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REVIEW ON CHANGING THE MATERIAL OF A DIESEL ENGINE CATALYTIC CONVERTER TO REDUCE EXHAUST EMISSIONS

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Abstract— In automobile industry, the exhaust from the internal combustion engine is a complex mixture of gases and fine particles. Many pollutants are introduced in the environment such as Carbon Monoxide (CO), Nitrogen Oxides (NOx), Hydrocarbons (HC), etc. These pollutants may lead to affect the respiratory system as well as increase the risk of heart problems, premature death and lung cancer. To control the emission of these pollutants in environment catalytic converters are used. The commonly used catalyst in converters is mostly a precious metal such as Palladium, Palladium and Rhodium. Platinum is widely used and very active catalyst, but is very expensive. Rhodium is used as reduction catalyst, while Palladium is used as oxidation catalyst. Since, these materials are expensive the cost of catalytic converter increases. Thus the purpose of the project is to improve effectiveness of catalytic converter by using a different material along with the regular used noble metals. These materials perform the same task along with the catalyst and the additional task of storing and releasing oxygen during rich mixture combustion.

Keywords – catalytic converter, material, exhaust emissions, diesel engine, copper oxide

I. INTRODUCTION

Whenever there is incomplete combustion of fuel many harmful gases are formed. In automobiles, the exhaust from the internal combustion engines is a major aspect which shows such phenomenon. Many harmful gaseous pollutants are emitted in the atmosphere such as carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC), etc. These harmful gases lead to various respiratory problems as well as heart issues, early death and lung cancer. To control these emissions in air catalytic convertors are used. The mostly used catalysts in these convertors are mostly noble metals such as Platinum, Palladium and Rhodium. Platinum is commonly used and very active catalyst, but very costly. Rhodium is used as a reduction catalyst and Palladium is used as an oxidation catalyst. The purpose of this project is to improve emission conversion of Catalytic converter with optimum cost by studying different catalysts. Catalyst such as cerium, iron, manganese and nickel are also used in catalytic converter. In this project emissions of different pollutants from a commercial Piaggio engine would be checked by changing the material of the catalyst used in a catalytic converter. By performing these tests we will optimize the engine performance by reducing in emissions of pollutants like carbon monoxide (CO), nitrogen oxides (NO_X) and hydrocarbons (HC) and this will result in reduced air pollution.

II. DIFFERENT TYPES OF CATALYTIC CONVERTERS

A. Two way catalytic converter

Fig. 1 Two way catalytic converter

This type is also known as a two-way catalytic converter, because it can only operate with hydrocarbons (unburned fuel) and carbon monoxide (caused by partially-burned fuel). Oxidation converter elements are usually covered in platinum.

Oxidation of carbon monoxide to carbon dioxide:

$$2CO + O2 \rightarrow 2CO2$$

Oxidation of unburnt hydrocarbons (unburnt and partially-burnt fuel) to carbon dioxide and water:

$$CxH2x+2 + 2xO2 \rightarrow xCO2 + 2xH2O$$

B. Three way catalytic converter

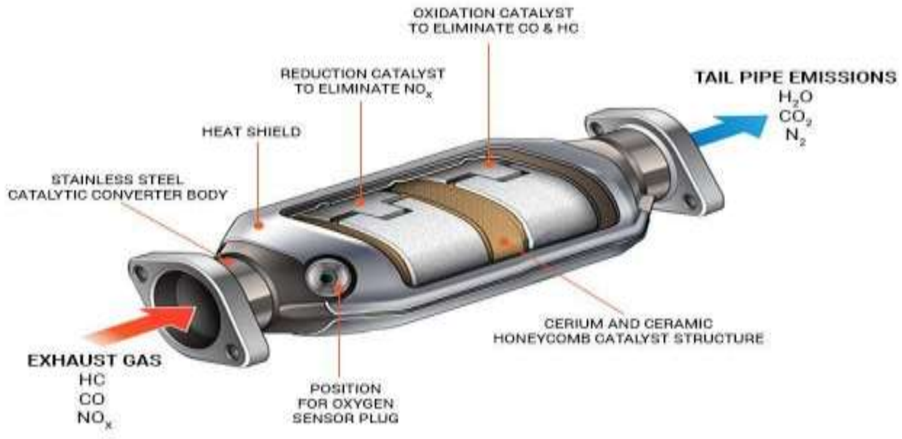

Fig. 2 Three way catalytic converter

Similar to the oxidation converter, the reduction catalytic converter helps eliminate hydrocarbons and carbon-monoxide emissions, plus oxides of nitrogen emissions, or NOx. NOx emissions are produced in the engine combustion chamber when it reaches extremely high temperatures more than 2,500 degrees Fahrenheit, approximately.

