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Comparative analysis of different catalysts used in catalytic converters for C. I. engine based automobiles

S.S.K. Deepak* **and Mukesh Thakur**
Rungta College of Engineering and Technology, Near Nandanvan, Raipur, CG, India
sskrungtacollege@gmail.com

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Abstract

Today, the environmental pollution has become a severe threat to not only the human race but also plants and animals. One of the main reasons for this is the high exhaust emission level from Compression Ignition engine based automobiles. At some places including India, the movement of automobiles has been restricted to odd or even days. So, an effective measure is required to prevent this hazard. One of the effective methods for reduction of exhaust emissions from the Compression Ignition engine based automobiles is the use of nano-coated catalytic converter. There are many nano-materials which have been used for various applications including prevention of exhaust emissions from automobiles. This research paper is focussed on the comparative analysis of various nano-materials used in catalytic converter. It will open a pathway as to which catalyst can be more effective for use in the catalytic converter for automobiles based on C. I. engine.

Keywords: Automobiles, Comparative analysis, Catalyst, Catalytic converter, Pollution.

Introduction

The main cause of environmental Pollution is the exhaust emissions from the tail-pipe of automobiles. There are primarily two methods of pollution control known as the pre-pollution control and the post pollution control. The method of post pollution control is cheaper and easy to implement in comparison to the method of the pre-pollution control. This research work is primarily centered on the post pollution control method in Compression Ignition engine based automobiles while using nano-particles as a catalyst coated on the catalytic converter.

Nanotechnology is a term covering a wide range of technologies dealing with structures and processes on the scale of a nanometer (one billionth of a meter, 10^{-9} m). It is considered to be the generation next technology and it will play a vital role in the future to develop more efficient products, processes and materials with improved properties as compared to bulk materials. Nano-particles have various special properties compared to bulk material due to very high surface area to volume ratio which is also known as aspect ratio.

Catalytic converter is a structure where the concentration of exhaust emissions from the automobiles is reduced with the help of catalyst coated on its surface. Nano-particles are very effective as catalysts for exhaust emissions due to very high reactivity. Catalytic converters are classified as two way and three way catalytic converters. The concentration of the exhaust emissions can be measured with the help of multi gas analyzer. So, Catalytic converter with coating of nano-particles can prove very useful in reducing the danger of environmental pollution from Compression Ignition engine based automobiles. This research work is aimed at performing comparative analysis of different nano-materials used as catalysts in catalytic converter for pollution prevention from automobiles.

Materials and methods

Deepak and Thakur stated that Nanotechnology is the generation next technology. It is an upcoming and rapidly developing field that covers various technologies which are based on nano-materials. It plays an important role in the emergence of innovative techniques to develop new products, to replace the existing products with superior performance products resulting in comparatively less consumption of energy as well as environmental protection. Nanotechnology is getting popular for its capacity to provide innovative solutions in reducing the pollution level in atmosphere[1].

Deepak and Thakur described that metal nano-particles, particularly precious metals including gold, platinum and palladium were used as catalysts in various industrial and environmental applications. The growing level of harmful exhaust emissions in the atmosphere calls for an innovative method based on nano-technology to keep a check on the exhaust emissions. The emissions from the automobiles include harmful components like Hydrocarbons, Carbon monoxide, Nitrogen oxides, lead and particulate matter. Inhalation of harmful emissions like Carbon monoxide leads to disruption of the Oxygen supply from the blood to the tissues because it combines with the Iron present in hemoglobin forming Carboxy Hemoglobin and ultimately leading to various ailments including Cancer. Carbon dioxide is the main cause for the increase in global warming[2].

Thakur et al. did modeling for a four stroke spark ignition engine with the help of a nano-sized copper coated catalytic converter. The behavioral modeling included analysis of the practical behavior of a four stroke engine with the designed catalytic converter and later on approximating the obtained behavior in terms of some mathematical equations. The catalytic converter was coated with copper nano-particles. Copper nano-particles are cheaper in comparison to metals like platinum, palladium and rhodium nano-particles used in the automobiles. The catalyst increased the reaction rate by adsorption of reactants leading to reduction of the energy for activation. Copper metal was selected for the research work as it adsorbs the reactants molecules strong enough so as to hold and activate the reactants, but, not so strong that the products can't breakaway[3].

