DEVELOPMENT AND PERFORMANCE ANALYSIS OF Zn BASED CATALYTIC CONVERTER

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Abstract -

***Background**: In last two decades there is boom in automobile sector, as more and more people are buying cars and standard of living has increased drastically. As we know there are several advantages of cars but is also comes with few disadvantages and one of the major disadvantage is pollution coming from the cars. The major air pollutants coming from car's exhaust gases are CO, HC & NOx. These air pollutants have severe effects not only to the nature but also to all the living beings.*

***Materials and Methods**: Hence to limit these harmful air pollutants, Catalytic converter are used. Catalytic converters purify these harmful pollutants. Example: CO → CO_2, HC → CO_2 & H_2O and NO_x → O_2 & N_2. These conversion of harmful pollutants (Gases) to harmless gases is done with help of catalyst used in Catalytic converter.*

These catalysts do oxidation and reduction reaction to the exhaust gases passing through them. Conventional catalytic converter uses Noble catalysts such as Pt, Pd & Rh. These catalysts are very expensive &rare and costs about 2% of total car price. Hence to limit these prices we replace the Noble catalyst with Non-Noble catalysts Cu & Zn.

***Results**: In this experiment we used **Zinc** as a catalyst and it does a fantastic job in limiting Exhaust emission gases but **not** as **efficient** as Copper (As we have tested earlier and published in our previous paper Article ID: FTP804F2314).*

***Key Words**: Catalytic converter; Noble catalysts; Pt; Pd; Rh; Non-Noble catalysts; Copper; Zinc.*

1. INTRODUCTION

It has been found that about 1/3 rd. of pollution on earth is due to automobile emissions. Hence to deal with these several standard emission norms introduced such Euro norms, BS norms in INDIA etc. These norms provide standard emission [i.e., Exhaust harmful emission (Pollutants) should be within the defined standard norms]. A standard catalytic converter purifies 90% of harmful gases passing through them. These Conventional catalytic converter costs about 60-70k Rs. Our aim is to reduce these costs of CC by significant amount, by replacing the Noble catalysts with Non-Noble catalyst i.e., Zinc. We choose Zinc as a non-noble catalyst because of its oxidation capabilities, melting point(As temp. inside CC reaches up to 800 ◦F) and its availability.

2. Experimental setup

In this experiment, four strokes single cylinder Diesel engine is used to carry out experiment. Experimental set up is shown in figure 1. This experimental setup consists of a single cylinder four strokes Diesel engine, U tube Tank, manometer, Burette, Display unit, Engine Flywheel, Dynamo meter, Catalytic Converter & Emission Analyzer. Catalytic Converter connected to Electric type dynamometer for loading and also there is Provision for measuring airflow, fuel flow, temperatures, Speed and Emission. There is also catalytic converter is attached at engine exhaust.

The fuel property of diesel is as given below in the table:

Fuel properties	Diesel
Density(gm/cc)	0.845
Viscosity(cst)	3.0
Flash point (?C)	32
Cetane number	48
Calorific value (KJ/Kg)	42000-46000

Fig -1: Experimental setup

Fig -2: CC connected to exhaust pipe

In above figure 2 we can see one end of catalytic converter connected to the engine and another end is connect to the exhaust pipe from which gases thrown out in environment.

3. Engine specification

[3.1] IC Engine Setup under Test Is Research Diesel

Power: 3.50 kW
Engine Speed: 1500 RPM which is One Cylinder, Four Stroke, Constant Speed, Water Cooled, Diesel Engine
Cylinder Bore: 87.5 mm
Stroke Length: 110.00 mm
Connecting Rod Length: 234 mm
Compression Ratio: 17.5
Swept Volume: 66.45 cc

[3.2] Combustion Parameters:

Specific Gas Constant (kJ/kg K): 1.00
Air Density (kg/m^3): 1.17
Adiabatic Index: 1.41
Polytrophic Index: 1.28
Number of Cycles: 10
Cylinder Pressure Reference: 4
Smoothing 2, TDC Reference: 0

