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Effect of Catalytic Converter with EGR and without EGR on a DI Diesel Engine Performance and Emission Characteristics

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ABSTRACT

The automobile growth cannot be controlled because of the needs of human beings, but the emissions can be controlled by research and making advancement in current technologies. In the present paper, experiments have been conducted with diesel as fuel in three different modes. In the first mode of operation base line reading has been taken with diesel as fuel along with emission test. In the second mode of operation Exhaust Gas Re-circulator (EGR) was connected and experiments were conducted. In the third mode of operation Exhaust Gas Recirculator along with catalytic converter were conducted. EGR reduces NO_x as it dilutes the intake charge and lowers the combustion temperature. Three way catalytic converter is performing better in terms of emission control like HC, CO, NO_x, SO_x etc.., which are very harmful and have tendency to deplete our atmosphere and also makes planet inhabitable. Most of the automobile manufacturers preferring 3 way catalytic converter because of its superiority over the 2 way catalytic converter. The brake thermal efficiency is maximum in the case of base line operation and comparatively low around 23.96% in the case of EGR with catalytic converter. And brake thermal efficiency of engine with EGR without catalytic converter is little low around 2.28% compared with EGR and catalytic converter. So the engine with EGR without catalytic converter can produce better efficiency compared to other two cases. And the emission test has been conducted in all three possibilities. Emission level has become high in the case of base line and engine with EGR without catalytic converter. Emission level is reduced in the case of engine with EGR and catalytic converter like CO (54.37%), HC (33.33%) compared with other two cases but CO_2 emission is increasing around 7.21% in this case. So the emission can be reduced by using catalytic converter.

Keywords: Catalytic converter, EGR, Emission, Performance, Diesel engine

I. INTRODUCTION

Diesel engine is a type of internal-combustion engine invented by the German Engineer Rudolf Diesel and patented by him in 1892. Although his engine was designed to use coal dust as fuel, the diesel engine now burns low cost fuel oil. The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio. Low-speed Diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) the largest of which can have a thermal efficiency that exceeds 50 %. When the gas is compressed, its temperature raises; a diesel engine uses this property to ignite the fuel. Air is drawn into the cylinder of a diesel engine and is compressed by moving the piston at a compression ratio as high as 25:1much higher than needed for spark ignition engine. At the end of compression stroke diesel fuel is injected into the combustion chamber at high pressure through the atomising nozzle.

The Combustion causes the gas in the chamber to heat up rapidly, which increases pressure, which in turn forces the piston outward. The connecting rod transmits this motion to crankshaft which delivers rotary power at its output end. The high compression ratio allows the air in the cylinder to become hot enough to ignite the fuel, because of high temperature operation, diesel engine must be water-cooled.

Robert David Garrick (2002), "Throttle Deposits in Automotive Internal Combustion Engines" studied the necessity of Exhaust Gas Recirculator which is used to increase the intake Air/Fuel Ratio and also improving the compression efficiency. This also invokes the controlled automatic Compression Ignition (with no Spark Plugs) on a traditional engine.

P.P.Kamble, S.S.Ingle (2008), "Copper Plate Catalytic Converter" studied exhaust emissions of much concern are Hydrocarbon (HC), Carbon monoxide (CO) and Nitrogen Oxides (NO_x) from the automotive vehicles. Catalytic converter oxidizes harmful CO and HC emissions into CO_2 and H_2O in the exhaust system and thus the emission is controlled. There are several types of problems associated with noble metal based catalytic converter. These factors encourage for the possible application of non-noble metal based material such as copper catalyst, which may be able to show the desired activity and can also offer better durability characteristics due to its poison resistant nature.

Barth M.S (2010), "Performance Studies oh Catalytic Converter Used in Automotive Exhaust System" described catalytic converter design requirements for better understanding of complex processes taking place involving fluid flow, heat and mass transfer, and chemical reactions. The paper deals with the study of fluid flow inside the catalytic converter and the study of temperature distribution and chemical reaction in catalytic converter. CATIAV5R15 was used for geometric modeling of catalytic converter. Domain discretization was carried out in Gambit 2.2. Fluent 6.2 was used for carrying out analysis. Flow field in the catalytic converter is influenced by the flow resistance of the substrate for a given geometric configuration. As the mass flow rate increases, the pressure drop also increases. At lower temperature, the catalytic converter will be inactive. The heat release due to chemical reaction at lower temperature does not play a significant role.

