Control Of Exhaust Emissions Using Nanosized Copper Metal Spray In The Catalytic Converter For Two Stroke Spark Ignition Engine

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ABSTRACT

Major developments in Nanotechnology have taken place across the world over the last few years. The transition from micro-particles to nano-particles can lead to substantial changes in the properties of materials. These properties can be very helpful in prevention of automobile pollution which has become a grave problem today. The major contributors towards automobile pollution are automobiles, especially two-wheelers. This research paper comments on the utility of the nano-particles towards automobile pollution control. 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. Nanotechnology is an emerging field that covers a wide range of technologies which are presently under development in nano-scale. It plays a major role in the development of innovative methods to produce new products, to substitute existing production equipment and to reformulate new materials and chemicals with improved performance resulting in less consumption of energy and materials and reduced harm to the environment as well as environmental remediation. The paper provides a summary of the work developed in a number of key reports on nano-particles combined with the authors views and opinions on developments in the nanotechnology field.

Keywords – Automobiles, catalytic converter, nano-particles.

1. Introduction :

Air pollution generated from mobile sources is a problem of general interest. In the last 60 years the world vehicle fleet has increased from about 40 million vehicles to over 700 million; this figure is projected to increase to 920 million by the year 2010 [1].The environmental concern originated by mobile sources is due to the fact that the majority of engines employ combustion of fuels derived from crude oil as a source of energy. Burning of hydrocarbon (HC) ideally leads to the formation of water and carbon dioxide; however, due to non-perfect combustion control and the high temperatures reached in the combustion chamber, the exhaust contains significant amounts of pollutants which need to be transformed into harmless compounds. In this paper, the control strategies and achievements in automotive pollution control using nano-particles are discussed. Major developments in Nanotechnology have taken place across the world over the last few years [2]. From a humble beginning, Ireland inc. became a leader in the Microelectronics industry and now has to face the challenge of developing a strategic plan to maintain its lead position in the nano field which in most cases will supersede the micro phase. Most countries are taking a similar path of development all be it alone or in collaboration with other countries. This process is expensive and requires market drivers and experts to lead and deliver demands from the industries of the future. The approach may be driven from a top down or bottom up, i.e. from macro to micro to nano or from sub nano to nano components and machines [3]. What are the development areas and implications for nano Biotechnology, nano-electronics and nano-materials, how are the industries developing and how are we educating our undergraduates and postgraduates in this technology. In the automotive industry, nanotechnology applications are manifold. They reach from power train, light-weight construction, energy conversion, pollution sensing and reduction, interior cooling, wear reduction, driving dynamics, surveillance control, up to recycle potential and much more [4]. Additionally, visions of ‘‘nano in cars’’ reach from contributions for carbon di-oxide free engines, safe driving, quiet cars, self-healing body and windscreens, up to a mood-depending choice of color and a self-forming car body. All this will meet the present society trends and customer demands for improved ecology, safety and comfort, often summarized by the term sustainability. Nanotechnology is a science of controlling individual atoms and molecules which has great future and is considered to be the manufacturing technology of 21st century. One of the serious problems facing the world is the drastic increase in environmental pollution by internal combustion engines. All transport vehicles; both Spark ignition and Compression ignition are equally responsible for emitting different kind of pollutants [5-6].Two stroke SI engines have certain advantages such as compactness, lightweight, simple construction and low cost and low nitric oxide emissions, but they suffer from problems of high specific fuel consumption, high hydrocarbon and high carbon monoxide emissions. The emissions exhausted into the surroundings to pollute the atmosphere and cause global warming, acid rain, smog, odors respiratory and other health hazards. The paper provides a summary of the work on nano-particles, combined with the author's views and opinions on developments in the nanotechnology field. Behavior of materials at nanoscale is not necessarily predictable from what we know at macroscale. At the nanoscale, often highly desirable, properties are created due to size confinement, dominance of interfacial phenomena, and quantum effects. These new and unique properties of nanostructured materials, nanoparticles, and other related nanotechnologies lead to improved catalysts, tunable photo activity, increased strength, and many other interesting characteristics [7-8].

As the exciting field of nanotechnology develops, the broader environmental impacts of nanotechnology will also need to be considered. Such considerations might include: the environmental implications of the cost, size and availability of advanced technological devices; models to determine potential benefits of reduction or prevention of pollutants from environmental sources; potential new directions in environmental science due to advanced sensors; effects of rapid advances in health care and health management as related to the environment; impact of artificial nanoparticles in the atmosphere; and impacts from the development of nanomachines [9].