[3.3] Performance Parameters:

Orifice Diameter (mm): 20.00
Orifice Coefficient of Discharge: 0.60
Dynamometer Arm Length (mm): 185
Fuel Pipe diameter (mm): 12.40
Ambient Temp. (◦C): 27
Pulses Per revolution: 360
Fuel Type: Diesel
Fuel Density (Kg/m^3): 830
Calorific Value of Fuel (kj/kg): 42000

4. Engine component details

[4.1] Dynamometer:

A dynamometer is an equipment to measure brake power which is produced by rotating shaft, in addition it has a device to measure the frictional resistance. By knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine.

[4.2] Exhaust gas Calorimeter:

Exhaust gas calorimeter is used to measure the thermal

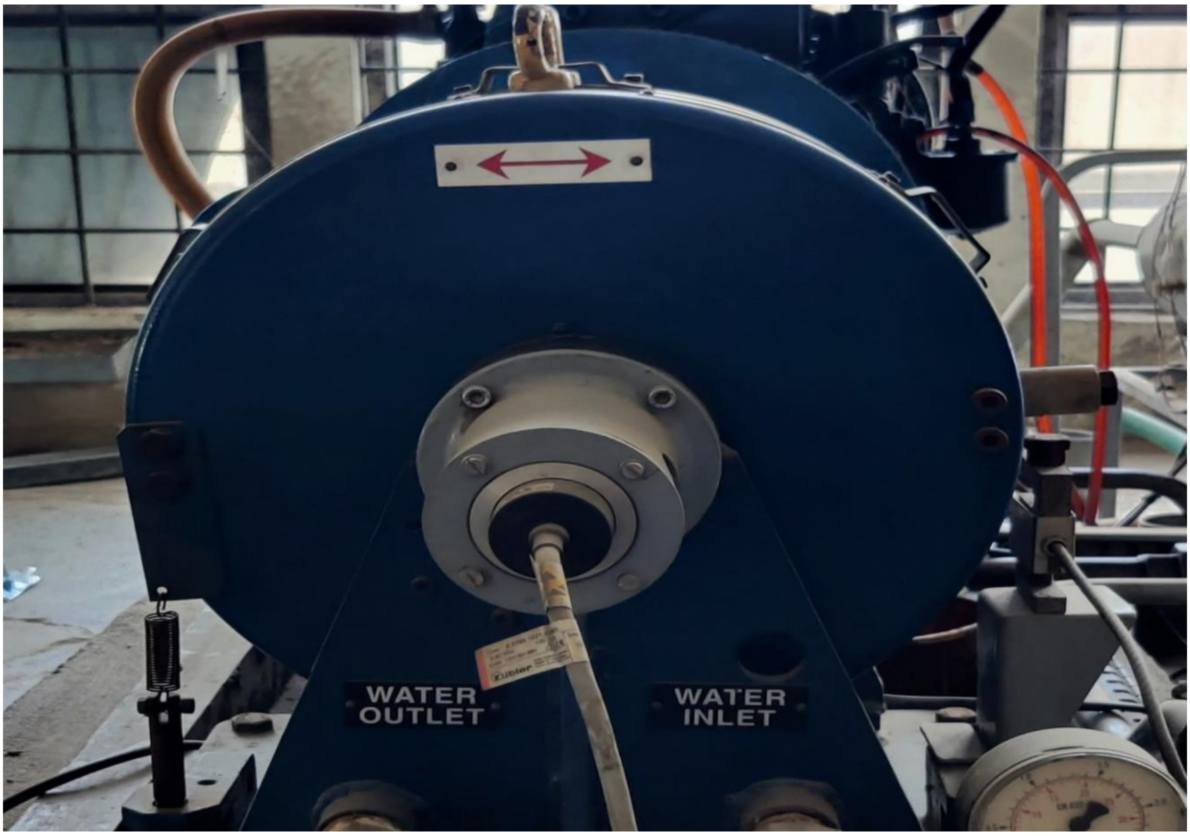

Fig -3: Dynamometer

energy which is carried by exhaust gas.

