Highly Efficient and Low Cost Substance Type Catalytic Convertor For Petrol Engine

Hardik J. Chauhan
B.E-Automobile, M. Engg. Studies AUT university, Newzealand

Abstract

Main focus of research paper is to develop efficient and low cost catalytic converter from metal oxides readily available in the market. Modern car are equipped with three way catalytic converter. Which are made from Platinum group metals (PGM) and Cerium oxide (CeO_2). Platinum group metals are 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, and PGM are costly. CeO_2 which is found in the Russia. It is required to Import in India for Manufacturing of catalytic converters. Work is to use metal oxides in Place of the PGM Group Metals and the oxide which are required to import such as CeO_2. In these work catalytic converter is developed based on catalyst materials consisting of metal oxides such as, Calcium oxide, titanium dioxide, Aluminium oxide and Silicate-kaolin and cobalt oxide in the form of pellet type. In which Cobalt oxide replaces PGM.

Keywords

CO: Carbone monoxide, CO2:Carbon dioxide, HC:Hydrocarbon, NOx:Oxides of nitrogen, Catco:catalytic convertor, Kw:Kilowatt, TWC:Three way catalytic converter , Pt.:Platinum, Rpm:Revolution per minute, Ppm:Part per minute, PGM:Platinum group metal, PCV:Positive crank case ventilation, EGR:Exhaust gas recirculation, Effi.:Efficiency, A/F:Air Fuel, CMC:Carbide methyl cellulose, Na2O3Si: Sodium silicate, TiO2:Titanium dioxide, CaO:Calcium oxide, CoO:Cobalt oxide, CeO2:Cerium oxide, Al2O3 :Aluminium oxide, SiO2:Silicon dioxide, Ec:Conversion efficiency.

1. Introduction

Background of ordinary catalytic convertor -

A catalytic converter has stainless steel box mounted in the exhaust system. An insulated chamber is there which consist of a porous bed coated with catalytic material through which hot exhaust oass es through before being discharged into the air. The substrate can be protected from vibration and shock by a resilient. The catalytic converter looks like a small muffler and is mounted in the exhaust system between the exhaust manifold and the actual muffler. It just forms a chamber for catalyst material in the exhaust systems through which the engine exhaust passes. When the exhaust gases of vehicle passes through catalyst material, the pollutants are converted into such products which pollute the environment in lesser amount.

The catalytic converter is made of following things:

1.1 The core or substrate. The core is is made of ceramic or stain less steel honeycomb in modern catalytic converters. The honey-comb surface increases the aviablity of contact that is between catalyst and exhaust, which makes it popular as "catalyst support".

1.2 The washcoat. A washcoat is used to make converters, It increases efficiency, , It id generally mix product of silica and alumina. when washcoat is added to the core, it creatres rough, irregular surface, which has greater surface area than the flat core surfaces do, so that converter core is able to create larger surface area. The catalyst is added to the washcoat (in suspension) before being applied to the core.The wash coat is very porous in order to increase the area between the gas phase and the catalyst. This is how it creates structure that exposes the maximum surface area of catalyst to the exhaust stream, it also helps to decrease the amount of catalyst required since they are very costly. The washcoat, in turn is, impregnated with the noble metals like Pd, Pt, and Rh which constitutes the active sites. It works as helping agent for the removal of the hazardous exhaust gases.

1.3 The catalyst this is working parts of converter most often a precious metal. It is a material that causes a chemical reaction without actually becoming a part of the reaction process. Platinum is the most active catalyst and is widely used. Many times it's not suitable for all operations because of unwanted additional reactions and higher cost. Palladium and rhodium are two other options, Platinum and rhodium can be used as a reduction catalyst, they have also quality of being used as an oxidization catalyst. Cerium, manganese and nickel are also used, although each has its own limitations .

2. Better and low cost catalyst preparation and fabrication-

The experimental methodology consists of two different parts. First one is catalyst and substrate preparation and fabrication of Catalyst. And the other one is emission test

In this work different type of configuration are chosen for the work.

1) Wire mesh substrate type.

2) Pellets types.

But we are working on pellet type catalytic convertor.

Method of preparation of above mentioned configuration is disused below.

2.1 Material selection

Titanium oxide, Sodium silicate, Calcium oxide, and Kaolin and Cobalt oxide were used as metal oxide catalyst. The pure cobalt oxide is used as reducing agent and other oxides as oxidizing agent. With each of above listed oxidizing metal oxide and cobalt oxides were paired for the catalyst as below. Metal oxides in the following combination were selected for the preparation of catalyst.