Reduction of nitrogen oxides to nitrogen and oxygen:

$$2NOx \rightarrow xO2 + N2$$

Oxidation of carbon monoxide to carbon dioxide:

$$2CO + O2 \rightarrow 2CO2$$

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

$$CxH2x+2 + 2xO2 \rightarrow xCO2 + 2xH2O$$

III. PURPOSE OF CATALYTIC CONVERTER

In the converter, the gases pass through a fine honeycomb structure made from ceramic and coated with the catalysts. The honeycomb structure is used for providing the gases a bigger area of catalyst so they can be converted more quickly and efficiently. There are two different sorts of catalysts in a catalytic converter:

One of them handles nitrogen oxide pollution using a chemical reaction called **reduction** (removal of oxygen). This disintegrates up nitrogen oxides into nitrogen and oxygen gases which are harmless and basically found around us.

The other catalyst works by an opposite chemical process called **oxidation** (addition of oxygen) which converts toxic carbon monoxide into non toxic carbon dioxide. Another oxidation reaction turns unburned harmful hydrocarbons in the exhaust into carbon dioxide and water which is in the form of steam.

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Simultaneously, three different chemical reactions are going on at the same time. That's why it is called **three-way catalytic converters**. After the catalyst has completed its job, exhaust is mostly nitrogen, oxygen, carbon dioxide, and water (steam).