Fig -4: Calorimeter

[4.3] U-tube Manometer:

This manometer consists of a U-shaped tube in which the monomeric liquid is filled. The manometer is used to measure the pressure of air in air chamber. It has a glass tube made up of pyralex glass. The graduations are made on the tube in terms of mm or in some condition it is graduated in kilo Pascal.

Fig -5: Manometer

[4.4] Burette:

Burette is the device which is used to measure the flow rate of diesel. A burette is a uniform glass tube with fine gradations and a stop valve at the bottom, used especially in laboratory *procedures for accurate fluid measurement.*

Fig -6: Burette

[4.5] Display Unit:

Display unit indicates the load applying on the engine.

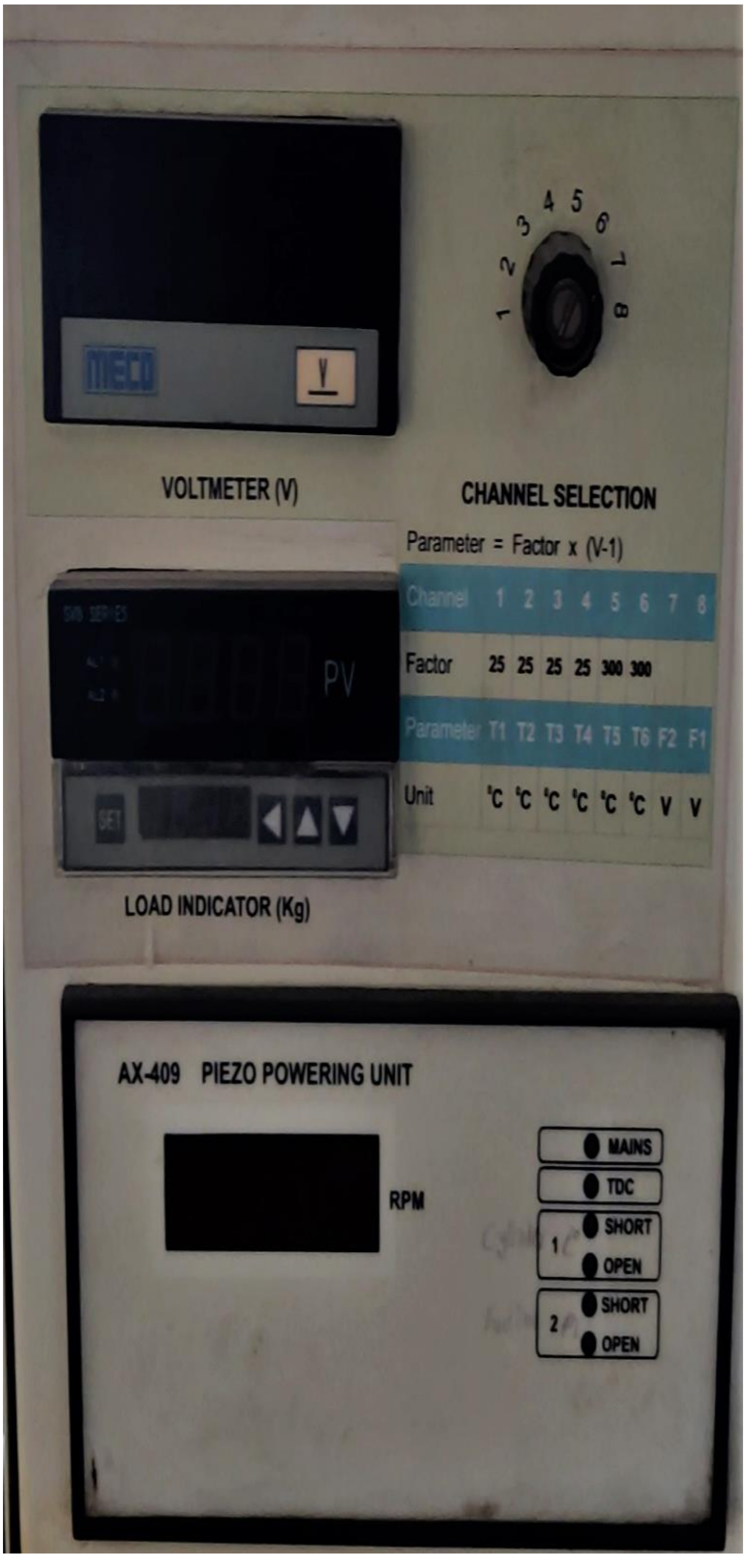

Fig -7: Display unit

[4.6] Catalytic Converter:

