DEVELOPMENT OF CATALYTIC CONVERTER FOR EMISSION CONTROL OF STATIONARY DIESEL ENGINE

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Abstract: A catalytic converter is device used to reduce the toxicity of emissions from an internal combustion engine. Also, catalytic converters are most commonly used in motor vehicle exhaust systems. The function of the catalytic convertor is to convert CO, HC and NOx emissions into CO_2, water, N_2 and O_2. In the present work, design specifications of catalytic converter for stationary diesel engine have been presented. According to this design, catalytic converter is developed and then, installed on the single cylinder stationary diesel engine. At the successful completion of present work it is expected that newly designed and developed catalytic converter system will work efficiently to reduce emissions significantly.

Keywords: Catalytic Converter, emissions.

1. Introduction:

Catalytic converters have been widely used on vehicles and have already been proved for many years to be the most effective technical solution to reduce exhaust emissions from gasoline engines. The pollutants have negative effect on air quality, environment and human health that leads in stringent norms of pollutant emission. Numbers of alternative technologies like improvement in engine design, fuel pretreatment, use of alternative fuels, fuel additives, exhaust treatment or better tuning of the combustion process etc. are being considered to reduce the emission levels of the engine. 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.

There are different catalytic converter systems used. They are as follows.

A. Oxidation Catalytic Converters*:*

This system ideally converts the oxidising components into H_2O and CO_2. The catalyst operates at excess air settings. The air required for the oxidation process is supplied by lean mixture settings or by secondary air injection. Oxidation catalysts were used for the first time in 1975 on U.S. vehicles. They are no longer used on passenger vehicles today since three-way catalytic converters are far more efficient and will additionally convert NOx emissions. Oxidation catalysts are used to an increasing degree on diesel engines, however, since they are capable of oxidising soluble particulate matter in addition to the above components.[2]

B. Dual-bed Catalytic Converters:

This system includes two catalyst systems mounted in line in the exhaust system. A reduction catalyst is fitted to minimize NOx emissions, and an oxidation catalyst is used to reduce HC and CO emissions. The engine must be operated at air deficiency (*Je*< 1). This system has therefore certain drawbacks in terms of fuel consumption and *CO2* emissions. Complex mixture formation control systems are not required. Since the engine is operated in the rich Je range, increased ammonia emissions may result. The nitrogen oxide conversion efficiency is far lower than with three-way catalytic converters.[2]

C. Three-way Catalytic Converters:

A characteristic feature of this system is that is reduces NOx, and HC and CO by the same high degree throughout. To achieve optimum emission control results, however, a complex control system (lambda control) is required. Uncontrolled systems with three-way catalytic converters of the type that was also marketed in Germany only reach conversion efficiencies of approx. 40 to 50%, whereas computer-controlled systems in new condition will reach conversion efficiencies of more than 95%. Three-way closed-loop catalytic converters currently are the most efficient emission control systems available for internal-combustion engines.[2]

D. Denox or Lean-burn Catalytic Converters:

Lean-burn or Denox catalytic converters allow not only CO and HC, but also NOx to be converted in the excess-air range. They are currently in the development stage. NOx conversion efficiencies in excess of 50% have already been demonstrated.[2]

2. Design Specifications of Catalytic Converter:

In this section, specifications of components of catalytic converter system have been presented. This catalytic converter system is designed for Kirloskar stationary diesel engine. The detailed engine specifications are described in experimentation section. From the engine specifications, catalytic converter system is designed. For this design, different parameters like space velocity, volume, shape have been considered. The specifications of designed catalytic converter are shown in following table.

Step 1: Outer Dimensions of Catalytic Converter

Table 1. Dimensions of Catalytic Converter

Catalytic Converter Volume	0.44178 L
Diameter of Catalytic Converter Body	75 mm
Length of Catalytic Converter Body	100 mm

Step 2: Dimensions of Substrate

The dimensions of substrate are selected from volume of catalytic converter. The standard dimensions are shown in following table. Depending on the volume of catalytic converter, 1200/2 cell density diemensions are selected for substrate.

Table 2. Dimensions of Substrate [1]

Parameter	Cell Density			
	400/6.5	600/4	900/2.5	1200/2
Substrate volume, l	0.86	0.67	0.67	0.31
GSA, m^2/ l	2.74	3.48	4.37	4.98
OFA, %	75.7	81.4	85.6	83.4
R_f, litres/ cm^2	3074	3990	5412	7589
Substrate mass, g	339	202	156	83

These diemensions of substrate 1200/2 cell density are selected because these dimensions gives less emissions as compared to other substrate. The emission results are shown in following table.

Table 3. Emission Reduction [1]

Cell Geometry	Relative HC Emissions	Relative NO_x Emissions
400/6.5	100	100
400/4.5	88	94
600/4.3	65-74	74-93
900/2.5	52-66	59-75
1200/2	41-57	57

3. Material of Catalytic Converter:

In this section, material used for components of catalytic converter have been dicussed. The main components of catalytic converter are –

1. Substrate
2. Catalyst
3. Washcoat

A. Substrate:

The substrate have two functions, first is, it supports the catalyst and second is, takes the catalyst into maximum contact with exhaust gases.

Requirements of Substrate: [1,2]

- Substrate must be covered with the washcoat
- Low thermal inertia and efficient heat transfer
- More surface area per unit volume

- Ability to withstand high operating temperature
- Long durability
- High resistance to thermal shocks

From this requirements, metallic substrate is used in this catalytic converter system and material used as steel because of following reasons.

