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RAPID CONTROL OF EXHAUST EMISSIONS AND ENHANCEMENT OF RETENTION TIME IN THE CATALYTIC CONVERTER USING NANOSIZED COPPER METAL SPRAY FOR SPARK IGNITION ENGINE

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ABSTRACT

The approach proposed here is to control the exhaust emissions from two stroke, single cylinder, spark ignition petrol engine having copper nanoparticles coated on copper sieve as catalytic converter.AVL-422 Gas analyzer was used for the measurement and comparison for CO and unburnt hydrocarbon in the exhaust of the engine at various speeds and loads. 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.

Keywords: S.I. engine; catalytic converter; Copper nanoparticles; retention time

ABBREVIATIONS:

CO	CARBON MONOOXIDE
HC	HYDROCARBON
S.I.	SPARK IGNITION
CC	CATALYTIC CONVERTER
RPM	REVOLUTION PER MINUTE
SERS	SURFACE ENHANCED RAMAN SCATTERING
PM	PARTICULATE MATTER
NO_X	OXIDES OF NITROGEN
HP	HORSE POWER

1. INTRODUCTION

Tremendous growth in the urbanization as well as commercialization has made the whole world is in the grip of severe environmental crisis. Air pollution can be defined as presence in atmosphere of one or more contaminants for such duration that is injurious to human health and animal or plant life. To predict the transport related air pollution Newer and newer models have been developed worldwide.

The oxidation of gasoline in the engine to CO_2 and H_2O 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 harmful substances that a car exhaust can release. The pollutants that are limited today by the regulations are hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x) and particulate matter (PM).

Among above pollutants CO 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. 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 gases leave the engine cylinders and also when they exit in the tail pipe and enter the atmosphere [2]. For this two methods are widely used, Air injection system and the Catalytic converter.

In the present method, catalytic converters have been used. The C.C. is the leading pollution control device with magnetic and chemical properties yielding applications in biological nanosensors, optoelectronics, nanodevices, nanoelectronics, information storage and catalysis[3].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[4]. Thus Copper will gain increasing importance as it is expected to be an essential component in the future nanodevices due to its excellent conductivity as well as good biocompatibility and its surface enhanced Raman scattering (SERS) activity [5]. Metallic copper nanocrystals homogeneously dispersed in silica layers have attracted great attention recently for the development of nonlinear optical devices [6].Such composite materials offer exciting possibilities of potential thin films device applications with novel function arising from size quantization effect. In the light of fast and growing applications of metallic copper nanoparticles, a reproductive method of synthesis with a specific size, well defined surface composition, isolable and redispersable properties remains a challenging task to a synthetic chemist. The ability to scale up the synthesis to bulk scale will gain increasing importance as more and more applications are being established. However, most of the synthetic methods either yielded particles of irregular shape with wide size distribution and required high temperature and pressure condition or produce particles with reduced catalytic activity and inability to reuse the particles.

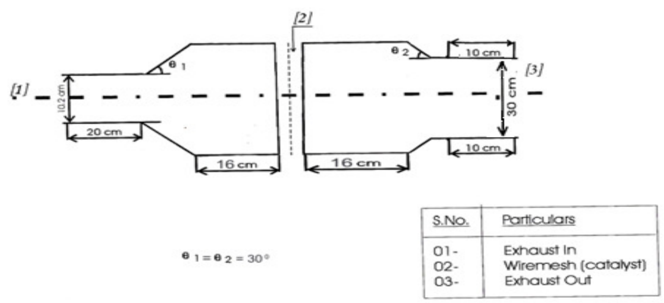
In this paper, we have reported the synthesis of copper nanoparticles by reducing the copper ions with sodium borohydride [7]. The particle size has been varied by modulating the concentrations of reactants and capping agent. The catalytic activities of these particles of different sizes have been tested on the catalytic converter in S.I. engine.

2. MATERIAL & METHOD

2.1 System Designing

The matrix as discussed above is designed and assembled as per the dimensions given in the Fig. 1. The arrangement was provided within the system to fix the wire gauge of copper. It is designed in such a way so that the area of cross section at the point where the wire gauge is fitted is about five times the area of cross-section of exhaust manifold of the engine. Wire gauge of mesh no. 20 is used and fitted with the help of nuts and bolts.

