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Comparative analysis of exhaust gases obtained in S.I and C.I of an internal combustion engine

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ABSTRACT

ICE which could be spark ignition (S.I) or compression ignition (C.I) engine is one of the building blocks of modern civilization. In light of this, an effective engine should be able to contribute immensely to a safe environment. Numerous factors like fuel economy, power and torque, reliability, pollution, safety and cost are necessary in determining and comparing the effectiveness of the engines. This paper identifies, examines and compares the rate of incombustible particles present in the engines (S.I and C.I) at varying loading and speed conditions via exhaust gas detector. Post-hoc analysis was carried out using SPSS. It was discovered that CO and HC are the most dangerous incombustible particles present in engines and also the incombustible rate is more pronounced in C.I than S.I engine, which confirmed that S.I. engine is far better in terms of pollution reduction. Probable recommendations were later made.

Keywords: ICE, Pollution, Exhaust gases, Gas detector, SPSS, Post-hoc

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INTRODUCTION

Internal combustion engines are the major consumer of fossil fuel around the globe. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting into entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases damped to environment. It is imperative that serious and concrete effort should be launched for conserving this energy through exhaust heat recovery techniques [1]. Recent trend about the best ways of using the deployable sources of energy into useful work is taken in order to reduce the rate of consumption of fossil fuel as well as pollution.

Automobile Emission is one of the major problems in environment. Engine emits the carbon monoxide (CO), hydrocarbon (HC), Nitrogen oxides (NOx) and smoke density etc. [2]. However, exhaust gas emissions from internal engines have significant effects on human, animal, plant, and environmental health and welfare [3]. This leads us to use different advanced technology to control the exhaust gas emission from internal combustion engines. The methods and techniques which are used to decrease exhaust emissions from internal combustion engines have some influences on engine performance [4]. Many researchers had directed their research to reduce emission and to increase the efficiency of the spark ignition engine. For spark ignition engines an effective solution for reducing emissions by regulating some combustion parameters such that engine performance is kept unaltered.

[5] as well as [6] also reported that traffic exhaust emissions are significant sources of air pollution in the world and may threaten human health and cause global warming effect. The two research works showed that three-way catalytic converter used in spark ignition (SI) engines could reduce most exhaust pollution, such as HC, CO and NOx towards achieving exhaust standards.

Thus, the adverse effect of vehicle emissions resulting from incomplete combustion is critical and difficult to measure. Some factors which should be put into consideration while carrying out the exhaust analysis in ICE include: composition of fuel used, power losses, ecological requirement, air-fuel ratio, engine load, engine speed, Fuel Consumption, Air Consumption, Smoke Density, Exhaust, Brake Power, Friction power and operating modes, spark ignition timing, fuel injection timing, air intake, operating modes like start up, idle, running etc. [7][8][9][10][11][12][13][14].

According to [5] and [15], the incombustible particles like CO, HC, NOx were measured as related to ICE but were limited to engines without catalytic converter, to obtain exact and accurate results. The test was observed on ***Toyota*** product for a specified period. Fig 1 and 2 represent various incombustible gases present in both C.I and S.I Engines.

Fig. 1: S.I Engine Exhaust [5]

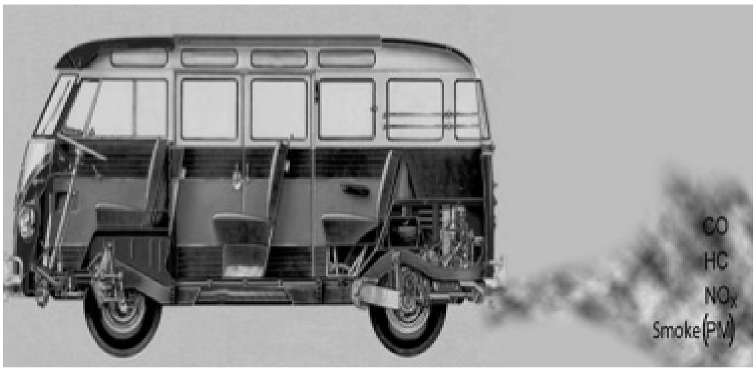

Fig. 2: C.I Engine Exhaust [5]

