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Comparative Study of Catalytic Converter on Single Cylinder CNG Engine

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Abstract -

Exhaust emissions of much concern are Hydrocarbon (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx) from the Automotive vehicles. Catalytic converter oxidizes harmful CO and HC emission to CO2 and H2O in the exhaust system and thus the emission is controlled.
This article considers briefly the system of catalytic converters and its functioning in automobiles with CNG engine. In the present research discuss on engine out emission (CO,HC ,and NOx) , various catalytic converters. And comparison of efficiency of catalytic converter.

Key Words: Air-Fuel ratio, Emission (CO, HC and NOx), Catalytic converter, Catalyst loading

1. INTRODUCTION

In internal combustion engines, the time available for combustion is limited by the engine's cycle to just a few milliseconds. There is incomplete combustion of the fuel and this leads to emissions of the partial oxidation product, carbon monoxide (CO), oxides of nitrogen (NOx) and a wide range of volatile organic compounds (VOC), including hydrocarbons (HC), aromatics and oxygenated species. These emissions are particularly high during both idling and

Deceleration, when insufficient air is taken in for complete combustion to occur.

Carbon monoxide is a product of a partial combustion of hydrocarbons in fuel. It is always present when there is a lack of oxygen during combustion and thus directly dependent on the applied engine air/fuel ratio. There are several paths that cause hydrocarbons in the exhaust. The most obvious is, as in the case of CO, a lack of oxygen when the air/fuel mixture is rich.

The catalytic converter is a device, used for decrease of toxicity of engine exhaust gas by chemical reaction of toxic substances with special substances situated on the catalyst surface, transforming the toxic substances into non-toxic ones. The role of a catalyst in reduction of pollution with exhaust impurities is relevant to controllability of the air-fuel ratio by the electronic control unit (ECU) of the car power train.

1.1 EXHAUST EMISSION

In the Europe, alarm was raised over automobile in the 1960s because of carbon monoxide emission directly harmful to the humans. This led to restriction of un-combusted exhaust components such as carbon monoxide and hydrocarbons. Because of increases in trace gases combustion and their dissemination to remote area tress become damaged due to acid rain and photo oxidants. Since nitrogen oxides and un-combusted hydrocarbon contribute to formation of these substances.

The air-fuel ratio is the major contributor which is directly related to the engine out emission.

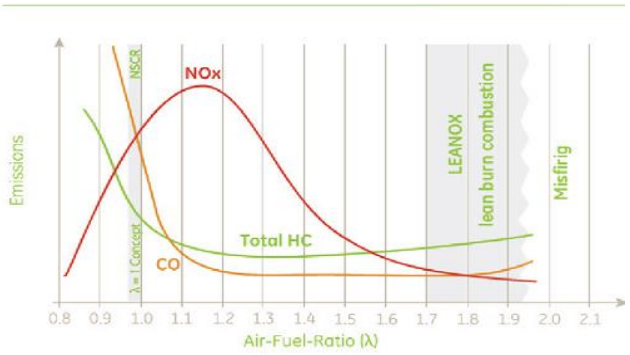

Figure 1: Emission VS Air Fuel ratio

2. CATALYTIC CONVERTER

Out of various technologies available for automobile exhaust emission control a catalytic converter is found to best option to control CO, HC and NOx emissions from petrol driven vehicles while diesel particulate filter and oxidation catalysts converter or diesel oxidation catalyst have so far been the most potential option to control particulates emissions from diesel driven vehicle.

The catalytic converter assembly consists most of these components, inlet/outlet pipes/flanges, Steel housing,

insulation material, seals, inlet/outlet cones, substrate(s), coating and sensor boss.

A steel housing provides protection and structure support for substrate; insulation material

(Mat or wire mesh) provides heat insulation and support between steel housing and substrate;

Seals are there to protect mat material from been burned by the exhaust gas.

• The substrate is often called a "catalyst support". It is a ceramic honeycomb or a stainless steel foil honeycomb in modern catalytic converters.

• The washcoat is used to make converters more efficient, often as a mixture of silica and alumina. When a washcoat is added to the substrate, it forms a rough, irregular surface, which has a far greater surface area than the flat core surfaces do, which then gives the substrate a larger surface area, providing more sites for active precious metal – the catalytic which is added to the washcoat (in suspension) before being applied to the substrate.

• The catalyst itself is most often a precious metal. Platinum is the most active catalyst and is widely used. However, because of unwanted additional reactions and/or cost, Palladium and rhodium are two other precious metals that are used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidization catalyst. Cerium, iron, manganese and nickel are also used, although each has its own limitations.

