Emission analysis in multi-cylinder SI Engine using metal oxide pellets as catalytic converter

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Abstract - Petrol engines are widely used in transportation and Agricultural sectors. The exhaust of petrol engine contains hazardous pollutants such as Hydrocarbons (HC), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), Sulphur Oxides (SO_x) and particulates. These emissions from engines causes a lot of health problems such as lung cancer, tuberculosis and other respiratory diseases to human beings. Further, burning of the fossil fuels creates a higher level of pollutant gases in the atmosphere, which increases the global warming. Therefore the emission from petrol engines has become a serious subject for research. Hence, Extensive research has been done in order to control the hazardous emission. New methodologies were introduced to control the pollutant emissions from the engines. An attempt has been made to control the emissions using low cost metal oxide pelletized catalytic converter by keeping in the exhaust manifold.

Key Words: Multi-cylinder, SI Engine, Catalytic converter, Ferric oxide, Cobalt oxide and Magnesium oxide.

1. INTRODUCTION

Increasingly, the strong and stringent air pollution regulations on emission standard provide serious challenges for automobile manufacturers. During the past decades, extensive research has been carried out to decrease the emission of toxic components of combustion gases. Considerable development has been made in fulfilling the standards in the recent years.

The new combustion systems and new technologies contribute to these achievements. Catalytic Converters are commonly utilized as a solution in meeting legislated emission requirements. As emission regulations have tightened the complexity of catalytic converter system has increased [1], [2] It may require increased converter volume, translating into the use of multiple catalytic converter elements within the Vehicle Exhaust system.

In this work different catalytic converters are designed and fabricated to reduce the harmful S.I Engine pollutants.[3],[7]

2. EXPERIMENTAL SETUP

Five gas analyzers were used for the measurement of HC, CO, NO_X and CO_2. Experiments were initially carried out on the engine in order to provide base line data. The engine was stabilized before taking all measurements subsequently. The experiments were repeated by keeping different low cost metal oxide pellets in the exhaust. A multi cylinder Four Stroke Petrol Engine was used. Engine details are given in Table-1.

Table -1: Engine Specification

Parameter	Details
Engine	Four-Stroke Multi cylinder SI Engine
Make	Premier Automobile Limited, India
Rated power	7.5 kW
Maximum speed	4500rpm
Bore diameter	68mm
Stroke	75mm
Displacement volume	1089cc
Compression ratio	7.3:1
Number of cylinders	Four
Cycle	Four
Cooling	Water
Lubrication	Forced Lubrication
Starting system	Battery Ignition System

The experimental set up is shown in Fig 1.

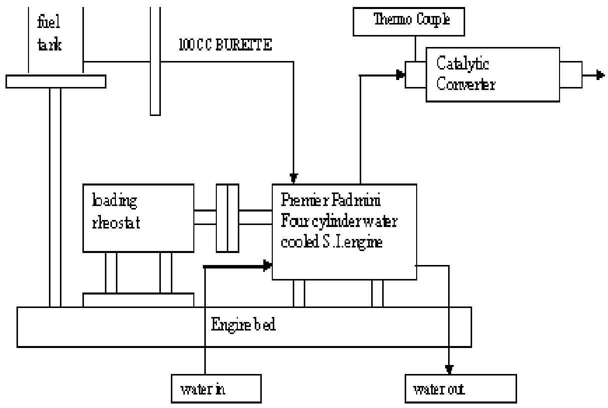

Fig 1: Layout of Test Engine

An electrical Dynamometer is used for loading the engine, the specification which is shown in table-2.

Table -1: Alternator Specification

Parameter	Details
Loading device	Electrical
Rated power	7kW
Rater speed	1500rpm

Schematic diagram of the Test Engine with Catalytic Coated Filters are shown in Fig 2 and Fig 3.

Fig 2: Test Engine

Fig3:Catalytic Coated Filter

3. Die Design and Manufacturing

In order to make a metal oxide tablets we have to go far a suitable die. A special die has been manufactured from two mild steel plate of 30 x 30 x2.5 cm, which contains 132 grooves for pouring the powder of metal oxide, and ejection pins are provided to remove the formed metal oxide tablets. Formed die has undergone various machining process such as turning, facing, drilling, reaming and chamfering. Guide pins are provided at four comers to guide upper and lower plates of the die.

Fig 4. Full Arrangement of Die

3.1 Preparation of Proportionate Mixture

In advance for making metal oxide tablets a proportionate mixture has to be prepared with various metal oxides, Aluminurn Hydroxide and steric acid which accounts to about 300 grams. For thorough mixing of rnetal oxides Aluminum hydroxide and steric acid, the mixture is diluted with water and it is kept under mechanical stirrer for about 6 hrs.

After stirrer the mixture is filtered out from water with the help of filter paper and the mixture is kept inside an electric oven at a temperature of about 200^{0}C.

TABLE 3				
Base : Aluminium Hydroxide				
S.No.	Name of the	Ratio		
1	Ferric Oxide	10:90	20:80	30:70
2	Copper Oxide	10:90	20:80	30:70
3	Magnesium	10:90	20:80	30:70

3.2 Formation of Metal Oxide Tablets

The dried powdered mixer is pour into the die cavity of die, and an impact load of 200 KN is given to the upper plate with the help of Universal Testing Machine (UTM). The formed metal oxide tablet is removed from cavity with the help of ejection pin provided at the bottom plate.

