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Improved and Latest Design of a Nanosized Catalytic Converter for Pollution Prevention Implemented to Four Stroke Engine with Experimental Validation by Modeling

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ABSTRACT

A great deal of emphasis is placed on the real societal benefits around nanotechnology for energy efficiency, renewable resources, environmental remediation and pollution prevention. In particular, new and better techniques for pollution control are emerging as nano-particles push the limits and capabilities of technology. Environmental Pollution by vehicles is caused due to tail-pipe exhaust emissions depending on changes in driving cycles, engine condition, fuel composition and air-fuel ratio. Malfunction of engine devices, especially fuel injection system, increases the emissions of the main exhaust components. In the present work, an improved design more suitable for implementation along with improved performance and efficiency in reducing the exhaust emissions from two stroke and four stroke spark ignition engine. In the present work some alterations and modifications have been designed so as to increase the retention period of exhaust gases to provide more time for its oxidation and thereby to reduce the harmful emission. In this research, modeling has been done for a four stroke spark ignition engine with nano-sized copper coated catalytic converter. It will throw a light on the reduction in emission achieved by nano-particle coating. This paper opens a gateway to study the changes in the concentration of exhaust emissions due to the nano-material coating. The modeling will help in understanding the mathematical nature of the process.

Keywords-catalytic converter; four-stroke engine; modeling; pollution

1. INTRODUCTION

A Today, one of the toughest challenges faced by the mankind is the increasing of pollution at an alarming rate. It is causing an environmental imbalance and contributing to increase in the green house effect. Automobile pollution is the major source of pollution. The majority of the environmental pollution is due to the two-wheeler automobiles due to their large number. There are two methods of control of pollution namely, pre-pollution control and post pollution control. This paper is based on the post pollution control method in two-wheeler automobiles using nano-particle as a catalyst. A study on nano-particle reveals that the ratio of surface area of nano-particle to the volume of the nano-particle is inversely proportional to the radius of the nano-particle. So, on decreasing the radius, this ratio is increased leading to an increased rate of reaction and the concentration of the pollutants is decreased. To achieve this objective, an innovative design of catalytic converter for two-wheeler automobiles is proposed using nano-particle as a catalyst. The proposed method is very effective in the prevention of environmental pollution contributed from two-wheeler automobiles. It involves the use of copper nano-particle which is cheaper than the platinum, palladium and rhodium nano-particles used in automobiles. At nanometer scales, the surface properties start becoming more dominant than the bulk material properties, generating unique material attributes and chemical reactions. Metal nano-particles are being considered for potential use in catalytic converters since the catalytic reactivity is significantly enhanced due to the increased surface area and altered electronic structure of the metal nano-particle. Coolants utilize nano-particles and nano-powders to increase the efficiency of heat transfer and potentially reduce the size of the automotive cooling equipment.

