Using Nano Coated Catalytic Converter in Gasoline Engine-Improvement of Retention Time and Air Pollution Control

Rajlaxmi Chaudhary[a], Dr. Mukesh Thakur[b]
[a]Research scholar, Rungta College of Engineering & Technology, Bhilai (C.G.), India-492001
[b]Principal NMDC DAV Polytechnic, Jawanga, Geedam District – South Bastar (C.G.), India

ABSTRACT

In the current scenario of the pollution control is a crucial area for research and development in the world, but the area is still lacking for an efficient techniques which can provide highly control the emission for all the operating conditions of vehicles. The approach of this work is to control the exhaust emissions from four stroke, spark ignition engine having copper nanoparticles coated on designed catalytic converter. Gas analyzer used for the measurement and comparison for carbon mono oxide and unburnt hydrocarbon in the exhaust of the engine at different speeds and loads.

In this work alterations and modifications have been designed that to increase the retention period of exhaust gases to provide more time for its oxidation and thereby to reduce the harmful emission.

Keywords: Spark Ignition Engine, Catalytic Converter, Copper Nanoparticles, Retention Time

INTRODUCTION

Gradually increase ofpopulation and need of sources in world results tremendous growth in the urbanization as well as commercialization has made the whole world is in the grip of environmental crisis like air pollution water pollution and noise pollution. Air pollution can be defined as presence in atmosphere of one or more toxic pollutants for such period that is harmful to human health and animal or plant life. To predict the transport related air pollution newer and newer models have been developed worldwide.Increasing the vehicles on roads, carbon monoxide concentration has reached a shocking level in the environment.

The oxidation of gasoline in the engine to carbon dioxide and water is far from desired completely efficient process. Various laws and regulations were made to cope up with this problem. The emission standards limit the maximum amount of injuriousmatters that automobileexhaust can release. The pollutants that are limited today by the regulations are hydrocarbons, carbon monoxide, oxides of nitrogen and particulate matter. Among above pollutants carbon monoxide is considered as most toxic pollutant, whose effective reduction can be achieved by using catalytic converter [1]. Unburnt hydrocarbons are present in exhaust emission due to incomplete combustion behind engine of automobiles. The level of unburned hydrocarbons is specified as parts per million of carbon molecules. The total hydrocarbon emissions are used as a measure of the combustion efficiency. Treatment of the exhaust gas means that some cleaning action must occur after the exhaust gases emission leave in the engine cylinders and also when they exit in the tail pipe and enter the atmosphere [2]. For these two methods are widely used for cleaning and purifying environmental air is - the Air injection system and the Catalytic converter.

In the present method, catalytic converters have been used to reduce the pollution which is spread by exhaust emission from automobile exhaust. The catalytic convertor is the leading pollution control device with magnetic and chemical properties yielding applications in biological nanosensors, optoelectronics, nanodevices, nanoelectronics, information storageand catalysis [3]. The all useful metals like Au, Ag, Pd, Pt, to which Nano-technology research is directed, copper and copper based compounds are the most significant. The metallic Copper plays important role in modern technology due to its excellent electrical conductivity and low cost of nanoparticles[4]. Thus Copper will gate highimportance as it is expected to benecessary component in the future Nano-devices due to its outstanding conductivity as well as good biocompatibility and its surface enhanced Raman scattering activity [5]. Nanocrystal Metal of copper consistentlyisolated in silica layers have concerned great attention newly for the development of nonlinear optical instruments anddevices [6].Such composite materials offer exciting possibilities of potential thin films device applications with novel function rising from size quantization effect. In the light very fast and highly growing applications of metal of copper nanoparticles, a procreative method of combinationwith a specific size, well defined surface composition, isolable properties remains a thought-provoking task to a synthetic chemist. The capability to scale up the synthesis to bulk scale will gain increasing position as more applications are being established.

However, most of the synthetic methods are required high temperature and pressure condition to reuse the particles either produce particles with reduced catalytic inability and activityor yielded particles of irregular shape with wide size distribution. The synthesis of copper nanoparticles by reducing the copper ions with sodium borohydride [7]. The particle size has been varied by modulating the concentrations of reactants and capping agent. The catalytic activities of these particles of different sizes have been tested on the catalytic converter in spark ignition engine.