Dimension of Metal Oxide Tablet	Diameter Thickness Weight	: 18 mm : 5 mm : 3gram

4. Results and Discussion

4.1 Cobalt Oxide Pellets as the Catalytic Converter

The pellets were made by mixing CoO with AlOH with different weight ratio. The weight ratio of CoO varied from 10 to 30 % and loaded the prepared pellets in the catalytic converter to study its emission performance. The variations in the emission of CO, CO_2, HC and NOx were analyzed before and after loading the pellets with different weight ratio. The recorded emission level is tabulated and the data were plotted as a function of load and shown in Figures 4.1a-d.

As shown in the Figures 4.1 a-d, the emissions of CO, CO_2, HC and NO_x were relatively low in the engine with CoO pellets loaded in the mesh when compared to the emission from the engine without pellets in the mesh. Moreover, the emissions of pollutants were effectively controlled when the CO weight ratio increases in the pellets.

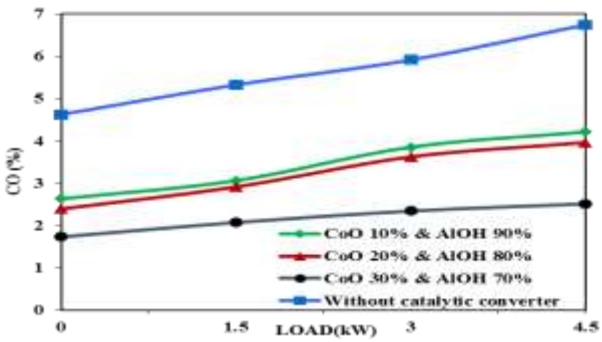

Figure 4.1a

Figure 4.1a shows the CO variation with respect to various load conditions for cobalt oxide pellets with different weight ratio loaded as the mesh as catalytic converter. The obtained trend clearly reveals that as cobalt oxide content increases CO content reducing further with increasing load conditions. The main reason behind this phenomenon is that cobalt oxide is has greater oxidizing trend which resulting oxidation of CO content in the exhaust as it exposes to converter; also cobalt oxide further reduces light off temperature of catalyst and increases conversion rate further. It is observed that when engine load increased exhaust temperature also has rise, which further increases the conversion rate.

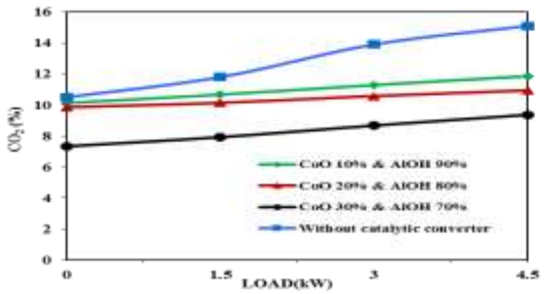

Figure 4.12b

Figure 4.1b illustrates the significance of CoO pellets as catalytic converter is oxidizing the CO to CO_2. Refer to earlier illustrations on CO_2 emission relatively higher order CO_2 content can be seen with pelletized converter; also unlike other case with pelletized converter mostly load is sensitive that can be seen.

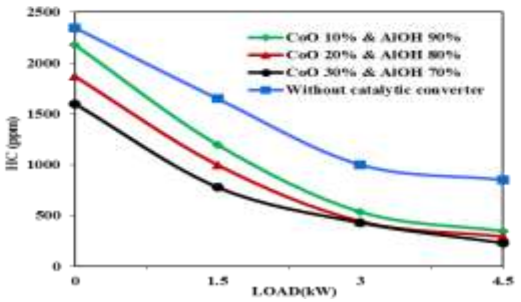

Figure 4.1c

Figure 4.1c shows the HC variation with respect to various load conditions for Cobalt oxide pellet, with different weight ratio loaded as the mesh as the catalytic converter. The obtained trend clearly reveals that as increased cobalt oxide content leads to reduction of HC content with increasing load conditions. The main reason behind this scenario is that cobalt oxide is having greater oxidizing properties while compare with other oxides present in the coating. This helps for oxidation of HC content in the exhaust as it exposes to converter and also cobalt oxide further reduces light off temperature of catalyst and it increases conversion rate further. It is also observed that when engine load increases exhaust temperature also has rise which further increases conversion rate.

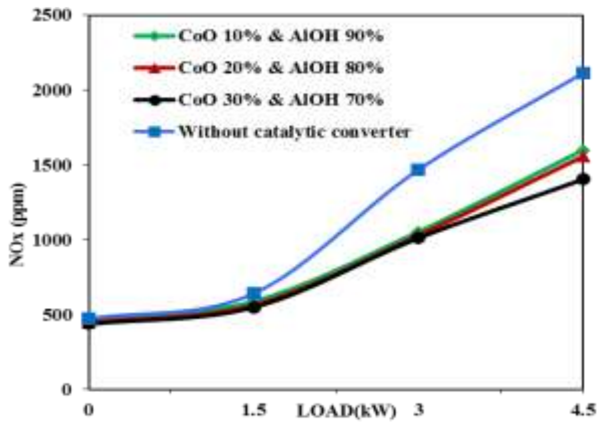

Figure 4.1d

The reduction percentages of pollutants from the engine were calculated from the measured values and the variations have been discussed. CoO pellets in the mesh of catalytic converter effectively controls the emission of CO, HC and NO_x especially, when the engine runs at the optimum load of 4.5 kW.

4.2 Ferric Oxide Pellets as the Catalytic Converter

The pellets were made by mixing FeO and AlOH with different weight ratio. The weight ratio of FeO varied from 10 to 30 % and loaded the prepared pellets in the catalytic converter to study its performance. The variations in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the pellets with different weight ratio. The data were plotted as a function of load shown in Figures 4.2 a-d.