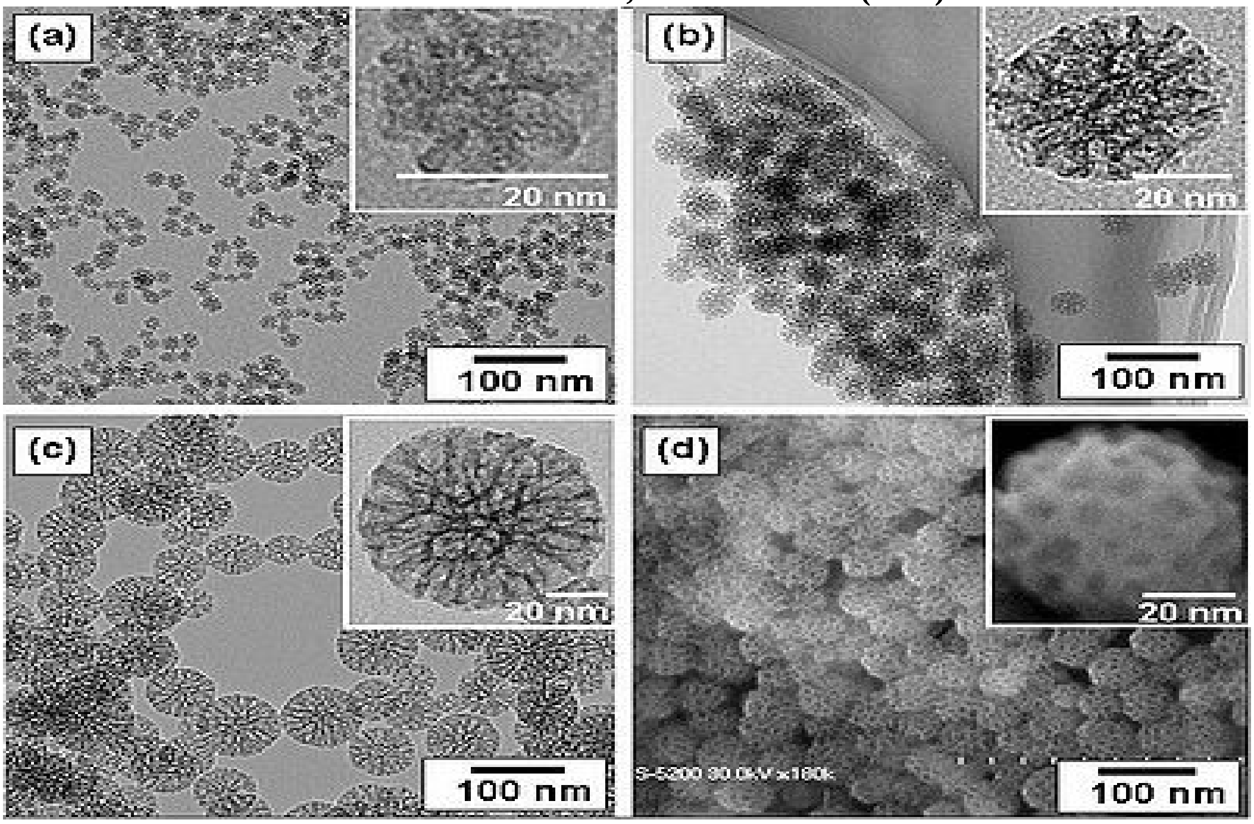

Figure 1. *The Nano-particles* [Thakur and Saikhedkar, 2012]

