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RESEARCH ARTICLE

EMISSION REDUCTION BY UREA INJECTION INTO DECOMPOSER IN SCR.

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Abstract

Due to the stringent emission norms, the reduction of emissions from the engines has become necessary. Diesel engines produce less carbon emissions when compared but it is necessary to reduce NOx emissions in the diesel engines. this project is focused on urea-SCR system as De-NOx system the urea in the form of Adblue solution is injected into the exhaust system by using a “decomposer” separated from the exhaust tail pipe. Urea is injected into the decomposer in the form of Adblue (aqueous solution of 32.5% urea) which is also known as diesel exhaust fluid. Decomposer is where the Adblue solution decomposes into ammonia and CO2. Adblue solution is injected into the decomposer by using a pump and an injector. A blower is inserted into the decomposer for the atomization of the urea droplets. Urea reacts with the exhaust gases in the exhaust line to form nitrogen gas (N2) and CO2. The decomposer and the injector is designed in “CATIA” the analysis of flow of exhaust gases are carried out in CFD. The experiment is conducted for different loads at different conditions and results are calculated.

Introduction:-

The emissions of diesel engines have many pollutants like CO2, CO, HC, NOx among them NOx is considered as most harmful to environment and human health they also contribute to the greenhouse effect. NOx emissions can cause respiratory problems in human beings. SCR technology is intended to allow pollutant (NOx) reduction reactions occurring in oxidizing atmosphere. ammonia as a reducer among a catalyst system. the chemical action is considered as "reduction" wherever the DEF is that the reductant that reacts with NOx to convert the pollutants(NOx) into nitrogen, water and small amounts of CO2. The DEF can be readily reduced to supply the oxidizing ammonia within the exhaust stream. SCR technology alone can do NOx reductions up to 90%.

There are many techniques being tried to control NOx emission from diesel engine. The following methods may be employed either as a single technique or as a combination.

- Modification of engine operations
- Changes in the engine design
- Modification of fuels
- After treatment of exhaust gases.

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After treatment of exhaust gasses is considered in this project. After treatment of exhaust gases involves many techniques

- EGR- exhaust gas recirculation.
- DOC- diesel oxidation catalyst.
- DPF- diesel particulate filter.
- SCR- selective catalytic reduction.

DEF- diesel exhaust Fluid:-

The pressure of Nitrogen in the atmosphere exists in the form of N2(di-atomic modulus of Nitrogen) which is highly stable. During the process of combustion, a high temperature will occur inside the cylinder at about 800°C to -1000°C. At this high temperature, the di-atomic molecule nitrogen N changes into monoatomic Nitrogen 2N which is highly reactive. This monoatomic Nitrogen reacts with the oxygen which is already present in the cylinder and from oxides of Nitrogen. Oxides of Nitrogen generally occurs mainly in the form of NO and NO2. These are generally formed at high temperature. Hence higher temperature and availability of free oxygen are the main two reasons for the formation of NO and NO2. Many other Nitrogen Oxides like N2O4, N2O, N2O3, N2O5 also formed in low concentrations but they decompose spontaneously at ambient conditions of NO2.

When the urea is injected into the decomposer the urea mixes with the exhaust gases and forms ammonia and nitrogen gas. The reactions depend on the velocity of the urea injected, the velocity and temperature of the exhaust gases in the exhaust line and the pressure conditions inside the tail pipe of the engine exhaust. Generally, the reaction of urea takes place in two ways they are.

- Evaporation of urea.
- The thermal decomposition of urea.

Evaporation of urea:-

$CO(NH_2)_2 \Rightarrow NH_3 + HNCO$ [1]

$HNCO + H_2O \Rightarrow NH_3 + CO_2$ [2]

- Adblue decomposes into ammonia and Isocyanic acid. Again, the Isocyanic acid combines with water vapor to form ammonia and CO2.

The thermal decomposition of urea:-

Due to thermal activity in the exhaust gas urea decomposes into Isocyanic acid and ammonia. Then ammonia reacts with the NOX oxides in the exhaust gases to form clean environment free nitrogen and water vapor. Excess ammonia present in the exhaust line readily reacts with the oxygen to form nitrogen and water vapor.

