficiency. Wire mesh copper catalytic converter is developed for a volume of 1.54 m^3.

The experimental study was conducted with the exhaust of a stationary, four stroke single cylinder, and water- cooled, constant speed (1500 rpm) diesel engine with a power output of 3.5 kW [10-14]. 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. The efficiency of a catalytic converter is very much dependent on temperature. When a converter in good working order is operating at a fully warmed temperature of 300˚ C or above, it reduces HC by 38% and CO by 33%. The studies on the performance capabilities and effectiveness of Manganese coated Copper catalyst which are designed in such a way to obtain the appropriate shape and type of Catalytic Converter catalyst and suitable for premium fuel motor vehicles [15-17]. Optimization of performance four model with different inside construction and variable cell size catalytic converter are fabricated. The experiment is carried out on stand Toyota 1500 CC machine with gas analyser of type QRO- 402 with tachometer. Model 2 gives the optimum result as it reduces the amount of CO by average 79.6%. The design and development of a catalytic converter with different catalysts were attempted. The pellets are coated with copper oxide (CuO), cerium oxide (CrO2) and zirconium dioxide (ZrO2). Pellets are held together in a circular housing at two ends of the converter shell. Cylindrical spacer was used in between circular housing containing pellets to vary the distance and to reduce back pressure on the engine. Experiments were carried out on computerized Kirloskar single cylinder four stroke (10 B.H.P, 7.4 KW) diesel engine test rig with an eddy current dynamometer. The converter was tested with different catalyst. There is considerable reduction in HC, CO and NOx. Zirconium dioxide catalysts reduce HC emission. All three catalysts (zirconium dioxide, cerium oxide and copper oxide) reduce CO emissions. The catalyst (zirconium dioxide + cerium oxide), reduce NOx emission.

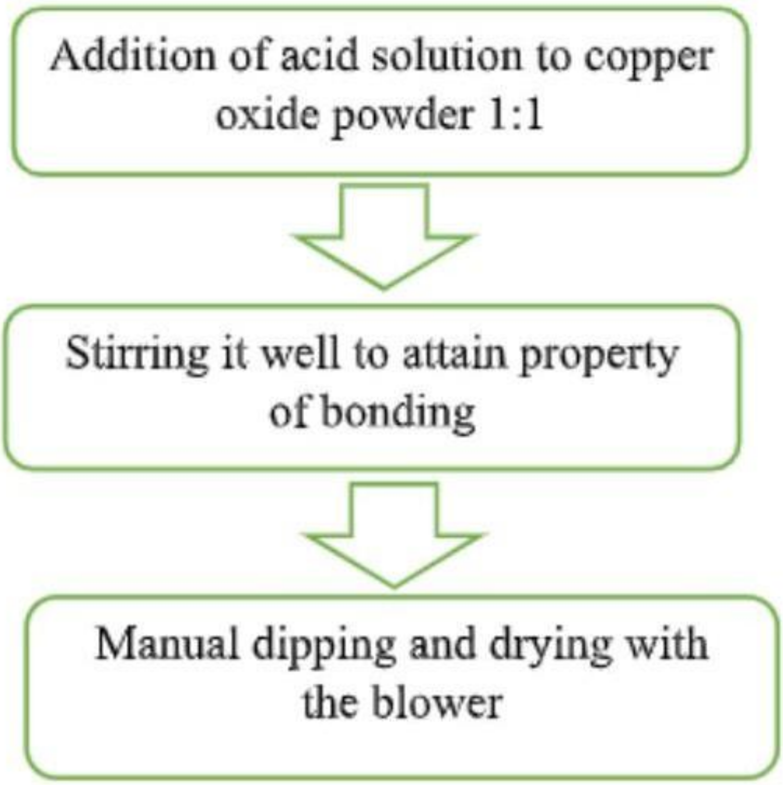
Brake thermal efficiency decreases with Catalytic converter. However, this decrease is marginal and it can be accepted in view of benefits on environment and health of human being. Several researchers [18-24] have studied the effect of different catalytic coatings on the exhaust emissions of a four-stroke engine. The results indicated that copper as a catalyst was very effective with significant reduction in HC and CO emissions with lean combustion in a four- stroke SI engine [25-31]. In the present study, non-noble metal catalysts such as copper, nickel and chromium have been used as catalyst and they are coated inside the combustion chamber walls. Detailed experimental study has been carried out to evaluate the catalyst performance and its influence on combustion and exhaust emission at various speeds.

2. Procedure to Make Copper Base Converter

2.1 Applying cupric oxide coating over honeycomb

A major consideration for the Manual Dispersion coating process is that the coating is done at a necessary thickness, and a number of different techniques are used to get this control, ranging from a simple brush for painting a wall to some various machinery applying coatings in the coating industry. A further measure for 'non-all-over' coatings is that control is needed according to the thickness of the coating to be applied.

