Investigational Study and Manage the Poisonous Emissions in IC Engines by Nano Materials

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Abstract: In present state of affairs, vehicles are plays an important role in contribution to the pollution. Air pollution is predominately emitted through the exhaust of motor (both light duty and heavy duty) vehicles and the combustion of fossil fuels. Pollution control is playing a important role to control the upcoming generation and noxious emissions like CO, NOX, HC and soot (particulates). Aim of this research study is to diminish the emissions from the automobiles through design and manufacturing of nano catalytic converter by replacing the offered costly metals such as Platinum. Nano Materials like nano Rhodium and nano Palladium were obtained by using chemical vapour deposition (CVD) method. The obtained nano powder was deposited in the honey comb formation structure. By using the nano catalytic converter the pollution is reduced in a marginal level.
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1. Introduction

A popularized the expression 'nanotech-nology' in the 1980's, all researchers talking about building machines on the scale of molecules, a small amount of nanometers wide-motors, robot arms and even whole computerized methods, far smaller than a cell. A scientist Drexler spent the next ten years describing and analyzing these unbelievable devices, and responding to accusations of science invention. Meanwhile, mundane technology was developing the ability to build simple structures on a molecular scale. As nanotechnology became a conventional concept, the meaning of the word shifted to cover the simpler kinds of nanometer-scale technology. Nanotechnology is a science of controlling individual atoms and molecules. One of the serious troubles facing the world is the radical increase in environmental pollution by internal combustion engines. All transport vehicles; both petrol engine (SI - Spark ignition) and diesel engine (CI – Compression ignition) are equally responsible for emitting different kind of pollutants (Rajadurai S and Tagomori M. (2000)). Two stroke SI engines have certain advantages such as compactness, lightweight, simple construction and low cost and low nitric oxide emissions; they suffer from problems of high specific fuel consumption, high hydrocarbon and high carbon monoxide emissions. Some of the primary kinds, its having direct hazardous effects such as carbon mono oxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) , particulates (soot) etc. In other hand the derivative pollutants which undertake a series of reactions in the atmosphere. It becomes hazardous to human health (Joseph, Y, et.al, (2001)). A vehicular exhausted emission passed to the surroundings to pollute the atmosphere and cause global warming, acidic rain, smoke, odor, and respiratory and other health hazards. A pollutant is a phenomenon which changes the balance of the environment and nature under normal condition.

Carbon-dioxide (CO2) not considered as pollutant, as nature recycles. If carbon-di-oxide exceeds 5000ppm, then it becomes a health hazard. Using nano catalytic converter, pollution is controlled by means of catalytic reaction (Ketteler G, et. al, (2002)).

2. Sources and Methods

Nanotechnology is a great deal discussed skill these days – a dominion in which machines operate at scales of billionth a metre. It is really a multitude of rapidly rising technologies based upon the scaling down of offered technologies to the next level of accuracy and efficiency. In the field of nano technologies research peoples are passionate about its potential applications in fields such as engineering, medicine, electronics, computing and material. Of late, one of the rising aspects dealing with Nanotechnology in mechanical grassland is the Internal Combustion Engine on a nano scale, which is in this research chosen as the area of curiosity. Heat engines have evolved from external combustion engines to internal combustion (IC) engines and the hot off the block is the nano internal combustion engine.

2.1 Sources

In all-purpose, synthesis of nanoparticles

refers to a combination of two or more entities that together form something new; alternately, it refers to the creating of something by artificial means (Table 1 and Table 2).

Table1. Physical method for Preparation of Nanoparticles

Sl.No	Method	Advantages	Limitations
1	Evaporation condensation	High purity powder	The limitation of mass production
2	Plasma heating method	Low vapor High melting point and (W, Al2O3, SiO2, C)	Very expensive equipment
3	CO2 laser method	low vapour pressure materials	Difficult for the application of Metal nano powder
4	Mechanical alloy method	Nano powder of metal alloy	Agglomeration & introduction of impurity
5	Pulsed wire evaporation	Metal wire source	Low energy consumption & Friendly environment

Table 2. Chemical method for preparation of Nanoparticles

Sl.No	Method	Advantages	Limitations
1	Chemical Vapor Deposition (CVD)	Mass production facility	Impurity contamination & the danger of chemical materials
2	Liquid phase reduction method		
3	Hydro-thermal synthesis		
4	Sol-gel method		