Figure 1: Proposed design of catalytic converter



2.2 Calculation of present work

Radius of tail pipe	**1.19 cm**
Area of copper sieve	$30.5*30.5=930.25cm^2$
Area of tail pipe	$3.01* (1.19)^2 = 4.44cm^2$
Area of tail pipe/ Area of copper sieve	4.44/930.25=1/209.52
Area of copper sieve	209.52* Area of tail pipe
Engine specification - Engine capacity Engine speed	150 c.c. $= 150\ cm^3$ 3000 rpm
Volume of gas at outlet of tail pipe	$150\ cm^3 * 3000$ rpm $= 450000\ cm^3$/minute.
Velocity of gas at tail pipe outlet in cm/minute	$\frac{45,0000\ cm^3 / minute}{4.44\ cm^2}$ =10,10,1351.35 cm/min
Velocity of gas at tail pipe outlet in m/sec	$\frac{10,1351.35 * 10^{-2}}{60}$ = 16.89 m/sec
Velocity of gas passes through copper sieve	$\frac{\text{velocity of gas at tail pipe}}{209.52}$ = 0.081 m/sec
$\frac{\text{Velocity of gas at tail pipe outlet in m/sec}}{\text{Velocity of gas passes through copper sieve}}$	$= \frac{16.89}{.081} = 208.52$ m/sec
Finally velocity of gas passes through copper sieve	$\frac{\text{Velocity of gas at tail pipe outlet m/sec}}{208.52}$

2.3 Preparation of copper nanoparticles

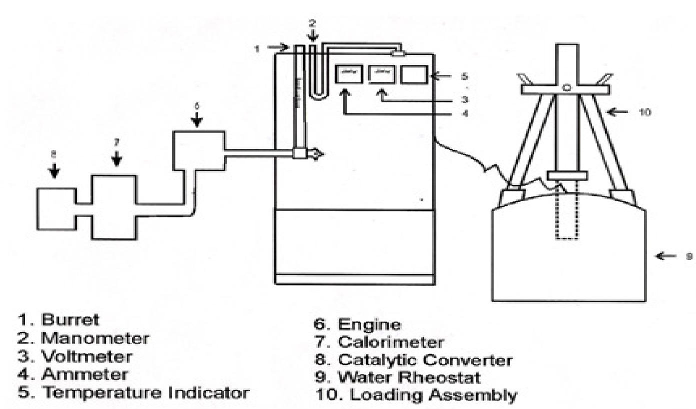
In a typical procedure, 20 ml ethylene glycol (EG) solution (0.1M) of CuSO4·5H2O was mixed with 20 ml EG mixed solution of NaOH and N_2H_4·H2O under magnetic stirring. The molar ratio of N_2H_4·H2O/CuSO4 was 1.5 and the molar ratio of NaOH/CuSO4 was 0.05. The mixture solution was placed in a microwave oven (2.45 GHz, GalanzWP750) and reacted under medium power (750 W, working cycle of 18 s on and 12 s 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. (The heating rate was then estimated to about 120 °C min^{-1}.) Then the mixture was irradiated for another 2 min to keep the mixture boiling. After cooling to room temperature, Cu 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 were prepared by drying a drop of the colloid on a TEM grid with the sample allowed to dry completely at room temperature. Approximately 100 nanoparticles from each sample were measured manually for size distribution. Triple distilled water was used for solution preparation.

2.4 Experimental Procedure

The experiments were carried out on a two stroke, single cylinder, horizontal air-cooled spark ignition engine. The dynamic test rig consists of a two stroke petrol engine coupled to electrical dynamometer, a rheostat is provided to load the engine, various measurements are provided so that performance of the 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 undertaken.

1) Put sufficient petrol along with self mixing 2T oil in the tank.
2) Check oil level in the gear box of the engine, if necessary add up SAE-40 .Oil level should always be up to the oil filling hole.

3) Confirm that the engine is in neutral gear, all switches of the load bank are off and ignition switch is 'on'.
4) Start water supply to the calorimeter.
5) Press the choke knob and give a sharp kick, engine will start. As the engine starts, release the choke knob, pull the clutch lever.
6) Uniformly increasing the accelerator and set the engine speed to say 1500 rpm at varying load conditions (0.25. 0.5, 0.75 and full load). Initially the experiment is performed at 0.25 load keeping the speed 1500 rpm. Same experimentation is performed using nano copper coated sieve.
7) Repeat the above procedure for another speed say 1800, 2000, 2200 and 2400 rpm at varying load conditions with & without using catalytic converter.
8) The above procedure were repeated for different speed with different load conditions using sieve coated with Cu nanoparticles.

