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Design, Fabrication and Testing of a MnO_2 based Catalytic Converter

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Abstract- Millions of people around the world who enjoy the benefits provided by automobiles also suffer the agony of traffic pollution. However, advances in automotive technology are helping to stem the tide of pollution and recent investigations into the success of one specific anti-pollution automotive component has uncovered one of the planet's greatest environmental success stories which may have global implications as the markets for new cars expand. The device is the catalytic converter, which cleans gases passing through vehicles' exhaust systems. As exhaust gases passes through the catalysts, the chemical reactions convert the pollutants into harmless gases and water. Hydrocarbons react with oxygen to form carbon dioxide, and oxides of nitrogen react with carbon monoxide to produce nitrogen and carbon dioxide and with hydrogen to produce nitrogen and water vapor. The catalyst, which causes a faster chemical reaction at a lower temperature, is usually a mixture of the noble metals platinum, palladium and rhodium.

In the present research a low-cost three-way catalytic converter was developed using MnO_2 (Manganese-di-Oxide) as an oxidizing agent in place of CoO (Cobalt Oxide) and testing it on an IC engine. The results obtained from the project will enable commercial application of MnO_2 in catalytic converters to reduce the cost as well as eliminate the possible health hazards of CoO which is used in the commercially available catalytic converters at present.

Keywords: Catalytic Converter, air pollutants, Back Pressure

INTRODUCTION

The large majority of today's automobile travel by using internal combustion engines that burn gasoline or other fossil fuels. The process of burning petrol or diesel to power automobiles results in an increase of air pollution by releasing hazardous emissions into the atmosphere. Emissions that are released directly into the atmosphere from the tailpipes of cars and trucks are the primary source of vehicular pollution. Vehicular emissions are major cause for global warming and account for around a quarter of greenhouse gases emission. Internal Combustion Engines generate undesirable emissions during the combustion process. In this, both SI and CI engines are equally responsible. Mainly IC engine produce unburned hydrocarbon (HC) and carbon monoxide (CO) emissions. The Nox emission either increases or decreases, as it strongly associated with in cylinder fuel combustion temperature characteristics that depend on air–fuel ratio and fuel injection system. However, the gaseous pollutants from engine exhaust can be reduced either by thermal or catalytic system. A Catalytic Converter is a device used to reduce the exhaust pollutant gases from an internal combustion engine. A schematic layout of catalytic converter is shown in Fig. 2.1.

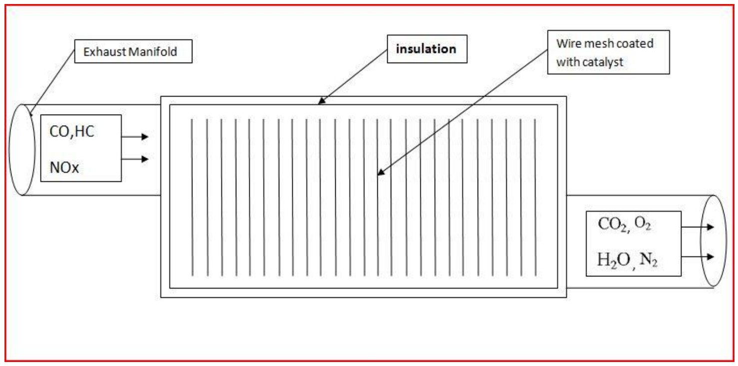

Fig 2.1 line diagram of a catalytic converter

The catalytic converter is placed between engine manifold and exhaust tailpipe. Pollutant gases flowing out of the engine pass through it and undergo chemical processes by which they are converted into relatively harmless gases. Gas flows through the passages and reacts with catalyst within the porous wash-coat. It can be said that a Catalytic Converter consists of steel cover plate or steel box, monolithic substrate (used to make tubular walls), wash-coat (as binder) usually alumina on which catalyst materials like Pt, Rh, Pd,TiO_2/CoO are dispersed with various ratio(s). Apart from catalyst materials, CeO_2, or CeO_2- ZrO_2 mixed oxides are also added in the wash-coat of three way catalytic (TWC) converter for improved oxygen storage capacity and thermal stability of alumina continuous exposition of the Catalytic Converter to high temperature may cause an alteration on its components that lead gradually to its deactivation.