A catalytic converter (CC) is placed inside the tailpipe through which deadly exhaust gases containing unburnt fuel, CO, NOx are emitted. The function of the catalytic convertor is to convert these gases into CO2, water, N2 and O2 and currently, it is compulsory for all automobiles plying on roads.

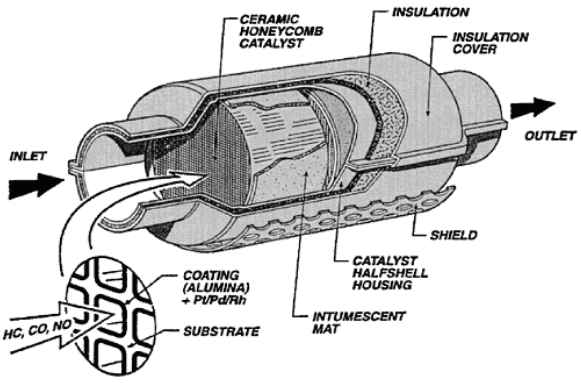

Figure 2: Construction of Catalytic Convertor

The catalyst detoxifies the harmful compounds in exhaust gases It contributes to the oxidation of unburnt hydrocarbons (HC) and carbon monoxide (CO) to harmless water vapour (H2O) and carbon dioxide (CO2) and the reduction of nitrogen oxides (NOX) to nitrogen (N2).

The oxidization catalytic converter:-

An oxidation catalyst is a device placed on the tailpipe of a car. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas.

$$2CO + O2 \longrightarrow 2CO2$$

$$HC + O2 \longrightarrow CO2 + H2O$$

2) The reduction catalytic converter

A reduction catalyst to control NOx can be used as a separate system in addition to the oxidation catalytic converter. The reduction catalyst is fitted upstream of the oxidation system. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to reduce the nitrogen oxide emissions. When such molecules come in contact with the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst forming N2.

$$2NO \longrightarrow N2 + O2$$

In three way catalytic converter-

Platinum and palladium – oxidising catalyst for HC and CO

Rhodium – reducing the NOx percentage.

Cerium – promotes the oxidation to improve oxidation efficiency

3. EXPERIMENTAL SETUP

Figure 3: Experimental Setup

The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data

acquisition device. The set-up has stand- alone panel box consisting of air box, manometer, fuel measuring unit, and transmitters for air and fuel flow measurements, gas analyzer, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement.

Table -1: Technical Specifications of test engine

Description	Specifications
Make	Apex Innovations Pvt. Ltd., Sangli.
Type	Single Cylinder, Four-Stroke, Vertical, Water-Cooled, Naturally Aspirated Variable Compression Ratio Multi-Fuel Engine
Power in Diesel Mode	Diesel mode: 3.5 KW @ 1500 rpm
Power in Petrol Mode	Petrol mode: 4.5 kW @ 1800 rpm
Number of Cylinders	One
Compression Ratio	5:1 - 20:1 (Variable Compression Ratio)
Bore X Stroke	87.5 mm X 110mm
Swept Volume	661 cc

The engine was tested with CNG fuel and various loading of catalytic converter.

1. Catalytic Converter (Type 1)

Type	Three Way
Cell density (cpsi)	100
Loading of catalyst (g/ft³)	20

2. Catalytic Converter (Type 2)

Type	Three Way
Cell density (cpsi)	100
Loading of catalyst (g/ft³)	29

3. RESULT AND DISCUSSION

The experiment is carried out on engine speed of 1200 rpm/min to 1800 rpm/min with compression ratio 12:1. The performance and emission are carried with the base engine without catalytic convertor and with catcon-1 and catcon-2.

Emission Parameters monitored were-

- Carbon Monoxide (CO) Emissions
- Unburned Hydro Carbon (HC) emissions
- Nitrogen Oxides (NOx) Emissions

The optimum catalytic convertor is decided on basis of emissions and catalytic convertor efficiency.

Lambda changes with increase in speed. The mixture is rich at 1200 rpm and 1800 rpm whereas it is lean at 1300-1700 rpm.