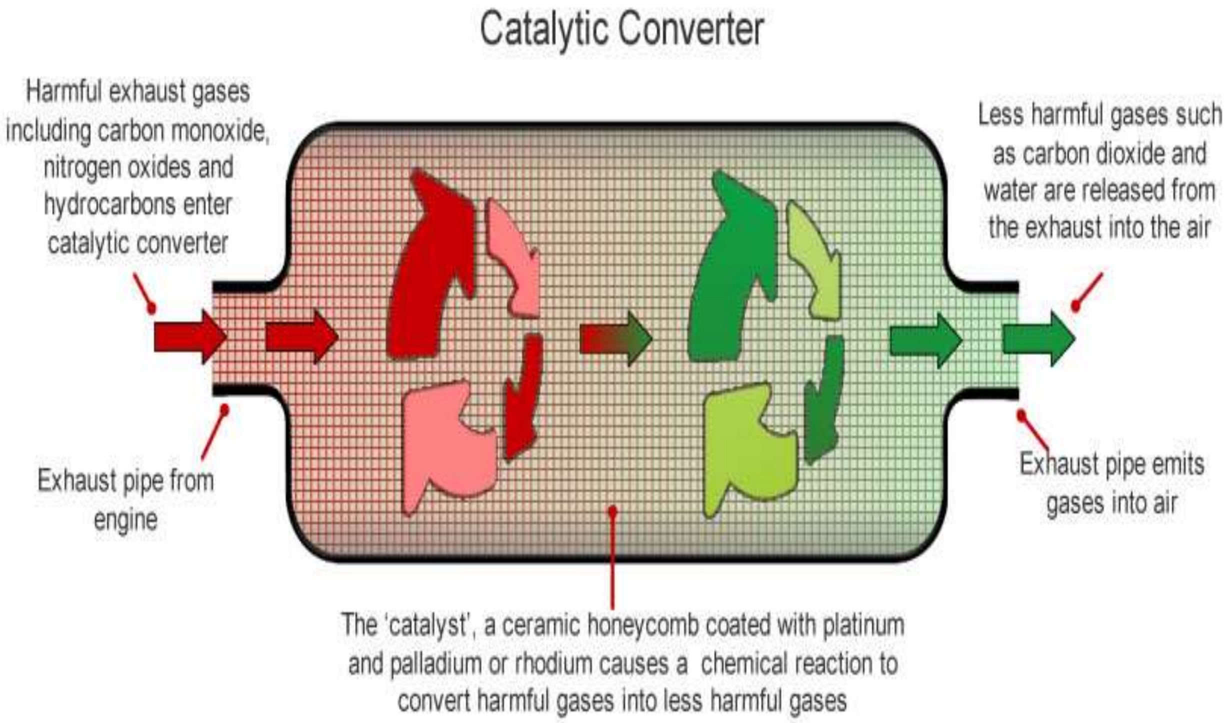

Fig. 3 Purpose of a catalytic converter

It is preferred to fulfill the following requirements:

1. To reduce the harmful engine exhaust
2. To overcome frequently optimizing emissions
3. For human health betterment
4. Reduction in HC and CO emission
5. To reduce air poolution.

IV. LITERATURE REVIEW

Table. 1 Literature Review

Sr.no	Title	Author	Conclusion
1	Experimental and CFD analysis of Selective Catalytic Reduction System on DeNOx Efficiency of Single Cylinder Diesel Engine Using NH3 as a Reducing Agent	Manoj Kumar A.P, Sreekumar J S, Mohanan P	At optimum exhaust gas temperature(654K) and 50% load conditions maximum of 56% of conversion is achieved and for higher loads the conversion rate decreases due to high temperature.

2	Optimum Design of Manganese-Coated Copper Catalytic Converter to Reduce Carbon Monoxide Emissions on Gasoline Motor	RM. Bagus Irawan, P. Purwanto , H. Hadiyanto	Use of manganese coated copper as a catalyst in Catco increases the reduction in CO emissions.
3	Exhaust analysis of C.I engine by using zirconium dioxide coated Wire mesh catalytic converter - Review study	Krunal P. Shah1 Dr. Pravin P. Rathod2	Zirconium dioxide is cheaper than platinum and palladium and it significantly reduces the exhaust emissions.
4	Development of Low Temperature Active Catalysts for CO and VOC Abatement	Monika Molin	The molar ratio of 80 mol% Palladium and 20 mol% Platinum is preferable for low light off temperature and high conversion. The addition of Cerium Dioxide further reduces light-off temperature.
5	Copper based catalytic converter	Chirag M. Amin, Prof. Pravin P. Rathod, Prof. Jigish J. Goswami	The use of copper based catalytic converter reduces emissions of HC by 38% and CO by 33% and it is also feasible to use as it is cheaper than noble metals.
6	Emission Characteristics Of A Compression Ignition Engine Using Different Catalyst	P. V. Walke, Dr. N. V. Deshpande, A.K.Mahalle	The catalyst zirconium dioxide+cerium oxide reduces NOx emissions. Zirconium dioxide alone decreases HC emissions. There is nominal decrease in Brake thermal efficiency.
7	Design and manufacturing of Nano catalytic converter for pollution control in automobiles for green environment	Durairajan, Kavitha, Rajendran, Kumaraswamidhas.	The nano catalytic convertor with no load condition there is reduction in 33.3% NOx, 72.1% HC and 60% CO. At peak load condition reduction is 84.3% in NOx, 78% in peak load and 69% in CO.

V. EXPERIMENTAL SETUP

A. Actual experimental setup

In the first stage the emissions are measured using emission testing machine without use of the catalytic converter in the exhaust system. This setup provides data about the actual emissions through the engine.

A rope brake dynamometer is attached to the engine to measure the torque initially and through this data the power can be obtained.

An emission testing machine is attached after the catalytic converter which will check the proportions of the emissions and show it on the digital display.

The experimental setup for the same is given as under.

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Fig. 4 Experimental Setup

Fig. 5 catalytic converter

We tested the engine emissions under the following conditions:

- No load condition.
- Peak load condition.
- Without catalytic converter.
- With catalytic converter.
- Keeping the conventional noble metal catalyst.
- Using the newly developed catalyst.

