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EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND ENGINE EMISSIONS ON SINGLE CYLINDER DI-DIESEL ENGINE WITH METAL COATED CATALYTIC CONVERTOR USING PURE DIESEL

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***Abstract*- Air pollution generated from mobile sources is a problem of general interest. Vehicle population is projected to grow close to 1300 million by the year 2030. Due to incomplete combustion in the engine, there are a number of incomplete combustion products CO, HC, NO_x, particulate matters etc. These pollutants have negative impact 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. Among all the types of technologies developed so far, use of catalytic converters based on aluminium (noble) group metal is the best way to control automotive exhaust emissions. This review paper discusses automotive exhaust emissions and its impact, automotive exhaust emission control by aluminium(noble) group metal based catalyst in catalytic converter, history of catalytic convertor, types of catalytic convertor, fabrication of a catalytic convertor, experimental procedure carried out using catalytic convertor, results and conclusions**

***Index Terms*- Automotive emission, Catalytic Converter, Catalyst, aluminium group metal**

I. INTRODUCTION

One of the main contributors is said to be the emission of harmful gases produced by vehicle exhaust lines. The number of vehicles miles travels per year continues to increase as a result of higher demand and needs. Consequently, an increasing the number led to the increase of the content of pollutants in air.

Most vehicular transportation relies on combustion of gasoline, diesel and jet fuels with large amount of emission of carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NO_x) and particulates matter (PM) are especially concern. HC and CO occur because the combustion efficiency is less than 100%. The NO_x is formed during the very high temperatures (>1500 0C) of the combustion process resulting in thermal fixation of the nitrogen in the air which forms NO_x. Typical exhaust gas composition at the normal engine operating conditions are: carbon monoxide (CO, 0.5 vol %), unburned hydrocarbons (HC, 350 ppm), nitrogen oxides (NO_x, 900 ppm) hydrogen (H2, 0.17 vol %), water (H2O, 10 vol.%),carbon dioxide (CO2, 10 vol.%), oxygen (O2, 0.5 vol.%).

This paper discusses performance of pure diesel using catalytic convertor

1.1. CATALYTIC CONVERTER

Out of various technologies available for automobile exhaust emission control a catalytic converter is found to best option to control CO, HC and NO_x 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. A catalytic converter (CC) is placed inside the tail pipe through which deadly exhaust gases containing un burnt fuel, CO, NO_x are emitted. The function of the catalytic convertor is to convert these gases into CO2, water, N2 and O2

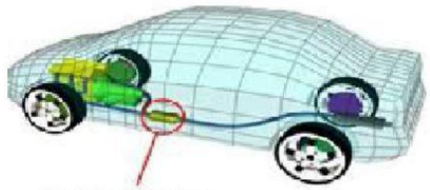


Fig. 1. Catalytic Converter Position in a Vehicle

1.2. HISTORY

The catalytic converter was invented by Eugene Houdry, a French mechanical engineer who lived in the United States. The catalytic converter was later on further developed by John J. Mooney and Carl D. Keith at the Engelhard Corporation creating the first production catalytic converter in 1973. Beginning in 1979, a mandated reduction in NO_x required the development and use of a three way catalyst for CO, HC and NO_x

Catalytic converter has gone through many processes and remarkable evolution for the past 30 years. It is said to be one of the most effective tool to fight against the overwhelming pollutant contents in our environment, as it reduces almost80% of the harmful gases resulting from the incomplete combustion of the engine. Catalytic converter is a stainless steel container mounted somewhere along the exhaust pipe of the engine and inside the container is a porous ceramic structure through which the exhaust gas flows (V.GANESAN). In most converters, the ceramic is a single honeycomb structure with many flow passages. The passages comprise of many shapes, including square, triangular, hexagonal and sinusoidal. Early converters used loose granular ceramic with the gas passing between the packed spheres. Since it is difficult to keep the spheres in place, many converter developers opted for ceramic monolith which offers various advantages. Among these advantages are smaller volumes, lower mass and greater ease of packaging.