The thermal aging of the catalytic converter may have an undesirable impact on both catalyst substrate and noble metal load in various ways. For operation temperatures of the Catalytic Converter above 600◦C, Rh_2O_3 reacts with alumina to form inactive Rh_2Al_2O4, while above 700◦C, Pt sintering occurs. For temperatures higher than 900◦C, sintering of γ -Al_2O_3 and alloying of the noble metals may occur. At even higher temperatures, severe sintering of γ -Al_2O_3 undergoes as a result of its crystalline phase, transformation into another as δ-Al_2O_3 or α-Al_2O_3, with a decrease in the alumina surface area. The formation of α-Al_2O_3 is accompanied by mechanical tensions which may cause substrate fragments and noble metal losses. Thermal deactivation is normally irreversible; although redispersion of the sintered metal surface is possible .The conventional catalyst materials are mainly noble metals or platinum group metals (PGM’s). The PGMs comprise the rare metals such as platinum (Pt), palladium (Pd), rhodium(Rh), ruthenium (Ru), iridium (Ir) and osmium (Os). All these materials have the common properties like inert as regards biological reactions or less chemical reactions; and to be immobile. However, the recent studies show that the application of these materials have been extensively increased in vehicle exhaust catalyst, industry, jewelers, anticancer drug, in dentistry as alloy that cause their anthropogenic emission and spread in the environment. Platinum content of road dusts can be soluble and consequently it enters the waters, sediments soil and finally the food chain. In addition, PGMs have also been associated with asthma, nausea, increased hair loss, increased spontaneous abortion, dermatitis and other serious health problems in humans. The advantages of this catalytic converter are stated as low-cost, domestically available and higher substrate area which is efficient to oxidize/reduction emission as compared to conventional catalytic converter. The aim of this project is to design, fabricate and test a TiO_2 and MnO_2 based Catalytic Converter to reduce harmful gases like CO, NO_x and unburnt hydro-carbons that are coming out of the Internal Combustion engine.

DESIGN OF CATALYTIC CONVERTER

2.1 Introduction

To develop the catalytic converter, the volume of the converter is decided from the fact that the converter volume must be equal to the volume of engine cylinder.The total converter volume to be maintained is 367.5 cm^3.The shape of catalytic Con verter is made square for ease of construction. Inlet and outlet is given for entry and escaping of exhaust gases.

2.2 Back Pressure Effect on Engine Performance

Internal combustion engines lose a small amount of work due to exhausting of burnt gases from the cylinder and the admission of fresh charge into the cylinder. This loss of power due to gas exchange process is due to pumping gas from lower inlet pressure to higher exhaust pressure. The gas exchange processes affects the volumetric efficien cy of the engine. The performance of the engine, to a great deal, depends on the volumetric efficiency. During the exhaust st roke when the pistonmoves from bottom dead centre to top dead centre, Pressure rises and gases are pushed into exhaust pipe.

Thus the power required to drive the exhaust gases is called the exhaust stroke loss and increase in speed increases the exhaust stroke loss. Therefore it is clear from the above discussion that the net work output per cycle from the engine is dependent on the pumping work consumed, which is directly proportional to the backpressure. To minimize the pumping work, the backpressure must be as low as possible for obtaining the maximum output from the engine. The backpressure is directly proportional to the pressure drop across the catalytic converter or design ofcomplete exhau st system components causing the back pressure. Therefore exhaust system
components and
devices such as catalytic converter, in this case must be designed for minimum backpressure so that it should not
Disturb the engine as well as other subsystems operation.

2.3 Materials used for fabrication

- Material for outer covering-M S sheet
- Material for wire mesh-M S mesh, size – 60 M
- Material for insulation-Glass wool
- Material for washer-Mild Steel

2.4 Design specifications

The Design specification of catalytic converter is as below

- length of arranged wire mesh substrate -7.5 cm
- Size of square mesh -7*7 cm
- No. of mesh - 25
- Thickness of insulation -0.5 cm
- Volume of inside chamber of catalytic converter - 367.5 cm

FABRICATION OF CATALYTIC CONVERTER

Fabrication of catalytic converter mainly consists of three stages as discussed below

3.1 Catalyst slurry preparation

Slurry is prepared to be coated on the mesh as shown in Fig. 3.1 (a). It includes usage of some chemicals. Steps involved in preparation of slurry are as follows

- Magnetic stirrer, 250 ml beaker, digital weighing scale are taken for performing experiment.
- 90 ml of distilled water is poured in beaker and magnetic stirrer is gradually switched on.
- After 5 minutes 90 gm of sodium silicate is added.
- Mixture is stirred for about 2 hr then 2 gm of MnO_2 and 1 gm of sodium meta bi sulphate is gradually added.
- Solution is stirred for around 3 hr after adding all these chemicals.
- 70% nitric acid is added to convert solution from basic to acidic.
- pH is maintained at 3.5 with help of pH paper .After attaining desired ph solution is ready for use.