1) Titanium oxide and Cobalt oxide

2) Sodium silicate and Cobalt oxide

3) Calcium oxide and Cobalt oxide

4) Kaolin and Cobalt oxide.

2.2 Catalytic converter fabrication

2.2.1 Catalytic converter chamber

The fabrication catalytic converter is made of minimum components e.g.converter chamber, substrate. To avoid thermal optimization and design validation .converter was purchased from the market. Catalytic converter used in study is of 2008 model Toyota corolla provided by Walker. It is of Oval body and features of OEM convers are as follow:

- ✓ Material: Stainless steel
- ✓ Color/Finish: Natural
- ✓ Converter Case production Material: Stainless steel
- ✓ Product Fit: OE replacement

OEM converter was modified for the purpose of testing. First Converter is cut from middle then Cordierite of ceramic was taken out to use for comparison of test results. Than oval shape flanged were welded with the both segments that is attached by bolts and nuts. So that during testing catalyst made from different metal oxides can be replace easily. In between the flange gasket were placed to prevent leakage of the exhaust gases which are made from high heat resist champion sheet. Tapping for the temperature measurement was given to the converter by welding the coupling of ¾ inch at the inlet of the converter. Similarly for the pressure drop measurement ½ inch coupling is wedded at the inlet of the converter and at the outlet of the converter. One more tapping was made for the inserting the probe of the gas analyzer.

It was purchased from the market to reed of thermal optimization and design validation. In this pellets catalyst were loaded in to the catalyst camber is made of stainless steel wire mesh.

2.3 Pellets type catalyst

2.3.1 Material selection

For pallets type catalyst material selection and pare of oxidized and reducing metal oxides.

2.3.2 Slurry preparation

This is the metals combination we use for a catalyst.

500gm Titanium oxide + 50gm cobalt oxide (10% CoO) + sodium silicate

500gm Calcium oxide + 50gm cobalt oxide (10% CoO) + sodium silicate

500gm Kaolin + 50gm cobalt oxide (10% CoO) + sodium silicate

Sodium silicate solution and carbide methyl cellulose (CMC) were used as binder and pore former respectively.100 grams of sodium silicate solution was added. into 1 kg of metal oxide(such as TiO_2) water was added to make paste than 100 gm. of Sodium silicate solution were added. The slurry then stirred well. 24 grams of CoO and 30·0 gm. of carbide methyl cellulose (CMC) was gradually added (See appendix A for selection of composition). To ensure homogenization, it milled for around 6·0 hours by using ball mill and then left dried in sunlight for few hours.

2.3.3 Pellets preparation

Pallets of approximate size ½Inch were prepared than dried in sunlight for two day before calcination in a natural gas fired open air furnace.

Calcination is a process in which a material is heated at high temperature without fusing in such a way which cause hydrates, carbonates, or other compounds to be decomposed and the volatile material is expelled.

(a) Slurry of TiO_2/CoO

(b) calcinated pellets of TiO_2/CoO

(c) Pellets in the Stainless steel bag.

Calcinations take 6·0 hours at a temperature of 500◦C with temperature ramping upon 10·0◦C/min and holding time of a 300 minutes. Similar method is followed for the all set of metal oxides.

(a) Slurry of CaO/CoO

(b) CaO/CoO Pellets

(c)Slurry of Kaolin/CoO

(d) calcinated pellets of Kaolin/CoO.

2.3.4 Catalytic converter fabrication

It was purchased from the market to reed of thermal optimization and design validation. In this pellets catalyst were loaded in to the catalyst camber is made of stainless steel wire mesh. With the size of 8cm by 15 cm by 10 cm.

2.4 Properties of metal oxides

Titanium dioxide (TiO_2): Titanium dioxide, Tio_2 served as dual function: catalyst and a titanium substrate for the wash coat. It is white in color. TiO_2 occurrence in nature in the three form rutile, anatase and brookite. In which Rutile form of TiO_2 was chosen because of its thermal stability from 500C and high durability. Both metastable anatase and brookite phase converter to rutile upon heating, density of TiO_2 is 4.2 g/cm^3 ,it melting point is 1843°C and boiling point is 2972°C.