B. Block Diagram for Test on the Engine emissions with catalytic converter attached in the setup.

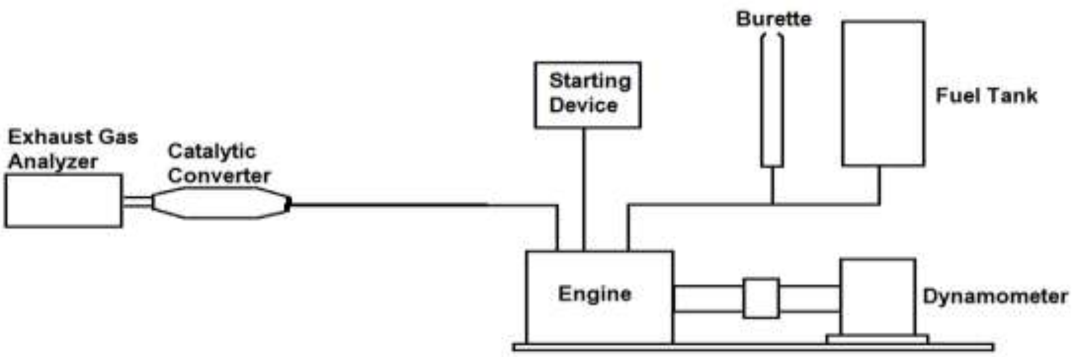


Fig. 6 Block Diagram for Test on the Engine emissions with catalytic converter attached in the setup.

C. Catalytic converter design

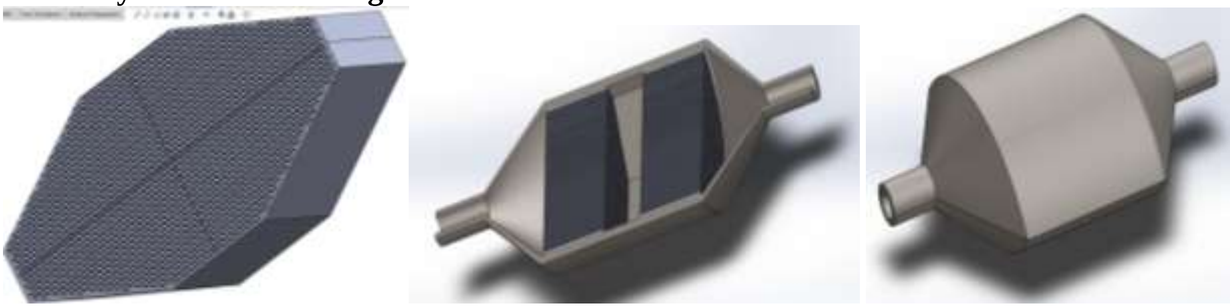


Fig. 7 Catalytic converter design.

