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# Design of Catalytic Converter for Stationary Diesel Engine

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**Abstract—***Air pollution from on road as well as off road vehicles is major problem. The harmful pollutants like CO, HC, $NO_x$, PM are emitted from on road and off road vehicles which causes hazardous effect on human health as well as environment. So, it is necessary to minimize these air pollution. For this purpose, different technologies are used like enhancement in engine design, pretreatment on fuel, exhaust treatment, etc. So, it is challenging to researchers to control emissions from stationary diesel engines. The present work comprises of design of catalytic converter for stationary diesel engine. In this work, catalytic converter is designed from engine specifications. There are different parameters to be considered for designing the catalytic converter system. Also, materials for catalytic converter are discussed. Finally it is possible that designed catalytic converter can reduce emissions significantly.*

## 1. INTRODUCTION

Air pollution and global warming from on road as well as off road vehicles are major issues nowadays. The utilization of vehicles has increased due to population growth, increased urbanization, and industrialization. The exhaust emissions from internal combustion engine takes part more than 60 to 70%. Harmful pollutant like CO, HC, $NO_x$, PM are emitted from internal combustion engines. These emissions causes hazardous effect on the human health and environment. Also, these pollutants are responsible for greenhouse effect, acid rain, etc. Hence, emission regulations are becoming very serious every year. There are different devices developed for aftertreatment of exhaust emissions. The most effective aftertreatment device for reducing exhaust emissions are catalytic converters.

The design of catalytic converter includes methodology, material required for components of catalytic converter. In practice design of catalytic converter is important task than science. The catalytic converter is best solution for emission reduction of internal combustion engines to fulfill with emission regulations. The catalytic converter is device which converts toxic pollutants into non toxic pollutants. The position of catalytic converter is also important in case of design consideration. So, catalytic converter is installed between engine exhaust manifold and muffler.

## 2. CATALYTIC CONVERTER DESIGN

In this section, some parameters are discussed to be considering for design of catalytic converter. After this, methodology of design and material selection for catalytic converter has been presented.

### 2.1. Shape of Catalytic Converter

The shape of catalytic converter should be selected as round honeycomb structure because it is easy for manufacturing. By choosing this shape, surface area of substrate increases. Also, with these shape, minimum time required for assembly and it is easy for maintenance. With the use of round honeycomb structure, mass of substrate get reduced and flow area increases. With use of round shape backpressure reduces about 10 to 15%. Also thermal conductivity goes on increases by choosing this shape. There are other shapes like oval, rectangular used. But in this shape, pressure drop is more as compared to round shape. Also wall thickness is more in case of the rectangular shape. Therefore surface area is reduced. For this reason shape of catalytic converter should be selected as round honeycomb structure [1].

### 2.2. Space velocity

Space velocity is the ratio of exhaust gas flow rate to the volume of converter [1]. Space velocity means residential time of exhaust gases in converter or reactor. In general space velocity means amount of entering volumetric flow rate of reactants divided by the reactor volume. If space velocity goes on increasing then converter volume decreases. i.e. performance of catalytic converter goes on decreasing. So, space velocity is assumed in proportion with converter volume. Space velocity varies from about 20000 to 25000 per hour depending upon the duty cycle of engine [1].

### 2.3. Volume of Catalytic Converter

This parameter is also important in designing of catalytic converter. The volume of catalytic converter is 0.5 to 1 times that of the engine swept volume [1]. Also, volume of catalytic converter depends upon engine swept volume and is inversely proportional to the space velocity. If, volume of catalytic converter is lower than half of the engine swept volume then, space velocity increases tremendously. Because of this, reaction between catalyst and exhaust gases does not take place and emission goes on increasing. Hence, it is kept in the range of engine swept volume.

## 3. METHODOLOGY

In this section, design steps of catalytic converter have been presented. The catalytic converter system means diesel oxidation catalyst and selective catalytic reduction technology used in diesel engine for conversion of HC, CO, $NO_x$, PM. The main components of catalytic converter are –

1. Substrate
2. Washcoat
3. Catalyst [2]

This Catalytic Converter system is designed for following engine.

**Table 1: Engine Specifications**

| | |
|---|---|
| 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 |

### 3.1. Design steps are as follows [5].

Step 1: Volume Flow Rate of Exhaust Gases

volume flow rate = swept volume × Number of intake stroke/hr

$$= \frac{\pi}{4} \times D^2 \times \mathrm{L} \times \frac{N}{2} \times 60$$
$$= \frac{\pi}{4} \times 0.0875^2 \times 0.110 \times \frac{1500}{2} \times 60$$
$$= 29.765\ m^3/\text{hr}$$
$$= 0.008268\ m^3/\text{sec}$$

Step 2: Catalytic Converter Volume

Assume, space velocity = 67375 $hr^{-1}$

Space velocity = $\frac{Volume\ \ flow\ rate}{converter\ \ volume}$ then,

Converter volume = $\frac{Volume\ \ flow\ rate}{space\ \ velocity}$

$$= \frac{29.765}{67375}$$
$$= 0.00044178\ m^3$$
$$= 441.78\ \text{cc}$$
$$= 0.44178\ \text{L}$$

Step 3: Outer Dimensions of Catalytic Converter

Catalytic converter is a cylindrical shell. Therefore, dimensions of catalytic converter are determined from volume above calculated.

Volume of Catalytic Converter = $\frac{\pi}{4} \times D^2 \times$ L

Assume, D = ¾ L

This proportion of diameter and length used in some gas engine vehicles models such as Mitsubishi 3000 GT, Jaguar cars, Acura cars, etc. But this proportion is not fixed. It is taken as per engine swept volume requirement.

Now, 0.00044178 = $\frac{\pi}{4} \times (3\mathrm{L}/4)^2 \times$ L

0.00044178 = $\frac{\pi}{4} \times 9/16 \times L^3$

L = 100 mm

Then, D = ¾ ×100 = 75 mm

D = 75 mm

Step 4: Substrate Dimensions

The standard dimensions of substrate are selected from volume of catalytic converter above calculated. The dimensions are selected as 1200/2 cell density from following table 2.

**Table 2: Substrate Dimensions [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 |

The cell density 1200/2 is selected because it gives better emission reduction as compared to other cell densities. Emissions reduction are shown in following table 3.

**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 |

## 4. MATERIAL OF CATALYTIC CONVERTER

In this section, material of three components of catalytic converter has been discussed.

### 4.1. Substrate

It is the component of catalytic converter which supports the catalysts. The function of substrate is to bring the active catalyst into maximum contact with the 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

There are different types of substrates used in catalytic converter like pellet, ceramic, metallic, etc. In this investigation, metallic substrate is used having following dimensions.

**Table 4: Substrate Dimension [1]**

| | |
|---|---|
| Cell Density | 1200/2 |
| Substrate volume, l | 0.31 |
| GSA, $m^2$/ l | 4.98 |
| OFA, % | 83.4 |
| $R_f$, litres/$cm^2$ | 7589 |
| Substrate mass, g | 83 |

Advantages over ceramic substrate: [1,2]

- 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

Because of the above reasons, material for metallic substrate is selected as steel.

### 4.2. Catalyst

The catalyst is a substance which increases the rate of reaction which does not take part in the reaction. 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].

### 4.3. 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].

## 5. CONCLUSION

The effects of parameters for design consideration have studied. Also, materials for catalytic converter have suggested. The catalytic converter for stationary diesel engine was successfully designed. So, designed catalytic converter can reduce emission significantly.

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