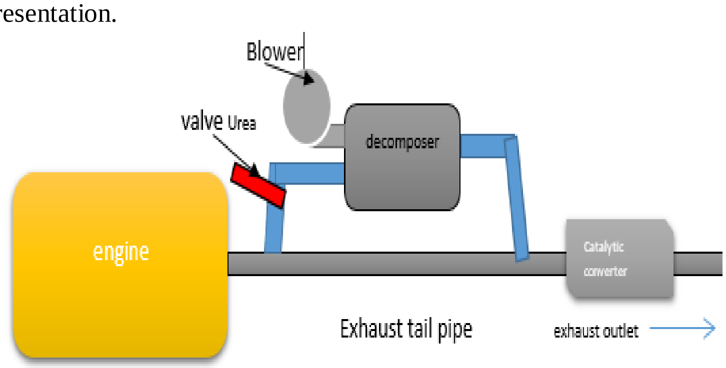
$2CO(NH_2)_2 + 6NO \Rightarrow 5N_2 + 2CO_2 + 4H_2O$ [3]

$4HNCO + 6NO \Rightarrow 5N_2 + 4CO_2 + 2H_2O$ [4]

$4NH_3 + 4NO + O_2 \Rightarrow 4N_2 + 6H_2O$ [5]

Experimental Procedure:-

The engine was calibrated for every variable load of 0%,25%,50%,75%,100% at a constant RPM. Once the engine and the setup was calibrated using the components. The testing was initiated by the checking the supply of fuel for a periodic time and the behavioral of the dynamometer, current supply and temperature difference was noted to provide the graphical representation.



Line Diagram of the Project

Working of the setup:-

The Adblue Urea is used it has constituents of parts of urea, water and other chemicals. Pump is being used to supply the urea into the mechanical injector with required pressure. It is a pump from kirloskar with 0.25 HP its modified for usage we have incorporated a cam into the setup. The cam is powered by the shaft from the motor. A full revolution of the cam will lead to one injection of urea via the urea injector. The injector used in our setup is a CRDI Diesel injector which is calibrated to 120 bars for providing the best suitable pressure for the mixture of urea with the gases.

The blower in the setup is used to atomize the liquid urea into gaseous so that there is no wastage of urea and the mixture is said to be complete. Once the exhaust gas reaches the decomposer the urea is been injected continuously so that the gas is mixed with the urea and the chemical reaction takes place and splitting of ions takes place, reaction continues during the flow of gas to the exhaust outlet. The temperature of the exhaust gas varies from 750^{o}C – 1200^{o}C this temperature leads to the formation of the NOx thus the liquid urea cools down the gas and travelling of the gases has increased so the temperature is reducing and flow region is increased than the conventional tail pipe so it provides more time for the chemical reaction to take place.

The splitting of the hydrocarbon is done and the remaining gases like CO_2 and NO_2 is present the exhaust pipe line. These gases are further cleared using the catalytic converter which aids the overall reaction and reduces the emission. The catalytic converter acts as a catalyst and speeds up the reaction and provides lesser emission. It is being possible because of the catalyst present in it and the structure in which the chambers are arranged. Whereas, in our experiment we have used Catalytic converter which has honeycomb structured chambers and they are titanium coated. Titanium readily reacts with CO_2 and NO_2 so the emission is reduced.

Analysis Results And Discussion:-

The decomposer chamber and the nozzle is designed in the "CATIA V5" software. A valve is provided to control the flow of exhaust gases into the decomposer the valve can be set in different positions to provide the better decomposition of urea and reduce NOx emissions from the engine. The SCR urea injection and the carbon container is fixed to the exhaust system and the exhaust gases are tested by a "AVL 5 gas analyzer" to determine the amounts of different exhaust gases coming out of the engine.

