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Development and Performance Analysis of New Catalytic Converter

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***Abstract*—** This project presents the characteristics of a new catalytic converter to be used for petrol and diesel fuelled engine. The catalytic converter were developed to reduce emission effectively with lowest cost. We are developing two type of converter. Which is based on the catalyst material used in the converter. The metal oxide such as titanium dioxide (TiO_2), cerium oxide (CeO_2) and copper nitrate ($Cu(NO_3)_2$) , Zirconium dioxide (ZiO_2) with wire mesh substrate. Both the catalyst material used in this are inexpensive in comparison with conventional catalyst such as nobal metals like Platinum (Pt), Palladium (Pd) and Rhodium (Rh) these are currently used catalyst. The nobal metals such as platinum group of metals are identified as human health risk due to their rapid emissions in the environment from various resources like conventional catalytic converter, jewelry and other medical usages. The Original Engine Manufacture Catalytic Converter was tested for comparison purposes. The OEM catalytic converter was based on noble metal catalyst with honey comb ceramic substrate. Current study focuses on new developed catalytic converter because existing available catalytic converter suffers from various problems like poisoning, fracture, melting and higher cost. The objective of this project is to develop a cost effective three way catalytic converter to be used with the petrol and diesel fuelled engine. Detailed review on catalytic converter, cost effective catalytic converter development characteristics and petrol (or) diesel fuelled engine test results have been presented with discussions

***Keywords*—** noble metals, 3-way catalytic converter, wire mesh.

I. INTRODUCTION

A. Catalytic Converter

A catalytic converter is a device used to reduce the toxicity of emission from an internal combustion engine. In catalytic converter there are two different types of catalyst at work, a reduction catalyst and an oxidation catalyst. Both types consist of a ceramic structure coated with a metal catalyst, usually Platinum, Palladium and Rhodium. The idea is to create a structure that exposes the maximum surface area of catalyst to the exhaust stream. The reduction catalyst is the first stage of the catalytic converter. It used platinum and rhodium to help reduce the NOx emission. When an NO or NO_2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing 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.

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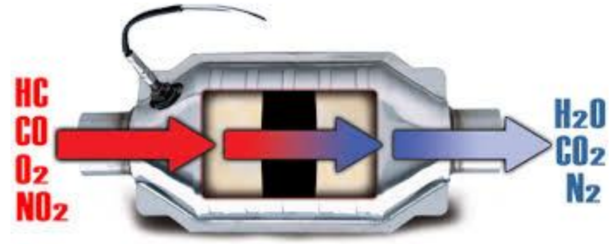

Fig 1.1.Basic catalytic converter

The oxidation catalyst is the second stage of catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by CO_2 and H_2O. This catalyst aids the reaction of the CO and HC with the remaining oxygen in the exhaust gas.

B. New Catalytic Converter Generation

The new catalytic converter can be developed based on the catalyst used in the converter. We are changing the catalyst in the existing catalytic converter to reduce the pollution and cost of the converter. The currently used catalyst are Platinum, Rhodium and Palladium these are very high cost catalyst. So, the cost of the catalytic converter also very high. In our project catalyst are very less cost and pollution control efficiency also better when compare to the existing catalyst.

We are fabricating two type of catalytic converter based on the catalyst preparation or used in the converter. We are using the wire mesh instead of honey comb ceramic duct. The wire mesh is made up of stainless steel. Our catalyst are Titanium Dioxide, Copper Nitrate, Cerium oxide, Zirconium Dioxide.

There are two types of converters are prepared,

- Titanium based catalytic converter:

Titanium Dioxide, Copper Nitrate, Zirconium Dioxide.

- Cerium based catalytic converter:

Cerium Oxide, Copper Nitrate, Zirconium Dioxide.

These catalyst are mixed in the magnetic stirrer with distilled water after the slurry preparation the wire mesh are dipped in the slurry and drying in the room temperature itself.

And the meshes are heat-treated in the hot air oven for a period of time and then the meshes are assembled and fitted into the converter to get further results. After the assembling the converter are proceeded to the emission testing and the results are compared and documented.

