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REVIEW ON EMISSION CONTROL SYSTEM IN IC ENGINE BY 3 WAY CATALYTIC CONVERTER WITH ALUMINIUM OXIDE AND TITANIUM DI-OXIDE

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Abstract

The issue of reduction of harmful pollutants emitted from an internal combustion engine has gained large prominence as a part of climate change and global warming. Automobile and power generation systems are identified to be one of the largest contributors to atmospheric pollution. Some of the major pollutants emitted from an engine are Oxides of Nitrogen (NOx), Carbon monoxide (CO), Unburnt Hydrocarbon (UBHC) and soot particles. This paper presents a catalytic converter with emission reduction catalysts to be used for compressed ignition engine. The catalytic converter is developed based on the catalyst materials consisting of metal oxides such as aluminum oxide and titanium dioxide coated with wire mesh filter. Both the catalyst materials – aluminum oxide and titanium dioxide are inexpensive in comparison with conventional catalysts such as palladium or platinum. The objective of this research work is to control the NOx emission and to develop a low-cost three way catalytic converter. This catalytic converter is assembled in the exhaust manifold region of a single cylinder four stroke diesel engine. The emissions from the engine are measured using a five gas analyser and the results are tabulated.

1.1. INTRODUCTION

The urban air pollution is a very complicated problem. The exhaust emissions from internal-combustion engines account for a major portion of this problem. It is realized that the content and concentrations of the exhaust emissions depend on various parameters. These parameters include engine design parameters, operational parameters, exhaust gas aftertreatment, fuel types, fuel additives and lubricants. The present review project will discusses the effect of some parameters on the emission level and characteristics from internal-combustion engines. The project begins with an introduction of general information on the nature of emissions of exhaust gases, including the toxicity and causes of emissions for both spark-ignition and diesel engines. The paper then shifts to an up-to-date information of the published research work on the subject matter.

1.1.1. Introduction to I.C. Engines

An internal combustion engine (IC engine) is a mechanical device that generates power by burning fuel within a confined space to produce high-pressure gas, which is then converted into mechanical work. IC engines are commonly found in various applications, including automobiles, motorcycles, aircraft, industrial machinery, power generators, and more. They play a crucial role in modern transportation and industry, powering a wide range of vehicles and equipment.

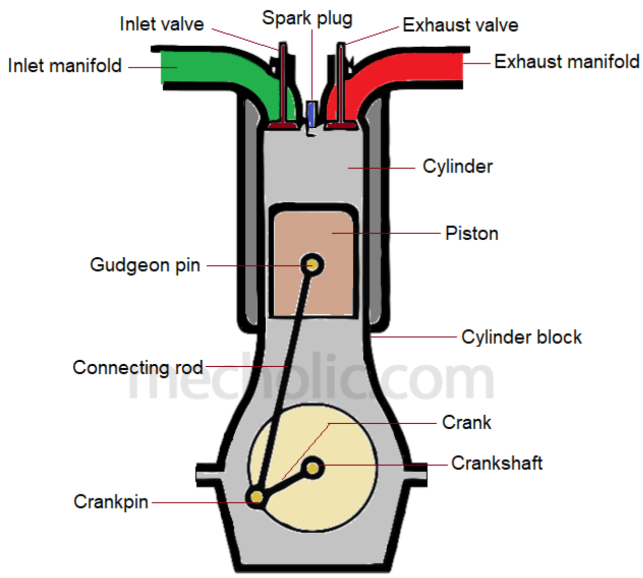


Fig.1.1 I.C. Engine

1.1.2. Key Components of an IC Engine:

1.1.2.1. **Cylinder:** The primary chamber where combustion takes place. In a typical IC engine, multiple cylinders are arranged in a specific configuration.

1.1.2.2. **Piston:** A cylindrical component that moves up and down within each cylinder. It helps compress the air-fuel mixture and converts the high-pressure gas generated during combustion into mechanical motion.

1.1.2.3. **Crankshaft:** A rotating shaft that connects to the pistons and converts their reciprocating motion into rotational motion. This drives the vehicle's wheels or powers machinery.

1.1.2.4. **Valves:** Valves control the flow of air and fuel into the cylinder and the expulsion of exhaust gases after combustion.

1.1.2.5. **Spark Plug** (in gasoline engines): It ignites the air-fuel mixture in the cylinder to initiate combustion.