3.2 Substrate coating

Substrate coating involves **coating** of square mesh with slurry as shown in Fig. 3.1(b). It includes several steps that are discussed below

- First slurry is poured into china dish so it can be dipped easily.
- Square mesh of size 7 x 7 cm is taken and dipped into slurry for 5 minutes.
- Mesh is taken out and dried at room temperature for 1 day.
- Then mesh is dried in oven at 120 °C for 2 hr.
- Mesh is taken out and allowed to cool and kept in muffle furnace for 3 hr at temperature of 300° C

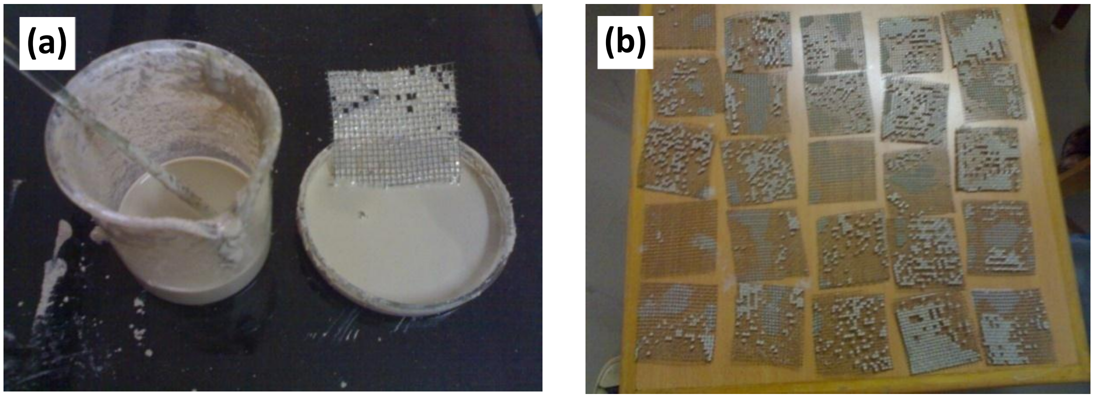

Fig 3.1 (a) MnO_2 substrate (b) Substrate coated M S mesh MnO_2 substrate

3.3 Outer Casing

Outer casing is made of M S sheet metal. Outer casing is open and close arrangement. It can be cleaned and number of mesh can be increased or decreased as per requirement. After construction of outer casing next step will be arranging of mesh coated with substrate. Steel wire is taken and mesh is arranged one after another by placing washer between each mesh. Washer separate one mesh from other and allow free passage of air. Fig 3.2 shows the arrangement of MS mesh and final assembly.