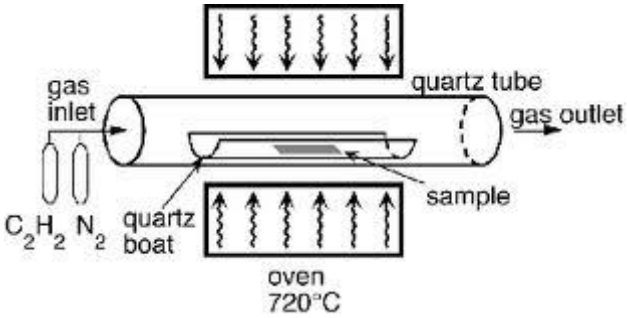

Figure 1. CVD – Schematic Representation

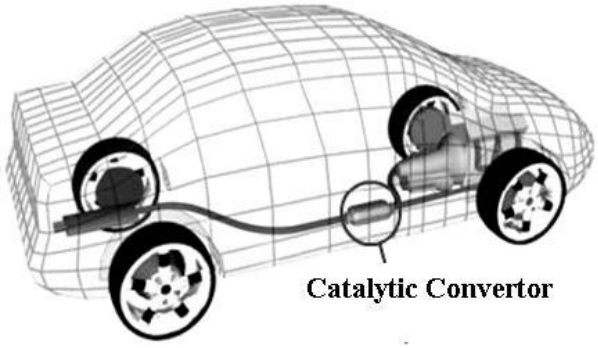

Figure 2. Placement of Catalytic Convertor

At this point we used CVD method (Figure 1) to synthesis the Nano palladium & Nano rhodium

1. Easy method
2. Gas phase deposition
3. Large scale possible
4. Relatively cheap

Here the oven is maintained at 720°C, palladium is kept above the quartz boat as a sample. The C_2H_2 and N_2 are passed through the quartz tube.

2.2 Vehicular Pollution & Catalytic Convertor

It is defined as the introduction of chemicals, particulate matter, or natural materials to the atmosphere that cause harm or discomfort to the living organisms. Due to the improvement in science and technology there is a drastic improvement in automobile production which results in more amount of harmful gas is let into the atmosphere. These gases react with the atmosphere and pollute it.

A "catalytic converter" is a device used to reduce the toxicity of emissions from an internal combustion engine. A catalytic converter converts the injurious noxious combustion products and it's by products into less-toxic substances. Catalysis is the process in which the rate of a chemical reaction is increased by means of a chemical substance known as a catalyst.

Unlike additional reagents a catalyst is not inspired during the chemical reaction (Apostolescu N, et.al (2006)). Thus, the catalyst may participate in multiple chemical transformations, although in observe catalysts are derived processes. There are millions of cars on the road that are potential sources of air pollution. In a key effort to reduce vehicle emissions, car makers have developed an interesting device called a catalytic converter, which treats the exhaust earlier than it leaves the car and removes a lot of the pollution (Hizbullah K, et.al (2004)).

It is the most effective after treatment process for reducing engine emission. Catalytic converter is generally called as three way catalytic converter, because it promotes in reduction of hydrocarbons (HC), carbon monoxide (CO) and

oxides of nitrogen (NOx). It consists of steel container of honeycomb structure inside which contains porous ceramic structure through which the gas flows. It consists of small rooted partials of catalytic materials that promote oxidation reaction in exhaust gas. Catalytic converter uses alumina the same as base material because it can withstand high temperature.

2.3 Catalytic Resources

Many types of material frequently used as catalyst in the current years. Proton acids are almost certainly the most commonly used catalysts, above all for the many reactions involving water, as well as hydrolyses and its reverse. Multifunctional solids repeatedly are catalytically active, for e.g. zeolites, alumina, certain forms of graphitic carbon etc. Transition metals such as platinum, palladium, rhodium, and iron, silver are often used to catalyses redox Reactions (Table 3 & Table 4) (Jacob Klimstr, et.al, (1989)).

Table 3. Nanoparticles-Categories and Applications

Sl.No	Nanostructure	Example Material or Application
1	Nanotubes	Carbon, (fullerenes)
2	Nanowires	Metals, semiconductors, oxides
3	Nanocrystals, quantum dots	Insulators, semiconductors, metals

Catalysts normally react with one or additional reactants to form midway substances that subsequently present the final reaction result, in the process regenerate the catalyst. The subsequent is a classic reaction, where C represents the catalyst, X and Y are reactants, and Z is the product of the reaction of X and Y:

$$X + C \rightarrow XC \quad (1)$$
$$Y + XC \rightarrow XYC \quad (2)$$
$$XYC \rightarrow CZ \quad (3)$$
$$CZ \rightarrow C + Z \quad (4)$$

Although the catalyst is inspired by reaction 1, it is after produced by reaction 4, thus the final reactions listed below:

$$X + Y \rightarrow Z \quad (5)$$

As a catalyst is regenerated in a reaction, frequently only small amounts are required to increase the rate of the reaction. In practice, on the other hand, catalysts are sometimes inspired in secondary processes.