1.1.2.6. **Fuel Injector** (in diesel engines): Instead of a spark plug, diesel engines use fuel injectors to spray fuel into the hot, compressed air, where it self-ignites due to the high pressure and temperature.

1.1.3. How IC Engines Work:

The operation of an IC engine generally follows a four-stroke cycle in most automotive and many industrial applications. This cycle consists of:

Intake Stroke: The piston moves downward, drawing in a mixture of air and fuel into the cylinder through the open intake valve.

Compression Stroke: The intake valve closes, and the piston moves upward, compressing the air-fuel mixture. This compression raises the temperature and pressure of the mixture.

Power Stroke: When the air-fuel mixture is compressed to its maximum, a spark plug ignites it in gasoline engines, while in diesel engines, the mixture self-ignites due to compression. This ignition creates a high-pressure gas, forcing the piston down, generating mechanical work.

Exhaust Stroke: After the power stroke, the exhaust valve opens, and the piston moves upward again, pushing the burned gases out of the cylinder and into the exhaust system.

This four-stroke cycle repeats continuously, providing a consistent source of mechanical power. IC engines can be further classified into two main types: gasoline (petrol) engines and diesel engines, each with its own ignition method and operating principles.

1.1.4. Advantages of IC Engines:

- Versatility: IC engines are used in a wide range of applications, from small, portable generators to massive ships and industrial machinery.
- High Power Density: They offer a high power-to-weight ratio, making them suitable for transportation.
- Quick Start-Up: IC engines can start and provide power rapidly, making them ideal for on-demand power generation.

1.1.5. Challenges and Considerations:

- Emissions: IC engines produce exhaust emissions, including carbon dioxide, nitrogen oxides, and particulate matter, which can contribute to air pollution and climate change.
- Efficiency: While IC engines have improved significantly in terms of efficiency, they still waste a substantial amount of energy as heat.
- Noise and Vibration: IC engines can be noisy and generate vibrations, which can affect comfort and durability.
- Fuel Dependency: IC engines rely on fossil fuels, making them susceptible to fluctuations in fuel prices and concerns about energy sustainability.

1.1.6. Emissions from internal combustion (IC) engines

Emissions from internal combustion (IC) engines are a significant environmental concern due to their impact on air quality and contributions to climate change. These emissions are a result of the combustion process and the incomplete combustion of fuel within the engine. The primary emissions from IC engines include:

Carbon Dioxide (CO_2):

CO_2 is a greenhouse gas that is a major contributor to global warming and climate change. It is a natural byproduct of the combustion process and is directly related to the amount of fuel burned.

Nitrogen Oxides (NOx):

NOx compounds, such as nitric oxide (NO) and nitrogen dioxide (NO_2), are formed during high-temperature combustion. They are responsible for the formation of smog, acid rain, and respiratory problems. NOx emissions also contribute to the depletion of the ozone layer.

Particulate Matter (PM):

PM includes tiny solid particles and liquid droplets that are emitted in the exhaust. These particles can be harmful when inhaled, causing respiratory problems and other health issues. Diesel engines are known for producing a significant amount of particulate matter.

Carbon Monoxide (CO):

CO is a colorless, odorless gas that can be harmful when inhaled in high concentrations. It interferes with the body's ability to transport oxygen and can cause health problems. It is a product of incomplete combustion.

Hydrocarbons (HC):

Hydrocarbons are unburned fuel molecules emitted from the engine. They can react in the atmosphere to form ground-level ozone, a major component of smog. Ozone can cause respiratory problems and damage crops.

Sulfur Dioxide (SO_2):

SO_2 emissions result from the combustion of sulfur-containing fuels, such as high-sulfur diesel. SO_2 contributes to acid rain, which can harm ecosystems, damage buildings, and affect human health.

Volatile Organic Compounds (VOCs):

VOCs are unburned hydrocarbons that can evaporate from the engine or its exhaust. They are precursors to the formation of ground-level ozone and smog.