Figure 4.2a shows the CO variation with respect to various load conditions for Ferric oxide pellet with different weight ratio loaded as the mesh as the catalytic converter. The obtained trend clearly reveals that as Ferric oxide content increases a reduction of CO content with increasing load conditions. Pelletized FeO converter is relatively less effective compared to CoO interms of CO content.

Figure 4.2b shows the CO_2 variation with respect to various load conditions for Ferric oxide pellet with different weight ratio loaded as the mesh as the catalytic converter. Referring to figure, it is seen that pelletized Ferric oxide catalytic converter confined the CO_2 emission to a lower level however CoO converter able to oxidize higher quantity of CO to CO_2.

Figure 4.2c shows the HC variation with respect to various load conditions for Ferric oxide pellet with different weight ratio loaded as the mesh as the catalytic converter. The obtained trend clearly reveals that as Ferric oxide content increases leads to reduction of HC content with increasing load conditions. However compared to CoO converter only reduced order of HC oxidation occurs in FeO converter.

As shown in the Figure 4.2 a-d, the emissions of NO_x, CO_2, HC and CO were relatively low in the engine with FeO pellets loaded in the mesh when compared to the emission from the engine without pellets. Moreover, the emission levels of pollutants were relatively decreased when the FeO weight ratio increases in the pellets. The emissions of pollutants were effectively controlled at higher loads.

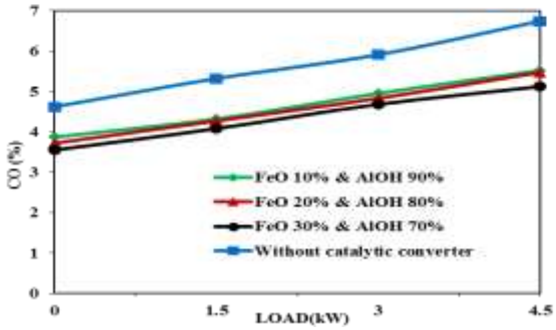

Figure 4.2a

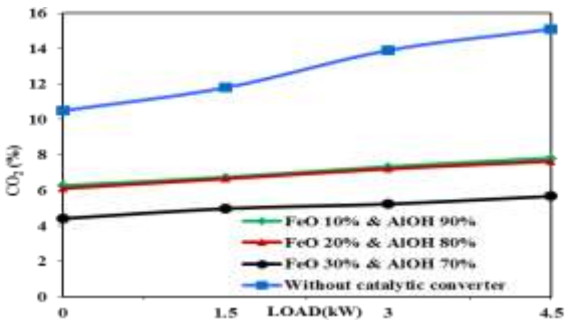

Figure 4.2b

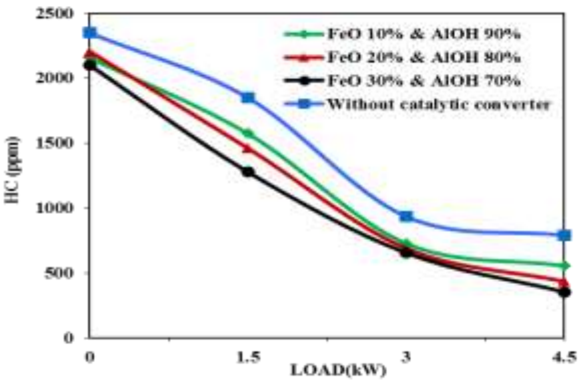

Figure 4.2c

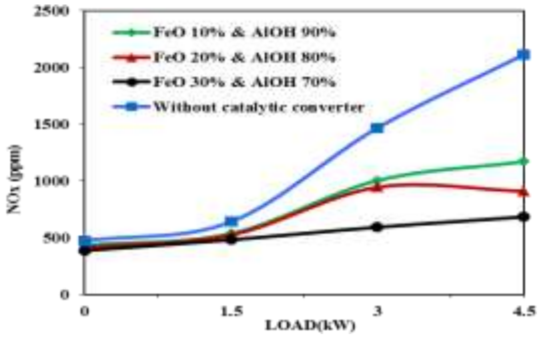

Figure 4.2d

4.3 Magnesium Oxide Pellets as the Catalytic Converter

The pellets were made by mixing MgO and AlOH with different weight ratio. The weight ratio of MgO varied from 10 to 30 % and loaded the prepared pellets in the catalytic converter to study its performance. The variations in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the pellets with different weight ratio. The data were plotted as a function of load and shown in Figures 4.3a-d.

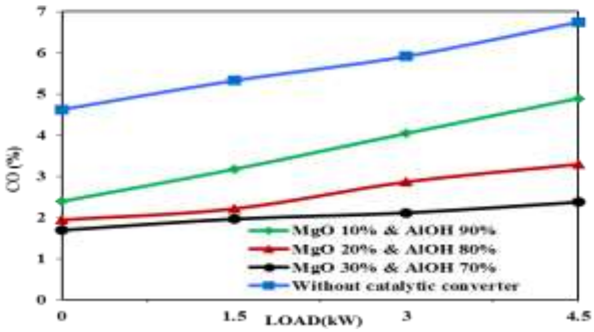

Figure 4.3a

Figure 4.3a shows the CO variation with respect to various load conditions for Magnesium oxide pellet with different weight ratio loaded as the mesh as the catalytic converter. The obtained trend clearly reveals that as magnesium oxide content increases leads to reduction of CO content with increasing load conditions. It is seen that compared to CoO converter, pelletized MgO converter constrained the quantity of CO emission.

