

I.C. Engine emission reduction by copper oxide catalytic converter

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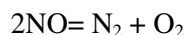
Abstract— The toxic gases emitted from diesel engines are more than petrol engines. Predicting the use of diesel engines, even more in future, this system is developed and can be used to minimize the harmful gases. Toxic gases include NO_x, CO, HC and Smoke which are harmful to the atmosphere as well as to the human beings. The main aim of this work is to fabricate system, where the level of intensity of toxic gases is controlled through chemical reaction to more agreeable level. This system acts itself as an exhaust system; hence there is no needs to fit separate the silencer. The whole assembly is fitted in the exhaust pipe from engine. In this work, catalytic converter with copper oxide as a catalyst, by replacing noble catalysts such as platinum, palladium and rhodium is fabricated and fitted in the engine exhaust. With and without catalytic converter, the experimentations are carried out at different loads such as 0%, 25%, 50%, 75%, and 100% of maximum rated load. From the experimental results it is found that the maximum reduction is 32%, 61% and 21% for HC, NO_x and CO respectively at 100% of maximum rated load when compared to that of without catalytic converter. This catalytic converter system is cash effective and more economical than the existing catalytic converter.

1. Introduction

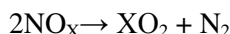
An exhaust system is a gadget utilized as a part of vehicle to control emanations by changing over dangerous results from ignition (happening in the I.C engine) to less harmful substances by moving synthetic responses through catalyzed. The responses change contingent on the sort of substrate or catalyst altered. Albeit exhaust systems are essentially utilized as a part of exhaust system in cars, trains, planes, generator sets, mining hardware, and other motor fitted gadgets. They are likewise utilized on some wood stoves to control discharges. There are three sorts of exhaust system 1)reduction catalytic converter 2) oxidization catalytic converter 3) three-way catalytic converter (TWC). An oxidation catalyst is a gadget that is set on the end of fumes pipe of an auto. The oxidation catalyst is the second phase of the catalytic converter. It diminishes the hydrocarbons and carbon monoxide by oxidizing them over a platinum and palladium impetus¹. This catalyst conveys the response of the CO and HC with the rest of the oxygen in the fumes gas. The reduction catalyst is utilized to control NO_x outflow and can be utilized as a different framework as a part of expansion to the oxidation exhaust system. The reduction catalyst is fitted at the underlying position of the oxidation framework. The reduction catalyst is the principal phase of the exhaust system. At the point when such particles interact with the catalyst, the catalyst evacuates the nitrogen iota out of the atom



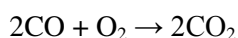
and clutches it, liberating the oxygen as O_2 . The nitrogen molecules bond with each other that are likewise adhered to the catalyst forming N_2 .



3-way catalytic converter (TWC) have the extra preferred standpoint of controlling the discharge of nitric oxide and nitrogen dioxide (both together shortened with NO_x and not to be mistaken for nitrous oxide). The diminishment and oxidation catalyst are in one finish single shell of the reactant convertor; in any case, in a few cases, they might be housed independently. A three-way exhaust system has three synchronous errands. Reduction of nitrogen oxides to nitrogen and oxygen².



Oxidation process of carbon monoxide:



Oxidation process of unburnt hydrocarbons (HC):



The above responses happen in reactant convertor; for the most part when the temperature of fumes discharge is somewhat over the stoichiometric point. 3-way converters are viable when the engine is worked inside the scope of air-fuel proportions close to the stoichiometric point, with the end goal that the fumes gas arrangement sways between rich (abundance fuel) and incline (overabundance oxygen)³. Shut circle engine control frameworks are fundamental for successful operation of 3-way exhaust systems as nonstop adjusting is required for viable NOX lessening and HC oxidation.