2. Methodology:

2.1 Role of metal nano-particle catalysts in automotive pollution prevention:

Catalysis involves the modification of a chemical reaction rate, mostly speeding up or accelerating the reaction rate by a substance called catalyst that is not consumed throughout the reaction. Usually, the catalyst participates in the reaction by interacting with one or more of the reactants and at the end of process; it is regenerated without any changes.

There are two main kinds of catalysts, homogeneous and heterogeneous. The homogeneous type is dispersed in the same phase as the reactants. The dispersal is ordinarily in a gas or a liquid solution. Heterogeneous catalyst is in a different phase from the reactants and is separated by a phase boundary. Heterogeneous catalytic reactions typically take place on the surface of a solid support, e.g. silica or alumina. These solid materials have very high surface areas that usually arise from their impregnation with acids or coating with catalytically active material e.g. platinum-coated surfaces. Metal nano-catalysts are being used in automobile emission control systems and in other pollution control and treatment applications, to facilitate petroleum extraction and production, and to produce chemicals and chemical products. It is expected that the increased affordability of the use of precious metals in these applications, due to the minute amount needed for each process, will increase overall demand for these metals. Catalysts usually have two principal roles in nanotechnology areas: (i) In macro quantities, they can be involved in some processes for the preparation of a variety of other nanostructures like quantum dots, nano-tubes, etc. (ii) Some nanostructures themselves can serve as catalysts for certain chemical reactions. Automotive catalysts use platinum, rhodium and palladium to speed up chemical reactions of pollutants such as nitrogen oxide, carbon monoxide and hydrocarbons, to create non-toxic emissions. By using nano-particles of the precious metals instead of larger particles; less metal is needed to produce the same surface area over the ceramic base of the catalyst as shown in figure 1.

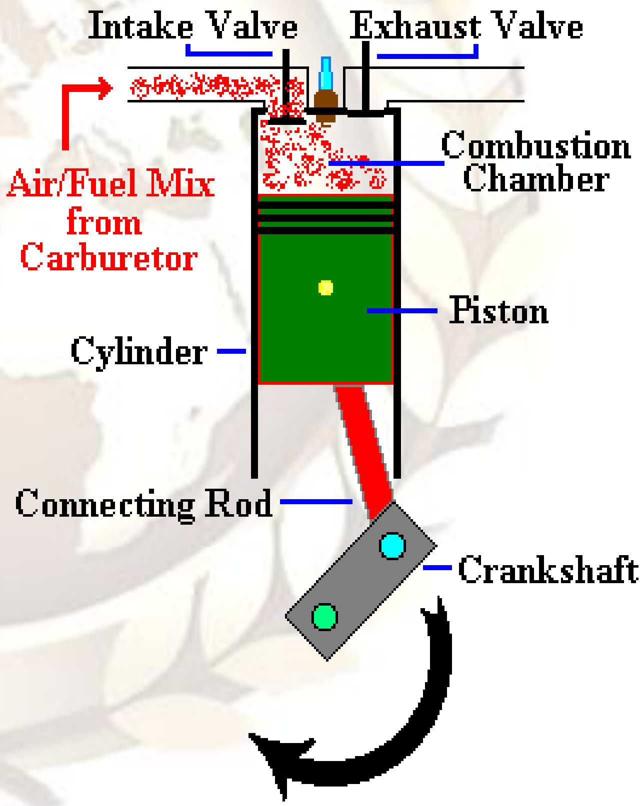

Figure 1: Use of nano catalyst coating in catalytic converter (indicated by red color)

