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EXHAUST EMISSION CONTROL BY USING COPPLER PLATE AND AMMONIA SOLUTION

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ABSTRACT
As we all know the numbers of vehicles are increasing at a very fast rate therefore causing great increase in environmental pollution which needs to be controlled. For reducing this pollution government has given norms and vehicular standards. Various companies also introduce different technologies for reducing the pollutants. Similarly, the step towards for creating the eco-friendly vehicle, we have worked on new technique that can be used in automobiles. Environmental pollution control using catalytic converter is most common and effective, which is widely used in automobiles. Catalytic converter typically consists of a ceramic or metal honeycombed monolith substrate carries precious metal catalysts. As the exhaust passes over the catalyst the harmful pollutants get converted into harmless gases by promoting chemical reactions, but catalytic converter method is higher in cost and hence we have worked on optional technique. In a selective non-catalytic reduction technique we have used copper plate and ammonia solution. The experiment is carried out on four stroke single cylinder petrol engine. For the reduction measurement we have used PUC testing machine authorized by State Government. By this catalytic converter it is found that CO reduced by 63 % and HC by 50 % at ideal condition.

KEYWORDS: Intake air flow, Exhaust air flow, Pressure drop, Space velocity.

INTRODUCTION
Exhaust gas or flue gas is emitted as a result of combustion of fuels such as a natural gas, gasoline/petrol, biodiesel blends, fuel or coal. Internal combustion engine generates undesirable emissions during the combustion process.
Figure:

Country	2014	2013	2012	2011	2010	2009
China	23,722,890	22,116,825	19,271,808	18,418,876	18,264,761	13,790,994
European Union	17,061,132	16,324,773	16,364,416	17,622,757	17,173,368	15,388,238
United States	11,660,699	11,066,432	10,335,765	8,661,535	7,743,093	5,709,431
Japan	9,774,558	9,630,181	9,943,077	8,398,630	9,628,920	7,934,057
Germany	5,907,548	5,718,222	5,649,260	6,146,948	5,905,985	5,209,857
South Korea	4,524,932	4,521,429	4,561,766	4,657,094	4,271,741	3,512,926
India	3,840,160	3,898,425	4,174,713	3,927,411	3,557,073	2,641,550

Fig -1: Annual Motor Vehicle Production by Country [5]

The main exhaust pollutants are HC, CO, NO_X, particulate matter, volatile organic compounds, etc. As the no. of vehicles are increasing rapidly. Over a period of last 10-15 years the numbers of vehicles are increased about 2-3 times of its initial quantity in India. [5] The drastic increased in vehicle use lead to increased vehicular pollution.

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Generally, to maintain the economy people are turn towards low expensive fuels. In which kerosene is generally used in different applications by mixing it in petrol and diesel fuels. After combustion of kerosene high amount of pollutants are produced.

NECESSITY

As the pollution is increasing continuously it affecting the life of living organisms and non-living things. These vehicle emissions, in the form of conventional pollutants can have adverse impacts such as premature mortality and morbidity from cardiopulmonary diseases, lower crop yields, environmental damage, global warming, etc. [6] To meet the green vehicle concept and make our vehicle better environment friendly we used an innovative concept in the catalytic converter. There are various methods are available for the emission control, such as PCV Valve, EGR Valve, Air Injection, Catalytic Converter, Scrubber Technology, BlueMotion Technology by Volkswagen, etc. All these methods having many disadvantages and hence we adopt this technology which can give opportunity to the same fuels with less pollutants.

OBJECTIVE

The main objective is to develop a catalytic converter which will be a suitable option for the existing one. The catalytic converter is to be manufactured in order to fulfill the customer's requirements viz. reduce increased emission, provide an alternative to costly catalyst materials like rhodium, palladium, platinum, etc.

