International Journal of Emerging Engineering Research and Technology
Volume 3, Issue 1, January 2015, PP 1-7
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Low Cost Catalytic Configurations for Mid-Range CNG Lean Burn Engines for BSIV Emission

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Abstract: *This paper deals with the optimization of the catalytic convertor for CNG Lean burn Engine based on BS4 compliances. In addition to the present catalytic convertor the work is carried out for the optimization of catalytic convertor and also to meet the BS4 compliance and also to reduced cost for the same.*

In this project we have prepared the samples with some variation in the substrate with respect to each other on which the Palladium group metals (PGM) coating is applied. The mass of the substrate and the Coating decides the weight and the cost of the Catalytic convertor which was reduced. Secondly main concern was the 100% utilization of the substrate. This was achieved by working on cann in terms of the Cone angle and the length before the substrate.

Keywords: *Catalytic configuration, CNG Lean burn engines, BS IV emission norms.*

1. INTRODUCTION

Lean-burn natural gas engines are very popular for applications involving power generation and co-generation. On-site power generation reduces power transmission losses and in the case of co-generation also supplies heat. Unfortunately, due to incomplete combustion within these engines the exhaust contains trace amount of hydrocarbons with up to 1000 ppm of methane. Since methane has a greenhouse warming potential of about 20 to 50 times that of carbon dioxide, its emissions are becoming an area of concern. Although Denmark is the only jurisdiction with methane regulations today, it is likely that other jurisdictions will follow. Regulatory agencies are continually lowering emissions requirements on engines and methane emission standards are the next logical progression. Reliable cost-effective technology to combat methane emissions is not yet available but is highly desirable.

The most common technology for exhaust gas cleanup is a catalytic converter. In most applications, the converter would be installed downstream of the turbocharger where temperatures are typically below 500°C. These temperatures are too low for achieving significant methane conversions with current oxidation catalyst technology. This paper will discuss a novel approach where the catalyst is installed upstream of the turbocharger where temperatures are 100 – 150°C higher. However, installing a catalyst upstream of a turbo presents other complications that will be addressed in this paper.

Lean burn spark ignited engines can experience misfires due to ignition failure, flame quenching, and incomplete flame propagation. This can lead to the catalyst being exposed to large concentrations of hydrocarbon during the misfiring event. In the pre-turbo position, temperatures are expected to be well above the catalyst light off temperature causing ignition of the excess fuel mixture. This could cause a rapid temperature rise across the catalyst leading to catalyst deactivation and/or catastrophic failure. This paper will discuss design issues and give suggestions for minimizing those risks.

In our project the 5samples of different configuration were prepared including the present configuration the details were provide to the supplier to decide the loading of PGM group metals on each sample. Since each sample was having different configuration with respect to each other there mass was reduced and hence the volume of PGM metals where reduced which was coated on the samples. Thus the primary concern of the project to reduced the cost was achieved but still work was carried out to increase the efficiency or to meet the targets set for the BSIV norms. For the reason we worked on the Cone angle and the length before the substrate so as to achieve 100% utilization of the substrate and obtain to good UDI (uniform distribution index) for the same.

2. CATALYST AND SUBSTRATE PREPARATION

2.1. Substrate

Substrate can be ceramic or metallic. Ceramic, being an insulator have good heat retention capability where as Metallic substrates are good conductor of heat. So we have selected the ceramic material as our substrate material.

Two primary factors are considered while designing Substrates.

Open frontal area Geometrical Surface area.

2.1.1. Open Frontal Area (OFA)

OFA is a cross section area of substrate which can be varied by changing the cell thickness. High OFA leads to lower back pressure and it also leads to improved engine performance

2.1.2. Geometrical Surface Area (GSA)

GSA is the overall surface area which will be in contact with Exhaust gases.GSA can be varied by changing the number of cells. Improved GSA leads to better efficiency of catalyst as more of the exhaust is exposed to reaction.

If we work on improving the OFA & GSA of the substrate we may be able to reduce the PGM content for the same efficiency or even improved efficiency against our content substrate. Also changing the substrate material from ceramic to metallic improve the efficiency with reduced PGM.

2.2. Washcoat

Wash coat in liquid form is applied over the substrate. Increases the roughness of the site which in turn increases the surface area of the site. So more exhaust go under reaction is an intellectual property right of coaters. PGM (Platinum group metals) Platinum, Palladium are two widely used oxidation agents and Rhodium acts as reducing agent, which is known as precious metals. PGM in liquid form are applied over slurry coated bricks. Catalyst Configurations are expressed in the form of Density(g/ft3) and Pt:Pd:Rh ratio of PGM.