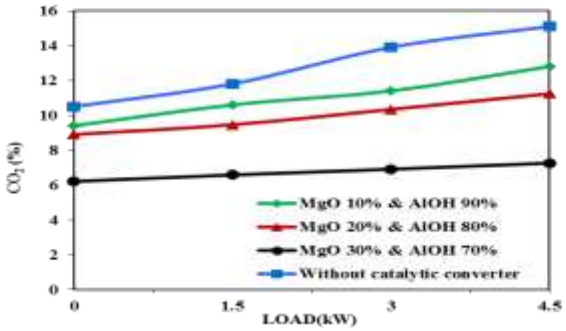

Figure 4.3b

Figure 4.3b shows the CO_2 variation with respect to various load conditions for Magnesium oxide pellet with different weight ratio loaded as the mesh as the catalytic converter. The obtained trend clearly reveals that as magnesium oxide content increases CO_2 content drops down with increasing load conditions. The main reason behind this phenomenon is that magnesium oxide is having greater oxidizing properties which helped for oxidation of CO_2 content in the exhaust as it exposes to converter and also magnesium oxide further reduces light off temperature of catalyst and it increases conversion rate further. It is observed that when engine load increased exhaust temperature also has rise which further increases conversion rate. This all above mentioned factors leads to oxidation of CO and increases CO_2 content.

Figure 4.4 shows the HC variation with respect to various load conditions for Magnesium oxide pellet with different weight ratio loaded as mesh as the catalytic converter. As magnesium oxide content increases a to reduction of HC content with increasing load conditions can be seen. Further compared to CoO pelletized converter, MgO pelletized converter exhibit marginally reduction of oxidation of HC.

Figure 4.14d illustrates the role of pelletized MgO converter, on the presence of NOx emission, unlike the case of CoO converter with reduction of MgO pelletized converter.

The rate of variation of pollutants percentage from the engine were calculated from the measured values and the variations have been discussed. MgO pellets in the mesh of catalytic converter effectively controls the emission of CO, CO_2, HC and NO_x especially, when the engine runs at the optimum load of 4.5 kW. Moreover, the emission level decreased when the MgO content increases in the pellet.

The pellet conditions with suitable weight ratios were optimized for three different metal oxides. In all the experiments, 30% of metal oxides are suitable for effectively control the gas pollutants. In order to further control the emission level, the metal oxide pellets with optimized weight ratios (30%) were mixed in various combinations and investigated after loading at the catalytic converter.

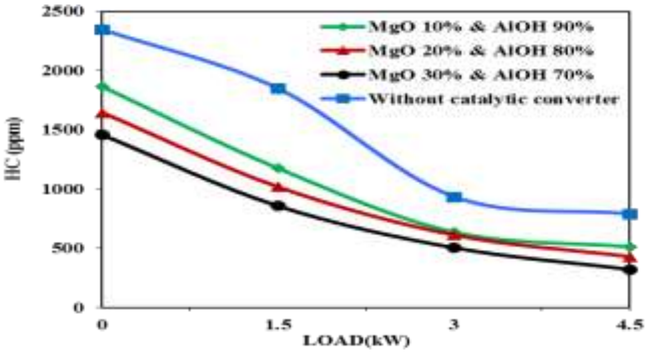

Figure 4.3c

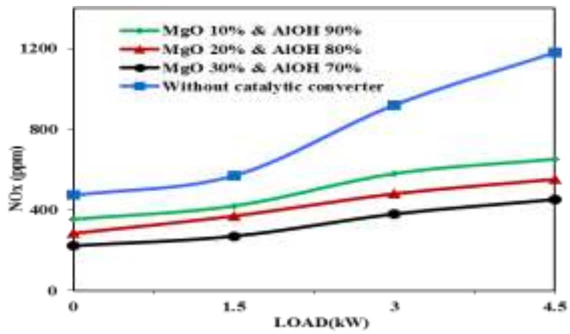

Figure 4.3d

4.4 Magnesium Oxide and Ferric Oxide Pellets as the Catalytic Converter

The pellets of MgO and FeO were placed at the catalytic converter and studied its performance. The variations in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the two pellets at the mesh. The data were plotted as a function of load and shown in Figure 4.4a-d.

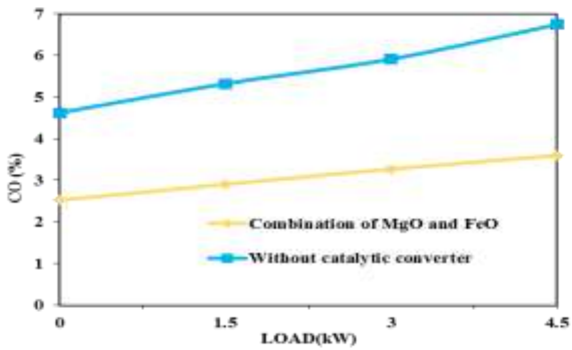

Figure 4.4a

The CO emissions for the base engine has increased with increase of load and it has reached 6% with for maximum load condition. The combination of Magnesium oxide and Ferric oxide pellet loaded as mesh as catalytic converter has facilitated oxidation reaction in the exhaust lead to a decrease in the overall percentage of

CO in the exhaust. The conversion is almost 45% in minimum load condition and progressively it has become close to 52% in the maximum load condition. Referring to illustrate Figure 4.4a the combination of MgO and FeO converter results in reduced order of CO emission.

