

“Analysis of emission characteristics of MPFI gasoline engine using the 5 gas analyser”

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ABSTRACT

The aim of the project is to conduct study of a 4 cylinder multi point fuel injection gasoline engine (of Maruti Suzuki Swift) emission characteristics and providing a suitable range of engine running speed and load for minimum emissions. The emission results were recorded under steady state operating conditions. Now a day the emission norms are very stringent. Emissions standards like Bharat Stage IV (Equal to EURO IV) have been implemented in India (in 13 major cities since April 2010). So we not only have to focus to meet the EURO IV norms but also have to think about the least emissions of the exhaust gases from the engines in order to keep health environment safe. In this project the engine is made to run at different engine speed keeping load constant and also vice versa. On an average we have observed that the exhaust emissions like HC, CO, CO₂ etc have least amount within a certain range of load and speed. This process is carried out to suggest an optimum running range of vehicle so that the emission should be less and ultimately have a complete combustion of a fuel in the engine.

INTRODUCTION:

Clean and green world is the requirement of today. For this, one should think and act as an environmentalist. The mode of transportation, especially the individual transportation signifies the advancement of civilization, by which more and more spark ignition (SI) engines come into existence, leading to emission of huge amount of pollutants from the exhaust of these engines, run by fossil fuels. The CO and UBHC are major pollutants formed due to incomplete combustion of the fuel in the automobile exhaust, breathing of which may cause many human health disorders [1-6], like reduction of oxygen supply in the blood, dizziness, breathing and respiratory problems, eye irritation, retarded mental activity etc. Such pollutants also cause detrimental effects on animal and plant life besides environmental disorders. The major reasons for incomplete combustion of the fuel are cold metal surface of the combustion chamber and imperfect air-fuel ratio. Further, the quality of the fuel dictates the amount of the pollutants emitted from the engine. Test procedures have an essential role in these regulations, and the setting of a limit value for any exhaust constituent has always needed in parallel a description of the procedure, how this emission is to be measured. To curb the emissions really effectively, these test procedures should be related to the actual conditions of vehicle use as closely as possible, because achieving low emissions in these regulatory tests is usually the primary target in the design of any emission control system. If the test conditions do not match real-world situations, non-optimum performance and higher emissions in normal, everyday driving are expected.

A drastic increase in the number of vehicles has resulted in a significant increase in the emission load of various pollutants. Vehicles in major metropolitan cities are estimated to account for 70% of CO, 50% of HC, 30-40% of NO_x, 30% of SPM, 10% of SO₂ of the total pollution load of these cities, of which two third is contributed by two wheelers alone.

The engine which is used for the study of such characteristic is advanced technology MPFI engine with inbuilt catalytic converter of Maruti Swift engine in which emission of gases will be less as compared to conventional engine. In MPFI system, each cylinder has one injector (which makes it multi-point). Each of these injectors is controlled by one central car computer. This computer is a small micro-processor, which keeps telling each injector about how much petrol and at what time it needs to inject near the cylinder so that only the required amount of petrol goes into the cylinder at the right moment. With three types of multi point injection (MPI) injectors available on the market, was compared for stationary and transient engine operation. There are several advantages of MPI, e.g., better possibility to equalize the air-fuel ratio of the cylinders, optimization of the gas

injection timing and of the gas pressure for different operating conditions. According to that the sequential or MPI system has advantages for the more efficiency.

The study of gases is being carried with the help of five gas analyser of AVL India Company. In this project we have studied all the theoretical cause of generation of all exhaust gases and then perform the test on the engine at different running condition of engine and observations and results for the data are generated by plotting the graphs between the different parameter and reason are given for those which we get in the graphs. Conclusions have been drawn by analysing the results and range has been suggested in which emission of the gases is least in amount. A Gas analyser is meant for monitoring CO, CO₂, HC, O₂ and NO in automotive exhaust. CO, CO₂ and HC (Hydrocarbon residue) are measured by NDIR technology and O₂ and NO by Electrochemical sensors. It is also supplied as a 4-gas analyser which can be upgraded easily to a version by the addition of an NO sensor. It has many control features to prevent faulty measurements.