1.1.7. Emission reduction method

Reducing emissions from IC engines is essential to mitigate their environmental impact. Governments and regulatory bodies have implemented emissions standards and regulations to limit the release of these pollutants. Common methods for reducing emissions from IC engines include:

1. **Catalytic Converters**: These devices reduce CO, NOx, and HC emissions by catalyzing chemical reactions that convert harmful pollutants into less harmful substances.
2. **Exhaust Gas Recirculation (EGR)**: EGR systems reduce NOx emissions by recirculating a portion of the exhaust gas back into the engine's combustion chambers, which lowers combustion temperatures.
3. **Selective Catalytic Reduction (SCR)**: SCR systems, commonly used in diesel engines, reduce NOx emissions by injecting a urea-based solution into the exhaust, which reacts with NOx to form harmless nitrogen and water.
4. **Particulate Filters**: These filters capture and remove particulate matter from the exhaust stream, particularly in diesel engines.

5. **Fuel Formulation**: Using cleaner-burning fuels with lower sulfur content can reduce SO2 emissions.
6. **Improved Engine Design**: Engine manufacturers work to optimize combustion processes and improve overall engine efficiency to reduce emissions.
7. **Hybrid and Electric Vehicles**: Transitioning to electric and hybrid vehicles can eliminate tailpipe emissions altogether.

Efforts to reduce IC engine emissions are ongoing and include research into advanced engine technologies, alternative fuels, and stricter emissions standards to protect both the envronment and public health.

1.1.8. Emission and their effects

Emission Type	Effects
Carbon Dioxide (CO2)	Global warming, climate change
Nitrogen Oxides (NOx)	Smog, respiratory problems
Particulate Matter	Respiratory problems, air pollution
Carbon Monoxide (CO)	Health problems, air pollution
Hydrocarbons (HC)	Smog, ground-level ozone

Chart.1.1. Emission and their effects

1.2. REVIEW OF LITERATURE

[1]. Andrés F. Duque Amaya, Adalberto Gabriel Díaz Torres, Diego A. Acosta et. al. discussed and studied mathematical model of emissions was developed in a Twingo D7F engine. The effects of variations in compression ratio, fuel/air equivalence ratio, spark advanced and combustion duration under pollutant emissions were studied. Analysis and data collection were performed in an engine bank using a data acquisition system integrated to an Interactive Engineering Environment. A control strategy was implemented to guarantee emissions reduction and concluded that In this work was developed an environment model based on the explosion of isooctane fuel to quantify and reduce the main emissions in a Twingo D7F engine. Analysis and data collection of the Twingo D7F engine were performed in the EAFIT University bank engines. Parametric study was performed to reduce HC, CO, NOX emissions and improve oxygen consumption from variation of engine operation parameters. air–fuel ratio (A_F = 14), spark timing (−15◦ CAD) and compression ratio (RC = 9) were optimum values to reduce emissions in this engine.

[2]. G Balaji, D Premnath, R Yuvaraj, Akshdeep Singh Kohli et. al. Studied Emissions from the automobile contribute to major air pollution problems in cities as well as villages along with industrialised areas in developed and developing countries. Air pollution is one of the major factor that is the cause for global warming and the climate change problems. This paper focuses on mitigation using regular three way catalytic convertor to reduce the level of emissions of CO, NOx and HC along with a neem blend biodiesel. Since most of the transportation vehicles rely solely on Petrol and Diesel for their operation. This results in large amount of carbon monoxide (CO), unburnt hydrocarbons (HC), nitrogen oxides (NOx), and particulate matters. Hence, for the experimental analysis of the three way catalytic converter Neem-diesel blend will be used as

alternatives of petrol and diesel. Nearly all (95%) of the world's transportation energy comes from petroleum-based fuels, largely gasoline and diesel. Thus an organized cultivation and methodical collection of Neem oil, is a potential bio-diesel substitute and will reduce the import burden of petroleum. And Concluded that the performance and emission characteristics of neem oil blend fuelled Compression Ignition engine with a Catalytic converter system were studied and analysed. Based on the results derived from the experimental investigation, conclusions were drawn as summarized below.