Catalytic converter used to reduce the amount of harmful gases NOx, HC, CO by converting it into N2, H2O and CO2.
Catalyst used in Conventional catalytic converter are Platinum, Palladium and Rhodium which are very expensive and rare.
Catalytic converter used in this experiment is as shown in figure 8, and it is from Hyundai Verna 2005 diesel model.

Fig -8: Catalytic converter

[4.7] Emission Analyzer:

Emission analyzer is used to analyze the exhaust gas emission and give its value. It gives the amount of CO, HC, CO2, O2, NOx in % as shown in figure.

Fig -9: Emission analyzer

[4.8] Fuel tank:

As the name suggest, fuel tank is used to store the fuel and, in this case, it is used to store diesel and it is also supplying the diesel to the diesel engine when there's a requirement of it.

5. Experiment working

Catalytic converter is very important device for any automobile. Catalyst are the compounds that can accelerates a chemical reaction without being part of it.

In automobiles, to reduce the harmful gases, variety of catalyst are used in catalytic converter. For operation of an automobile's IC engine, the combustion reaction should occur in predetermined controlled conditions in the combustion chamber. But by-product of this combustion processes i.e., hazardous gases are produced which cause environmental pollution.

Hence it is compulsory to use catalytic converter in any vehicle for every automobile manufacturer to reduce the amount of hazardous gases which is coming out from vehicle exhaust.

catalytic converter which reduces emissions of three hazardous compounds and gases found in automobile exhaust:

i. Hydrocarbons (a cause of the mixture of smoke and fog in the air)
ii. Carbon monoxide (a hazardous gas)
iii. Nitrogen oxides (a cause of the mixture of smoke and fog in the air and acid rain)

Before development of catalytic converters, exhaust gases produce by engine is thrown out directly into environment through muffler. These catalytic converter fits between the engine and the muffler, which doesn't work like a simple filter: it alters the chemical structure of the exhaust gases by reorganizing the atoms from which they're made:

i. Molecules of exhaust gases are pumped through the honeycomb structure, consisting catalyst platinum, palladium & rhodium and in our case it passes through Copper mesh.
ii. The catalyst splits up the molecules into their atoms.
iii. The atoms then reorganize into molecules of relatively less harmful compounds like CO2 (carbon dioxide), N2 (nitrogen), and H2O (water).

The mixture of platinum (Pt), palladium (Pd), and rhodium (Rh) are used as catalyst material in the catalytic converter. The ceramic honeycomb or ceramic beads is coated with these metals within metal casing which is fitted in tailpipe. The catalytic converter's honeycomb structure facilitates the maximum contact area on which reactions can take place easily by using Harmful exhaust gases including HC, CO, NOx Exhaust pipe from engine The 'catalyst', a ceramic honeycomb coated with platinum and palladium or rhodium causes a chemical reaction to convert harmful gases into less harmful gases Less harmful gases such as CO2 and H2O are released from the exhaust into the air Exhaust pipe emits gases into air minimum amount of catalyst in which a reduction and oxidation reaction takes place inside the device.

Hydrocarbons (HC) are converted into carbon dioxide (CO2) and water (H2O). Carbon monoxide (CO) is converted into carbon dioxide (CO2). Nitrogen oxides (NOx) are broken down into nitrogen gas (N2) and oxygen gas (O2).

From the above information it quite understanding that catalytic converter is very much Important for environment safety and human safety point of view. But the catalyst used in in catalytic converter is very expensive and rare which increase the cost of catalytic converter about 60k-70k and which directly increase the overall cost of the vehicle.