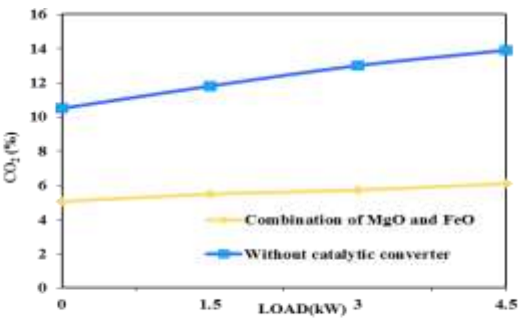

Figure 4.4b

The CO_2 concentration increases with increase in load for the base engine. This can be due to the presence of rich air fuel mixture in with increasing loads. The combination of Magnesium oxide and ferric oxide pellets loaded as mesh as the catalytic converter leads to a reduced overall CO_2 percentage in the exhaust. The conversion percentage is almost 52% in minimum load condition and progressively it has become close to 64% in the maximum load condition. Further, it is seen that compared to FeO converter combination of MgO and FeO exhibits a better control of all the pollutants.

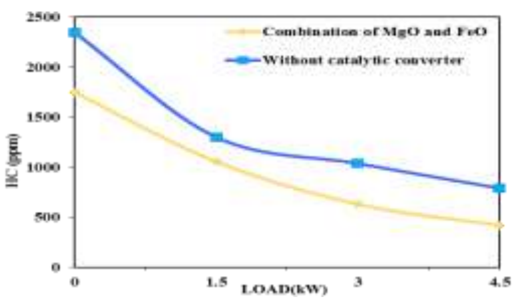

Figure 4.4c

The HC concentration has decreased with increase of load for the base engine and this can be due to complete combustion occurred while increasing loads. The implementation of combination of Magnesium oxide and Ferric oxide pellets loaded as mesh as catalytic converter facilitated the oxidation reaction in the exhaust has lead to a reduced HC percentage in the exhaust. The conversion percentage is almost 23% in minimum load condition and progressively it has become close to 55% in the maximum load condition. This can be due to the oxidizing properties of Magnesium oxide and Ferric oxide. The trend of variation of HC influenced by combination of MgO and FeO converter enhanced oxidation of HC.

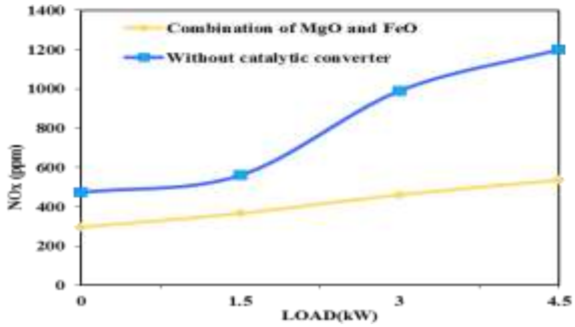

Figure 4.4d

The NO_x concentration has increased with increase of load for the base engine. This is due to complete combustion occurred while increasing loads and the presence of excess oxygen leading to complete combustion of charge. The implementation of combination of Magnesium oxide and ferric oxide pellets loaded as mesh as the catalytic converter increased NO_x percentage in the exhaust. The conversion percentage is almost 37% in minimum load condition and it becomes close to 43% in the maximum load condition. From this trend variation of NOx (Figure 4.4d) it is seen that enhanced reduction of NOx occurred with combination of MgO and FeO pellets.

As shown in the Figures 4.4 a-d, the emissions of NO_x, CO_2, HC and CO were relatively low in the engine with MgO and FeO pellets loaded in the mesh when compared to the emission from the engine without pellets. Moreover, the emission levels of pollutants were relatively decreased when the MgO and FeO pellets loaded in the mesh. Furthermore, the emissions of pollutants were effectively controlled at higher loads.

The rate of variation of pollutants percentage from the engine were calculated from the measured values and the variations have been discussed. MgO and FeO pellets in the mesh of catalytic converter effectively controls the emission of CO, HC and NO_x especially, when the engine runs at the optimum load of 4.5 kW. Moreover, the emission level decreased at higher loads.

4.5 Magnesium Oxide and Cobalt Oxide Pellets as the Catalytic Converter

The pellets of MgO and CoO were placed at the catalytic converter and studied its performance. The variation in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the two different pellets at the mesh. The data were plotted as a function of load and shown in Figure 4.5 a-d.

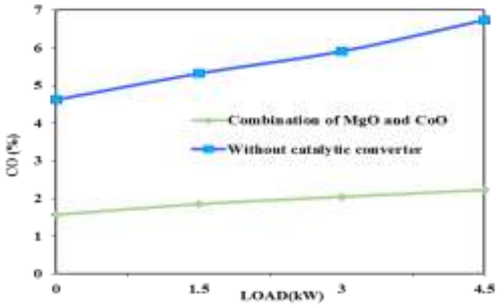

Figure 4.5a

The CO emissions for the base engine has increased with increase of load and it has reached 6% with for maximum load condition. The implementation of a Magnesium oxide and cobalt oxide pellets loaded as mesh as catalytic converter facilitated oxidation reaction in the exhaust leading to a reduction in the overall CO percentage in the exhaust. The conversion percentage is almost 41% in minimum load condition and it becomes close to 68% in the maximum load condition. This is due to the oxidation property of Magnesium oxide and cobalt oxide in the catalytic converter. Referring to the illustration of CO emission in exhaust due to CoO and MgO converter it is seen that combination facilitates better control of CO pollutants.