- Higher mechanical strength
- High thermal conductivity for faster warm-up
- Reduced space requirement and no special mounting is required
- High flow area due to lower cell wall thickness and hence reduced pressure drop
- Higher conversion efficiency[1,2]

B. Catalyst:

The substance which increases rate of reaction without takes part in the reaction is called as catalyst. There are different types of catalysts used for conversion of pollutants. In this, oxides of base metals like copper, chromium, nickel, cobalt etc. and the noble metals like platinum, palladium and rhodium are used. In this investigation, platinum is used as a catalyst because, at high end exhaust temperature base metals oxide becomes deactivate and sintering occurs. Due to this, conversion efficiency of catalytic converter decreases. Another advantage of platinum is good cold start performance.[1]

C. Washcoat:

It is component of catalytic converter which increase the oxygen storage capacity [2]. It increases the surface area of substrate. Alloy coating is done on the washcoat. It consists of Al_2O_3 [2]. Also, titanium dioxide will be used for washcoat as alternative material [3].

4. Manufacturing of Catalytic Converter:

In this section, manufacturing of the components of selected catalytic converter have been discussed. There are three main components of catalytic converter i.e. substrate, catalyst, washcoat. These components are discussed in above section.

A. Substrate:

An oxidation catalytic converter is a catalyst coated honeycomb-like, channeled metallic substrate, through which exhaust gas passes. The ceramic substrate is constructed by extruding or compressing a ceramic material into a honeycomb structure of desired length and width. Treating the honeycomb substrate with catalyst materials is achieved by drenching the substrate with a slurry containing ceramic and catalytic materials whereby the surface area along the length of every channel is coated and impregnated with catalytic materials. Diesel oxidation catalytic converter substrates are also made from metal foil material which is fan folded and fashioned into a honeycomb substrate with catalyst materials in a similar manner as ceramic substrates. [3]

B. Washcoat:

A washcoat is a carrier for the catalytic materials and is used to separate the materials over a large surface area. The washcoat is a mixture of silica and alumina. The catalytic materials are suspended in the washcoat prior to applying to the core. Washcoat materials are selected to form a rough, irregular surface, which greatly increases the surface area compared to the smooth surface of the uncovered substrate. This in turn maximizes the catalytically active surface available to react with the engine exhaust. The coat must retain its surface area and prevent sintering of the catalytic metal particles even at high temperatures. [1-3]

C. Catalyst:

A catalyst is component of catalytic converter which increases the rate of reaction. In this investigation, platinum is used as catalyst. The coating of catalyst is done on the surface of substrate.

5. Experimental Set-up:

In this section, detail about experimental set up have been discussed. The engine selected for conducting tests is Kirloskar, four-stroke, single-cylinder, water-cooled, naturally aspirated, DI (open chamber), diesel engine. The tests will be performed on experimental set-up shown in Fig. The detail specifications of engine are represented in Table 4. Eddy current dynamometer has been used for loading the engine. The engine will operated at a rated constant speed, 1500 rev/min.

Table 4. Specifications of Engine

Make and Model	Kirloskar,
No. of Cylinders	One
Orientation	Vertical
Cycle	4 Stroke
Ignition System	Compression Ignition
Bore X Stroke	87.5 mm X 110 mm
Displacement Volume	661 cc
Compression Ration	17.5 : 1
Arrangement of valves	Overhead
Combustion Chamber	Open Chamber (Direct Injection)
Rated Power	5.2 kW (7 HP) @1500 rpm
Cooling Medium	Water cooled

The catalytic converter system is installed with above engine and test will be conducted on this engine such as with catalytic converter system and without catalytic converter system. The photograph of this systems are shown below.

Fig. 1 Engine without catalytic converter

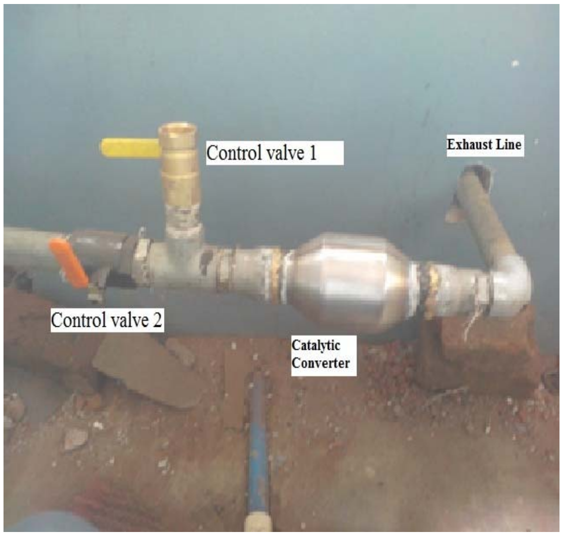

Fig.2 Engine with catalytic converter

In above figure, control valve 1, control valve 2, catalytic converter and exhaust line are shown. The control valve 1 is used for injection of diesel exhaust fluid for reduction of NOx emission. The diesel exhaust fluid is a solution of urea and water. In this investigation, catalytic converter is connected in exhaust line of engine with the help of brazing.

6. Conclusion:

From study of designed catalytic converter, suitable material for components of catalytic converter is selected. The parameters required for design of catalytic converter are identified. The designed catalytic converter is successfully manufactured and installed with engine. The installed catalytic converter will reduce emissions significantly.

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