Catalyst is used serves for two purposes,

1. Enhances the reaction rate.
2. Direct the reactants to specified product.

In general potential energy diagram shows the effect of a catalyst in the chemical reaction of X + Y to give Z.

Outstanding to presence of the catalyst reaction occurs in unusual pathway which results in lower activation energy. The end result and the overall thermodynamics are the same. Potential energy diagram is shown in Figure 3.

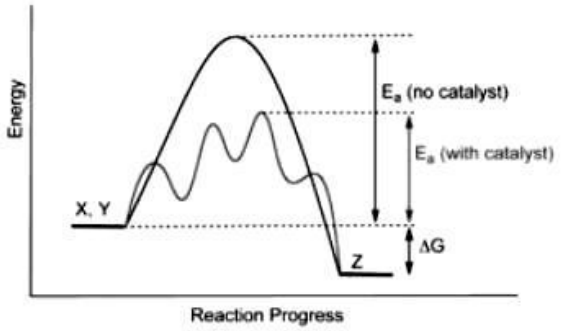

Figure 3. General Diagram of Potential Energy

Rate of reaction(R) is inversely proportional to exponential of the activation energy. Let k denotes reaction rate constant, Ca and Cb be the concentration at point of time of reactant molecules, x and y be the reaction order.

Thus rate of reaction is represented as Rate of reaction $R = k\ Ca^x\ Cb^y$

Catalysts work by providing an (alternative) mechanism involving a different transition state and minimum activation energy. The effect is owing to the molecular collisions have the energy needed to reach the transition state. Catalysts do not modify the favorableness of a reaction: they have no effect on the chemical equilibrium of a reaction because the rate of both the forward and the reverse reaction are both affected.

Mechanism of catalyst was approved by chemisorptions which is the type of adsorption where the molecules hold to the surface of catalyst through the structure of chemical bond. Strength of the adsorption was arranged in the order of, $O_2 > C_2H_2 > CO > H_2 > CO > N_2$. Variation of chemisorptions among metals is represented as follows, u > Cu > Pd > Pt > Rh > CO > Ni > Ag > Mn > Fe > Mo > W > Nb > Ta > Ti Based on this it is clearly represented that Au can readily react with metal and can act as efficient catalyst for most of the reaction. At the same time Ti has low chemisorptions thus it cannot be used as catalyst.

2.4 Steps for Dispersion of Particles on to the Catalytic Convertor

1. Capillary Impregnation It is the process by which adsorption of minute nano particles on to the surface of catalyst converter as the particles are dispersed in the liquid medium. The adsorption of minute particles on to catalytic converter takes place up to saturation limit.

2. Drying Drying process takes place at 110^{o}C for the matter of 1 hour in the closed furnace.

3. Calcinations Calcinations process take place at 550^{o}C for the matter of five hour in the closed furnace.

Thus final outcome is to fixing of particles on to the catalytic converter. Calcination (calcining) is a thermal action process in presence of air applied to ores and other solid materials to bring about a thermal decomposition, phase transition, or taking away of a volatile fraction. The calcination process usually takes place at temperatures below the melting point of the product materials. Generally catalyst can be classified into three type's Homogeneous catalyst, Heterogeneous catalyst & Electro catalyst.

2.5 Types of Convertors

The types of converters are listed below,

- Monolythic Convertor
- Two way convertor
- Three way convertor
- Dual bed convertor

Three-way catalytic converter is widely used in the vehicle industries. The three-way catalytic converter is scheduled to perform three simultaneous tasks, a) nano palladium: reduction catalyst, b) nano rhodium: oxidation catalyst, and c) the control system (Figure 4 and Figure 5).