1. The emission of NOx for neat neem oil blend decreases by 38.77% in presence of converter.
2. The emission of CO for neem oil blend decreased by 45.67% in presence of converter on comparison when converter isn't present.
3. The Brake Thermal Efficiency for neem oil blend decreases by 2.14% in presence of converter on comparison when converter isn't present. Also on comparison to diesel the BTE of neem blend with converter falls by 3.15%. In all the remaining loads when coupled with catalytic converter neem blend has better brake thermal efficiency than diesel.
4. The emission of HCfor neem oil blend decreases by 2.32% in presence of converter.
5. The emission of CO2 for neem oil blend increases by 47.41% when converter is placed. Also on comparison to diesel the CO2 emissions of neem blend with converter rises by 1.75%

[3] Kim Timmermans, MSc, Michiel Vaneker, MD, PhD, Gert Jan Scheffer, MD, PhD Pauline Maassen, Stephanie Janssen , Matthijs Kox, PhD, Peter Pickkers et. al. studied Soluble urokinase-type plasminogen activator (suPAR) represents a marker for immune activation and has predictive value in critically ill patients. The kinetics of suPAR and its correlation with the immune response and outcome in trauma patients are unknown. Methods: Plasma concentrations of inflammatory cytokines and suPAR were determined in adult trauma patient (n = 69) samples obtained by the Helicopter Emergency Medical Services at arrival at the emergency department (ED) and at days 1, 3, 5, 7, 10, and 14. Results: Initial suPAR levels were unrelated to injury severity score and higher in nonsurvivors compared with survivors, although no difference was observed between early and late mortality. The area under the receiver operating characteristic curve to predict mortality was 0.6 (95% confidence interval, 0.48-0.72). Soluble urokinasetype plasminogen activator levels increased over time in 94% of patients, although suPAR increase did not precede death. Tumor necrosis factor α at the ED correlated with suPAR at that time point, whereas concentrations of other proinflammatory cytokines at the ED correlated with suPAR levels at days 1 and 5. Conclusions: After trauma, initial suPAR plasma concentrations are higher in nonsurvivors compared with survivors, but its predictive value is low. Soluble urokinase-type plasminogen activator levels increase over time after trauma, and concentrations at later time points are related to cytokine levels at. And concluded early suPAR concentrations are higher in nonsurvivors than in survivors, and levels at later time points are related to preceding cytokine levels. However, the predictive value of suPAR for mortality and, therefore, its clinical relevance is low. The steady increase over time related to the initial inflammatory response is not related to mortality.

[4] A. A. Abdel-Rahman revived and studied that The urban air pollution is a very complicated problem. The exhaust emissions from internal-combustion engines account for a major portion of this problem. It is realized that the content and concentrations of the exhaust emissions depend on various parameters. These parameters include engine design parameters, operational parameters, exhaust gas after treatment, fuel types, fuel additives and lubricants. The present review paper discusses the effect of some parameters on the emission level and characteristics from internal-combustion engines. The paper begins with an introduction of general information on the nature of emissions of exhaust gases, including the toxicity and causes of emissions for both spark-ignition and diesel engines. The paper then shifts to an up-to-date information of the published research work on the subject matter.

[5] Vembathu Rajesh , C. Mathalai Sundaram, V. Sivaganesan, B. Nagarajan, S. Harikishore et. al. studied that The issue of reduction of harmful pollutants emitted from an internal combustion engine has gained large prominence as a part of climate change and global warming. Automobile and power generation systems are identified to be one of the largest contributors to atmospheric pollution. Some of the major pollutants emitted from an engine are Oxides of Nitrogen (NOx), Carbon monoxide (CO), Unburnt Hydrocarbon (UBHC) and soot particles. This paper presents a catalytic converter with emission reduction catalysts to be used for compressed ignition engine. The catalytic converter is developed based on the catalyst materials consisting of metal oxides such as aluminum oxide and titanium dioxide coated with wire mesh filter. Both the catalyst materials – aluminum oxide and titanium dioxide are inexpensive in comparison with conventional catalysts such as palladium or platinum. The objective of this research work is to control the NOx emission and to develop a low-cost three way catalytic converter. The emissions from the engine are measured using a five gas analyser and the results are tabulated.and concluded that he current catalytic converters are utilizing precious metals like platinum and palladium for oxidizing the emission. To overcome the cost and to reduce the rare metal usage, this paper made the drive to develop an alternate source of oxidation catalyst for oxidation reaction and thus reduce the CO, HC and NOx emissions. The catalytic converter with Aluminium oxide and Titanium dioxide as catalysts reduces the harmful pollutant more efficiently and at a lower cost than the conventional catalytic converter.

2. METHODOLOGY

2.1.Problem Statement

In day to day life number automobiles are increasing which directly increases the level of pollution. This pollution affects very badly on human and environment. Humans are facing lots of health issues due to this pollution. As technology becomes legs of development we can not stop these technology but we can control the pollution which is done by technology.