Kandilli, Nur M.SC (2010), "Development of a Three Way Catalytic Converter For Elimination OF Hydrocarbon, Carbon Monoxide and Nitric Oxide in Automotive Exhaust" experimented the slurries of powder catalysts with washed coated on 22 mm diameter and 13 mm height cordierite monoliths. CeO2-ZrO2 (CZO) and CeO2-ZrO2-Al2O3 (CZAO) mixed oxides are synthesized by co-precipitation and sol-gel methods respectively, to be used as support materials of Pd and Rh metals. Metal loaded CZO is mixed with gamma phase alumina. Powder catalysts and their slurries are characterized by XRD, ICP-MS and the monolithic catalysts are imaged by SEM. Catalytic activities of monolithic catalysts are tested in dynamic test system which is computerized and basically composed of gas flow control and conditioning units, split furnace, quartz reactor, mass spectrometer and CO analyzer

EXPERIMENTAL SET-UP

Fig. 1. Experimental setup with Catalytic converter attached to Exhaust line

Fig.2 Engine with EGR and Catalytic Converter

Table. 1. Test Engine Specification

S.NO	Details	Specification
1	Manufacturer	Kirloskar
2	Power	7.4 kW
3	Brake Horse Power	10 bhp
4	Speed	1500 rpm
5	Compression Ratio	11.5:1
6	Total Displacement Volume	10.5 cc
7	Voltage	230 volts
8	Current	30 Amps
9	Frequency	50 Hertz
10	Maximum Load	34kW
11	Number of cylinders	Twin Cylinder

Table. 2 Prescribed Emission Limits

Stage	CO(g/km)	HC=NO_X (g/km)	NO_X (g/km)
BS – I	2.72/3.16*	0.97/1.30*	1.0
BS – II	2.20	0.50	0.7
BS – III	2.30	0.20	0.15
BS - 1V	1.00	0.10	0.08

EXHAUST GAS RECIRCULATOR

Exhaust gas recirculation (EGR) has been used in recent years to reduce NO_x emissions in light duty diesel engines. EGR involves diverting a fraction of the exhaust gas into the intake manifold where the recirculated exhaust gas mixes with the incoming air before being inducted into the combustion chamber. EGR reduces NO_x because it dilutes the intake charge and lowers the combustion temperature.

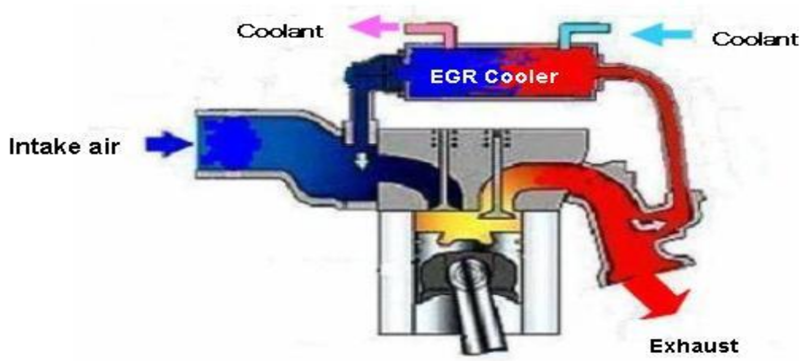
A practical problem in fully exploiting EGR is that, at very high levels, EGR suppresses flame speed sufficiently that combustion becomes incomplete and unacceptable levels of particulate matter (PM) and hydrocarbons (HC) are released in the exhaust. This transition to incomplete combustion is characteristically very abrupt due to the highly nonlinear effect of EGR on flame speed. In a transient operating environment, it is particularly difficult to reliably approach this instability limit without occasionally producing undesirable bursts of HC and PM emissions.

The objective of this work is to characterize the effect of EGR on the development of combustion instability and particulate formation so that options can be explored for maximizing the practical EGR limit. We are specifically interested in the dynamic details of the combustion transition with EGR and how the transition might be altered by appropriate high-speed adjustments to the engine. In the long run, we conjecture that it may be possible to alter the effective EGR limit by using advanced engine control strategies and work.