Cost calculation for the TiO_2/CoO pellets catalyst.	
1Kg. Tio_2@157Rs./Kg	9.42 Rs.
24 gm. CoO@6144Rs./Kg.	147.45 Rs.
100 gm. Sodium silicate@85Rs./Kg	8.5 Rs.
30gm CMC@60 Rs./Kg	1.8 Rs.
Total cost.	314.76 Rs.

Calcium oxide (CaO): commonly known as quicklime or burnt lime, is a widely used chemical compound. Appearance of CaO is white to pale yellow powder. The broadly used term lime connotes calcium , it is made of inorganic materials. Such inorganics are silicon, magnesium, carbonates, oxides and hydroxides of calcium, aluminum, & iron prominate. On other hand, quicklime is mostly appllied to a single chemical compound. Calcium oxide is produced by the thermal decomposition of materials such as limestone, this cmaterial always ontains calcium carbonate in a lime kiln. This is possible by heating of material above 825 °C, a process called calcination, to liberate a molecule of carbon dioxide (CO_2); leaving quicklime. The quicklime is not stable material. when it is cooled it spontaneously reacts with CO_2 from the air, after enough time, it is completely converted back to calcium carbonate. It having density 3.35 g/cm^3, melting point 2572 °C, and boiling point 2850°C.

Cobalt oxide (CoO): Cobalt oxide is Black- gray crystalline power It is a metallic pigment that provides blue coloring in porcelains and glass. Various forms of cobalt oxide can be achieved. One of them is CoO at 850-900°C. CoO is basically grayish brown powder which can be decomposed at 1935 °C and it is insoluble in water. It is also possible to use it as a drying agent in inks, varnishes and fertilizer additive. Cobalt Oxide remains stable in air. It have specific gravity 6.11, melting point 895 °C and boiling point 3800°C.

Kaolin (Al_2O_3+SiO_2): Kaolin is a clay mineral, also considered in the group of industrial minerals, which contain SiO_2 and Al_2O_3. Kaolin contains around 36% of Al_2O_3 and reaming main is SiO_2. It is a layered silicate mineral which consist tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedra. Basically rocks which are rich in kaolinite are known as china clay, white clay or kaolin. China clay is used widely in ceramic , paints, plastic, paper and many more industries. It appearance is white fine powder and specific gravity 2.6.

2.5 Cost estimation of catalyst

Specific cost shown here are drawn from global inquiry magazine these cost have also be validate by Ceramic industrialist.

Sr. no	Material	Price
1	Cobalt oxide	4500 Rs/Kg
2	Titanium dioxide	300 Rs/Kg
3	Calcium oxide	18 Rs/Kg
4	Kaolin	100 Rs/Kg
5	Sodium silicate	60 Rs/Kg
6	Steel wire mesh	24 Rs./ft2
7	Platinum(for comparison)	2203079 Rs/Kg

Similarly cost calculation have been done for the other catalyst of wiremesh as shown below:

Catalyst according cost Rank	Catalyst	Cost
1.	CaO/CoO Pellets	175.76
2.	Kaolin/CoO Pellets	177.76
4.	TiO_2/CoO Pellets	314.76
5.	OEM catalyst. 1gm Pt.	2203

3.0 experimental study carried:

All of the test experiments were conducted with Kirloskar engine 1.0L gasoline engine 3 cylinder, 4-stroke. .Having maximum power 54.0 hp at 5500 rpm, compression ratio 9.5:1

3.1 Exhaust gas analyser

In this study gas analyzer used is high quality infra-red gas analyzer from Neptune Equipment Model PE-A-205 was used for the testing the performance of the catalytic converter, with an ability to measure potentially harmful emissions from petrol engines. Along with measuring the exhaust gases it also measures the engine speed (RPM), which avoids the use of tachometer. Main features of Exhaust gas analyser are measurement of carbon monoxide (CO) in %; measurement of hydrocarbons (HC) in PPM; engine speed in RPM; easy to read bright red 1" LED display with an option to read either CO and HC or CO and RPM; It measure CO emission in the range of 0-10% vol with accuracy 0.6% and HC emission in the range of 0-200000 ppm with accuracy 10ppm.