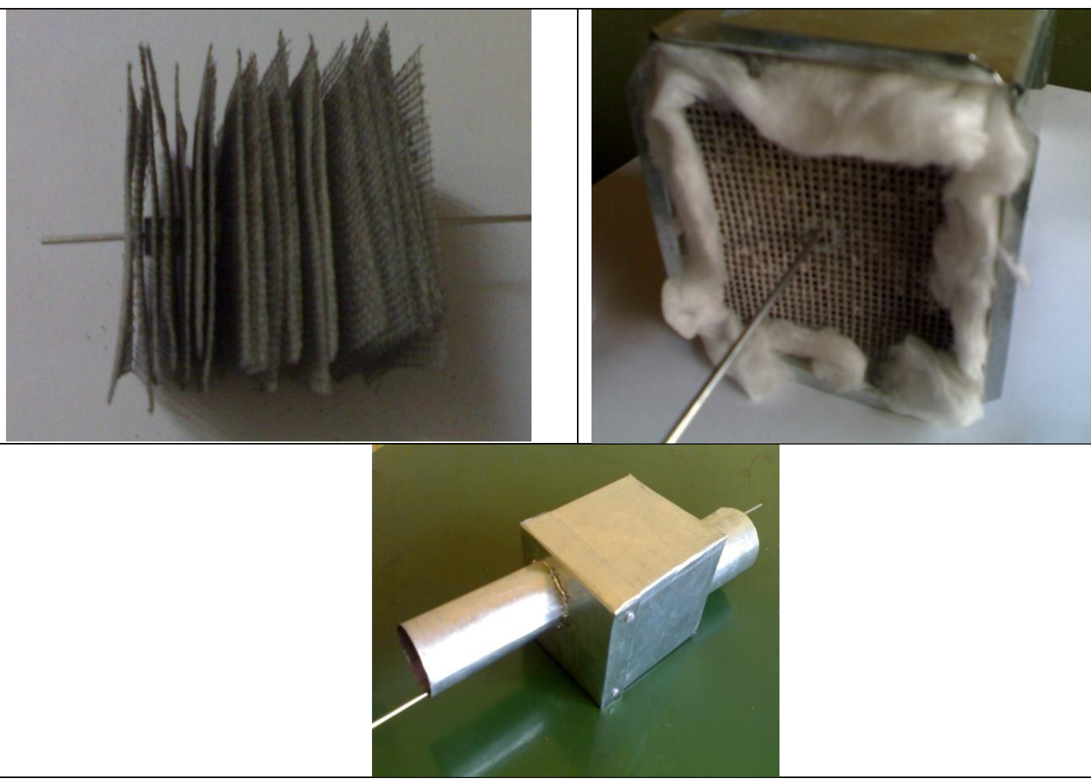

Fig. 3.2 Arrangement of MS meash and final assembly of catalytic converter.

TESTING OF CATALYTIC CONVERTER

After fabricating catalytic converter it’s put on test .Catalytic converter is tested on two types of fuel i.e. petrol and diesel .Single cylinder 2-stroke multi fuel engine is used for testing. KM9106 flue gas analyzer is used for getting values of flue gases that comes from engine exhaust as shown in Fig. 4.1.

Totally six graphs are plotted three each for petrol and diesel. Readings are taken for five different loading conditions i.e. 0 kg to 10 kg. First emission of engine without catalytic converter is noted and after that catalytic converter is placed and emissions are noted.

Catalytic converter is placed for some time after exhaust pipe in order to increase the temperature and allow chemicals to start reacting. Flue gas analyzer contains a probe that is inserted in the exhaust pipe. Probe has a sensor at its tip which is capable of sensing percentage of flue gases and their temperatures. The result is obtained as hard copy.

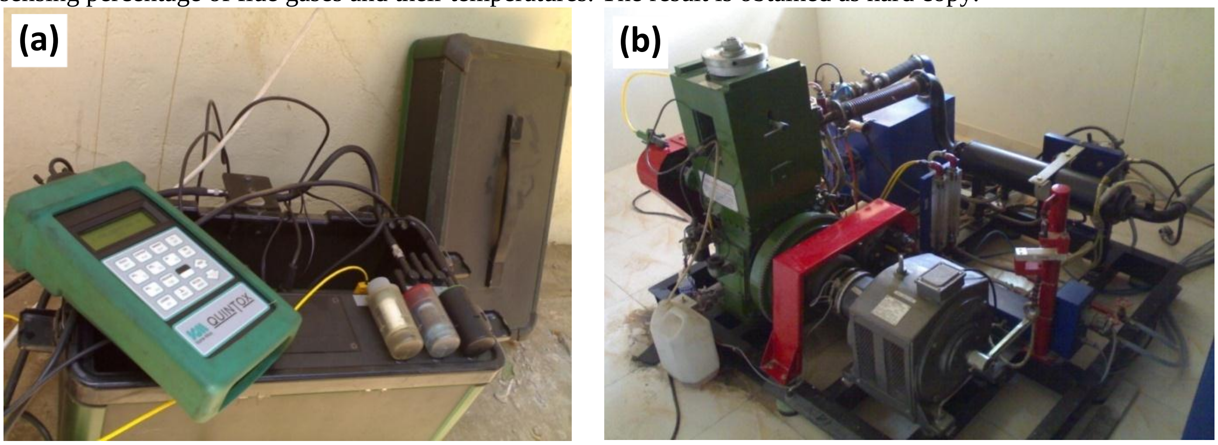

Fig. 4.1 (a) KM9106 flue gas analyzer (b) Single cylinder 2-stroke multi fuel engine