The exhaust emission measurements were carried out by using a calibrated standard instruments AVL 422 gas analyzer for CO and HC at each operating point for both conditions with and without catalytic converter is recorded and figures were plotted between varying load and pollutant concentration.

AVL 422 Gas Analyzer- In exhaust gas analyzer insert a probe in to tail pipe of scooter engine.the probe draws out some of the exhaust gas and carries it through the analyzer. There are two display units in exhaust gas analyzer to measure the HC in ppm and CO in a percentage. The exhaust gas sample was of the tubing approximately 15 cm in to scooter tail pipe.

Specification-1.Engine type-Two stroke, single cylinder horizontal air cooled petrol engine.

2. Maximum speed -3000 rpm.
3. Brake horse power- 4.5hp.

3. RESULT AND DISCUSSION

Emission parameters of a S.I. engine with and without catalytic converter are studied by changing load and speed as shown in Fig. 3-6. By studying various graphs for carbon monoxide and hydrocarbon in varying speed and load, the following results were obtained.

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

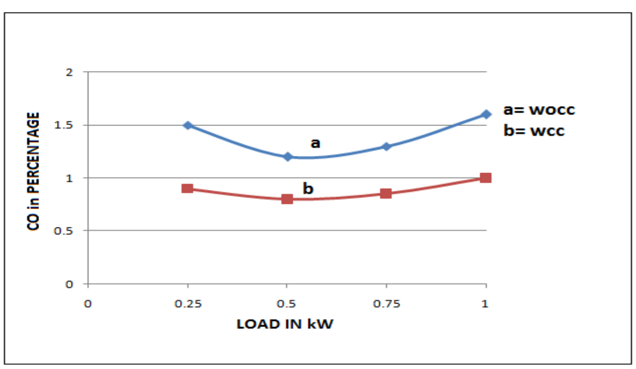
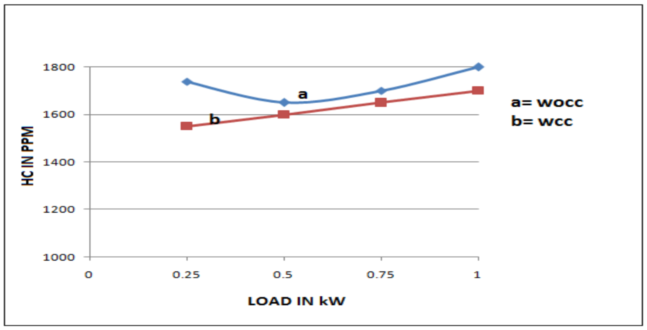


Figure 3b: Effect of changing load on HC in ppm emission at 1500 rpm



a) Figure 3a & 3b showed the effect of changing load on CO & HC percentage emission at 1500 rpm. It is clear from the figure that CO & HC emission at 0.25 load is somewhat higher than the moderate load (0.5 & 0.75 load) because the temperature outside the burning flame zone is much lower leading to formation of hydrocarbons also the air-fuel ratio is 10:1 leading to slow oxidation. As the load increases from 0.25 to 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 CO and HC increases from 1.3% to 1.6% and 1700 ppm to 1800 ppm respectively. On repeating the same step using catalytic converter the emission of HC and CO are found to be lowered.

b) At varying increased load with increasing speed it is found that emission of CO & HC decreases. Emission of CO decreases from 1.5% to 1.2% when speed increases from 1500 to 1800 rpm as shown in Fig. 4a & 4b.