Pollutants present in the exhaust gases coming out from the motor vehicles engine into the atmosphere by partial oxidation of carbon-containing products are reduced by passing them through catalytic converters thereby decreasing air pollution substantially. A catalytic converter is an emission control device that converts more toxic pollutants present in the automobile exhaust into less toxic by catalytic reactions. In order to improve the design of the catalytic converters, mathematical modeling and numerical simulation helps not only to reduce the number of experiments but is also time saving.

MATERIAL & METHOD

System Designing

In the present work, an improved design having reduced diameter at inlet, outlet and increased inclination angle is proposed. The new design is more suitable for implementation along with improved performance and efficiency in reducing the exhaust emissions from four stroke spark ignition engine

The theory revolves around the principle of nano-particles acting to reduce the production of harmful compounds of combustion by this method. The converter uses two different types of catalyst first is for reduction purpose and other is for oxidation purpose catalyst. Logic of this work is to generate a structure that exposes the maximum surface area of catalyst to exhaust stream, also minimizing the amount of catalyst required. The vehicle exhaust gases pass through a bed of catalyst and after come on contact the catalytic action takes place at surface of nano Copper which is porous and have higher catalytic activity towards the oxidation of carbon mono oxide (CO) and hydro carbon (HC) could be due to the higher catalytic surface area of small nano-particles.

The catalytic convertor as discussed above is designed and assembled as per the design given Figure 1. The arrangement was provided within the system to tubular structure with circular grid formation in inner surface.It is designed in such a way that the area of contact of gasesand surface area of system is very lasge and the time of contact is also increased.

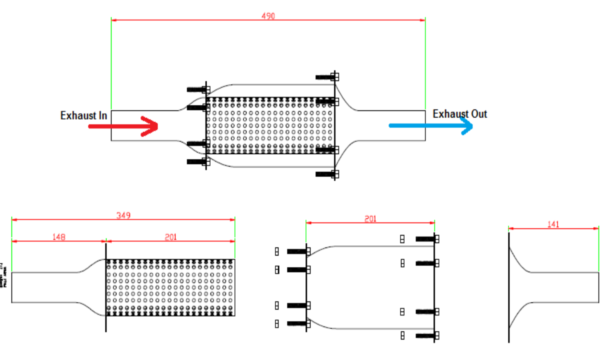

Figure 1: Proposed design of catalytic converter

Calculation for present work

Radius of tail pipe	2 cm
Area of copper sieve	475.7 cm^2
Area of tail pipe	$3.14*2^2=12.56$ cm^2
Area of tail pipe/ Area of copper sieve	12.56/475.7=1/36.4
Engine specification - Engine capacity Engine speed	256.56 c.c. = 256.56 cm3 3000 rpm
Volume of gas at outlet of tail	256.56cm3*3000/2 rpm=384,840 cm3/minute.
Velocity of gas at tail pipe outlet in cm/minute	$\frac{384{,}840 \text{ cm3 / minute}}{12.56 \text{ cm2}}$ = 30640.12 cm /min
Velocity of gas at tail pipe outlet in m/sec	$\frac{30640.12 * 10-2}{60}$ = 5.10 m/sec
Velocity of gas passes through copper sieve	$\frac{5.10}{36.4} = 0.14\ m/sec$
$\frac{\text{Velocity of gas at tail pipe}}{\text{Velocity of gas passes throu}}$	$\frac{5.1}{0.14} = 36.4$
Finally velocity of gas passes through copper sieve	$\frac{Velocity\ of\ gas\ at\ ta}{36.}$

Preparation of copper nanoparticles

In a typical procedure, 20 ml ethylene glycol solution (0.1M) of $CuSO_4 \cdot 5H_2O$ was mixed with 20 ml EG mixed solution of NaOH and $N_2H_4 \cdot H_2O$ under magnetic stirring. The molar ratio of $N_2H_4 \cdot H_2O/CuSO_4$ was 1.5 and the molar ratio of NaOH /$CuSO_4$ was 0.05. The mixture solution was placed in a microwave oven (2.45 GHz, GalanzWP750) and reacted under medium power (750 W, working cycle of 18s on and 12s off) for 3 min. Upon irradiating for about 30 s, the mixture turned from light blue to black; at about 90 s, the mixture boiled at about 196°C.