Hence, the problem of estimating pollution emission from cars during cold and motion cannot be analyzed using universal engine characteristics, which are determined after test of fully heated engines. Since no adequate research has been done on how to quantify the rate at which these hazardous pollutants are been dispersed, hence this study would create a formidable means of analyzing exhaust gases using exhaust gas analyzer [15][16]. This paper is aimed at analyzing, determining and comparing the composition of exhaust gases of automobile ICE through experimental determination of the exhaust gas values at different loads and speeds of both engines; and determination of the effect of engine speeds and loads on exhaust emissions of both engines. This research would sensitize the general public on the effect of some variables like engine loads and engine speeds on the vehicle with spark ignition and compression ignition engines. It would also help in engine's selection in terms of emission reduction.

MATERIALS AND METHODS

The following steps were necessary in exhaust gas measurement and analysis:

I. Selection of parameters:
II. Experimental materials
III. Analysis

(A) Parameters

The two parameters under consideration were loads and engine speeds. These were required to know the percentage composition of CO, HC, and NOx at different levels of such parameters.

(b) Materials

i. Motor vehicles (4-stroke, 4 cylinder spark Ignition engine, In-line, water cooled, Toyota 2.0L engines).
ii. Gas detector (mobile gas analyzer)
iii. Test bed

Fig. 3: A mobile gas detector (analyzer) **[15]**

(C) Analysis

SPSS was used for the analysis. The two parameters involved were engine speeds and loads varied at different level with loads in **percent (%)** while the speeds were in **revolution per minute (rpm)**. The known variables x were chosen while another called y was the target value. The known variables, x are engine loads and speeds while the target value y is the values of HC, CO, NO and NO_2 at each levels of combination in **parts per million (ppm)**.

i. General linear model was developed using multivariate analysis.
ii. Estimated marginal means was then calculated at 95% confidence interval, taken those emissions as dependent variable to get the standard error, lower bound and upper bound.
iii. Exhaust gases were then taken as a function of engine speed and also as a function of engine load at 95% confidence limit, to study the level of significance.
iv. Post Hoc Test was later carried out for multiple comparisons as a function of engine speed and also as a function of engine load at 95% confidence limit, to study the level of significance.

RESULTS AND DISCUSSION

The profile plots of the results obtained for S.I engines during the exhaust gas analysis are represented in the figures below:

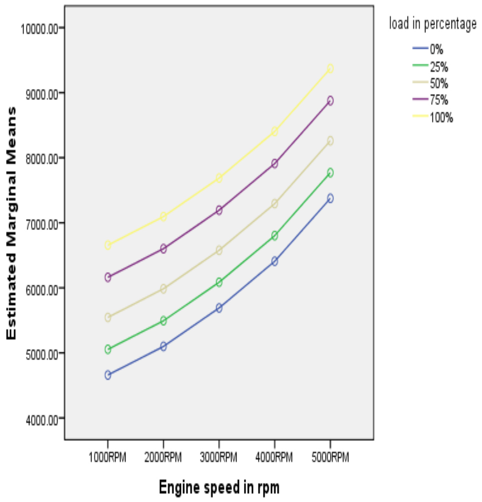

Fig 4: Relationship between estimated marginal Means of CO and engine speeds at constant engine load