1.4. Catalyst:-

These include oxides of base metals e.g. copper, chromium, nickel, cobalt etc. and the noble metals platinum (Pt), palladium (Pd) and rhodium (Rh). Base metal oxides although found to be effective at higher temperature but they sinter and deactivate when subjected to high-end exhaust gas temperature of conventional SI (Spark-Ignition) engine operation. A mixture of platinum and palladium in 2:1 mass ratio is usually employed as oxidation catalyst. Palladium has higher specific activity than Pt for oxidation of CO, olefins and methane.

II. LITERATURE REVIEW

P.K.V.S.Subramanyeswararao, *et al*, 2014investigated on back pressure for different models catalytic converters by changing the lengths and diameters of the substrate. In his study, it is also seen that the increase in catalyst diameter would result in decrease of exhaust emissions. Comparison between catalytic converters with external air supply and without external air supply was done and concluded that NO emissions are lower in case of external air supply.

Andreassi, *et al*, 2004:It has been observed and investigated that the role of channel cross section shape on mass and heat transfer processes. The development of catalytic converter systems for automotive applications is, to a great extent, related to monolith catalyst support materials and design. In this paper improvements of converter channels fluid-dynamics aiming to enhance pollutant conversion in all the engine operating conditions are studied

Ekstrom and Andersson, *et al*, 2002 Investigated the pressure drop behavior of catalytic converter for a number of different substrates, suitable for high performance IC-engines, regarding cell density, wall thickness and coating. The measurements have been performed on an experimental rig with room-air flow and hot-air flow. The data has been used to develop an empirical model for pressure drop in catalytic converters.

Narasimha Kumar, *et al*, 2011: Investigations have been carried out for reducing pollutants from a variable compression ratio, copper-coated spark ignition engine fitted with catalytic converter containing sponge iron catalyst run with gasohol (blend of 20% ethanol and 80% gasoline by volume).The major pollutants emitted from spark ignition engine are carbon monoxide (CO) and unburnt hydrocarbons (UHC).

Mohiuddin and Nurhafez, *et al*, 2007 conducted an experiment to study the performance and conversion efficiencies of ceramic monolith three-way catalytic converters (TWCC) employed in automotive exhaust lines for the reduction of gasoline emissions. Two ceramic converters of different cell density, substrate length, and hydraulic channel diameter and wall thickness were studied to investigate the effect of varying key parameters on conversion efficiencies and pressure drop.

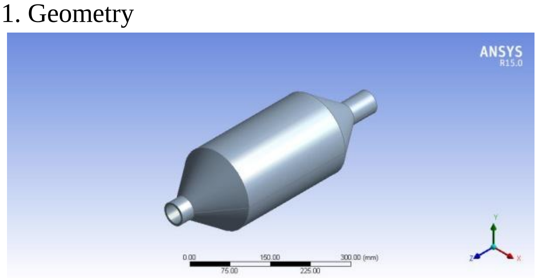
Muthaiah, *et al,* 2010 conducted an experimental test on a 10 hp, twin-cylinder, and four-stroke, direct-injection, vertical diesel engine. At present, the wall flow ceramic substrate is used as filters which are expensive and also offer more back pressure resulting in more fuel consumption. In the present study, catalytic-coated steel wire mesh materials with coarse, fine, and very fine grid sizes are used for PM filtration. The soluble organic fractions of diesel PM is oxidized by DOC system. So this provides strong motivation for development of improved catalytic converter.

Heywood, *et al,* 1988 conducted experimental test in which rhodium is used as the main catalyst to reduce NOx emissions.

Schmidt, Franz and Merdes, *et al,* 2002 used a ceramic substrate inserted into a metal container called a can, inorder to mount the catalytic converter to the exhaust system.

III. EXPERIMENTAL SETUP

3.1. Geometry



The geometry has been modeled by using computational fluid dynamics (cfd) analysis. The geometry which is modeled is taken and fabricated an used for experimental purpose. The cylinder has undergone several tests and through five gas analyser emissions are checked. The main advantage of using a catalytic convertor is that when this is fitted to the exhaust pipe of an diesel engine heavier particles of dust comes out through the engine which when inhaled gives lot of pollution problem. The main work of this catalytic convertor is that these heavier particles settles down at the mesh and lighter particles only comes out into the atmosphere which when inhaled is not so harmful.