Experimental setup and Procedure:

A 0.8 litre multi point fuel injection gasoline engine (Maruti swift) sequential type port fuel injection which is connected to an eddy current dynamometer for loading. The specifications of the engine are listed above and the experimental setup and the schematic diagram are shown in Fig.1 respectively. An eddy current dynamometer and Ni-DAQ data acquisition system were used to program the engine test as well as recording engine performance data. The engine was run at steady state conditions with wide open throttle at constant speed ranging from 1000 to 24000 rpm with 200 rpm increment at constant load condition and load ranging from 0 to 18 Nm with 3 Nm increment at constant rpm condition. Exhaust emissions for gasoline fuel were measured by AVL 5 gas analyzer by putting the gas sensor in the exhaust tail pipe of the engine. The reading were taken at different ambient air conditions such that we can provide optimum range of driving the vehicle according to different weather condition.

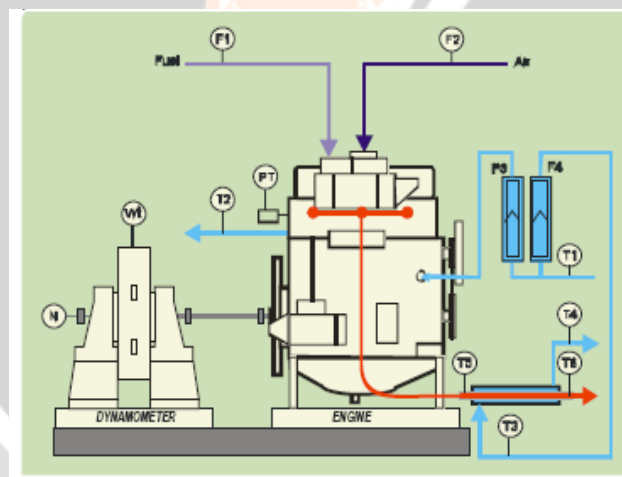


Figure 1: Shows MPFI engine setup

Table 1: Engine and Dynamometer specification

Engine model	Maruti Suzuki Swift
Number of cylinders	4, Inline DOHC
Bore in mm	73 mm
Stroke in mm	72 mm
Connecting rod length in mm	120 mm

Compression ratio	10: 1
Cooling	Water cooled
Fuel system	Multipoint fuel injection
Dynamometer type	Eddy current
Orifice diameter	35 mm
Dynamometer arm length	210 mm

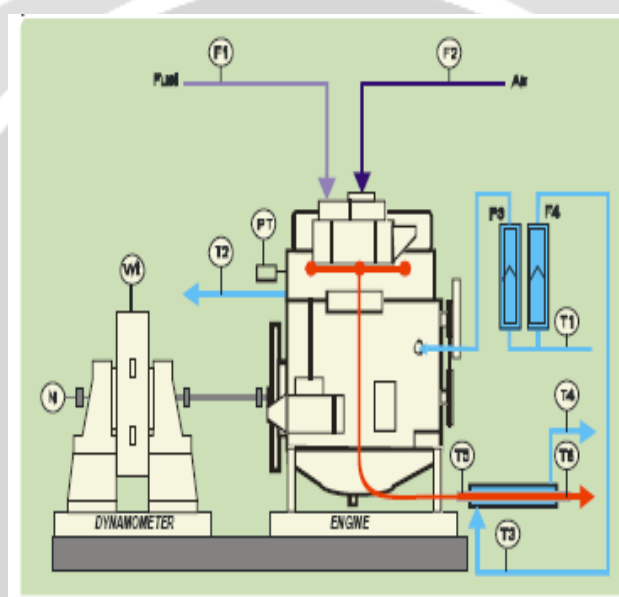


Fig. 2 Schematic of Experimental set up

- T1 – Inlet water temperature to the Engine
- T2 – Outlet water temperature from engine
- T3 – Inlet water temperature to exhaust gas calorimeter
- T4 – Outlet water temperature at exhaust gas calorimeter
- T5 – Temperature of water at Engine outlet / at Calorimeter inlet
- T6 – Temperature of water at Calorimeter outlet

Observations and Results

I. Emission Testing at constant Engine speed (RPM):-

Carbon monoxide (CO) vs. Load

Percentage of carbon monoxide with respect to load is shown in following graph (as per experimental results). From the graph we have concluded that percentage of the carbon monoxide gases increases with the load because the fuel which is required for that load is very much high, hence air-fuel ratio goes down. This lets to incomplete combustion of the fuel. This finally justifies that the CO level increases with increase in load.