Nomenclature	
HC	Hydrocarbon
CO	Carbon monoxide
CO_2	Carbon dioxide
NO_X	Nitrous Oxide
DC	Direct Current
PUC	Pollution Under Control
PCV	Positive Crankcase Ventilation
EGR	Exhaust Gas Recirculation
OHC	Over Head Camshaft
cc	Cubic centimeter
CID	Cubic Inch Displacement
RPM	Revolution per minute
CFM	Cubic feet/minute
Hg	Mercury
D	Diameter
L	Length
hr	Hour
GI	Galvanized Iron
C_d	Coefficient of discharge for welded joint
β	Throat diameter
Q	Flow rate
ε	Expansion factor

SYSTEM DEVELOPMENT

After the studying various literature we have design the layout. The primary layout will be shown as follow:

Figure:

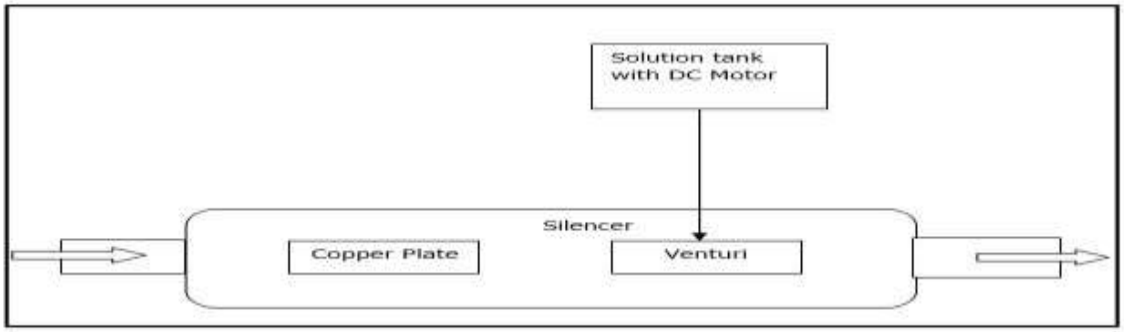

Fig -2: Schematic view of catalytic converter

Engine Selection

For the testing and calculation purpose we have used the four stroke single cylinder engine. The detail specification is given below:

Table :

Table -1: Specification of engine [7]

No.	Type	Air Cooled, 4 Stroke Single Cylinder OHC Engine
1	Displacement	150 cc
2	Compression Ratio	10:1
3	Maximum Power	11.64 KW @ 8500 rpm
4	Maximum Torque	13.50 Nm @ 7000 rpm

Converter Shell

Material Selection

Material selection of the converter shell is the crucial parameter because of the consideration of heat conductivity, corrosiveness, and cost.

Requirement of good shell material:

1. It should be heat conductive.
2. The thermal conductivity of material must not be high enough so that it will liberate all of its heat and will cause less effective temperature for necessary reactions.
3. The material should have good resistance to corrosiveness and erosion.

By considering all the factors we choose three materials for shell design.

1. Cast iron
2. Mild steel
3. Aluminium

The most important consideration is thermal conductivity of the material. In case of temperature aluminium having low melting point as compared to mild steel and cast iron. The thermal conductivity of the aluminium is 4-5 times more that cast iron and mild steel thus it is not possible to use it for the particular application. [8] Cast iron has very less resistance to corrosion than mild steel. By considering these all point we selected mild steel for shell design.

Design Calculation

Exhaust flow rate will require for the converter design. Exhaust temperature and intake air-fuel flow rate must be determined to calculate the exhaust flow rate.

Intake Air Flow:

= [Engine Size (CID)×RPM/3456]×Volumetric Efficiency

= [9.15×8500/3456] ×0.75

= 7.547 CFM

Exhaust Flow:

= ((Exhaust Temperature+460)/540) ×Intake Flow Rate

= ((1000+460)/540) ×7.547

= 20.404 CFM

Here we have considered the volumetric efficiency 0.75, exhaust pressure 1000º F (537º C) and maximum back pressure 3" (76.2 mm) of Hg for our engine capacity from international standard engine design data book. This indicates the pressure of the exhaust gases directly coming out of the engine. [1]

Volume of Catalyst:

Space Velocity: The space time necessary to process one reactor volume of fluid.