C. Materials Needed For New Catalytic Converter

Materials required for fabrication of new catalyst based catalytic converter are as follows,

1. Wire mesh.
2. Distilled water and Concentrated HCL
3. Chemical catalyst.

3.1 Titanium Based Converter.
3.1.1 Titanium Dioxide.
3.1.2. Copper Nitrate.
3.1.3. Zirconium Dioxide.
3.2 Cerium Based Converter.
3.2.1 Cerium Oxide.
3.2.2. Copper Nitrate.
3.2.3. Zirconium Dioxide
4. Insulation

II. Experimental Procedure

A.Wire mesh is fabricated as per the size of the catalytic convertor. Titanium based catalytic convertor is prepared with Titanium dioxide, Copper nitrate, Zirconium dioxide. Wire mesh is dipped into the HCL solution to improve its properties and it is dipped into the distilled water.

Wire meshes are placed into the hot air oven to increase its hardness. Titanium based solution is prepared and the wire meshes are dipped into the solution. To avoid the sedimentation of chemical particles. It is mixed thoroughly with the help of magnetic stirrer. After the 30 minutes of coating titanium based convertor is prepared. Now the chemicals for cerium based chemicals is coated with the help for stirrer. Finally it is dried. Wire meshes are placed inside the convertor. Titanium based and cerium based are separated and the wire meshes are arranged before welding.

Fig2.1.Wire mesh

Wire meshes are fabricated according to present catalytic converter ceramic substrate. The surface area of the wire mesh is 8560 mm^2 and thickness of the wire mesh is 2 mm and also the distance between each wire in the mesh is 1.5 mm.

A. Preparing Stirring Mixture

The reaction salt mixture is prepared by mixing of chemical catalyst for titanium based catalytic converter are Cerium Dioxide, Zirconium Dioxide and Copper Nitrate. These catalyst are responsible for the oxidation hand reduction reaction in exhaust emission gases. These catalyst react on exhaust and convert the harmful gases into unharmed CO_2, H_2O,N_2 and O_2. The salt mixture is prepared by addition salt in particular ratios such as follows

15 grams of **Cu $(NO_3)_2$**, 7.5 grams of **CeO_2**, 2.5 grams of **ZrO_2** were added in 200 ml of distilled water.

As per the ratios we used 1800 ml of distilled water which accompanied by 225 grams of Cu $(NO_3)_2$, 67.5 grams of CeO_2, 22.5 grams of ZrO_2 were added in the mixture .these salts are mixed in the beaker and ready for stirring process.

B. Stirring Process

Stirring process is carried out in magnetic stirrer machine , the stirrer magnet is placed inside the beaker containing the solution mixture. Thus after placing of magnet, the beaker is placed on the magnetic stirrer. The magnet inside the beaker tends to rotate at particular rpm controlled by us. The oxidation and reduction catalyst are allowed to mix well in stirrer. The main purpose of stirrer is to prevent the salt from deposition and for effective mixture formation. The stirring mixture is stirrer for about 8 hours at 60℃ to get proper dissolving of salt mixture and to get slurry mixture.

C. Formation Of Slurry Mixture

After the stirring process, Cerium based reaction mixture is not in the required form for the reaction since some of the catalysts are not soluble in water, they may settle down at the bottom to retain the required slurry mixture. The slurry catalytic mixture is allowed to evaporate the water content in it to form perfect slurry. This evaporation process is carried out in a tray by pouring the stirred mixture and allowed in room temperature for 4 hours. After the water content removed from the catalytic stirred mixture, it will become more slurry. This condition of slurry will be capable of sticking in wire meshes without scattering. This Cerium based catalytic slurry mixture ($CeO_2/Cu(NO_3)_2/ZrO_2$) is now well suited for the coating on the wire meshes.

D. Welding Process

The welding of catalytic converter consist of few components, namely the converter chamber, substrate and insulator to be welded together. The catalytic converter casing and chamber remain as same as originally installed in to 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.

