

Investigation and Validation of Catalytic Converter

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ABSTRACT: This paper presents a new catalytic converter to be used for spark ignition engine. The catalytic converter were developed based on catalyst materials consisting of metal oxides such as Cobalt nitrate $\text{Co}(\text{NO}_3)_2$, and Aluminium Oxide Al_2O_3 . Both the catalyst materials which are $\text{Co}(\text{NO}_3)_2$ and Al_2O_3 are inexpensive in comparison with conventional catalysts such as Palladium, Rhodium, Platinum. In addition, the noble metals such as platinum group metals are now identified as human health risk due to their rapid emissions in the environment from various resources like conventional catalytic converter, jewellers and other medical usages. The conventional catalytic converter was based on noble metal catalyst with honeycomb ceramic substrate. **The objective of this paper is to develop a low-cost three way catalytic converter.**

1. INTRODUCTION

1.1. Pollution

Pollution may be defined as “an unwanted/undesirable foreign matter added to environment in other words, Pollution may be defined as “the excessive discharge or addition of undesirable substances or unwanted foreign matter into the environment, thereby adversely altering the natural quality of the environment, and causing damage to human, plant and animal life or it may be unreasonable interference with the comfortable enjoyment of life or the conduct of business”. The term environment includes air, water and land.

Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment.

These substances include gases (sulphur oxides, nitrogen-oxides, carbon monoxide, hydrocarbons etc), particulate matter (smoke, dust, fumes, aerosols etc) and radioactive materials and many others. Most of these substances are naturally present in the atmospheric in low (background) concentrations and are usually considered to be harmless.

Air is polluted by dust, cement, coal and some gases. An individual inhales about 16 kg of air in a day. If the air is polluted it causes many ill-effects on human beings. Polluted air also affects plant life, promotes corrosion, blocks out day-light, and causes deterioration of rubber, paints etc.

Pollution has become a major source of problem during the last 25 years. It is harmful to natural resources and human health. Automobile contributes 25% of the air pollution. Government has proposed various emission control norms in order to prevent the air pollution from automobiles.

1.2. Major sources of pollution from automobiles

- Primary pollution.
- Secondary pollution.

Primary pollution contributes emission of harmful carbon monoxide (CO), unburned hydrocarbon (UHC), and oxides of nitrogen (NO_x) and particulate matter, where as secondary pollution contributes the green house effect.

Carbon monoxide is formed due to incomplete combustion in combustion chamber. Unburned hydrocarbon is due to the evaporation of fuel from the fuel tank and also due to formation of unburned gases in the exhaust oxides of nitrogen (NO_x) and particulate matter is formed due to improper combustion and formation of NO_x increases with increase in temperature at the exhaust.

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For diesel vehicles, the major challenge of exhaust emission control is particulate removal and control of NO_x. Because of excess air in the engine, there are lower level of CO and unburned gaseous hydrocarbons (UBF) when compared with the emission of petrol engines. However, the particulate, which are minute particles of unburned carbon, may be coated with carcinogenic poly aromatic hydrocarbons and sulphates resulting from the combustion of sulphur in the fuel or lubricator.

Today, NO_x emissions are controlled by engine design and calibration, often at the expense of increased particulate emission. It also can be reduced with the help of reduction catalytic converters. An effective three-way catalytic converter reduces HC, CO and NO_x.

Fortunately though it has not been recognized widely, automobile exhaust is known enemy since this is signalled by the emission of visible smoke as encountered in a over loaded vehicle or the fuel is adulterated. First job is to screen vehicle by visual inspection, send those discharging excessive visible smoke to mobile or stationary workshop for smoke meter testing and subsequent maintenance. Recording petrol engines it may be fitted with catalytic converter. It is also necessary to use the SCR to reduce NO_x, CO and unburnt HC coming from the engine.

It has been seen that pure gasoline or oxygenated fuel used in the engine could not satisfy the emission norms proposed by the government. Therefore it is also necessary to use an SCR to reduce the level of pollutants.

II. LITERATURE REVIEW

M.A. KALAM et al (2009), developed characteristics of a new catalytic converter (catco) to be used for natural gas fuelled engine in “**Development and test of a new catalytic converter for natural gas fuelled engine**” The catco were developed based on catalyst materials consisting of metal oxides such as titanium dioxide (TiO₂) and cobalt oxide (CoO) with wire mesh substrate.

The original engine manufacture catalytic converter (OEM catco) was tested for comparison purposes. The OEM catco was based on noble metal catalyst with honeycomb ceramic substrate. It is experimentally found that the conversion efficiencies of TiO₂/CoO based catalytic converter are 93%, 89% and 82% for NO_x, CO and HC emissions respectively. It is calculated that the TiO₂/CoO based catalytic converter reduces 24%, 41% and 40% higher NO_x, CO and HC emissions in comparison to OEM catco respectively.