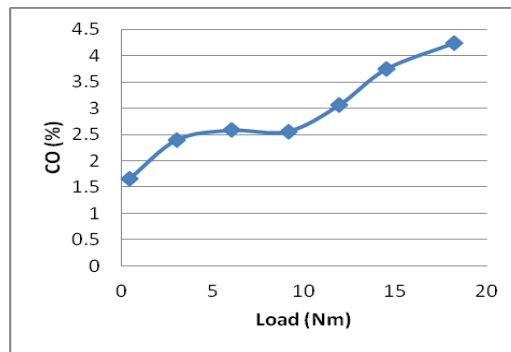


Fig. 3: CO vs load

Hydrocarbon vs. Load

Ppm of hydrocarbon with respect to load is shown in following graph (as per experimental results).From the graph we have concluded that the particulates of hydrocarbon increase with the increase in load, because the ignition misfiring increases excessively due to the rich air fuel mixture. This represents the amount of unburned petrol due to incomplete combustion exiting through the exhaust. And most unburned particulates are HC.

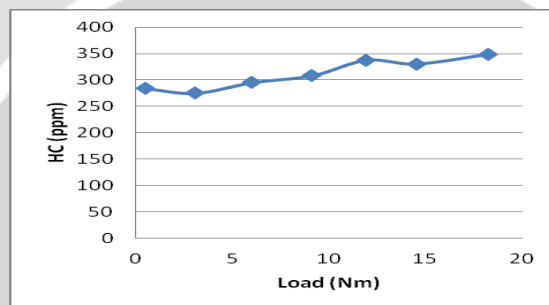


Fig. 4: HC vs. Load

CO2 Percentage vs. Load

Percentage of carbon dioxide with respect to load is shown in following graph (as per experimental results).From the graph we have concluded that percentage of the carbon dioxide gases decreases with the increase in load.CO2 gas gives a direct indication of combustion efficiency. Here the decreasing percentage of the carbon dioxide gas indicates that there is incomplete combustion of the fuel which is an indication of rich fuel mixture. So the combustion efficiency of the engine decreases with the load.

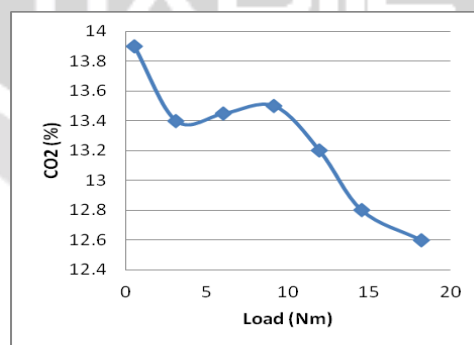


Fig. 5: CO2 vs. load

O2 Percentage vs. Load

Percentage of oxygen with respect to load is shown in following graph (as per experimental results).From the graph we have concluded that percentage of the oxygen gas decreases with the increase in load, because the air fuel mixture is rich which indicates the less percentage of the oxygen in the combustion chamber. As a result percentage of oxygen decreases with increase in load.

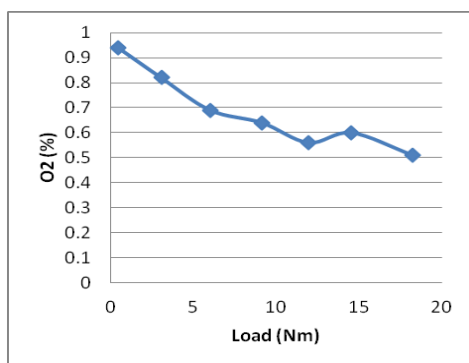


Fig. 6: O2 vs. Load

NOX vs. Load

Percentage of NOX with respect to load is shown in following graph (as per experimental results). From the graph we have concluded that percentage of the NOX gases increases with the increase in load. Because the temperature and pressure in the combustion chamber is low and also there will be a shortage of O2 molecules which combine with the nitrogen to create NOX. It is a highly dangerous for humans to be inhaled.