Analysis:-

The design and the analysis of the decomposer and nozzle is done in the software. The parameters determined in the analysis is the flow of the exhaust gases in the exhaust line, the mixture analysis of the ammonia and the exhaust gases in the exhaust line. The thermodynamic analysis of the urea and exhaust gases are also determined using CFD. The mixture analysis can give the reactions of the urea and the exhaust gases in the decomposer and the exhaust line. the decomposition of urea into ammonia and isocyanic acid can be roughly determined the isocyanic acid is a harmful gas and is not allowed to release into the atmosphere so the isocyanic acid has to be again decomposed into nitrogen(N2) and carbon dioxide (CO2).

The flow analysis of the exhaust gases in the decomposer gives the amount of exhaust gases entering into the decomposer it helps to determine the amount of urea to be sprayed into the decomposer to avoid the formation of isocyanic acid which is unwanted. The mean value is calculated for the optimum reduction of NOx and carbon emissions from the engine and the urea is allowed to spray in such a pressure.

The urea is sprayed into the decomposer with the help of a pump, it is connected with a cam shaft which rotates to lift the plunger of the pump when the plunger is lifted it allows the urea to spray inside the decomposer. The pump designed to operate at pressures up to 180 bar but the urea is sprayed with optimum pressure of 120 bar, which allows the atomization of urea sprayed.

Results:-

The results are calculated for the different loads at different conditions as mentioned and the comparison graphs are plotted for the different conditions. Table:1 gives the emissions from the engine when the engine is provided with urea injection, activated carbon and the catalytic converter. Table:2 gives the smoke properties of the engine in the same conditions.

Table 1:- Emission readings for urea injection with activated carbon combined with catalytic converter.

S.No	Load (%)	CO (%)	HC (%)	CO2 (%)	O2	NOx (PPM)
1	100	0.04	6	6.9	20.95	1346
2	75	0.06	11	8.2	20.95	1137
3	50	0.04	8	6.3	20.95	1079
4	25	0.03	2	4.2	20.95	797
5	0	0.03	1	2.3	20.95	456

Table 2:- Smoke properties of exhaust gas urea injection with activated carbon combined with catalytic converter.

Load (%)	100	75	50	25	0
Opacity(%)	0	7.4	39.2	58.8	45.1
ABS / m	0	0.17	1.15	2.06	1.39

Table:3 gives the emission readings of the engine when the engine is connected with decomposer provided with urea injection. the table shows more significant reduction in NOx when compared with the other conditions where the engine is tested. The oxygen in the exhaust gases is negligible and the HC emissions are comparatively high. Table:4 gives the smoke properties of the exhaust gas when only the urea injection is carried out for the reduction of emissions from the exhaust gases.

Table 3:- Emission readings for urea injection into decomposer.

S.No	Load (%)	CO (%)	HC (%)	CO2(%)	O2	NOx (PPM)
1	100	0.07	7	5	Nil	1124
2	75	0.03	10	5.6	Nil	1204
3	50	0.02	7	5.3	Nil	1125
4	25	0.02	7	3	Nil	605
5	0	0.03	6	1.8	Nil	308

Table 4:- Smoke properties for exhaust gas of urea injection into decomposer.

Load (%)	100	75	50	25	0
Opacity(%)	0.3	4.8	44.4	50.8	56.1
ABS / m	0	0.11	1.36	1.62	1.91

The opacity of the smoke from the engine when only urea injection is carried is relatively high. This is because no further treatment is done for the exhaust gases to reduce the carbon emissions or smoke unless the urea injection for NOx reduction. When the engine is running in high load conditions the opacity of the smoke is low because all the carbon particles are burnt due to high temperatures in the exhaust gas when the load decreases the opacity of the exhaust gas increases.

Table:5 gives the emission readings of the exhaust gases from the engine when the engine is connected with urea injection and the catalytic converter. Urea injection plays a major role in reducing the NOx emissions from the engine and the carbon emissions and the HC emissions are greatly reduced by the catalytic converter. The NOx reduction is not so efficient as in the previous case because the time for urea to mix with exhaust gases reduces because the exhaust gases enters to the catalytic converter. Table:6 gives the smoke properties of the exhaust gases when urea injection is combined with the catalytic converter.