The objective of this paper is to develop a low-cost three way catalytic converter to be used with the newly developed CNG-DI engine. Detailed review on catalytic converter, low-cost catalytic converter development characteristics and CNGDI engine test results have been presented with discussions.

CoO/TiO₂ catalyst and wire mesh based substrate based catalytic converter has been successfully developed. The surface area of wire mesh substrate is about 25 times higher than ceramic substrate. The NO_x conversion efficiency of OEM and wire mesh catalytic converters are 69% and 93% respectively. Wire mesh reduces 24% higher than OEM catalytic converter. The CO conversion efficiency of OEM and wire mesh catalytic converters are 48% and 89% respectively. Wire mesh reduces 41% higher than OEM catalytic converter. The HC conversion efficiency of OEM and wire mesh catalytic converters are 42% and 82% respectively. Wire mesh reduces 40% higher than OEM catalytic converter.

IMRAN SYAKIR MOHAMADet al (2009), analysed Tin (IV) oxide has been recognized as an alternative catalyst for carbon monoxide gas treatment generated from vehicular and industrial activities were investigated in “**Development of tin (IV) oxide based catalyst for carbon monoxide emission control**” tin (IV) oxide was used as a catalyst with the addition of cobalt (II) oxide and nickel (II) oxide as dopants, prepared by modification of sol-gel method. The catalytic ability was tested towards the oxidation of carbon monoxide using continuous fixed bed reactor (SELOX) instrument. Two catalysts, ECAT1-400 calcined at 400°C and ECAT2-600 calcined at 600°C gave a promising catalytic ability towards carbon monoxide oxidation. Both catalysts completed the carbon monoxide

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oxidation to carbon dioxide at 215°C and 200°C. Several techniques were used in this research to characterize the physical and chemical properties of the catalyst materials.

Catalytic activity testing was carried out to investigate the ability of the catalyst to convert a toxic gas (carbon monoxide) to nontoxic gas (carbon dioxide). This technique has been done in COMBICAT, UM using SELOX instrument. Since these materials are good high activity, an in depth investigation into the properties of the catalyst was carried using various characterization techniques. The catalytic activity testing showed that ECAT2-600 catalyst calcined at 600°C gave the best activity with $T_{100}(\text{CO}) = 200^\circ\text{C}$. The catalytic activity is good when the material observes cobalt oxide, Co_3O_4 (combination of CoO and Co_2O_3) peaks. In this case, both oxidation number of cobalt oxide, Co^{2+} and Co^{3+} ($\text{Co}^{2+} > \text{Co}^{3+}$) expected to increase the catalytic activity.

III. OBJECTIVE AND METHODOLOGY

3.1. Objective

The objective of the project is to research on engine exhaust after treatment control by using alternate source of material like alumina for doing oxidising reaction in catalytic converter to make cost effective solution.

In the scope of the project two combination of wash coat technology is under experimentation research.

I. Cobalt nitrate

II. Aluminum oxide.

Based on the result best wash coat technology will be selected

3.2. Methodology

In an existing catalytic converter the precious metals like platinum, palladium, are normally used. To overcome from the cost and usage of precious metals, it was an effort to identify by project experiment results by using alternate source of material like alumina.

The ceramic honey comb is taken and dipped into the chromium, cobalt nitrate and aluminum oxide solution in the wash coat technology. Wash coat assist in oxidation process to reduce the CO, HC emission and reduction process to reduce the NO_x emission. The new trials will prove the concept of alternate material comparison over precious metals employed in recent trends, and will enhance the feasibility of cost effective solution.

IV. AFTER TREATMENT DEVICE – STUDY

OVERVIEW

Today the most successful exhaust gas treatment technique used commercial has been air injection to exhaust system. Both catalytic and thermal reactors have the potential for very low emission of hydrocarbons, carbon monoxide and NO_x.

4.1. Thermal reactor

One of the methods used in production to reduce hydrocarbons and CO emission is air injection into the exhaust system. In this method oxides of nitrogen are injection into the exhaust system .in this method oxides of nitrogen are not reduced. In fact, they may be increased if sufficiently high exhaust gas temperature results from the combustion of the CO and HC with the added air enters the cylinder during the overlap period, there by leaning the mixture in the cylinder.

To achieve this high degree of exhaust system oxidation of hydrocarbons and CO and high exhaust temperature coupled with sufficient O₂ and residence time to complete the CO and HC keeps the reaction going.