This process is followed by manual dipping of the honeycomb structure into the solution of copper oxide and the acid solution and then air-jet spraying over the honeycomb/monolith10. Hence, this is the cost-effective coating process compared to all the above processes, this is the process that is used for coating honeycomb. The flow chart of the manual dispersion technique is shown in Figure-1



2.2 Preparation of coating material

Cupric oxide powder of 50 grams was mixed with the acid solution of dilute nitric acid in the ratio 1:1 until and mixed well to obtain bonding.

Figure-2 Cupric Oxide

2.3 Cleaning of a catalytic converter

The catalytic converter needs to be cleaned properly before using it for the project. First of all, the converter monolith needs to be removed from the casing. Later the casing is cleaned properly using petroleum products such as kerosene, petrol, etc., to remove soot from the converter. Then the monolith is washed with kerosene and is water-washed under high-pressure. After this, the monolith is again washed with a small quantity of acid and water Addition of acid solution to copper oxide powder 1:1 Stirring it well to attain property of bonding Manual dipping and drying with the blower washed. Finally, the monolith is dried and cupric oxide is applied by a sprayer onto the monolith.

Specifications Of Engine

No of cylinders	One
No of Strokes performed by engine	Four
Power of engine	4.5 KW (6 HP)
Speed of engine	650 RPM
Size of bore	110 mm
Length of stroke	150 mm

Table 1. Engine Specifications

2.4 Process of coating

The process used for the coating process is called manual dispersion technique, where the honeycomb is manually dipped and is subjected to air jet spraying, so the pores of the honeycomb structures are clear to allow the passage of smoke. Later, it is dried well for 24 hours.

3. Testing

3.1 Testing Without Catalytic Converter

A test was conducted on a single-cylinder four-stroke diesel engine in the project. The specification of the four-stroke diesel engine is mentioned in table-1 below. A five-gas analyser is used to measure the gases which are released from the exhaust of the engine. A test is conducted to measure the gases released, without a catalytic converter, and readings are noted down in the table-2.

Figure-3 Engine

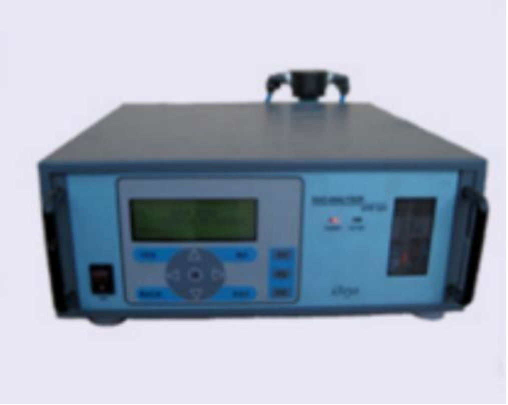


Figure-4 Gas Analyser

Load (kg)	CO (%)	HC (ppm)	CO_2 (%)	NO_X (ppm)
0	0.456	40	3.39	52
5	0.52	58	4.6	79
10	.89	110	6.9	120
15	1.3	200	8.12	153
20	1.82	330	9.74	170

Table-2 Data without Catalytic Converter

3.2 Testing with Catalytic Converter

The test is repeated by using a catalytic converter by using cupric oxide as the catalyst. The following data is noted in table-3 and the percentage error is noted in table-4. Some graphs are drawn in comparison of data in table-2 and table-3 for compounds such as CO, HC, and NOx.

Load (kg)	CO (%)	HC (ppm)	CO_2 (%)	NO_X (ppm)
0	0.261	26	7.681	41
5	0.296	38	10.52	60
10	0.503	71	16.64	90
15	0.728	127	20.47	112
20	1.012	205	25.12	120