6. CC Modification

Catalytic converter generally consists Platinum, Palladium and Rhodium as a catalyst but they are very expensive so in this experiment we try to modify the catalytic converter with different Non-Noble catalyst i.e., **Zinc** which are very cheap Comparision to platinum, palladium and rhodium and are easily available. For modification of catalytic converter, we cut the catalytic converter length wise from one side of catalytic converter and remove honeycomb structure from it as shown in figure 10.

Fig -10: Conventional CC cut lengthwise

Fig -11: Honeycomb structure from conventional CC

After removing honeycomb structure, we also remove platinum, palladium and rhodium insulation from it and clean it from inside. After that we add **Zinc mesh**, which are cut according to the inner diameter of catalytic converter i.e., 116 mm and then is fix inside CC in such a way that it does not move when exhaust gases flow past them and after fixing mesh, CC is welded it by **Argon welding** for better joint so there will be no chance of any leakage of any hazardous gases when it is working.

Here 60 units of Zinc mesh are used for better purification of harmful gases.

Fig -12: Zinc mesh fitted inside modified CC

Fig -13: Argon welded modified CC

7. Platinum catalyst readings and graphs

Load	CO	HC	CO_2	O_2	NO_x	λ	RPM
2	0.14	62	1.3	18.3	69	9.64	1500
4	0.13	64	2.5	16.2	284	7.42	1500
6	0.1	65	2.8	16.6	362	5.8	1500
8	0.07	67	3	15.91	484	4.52	1500
10	0.05	69	2.3	16.87	568	5.97	1500