3.2. Fabrication data

3.2.1. Outer shell

- The outer diameter of the shell is 160mm
- The inner diameter of the shell is 154mm
- Thickness of the shell is 3mm
- Length of the shell is 254mm
- Operations performed are lathe machining

3.2.2.Mesh

Fig.7: Mesh

- The outer diameter of the mesh is 154mm
- The inner diameter of the mesh is 148mm
- Thickness of the mesh is 3mm
- Grid 8*8
- Operations performed are slotting and arc welding

3.2.3. Welded geometry

Fig.8: Welded geometry

- Outer diameter of shell=160mm
- Inner diameter of shell=154mm
- Length=254mm
- Thickness of plate=3mm
- Operations performed are Lathe machining and Arc welding

The mesh is now connected as channels and is welded together and this is galvanized by using Al_2O_3 (aluminium oxide) and then is placed inside the outer shell and welded together

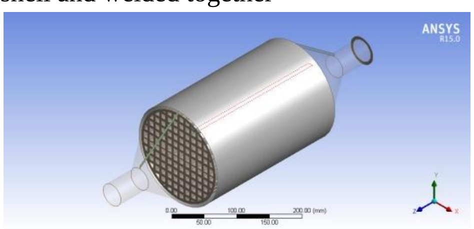


Fig.9: grid with channels

3.2.4. Final Geometry

Fig.10: final geometry

- Funnel length=144mm
- Angle=6 degrees
- Overall length =542mm
- Funnel outer diameter=48.1mm
- Funnel inner diameter=42.1mm
- Outer diameter of shell=160mm
- Inner diameter of shell=154mm
- The inner diameter of the mesh is 148mm
- Grid 8*8
- Length=254mm
- Operations performed are Galvanizing of inner mesh with aluminium oxide (Al2O3),Grinding, Fitting, Arc welding and Lathe machining

3.2.5. Engine setup

Engine specifications

- Single cylinder DI-diesel engine
- Stroke length=185mm
- Diameter=87.5mm
- Length of the cylinder=1100mm
- Speed =1500 r.p.m

Fig.11: Engine setup

3.2.6. Catalytic convertor fitted to engine exhaust

Fig.12: Catalytic convertor fitted to engine

3.2.7. Five GAS Analyser

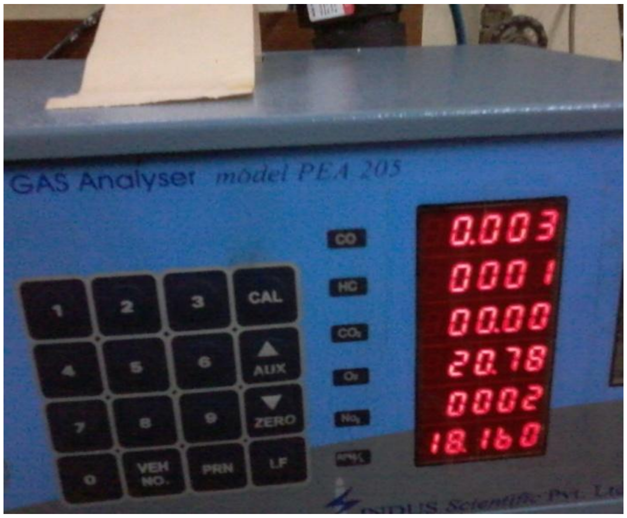


Fig.13: 5 Gas analyser

This is mainly used to check the emissions generated by the engine. The five gas analyser is placed inside the exhaust of the catalytic convertor and the exhaust is completely blocked so that no air enters enters into the exhaust which thereby helps the five gas analyser to get accurate values for emissions. The five gases which this analyser works on is CO(carbon monoxide), HC(hydrogen carbide), CO2(carbon dioxide), O2(oxygen), NO2(nitrogen dioxide).

3.3.Experimental procedure

Using this experimental setup we have conducted the test Diesel with catalytic convertor

When catalytic convertor is fitted to the exhaust of the engine where diesel is used as a fuel for running the engine. First the engine is started and made to run at no load condition and the time taken for consumption for 10c.c fuel is taken and the same procedure is carried out at one fourth load, half load, three fourth load and full load.