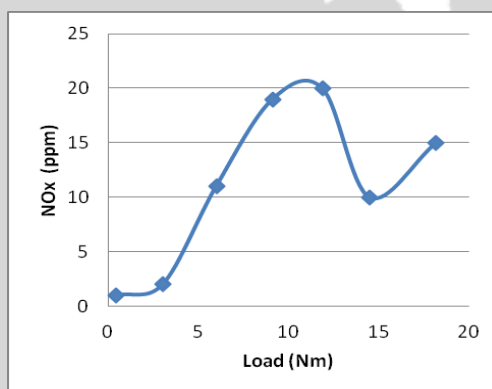


Fig. 7: NOx vs. load

Lambda vs. Load

Air-Fuel equivalence ratio, λ (lambda), is the ratio of actual Air Fuel Ratio (AFR) to stoichiometric AFR. For a given mixture, $\lambda = 1.0$ is at stoichiometric AFR, rich mixtures has $\lambda < 1.0$, and lean mixtures has $\lambda > 1.0$. There is a direct relationship between λ and AFR. To calculate AFR from a given λ , multiply the measured λ by the stoichiometric AFR for that fuel. Alternatively, to recover λ from an AFR, divide AFR by the stoichiometric AFR for that fuel. This last equation is often used as the definition of λ :

$$\lambda = \frac{AFR}{AFR_{stoich}}$$

Because the composition of common fuels varies seasonally, and because many modern vehicles can handle different fuels, when tuning, it makes more sense to talk about λ values rather than AFR.

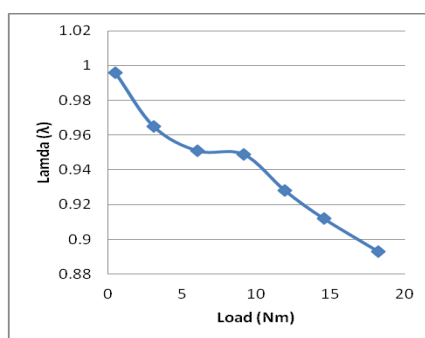


Fig. 8: lambda vs. load

II. Comparison of results at two different load conditions with varying engine speed

Carbon monoxide emission

From the graph which is shown below shows that the percentage of CO gas is more at 2000 RPM as compared to 1500 RPM at respective load'. This is because the combustion time for complete combustion of air fuel mixture is less as compared to lower engine speed and also the mixture is richer and more in amount in combustion chamber.

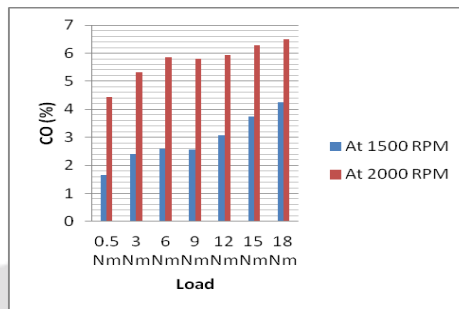


Fig.9: comparison of CO(%) at differnt load on engine.

Hydro carbon emission

From the graph which is shown below shows that the percentage of HC gas is more at 2000 RPM as compared to 1500 RPM at respective load' because the misfiring in the combustion chamber occurs more at higher engine speed due to which the amount of HC through exhaust is more.