Working of Exhaust Gas Recirculator

Exhaust gas recirculation (EGR) is a NO_X (Nitrogen oxide and Nitrogen dioxide) reduction technique used in most gasoline and diesel engines.

- EGR works by re-circulating a portion of an engine exhaust gas back to the engine cylinders.
- Intermixing the incoming air with recirculated exhaust gas dilutes the mix with inert gas, lowering the peak combustion temperatures and (in diesel engines) reducing the amount of excess oxygen. Because NO_X formation progresses much faster at high temperatures.
- EGR serves to limit the generation of NO_X. NO_X is primarily formed when a mix of nitrogen and oxygen is subjected to high temperatures.



CATALYTIC CONVERTER

A catalytic converter is an exhaust emission control device which converts toxic chemicals in the exhaust of an internal combustion engine into less toxic substances. Inside a catalytic converter, a catalyst stimulates a chemical reaction, in which by products of combustion are converted to less toxic substances by way of catalyzed chemical reactions. The specific reactions vary with the type of catalyst installed.

Most present-day vehicles that run on gasoline are fitted with a "three way" converter, so named because it converts the three main pollutants in automobile exhaust: an oxidizing reaction converts carbon monoxide (CO) and unburned hydrocarbons (HC), and a reduction reaction converts oxides of nitrogen (NO_x) to produce carbon dioxide (CO_2), nitrogen (N_2), and water (H_2O). These were "two-way" converters which combined carbon monoxide (CO) and unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O).

Two-way catalytic converters of this type are now considered obsolete, having been supplanted except on lean burn engine by "three-way" converters which also reduce oxides of nitrogen (NOx).

Catalytic converters are still most commonly used on automobile exhaust systems, but are also used on generator sets, forklifts, mining equipment, trucks, buses, locomotives, motorcycles, airplanes and other engine fitted devices. They are also used on some wood stoves to control emissions. This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulation.

Specification of Catalytic Converter

S.NO	SPECIFICATIONS	VALUE
1	Size(W*H*L)	136*116*173
2	Type	Rectangle
3	Volume(m^3)	114
4	Weight(kg)	3.4
5	Canning	Stuffed end plate
6	Mounting	MCC

Table.3 Experimental Values for Engine without Exhaust Gas Recirculator and Catalytic Converter

S. NO	Load, (%)	Current, (Amps)	Voltage, (Volts)	Exhaust Gas Temp, (°C)	Outlet Water Temp, (°C)	Time Taken for 10cc, (mm:ss)
1	0	0	230	122	26	38.40
2	25	8	230	162	33	26.97
3	50	17	230	222	44.5	20.10
4	75	25	230	295	50	15.47
5	100	34	230	375	60	12.97

Table 4. Experimental Values for Engine with Exhaust Gas Recirculator without Catalytic Converter

S. NO	Load, (%)	Current, (Amps)	Voltage, (Volts)	Exhaust Gas Temp, (ºC)	Outlet Water Temp, (ºC)	Time Taken for 10cc, (mm:ss)
1	0	0	230	160	25	27.93
2	25	8	230	225	32	20.76
3	50	17	230	305	44	16.07
4	75	25	230	352	53	12.40
5	100	34	230	406	66	9.54