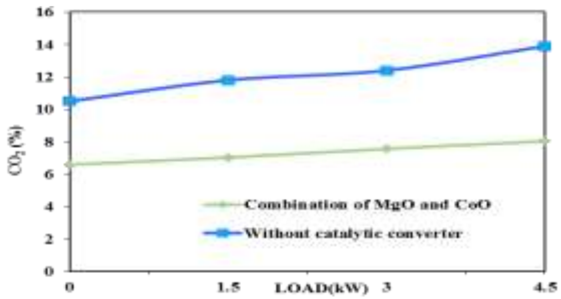

Figure 4.5b

The CO_2 concentration has increased with increase of load for the base engine. This can be due to the presence of rich air fuel mixture in with increasing loads. The combination of Magnesium oxide and cobalt oxide pellets loaded as mesh as the catalytic converter leads to a reduced overall CO_2 percentage in the exhaust. The conversion percentage is almost 41% in minimum load condition and it becomes close to 45% in the maximum load conditions. Further compare to the influence of CoO and any MgO it is possible to attain enhanced oxidation of CO in the exhaust.

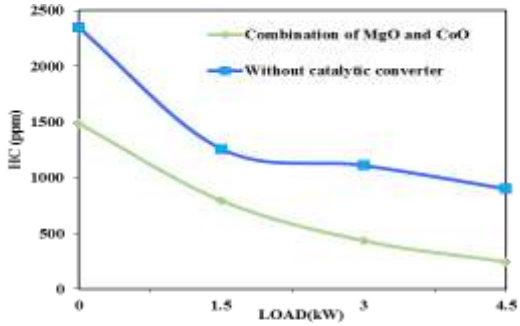

Figure 4.5c

The HC concentration has decreased with increase of load for the base engine. This can be due to complete combustion occurred while increasing loads. The implementation of combination of Magnesium oxide and cobalt oxide pellets loaded as mesh as the catalytic converter facilitated oxidation reaction in the exhaust leading to a reduced HC percentage in the exhaust. The conversion percentage is almost 66% in minimum load condition and progressively becomes close to 64% in the maximum load condition. This can be due to the oxidation properties of Magnesium oxide and cobalt oxide. Referring to the significance of pelletized converter it is seen that with MgO and CoO combination better control of HC in the emission occur.

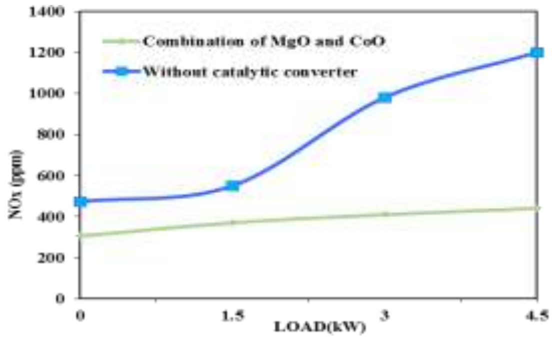

Figure 4.5d

The NO_x concentration has increased with increase of load for the base engine. This is due to complete combustion occurred while increasing loads and the presence of excess oxygen leading to complete combustion of charge. The implementation of a Magnesium oxide and cobalt oxide coated converter increase NO_x percentage in the exhaust. The conversion percentage is almost 35% in minimum load condition and it becomes close to 53% in the maximum load condition. Illustration on NOx variation (Figure 4.16d) shows marginally increased reduction of NOx with the combination MgO and CoO converter.

As shown in the Figures 4.5 a-d, the emissions of NO_x, CO_2, HC and CO were relatively low in the engine with MgO and CoO pellets loaded in the mesh when compared to the emission from the engine without pellets. Moreover, the emission levels of pollutants were relatively decreased when the MgO and CoO pellets loaded in the mesh. Further, the emissions of pollutants were effectively controlled at higher loads. The rate of variation of pollutants percentage from the engine was calculated from the measured values and the variations have been discussed. An MgO and CoO pellet in the mesh of catalytic converter effectively controls the emission of CO, HC and NO_x especially, when the engine runs at the load of 4.5 kW.

4.6 Cobalt Oxide and Ferric Oxide Pellets as the Catalytic Converter

The pellets of CoO and FeO were placed at the catalytic converter and studied its performance. The variations in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the two different pellets at the mesh. The data were plotted as a function of load and shown in Figure 4.6 a-d.

The CO emission for the base engine has increased with increase of load and it has reached 6% for maximum load condition. The implementation of combination of Cobalt oxide and Ferric oxide pellets loaded as mesh as the catalytic converter facilitated oxidation reaction in the exhaust leading to a drop in the overall CO percentage in the exhaust. The conversion percentage is almost 45% in minimum load condition and it becomes close to 41% in the maximum load condition. This is due to the oxidation property of Cobalt oxide and Ferric oxide in the catalytic converter. Compared to the influence of combination of three pelletized converter CoO and FeO contains the CO emission to a larger extent.