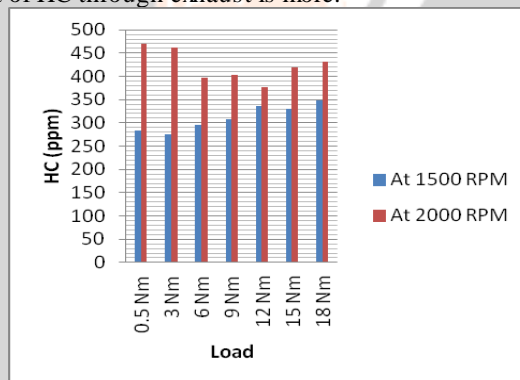


Fig.10: comparison of HC(ppm) at differnt load on engine.

Carbon dioxide emission

From the graph which is shown below shows that the percentage of CO₂ gas is less at 2000 RPM as compared to 1500 RPM at respective load'. There is less combustion time at high engine speed and also the amount of fuel inducted is more due to which incomplete combustions takes place and so less amount of CO₂ produced.

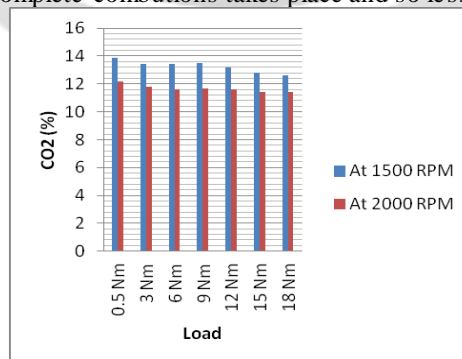


Fig.11: comparison of CO2(%) at differnt load on engine.

Oxygen emission

From the graph which is shown below shows that the percentage of O₂ gas is less at 2000 RPM as compared to 1500 RPM at respective load's because air fuel mixture at higher engine speed is richer then at lower speed due to which less amount of air is available for combustion of fuel .so less amount of oxygen comes out through

exhaust system.

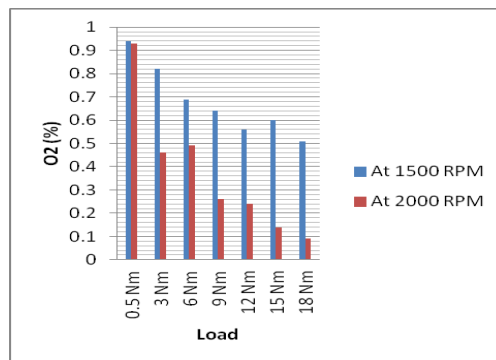


Fig.12: comparison of O₂(%) at differnt load on engine.

Nitro oxide

From the graph which is shown below shows that the percentage of NO_x gas is less at 2000 RPM as compared to 1500 RPM up to certain load's after that it is more . this is due to temperature varition in the combustion chamber which depends on the amount of fuel burned.

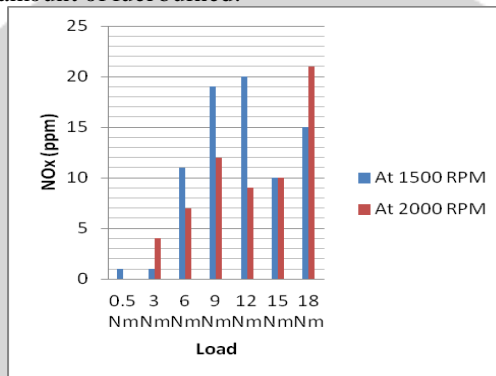


Fig.13: comparison of HC(ppm) at differnt load on engine.

**III. Emission testing with varying Engine speed at contant Load condition
Carbon monoxide vs. RPM**

The variation of carbon monoxide (CO) emission with speed at constant load is shown in Figure 7. From the figure it can be inferred that CO emissions decreases up to a certain value speed and after which increase in value of co will be noted. Since engine rpm is increased, throttle valve opens wide. This increases fuel entry and reduces air/fuel ratio, thereby reducing CO level. Because CO level increases with incomplete combustion, which increase by decrease in air/fuel ratio. At wide throttle valve opening positions, the total quantity of air and fuel which is inducted into the engine is more than that of half or quarter throttle positions. The lower combustion duration at higher engine speeds is not sufficient for the complete combustion of fuel. As a result of this, CO emissions increase at higher engine speeds (greater than 3500 rpm).