Then the mixture was irradiated for another 2 min to keep the mixture boiling. After cooling at room temperature, Copper nanoparticles were obtained by centrifuging and washing with ethanol, several times. Transmission Electron microscopic (TEM) analyses were performed with Morgagni 268D Transmission electron microscope operating at 80kB (Mega view III Camera CCD), all India Institute of Medical Sciences (AIIMS), New Delhi. Samples of nanoparticlewere prepared by drying a drop of the colloid on the surface of system with the sample material allowed to dry completely at room temperature Triple distilled water was used for solution preparation.

Experimental Procedure

The experiments were carried out on a four stroke with 3 HP RPM petrol engine single cylinder, Bore diameter 70 mm, stroke length: 70 mm horizontalair-cooled engine. The dynamic test rig consists of a four stroke petrol engine coupled to electrical dynamometer, a rheostat is provided to load the engine, various measurements are provided so that performance of the spark ignition engine at various loads and speed can be estimated shown in Fig. 2.

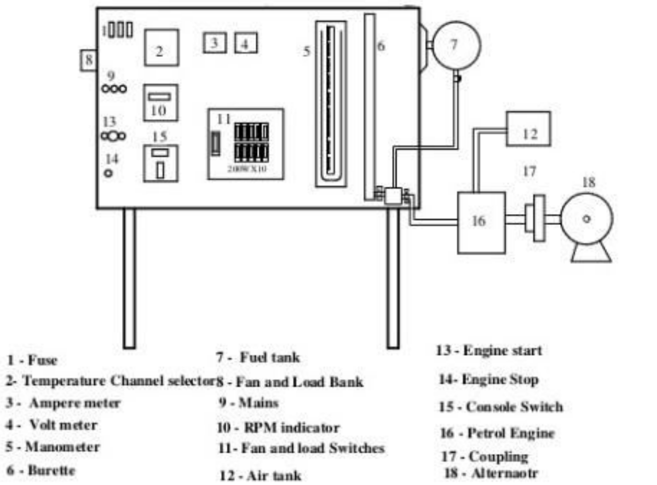

Figure 2: Experimental setup of S.I. engine

Following steps and precautions were take on.

1) Put enough petrol as a fuel along with self-mixing 2T oil in the tank.
2) Check lubricating oil level in the gear box/sumpof the engine, and calorie meter and adjust the flow rate.Oil level should be always up to the oil filling hole.
3) Start the engine with the help of self-start arrangement.
4) Confirm that the engine is in neutral gear, all switches of the load bank are off and ignition switch is 'on'.
5) Start water supply to the calorimeter.
6) Press the choke knob and give a sharp kick, engine will start. As the engine starts, release the choke knob, and pull clutch lever.
7) Uniformly increasing the accelerator and set the engine speed
8) Initially the experiment is performed at 0.25 load keeping the speed 1500 rpm. Same testing is performed again using Nano copper coated sieve.
9) Repeat the above procedure for another speed say 1800, 2000, 2200 and 2400 rpm at varying load conditions with & without using catalytic converter.
10) The above procedure were repeated for different speed with different load conditions using sieve coated with Cu nanoparticles.

The four stork exhaust emission measurements were carried out by using a standardizedinstruments AVL 422 gas analyzer for carbon mono oxide and hydro carbon at each operating point for both conditions with and without catalytic converter is recorded and figures were plotted between varying load and pollutant concentration CO and HC.

AVL 422 Gas Analyzer- this is the exhaust gas analyzer inserting a probe in to tail pipe of spark ignition engine. Theexamination draws out some of the exhaust gas and carries it through the gas analyzer. There are two display units in exhaust gas analyzer to measure the hydrocarbon in ppm and carbon mono oxide in the percentage. The exhaust gas was the tubing approximately 2 cm in to engine tail pipe.