Table 5:- Emission readings for urea injection into decomposer combined with catalytic converter.

S.No	Load (%)	CO (%)	HC (%)	CO2(%)	O2	NOx (PPM)
1	100	0.04	2	6.9	20.37	1424
2	75	0.04	7	6.8	20.79	1248
3	50	0.03	1	5.5	20.79	1060
4	25	0.02	3	3.4	20.79	695
5	0	0.02	2	1.8	20.79	370

Table 6:- Smoke properties for exhaust gas of urea injection into decomposer combined with catalytic converter.

Load (%)	100	75	50	25	0
Opacity(%)	0	16.4	45.7	62.7	52.9
ABS / m	0	0.4	1.42	2.29	1.75

The opacity of the exhaust gas is not greatly reduced a in the case of where only urea injection is carried. When the engine is running in low load conditions the opacity is high and during the high load conditions the opacity is low. When the engine is running at full load conditions the opacity of the exhaust gas is completely reduced.

The comparison graphs are drawn for the different conditions and at different loads. The emissions of different gases from the tables 1,3 and 5 for different conditions mentioned in the paper.

1. activated carbon and urea injection combined with catalytic converter (NO PPM)
2. urea injection and catalytic converter combined (NO PPM 2)
3. only urea injection into decomposer (NO PPM 3)

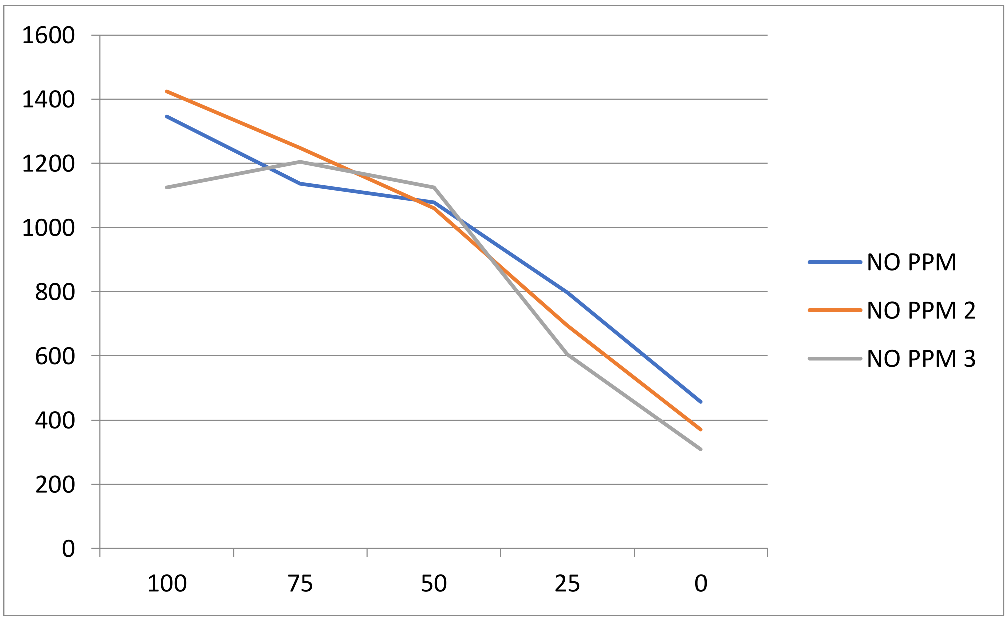


Fig 2:- Comparison of NOx emissions for different loads with different conditions