Results and Discussions

Comparison of Total Fuel Consumption Vs Percentage of Load

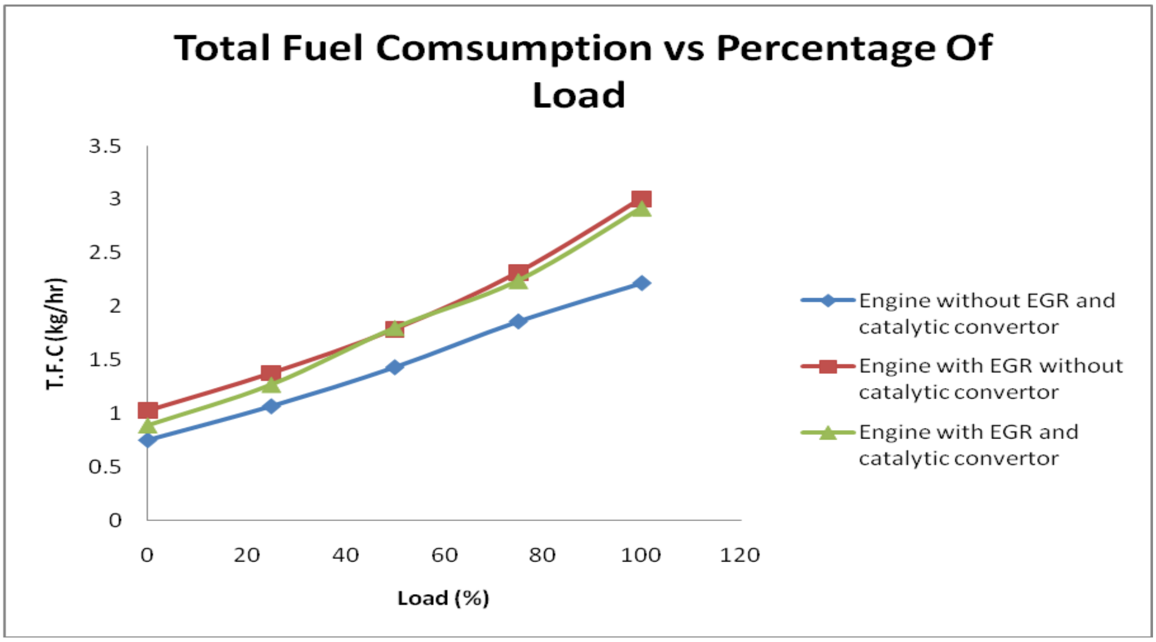


Fig.3. Variation of Total Fuel Consumption with load for various methods.

Fig 9.1.1 shows that comparison of total fuel consumption and Percentage of Load. In all three cases total fuel consumption is increase with increasing the percentage of load. But the fuel consumption for Engine with EGR and without catalytic converter is high around 36.1% compare to Engine without EGR and catalytic converter. And also the fuel consumption for Engine with EGR and catalytic converter is little low around 3.37% compare to Engine with EGR and without catalytic converter. So Engine without EGR and catalytic converter is better fuel consumption compared to other two cases.