RESULT AND DISCUSSION

Emission parameters of a Spark Ignition engine with and without catalytic converter are performedby changing load and speed as shown in Figure 3 to 6. By using various graphs for carbon monoxide and hydrocarbon in variable speed and load, the following results were obtained.

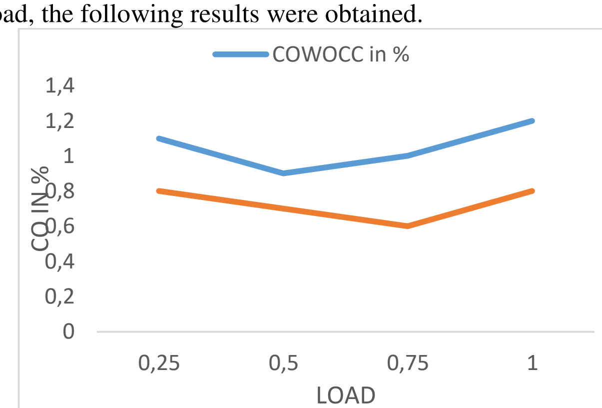

Figure 3a: Effect of changing load on CO percentage emission at 1500 rpm

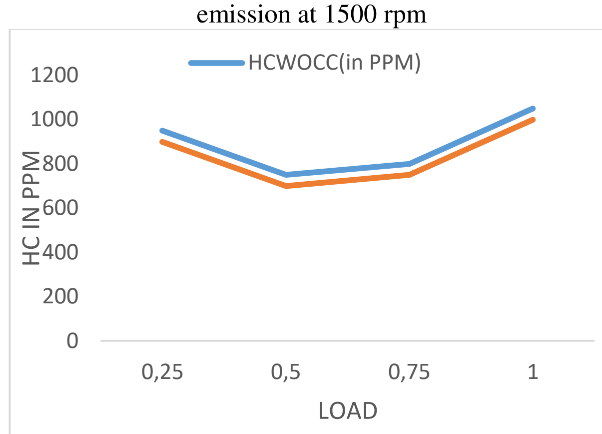

Figure 3b: Effect of changing load on HC in ppm emission at 1500 rpm

a) Figure 3a & 3b showed the effect of changing load on carbon mono oxide and hydro carbonpercentage emission at 1500 rpm. It is clear from the figure that carbon mono oxide and hydro carbonemission at 0.25 load is littlehigher than the moderate load of 0.5 and 0.75 because the temperature of the burning flame zone is much lower leading to formation of hydrocarbons also the air-fuel ratio is 10:1 leading slow oxidation. As the load increases from 0.25 to 0.5 and 0.5 to 0.75, more amount of charge is supplied inside the cylinder and the oxidation process is accelerated. Finally when load increases from 0.75 to 1, emission of carbon mono oxide and hydro carbonincreases from 1.3% to 1.6% and 1700 ppm to 1800 ppm respectively. On repeating the same step using catalytic converter the emission of carbon mono oxide and hydro carbonare found to be lowered.

b) At varying increased load with increasing speed it is found that emission of carbon mono oxide and hydro carbondecreases. Emission of CO decreases from 1.5% to 1.2% when speed increases from 1500 to 2000 rpm as shown in Fig. 4a & 4b.