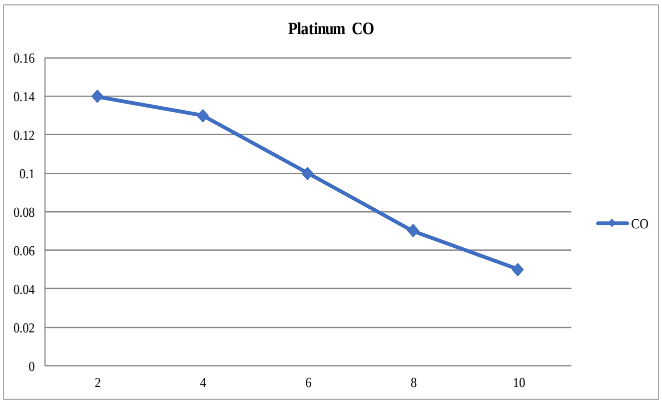

Chart -1: Platinum CO graph

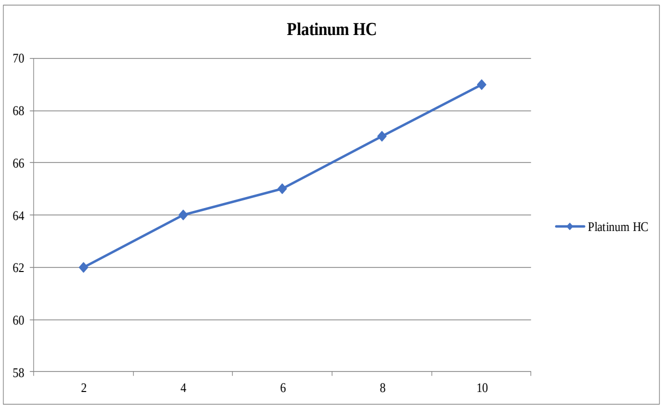

Chart -2: Platinum HC graph

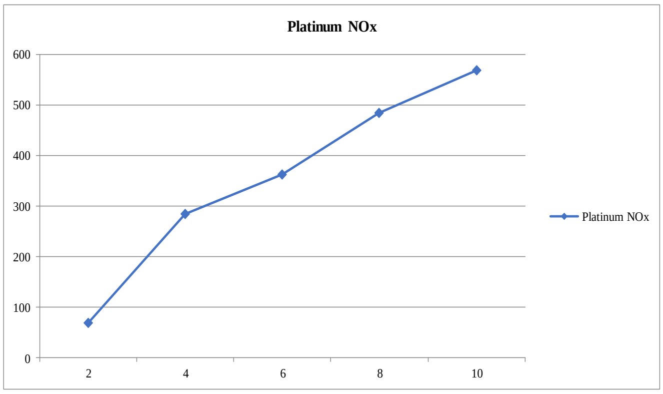

Chart -3: Platinum NO_x graph

8. Zinc catalyst readings and graphs

Load	CO	HC	CO_2	O_2	NO_x	λ	RPM
2	0.27	76	1.2	18.45	3	9.44	1500
4	0.1	44	2.1	17	220	6.335	1500
6	0.07	42	2.3	16.72	363	5.88	1500
8	0.06	48	2.7	16.28	538	5.078	1500
10	0.06	65	3.2	15.53	779	4.28	1500

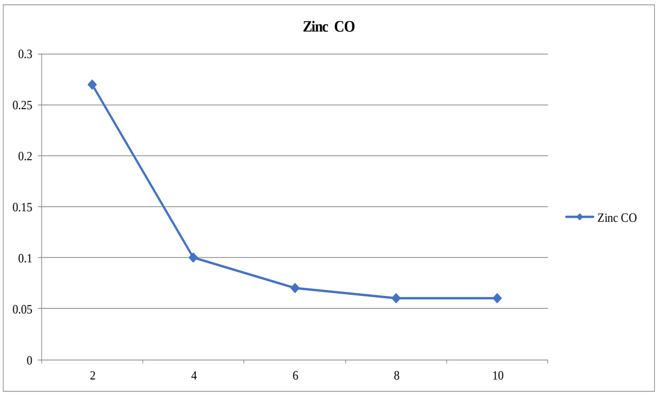

Chart -4: Zinc CO graph

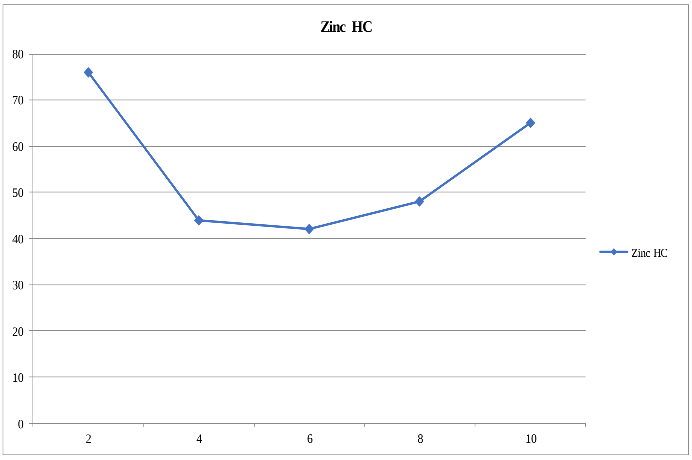

Chart -5: Zinc HC graph

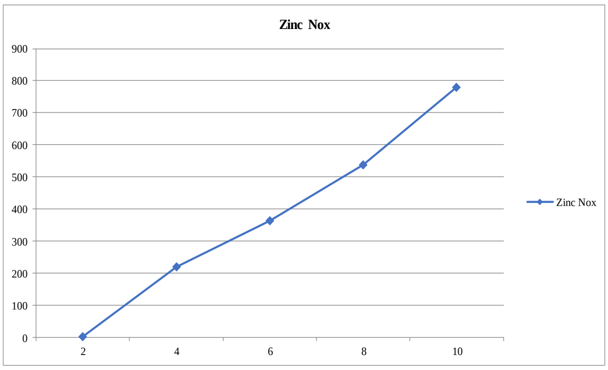

Chart -6: Zinc NO_x graph

9. Comparision of Pt &Cu catalyst readings and graphs

[9.1] Comparision of CO emission obtained from both catalysts.