Fazeli et al. analyzed and concluded that bulk gold is inert chemically and so, it is generally considered as a poor catalyst. But, when gold is in used in the form of very small particles, that is, with diameters below 10 nm, it behaves surprisingly active, especially, at low temperatures for many reactions involved in chemical processing and other applications involved in control of environmental pollution. Amongst the most important reactions known to be catalyzed by the gold particles, the oxidation process of carbon monoxide is considered to be of outstanding significance[4].

Mesut et al. described that owing to the developments in the field of nanotechnology, the approach involved in catalytic design is changing from trial-and-error method to planned method of design and control. Expected improvements in future can realize the development of catalysts for the purpose of increasing the reaction speed, durability of catalyst, yield and simultaneously reducing the loading levels of active species[5].

Cole and Hamiltion studied that the difference between homogeneous and heterogeneous catalysis is mainly owing to the materials employed as catalysts and to the conditions in which catalytic reaction takes place. Heterogeneous catalysts can be easily recovered but have some shortcomings like the drastic conditions they need to be efficient. On the contrary, homogeneous catalysts are known for their high activity and selectivity[6].

Tanaka et al. described that the selection of an appropriate catalyst is one of the fundamental steps for reducing the hazardous by-products of combustion. The use of noble metals as catalyst greatly increases the cost, so, the emphasis on oxide-based catalysts has increased to a great extent. Gold has been rated for many years as almost catalytically inactive as compared with, for example, the noble metals[7].

Dunworth and Nord described that although colloidal metals belonging to Group 8 were one of the first catalysts utilized in the process of hydrogenation of organic compounds. The development of high pressure hydrogenation and skeletal catalysts implies that the colloidal catalysis had hardly been surveyed for so many years[8].

Syed Aalam et al. performed the analysis of exhaust emissions from diesel engine based automobiles by using aluminum oxide as catalyst on catalytic converter. The analyzed the level of exhaust emissions before and after the application of aluminum oxide nano-particles on the catalytic converter. They concluded that the emissions level decrease as compared to conventional catalytic converter. The level of decrease of exhaust emissions was dependent on the dosage of aluminum oxide nano-particles used in the catalytic converter[9].

Durairajan et al. analyzed the performance of a nano-coated catalytic converter. They replaced platinum and cerium oxide as catalysts with nano-rhodium and nano-palladium obtained by the use of Chemical Vapor Deposition (CVD) Technique. Spin coating method was used to deposit the obtained nano-powder on the catalytic converter having honey comb structure. Characterization of nano-rhodium and nano-palladium powder was made by X-ray diffraction. They concluded that the nano-rhodium and nano-palladium powder gave a better performance as compared to platinum and cerium oxide[10].

Cortie et al. analyzed the catalytic activity of gold nano-particles. They explained that the catalytic activity of gold is dependent of the availability of the gold atoms at the surface having small coordination numbers and the related electron density. Gold is one of the most inert metals; it has also the properties of a heterogeneous catalyst. The major drawback of using gold is that it is very costly. So, it also increases the chances of theft of the catalytic converter[11].

Syed Aalam et al. experimented by using Mahua biodiesel with Aluminum oxide nano-particles in different proportions on a four stroke single cylinder diesel engine. Different tests were conducted using different proportions of the mixture. The results showed that there was a significant improvement in thermal efficiency and a marginal reduction of around 26 % in the concentration of exhaust emissions[12].

Makwana et al. analyzed the performance of catalytic converter using nickel as a catalyst. In the experimental setup, a four cylinder and four stroke diesel engine coupled with a dynamometer was used for the purpose of data collection. With the help of nickel based catalyst converter, the exhaust emissions were found to be reduced by around 35 %. Nickel is comparatively cheaper as compared platinum, rhodium and palladium[13].