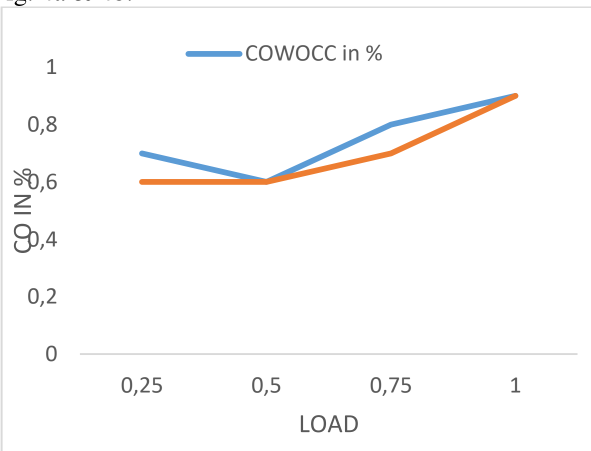

Figure 4a: Effect of changing load on CO percentage emission at 2000 rpm

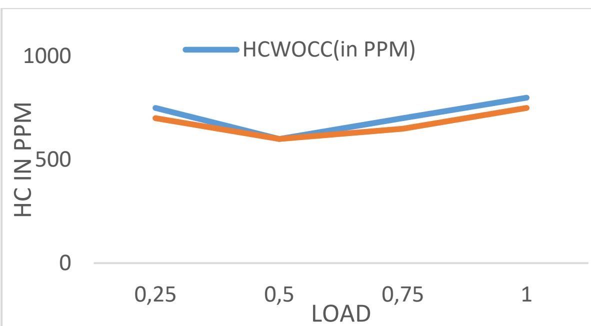

Figure 4b: Effect of changing load on HC in ppm emission at 2000 rpm

c) The emission of carbon mono oxide and hydro carbondecreases till the speed reaches to 2200 rpm, and onfurther increasing the speed the emission again increases as the valve timing spark timing did not match which results in incomplete combustion of fuel shown in Fig. 5a and 5b.

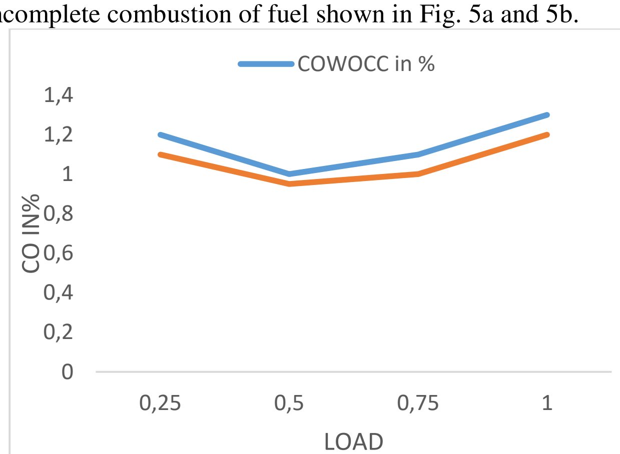

Figure 5a: Effect of changing load on CO percentage emission at 2200 rpm

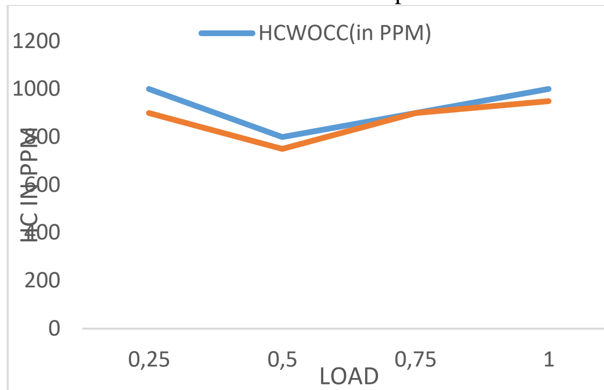

Figure 5b: Effect of changing load on HC in ppm emission at 2200 rpm

d) On repeating the above steps for 2400 rpm using catalytic converter (Cu sieve) coated with copper nanoparticle, the emission of carbon mono oxide and hydro carbonare found to be lowered & more efficient than bulk copper.As shown in Fig. 6a and 6b.