Loading is decided on the basis of engineering targets and margins desired. Other inputs desired for loading finalization are engine out emissions and exhaust temperature profile along with exhaust gas flow rates. Ratio is decided on the basis of chemistry between wash coat and PGM. Also it is proprietary information of catalyst coaters. Six and geometry of substrate also play an important part for loading finalization.

2.3. Canning

Acts as a packaging for the coated substrate. Canning angle is the important parameter for uniform flow distribution of the Exhaust and to utilize the maximum surface area of the substrate.

As mention in the earlier paragraph, Can angle plays an important part for the uniform distribution of gasses inside it for utilization maximum portion of the catalyst coating.

A brain storming session was done with CES representative and conclusion came out be the verification of FDI (flow distribution index) of current design and go for the optimized design. This will be carried out by doing CFD analysis at CRTI.

Different methods employed for canning are:-

Clamshell

Tourniquet

Shoebox

Stuffing

Swaging

3. CHARACTERISTICS OF PGM

3.1. Platinum (Pt)

- Is an Oxidizing Agent. Used for CO & THC Conversion.
- Better Light off Characteristics
- Better for Carbon Monoxide Conversion.
- Higher Cost than Pd

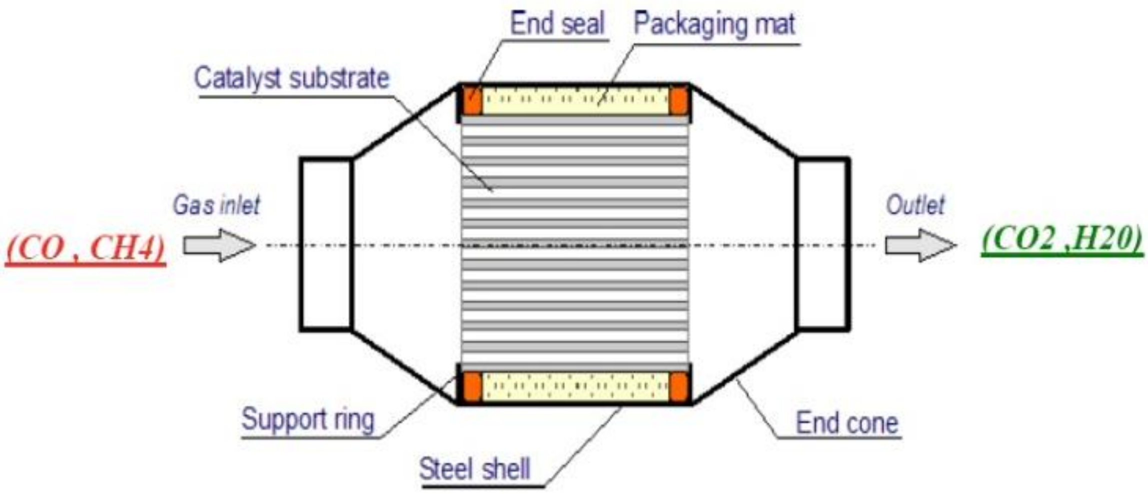
3.2. Palladium (Pd)

- Is an Oxidizing Agent. Used for CO & THC Conversion.
- Better for CH4 Conversion
- Highly susceptible to Sulphur Poisoning.
- Preferred Oxidizing agent now-a-days as it is Cheaper than Platinum and good for CH4 Conversion which is the most challenging task for after treatment

3.3. Rhodium (Rh)

- Is a Reducing Agent
- Used for NOx Conversion
- Also act as a binder to reduce dispersion of Platinum or Palladium.

4. TESTING



Chemical Reactions Inside Oxidation Catalytic Converter:

$$2CO + O2 \xrightarrow{Pt/Pd} 2CO2 ;$$

$$HC + O2 \xrightarrow{Pt/Pd} CO2 + H2O$$

Fig1. *2way catalytic convertor*

Testing was carried out as per MIMIC ETC Cycle. Various samples were evaluated and tested according to MIMIC ETC cycle and the emission & performance were found out from the prepared samples.