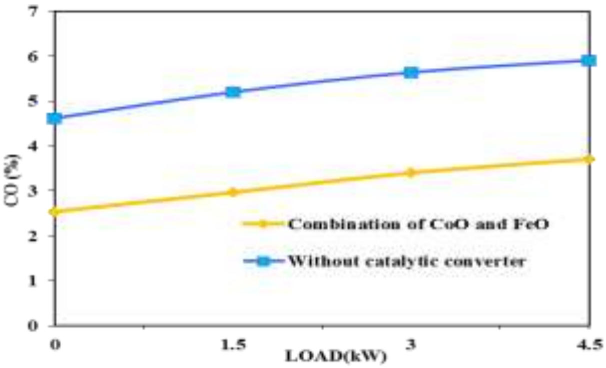

Figure 4.6a

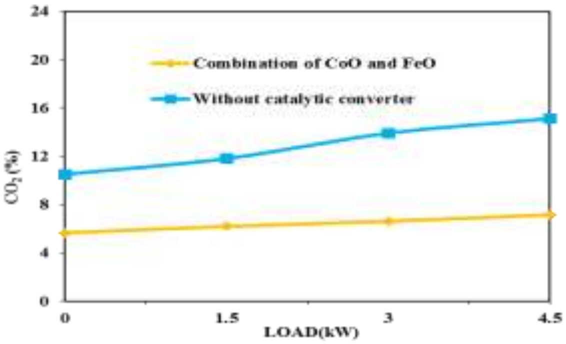

Figure 4.6b

The CO_2 concentration has increased with increase of load for the base engine. This can be due to the presence of rich air fuel mixture in with increasing load. The combination of Cobalt oxide and Ferric oxide pellets loaded as mesh as the catalytic converter leads to a reduced overall CO_2 percentage in the exhaust. The conversion percentage is almost 46% in minimum load condition and it becomes close to 51% in the maximum load condition. With CoO and FeO pelletized converter it is possible to attain more or less load insensitive CO_2 %. This is attributable to the significance of pelletizing in the converter.

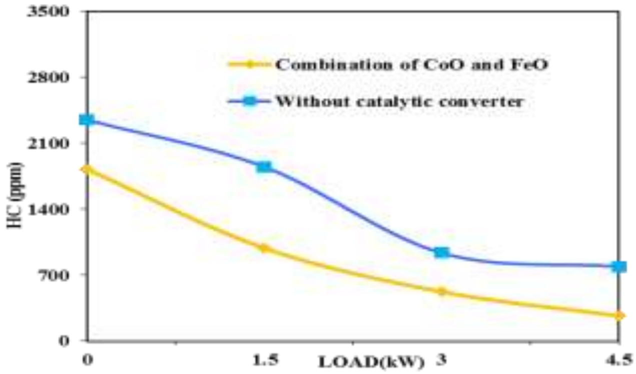

Figure 4.6c

The HC concentration has decreased with increase of load for the base engine. This can be due to complete combustion occurred while increasing load. The combination of Cobalt oxide and Ferric oxide pellets loaded as mesh as the catalytic converter facilitated enhanced oxidation reaction in the exhaust leading to a reduced HC percentage in the exhaust. The conversion percentage is almost 20% in minimum load condition and progressively becomes close to 66% in the maximum load condition. This can be due to the oxidation properties of Cobalt oxide and Ferric oxide.

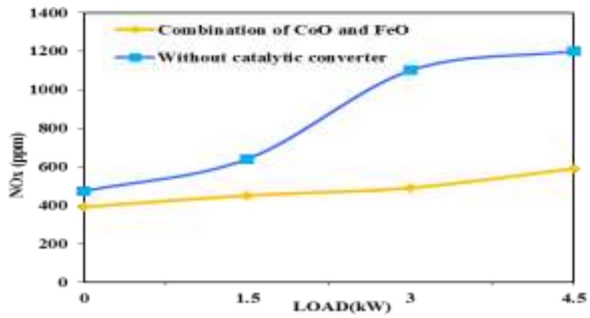

Figure 4.6d

The NO_x concentration has increased with increase of load for the base engine. This is due to the presence of excess oxygen leading to complete combustion of charge. The combination of Cobalt and Ferric oxide pellets loaded as mesh as the catalytic converter leads NO_x reduction percentage in the exhaust especially at higher load. The conversion percentage is almost 17% in minimum load condition and progressively becomes close to 52% in the maximum load condition.

As shown in the Figures 4.6 a-d, the emissions of NO_x, CO_2, HC and CO were relatively low in the engine with CoO and FeO pellets loaded mesh when compared to the emission from the engine without pellets. Moreover, the emission levels of pollutants were relatively decreased when the CoO and FeO pellets loaded in the mesh. Furthermore, the emissions of pollutants were effectively controlled at higher loads. The rate of variation of pollutants percentage from the engine were calculated from the measured values and the variations have been discussed. CoO and FeO pellets in the mesh of catalytic converter effectively controls the emission of CO, CO_2, HC and NO_x especially, when the engine runs at the load of 4.5 kW.

4.7 Magnesium Oxide, Cobalt Oxide and Ferric Oxide pellets as the Catalytic Converter

The pellets of MgO, CoO and FeO were placed at the catalytic converter and studied its performance. The variations in the emission of CO, CO_2, HC and NO_x were analyzed before and after loading the three different pellets at the mesh. The recorded emission level is observed and the data were plotted as a function of load and shown in Figures 4.7 a-d. As shown in the Figures 4.18 a-d, the emissions of CO, CO_2, HC and NO_x were relatively low in the engine with MgO, CoO and FeO pellets loaded mesh when compared to the emission from the engine without pellets. Moreover, the emission levels of pollutants were relatively decreased when the MgO, CoO and FeO pellets loaded in the mesh. Furthermore, the emissions of pollutants were effectively controlled at higher loads.

The CO emissions for the base engine has increased with increase of load and it has reached 6% for maximum load condition. The combination of Magnesium oxide, Ferric oxide and Cobalt oxide pellets loaded as mesh as the catalytic converter facilitated oxidation reaction in the exhaust leading to a reduction in the overall CO percentage in the exhaust. The conversion percentage is almost 57% in minimum load condition and progressively becomes close to 58% in the maximum load condition. This is due to the oxidation property of a Magnesium oxide, Ferric oxide and Cobalt oxide in the catalytic converter.