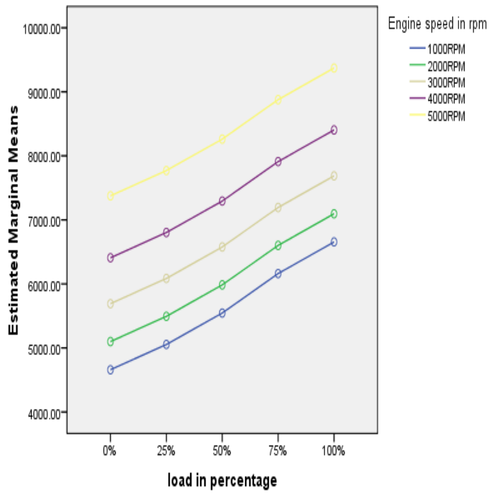

Fig 5: Relationship between EMM of CO and Engine load at constant Engine Speed

From fig. 4, the load is kept constant and as engine speed increases, the estimated marginal mean of CO increases sharply. Invariably, the engine speed is directly proportional to the estimated marginal means of CO, while engine loads is kept constant. The emissions are measured in parts per million (ppm).

From Fig. 5 at constant engine speed, the engine load is directly proportional to the estimated marginal means of the CO emissions. This shows that, the higher the engine loads, the higher (marginal increase) the estimated marginal means of CO at constant engine speeds.

From Fig. 6, at constant engine load, the engine speed is inversely proportional in the estimated marginal means of the NO emission. It also shows that, the higher the engine speed, the lower (decreases sharply) the estimated marginal means of NO at constant engine load.

From Fig. 7, at constant engine speed, the engine load is directly proportional to the estimated marginal means of the NO emission. This shows that, the higher the engine loads, the higher (marginal increase) the estimated marginal means of NO at constant engine speeds.

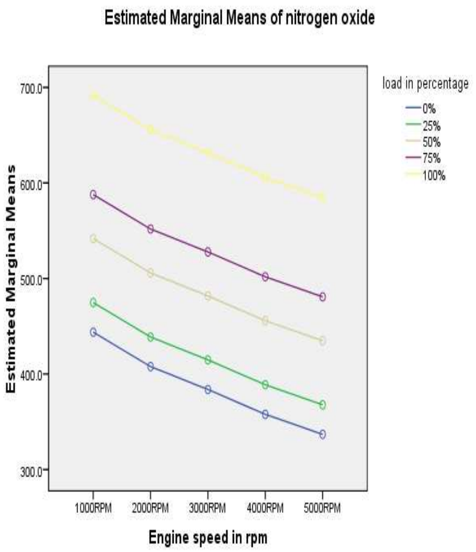

Fig 6: Relationship between EMM of NO and engine speed at constant engine load

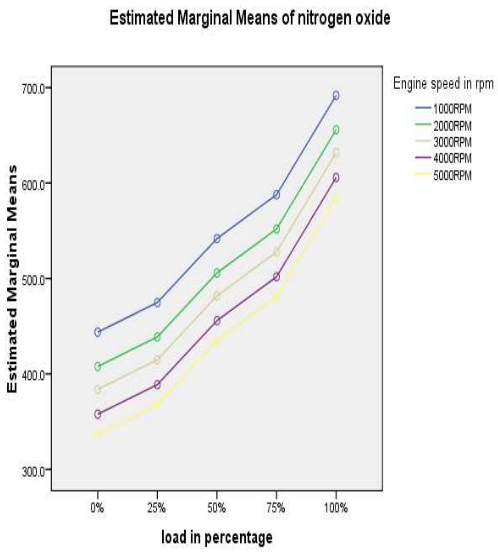

Fig 7: Relationship between EMM of NO and engine load at constant engine speed.