D. Reading table

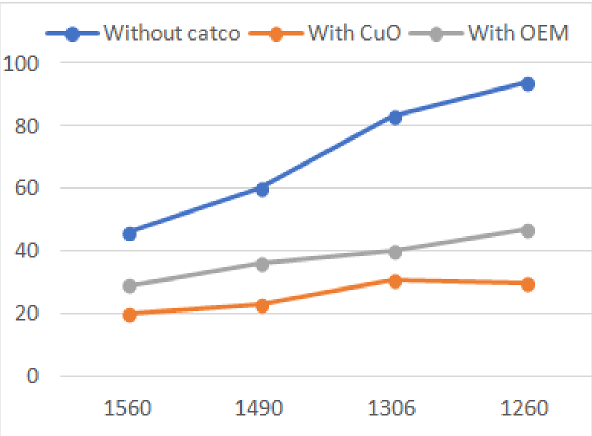
Load	Speed	Manometer Height	Fuel Consumption	Exhaust content			Exhaust Content (CuO)			Exhauast Content (OEM)			EXHAUST TEMP	BP	BSFC	TORQUE	Reduction in HC	Reduction in CO
			10 ml	HC	CO	CO2	HC	CO	CO2	HC	CO	CO2						
Kg	rpm	cm	sec	ppm	%	%	ppm	%	%	ppm	%	%	C	kW	g/kWh	Nm	%	%
0	1560	10.7	57	46	0.08	2.24	20	0.07	2.57	29	0.08	2.36	112.35	0	[redacted]	0	31.03	12.50
	1490	9.6	91	60	0.09	1.89	23	0.08	2.02	36	0.09	1.93	118.67	0	[redacted]	0	36.11	11.11
	1306	8.2	110	83	0.11	1.46	31	0.08	1.74	40	0.11	1.64	123.86	0	[redacted]	0	22.50	27.27
	1260	7.6	122	94	0.12	1.22	30	0.09	1.49	47	0.11	1.36	128.95	0	[redacted]	0	36.17	18.18
3	1480	10.5	55	56	0.08	2.57	22	0.06	2.85	32	0.08	2.67	131.44	0.681	0.266	4.4	31.25	25.00
	1360	8.8	80	61	0.10	2.25	26	0.07	2.48	34	0.08	2.36	134.57	0.626	0.199	4.4	23.53	12.50
	1270	8.0	100	86	0.11	1.62	31	0.07	2.06	45	0.09	1.85	136.92	0.585	0.17	4.4	31.11	22.22
	1180	7.4	114	97	0.12	1.32	35	0.08	1.64	53	0.1	1.48	141.24	0.543	0.161	4.4	33.96	20.00
5	1100	7.2	47	62	0.06	2.89	22	0.05	3.36	36	0.05	3.03	143.65	0.852	0.249	7.4	38.89	0.00
	1010	6.5	78	71	0.07	2.43	30	0.06	2.78	41	0.06	2.57	146.78	0.782	0.163	7.4	26.83	0.00
	950	6.2	95	85	0.07	1.79	34	0.06	2.14	45	0.07	1.93	148.64	0.736	0.143	7.4	24.44	14.29
	876	6.0	106	103	0.08	1.48	43	0.07	1.78	64	0.09	1.59	153.54	0.678	0.139	7.4	32.81	22.22
8	1009	6.3	43	60	0.06	3.24	28	0.03	4.23	41	0.04	3.83	156.65	1.267	0.182	12	31.71	25.00
	910	5.7	72	76	0.06	2.92	32	0.03	3.82	47	0.04	3.34	160.73	1.143	0.121	12	31.91	25.00

	850	5.2	89	97	0.06	2.53	39	0.04	3.02	60	0.05	2.76	163.88	1.068	0.105	12	35.00	20.00
	767	4.9	99	112	0.07	1.92	56	0.05	2.76	72	0.06	2.27	168.76	0.963	0.104	12	22.22	16.67