4.1 Testing with diesel

First catalytic converter is tested with diesel. Totally three graphs are plotted between CO (Vol. %), NO_x (ppm), HC (ppm) Vs. Load (kg). percentage of CO coming out increases for first two loads i.e. 0 kg and 2 kg. After this all reading shows a reduction in percentage of CO coming out of engine as shown in Fig. 4.2. There is also increase in percentage of CO_2 as CO is getting oxidized. Second graph is plotted between NO_x (ppm) and Load(kg).emission of NO_x reduces for all loads from 0 kg to 10 kg .NO_x is getting reduced free nitrogen which bring down emission of NO_x**.** It can be seen in Fig. 4.3. Third graph is plotted between unburnt hydrocarbon and load (kg). unburnt hydrocarbon tends to increase after putting catalytic converter. There is a steady increase in emission from no load to maximum load. It can be seen in Fig. 4.4.

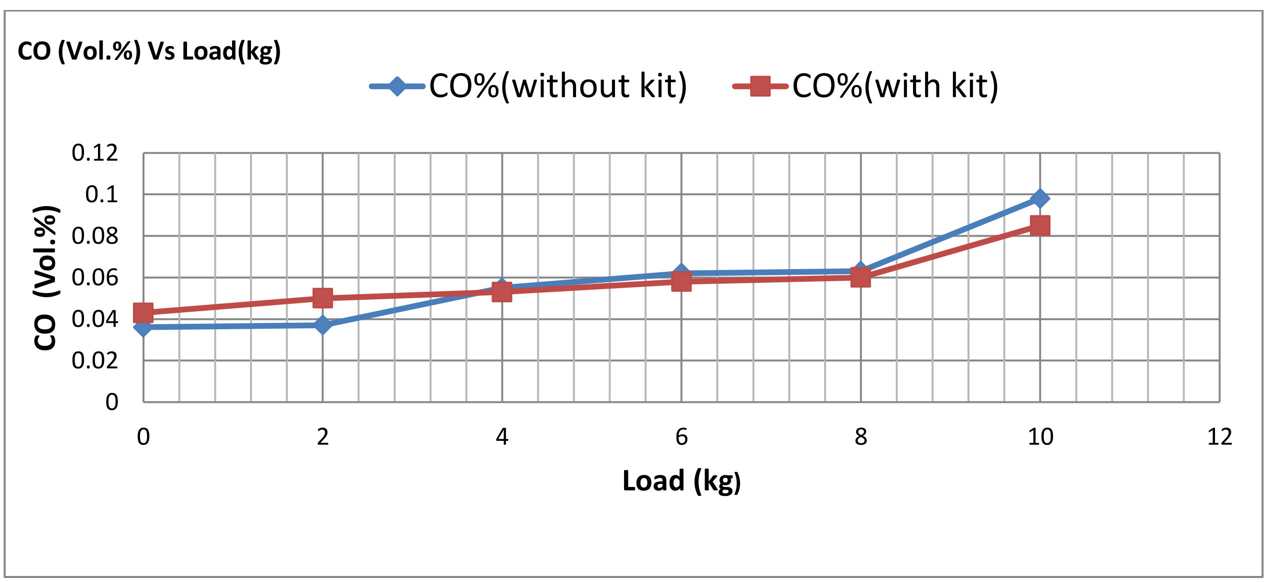

Fig. 4.2 Graph between CO (Vol. %) and Load (kg)