2.2 Use of copper nano-particles:

Copper — the stuff of pennies and tea kettles — is also one of the few metals that can turn carbon dioxide into hydrocarbon fuels with relatively little energy. When fashioned into an electrode and stimulated with voltage, copper acts as a strong catalyst, setting off an electrochemical reaction with carbon dioxide that reduces the greenhouse gas to methane or methanol. Various researchers around the world have studied copper's potential as an energy-efficient means of recycling carbon dioxide emissions in power plants: Instead of being released into the atmosphere, carbon dioxide would be circulated through a copper catalyst and turned into methane or methanol — which could then power the rest of the plant by combustion, or be converted to chemical products such as ethylene. Such a system, paired with energy from solar or wind, could vastly reduce greenhouse gas emissions from coal-fired and natural gas-powered plants. But copper is temperamental: easily oxidized, as when an old penny turns green. As a result, the metal is unstable, which can significantly slow its reaction with carbon dioxide and produce unwanted byproducts such as carbon monoxide and formic acid. Now researchers at MIT have come up with a solution that may further reduce the energy needed for copper to convert carbon dioxide, while also making the metal much more stable. The group has engineered tiny nano-particles of copper mixed with gold, which is resistant to corrosion and oxidation. The researchers observed that just a touch of gold makes copper much more stable. In experiments, they coated electrodes with the hybrid nano-particles and found that much less energy was needed for these engineered nano-particles to react with carbon dioxide, compared to the nano-particles of pure copper.

2.2 Use of platinum catalysts:

Platinum is a rare element and therefore in demand for use in both jewelry and as a catalyst. In bulk form, platinum is one of the most effective but expensive catalysts available. You probably use platinum as a catalyst every day in the catalytic converter in your car. The platinum in a catalytic converter helps change air-polluting molecules from your car exhaust into less harmful molecules. The atoms in molecules, such as hydrogen, bond with platinum atoms, and then the platinum atoms release the hydrogen atoms, allowing them to react with other molecules. By breaking up molecules into atoms, platinum facilitates chemical reactions and allows them to occur at a lower temperature than they could without a catalyst. Using nano-particles of platinum increases the surface area available for a reaction and also increases the percentage of platinum atoms available for contact with molecules involved in the reaction. This difference allows researchers and manufacturers to use smaller quantities of platinum, which is important given its high cost. These improved catalysts have a better capability to break down air pollutants and also reduce the cost of catalysts used in fuel cells. But platinum comes at a high price, so nanotechnologists may choose other options in some cases.

3. Methodology

3.1 Experimental work:

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 figure 2.

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 1600 rpm at varying load conditions (0.25. 0.5, 0.75 and full load). Initially the experiment is performed at 0.25 loads keeping the speed 1600 rpm. Same experimentation is performed using nano copper coated sieve.

7) Repeat the above procedure for another speed say 1900 rpm at varying load conditions with & without using catalytic converter.

8) The above procedure was repeated for different speed with different load conditions using sieve coated with Cu nano-particles.

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 inserts 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.