2.2.Proposed Solution.

We are designing and developing a catalytic convertor with aluminium oxide and Titanium oxide. Which will tend to reduce the emission of toxic gasses from the engine.

2.3.Catalytic convertor

As we all had seen one part attached with the Automobiles it may be car or Bike or any heavy vehicle i. e. The Catalytic converter.

A catalytic converter is an essential component in the exhaust system of most modern vehicles, including cars and trucks. Its primary function is to reduce harmful emissions produced during the combustion of fuel in an internal combustion engine. Catalytic converters play a crucial role in minimizing air pollution and meeting emissions regulations. Here's some key information about catalytic converters.

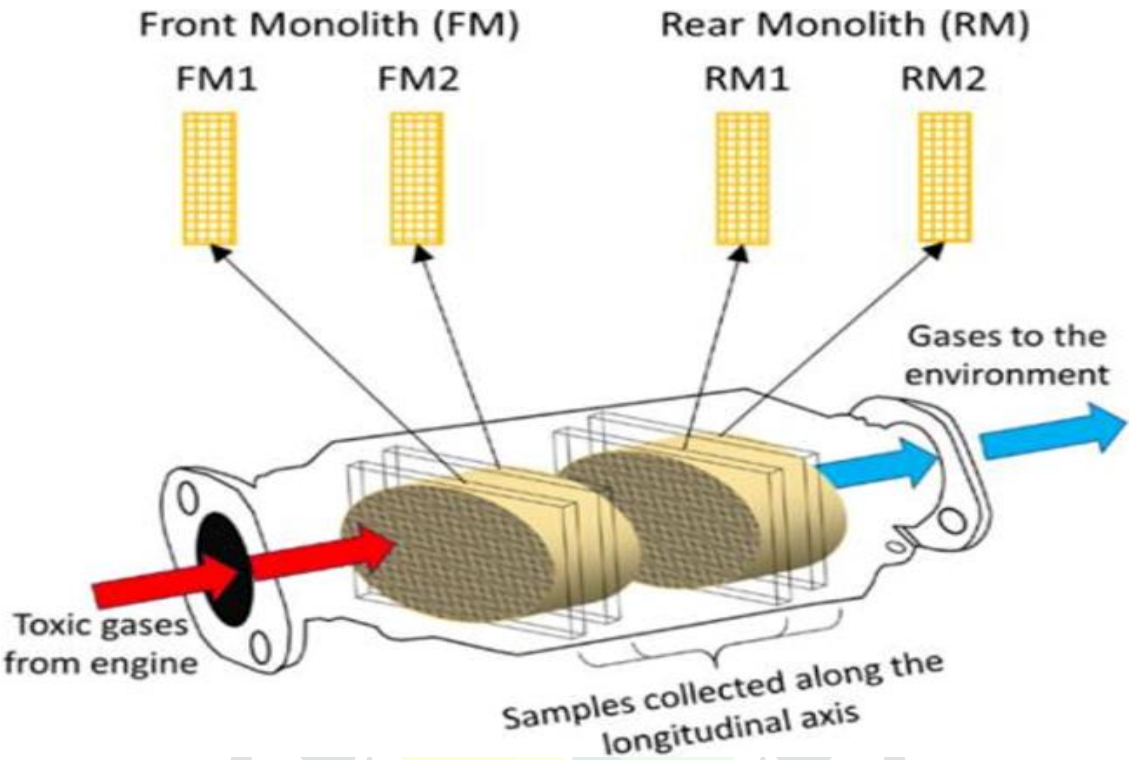


Fig.2.1. Catalytic Convertor

2.3.1. Purpose:

Catalytic converters are designed to:

- **Reduce Emissions**: They help reduce the levels of harmful pollutants in exhaust gases, including carbon monoxide (CO), nitrogen oxides (NOx), and unburned hydrocarbons (HC).
- **Catalyze Chemical Reactions**: They facilitate the conversion of these pollutants into less harmful substances through chemical reactions.

2.3.2. Structure:

Catalytic converters consist of a metal housing with a honeycomb-like ceramic or metallic catalyst substrate coated with precious metals such as platinum, palladium, and rhodium. These metals act as catalysts to speed up chemical reactions.