Thus packed wire mesh substrate is to be placed inside the converter chamber to react with the exhaust gases from engine. Since two sets of chemical catalytic substrate prepared, separate catalytic chambers are required . before placing the substrate insulation is necessarily placed to prevent the vibration of vehicle systems affecting substrate. Gas welding technique is used to weld the substrate and catalytic chamber cover. The catalytic converter is now allowed to cool to in room temperature

III. Catalyst Material

A. Titanium Based Catalytic Converter

There are three catalyst material purchased to the titanium based catalytic converter,

1. Titanium Dioxide.

2. Copper Nitrate.
3. Zirconium Dioxide.

- *Titanium Dioxide*

Titanium dioxide also known as titanium (IV) oxide or Titania, is the naturally occurring oxide of titanium, chemical formula TiO_2. It has a wide range of applications, from paint to sunscreen to food coloring. When used as food coloring, it has E number.

Fig 3.1.Titanium Dioxide.

Titanium dioxide occurs in nature as well=known minerals rutile, anatase and brookite, and additionally as two high pressure forms a monoclinic baddeleyite .it has mainly source from ilmenite ore. Rutile is the next most abundant and contains around 98% titanium dioxide in the ore. The metabaseanatase upon heating temperature in the range 600 to 800^0C.

PROPERITIES:

Molecular Formula - TiO_2.
Density - 4.23 g/cm^3.
Melting Point - 1843^0C.

- *Copper Nitrate*

Copper nitrate is an inorganic compound that forms a blue crystalline solid. Anhydrous copper nitrate forms deep blue green crystals and sublimes in a vaccum at 150-200^0C.

Copper nitrate also occurs as five different hydrates, the most common ones being the trihydrate and hexahydrate, these materials are more commonly encountered in commerce than in the laboratory.

Fig.3.2.Copper Nitrate.

Hydrated copper nitrate can be prepared by hydration of the anhydrous material or by treating copper metal with an aqueous solution of silver nitrate or concentrated nitric acid.

PROPERITIES:

Molecular Formula - Cu $(No_3)_2$.
Density - 3.05 g/cm^3.
Melting Point - 2715^0C.

Zirconium Dioxide

Zirconium dioxide sometimes known as zirconia, is a white crystalline oxide of zirconium. It is most naturally occurring from, with a monoclinic crystalline structure, is the mineral baddeleyite. Zirconia is produced by calcining zirconium compounds, exploiting its high thermal stability.

Zirconia is chemically unreactive. It is slowly attacked by concentrated hydrofluoric acid and sulfuric acid. When heated with carbon, it converts to zirconium carbide.

Fig.3.3.Zirconium Dioxide.

When heated with carbon in the presence of chlorine, it converts to zirconium tetrachloride. This conversion is the basis for the purification of zirconium metals and is analogous to the kroll process.

PROPERITIES:

Molecular Formula - ZiO_2.
Density - 5.68 g/cm^3.
Melting Point - 256^0C.

B. Cerium Based Catalytic Converter

There are three catalyst material purchased to the Cerium based catalytic converter,

1. Cerium oxide.
2. Copper Nitrate.
3. Zirconium Dioxide.

- *Cerium Oxide*

Cerium oxide also known as ceric oxide, is an oxide of the rare earth metal cerium. It is the pale yellow powder with the chemical formula CeO_2. Cerium oxide is formed by the calcinations of cerium oxalate or cerium hydroxide.

The non-stoichiometric forms has a blue to black color, and exist both ionic and electronic condition with ionic being the most significant at temperature >500^oC.

It is used in ceramics to sensitize photosensitive glass, as a catalyst support to polish glass and stones, in lapidary as an alternative to "20eweler's rouge". It is also known as "optician's rouge".

While it is transparent for visible light, it absorbs ultraviolet radiation strongly, so it is an prospective replacement of zinc oxide and titanium dioxide in sunscreen.

Fig.3.4.Cerium oxide salt.

PROPERITIES:
Molecular Formula - CeO_2.
Density - 7.65 g/cm^3.
Melting Point - 2400^0C.

- *Copper Nitrate*

Copper nitrate is an inorganic compound that forms a blue crystalline solid. Anhydrous copper nitrate forms deep blue green crystals and sublimes in a vaccum at 150-200^0C.

Copper nitrate also occurs as five different hydrates, the most common ones being the trihydrate and hexahydrate, these materials are more commonly encountered in commerce than in the laboratory.

Fig.3.5 Copper Nitrate

Hydrated copper nitrate can be prepared by hydration of the anhydrous material or by treating copper metal with an aqueous solution of silver nitrate or concentrated nitric acid.