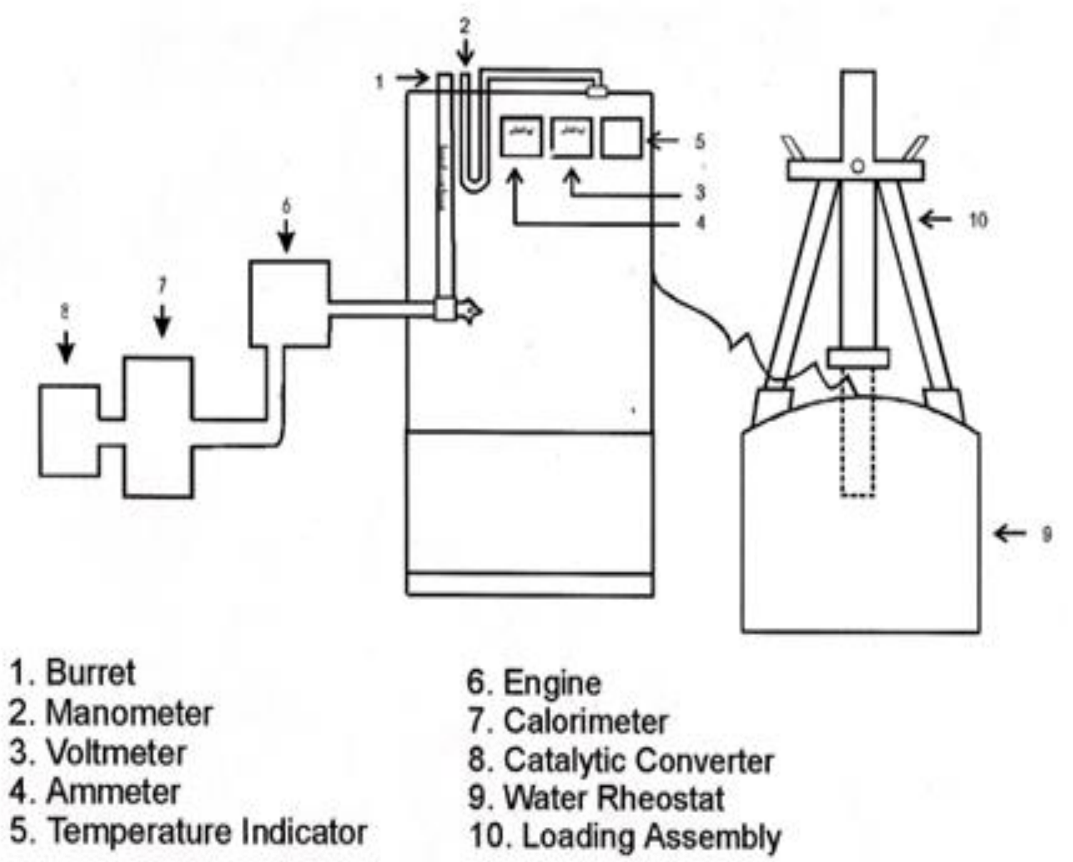

Figure 2: Arrangement for understanding the effect of catalysts

3. Results 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:

a) Figure 3and 4 showed the effect of changing load on CO & HC percentage emission at 1600 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 CO are found to be lowered.

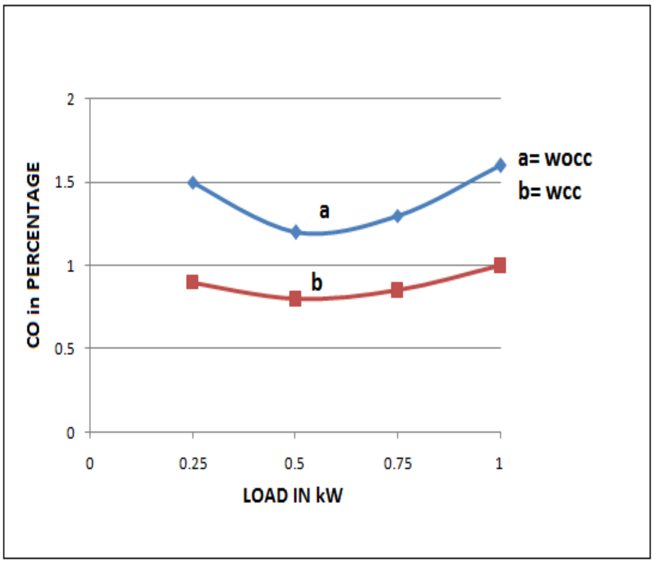

Figure 3: Effect of changing load on CO percentage emission at 1600 rpm.

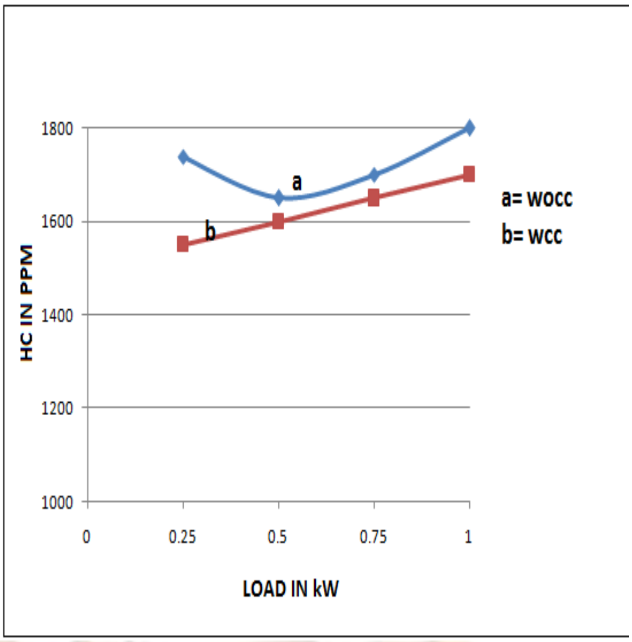

Figure 4: Effect of changing load on HC in ppm emission at 1600 rpm.

Wocc : without catalytic converter
Wcc : with catalytic converter

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 1600 to 1900 rpm as shown in figures 5 and 6. c) On repeating the above steps for 1600 to1900 rpm using catalytic converter (Cu sieve) coated with copper nano-particle, the emission of HC and CO are found to be lowered & more efficient than bulk copper.