Assuming for single cylinder engine= 2000/hr

Space velocity = Volume flow rate/Catalyst volume

Volume flow rate [9]

= Swept volume× No. of intake strokes/hr

= $(150\times10^{-6}) \times (8500\times60/4)$

= 19.11 m^3

Catalyst volume = 955 ml

Catalyst Volume = $\pi/4\times D^2\times L$

By keeping, L= 5D

D_{mini}= 62 mm, L_{mini}= 310 mm

Available shell dimensions: D=104 mm, L=400 mm

Copper Plate

1. It is noble metal able to resist under the corrosive condition.
2. It acts as an oxidizing agent for HC and CO.
3. It acts as a reducing agent for NO_X.

Dimensions:

Diameter= 104 mm, Thickness= 1.5 mm

For this particular flow rate the total surface area available at the copper plate must be equal or greater than to it. For this purpose 60 holes of 4mm diameter are drilled on the surface of the plate, which gives total surface area for flow as 30 cm^2 and surface area exposed to the exhaust gas in a converter as 85 cm^2. This plate was assembled by using a metal strip attached to the outer shell of the silencer body along with the clamping bolt.

Pressure drop due to copper plate= 0.0045 bar (by using Bernoulli's Principle).

Figure:

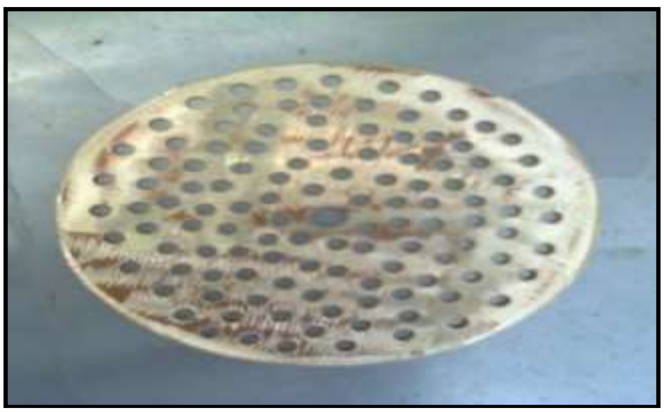

Fig -3: Copper Plate

Venturi

Main intention to use venturi in catalytic converter is to provide a low pressure zone for injection of ammonia solution. The venturi will helps the exhaust gases to mix with the aqueous urea solution much easily. This will serve in better emission control, as the proper mixing of aqueous solution will easily reduce the NO_X emissions significantly.

Venturi Principle

Venturi works on the principle of Bernoulli's principle which states that the pressure energy will drop with the raise of velocity energy of flow where total energy will remain constant.

Equation:

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$$\frac{p_1}{\rho g}+\frac{{v_1}^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{{v_2}^2}{2g}+z_2$$

Figure:

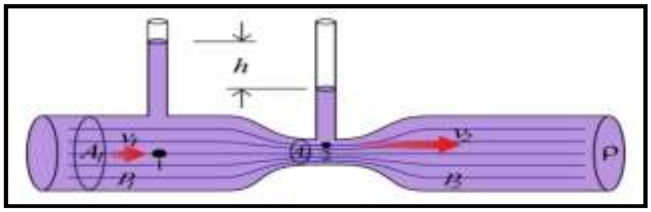

Fig -4: Venturi Design

The venturi effect is a jet effect, the velocity of the fluid increases as the cross sectional area decreases, with the static pressure correspondingly decreasing and fluid flow rate remain constant.

Flow Rate= Area × Velocity

The fig. 5 shows, as the fluid passes through the convergent section Mach number increases and at the throat section it will be maximum i.e. 1 which indicates that the flow is sonic flow(velocity of flow is equal to velocity of sound). After the throat section the Mach number will get decreases and the velocity of flow will be less than the sound velocity.