Fig. Exhaust Gas analyser

3.2 Experiment data

Table 1- Exhaust emission of engine when Original catalytic converter (OEM Catalytic convertor) is fitted

SPEED (RPM)	LOAD (KW)	TEMP (°C)	CO		HC	
			IN	OUT	IN	OUT
	0	175	4.1	4	510	500
	1	200	5.5	4.2	670	600
	2	215	8.5	6	800	710
	3	250	8	5.2	820	790
	4	310	6.2	4.2	700	530
	5	320	6.4	4.5	680	620
	6	322	9.4	6	760	710
1500	7	325	10.5	6.5	1100	750
	8	320	6.9	3.6	850	600
	9	325	9	7	880	750
	10	328	9.5	7.2	1000	760
	11	330	9.8	7.5	980	800
	12	332	7.2	3.7	1050	700
	13	335	9.5	7.1	1200	800
	14	340	9.8	7.3	1700	860
	15	360	11	7.5	1500	880

Table 2- Exhaust emission of engine when Tio2/CoO Pallets type converter is fitted

SPEED (RPM)	LOAD (KW)	TEMP (°C)	CO		HC	
			IN	OUT	IN	OUT
	0	175	4.1	1.1	510	390
	1	200	5.5	1.4	670	330
	2	215	8.5	6.5	800	270
	3	250	8	4.2	820	300
	4	310	6.2	1.2	700	450
	5	320	6.4	1.5	680	400
	6	322	9.4	5	760	280
	7	325	10.5	6	1100	250
1500	8	320	6.9	1.1	850	360
	9	325	9	5	880	270
	10	328	9.5	6.2	1000	270
	11	330	9.8	6.8	980	360
	12	332	7.2	1.3	1050	360
	13	335	9.5	5.2	1200	280
	14	340	9.8	6.7	1700	270
	15	360	11	7	1500	270

Table 3- Exhaust emission of engine when CaO/CoO Pallets type converter is fitted

SPEED (RPM)	LOAD(KW)	TEMP (°C)	CO		HC	
			IN	OUT	IN	OUT
	0	175	4.1	2.5	510	350
	1	200	5.5	3.9	670	300
	2	215	8.5	2.9	800	400
	3	250	8	5	820	460
	4	310	6.2	4.5	700	330
	5	320	6.4	5	680	270
	6	322	9.4	5.9	760	300
	7	325	10.5	7	1100	410
1500	8	320	6.9	2.5	850	440
	9	325	9	5.2	880	500
	10	328	9.5	6	1000	370
	11	330	9.8	7.3	980	490
	12	332	7.2	5.2	1050	340
	13	335	9.5	7	1200	270
	14	340	9.8	7.5	1700	390
	15	360	11	7.4	1500	500

Table 4- Exhaust emission of engine when Kaolin/CoO Pallets type converter is fitted

SPEED (RPM)	LOAD (KW)	TEMP (°C)	CO		HC	
			IN	OUT	IN	OUT
	0	175	4.1	2	510	380
	1	200	5.5	3.2	670	310
	2	215	8.5	2.1	800	390
	3	250	8	4.9	820	420
	4	310	6.2	2.5	700	400
	5	320	6.4	4.2	680	300
	6	322	9.4	4.9	760	400
	7	325	10.5	5	1100	440
1500	8	320	6.9	2.4	850	300
	9	325	9	5	880	290
	10	328	9.5	6.5	1000	430
	11	330	9.8	7	980	470
	12	332	7.2	5	1050	320
	13	335	9.5	6	1200	330
	14	340	9.8	7	1700	500
	15	360	11	7.3	1500	490

4.0 Comparison of Each type of catalytic convertor with respect to Experiment data

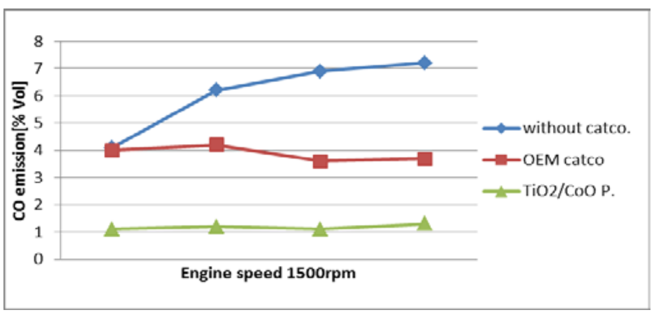

Figure: CO Emission Vs. engine speed (without catco, with OEM and TiO2/CoO converter) (According to data of Table No 2)