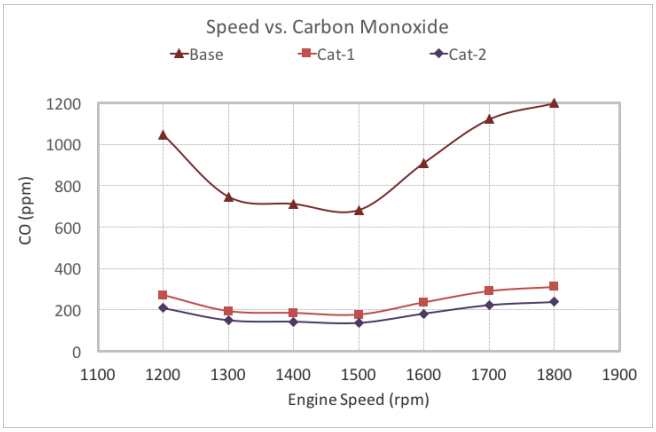

Chart 1: Variation of CO with Engine Speed

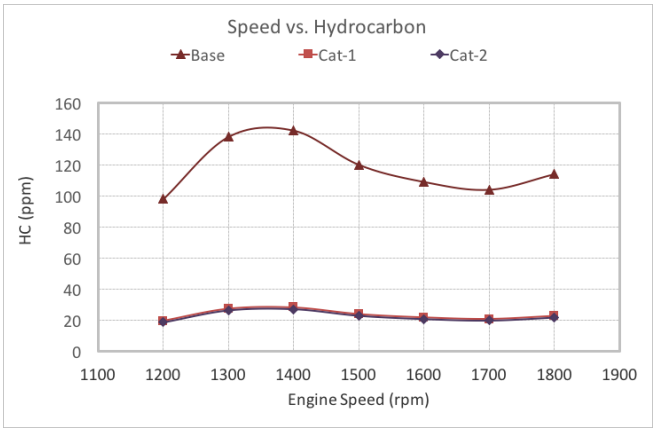

Chart 2: Variation of HC with Engine Speed

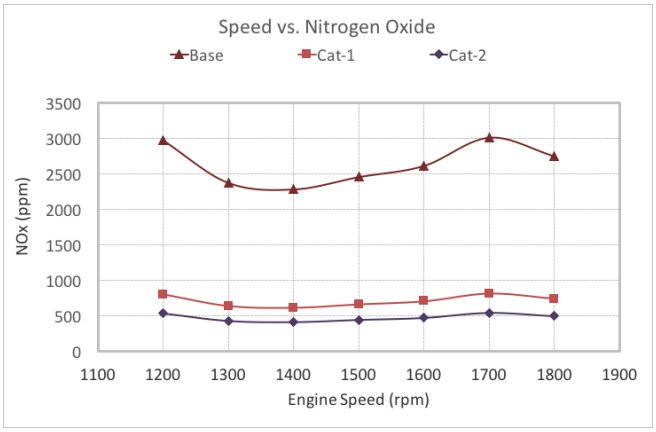

Chart 3: Variation of NOx with Engine Speed

Chart. 4 shows that CO emissions are high when the mixture is rich and goes on decreasing as mixture becomes lean. Chart. 5 shows that HC emissions are high when the mixture is rich. HC emissions decrease as lambda comes closer to stoichiometric ratio. It goes on increasing as lambda increases.

Chart. 6 shows that NOx emissions increases as lambda changes from rich towards stoichiometric and goes on decreasing as lambda increases further.

Chart. 4,5,6 shows that CO, HC and NOx emissions with Cat-2 are superior than Cat-1 because of its higher conversion efficiency.

5. CONCLUSIONS

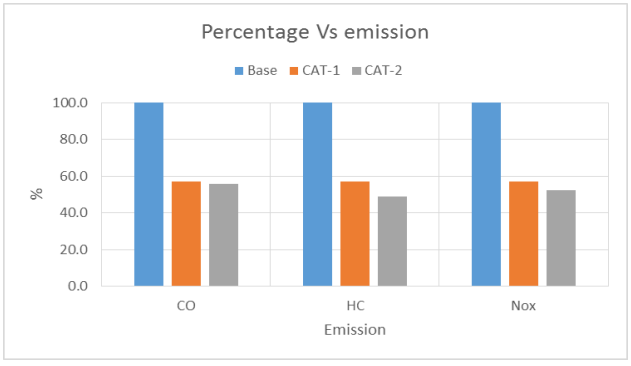

Chart 4: Efficiency of catalytic converter

The objective of this project was to test and optimise the catalytic converter on a CNG engine which should deliver better performance & emissions.

In the experiment the engine was tested with and without catalytic converter and results shows that the conversion efficiency of first catalytic converter is near about 73% whereas the conversion efficiency of second catalytic converter is near about 80%. So reduction of the CO, HC and NOx are better with second catalytic converter.

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