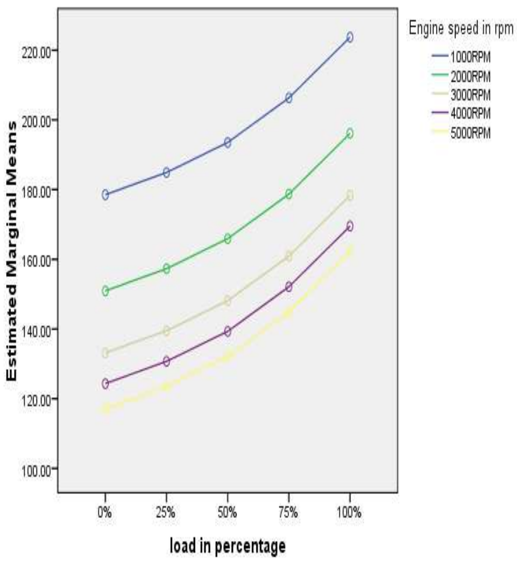

Fig 8: Relationship between EMM of NO_2 and engine speed at constant engine load

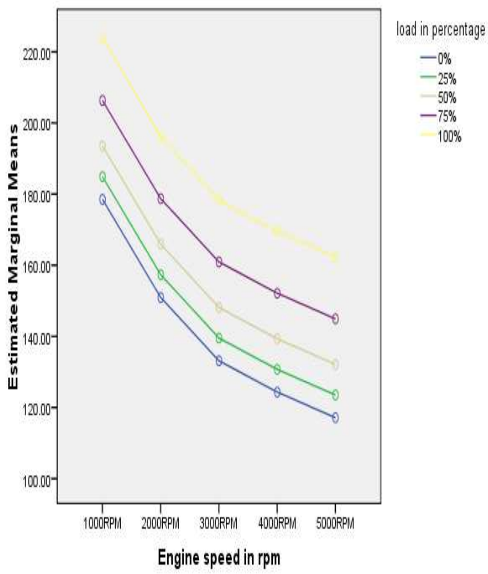

Fig 9: Relationship between EMM of NO_2 and engine load at constant engine speed

From Fig. 8, at constant engine speed, the engine load is directly proportional to the estimated marginal means of the NO_2 emission. This shows that, the higher the engine load, the higher the estimated marginal means of NO_2 at constant engine speed.

From Fig. 9, at constant engine load, the engine speed is inversely proportional to the estimated marginal means of the NO_2 emission. It also shows that, the higher the engine speed, the lower the estimated marginal means of NO at constant engine load.

From Fig. 10, at constant engine load, the engine speed is directly proportional to the estimated marginal means of the HC emission. It also shows that, the higher the engine speed, the higher the estimated marginal means of HC at constant engine load.

From Fig. 11, at constant engine speed, the engine load is directly proportional to the estimated marginal means of the HC emission. This shows that, the higher the engine loads, the higher the estimated marginal means of HC at constant engine speeds.

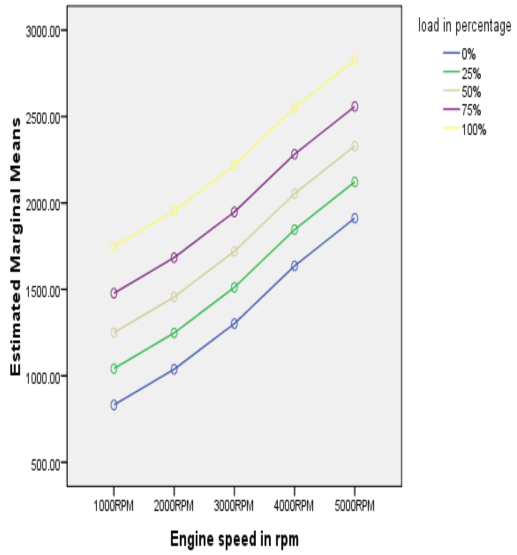

Fig. 10: Relationship between EMM of HC and engine speed at constant engine load

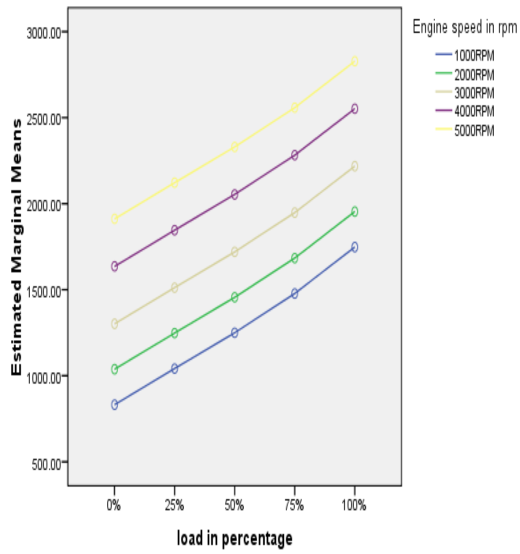

Fig. 11: Relationship between EMM of HC and engine load at constant engine.