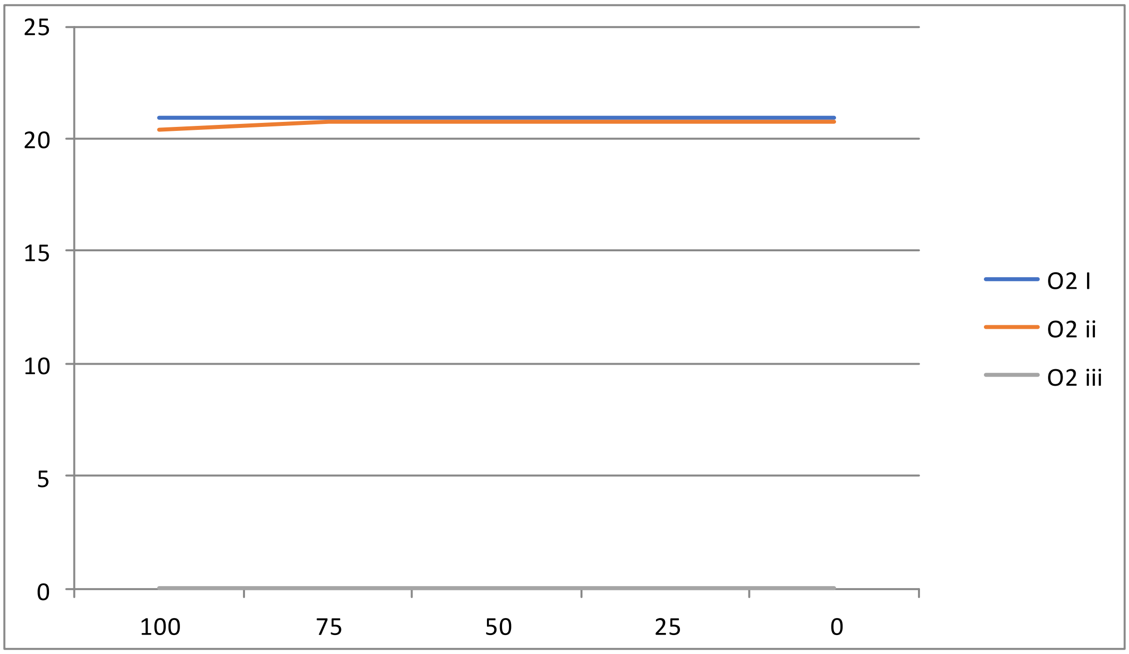


Fig 3:- Comparison of O2 emissions for different loads with different conditions.