Sanjeevan et al. analyzed the effect of cerium oxide nano-particles on the exhaust emissions from a diesel engine. Cerium oxide is considered as a rare earth material with two valence electrons and a good oxidizing capability. It was used as an additive in the fuel with the help of an ultrasonic shaker so as to obtain a stable suspension. It led to reduction of nitrogen oxide and oxidation of hydrocarbons. An approximate reduction of 35 % reduction of exhaust emissions was achieved by this method[14].

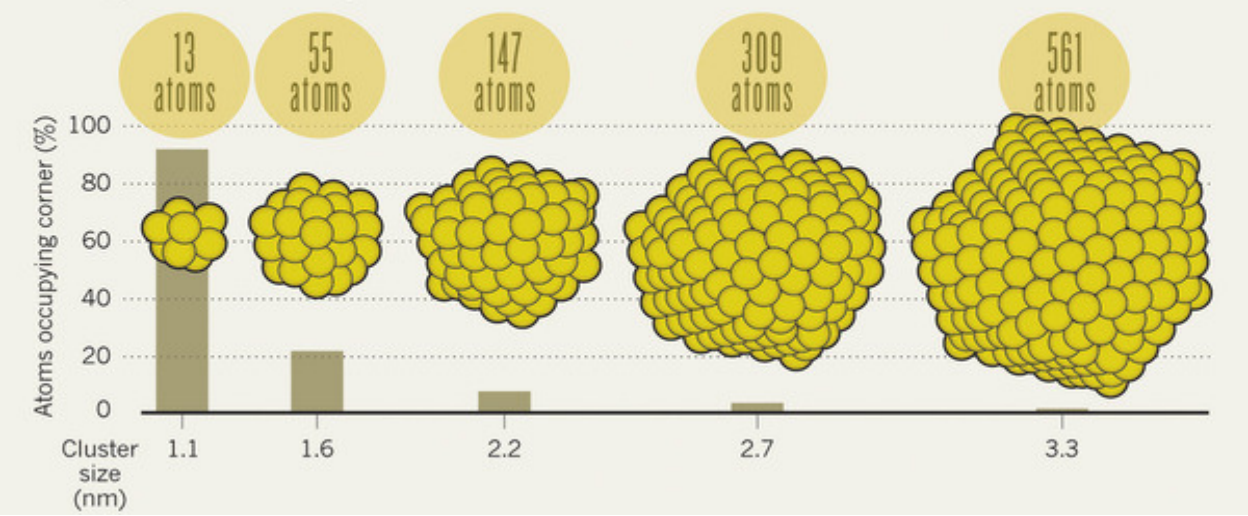

Figure-1: Gold Nano-particles. Gold atoms sitting at the corners of catalyst particles are most able to participate in a chemical reaction. So using smaller clusters of gold atoms can maximize the number of these active atoms.