Also the profile plots of the results obtained for C.I engines during the exhaust gas analysis are represented in the figures below:

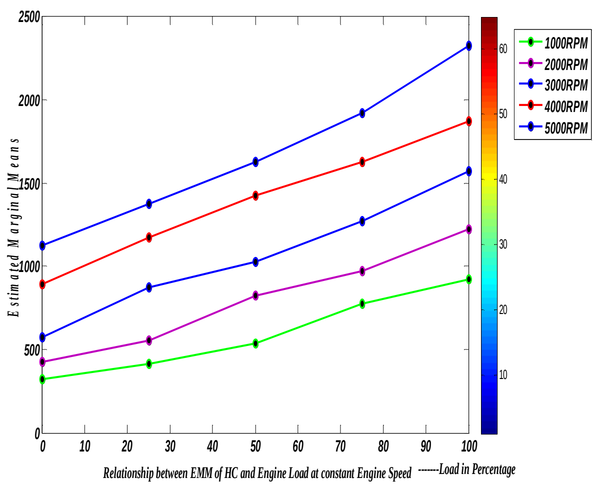

Fig. 12: Relationship between EMM of HC and Engine speed

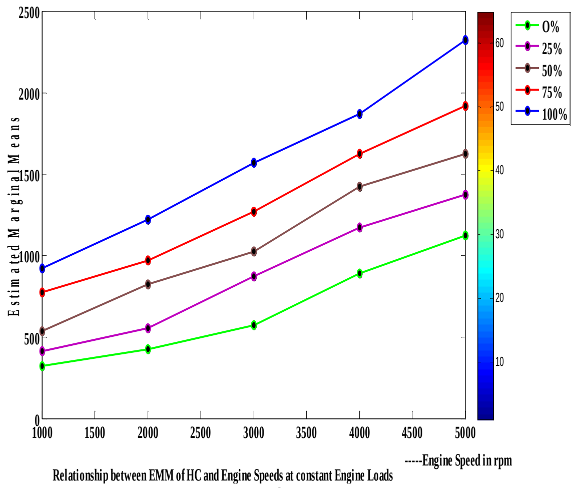

Fig.13: Relationship between EMM of HC and Engine load at constant Engine Speed at constant Engine load

From the Fig. 12 at constant engine speed, the engine load is directly proportional to the estimated marginal means of the HC emissions. This shows that, the higher the engine loads, the higher the estimated marginal means of HC at constant engine speeds.

From fig. 13, the load is kept constant and as engine speed increases, the estimated marginal mean of HC increases. Invariably, the engine speed is directly proportional to the estimated marginal means of HC, while engine loads is kept constant. The emissions are measured in parts per million (ppm).