10.2 Comparison of Specific Fuel Consumption Vs Percentage of Load

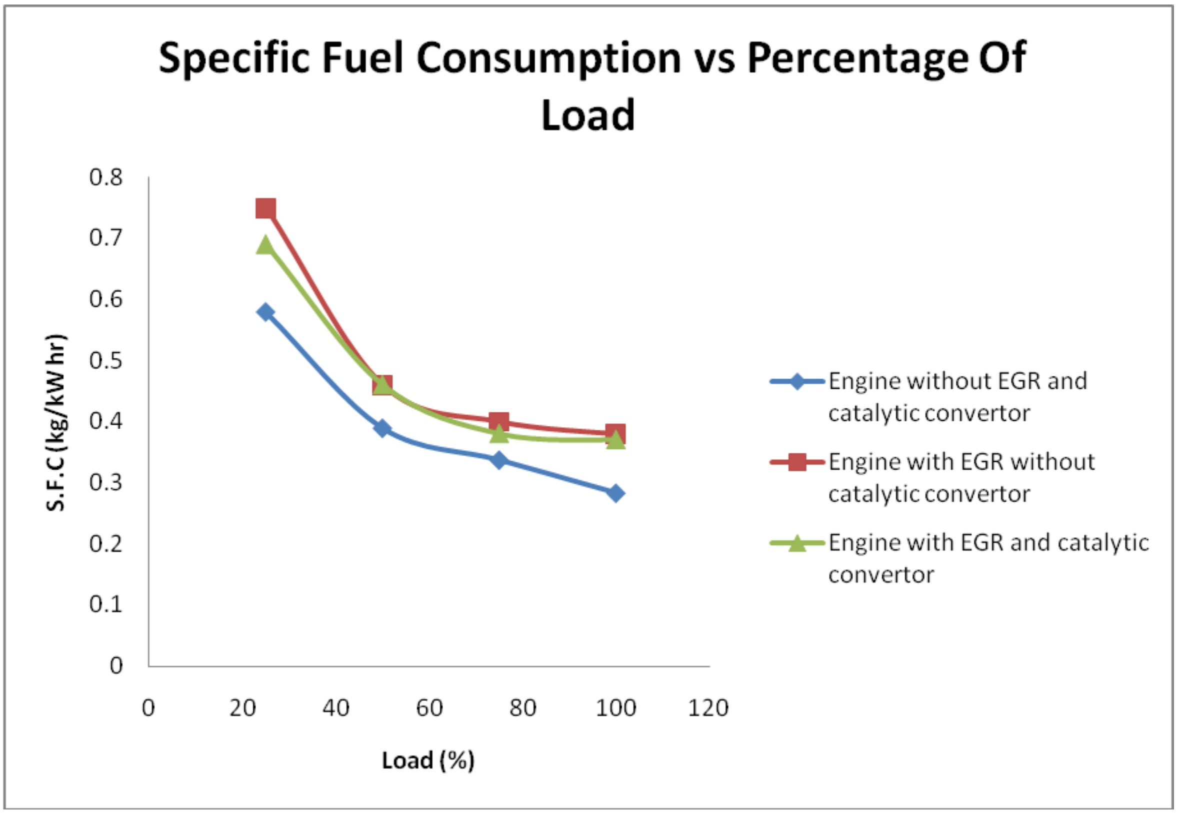


Fig.4. Variation of Specific Fuel Consumption with load for various methods.

Fig 9.2.1 shows that comparison of specific fuel consumption and Percentage of Load. In all three cases specific fuel consumption is decrease with increasing the percentage of load. But the specific fuel consumption for Engine with EGR and without catalytic converter is high around 34.28% compare to Engine without EGR and catalytic converter. And also the specific fuel consumption for Engine with EGR and catalytic converter is little low around 4.24% compare to Engine with EGR and without catalytic converter. So Engine without EGR and catalytic converter is better fuel consumption compared to other two cases.

Fig 9.3.1 shows that comparison of Brake Thermal Efficiency and Percentage of Load. In all three cases brake thermal efficiency is increase with increasing the percentage of load. But the brake thermal efficiency of engine with EGR and without catalytic converter is reduced around 26.24% compare to engine without EGR and catalytic converter. And also brake thermal efficiency of engine with EGR and catalytic converter is high around 2.28% compare to engine with EGR and without catalytic converter, due to some back pressure can occur. Normally the brake thermal efficiency of the engine is reduced then the mechanical efficiency of the engine is increased. So the engine with EGR and without catalytic converter is produced better efficiency compared to other two cases.

