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AN INNOVATIVE APPROACH FOR EMISSION CONTROL USING COPPER PLATE CATALYTIC CONVERTER

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ABSTRACT

Nowadays, controlling emissions are not simply a case of engine design and engine management. Exhaust gas after-treatment systems play an important role, as current and future automobile emission regulations become more stringent. The most effective after treatment for reducing engine emission is the catalytic converter found on most automobiles.

Catalytic converters typically consist of a ceramic or metal honeycombed monolith substrate that carries precious metal catalysts. The coated substrate is wrapped in an in tumescent mat that expands when heated, securing and insulating the substrate which is packaged in a stainless steel shell and fitted into the engine exhaust system.

As exhaust gases pass over the catalysts, they promote chemical reactions that convert pollutants into harmless gases and water. Hydrocarbons (HC) combine with oxygen (O_2) to become carbon dioxide (CO_2); oxides of nitrogen (NO, NO_2) react with carbon monoxide (CO) to produce nitrogen (N_2) and carbon dioxide (CO_2); and with hydrogen (H_2) to produce nitrogen (N_2) and water vapour (H_2O).

There are several types of problems associated with precious metal based catalytic converter. These factors encourage for the possible application of non noble metal based material. So we decided to use copper as a catalyst, which may by proper implementation be able to show the desired activity and can also offer better durability characteristics due to its poison resistant nature.

Keywords: Intake air flow, Exhaust flow, Space velocity, Stoichiometry, Exhaust gases.

INTRODUCTION

To meet the green vehicle concept and make our vehicle better environment friendly we used an innovative concept in the catalytic converter. Our vehicle emission standard is as per BSIII. Bharat stage emission standards are emission standards instituted by Government of India to regulate the output of air pollutants from internal combustion engine equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment & Forests.

The main emissions after treatment, of an engine are:

- Nitrogen gas (N_2) - Air is 78% nitrogen gas, and most of this passes right through the car engine.
- Carbon dioxide (CO_2) - This is one product of combustion. The carbon in the fuel bonds with the oxygen in the air.
- Water vapour (H_2O) - This is another product of combustion. The hydrogen in the fuel bonds with the oxygen in the air.

These emissions are mostly nonthreatening, although carbon dioxide emissions are believed to contribute to global warming.

Because the combustion process is never perfect, some smaller amounts of more harmful emissions are also produced in engines they are:

- Carbon monoxide (CO) is a poisonous gas that is colourless and odourless.
- Hydrocarbons or volatile organic compounds (VOCs) are a major component of smog produced mostly from evaporated, unburned .fuel.
- Nitrogen oxides (NO and NO_2, together called NOx) are a contributor to smog and acid rain, which also causes irritation to human mucus membranes.

These pollutants are known to cause global warming, acid rain, smog and respiratory and other health hazards. Therefore, there are laws on emission standards, which limit the amount of each pollutant in the exhaust gas emitted. Our design work is focused upon the reduction of such emissions by non-noble metal copper as a catalyst in catalytic converter.

PROBLEM STATEMENT

The conventional three-way catalytic converters use precious noble metals such as platinum, palladium and rhodium as catalyst.

Issues:

• Catalysts: Platinum (Pt), Palladium (Pd) or Rhodium (Rh)

- All are very expensive, have very limited supply sources, and limited future availability.

- Price makes them attractive to steal.

•Catalysts only work at fairly high temperatures

No	Failure Mode	Technical Description	Effect
1	Converter Meltdown	Excess heat generation due to long reaction time to clean up excess HC or CO	Small particles come apart and clog the flow of exhaust through converter
2	Carbon Deposit	Contamination like carbon, oil, coolant and other stuff	Reduces surface area thus efficiency
3	Catalyst Fracture	Deposition of clogged particles	Loss of power at higher engine speed, hard to start, poor acceleration
4	Poisoning	Chemical Reaction	Harmful gases and acids
5	Reduced Engine Performan ce	Back pressure	Engine speed and fuel economy

Table: 1. Various Causes of failure

DESIGN

To improve all these factors described above we decided to go for an alternative idea by using a newly developed copper containing catalyst system. Catalysts have been studied in relation to NOx reduction by hydrocarbon additions with respect to hydrocarbon oxidation.

Fundamental interactions between NOx, oxygen and hydrocarbons over the copper based. The detailed calculation is given below:

No	Type	Briggs and Stratton(Model Intek 1450), 4 Stroke Engine
1	Displacement	305 cc
2	Compression Ratio	8:1
3	Maximum Power	7.5 KW @ 3800 rpm
4	Maximum Torque	18.5Nm @ 2600 rpm

Table: 2. Specification of engine

CALCULATION

Exhaust flow rate may be calculated using the following formula. Exhaust temperature and intake airflow rate must be determined to calculate the exhaust flow rate.

Intake air flow (CFM) = (Engine Size (CID) x RPM/3456) x volumetric efficiency

=(18.605x3800/3456) x 0.75

= 15.342 CFM

Considering an efficiency of 0.75 and Exhaust Temp 1000 °F (537 °C) and max back pressure 3” (76.2 mm) Hg for our engine capacity from international standard engine design data book.