2. Materials Used in Catalytic Converters

The catalytic converter is comprised of different materials. The catalyst substrate or monolith fluctuates as indicated by the vehicle. For example, in car catalytic converters the monolith is normally an ceramic monolith with a honeycomb like structure. At the point when created in vast amounts, artistic centers can be extremely modest. Metallic foil monoliths are made of iron-chromium-aluminum blend, and utilized as a part of different applications. Metallic centers are less costly when made for little creation runs, for example, in sports cars in which low back weight and solid consistent high load is vital⁴. Every one of these materials are intended to give a high surface range to bolster the catalyst shell. Cordierite ceramic substrates are additionally utilized as a part of most catalytic converters. The catalyst washcoat is a transporter for the catalytic materials, which is utilized to coat the materials over a high surface territory. Titanium dioxide, aluminum oxide, silicon dioxide or a blend of both silica and alumina can likewise be utilized⁵. The catalytic materials are suspended in the washcoat before settling it to the center. Washcoat materials have unpleasant, sporadic surface to expand surface zone, which augments the catalyst dynamic surface accessible to respond with the motor discharges. The catalyst utilized as a part of the converter is for the most part a valuable metal, for example, platinum, palladium and rhodium⁶. Platinum is utilized as a lessening catalyst and in addition an oxidation catalyst. Despite the fact that platinum is an exceptionally dynamic catalyst and broadly utilized, it is extremely costly and not reasonable for all applications. Rhodium is utilized as a decrease catalyst, while palladium is utilized as an oxidation catalyst. Sometimes, cerium, iron, manganese and nickel are likewise utilized⁷. In any case, a few organizations prohibit the utilization of some of these. In this present work copper oxide is utilized as a catalyst which is exceptionally savvy catalyst when contrasted and other catalyst like platinum, rhodium and palladium etc.

2.1. Preparation of honeycomb/ monolith

A monolith/honeycomb is a ceramic structure comprising of an extensive number of little straight and parallel directs as appeared in the Figure 1. The monoliths are made by expulsion. An extraordinary blend of additives and claybinder is pushed through a modern color to make the monolith structure⁸. The material is dried sliced to the required length and let go at high temperatures. The monolithic structure has a width of around 15 cm and can have distinctive shapes. The distance across of the channels ranges from 0.5 to 10 mm and the length of the honeycomb/monolith can be up to 1m long. On the surface of these channels a catalyst can be connected in which concoction responses can occur. As a result of the expansive number of channels the contact zone between the catalytic layer and the fumes gas that goes inside the channels is extensive⁹. Encourage the channels are straight and parallel so that the stream is not deterred.

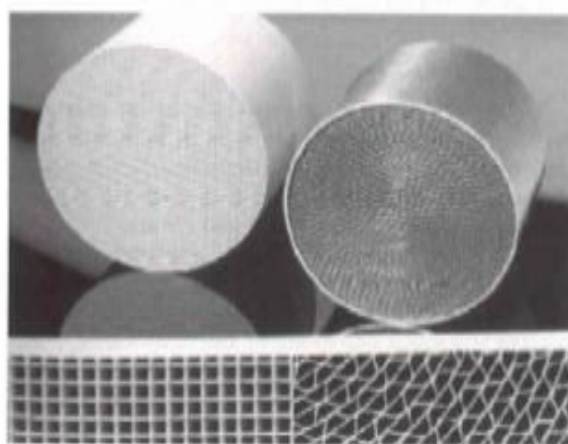


Figure 1. monolith/honeycomb structure

2.2. Applying copper oxide coating over honeycomb

A major consideration for 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 thickness of 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 above process, this is the process which is used for coating of honeycomb.

Flow chart of manual dispersion technique is shown in the Figure 2.

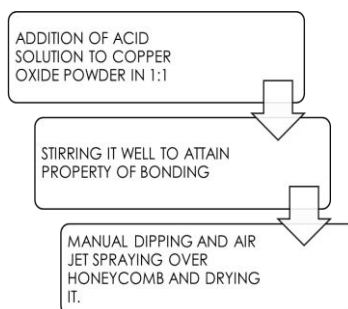


Figure 2. Flow chart of manual dispersion technique

2.3. Preparation of coating material

Copper oxide powder of 480 grams was mixed with the acid solution of dilute nitric acid in the ratio 1:1 until and mixed well to obtain bonding.

2.4 Process of coating

The process used for the coating process is called as manual dispersion technique, where the honeycomb is manually dipped and is subjected to air jet spraying so the pores of the honeycomb structure are clear to allow the passage of smoke. Later, it is dried well for 48 hours.

2.5 Assembling of catalytic converter

Catalytic converters are typically assembled by inserting a coated substrate assembly with copper oxide into a catalytic converter outer shell. The substrate assembly is nothing but insulating mat surrounding catalytic substrate. The mat is then held in place by adhesive. Force is applied to the substrate assembly to compress the mat around the catalytic substrate and stick to adhesive. An outer diameter of the substrate assembly is measured during application of the force. The outer diameter of the converter outer shell is then determined based on this outer diameter measurement of the substrate assembly. The substrate assembly is then fitted into the converter outer shell and the converter outer shell is subjected to subsequent welding operations to reduce the converter outer shell to the determined outer diameter. The subsequent welding operations utilizes electrode welding to pack the converter substrate into the shell. Further, each final assembled catalytic converter which is shown the Figure 3 should have a desired density characteristic, back pressure and other gas flow characteristics are calculated.