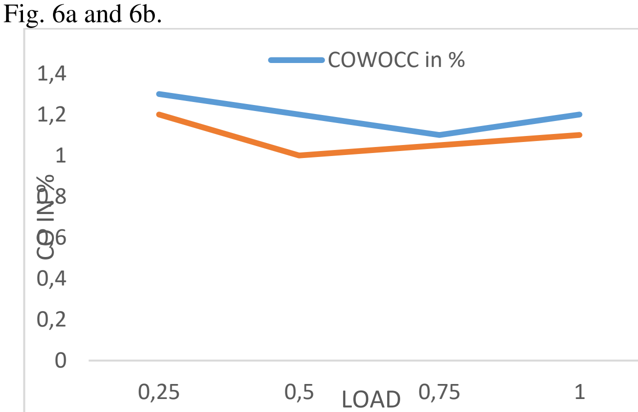

Figure 6a: Effect of changing load on CO percentage emission at 2400 rpm.

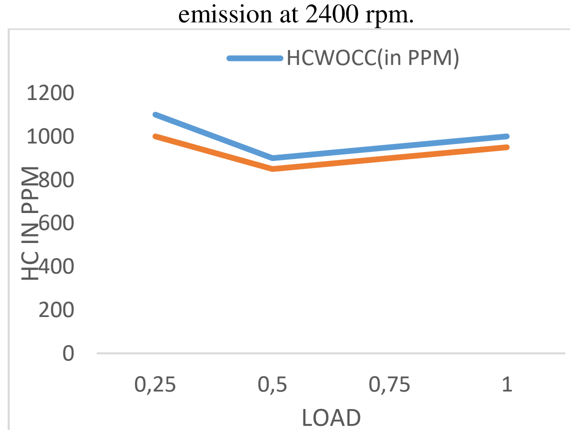

Figure 6b: Effect of changing load on HC in ppm emission at 2400 rpm.

CONCLUSION

The engine is always designed to run at medium load (0.5 load) for best efficiency and a longer time due to less emission of carbon mono oxide and hydro carbon. At full load, emission of carbon mono oxide and hydro carbonare higher so it is not desirable to run engine at full load. In spark ignition engine catalytic convertor used for reduction and oxidation of exhaust gases reaction. The actual aim of this work is to create a structure that exposes and provide the maximum surface area of catalyst to exhaust stream, also minimizing the amount of catalyst required. The exhaust gases pass through a bed of catalyst structure and then catalytic action takes place on the surface of Copper which are porous and have comparatively higher catalytic activity towards the oxidation of carbon mono oxide and hydro carboncould be due to the higher catalytic surface area of small nanoparticles. It is presumed that the electrophilic nature of the catalyst surface a weak bond between the carbon mono oxide and vacant d system of copper atoms.The electrophilic nature of copper surface removes that when the particles are extremely small in size, the electrons are pumped into copper by emission which usually reduction of the band gap between Fermi level and conduction band significantly so that the catalytic activity is also expected to be reduced [8]. Any aggregation of the particles in aqueous dispersion leads to lower efficiency. The freshly prepared and capped Cu Nano particles(12nm- 20 nm)also showed good activity for this oxidation.

The catalyst increases the rate of reaction by adsorption of reactants in such a form that the activation energy for reaction is reduced far below its value in un-catalyzed reaction.Copper metal is selected for the present work as a catalyst, it is cheaper than platinum, palladium and rhodium. Also it adsorbs the reactants molecule very strongly to clamp and active the reactants but not so strongly, it means products are break in there less polluted gasesalso the diffusion of reactants and products into and out of the pore structure of copper coated surface take place efficiently. Due to this, the pollution level for the exhaust emission of spark ignition engine has found to be reduced which is better with Nano sized catalytic converter.

This work is also show a pathway for some future prospects such as exhaust gas recirculation model for reduction of $NO_x$and other polluted gases concentration level which is already available in atmosphereand has to be incorporated with present catalytic converter model and tested against experiments.

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ABBREVIATIONS:

CO – Carbon Monoxide
CC – Catalytic Converter
HC – Hydrocarbon
COWCC – CO emission in % with catalytic converter
COWOCC – CO emission in % without catalytic converter
HCWCC – HC emission in PPM with catalytic converter
HCWOCC – HC emission in PPM without catalytic converter
CC - Catalytic Converter
RPM - Revolution per Minute
SERS - Surface Enhanced Raman Scattering
PM - Particulate Matter
NOX - Oxides of Nitrogen
HP - Horse Power

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