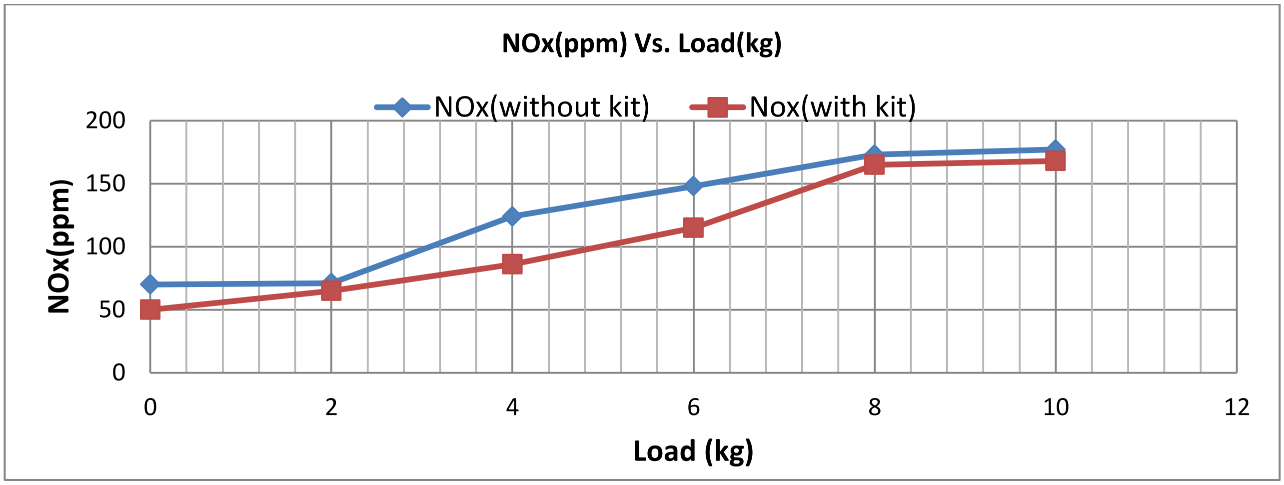

Fig 4.3 Graph between NO_x (ppm) and Load (kg)

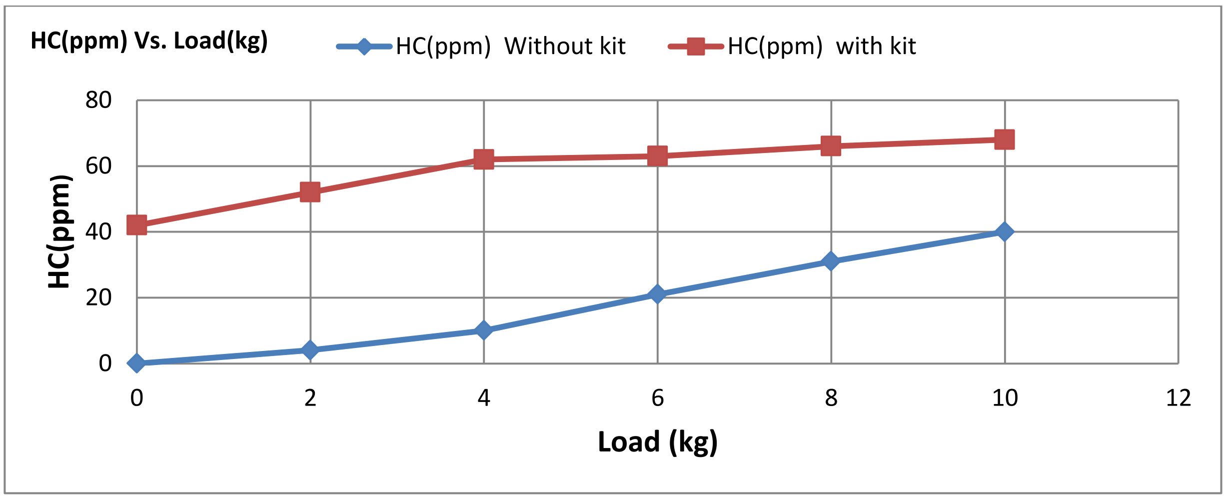

Fig.4.4 Graph between HC (ppm) and Load (kg)

4.2 Testing with petrol

After testing with diesel engine catalytic converter is tested with petrol engine. First graph is plotted between carbon monoxide and Load (kg). First four readings remain same, for fifth and sixth reading there is reduction in emission. This can be seen in Fig. 4.5. Second graph is plotted between nitrogen oxide emission and Load (kg).Emission of NO_x reduces for every load i.e. from no load to maximum load. This can be seen in Fig. 4.6. Last graph is plotted between unburnt hydrocarbon and Load (kg). It's noticed that for all the loads emission of hydrocarbon tends to increase. This can be seen in Fig. 4.7.