Thermal reactor can reduce only up to 30% and catalytic converter can reduce up to more than 50% emission on continuous working so it has been seen that all the new vehicles is being effectively fitted with a 3 way catalytic converter that reduce all the 3 pollutants namely hydrocarbons, carbon monoxide and oxides of nitrogen.

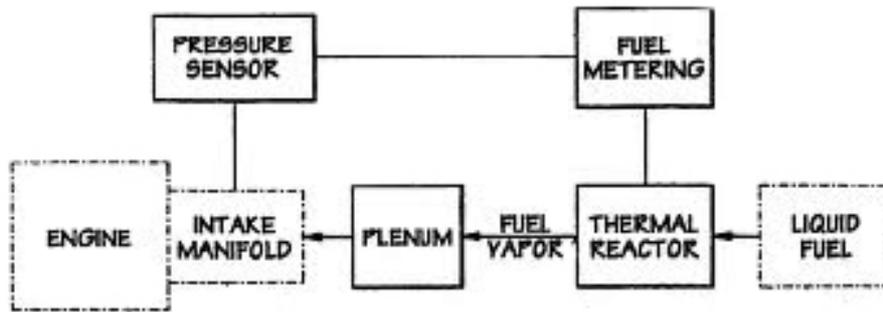


Fig.4.1. Thermal reactor for ic engine fuel management

4.2. Catalytic Converter

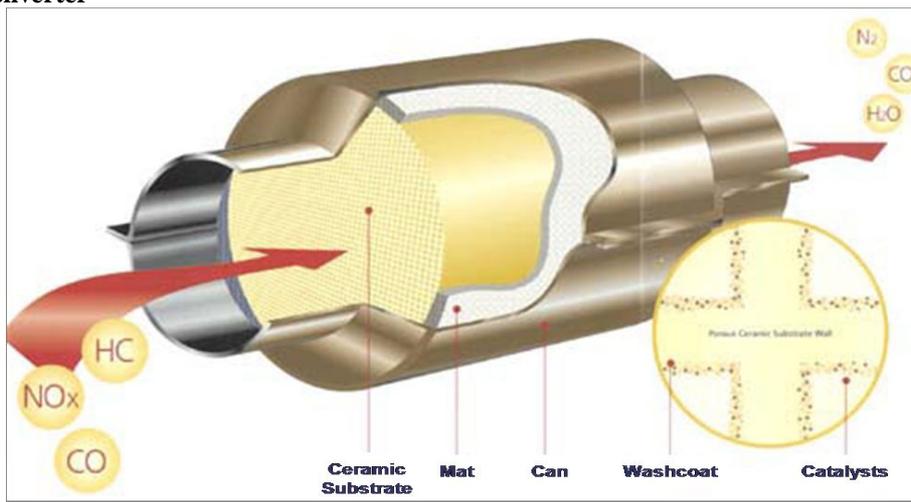


Fig.4.2. Cut Section of the Catalytic Converter

A catalytic converter is an after treatment device that reduce the pollutants from automobiles to exhaust to very low emission levels.

Nitrogen oxide can be reduced in the presence of some reducing agents. Unburnt HC, CO can be oxidized using oxidant. HC/CO can be oxidized to completion in the presence of certain catalysts with secondary air injection in front of catalyst bed.



Fig.4.3. Honeycomb Structure

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The Core or Substrate:

This is often a ceramic honeycomb in modern catalytic converters, but stainless steel foil honeycombs are used, too. The honey-comb surface increases the amount of surface area available to support the catalyst, and therefore is often called a “catalyst support”.

The Wash Coat:

A wash coat is used to make converter more efficient, often as a mixture of silica and alumina. The wash coat, when added to the core, forms a rough, irregular surface, which has a far greater surface area than the flat core surfaces do, which then gives the converter core the larger surface area, and therefore more places for active precious metal sites. The catalyst is added to the wash coat (in suspension) before being applied to the core.

The catalyst itself is most often a precious metal. Platinum is the most active catalyst and is widely used. It is not suitable for all applications, however, because of unwanted additional reaction and/or cost. Palladium and rhodium are two other precious metal used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidation catalyst. Cerium, iron, manganese and nickel are also used, although each has its own Limitation. Nickel is not legal for use in the European Union (due to reaction with carbon monoxide).

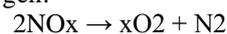
Three Way Catalytic Converter

Since 1981, three-way catalytic converters have been used in vehicle emission control systems in North America and many other countries on road going vehicles. A three-way catalytic converter has three simultaneous tasks.