Comparison of Brake Thermal Efficiency Vs Percentage of Load

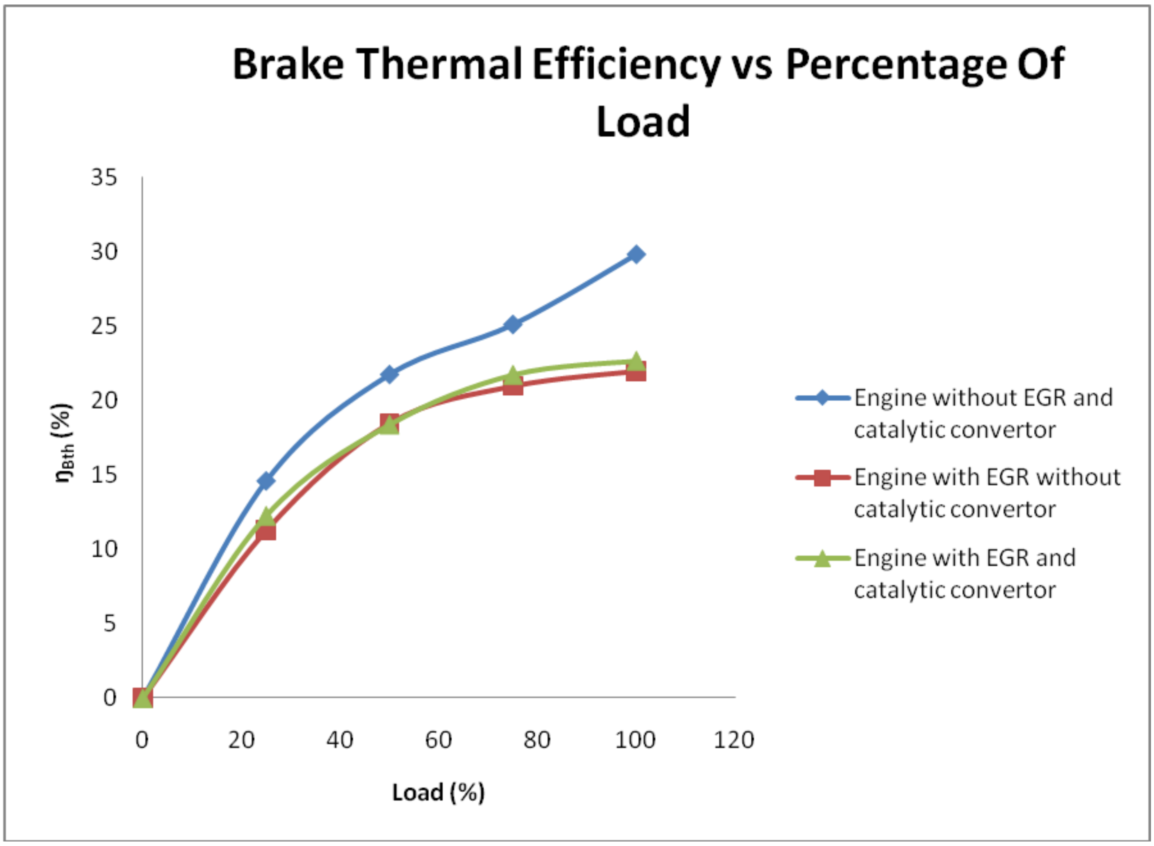


Fig.5. Variation of Brake thermal efficiency with load for various methods.

EMISSION ANALYSIS

Comparison of CO Emission Vs Percentage of Load

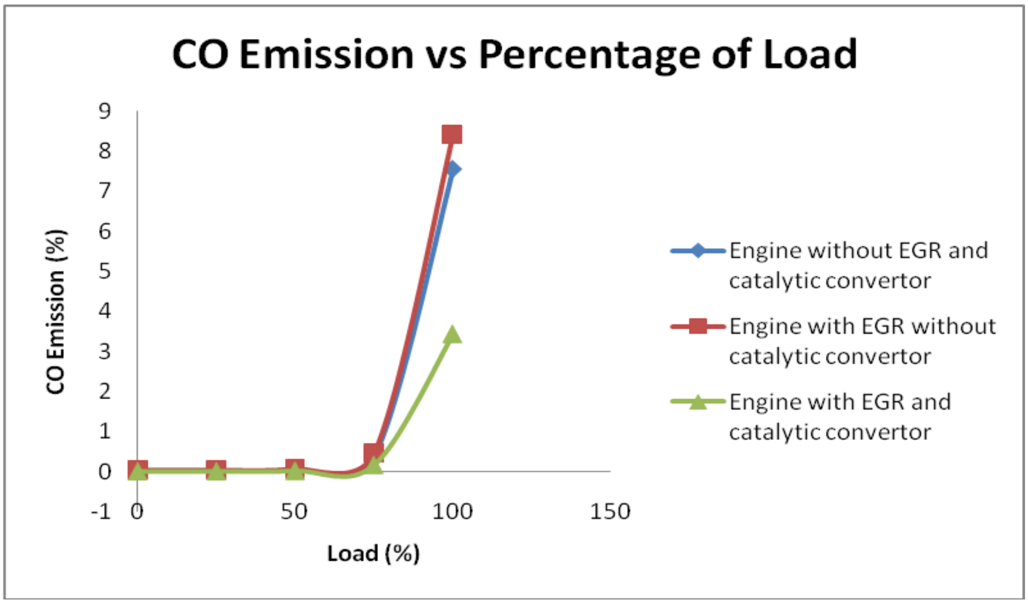


Fig.6. Variation of CO emission with load for various methods.

Graph 11.1

Graph 11.1 shows that comparison of carbon monoxide (CO) emission and percentage of load. In all three cases CO emission is increase with increasing the percentage of load. But CO emission for engine with EGR and catalytic converter is reduced around 54.37% compare to engine without EGR and catalytic converter. And also CO emission for engine with EGR and without catalytic converter is increased around 11.51% compare to engine without EGR and catalytic converter. So the CO emission is very less by using both EGR and catalytic converter.