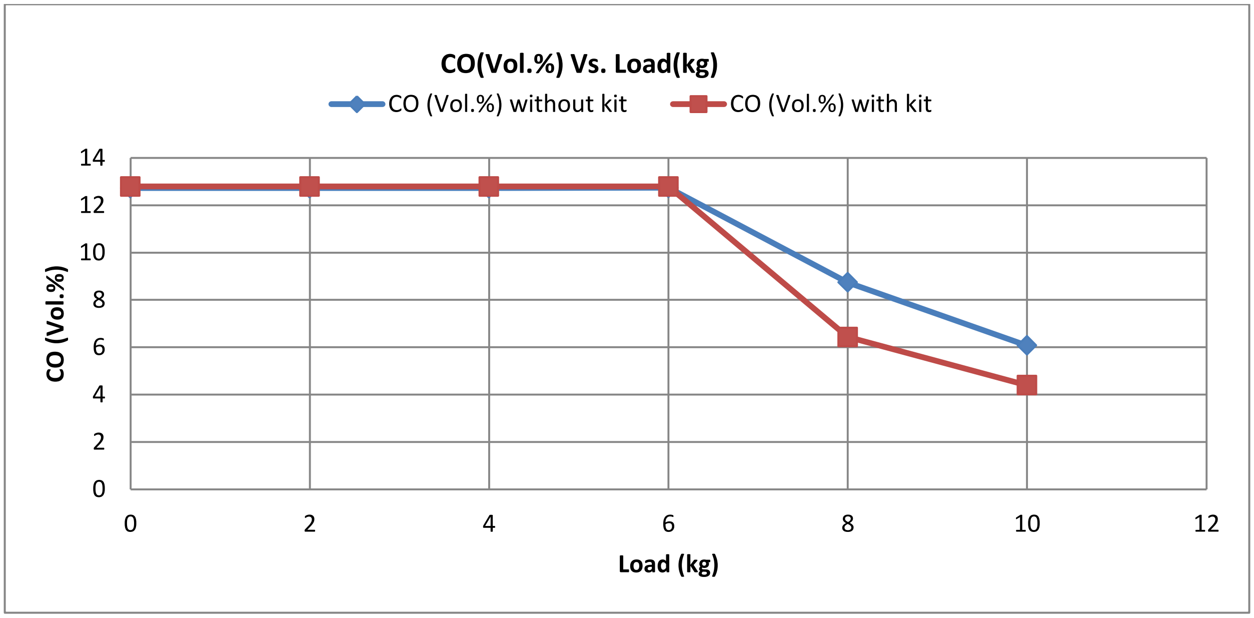

Fig. 4.5 Graph between CO (Vol. %) and Load(kg)

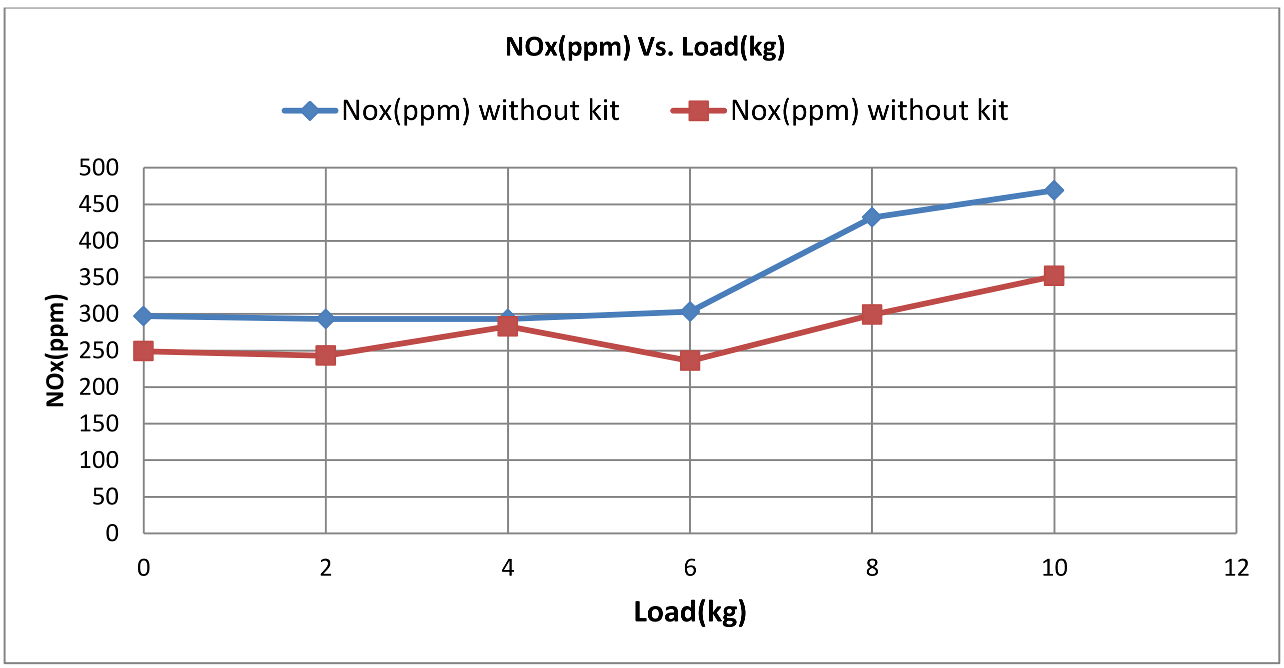

Fig. 4.6 Graph between NO_x (ppm) and Load (kg)