A great deal of emphasis is placed on the real societal benefits around nanotechnology for energy efficiency, renewable resources, environmental remediation and pollution prevention. In particular, new and better techniques for pollution control are emerging as nano-particles push the limits and capabilities of technology. Environmental Pollution by vehicles is caused due to tail-pipe exhaust emissions depending on changes in driving cycles, engine condition, fuel composition and air-fuel ratio. Malfunction of engine devices, especially fuel injection system, increases the emissions of the main exhaust components. Vehicular emissions consist of Carbon dioxide, Carbon monoxide, Nitrogen oxide, hydrocarbons including lead, particulate matter etc. Inhaling of Carbon monoxide hinders Oxygen supply from blood into the tissues, as it combines with the Iron in hemoglobin, leading to variety of ailments, viz. Cancer (Gilmour *et al*, 2004). Carbon dioxide causes environmental problems related to global warming. Among above pollutants, CO is considered as most toxic pollutant, whose effective reduction can be achieved by using catalytic converter (Twigg, 2006). Unburnt hydrocarbons are present in exhaust emission due to incomplete combustion. The level of unburned hydrocarbons is specified as parts per million (ppm) carbon atoms. 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 emissions leave the engine cylinder and exit from the tail pipe which enters in to atmosphere (Kishore and Krishna, 2008). A comprehensive review on the recent trends in application of nano-technology in automotive pollution control was covered. First, the essential aspects of environmental problems due to automotive industry were discussed and then the application of nanotechnology towards the prevention and control of these problems were suggested in detail (Thakur and Saikhedkar, 2012). The utility of the nano-particles towards automobile pollution control was explained in detail. The nano-particle coating on the catalytic converter of automobiles can be very helpful in the reduction of pollutant concentration and thus reduce the pollution level in atmosphere (Thakur and Saikhedkar, 2012). Amongst main metals like Au, Ag, Pd, Pt, towards which nanotechnology research is directed, copper and copper based compounds are the most important. The metallic Copper plays a significant role in modern electronics circuits due to its excellent electrical conductivity and low cost nanoparticles (Feldheim *et al*, 2004). Thus copper will gain increasing importance as it is expected to be an essential component in the future nano-devices due to its excellent conductivity as well as good biocompatibility and its surface enhanced Raman scattering (SERS) activity (Schaper *et al.*, 2004). The post pollution control method in two-wheeler automobiles using nano-particle as a catalyst was proposed. A study on nano-particle reveals that the ratio of surface area of nano-particle to the volume of the nano-particle is inversely proportional to the radius of the nano-particle. So, on decreasing the radius, this ratio is increased leading to an increased rate of reaction and the concentration of the pollutants is decreased (Thakur and Saikhedkar, 2012). It involves the use of copper nano-particle which is cheaper than the platinum, palladium and rhodium nano-particles used in automobiles (Thakur and Saikhedkar, 2012). A microprocessor based analyzer was used for measurement of CO and HC emissions (Murali Krishna *et* al., 2012). To control the exhaust emissions from two stroke single cylinder spark ignition petrol engine having copper nano-particles coated on copper sieve as catalytic converter was used. AVL-422 Gas analyzer was used for the measurement and comparison for CO and unburned hydrocarbon in the exhaust of the engine at various speeds and loads (Thakur and Saikhedkar, 2012). The conversion efficiency of a catalytic converter mounted on a vehicle with spark ignition engine was evaluated under steady operating conditions (Silva *et* al., 2006). Three way converters have been compared to understand the influence of the substrate on the exhaust gas conversions for many operating conditions of vehicle (Silva and Costa, 2008). Various tests conducted on four stroke engine reveal that the copper coated engine showed a better performance than a normal engine (Murali and Kishor, 2008). On using copper powder, the catalytic efficiency was found to increase as the size of the powder decreased (Samim *et* al., 2007). A nano catalytic converter was designed and manufactured to reduce the pollution in the environment (Durairajan *et* al., 2012). Nano-coatings can be used to reduce surface roughness of engine components and to act as protective coating against wear of components (Prabhu and Vinayagam, 2009). Experiments were conducted to improve the engine performance and reduce the emissions of HC and CO from vehicle (Shehata and Razak, 2008). Some alterations and modifications have been designed so as to increase the retention period of exhaust gases to provide more time for its oxidation and thereby to reduce harmful emissions (Thakur and Saikhedkar, 2013). In the present work some alterations and modifications have been designed so as to increase the retention period of exhaust gases to provide more time for its oxidation and thereby to reduce the harmful emission. In this research, modeling has been done for a four stroke spark ignition engine with catalytic converter. It will throw a light on the reduction in emission achieved by nano-particle coating.

2. MODELING OF FOUR STROKE ENGINE

2.1 Behavioral Modeling

This subsection presents the complete behavioral modeling of four stroke engine; during modeling of engine following parameters are important and has to be addressed during modeling. The engine specifications are as follows:

POWER	3 HP
FUEL	PETROL
NUMBER OF CYLINDERS	SINGLE
BORE	70 mm
STROKE LENGTH	70 mm

These three important parameters are basically independent variable for modeling, and it is difficult to address simultaneously. However among these three on can be assume constant, so for modeling of four-stroke engine. In this paper horse power of engine is taken as constant, this leads the reduction of one independent variable from the list.

Now following steps provide complete idea of behavioral modeling of four stroke engine.

1. Define the behavior of four stroke engine in terms of input and output variables. For modeling of this paper the input variables are,

i. Speed of engine in RPM.

ii. Applicable load during running condition.