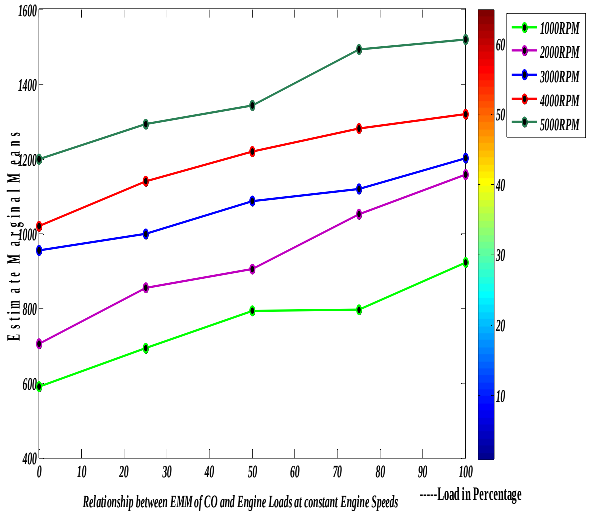

Fig. 14: Relationship between EMM of CO and Engine load at constant Engine speed

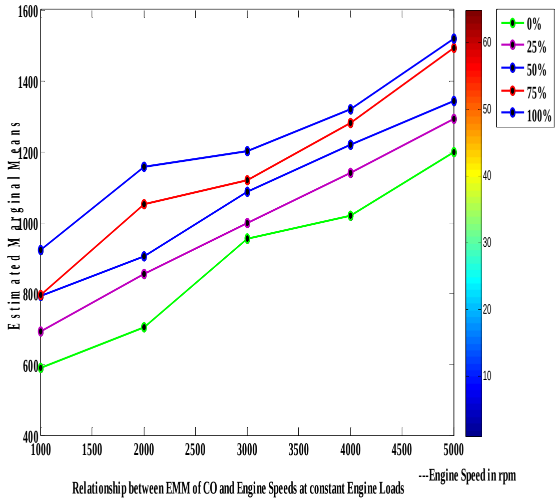

Fig. 15: Relationship between EMM of CO and Engine Speed at constant Engine load

From the Fig. 14 at constant engine speed, the engine load is directly proportional to the estimated marginal means of the CO emissions. This shows that, the higher the engine loads, the higher the estimated marginal means of HC at constant engine speeds.

From fig. 15, the load is kept constant and as engine speed increases, the estimated marginal mean of HC increases. Invariably, the engine speed is directly proportional to the estimated marginal means of CO, while engine loads is kept constant. The emissions are measured in parts per million (ppm).

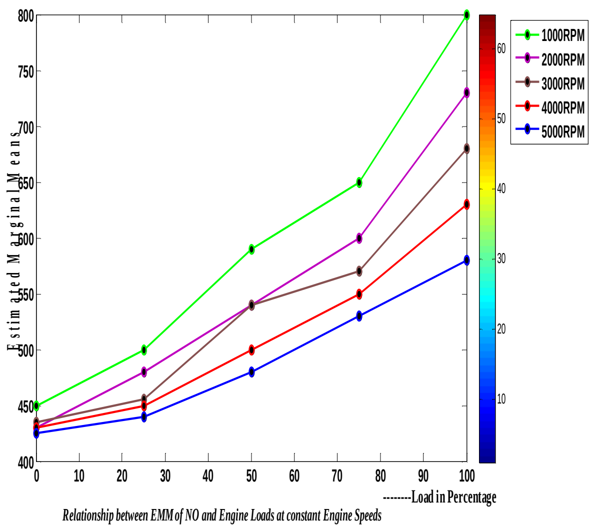

Fig.16 Relationship between EMM of NO and Engine load at constant Engine speed

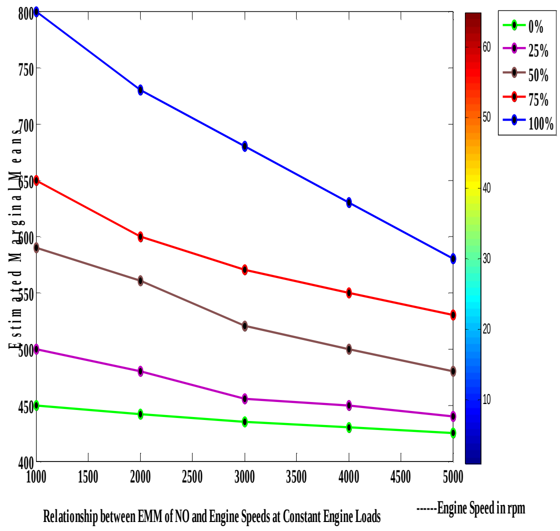

Fig.17: Relationship between EMM of NO and Engine Speed at constant Engine load

From Fig. 16, at constant engine speeds, the engine load is inversely proportional to the estimated marginal means of the NO emission. It also shows that, the higher the engine loads, the lower the estimated marginal means of NO at constant engine speeds.