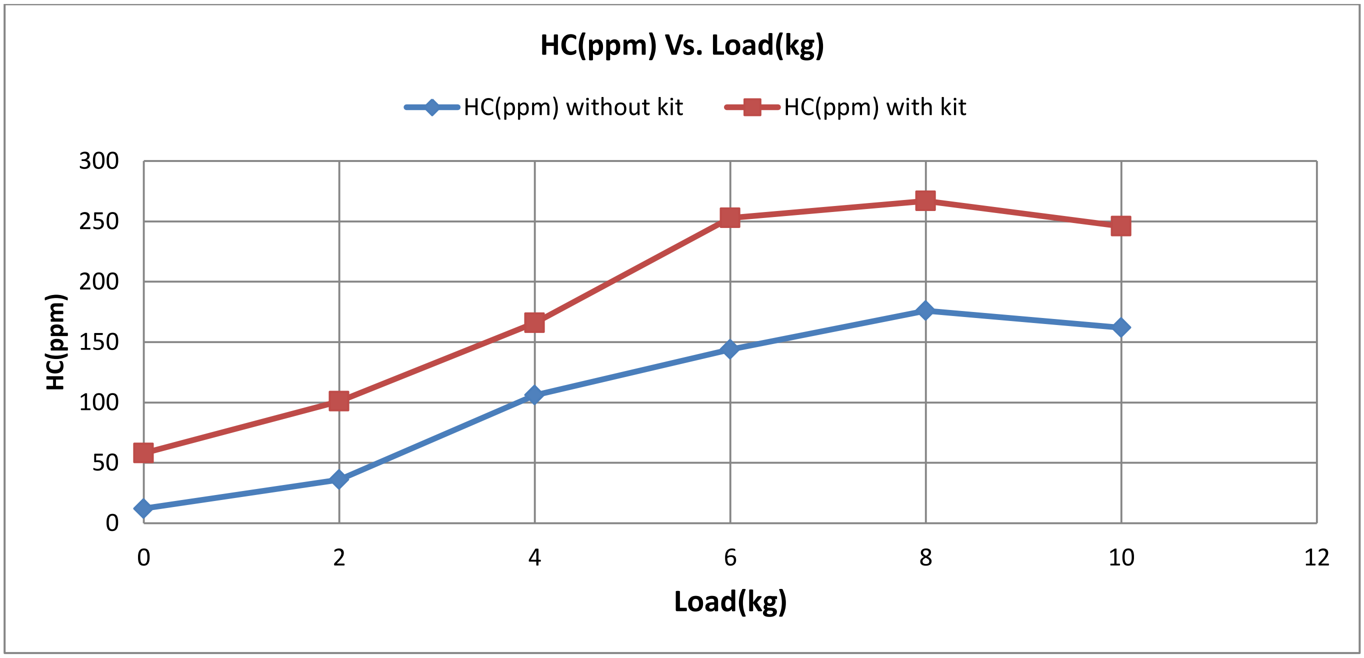

Fig. 4.7 Graph between HC (ppm) and Load (kg)

CONCLUSION

The following conclusions may be drawn from the present study.
1. MnO_2 catalyst and wire mesh based substrate based catalytic converter has been successfully developed.
2. MnO_2 based catalytic converter is able to oxidize CO to CO_2 for both petrol and diesel as fuel. This is mainly due to MnO_2 which is used as oxidizing agent and coverts CO into CO_2.
3. There is reduction in emission of NO_x after using catalytic converter. This is due to MnO_2 which act as reducing agent and decompose NO_x into N_2 and O_2.this reduction is noticed in both the fuels
4. There is increase in emission of unburnt hydrocarbon with the application of catalytic converter for both the fuels. With the application of catalytic converter there is increase in backpressure, due to this increased backpressure there is improper combustion. This leads to more emission of unburnt hydrocarbon.
5. Volume of catalytic converter should be kept as low as possible. This reduces the backpressure and increase efficiency of engine.

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