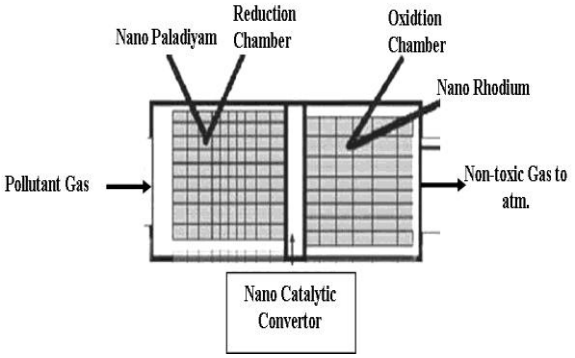

Figure 4. Three way catalytic convertor

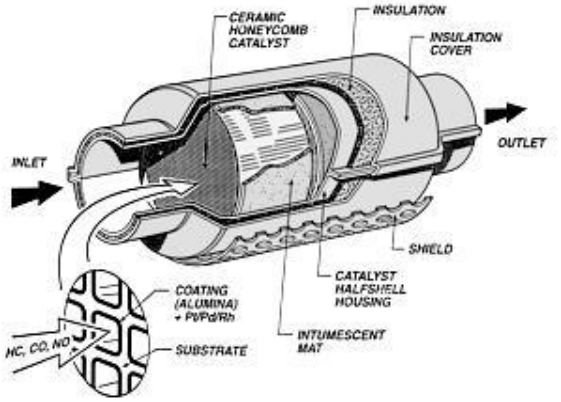

Figure 5. Three way catalytic convertor

Important Properties of Catalyst are mentioned below. i.e., Surface area and pore size, Particle size distribution, Wash coat thickness& Adhesion.

The Reduction Catalyst

The reduction catalyst is the first stage of the catalytic converter. It uses Nano palladium to assist reduce the nitrogen oxide emissions. When such molecules come in contact with the catalyst, the catalyst rips the nitrogen atom out of the molecule and hold on to it, freezing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.

The Oxidization Catalyst

The oxidation catalyst is the next stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (Oxidizing) them over a nano rhodium catalyst. This catalyst aid the effect of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

2.6 Control Systems

The third stage is a control system that monitors the exhaust stream, and uses this dats to control the fuel injection system. There is a hot oxygen sensor (also called a Lambda Sensor) mounted upstream of the catalytic converter (Figure 6), meaning it is closer to the engine than the converter. This sensor tells the EECV PCM how much oxygen is in the exhaust. The EECV be able to increase or decrease the amount of oxygen in the exhaust by adjusting the air-to-fuel ratio. (Stanley L.Genslak, 1972).

This control scheme permits the EEC-V to ensure that the engine is running at close to the stoichiometric point, although also making sure that there is enough oxygen in the exhaust to allow the oxidization catalyst to burn the unburned hydrocarbons and carbon monoxide (Kureti S, et.al, 2003). The rear most Lambda sensors are not used to adjust the engine mixture but simply to identify the performance of the Catalytic Converters. In ideal circumstances they should show a constant output indicating that the CATs are working as projected. Ripple which mirrors the output of the pre- CAT sensors indicates Cats that are starting to fail.

Figure 6. LAMBDA Sensor

Recent cars are equipped with three-way catalytic converters. "Three-way" means is to the three regulated emissions it helps to reduce the following emission characteristics carbon monoxide, hydrocarbons, particulate traps and nitrogen oxide molecules. The converter uses two dissimilar types of catalysts, a reduction catalyst in addition to an oxidization catalyst (Steve Seldlitz, 1974). Both types consist of a ceramic structure coated with a metal catalyst; we used nano palladium and nano rhodium. The idea is to create a structure that exposes the maximum surface area of the catalyst to the exhaust stream, despite the fact that also minimizing the amount of catalyst required. There are three main types of structures used in catalytic converters – ceramic honeycomb, metal plate and ceramic beads Reduction of nitrogen oxides to nitrogen and oxygen (Lyon DY, et.al, 2006).

$2NOx \rightarrow xO_2 + N_2$

Oxidation of carbon monoxide to carbon dioxide,

$2CO + O_2 \rightarrow 2CO_2$

Oxidation of un-burnt hydrocarbons (HC) to carbon dioxide and water,

$CxH_2x + 2xO_2 \rightarrow xCO_2 + 2xH_2O$

Catalytic convertors are mainly used in the area of Petrol engine emission control, Diesel engine emission control, Food processing industries, Chemical manufacturing industries & Gas turbines.