Similarly the output variables for our work are

i. CO in percentage.

ii. HC in PPM.

To analyze the behavior of four stroke engine, practical experiment has been performed and data collected is as shown in table (1).

Table 1. *Values of Load, CO and HC*

Speed In RPM	Load	CO in %	HC in PPM
1500	0.25	1.2	1000
	0.5	1	800
	0.75	1.1	900
	1	1.3	1100

1800	0.25	1	900
	0.5	0.8	750
	0.75	0.9	800
	1	1.1	1000
2000	0.25	0.8	800
	0.5	0.7	700
	0.75	0.9	750
	1	1	850
2200	0.25	1.3	1100
	0.5	1.1	850
	0.75	1.2	950
	1	1.4	1150

2. From table (1), it is clear that there are four different speed conditions and each speed value consist four different load conditions. So, for proper behavioral analysis of four stroke engine, we have to analyze the complete behavior in four parts based on different speed conditions. Hence the complete modeling is also divided in four parts.

3. Modeling of four stroke engine for speed = 1500 RPM. Table (2) shows the behavior of engine for 1500 RPM.

Table 2. *Values of CO and HC at a load of 1500 RPM*

Speed In RPM	Load	CO in %	HC(in PPM)
1500	0.25	1.2	1000
	0.5	1	800
	0.75	1.1	900
	1	1.3	1100

Now by dividing the modeling in four parts actually provides reduction of second independent variable and hence for modeling now we have only one independent variable and two dependent output variables. Figure (2) and (3) shows plot of CO and HC with respect to Load values for fixed speed 1500 rpm.