Fig.4.4. Cut Section of Three Way Catalytic Converter

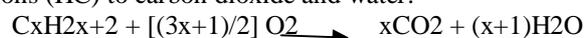
Reduction of nitrogen oxides to nitrogen and oxygen:



Oxidation of carbon monoxides to carbon dioxide:



Oxidation of Unburnt hydrocarbons (HC) to carbon dioxide and water:



These three reactions occurs most efficiency when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. This is between 14.6 and 14.8 parts air to 1 part fuel, by weight, for gasoline. The ratio for LPG, natural gas and ethanol fuels is slightly different, requiring modified fuel system settings when using those fuels. Generally, engines fitted with 3-way catalytic converters are equipped with a computerized closed-loop feedback fuel injection system employing one or more oxygen sensors, though early in the deployment of

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3-way converters, carburettor's equipped for feedback mixture control were used. While a 3-way catalyst can be used in an open-loop system, NO_x reduction efficiency is low.

Within a narrow fuel/air ratio band surrounding stoichiometric, conversion of all three pollutants is nearly complete. However, outside of that band, conversion efficiency falls off very rapidly. When there is more oxygen than required, then the system is in oxidizing condition. In that case, the converter's two oxidizing reactions (oxidation of CO and hydrocarbons) are favoured, at the expense of the reducing reaction. When there is excessive fuel, then the engine is running rich. The reduction of NO_x is favoured, at the expense of CO and HC oxidation.

V. EXPERIMENTAL / TEST SET UP

5.1. Material selection

- Chromium oxide
- Cobalt nitrate
- Aluminium oxide
- Ammonia hydroxide liquid

Chromium (III) Oxide:

Chromium (III) Oxide is the inorganic compound of the formula Cr₂O₃. It is one of the principal oxides of Chromium and used as a pigment. In nature, it occurs as the rare mineral eskolaite.

Properties:

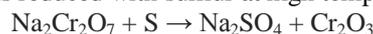
Molecular formula: Cr₂O₃; Molar mass: 151.9904 g/mol; Appearance: Light to Dark green colour, fine crystals. Melting Point: 2,708K and its Boiling point: 4,270K. It is insoluble in water but soluble in alcohol except alcohol acetone acids. Refractive index is 2.551. It has a hexagonal crystal structure.



Fig.5.1. Chromium (III) Oxide

Preparation:

The Parisians Pannetiers and Binet first prepared the transparent hydrated form of Cr₂O₃ in 1838 via a secret process, sold as a pigment. It is derived from the mineral chromite, (Fe, Mg)Cr₂O₄. The conversion of chromite to chromia proceeds via Na₂Cr₂O₇. Which is reduced with sulfur at high temperatures.



The oxide is also formed by the decomposition of chromium salts such as chromium nitrate or by the exothermic decomposition of ammonium dichromate.



The reaction has a low ignition temperature of less than 200°C and is frequently used in "volcano" demonstrations.

Cobalt (II) Nitrate

Formula: Co(NO₃)₂; Molecular weight: 182.94; occurs in common hexahydrate form, Co(NO₃)₂·6H₂O, Molecular weight: 291.03.

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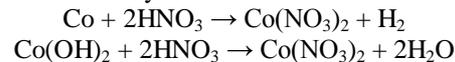
Fig.5.2.Cobalt(II) nitrate hexahydrate

Physical Properties

The hexahydrate is red monoclinic crystal; deliquescent in moist air; density 1.87 g/cm³; decomposes at 55°C, losing three molecules of water; decomposes to green cobalt(II) oxide on further heating at 74°C; very soluble in water (134 g/100mL at 0°C); also soluble in alcohols and acetone. The anhydrous salt is pale red powder; soluble in water. Boiling point is 100-105°C.

Preparation

Cobalt (II) nitrate is prepared by treating the metal, or its oxide, hydroxide or carbonates with dilute nitric acid. The solution on evaporation yields red crystals of hexahydrate:



Aluminium oxide:

Aluminium oxide is an amphoteric oxide with the chemical formula Al₂O₃. It is commonly referred to as alumina, or corundum in its crystalline form, as well as many other names, reflecting its widespread occurrence in nature and industry. Its most significant use is in the production of aluminium metal, although it is also used as an abrasive owing to its hardness and as a refractory material owing to its high melting point.



Fig.5.3. Aluminium oxide in its powdered form

VI. CONCLUSION

The fabrication of catalytic converter consists of few components, namely the inner shell and outer shell. The catalytic converter casing and inner chamber remain as same as typical catalytic converter installed in the vehicle system. The same outer dimensions were purposely fixed in order to avoid redesign of the existing exhaust system, which then required further thermal optimization and design validation studies. The Honeycomb structure were then coated with metal catalyst before arranged onto a catalytic converter. Catalytic converter 1litre capacity is selected for the experiment.

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