2.7 Carbon Nanotube

The scientists found that diesel soot contains C60, C70 and additional fullerenes. These fullerenes are thought to be formed during the combustion of light or heavy oil. They also identified that diameters of SWCNTs synthesized from diesel soot are smaller than those of SWCNTs synthesized from the graphite. Although the researchers didn't examine the detailed behavior of the toxic chemicals contained in diesel soot in the synthesis process for SWCNTs, they believe that almost all noxious chemicals get destroyed during the laser vaporization process. They concede the possibility of the CNT, that was might remain in the SOF. Emission factors for CNT/FULs from common combustion sources have not been available to our awareness, though these morphologies have been identified in exhaust from natural gas (NG) stoves (Murr et al. 2004) and tentatively from a diesel engine (Evelyn et al. 2003) and gasoline engines (Ortner et al. 1998). Blom et al. (2000) found structures that might have been FULs but were not identified as such by those researchers.

3. Results and Discussions

3.1. NOx Reduction

Reductions of NOx value based on break power value at different conditions are shown in the following graph. Figure 7 indicates the value of BP vs NOx. The NOx value keeps on diminishing on introducing a catalytic converter and at last it reaches the minimum value on using nano catalytic converter. Therefore at no load condition there is about 34% decrease in NOx value and at maximum load condition there is about 54 % decrease in NOx value.

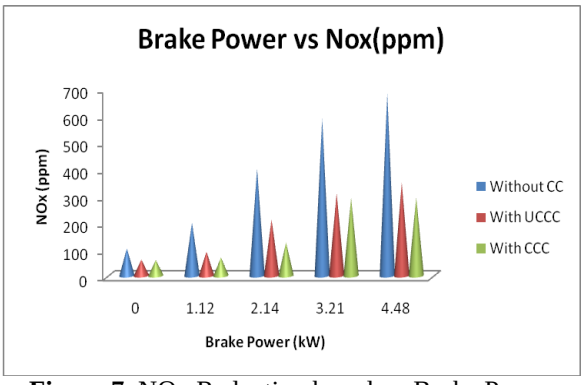

Figure 7. NOx Reduction based on Brake Power

This is due to the truth that NOx undergoes catalytic reaction with catalytic particles such as Nano palladium, Nano rhodium, results in the production nitrogen and oxygen as the final product. Thus there is steady decrease in NOx value with the introduction of the Nano catalytic converter.

3.2. HC Reduction

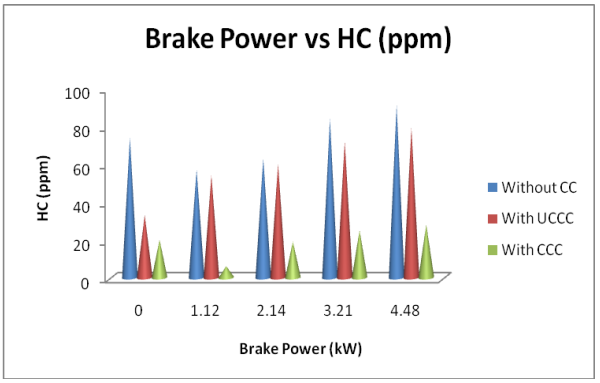

Figure 8. HC Reduction based on Brake Power

The HC value keeps on diminishing on introducing a catalytic converter and at the end it was reaches the minimum value on using Nano catalytic converter shown in Figure 8. Thus at no load condition there is about 72.5% decrease in HC value and at maximum load condition there is about 69 % decrease in HC value. This is due to the fact that HC undergoes catalytic reaction with catalytic particles such as nano palladium, nano rhodium results in the production water and oxygen as the end product. Thus there is steady decrease in HC value with the introduction of the nano catalytic converter.

3.3. CO Reduction

The CO value keeps on decreasing, when we introduce a catalytic converter and finally reaches

the minimum value on Nano catalytic converter as shown in Figure 9.

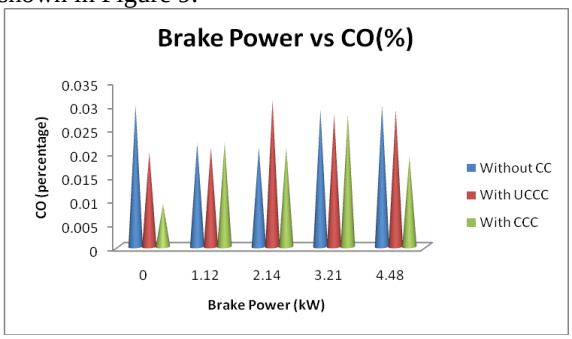

Figure 9. HC Reduction based on Brake Power

At no load condition there is about 59% decrease in CO value and at peak load condition there is about 41 % decrease in CO value. This is due to the fact that CO undergoes catalytic reaction with catalytic particles such as nano palladium, nano rhodium results in the production CO2 and oxygen as the end product. Thus there is steady decrease in CO value with the introduction of the nano catalytic converter**.**