Figure 3. Assembled Catalytic Converter

3. Experimental Setup

Figure 4 demonstrates the Catalytic Converter of width 150 mm and a spine measurement of 40 mm fitted Kirloskar engine. Before settling of catalytic converter the outflows originating from engine were watched. Then the spine of the catalytic converter was altered as needs be to the rib of the engine with the assistance of tightens and dashes as demonstrated the figure. The determination of motor is appeared in the Table 1. The motor is made to run utilizing diesel of Calorific Estimation of 45000 KJ/kg. Legitimate measures are taken to abstain from dismantling of the rib of catalytic converter and engine. At first the motor is made to keep running at no load condition. After the enactment of catalytic converter i.e. 2 hours, load was expanded bit by bit and emanation of NO_x, CO, HC and Smoke are noted and definite investigation is given underneath. The gulf of the AVL smoke meter appeared in the Figure 5 was associated with the fumes of the catalytic converter to quantify the

emanation. The particular of engine and AVL 437 smoke meter are appeared in the Table 1 and Table 2.



Figure 4. Catalytic converter fitted test engine

Table 1. Engine Specification

PART	SPECIFICATION
Product	Single cylinder , 4 stroke, multi-fuel VCR (computerised)
Product code	240PE, Make: apex innovation pvt. Ltd.
Engine	Single cylinder, 4 stroke, water cooled, bore 87.5mm, capacity 661cc. Diesel mode: power 3.5 kw, speed 1500 rpm, Injection variation: 0 – 25 degree bTDC power 3.5 kW @1500 rpm, speed range 1200-1800 rpm,
Dynamometer	Eddy current i.e water cooled, with loading unit Model iag10 of Sai test plant pvt. Ltd.
Fuel tank	Capacity 15 lit. Type: dual compartment, with fuel metering pipe of glass
Piezosensor	Combustion: range 5000 psi, Diesel line: range 5000 psi
Crank angle sensor	Resolution 1degree, speed 5500 rpm with TDC pulse
Data acquisition device	Ni usb-6210, 16 bit, 250 ks/s
Engine control hardware	Fuel injector, fuel pump, ignition coil, idle air
Temperature sensor	Type rtd, pt100 and thermocouple, type k
Load indicator	Digital, range 0-50 kg, supply 230 v ac
Load sensor	Load cell, type strain gauge, range 0-50 kg
Software	“Enginesoft” engine performance analysis software

Table 2. Specification Of AVL 437 Smoke Meter

ITEM	DETAIL
Measurement principle	Measurement of filter paper blackening
Measured value output	FSN (filter smoke number) or mg/m ³ (soot concentration)
Measurement range	0 – 10 fsn
Detection limit	0.002 fsn or 0.02 mg/m ³

Resolution	0.001 fsn or 0.01 mg/m ³
Exhaust pressure ranges	(-300*) – 100 to 400mbars (-500*) – 200 to 750 mbars 0 – 3000 mbars with the high pressure option (*) with activate altitude simulation
Maximum exhaust temperature	600° C with standard 340 mm sample probe
Interfaces	2 serial rs 232 interfaces with a k protocol Digital via instrument 6approx.6per 4210 1 ether net interface with in port option install
Power supply Power consumption	100 – 115V ac or 230V ac, 50/60 hz 700 va
Compressed air	150i/min during purge Grades 1.1.1 to 1.4.1 according to ISO 8573.1:2001I Recommended connection pressure on the AVL smoke meter: 5 to 8 bars at the measurement device input
Weight	<40 kg
Dimensions(w x h x d)	560 x 620 x 300 mm
Sample flow	10 i/min
Ambient condition	5 to 55° C /max. 95 rh; without condensation Sea level -500 to +5000m
Repeatability	Standard deviation is+/- (0.005 fsn+3% of the measured value@ 10 sec intake time)



Figure 5. AVL digital smoke meter

4. Result and Discussions

4.1 Study of NO_x emission

The reduction of NO_x emission with and without using catalytic convertor is shown in the Figure 6. The reduction of NO_x considered the main reaction. Idea depends on fuse of a water gas shift and steam transforming responses. The reduction of NO_x is approx. 61% with using copper oxide based catalytic converter. Nitrogen Oxides (NO_x) are reduced into nitrogen (N₂) and carbon dioxide (CO₂).