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

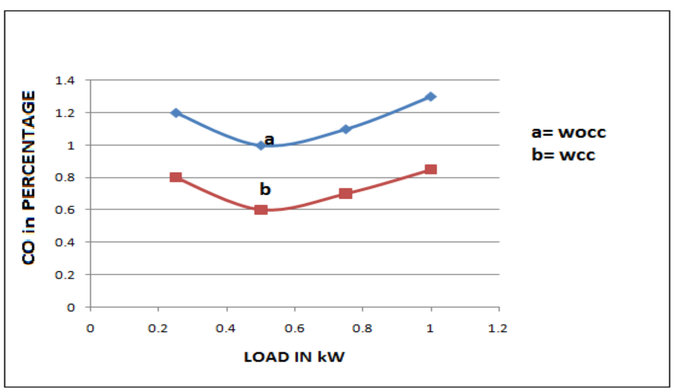
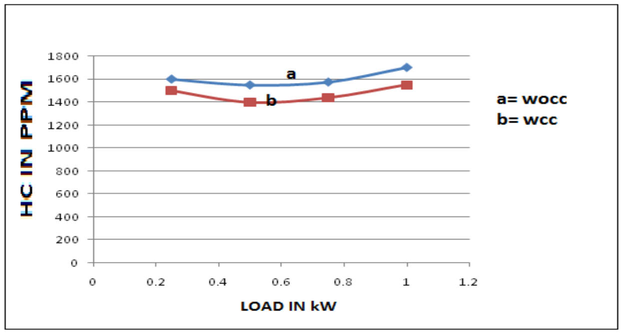


Figure 4b: Effect of changing load on HC in ppm emission at 2000 rpm



c) The emission of CO and HC decreases till the speed reaches to 2000 rpm, and on further increasing the speed the emission again increases as the port and spark timing did not match which results in incomplete combustion of fuel shown in Fig. 5a&b.

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

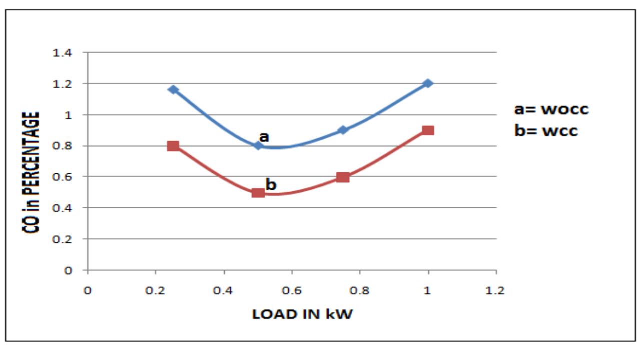
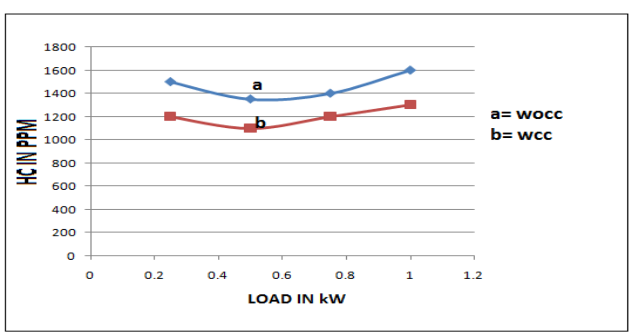


Figure 5b: Effect of changing load on HC in ppm emission at 2200 rpm



d) On repeating the above steps for 1500-2400 rpm using catalytic converter (Cu sieve) coated with copper nanoparticle, the emission of HC and CO are found to be lowered & more efficient than bulk copper.

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

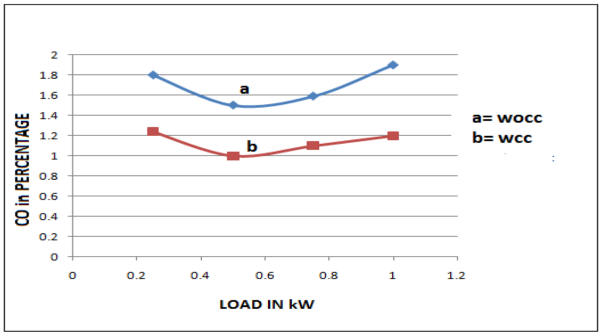
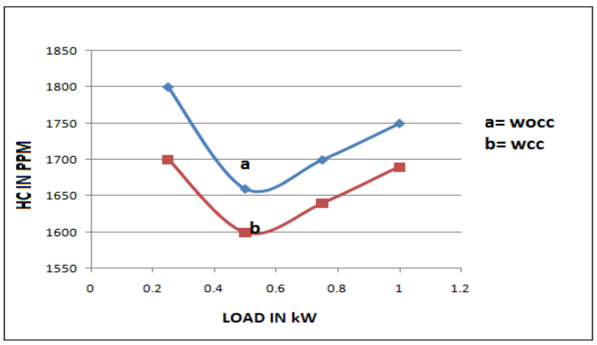


Figure 6b: Effect of changing load on HC in ppm emission at 2400 rpm.