Comparison of HC Emission Vs Percentage of Load

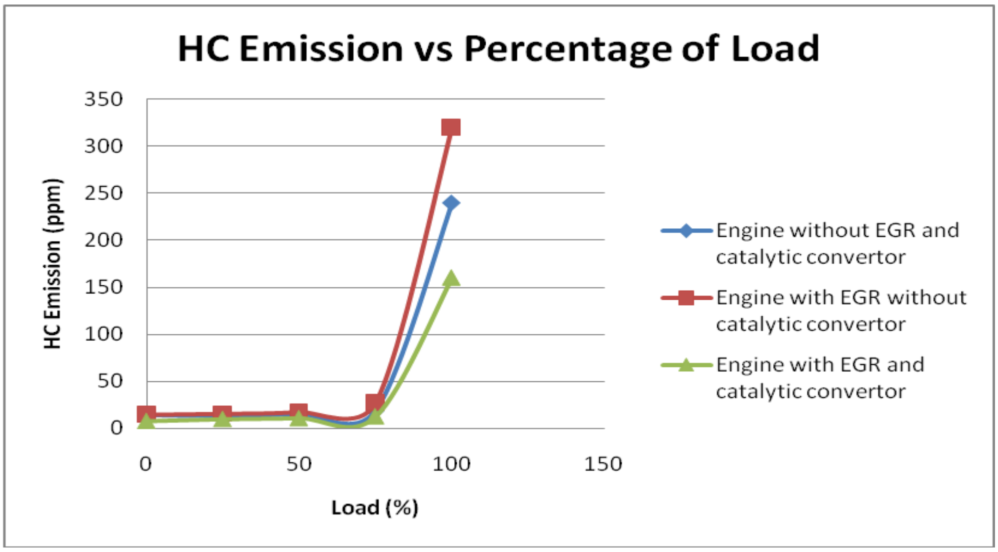


Fig.7. Variation of HC emission with load for various methods.

Graph 11.2 shows that comparison of Hydro Carbon (HC) emission and percentage of load. In all three cases HC emission is increase with increasing the percentage of load. But HC emission for engine with EGR and catalytic converter is reduced around 33.33% compare to engine without EGR and catalytic converter. And also HC emission for engine with EGR and without catalytic converter is increased around 33.33% compare to engine without EGR and catalytic converter. So the HC emission is very less by using both EGR and catalytic converter.

Comparison of CO_2 Emission Vs Percentage of Load

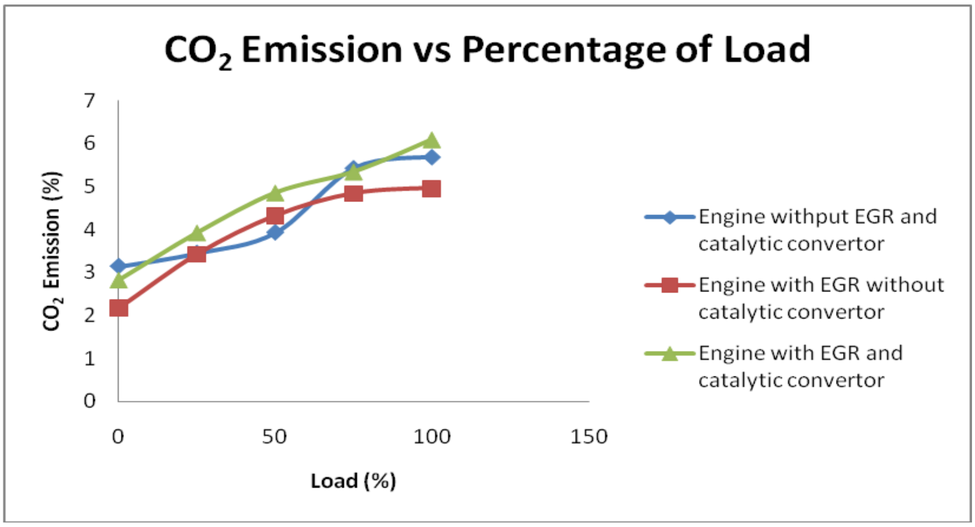


Fig.8. Variation of CO_2 emission with load for various methods.