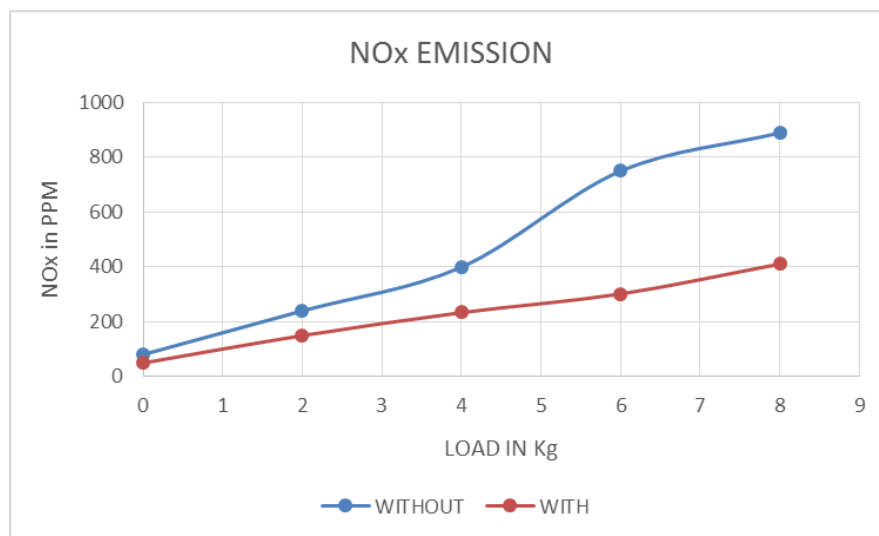


Figure 6. Variation of NOx emission with load

4.2 Smoke analysis

The Figure 7 shows the reduction of Smoke emission by using Catalytic Converter. Soot or smoke made up of particles in the micrometer size range: Particulate matter causes negative health effects, including but not limited to respiratory disease and cancer. The Density of Smoke is Approx. 38 kg/m^3 . The reduction of Smoke is approx. 32% by using Copper based Catalytic converter.

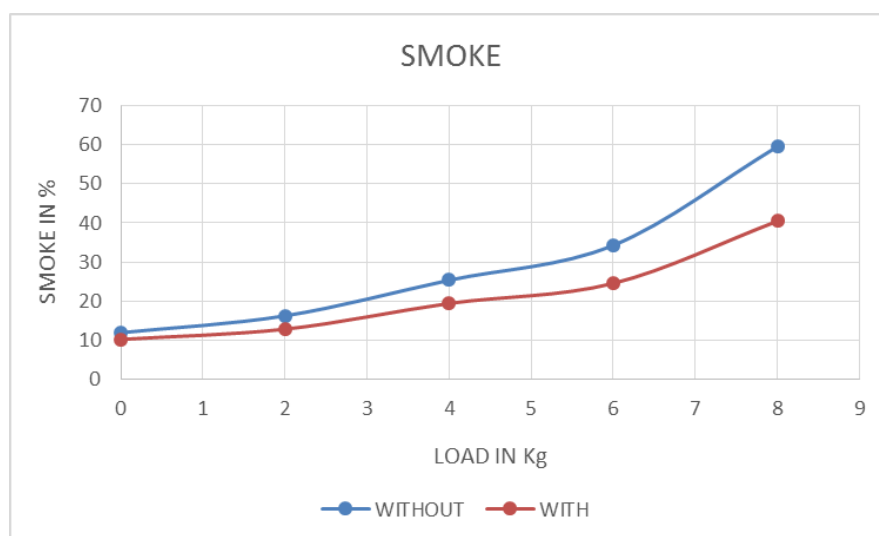


Figure 7. Variation of smoke emission with load

4.3 Analysis of CO emission

The reduction of CO emission with and without using catalytic converter is shown in the Figure 8. The reduction of CO is approx. 21% with using copper oxide based catalytic converter. Carbon mono oxide is oxidized to carbon dioxide. Copper oxide when reacts with carbon mono oxide reduces it to carbon dioxide and deposition of copper, due to reduction property CO.