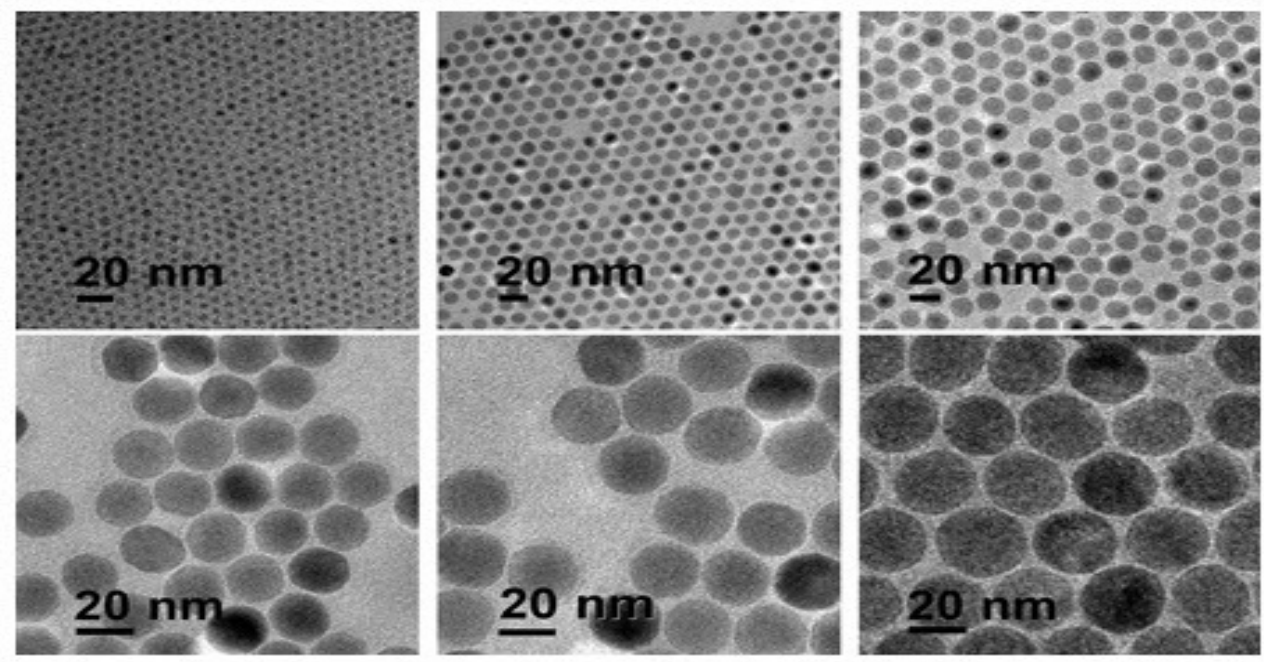

Figure-2: TEM Image of Iron Oxide Nano-particles

Nalcaci analyzed the effect of using iron oxide nano-particles as a catalyst in the reduction of carbon monoxide concentration from a car exhaust. It was observed that with the help of Iron oxide nano-particles, the complete conversion of carbon monoxide in to carbon dioxide took place. The results were mainly attributed to the increased surface area of iron oxide nano-particles. The results were promising both under normal and heavy load conditions[15].

Deepak et al. analyzed the nano-particles atomic activity and its importance for exhaust emissions control from the tail pipe of automobiles. They emphasized that owing to a very large number of surface molecules in a given volume, the nano-particles exhibited excellent performance in the reduction of concentration of harmful exhaust emissions[16].

Deepak et al. analyzed that the post pollution control method of exhaust emissions reduction is cheaper and also, implementation is easier when compared to the method of pre-pollution control[17].

Deepak and Thakur proposed an innovative method for the reduction in the concentration of harmful exhaust emissions from Compression Ignition engine based automobiles using nano-particles as a catalyst. They investigated that as the size of the nano-particles decreases, their surface area increases thereby increasing the rate of reaction[18].

Results and discussion

Atmospheric air pollution prevention is achievable with the application of nano-particles as catalyst in a catalytic converter. Nano-particles act as catalysts and lead to increase in the speed of chemical reactions involving the conversion of harmful automotive exhaust emissions into harmless and less polluting gases. Various metal nano-particles are generally used for application on the catalytic converter. Reactions like catalytic oxidation and catalytic reduction occur inside the catalytic converter due to which the high concentration of harmful exhaust emissions is effectively reduced and a cleaner as well as a greener atmosphere is achievable.

Conclusion

The present research paper is based on the comparative analysis of different nano-materials used as a catalyst for control of exhaust emissions from automobiles. Out of the many nano-materials investigated the most effective and promising results were obtained with the use of iron oxide nano-particles.

The iron oxide nano-particles exhibited excellent conversion effectiveness of harmful exhaust emissions in to harmless gases. Also, the cost effectiveness and easy availability of iron oxide nano-particles was found very suitable for its use in a catalytic converter. These characteristics can be utilized to effectively reduce the concentration of automotive exhaust emissions in the atmosphere, especially due to the C. I. engine based automobiles. This research paper paves the way for advanced approach in this direction which includes the design of the catalytic converter and its experimentation.

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