PROPERITIES:
Molecular Formula - $Cu(No_3)_2$.
Density - 3.05 g/cm^3.
Melting Point - 2715^0C.

- *Zirconium Dioxide*

Zirconium dioxide sometimes known as zirconia, is a white crystalline oxide of zirconium. It is most naturally occurring from, with a monoclinic crystalline structure, is the mineral baddeleyite. Zirconia is produced by calcining zirconium compounds, exploiting its high thermal stability.

Zirconia is chemically unreactive. It is slowly attacked by concentrated hydrofluoric acid and sulfuric acid. When heated with carbon, it converts to zirconium carbide.

Fig.3.6.Zirconium Dioxide.

When heated with carbon in the presence of chlorine, it converts to zirconium tetrachloride. This conversion is the basis for the purification of zirconium metals and is analogous to the kroll process.

PROPERITIES:
Molecular Formula - ZiO_2.
Density - 5.68 g/cm^3.
Melting Point - 256^0C.

IV. HEAT TREATMENT

Heat treatment are done to get the complete catalyst substrate. Heat treatment is a process of treating the dried wire meshes with presence of required heat for a period of time.

Fig4.1.Heat Treatment.

The heat treatment of the meshes are carried out in the "HOT AIR OVEN". Before placing the meshes the oven is heated up to 100℃ for 1 hour. It is a pretreatment of the oven. The oven is maintained at 100℃ for 4 hour with the meshes. The meshes are arranged evenly in stainless steel tray to get complete heat treatment.

After the heat treatment the oven switched OFF and the meshes are allowed to cool the oven itself. Finally the Cerium based substrate is prepared.

A. Packing Of Wire Meshes Into The Converter

1. Titanium Based Catalytic Converter.
2. Cerium Based Catalytic Converter.

- *Titanium Based Catalytic Converter: (Tio$_2$/Cu(NO$_3$)$_2$/Zro$_2$)*

The stainless steel wire mesh pieces were then coated with Titanium catalyst before arranged onto a straight bar. The length of stainless steel wire mesh was around 15 cm. The gap between each of stainless steel wire mesh was around 0.2 cm and the gap between each wire mesh pack is 2 cm that was created by using the stainless steel washer and nut.

The size of the washer used in the packing was 1 cm in a diameter and 1cm of hollow diameter with thickness around 0.2 cm. The size of the nut is 1.6 cm in thickness and 1.5 cm outer diameter and 1 cm inner diameter. The stainless steel bars which was used as a wire mesh support which was screw type bar with a diameter of 1.2 cm and 20 cm length.

Fig.4.2.Mesh Package or Converter Substrate.

A total of 50 pieces were used in an arrangement for 15 cm length. After the packing the package is placed inside converter and the welding process is takes place.

- Cerium Based Catalytic Converter: ($CeO_2/Cu(NO_3)_2/ZrO_2$)

The stainless steel wire mesh pieces were then coated with cerium catalyst before arranged onto a straight bar. The length of stainless steel wire mesh was around 15 cm. The gap between each of stainless steel wire mesh was around 0.2 cm and the gap between each wire mesh pack is 2 cm that was created by using the stainless steel washer and nut.

The size of the washer used in the packing was 1 cm in a diameter and 1cm of hollow diameter with thickness around 0.2 cm.

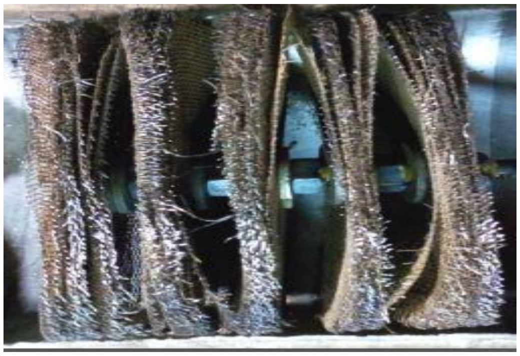

Fig.4.3.Mesh Package or Converter Substrate.