Exhaust flow (CFM) = ((Exhaust Temp. (°F) + 460)/540) x Intake air flow (CFM)

= ((1000 + 460)/540) x 15.342

= 41.48 CFM

= 71.06 m^3/hr.

From the above calculation we designed a catalytic convertor. The total converter volume to be maintained is 304 cc.

The shape of catalytic converter to be developed consists of three parts viz. the central cylindrical shell (housing), the diverging inlet cone and converging outlet cone.

To provide the maximum area for catalytic reaction, the volume of central shell is assumed as 205 cc and 50 cc each for diverging inlet and converging outlet cone and thus maintaining the total converter as 305 cc.

Catalyst Model:

Core Diameter (cm): 6.1

Core Length (cm): 7

Space Velocity (1/h): 101296

Pressure Drop (KPa): 0.3

A perforated copper plate of thickness 1 mm, and 170 holes of 0.5 mm diameter per cm^2, is used.

This plate gives total surface area that is exposed to the exhaust gas in a converter as 3.00 cm^2 per sq. cm of plate.

The diameter of the plate to be accommodated in converter shell is 6.1 cm as such a plate gives total exposed area of 117 cm^2.

These plates were assembled on a long bolt by putting spacers of appropriate length and inserted in the converter.

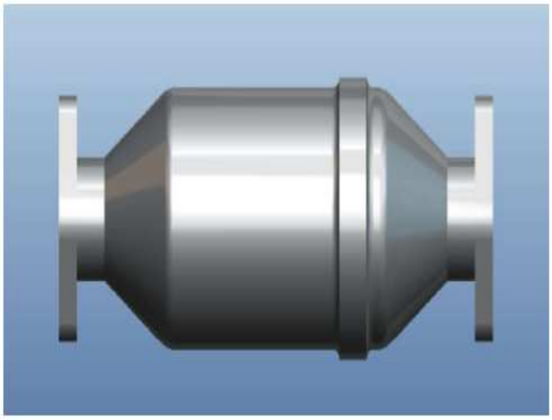

Fig: 1. 3-D Concept of catalytic converter

CONSTRUCTION AND FUNCTION

Copper:

- Oxidizing catalysts for HC and CO
- Reducing catalyst for NOx

Cerium:

- Promotes oxygen storage to improve oxidation efficiency the diagram below shows the chemical reaction that takes place inside the converter.

A modified and thermally stable alumina wash coat has been developed for application of non-noble metal catalyst. As engine exhaust gases flow through the converter passageways, they contact the copper surface which initiates the catalytic process. As exhaust and catalyst temperatures rise, the following reaction occurs:

- `Oxides of nitrogen (NOx) are reduced into simple nitrogen (N_2) and carbon dioxide (CO_2)
- Hydrocarbons (HC) and carbon monoxide (CO) are oxidized to create water (H_2O) and carbon dioxide (CO_2).

Catalyst operating efficiency is greatly affected by two factors; operating temperature and feed gas composition. The newly developed catalyst system combined with a diesel fuel or heavy saturated hydrocarbon spray system effectively reduces NOx by 20% over an exhaust temperature range of 350 □C to 550 □C. Also, the converter feed gases (engine-out exhaust gases) must alternate rapidly between high CO content, to reduce NOx emissions, and high O_2 content, to oxidize HC and CO emissions.

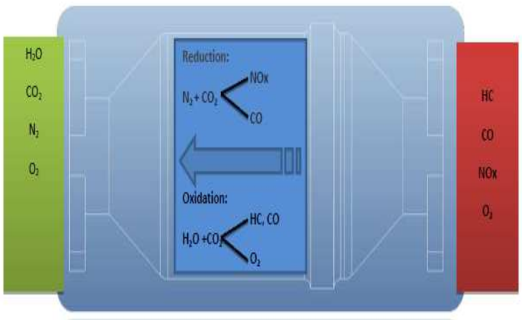

Fig: 2. Reaction occurring in catalytic converter

When the A/F ratio is leaner than stoichiometry, the oxygen content of the exhaust Stream raises and the carbon monoxide content falls. This provides a high efficiency operating environment for the oxidizing catalysts (Copper). During this lean cycle, the catalyst (by using cerium) also stores excess oxygen which will be released to promote better oxidation during the rich cycle.

When the A/F ratio is richer than stoichiometry, the carbon monoxide content of the exhaust rises and the oxygen content falls. This provides a high efficiency operating environment for the reducing catalyst (Copper). The oxidizing catalyst maintains its efficiency as stored oxygen is released.

Thus the catalytic converter is efficient at the oxidation of HC's and CO and very efficient at the reduction of NOx, storing O_2, and the steady release of O_2 into the exhaust stream.

CONCLUSION

- Minimize exhaust loss and increase in engine performance.
- Efficiency for HC (55.44 %), CO (62.96 %) and NOx (40.41 %) emission at full load.
- Low cost and best performance for the vehicle, where the economic use of engine power is very much essential without compromising the quality.
- Availability of copper compared to noble materials makes the advanced catalytic convertor more useful.
- Recycling of copper is possible.
- Reduction of catalyst fracture and convertor meltdown problems.
- Extensive use of 3R concept.
- On integrated with oxygen sensor it solves problems like Silicon, Lead and Carbon contamination.

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