2.3.3. Types:

There are two common types of catalytic converters:

- **Three-Way Catalytic Converter (TWC)**: This type is most commonly used in gasoline-powered vehicles. It simultaneously reduces CO, NOx, and HC emissions.
- **Diesel Oxidation Catalyst (DOC)**: Used in diesel engines, this type primarily reduces CO and HC emissions.

2.3.4. How It Works:

The catalytic converter works by promoting three essential chemical reactions:

- **Oxidation of Carbon Monoxide (CO)**: CO is converted into carbon dioxide (CO2).
- **Reduction of Nitrogen Oxides (NOx)**: NOx compounds are converted into nitrogen (N2) and oxygen (O2).
- **Oxidation of Unburned Hydrocarbons (HC)**: Unburned hydrocarbons are converted into carbon dioxide (CO2) and water (H2O).

2.3.5. Impact on Emissions:

Catalytic converters are highly effective in reducing harmful emissions. They are essential for compliance with emissions standards and regulations set by government authorities worldwide. Their use significantly reduces air pollution, smog formation, and greenhouse gas emissions.

2.3.6. Maintenance:

Catalytic converters generally have a long lifespan, but they can become damaged or fail due to various reasons, such as exposure to leaded gasoline, engine problems, or physical damage. Regular vehicle maintenance can help ensure their proper operation.

2.3.7. Environmental Considerations:

Catalytic converters use precious metals like platinum, which can be resource-intensive and expensive to produce. Recycling and responsible disposal of old catalytic converters are important for reducing their environmental impact.

2.3.8. Innovations:

Advancements in catalytic converter technology continue, including the development of more efficient catalyst formulations, improved materials, and the exploration of alternative catalysts to reduce costs and resource consumption.

2.4.Proposed Design

n diesel engines, conditions in the engine differ from the sparkignition engine, since power is directly controlled by the fuel supply, rather than by controlling the air supply. Thus when the engine runs at low power, there is enough oxygen present to burn the fuel, and diesel engines only make significant amounts of carbon monoxide when running under a load. Diesel exhaust has been found to contain many toxic air contaminants. The lean-burning nature of diesel engines combined with the high temperatures and pressures of the combustion process results in significant production of nitrogen oxides, and provides a unique challenge in the reduction of these compounds.

catalytic converter (colloquially, ‘‘cat” or ‘‘catcon”) is a device used to reduce the toxicity of emissions from an internal combustion engine. A catalytic converter provides an environment for a chemical reaction wherein toxic combustion by-products are converted to less-toxic substances. Silicon dioxide and alumina with silica as a catalyst in the catalytic converter was developed for diesel engine.

An EGR system is developed to reduce the NOx emission very efficiently. Catalytic converter with copper oxide as a catalyst, by replacing noble catalysts such as platinum, palladium and rhodium is fabricated and fitted in the engine exhaust. From the experimental results it is found that the maximum reduction is 32%, 61% and 21% for HC, NOx and CO respectively at 100% of maximum rated load when compared to that of without catalytic converter. Develop and manufacturing of Copper Cerium oxide based catalytic converter by replacing the existing costly Nobel metals such as Platinum, Palladium, and Rhodium has great impact in reducing the emissions from the automobiles. Two separate catalytic converters with diversified composition of catalyst, one thermally coated while the other no longer, a thermal barrier coating enables the cats to reach light-off temperature sooner to shrink cold emissions. The coating can even help preserve the converter lit at idle and low pace for extra efficient operation and cleaner exhaust. The outcome are compared to determine better Emission reduction with higher of the two catalytic converters.