Graph 11.3 shows that comparison of Carbon Dioxide (CO_2) emission and percentage of load. In all three cases CO_2 emission is increase with increasing the percentage of load. But CO_2 emission for engine with EGR and catalytic converter is increased around 7.21% compare to engine without EGR and catalytic converter. And also CO_2 emission for engine with EGR and without catalytic converter is reduced around 12.83% compare to engine without EGR and catalytic converter. So the CO_2 emission is increased by using both EGR and catalytic converter.

Comparison O_2 Emission Vs Percentage of Load

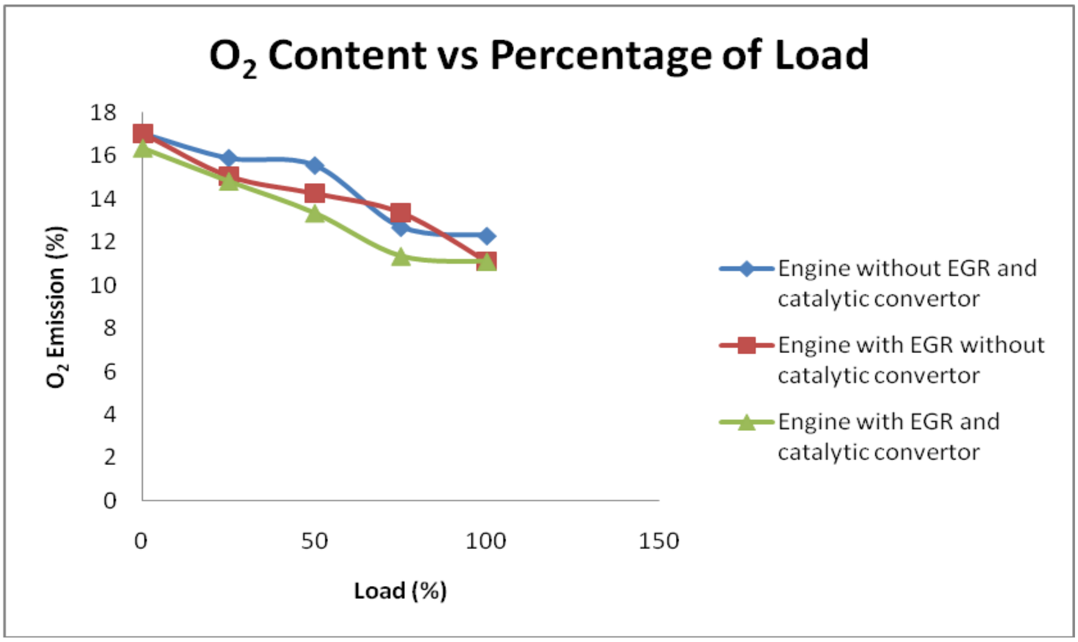


Fig.9. Variation of O_2 emission with load for various methods.

Graph 11.4 shows that comparison of Oxygen (O_2) content and percentage of load. In all three cases O_2 content is decrease with increasing the percentage of load. So O_2 content for engine with EGR and catalytic converter is decreased around 9.76% compare to engine without EGR and catalytic converter. And also O_2 content for engine with EGR and without catalytic converter is reduced around 9.92% compare to engine without EGR and catalytic converter. So that the O_2 content is reduced for both cases.

CONCLUSION

Experiments have been conducted with diesel as fuel in three different modes. In the first mode of operation base line reading has been taken with diesel as fuel along with emission test. In the second mode of operation Exhaust Gas Re-circulator was connected and experiments were conducted. In the third mode of operation Exhaust Gas Recirculator along with catalytic converter were conducted.

The brake thermal efficiency is maximum in the case of base line operation and comparatively low around (23.96%) in the case of EGR with catalytic converter. And brake thermal efficiency of engine with EGR without catalytic converter is little low around (2.28%) compare EGR with catalytic converter. So the engine with EGR without catalytic converter can produced better efficiency compare other two cases.

And the emission test has been conducted in all three possibilities. Emission level has become high in the case of base line and engine with EGR without catalytic converter. Emission level is reduced in the case of engine with EGR and catalytic converter like CO (54.37%), HC (33.33%) compared with other two cases but CO_2 emission is increasing around 7.21% in this case. So the emission can be reduced by using catalytic converter.

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