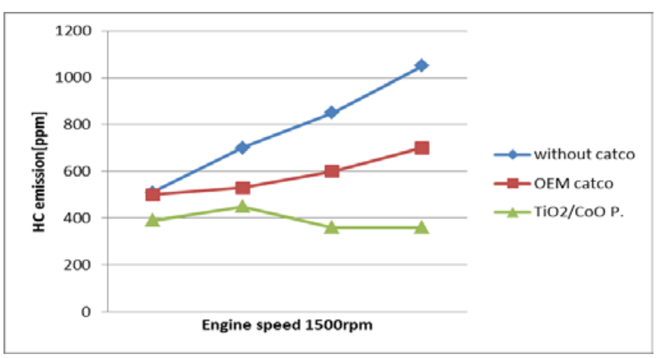

Figure : HC emissions Vs. engine speed (without catco, with OEM and TiO_2/CoO converter) (According to data of Table No 2)

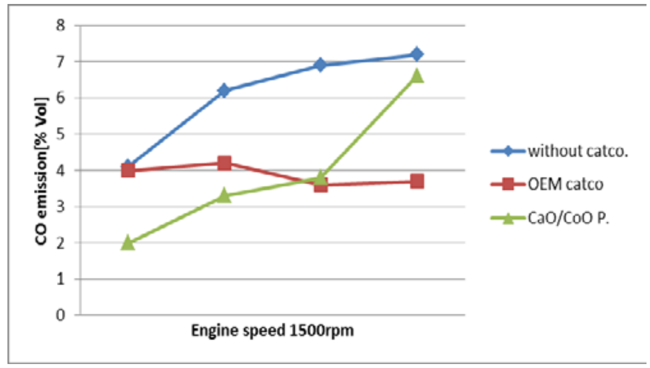

Figure: CO Emission Vs. engine speed (without catco, OEM and CaO/CoO converter) (According to data of Table No 3)

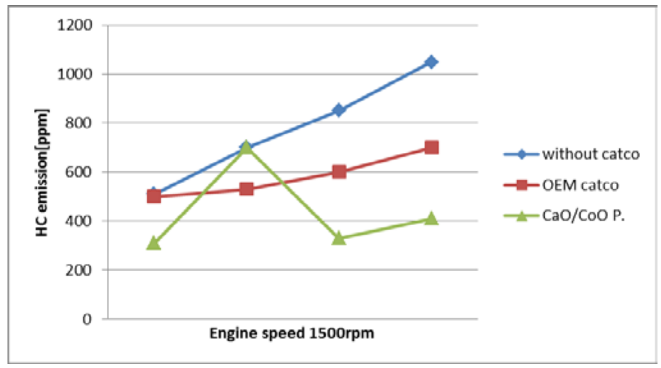

Figure: HC Emission Vs. engine speed (without catco, with OEM and CaO/CoO) (According to data of Table No 3)

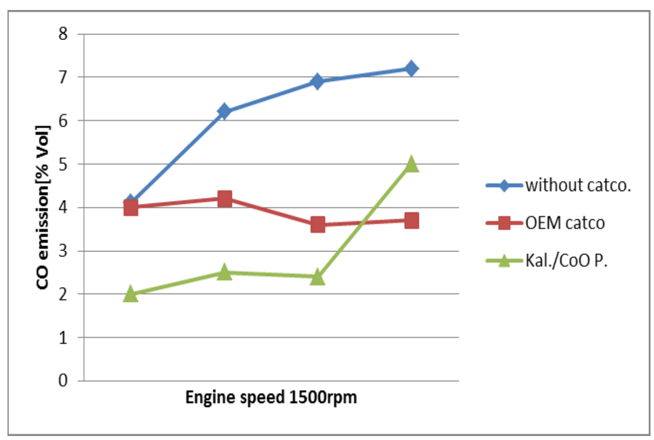

Figure: CO Emission Vs. engine speed (without catco, with OEM and Kal. /CoO) (According to data of Table No 4)

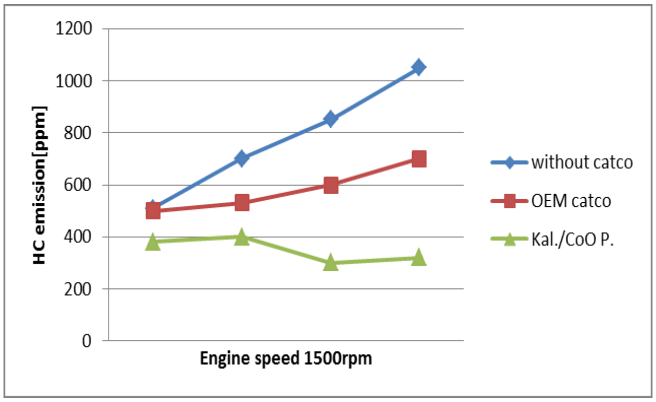

Figure: HC Emission Vs. engine speed (without catco, with OEM and Kal. /CoO) (According to data of Table No 4)