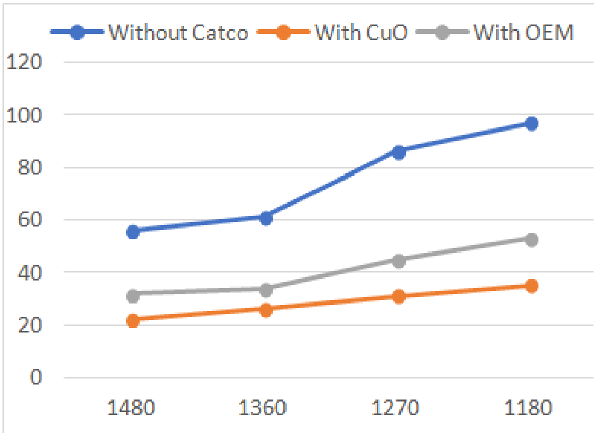
Table.1 Reading Table

VI. COMPARATIVE ANALYSIS

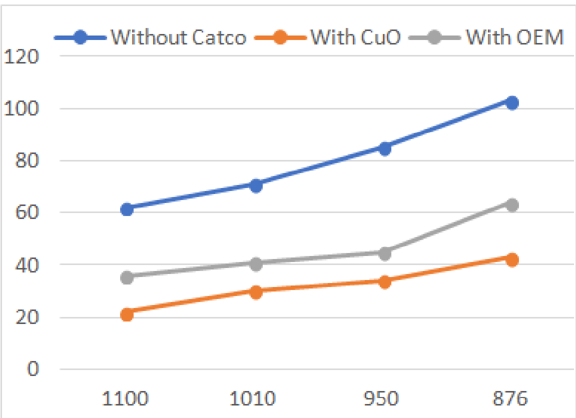
The graph of rpm versus hydro carbon emissions is plotted as shown below. From the graph we can observe that as the rpm decreases the hydro carbon emissions increases. It can also be noted from all the four graphs that as the load increases from no load condition to 3kg, 5kg, 8kg load conditions the emissions of hydrocarbons also increases. It is seen in the graph that the emissions are high for the readings taken without using a catalytic converter. The emissions from the copper oxide based catalyst are quite less than the emissions from the OEM catalytic converter. This effect is seen because of the oxygen storage capacity of copper oxide with is further helpful in conversion of HC and CO to H2O and CO2.



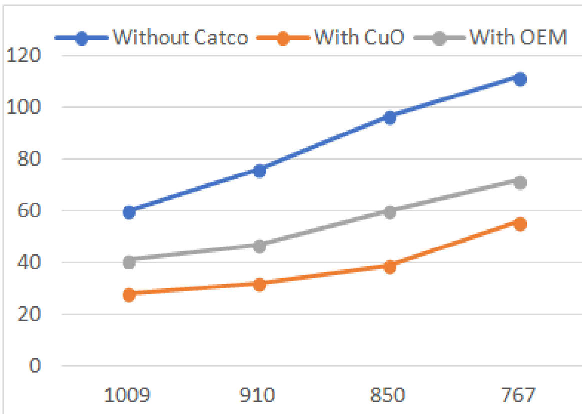
g-1.1 rpm vs hc emissions(ppm)-load 0 kg