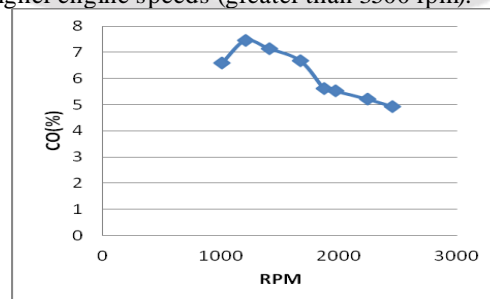


Fig.14 : CO vs. Engine speed

Hydrocarbons(HC) vs. Engine speed (RPM)

Figure 14 depicts the variation of un-burnt hydrocarbon emissions with engine speed at WOT condition. From the fig, it can infer that un-burnt hydrocarbons emission decreases with increase in engine speed. If the mixture of fuel and air is too lean - meaning there is more air than fuel - then it will be unable to ignite, even if the spark plugs are working. At higher rpm, more fuel enters the cylinder making mixture rich, thereby reducing HC emissions. Oxidation of unburned HC within the cylinder and in exhaust pipe line may be enhanced at higher speeds, since expansion and exhaust stroke gas temperatures increases significantly due to reduced heat transfer. This may be the reason for the gasoline HC emission trend.

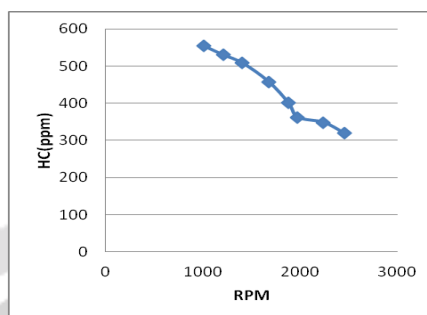


Fig.15: HC vs engine speed

Carbon dioxide(CO₂) vs. Engine speed(RPM)

Figure 14 depicts the variation of carbon dioxide emissions with engine speed. From the fig. it can be seen that Carbon dioxide emission increases with increase in engine speed up to certain engine speed after which it decreases due to increase in incomplete combustion behaviour. At wide throttle valve opening positions, the total quantity of air and fuel which is inducted into the engine is more than that of half or quarter throttle positions. The lower combustion duration at higher engine speeds is not sufficient for the complete combustion of fuel. As a result of this, CO₂ emissions decrease at higher engine speeds (greater than 3500 rpm) which shows the opposite behaviour with behaviour of carbon monoxide. It also depicts the combustion efficiency of the engine.

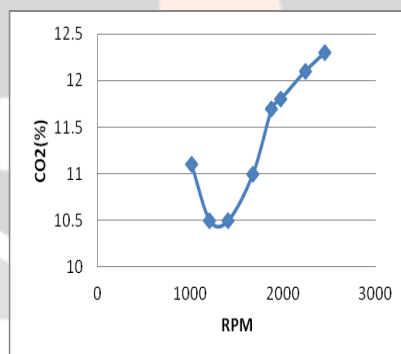


Fig.16: CO₂ vs. Engine speed

Nitro oxide (NO_x) vs. Engine speed (RPM)

The variation of NO_x at different engine speeds at wide open throttle opening is shown in Figure 16. Generally as the engine speed increases the NO_x emissions also show an increasing trend. Higher flame propagation speed and proper mixing of gaseous fuels with air causes an increase in the burning rate of the fuel and thus results in the complete combustion of the fuel. Hence the cylinder pressures and combustion temperatures are higher for gasoline. As a final outcome of this, more NO_x emissions occur in at higher speeds. The reason for lower NO_x emissions at lower engine speeds may be attributed to lower peak combustion temperature due to too lean mixtures as it might result in quenching effect.