5.0 Performance comparison of All Metal oxide based Catalytic Converters

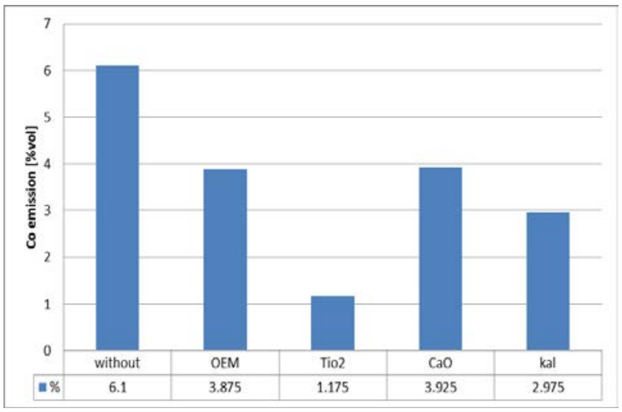

Figure: CO emission without catco, OEM and Metal oxide catalytic converters.

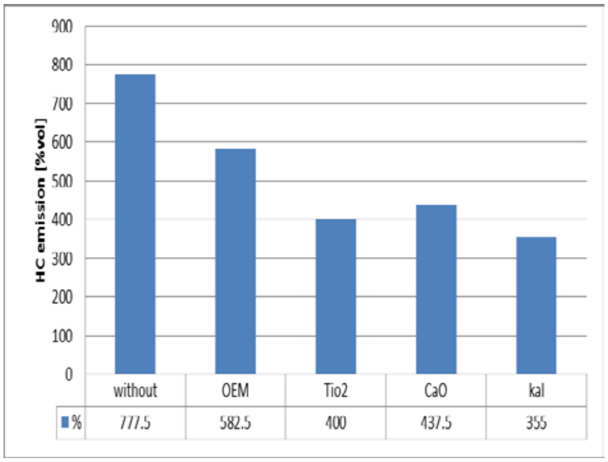

Figure: HC emission without catco, OEM and Metal oxide catalytic converter

6.0 Conclusion

Three-way catalytic converters have been improved a lot since its launch in late 1970's. Though their main purpose has remained the same, Conversion from harmful CO, HC and NO into CO_2, H_2O and N_2, have been constantly improving with respect to system performance. All modern cars are equipped with three way catalytic converter, which are made from Platinum group metals (PGM) and Cerium oxide (CeO_2). Platinum group metals are identified as human health risk due to their rapid emissions in the environment from various resources like conventional catalytic converter. The CeO_2 is found in the Russia. It is required to Import in India for Manufacturing of catalytic converters. By this research try was attempted to manufacture raw material of catalytic convertors in India itself. Metal oxides are readily available in Indian market, so manufacturing of low cost catalytic convertors is possible.

Based on the present experimental study, use of metal oxides as catalyst in the catalytic converter for gasoline fuelled engine were investigated and the following Judgment can be drawn:

(1) Negligible reduction in CO and HC emission were observed at low temperature with OEM converter
(2) It is also experimentally proved that highest conversion efficiency from the tested catalytic convertor was obtained by TiO_2/CoO pellets. CO and HC conversion efficiency are 53.42% and 61.47% respectively and it is reduced to 23.70 % and 39.32% in OEM system. Na_2O_3Si /CoO based pellets catalytic converter reduced 19.48% CO emission and 37.64% HC emission which is also more than the OEM Catalytic Converter reduction rate. Least reduction was by the CaO/CoO pellets catalytic converter.
(3) From the tested catalysts, Least price offered by the CaO/CoO pellets catalyst, material cost was INR 175. The highest material cost offered by the TiO_2/CoO catalyst of INR 314. When it is compared with the OEM catalyst and considered only cost of Platinum contain in the catalyst, best performance is given by catalyst (TiO_2/CoO pellets). It shows 85% cost reduction.

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