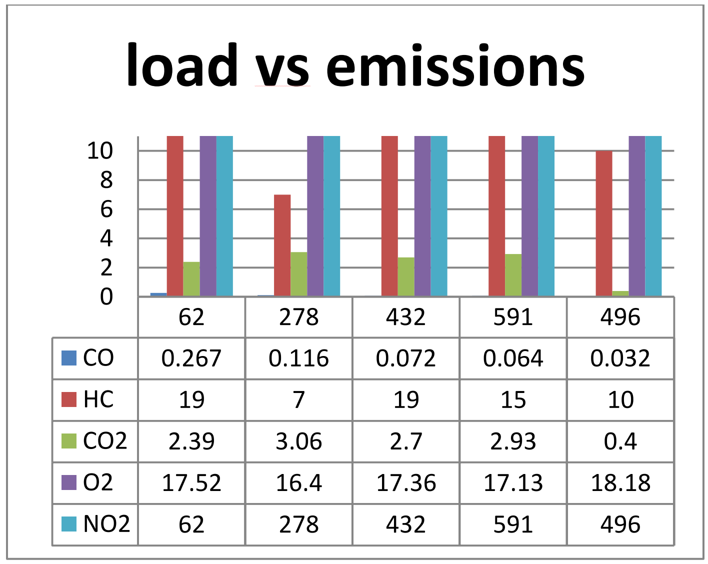
IV. RESULTS

4.1. Emissions using pure diesel with catalytic convertor

Load/compounds	CO	HC	CO2	O2	NOx
0	0.26	0.01	2.3	17.5	62
3	0.11	0.00	3.0	16.4	278
6	0.07	0.01	2.7	17.3	432
9	0.06	0.01	2.9	17.1	591
11	0.03	0.010	0.40	18.18	496

Table 1: diesel with catalytic convertor

4.1.1. Graphical representation of load versus emissions

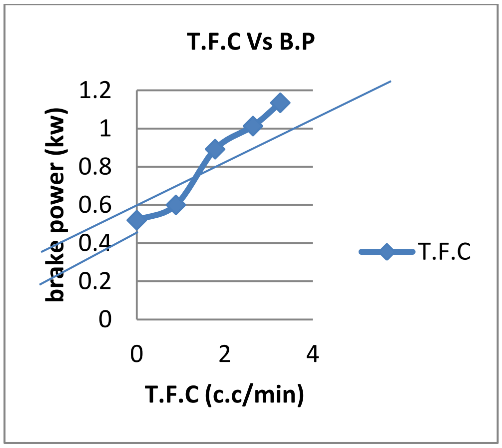


4.2. Performance curves of pure diesel on single cylinder DI-diesel engine

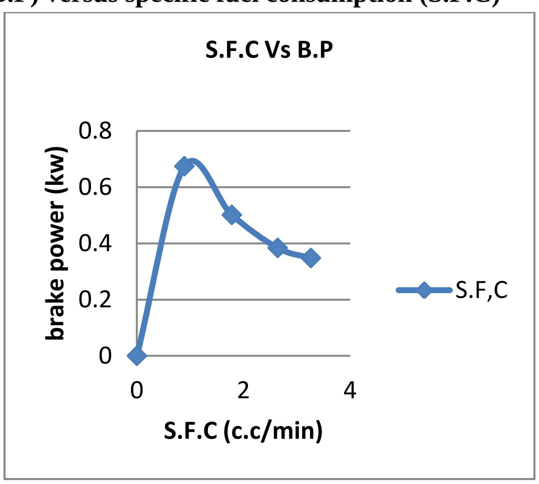
B.P	T.F.C	S.F.C	Mechanical efficiency	Brake thermal efficiency	Indicated thermal efficiency
0	0.52	∞	0	0	0.43
0.89	0.6	0.6741	0.244	0.1271	0.44
1.78	0.8921	0.5011	0.3929	0.1714	0.4485
2.64	1.013	0.38375	0.4897	0.2233	0.4560
3.263	1.135	0.3478	0.5426	0.2464	0.4580

Specifications:-
Calorific value=42000
Specific gravity=0.824
Engine specifications:
l=185mm
D=87.5mm
L=1100mm
N=1500 r.p.m