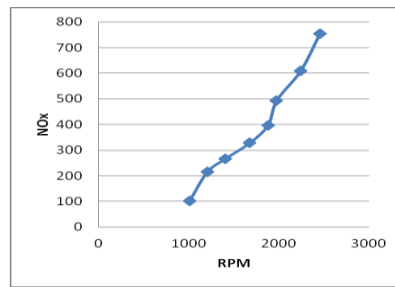


Fig.17: NOx vs. Engine speed

Oxygen (O2) vs. Engine speed (RPM)

The variation of O2 at different engine speeds at wide open throttle opening is shown in Figure 16. Generally as the engine speed increases the O2 emissions decreases on an average also show an increasing trend. On an average it can be seen that oxygen is decreasing because complete combustion is taking place as rpm gets increased.

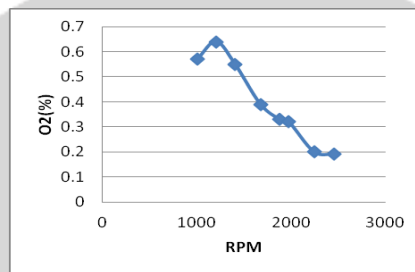


Fig.18: O2 vs. Engine speed

Lambda (λ) vs. Engine speed(RPM)

The variation of Lambda at different engine speeds is shown in Figure 16. Generally as the engine speed increases the value of lambda increases on an average this indicates that air fuel mixture progress from rich mixture to stoichiometry mixture and after certain speed it becomes lean because fuel inducted is less because of less induction time.

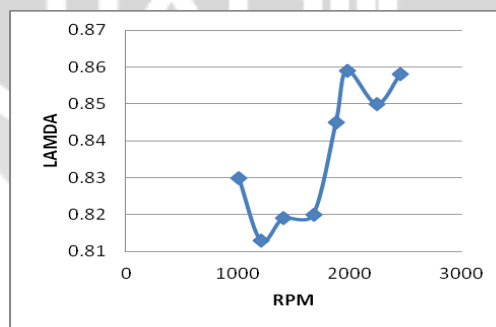


Fig.19: Lambda vs. Engine speed

IV. Comparing the result of the two different load condition

Carbon monoxide emission

From the graph which is shown below shows that the percentage of CO gas is more at 20 Nm load as compared to 10 Nm at respective rpm's . The reason being more induction of fuel air mixture in the combustion chamber due to which percentage of incomplete combustion is more leads to more carbon monoxide.

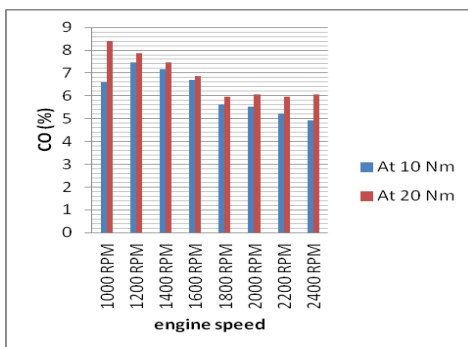


Fig.20: comparison of CO(%) at each engine speed .

Hydro carbons emission

From the graph which is shown below shows that the percentage of HC gas is less at 20Nm load as compared to 10 Nm load at respective rpm's. This happen because misfiring occurs in engine is less due to stoichiometric air fuel mixture at higher load and also fuel percentage is more.

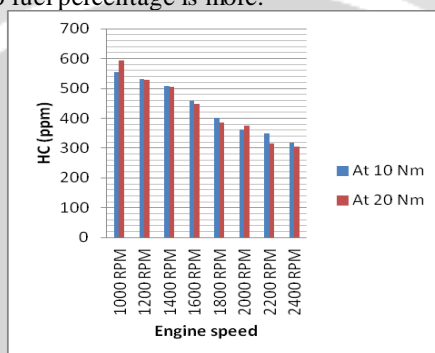


Fig.21: comparison of HC(ppm) at differnt engine speed.

Carbon dioxide emission

From the graph which is shown below shows that the percentage of CO₂ gas is less at 20Nm load as compared to 10 Nm load at respective rpm's because the air fuel mixture in the combustion is near to stoichiometry at higher load which intially more richer than at higher load.