Figure:

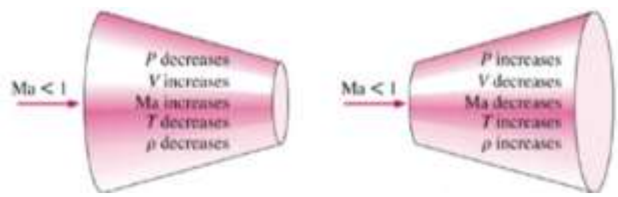

Fig -5: Bernoulli's Principle

Venturi Design Considerations

Convergent Cone

1. It is mainly to accelerate the flow for achieving the sonic flow.
2. It also causes flow separation.
3. As per the standards, the angle of this cone should be $21^0 \pm 1^0$.
4. Diameter of cone = 80mm.

Throat

1. It helps to vaporize the atomized ammonia.
2. As per the standards, length of throat should be d±0.03d.
3. Diameter of throat is 30mm.
4. Length of throat is 30mm.

Divergent Cone

1. It has less cone angle to avoid flow separation.
2. It decelerates the flow.
3. As per the standards, angle of this cone should be in between 7^0 to 15^0.
4. Diameter of cone is 80mm.[11]

Figure:

Fig -6: Venturi

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Design Validation

The venturi for the catalytic converter is developed from a GI sheet. The benefit behind using GI sheet for this purpose was the manufacturing time and cost requirement will be less as compared with a mild steel venturi or cast iron venturi.

Rate of exhaust flow through venturi:

$$Q = C_d \frac{\pi d^2}{4} \varepsilon \frac{1}{\sqrt{(1-\beta^4)}} \sqrt{2\frac{(p_1 - p_2)}{\rho}}$$

Where,

C_d = 0.985

β = 0.38

ε = 0.33

By substituting,

Q=0.019 m^3/sec

The volume flow rate for the shell was calculated as 20.404 CFM.

The selected venturi is suitable for this particular application gives the flow rate close to the desired one. Thus the venturi with the given dimensions is selected for this purpose. By using the Bernoulli's principle:

Pressure drop into the venture is calculated as 2.18 bar.

Nozzle

The injector nozzle is used for the atomization of ammonia solution by increasing the flow velocity before entering into the venturi. The working principle of nozzle is same as a convergent section of venturi. It helps for the proper mixing of solution with the exhaust gas.

DC Motor

For creating the pressure at the time of solution injection in to the venturi we were used two 12 Volts DC motors which has inbuilt vane pump. The pump delivers the solution from reservoir to the injector under pressure. The pump creates the pressure of 0.2-0.3 bar. The voltage input for motor is taken out from 12V battery.

Figure:

Fig -7: DC Motor with Vane Pump

Ammonia Solution

We have use the dilute ammonia solution for maintaining the economy of the project. The proportion of water and ammonia is 1:1. With the practical test we find that the half liter solution will run for nearly 20 minute run of engine.

SETUP ASSEEMBLY

We have prepared 3D model. The prototype is arranged same as the 3D model. The complete assembly of the project is shown below:

Figture:

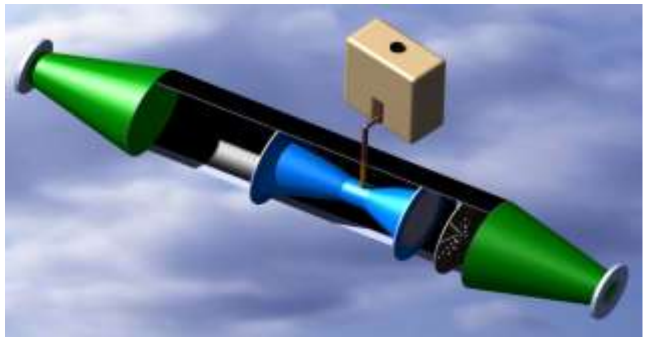

Fig -8: Catalytic Converter

The prototype is shown in fig no. 9. The setup arrangement is in such a way that the when exhaust gas will enter into the converter shell and firstly it will come into contact with the copper plate. At the high temperature, copper plate acts as an oxidizing agent for HC and CO.