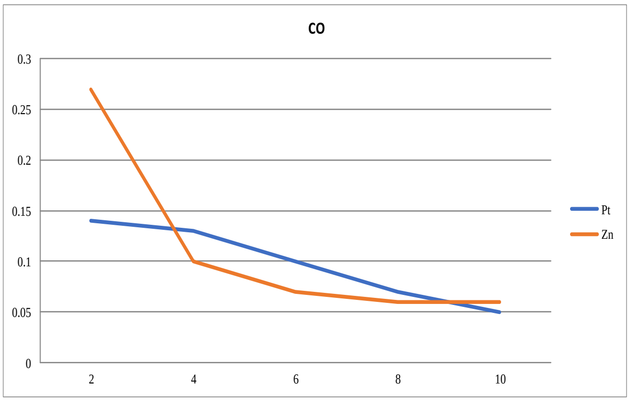

Chart -7: Zn & Pt CO graph

[9.2] Comparison of HC emission obtained from both catalyst

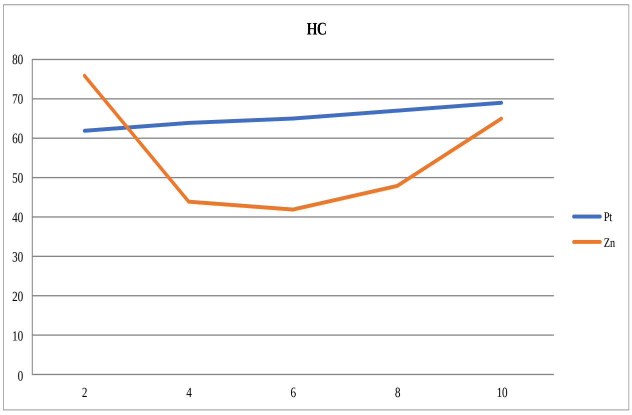

Chart -8: Zn & Pt HC graph

[9.3] Comparision of NO_x emission obtained from both catalyst

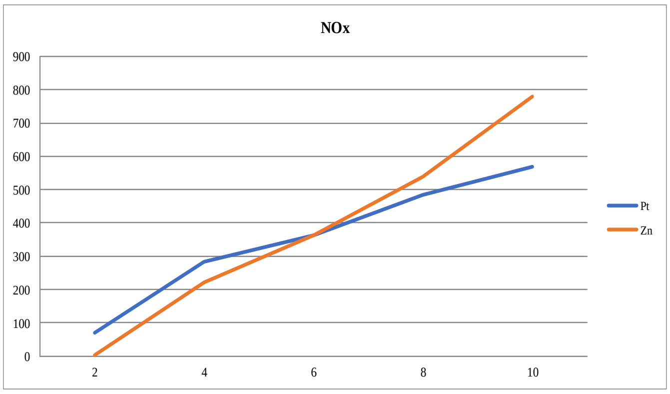

Chart -9: Zn & Pt NO_x graph

10. Conclusion

After various investigations on Noble (i.e., Pt) and Non-Noble (i.e., Zn) catalysts used in CC, we concluded that **Zinc** performs Excellently as a Non-noble catalyst. Zinc has **84.09%** efficiency for reducing **HC** emission as compared to Pt as a catalyst, while Pt has better CO reducing capabilities i.e., 87.5% as compared to Zn. As compared to other non-noble catalyst that we investigated previously i.e., **Copper,** Zinc performs moderately (As compared to Copper). **Zn's** CO and HC emission reducing capabilities meets the current **BS-VI** norms. But both Zn and Pt's (As the cc was installed in 2005 so it does not match current standard's) NO_x emission reducing capabilities does not meet to current norms standard. These modified CC still can't be used in modern vehicle as it doesn't meet current Indian emission norms (NOx).

11. Cost Comparision

A new automobile CC cost's around **60-70k Rs** depending upon type of vehicle and will be increasing as new emission norms will be introduced as it gets difficult to control the emissions.

Our modified CC costs around **6000 Rs** (Including Cast iron body, Catalyst) and can be further reduced if produced in bulk(mass).