4. Conclusions

In current investigation nano material's like Nano palladium and nano rhodium (90-100 nm) were synthesized and characterized by using chemical vapor deposition method. The nano catalytic converter efficiently decreases the emission of NOx, HC and CO components. A detailed work has been done on synthesis and characterization of nano palladium and nano rhodium by using chemical vapor deposition. The particles are found to be in dispersed state with the particle size ranging from 90-100 nm. The engine exhaust test has been carried out. By using, the nano catalytic converter 34% decrease in NOx value at no load condition and about 54 % decrease in NOx value at peak load condition. Also HC value is decreasing 72.5% at no load condition and 69% at peak load condition. At no load condition 59% decrease in CO value and at peak load condition 41% decrease in CO value. At last, involvement of nano catalytic converter, the pollution level was reduced marginally. After our study we are focusing what is the other chemical vapor depositions based on nanoparticles in pollution control strategy. Then which methodology is applicable to make the efficient preparation of nano palladium and nano rhodium particles. But only one factor was disqualify the researchers point of vie for this much production of nano materials, i.e., cost.

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References

[1] Rajadurai S and Tagomori M. Catalytic Converter Design Development and Manufacturing, *SAE Technical Paper*, No-01-1417, 2000.

[2] Joseph, Y., Ketteler, G., Kuhrs, C., Ranke, W., Weiss, W., Schlögl, R., On the Preparation and Composition of Potassium Promoted Iron Oxide Model Catalyst Films, 2001, Phys. Chem. Chem. Phys. 3, (18) , 4141-4153.

[3] Ketteler G, Ranke W, Schl R. Potassium-Promoted Iron Oxide Model Catalyst Films for the Dehydrogenation of ethyl benzene: An Example for Complex Model Systems. *J. Catal.*, 2002, 212(1), 104–111.

[4] Apostolescu N, Geiger B, Hizbullahb K, Jan MT, Kureti S, Reichert D, Schott F, Weisweiler W. Selective catalytic reduction of nitrogen oxides by ammonia on iron oxide catalysts. *Appl. Catal. B: Environ.* 2006, 62(1-2), 104–114.

[5] Hizbullah K, Kureti S, Weisweiler W. Potassium promoted iron oxide catalysts for simultaneous catalytic removal of nitrogen oxides and soot from diesel exhaust gas. *Catal. Today*, 2004, 93-95, 839-843.

[6] Jacob Klimstra and Nederlandse Gasunie NV.Carburetors for Gaseous Fuels-On Air-to-Fuel Ratio, *Homogeneity and Flow Restriction*, SAE paper, No.892141, 1989.

[7] Stanley L.Genslak. Evaluation of Gaseous Fuels for Automobiles, SAE paper, No.720125, 1972.

[8] Kureti S, Weisweiler W, Hizbullah K. Simultaneous conversion of nitrogen oxides and soot into nitrogen and carbon dioxide over iron containing oxide catalysts in diesel exhaust gas. *J. Appl. Cata. B: Environ.*, 2003, 43, 281-291.

[9] Steve Seldlitz. Converting a Gasoline Air-Cooled Engine to Propane, SAE paper, No.740746, 1974.

[10] Lyon DY, Adams LK, Falkner JC, Alvarez PJJ. Antibacterial activity of fullerene water suspensions (nC60) is not due to ROS-mediated damage. *Environ. Sci. Technol.*, 2006, 40(14), 4360-4366.

[11] Oberdeorster E, Zhu S, Blickley TM, McClellan-Green P, Haasch ML. Ecotoxicology of carbon-based engineered nanoparticles: Effects of fullerene (C60) on aquatic organisms. *Carbon*, 2006, 44(6), 1112-1120.

[12] Murr, L., Bang, J., Esquivel, E., Guerrero, P., and Lopez, D. (2004). Carbon Nanotubes, Nanocrystal Forms, and Complex Nanoparticle Aggregates in Common Fuel-Gas Combustion Sources and the Ambient Air. *J. Nanopart. Res.*, 6(2/3):241–251.

[13] Evelyn, A., Mannick, S., and Sermon, P. A. (2003). Unusual Carbon- Based Nanofibers and Chains among Diesel-Emitted Particles. *Nano Lett.*, 3(1):63–64.

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