Table-3 data with copper based catalytic converter

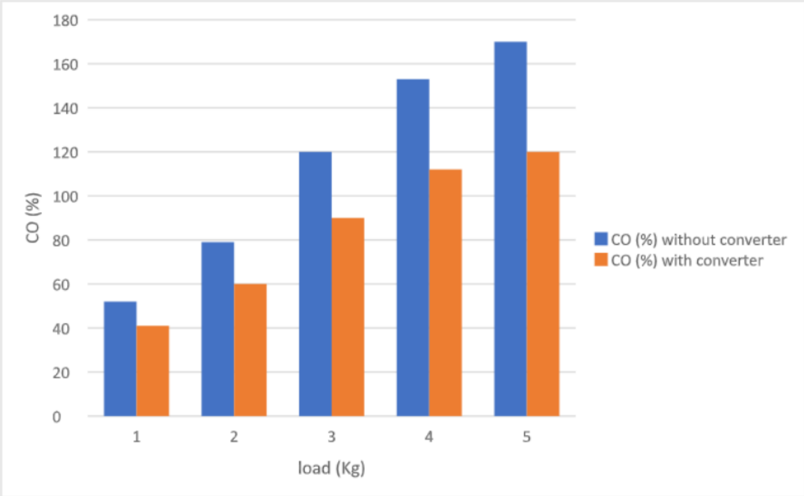


Figure-5 CO without converter vs with converter

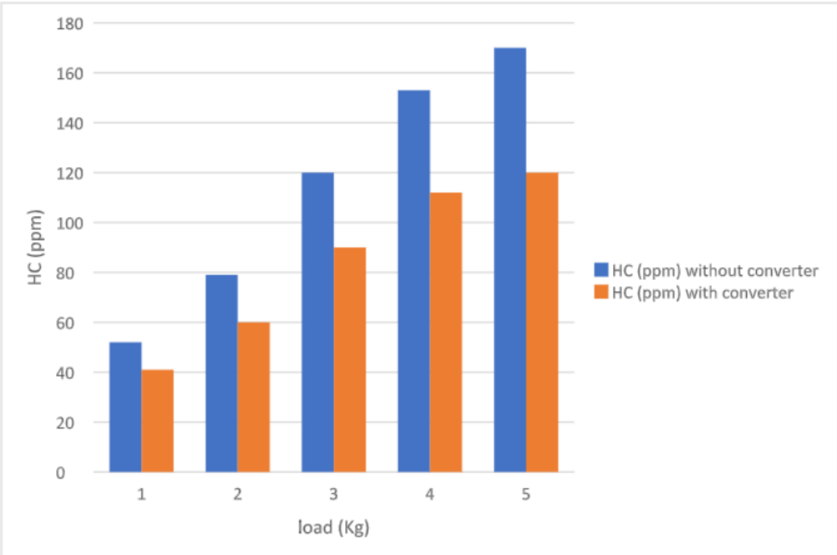


Figure-6 HC without converter vs with converter

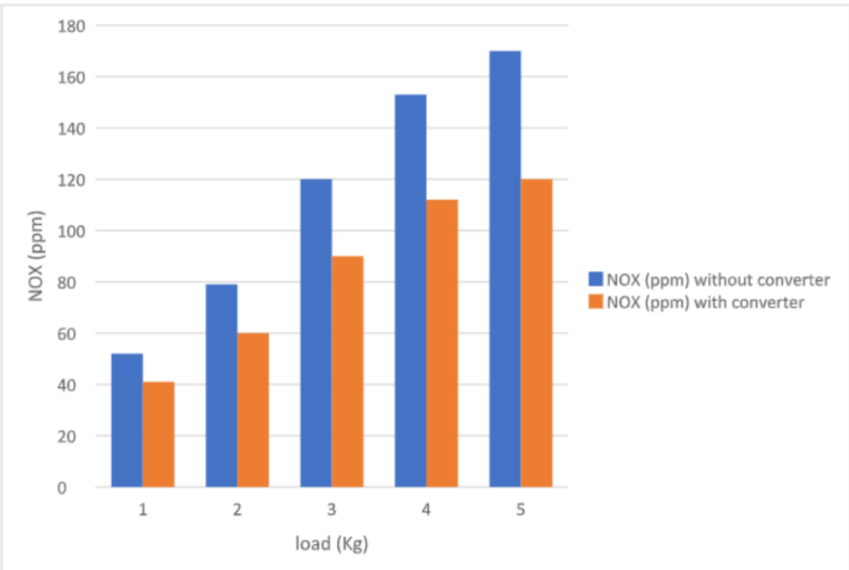


Figure-7 NO X without converter vs with converter

Load (kg)	CO (%)	HC (%)	CO_2 (%)	NO_X (%)
0	74.7	52.67	55.87	28.35
5	75.42	54.28	56.28	30.68
10	76.66	55.45	58.54	33.48
15	78.54	57.36	60.35	36.37
20	79.78	60.58	61.24	41.25

Table - Percentage Error

Figures 5-7 show the comparison of the emissions of Carbon monoxide, hydrocarbons, and NOx from the IC engine when the catalytic converter is used and not used. The emissions increased with the increase in the loads acting on the engine. The higher loads need large amounts of fuel to run which reduces the time available for the complete combustion of the carbon leading to the emissions of CO and hydrocarbons. The engine temperatures also increase when it is running at higher loads. The higher temperatures increase the emission of NOx gases. The addition of the catalytic converter to the engine chemically oxidizes the CO and HC, but with the higher amount of fuel burning at higher loads, the emissions with the increment of the loads still follow the same trend observed when the catalytic converter is not used.

CONCLUSION

Catalytic converter plays a major role in the reduction of harmful exhaust emissions from automobiles. It is found that by using cupric oxide instead of noble metals like platinum, palladium, and rhodium the pollutants are reduced by the following percentage at 100% rated load as follows 79.78%, 60.58%, and 41.25% for CO, HC, and NO x respectively. Hence it observed that by using non-noble metals like copper oxide the harmful emissions can be reduced by nearly 60.53% overall.

DATA AVAILABILITY STATEMENT

All the data obtained from the experimentation was presented in the manuscript. No Additional data is attached.

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