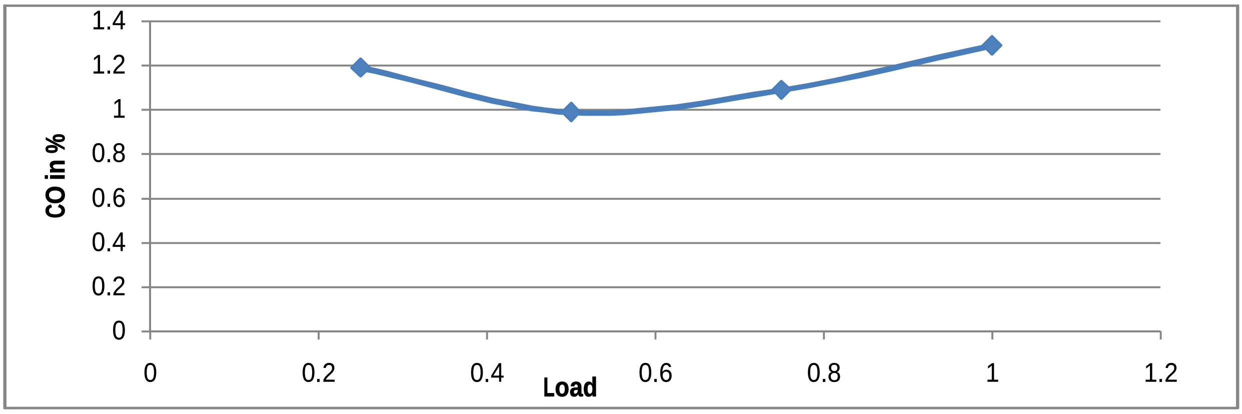

Figure 2. *The Variation of CO in percentage versus load*

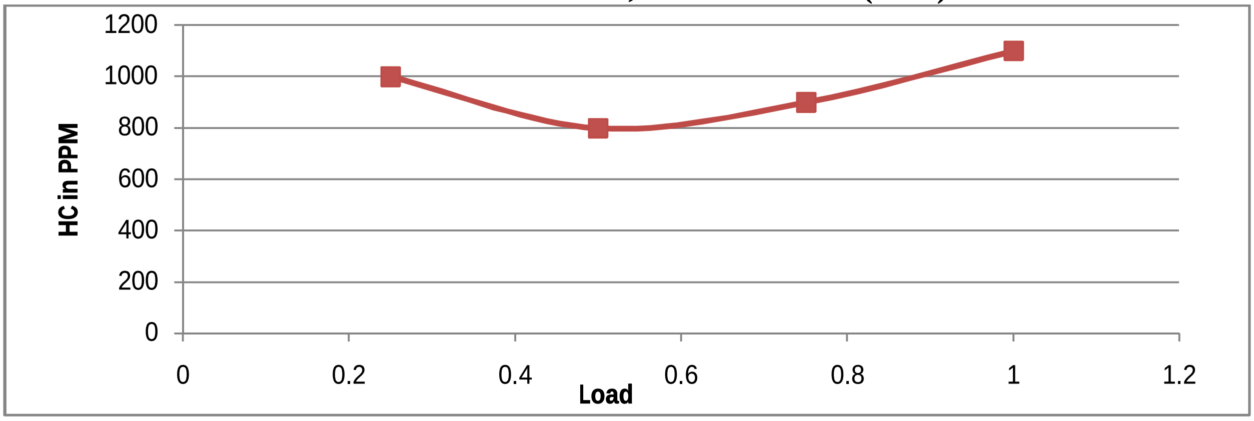

Figure 3. *The Variation of HC in PPM versus load*

After using above figures, mathematical equations for CO and HC obtained are as follows:

$$CO = -2.1333x^3 + 5.6\,x^2 - 4.0667x + 1.89 \quad (1)$$

$$HC = -2.1333x^3 + 5600\,x^2 - 4066x + 1698 \quad (2)$$

In this subsection, we provide behavioral modeling of physically designed catalytic convertor for getting reduction in amount of CO and HC obtained from four stroke engine coated with copper nano-particles. Fundamental steps are same as we have discussed in earlier subsection.

1. Behavior analysis: table (3) and table (4), shows the practical behavior of physically designed catalytic convertor. Figure (4) and (5) shows corresponding plots.

Table 3. *Comparision of COWOCC and COWOCC*

COWOCC in %	COWCC in %
0.7	0.3
0.8	0.4
0.9	0.35
1	0.45
1.1	0.5
1.2	0.6
1.3	0.65
1.4	0.7