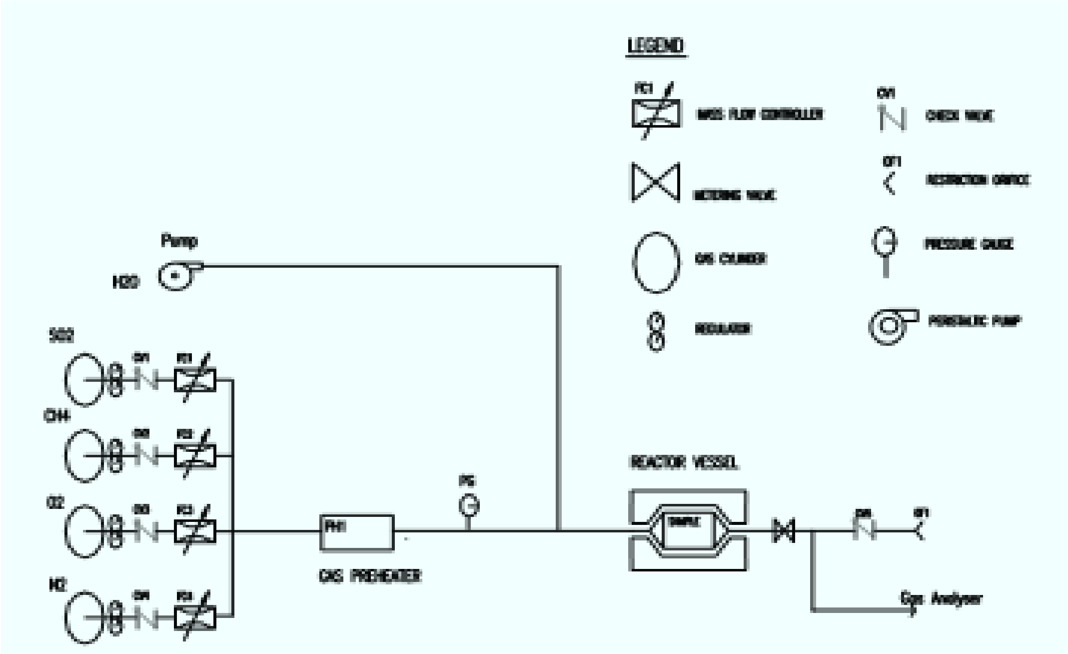


Fig2. *Testing arrangement*

Total 4 samples were prepared having configurations different from each other in dimension and the cells per square inch. Due to which total weight of the PGM metals used was reduced.

Then the canning was concentrated and the cann angle was optimised as so as to increase the flow distribution index for the gas and hence to increase the make 100% utilisation of the Substrate due to which efficiency of the catcon was maintained.

And then the optimised design was found out and were tested according to the MIMIC ETC Cycle for