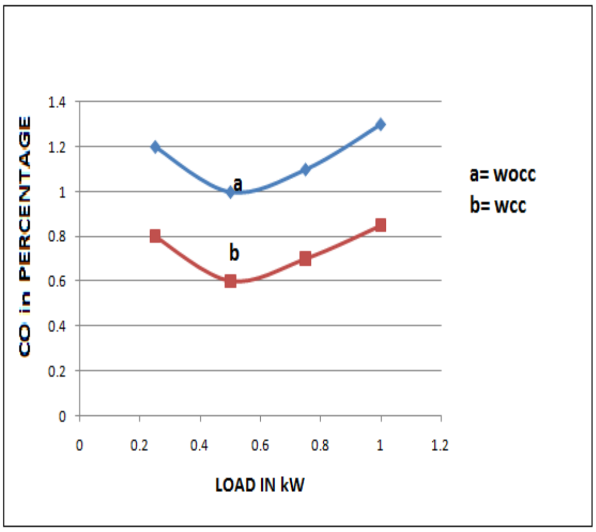

Figure 5: Effect of changing load on CO percentage emission at 1900 rpm.

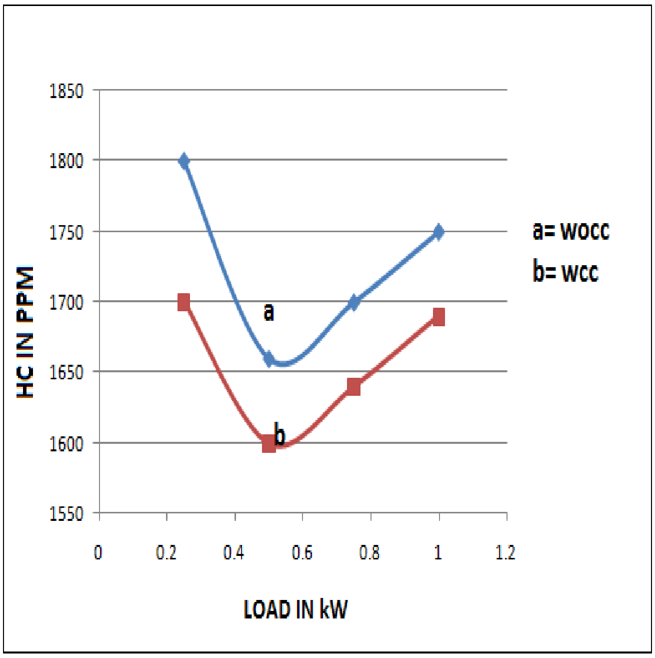

Figure 6: Effect of changing load on HC in ppm emission at 1900 rpm.

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 is 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. However, copper has d-bands well below the Fermi level and the anti bonding stage at the top of the d bands end up below the Fermi level and are filled. 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. 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.

REFERENCES

[1] V. S., Shrivastava, Metallic and organic nano-materials and their use in pollution control: A Review, Archives of Applied Science Research, 2010, 2 (6): 82-92.

[2] David. M. Kennedy, The role and future of nano-technology in research, industry and education, Conference on Materials, Processes, Friction and Wear, MATRIB'06, Vela Luka, 2006.

[3] Simonetta Giordano, Paola Adamo, Valeria Spagnuolo, Bianca Maria Vaglieco, Instrumental and bio-monitoring of heavy metal and nano-particle emissions from diesel engine exhaust in controlled environment, Journal of Environmental Sciences 2010, 22(9) 1357–1363

[4] Hartmut Presting, Ulf Konig, Future nanotechnology developments for automotive applications, Materials Science and Engineering C 23 (2003) 737–741.

[5] Bari A, Rosso A, Minciardi M R, Troiani F, Piervittori R, Analysis of heavy metals in atmospheric particulates, Environmental Monitoring and Assessment, (2001), 69, 205–220.

[6] Tornatore C, Merola S S, Vaglieco B M, (2008), Particles and nano-particles characterization at the exhaust of internal combustion engines. *Journal of Automobile Engineering*, 222: 2195–2217.

[7] G.A. Mansoori, G.R. Vakili-Nezhaad, and A.R. Ashrafi, (2005), Int'l J. Pure & Applied Math. Sci. 2, 58.

[8] G.A. Mansoori, May (2003), "Phase Transitions in Small Systems", Proceed. Nano. Sci. Tech. Workshop, Kashan Univ.

[9] G.A. Mansoori, "Nanothermodynamics & Phase Transitions in Nanosystems", The 4th Int'l Conf. Fluids & Thermal Energy Conversion, 7, (2003).