4. CONCLUSION

The engine is designed to run at medium load (0.5 load) for a longer time due to less emission of HC and CO . At full load, emission of HC and CO are higher so it is not desirable to run engine at full load. The converter uses two different types of catalyst, reduction and oxidation catalyst. 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 Cu which are porous and the the higher catalytic activity towards the oxidation of CO and HC could be due to the higher catalytic surface area of small nanoparticles. It is presumed that the electrophilic nature of the catalyst surface renders a weak bond between the CO and vacant d system of copper atoms.The electrophilic nature of copper surface obviates that when the particles are extremely small in size, the electrons are pumped into copper by emission which usually reduces the band gap between Fermi level and conduction band considerably so that the catalytic activity is also expected to be reduced [8]. However, copper has d-bands well below the Fermi level and the antibonding stage at the top of the d bands end up below the Fermi level and are filled[9]. As a result, the catalytic activity did not decrease rather it remained constant. Any aggregation of the particles in aqueous dispersion leads to lower efficiency. The freshly prepared and capped Cu nanoparticles(12nm- 20 nm)also showed good activity for this oxidation. Besides catalyst the convergent divergent section for flow provides a narrow pathway for exhaust due to which its velocity decreases which in turn increases the retention period and the emission are in more contact with catalyst thus increasing the oxidation time [10].

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 uncatalyzed reaction. Copper metal is selected for the present work as it is cheaper than platinum, palladium and rhodium. Also it adsorbs the reactants molecule strongly enough to hold and active the reactants but not so strongly that the product can't breakaway also the diffusion of reactants and products into and out of the pore structure of copper took place efficiently. Due to this, the pollution level for the exhaust emission of S.I. engine has found to be reduced which is better with nanosized catalytic converter.

The above work also opens a pathway for some future prospects such as exhaust gas recirculation model for reduction of NO_x concentration level which is already available and has to be incorporated with present catalytic converter model and tested against experiments. Catalytic converter based on spray of copper nanoparticle on copper sieve demonstrate superior performance. Nanoparticle exhibit high temperature stability beyond that normally encountered in catalytic converter applications.

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REFERENCES

1. Twigg, M. V., 2006, "Roles of catalytic oxidation in control of vehicle exhaust emissions", Catalysis Today, 117(4), pp. 407-418.
2. Krishna M.V.S., Kishore K., 2008, "Performance of Copper Coated Spark Ignition Engine with Methanol Bended Gasoline with Catalytic Converter", Journal of Scientific and Industrial Research, 67, pp.543-548.
3. Feldheim D. L., Foss C. A., 2004, "Metal Nanoparticles: Synthesis, Characterization and Applications", Appl. Phys. A Mater. Sci. Process. 78, pp.73.
4. Schaper A. K, Hou H., Greiner A.,Schneider R., Philips F., 2004, "One Pot Synthesis of Copper Nanoparticles at Room Temperature and its Catalytic Activity", Appl. Phys. A Mater. Sci. Process. ,78, pp.73.
5. Pergolese B, Muniz-Miranda M. , Bigotto A., 2004, "SERS: a versatile tool in Chemical and Biochemical diagnostics", J. Phys. Chem.,110 (92), pp.41.
6. Flytzanis C. J., 2005, " Nonlinear optics in Mesoscopic Composite materials", Physics B, 38 , pp.661.
7. M. SAMIM, N. K. KAUSHIK, A. MAITRA, 2007, "Effect of Size of Copper Nanoparticles on its Catalytic Behaviour in Ullman Reaction", Bull. Mater. Sci., 30 (5), pp.535-540.

8. Huynh W., U, Dittmer J.,Libby William C., Whiting ,G. L , Alvisatos A .Paul , 2003, "Shape control and applications of nanocrystals", Adv. Funct. Mater. ,13, pp.73.

9. Sharma R. K., Sharma P., Maitra A. N., 2003, "Metal nanoparticles with high catalytic activity in degradation of methyl orange: An electron relay effect", J. Colloid. Sci. 265, pp.134.
10. Silva C.M., Costa M., Farias T.L., Santos H., 2006, "Evaluation of S.I. Engine Exhaust Gas Emissions Upstream and Downstream of the Catalytic Converter", Energy Conversion & Management,47, , pp. 2811-2828.