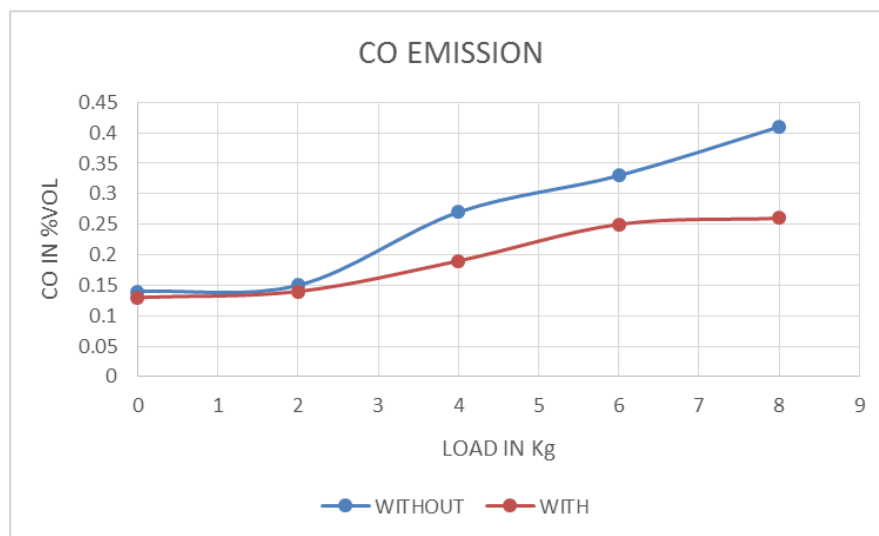


Figure 8. Variation of CO emission with load

4.4 Study of HC emission

The reduction of HC emission by using Catalytic Converter is shown in the figure 9. Reducing of hydrocarbons by catalytic converter is due to Small amount of fuel in large mass of air causes smaller values of emission both CO and HC, but engine worked steady during experimental tests. The reduction of HC is approx. 32% by using Copper based Catalytic Converter. Hydrocarbons (HC) are oxidized to create water (H_2O) and carbon dioxide (CO_2).

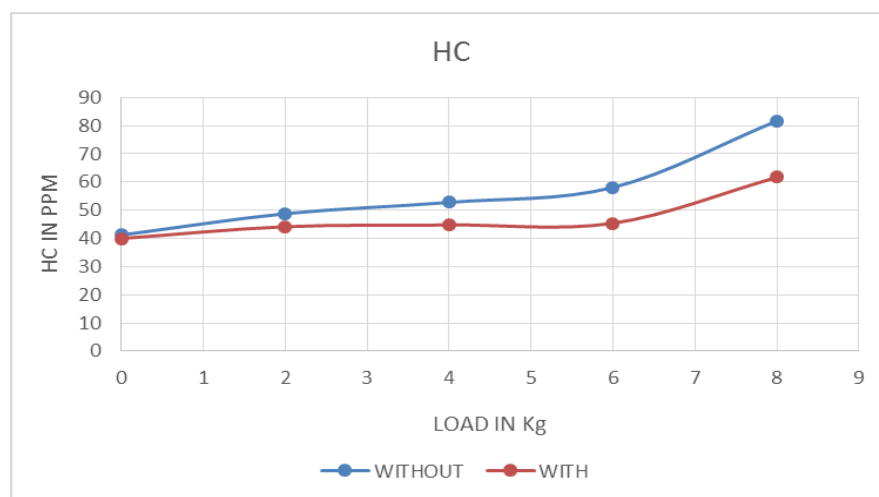


Figure 9. Variation of HC emission with load

5. Conclusion

The experimental investigation findings on emissions of catalytic converter fitted diesel engine are given below

- The catalyst (copper oxide) used in this catalytic converter is economically cost effective when compared to presently using noble catalysts
- It is found that NO_x is significantly reduced when the engine is allowed to run with a catalytic converter at all loads. The result shows that the maximum reduction of 61% in NO_x emission is recorded at full load when compared with that of without catalytic converter.

- From the emissions results, it is noticed that HC emission is reduced for copper oxide based catalytic converter when compared with that of without catalytic converter at all loads. The maximum reduction in HC is observed as 32% at full load.
- Copper oxide catalytic converter shows a remarkable reduction in smoke and CO emission when compared to those of without catalytic converter. The maximum reduction in smoke and CO is observed as 32% and 21% at full load.

As the catalytic activity of copper oxide on the engine exhaust gas which is passing over it is found to be similar to the noble catalyst, it is a better alternate for noble catalysts.

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