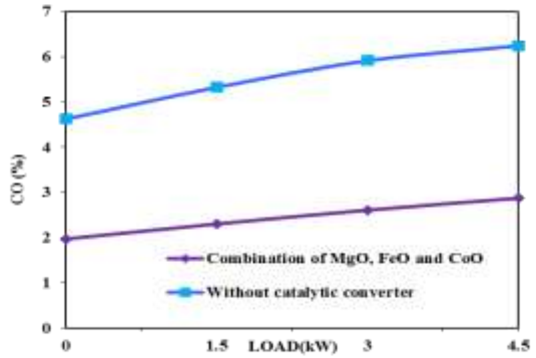

Figure 4.7a

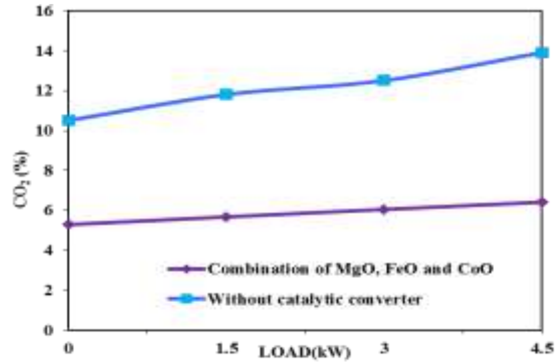

Figure 4.7b

The CO_2 concentration has increased with increase of load for the base engine. This can be due to the presence of rich air fuel mixture in with increasing load. The combination of Magnesium oxide, Ferric oxide and Cobalt oxide pellets loaded as mesh as the catalytic converter which leads to a reduced overall CO_2 percentage in the exhaust. Also referring to the significance of combination of any two converter it is possible to attain better control of pollution in combination of all the three converter. The conversion percentage is almost 49% in minimum load condition and it becomes close to 54% in the maximum load condition.

The HC concentration has decreased with increase of load for the base engine. This can be due to complete combustion occurred increasing load. The combination of Magnesium oxide, Ferric oxide and Cobalt oxide pellets loaded as mesh as the catalytic converter facilitated oxidation reaction in the exhaust has lead to a reduced HC percentage in the exhaust. The conversion percentage is almost 29% in minimum load condition and it becomes close to 71% in the maximum load condition. This can be due to the oxidation properties of Magnesium oxide, Ferric oxide and Cobalt oxide in the catalytic converter. The trend of variation is almost similar to that of combination of CoO-FeO / MgO-FeO.

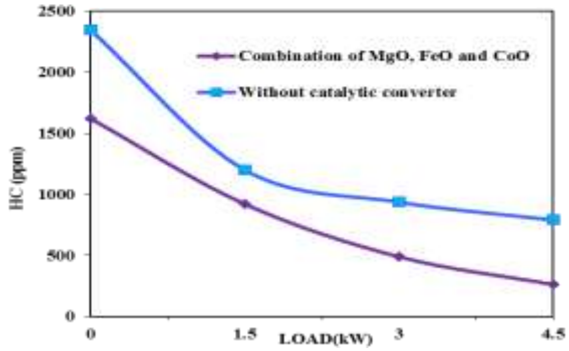

Figure 4.7c

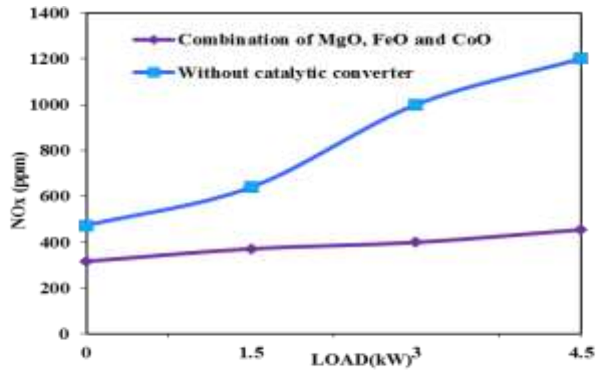

Figure 4.7d

The NO_x concentration has increased with increase of load for the base engine. This is due to complete combustion occurred while increasing load and the presence of excess oxygen has lead to complete combustion of charge. The combination of Magnesium oxide, Ferric oxide and Cobalt oxide pellets loaded as mesh as the catalytic converter facilitates reduced NO_x percentage in the exhaust. The conversion percentage is almost 47% in minimum load condition and progressively becomes close to 63% in the maximum load condition. Also compared to the other combination of all three converter facilitates better reaction as seen in the better reduction of NO_x.

The rates of variation of pollutants percentage from the engine were calculated from the measured values and the variations have been discussed. MgO, CoO and FeO pellets in the mesh of catalytic converter effectively controls the emission of CO, CO_2, HC and NO_x especially, when the engine runs at the load of 4.5 kW.

In comparison, the level of emission of pollutants were relatively decreased in the engine with two different metal oxides loading at the mesh compared to the emission level in the engine with single metal oxide at the mesh. The emission levels of gas pollutant were further decreased in the engine with three different metal oxides loading at the mesh.

5. CONCLUSIONS

Following are the conclusions based on experimental results.

- The use of Ferric Oxide coated filter reduces the emission of NO_x by 71.24 percent.
- When Cobalt Oxide catalytic filter is used, the maximum reduction of CO emission achieved is 64.26 percent.
- The use of Ferric Oxide coated filter reduces the emission of HC by 67.59 percent.
- When Magnesium Oxide catalytic filter is used, the maximum reduction of CO_2 emission achieved is 65.22 percent.

From the conclusions it is found that the Fe_2O_3 was the best catalyst to control the emission from the engines. When all these catalyst combination were used, it may yield better results in reducing the NO_x, HC, CO and CO_2.

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