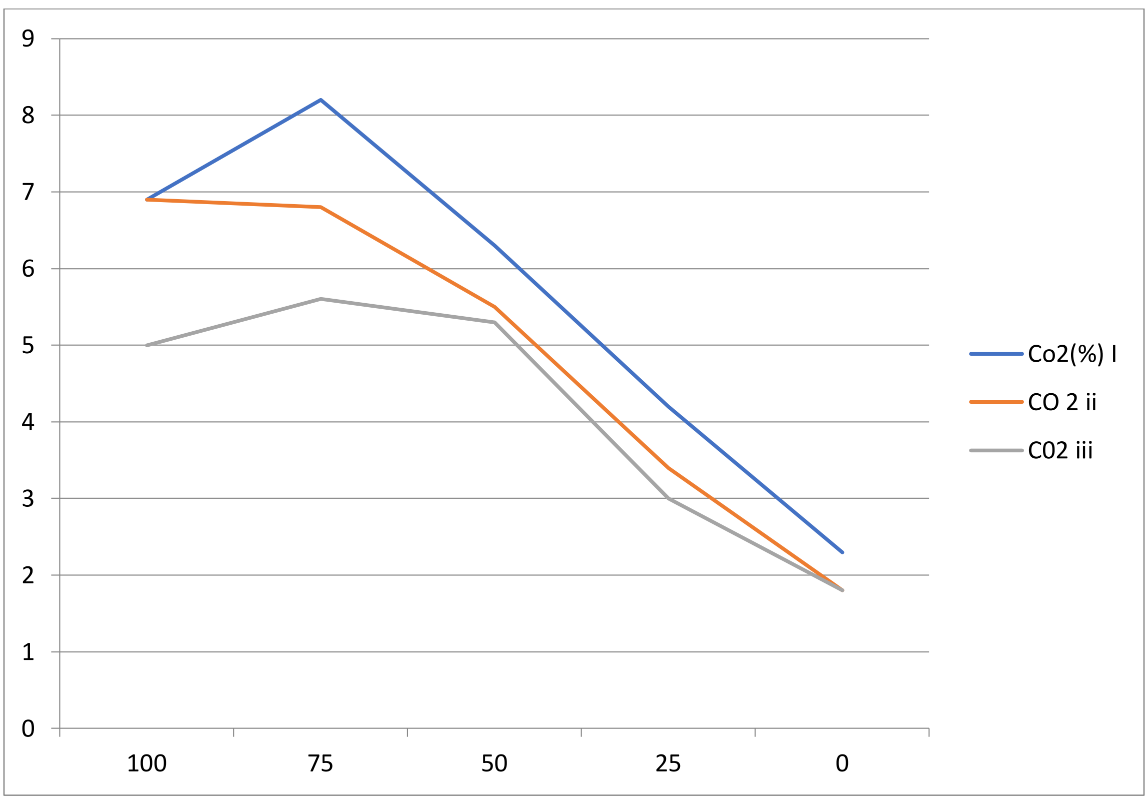


Fig 4:- Comparison of CO2 emissions for different loads with different conditions

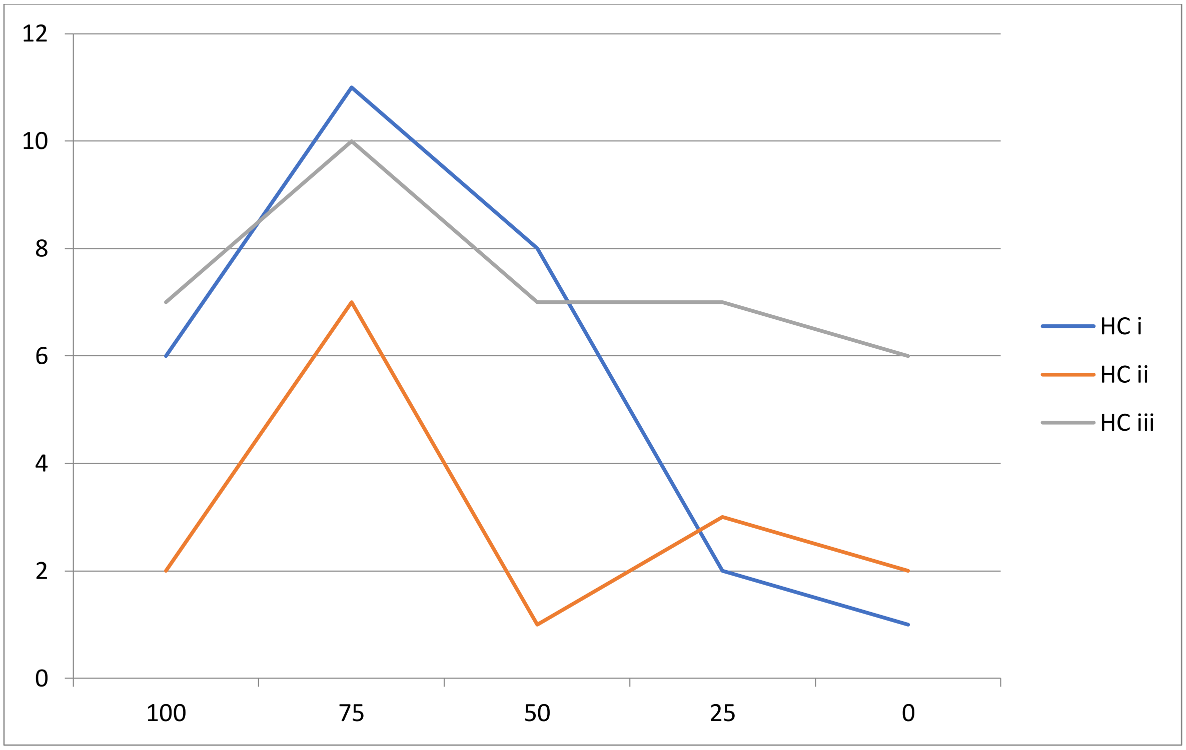


Fig 5:- Comparison of HC emissions for different loads with different conditions.