The size of the nut is 1.6 cm in thickness and 1.5 cm outer diameter and 1 cm inner diameter. The stainless steel bars which was used as a wire mesh support which was screw type bar with a diameter of 1.2 cm and 20 cm length. A total of 50 pieces were used in an arrangement for 15 cm length. After the packing the package is placed inside converter and the welding process is takes place.

V. Welding Process

The welding of catalytic converter consist of few components, namely the converter chamber, substrate and insulator to be welded together. The catalytic converter casing and chamber remain as same as originally installed in to 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.

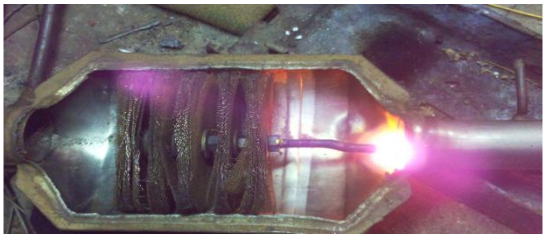

Fig.5.1.Welding of Catalyst substrate Package.

Thus packed wire mesh substrate is to be placed inside the converter chamber to react with the exhaust gases from engine. Since two sets of chemical catalytic substrate prepared, separate catalytic chambers are required.

Before placing the substrate insulation is necessarily placed to prevent the vibration of vehicle systems affecting substrate. Gas welding technique is used to weld the substrate and catalytic chamber cover. The catalytic converter is now allowed to cool to in room temperature.

- *Fabricated Catalytic Convertors*

After the welding process completed the new catalytic converter is ready for final testing procedures. There two converters prepared finally since two separate catalytic substrate is prepared for reducing the exhaust harmfulness from the automobiles.

Fig.5.2.Titanium Based catalytic Converter.

After preparing the catalytic converter are ready for fitting and testing in their respective make cars. Since we choose present catalytic converter to reduce fabrication work and also produced product should be able to fit in vehicle .we chosen “TATA INDICA” converter for preparing the prototype of new catalytic converter.

VI. Result And Discussion

- *Emission Testing*

The prepared new catalytic converter is to be subjected for emission testing for the effectiveness of the prepared catalyst. Emission testing is process in which a vehicle will be subjected to some tests to give the emission of harmful gases from that vehicle exhaust. Today’s government has giving more importance to the environment to protect atmosphere from pollution and public health. It publishes emission norms with reference to European standards. Since it also passes GO as Bharat Stage II (which is equivalent to European environment norm I) in 2000. After evolution of vehicles leads generation of various emission norms as Bharat Stage III and IV which are equivalent to European III and IV norms where announced in 2010.

Emission norms are certain values of exhaust emitted particles amount such as CO, HC, NO_x and Sulphur compounds which causes more pollution in environment to be restricted as per the norms published by the government.

- *Emission Testing Of Deisel Engine*

In testing of diesel engine totally depends on four parameters such as engine coolant temperature, fuel pump pressure, battery level and exhaust of engine. Coolant temperature is measured to prevent the detonations and unburnt fuel mixture levels. Fuel pumps pressure to ensure pressure of fuel pump on injecting into cylinder to maximum efficiency. Exhaust gas for analyzing the emission of the gases from the engine chamber after ignition.

Fig.6.1.Emission Testing of Diesel Engine.

1. Pump pressure output. 2. Battery and Inlet Manifold Output.
2. Engine Exhaust Output. 4. Emission Testing Equipment.

The above mentioned all four outputs are given to the input to the emission testing equipment. The emission level is indicated in the digital smoke meter indicator.

Fig.6.2.Smoke meter

- *Digital Indicator*

Emission testing done under four conditions such as without catalytic converter, with present catalytic converter, cerium based converter and titanium based converter.

- *Comparison Of Catalytic Converter Emission*

S. NO	CATALYTIC CONVERTER	K - VALUE	HSU - VALUE
1	Titanium Based Catalytic Converter	1.22	40.82
2	Cerium Based Catalytic Converter	1.32	43.31

VII. Conclusion

Finally the results of controlling emissions has revealed which states the performance of new catalytic converter and effectiveness of converting harmful compounds from the exhaust of engine. Comparison of catalytic converter with their emission values through testing.

The results are positive that is the new two catalyst catalytic converters are effective than the present OEM catalytic converter. The emission from exhaust is rectified up to 20% than the OEM fitted values.

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