Figure:

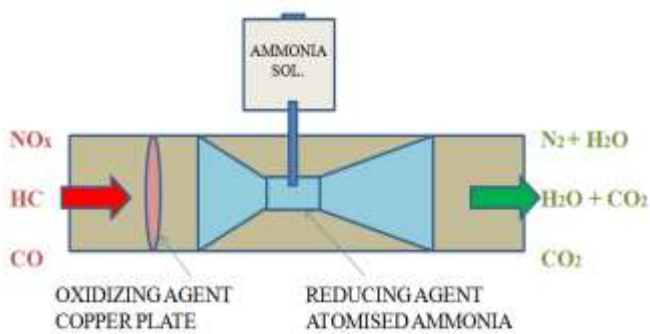

Fig -9: Conversions occurring in catalytic converter

Plate will react with these pollutants and convert into water vapor and carbon dioxide. During these reactions the exhaust pressure will drop which helps for the uniform mixing of exhaust gas with ammonia solution. Now the gas will pass through the convergent cone where the velocity of flow will increase and pressure will drop. At the throat section the gas will mix with the ammonia solution. Ammonia will act as a reducing agent for NO_X pollutants. At this high temperature ammonia will flow through the injector and get vaporizes. With the uniform mixing, it will react with NO_X and convert into nitrogen and water vapor.

The reaction of exhaust gas with the copper plate and ammonia will result as follows:

Figure:

Reactions: $4NO + O_2 + NH_3 \longrightarrow 4N_2 + 6H_2O$

$$2CO + O_2 \longrightarrow 2CO_2$$

$$4HC + 5O_2 \longrightarrow 2H_2O + 4CO_2$$

Fig -10: Reaction occurring in catalytic converter

For the desired flow of ammonia we have used the DC motor with inlet vane pump. The inlet of pump is connected to the solution storage tank and outlet is connected to injectors through the flexible pipe.

PERFORMANCE ANALYSIS

Testing

The test of the catalytic converter is conducted at PUC center. For the testing we have used a two wheeler Hero Hunk vehicle's engine. The engine is single cylinder, 4-stroke, and air cooled.

Figure:

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Fig -11: Converter testing

RESULTS AND CONCLUSION

Result

In this we have completed project test. The reports of PUC are shown as follows:

Figure:

Fig -12: PUC report

Chart:

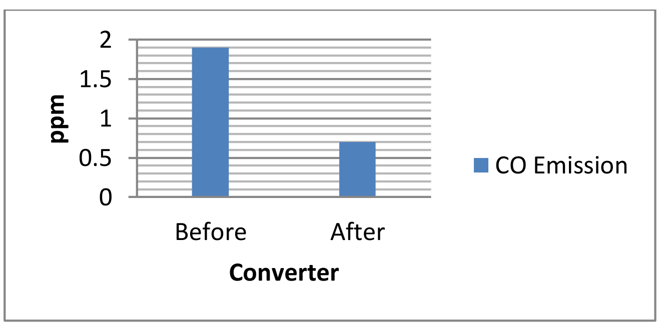

Chart -1: CO Emission

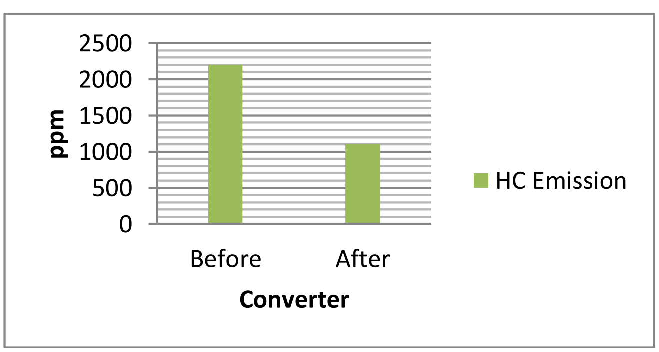

Chart -2: HC Emission

With the best efficient model we have reduced CO and HC by 63% and 50% respectively.

CONCLUSION

1. The exhaust pollutants are reduced.
2. It increases the engine performance.
3. Availability of copper compared to noble materials makes the advanced catalytic convertor more useful.
4. Ammonia solution will play important role for emission control in future.
5. Low cost and best performance project for light vehicles.

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