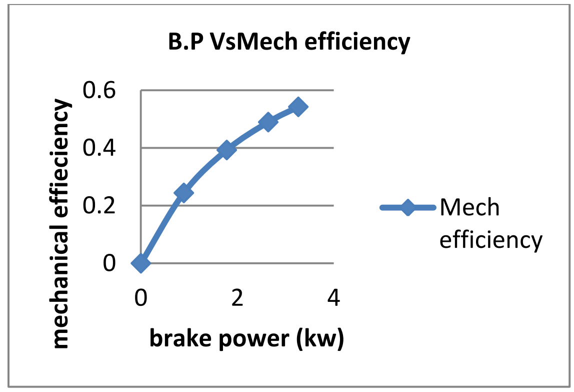
4.2.1.Graphical representation of Brake power (B.P) versus total fuel consumption (T.F.C)



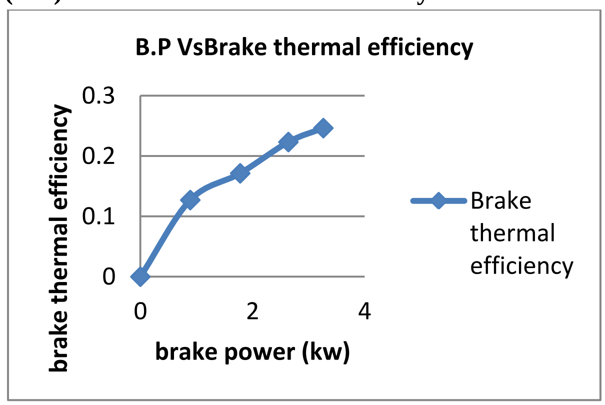
4.2.2. Graphical representation of Brake power (B.P) versus specific fuel consumption (S.F.C)



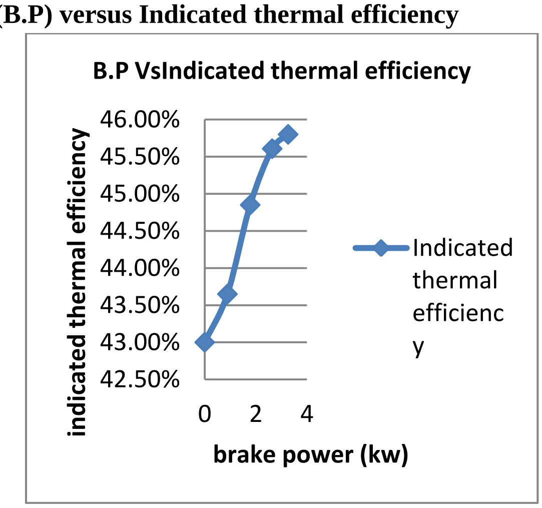
4.2.3. Graphical representation of Brake power (B.P) versus Mechanical efficiency



4.2.4. Graphical representation of Brake power (B.P) versus Brake thermal efficiency



4.2.5. Graphical representation of Brake power (B.P) versus Indicated thermal efficiency



V. CONCLUSIONS

Today's automobiles are meeting emission standards thatrequire reductions of up to 99 percent for HC, CO and NOxcompared to the uncontrolled levels of automobiles sold in the1960s.

Environmental, ecological and health concern result in increasingly stringent emissions regulations of pollutant emissions from vehicle engines. Among all the types of technologies developed so far, use of Metal Monolith type catalytic converters is the best way to control auto exhaust emission. Three-way catalyst with stoichiometric engine control systems remain the state of art method forsimultaneously controlling hydrocarbon, CO and NOx emissions from vehicle. The economical reasons, limited resources of platinum group (noble) metal and some operating limitations of platinum group metal based catalytic converters have motivated the investigation of alternative catalyst materials

This type of Catalytic converters have also been developed for use on trucks, buses and motorcycles as well as on construction equipment lawn and garden equipment marine engines and other non-road engines. Catalytic converters are also used to reduce emissions from alternative fuel vehicles powered by natural gas, methanol, ethanol and propane. To date more than 500 million vehicles equipped with catalytic converters have been sold worldwide. In 2005, 100 percent of new cars sold in the U.S. were equipped with a catalytic converter, and worldwide over 90 percent of new cars sold had a of metal monolith type catalyst.

FUTURE SCOPE

Further by using catalysts like platinum, rhodium, palladium there can be more reduction in NOx values which thereby reduces release of toxic substances into the atmosphere.

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