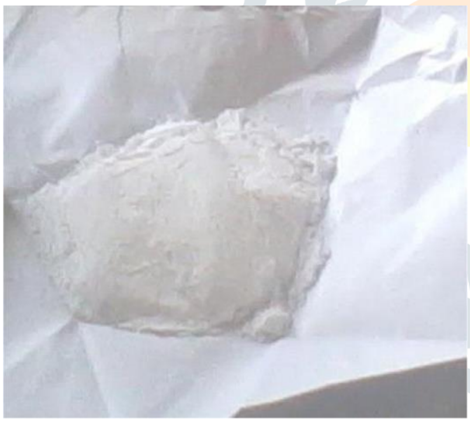
3. DESIGN OF CATLYTIC CONVERTOR

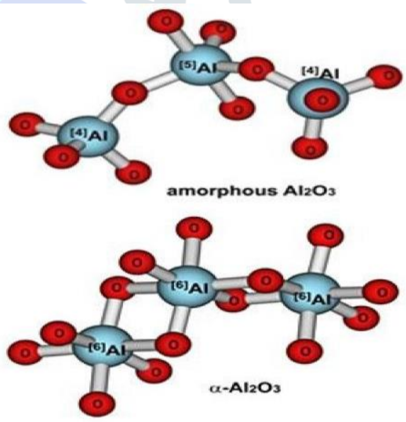
3.1.Material Selection

3.1.1. Aluminium oxide

Aluminium oxide is an amphoteric oxide with the chemical formula Al2O3. It is commonly referred to as alumina, or corundum in its crystalline form, as well as many other names, reflecting its wide spread occurrence in nature and industry. Its most significant use is in the production of Aluminium metal, although it is also used as abrasive due to its hardness and as a refractory material due to its high melting point.

Fig. Aluminum Oxide Fig. Structure of Aluminum Oxide





3.1.2. Titanium dioxide

Titanium dioxide, also known as titanium (IV) oxide or titania, is the naturally occurring oxide of titanium, chemical formula TiO2. When used as a pigment, it is called titanium white, Pigment White 6, or CI 77891. Generally it is sourced from ilmenite, rutile and anatase. It has a wide range of applications, from paint to sunscreen to food coloring. When used as a food colorings, it has E number E171.

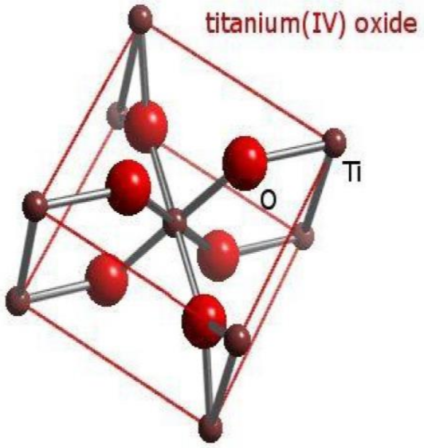


Fig. Titanium dioxide Fig. Structure Titanium dioxide

3.2. Design of catalytic converter

3.2.1. Fabrication

Assembly of all sub components along with filled wash coat catalyst will make the new catalytic converter ready for testing.

3.2.2. Catalytic converter chamber

The fabrication of catalytic converter consists of few components, namely the inner shell, outer shell, cone and wire mesh. The catalytic converter casing and inner chamber remain as same as typical catalytic converter installed in the vehicle system. The same outer dimensions were purposely fixed in order to avoid redesign of the existing exhaust system, which then required further thermal optimization and design validation studies. The aluminum oxide and titanium dioxide were coated with filter before arranged on to a catalytic converter.