g-1.2 rpm vs hc emissions(ppm)-load 3 kg

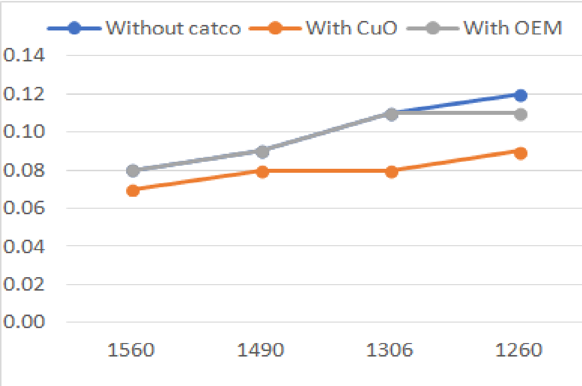


g-1.3 rpm vs hc emissions(ppm)-load 5 kg

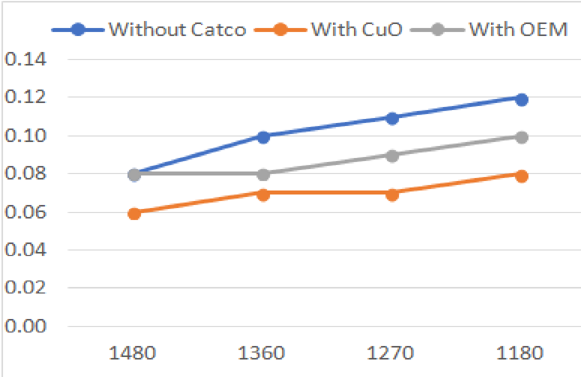


g-1.4 rpm vs hc emissions(ppm)-load 8 kg

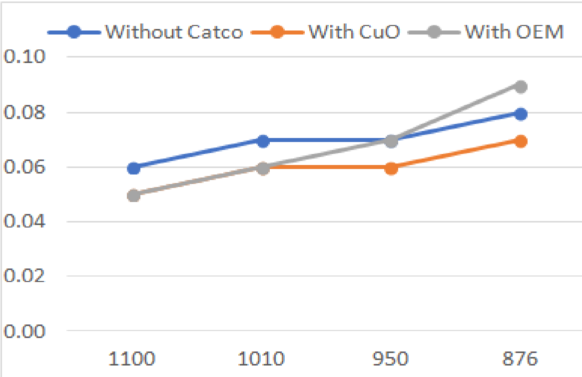
The graph of rpm versus carbon monoxide emissions is plotted as shown below. From the graph we can observe that as the rpm decreases the carbon monoxide emissions increases. It can also be noted from all the four graphs that as the load increases from no load condition to 3kg, 5kg, 8kg load conditions the emissions of carbon monoxide also increases. It is seen in the graph that the emissions are high for the readings taken without using a catalytic converter. The emissions from the copper oxide based catalyst are quite less than the emissions from the OEM catalytic converter. This effect is seen because of the oxygen storage capacity of copper oxide with is further helpful in conversion of HC and CO to H2O and CO2. Actually the variations are not much visible in carbon monoxide emissions because the exhaust gas analyser was showing CO percentage by volume up to two decimal points only.



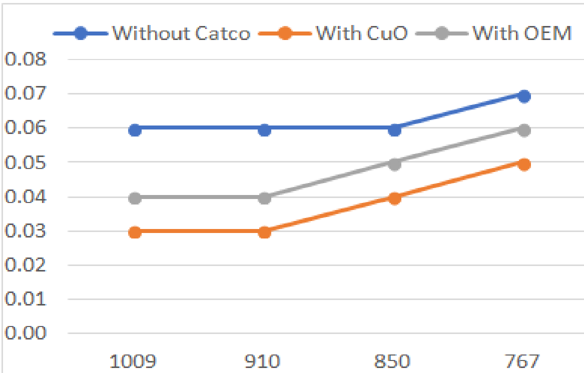
g-2.1 rpm vs co emissions(%)-load 0 kg



g-2.2 rpm vs co emissions(%)-load 3 kg

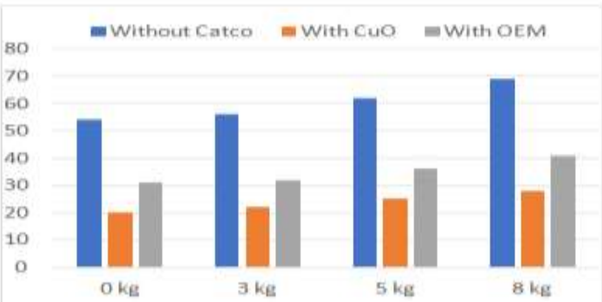


g-2.3 rpm vs co emissions(%)-load 5 kg

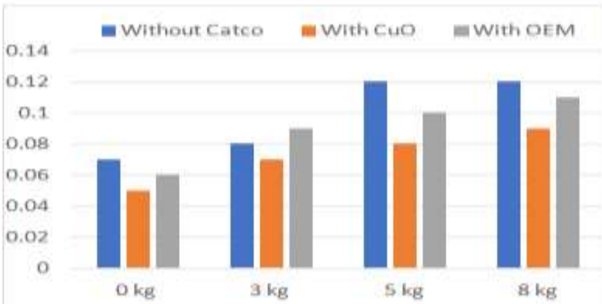


g-2.4 rpm vs co emissions (%)-load 8 kg

The graphs for emissions from the engine at different load variations are shown below for carbon monoxide, carbon dioxide and hydrocarbons. The readings are shown for the maximum rpm condition. It can be seen that there is a notable rise in the emissions as the load increases. But it is also noted that the emissions in the copper based catalyst are less than the OEM catalytic converter.



g-4.1 load vs hc emissions (ppm)



g-4.2 load vs co emissions (%)

VII. CONCLUSION

After conducting the experiment it can be seen that the use of Copper Oxide along with the noble metals Platinum, Palladium and Rhodium, provide quite satisfactory results. The experiment was carried out for different speed at different load conditions. The use of Copper Oxide along with the conventional noble metals as catalysts reduces the emission content of the hydrocarbons and carbon monoxide significantly. The results show that there is around 30-40 % decrease in the hydrocarbon emission and 20-25 % decrease in carbon monoxide emissions compared to the existing catalytic converter. The results show that on increasing the speed the emission content decreases and on increasing the load the emission content increases. Thus, the reduction in environment pollution can be achieved at optimum cost by using copper oxide to construct effective catalytic convertor.

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