Table 4. *Comparision of HCWOCC and HCWCC*

HCWOCC in PPM	HCWCC in PPM
700	500
750	530
800	550
850	600
900	650
950	750
1000	650
1100	750
1150	850

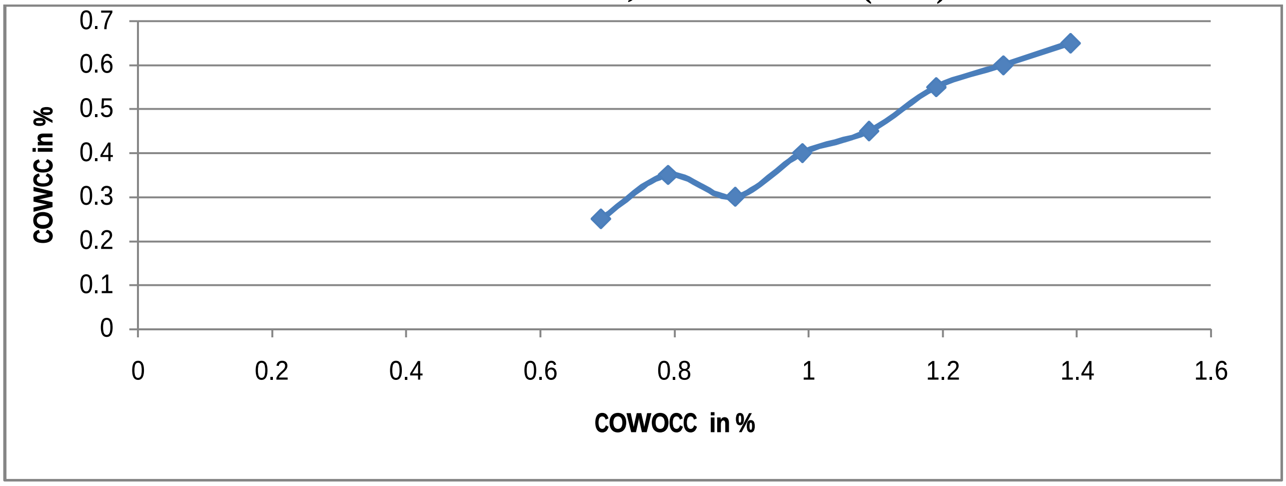

Figure 4. *The Variation of COWOCC and COWCC*

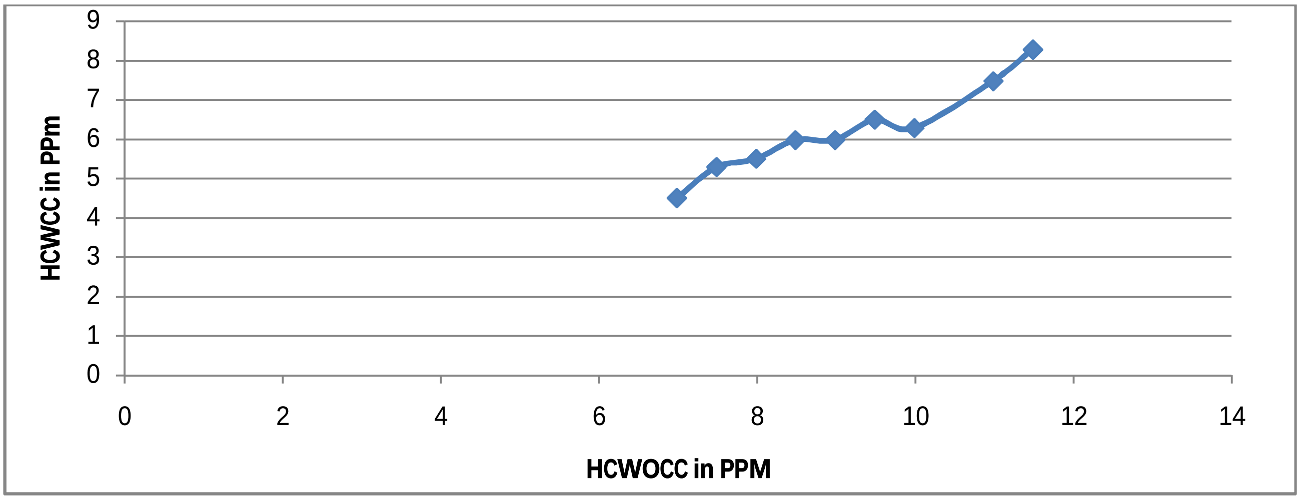

Figure 5. *The Variation of HCWOCC and HCWCC*

2.2 Generation Of mathematical equations

With the help of figures (4) and (5), the equations for reduced CO and HC are as follows:

$$COWCC = 65.705CO^5 - 350.66CO^4 + 736.8CO^3 - 760.84\,CO^2 + 386.2CO - 76.826 \quad (3)$$

$$HCWCC = 0.0114HC^4 - 0.3188HC^3 + 2.981\,HC^2 - 9.1532HC + 4.5 \quad (4)$$

3. CONCLUSIONS

The idea behind the work is to create a structure that exposes 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 and the catalytic action takes place at surface of copper which are porous and the higher catalytic activity towards the oxidation of CO and HC could be due to the higher catalytic surface area of small nanoparticles.

The proposed method is very effective in the prevention of environmental pollution contributed from two-wheeler automobiles. It involves the use of copper nano-particle which is cheaper than the platinum, palladium and rhodium nano-particles used in automobiles. This paper opens a gateway to study the changes in the concentration of exhaust emissions due to the nano-material copper coating. The modeling will help in understanding the mathematical nature of the process and simulation will help in predicting the results with ease.

Nomenclature:

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

x - Load

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