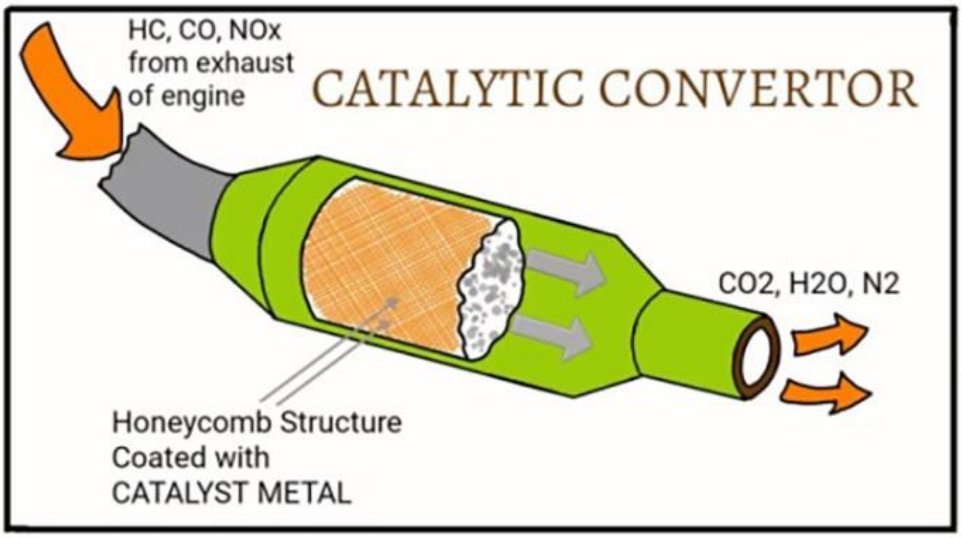


Fig.3.2 Enhanced design of Catalytic Convertor

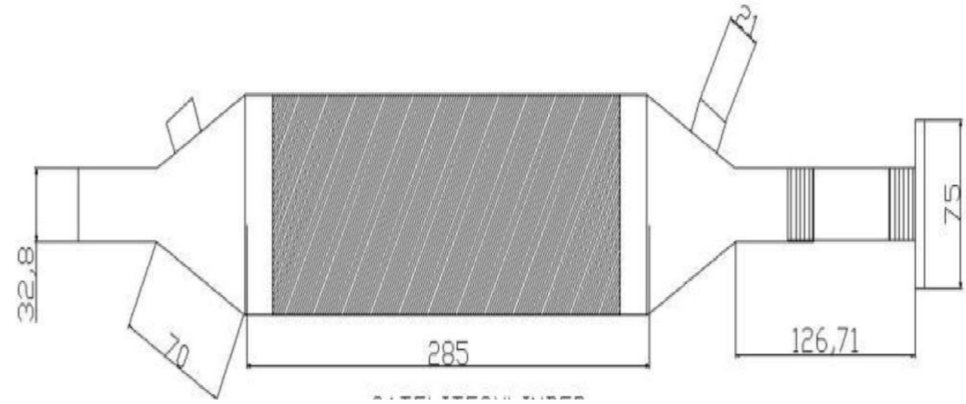
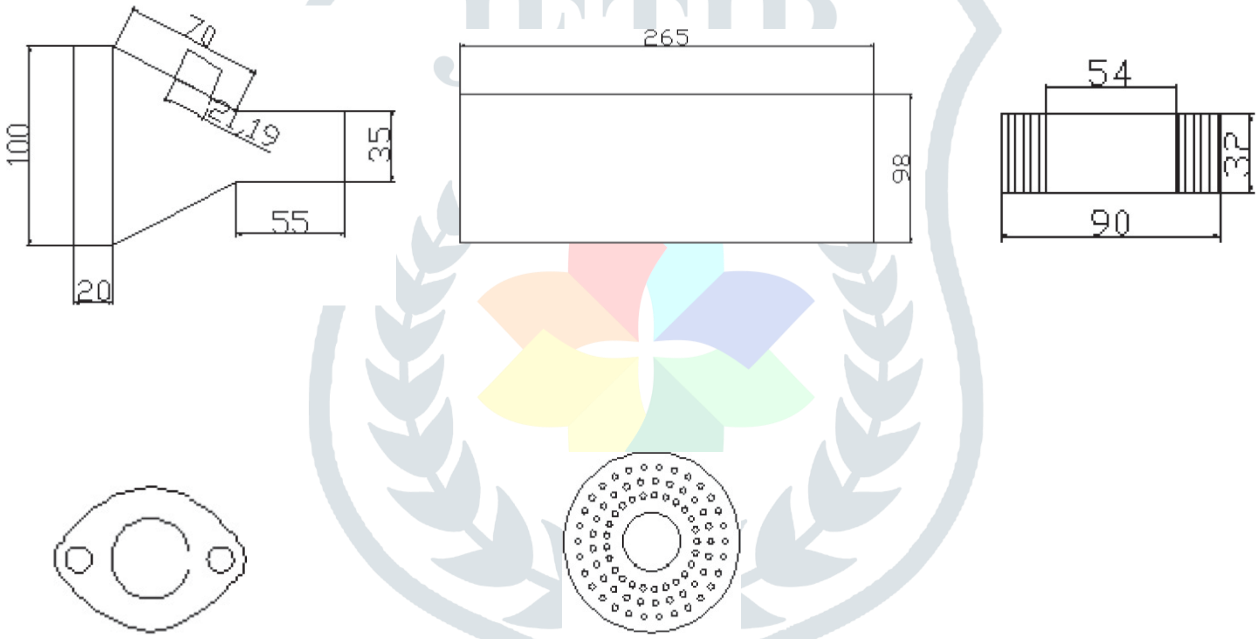


Fig. Assembled Drawing of Catalytic Converter.



3.3.Test to be perform

Sr. No.	Test
1	Load Vs Hydrocarbon
2	Load Vs Carbon monoxide
3	Load Vs Carbon-di-oxide

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