BS 4 Norms

4.1. Parameter Diagram

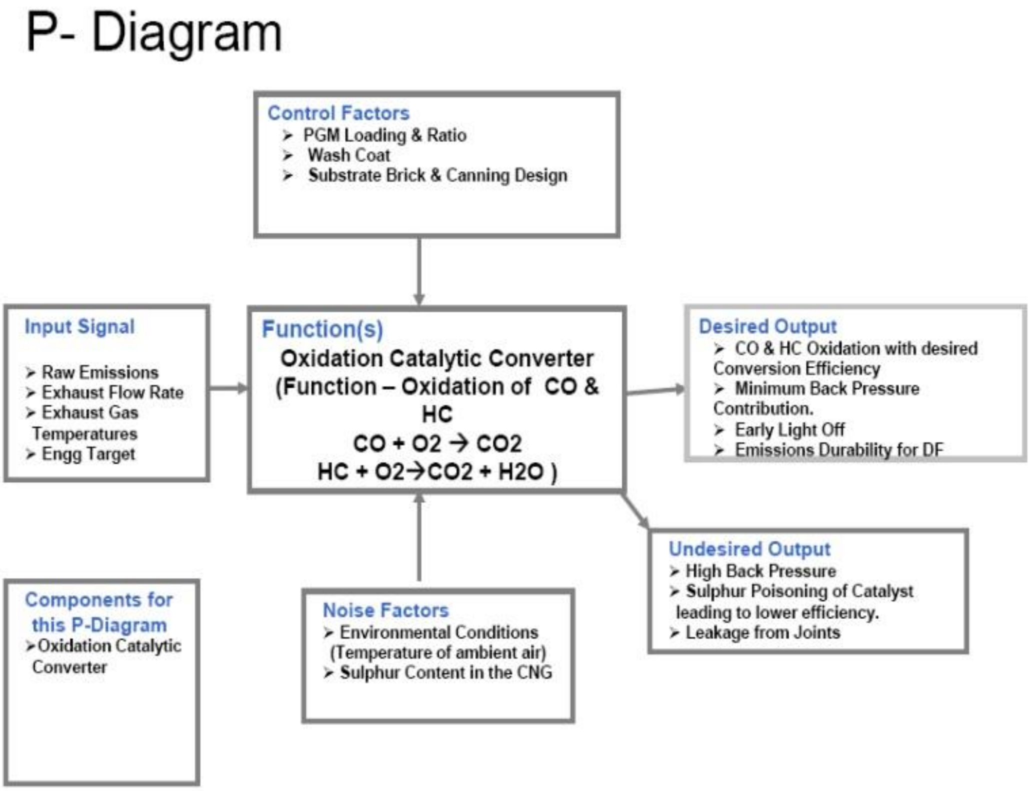


Fig3. *Parameter Diagram*

5. RESULTS

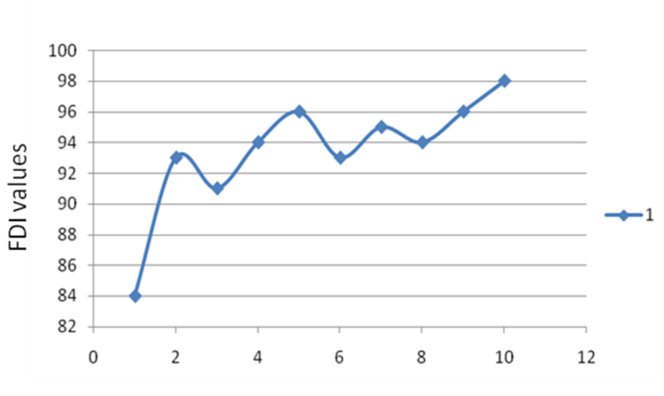
According to the current design of substrate the length and the diameter of the substrate was changed. Which led to the changes in the substrate size and hence the substrate volume was changed which indirectly affected the PGM coating.

As the Substrate volume was been changed hence the PGM coating required to be coated on the new developed substrate was also reduced as compared to the existing Design. Hence the cost was also reduced, but as the PGM coating was reduced hence now the effectiveness was also been affected due to which we have worked on the canning and with the optimized cone angle and the length before the substrate FDI values were calculated which are given below and hence the efficiency of the Catalytic convertor was maintain.

Table1. *PGM mass calculation*

Sr. No.	Substrate	Mass/pc(gms)
1	Base sample	44
2	Sample 2	35
3	Sample 3	42
4	Sample4	33

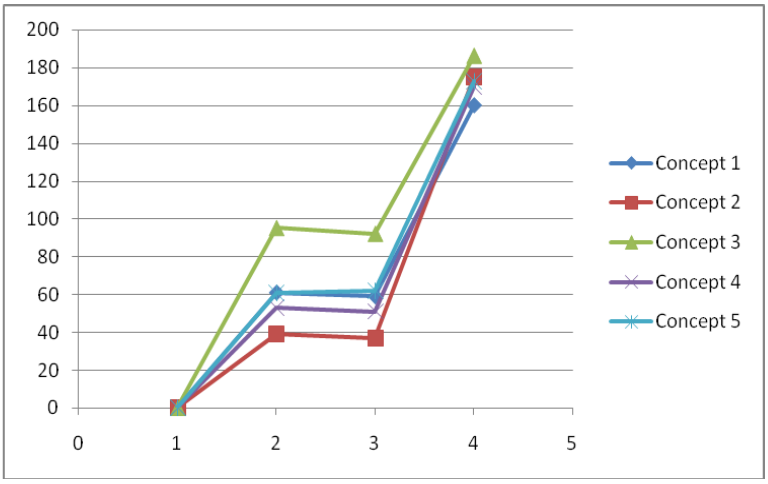
By changing the length before the substrate and the cone angles the below shown substrate utilisation values where achieved.



Graph1. *FDI Values for Base samples.*

The first samples indicates the base sample with existing cone angle and also the length before the substrate. Later on the cone angle and the length before the substrate was varied and the FDI number for each was calculated.

Below results were obtain with the Optimised design of catalytic convertor when tested with the Mimic ETC cycle.



Graph2. *Cost saving*

6. CONCLUSION

After the study existing catcon generated the idea for the design of the substrate which varied from the existing substrate so as to reduce the PGM metal coating on the substrate. Secondly the cann design was optimized in which we concentrated on the cone angle and the length before the substrate due to which we were able to effectively utilize the total substrate and hence optimized the PGM coating and after performing the experiments following findings made.

Impact of Cone Angle and Length before substrate on Catalyst Efficiency.

Due to which the exhaust from engine was distributes uniformly over the substrate due to which the substrate was completely utilized and hence the efficiency of the catcon was increased.

Impact of Substrate Geometry on Catalyst Efficiency.

Due to which the PGM coating was reduced which resulted in the reduction in the cost of the catcon and also due to the improved FDI the efficiency of the catcon was improved with reduction in the cost is as follows.

Graph3. *Costing of all samples*

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