Development of a New, Effective and Cheap catalytic Convertor with Electrostatic Precipitator

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Abstract- *This paper discusses the method to prepare a cheap and efficient catalytic convertor coupled with an electrostatic precipitator for exhaust of diesel engines. Conventional catalytic convertors use PGMs to reduce harmful exhaust gases which make them expensive. Moreover for diesel engines, solid particulate exhaust is a major problem.*

Keywords:- Catalytic Convertor, Migration Velocity, ESP, solid particulate exhaust, PGMs.

I. INTRODUCTION

At the starting of the 19^{th} century the door toward individual mobility was opened, with the start of the mass production of automobiles. In 20^{th} century, the number of gasoline-driven vehicles increased from a few thousand to several hundred million on the planet. By the year 2000, approximately 500,000,000 passenger cars were registered world-wide and even more number of commercial diesel powered vehicles. In India, subsidy on diesel lures more and more people to use diesel powered engines.

This type of increase is expected to continue at least for the next three decades, is accompanied by a corresponding growth in pollution in the atmosphere, since almost every vehicle is driven by an internal combustion engine. Because these pollutants affect both the environment and human health in many unpleasant ways, it became clear during the 20^{th} century that measures had to be taken to reduce the levels of emission to tolerable limits. Soon it became apparent that the improvement of the combustion in gasoline engines alone was not sufficient to reach the desired emission levels. Therefore, exhaust gas after treatment systems were introduced, which are capable of completing the combustion by means of catalysts, thus reducing the levels of undesired emission components to very low concentration.

II. RESEARCH ELABORATIONS

A catalytic convertor is a vehicle emissions control device that converts toxic pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction (Oxidation & Reduction). Catalytic convertors are used in Internal Combustion Engines fuelled by either petrol (Gasoline) or Diesel – including Lean Burn Engines.

Diesel exhaust contains relatively high levels of particulate matter (Soot), consisting in large part of elemental carbon. Catalytic convertors cannot clean up this elemental carbon, thouigh they do remove upto 90% of the soluble prganic fraction, so particulates are cleaned up by a soot trap or diesel particulate filter(DPFs). Historically, a DPF consist of cordierite of silicon carbide substrate with a geometry that forces the exhaust flow througjhb the substrate walls, leaving behing traped soot particles.

Diesel Engine Exhaust Major Pollutants

Ideally, the emissions of an internal combustion engine only consist of:

- Carbon dioxide (CO_2)
- Carbon mono Oxide (CO)
- Nitrogen Oxide (NO_x)

A. Catalyst Material

Conventional internal combustion engines are facing problem with in-cylinder combustion as they produces higher unburned hydrocarbon (HC) and carbon mono oxide (CO) emissions. However, the gaseous pollutants from engine exhaust can be reduced by catalytic system.

A catalytic convertor is a device used to reduce the exhaust pollutant gases from an internal combustion engine. The catalytic convertor is placed between engine manifold and exhaust tailpipe. Pollutant gases coming out of the engine pass through catalytic convertor where these gases undergo chemical process by which they are converted into relatively harmless gases. Continuous exposition of the catalytic convertor to high temperature may cause an alteration on its components that lead gradually to its deactivation as because the conventional catalytic convertor consisting of catalyst materials mainly noble metals or platinum group metals (PGMs). The PGMs comprises the rare material such as iridium, rhodium, osmium, platinum, palladium, ruthenium, etc – all these metals have that they are immobile.

In this paper we are introducing a new type of catalytic convertor based on CoO/TiO_2 material which has been developed with wire metal substrate to oxidize/reduction/emission from diesel engine. Its advantages are low cost, higher substrate area and domestically available.

B. Electrostatic Precipitator

An electrostatic precipitator (ESP) is a highly efficient filtration device that removes fine particles like dust and smoke from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.

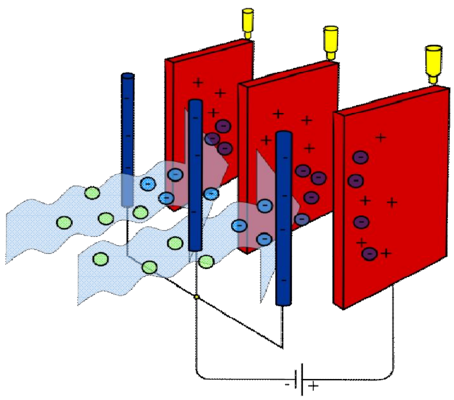

Figure2.1: conceptual Diagram of an Electrostatic Precipitator
Source: en.wikipedia.org

III. METHODOLOGY

The construction consists of two parts: catalytic convertor and Electrostatic precipitator.