From Fig. 17, at constant engine loads, the engine speed is directly proportional to the estimated marginal means of the NO emission. This shows that, the higher the engine speeds, the higher the estimated marginal means of NO at constant engine speeds.

From Fig. 18, at constant engine speeds, the engine load is inversely proportional to the estimated marginal means of the NO_2 emission. It also shows that, the higher the engine loads, the lower the estimated marginal means of NO_2 at constant engine speeds.

From Fig. 19, at constant engine loads, the engine speed is directly proportional to the estimated marginal means of the NO_2 emission. This shows that, the higher the engine speeds, the higher the estimated marginal means of NO_2 at constant engine speeds.

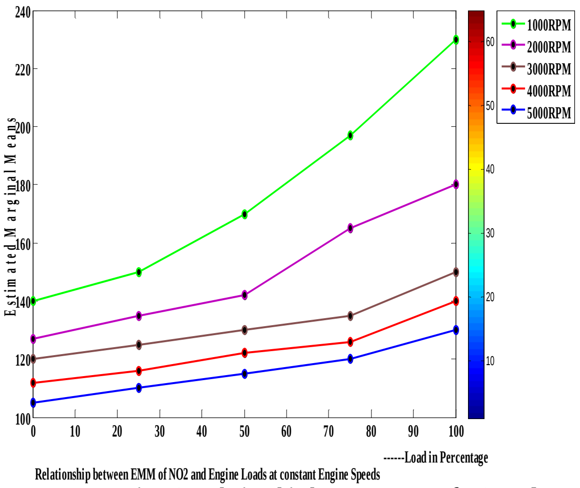

Fig. 18: Relationship between EMM of NO_2 and Engine load at constant Engine speed

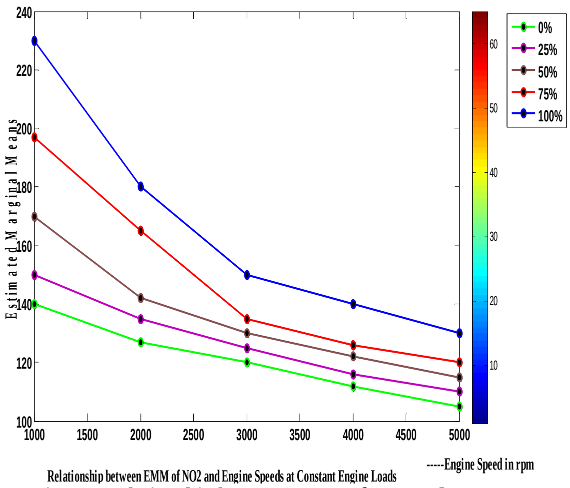

Fig. 19: Relationship between EMM of NO_2 and Engine Speed at constant Engine load

CONCLUSION

The experiment to determine the effect of engine operating parameters on exhaust emission was performed and results were presented in this paper. For the S.I Engines, it was shown that as the engine speed increases, both HC and CO emission increases sharply while NO and NO_2 emissions decreases marginally. Also, as the engine load increases all the four exhaust gas emissions increases. It has been shown that the emission of NO is about 3 times that of NO_2 and CO emission is about four times that of HC emission. However, the obtained results for the C.I Engines are similar to those obtained in S.I Engines. Only that the S.I emission results are far better compare to C.I emission results. This is an indication that S.I. engines are far better in terms of pollution reduction. It is highly recommended that lower values of loading (20%) and speeds (600 rpm) be used while operating the engines to reduce the values of HC, CO, NO and NO_2 emissions in automobile four stroke spark ignition Engines. Apart from engine loads and engine speeds, factors like mixture strength; compression ratio could also be investigated to determine their effect on emissions. Government can establish vehicle emission testing centers where one can carry out the analysis at cheaper rate, even general public can test exhaust emissions, for them to know how to maintain their car engines which will also lead to pollution reduction (safe environment).

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