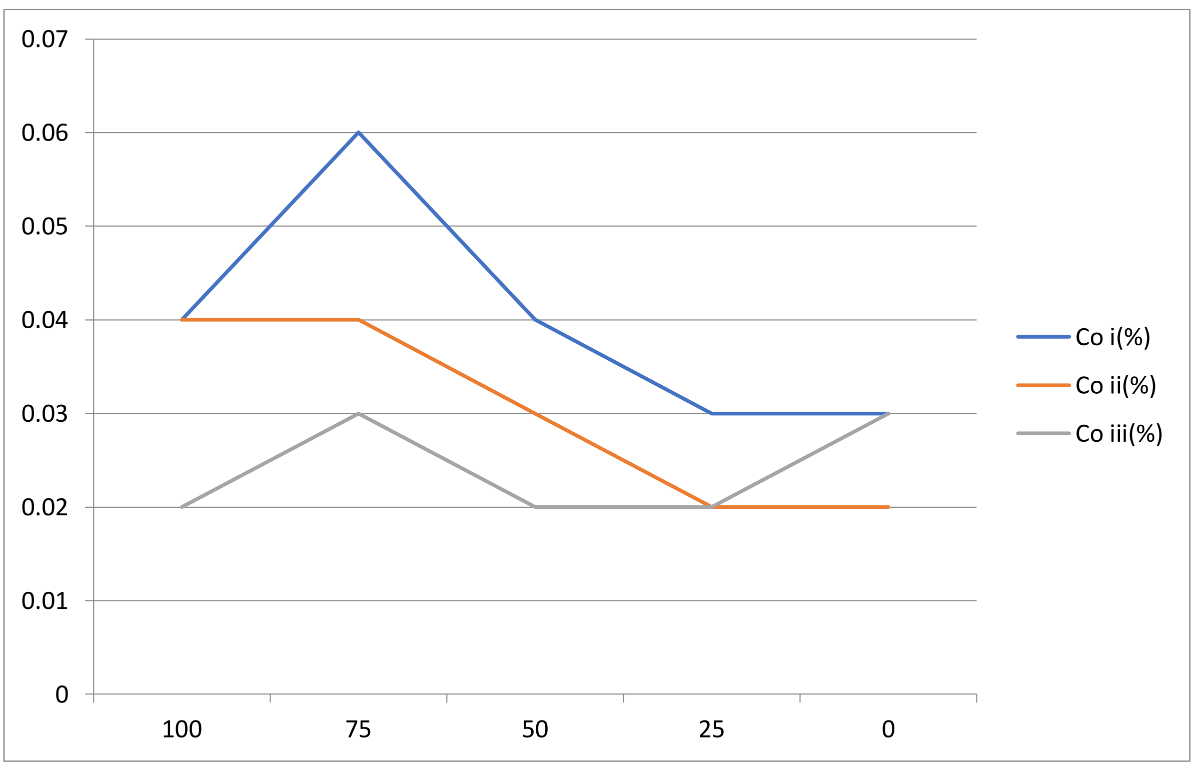


Fig 6:- Comparison of CO emissions for different loads with different conditions.

The comparison graphs of NOx, CO2, HC, CO, and O2 are plotted for the determination of better processes for the optimum reduction of all the emissions from the engine to meet the stringent emission norms. The details of these comparison graphs are given from the figures 2 to 6 respectively.

Conclusion:-

The work done in this project determines using the technique of urea injection into decomposer to reduce the NOx emissions from the exhaust gases of the engine. the urea employed emission reduction technique uses a pump coupled with an injector to spray the urea into the decomposer. The engine is coupled with decomposer and catalytic converter and each of the system employed is tested for different load conditions i.e. 100%, 75%, 50%, 25%, 0%. It is concluded that the conversion efficiency of the SCR by using titanium and vanadium as catalyst system reduces the NOX emissions by 36%-80% at different load conditions carried out at normal injection pressure.

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