12. Scope for further research

Indian standard norms i.e., Bharat stage (BS) for petrol engine and diesel engine from year 2020 i.e., BS VI are as follow:

EMISSION TARGETS

Engine Type	Mass of Exhaust Gas	BS4 Limits	BS6 Limits	Percentage Decrease
Petrol	CO (in mg/km)	1000	1000	Nil
	HC (in mg/km)	100	100	Nil
	NOx (in mg/km)	80	60	25%
	PM (in mg/km)		4.5 (for gasoline direct injection engines only)	
Diesel	CO (in mg/km)	500	500	Nil
	HC + NOx (in mg/km)	300	170	43%
	NOx (in mg/km)	250	80	68%
	PM (in mg/km)	25	4.5	82%

Fig -14: BS VI Emission norms

As our modified catalytic converter does not meet the current emission norms i.e., NOx norms it still requires further research. NOx limiting catalyst is needed to be used in our modified CC, so that it can be used in modern vehicles.

➢ Abbreviations and acronyms

CO → Carbon monoxide
HC → Hydrocarbon
NOx → Nitrogen oxides
Cu → Copper
Zn → Zinc
Rh → Rhodium
Pt → Platinum
Pd → Palladium

13. References

[1] Ronald M. Heck, Robert J. Farrauto, Automobile exhaust catalysts, Catalysis A: General 221 (2001) 443–457

[2] Akash Pathak, K. Venkadeshwaran, Alok Kumar Rohit, Niranjan Kumar Naulakha, Review Paper on Improved Exhaust Emission Control by The Use of Cu-Zeolite Catalyst Based Catalytic Converter, IJTSRD Volume – 2 | Issue – 4 | May-Jun 2018

[3] Advanced Catalytic Converter in Gasoline Engineer Emission Control: A Review, A.M. Leman, Afiqah Jajuli, Dafit Feriyanto, Fakhrurrazi Rahman and Supaat Zakaria, *ENCON 2016* 10.1051/ matecconf/20178702020

[4] Chirag Amin1, Pravin P. Rathod, CATALYTIC CONVERTER BASED ON NON-NOBLE
MATERIAL, International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974IJAERS/Vol. I/ Issue II/January-March, 2012/118-120.

[5] Nadim Bagwan, Sanjay Satpute, A Review on Properties of Catalyst Materials for a Three-Way Catalytic Converter International Journal of Advanced Production and Industrial Engineering IJAPIE-SI-MM 504 (2017) 22–26.

[6] Nitin Rathod, Rohan Panage, Prof. W. S. Rathod, Design and Performance Analysis of a Three Way
Catalytic Converter, International Journal of Research and Scientific Innovation (IJRSI) | Volume V, Issue VI, June 2018 | ISSN 2321–2705

[7] Samiksha Rathore, Dr. Mukesh Thakur and S.S.K Deepak, Experimental Investigation of Exhaust Emissions Using Nano-Particle Coated Catalytic Converter for Four Stroke Spark Ignition Engine, International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 Volume 6 Issue VI, June 2018

[8] Jay M. Parmar and Prof. Keyur D. Tandel, Performance Analysis of Limestone Coated WIREMESH Catalytic Converter for Emission Control of C.I Engine, International Journal for Scientific Research & Development| Vol. 1, Issue 11, 2014 | ISSN (online): 2321-0613

[9] Grigorios C. Koltsakis and Anastasios M. Stamatelos, CATALYTIC AUTOMOTIVE EXHAUST AFTERTREATMENT, Prog. Energy Combust. Sci. Vol. 23, pp. 1-39, 1997.

[10] Sakshi Khurana, Kiratpreet Kaur Rayat, Srinivas Tadepalli, Shyamsunder Mishra, Review paper on Catalytic Converter for Automotive Exhaust Emission, INTERNATIONAL JOURNAL OF INFORMATION AND COMPUTING SCIENCE Volume 5, Issue 6, June 2018.

[11] Internal combustion engines book by V.M.Domkundwar and A.V. Domkundwar