A. Catalytic convertor

In this study, several stock solutions with different aqueous molar ratios and weight ratios will be used. Titanium oxide and cobalt oxide will be used as a metal oxide catalyst whereas pure cobalt oxide is used as the reducing agent and titanium dioxide is the oxidizing agent.

Catalyst slurry preparation

Sodium silicate will be used to wash coat material to increase its coating strength; 90 gm of sodium silicate solution will be added further to 10 gm TiO_2. This slurry is then stirred at 500 rpm for two hours.

Material selection for substrate

The substrate material we are using is stainless steel, not only because of its mechanical properties but also for its low coast.

Treatment of wire mesh substrate

The wire mesh substrate will be immersed in a preparation of 10% HCL for around 30 minutes to remove all impurities and then it will rinsed in distilled water before being dried in an oven at a temperature of 100^0 C. this drying process takes about 1.0 hour before coating it with catalyst.

Substrate coating

The steel wire mesh will be coated with the metal catalyst by dipping technique; this immersed wire mesh is then blowered using air which is further dried in an oven at a temperature 120^{o}C. Then wire mesh is calcined in a muffler furnace after which stainless wire mesh will be arranged into straight bar so as to became a substrate for use as a catalytic convertor.

B. Electrostatic Precipitator

For controlling exhaust gas temperature at the time entering ESP, the exhaust gas cooler should be installed in the system. This exhaust gases has to be cooled in 1500^{0}C. Exhaust gas flow is controlled by manual control valve.

Design Method

We use mathematical equations to estimate collection efficiency or collection area. We also use a CAD Model to test the design features and operating parameter in a simulation of the final design.

Particle Migration Velocity

Before estimation of collection area and collection efficiency, we measure the particle migration velocity. This is the speed at which a particle, once charged, migrates toward the grounded collection electrode.

The charged particles move to the collection electrode is denoted by symbol, "w", called particle migration velocity or drift velocity. Expression of migration velocity is –

$$w = (d_P E_o E_P) / 4\mu\pi$$

where:
d_P = diameter of the particle (μm)
E_o = strength of field in which particles are charged (V/m)
E_P = strength of field in which particles are collected (V/m)
μ = gas velocity (pa.s)
π = 3.14

as shown in the equation, migration velocity depends on voltage strength of charging field and collection fields, thus the precipitator must be designed using maximum electric field voltage for maximum collection efficiency.

Table 3.1: Typical effective particle migration velocity rates for various applications

Application	Migration Velocity (ft/sec)	Migration Velocity (cm/sec)
Utility fly ash	0.13-0.67	4.0-20.4
Pulverized coal fly ash	0.33-0.44	10.1-13.4
Pulp and paper mills	0.21-0.31	6.4-9.5
Sulphuric acid mist	0.19-0.25	5.8-7.62
Cement(wet process)	0.33-0.37	10.1-11.3
Cement(dry process)	0.19-0.23	6.4-7.0
Gypsum	0.52-0.64	15.8-19.5
Smelter	0.06	1.8
Open-hearth furnace	0.16-0.19	4.9-5.8
Blast furnace	0.20-0.46	6.1-14.0
Hot phosphorous	0.09	2.7
Flash roaster	0.25	7.6
Multiple-hearth roaster	0.26	7.9
Catalyst duct	0.25	7.6
Cupola	0.10-0.12	3.0-3.7

Source: Theodore and Buonicore 1976: U.S. EPA 1979.

Deutsch-Anderson Equation

Probably the best way to gain insight into the process of electrostatic precipitation is to study the relationship known as Deutsch-Anderson equation. It is used to determine the collection efficiency of the precipitator under ideal conditions. Expression of Deutsch-Anderson Equation is –

$$\eta = 1-e^{-w\,(A/Q)}$$

where:
η = collection efficiency of the precipitator
e = base of natural logarithm = 2.718
w = migration velocity, (cm/s)
A = the effective collecting plate area of the precipitator (m^2)
Q = gas flow through the precipitator (m^3)

IV. APPROXIMATED RESULTS

The CO conversion efficiency of wire mesh catalytic convertor is expected to be around 75%.

The HC conversion efficiency of wire mesh catalytic convertor is expected to be around 81%.

The NO_X conversion efficiency of wire mesh catalytic convertor is expected to be around 89%.

V. CONCLUSION

However the synthesis of the catalytic convertor is cheap and easier to construct, the electrostatic precipitator still poses difficulty and it is not very cheap. We devoted most of the time analyzing the availability and costing of the components and various roadblocks that may occur when the catalytic convertor will ne actually fabricated.

We also desire that such products should be promoted so that everyone can enjoy the innovations of technology while doing minimum amount of damage to the environment.

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