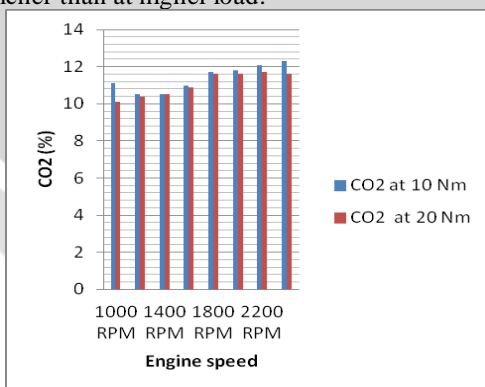


Fig.22: comparison of CO2(%) at differnt engine speed.

Oxygen emission

From the graph which is shown below shows that the percentage of O₂ gas is less at 20Nm load as compared to 10 Nm load at respective rpm's. At higher load the air fuel mixture is stoichiometric due to which amount of air in the chamber is exact which is required for complete combustion .

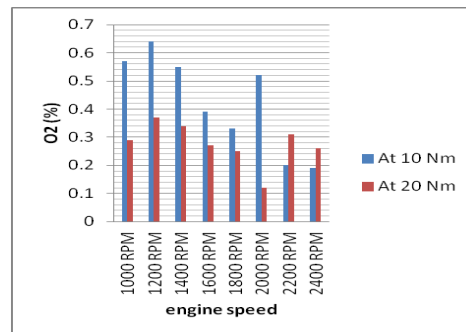


Fig.23: comparison of O₂(%) at different engine speed.

Nitro oxide emission

From the graph which is shown below shows that the percentage of NO_x gas is more at 20Nm load as compared to 10 Nm load at respective rpm's. The reason behind this phenomenon is that temperature of the combustion chamber is more due to burning of large amount of fuel which is more at higher load.

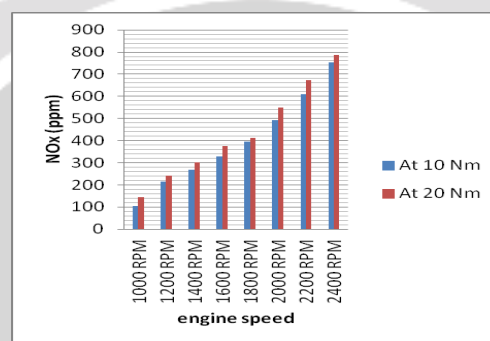


Fig.24: comparison of NO_x(ppm) at different engine speed.

Conclusion:

I. Varying load on the engine with constant engine speed

By observing and analysing the results of the constant engine speed case we have founded the conclusion for the minimum emissions of each gas are:

- The emissions of Carbon monoxides are Minimum when the range of load on the engine of the vehicle is varying between 0.36 Nm to 0.47 Nm.
- The emissions of Hydrocarbons are Minimum when the range of load on the engine of the vehicle is varying between 3.06 Nm to 11.6 Nm.
- The emissions of Carbon dioxides are Minimum when the range of load on the engine of the vehicle is varying between 0.36 Nm to 0.47 Nm.
- The emissions of Oxygen are Minimum when the range of load on the engine of the vehicle is varying between 17.99 Nm to 18.2 Nm.
- The emissions of Oxides of Nitrogen are Minimum when the range of load on the engine of the vehicle is varying between 4.04 Nm to 7.91 Nm.

II. Varying engine speed with constant load on the engine

By observing and analysing the results of the constant load on the engine case we have founded the conclusion for the minimum emissions of each gas are:

- The emissions of carbon monoxides are Minimum when the range of engine speed of the vehicle is varying between 2229 rpm to 2453 rpm.
- The emissions of Hydro carbons are Minimum when the range of engine speed of the vehicle is varying between 2386 rpm to 2453 rpm.
- The emissions of Carbon dioxides are Minimum when the range of engine speed of the vehicle is varying between 2229 rpm to 2453 rpm.
- The emissions of Oxygen are Minimum when the range of engine speed of the vehicle is varying between 2013 rpm to 2453 rpm.
- The emissions of Oxides of nitrogen are Minimum when the range of engine speed of the vehicle is

varying between 2144 rpm to 2212 rpm.

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